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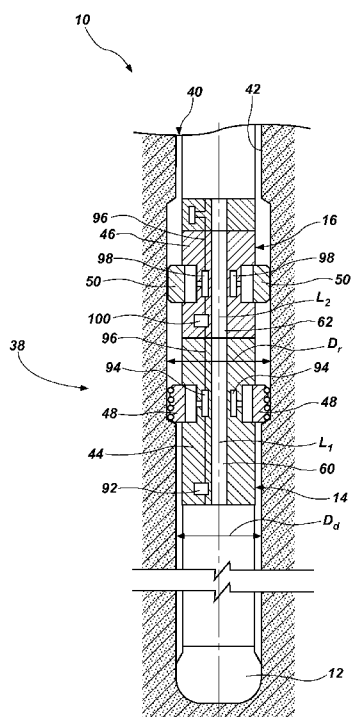


FIG. 5

(57) Abstract: A drilling assembly for drilling a subterranean wellbore includes an expandable reamer and an expandable stabilizer. The expandable reamer and the expandable stabilizer each have a tubular body with a longitudinal axis and a drilling fluid flow path extending therethrough. A plurality of blades is carried by the reamer and a plurality of bearing pads is carried by the stabilizer. The blades and bearing pads are outwardly movable from a retracted position to an extended position with respect to the longitudinal axes of the reamer and stabilizer, respectively. The reamer and stabilizer each include an actuation device for moving the blades and bearing pads, respectively, from the retracted position to the extended position.



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TITLE

**DRILLING ASSEMBLIES INCLUDING EXPANDABLE REAMERS AND
EXPANDABLE STABILIZERS, AND RELATED METHODS**

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PRIORITY CLAIM

This application claims the benefit of U.S. Patent Application Serial
No. 13/841,422, filed March 15, 2013, which is a utility conversion of U.S. Provisional
10 Patent Application Serial No. 61/642,026, filed May 3, 2012, titled "Drilling
Assemblies Including Expandable Reamers and Expandable Stabilizers, and Related
Methods."

TECHNICAL FIELD

15 Embodiments of the present disclosure relate generally to drilling assemblies
for use in drilling subterranean boreholes and, more particularly, to drilling assemblies
that include both an actuatable expandable reamer and an actuatable expandable
stabilizer, and to methods of making and using such drilling assemblies.

20

BACKGROUND

Expandable reamers are typically employed for enlarging subterranean
boreholes. In drilling oil, gas, and geothermal wells, casing is installed and cemented
to prevent the wellbore walls from caving into the subterranean borehole while also
providing requisite shoring for subsequent drilling operation to achieve greater depths.
25 Casing is also conventionally installed to mutually isolate different formations, to
prevent crossflow of formation fluids, and to enable control of formation fluids and
pressure as the borehole is being drilled. To increase the depth of a previously drilled
borehole, new and smaller diameter casing, or "liner," is disposed within and extended
below the previous casing. However, while adding additional casing allows a borehole
30 to reach greater depths, the additional, smaller casing has the disadvantage of
narrowing the borehole. Narrowing the borehole restricts the diameter of any
subsequent sections of the well because the drill bit and any further casing must pass
through the smaller casing. As reductions in the borehole diameter are undesirable
because they limit the production flow rate of oil and gas through the borehole, it is
35 often desirable to enlarge a subterranean borehole to provide a larger borehole diameter

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beyond previously installed casing to enable better production flow rates of hydrocarbons through the borehole.

Various approaches to expand a borehole may include expandable stabilizer blocks or bearing pads used in an expandable stabilizer located longitudinally above an expandable reamer to increase stability and reduce dysfunctional loads, *i.e.*, lateral vibrational loads, thereupon while reaming. In most instances, fixed stabilizer pads or blocks, being sized and configured for a corresponding hole diameter cut by a pilot bit or drill bit, are located in a drill string between the bit and the expandable reamer. The stabilizer bearing pads or blocks help to control stability, particularly when conducting a so called "down drill" operation, *e.g.*, drilling in the down-hole direction. Also, stability is further improved by providing a point of control above an expandable reamer to decrease the flexibility of the drill string about the expandable reamer.

DISCLOSURE

This summary is provided to introduce a selection of concepts in a simplified form. These concepts are described in further detail in the detailed description of example embodiments of the disclosure below. This summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used to limit the scope of the claimed subject matter.

In some embodiments, the present disclosure includes a drilling assembly for drilling a subterranean wellbore. The drilling assembly includes an expandable reamer having a first tubular body with a first longitudinal axis and a first drilling fluid flow path extending therethrough. A plurality of blades is carried by the first tubular body, and a cutting structure is carried by at least one blade of the plurality of blades wherein the at least one blade is outwardly movable from a retracted position to an extended position with respect to the first longitudinal axis. The drilling assembly also includes an expandable stabilizer axially located a distance of about 25 feet (7.62 m) or less above the expandable reamer in the drilling assembly, the expandable stabilizer has a second tubular body with a second longitudinal axis and a second drilling fluid flow path extending therethrough. A plurality of bearing pads is carried by the second tubular body, wherein at least one bearing pad of the plurality of bearing pads is outwardly movable from a retracted position to an extended position with respect to the second longitudinal axis.

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In additional embodiments, the present disclosure includes a drilling assembly for drilling a subterranean wellbore, including an expandable reamer having a first tubular body with a first longitudinal axis and a first drilling fluid flow path extending therethrough. A plurality of blades is carried by the first tubular body, and a cutting structure is carried by at least one blade of the plurality of blades, wherein the at least one blade is outwardly movable from a retracted position to an extended position with respect to the first longitudinal axis. The expandable reamer also includes a first actuation device for moving the at least one blade from the retracted position to the extended position and a first electrical device configured to receive a first electronic signal and actuate the first actuation device responsive to the first electronic signal. The drilling assembly also includes an expandable stabilizer axially spaced from the expandable reamer, the expandable stabilizer has a second tubular body with a second longitudinal axis and a second drilling fluid flow path extending therethrough. A plurality of bearing pads is carried by the second tubular body, wherein at least one bearing pad of the plurality of bearing pads is outwardly movable from a retracted position to an extended position with respect to the second longitudinal axis. The expandable stabilizer also includes a second actuation device for moving the at least one bearing pad from the retracted position to the extended position and a second electrical device configured to receive a second electronic signal and actuate the second actuation device responsive to the second electronic signal.

In yet other embodiments, the present disclosure includes a method of forming a drilling assembly for drilling a subterranean wellbore. The method includes coupling an expandable stabilizer to an expandable reamer. The expandable reamer has a first tubular body with a first longitudinal axis and a first drilling fluid flow path extending therethrough. A plurality of blades is carried by the first tubular body, and a cutting structure is carried by at least one blade of the plurality of blades, wherein the at least one blade is outwardly movable from a retracted position to an extended position with respect to the first longitudinal axis for reaming a section of the wellbore. The expandable stabilizer has a second tubular body with a second longitudinal axis and a second drilling fluid flow path extending therethrough. A plurality of bearing pads is carried by the second tubular body, wherein at least one bearing pad of the plurality of bearing pads is outwardly movable from a retracted position to an extended position with respect to the second longitudinal axis. The method also includes axially locating

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the expandable stabilizer a distance of about 25 feet (7.62 m) or less above the blades of the expandable reamer.

BRIEF DESCRIPTION OF DRAWINGS

5 While the specification concludes with claims particularly pointing out and distinctly claiming what are regarded as embodiments of the present disclosure, the advantages of embodiments of the disclosure may be more readily ascertained from the description of certain examples of embodiments of the disclosure when read in conjunction with the accompanying drawings, in which:

10 FIG. 1 is a schematic illustration of a bottom hole assembly including a drilling assembly that comprises an expandable reamer and an expandable stabilizer;

FIG. 2 is a simplified and schematic longitudinal cross-sectional view of a drilling assembly in a wellbore, the drilling assembly having an expandable stabilizer adjacent an expandable reamer;

15 FIG. 3 is a simplified and schematic longitudinal cross-sectional view of the drilling assembly of FIG. 2 showing the blades of the expandable reamer in the extended position engaging the wellbore;

FIG. 4 is a simplified and schematic longitudinal cross-sectional view of the drilling assembly of FIG. 3 having reamed a section of the wellbore;

20 FIG. 5 is a simplified and schematic longitudinal cross-sectional view of the drilling assembly of FIG. 4 showing the bearing pads of the expandable stabilizer in the extended position engaging the wellbore;

25 FIG. 6 is a simplified and schematic longitudinal cross-sectional view of another embodiment of a drilling assembly including an expandable reamer and an expandable stabilizer comprising separate portions of a unitary tubular body;

FIG. 7 is a simplified and schematic longitudinal cross-sectional view of another embodiment of a drilling assembly having a single electrical device for actuating the blades and bearing pads of an expandable reamer and an expandable stabilizer, respectively; and

30 FIG. 8 is a simplified and schematic illustration of an electrical device of a drilling assembly, which may be employed to blades of an expandable reamer and/or pads of an expandable stabilizer of the drilling assembly.

