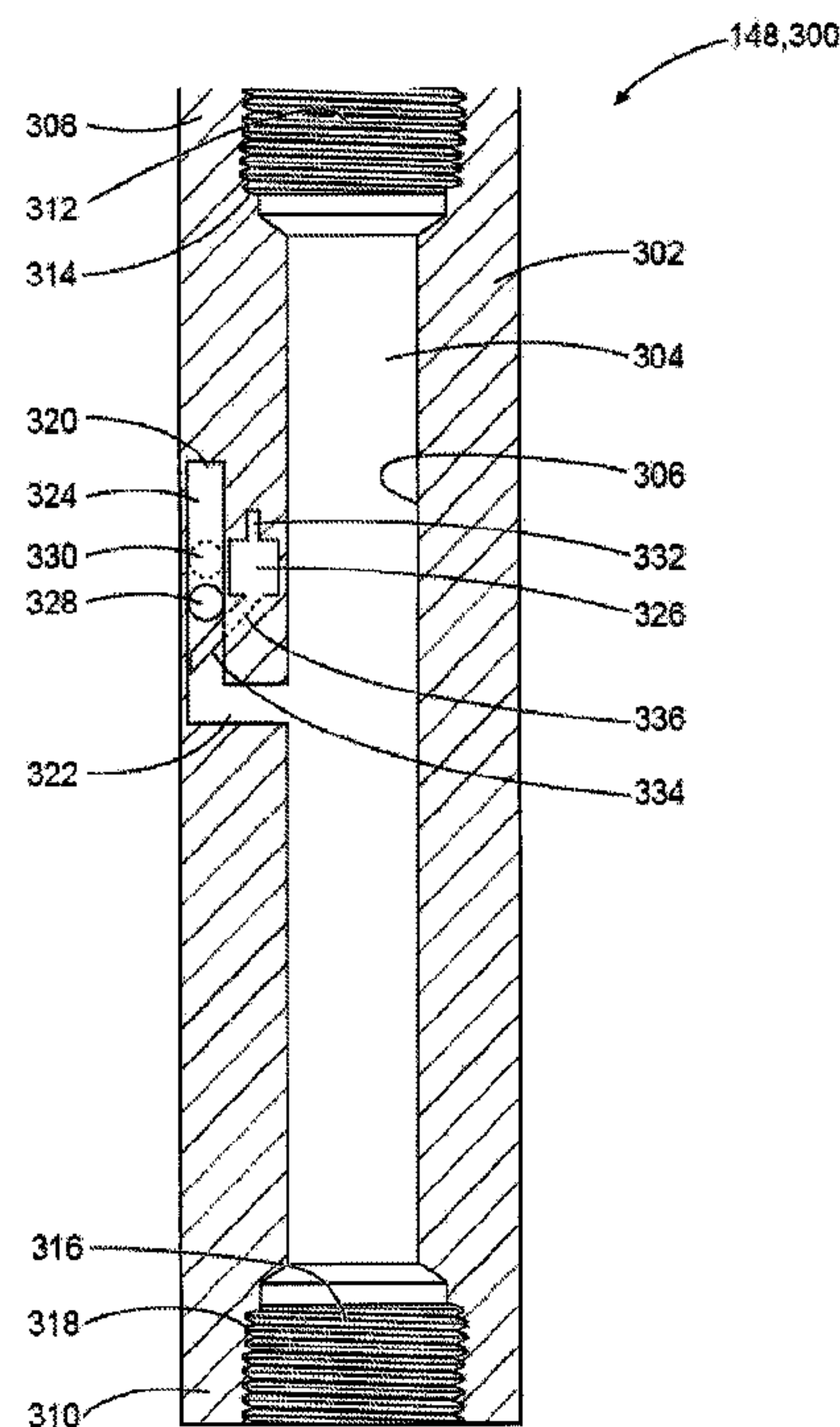




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(57) **Abrégé/Abstract:**

Disclosed embodiments include a method and apparatus for dropping a ball in a tool string. One example embodiment is a downhole ball drop tool that releases an activation ball in response to a downlink signal provided from the surface. The ball drop tool is provided as a part of a tool string. A variety of tools connected in a tool string may have a ball seat for receiving an activation ball dropped from the ball drop tool. Once the ball has engaged the ball seat, fluid pressure can be increased in the tool string to activate a mechanism in a downhole tool.



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## BALL DROP TOOL AND METHODS OF USE

BACKGROUND

[0001] The present disclosure relates generally to methods and apparatus for dropping an activation ball from a downhole tool, and more particularly to a downhole ball drop tool that releases an activation ball in response to a downlink signal provided from the surface.

[0002] In the drilling and completion of oil and gas wells, a borehole is drilled into the subterranean producing formation. In many types of operations it is necessary to remotely activate one or more downhole tools to perform a desired operation. As one of many possible examples of such tools and operations, it may be desirable to remotely operate a reamer to facilitate expanding the dimension of a drilled borehole. In operation of a drill string, a drill bit creates a borehole with a diameter equal to the of the drill bit. In some cases, it may be needed to enlarge the diameter borehole (now sometimes called the pilot hole) with a reamer. Such reamers will be in a retracted, or inactivated, state during drilling operations, but will then need to activated, with the reamer arms extended, to enlarge the borehole.

