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EP 1488073 B2
US 20080029306 A
US 20050096848 A1
US 20110094799 A1
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US 20050092523 A1

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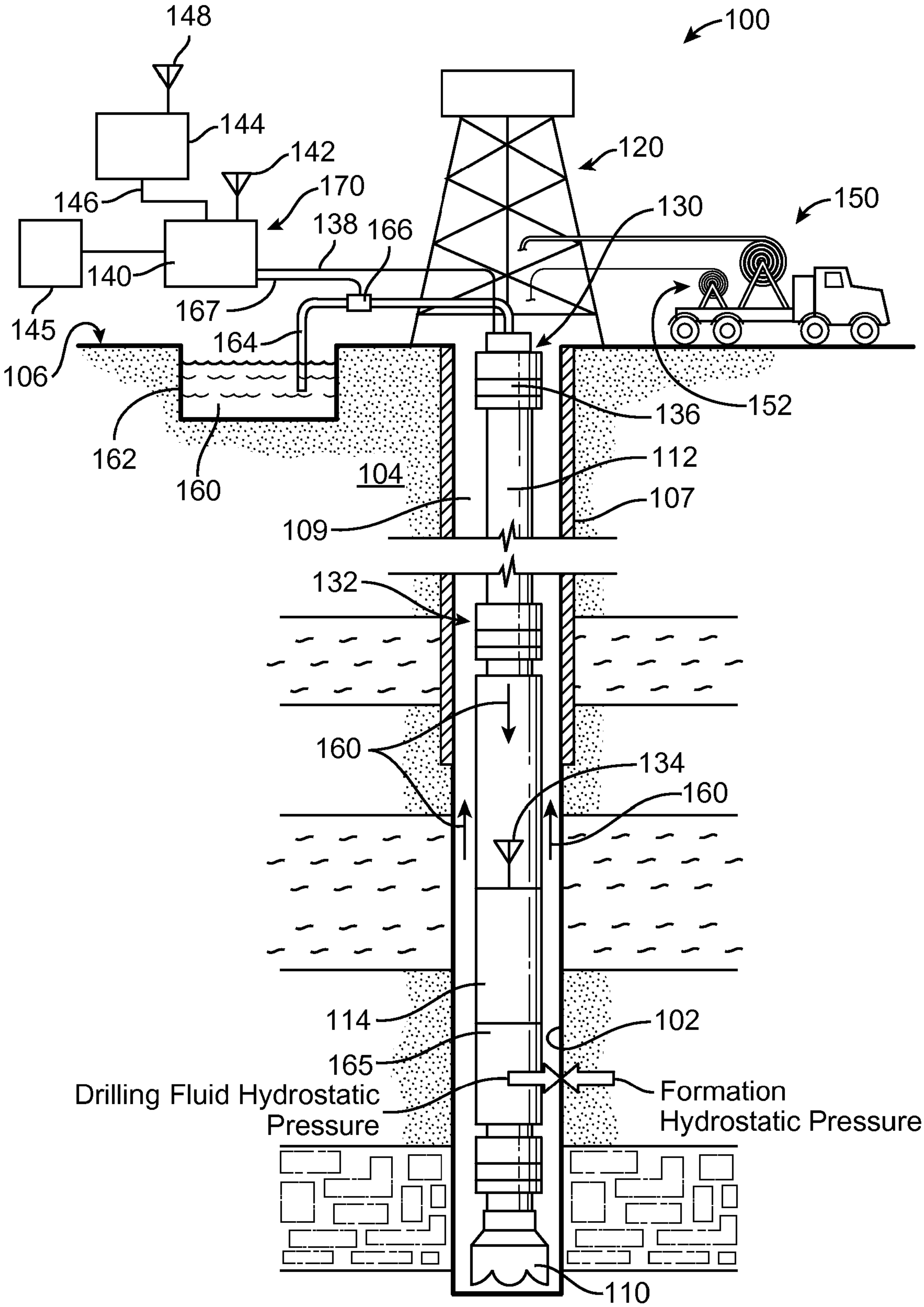
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100
144
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130
150
138
166
140
145
167
164
106
136
152
162
160
104
112
109
107
132
160
134
160
114
102
165
Drilling Fluid Hydrostatic Pressure
Formation Hydrostatic Pressure
110

