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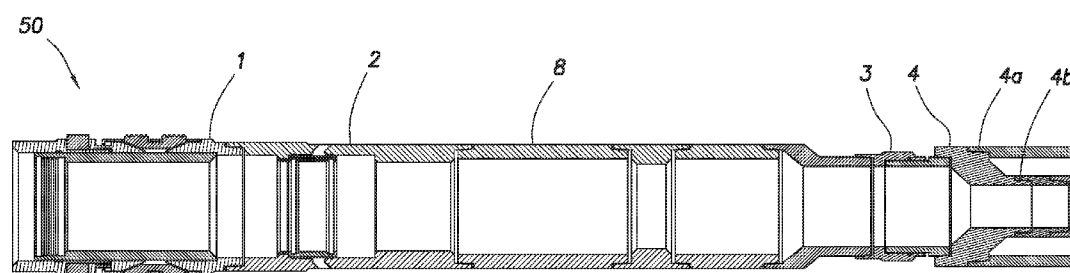


FIG. 1A

(57) Abstract: A slow pressure triggered valve for a downhole tool may include an outer housing and a sliding sleeve. The sliding sleeve may slide within the outer housing such that apertures formed on the sliding sleeve do not align with fixed apertures of the outer housing until the sliding sleeve moves from a closed position into an open position. The sliding sleeve may be mechanically coupled to a damping piston. The damping piston may be positioned within a damping chamber and may have a flowpath formed therethrough such that as the damping piston moves with the sliding sleeve from the closed position to the open position, fluid within the damping chamber flows through the flowpath. The flowpath may include a low pressure relief valve and a flow restrictor. The sliding sleeve may be held in the closed position by a lock piston temporary retainer until a predetermined pressure is reached within the valve.



CONTROLLED OPENING VALVE

Cross-Reference to Related Applications

[0001] This application is a nonprovisional application which claims priority from U.S. provisional application number 62/338,879, filed May 19, 2016.

Technical Field/Field of the Disclosure

[0002] The present disclosure relates generally to well completion assemblies for use in a wellbore, and specifically to pressure actuated valves for production or injection zone isolation.

Background of the Disclosure

[0003] Isolation sleeve assemblies may be utilized in a wellbore to allow selective opening of the interior of a downhole tool to the surrounding wellbore. Isolation sleeve assemblies may be used with a drill string or production string. Typically, isolation sleeves are mechanically actuated or pressure actuated such that modification of the pressure within the string, referred to herein as an interior pressure, causes the selective opening of the valve. Certain traditional isolation sleeves operate such that the valves open immediately when the interior pressure reaches a desired threshold. However, the flow through the valve at a high interior pressure may be rapid and may damage one or more of the valve, isolation sleeve, or formation. Additionally, the lowering of the pressure may prevent the reliable operation of other pressure actuated tools. Other traditional isolation sleeves may operate such that the valve opens after the interior pressure rises above the desired threshold and is bled to equal or be less than the pressure in the wellbore. However, equaling or being lower than the wellbore pressure may be difficult or impractical.

Summary

[0004] In one embodiment, a slow pressure triggered valve for a downhole tool is disclosed. The slow pressure trigger valve includes an outer housing, the outer housing including a ported housing. The ported housing includes a fixed aperture, the fixed aperture fluidly coupling the interior of the ported housing with the exterior of the ported housing. The slow pressure trigger valve also includes a sliding sleeve positioned within the outer housing, the sliding sleeve including a closing sleeve having an aperture. The aperture is not in alignment with the fixed aperture when the closing sleeve is in a closed position and in alignment with the fixed aperture when the closing sleeve is in an open position. The slow pressure valve also includes a damping piston mechanically coupled to the closing sleeve, the damping piston positioned within a damping chamber. The damping chamber is an annular space formed between the outer housing and the sliding sleeve. The damping chamber has a fluid positioned therein, and the damping piston separates the damping chamber into a first and second portion. The damping piston includes a flowpath fluidly coupling the first and second portions of the damping chamber. The second portion of the damping chamber is fluidly coupled to an interior of the sliding sleeve.

[0005] In another embodiment, a method is disclosed. The method includes positioning a slow pressure triggered valve in a wellbore. The slow pressure triggered valve includes an outer housing, the outer housing including a ported housing. The ported housing includes a fixed aperture, where the fixed aperture fluidly couples the interior of the ported housing with the exterior of the ported housing. The slow pressure trigger valve also includes a sliding sleeve positioned within the outer housing, the sliding sleeve including a closing sleeve having an aperture. The aperture is not in alignment with the fixed aperture when the closing sleeve is in a closed position and in alignment with the fixed aperture when the closing sleeve is in an open

position. The slow pressure triggered valve additionally includes a damping piston mechanically coupled to the closing sleeve, the damping piston positioned within a damping chamber. The damping chamber is an annular space formed between the outer housing and the sliding sleeve. The damping chamber has a fluid positioned therein, where the damping piston separates the damping chamber into a first and second portion. The damping piston includes a flowpath fluidly coupling the first and second portions of the damping chamber. The second portion of the damping chamber is in fluid communication with an interior of the closing sleeve. The method also includes increasing the pressure within the slow pressure triggered valve and moving the closing sleeve from the closed position to the open position. In addition, the method includes flowing a fluid from the first portion of the damping chamber to the second portion of the damping chamber through the flowpath and thereby slowing motion of the closing sleeve. Further, the method includes flowing a fluid through the aperture of the closing sleeve and the fixed aperture to or from the wellbore.

Brief Description of the Drawings

[0006] The present disclosure is best understood from the following detailed description when read with the accompanying figures. It is emphasized that, in accordance with the standard practice in the industry, various features are not drawn to scale. In fact, the dimensions of the various features may be arbitrarily increased or reduced for clarity of discussion.

[0007] FIGS. 1A and 1B are cross section views of a production tubing assembly in a closed configuration consistent with at least one embodiment of the present disclosure.

[0008] FIGS. 2A and 2B are cross section views of a downhole valve consistent with at least one embodiment of the present disclosure shown in a closed position.

[0009] FIGS. 2C and 2D are cross section views of the downhole valve of FIGS. 2A and 2B in an open position.

[0010] FIG. 3 is a detail view of the valve of FIGS. 2A, 2B.

[0011] FIG 3A is a detail view of an alternate valve consistent with at least one embodiment of the present disclosure.

[0012] FIGS. 4A and 4B are cross section views of a production tubing assembly incorporating a downhole valve consistent with at least one embodiment of the present disclosure.

[0013] FIGS. 5A and 5B are cross section views of a downhole valve consistent with at least one embodiment of the present disclosure shown in the closed position.

[0014] FIGS. 6A and 6B are cross section views of a production tubing assembly incorporating a downhole valve consistent with at least one embodiment of the present disclosure.

[0015] FIGS. 7A and 7B are cross section views of a downhole valve consistent with at least one embodiment of the present disclosure shown in the closed position.

[0016] FIGS. 8A, 8B, and 8C are cross section views of a production tubing assembly incorporating a downhole valve consistent with at least one embodiment of the present disclosure.

[0017] FIGS. 9A, 9B, and 9C are cross section views of a downhole valve consistent with at least one embodiment of the present disclosure shown in the closed position.

[0018] FIGS. 10A, 10B, 10C, and 10D are cross section views of a dual zone production tubing assembly consistent with at least one embodiment of the present disclosure.

[0019] FIGS. 11A, 11B, and 11C depict partial cross section views of a downhole valve consistent with at least one embodiment of the present disclosure.

Detailed Description

[0020] It is to be understood that the following disclosure provides many different embodiments, or examples, for implementing different features of various embodiments. Specific examples of components and arrangements are described below to simplify the present disclosure. These are, of course, merely examples and are not intended to be limiting. In addition, the present disclosure may repeat reference numerals and/or letters in the various examples. This repetition is for the purpose of simplicity and clarity and does not in itself dictate a relationship between the various embodiments and/or configurations discussed.

[0021] With respect to FIGS. 1A, 1B, in at least one embodiment of the present disclosure, production tubing assembly 50 may include production packer 1. Production packer 1 may be mechanically coupled to a production string (not shown) that may extend to the surface through the wellbore. In some embodiments, production packer 1 may include a sealed bore in fluid communication with the production string. In some embodiments, one or more additional production tubing assemblies (not shown) may be coupled between production packer 1 and the production string. In some embodiments, production tubing assembly 50 may include frac valve 2 mechanically coupled to production packer 1. Frac valve 2 may be a conventional frac valve and may be used in gravel packing operations. In some embodiments, production tubing assembly 50 may include emergency shear joint 3. Emergency shear joint 3 may be mechanically coupled to frac valve 2 by pipe 8. In some embodiments, emergency shear joint 3 may be mechanically coupled to a length of blank pipe 9 through double pin sub 4. Blank pipe 9 may mechanically couple between outer connection 4a of double pin sub 4 and screen assembly 7. In

some embodiments, inner connection 4b of double pin sub 4 may be mechanically coupled to isolation valve assembly 10. Isolation valve assembly 10 may include slow pressure triggered (SPT) valve 5. In some embodiments, isolation valve assembly 10 may include mechanically operated sleeve valve 6. SPT valve 5 may be positioned to selectively open a fluid connection between the interior of isolation valve assembly 10 and the wellbore. In some embodiments, SPT valve 5 may be configured such that the opening of the valve is slowed or retarded by a retarding mechanism as discussed further herein below.

[0022] Although described herein with respect to a production zone, production tubing assembly 50 and isolation valve assembly 10 is not limited to use in a production zone. Likewise, the specific components and arrangement of production tubing assembly 50 described herein above is not intended to limit the possible configurations of embodiments of the present disclosure. Isolation valve assembly 10 may have uses other than at a production zone and may be mated in combination with a wide variety of elements as understood by a person skilled in the art. Further while only a single isolation valve assembly 10 is depicted, it is contemplated that multiple isolation valve assemblies 10 may be placed within the production screen or blank pipe depending on the length of the producing formation and the amount of redundancy desired. In some embodiments, although screen assembly 7 is depicted, it is contemplated that the screen may include any of a variety of external or internal filtering mechanisms including but not limited to screens, sintered filters, and slotted liners. Alternatively, isolation valve assembly 10 may be utilized without any filtering mechanisms.

[0023] With respect to FIGS. 2A and 2B, SPT valve 5 of isolation valve assembly 10 is depicted in a closed position. In some embodiments, SPT valve 5 may include outer housing 10a. In some embodiments, outer housing 10a may include one or more tubular members including, for

example and without limitation, top sub 11, spring housing 12, upper connector 16, ported housing 20, lower connector 22, and bottom sub 24 as described herein. One having ordinary skill in the art with the benefit of this disclosure will understand that any configuration of tubulars may be utilized, and that the specific members described herein are merely exemplary and are not intended to limit the scope of this disclosure.

[0024] In some embodiments, SPT valve 5 may include sliding sleeve 10b. Sliding sleeve 10b may be positioned within outer housing 10a. Sliding sleeve 10b may, in some embodiments, include one or more tubular members, including, for example and without limitation, closing sleeve 18, spring mandrel 27, damping piston 14, and shear piston 21 as described herein. One having ordinary skill in the art with the benefit of this disclosure will understand that any configuration of tubulars and components may be utilized, and that the specific members described herein are merely exemplary and are not intended to limit the scope of this disclosure. Sliding sleeve 10b may be positioned to selectively slide within outer housing 10a in order to selectively open or close SPT valve 5 as further discussed herein below. As further discussed herein below, SPT valve 5 may include a retarding mechanism for slowing the opening of SPT valve 5. Additionally, although described with respect to damping piston 14, SPT valve 5 may include one or more retarding mechanisms including, for example and without limitation, a friction-based device, spring wheel, butterfly wheel, or other mechanisms as known in the art.

[0025] In some embodiments, SPT valve 5 may include top sub 11. Top sub 11 may be a generally tubular member. Top sub 11 may serve to mechanically couple SPT valve 5 to a production string, section of production tubing, or other downhole device. Top sub 11 may be mechanically coupled to spring housing 12. Spring housing 12 may be generally tubular. Spring 13 may be positioned within spring chamber 36 formed by spring housing 12 and about spring

mandrel 27. In some embodiments, spring chamber 36 may be fluidly coupled to the interior of SPT valve 5. Spring 13 may be positioned to exert a force between spring housing 12 and spring mandrel 27. Spring mandrel 27 may in turn exert a force on damping piston 14 as discussed further herein below.

[0026] In some embodiments, spring housing 12 may be mechanically coupled to upper connector 16. In some embodiments, damping chamber 15 may be an annular space formed between outer housing 10a and sliding sleeve 10b. In some embodiments, damping chamber 15 may be formed between upper connector 16, spring housing 12, spring mandrel 27, and damping piston 14. In other embodiments, damping chamber 15 may be formed between any two tubular members of SPT valve 5. In some embodiments, prior to running into the wellbore, damping chamber 15 may be filled with fluid and may be fluidly sealed by filler plug 17.

[0027] In some embodiments, upper connector 16 may mechanically couple to ported housing 20. Ported housing 20 may include one or more fixed apertures 20a fluidly coupling the interior and exterior of ported housing 20. In some embodiments, ported housing 20 may mechanically couple to lower connector 22, which in turn may mechanically couple to bottom sub 24.

[0028] In some embodiments, damping piston 14 may transfer the force from spring 13 onto closing sleeve 18. Closing sleeve 18 may include one or more apertures 19 fluidly coupling the interior and exterior of closing sleeve 18. Closing sleeve 18 may in turn exert a force against shear piston 21. Shear piston 21 may be mechanically coupled to bottom sub 24 by one or more opening temporary retainers 23. Temporary retainer, as used herein, is intended to refer to any mechanism for mechanically coupling two or more components until a predetermined condition is met, such as, for example and without limitation, when the force imparted on the temporary

retainer by the coupled components is sufficient to cause mechanical failure of at least part of the temporary retainer. As used herein, a temporary retainer may include, for example and without limitation, one or more shear screws, shear bolts, or shear pins. In some embodiments, while in the closed position as depicted in FIGS. 2A and 2B, closing sleeve 18 may be positioned within ported housing 20 such that apertures 19 are not aligned with fixed apertures 20a of ported housing 20, thereby preventing fluid communication between the interior of SPT valve 5 and the wellbore. In an open position as depicted in FIGS. 2C and 2D, once closing sleeve 18 shifts into the open position as discussed herein below, apertures 19 of closing sleeve 18 may be substantially aligned with fixed apertures 20a of ported housing 20, opening a flow path for fluid communication between the interior of SPT valve 5 and the wellbore through apertures 19 and fixed apertures 20a.

[0029] FIG. 3 depicts a detail view of the top end of damping piston 14. In some embodiments, damping piston 14 may separate damping chamber 15 into first and second portions 15a, 15b respectively. In some embodiments, damping piston 14 may include flowpath 14a formed therein between the first and second portions 15a, 15b of damping chamber 15. In some embodiments, flowpath 14a may restrict or slow fluid flow between the first and second portions 15a, 15b of damping chamber 15 as sliding sleeve 10b moves within outer housing 10a. In some embodiments, first portion 15a of damping chamber 15 may be sealed from the interior of SPT valve 5 and the wellbore. In some embodiments, second portion 15b of damping chamber 15 may be fluidly coupled to the interior of SPT valve 5. In some embodiments, second portion 15b of damping chamber 15 may be fluidly coupled to spring chamber 36, which may be fluidly coupled to the interior of SPT valve 5. In some embodiments, second portion 15b may be any part of SPT valve 5 fluidly coupled to the interior of SPT valve 5.