[0003] In some cases an activation ball is dropped to engage a seat operatively associated with the tool to be activated. Once the ball engages the seat and closes or restricts the flow passage containing the seat, fluid can be pressurized above the ball to cause activation of the tool. In some cases, there may be a restriction in some portion of a tool string above the tool to be activated that would preclude passage of a ball, and thus the ball may be retained in a ball drop sub placed below the restriction. This disclosure addresses how such a ball drop sub may be actuated.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] FIG. 1 depicts a schematic view of an example system for controlling the activation of a downhole tool.

[0005] FIG. 2 shows an example embodiment of a downhole tool that may be activated using an activation ball dropped from a ball drop tool.

[0006] FIG. 3 illustrates an example embodiment ball drop tool.

DETAILED DESCRIPTION

[0007] The following detailed description refers to the accompanying drawings that depict various details of examples selected to show how particular embodiments may be implemented. The discussion herein addresses various examples of the inventive subject matter at least partially in reference to these drawings and describes the depicted embodiments in sufficient detail to enable those skilled in the art to practice the invention. Many other embodiments may be utilized for practicing the inventive subject matter than the illustrative examples discussed herein, and many structural and operational changes in addition to the alternatives specifically discussed herein may be made without departing from the scope of the inventive subject matter.

[0008] In this description, references to “one embodiment” or “an embodiment,” or to “one example” or “an example” mean that the feature being referred to is, or may be, included in at least one embodiment. Separate references to “an embodiment” or “one embodiment” or to “one example” or “an example” in this description are not intended to necessarily refer to the same embodiment or example; however, neither are such embodiments mutually exclusive, unless so stated or as will be readily apparent to those of ordinary skill in the art having the benefit of this disclosure. Thus, the present disclosure includes a variety of combinations and/or integrations of the embodiments and examples described herein, as well as further embodiments and examples as defined within the scope of all claims based on this disclosure, as well as all legal equivalents of such claims.

[0009] This disclosure describes a method and apparatus for dropping a ball from a sub-assembly in a tool string. In most examples, the tool string is run into a well with one or more balls retained within the sub-assembly, though in some cases, it may be possible to communicate the balls to the sub-assembly, after the tool string is in the borehole. The sub-assembly can be actuated to drop a ball in response to a downlink control signal.

[0010] For purposes of the present example, the ball drop tool is described specifically in the context of facilitating the opening of a reamer within the tool string. One skilled in the art will readily recognize that although the description of this example is to use the ball drop tool for actuating a reamer, the embodiments described herein are similarly applicable to other tools that may utilize a dropped ball to engage a ball seat for activating a mechanism in a tool that has been lowered into a wellbore. Once the ball has engaged a ball



seat within a fluid path, as described above, fluid pressure can be increased in the tool string to raise the pressure in the blocked fluid path to activate a mechanism in the tool string such as a sliding sleeve mechanism or another form of piston, for example.

[0011] Further, although described in the embodiments having a spherical configuration, the term “balls” is used throughout this disclosure to be generic to other configurations of devices configured to engage a seat as described above, specifically including non-spherical configurations, for example, darts, plugs, semi-ellipsoidal configurations, and other configurations capable to sealing or restricting fluids by engaging a seat of an activation or de-activation mechanism in the tool string

[0012] FIG. 1 depicts a schematic view of an example system for controlling the activation and deactivation of a downhole tool by operator control in providing a downlink signal. A drilling installation 100 includes a subterranean borehole 104 in which a drill string 108 is located. The drill string 108 may comprise jointed sections of drill pipe 106 suspended from a drilling platform 112 secured at a wellhead, as known in the art. A downhole assembly or bottom hole assembly (BHA) 151 at a bottom end of the drill string 108 includes a drill bit 116 to penetrate earth formations, and for purposes of this example, includes a reamer assembly 118 positioned uphole of the drill bit 116 to widen the borehole 104 by operation of selectively deployable cutting elements. The BHA 151 may further include other components such as a rotary steerable system, measurement while drilling (MWD) and logging while drilling (LWD) tools. For example, a measurement and control assembly 120 may be included in the BHA 151, which includes measurement instruments to measure borehole and/or drilling parameters.

[0013] The borehole 104 is thus an elongated cavity that is substantially cylindrical, having a substantially circular cross-sectional outline that remains more or less constant along the length of the borehole 104. The borehole 104 may in some cases be linear, but more commonly will include one or more curves, bends, doglegs, or angles along its length. As used with reference to the borehole 104 and components therein, the “axis” of the borehole 104 (and therefore of the drill string 108 or part thereof) means the longitudinally extending centerline of the generally cylindrical borehole 104 (corresponding, for example, to longitudinal axis 367 in FIG. 3).

[0014] “Axial” and “longitudinal” thus means a direction along a line substantially

parallel with the lengthwise direction of the borehole 104 at the relevant point or portion of the borehole 104 under discussion; “radial” means a direction or including a directional component substantially along a line that intersects the borehole axis and lies in a plane perpendicular to the borehole axis; “tangential” means a direction substantially along a line that does not intersect the borehole axis and that lies in a plane perpendicular to the borehole axis; and “circumferential” or “rotational” means a substantially arcuate or circular path described by rotation of a tangential vector about the borehole axis. “Rotation” and its derivatives mean not only continuous or repeated rotation through 360° or more, but also includes angular or circumferential displacement of less than 360°.