FIG. 1

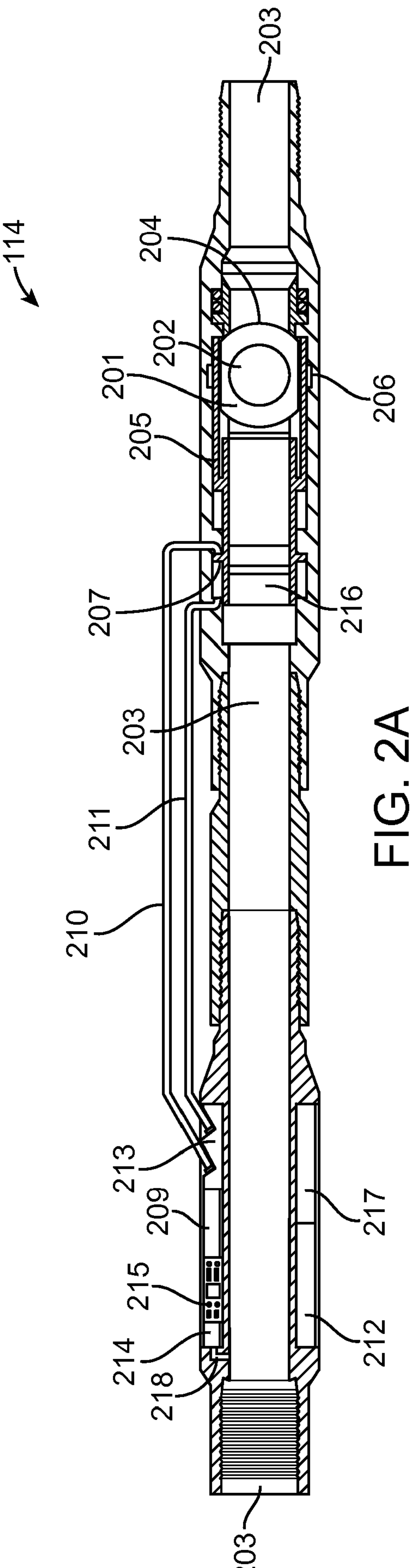

114
203
204
202
201
206
205
207
216
203
211
210
213
209
217
215
212
214
218
203

FIG. 2A

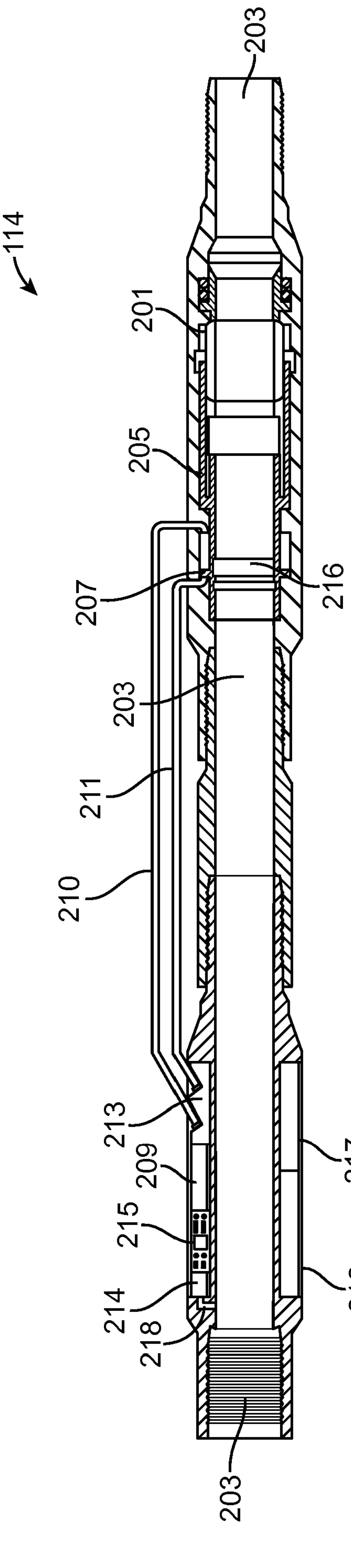

114
203
201
205
207
216
203
211
210
213
209
215
214
218
217
212
203

FIG. 2B

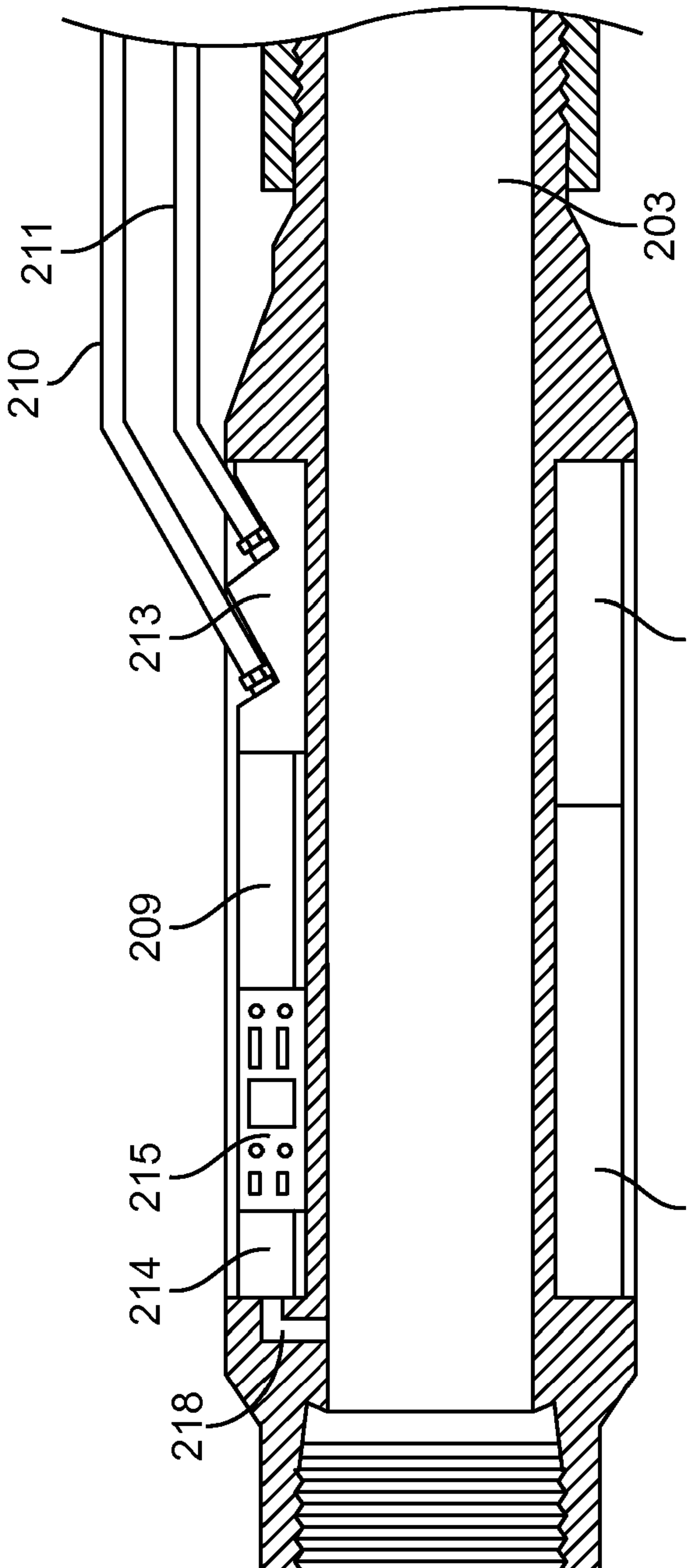


FIG. 3

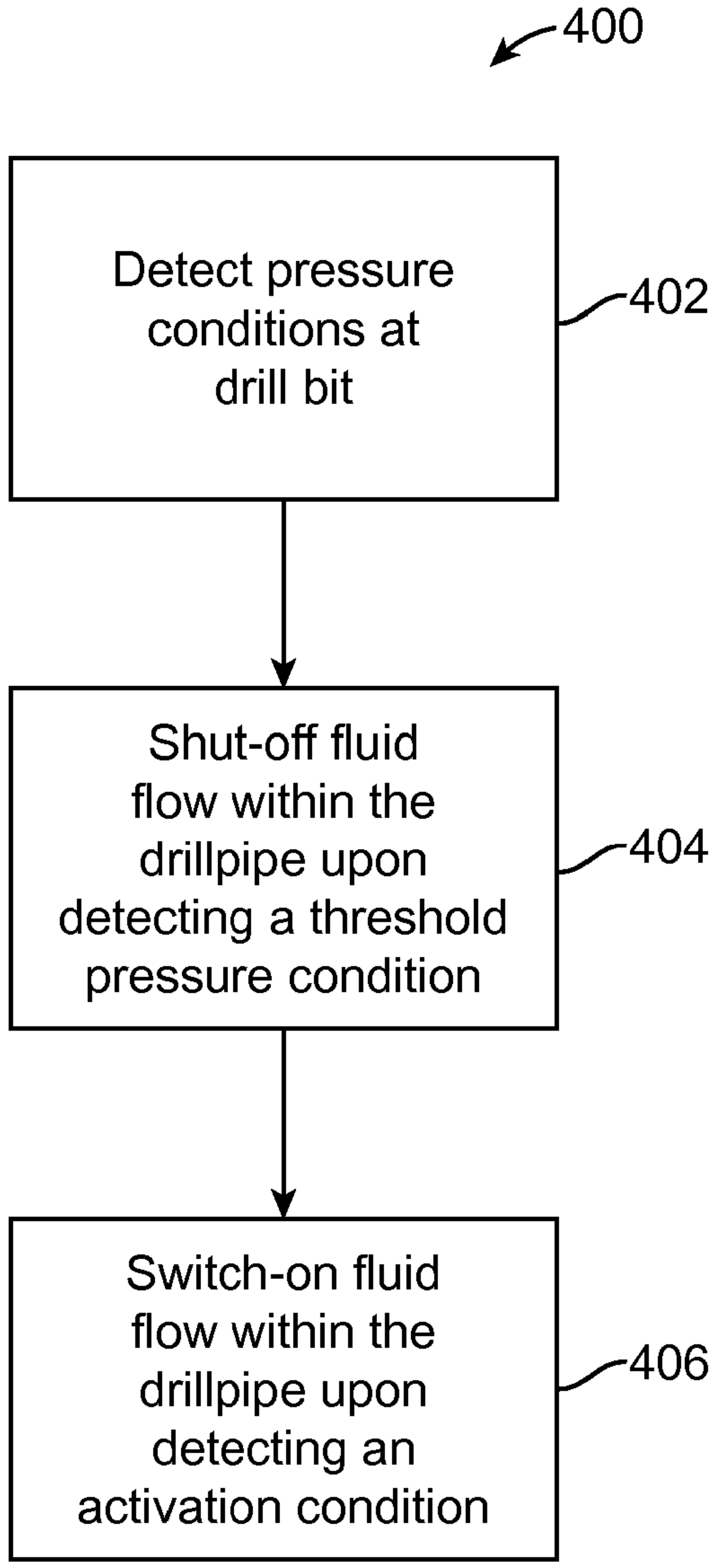
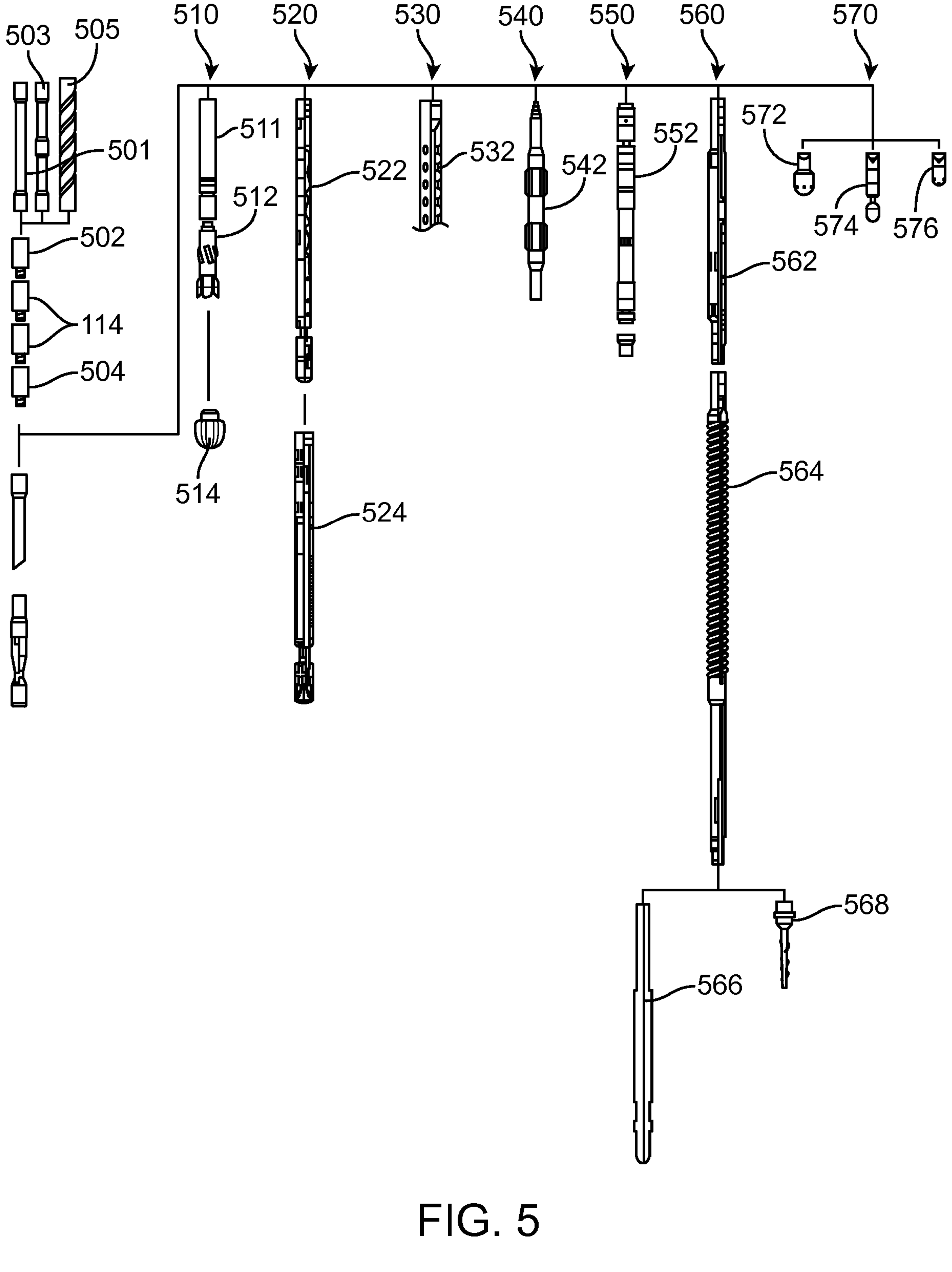