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MODE(S) FOR CARRYING OUT THE INVENTION

The illustrations presented herein are not meant to be actual views of any particular drilling assembly, component, structure, or device, but are merely idealized representations that are used to describe embodiments of the disclosure.

5 When used herein in reference to a location in the wellbore, the terms “above,” “upper” and “uphole” mean and include a relative position proximate the surface of the well, whereas the terms “below,” “lower” and “downhole” mean and include a relative position distal the surface of the well.

Referring now to FIG. 1, a downhole assembly is illustrated. The downhole
10 assembly may comprise a so-called “bottom-hole assembly” (BHA) 10 used for reaming a well to a larger diameter than that initially drilled, for concurrently drilling and reaming a wellbore, or for drilling a wellbore. The bottom hole assembly 10, as illustrated, includes a pilot drill bit 12, an expandable reamer 14 and an expandable stabilizer 16. The bottom hole assembly 10 optionally may include various other types
15 of drilling tools such as, for example, a steering unit 18, one or more additional stabilizers 20, a measurement while drilling (MWD) tool 22, one or more bi-directional communications pulse modules (BCPM) 24, one or more mechanics and dynamics tools 26, one or more electronic devices, which may include, for example, additional measurement devices or sensors 30, such as sonic calipers and RPM recognition
20 devices. The bottom hole assembly 10 may additionally include one or more drill collars 32, one or more segments of electrically communicative drill pipe 34, and one or more heavy weight drill pipe (HWDP) segments 36. Components of the bottom hole assembly 10 may communicate with controllers and/or operators at the well surface in a variety of ways, including direct-line electronic communication and
25 command pattern signals, as will be discussed in more detail below.

FIG. 2 is a longitudinal schematic view of a drilling assembly reaming a wellbore in accordance with an embodiment of the present disclosure. A cross-section of a drilling assembly generally designated by reference numeral 38 is shown reaming a wellbore 40 extending through a formation 42 with an expandable reamer 14 having
30 a first tubular body 44 directly and coaxially coupled below a second tubular body 46 of an expandable stabilizer 16. The expandable reamer 14 and the expandable stabilizer 16 include blades 48 and bearing pads 50, respectively. The blades 48 and bearing pads 50 may be positionally retained in circumferentially spaced relationships

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in the first and second tubular bodies 44, 46, respectively, and the blades 48 may have a cutting structure thereon for engaging the formation 42. Moreover, in one embodiment, the blades 48 and the bearing pads 50 may be symmetrically circumferentially positioned in their respective tubular bodies 44, 46, and in other
5 embodiments, the blades 48 and bearing pads 50 may be positioned circumferentially asymmetrically in their respective tubular bodies 44, 46. The reamer blades 48 and stabilizer bearing pads 50 may also be provided at a position between a lower end 52, 56 and an upper end 54, 58 of the reamer 14 and stabilizer 16, respectively.

10 The blades 48 and bearing pads 50 are each retained in an initial, retracted position within their respective tubular bodies 44, 46, as shown in FIG. 2, but may be moved outwardly from their respective longitudinal axes L_1 , L_2 to the extended position, as shown in FIG. 5, and moved back into a retracted position when desired.

15 The expandable reamer 14, including the blades 48, may be configured as described in any of United States Patent Nos. 8,020,635, issued September 20, 2011 to Radford; 7,900,717, issued March 8, 2011 to Radford et al.; 7,681,666, issued March 23, 2010 to Radford et al.; 7,549,485, issued June 23, 2009 to Radford et al.; 7,036,611, issued May 2, 2006 to Radford et al.; and United States Patent Publication Nos. 2011/0127044, published June 2, 2011 to Radford et al.; 2011/0005836, published January 13, 2011 to Radford et al.; and 2009/0294178, published December 3, 2009 to
20 Radford. The expandable stabilizer 16, including the bearing pads 50, may be configured as described in any of United States Patent Publication Nos. 2011/0127044, published June 2, 2011 to Radford et al., and 2009/0294178, published December 3, 2009 to Radford.

25 The reamer blades 48 and stabilizer bearing pads 50 may be operationally configured to extend and retract responsive to hydraulic pressure acting against the blades 48 and bearing pads 50, respectively, as described in United States Patent Nos. 7,900,717; 7,549,485; 8,020,635; and 7,681,666; and United States Patent Publication Nos. 2011/0127044 and 2009/0294178.

30 In other embodiments, the reamer blades 48 and/or stabilizer bearing pads 50 may be configured for lateral outward extension by pressurized drilling fluid separately controlled by a closed-loop hydraulic system, as provided in United States Patent Nos. 8,020,635; 7,681,666 and 7,549,485, and United States Patent Publication No. 2011/0127044. For example, the blades 48 and/or bearing pads 50 may be

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actuated by a piston element (not shown) coaxially aligned with the tubular body of the respective reamer 14 or stabilizer 16 and having a drilling fluid flow path extending through a central bore of the piston, as disclosed in United States Patent Publication No. 2011/0127044, referenced above. In such embodiments, the piston element may
5 move axially as influenced by pressure of the drilling fluid flowing through the tubular bodies of the reamer 14 and stabilizer 16, which axial movement may bring lateral ports in the piston into fluid communication with lateral ports in a housing of the piston element, providing pressurized fluid flow directed to act against the blades 48 and/or bearing pads 50. The axial position of such a piston element may further be controlled
10 by a sealed, closed-loop hydraulic system, comprising a first and second fluid chamber axially located on opposite sides of a laterally extending member of the piston. A bi-directional valve may be used to control the flow of the sealed hydraulic fluid within the first and second chambers in a manner to control the axial position of the laterally extending member of the piston. The valve may be controlled by a unit including a
15 processor, memory device and software programs.

In still further embodiments, pressurized hydraulic fluid in a controlled, closed-loop hydraulic system may directly displace a reamer blade 48 or stabilizer bearing pad 50, as disclosed in United States Patent Nos. 8,020,635; 7,681,666 and 7,549,485. In such embodiments, the pressurized hydraulic fluid may be communicated to a
20 chamber housing a portion of a lateral piston element coupled to the blade 48 or bearing pad 50. The pressurized fluid may be communicated to the chamber by way of a pressure source, such as a downhole pump or turbine operatively coupled to a control valve apparatus. The control valve apparatus may be selectively and reversibly operable, and may comprise a solenoid actuated valve.

25 It is to be appreciated that any of the embodiments of the references incorporated by reference herein may be modified and reconfigured in accordance with the teachings of the present disclosure. Furthermore, any conventional expandable reamer or expandable stabilizer modified and reconfigured in accordance with the teachings of the disclosure herein may be utilized to advantage to provide an improved
30 system or drilling assembly for stabilizing the drill string while performing a reaming operation. Additionally, the reamer blades 48 and/or the stabilizer bearing pads 50 may be configured for lateral outward extension by any other mechanical means, such

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as a push rod, wedge or actuating motor or as conventionally understood to a person having ordinary skill in the art of expandable reamers and/or expandable stabilizers.

The expandable stabilizer 16 may be coupled directly to the expandable reamer 14, as shown in FIGS. 2 through 5, or an intermediate piece of the drill string may be positioned between the reamer 14 and stabilizer 16. Referring to FIGS. 2 through 5, the expandable stabilizer 16 may be positioned in the drilling assembly 38 to be in the range of about 10 feet to 35 feet (3.05 m to 10.7 m) above the expandable reamer 14, regardless of whether the reamer 14 and stabilizer 16 are directly or indirectly coupled together. The axial distance between the reamer 14 and stabilizer 16 may be measured from the center of the stabilizer bearing pad 50 in the retracted position to the center of the reamer blade 48 in the retracted position. The close proximity of the expandable stabilizer 16 to the expandable reamer 14 provides increased operational stability for the drill string during reaming operations.