[0015] As used herein, movement or location “forwards” or “downhole” (and related terms) means axial movement or relative axial location towards the drill bit 116, away from the earth’s surface. Conversely, “backwards,” “rearwards,” or “uphole” means movement or relative location axially along the borehole 104, away from the drill bit 116 and towards the earth’s surface. Note that in FIGS. 2, 3, and 4 of the drawings, the uphole end of the depicted tool lies to the left.

[0016] Drilling fluid (e.g. drilling “mud,” or other fluids that may be in the well), is circulated from a drilling fluid reservoir, for example a storage pit, at the earth’s surface (and coupled to the wellhead) by a pump system 132 that forces the drilling fluid down a drilling bore 128 provided by a hollow interior of the drill string 108, so that the drilling fluid exits under relatively high pressure through the drill bit 116. After exiting from the drill string 108, the drilling fluid moves back upwards along the borehole 104, occupying a borehole annulus 134 defined between the drill string 108 and a wall of the borehole 104. Although many other annular spaces may be associated with the system, references to annular pressure, annular clearance, and the like, refer to features of the borehole annulus 134, unless otherwise specified or unless the context clearly indicates otherwise.

[0017] Note that the drilling fluid is typically pumped along the inner diameter (i.e., the bore 128) of the drill string 108, with fluid flow out of the bore 128 being restricted at the drill bit 116. The drilling fluid then flows upwards along the annulus 134, carrying cuttings from the bottom of the borehole 104 to the wellhead, where the cuttings are removed and the drilling fluid may be returned to the drilling fluid reservoir 132. Fluid pressure in the bore 128 is therefore greater than fluid pressure in the annulus 134. Pressure differentials



exist between the bore 128 and the annulus 134, although downhole drilling fluid conditions may, in other embodiments, be referenced to isolated pressure values in the bore 128. Unless the context indicates otherwise, the term “pressure differential” means the difference between general fluid pressure in the bore 128 and pressure in the annulus 134.

**[0018]** System 100 includes a surface control system 140, to send and receive signals to and from downhole equipment incorporated in the drill string 108, for example, which may in some cases be part of the downhole measurement and control assembly 120. The surface control system 140 may process data relating to the drilling operations, data from sensors and devices at the surface, data received from downhole, and may control one or more operations of downhole tools and/or surface devices.

**[0019]** The drill string 108 may include one or more downhole tools instead of or in addition to the reamer assembly 118. The downhole tools of the drill string 108, in this example, includes a reamer assembly 118 located in the BHA 151 to enlarge the diameter of the borehole 104 as the BHA 151 penetrates the formation. In other embodiments, the drill string 108 may comprise multiple reamer assemblies 118.

**[0020]** Each reamer assembly 118 will comprise one or more circumferentially spaced blades or other structures that carry cutting elements (e.g., reamer arms 202 in FIG. 2). The reamer assembly 118 includes a reamer 144 comprising a generally tubular reamer housing 204 connected in-line in the drill string 108 and carrying the reamer arms 202, which are radially extendable and retractable from a radially outer surface of the reamer housing 204, to selectively expand and contract the reamer’s effective diameter.

**[0021]** Controlling deployment and retraction of the reamer 144 (e.g., to switch the reamer 144 between a deployed condition in which the reamer arms 202 project radially outwards for cutting into the borehole wall, and a dormant condition in which the reamer arms 202 are retracted) may be controlled by controlling pressure conditions in the drilling fluid or hydraulically actuated by agency of the drilling fluid. In addition, deployment of the reamer arms 202 may be actuated by a ball dropped to engage a ball seat a ball for activating a mechanism in the reamer 144.

**[0022]** FIG. 2 shows an example embodiment of a reamer assembly 118 that may form part of the drill string 108, with the reamer 144 that forms part of the reamer assembly 118



depicted in a deployed condition. In this deployed (or activated) condition, the reamer arms 202 and the supported cutting elements are radially extended from the reamer housing 204 and to enable contact with the borehole sidewall for reaming of the borehole 104 when the reamer housing 204 rotates with the drill string 108. In this example, the reamer arms 202 are mounted on the reamer housing 204 in axially aligned, hingedly connected pairs that jackknife into deployment, when activated. When, in contrast, the reamer 144 is in the deactivated condition (not shown), the reamer arms 202 are retracted into the tubular reamer housing 204, in which the reamer arms 202 do not project beyond the radially outer surface of the reamer housing 204, therefore clearing the annulus 134 and allowing axial and rotational displacement of the reamer housing 204 as part of the drill string 108, without engagement of a borehole wall by the reamer arms 202. Different activation mechanisms for the reamer 144 may be employed in various embodiments.

**[0023]** In some applications, activation balls are dropped from the surface to travel down the drillstring or tubing and engage a ball seat. However, in many applications there will be downhole devices in the tool string that have restrictions which would prevent a ball from passing therethrough to the reamer or other tool to be activated. For example, filter screens are often run downhole to keep debris and drilling fluid particulate from plugging off small passages in tools positioned below. Activation balls are unable to pass through the filter screens. Similarly, in many cases a MWD (or LWD) tool also provides a flow path obstruction that prohibits a dropped ball from actuating tools positioned downhole of the MWD tool. As a result, in many cases the use of a downhole ball drop assembly, located with a clear path for a released ball to reach the ball seat to activate the desired tool, serves to facilitate ball/pressure actuation.