400
Detect pressure conditions at drill bit
402
Shut-off fluid flow within the drillpipe upon detecting a threshold pressure condition
404
Switch-on fluid flow within the drillpipe upon detecting an activation condition
406

FIG. 4


503
505
501
502
114
504
510
511
512
514
520
522
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576

FIG. 5

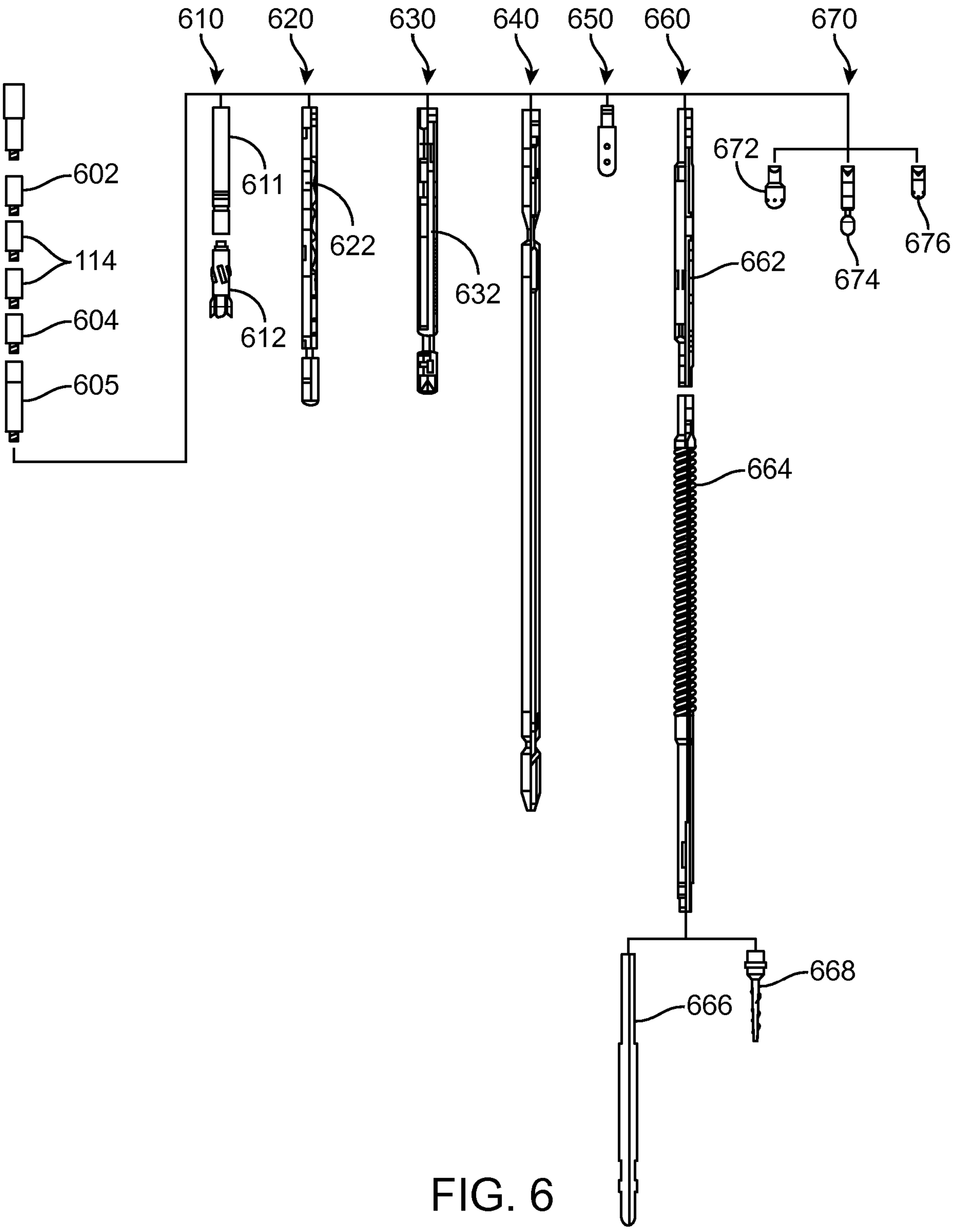
610
620
630
640
650
660
670
602
114
604
605
611
612
622
632
662
664
666
668
672
674
676

FIG. 6

DOWNHOLE PRESSURE SENSING DEVICE FOR OPEN-HOLE OPERATIONS

FIELD

[0001] The present disclosure relates generally to drilling systems and particularly to a controllable downhole barrier employed during drilling operations. More specifically, the present disclosure describes an automatically triggered downhole barrier employed during drilling operations.

BACKGROUND

[0002] Barriers are typically employed to prevent hydrocarbon influx to the surface. Cased-hole operations, such as well completion and well intervention, generally employ sophisticated pressure control systems at the wellhead and in the production tubing.

[0003] By contrast, open-hole operations typically employ less sophisticated pressure control systems. For example, a drilling fluid barrier is generally employed during open-hole well construction to prevent formation pressures from overcoming hydrostatic head pressure, which may result in hydrocarbon influx. Conventional open-hole pressure control systems include human operators that monitor and react to well conditions. For example, human operators adjust drilling fluid characteristics or drilling fluid pressures to maintain a regulated overbalance to prevent hydrocarbon influx. What is needed is a pressure control system for open-hole operations that automatically monitors and reacts to well conditions in real-time, without human operator intervention, to prevent uncontrolled influx.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] Implementations of the present technology will now be described, by way of example only, with reference to the attached figures, wherein:

[0005] FIG. 1 is a partial cross-section view illustrating an embodiment of a drilling rig for drilling a wellbore with the drilling system configured in accordance with principles of the present disclosure;

[0006] FIG. 2A is a diagram illustrating the pressure control module 114 in a shut-off state according to one example;

[0007] FIG. 2B is a diagram illustrating the pressure control module 114 in a fluid-flow state according to one example;

[0008] FIG. 3 is a diagram illustrating a close-up view of a mechanism in the pressure control module that controls fluid flow there through;

[0009] FIG. 4 is a flowchart of an example method according to the present disclosure;

[0010] FIG. 5 is a diagram illustrating various drilling assembly designs that include the pressure control module and supporting components according to the present disclosure; and

[0011] FIG. 6 is a diagram illustrating various completion assembly designs that include the pressure control module and supporting components according to the present disclosure.