[0030] In some embodiments, flowpath 14a may include at least one low pressure relief valve 26 and at least one flow restrictor 25 positioned to fluidly couple between spring chamber 36 and damping chamber 15 in series. Low pressure relief valve 26 may be any type of valve known in the art that prevents fluid flow below a desired pressure threshold. In some embodiments, low pressure relief valve 26 may be a relief valve as understood in the art. In some embodiments, low pressure relief valve 26 may be a check valve such as a ball check valve, diaphragm check valve, swing check valve, clapper valve, or a stop-check valve. In some embodiments, the pressure threshold required to permit flow across low pressure relief valve 26 may be between 1PSI and 200PSI. In some embodiments, flow restrictor 25 may be a member positioned to restrict fluid flow therethrough. In some embodiments, flow restrictor 25 may include one or more components with one or more flow paths formed therein, positioned to slow fluid flow through flow restrictor 25. In some embodiments, flow restrictor 25 may be an insert-type flow restrictor, orifice flow restrictor, or other flow restrictor as known in the art. In some embodiments, flow restrictor 25 may be a Lee JEVA Jet flow restrictor or a Lee VISCO jet flow restrictor.

[0031] Damping piston 14 may also contain at least one reverse pressure relief valve (not shown) installed to allow flow through flowpath 14a in a direction opposite low pressure relief valve 26. In some embodiments, the reverse pressure relief valve may reduce leakage from damping chamber 15 during, for example and without limitation, assembly and handling. The reverse pressure relief valve may also prevent a high pressure differential build up between damping chamber 15 and the interior of SPT Valve 5.

[0032] In some embodiments, as depicted in FIG. 3A, damping piston 14' may not include a flowpath as described with respect to damping piston 14. Instead, in some such embodiments, second portion 15b of damping chamber 15 may be fluidly coupled to the interior of SPT valve 5

through flowpath 14a'. Flowpath 14a' may include one or more of flow restrictor 25', low pressure relief valve 26', and reverse pressure relief valve as discussed with respect to flowpath 14a. In some such embodiments, flowpath 14a' may be formed in, for example and without limitation, spring housing or other component of outer housing 10a. In such an embodiment, secondary flowpath 14b' may couple between flowpath 14a' and the interior of SPT valve 5. Flow restrictor 25' may slow fluid flow from the interior of SPT valve 5 into second portion 15b of damping chamber 15. In such an embodiment, as damping piston 14 traverses damping chamber 15, flow into second portion 15b of damping chamber 15 may be slowed by flow restrictor 25'.

[0033] In an exemplary operation, SPT Valve 5, in the closed position, may be mated with production tubing, screen and other devices to form production tubing assembly 50. Production tubing assembly 50 may then be lowered into the wellbore and positioned adjacent a production zone (not shown). Normal gravel packing or other formation treatment operations may be conducted normally without opening SPT Valve 5. When access to the formation is desired, a predetermined pressure differential between the interior of SPT valve 5 and the formation may be applied. The pressure differential across shear piston 21 may place a force on the shear piston 21 sufficient to shear opening temporary retainers 23 allowing shear piston 21 to shift downward sliding sleeve 10b. In some embodiments, the amount of pressure differential required may be determined by the number and size of opening temporary retainers 23.

[0034] Subsequently, spring 13 may push spring mandrel 27 and in turn, damping piston 14 and closing sleeve 18 downward to an open position as depicted in FIGS. 2C and 2D. As damping piston 14 moves down, pressure within damping chamber 15 may increase. The increase in pressure within damping chamber 15 may slow down motion of damping piston 14 as fluid flows

through flow restrictor 25 and low pressure relief valve 26 of flowpath 14a from the first portion 15a to the second portion 15b of damping chamber 15. The speed of damping piston 14 and closing sleeve 18 may be controlled by how fast fluid is released through flow restrictor 25 and low pressure relief valve 26. As closing sleeve 18 moves downward, apertures 19 of closing sleeve 18 may move into substantial alignment with fixed apertures 20a of ported housing 20, opening fluid communication between the interior of SPT valve 5 and the wellbore through apertures 19 and fixed apertures 20a. The full opening time may be varied from a few seconds to several hours by changing the configuration of flow restrictor 25, including, for example and without limitation, the diameter and flow path geometry of flow restrictor 25. In some embodiments, the opening flow area may be controlled further by varying the size and location of apertures 19 of closing sleeve 18. In some embodiments, closing sleeve 18 may include one or more low-flow apertures 19b positioned such that as closing sleeve 18 moves from the closed position depicted in FIGS. 2A and 2B to the open position depicted in FIGS. 2C and 2D, the flow area from the interior of SPT valve 5 to the exterior gradually increases as low-flow aperture 19b and subsequently apertures 19 become aligned with fixed apertures 20a of ported housing 20.

[0035] FIGS. 4A and 4B depict isolation valve assembly 100 consistent with at least one embodiment of the present disclosure. In such an embodiment, SPT Valve 105' may be positioned at an upper end of isolation valve assembly 100 may be combined with double pin sub 4'. Flow inlet area 106 of SPT valve 105' may extend down into screen assembly 7' and blank pipe 9'. The top portion of SPT valve 105' may extend above the isolation valve assembly 10' and may mechanically couple to emergency shear joint 3 and pipe 8.

[0036] FIGS. 5A and 5B depict a cross section view of SPT valve 105 consistent with at least one embodiment of the present disclosure in the closed position. In some embodiments, SPT valve 105 may include outer housing 105a and sliding sleeve 105b. Outer housing 105a may include, for example and without limitation, top sub 111, spring housing 112, upper connector 116, ported housing 120, and lower connector 122. Sliding sleeve 105b may include, for example and without limitation, spring mandrel 127, damping piston 114, and closing sleeve 118. In some embodiments, SPT valve 105 may include top sub 111, which may mechanically couple SPT valve 105 to emergency shear joint 3 or other device above. The lower end of top sub 111 may mechanically couple to spring housing 112. Spring housing 112 may be generally tubular. Spring 113 may be positioned within spring chamber 136 formed by spring housing 112 and about spring mandrel 127. Spring 113 may be positioned to exert a force between spring housing 112 and spring mandrel 127. Spring mandrel 127 may in turn exert a force on damping piston 114 as discussed further herein below.

[0037] In some embodiments, spring housing 112 may be mechanically coupled to upper connector 116. Damping chamber 115 may be an annular space formed between outer housing 105a and sliding sleeve 105b. In some embodiments, damping chamber 115 may be formed between upper connector 116, spring housing 112, spring mandrel 127, and damping piston 114. In some embodiments, prior to running into the wellbore, damping chamber 115 may be filled with fluid and may be fluidly sealed by filler plug 117.

[0038] In some embodiments, upper connector 116 may mechanically couple to ported housing 120. Ported housing 120 may include one or more fixed apertures 120a fluidly coupling the interior and exterior of ported housing 120. In some embodiments, ported housing 120 may

mechanically couple to lower connector 122, which in turn may mechanically couple to bottom sub 124.

[0039] In some embodiments, damping piston 114 may transfer the force from spring 113 onto closing sleeve 118. Closing sleeve 118 may include one or more apertures 119 fluidly coupling the interior and exterior of closing sleeve 118. Closing sleeve 118 may in turn exert a force against shear piston 121. Shear piston 121 may be mechanically coupled to bottom sub 124 by one or more opening temporary retainers 123. In some embodiments, while in the closed position as depicted in FIGS. 5A and 5B, closing sleeve 118 may be positioned within ported housing 120 such that apertures 119 are not aligned with fixed apertures 120a of ported housing 120, thereby preventing fluid communication between the interior of SPT valve 105' and the wellbore.

[0040] In some embodiments, damping piston 114 may include at least one low pressure relief valve 26 and at least one flow restrictor 25 positioned to fluidly couple between spring chamber 136 and damping chamber 115 in series as discussed herein above with respect to damping piston 14. Damping piston 114 may also contain at least one relief valve (not shown) installed in the reverse direction.

[0041] In operation, SPT valve 105, in the closed position, may be mated with production tubing, screen and other devices to form production tubing assembly 50. Production tubing assembly 50 may be lowered into the wellbore and positioned adjacent a production zone (not shown). Gravel packing or other formation treatment operations may be conducted normally without opening SPT valve 105. When access to the formation is desired, a predetermined pressure differential between the interior of SPT valve 105 and the formation may be applied. The pressure differential may shear opening temporary retainers 123 and shift shear piston 121

downward. The amount of pressure differential required may be determined by the number and size of opening temporary retainers 123.

[0042] Once shear piston 121 shifts downward, spring 113 may push spring mandrel 127 and in turn, damping piston 114 and closing sleeve 118 downward. As damping piston 114 moves down, pressure within damping chamber 115 may increase. The increase in pressure within damping chamber 115 may slow down motion of damping piston 114. The speed of damping piston 114 and closing sleeve 118 may be controlled by how fast fluid is released through flow restrictor 25 and low pressure relief valve 26. The full opening time may be varied from a few seconds to several hours by changing the configuration of flow restrictor 25, including, for example and without limitation, the diameter and flow path geometry of flow restrictor 25. In some embodiments, the opening flow area may be controlled further by varying the size and location of apertures 119 in closing sleeve 118.

[0043] FIGS. 6A and 6B depict production tubing assembly 250 consistent with at least one embodiment of the present disclosure. In some embodiments, production tubing assembly 250 may include SPT valve assembly 200. In such an embodiment, SPT valve assembly 200 may be positioned on production tubing assembly 250 such that it incorporates the functionality of a double pin sub such as double pin sub 4 as discussed herein above. In some embodiments, flow inlet area f of SPT valve assembly 200 may be positioned at the bottom of SPT valve assembly 200. In such an embodiment, SPT Valve assembly 200 may be located above blank pipe 9.

[0044] FIGS. 7A and 7B depict a cross section view of SPT valve assembly 200 in the closed position. In some embodiments, SPT valve assembly 200 may include outer housing 200a, upper sliding sleeve 200b, and lower sliding sleeve 200c. Outer housing 200a may include, for example

and without limitation, top sub 201, piston connector 204, upper flow tube 231, piston housing 205, upper connector 211, spring housing 216, lower connector 218, lower housing 219, ported housing 221, bottom connector 225, outer bottom sub 226, and inner bottom sub 224. In some embodiments, upper sliding sleeve 200b may include lock piston 206. In some embodiments, lower sliding sleeve 200c may include closing sleeve carrier 228, closing sleeve 210, and damping piston 214.

[0045] In some embodiments, SPT valve assembly 200 may include top sub 201. Top sub 201 may be a generally tubular member. Top sub 201 may serve to mechanically couple SPT valve assembly 200 to a production string, section of production tubing, or other downhole device. In some embodiments, the lower end of top sub 201 may be mechanically coupled to piston connector 204. Piston connector 204 may be mechanically coupled internally to upper flow tube 231 and externally to piston housing 205. In some embodiments, piston connector 204 may house piston snap ring 229 and lock piston 206.

[0046] In some embodiments, piston housing 205 may be mechanically coupled to upper connector 211. Upper connector 211 may be mechanically coupled to spring housing 216. In some embodiments, lock piston temporary retainers 207 may be mechanically coupled between upper connector 211 and lock piston 206. In some embodiments, upper connector 211 may house locking dogs 208. In some embodiments, locking dogs 208 extend through windows 208a formed in upper connector 211. Locking dogs 208 may engage groove 267 formed in the outer surface of closing sleeve carrier 228. In some embodiments, closing sleeve carrier 228 may be mechanically coupled to closing sleeve 210 by backup temporary retainers 209. Closing sleeve 210 may include one or more apertures 222. Apertures 222 may form fluid paths from the interior of closing sleeve 210 to the exterior thereof. Closing sleeve 210 may be positioned such

that when in the closed position, apertures 222 are not aligned with fixed apertures 220 formed in ported housing 221, closing a flow path between the interior of SPT valve assembly 200 and a flow path formed between ported housing 221 and lower housing 219.

[0047] In some embodiments, spring housing 216 may mechanically couple to lower connector 218. In some embodiments, spring housing 216 may house spring 217 and damping piston 214. In some embodiments, prior to running into the wellbore, damping chamber 213 may be filled with fluid and filler plug 233 may be installed. Spring 217 may be compressed between lower connector 218 and damping piston 214. Damping piston 214 may transfer the force from spring 217 onto closing sleeve carrier 228. Lower connector 218 may mechanically couple externally to lower housing 219, and internally to ported housing 221. Lower housing 219 may be mechanically coupled to bottom connector 225 which in turn may be mechanically coupled to outer bottom sub 226. Ported housing 221 may be mechanically coupled to inner bottom sub 224.

[0048] In some embodiments as discussed herein above, damping piston 214 may include at least one insert type low pressure relief valve 26 and at least one flow restrictor 25.

[0049] In operation, SPT valve assembly 200, in the closed position, may be mated with production tubing, screen, and other devices to form production tubing assembly 250. Production tubing assembly 250 may be lowered into the wellbore and positioned adjacent a production zone (not shown). Gravel packing or other formation treatment operations may be conducted without opening SPT valve assembly 200. In some embodiments, lock piston 206 may be exposed to formation pressure on the top side thru ports 203 in the top sub 201. The lower side of lock piston 206 may be exposed to pressure from the interior of SPT valve assembly 200. When

access to the formation is desired, a predetermined pressure differential between the interior of SPT valve assembly 200 and the formation may be applied. The pressure differential may shear lock piston temporary retainers 207 and shift lock piston 206 upward from the locked position to an unlocked position. The amount of pressure differential required may be determined by the number and size of lock piston temporary retainers 207. When lock piston 206 moves upward, locking dogs 208 may be released, allowing spring 217 to push damping piston 214, closing sleeve carrier 228, and closing sleeve 210 upward. Because closing sleeve 210 is moved by spring 217, pressure within SPT valve assembly 200 may not be needed to move closing sleeve 210 upward, and pressure variations within the interior of SPT valve assembly 200 and the wellbore may not affect the movement of closing sleeve 210. As closing sleeve 210 moves upward, one or more of apertures 222 may be substantially aligned with fixed apertures 220 of ported housing 221, opening a flow path between the interior of SPT valve assembly 200 and the wellbore through flow inlet area 230. As damping piston 214 moves upward it creates pressure in damping chamber 213 which tends to slow down motion of damping piston 214. The speed of damping piston 214 and the closing sleeve 210 may be controlled by how fast fluid is released through flow restrictor 25 and low pressure relief valve 26. The full opening time may be varied from a few seconds to several hours by changing flow restrictor 25. The opening flow area may be controlled further by varying the size and location of fixed apertures 220 in ported housing 221 and the size and location of apertures 222 in closing sleeve 210. In some embodiments, apertures 222 may be arranged such that as closing sleeve 210 moves upward into the open position, apertures 222 become sequentially aligned with fixed apertures 220 in ported housing 221, such that the total flow area through SPT valve assembly 200 increases gradually as closing sleeve 210 moves into the open position.

