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(54) Title: HYDRAULICALLY ACTUATED TOOL WITH ELECTRICAL THROUGHBORE

(57) Abstract: A bottom hole assembly includes a drill string, a bit coupled to an end of the drill string, a rotary steerable system coupled to the drill string above the bit, a hydraulically actuated tool assembly coupled to the drill string above the rotary steerable system, and an electrically controlled tool coupled to the drill string above the hydraulically actuated tool assembly and electrically coupled to the rotary steerable system. A method includes running a bottom hole assembly downhole, the bottom hole assembly including a drill bit, a rotary steerable system, an electrically controlled tool, and a hydraulically actuated tool assembly disposed between the rotary steerable system and the electrically controlled tool. The method includes cutting a formation with the drill bit, actuating the hydraulically actuated tool assembly, and maintaining an electrical connection between the rotary steerable system and the electrically controlled tool during the running, the cutting, and the actuating.

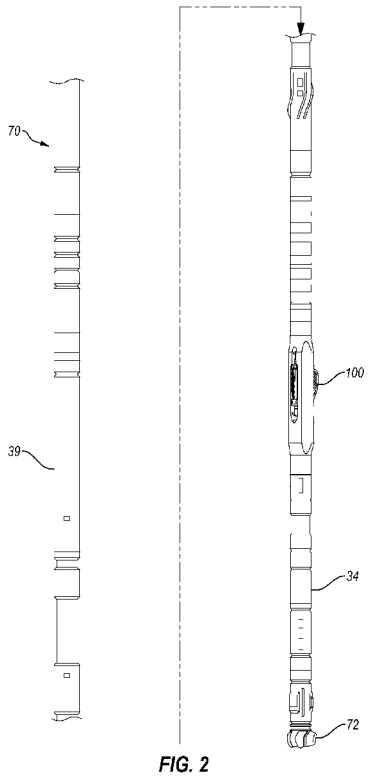

FIG. 2

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HYDRAULICALLY ACTUATED TOOL WITH ELECTRICAL THROUGHBORE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims priority to United States Provisional Application 61/909,456, filed November 27, 2013, and United States Application No. 14/552,187, filed November 24, 2014, both of which are hereby incorporated by reference in their entireties.

FIELD OF THE INVENTION

[0002] Aspects relate to downhole drilling operations. More specifically, aspects relate to a hydraulically actuated tool with electrical throughbore.

BACKGROUND

[0003] Downhole drilling operations commonly require a downhole tool to be actuated after the tool has been deployed in the borehole. For example, underreamers are commonly tripped into the borehole in a collapsed state (*i.e.*, with the cutting structures retracted into the underreamer tool body). At some predetermined depth, the underreamer is actuated such that the cutting structures expand radially outward from the tool body. Hydraulic actuation mechanisms are used in oilfield services operations and are commonly employed in such operations.

[0004] For example, one hydraulic actuation methodology involves wireline retrieval of a plug (or "dart") through the interior of the drill string to enable differential hydraulic pressure to actuate an underreamer. Upon completion of the reaming operation, the underreamer may be deactuated by redeploying the dart. While commercially serviceable, such wireline actuation and deactuation is both expensive and time-consuming in that it requires concurrent use of wireline or slickline assemblies.

[0005] Another commonly used hydraulic actuation methodology makes use of shear pins configured to shear at a specific differential pressure (or in a predetermined range of pressures). Ball drop mechanisms are also known in the art, in which a ball is dropped down through the drill string to a ball seat. Engagement of the ball with the seat typically causes an increase in differential pressure which in turn actuates the downhole tool. The tool may be deactuated by increasing the pressure beyond a predetermined threshold such that the ball and ball seat are released (*e.g.*, via the breaking of shear pins). While such sheer pin and ball

drop mechanisms are also commercially serviceable, they are generally one-time or one-cycle mechanisms and do not allow for repeated actuation and deactuation of a downhole tool.

[0006] Various other hydraulic actuation mechanisms make use of measurement while drilling (MWD), logging while drilling (LWD) and/or other electronically controllable systems including, for example, computer controllable solenoid valves and the like. Electronic actuation advantageously enables a wide range of actuation and deactuation instructions to be executed and may further enable two-way communication with the surface (*e.g.*, via conventional telemetry techniques). However, these actuation systems tend to be highly complex and expensive and can be limited by the reliability and accuracy of MWD, telemetry, and other electronically controllable systems deployed in the borehole.

SUMMARY

[0007] In one aspect, embodiments disclosed herein relate to a tool assembly that includes a tool body configured to connect with a drill string, a mandrel disposed in the tool body, a piston assembly disposed in the mandrel, and a spring member disposed in the tool body and configured to bias the piston assembly towards a first axial position. The piston assembly has a throughbore and includes a valve piston and a cam piston configured to reciprocate axially in the mandrel. The tool assembly further includes a tubular disposed in the tool body and the throughbore of the piston assembly. The tubular is configured to carry an electrical wire.

[0008] In another aspect, embodiments disclosed herein relate to a bottom hole assembly that includes a drill string, a bit coupled to an end of the drill string, a rotary steerable system coupled to the drill string axially above the bit, a hydraulically actuated tool assembly coupled to the drill string axially above the rotary steerable system, and an electrically controlled tool coupled to the drill string axially above the hydraulically actuated tool assembly. The electrically controlled tool is electrically coupled to the rotary steerable system.

[0009] In another aspect, embodiments disclosed herein relate to a method including running a bottom hole assembly downhole, the bottom hole assembly including a drill bit, a rotary steerable system, an electrically controlled tool, and a hydraulically actuated tool assembly disposed between the rotary steerable system and the electrically controlled tool. The method further includes cutting a formation with the drill bit, actuating the hydraulically actuated tool

assembly, and maintaining an electrical connection between the rotary steerable system and the electrically controlled tool during the running, the cutting, and the actuating.

[0010] In another aspect, embodiments disclosed herein relate to a method including running a bottom hole assembly downhole, the bottom hole assembly including a drill bit, a rotary steerable system a hydraulically actuated reamer tool assembly, a measurement-while drilling/logging-while-drilling (MWD/LWD) tool, and a reamer. The method further includes dropping an activation ball into the bottom hole assembly and actuating the reamer, cutting a formation with the drill bit and the reamer, the cutting the formation forming a rathole between the drill bit and the reamer, and deactuating the reamer and pulling the BHA upward to position the reamer tool assembly proximate the top of the rathole. The method further includes activating the reamer tool assembly and cutting the rathole with the reamer tool assembly, the running, dropping, cutting the formation, deactuating, actuating, and the cutting the rathole being performed while maintaining electrical connection between the rotary steerable system and the MWD/LWD.

[0011] This summary is provided to introduce a selection of concepts that are further described below in the detailed description. This summary is not intended to identify key or essential features of the claimed subject matter, nor is it intended to be used as an aid in limiting the scope of the claimed subject matter.

BRIEF DESCRIPTION OF DRAWINGS

[0012] Figure 1 shows a conventional drilling rig and bottom hole assembly.

[0013] Figure 2 is a schematic of a bottom hole assembly in accordance with embodiments disclosed herein.

[0014] Figure 3 is partial cross-sectional view of an underreamer in a retracted configuration in accordance with embodiments disclosed herein.

[0015] Figure 4 is a partial cross-sectional view of the underreamer of Figure 3 in an extended configuration in accordance with embodiments disclosed herein.

[0016] Figure 5 is a cross-sectional view of a hydraulically actuated tool assembly in accordance with embodiments disclosed herein.

[0017] Figure 6 is a partial cross-sectional view of a portion of the tool assembly shown in Figure 5 in a first configuration in accordance with embodiments disclosed herein.

[0018] Figure 7 is a partial cross-sectional view of a portion of the tool assembly shown in Figure 5 in a second configuration in accordance with embodiments disclosed herein.

[0019] Figure 8 is a side view of a tubular configured to carry an electrical wire or cable through a tool assembly in accordance with embodiments disclosed herein.

[0020] Figure 9 is a cross-sectional view of a tool assembly having a tubular configured to carry an electrical wire or cable in accordance with embodiments disclosed herein.

[0021] Figure 10 is a schematic of a bottom hole assembly in accordance with embodiments disclosed herein.

[0022] Figure 11 is a perspective view of a reamer block for a tool assembly in accordance with embodiments disclosed herein.

[0023] Figure 12 is a perspective view of a cutter block for a tool assembly in accordance with embodiments disclosed herein.

DETAILED DESCRIPTION

[0024] Embodiments disclosed herein generally relate to a bottom hole assembly (BHA). More specifically, embodiments disclosed herein relate to a bottom hole assembly including a power drive and a reamer. A bottom hole assembly in accordance with embodiments described herein may include a reamer that allows electrical communication through a central throughbore of the reamer, for example, from a power drive to an electrically controlled or actuated tool, such as a measurement-while-drilling (MWD) and/or logging-while-drilling (LWD) tool, or a caliper tool.

[0025] Figure 1 depicts an offshore drilling assembly, generally denoted 50, suitable for use with a downhole tool in accordance with embodiments disclosed herein. In Figure 1 a semisubmersible drilling platform 52 is positioned over an oil or gas formation (not shown) disposed below the sea floor 56. A subsea conduit 58 extends from deck 60 of platform 52 to a wellhead installation 62. The platform may include a derrick and a hoisting apparatus for raising and lowering the drill string 70, which, as shown, extends into borehole 80 and includes drill bit 72 and a hydraulically actuated tool assembly 100 disposed. The drill string 70 may optionally further include substantially any number of other downhole tools (collectively referred to as the BHA 33) including, for example, MWD/LWD tools, stabilizers, a drilling jar, a rotary steerable tool, and a downhole drilling motor. The

hydraulically actuated tool assembly 100 may be disposed in substantially any location along the string, for example, just above the bit 72 or further uphole above various MWD/LWD tools. The invention is explicitly not limited in these regards.