**[0024]** In an example, the drill string 108 may include a sub-assembly in the example form of a ball drop sub-assembly 148 that provides deployment control mechanisms configured to provide ball actuated deployment of the reamer 144 responsive to a downlink signal received at the ball drop sub-assembly 148. The ball drop sub-assembly is preferably positioned downhole from any flow path obstructions that would prevent a dropped ball from landing on a seat operably associated with an activating mechanism. The ball drop sub-assembly 148 will typically include body or housing 200 (see FIG. 2) connected in-line in the drill string 108. In some cases, the housing for the ball drop sub-assembly may be a

portion of a housing (or housing assembly) associated with another tool in the tool string. In the example embodiment of FIG. 1, the ball drop sub-assembly 148 is mounted directly uphole of the reamer 144, but in other embodiments, the positional arrangement of the ball drop sub-assembly 148 and the reamer 144 (or other tool to be actuated) may be different.

**[0025]** FIG. 3 illustrates an example ball drop tool 300, which may also be referred to as the ball drop sub-assembly 148, comprising a ball drop housing 302 having a central opening 304 defined by a central bore 306 running longitudinally therethrough, from an uphole end 308 to a downhole end 310. The downhole end 310 of the ball drop housing 302 is open to allow the passage of balls and drilling fluids therethrough. Each end of the ball drop tool 300 may include connecting means, such as threads, by which the ball drop tool 300 may be connected into a drill string, such that the central bore 306 through the ball drop housing 302 is continuous with a bore of the drill string. For example, threads 312 may be defined on inner surface 314 at the uphole end 308 of the ball drop housing 302. The ball drop housing 302 is thus adapted to be connected to a lower end of a different portion of the drill string 108 (e.g., drill pipe 106) or a different component in the bottom hole assembly 151. Similarly, threads 316 may be defined on inner surface 318 at the downhole end 310 of the ball drop housing 302. The ball drop housing 302 is thus adapted to be connected to an upper end of a reamer, a tool joint, or other threaded member positioned downhole of the ball drop tool 300.

**[0026]** The ball drop tool 300 has a mandrel for retaining balls to be dropped. In ball drop tool 300, the mandrel is a side mandrel 320 that is offset from and extends alongside the central bore 306 of the ball drop housing 302. The side mandrel 320 includes a radial bore 322 provided in the wall of the ball drop housing 302 to communicate a ball drop bore 324 of the side mandrel 320 with the central bore 306 of the ball drop housing 302. The side mandrel 320 is adapted to contain drop balls in sealing and locking engagement therewith. Passage of drop balls from the ball drop bore 324 to the central bore 306 through the radial bore 322 is controlled by an electromechanical deployment mechanism 326 to access downhole components below. In this manner, the ball drop housing 302 and any drop balls disposed within the side mandrel 320 do not obstruct flowing of drilling fluid through the central bore 306.



[0027] The ball drop tool 300 may be utilized with one or more drop balls. The embodiment shown in FIG. 3 has drop balls comprising at least a first or lower ball 328. In the embodiment shown, the ball drop tool 300 may further comprise a second or upper ball 330, which is an optional component for the ball drop tool 300 as indicated by the dashed lines identifying the additional drop ball and its orientation within the tool. In an embodiment, the first ball 328 and the second ball 330 are approximately the same size. Balls of differing sizes may be used depending on the configuration of the tool and the ball seats to be utilized. For example, the first ball 328 may be smaller than the second ball 330. Alternatively, the first ball 328 may be larger than the second ball 330. Further, additional balls may be added by lengthening the ball drop bore 324 of the side mandrel 320 and placing the additional balls therein.

[0028] Downlink signaling, or communicating from the surface to downhole tools, is typically performed to provide instructions in the form of commands to the drilling tools. For example, in a reaming operation, downlink commands may instruct the ball drop tool 300 to release a pre-installed ball (e.g., the first ball 328 or the second ball 330) for activating or deactivating the reamer assembly 148 positioned downhole of the ball drop tool 300. In an embodiment, a downlink command is communicated to the ball drop tool 300 from the surface and received at a downlink receiver 332. Various methods of downlink signaling may be performed to communicate the downlink command to the downlink receiver 332. For example, mud pulse telemetry may be used to create a series of momentary pressure changes, or pulses, in the drilling fluid to be detected at the downlink receiver 332. The pulse duration, amplitude, and time between pulses, is detected by the downlink receiver 332 and interpreted as a particular instruction to release a pre-installed ball in the ball drop tool 300. Mud pulse telemetry may include various methods for introducing positive or negative pressure pulses into the drilling fluid. With mud pulse telemetry, the downlink receiver 332 may comprises either a flow meter or a pressure sensor (e.g., a pressure transducer), and a microprocessor, programmed with a telemetry scheme and algorithm for filtering and decoding the pressure pulses received downhole.

[0029] In an example, the pressure sensor may be a differential pressure transducer. Substantially any suitable differential transducer may be utilized, however, a differential transducer having a relatively low-pressure range (as compared to the drilling fluid pressure



in the central bore 306 of the ball drop tool 300) tends to advantageously increase a signal amplitude (and therefore the signal to noise ratio). For example, in one exemplary embodiment, a differential transducer having a differential pressure range from 0 to 1000 psi may be advantageously utilized.