[0050] In some embodiments, closing sleeve 210 may include lower shifting profile 223 and upper shifting profile 227. Lower shifting profile 223 and upper shifting profile 227 may be used to mechanically close or open SPT valve assembly 200. Lower shifting profile 223 may be engaged with a standard wireline shifting tool and may be utilized to shear backup temporary retainers 209 in order to reclose SPT valve assembly 200. In some embodiments, upper shifting profile 227 may be engaged with a standard wireline shifting tool to reopen SPT valve assembly 200 or to perform the initial opening if the pressure actuated opening fails.

[0051] FIGS. 8A, 8B, and 8C depict production tubing assembly 300 consistent with at least one embodiment of the present disclosure. In some embodiments, SPT valve 350 may be positioned on production tubing assembly 300 such that it incorporates double pin sub 382. Flow inlet area 330 of SPT valve 350 may be positioned at a lower end of SPT valve 350. In some such embodiments, SPT Valve 350 may be positioned above blank pipe 9.

[0052] FIGS. 9A, 9B, and 9C depict cross section views of SPT valve 350 in the closed position. In some embodiments, SPT valve 350 may include outer housing 350a, upper sliding sleeve 350b, and lower sliding sleeve 350c. Outer housing 350a may include, for example and without limitation, top sub 341, seal bore 344, upper flow tube 331, piston connector 304, piston housing 305, upper connector 311, spring housing 316, ported housing 321, lower housing 319, outer bottom sub 326 and inner bottom sub 324. In some embodiments, upper sliding sleeve 350b may include lock piston 306. In some embodiments, lower sliding sleeve 350c may include closing sleeve carrier 328 and closing sleeve 310

[0053] In some embodiments, SPT valve 350 may include top sub 341. Top sub 341 may mechanically couple SPT valve 350 to emergency shear joint 3 or other device. In some

embodiments, top sub 341 may be mechanically coupled to seal bore housing 345. In some embodiments, seal bore 344 may include screen 342 and screen mandrel 343. In some embodiments, screen mandrel 343 may be a close fit in the top of seal bore housing 345.

[0054] In some embodiments, seal bore housing 345 may be fluidly coupled to upper flow tube 331. Upper flow tube 331 may mechanically couple to piston connector 304. In some embodiments, piston connector 304 may house piston snap ring 329 and lock piston 306. The bottom end of piston connector 304 may mechanically couple to piston housing 305.

[0055] Piston housing 305 may be mechanically coupled to upper connector 311, which in turn may mechanically couple to spring housing 316. Upper connector 311 may include lock piston temporary retainers 307 which may extend into lock piston 306.

[0056] In some embodiments, upper connector 311 may house locking dogs 308. In some embodiments, locking dogs 308 extend through windows 308a formed in upper connector 311. Locking dogs 308 may engage groove 367 formed in closing sleeve carrier 328. In some embodiments, closing sleeve carrier 328 may be mechanically coupled to closing sleeve 310 by backup temporary retainers 309. Closing sleeve 310 may include one or more apertures 322. Apertures 322 may form fluid paths from the interior of closing sleeve 310 to the exterior thereof. Closing sleeve 310 may be positioned such that when in the closed position, apertures 322 are not aligned with fixed apertures 320 formed in ported housing 321, closing a flow path between the interior of SPT valve 350 and the wellbore.

[0057] In some embodiments, spring housing 316 may mechanically couple to lower connector 318. In some embodiments, spring housing 316 may house spring 317 and damping piston 314. In some embodiments, prior to running into the wellbore, damping chamber 313 may be filled

with fluid and filler plug 335 may be installed. Spring 317 may be compressed between lower connector 318 and damping piston 314. Damping piston 314 may transfer the force from spring 317 onto closing sleeve carrier 328. Lower connector 318 may mechanically couple externally to lower housing 319, and internally to ported housing 321. Lower housing 319 may be mechanically coupled to bottom connector 325 which in turn may be mechanically coupled to outer bottom sub 326. Ported housing 321 may be mechanically coupled to inner bottom sub 324.

[0058] In some embodiments as discussed herein above, damping piston 314 may include at least one insert type low pressure relief valve 26 and at least one flow restrictor 25.

[0059] Such an embodiment of SPT valve 350 may be used on a lowermost zone of a multi-zone wellbore completion. In operation, SPT valve 350, in the closed position, may be mechanically coupled to a production tubing string, screen, and other devices to form production tubing assembly 300. Production tubing assembly 300 may be lowered into the wellbore and positioned adjacent a production zone (not shown).

[0060] In some such embodiments, lock piston 306 may be exposed on one side to internal pressure pushing it upward. The other side of lock piston 306 may be exposed to internal pressure coming through the annular area between seal bore 344 and seal bore housing 345. In such an embodiment, lock piston 306 may not be exposed to a pressure differential during normal gravel packing or other formation treatment operations on the zone where SPT valve 350 is located or on a zone above. After gravel packing operations on the zone above are completed and all valves used in gravel packing are closed, the top side of lock piston 306 may be exposed to pressure from the upper zone. When access to the formation is desired, a predetermined

pressure differential between the interior of SPT valve 350 and the upper formation is applied. The pressure differential may shear lock piston temporary retainers 307, allowing lock piston 306 to shift upward. The amount of pressure differential required may be determined by the number and size of lock piston temporary retainers 307. When lock piston 306 moves upward, locking dogs 308 may be released, allowing spring 317 to push damping piston 314, closing sleeve carrier 328, and closing sleeve 310 upward. As closing sleeve 310 moves upward, one or more of apertures 322 may be substantially aligned with fixed apertures 320 of ported housing 321, opening a flow path between the interior of SPT valve 350 and the wellbore. As damping piston 314 moves upward it creates pressure in damping chamber 313 which tends to slow down motion of damping piston 314. The speed of damping piston 314 and closing sleeve 310 may be controlled by how fast fluid is released through flow restrictor 25 and low pressure relief valve 26. The full opening time may be varied from a few seconds to several hours by changing flow restrictor 25. The opening flow area may be controlled further by varying the size and location of fixed apertures 320 of ported housing 321 and the size and location of apertures 322 in closing sleeve 310. In some embodiments, apertures 322 may be arranged such that as closing sleeve 310 moves upward into the open position, apertures 322 become sequentially aligned with fixed apertures 320 in ported housing 321, such that the total flow area through SPT valve 350 increases gradually as closing sleeve 310 moves into the open position.

[0061] In some embodiments, closing sleeve 310 may include lower shifting profile 323 and upper shifting profile 327. Lower shifting profile 323 and upper shifting profile 327 may be used to mechanically close or open SPT valve 350. Lower shifting profile 323 may be engaged with a standard wireline shifting tool and utilized to shear backup temporary retainers 209 in order to reclose SPT valve 350. Upper shifting profile 327 may be engaged with a standard wireline

shifting tool to reopen SPT valve 350 or to perform the initial opening if the spring powered opening fails.

[0062] FIGS. 10A, 10B, 10C, and 10D depict upper zone production assembly 400 and lower zone production assembly 500 consistent with at least one embodiment of the present disclosure. Each of upper zone production assembly 400 and lower zone production assembly 500 may include an SPT valve, here upper zone SPT valve 450 and lower zone SPT valve 550 as described herein above. Upper zone production assembly 400 and lower zone production assembly 500 may, in some embodiments, be utilized for a dual zone comingled completion. In such an embodiment, upper zone production assembly 400 may include upper zone production packer 401. Below upper zone production packer 401, upper zone production assembly 400 may include frac valve 402, which may be used in gravel packing operations. Frac valve 402 may mechanically couple to upper zone SPT Valve 450. The bottom outer connection of upper zone SPT Valve 450 may be mechanically coupled to a length of pipe 409 which may be mechanically coupled in turn to emergency shear joint 403. Emergency shear joint 403 may mechanically couple to upper zone screen assembly 404. Upper zone screen assembly 404 may be mechanically coupled to seal assembly 405. Seal assembly 405 may, in some embodiments, seal in the bore of lower zone production packer 501.

[0063] In some embodiments, the bottom inner connection of upper SPT valve 450 may be mechanically coupled to isolation tube assembly 486. Isolation tube assembly 486 may include sleeve valve 406. Sleeve valve 406 may, in some embodiments, be mechanically operated. In some embodiments, isolation tube assembly 486 may include length of pipe 407. Pipe 407 may extend through seal assembly 405 and mechanically couple to seal assembly 408. In some

embodiments, seal assembly 408 may seal in seal bore 488 at the top of the lower zone SPT valve 550.

[0064] In some embodiments, lower zone production assembly 500 may include lower zone production packer 501. Lower zone production packer 501 may be mechanically coupled to frac valve 502, which is used in gravel packing operations. Frac valve 502 may mechanically couple to lower zone SPT Valve 550. In some embodiments, the bottom outer connection of lower SPT Valve 550 may be mechanically coupled to pipe 509, which may, in turn, be mechanically coupled to lower emergency shear joint 503. Lower emergency shear joint 503 may be mechanically coupled to pipe 510 and lower zone screen assembly 511. Lower zone screen assembly 511 may be mechanically coupled to seal assembly 512 which may seal in the bore 489 of sump packer 600.

[0065] In some embodiments, the bottom inner connection of lower SPT Valve 550 may be mechanically coupled to lower isolation tube assembly 580. Lower isolation tube assembly 580 may include lower sleeve valve 506. Lower sleeve valve 506 may be mechanically operated. In some embodiments, lower sleeve valve 506 may be closed near the end of gravel packing operations. In some embodiments, lower isolation tube assembly 580 may include pipe 514. In some embodiments, pipe 514 may be capped. In other embodiments, pipe 514 may extend through pipe 510, through lower zone screen assembly 511 and through sump packer 600. Pipe 514 may extend through lower seal assembly 513. In some embodiments, lower seal assembly 513 may seal pipe 514 to pipe 510.

[0066] In operation, sump packer 600 may be positioned in the wellbore first and set below the bottom zone. Sump packer 600 may include locating shoulder 601. If not previously perforated,

the wellbore and formation may be perforated at this time. Lower zone production assembly 500 may be assembled at the surface. Lower zone production assembly 500 may be mechanically coupled to a conventional gravel pack service tool and run into the wellbore. Lower zone production assembly 500 may be positioned such that seal assembly 512 is stabbed into sump packer 600 such that it contacts locating shoulder 601 and such that lower zone screen assembly 511 is positioned adjacent the producing formation. Lower zone production packer 501 may be set, and normal gravel packing or other operations may be conducted. Lower zone lock piston 508, as described herein above with respect to lock piston 306, of lower zone SPT valve 550 may remain balanced throughout this setting and gravel packing operation. Lower zone SPT valve 550 may therefore remain closed.

[0067] In some embodiments, upper zone production assembly 400 may be assembled at the surface. In some embodiments, upper zone production assembly 400 may be mechanically coupled to a conventional gravel pack service tool and run into the wellbore. Upper zone production assembly 400 may be positioned such that seal assembly 408 is stabbed into the lower zone production assembly 500 and seal assembly 405 is stabbed into lower zone production packer 501 and upper zone screen assembly 404 adjacent the producing formation. Upper zone production packer 401 may be set, and normal gravel packing or other operations may be conducted.

[0068] In some embodiments, upper zone lock piston 468 and lower zone lock piston 508 may remain balanced throughout this setting and gravel packing operation. In some embodiments, sleeve valve 406 may be closed near the end of gravel packing operations, and upper zone SPT valve 450 and lower zone SPT valve 550 remain closed.

[0069] After the conclusion of gravel packing or other treatment operations, a production tubing string with a seal assembly (not shown) may be run into the well and the seal assembly may be stabbed into the seal bore at the top of the upper zone SPT valve 450. The production tubing string may include additional packers, valves, and other devices. To start production, pressure within the production tubing string may be increased to slightly above the predetermined set pressure differential of upper zone SPT valve 450 and lower zone SPT valve 550, causing upper zone SPT valve 450 and lower zone SPT valve 550 to open. In some embodiments, pressure within the tubing string may be bled off into the formation, at the surface, or both.

[0070] In the previously described embodiments, the respective closing sleeves 18, 118, 210, and 310 each included apertures 19a, 119, 222, and 322 respectively that, when in alignment with fixed apertures 20a, 120a, 220, and 320 in the respective ported housings 20, 120, 221, and 321, a flow path was opened to the wellbore. In some embodiments of SPT valve 800, as depicted in FIGS. 11A, 11B, and 11C, closing sleeve 810 may be positioned such that when in the closed position, closing sleeve 810 substantially obstructs fixed apertures 820 thereby closing SPT valve 800 as depicted in FIG. 11A. In some embodiments, SPT valve 800 may include closing sleeve 810, closing sleeve carrier 828, damping piston 814, spring 817, lock piston 806, locking dogs 808, and lock piston temporary retainers 807, each of which may operate as described herein above with respect to other embodiments. In some embodiments, closing sleeve 810, when in the open position as previously described, may move such that fixed apertures 820 are at least partially unblocked by closing sleeve 810, thereby opening a flow path to the wellbore as depicted in FIG. 11C.

[0071] In some embodiments, closing sleeve 810 may include one or more low flow apertures 822. Low flow apertures 822 may form a flow path from the interior of closing sleeve 810 to the

exterior thereof. Low flow apertures 822 may be positioned such that they are not aligned with fixed apertures 820 of lower flow tube 821 when closing sleeve 810 is in the closed position as depicted in FIG. 11A. As closing sleeve 810 moves from the closed position depicted in FIG. 11A, low flow apertures 822 may move into alignment with fixed apertures 820 formed in lower flow tube 821 as depicted in FIG. 11B. In such an intermediate position, low flow apertures 822 may provide a flow path from the interior of SPT valve 800 to the wellbore such that the flow area of the flow path is less than the flow area of SPT valve 800 when closing sleeve 810 is in the fully opened position depicted in FIG. 11C. In such an embodiment, flow rate through SPT valve 800 may increase from little to no flow in the closed position depicted in FIG. 11A, an intermediate flow rate in the intermediate position depicted in FIG. 11B, and full flow rate in the open position depicted in FIG. 11C.

[0072] In some embodiments, closing sleeve 810 may be mechanically coupled to closing sleeve carrier 828 by one or more backup temporary retainers 809. In some embodiments, closing sleeve 810 may include upper shifting profile 827. Upper shifting profile 827 may be used to mechanically open SPT valve 800. Upper shifting profile 827 may be engaged with a standard wireline shifting tool to open SPT valve 800 if the pressure actuated opening fails and may be utilized to shear backup temporary retainers 809, thereby separating closing sleeve 810 from closing sleeve carrier 828 and allowing closing sleeve 810 to be moved into the open position. In some embodiments, closing sleeve 810 may include securing flange 850. Securing flange 850 may mate with an upper surface of closing sleeve carrier 828. Securing flange 850 may, in some embodiments, restrict downward motion of closing sleeve 810 relative to closing sleeve carrier 828. In some embodiments, securing flange 850 may reduce the risk of shearing backup temporary retainers 809 while running additional downhole tools through SPT valve 800 in the

case that incidental contact between the additional downhole tool and closing sleeve 810 occurs. In some embodiments, securing flange 850 may be formed integrally with closing sleeve 810. In some embodiments, securing flange 850 may be formed as a snap ring or other collar mechanically coupled to closing sleeve 810.