DETAILED DESCRIPTION

[0012] It will be appreciated that for simplicity and clarity of illustration, where appropriate, reference numerals have been repeated among the different figures to indicate corresponding or analogous elements. In addition, numerous specific details are set forth in order to provide a thorough understanding of the embodiments described herein. However, it will be understood by those of ordinary skill in the art that the embodiments described herein can be practiced without these specific details. In other instances, methods, procedures and, components have not been described in detail so as not to obscure the related relevant feature being described. Also, the description is not to be considered as limiting the scope of the embodiments described herein. The drawings are not necessarily to scale and the proportions of certain parts have been exaggerated to better illustrate details and features of the present disclosure.

[0013] Throughout this description, terms such as "upper," "upward," "lower," "downward," "above," "below," "downhole," "uphole," "longitudinal," "lateral," and the like, as used herein, are descriptive of a relationship with, and are used with reference to, the bottom or furthest extent of the surrounding wellbore, even though the wellbore or portions of it may be deviated or horizontal. Correspondingly, the transverse, axial, lateral, longitudinal, radial, etc., orientations shall mean orientations relative to the orientation of the surrounding wellbore or wellbore tool in question. Additionally, the non-limiting embodiments within this disclosure are illustrated such that the orientation is such that the right-hand side is down hole compared to the left-hand side.

[0014] Several definitions that apply throughout this disclosure will now be presented. The term "coupled" is defined as connected, whether directly or indirectly through intervening components, and is not necessarily limited to physical connections. The connection can be such that the objects are permanently connected or releasably connected. The term "outside" refers to a region that is beyond the outermost confines of a physical object. The term "inside" indicates that at least a portion of a region is partially contained within a boundary formed by the object. The term "substantially" is defined to be essentially conforming to the particular dimension, shape, or other word that substantially modifies, such that the component need not be exact. For example, substantially cylindrical means that the object resembles a cylinder, but can have one or more deviations from a true cylinder.

[0015] The term "radially" means substantially in a direction along a radius of the object, even if the object is not exactly circular or cylindrical. The term "axially" means substantially along a direction of the axis of the object. If not specified, the term axially is such that it refers to the longer axis of the object.

[0016] The term "drillpipe" means any conduit that extends downhole to support drilling operations. The drillpipe is coupled to a drill bit provided at the downhole end of the drillpipe. The drillpipe may include a drill string, coil tubing, or any other conduit that extends downhole to support drilling or workover operations. The drill string may include drillpipe of pre-determined lengths, such as 30 feet, 90 feet, or the like. The coil tubing may include continuous piping of several hundred feet or greater.

[0017] "Processor" as used herein is an electronic circuit that can make determinations based upon inputs and is interchangeable with the term "controller". A processor can include a microprocessor, a microcontroller, and a central processing unit, among others. While a single processor can be used, the present disclosure can be implemented over a plurality of processors, including local controllers provided in a tool or sensors provided along the drillpipe.

[0018] According to one example, open-hole operations are employed during well construction. The open-hole operations typically include forming casing strings, such as a surface casing and intermediate casing. If a well is determined to be viable, then well completion may include forming a production casing for cased-hole operations.

[0019] FIG. 1 schematically illustrates an open-hole drilling operation 100 used to form a subterranean well according to one example. A wellbore 102 is illustrated drilled into the earth 104 from the ground's surface 106 using a drill bit 110 provided on a drillpipe 112. For illustrative purposes, the top portion of the wellbore 102 includes the surface casing 107, which is typically at least partially comprised of cement and which defines and stabilizes the wellbore 102 after being drilled. The wellbore 102 also may include intermediate casings (not shown), which may be stabilized with cement. The cement performs several functions, including preventing wellbore collapse, maintaining a physical separation between the Earth's layers, providing a barrier to prevent fluid migration, enhancing safety, and protecting the Earth's layers from any contaminants introduced during open-hole operations, or the like.

[0020] As illustrated in FIG. 1, the drill bit 110 is located at the bottom, distal end of the drillpipe 112 that supports components along its length. During the open-hole operations, the drill bit 110 and drillpipe 112 are advanced into the earth 104 by a drilling rig 120. The drilling rig 120 may be supported directly on land as illustrated or on an intermediate platform if at sea.

[0021] A pressure control module 114 is illustrated on the drillpipe 112 for controlling pressure conditions near the drill bit 110. Measurement while drilling (MWD)/logging while drilling (LWD) procedures are supported both structurally and communicatively. The lower end portion of the drillpipe 112 may include a drill collar proximate the drilling bit 110. The drill bit 110 may take the form of a roller cone bit or fixed cutter bit or any other type of bit known in the art. Sensor sub-units 130, 132 are shown within the cased portion of the well and can be enabled to sense nearby characteristics and conditions of the drillpipe, formation fluid, casing, and surrounding formation. Data indicative of sensed conditions and characteristics is either recorded downhole, for instance at a processor (now shown) for later download or communicated to the surface either by wire using repeaters 134,136 up to surface wire 138, or wirelessly or otherwise. If wirelessly, the downhole transceiver (antenna) 134 may be utilized to send data to a local processor 140, via surface transceiver (antenna) 142. The data may be either processed at processor 140 or further transmitted along to a remote processor 144 via wire 146 or wirelessly via antennae 142 and 148. For purposes of completeness, FIG. 1 illustrates coiled tubing 150 and wireline 152 deployment, which are contemplated and within the context of this disclosure.

[0022] A drilling fluid 160 may be circulated through the drilling components to perform functions such as preventing blow-out and preventing collapse of the wellbore 102. According to one example, the drilling fluid 160 may be circulated during drilling operations through the drillpipe 112, the pressure control module 114, the drill bit 110, and the annulus 109. According to one example, the drill bit 110 may include nozzles that direct a flow of drilling fluid 160. After passing through the drilling components, the drilling fluid 160 may be circulated to the surface 106, where it passes through a filter (not shown) to remove any drilling debris, such as cuttings or the like. According to one example, the filter may include a shale shaker or the like. The filtered drilling fluid 160 may be collected in a tank 162 for re-circulation through the drilling components. The drilling fluid 160 may be formulated to perform other functions, including lubricating the drill bit 110, cooling the drill bit 110, flushing drilling debris, such as rock, away from the drill bit 110 and upward to the Earth's surface 106 through the annulus 109 formed between the wellbore 102 and the drillpipe 112, and reducing friction between the drillpipe 112 and the wellbore 102, or the like.

[0023] An additional mode of communication is contemplated using drilling fluid 160 pumped via conduit 164 to a downhole drilling fluid motor 165. The drilling fluid is circulated down through the drillpipe 112 and up the annulus 109 around the drillpipe 112. For purposes of communication, resistance to the incoming flow of drilling fluid may be modulated downhole to send backpressure pulses up to the surface for detection at sensor 166. Data from sensor 166 may be sent along communication channel 167 (wired or wirelessly) to one or more processors 140, 144 for recordation and/or processing. A surface installation 170 may be provided to send and receive data to and from the well. The surface installation 170 may include a local processor 140 that may optionally communicate with one or more remote processors 144, 145 by wire 146 or wirelessly using transceivers 142, 148.

[0024] FIG. 1 further illustrates that the wellbore 102, which extends downhole into the Earth's layers, is subjected to hydrostatic pressure originating from subterranean destinations or formations. The hydrostatic pressure originating from outside the wellbore 102 is identified as formation hydrostatic pressure. The hydrostatic pressure originating from inside the wellbore 102 is defined as drilling fluid hydrostatic pressure. As the drilling depth increases, a hydrostatic pressure differential varies between the outside formation hydrostatic pressure and the drilling fluid hydrostatic pressure. For example, the hydrostatic pressure differential may increase as the drilling depth increases. The hydrostatic pressure differential may force minerals, such as oil and gas, from the formation into the wellbore 102. Alternatively, the hydrostatic pressure differential may force drilling fluid 160 from the wellbore 102 into the formation. In either of these situations, the effect of the hydrostatic pressure differential may disrupt drilling operations.

[0025] According to one example, the hydrostatic pressure may be under-balanced when the formation hydrostatic pressure is greater than the drilling fluid hydrostatic pressure. During under-balanced conditions, any minerals that enter the wellbore 102 may ascend under pressure through the drillpipe 112 and the annulus 109 causing a blow-out at the surface 106. The blow-out may damage equipment and cause injury or death to workers at the surface 106. Additionally or alternatively, during under-balanced conditions, the hydrostatic pressure difference may collapse or restrict the diameter of the wellbore 102, which may cause disruptions to drilling operations.

[0026] During over-balanced conditions, the drilling fluid 160 may exit the wellbore 102 and leach into the formation. Loss of drilling fluid 160 is financially and environmentally undesirable. Furthermore, the drilling fluid 160 may cause the formation to swell proximate to the wellbore 102. The swelling may restrict the diameter of the wellbore 102, which may cause disruptions to drilling operations.