The expandable stabilizer 16, when positioned above and proximate the expandable reamer 14, helps to reduce vibration and stabilize the expandable reamer 14 as the wellbore 40 is reamed to a larger diameter, or reamed diameter, D_r , above the smaller drilled diameter, D_d . FIGS. 3 through 5 illustrates the drilling assembly 38 having enlarged the diameter of wellbore 40 in the "down-hole" direction with the blades 48 being fully extended to remove the material of the formation 42. As shown in FIG. 5, the expandable reamer 14 is stabilized by the fully extended bearing pads 50 of the expandable stabilizer 16 making stabilizing contact with the wall of the wellbore 40 above the expandable reamer 14.

Referring to FIGS. 2 through 5, the expandable reamer 14 may have a first generally tubular body 44 having a first drilling fluid flow path 60 extending therethrough along a first longitudinal axis L_1 . Similarly, the expandable stabilizer 16 may have a second generally tubular body 46 having a second drilling fluid flow path 62 extending therethrough along a second longitudinal axis L_2 . The first and second longitudinal axes L_1 , L_2 axes may be co-axially aligned.

Actuation of the expandable reamer 14 and the expandable stabilizer 16 may be controlled by a surface operator. The embodiments of the present disclosure provide the surface operators with a variety of options to separately control actuation of the reamer 14 and stabilizer 16, via direct-line electronic command signals, or, alternatively, command pattern signals which may be sensed downhole and relayed to

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the drilling assembly 38. Additionally, one or both of the reamer 14 and stabilizer 16 may be actuated automatically upon the recognition of a predetermined parameter by a downhole sensor. The embodiments of the assembly 38 illustrated in FIGS. 2 through 5 are capable of providing actuation control of the assembly 38 according to any of such methods, as will now be described. It is to be appreciated that the embodiments illustrated in FIGS. 2 through 5 do not employ a ball trap mechanism.

As shown in FIGS. 2 through 5, the expandable reamer blades 48 may be operationally coupled to a first actuation device 94 located in or on the first tubular body 44. Also located in or on the first tubular body 44 is a first electrical device 92 operatively coupled to the first actuation device 94 and in electronic communication with a first electronic signal source (not shown). It is to be appreciated that a variety of alternative components may comprise the first electronic signal source, and such components may be positioned in a wide variety of locations relative to the drill string. For example, if the reamer 14 is controlled by direct-line electronic command signals, the first electronic signal source may be a switch or computer at the controller's work station on a drilling rig at the well surface, by way of a non-limiting example. If the reamer 14 is at least partially controlled by command pattern signals, such as mud pulses sent downhole, the first electronic signal source may alternatively be a downhole sensor 30, such as a pressure sensor with a microprocessor that interprets the command pattern signal and responsively transmits the first electronic signal to the reamer 14. Such signal sources may also be the signal source for the expandable stabilizer 16, as discussed in more detail below.

The first electrical device 92 may communicate with the first electronic signal source by one or more lines or wires 96 extending the length of the first tubular body 44 and electronically coupling the first electrical device 92 to additional components of the drill string, such as one or more BCPMs, sections of electrically communicative drill pipe, and downhole sensors 30, such as RPM recognition devices, accelerometers, pressure sensors, sonic calipers, and flow meters, as further disclosed below. The wires 96 may be located on an outer surface or inner surface of the first tubular body 44, or may be located within the body material thereof. Upon receiving a first electronic signal from the first electronic signal source, the first electrical device 92 may actuate the first actuation device 94, moving the reamer blades 48 from the retracted position to the extended position, as shown in FIG. 3. The first actuation

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device 94 may be configured to move the reamer blades 48 to the extended position by using any of the mechanisms and methods disclosed above.

As described above, the expandable stabilizer 16 may be configured similar to the configuration of the expandable reamer 14. The expandable stabilizer 16 may have a second generally tubular body 46 having a second drilling fluid flow path 62 extending therethrough along a second longitudinal axis L_2 . The expandable bearing pads 50 may be operationally coupled to a second actuation device 98 located in or on the second tubular body 46. Also located in the second tubular body 46 is a second electrical device 100 operatively coupled to the second actuation device 98 and in electronic communication with a second electronic signal source. Similarly to the first electronic signal source, as discussed above, it is to be appreciated that a variety of alternative components may comprise the second electronic signal source. Moreover, the second electronic signal source may be the same as the first electronic signal source; although, in additional embodiments, the second electronic source may be separate from the first electronic source, as will be described in more detail below. The second electrical device 100 may communicate with the second electronic signal source by one or more wires 96 extending the length of the second tubular body 46 and electronically coupling the second electrical device 100 with additional components of the drill string, as further disclosed below. The wires 96 may be located on an outer surface or inner surface of the second tubular body 46, or may be located within the body 46. Upon receiving a second electronic signal from the second electronic signal source, the second electrical device 100 may actuate the second actuation device 98, moving the stabilizer bearing pads 50 from the retracted position to the extended position, as shown in FIG. 5. The second actuation device 98 may be configured to move the stabilizer bearing pads 50 to the extended position by using any of the mechanisms and methods disclosed above.

It is to be appreciated that the expandable reamer blades 48 and bearing pads 50 may be retracted similar to the manner in which they are extended. For example, upon receiving another electronic signal, the first electrical device 92 may actuate the first actuation device 94 in a manner to move the reamer blades 48 from the extended position to the retracted position. Similarly, upon receiving yet another electronic signal, the second electrical device may actuate the second actuation device 98 in a manner to move the stabilizer bearing pads 50 from the extended position to the

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retracted position. Alternatively, the first and second electrical devices 92, 100 may respectively actuate the first and second actuation devices 94, 98 upon reception of the same electronic signal. In additional embodiments, retention elements (not shown), such as springs or other retention elements, may respectively retract the reamer
5 blades 48 and bearing pads 50 from the extended position to the retracted position upon deactivation of the first and second actuation devices 94, 98, respectively, by the first and second electrical devices 92, 100.

The first tubular body 44 and the second tubular body 46 each have respective lower ends 52, 56 and upper ends 54, 58. The lower ends 52, 56 may include a set of
10 threads (e.g., a threaded-male pin member) (not shown) for connecting the lower ends 52, 56 to another component of the drill string or bottom-hole assembly, such as, for example, a drill collar or collars carrying a pilot drill bit 12 for drilling the wellbore 40. Similarly, the upper ends 54, 58 of the first tubular body 44 and the second tubular body 46 may include a set of threads (e.g., a threaded-female box
15 member) (not shown) for connecting the upper ends 54, 58 to a set of threads (e.g., a threaded-male pin member) to another component of the drill string or bottom-hole assembly. By way of example and not limitation, the threaded-female box member at the lower end 56 of the stabilizer 46 may be threadedly connected to the corresponding threaded-male pin member at the upper end 54 of the reamer 44. In other
20 embodiments, the threaded-female box member at the lower end 56 of the stabilizer 46 may be threadedly connected to a drill collar, and a lower end of the drill collar may be threadedly connected to the threaded-male pin member at the upper end 54 of the reamer 44. The threads in the lower and upper ends of the reamer 14 and stabilizer 16 can be of any suitable type for mating with another section of a drill string or another
25 component of a bottom-hole assembly. Moreover, the threads at the respective upper ends 54, 58 and lower ends 52, 56 of the first and second tubular body 44, 46 may be configured with an electrical contact pad or ring (not shown) electrically coupled with the one or more wires 96 extending the length of the respective first and second tubular body 44, 46. The electrical contact pad or ring may be configured to engage a
30 corresponding electrical contact pad or ring in the threads of a mating component of the bottom-hole assembly. In this manner, some or all of the components of the bottom-hole assembly may be in electronic communication with one another.

The drill string may also contain one or more sections of electrically communicative drill pipe 34 (shown in FIG. 1), which are necessary if the assembly 38 is to be controlled by direct-line electronic commands sent from a surface controller. Sections of electrically communicative drill pipe 34 are configured with one or more electronic wires 96 (not shown) extending the length of the pipe section 34. The wires 96 may be located on an outer surface or inner surface of the pipe section 34, or may be located within the body material of the pipe 34. A lower end of each pipe section 34 may include a set of threads (e.g., a threaded-male pin member) (not shown) for connecting the lower end to another pipe section or another component of a bottom-hole assembly. Similarly, the upper end of the pipe section 34 may include a set of threads (e.g., a threaded-female box member) for connecting the upper end to a set of threads (e.g., a threaded-male pin member) of another pipe section 34 or another component of the bottom-hole assembly. The threads in the lower and upper ends of the pipe section 34 can be of any suitable type for mating with another section of a drill string or another component of a bottom-hole assembly. Moreover, the threads at the upper and lower ends of each pipe section 34 may be configured with an electrical contact pad or ring (not shown) electrically coupled with the one or more wires 96 extending the length of the pipe section. The electrical contact pad or ring may be configured to engage a corresponding electrical contact pad or ring in the threads of a mating pipe section 34 or component of the bottom-hole assembly. In this manner, some or all of the components of the bottom-hole assembly may be in electronic communication with the surface or with other sections of the drill string.