[0073] The foregoing outlines features of several embodiments so that a person of ordinary skill in the art may better understand the aspects of the present disclosure. Such features may be replaced by any one of numerous equivalent alternatives, only some of which are disclosed herein. One of ordinary skill in the art should appreciate that they may readily use the present disclosure as a basis for designing or modifying other processes and structures for carrying out the same purposes and/or achieving the same advantages of the embodiments introduced herein. One of ordinary skill in the art should also realize that such equivalent constructions do not depart from the spirit and scope of the present disclosure and that they may make various changes, substitutions, and alterations herein without departing from the spirit and scope of the present disclosure.

Claims:

1. A slow pressure triggered valve for a downhole tool comprising:

an outer housing, the outer housing including a ported housing, the ported housing including a fixed aperture, the fixed aperture fluidly coupling the interior of the ported housing with the exterior of the ported housing;

a sliding sleeve positioned within the outer housing, the sliding sleeve including a closing sleeve having an aperture, the aperture not in alignment with the fixed aperture when the closing sleeve is in a closed position and in alignment with the fixed aperture when the closing sleeve is in an open position; and

a damping piston mechanically coupled to the closing sleeve, the damping piston positioned within a damping chamber, the damping chamber being an annular space formed between the outer housing and the sliding sleeve, the damping chamber having a fluid positioned therein, the damping piston separating the damping chamber into a first and second portion, the damping piston including a flowpath fluidly coupling the first and second portions of the damping chamber, the second portion of the damping chamber fluidly coupled to an interior of the sliding sleeve.

2. The slow pressure triggered valve of claim 1, wherein the flowpath comprises one or more of a low pressure relief valve and a flow restrictor.

3. The slow pressure triggered valve of claim 2, wherein the low pressure relief valve is a ball check valve, diaphragm check valve, swing check valve, clapper valve, or a stop-check valve.
4. The slow pressure triggered valve of claim 2, wherein the flow restrictor is an insert-type flow restrictor, orifice flow restrictor, or other flow restrictor.
5. The slow pressure triggered valve of claim 1, further comprising a spring positioned between the outer housing and the sliding sleeve, the spring biasing the closing sleeve into the open position.
6. The slow pressure triggered valve of claim 1, wherein the sliding sleeve further comprises a shear piston, the shear piston mechanically coupled to the outer housing by one or more opening temporary retainers, the opening temporary retainers maintaining the closing sleeve in the closed position until sheared.
7. The slow pressure triggered valve of claim 1, further comprising;
 - a lock piston, the lock piston positioned within the outer housing, the lock piston mechanically coupled to the outer housing and held in a locked position by a lock piston temporary retainer; and
 - a locking dog, the locking dog engaging the sliding sleeve and retaining the sliding sleeve in the closed position, the locking dog biased into the sliding sleeve by the lock piston.
8. The slow pressure triggered valve of claim 7, wherein the sliding sleeve further comprises a closing sleeve carrier, the closing sleeve mechanically coupled to the closing sleeve carrier,

the closing sleeve carrier having a groove formed in the outer surface of the closing sleeve carrier, the locking dogs engaging the groove.

9. The slow pressure triggered valve of claim 8, wherein the closing sleeve is mechanically coupled to the closing sleeve carrier by a backup temporary retainer.
10. The slow pressure triggered valve of claim 9, wherein the closing sleeve further comprises a shifting profile, the shifting profile engageable by a wireline shifting tool to shear the backup temporary retainer and shift the closing sleeve separately from the closing sleeve carrier.
11. The slow pressure triggered valve of claim 9, wherein the closing sleeve further comprises a securing flange extending about the closing sleeve and engaging an upper surface of the closing sleeve carrier.
12. The slow pressure triggered valve of claim 1, wherein the closing sleeve further comprises a low flow aperture, the low flow aperture not in alignment with the fixed aperture when the closing sleeve is in the closed position and in alignment with the fixed aperture when the closing sleeve is in an intermediate position between the closed and open position.
13. A method comprising:

positioning a slow pressure triggered valve in a wellbore, the slow pressure triggered valve including:

an outer housing, the outer housing including a ported housing, the ported housing including a fixed aperture, the fixed aperture fluidly coupling the interior of the ported housing with the exterior of the ported housing;

a sliding sleeve positioned within the outer housing, the sliding sleeve including a closing sleeve having an aperture, the aperture not in alignment with the fixed aperture when the closing sleeve is in a closed position and in alignment with the fixed aperture when the closing sleeve is in an open position; and

a damping piston mechanically coupled to the closing sleeve, the damping piston positioned within a damping chamber, the damping chamber being an annular space formed between the outer housing and the sliding sleeve, the damping chamber having a fluid positioned therein, the damping piston separating the damping chamber into a first and second portion, the damping piston including a flowpath fluidly coupling the first and second portions of the damping chamber, the second portion of the damping chamber in fluid communication with an interior of the closing sleeve;

increasing the pressure within the slow pressure triggered valve;

moving the closing sleeve from the closed position to the open position;

flowing a fluid from the first portion of the damping chamber to the second portion of the damping chamber through the flowpath and thereby slowing motion of the closing sleeve; and

flowing a fluid through the aperture of the closing sleeve and the fixed aperture to or from the wellbore.

14. The method of claim 13, wherein the flowpath comprises one or more of a low pressure relief valve and a flow restrictor, wherein the fluid flowing through the flowpath flows through the low pressure relief valve and flow restrictor.
15. The method of claim 14, wherein the low pressure relief valve is a ball check valve, diaphragm check valve, swing check valve, clapper valve, or a stop-check valve.
16. The method of claim 14, wherein the flow restrictor is an insert-type flow restrictor, orifice flow restrictor, or other flow restrictor.
17. The method of claim 13, wherein the slow pressure triggered valve further comprises a spring positioned between the outer housing and the sliding sleeve, and the moving operation comprises biasing the closing sleeve into the open position with the spring.
18. The method of claim 13, wherein the sliding sleeve further comprises a shear piston, the shear piston mechanically coupled to the outer housing by one or more opening temporary retainers when in the closed position, and the method further comprises shearing the opening temporary retainers before the moving operation.
19. The method of claim 13, wherein the slow pressure triggered valve further comprises:
 - a lock piston, the lock piston positioned within the outer housing, the lock piston mechanically coupled to the outer housing and held in a locked position by a lock piston temporary retainer; and
 - a locking dog, the locking dog engaging the sliding sleeve and retaining the sliding sleeve in the closed position, the locking dog biased into the sliding sleeve by the lock piston;

wherein the method further comprises shearing the lock piston temporary retainer;
sliding the lock piston into an unlocked position; and
disengaging the sliding sleeve with the locking dog.

20. The method of claim 19, wherein the sliding sleeve further comprises a closing sleeve carrier, the closing sleeve mechanically coupled to the closing sleeve carrier, the closing sleeve carrier having a groove formed in the closing sleeve, the locking dogs engaging the groove.

21. The method of claim 20, wherein the closing sleeve is mechanically coupled to the closing sleeve carrier by a backup temporary retainer.

22. The method of claim 21, wherein the closing sleeve further comprises a shifting profile, and the method further comprises:

engaging the shifting profile with a wireline shifting tool;
shearing the backup temporary retainer; and
shifting the closing sleeve separate from the closing sleeve carrier.

23. The method of claim 13, wherein the closing sleeve further comprises a low flow aperture, the low flow aperture not in alignment with the fixed aperture when the closing sleeve is in the closed position and in alignment with the fixed aperture when the closing sleeve is in an intermediate position between the closed and open position, and wherein the method further comprises:

moving the closing sleeve to the intermediate position; and

flowing fluid through the low flow aperture and the fixed aperture.