**[0030]** In a different example, the ball drop tool 300 may be further used with bi-directional communication, allowing for downlink and uplink signals to be sent at the same time without interference between the two signals. Such interference is avoided by sending downlink and uplink pulses within different frequency bands. For example, the uplink pulses may have a high frequency, while the downlink pulses may have a low frequency, or vice versa. Although bi-directional communication, including the downlink signaling described herein, is achievable using mud pulse telemetry, other types of telemetry schemes may be used, or a combination of telemetry schemes may be used. For example, assuming downlink signals are generated using mud pulse telemetry, uplink signals may be generated using another type of telemetry, such as electromagnetic telemetry, for example, or vice versa. If the telemetry media is the same for uplink and downlink signaling, then the frequency band of the uplink and downlink signals may be sufficiently different to achieve bi-directional communication. Bi-directional communication may be achieved using any telemetry system with its appropriate uplink receivers and transmitters, for example, pressure transducers for mud pulse telemetry. Bi-directional communication provides the advantage of continuous communication between the surface and downhole tools. In some cases, the downlink may include signals communicated from the surface (or from a lower location in the tool string) through wired pipe.

**[0031]** After pressure pulses representing downlink signals are generated at the surface and transmitted downhole, the downlink receiver 332 disposed in the downhole ball drop tool 300 receives the downlink signals for decoding. With respect to downlink signals, a downlink command decoded from the downlink signal may be limited to a narrow frequency band over a particular time interval. Therefore, a relevant metric for the downlink receiver 332 may be a frequency band and time of reception for detected downlink signals. The downlink receiver 332 will detect noise associated with drilling operations in addition to the downlink signal. Therefore, decoding the downlink signal at the downlink receiver 332 comprises filtering steps to remove the noise and using a

detection algorithm to match a pressure pulse sequence of the downlink signal to a particular pre-programmed downlink command. For example, downlink signals may first pass through a lock-in amplifier filter to separate a narrow-band frequency signal from interfering noise. The shape or duration of each pressure pulse may be analyzed to determine a data value associated with each pressure pulse and decode the downlink command being transmitted.

[0032] In the example of FIG. 3, the downlink receiver 332 is illustrated as being positioned within the ball drop tool 300 for instructing the release of a pre-installed ball. One skilled in the art will recognize that the downlink receiver 332 present in the ball drop tool 300 is useful in a broad range of applications, such as instructing another tool in a different downhole assembly. Alternatively, the ball drop tool 300 may be implemented without a downlink receiver present within the ball drop housing 302, but in communication with a downhole receiver located in a different downhole assembly. The downhole receiver may work in conjunction with a master controller disposed in the downhole assembly for facilitating communication. The telemetry scheme and algorithm for decoding downlink signals are programmed primarily into the downhole receiver. The master controller completes the signal decoding and distributes decoded downlink commands to the an appropriate downhole tool, such as the ball drop tool 300. Once the algorithm decodes the instruction, the master controller housed in the downhole assembly determines which particular tool the instruction is directed to. The master controller then distributes the instruction to that tool, and the particular downhole tool is thereby controlled and changed as a result of the signals being sent.

[0033] In the example of FIG. 3, the downlink command is received at the downlink receiver 332 housed in the ball drop tool 300 and instructs the electromechanical deployment mechanism 326 to release a pre-installed ball from the side mandrel 320 into the central bore 306 of the ball drop tool 300. In an embodiment, the electromechanical deployment mechanism 326 comprises a solenoid-driven actuator that responds to a downlink command received at the downlink receiver 332 to linearly transition between a retaining position 334 and a releasing position 336. Electromechanical actuators, such as the solenoid-driven actuator, provide control over a force and a motion profile between the retaining position 334 and the releasing position 336. Electromechanical actuators may



have an integrated encoder that can be used to accurately control velocity and position.

**[0034]** The solenoid-driven actuator comprises an electromagnetically inductive coil, wound around an armature (e.g., movable steel or iron slug). The electromagnetically inductive coil is shaped such that the armature can be moved in and out of the center, altering the electromagnetically inductive coil's inductance and thereby becoming an electromagnet. The armature is used in the retaining position 334 to hold the pre-installed balls (e.g., the first ball 328 or the second ball 330) within the ball drop bore 324 of the side mandrel 320. The force applied to the armature is proportional to the change in inductance of the electromagnetically inductive coil with respect to a change in position of the armature, and the current flowing through the coil that is applied in response to the downlink command is received at the downlink receiver 332. The force applied to the armature will always move the armature in a direction that increases the inductance of the electromagnetically inductive coil. Additionally, other types of linear actuators may be utilized for transitioning between the retaining position 334 and the releasing position 336, including: mechanical, hydraulic, pneumatic, and piezoelectric actuators.

**[0035]** When the electromechanical deployment mechanism 326 is actuated, a single ball (e.g., the first ball 328) is released from the ball drop bore 324 of the side mandrel 320. The first ball 328 travels along the radial bore 322 and drops down the central bore 306 of the ball drop tool 300. Flow of drilling fluid within the central bore 306 will displace the first ball 328 downwardly until it lands in a ball seat or a ball seat mandrel disposed in a tool located downhole of the ball drop tool 300, such as the reamer 144. When the first ball 328 reaches and engages the ball seat, it operates as an activation ball by allowing the increase pressure in the tool string to activate a desired mechanism associated with the ball seat, including the reaming operations described above, or any other tool or mechanism that requires an increase in pressure, or a redirection of drilling fluid flow caused by an activation ball engaging a ball seat.