[0026] As used herein, a MWD/LWD tool(s) refers to a MWD tool and/or a LWD tool. The MWD/LWD tool may include one or more individual tools. The MWD/LWD tool may evaluate physical properties including, for example, pressure, temperature, and wellbore trajectory, and formation parameters, such as resistivity, porosity, and sonic velocity, as the tool is run downhole. This information may be stored and/or transmitted to the surface by any method known in the art, for example, by wireline.

[0027] During a drilling operation, drilling fluid (commonly referred to as "mud" in the art) is pumped downward through the drill string 70 and the bottom hole assembly (BHA) where it emerges at or near the drill bit 72 at the bottom of the borehole. The mud serves several purposes, for example, including cooling and lubricating the drill bit, clearing cuttings away from the drill bit and transporting them to the surface, and stabilizing and sealing the formation(s) through which the borehole traverses. The discharged mud, along with the borehole cuttings and sometimes other borehole fluids, then flow upwards through the annulus 82 (the space between the drill string 70 and the borehole wall) to the surface. In some embodiments of the present disclosure, the tool assembly 100 makes use of the differential pressure between an internal flow channel and the annulus to selectively actuate and deactuate certain tool functionality (*e.g.*, the radial extension of a cutting structure outward from a tool body).

[0028] It will be understood by those of ordinary skill in the art that the configuration illustrated in Figure 1 is an example of a drilling assembly in which a bottom hole assembly in accordance with the present disclosure may be used. It will be further understood that embodiments in accordance with the present disclosure are not limited to use with a semisubmersible platform 52 as illustrated in Figure 1. Embodiments of the present disclosure may also be used with any kind of subterranean drilling operation, either offshore or onshore.

[0029] Referring now to Figure 2, in accordance with embodiments of the present disclosure, the BHA 33 may include drill bit 72, tool assembly 100, one or more MWD/LWD tool 39, and a rotary steerable system 34. One of ordinary skill in the art will understand that the rotary steerable system 34 is a power driven tool used for directional drilling. The rotary

steerable system 34 allows continuous rotation of the drill string while steering the bit. Rotary steerable system 34 may be any rotary steerable system known in the art, including push-the-bit systems and point-the-bit systems. The rotary steerable system 34 includes a bias unit (not shown) and a control unit (not shown). The bias unit applies a force to the bit 72 in a controlled direction. The control unit may include self-powered electronics, sensors, and a control mechanism. The MWD/LWD tool 39 may be electrically coupled to the rotary steerable system 34. The electrical connection between the rotary steerable system 34 and the MWD/LWD tool 39 may provide power to the MWD/LWD tool for operating the various components of the MWD/LWD tool, such as sensors, transducers, and transmitters.

[0030] As shown in Figure 2, the BHA 33 includes a tool assembly 100 disposed axially (*i.e.*, along the length or longitudinal axis of the drill string 70) above the rotary steerable system 34 and axially below the MWD/LWD tool 39. In other words, the tool assembly 100 is disposed on the drill string between the MWD/LWD tool 39 and the rotary steerable system 34.

[0031] In one embodiment of the present disclosure, tool assembly 100 may include an underreamer configured for selective hydraulic actuation and deactuation. By actuate and deactuate (or activate and deactivate) it is meant that the reamer cutting structures 105 (referred to herein as blades or blocks) may be extended radially outward from the tool body 110 and retracted radially inward towards (or into) the tool body 110. Figures 3 and 4 depict one embodiment of an underreamer in retracted (*i.e.*, deactivated as shown on Figure 3) and extended (activated as shown on Figure 4) configurations. In certain tool configurations, the blades may be fully extended when the hydraulic pressure exceeds a predetermined threshold. The blades may be spring biased inwards and retract upon removal of the pressure. These reamers may therefore be thought of as having two operational configurations: (i) a low flow (low pressure) configuration in which the blades are retracted and (ii) a high flow (high pressure) configuration in which the blades are extended. Additional configurations, for example, including a high flow (high pressure) configuration in which the blades are retracted and a mechanism for selecting among the various configurations during a drilling/reaming operation may also be provided. For example, a reamer may be configured to provide an actuation/deactuation system that enables the reamer to be actuated and deactuated substantially any number of times without breaking the tool string or tripping it out of the borehole. For example, a drilling tool assembly, including a reamer disposed axial above a

drill bit, may be configured to drill a portion of the wellbore with the reamer deactivated (with the reamer blades 105 retracted as depicted on Figure 3). At some specific (or predetermined) location, the reamer may be activated (with the reamer blades 105 extended as depicted on Figure 4) so as to form a wellbore having an increased diameter. The reamer may then be deactivated at substantially any other suitable location and the drill bit alone may be used to drill another length of the wellbore. Substantially any number of such activation/deactivation cycles may be performed in drilling the wellbore.

[0032] It will be understood that tool assembly embodiments in accordance with the present disclosure are not limited to underreamers such as depicted on Figures 3 and 4. Various embodiments of tool assemblies disclosed herein may be used to actuate substantially any downhole tool for which hydraulic actuation and deactuation may be advantageous. Such tools may include hydraulically actuated stabilizers, milling tools, packers, impact tools, and the like.

[0033] One example of a tool assembly that may be used in accordance with embodiments disclosed herein is shown and disclosed in U.S. Application No. 13/112,326 (U.S. Publication No. 2011/0284233), which is incorporated herein by reference in its entirety.

[0034] Figure 5 depicts one embodiment of a hydraulically actuated tool assembly 100 in longitudinal cross section in accordance with the present disclosure. In the embodiment shown, the tool assembly 100 includes an underreamer tool body 110 connected to a sub body 120. While the embodiments described herein are specific to reamers, it will be understood that embodiments of the present disclosure may be used to activate/deactivate various downhole tools as described above. A piston assembly 200 is disposed substantially co-axially in the tool and sub bodies 110 and 120 and is configured to reciprocate axially therein. Piston assembly 200 includes a valve piston 210 connected to a cam piston 240 (*e.g.*, via locking nut 238). A helical compression spring 252 is disposed axially between a lower face of the cam piston 240 and a mandrel cap 222 disposed in the sub body 120. In the embodiment shown, the cam piston 240 and the spring 252 are disposed about a cam mandrel 265, with an outer surface of the mandrel 265 being sealingly engaged with an inner surface 241 of the cam piston 240. Compression spring 252 is configured to bias the cam piston 240 (and therefore piston assembly 200) in the uphole direction (towards the underreamer tool body 110).

[0035] The piston assembly 200 is configured to reciprocate between a first low flow position and second and third high (or full) flow positions. In the low flow position, the spring force urges (biases) the assembly 200 in the uphole direction such that an uphole engagement face 245 engages internal shoulder 224 of sub body 120 (as shown in Figures 5 and 6). In the second high flow position, fluid force exceeds the spring force and urges the assembly 200 in a downhole direction such that at least one shoulder portion 282 of the cam piston engages at least one stop block 229. In the third high flow position, fluid force again exceeds the spring force and urges the assembly 200 in a downhole direction such that the stop block 229 slides past the shoulder portion 282 of the cam and engages a cam slot 484 (as shown in Figure 6). In the embodiment shown, the stop blocks 229 are disposed in corresponding recesses formed in the sub body and extend radially into the central bore 221 of the sub body 120 where they may engage the cam piston 240 as described above.

[0036] Figure 6 depicts a partial cross section of tool assembly 100 in the low flow configuration. In the embodiment shown, valve piston 210 is disposed substantially co-axially in and sealingly engaged with mandrel sleeve 370 and mandrel 380. Valve piston 210 includes first and second axially spaced sets of circumferentially spaced ports 416 and 418. In the low flow configuration depicted on Figures 5 and 6, ports 416 are sealingly engaged with an inner surface 371 of mandrel sleeve 370 (*i.e.*, such that they are axially misaligned with mandrel ports 385) and ports 418 are sealingly engaged with an inner surface 381 of the mandrel 380. Moreover, as depicted the mandrel ports 385 formed in the mandrel 380 are sealingly engaged with outer surface 411 of valve piston 210 such that there is no fluid communication between ports 385 and the through bore 375. As described in more detail below, tool actuation requires that the valve piston be translated axially such that the first set of ports 416 (the uphole ports) become axially aligned with mandrel ports 385. Such alignment provides fluid communication between the internal bore 375 and the downhole tool via the lower mandrel ports 385.

[0037] With continued reference to Figure 6, cam piston 240 is disposed in and sealingly engaged with sub body 120. The cam piston 240 shown includes first, second, and third axial portions 450, 460, and 480 having distinct outer diameters. The first portion 450 of the cam piston 240 includes a plurality of circumferentially spaced apertures 452 configured to provide fluid communication between the internal bore of the cam and an annular area 318 formed internal to the tool and sub bodies 110 and 120. A second portion 460 of the cam

piston 240 includes a plurality of cam grooves 465 formed in an outer surface thereof. The cam grooves 465 are configured to engage one or more guide pins 327 that extend radially inward from the sub body 120. In the embodiment shown, four guide pins 327 are circumferentially spaced at 90 degree intervals about the sub body (although the present disclosure is not limited in this regard). The guide pins 327 are configured to travel within the cam grooves 465 and rotate the cam piston 240 and the valve piston 210 as the piston assembly 200 reciprocates axially. A third portion 480 of the cam piston 24, having an enlarged diameter and a plurality of lower cam slots 484, is configured to engage at least one stop block 229. In the embodiment shown, four stop blocks 229 are circumferentially spaced at 90 degree intervals about the sub body (although the present disclosure is again not limited in this regard). The guide pin/cam groove and stop block/cam slot interactions are discussed in more detail below with respect to the activation and deactivation mechanisms.