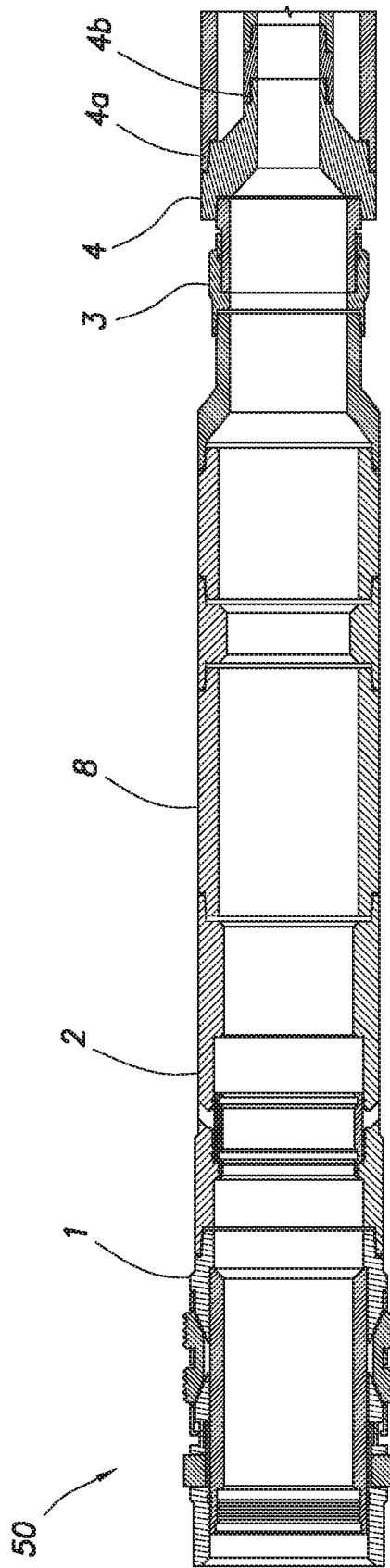


FIG. 1A

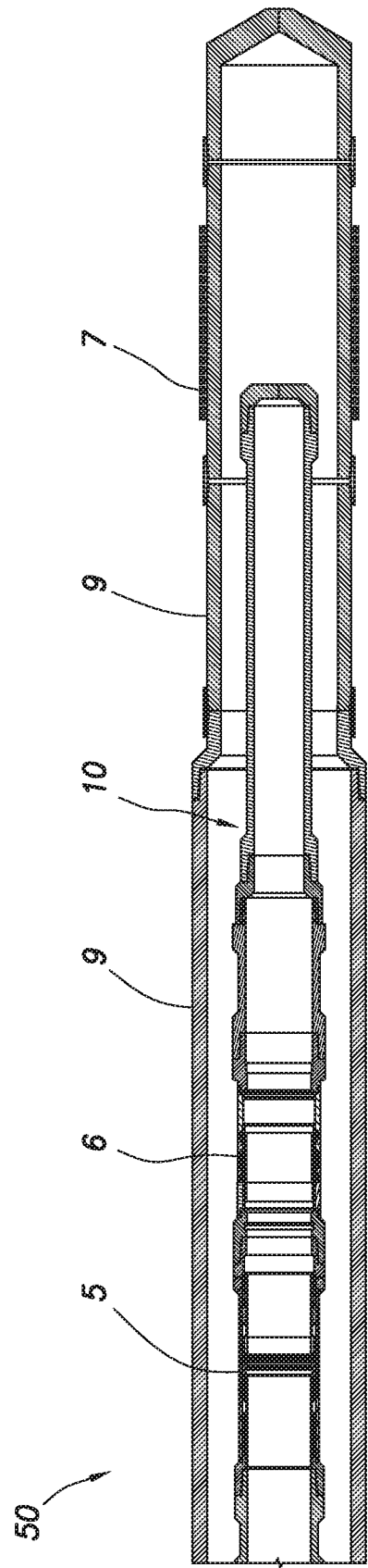


FIG. 1B

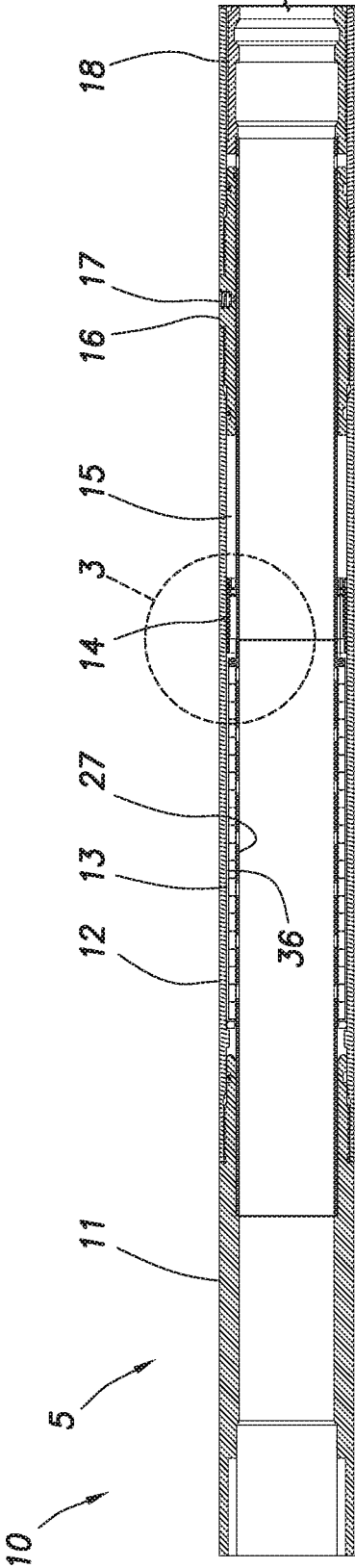


FIG. 2A

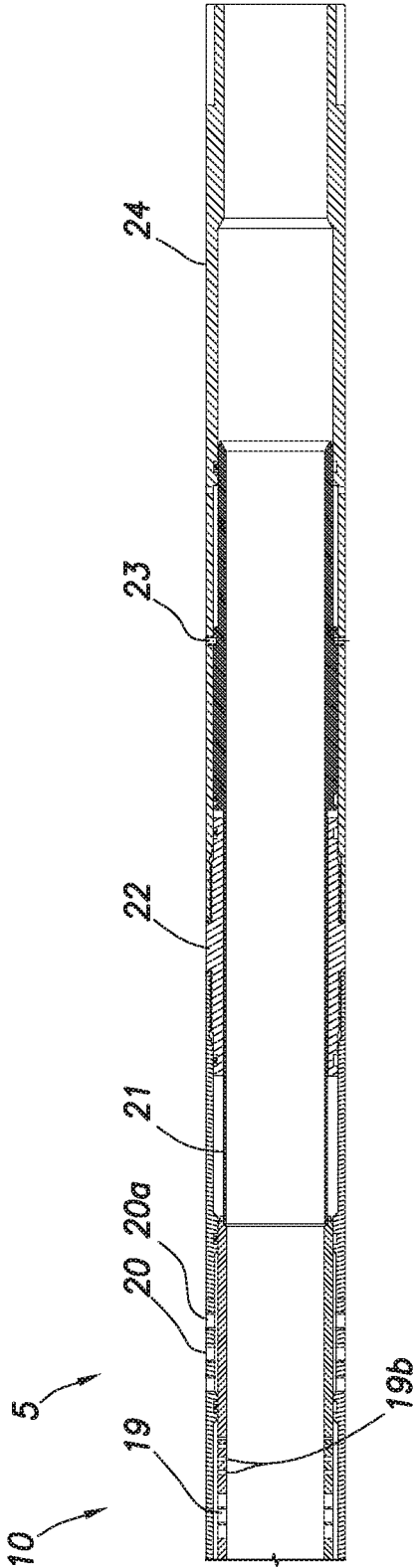


FIG. 2B

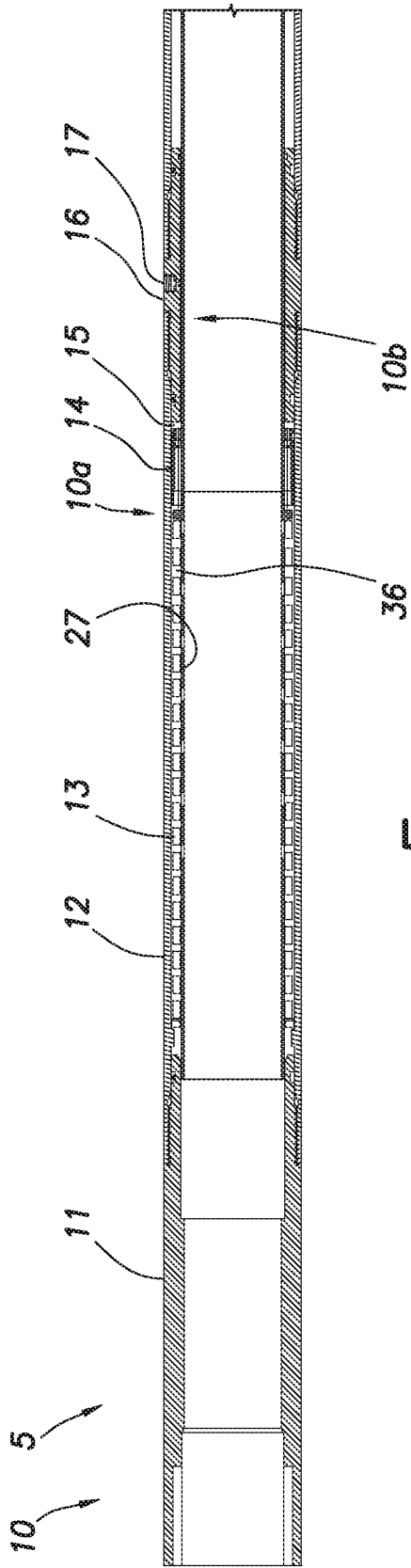


FIG. 2C

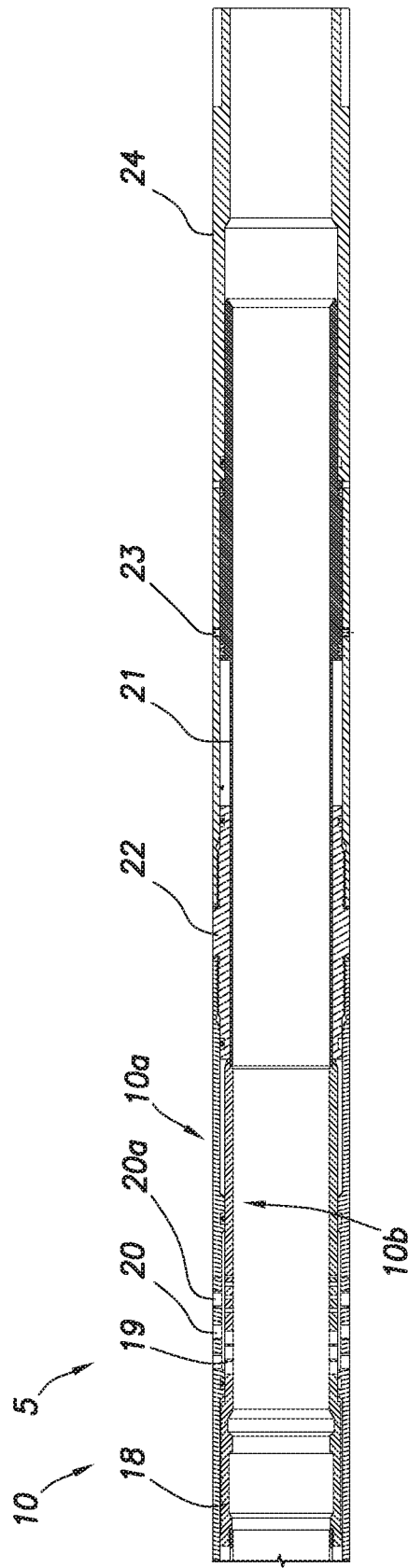
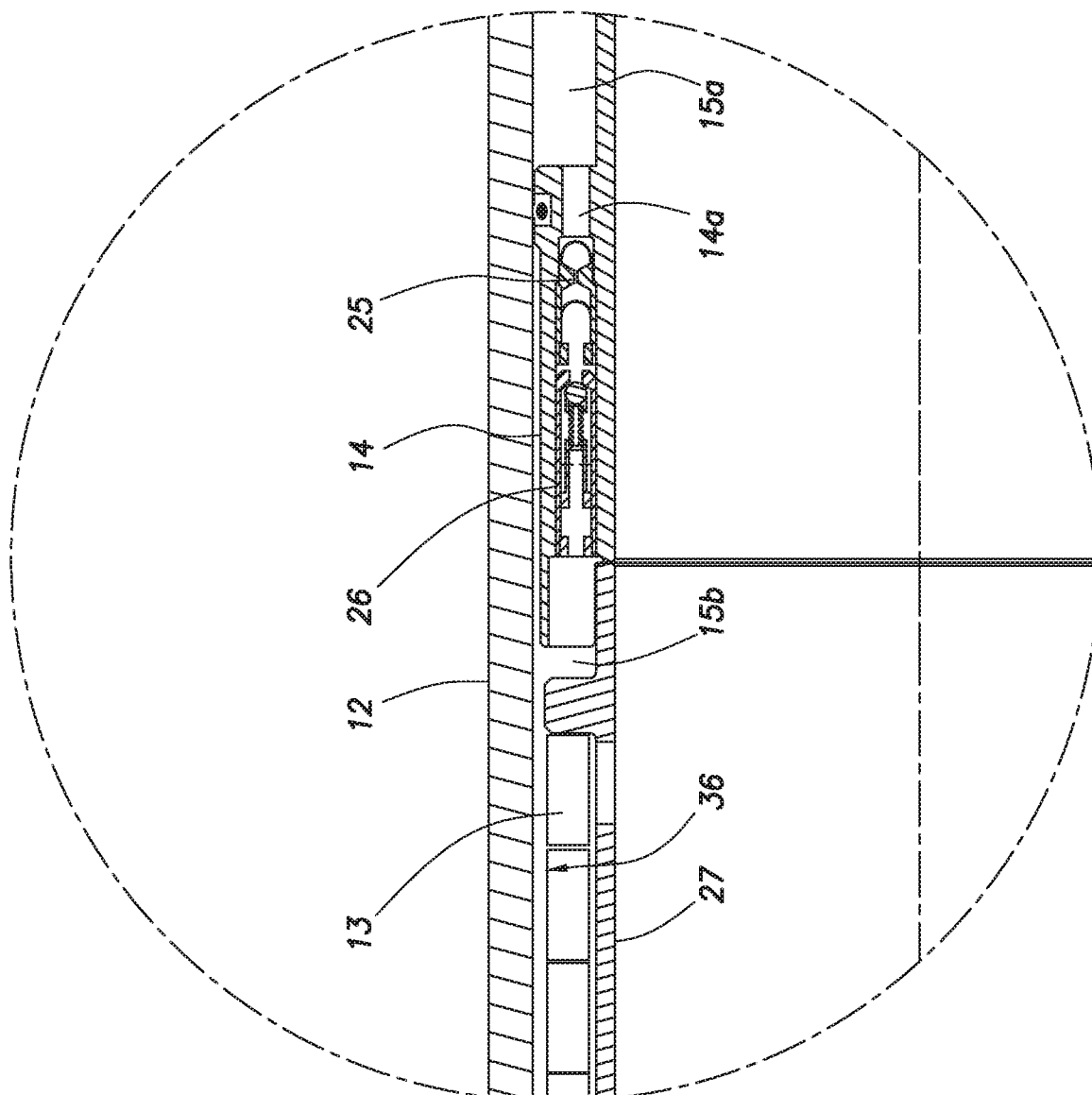


FIG. 2D

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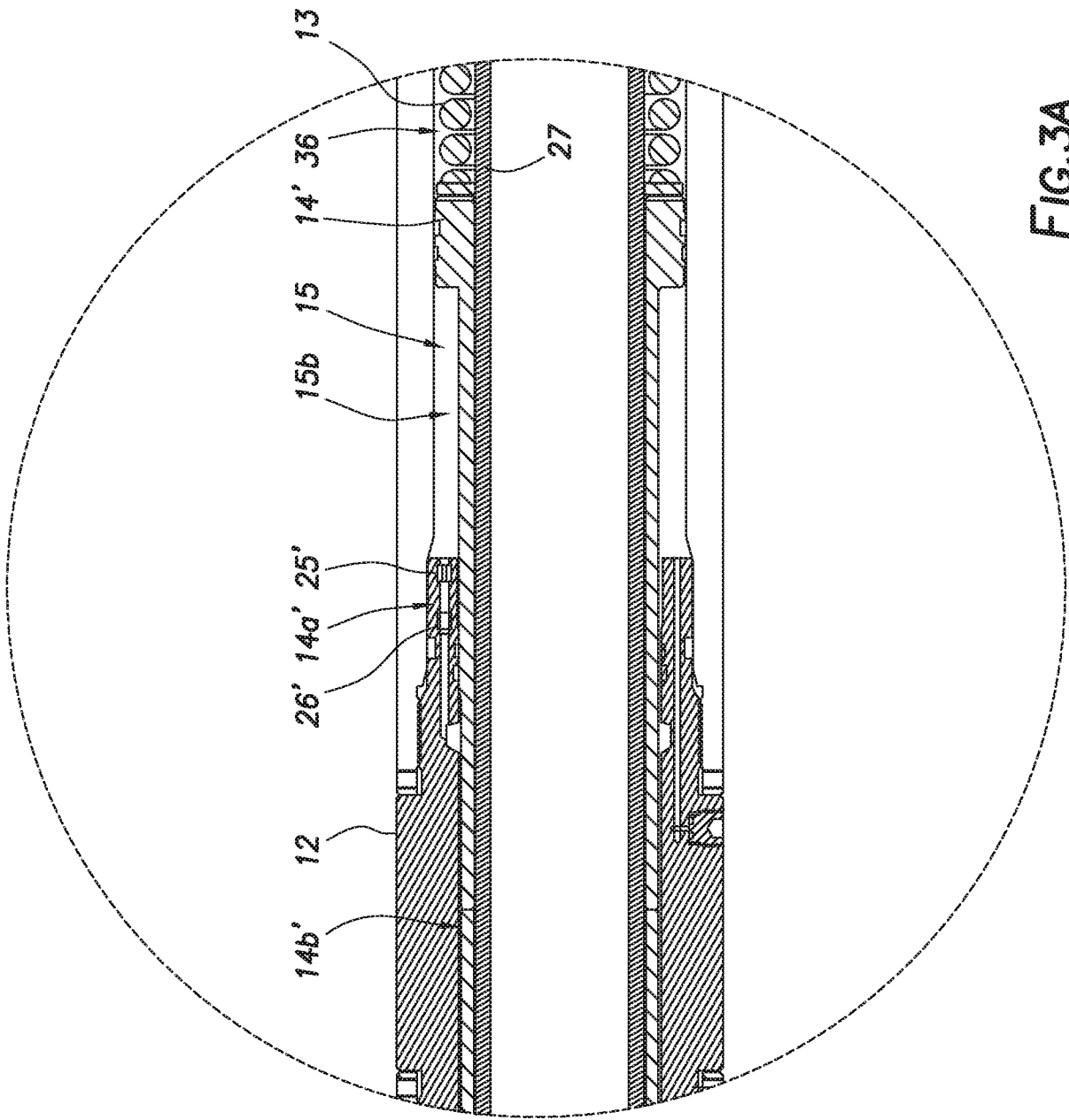