[0027] According to one example, the hydrostatic pressure differential may be controlled during open-hole operations by adjusting characteristics of the drilling fluid 160, such as density or drilling fluid weight, viscosity, or the like. For example, the drilling fluid characteristics may be adjusted using additives or the like. Drilling fluid engineers and drilling fluid loggers may constantly monitor and adjust the drilling fluid characteristics to maintain desired hydrostatic pressure differentials during open-hole drilling operations. The drilling fluid characteristics may be adjusted to accommodate for drilling depth, detected properties of the exposed formation, or the like. When desired drilling fluid characteristics are reached, the drilling fluid 160 may be employed to control the hydrostatic pressure differential downhole. For example, the drilling fluid 160 may be used to exert appropriate back pressure through the drillpipe 112. The drilling fluid characteristics may be continuously monitored and adjusted during the open-hole drilling operations to control the hydrostatic pressure differential. For example, the hydrostatic pressure differential may be controlled to one of an over-balanced condition or an under-balanced condition, as desired. Furthermore, the hydrostatic pressure differential may be controlled to equalize the formation hydrostatic pressure and the drilling fluid hydrostatic pressure.

[0028] According to another example, managed pressure drilling ("MPD") may be applied to control the hydrostatic pressure differential during open-hole operations. With MPD, the open-hole drilling operations are not disrupted to change drilling fluid characteristics. Instead, the drilling fluid pressure exerted within annulus 109 and within the drillpipe 112 may be adjusted during the open-hole drilling operations without disrupting operations. For example, the drilling fluid pressure may be adjusted during the open-hole drilling operations to increase or decrease the drilling fluid hydrostatic pressure. Thus, MPD eliminates delays to open-hole drilling operations, such as delays associated with stopping open-hole drilling operations to adjust drilling fluid characteristics.

[0029] As described above, the hydrostatic pressure differential may be controlled downhole by adjusting drilling fluid characteristics and/or by applying managed pressure drilling techniques. These techniques suffer from various drawbacks such as relying on a human operator for implementation. The human operator is typically located at the surface 106 of the open well and is tasked with monitoring and reacting to open-hole conditions as they occur. The activities of monitoring and reacting should occur in substantially real-time to be effective. For example, the human operator should detect and react to a hydrostatic pressure change substantially immediately upon its occurrence downhole. For various reasons, however, detection and reaction delays may be introduced.

[0030] Detection time delays may be introduced due to propagation delays resulting from a physical distance between the location of the pressure change event location and the location of the human operator. Reaction time delays may be introduced due to varying reaction times of human operators. Yet, other reasons for detection and reaction time delays may be due to experience levels of the human operators and their ability to determine a significance of a pressure change event.

[0031] Furthermore, once the pressure change event is detected during open-hole operations, there is a reaction time delay associated with adjusting drilling fluid characteristics and/or adjusting the drilling fluid pressure within the annulus 109 and/or the drillpipe 112. Any time delays associated with detecting and reacting to the pressure change event may result in the hydrostatic pressure differential disrupting drilling operations. For example, the hydrostatic pressure difference may result in a collapse or restriction of a diameter of the wellbore 102. Additionally or alternatively, any time delay associated with detecting and/or reacting to the pressure change event may result in a blow-out which may damage equipment and cause injury or death to workers located at the surface 106.

[0032] These drawbacks associated with open-hole operations are overcome by introducing a pressure control module 114 on the drillpipe 112.

The pressure control module 114 may monitor well conditions in real-time and may automatically trigger to shut-off fluid flow in the drillpipe 112. For example, the pressure control module 114 may include components that monitor a pressure differential proximate to the drill bit 110 in real-time and may automatically trigger the fluid flow in the drillpipe 112 to shut-off if the pressure differential reaches a predetermined amount. Positioning the pressure control module 114 proximate to the location of the pressure change event provides a substantially instantaneous reaction time, which may minimize or eliminate any time delays. Also, removing the human operator from a monitoring role may eliminate any reaction delay time.

[0033] According to one example, a signal may be sent via repeaters 134,136 to alert the human operator of the existence of a fluid flow shut-off event within the drillpipe 112. Additionally, the signal may provide data that includes corresponding to well conditions that triggered the shut-off condition. The human operator may evaluate the data to determine causes of the shut-off condition. If needed, drilling fluid characteristics may be adjusted and/or the drilling fluid pressure may be adjusted within the annulus 109 and within the drillpipe 112 to adjust the hydrostatic pressure differential to desired conditions. Additionally, a trigger threshold value may be adjusted to change that shut-off trigger conditions for the pressure control module 114. While this example is described with reference open-hole operations, one of ordinary skill in the art will readily appreciate that the pressure control module 114 may be applied to closed-hole operations.

[0034] The near instantaneous detection of any pressure change events and near instantaneous reaction by the pressure control module 114 enhances safety conditions during open-hole operations, such as drilling operations. For example, the near instantaneous detection and reaction to a pressure change event may increase safety by automatically cycling the drillpipe 112 from a flow-through condition to a shut-off condition without delays typically introduced by human intervention. In this way, the pressure control module 114 may reduce drilling delays and may eliminate blow-back during open-hole operations. Accordingly, the pressure control module 114 may eliminate damage to equipment located at the surface 106 and may avoid injury or death to workers located at the surface 106.

[0035] According to one example, the pressure control module 114 may include a processor that communicates with a computer-readable storage medium having instructions stored thereon that, when executed by the processor, cause the processor to detect pressure conditions and control fluid flow. According to one example, the processor is configured to shut-off fluid flow upon detecting a threshold pressure condition. Upon detecting an activation condition, the processor may be configured to switched-on the fluid flow.

[0036] FIG. 2A illustrates the pressure control module 114 in a shut-off state according to one example. The pressure control module 114 may include a valve that controls fluid flow through the conduit 203. For example, the valve may include a ball 201 having a channel 202 bored therethrough such that when the channel 202 is aligned with the conduit 203, fluid flows through the conduit 203. The ball 201 also may include a solid portion 204 such that when the solid portion 204 is provided to the conduit 203, fluid flow through the conduit 203 is blocked. One of ordinary skill in the art will readily appreciate that other mechanisms may be employed to control fluid flow through the conduit 203. For example, the pressure control module 114 may include a flapper valve, a butterfly valve, a choke valve, a globe valve, a piston valve, a plug valve, a spool valve, or the like.

[0037] Returning to FIG. 2A, the ball 201 may be configured to rotate about an axis 206 to flip between the closed position and an open position. According to one example, an actuation arm 205 is provided to rotate the ball 201 between the closed position and the open position. According to one example, the actuation arm 205 may be controlled by a hydraulic piston 207 that is fluidly coupled to a hydraulic pump 209 via a hydraulic circuit that includes fluid lines 210,211. A hydraulic reservoir 212 is provided to store hydraulic fluid. One of ordinary skill in the art will readily appreciate that other mechanisms may be employed to rotate the ball 201 between the closed position and the open position.

[0038] FIG. 3 illustrates a close-up view of the mechanism that controls rotation of the ball 201 between the closed position and the open position. A battery 217 may be provided to energize components of the pressure control module 114. A diverter block 213 is fluidly coupled to the fluid lines 210,211 and the hydraulic reservoir 212 to divert hydraulic fluid between corresponding fluid lines 210,211 in order to actuate the hydraulic piston 207. The hydraulic piston 207 may be configured to slide the actuation arm 205 in order to rotate the ball 201 between the closed position and the open position. A processor 215 is communicatively coupled to the hydraulic pump 209 to control operation of the hydraulic pump 209 according to signals received from a pressure sensor 214 that is fluidly coupled to a pressure port 218. According to one example, the pressure sensor 214 monitors the pressure of fluid flowing through the pressure control module 114. According to one example, the processor 215 may communicate with the sub-unit 132 to relay information to the surface 106.

[0039] According to one example, the pressure control module 114 may be provided along the drillpipe 112 and may be positioned proximate to the drill bit 110 in order to detect pressure conditions at the drill bit 110. When the ball 201 is oriented in the open position, the pressure sensor 214 may be monitoring the drilling fluid hydrostatic pressure and the formation hydrostatic pressure. Thus, the pressure sensor 214 may detect a kick or surge in the formation hydrostatic pressure. In contrast, when the ball 201 is oriented in the closed position, the pressure sensor 214 may be isolated from the formation hydrostatic pressure. Accordingly, the pressure sensor 214 may be monitoring only the drilling fluid hydrostatic pressure when the ball 201 is oriented in the closed position. One of ordinary skill in the art will readily appreciate that the pressure control module 114 may be provided at any position along the drillpipe 112.