Referring now to FIG. 6, a drilling assembly 38 is shown wherein the expandable reamer 16 and the expandable stabilizer 14 comprise respective first and second portions 102, 104 of a single unitary tubular body 106, as indicated by broken line 107. The unitary tubular body 106 has a drilling fluid flow path 108 extending therethrough along a longitudinal axis L. Similar to the drilling assembly 38 shown in FIGS. 2 through 5, the expandable reamer blades 48 and the expandable bearing pads 50 of the unitary tubular body 106 may be operationally coupled to first and second actuation devices 94, 98, respectively, located in or on the tubular body 106. Also located in or on the unitary tubular body 106 are first and second electrical devices 92, 100 operatively coupled to the first and second actuation devices 94, 98, respectively. The first and second electrical devices 92, 100 may communicate with

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(e.g., receive electronic signals from) one or more electronic signal sources by one or more wires 96 extending the length of the unitary tubular body 106 and electronically coupling the first and second electrical devices 92, 100 to one another and to additional components of the drill string. The wires 96 may be located on an outer surface or
5 inner surface of the unitary tubular body 106 or may be located within the body 106. As discussed above in reference to FIGS. 2 through 5, a variety of alternative components may comprise the electronic signal sources. Furthermore, such components may be positioned in a wide variety of locations relative to the drill string. Referring again to FIG. 6, the first and second electrical devices 92, 100 may
10 respectively actuate the first and second actuation devices 94, 98 in the same manner as disclosed above in reference to FIGS. 2 through 5, and the first and second actuation devices 94, 98 may be configured to move the blades 48 and bearing pads 50, respectively, outwardly from the retracted position to the extended position by using any of the mechanisms and method disclosed above. It is to be appreciated that the
15 embodiments illustrated in FIGS. 6 and 7 do not employ a ball trap mechanism.

Referring to FIG. 7, the unitary tubular body 106 may alternatively comprise a single electrical device 110 that actuates both the first actuation device 94 and the second actuation device 98. The electrical device 110 may communicate with one or more electronic signal sources by one or more wires 96 extending the length of the
20 unitary tubular body 106 and coupling the electrical device 110 to additional components of the drill string. As discussed above, a variety of alternative components may comprise the electronic signal sources. Furthermore, such signal source components may be positioned in a wide variety of locations relative to the drill string. Referring again to FIG. 7, upon receiving the first electronic signal, the electrical
25 device 110 may actuate the first actuation device 94 to expand the reamer blades 48 to the extended position, and upon receiving the second electronic signal, the electrical device 110 may actuate the second actuation device 98 to expand the stabilizer bearing pads 50 to the extended position. The first and second actuation devices 94, 98 may be configured to move the blades 48 and bearing pads 50, respectively, outwardly from
30 the retracted position to the extended position by using any of the mechanisms and method disclosed above.

FIG. 8 illustrates a representative embodiment of the first and second electrical devices 92, 100, and is indicated by broken circle 111 in FIG. 6. The first and second

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electrical devices 92, 100 may each comprise a processor 112 and a memory device 116, wherein one or more software programs 120 are configured to run on the processors 112 and memory devices 116. The processors 112 may be microprocessors configured to respectively control the first and second actuation devices 94, 98. As
5 disclosed above, each of the first and second actuation devices 94, 98 may comprise a closed loop hydraulic (not shown). In such embodiments, the processors 112 may each be coupled to a control valve unit, which may comprise a solenoid actuated valve, for selectively controlling flow of hydraulic fluid to control the position of the blades 48 and bearing pads 50, respectively.

10 The processors 112 may be configured to actuate the first and second actuation devices 94, 98 responsive to any of the control methods discussed above. In some embodiments, one or both of the expandable reamer 14 and the expandable stabilizer 16 may be controlled by direct-line electronic signals sent directly from a surface controller and transmitted through the drill string via wire lines or through
15 sections of electrically communicative drill pipe 34 (shown in FIG. 1) to the first and second electrical devices 92, 100. The direct-line electronic signals may comprise one or both of the first and second electronic signals discussed above. The direct-line electronic signal may be received by the first and second electrical devices 92, 100, wherein the first and second actuation devices 94, 98 are actuated based on the control
20 of the respective processors 112, memory devices 116, and software programs 120 operating respectively within the first and second electrical devices 92, 100.

In other embodiments, one or both of the expandable reamer 14 and the expandable stabilizer 16 may be controlled by command patterns sent downhole by a surface controller. The command patterns may be any signal that allows
25 communication between the surface drilling rig and a downhole tool, such as changes in drill string rotation rate (revolutions per minute, or "RPM"), changes in mud pulse frequency, changes in flow rates of the drilling fluid, and axial motion of the drill string.

One example of a command pattern signal comprises a predefined sequence of
30 rotational speed (revolutions per minute (RPM)) duration periods may be used to provide a command pattern signal that is detected downhole by a sensor 30, such as an RPM recognition device, which may comprise an accelerometer, which may control one or both of the expandable reamer 14 and the expandable stabilizer 16. By way of a

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non-limiting example, the drill string may be rotated by a drilling rig at 40 RPM for 10 seconds, followed by a rotation of 20 RPM for 30 seconds, where one or more sensors 30 detect the drill string rotational speed. The RPM recognition device may include a processor (not shown), which transforms the detected rotation speeds into an electronic data signal and transmits the electronic data signal to the processors 112 through one or more wires 96, as described above, or another signal communication pathway. The processors 112 decode the pattern of rotational speeds and durations by comparing the data signal to patterns stored in the memory devices 116 corresponding to predetermined positions of the blades 48 and/or bearing pads 50. When the processors 112 identify a stored pattern corresponding to the pattern communicated by the data signal, the processors may respectively actuate the first and second actuation devices 94, 98 to move the blades 48 and/or bearing pads 50 to the corresponding predetermined positions.

Another example of a command pattern signal comprises a sequence of pulses of hydraulic pressure in the drilling fluid, or "mud pulses," as known in the art, of a varying parameter, such as duration, amplitude and/or frequency, that may be detected by a pressure sensor in the bottom-hole assembly. The pressure sensor may be located in a BCPM positioned in the bottom-hole assembly (shown in FIG. 1), as known in the art. The BCPM may comprise a processor (not shown), which transforms the detected mud pulse pattern, including one or more of pressure, frequency and amplitude, into an electronic data signal and transmits the electronic data signal to the processors 112 through one or more wires 96, as described above, or another signal communication pathway. The processors 112 decode the pattern communicated by the data signal by comparing the data signal to patterns stored in the memory devices 116 corresponding to predetermined positions of the blades 48 and/or bearing pads 50. When the processors 112 identify a stored pattern corresponding to the pattern communicated by the data signal, the processors 112 may respectively actuate the first and second actuation devices 94, 98 to move the blades 48 and/or bearing pads 50 to the corresponding predetermined position.

In additional embodiments, one or both of the expandable reamer 14 and the expandable stabilizer 16 may be controlled automatically or independently based on sensed downhole parameters, such as the diameter of the wellbore proximate the stabilizer bearing pads 50. For example, a measurement device, such as a sonic caliper,

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which may be represented by sensor 30 in FIGS. 2 through 7, may be configured to measure the diameter of the wellbore 40 proximate the stabilizer bearing pads 50. The sonic caliper may have a microprocessor (not shown) which transmits an electronic signal to the second electrical device 100 when the diameter of the wellbore 40 proximate the bearing pads 50 corresponds to the reamed diameter D_r of the wellbore 40. Upon receiving the electronic signal from the sonic caliper, the processor 82 of the second electrical device 100 may actuate the second actuation device 98 to move the stabilizer bearing pads 50 to a predetermined position corresponding to the reamed diameter D_r of the wellbore 40. Thus, the drilling assembly 38 may be configured to expand the stabilizer bearing pads 50 automatically after the reamer 14 has reamed a portion of the borehole corresponding to the axial distance between the stabilizer bearing pads 50 and the reamer blades 48.