[0038] Referring back to Figure 5, the tool assembly 100 further includes a conduit or tubular 290 extending through a central bore of the tool assembly 100, *i.e.* through central bores of the tool body 110 and the sub body 120. The tubular 290 may be formed from any material known in the art, for example, steel, alloys, and composites. Tubular 290 may be rigid or flexible. As shown, the tubular 290 extends from an upper end of the tool body 110 through a central bore of the valve piston 210 and a central bore of the cam piston 240 to a lower end of the sub body 120. A locking apparatus 137 may be used to secure each end of the tubular 290 to the tool assembly 100. As shown in Figure 5, the tool assembly 100 may further include a bottom sub 119 coupled to the lower end of the sub body 120. In the embodiment shown, a locking apparatus 137 is disposed in a bottom sub 119 and in an upper end of the tool body 110 to secure the tubular 290 within the tool assembly. In one embodiment, the locking apparatus may include a locking sleeve coupled to the inner surface of the tool body 110, the sub body 120, and/or the bottom sub 119. The tubular 290 may extend through the locking sleeve and may be threadedly coupled to the locking sleeve.

[0039] In other embodiments, as shown in Figure 5, the tubular 290 may extend through a first locking sleeve 104 disposed at one end of the tubular 290 and coupled to the upper end of the tool body 110 and through a second locking sleeve 106 disposed at an opposite end of the tubular 290 and coupled to the bottom sub 119. A locking element 103, 107 may be disposed around the tubular 290 and configured to secure the tubular 290 between the two locking sleeves 104, 106, respectively. For example, the locking elements 103, 107 may be

threadedly engaged with the ends of the tubular and tightened against the locking sleeves 104, 106. In some embodiments, locking elements may include jam nuts. One of ordinary skill in the art will appreciate that other apparatus and mechanisms may be used to secure the ends of the tubular 290 within the tool assembly 100 without departing from the scope of the present disclosure. The locking sleeves 104, 106 and locking elements 103, 107 may also provide tension to the tubular 290 to provide stabilization and centralization of the tubular 290 within the tool assembly. One of ordinary skill in the art will appreciate that various locking apparatus may be used to secure the tubular 290 within the tool assembly without departing from the scope of the present disclosure.

[0040] Tubular 290 includes a throughbore 273 configured to carry or house an electrical wire or cable extending from one end of the tool assembly 100 to an opposite end of the tool assembly 100. The electrical wire or cable may connect electrical components disposed on the drill string at opposite ends of the tool assembly 100. For example, referring back to Figure 2, tubular 290 is configured to carry an electrical wire or cable through the tool assembly 100 that electrically connects the rotary steerable system 34 to the MWD/LWD tool 39. Thus, a hydraulically actuated tool in accordance with embodiments disclosed herein may be disposed between a power source (*e.g.*, a rotary steerable system) and a tool electrically connected to the power source.

[0041] Referring now to Figures 8 and 9, tubular 290 may include a single tubular component or multiple tubular components coupled to one another at each end (*e.g.*, by threaded engagement, press fit, welded, or the like). Tubular 290 may also include one or more centralizers 255 coupled to an outer surface of the tubular 290. The centralizer 255 is configured to centralize and/or stabilize the tubular within the tool assembly, thereby stably securing the electrical wire or cable within the tool assembly 100. A centralizer 255 may include a block formed to fit against the outer curved surface of the tubular 290 and extend radially outward from the tubular 290 a predetermined distance, *i.e.*, an extension height. The extension height of the centralizer may be determined based on the inside diameters of the components of the tool assembly 100 (Figure 5). For example, the extension height of the centralizer may be determined based the outer diameter of the tubular 290 and the inside diameter of one or more of the tool body 110, the sub body 120, the valve piston 210, and the cam piston 240. The outer surface 278 of the centralizer 255 is configured to contact the inside diameter of at least one component of the tool assembly 100. The centralizer 255

block may be formed from any material known in the art, for example, a polymer, a metal, a composite material. The centralizer 255 may be coupled to the tubular 290 by any method known in the art, for example, by mechanical fasteners 277, such a screws or bolts, adhesives, or welding.

[0042] As shown in Figure 8, the tubular 290 may include multiple sets of centralizers 255 disposed along the length of the tubular 290. Each set of centralizers may include two or three or more centralizer 255 blocks disposed azimuthally around the tubular 290. For example, three centralizers 255 may be disposed at a same axial position along the tubular 290 and positioned 120 degrees from each other, as shown near the upper end of the tubular 290 in Figure 8. In other embodiments, four centralizers 255 may be disposed at a same axial position along tubular 290 and positioned 90 degrees from each other, as shown near the lower end of the tubular 290 in Figure 8. One of ordinary skill in the art will appreciate that various numbers of centralizers at various azimuthal angles and various numbers of sets of centralizers may be used with the tubulars 290 in accordance with the present disclosure. Further, a second set of centralizers 255 adjacent a first set of centralizers 255 may be positioned rotationally offset from the first set of centralizers 255, as shown in Figure 8.

[0043] With reference to Figure 5, in certain embodiments, the tubular 290 may include one or more centralizers 255 disposed proximate an upper end of the tubular 290 and one or more centralizers 255 disposed proximate the lower end of the tubular 290, while a central portion 274 of the tubular 290 is free of centralizers 255. When the tubular 290 is disposed inside the tool assembly 100, central portion 274 of tubular 290 may be positioned radially inward of the piston assembly 200. The tubular 290 is free of centralizers 255 in the central portion 274 to allow movement of the valve piston 210 and the cam piston 240 within the tool assembly 100. Thus, the piston assembly 200 may be used to actuate and deactuate the tool assembly 100 downhole while the tubular 290 allows for electrical communication through the tool assembly 100 from a first downhole component (*e.g.*, a rotary steerable system) to a second downhole component (*e.g.*, a MWD/LWD tool).

[0044] Downhole tool actuation and deactuation is described in detail in U.S. Application No. 13/112,326 (U.S. Publication No. 2011/0284233). In general, a hydraulically actuated tool assembly as described herein may be selectively switched between the three aforementioned modes of operation. In one embodiment, changing the drilling fluid flow rate to a low flow state and then back to a high (or full) flow state changes actuation modes (from

deactivated to activated or from activated to deactivated). This may be accomplished, for example, via cycling the mud pumps off and then back on. In other embodiments, such cycling of the mud pumps may be insufficient to activate or deactivate the downhole tool, and therefore the mud pumps may be cycled substantially any number of times without changing the tool mode (*i.e.*, without activating or deactivating the downhole tool). As described in more detail below, actuation (or deactuation) of the tool assembly may include a fourth mode, referred to herein as an indexing mode that makes use of a corresponding index (indexing) flow.

[0045] In Figure 7, tool assembly 100 is depicted in a second mode, in which high (or full) full flow is provided while the downhole tool remains inactive. To switch the assembly 100 from the first mode (low flow) to the second mode, high (or full) flow is turned on at the wellbore surface. Increasing the pressure beyond a predetermined threshold overcomes the spring bias and urges the cam piston 240 in the downhole direction. The increased flow (pressure) acts, for example, on uphole face 454 of cam piston 240 thereby urging valve piston 210 and cam piston 240 in the downhole direction such that shoulders 282 engage stop blocks 229. Engagement of the guide pins 327 with cam groove 465 rotates the cam piston 240 (due to the profile of the groove). In the embodiment shown, valve piston 210 and cam piston 240 are connected to one another (*e.g.*, via locking nut 238) and therefore rotate together, although the present disclosure is not limited in this regard.

[0046] Despite valve piston 210 being urged downhole with cam piston 240, ports 416 remain sealingly engaged with the inner surface 371 of mandrel sleeve 370 (*i.e.*, such that they are axially misaligned with ports 385). Ports 418 also remain sealingly engaged with the inner surface 381 of mandrel 380. Moreover, as also depicted the mandrel ports 385 remain sealingly engaged with the outer surface 411 of valve piston 210. Therefore, the downhole tool remains inactive (in the deactuated state) while substantially full flow is provided through the bore, for example, to a drill bit for a drilling operation.

[0047] As described above, cycling the mud pumps between high and low flow is insufficient to activate and deactivate the downhole tool. The mud pumps may be cycled substantially any number of times such that the tool cycles between the first and second operational modes depicted on Figures 6 and 7 without activating the downhole tool. The cam piston 240 shown includes a groove pattern having a plurality of upper and lower axial end portions 462 and 464. In the embodiment depicted, half of the axial end portions 462*a*

and 464*a* are circumferentially aligned with corresponding cam shoulders 282 and the other half 462*b* and 464*b* are circumferentially aligned with corresponding cam slots 484 (and therefore misaligned with the cam shoulders 282). The axial portions 462*a* and 464*a* that are aligned with the cam shoulders 282 alternate with the axial portions 462*b* and 464*b* that are aligned with the cam slots 484.

[0048] The guide pins 327 are initially located in a lower axial end portion 464*b* of the cam groove that is circumferentially aligned with a cam slot 484. Increased flow urges the cam piston 240 downward causing the guide pins 327 to travel along the groove 465 to upper axial end portion 462*a*. Movement of the cam piston 240 past the guide pins 327 rotates the cam through an angle of 45 degrees in the embodiment shown such that the guide pin(s) 327 align with cam shoulders 482 (see Figure 6). In this mode, the tool assembly remains deactivated (Figure 7) while high flow is provided. Decreasing fluid flow allows the cam piston 240 to move upwards via spring bias causing the guide pins 327 to travel along groove 465 to lower axial end portion 464*b*. Movement of the cam piston 240 past the guide pins 327 further rotates the cam piston 240 by an additional 45 degrees such that it is again aligned with an adjacent cam slot 484. Irrespective of the number of high-low mud pump cycles, the guide pin(s) returns to the same alignment after each cycle (*i.e.*, circumferentially aligned with a slot or a shoulder). In this way, repeated cycling is insufficient to activate and/or deactivate the downhole tool (*i.e.*, is insufficient to change the operational mode of the tool).