[0040] With reference to FIG. 2B, the ball 201 is illustrated in the open position. Thus, the pressure sensor 214 is monitoring the drilling fluid hydrostatic pressure and the formation hydrostatic pressure. According to one example, the processor 215 executes instructions that cause the hydraulic pump 209 and diverter block 213 to supply hydraulic fluid through the fluid line 211 to push a piston 216 in a direction toward the ball 201 when the formation hydrostatic pressure exceeds the drilling fluid hydrostatic pressure. Alternatively, the processor 215 executes instructions that cause the hydraulic pump 209 and diverter block 213 to supply hydraulic fluid through the fluid line 211 to push a piston 216 in a direction toward the ball 201 when the fluid pressure detected at the pressure sensor 214 exceeds a predetermined threshold. When the piston 216 is pushed in the direction toward the ball 201, then the actuation arm 205 is pushed toward the ball 201, which orients the ball 201 in the closed position. One of ordinary skill in the art will readily appreciate that other algorithms may be employed to orient the ball 201 in the closed position.

[0041] With reference to FIG. 2A, the ball 201 is illustrated in the closed position. Thus, the pressure sensor 214 monitors only the drilling fluid hydrostatic pressure. In this example, the processor 215 may be programmed to monitor for predetermined conditions before executing instructions to orient the ball 201 in the open position. Thus, the flow-through condition may be activated remotely after the pressure control module 114 is triggered to the shut-off condition. For example, the predetermined conditions may include a preselected pressure for a preselected amount of time, lapsing of a preselected amount of time, or the like. If the fluid pressure detected at the pressure sensor 214 correspondence to the predetermined conditions, then the processor 215 executes instructions that cause the hydraulic pump 209 and diverter block 213 to supply hydraulic fluid through the fluid line 210 to push a piston 216 in a direction away from the ball 201. When the piston 216 is pushed in the direction away from the ball 201, then the actuation arm 205 is pushed away from the ball 201, which orients the ball 201 in the open position. One of ordinary skill in the art will readily appreciate that other algorithms may be employed to orient the ball 201 in the open position.

[0042] One of ordinary skill in the art will readily appreciate that the pressure control module 114 may be implemented in various other ways. Additionally, the pressure control module 114 may be modified structurally without impacting the manner of operation. For example, the control lines 210, 211 may be embedded within walls of the pressure control module 114. Furthermore, the pressure control module 114 may be formed in a uni-body construction or separated into additional modules.

[0043] According to another example, two or more automatically triggered pressure control modules 114 may be provided along the drillpipe 112. For example, the pressure control modules 114 may be deployed at different depths along the drillpipe 112. Each of the pressure control modules 114 may act independently of one another. Additionally, each of the pressure control modules 114 may be programmed to trigger at different predetermined pressure threshold conditions to orient the ball 201 in the closed position. Furthermore, each of the pressure control modules 114 may be programmed to monitor for a different predetermined condition before executing instructions to orient the ball 201 in the open position. In other words, each of the pressure control modules 114 may be reset to the flow-through condition based upon different activation parameters. For example, the first pressure control module 114 may be subjected to a first pre-selected pressure condition for a first pre-selected amount of time, whereas the second pressure control module 114 may be subjected to a second pre-selected pressure condition for a second pre-selected amount of time. One of ordinary skill in the art will readily appreciate that only one activation parameter may be different between the first and second pressure control modules 114.

[0044] According to yet another example, the pressure control module 103 may be applied to closed-hole operations, such as well stimulation liners. In closed-hole operations, the pressure control module 114 may operate as an automatic closing float shoe after the stimulation fluid is displaced with the completion fluid or after cement is pumped. In closed-hole operations, the pressure control module 114 may be operated using a combination of rate (or pressure), density, time (or duration), or the like.

[0045] FIG. 4 illustrates a flowchart of an example method 400 according to the present disclosure. The method 400 can be implemented using the above described components. For example, the method 400 can be implemented by the processor 215 configured to directly or indirectly control operation of the various components. In other implementations, other controls of the various components are considered within the scope of this disclosure.

[0046] The method 400 may include detecting pressure conditions at the drill bit 110 (block 402). The pressure conditions associated with the drilling fluid hydrostatic pressure and the formation hydrostatic pressure may be monitored by the pressure sensor 214 as described above. The method 400 may further include automatically shutting-off fluid flow within the drillpipe 112 upon detecting a threshold pressure condition (block 404). The processor 215 may execute instructions to orient the ball 201 in the closed position as described above when the fluid pressure detected at the pressure sensor 214 exceeds a predetermined threshold.

[0047] The present method 400 may also include switching-on fluid flow within the drillpipe upon detecting an activation pressure condition (block 406). When the ball 201 is provided in the closed position, the pressure sensor 214 is monitoring only the drilling fluid hydrostatic pressure. The processor 215 may be programmed to monitor the drilling fluid hydrostatic pressure for predetermined conditions before executing instructions to orient the ball 201 in the open position.

[0048] Numerous examples are provided herein to enhance understanding of the present disclosure. A specific set of examples are provided as follows.

[0049] FIG. 5 illustrates the pressure control module 114 and supporting components provided along a length of the drillpipe 112 for open-hole operations. According to one example, the drillpipe 112 may include a drill pipe 501, HWO pipe 503, drill collars, and spiral drill collars 505, or the like. A supporting component provided along a length of the drillpipe 112 may include an alternator 502 that is provided downhole and may be positioned proximate to the pressure control module 114. According to one example, the alternator 502 may include an axial flow design may be configured to energize electronics in the pressure control module 114. The alternator 502 may be electrically coupled to the pressure control module 114 via an inductive coupling or by an internal hardwire. Another supporting component provided along a length of the drillpipe 112 may include a float valve 504 that is provided downhole and may be positioned proximate to the pressure control module 114. A float valve 504 may be provided to prevent entry of the drilling fluid 160 into the drillpipe 112 while the drillpipe 112 is being lowered. Thus, the drillpipe 112 may float during the descent, which may decrease a little on the derrick or mast.

[0050] FIG. 5 illustrates various drilling assemblies 510, 520, 530, 540, 550, 560, 570 that may be coupled below the pressure control module 114. According to one example, a milling assembly 510 may be provided below the pressure control module 114 that includes a motor 511, a mill 512, and a drill bit 514. For example, the mill 512 may include junk mills, taper mills, cement mills, under-reamers, cone mills, skirted mills, burn shoes, plug mills, window mills, round nose mills, watermelon mills, CPE mills, tri-blade mills, and guide mills, or the like. For example, the drill bit 514 may include tri-cone bits, multiple tri-cone bits, rock bits, coring bits, and PDC bits.

[0051] According to another example, a hydra blast assembly 520 may be provided below the pressure control module 114 and may include a hydra blast pro-rotating tool 522 or a hydra blast indexing tool 524. According to yet another example, a hydra jet assembly 530 may be provided below the pressure control module 114 and may include a hydra jet tool 532. According to another example, a casing scraper assembly 540 may be provided below the pressure control module 114 and may include a casing scraper tool 542. According to another example, a packer assembly 550 may be provided below the pressure control module 114 and may include a packer tool 552. According to yet another example, a fishing assembly 560 may be provided below the pressure control module 114 and may include an up/down hydraulic jar tool 562, an up/down accelerator tool 564, and a GS pulling tool 566 or a rope spear tool 568. According to another example, a cleaning assembly 570 may be provided below the pressure control module 114 and may include a washing tool 572, a nitrogen jet tool 574, or other cleaning tool 576.

[0052] FIG. 6 illustrates the pressure control module 114 and supporting components provided along a length of the drillpipe 112 for open-hole operations. According to one example, the drill tubing 112 may include coiled tubing. A supporting component provided along a length of the drillpipe 112 may include an alternator 602 that is provided downhole and may be positioned proximate to the pressure control module 114. According to one example, the alternator 602 may include an axial flow design may be configured to energize electronics in the pressure control module 114. The alternator 602 may be electrically coupled to the pressure control module 114 via an inductive coupling or by an internal hardwire. Another supporting component provided along a length of the drillpipe 112 may include a float valve 604 that is provided downhole and may be positioned proximate to the pressure control module 114. A float valve 604 may be provided to prevent entry of the drilling fluid 160 into the drillpipe 112 while the drillpipe 112 is being lowered. Thus, the drillpipe 112 may float during the descent, which may decrease a little on the derrick or mast. A hydraulic/mechanical disconnect 605 also may be provided to enable detachment of tools.

[0053] FIG. 6 illustrates various drilling assemblies 610, 620, 630, 640, 650, 660, 670 that may be coupled below the pressure control module 114. According to one example, a milling assembly 610 may be provided below the pressure control module 114 that includes a motor 611 and a mill 612. For example, the mill 512 may include junk mills, taper mills, cement mills, under-reamers, cone mills, skirted mills, burn shoes, plug mills, window mills, round nose mills, watermelon mills, CPE mills, tri-blade mills, and guide mills, or the like.