FIG. 3A

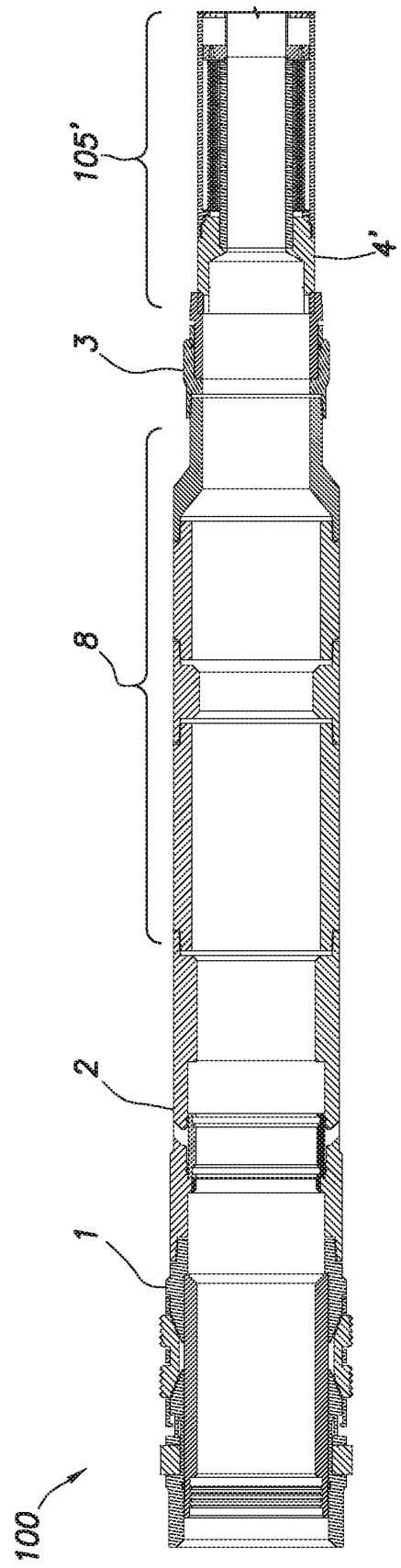


FIG. 4A

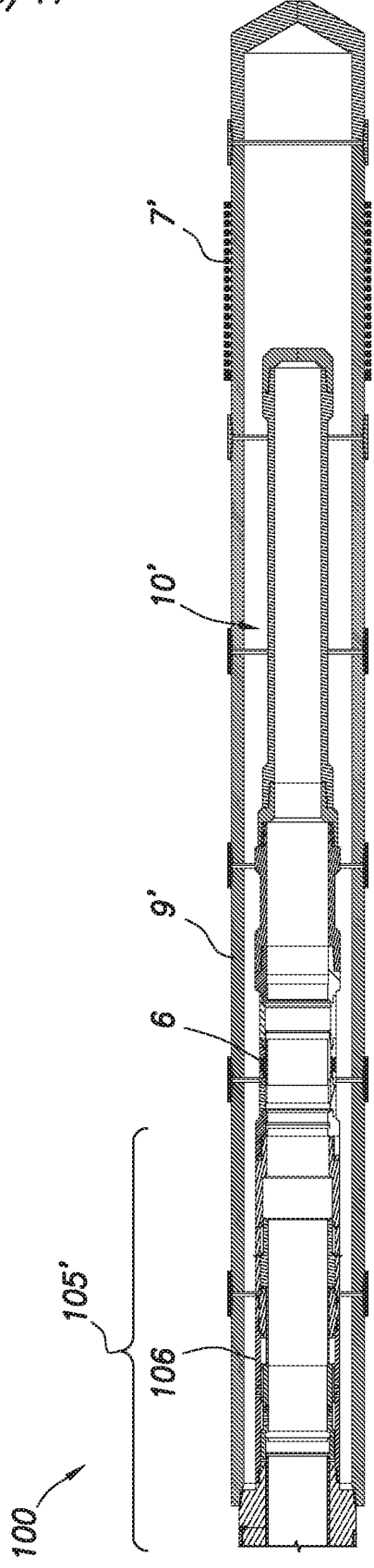


FIG. 4B

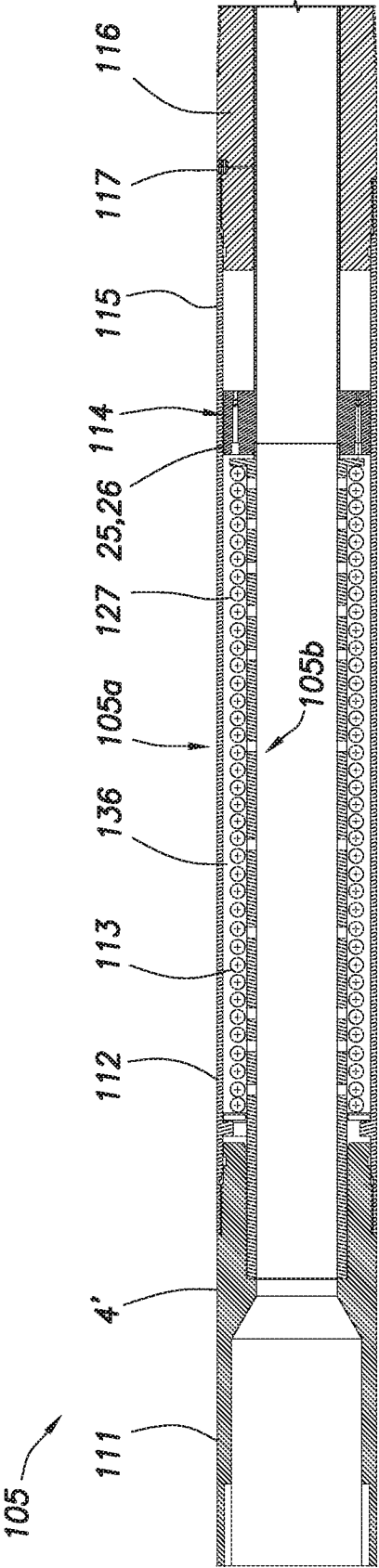


FIG. 5A

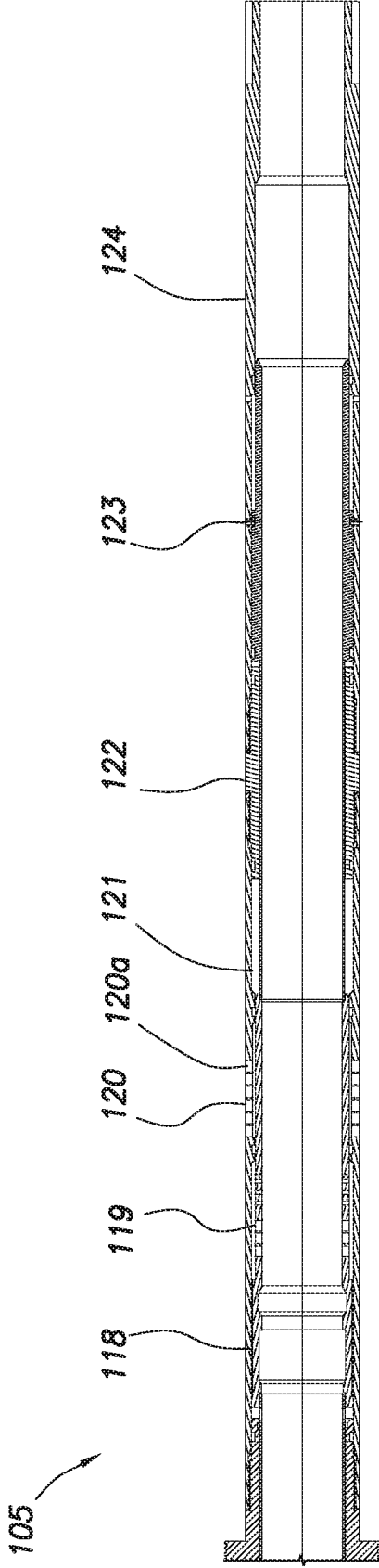


FIG. 5B

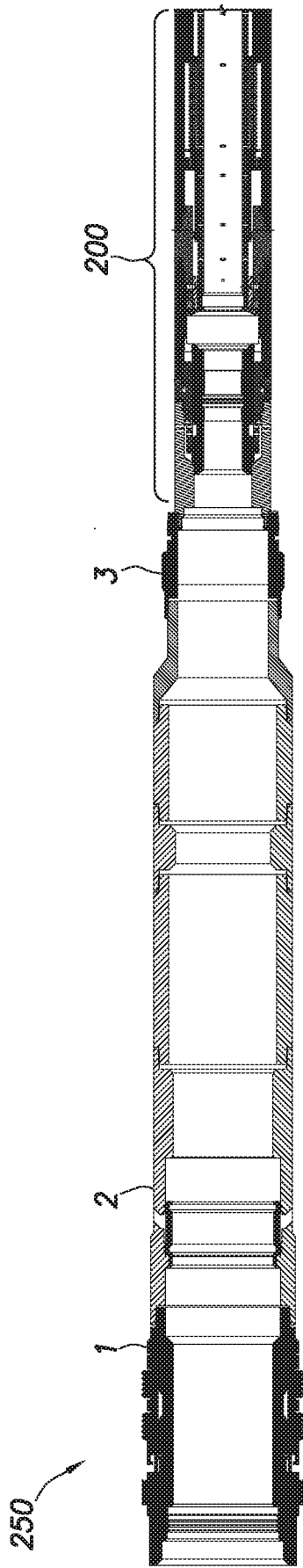


FIG. 6A

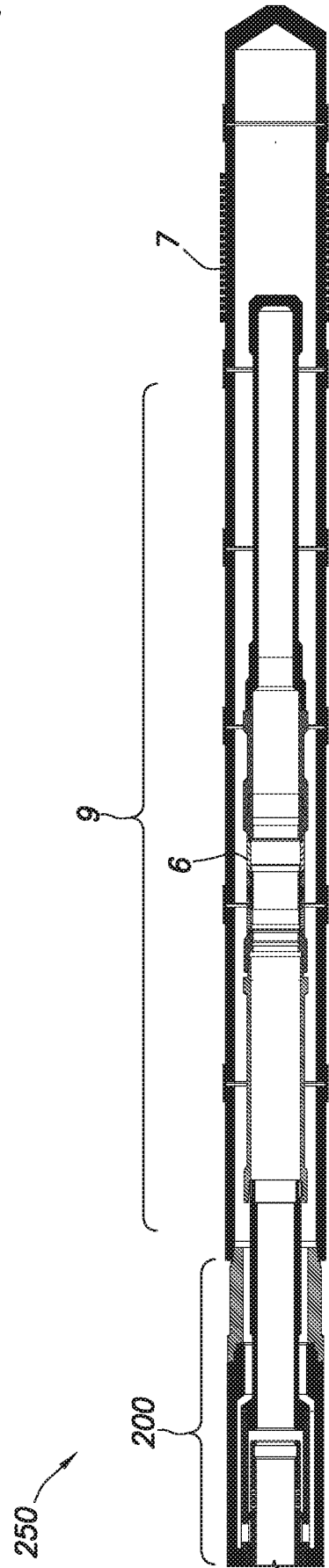


FIG. 6B

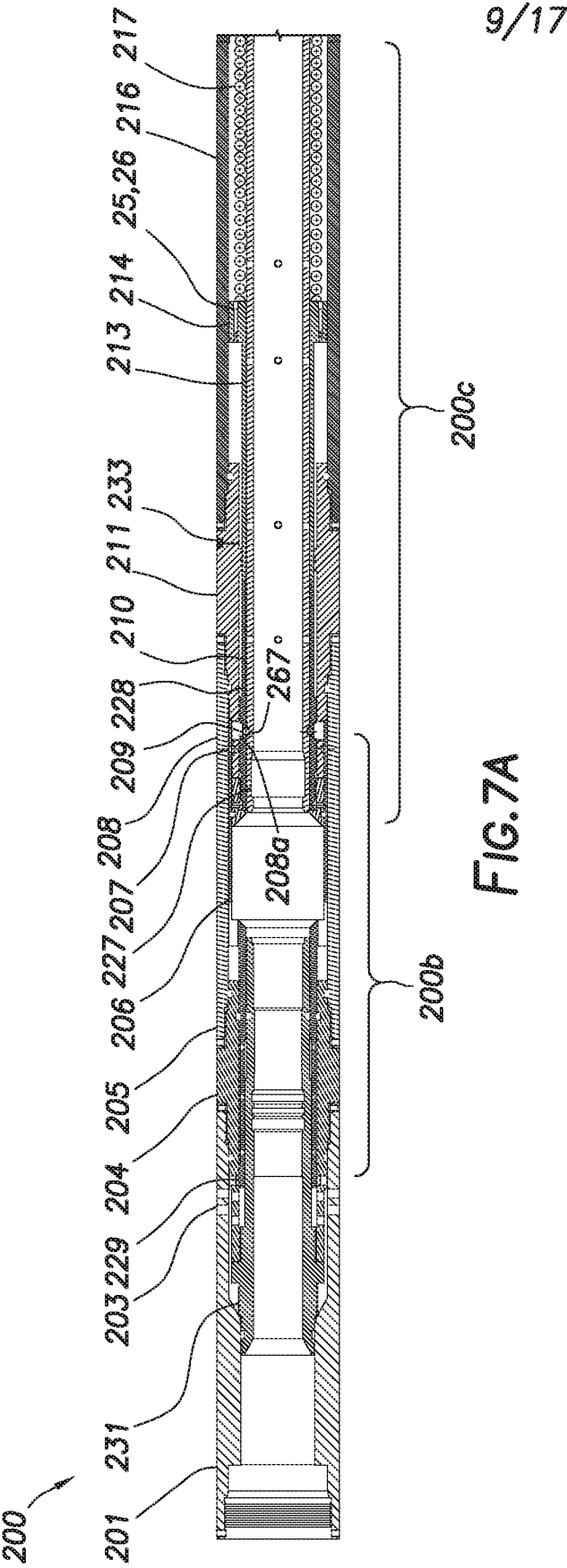


FIG. 7A

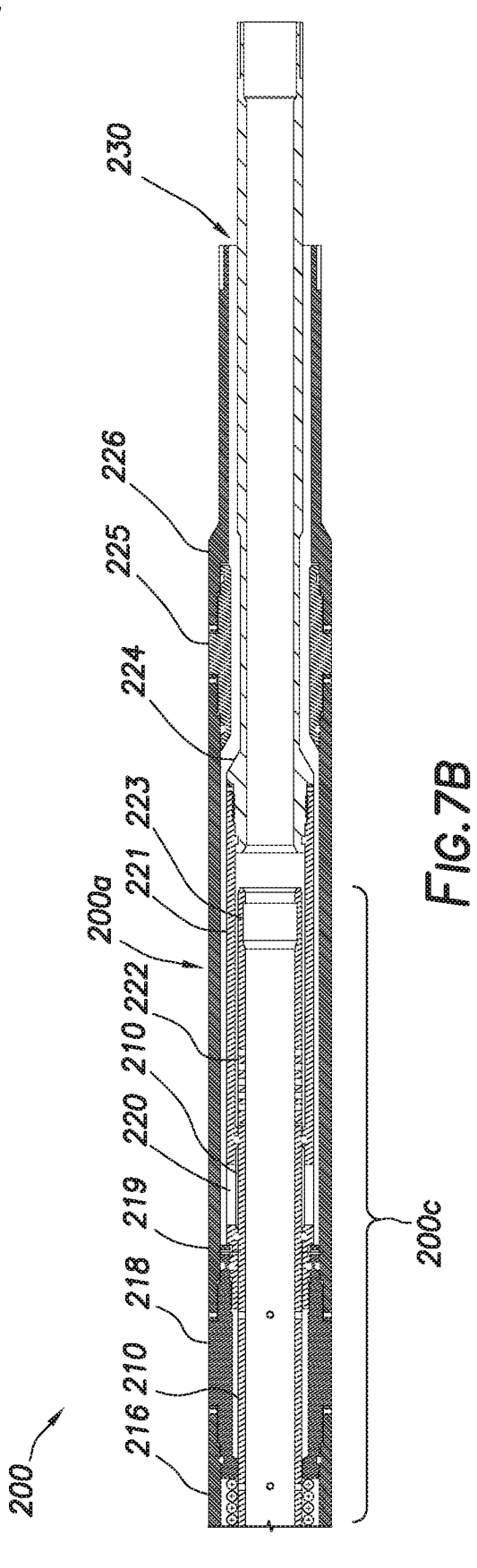


FIG. 7B

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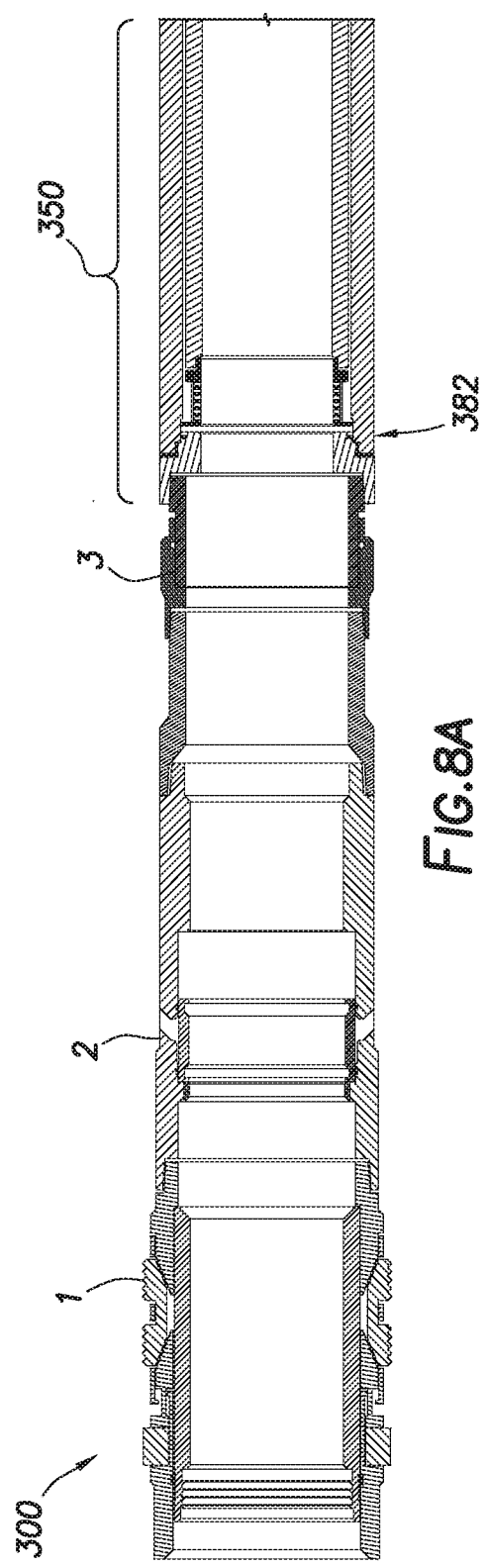