[0049] In the embodiment shown, actuation of the downhole tool may be effected by indexing the cam such that the guide pins 327 move from one axial end portion of the cam groove to an adjacent axial end portion (from end portion 462*a* to end portion 462*b* or from end portion 462*b* to end portion 462*a*). This may be accomplished by (i) decreasing the flow rate from high flow to low flow thereby returning the tool to the first mode as depicted on Figure 6, (ii) increasing the flow rate from low flow to an intermediate 'indexing' flow rate, (iii) decreasing the flow rate from the indexing flow to the low flow, and (iv) increasing the flow rate from low flow back to high flow.

[0050] As discussed above, a tool assembly in accordance with embodiments of the present disclosure provides hydraulic actuation of the tool assembly while simultaneously providing electrical communication through the throughbore of the tool assembly. Therefore, a tool assembly in accordance with embodiments disclosed herein may allow for various

configurations of a BHA that may provide an improved rate of penetration, reduced drilling costs, and faster drill times.

[0051] Figure 10 is a schematic of a BHA 333 in accordance with embodiments of the present disclosure. BHA 333 includes a bit 372, a rotary steerable system 334, a tool assembly 300, a MWD/LWD tool 339, and a reamer 383. Tool assembly 300 is a tool assembly similar to that described above with respect to tool assembly 100 in Figures 2-7. Specifically, tool assembly 300 is a hydraulically actuated tool assembly as described above and includes a tubular extending through the central throughbore of the tool assembly 300 configured to carry or house an electrical wire or cable. As shown in Figure 10, the tool assembly 300 is disposed between a rotary steerable system 334 and a MWD/LWD tool 339. Thus, tool assembly 100 may be hydraulically actuated from the surface, while the MWD/LWD tool 339 is powered by the rotary steerable system 334. While a MWD/LWD tool 339 is described here, one of ordinary skill in the art will appreciate that any electrically controlled or actuated tool may be disposed above the tool assembly 300 and be powered by the rotary steerable system 334 by an electrical wire or cable extending from the rotary steerable system 334, through a tubular of the tool assembly 300, as described above with reference to tool assembly 100 in Figure 5, and coupled to an electrically controlled or actuated tool. By providing electrical communication through the tool assembly 300, the tool assembly 300 may be positioned closer to the drill bit 372 than in conventional BHAs.

[0052] For example, in one embodiment, the tool assembly 300 of Figure 10 may be a hydraulically actuated reamer. Because the tool assembly 300 provides for electrical communication through the tool assembly 300, the tool assembly 300 may provide for reaming of the wellbore at an axial location above the drill bit 372 and below the MWD/LWD tool 339 (or other electrically controlled and/or actuated tool).

[0053] In one embodiment, BHA 333 of Figure 10 may be used for hole enlargement while drilling (HEWD) applications. HEWD applications may use concentric expandable underreamers housed in a conventional BHA configuration with a rotary steerable system and an underreamer placed above the MWD/LWD tool. HEWD applications using a BHA with an underreamer above the rotary steerable system and the MWD/LWD tool results in the creation of a long, un-enlarged section of the borehole, known as a “rathole,” between the drill bit and the underreamer at a total depth. The rathole can range between, for example, 100 feet and 200 feet in length. Setting an appropriate casing depth and landing a liner

hanger package may be complicated with a lengthy rathole. If a liner is run after a drilling operation, the length of the rathole is a factor in determining the distance between a liner shoe and a liner hanger setting depth. A rathole may also complicate cementing operations because the equivalent circulating density (ECD) during cementing while circulating around the casing shoe may increase in the rathole due to a reduced annular clearance between the casing and the borehole. Zones with a tight window between ECD and fracture gradients may be impacted further when cement needs to be circulated up the rathole using a heave mud. To alleviate such complications in a HEWD application, a second BHA may be run to cleanout or open the hole, thereby removing the removing or reducing the rathole.

[0054] BHA 333 of Figure 10 may be used for such a HEWD application such that the rathole may be removed or reduced in a single trip of BHA 333. In such a HEWD application, the tool assembly 300 is a hydraulically actuated reamer and is positioned between the rotary steerable system 334 and the MWD/LWD tool 339, as shown. The hydraulic actuation of the tool assembly 300, as discussed above, activates or deactivates cutting blocks of the reamer tool assembly 300. Open and closed modes of the reamer tool assembly (*i.e.*, extended cutter blocks or collapsed cutter blocks) may be accomplished by using a predetermined sequence of indexing flow rates. Operators may monitor flow rates between the modes by observing parameters such as standpipe pressure, surface torque, hookload and downhole data that measure flow rate changes through the MWD/LWD tool 339. Because the reamer tool assembly 300 allows electrical communication through the throughbore of the reamer tool assembly 300, the reamer tool assembly may be disposed closer to the drill bit 372 in the BHA 333, which reduces the length of the rathole.

[0055] In the embodiment shown in Figure 10, reamer 383 may be a standard ball-drop actuated underreamer disposed above the MWD/LWD tool 339. In this embodiment, the BHA 333 may be run down hole. After drilling out a casing shoe and obtaining an acceptable formation integrity test, the reamer 383 may be actuated by dropping an activation ball from the surface. While the drill bit 372 and the reamer 383 cut the formation, the reamer tool assembly 300 may remain in the deactivated mode. After reaching total depth, reamer 383 may be deactivated by increasing a pressure above the dropped activation ball or dropping a deactivation ball and the BHA 333 may be pulled back. The reamer tool assembly 300 may then be positioned proximate the top of the rathole and activated. The BHA is then lowered again to total depth with the reamer tool assembly 300 cutting the formation to enlarge the

rathole. This dual reamer system (BHA 333 with reamer 383 and reamer tool assembly 300) may provide a BHA that may reduce or remove long ratholes without a second or dedicated cleanout run and without impacting the functionality of MWD/LWD tools during the drilling operation.

[0056] One of ordinary skill in the art will appreciate that a hydraulically actuated tool assembly including a tubular extending through a central bore of the tool assembly and configured to carry or house an electrical wire or cable in accordance with embodiments disclosed herein may be disposed at various locations in a BHA. For example, in some embodiments, the hydraulically actuated tool assembly may be disposed above a MWD/LWD tool. A hydraulically actuated tool assembly as described herein may include a caliper measurement tool, a reamer, a stabilizer, or any downhole tool having actuatable (extendable) arms.

[0057] One of ordinary skill in the art will appreciate that other hydraulically actuated tools similar to that described with respect to Figure 5 may be modified to include a tubular or conduit as discussed above without departing from the scope of embodiments disclosed herein. For example, other tool assemblies, for example, those shown in U.S. Application No. 13/112,326 (U.S. Publication No. 2011/0284233), may be modified to include a tubular configured to carry or house an electrical wire or cable extending from one end to an opposite end of the tool assembly. The tool assemblies disclosed in U.S. Application No. 13/112,326 (U.S. Publication No. 2011/0284233) may be modified, for example, by enlarging the central bores of the valve piston, the cam piston, and/or the tool and sub bodies to accommodate the outer diameter of the tubular. Additionally, retaining mechanisms for securing the tubular within the tool assembly body may be coupled to one or both ends of the tool assembly body, as discussed above.

[0058] With reference to Figure 10, the BHA 333 may also include a stabilizer (not shown) disposed between the rotary steerable system 334 and the tool assembly 300. The stabilizer may act as a fulcrum for a deflection assembly (*i.e.*, the lower end of the BHA including the rotary steerable assembly and the bit). In other embodiments, the reamer tool assembly 300 may act as a stabilizer when the tool assembly 300 is in the deactivated mode. Thus, when the reamer tool assembly 300 is in the deactivated mode (*i.e.*, the blades are retracted), the reamer tool assembly 300 may provide a fulcrum for the rotary steerable system 334 and drill bit 372. Then, the blades of the reamer tool assembly 300 may be moved into the activated

mode (*i.e.*, the blades are extended) to cut the formation (*e.g.*, reduce the rathole). Use of the reamer tool assembly 300 as a reamer during activated mode and a stabilizer during deactivated mode may allow for the reamer tool assembly 300 to be positioned closer to the rotary steerable system, and therefore reduce the rathole length before reaming.

[0059] The reamer tool assembly 300 may include one or more reamer blocks 597 having two reamer blades 594 disposed, as shown in Figure 11. Each blade 594 includes a plurality of cutting elements 593 disposed on a lower end of the blade 594 and a plurality of cutting elements 593 disposed on an upper end of the blade 594, such that the reamer blocks 597 provide an overall active gauge cutting structure. In other embodiments, the reamer tool assembly 300 may include cutter blocks 599, as shown in Figure 12. Cutter blocks 599 may be, for example, cement removal cutter blocks. Each cutter block 599 may include two reamer blades disposed on a lower end of the cutter block 599 having a plurality of cutting elements 593 disposed thereon. An upper end of each cutter block 599 may include a stabilizer pad 595 with a plurality of stabilizer elements disposed thereon, such that the cutter block 599 provides an overall passive gauge cutting structure. In other words, the number of cutting elements on the gauge surface of the cutter block 599 may be small and provide passive gauge interaction with the formation when the cutter block 599 is retracted. Thus, the cutter block 599 may be used with the tool assembly 300 and act as a stabilizer for the rotary steerable system when the tool assembly 300 is in the deactivated mode.