It is to be appreciated that the drilling assembly 38 comprising the expandable reamer 14 and the expandable stabilizer 16 may be controlled by any combination of the control methods described above. For example, in one embodiment, both the first and second actuation devices 94, 98 may respectively move the reamer blades 48 and stabilizer bearing pads 50 responsive to a direct electronic signal sent from a surface controller.

In an additional embodiment, the first actuation device 94 may move the reamer blades 48 responsive to a direct electronic signal sent from a surface controller while the second actuation device 98 may move the stabilizer bearing pads 50 responsive to a pattern command sent downhole from a surface controller and detected by a downhole sensor.

In yet additional embodiments, the first actuation device 94 may move the reamer blades 48 responsive to a direct electronic signal sent from a surface controller while the second actuation device 98 may automatically move the stabilizer bearing pads 50 responsive to a sensed downhole parameter, such as when the diameter of the wellbore 40 proximate the stabilizer bearing pads 50, as sensed by a sonic caliper, corresponds to the reamed diameter D_r of the wellbore 40.

In yet further additional embodiments, both the first and second actuation devices 94, 98 may respectively move the reamer blades 48 and stabilizer bearing pads 50 responsive to command patterns sent downhole from a surface controller and detected by one or more downhole sensors.

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In still yet further additional embodiments, the first actuation device 94 may move the reamer blades 48 responsive to a command pattern sent downhole from a surface controller and detected by a downhole sensor while the second actuation device may 74 may move the stabilizer bearing pads 50 responsive to a direct electronic signal sent from a surface controller.

In other further additional embodiments, the first actuation device 94 may move the reamer blades 48 responsive to a command pattern sent downhole from a surface controller and detected by a downhole sensor while the second actuation device 98 may automatically move the stabilizer bearing pads 50 responsive to a sensed downhole parameter, such as when the diameter of the wellbore 40 proximate the stabilizer bearing pads 50, as sensed by a sonic caliper, corresponds to the reamed diameter D_r of the wellbore 40.

It is to be appreciated that one or both of the blades 48 and bearing pads 50 may be retracted from the extended position to the retracted position by any of the methods and mechanisms described above.

Additional non-limiting example embodiments of the present disclosure are set forth below.

Embodiment 1: A drilling assembly for drilling a subterranean wellbore, comprising: an expandable reamer comprising a first tubular body having a first longitudinal axis and a first drilling fluid flow path extending therethrough, a plurality of blades carried by the first tubular body, and a cutting structure carried by at least one blade of the plurality of blades, wherein at least one blade of the plurality of blades is outwardly movable from a retracted position to an extended position with respect to the first longitudinal axis; and an expandable stabilizer axially located a distance of about 7.62 meters or less above the expandable reamer in the drilling assembly, the expandable stabilizer comprising a second tubular body having a second longitudinal axis and a second drilling fluid flow path extending therethrough, a plurality of bearing pads carried by the second tubular body, wherein at least one bearing pad of the plurality of bearing pads is outwardly movable from a retracted position to an extended position with respect to the second longitudinal axis.

Embodiment 2: The drilling assembly of Embodiment 1, wherein the first tubular body of the expandable reamer and the second tubular body of the expandable stabilizer are separate tubular bodies coupled directly together.

Embodiment 3: The drilling assembly of Embodiment 1, wherein the first tubular body of the expandable reamer and the second tubular body of the expandable stabilizer comprise different regions of a unitary tool body.

Embodiment 4: The drilling assembly of any one of Embodiments 1 through 3,
5 wherein the bearing pads are located a distance in a range extending from about 3.05 meters to about 4.57 meters above the blades.

Embodiment 5: The drilling assembly of any one of Embodiments 1 through 4, wherein the bearing pads are located a distance in a range extending from about 4.57 meters to about 7.62 meters above the blades.

10 Embodiment 6: The drilling assembly of any one of Embodiments 1 through 5, wherein the first longitudinal axis of the expandable reamer is co-axial with the second longitudinal axis of the expandable stabilizer.

Embodiment 7: A drilling assembly for drilling a subterranean wellbore, comprising: an expandable reamer comprising a first tubular body having a first
15 longitudinal axis and a first drilling fluid flow path extending therethrough, a plurality of blades carried by the first tubular body, and a cutting structure carried by at least one blade of the plurality of blades, wherein the at least one blade is outwardly movable from a retracted position to an extended position with respect to the first longitudinal axis, the expandable reamer further comprising a first actuation device for moving the
20 at least one blade from the retracted position to the extended position and a first electrical device configured to receive a first electronic signal and actuate the first actuation device responsive to the first electronic signal; and an expandable stabilizer axially spaced from the expandable reamer and comprising a second tubular body having a second longitudinal axis and a second drilling fluid flow path extending
25 therethrough, a plurality of bearing pads carried by the second tubular body, wherein at least one bearing pad of the plurality of bearing pads is outwardly movable from a retracted position to an extended position with respect to the second longitudinal axis, the expandable stabilizer further comprising a second actuation device for moving the at least one bearing pad from the retracted position to the extended position and a
30 second electrical device configured to receive a second electronic signal and actuate the second actuation device responsive to the second electronic signal.

Embodiment 8: The drilling assembly of Embodiment 7, further comprising a bi-directional communication pulse module (BCPM) configured to transmit the first electronic signal to the first electrical device of the expandable reamer.

Embodiment 9: The drilling assembly of Embodiment 8, wherein the BCPM is
5 configured to transmit the second electronic signal to the second electrical device of the expandable stabilizer.

Embodiment 10: The drilling assembly of any one of Embodiments 7 through 9, further comprising a sensor device configured to indicate a diameter of the wellbore proximate the expandable stabilizer, the sensor device comprising an electronic device
10 configured to transmit the second electronic signal to the second electrical device of the expandable stabilizer when the diameter of the wellbore corresponds to a predetermined diameter.

Embodiment 11: The drilling assembly of any one of Embodiments 7 through 10, further comprising at least one section of electrically communicative drill pipe
15 located in the drilling assembly, the at least one section of electrically communicative drill pipe providing an electrical interconnection between two components of the drilling assembly coupled directly to opposing ends of the at least one section of electrically communicative drill pipe, wherein the first electronic signal is transmitted through the at least one section of electrically communicative drill pipe to the first
20 electrical device of the expandable reamer.

Embodiment 12: The drilling assembly of any one of Embodiments 7 through 11, wherein the second electronic signal is transmitted through the at least one section of electrically communicative drill pipe to the second electrical device of the expandable stabilizer.

Embodiment 13: The drilling assembly of any one of Embodiments 7 through 12, further comprising a revolution-per-minute (RPM) recognition device configured to transmit the second electronic signal to the second electrical device of the expandable stabilizer responsive to detection of a predetermined series of operating revolution-per-minute intervals.

Embodiment 14: The drilling assembly of any one of Embodiments 7 through 13, wherein the first actuation device does not comprise a ball trap mechanism.

Embodiment 15: The drilling assembly of any one of Embodiments 7 through 14, wherein the first actuation device comprises at least one of a downhole pump and a

downhole turbine configured to pressurize hydraulic fluid enclosed and sealed within the first tubular body of the expandable reamer.

Embodiment 16: The drilling assembly of any one of Embodiments 7 through 15, wherein the second actuation device does not comprise a ball trap mechanism.

5 Embodiment 17: The drilling assembly of any one of Embodiments 7 through 16, wherein the second actuation device comprises at least one of a downhole pump and a downhole turbine configured to pressurize hydraulic fluid enclosed and sealed within the second tubular body of the expandable stabilizer.

Embodiment 18: A method of forming a drilling assembly for drilling a
10 subterranean wellbore, comprising: coupling an expandable stabilizer to an expandable reamer, the expandable reamer comprising a first tubular body having a first longitudinal axis and a first drilling fluid flow path extending therethrough, a plurality of blades carried by the first tubular body, and a cutting structure carried by at least one blade of the plurality of blades, wherein the at least one blade is outwardly movable
15 from a retracted position to an extended position with respect to the first longitudinal axis for reaming a section of the wellbore, the expandable stabilizer comprising a second tubular body having a second longitudinal axis and a second drilling fluid flow path extending therethrough, a plurality of bearing pads carried by the second tubular body, wherein at least one bearing pad of the plurality of bearing pads is outwardly
20 movable from a retracted position to an extended position with respect to the second longitudinal axis; and axially locating the expandable stabilizer a distance of about 7.62 meters or less above the blades of the expandable reamer.