FIG. 8A

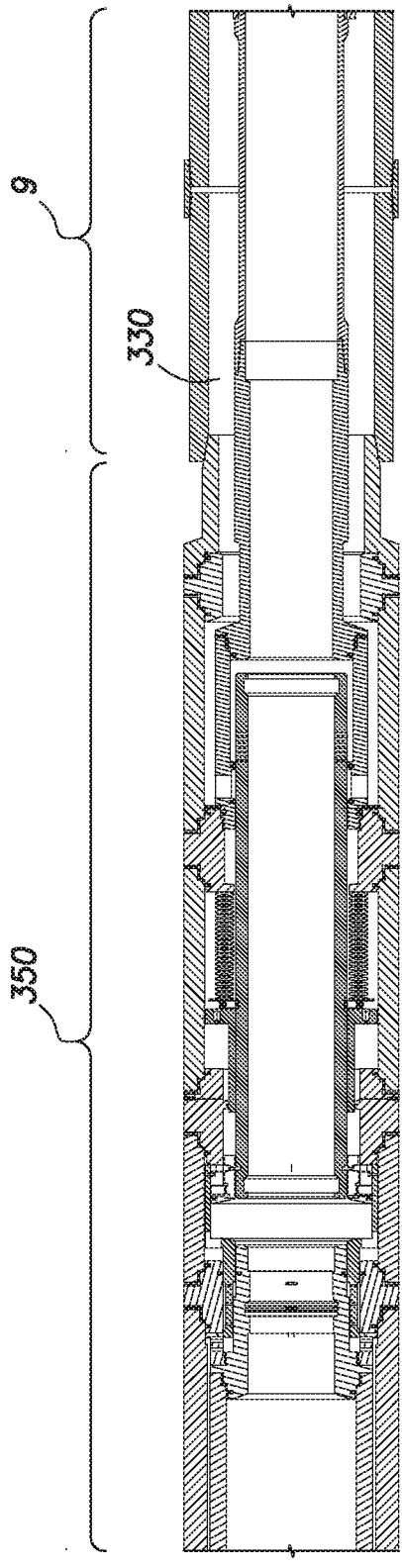


FIG. 8B

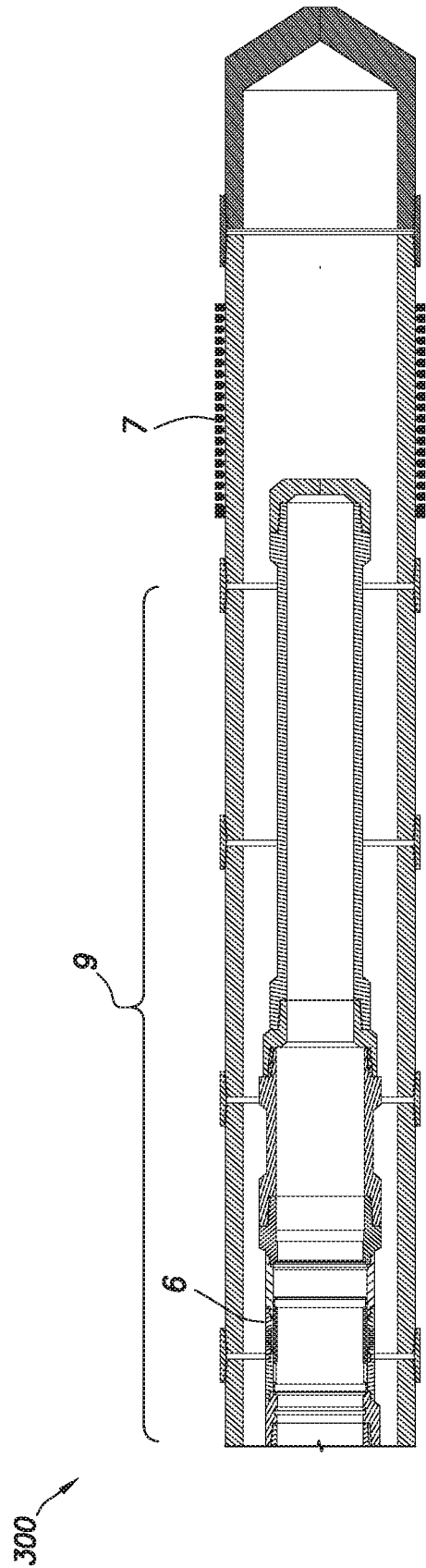


FIG. 8C

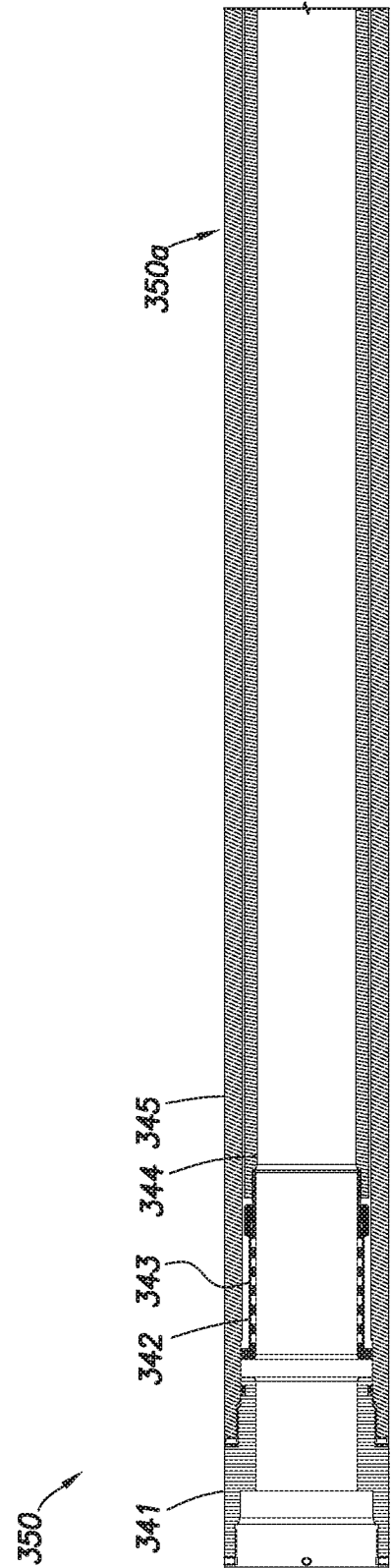
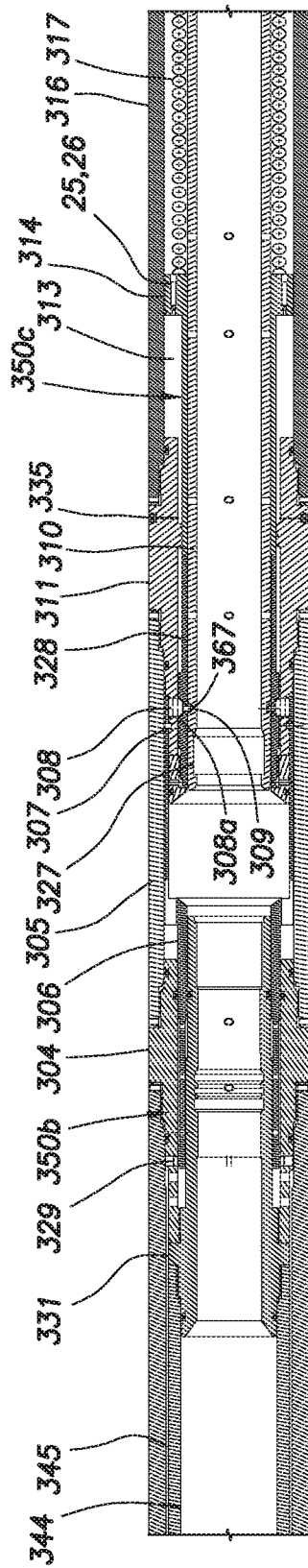


FIG. 9A



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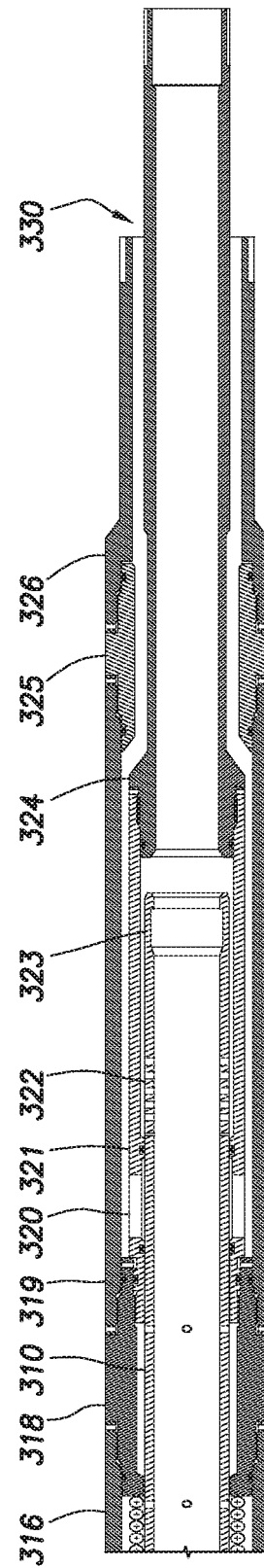


Fig. 9.

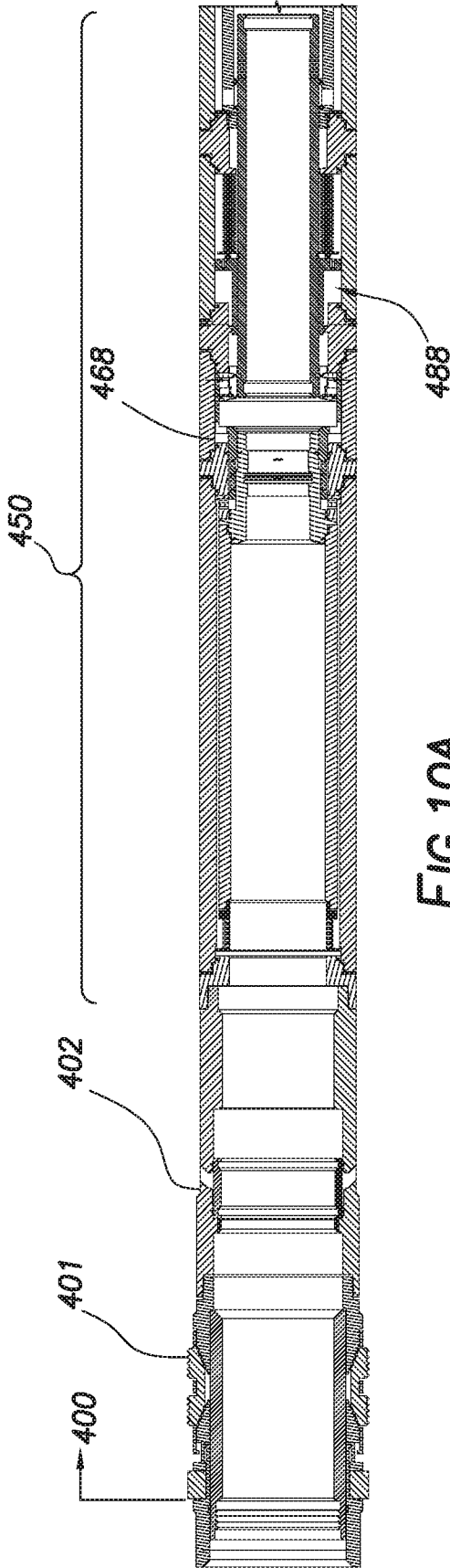


FIG. 10A

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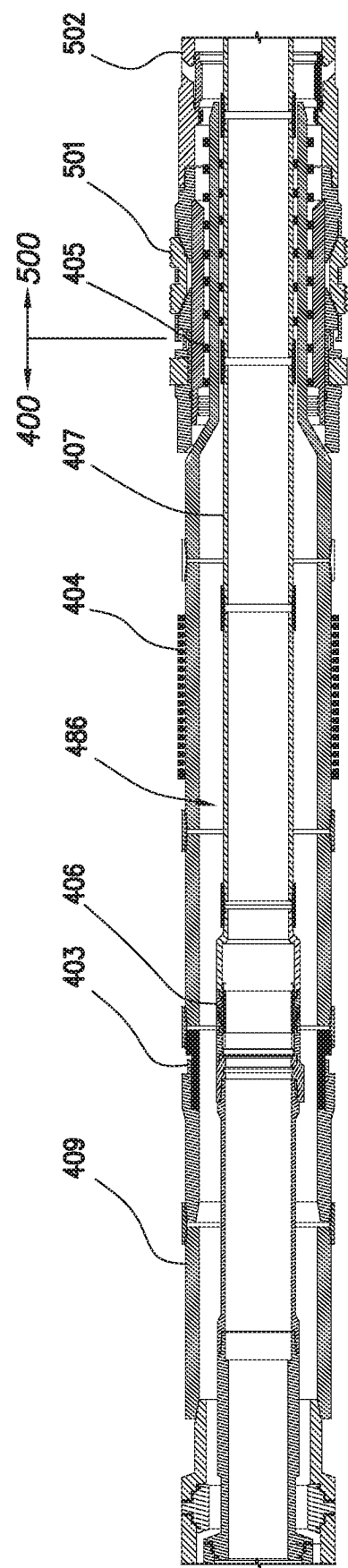