[0060] Embodiments disclosed herein may provide a hydraulically actuated tool assembly that allows electrical communication through a throughbore of the tool assembly. Thus, embodiments disclosed herein may provide a tool assembly that may be positioned between electrically connected components of a bottom hole assembly. Further, embodiments disclosed herein may provide a reamer tool assembly that may provide for a reduced rathole during drilling operations.

[0061] Although only a few example embodiments have been described in detail above, those skilled in the art will readily appreciate that many modifications are possible in the example embodiments without materially departing from scope of the present disclosure. Accordingly, all such modifications are intended to be included within the scope of this disclosure and the following claims. In the claims, means-plus-function clauses are intended to cover the structures described herein as performing the recited function and not only structural equivalents, but also equivalent structures. Thus, although a nail and a screw may

not be structural equivalents in that a nail employs a cylindrical surface to secure wooden parts together, whereas a screw employs a helical surface, in the environment of fastening wooden parts, a nail and a screw may be equivalent structures.

CLAIMS

What is claimed:

1. A tool assembly comprising:
   a tool body configured to connect with a drill string;
   a mandrel disposed in the tool body;
   a piston assembly disposed in the mandrel, the piston assembly having a throughbore and including a valve piston and a cam piston configured to reciprocate axially in the mandrel;
   a spring member disposed in the tool body and configured to bias the piston assembly towards a first axial position; and
   a tubular disposed in the tool body and the throughbore of the piston assembly, the tubular having a throughbore configured to carry an electrical wire.

2. The tool assembly of claim 1, further comprising a first locking apparatus disposed at an upper end and a second locking apparatus disposed at a lower end, the first and second locking apparatus configured to secure the tubular within the tool assembly.

3. The tool assembly of claim 2, wherein the first locking apparatus and the second locking apparatus each include a locking sleeve.

4. The tool assembly of claim 2, wherein the first locking apparatus and the second locking apparatus each include a jam nut.

5. The tool assembly of claim 1, wherein the tubular comprises a centralizer coupled to an outer surface of the tubular and extending radially therefrom.

6. The tool assembly of claim 5, wherein a portion of the tubular radially adjacent the piston assembly is free of the centralizer.

7. The tool assembly of claim 1, further comprising at least one reamer blade coupled to the tool body and configured to extend radially therefrom.

8. A bottom hole assembly comprising:
   a drill string;

a bit coupled to an end of the drill string;

a rotary steerable system coupled to the drill string axially above the bit;

a hydraulically actuated tool assembly coupled to the drill string axially above the rotary steerable system; and

an electrically controlled tool coupled to the drill string axially above the hydraulically actuated tool assembly, the electrically controlled tool electrically coupled to the rotary steerable system.

9. The bottom hole assembly of claim 8, wherein the electrically controlled tool is a measurement-while-drilling/logging-while-drilling (MWD/LWD) tool.

10. The bottom hole assembly of claim 8, further comprising a reamer coupled to the drill string axially above the electrically controlled tool.

11. The bottom hole assembly of claim 8, wherein the hydraulically actuated tool assembly comprises a tubular disposed in a central throughbore of the hydraulically actuated tool assembly and extending from proximate a first end of the hydraulically actuated tool assembly to proximate a second end of the hydraulically actuated tool assembly.

12. The bottom hole assembly of claim 11, further comprising an electrical wire coupled at a first end to the rotary steerable system, extending through the tubular, and coupled at a second end to the electrically controlled tool.

13. The bottom hole assembly of claim 8, wherein the hydraulically actuated tool assembly is a reamer.

14. The bottom hole assembly of claim 8, wherein the hydraulically actuated tool assembly is a caliper measurement tool.

15. The bottom hole assembly of claim 8, wherein the hydraulically actuated tool assembly is a stabilizer when in a deactuated mode and a reamer when in an actuated mode.

16. A method comprising:

running a bottom hole assembly downhole, the bottom hole assembly including a drill bit, a rotary steerable system, an electrically controlled tool, and a hydraulically actuated tool assembly disposed between the rotary steerable system and the electrically controlled tool;

cutting a formation with the drill bit;

actuating the hydraulically actuated tool assembly; and

maintaining an electrical connection between the rotary steerable system and the electrically controlled tool during the running, the cutting, and the actuating.

17. The method of claim 15, wherein the maintaining the electrical connection between the rotary steerable system and the electrically controlled tool comprises running an electrical wire through a tubular disposed within the hydraulically actuated tool assembly and coupling the electrical wire to the rotary steerable system and the electrically controlled tool.

18. The method of claim 16, further comprising stabilizing the tubular within the hydraulically actuated tool assembly with at least one centralizer.

19. The method of claim 15, wherein the bottom hole assembly further includes a reamer disposed above the electrically controlled tool and wherein the hydraulically actuated tool assembly includes at least one radially actuated reamer blade, the method further comprising:

dropping an activation ball into the bottom hole assembly and actuating the reamer;

cutting the formation with the reamer, the cutting the formation with the drill bit and the cutting the formation with the reamer forming a rathole between drill bit and the reamer;

deactuating the reamer and pulling the BHA upward to position the hydraulically actuated tool assembly proximate the top of the rathole;

activating the tool assembly; and

cutting the rathole with the at least one radially actuated reamer blade of the hydraulically actuated tool assembly,

wherein the electrical connection is maintained during the dropping, the cutting the formation with the reamer, the deactuating, the activating, and the cutting the rathole.

20. A method comprising:

running a bottom hole assembly downhole, the bottom hole assembly including a drill bit, a rotary steerable system, a hydraulically actuated reamer tool assembly, a measurement-while-drilling/logging-while-drilling (MWD/LWD) tool, and a reamer;

dropping an activation ball into the bottom hole assembly and actuating the reamer;

cutting a formation with the drill bit and the reamer, the cutting the formation forming a rathole between the drill bit and the reamer;

deactuating the reamer and pulling the BHA upward to position the reamer tool assembly proximate the top of the rathole;

activating the reamer tool assembly; and

cutting the rathole with the reamer tool assembly,

the running, dropping, cutting the formation, deactuating, actuating, and cutting the rathole being performed while maintaining electrical connection between the rotary steerable system and the MWD/LWD tool.