**[0036]** Referring still to FIG. 3, a near bit reamer (not shown) may be activated while drilling a borehole to enlarge the borehole diameter, thus avoiding a long rathole that would require an extra trip to enlarge. Ratholes may result from a reamer positioned at a distance from the drill bit (e.g., above the rotary steerable system and LWD tools). The near bit reamer may be placed just above the drill bit, thereby minimizing the length of the



rathole after enlarging the borehole. Alternatively, the reamer may be placed higher in the BHA, for example, above the rotary steerable system or between the drill bit and the rotary steerable system. The near bit reamer is dormant during drilling and may be activated using a dropped activation ball to enlarge the rathole.

**[0037]** When the first ball 328 lands to engage a ball seat mandrel or a ball seat of the ball seat mandrel, pressure of drilling fluid in the tool string is increased to activate a mechanism in the tool string. The ball set mandrel may include at least two ball seats configured to engage dropped balls. For example, the first ball 328 may land in a ball seat in the near bit reamer and fluid pressure is then applied to the top of the first ball 328. Positive surface pressure on the first ball 328 increases the flow rate of the drilling fluid and hydraulically activates the reamer, causing borehole enlargement. Pressure drop through the ball seat mandrel is used to maintain the reamer in an activated, open position.

**[0038]** After enlarging the hole, the reamer may be deactivated to resume normal drilling ahead or tripping out operations. In an embodiment, sufficient drilling fluid pressure is applied to the top of the first ball 328 to extrude it through the ball seat. To increase the pressure to a sufficient amount to discharge the first ball 328, it may be necessary to instruct the electromechanical deployment mechanism 326 to release the second ball 330 from the side mandrel 320 into the central bore 306 of the ball drop tool 300. The second ball 330, when dropped, acts as a de-activation ball by engaging with a second ball seat of the ball seat mandrel and further increasing drilling fluid pressure in the tool string. Once the second ball 330 engages the second ball seat, positive surface pressures on both the first ball 328 and the second ball 330 is increased until a sufficient pressure is applied to extrude the balls through their respective ball seats. After the first ball 328 and the second ball 330 have been extruded through or otherwise removed from their respective ball seats, the flow rate and pressure of drilling fluid may be decreased such that the reamer is hydraulically deactivated.

**[0039]** Although ball drop tool 300 is shown disposed in the drill string 108, it is apparent that the tool can be utilized in production tubing or in wellbore casing. It will be seen, therefore, that the ball drop tool is well adapted to carry out the ends and advantages mentioned, as well as those inherent therein. The ball drop tool 300 can be utilized with any tool which requires that a ball be dropped to engage a ball seat therein and is not limited by

the specific examples provided. While specific example embodiments of the apparatus have been described for the purposes of this disclosure, numerous changes in the arrangement and construction of parts may be made by those skilled in the art. Various modifications and changes may be made to these embodiments without departing from the broader spirit and scope of the invention. Accordingly, the specification and drawings are to be regarded in an illustrative rather than a restrictive sense. All such changes are encompassed within the spirit and scope of the claims.

**[0040]** The accompanying drawings that form a part hereof, show by way of illustration, and not of limitation, specific embodiments in which the subject matter may be practiced. The embodiments illustrated are described in sufficient detail to enable those skilled in the art to practice the teachings disclosed herein. Other embodiments may be used and derived therefrom, such that structural and logical substitutions and changes may be made without departing from the scope of this disclosure. This Detailed Description, therefore, is not to be taken in a limiting sense, and the scope of various embodiments is defined only by the appended claims, along with the full range of equivalents to which such claims are entitled.

**[0041]** Although specific embodiments have been illustrated and described herein, it should be appreciated that any arrangement calculated to achieve the same purpose may be substituted for the specific embodiments shown. This disclosure is intended to cover any and all adaptations or variations of various embodiments. Combinations of the above embodiments, and other embodiments not specifically described herein, will be apparent to those of skill in the art upon reviewing the above description.

## CLAIMS

What is claimed is:

1. An apparatus comprising:
  - a housing adapted to be connected within a tool string, wherein the housing includes a central bore defining a flow path through the housing;
  - a side mandrel comprising a ball drop bore and a radial bore located in the housing for retaining at least one drop ball;
  - a downlink receiver; and
  - a deployment mechanism configured to retain at least one drop ball in the side mandrel, the deployment mechanism in operable communication with the downlink receiver, the deployment mechanism actuable in response to a signal from the downlink receiver to release a retained drop ball from the side mandrel into the central bore
    - wherein the retained drop ball passes from the ball drop bore through the radial bore before reaching the central bore.
2. The apparatus of claim 1, wherein the side mandrel is positioned to be radially offset from the central bore.
3. The apparatus of claim 1 or 2, further comprising a second ball releasably retained within the side mandrel.
4. The apparatus of claim 3, wherein the first ball is an activation ball and the second ball is a de-activation ball.
5. The apparatus of any one of claims 1 to 4, wherein the deployment mechanism comprises a solenoid-driven actuator.
6. The apparatus of any one of claims 1 to 5, wherein the downlink receiver comprises a pressure sensor.
7. The apparatus of any one of claims 1 to 6, wherein the signal from the downlink receiver causes the deployment mechanism to actuate between a retaining position and a releasing position.