Embodiment 19: The method of Embodiment 18, wherein coupling the expandable stabilizer to the expandable reamer comprises forming the expandable
25 stabilizer and the expandable reamer to comprise different regions of a unitary tubular body.

Embodiment 20: The method of Embodiment 18 or Embodiment 19, further comprising configuring the at least one outwardly movable bearing pad to move from the retracted position to the extended position at least substantially automatically after
30 the expandable reamer has reamed a section of the wellbore having a length equal to or greater than the distance the expandable stabilizer is axially located above the blades of the expandable reamer.

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While certain illustrative embodiments have been described in connection with the figures, those of ordinary skill in the art will recognize and appreciate that embodiments of the present disclosure are not limited to those embodiments explicitly shown and described herein. Rather, many additions, deletions, and modifications to the embodiments described herein may be made without departing from the scope of
5 embodiments of the present disclosure as hereinafter claimed, including legal equivalents. In addition, features from one disclosed embodiment may be combined with features of another disclosed embodiment while still being encompassed within the scope of embodiments of the present disclosure as contemplated by the inventor.

10

CLAIMS

What is claimed is:

- 5 1. A drilling assembly for drilling a subterranean wellbore, comprising:
an expandable reamer comprising a first tubular body having a first longitudinal axis
and a first drilling fluid flow path extending therethrough, a plurality of
blades carried by the first tubular body, and a cutting structure carried by at
least one blade of the plurality of blades, wherein at least one blade of the
10 plurality of blades is outwardly movable from a retracted position to an
extended position with respect to the first longitudinal axis; and
an expandable stabilizer axially located a distance of about 7.62 meters or less
above the expandable reamer in the drilling assembly, the expandable
stabilizer comprising a second tubular body having a second longitudinal
15 axis and a second drilling fluid flow path extending therethrough, a plurality
of bearing pads carried by the second tubular body, wherein at least one
bearing pad of the plurality of bearing pads is outwardly movable from a
retracted position to an extended position with respect to the second
longitudinal axis.
20
2. The drilling assembly of claim 1, wherein the first tubular body of the
expandable reamer and the second tubular body of the expandable stabilizer are
separate tubular bodies coupled directly together.
- 25 3. The drilling assembly of claim 1, wherein the first tubular body of the
expandable reamer and the second tubular body of the expandable stabilizer
comprise different regions of a unitary tool body.
4. The drilling assembly of any one of claims 1 through 3, wherein the
30 bearing pads are located a distance in a range extending from about 3.05 meters to
about 4.57 meters above the blades.

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5. The drilling assembly of claim 2, wherein the bearing pads are located a distance in a range extending from about 4.57 meters to about 7.62 meters above the blades.

5 6. The drilling assembly of any one of claims 1 through 3 and 5, wherein the first longitudinal axis of the expandable reamer is co-axial with the second longitudinal axis of the expandable stabilizer.

7. The drilling assembly of claim 1, wherein:
10 the expandable reamer further comprises:
a first actuation device for moving the at least one blade from the retracted position to the extended position; and
a first electrical device configured to receive a first electronic signal and actuate the first actuation device responsive to the first electronic
15 signal; and
the expandable stabilizer further comprises:
a second actuation device for moving the at least one bearing pad from the retracted position to the extended position; and
a second electrical device configured to receive a second electronic signal
20 and actuate the second actuation device responsive to the second electronic signal.

8. The drilling assembly of claim 7, further comprising a bi-directional communication pulse module (BCPM) configured to transmit the first electronic
25 signal to the first electrical device of the expandable reamer.

9. The drilling assembly of claim 8, wherein the BCPM is configured to transmit the second electronic signal to the second electrical device of the expandable stabilizer.

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10. The drilling assembly of any one of claims 7 through 9, further comprising a sensor device configured to indicate a diameter of the wellbore proximate the expandable stabilizer, the sensor device comprising an electronic device configured to transmit the second electronic signal to the second electrical device of the expandable stabilizer when the diameter of the wellbore corresponds to a predetermined diameter.

11. The drilling assembly of any one of claims 7 through 9, further comprising at least one section of electrically communicative drill pipe located in the drilling assembly, the at least one section of electrically communicative drill pipe providing an electrical interconnection between two components of the drilling assembly coupled directly to opposing ends of the at least one section of electrically communicative drill pipe, wherein the first electronic signal is transmitted through the at least one section of electrically communicative drill pipe to the first electrical device of the expandable reamer.

12. The drilling assembly of claim 11, wherein the second electronic signal is transmitted through the at least one section of electrically communicative drill pipe to the second electrical device of the expandable stabilizer.

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13. The drilling assembly of any one of claims 7 through 9 and 12, further comprising a revolution-per-minute (RPM) recognition device configured to transmit the second electronic signal to the second electrical device of the expandable stabilizer responsive to detection of a predetermined series of operating revolution-per-minute intervals.

25

14. The drilling assembly of any one of claims 7 through 9 and 12, wherein the first actuation device does not comprise a ball trap mechanism.

15. The drilling assembly of claim 14, wherein the first actuation device comprises at least one of a downhole pump and a downhole turbine configured to pressurize hydraulic fluid enclosed and sealed within the first tubular body of the expandable reamer.

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16. The drilling assembly of any one of claims 7 through 9 and 12, wherein the second actuation device does not comprise a ball trap mechanism.

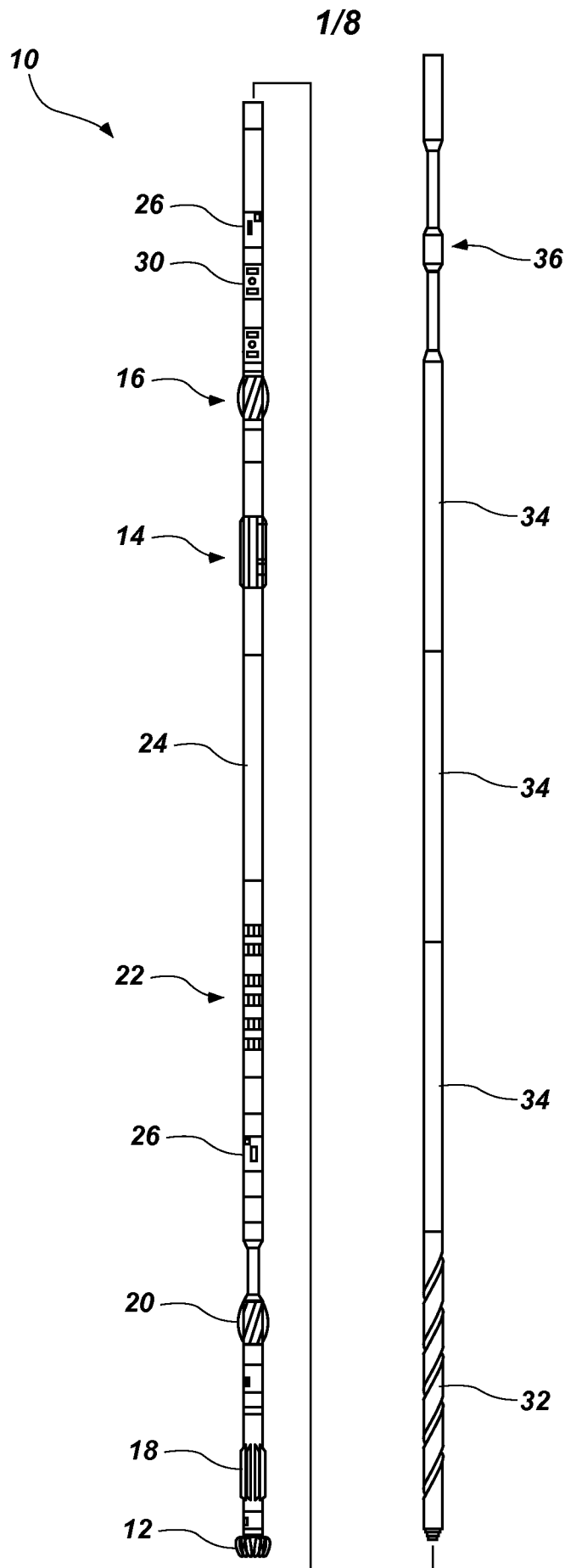
5 17. The drilling assembly of claim 16, wherein the second actuation device comprises at least one of a downhole pump and a downhole turbine configured to pressurize hydraulic fluid enclosed and sealed within the second tubular body of the expandable stabilizer.