FIG. 10B

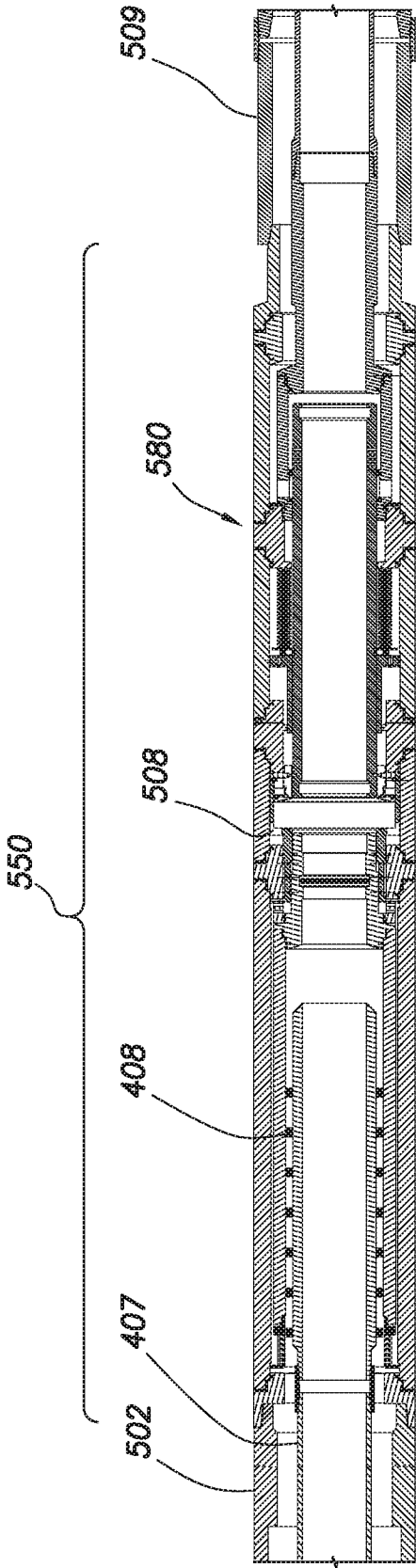


FIG. 10C

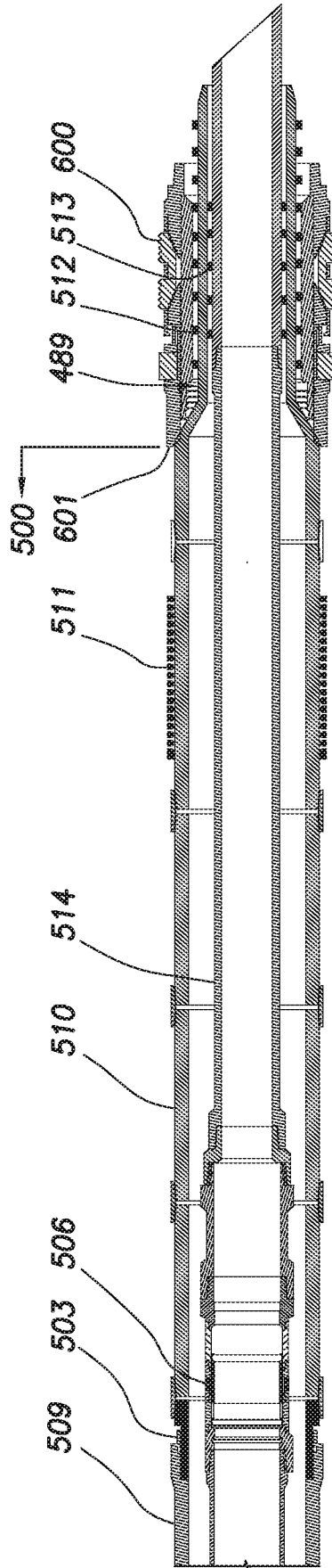


FIG. 10D

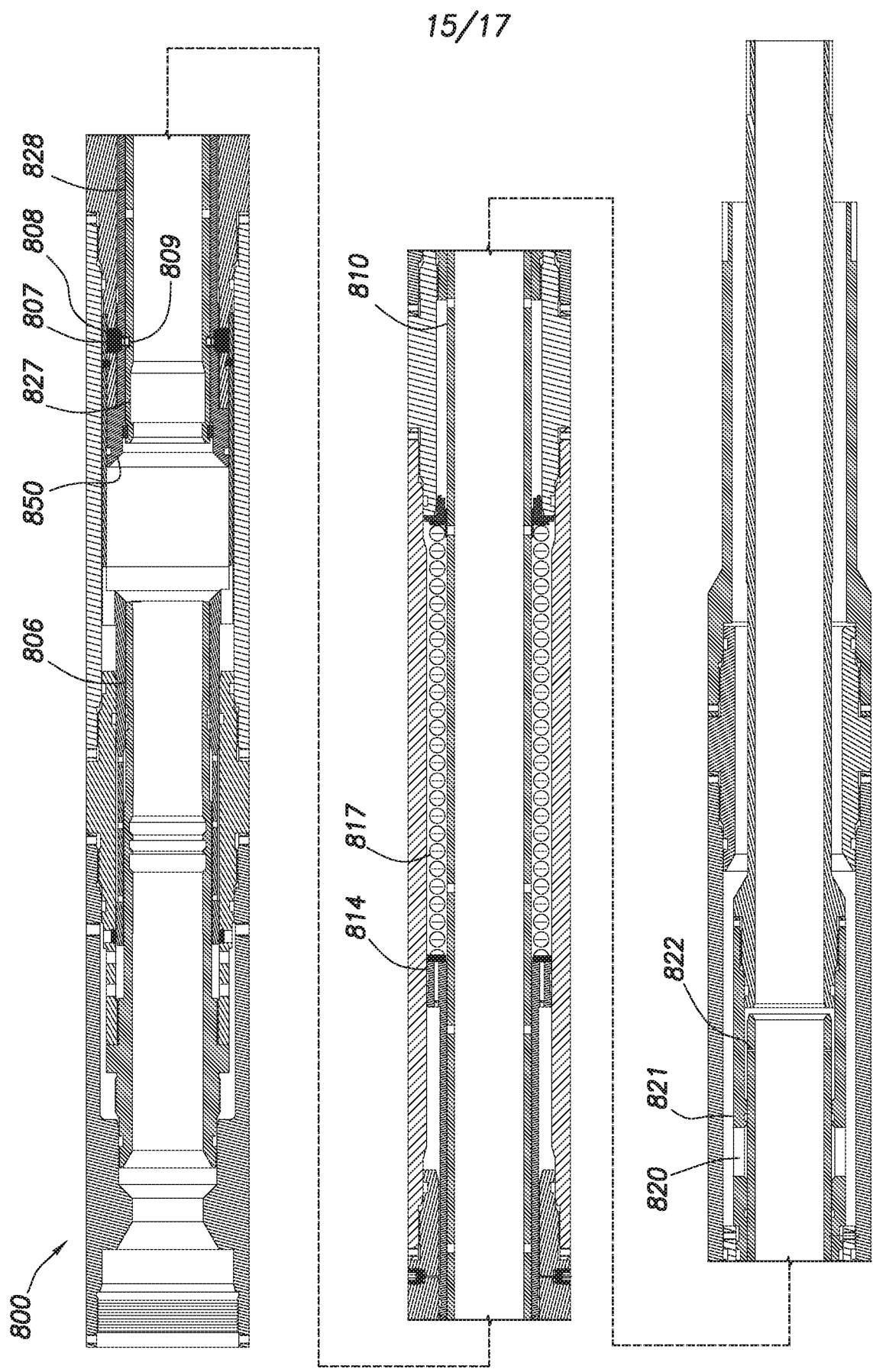


FIG. 11A

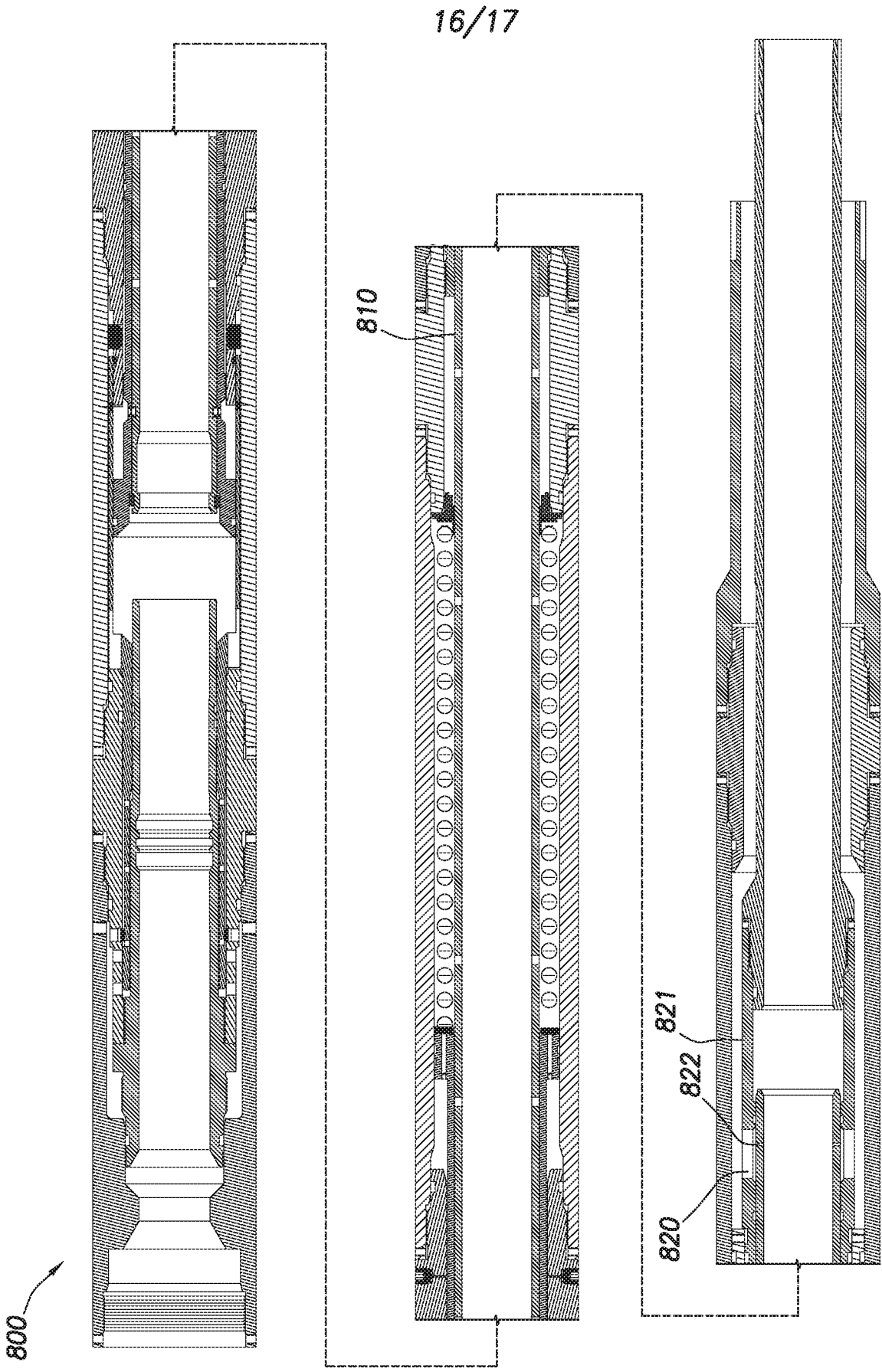


FIG. 11B

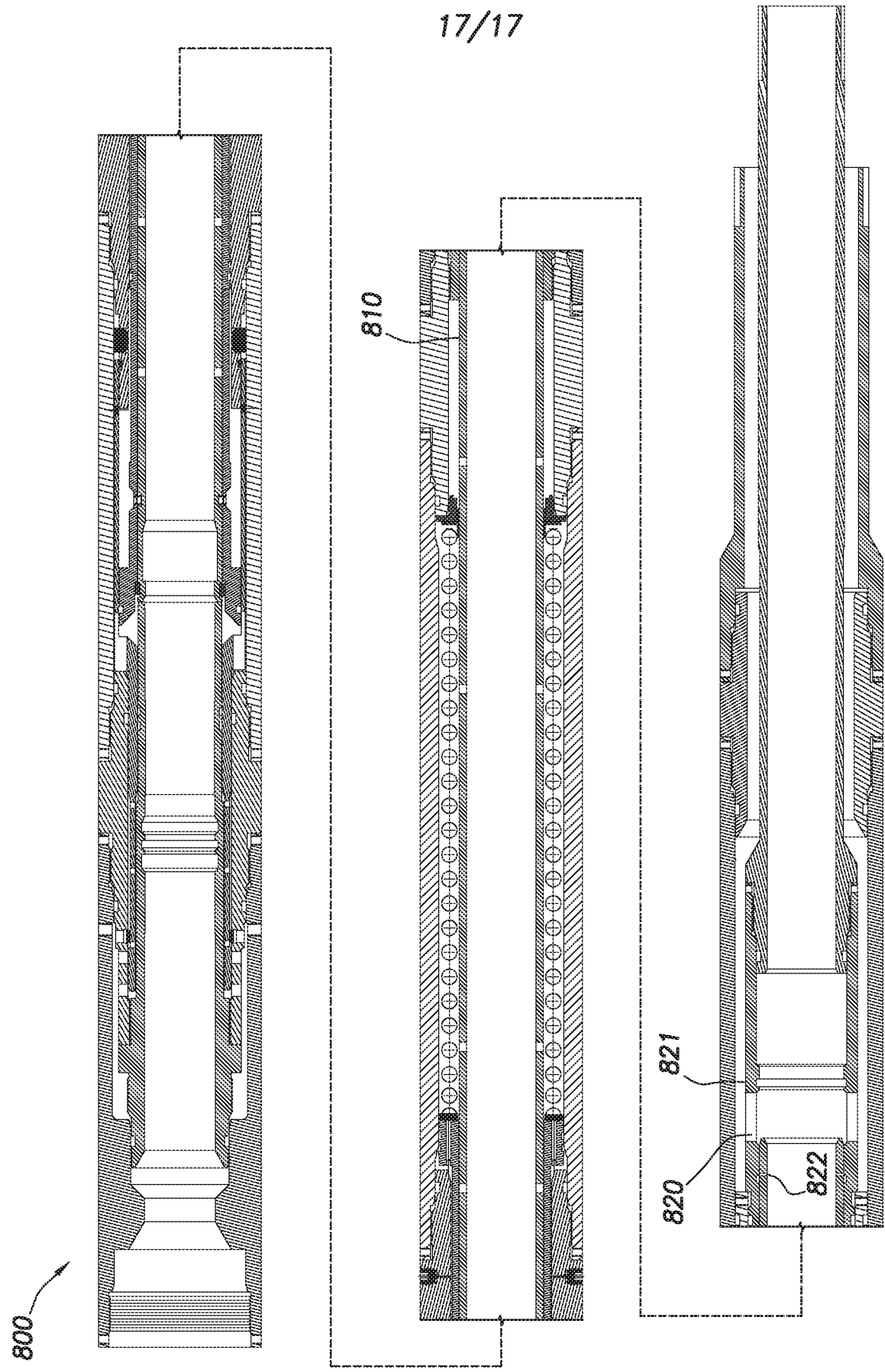


FIG.11C

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2017/031553

A. CLASSIFICATION OF SUBJECT MATTER
 IPC(8) - E21B 34/10; E21B 34/00; E21B 34/06 (2017.01)
 CPC - E21B 34/108; E21B 34/06; E21B 34/10 (2017.05)

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)

See Search History document

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

USPC - 166/319; 166/383; 166/386; 166/387 (keyword delimited)

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

See Search History document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2011/0315389 A1 (CRIDER et al) 29 December 2011 (29.12.2011) entire document	1, 2, 4-6, 13, 14, 16-18
Y	US 2,771,968 A (MERCIER) 27 November 1956 (27.11.1956) entire document	1, 2, 4-6, 13, 14, 16-18
Y	US 6,325,151 B1 (VINCENT et al) 04 December 2001 (04.12.2001) entire document	6, 18
A	US 2011/0315390 A1 (GUILLORY et al) 29 December 2011 (29.12.2011) entire document	1-23
A	US 5,156,210 A (ROTH) 20 October 1992 (20.10.1992) entire document	1-23

☐ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

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"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

03 July 2017

Date of mailing of the international search report

20 JUL 2017

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