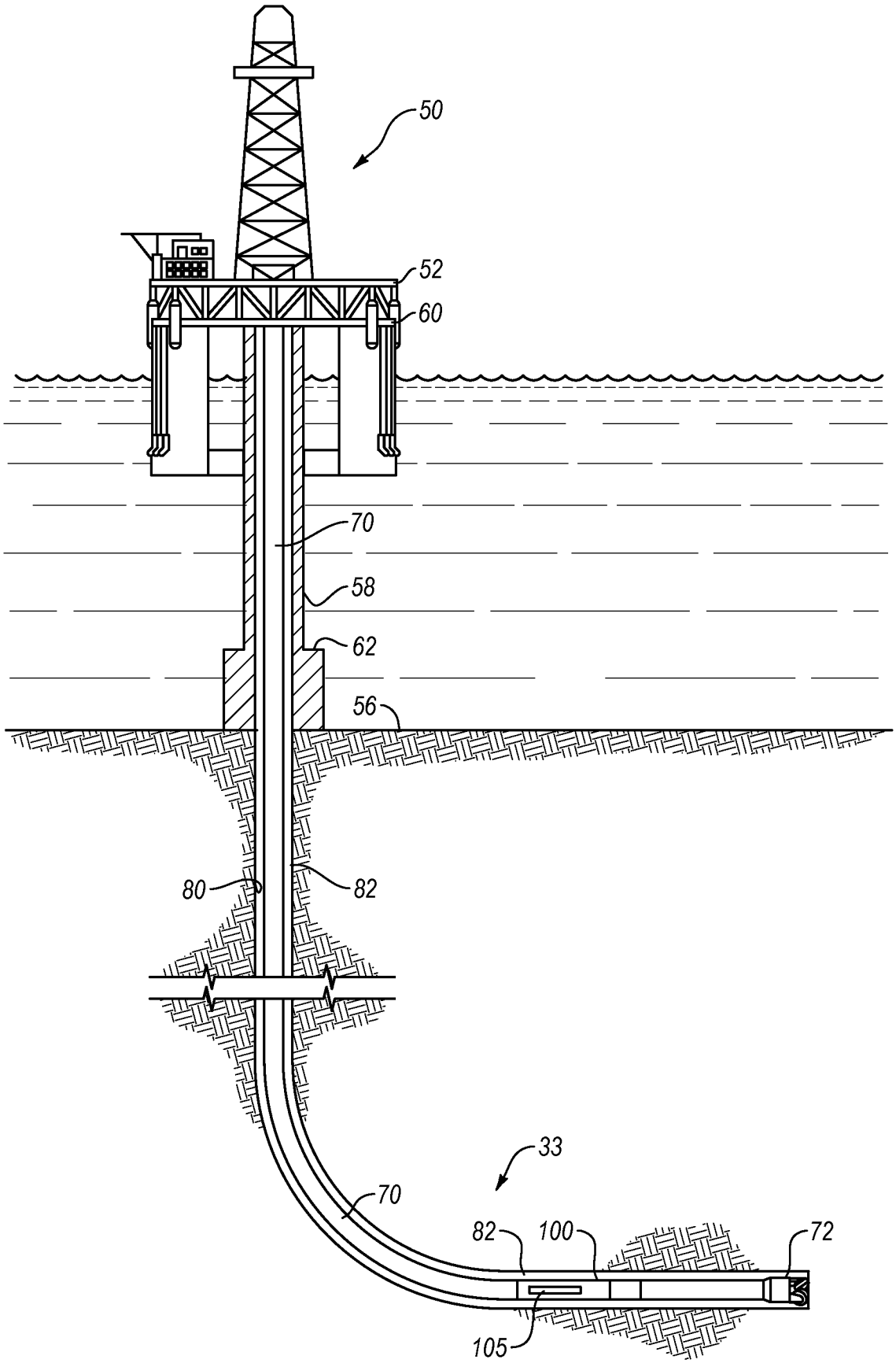

FIG. 1

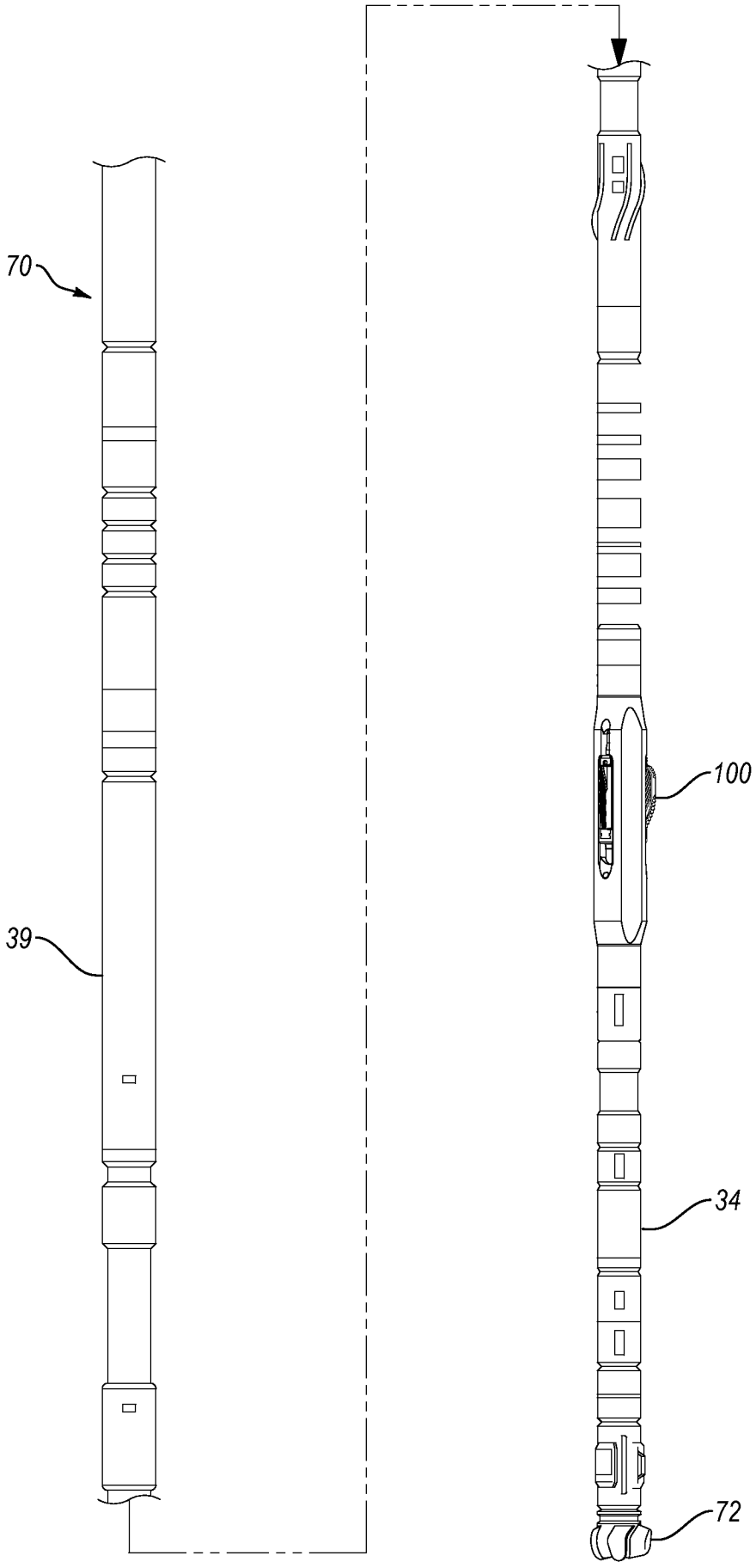

FIG. 2

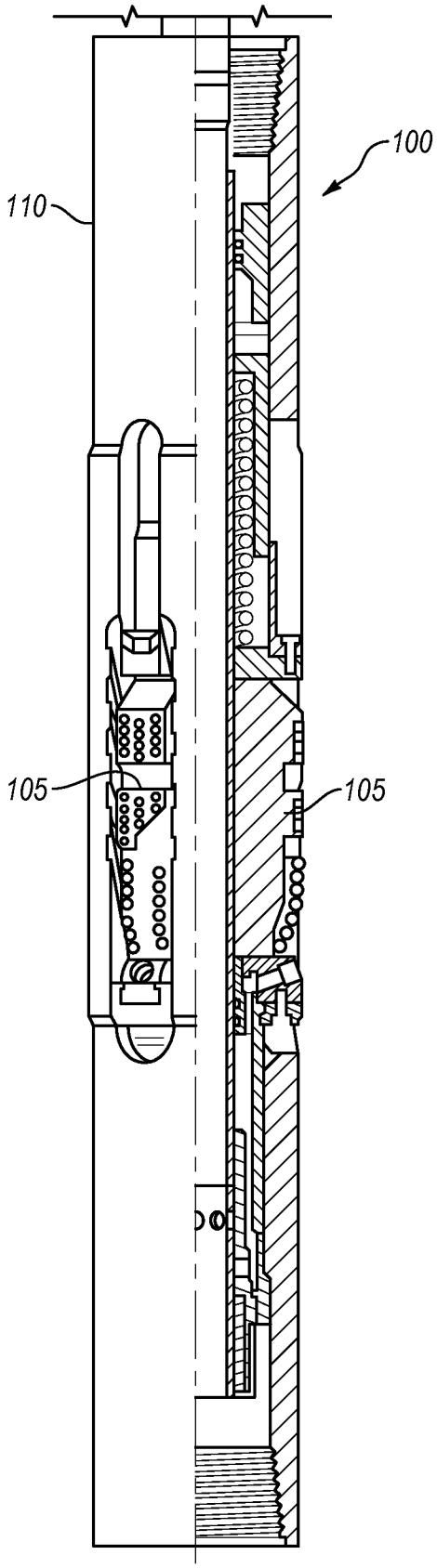

FIG. 3

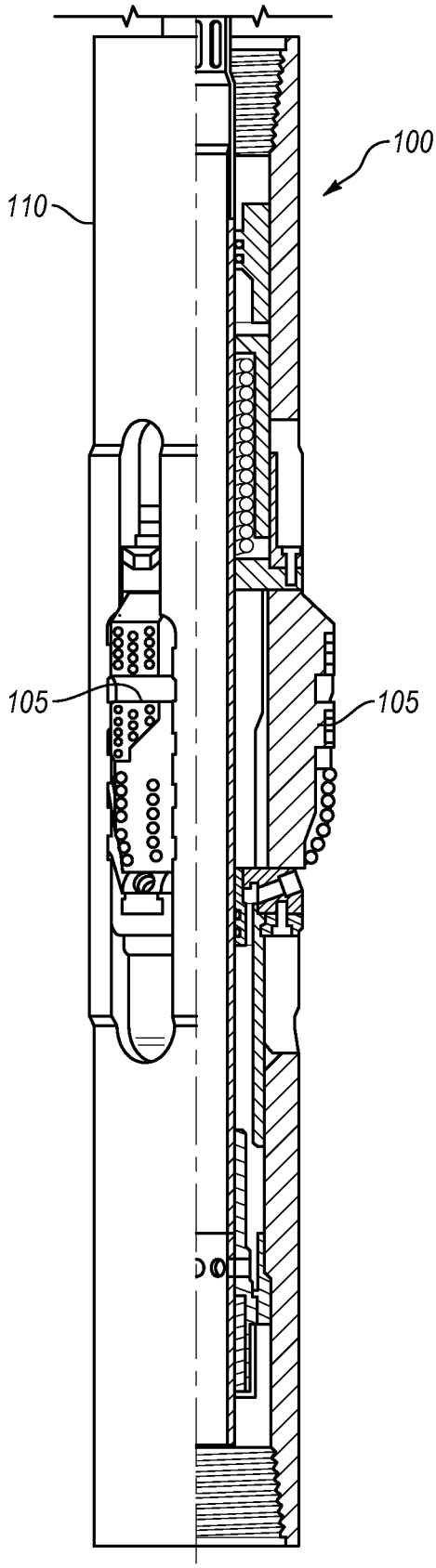

FIG. 4

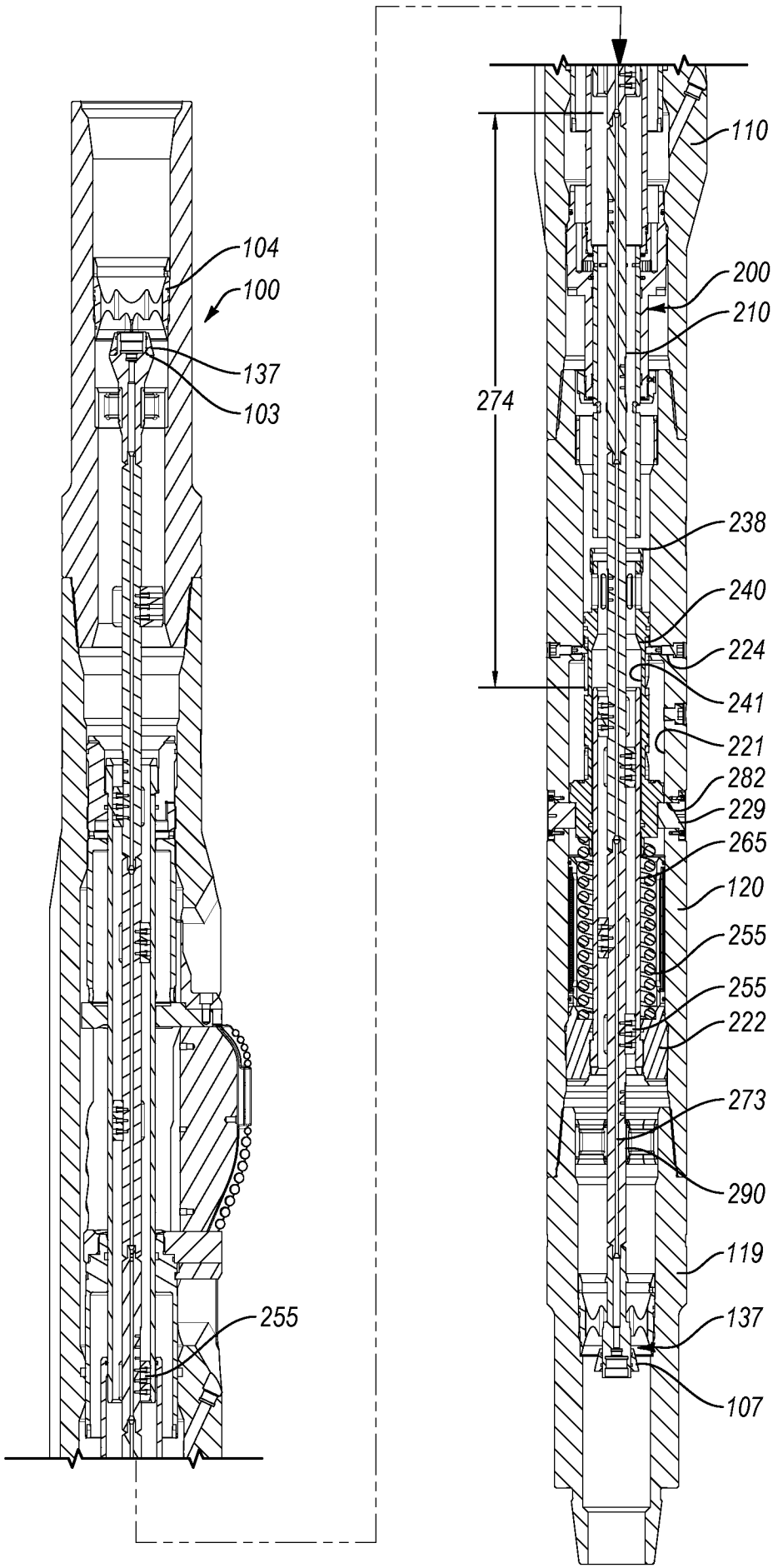
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FIG. 5