[0054] According to another example, a hydra blast pro-rotating tool 622 may be provided below the pressure control module 114. According to another example, a hydra blast indexing tool 632 may be provided below the pressure control module 114. According to yet another example, a coil sweep 640 may be provided below the pressure control module 114. According to another example, a Pulsonix TF 650 may be provided below the pressure control module 114. According to yet another example, a fishing assembly 660 may be provided below the pressure control module 114 and may include an up/down hydraulic jar tool 662, an up/down accelerator tool 664, and a GS pulling tool 666 or a rope spear tool 668. According to another example, a cleaning assembly 670 may be provided below the pressure control module 114 and may include a washing tool 672, a nitrogen jet tool 674, or other cleaning tool 676.

[0055] Although not illustrated, one of ordinary skill in the art will readily appreciate that the pressure control module 114 and supporting components may be provided anywhere along a length of workstring for open-hole operations, such as stimulation operations. According to one example, the pressure control module 114 may be coupled onto a downhole end of the workstring, such as by threading or the like.

[0056] Although not illustrated, one of ordinary skill in the art will also readily appreciate that the pressure control module 114 and supporting components may be provided along a length of completion tubes during closed-hole operations.

[0057] Numerous examples are provided herein to enhance understanding of the present disclosure. A specific set of examples are provided as follows. In a first example, a drilling assembly is disclosed that includes a pressure control module positioned proximate to a drill bit, the pressure control module comprising: a first pressure sensor that detects pressure conditions at the downhole end at the drill bit at a first depth in real-time and a second pressure sensor that detects pressure conditions at the downhole end at the drill bit at a second depth in real-time, the first pressure sensor and the second pressure sensor independent from one another; a valve having a ball that is configured to rotate about an axis to flip between a closed position and an open position; and a processor communicatively coupled with the first pressure sensor, the second pressure sensor, and the valve, the processor configured to cause the valve to rotate the ball to the closed position to automatically shut-off fluid flow within a drillpipe immediately in real-time when one of the first pressure sensor and the second pressure sensor detects a threshold pressure condition associated with a formation hydrostatic pressure and provide an alert immediately in real-time that indicates the pressure conditions that caused the valve to automatically shut-off fluid flow.

[0058] In a second example, there is disclosed herein the drilling assembly according to the first example, further including a drillpipe having the drill bit provided at a downhole end, the drillpipe including one of a drill string or coil tubing.

[0059] In a third example, there is disclosed herein the drilling assembly according to the first or second examples, wherein one of the first pressure sensor and the second pressure sensor detects pressure conditions associated with a drilling fluid hydrostatic pressure and a formation hydrostatic pressure.

[0060] In a fourth example, there is disclosed herein the drilling assembly according to any of the preceding examples first to the third, wherein the valve automatically shuts-off fluid flow within the drillpipe when the formation hydrostatic pressure exceeds the drilling fluid hydrostatic pressure.

[0061] In a fifth example, there is disclosed herein the drilling assembly according to any of the preceding examples first to the fourth, wherein the valve switches-on fluid flow within the drillpipe when one of the first pressure sensor and the second pressure sensor detects an activation condition.

[0062] In a sixth example, there is disclosed herein the drilling assembly according to any of the preceding examples first to the fifth, wherein the activation condition includes at least one of a preselected pressure for a preselected amount of time and lapsing of a preselected amount of time.

[0063] In a seventh example, there is disclosed herein the drilling assembly according to any of the preceding examples first to the sixth, further comprising a second pressure control module positioned along the drillpipe, the second pressure control module including a second pressure sensor that detects pressure conditions along the drillpipe and a second valve that automatically shuts-off fluid flow within the drillpipe when the second pressure sensor detects second threshold pressure condition different from the first threshold pressure condition.

[0064] In an eighth example, there is disclosed herein a method of performing open-hole drilling operations, including detecting in real-time, by one of a first sensor positioned along a drillpipe at a downhole end of a drillpipe at a first depth and a second sensor positioned along the drillpipe at the downhole end of the drillpipe, pressure conditions at a drill bit provided at the downhole end of the drillpipe, the first sensor and the second sensor independent from one another; automatically, via a downhole processor communicatively coupled with the first sensor and the second sensor, rotating a ball about an axis from an open position to a closed position and shutting-off fluid flow within the drillpipe immediately in real-time upon detecting a threshold pressure condition associated with a formation hydrostatic pressure by one of the first sensor and the second sensor; providing an alert immediately in real-time that indicates the pressure conditions that caused the valve to automatically shut-off fluid flow; and rotating the ball about the axis from the closed position to the open position and switching-on fluid flow within the drillpipe upon detecting an activation condition.

[0065] In a ninth example, there is disclosed herein a method according to the preceding eighth example, wherein detecting the pressure conditions includes detecting a drilling fluid hydrostatic pressure and detecting a formation hydrostatic pressure.

[0066] In a tenth example, there is disclosed herein a method according to any of the preceding examples eighth to ninth, wherein automatically shutting-off fluid flow within the drillpipe is performed when the formation hydrostatic pressure exceeds the drilling fluid hydrostatic pressure.

[0067] In an eleventh example, there is disclosed herein a method according to any of the preceding examples eighth to tenth, wherein the activation condition includes at least one of a preselected pressure for a preselected amount of time and lapsing of a preselected amount of time.

[0068] In a twelfth example, there is disclosed herein a method according to any of the preceding examples eighth to eleventh, wherein the preselected pressure for the preselected amount of time is actuated from a remote location.

[0069] In a thirteenth example, there is disclosed herein a method according to any of the preceding examples eighth to twelfth, wherein the activation condition includes detecting a drilling fluid hydrostatic pressure.

[0070] In a fourteenth example a drilling assembly is disclosed that includes a drillpipe; a drill bit provided at a downhole end of the drillpipe; a first pressure sensor that detects pressure conditions at the downhole end at the drill bit at a first depth in real-time and a second pressure sensor that detects pressure conditions at the downhole end at the drill bit at a second depth in real-time, the first pressure sensor and the second pressure sensor independent from each other; a pressure control module positioned along the drillpipe at the downhole end and proximate to the drill bit; and a processor provided at the pressure control module, the processor communicating with a computer-readable storage medium having instructions stored thereon that, when executed by the processor, cause the processor to: detect pressure conditions associated with a formation hydrostatic pressure at the drill bit via the first pressure sensor and the second pressure sensor in real-time; rotate a ball about an axis from an open position to a closed position ad automatically shut-off fluid flow within the drillpipe immediately in real-time upon detecting a threshold pressure condition; providing an alert immediately in real-time that indicates the pressure conditions that caused the valve to automatically shut-off fluid flow; and rotate the ball about the axis from the closed position to the open position and switch-on fluid flow within the drillpipe upon detecting an activation condition.

[0071] In a fifteenth example, there is disclosed herein the drilling assembly according to the first example, wherein the drillpipe includes one of a drill string or coil tubing.

[0072] In a sixteenth example, there is disclosed herein the drilling assembly according to the examples fourteenth and fifteenth, wherein the processor is further configured to detect a signal from one of the first pressure sensor and the second pressure sensor that detects the pressure conditions including a drilling fluid hydrostatic pressure and a formation hydrostatic pressure.

[0073] In a seventeenth example, there is disclosed herein the drilling assembly according to the examples fourteenth and sixteenth, further comprising an alternator that provides electrical energy to the processor.

[0074] In an eighteenth example, there is disclosed herein the drilling assembly according to the examples fourteenth and seventeenth, wherein the activation condition includes at least one of a preselected pressure for a preselected amount of time and lapse of a preselected amount of time.

[0075] In a nineteenth example, there is disclosed herein the drilling assembly according to the examples fourteenth and eighteenth, wherein the preselected pressure for the preselected amount of time is actuated from a remote location.

[0076] In a twentieth example, there is disclosed herein the drilling assembly according to the examples fourteenth and nineteenth, further comprising a second pressure control module positioned along the drillpipe; and a second processor provided at the second pressure control module, the second processor communicating with a computer-readable storage medium having instructions stored thereon that, when executed by the second processor, cause the second processor to detect pressure conditions along the drillpipe; automatically shut-off fluid flow within the drillpipe upon detecting a second threshold pressure condition; and switch-on fluid flow within the drillpipe upon detecting a second activation condition.