8. The apparatus of any one of claims 1 to 7, wherein the housing is threaded at an upper end and a lower end to be connected within the tool string.
9. The apparatus of any one of claims 1 to 8, further comprising a radial bore connecting the side mandrel and the central bore of the housing.
10. The apparatus of any one of claims 1 to 9, wherein the signal from the downlink receiver is generated in response to a flow of fluid along the flow path through the housing.
11. The apparatus of any one of claims 1 to 10, wherein the housing is connected in the drill string above a reamer.
12. A method of dropping a ball to engage a ball seat located in a downhole tool, the method comprising:
- providing a ball drop tool along a tool string, wherein the ball drop tool is positioned uphole of the downhole tool and has a central bore defining a flow path through the ball drop tool;
  - retaining a first ball within a side mandrel of the ball drop tool, the side mandrel having a ball drop bore and a radial bore;
  - receiving a downlink signal at a downlink receiver;
  - actuating, in response to the received signal, an electromechanical deployment mechanism to release the first ball from the side mandrel; and
  - releasing the first ball from the side mandrel
- wherein upon release the first ball passes from the ball drop bore through the radial bore into the central bore.
13. The method of claim 12, wherein receiving the downlink signal comprises detecting a series of pulses transmitted along the tool string using mud pulse telemetry.
14. The method of claim 12 or 13, wherein the downlink signal is generated at a surface transmitter and transmitted downhole using mud pulse telemetry.

15. The method of any one of claims 12 to 14, wherein actuating the electromechanical deployment mechanism comprises actuating a solenoid-driven actuator between a retaining position and a releasing position.

16. The method of any one of claims 12 to 15, further comprising:  
engaging the ball seat in the downhole tool with the first ball; and  
activating a mechanism of the downhole tool.

17. The method of claim 16, wherein activating the mechanism comprises hydraulically activating a reamer.

18. The method of any one of claims 12 to 17, further comprising:  
retaining a second ball within the side mandrel of the ball drop tool; and  
releasing the second ball from the side mandrel in response to a deactivation signal received at the downlink receiver.

19. The method of any one of claims 12 to 18, further comprising displacing drilling fluid into the tool string to displace the released first ball in a downhole direction towards the ball seat.

20. A downhole ball dropping system, the system comprising:  
a ball drop tool having a central bore connected within a drill string, wherein the ball drop tool is communicably coupled to a downlink receiver, the ball drop tool having a side mandrel configured to retain a drop ball in a ball drop bore; and  
an electromechanical deployment mechanism configured to be actuated in response to a signal from the downlink receiver to release the drop ball from the side mandrel  
wherein the released drop ball passes from the ball drop bore through a radial bore of the side mandrel and into the central bore.