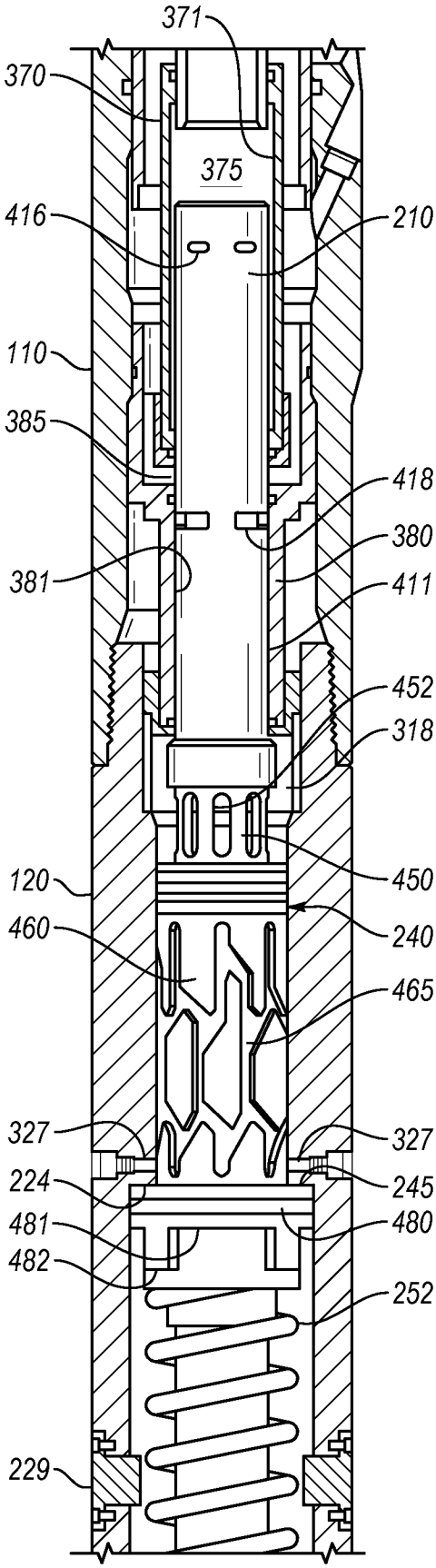
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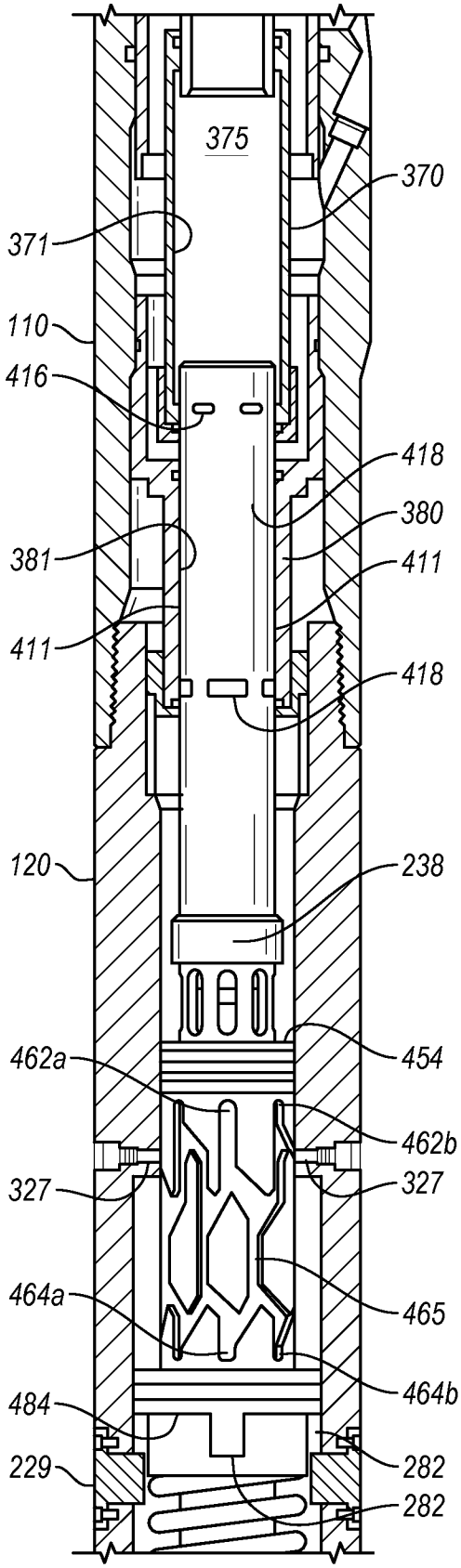
FIG. 6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464b
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FIG. 7