[0077] In a twenty-first example, there is disclosed herein the drilling assembly according to the examples fourteenth and twentieth, wherein the processor obtains a first signal from a pressure sensor that detects pressure conditions at the drill bit; automatically actuates a valve to shut-off fluid flow within the drillpipe upon obtaining a second signal from the pressure sensor detecting a threshold pressure condition; and actuates the valve to switch-on fluid flow within the drillpipe upon detecting an activation condition received from the pressure sensor or calculated by the processor.

[0078] In a twenty-second example, there is disclosed herein the drilling assembly according to the examples fourteenth and twenty-first, wherein the processor is further configured to obtain a signal from the pressure sensor that detects the pressure conditions including a drilling fluid hydrostatic pressure and a formation hydrostatic pressure.

[0079] In a twenty-second example, there is disclosed herein the drilling assembly according to the examples fourteenth and twenty-first, wherein the second processor obtains a first signal from a second pressure sensor that detects pressure conditions along the drillpipe; automatically actuates a valve to shut-off fluid flow within the drillpipe upon obtaining a second signal from the second pressure sensor detecting a second threshold pressure condition; and actuates the valve to switch-on fluid flow within the drillpipe upon detecting a second activation condition received from the second pressure sensor or calculated by the second processor.

[0080] The embodiments shown and described above are only examples. Many details are often found in the art and therefore are neither shown nor described. Even though numerous characteristics and advantages of the present technology have been set forth in the foregoing description, together with details of the structure and function of the present disclosure, the disclosure is illustrative only, and changes may be made in the detail, especially in matters of shape, size and arrangement of the parts within the principles of the present disclosure to the full extent indicated by the broad general meaning of the terms used in the attached claims. It will therefore be appreciated that the embodiments described above may be modified within the scope of the appended claims.

CLAIMS

1. A drilling assembly, comprising:

a pressure control module positioned proximate to a drill bit, the pressure control module comprising:

a first pressure sensor that detects pressure conditions at the downhole end at the drill bit at a first depth in real-time and a second pressure sensor that detects pressure conditions at the downhole end at the drill bit at a second depth in real-time, the first pressure sensor and the second pressure sensor independent from one another;

a valve having a ball that is configured to rotate about an axis to flip between a closed position and an open position; and

a processor communicatively coupled with the first pressure sensor, the second pressure sensor, and the valve, the processor configured to cause the valve to rotate the ball to the closed position to automatically shut-off fluid flow within a drillpipe immediately in real-time when one of the first pressure sensor and the second pressure sensor detects a threshold pressure condition associated with a formation hydrostatic pressure and provide an alert immediately in real-time that indicates the pressure conditions that caused the valve to automatically shut-off fluid flow.

2. The drill assembly of claim 1, further comprising:

a drillpipe having the drill bit provided at a downhole end, the drillpipe including one of a drill string or coil tubing.

3. The drill assembly of claim 1 or 2, wherein one of the first pressure sensor and the second pressure sensor detects pressure conditions associated with a drilling fluid hydrostatic pressure and a formation hydrostatic pressure.

4. The drill assembly of claim 2, wherein the valve automatically shuts-off fluid flow within the drillpipe when the formation hydrostatic pressure exceeds the drilling fluid hydrostatic pressure.

5. The drill assembly of claim 2, wherein the valve switches-on fluid flow within the drillpipe when one of the first pressure sensor and the second pressure sensor detects an activation condition.

6. The drill assembly of claim 5, wherein the activation condition includes at least one of a preselected pressure for a preselected amount of time and lapsing of a preselected amount of time.

7. The drill assembly of claim 2, further comprising a second pressure control module positioned along the drillpipe, the second pressure control module comprising:

a second pressure sensor that detects pressure conditions along the drillpipe; and

a second valve that automatically shuts-off fluid flow within the drillpipe when the second pressure sensor detects a second threshold pressure condition different from the first threshold pressure condition.

8. A method of performing open-hole drilling operations, the method

comprising:

detecting in real-time, by one of a first sensor positioned along a drillpipe at a downhole end of a drillpipe at a first depth and a second sensor positioned along the drillpipe at the downhole end of the drillpipe, pressure conditions at a drill bit provided at the downhole end of the drillpipe, the first sensor and the second sensor independent from one another;

automatically, via a downhole processor communicatively coupled with the first sensor and the second sensor, rotating a ball about an axis from an open position to a closed position and shutting-off fluid flow within the drillpipe immediately in real-time upon detecting a threshold pressure condition associated with a formation hydrostatic pressure by one of the first sensor and the second sensor;

providing an alert immediately in real-time that indicates the pressure conditions that caused the valve to automatically shut-off fluid flow; and

rotating the ball about the axis from the closed position to the open position and switching-on fluid flow within the drillpipe upon detecting an activation condition.

9. The method of claim 8, wherein detecting the pressure conditions includes detecting a drilling fluid hydrostatic pressure and detecting a formation hydrostatic pressure.

10. The method of claim 9, wherein automatically shutting-off fluid flow within the drillpipe is performed when the formation hydrostatic pressure exceeds the drilling fluid hydrostatic pressure.

11. The method of any one of claims 8 to 10, wherein the activation condition includes at least one of a preselected pressure for a preselected amount of time and lapsing of a preselected amount of time.

12. The method of claim 11, wherein the preselected pressure for the preselected amount of time is actuated from a remote location.

13. The method of claim 8, wherein the activation condition includes detecting a drilling fluid hydrostatic pressure.

14. A drilling assembly, comprising:

a drillpipe;

a drill bit provided at a downhole end of the drillpipe;

a first pressure sensor that detects pressure conditions at the downhole end at the drill bit at a first depth in real-time and a second pressure sensor that detects pressure conditions at the downhole end at the drill bit at a second depth in real-time, the first pressure sensor and the second pressure sensor independent from each other;

a pressure control module positioned along the drillpipe at the downhole end and proximate to the drill bit; and

a processor provided at the pressure control module, the processor communicating with a computer-readable storage medium having instructions stored thereon that, when executed by the processor, cause the processor to:

detect pressure conditions associated with a formation hydrostatic pressure at the drill bit via the first pressure sensor and the second pressure sensor in real-time;

rotate a ball about an axis from an open position to a closed position ad automatically shut-off fluid flow within the drillpipe immediately in real-time upon detecting a threshold pressure condition;

providing an alert immediately in real-time that indicates the pressure conditions that caused the valve to automatically shut-off fluid flow; and

rotate the ball about the axis from the closed position to the open position and switch-on fluid flow within the drillpipe upon detecting an activation condition.

15. The drilling assembly of claim 14, wherein the drillpipe includes one of a drill string or coil tubing.

16. The drilling assembly of claim 14 or 15, wherein the processor is further configured to obtain a signal from one of the first pressure sensor and the second pressure sensor that detects the pressure conditions including a drilling fluid hydrostatic pressure and a formation hydrostatic pressure.

17. The drilling assembly of any one of claims 14 to 16, further comprising an alternator that provides electrical energy to the processor.

18. The drilling assembly of any one of claims 14 to 17, wherein the activation condition includes at least one of a preselected pressure for a preselected amount of time and lapse of a preselected amount of time.

19. The drilling assembly of claim 18, wherein the preselected pressure

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for the preselected amount of time is actuated from a remote location.

20. The drilling assembly of claim 14, further comprising:

a second pressure control module positioned along the drillpipe; and

a second processor provided at the second pressure control module, the second processor communicating with a computer-readable storage medium having instructions stored thereon that, when executed by the second processor, cause the second processor to:

detect pressure conditions along the drillpipe;

automatically shut-off fluid flow within the drillpipe upon detecting a second threshold pressure condition; and

switch-on fluid flow within the drillpipe upon detecting a second activation condition.

21. The drilling assembly of claim 1, further comprising

a hydraulic flow line coupled with the valve, the hydraulic flow line containing hydraulic fluid and the processor configured to cause the hydraulic fluid to close the valve upon detecting the threshold pressure condition by one of the first sensor and the second sensor thereby shutting-off fluid flow within the drillpipe.

22. The drilling assembly of claim 5, further comprising

a hydraulic flow circuit having a first hydraulic flow line and a second hydraulic flow line fluidically coupled with the valve,

the processor configured to cause the hydraulic fluid to flow through the first hydraulic flow line upon detecting the threshold pressure condition by one of the first sensor and the second sensor to close the valve thereby shutting-off fluid flow within the drillpipe, and

the processor configured to cause the hydraulic fluid to flow through the second hydraulic flow line upon detecting the activation condition by one of the first sensor and the second sensor to open the valve thereby switching on fluid flow within the drillpipe.

23. The drilling assembly of claim 5, wherein one of the first sensor and the second sensor is exposed to the formation hydrostatic pressure when the valve is open and isolated from the formation hydrostatic pressure and monitors only a drilling fluid hydrostatic pressure in the drilling pipe when the valve is closed.

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