FIG. 1

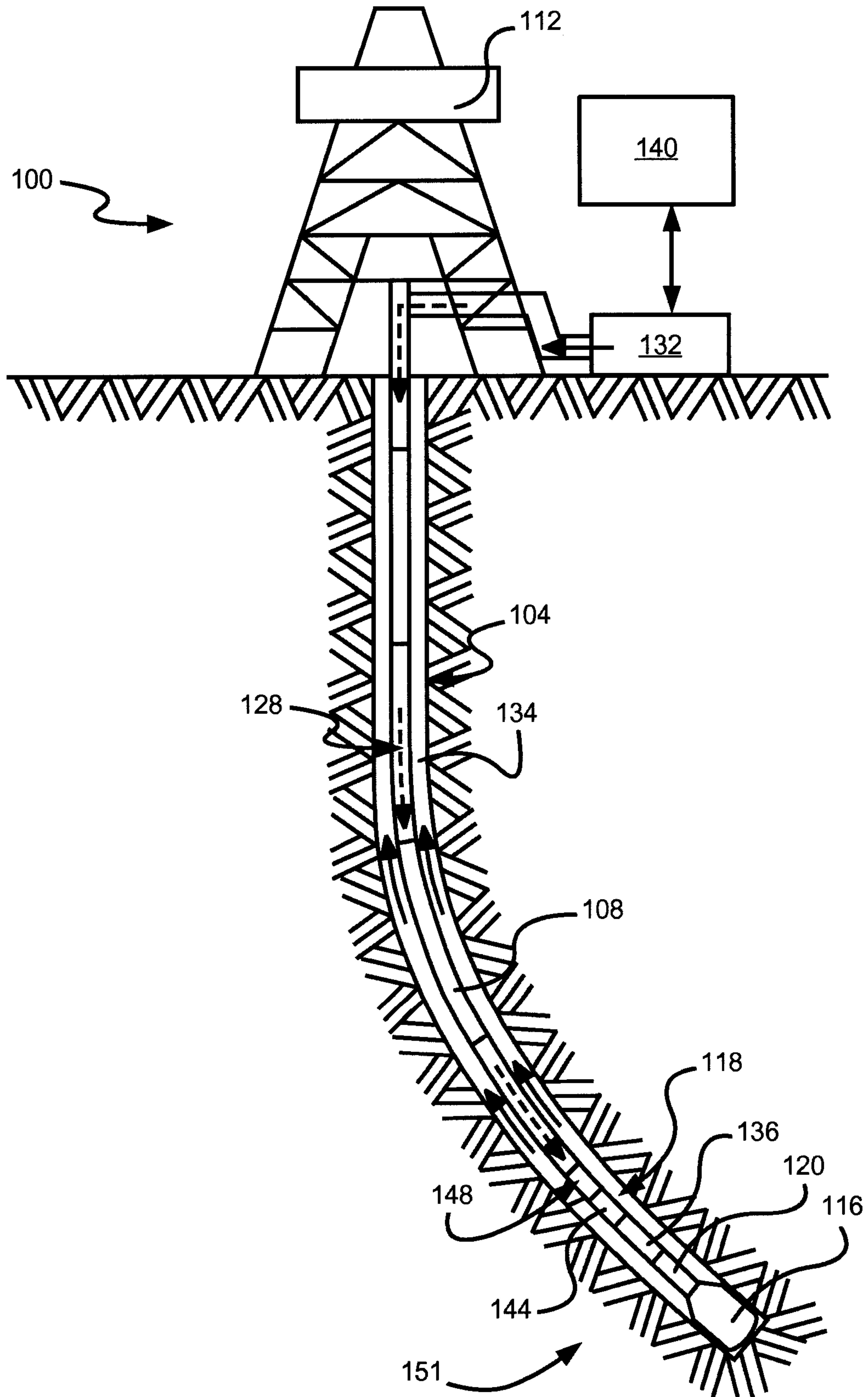




FIG. 2

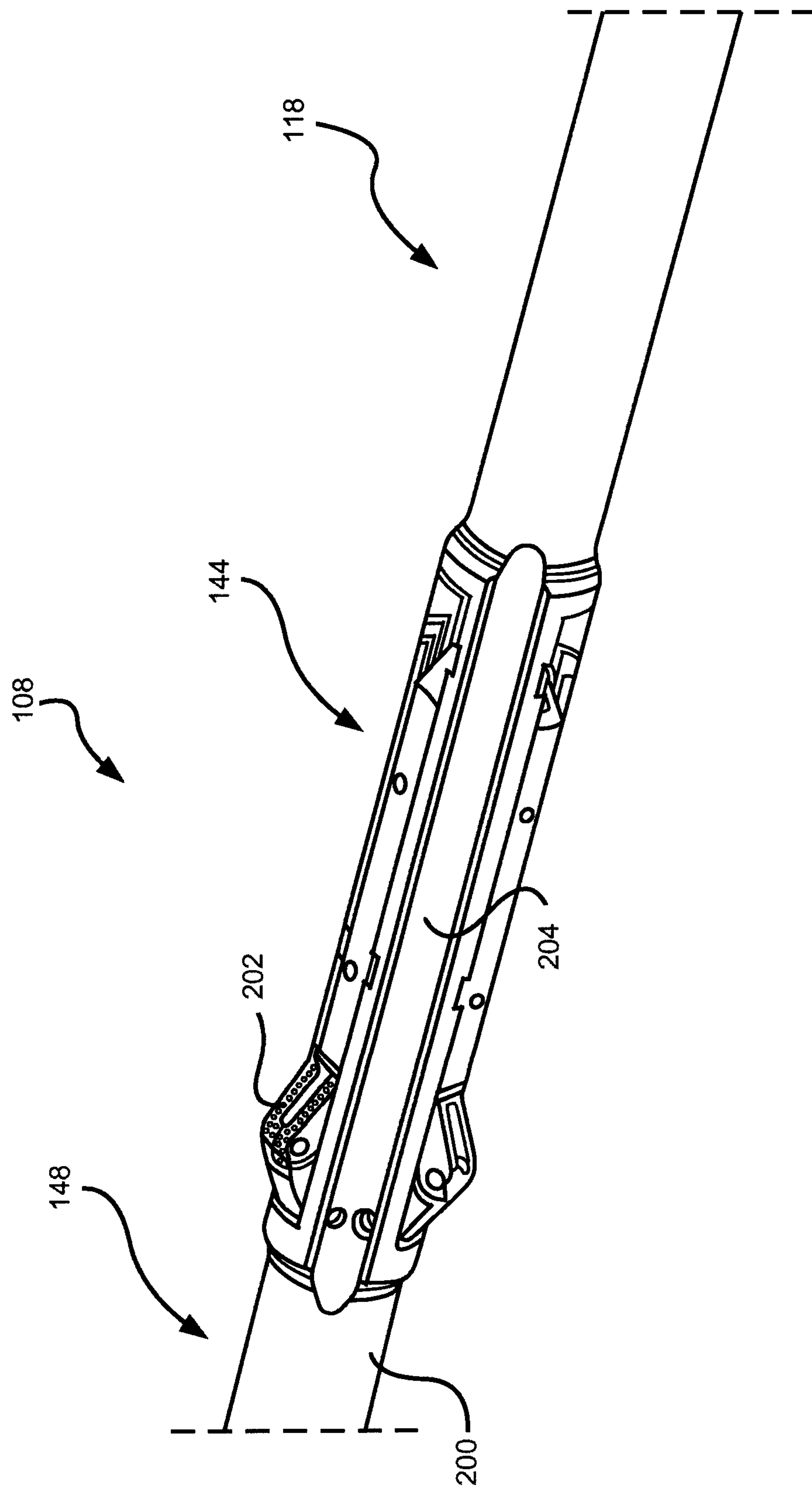


FIG. 3