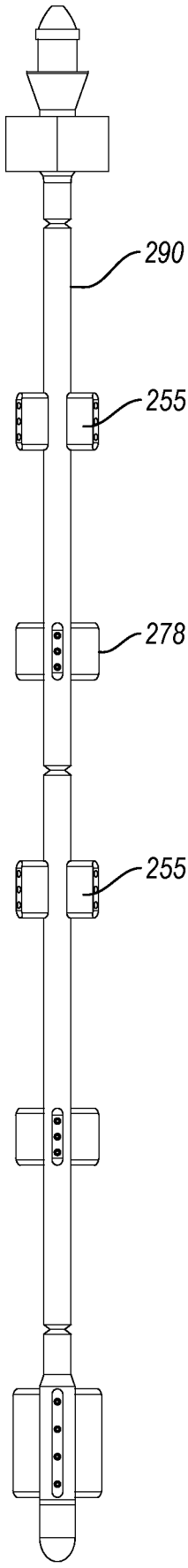

FIG. 8

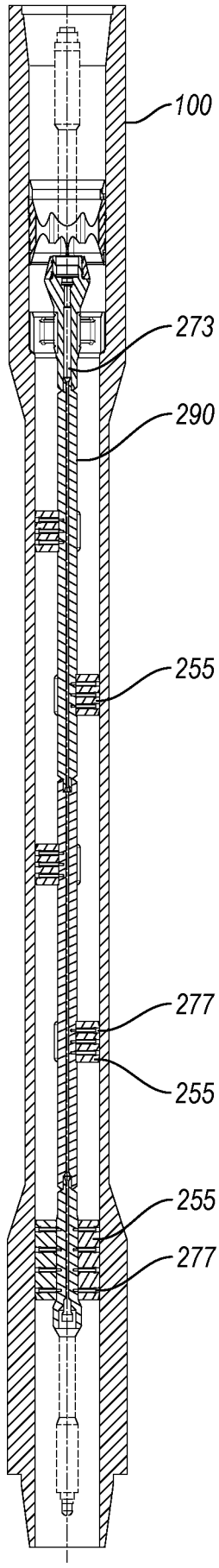

FIG. 9

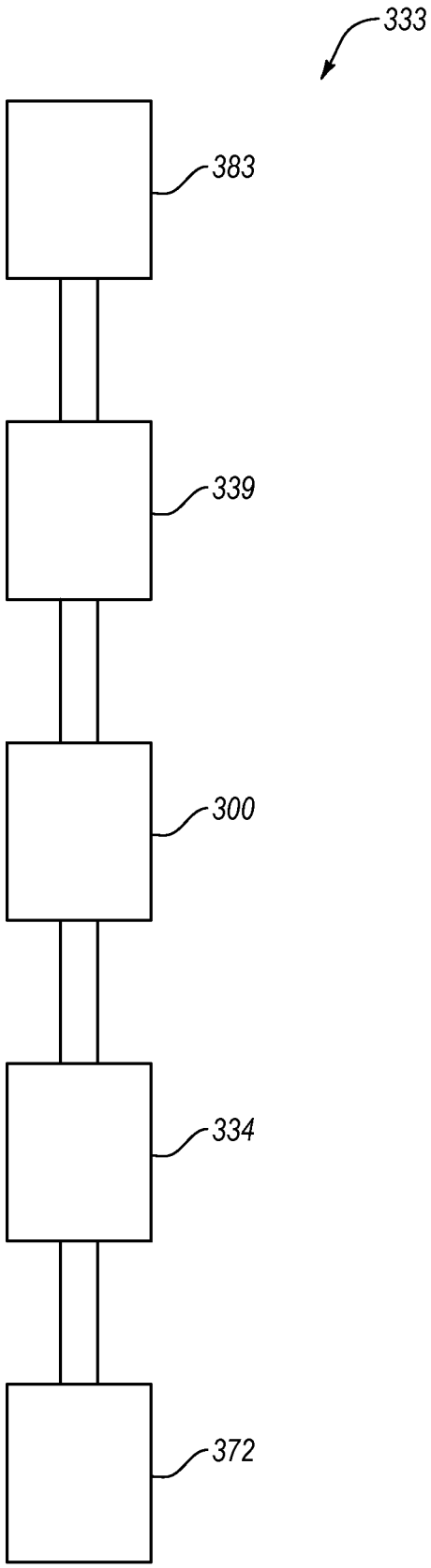

FIG. 10

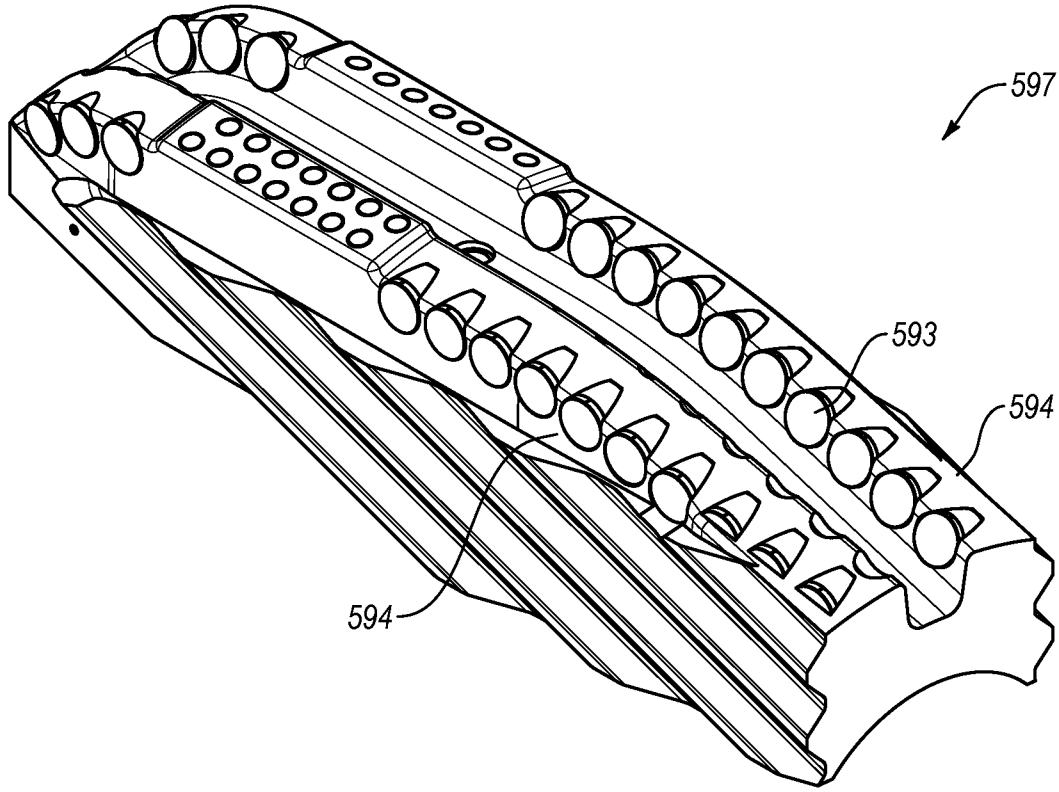

FIG. 11

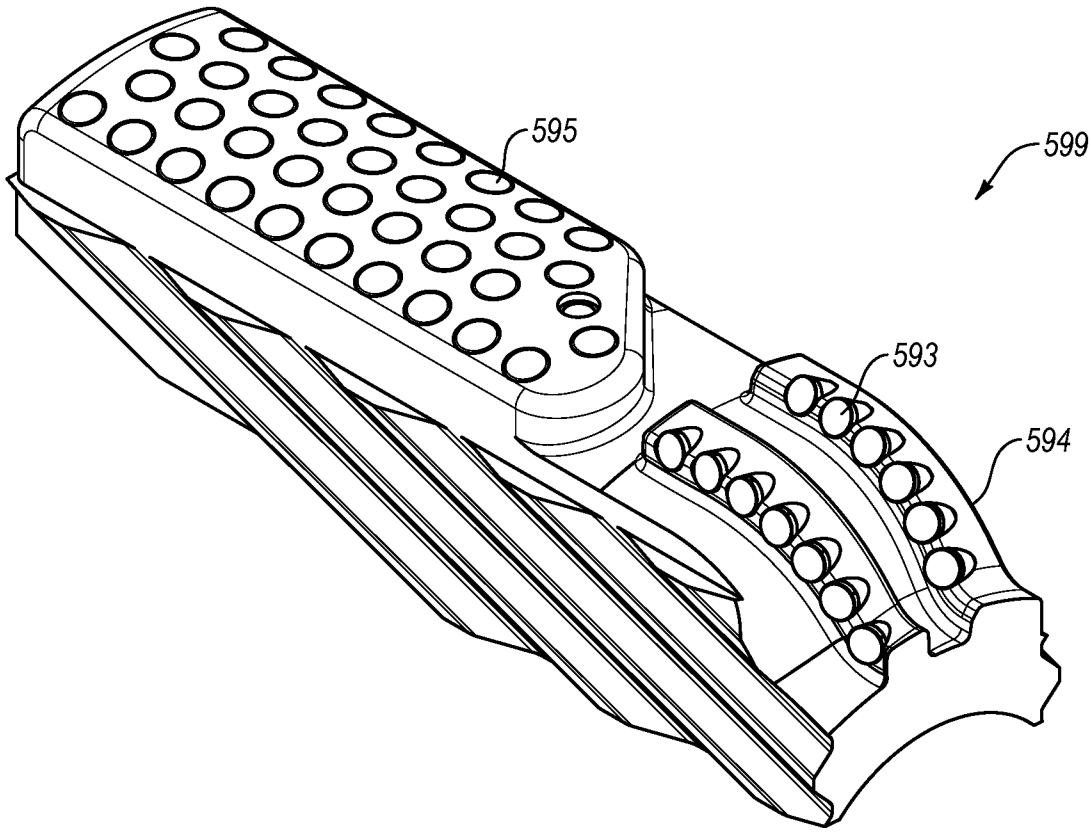

FIG. 12

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/067276

A. CLASSIFICATION OF SUBJECT MATTER

E21B 10/32(2006.01)i, E21B 7/28(2006.01)i, E21B 17/00(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 10/32; E21B 23/04; E21B 10/36; E21B 34/00; E21B 7/08; E21B 29/10; F16L 55/162; E21B 23/00; E21B 7/28; E21B 17/00

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: drill string, mandrel, piston, throughbore, tubular, electrical wire, hydraulic

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2011-0284233 A1 (WU et al.) 24 November 2011 See paragraphs [0005]-[0006], [0035]-[0038]; claim 1; and figures 1-3B.	8-10,13-16,19-20
Y		11,18
A		1-7,12,17
Y	US 2004-0055755 A1 (ROESNER et al.) 25 March 2004 See paragraph [0044]; and figure 3.	11
Y	EP 0948703 B1 (WEATHERFORD/LAMB INC.) 18 January 2006 See paragraph [0024]; and figure 1A.	18
A	WO 2011-146836 A2 (SMITH INTERNATIONAL, INC.) 24 November 2011 See paragraphs [0050]-[0051]; and figures 9A-9B.	1-20
A	US 2002-0060096 A1 (BRUNNERT et al.) 23 May 2002 See paragraph [0043]; and figure 5.	1-20

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

☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"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	Date of mailing of the international search report
23 March 2015 (23.03.2015)	**23 March 2015 (23.03.2015)**

Name and mailing address of the ISA/KR
International Application Division
Korean Intellectual Property Office
189 Cheongsa-ro, Seo-gu, Daejeon Metropolitan City, 302-701, Republic of Korea
Facsimile No. ++82 42 472 7140

Authorized officer
LEE, Chang Ho
Telephone No. +82-42-481-8398

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2014/067276

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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US 2004-0055755 A1	25/03/2004	CA 2441738 A1	20/03/2004
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