10 18. A method of forming a drilling assembly for drilling a subterranean wellbore, comprising:
coupling an expandable stabilizer to an expandable reamer, the expandable reamer comprising a first tubular body having a first longitudinal axis and a first drilling fluid flow path extending therethrough, a plurality of blades carried
15 by the first tubular body, and a cutting structure carried by at least one blade of the plurality of blades, wherein the at least one blade is outwardly movable from a retracted position to an extended position with respect to the first longitudinal axis for reaming a section of the wellbore, the expandable stabilizer comprising a second tubular body having a second longitudinal
20 axis and a second drilling fluid flow path extending therethrough, a plurality of bearing pads carried by the second tubular body, wherein at least one bearing pad of the plurality of bearing pads is outwardly movable from a retracted position to an extended position with respect to the second longitudinal axis; and
25 axially locating the expandable stabilizer a distance of about 7.62 meters or less above the blades of the expandable reamer.

19. The method of claim 18, wherein coupling the expandable stabilizer to the expandable reamer comprises forming the expandable stabilizer and the
30 expandable reamer to comprise different regions of a unitary tubular body.

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20. The method of claim 18 or claim 19, further comprising configuring the at least one outwardly movable bearing pad to move from the retracted position to the extended position at least substantially automatically after the expandable reamer has reamed a section of the wellbore having a length equal to or greater than
5 the distance the expandable stabilizer is axially located above the blades of the expandable reamer.

**FIG. 1**

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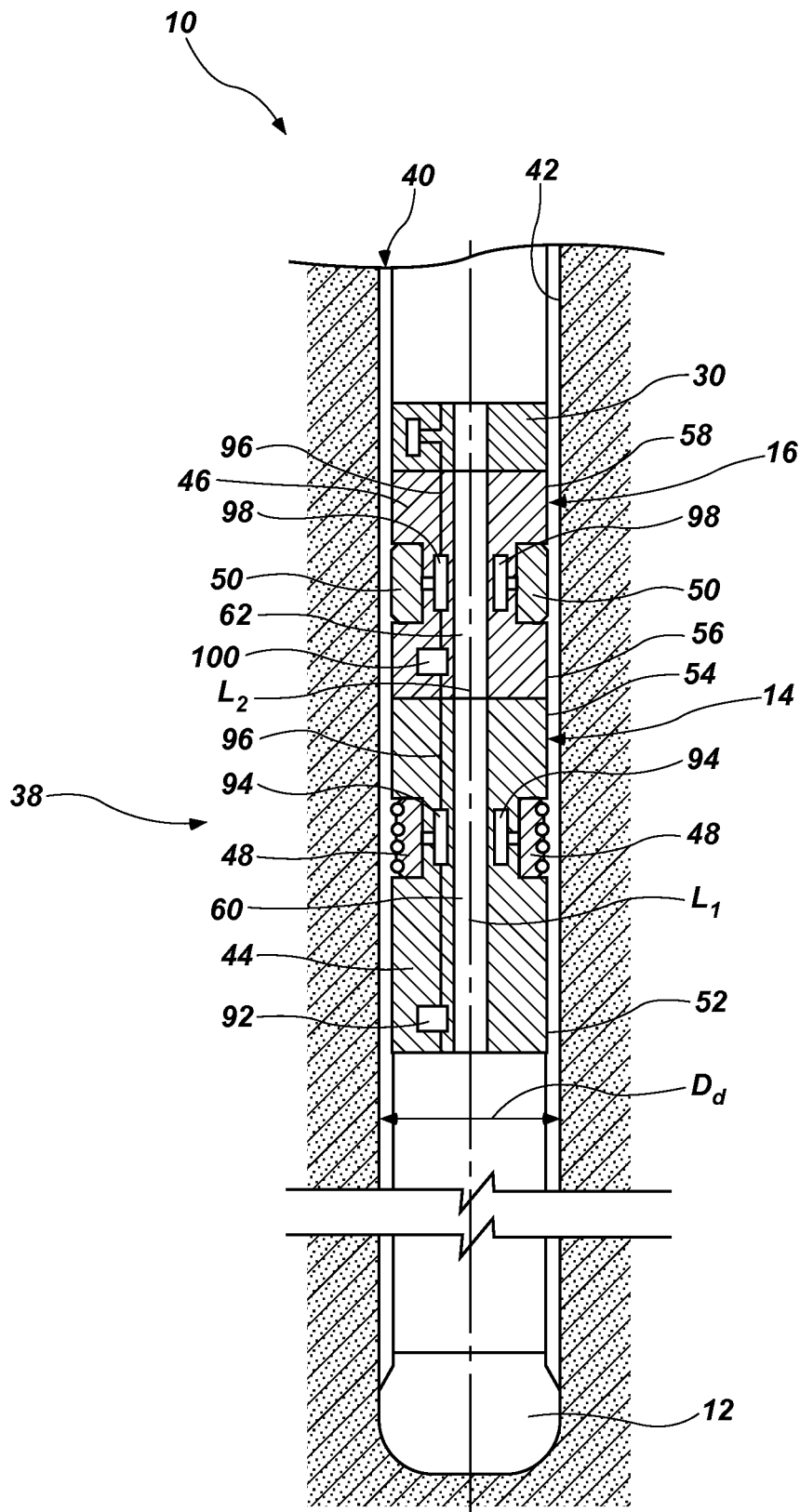


FIG. 2

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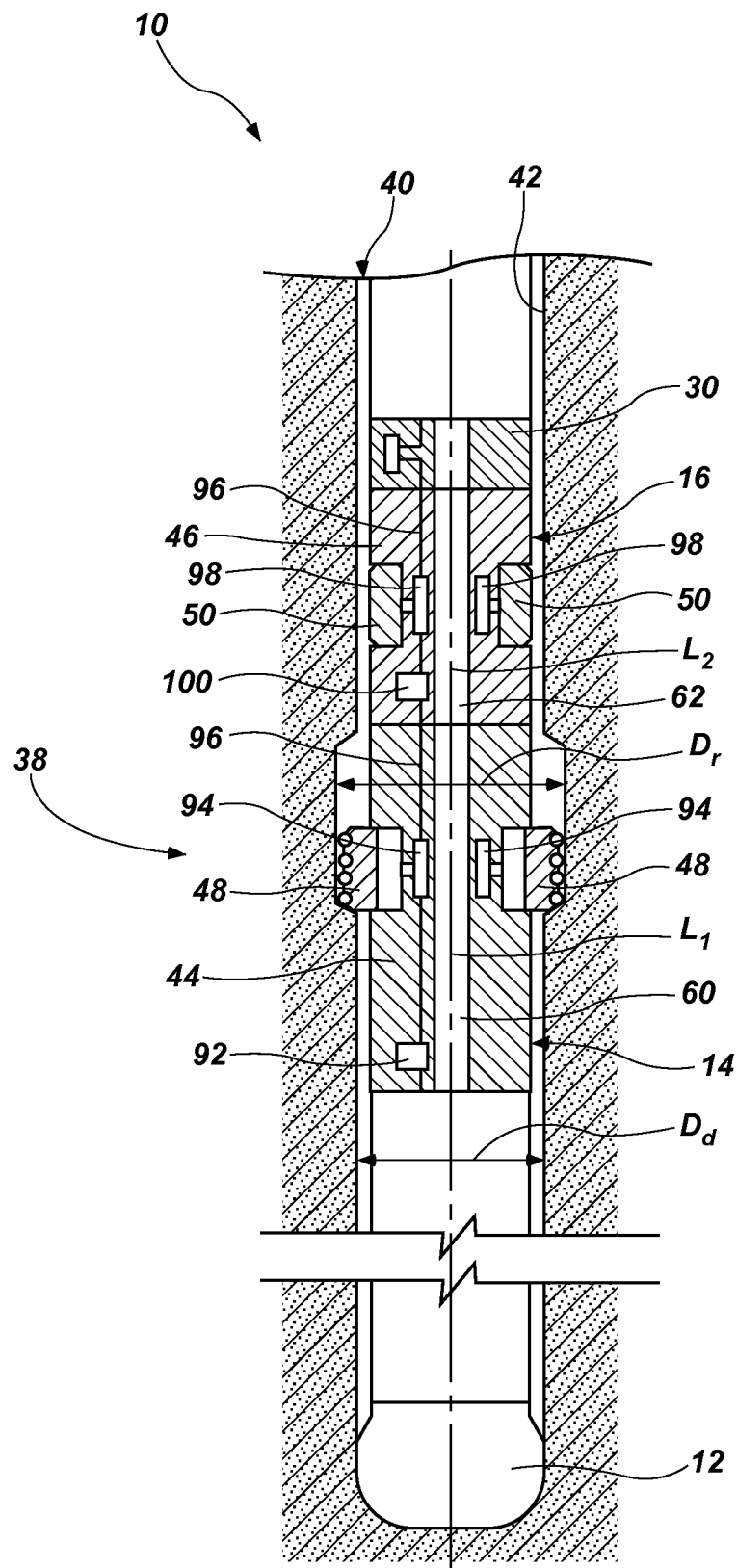


FIG. 3

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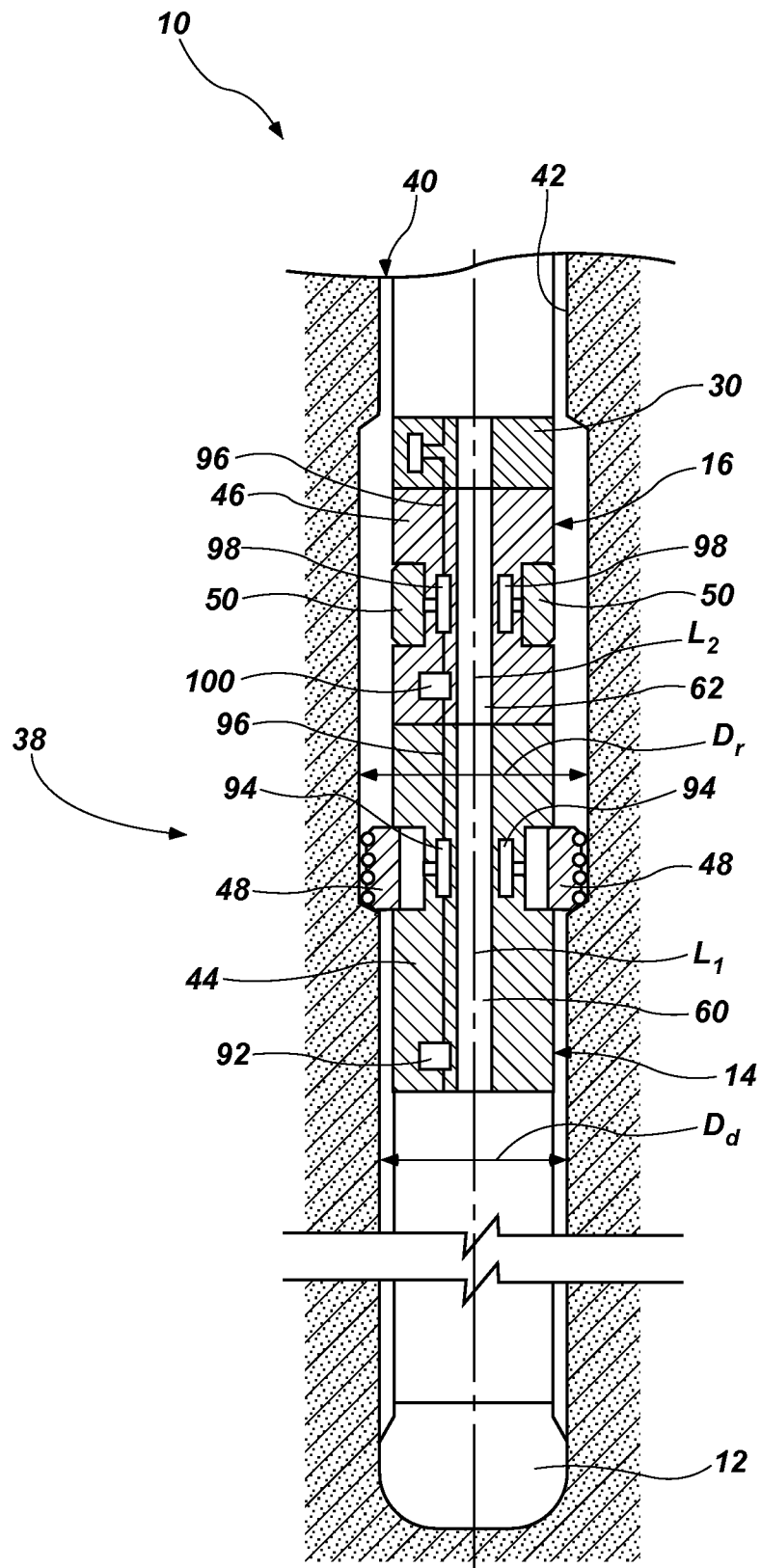


FIG. 4

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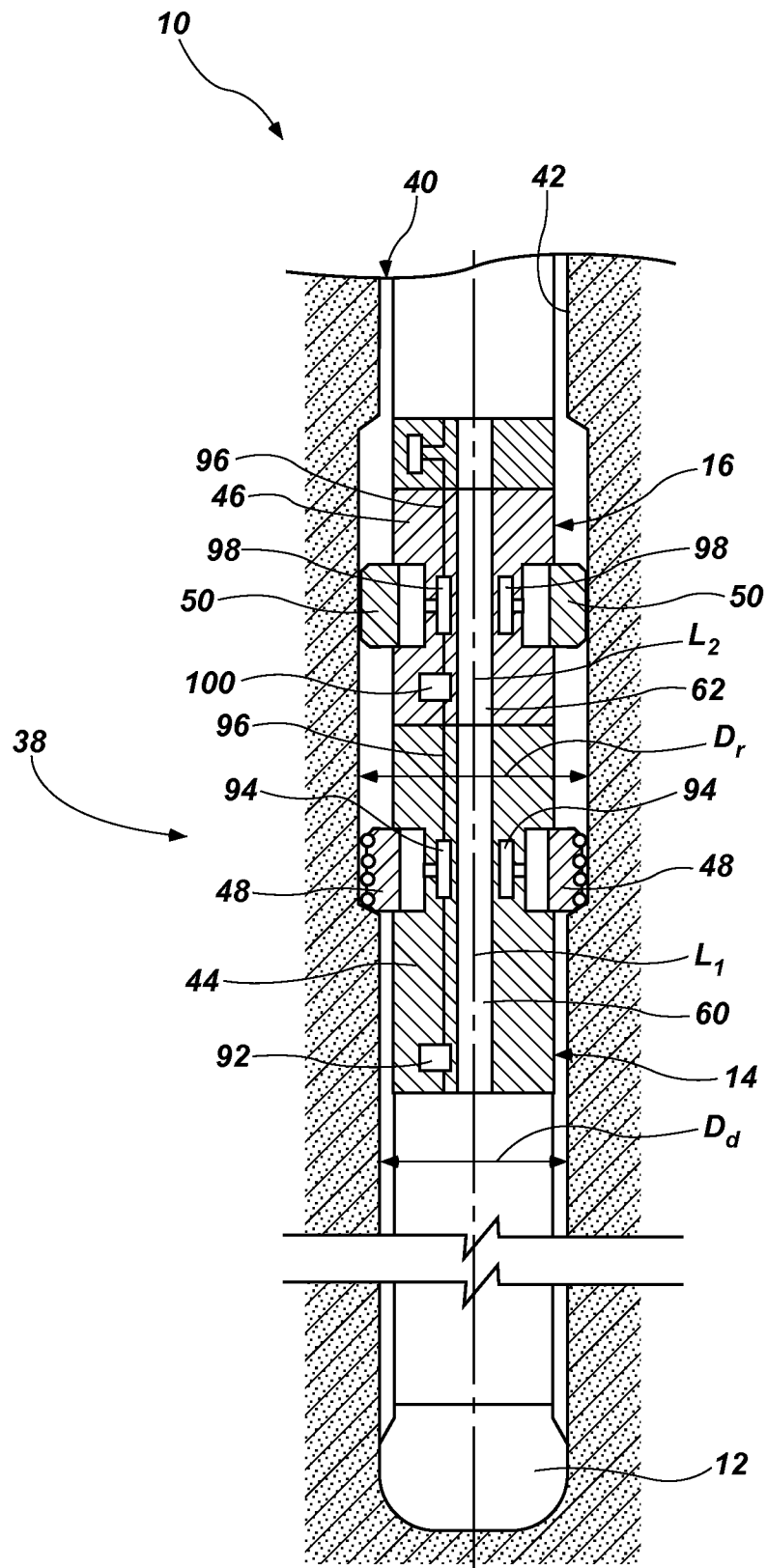


FIG. 5

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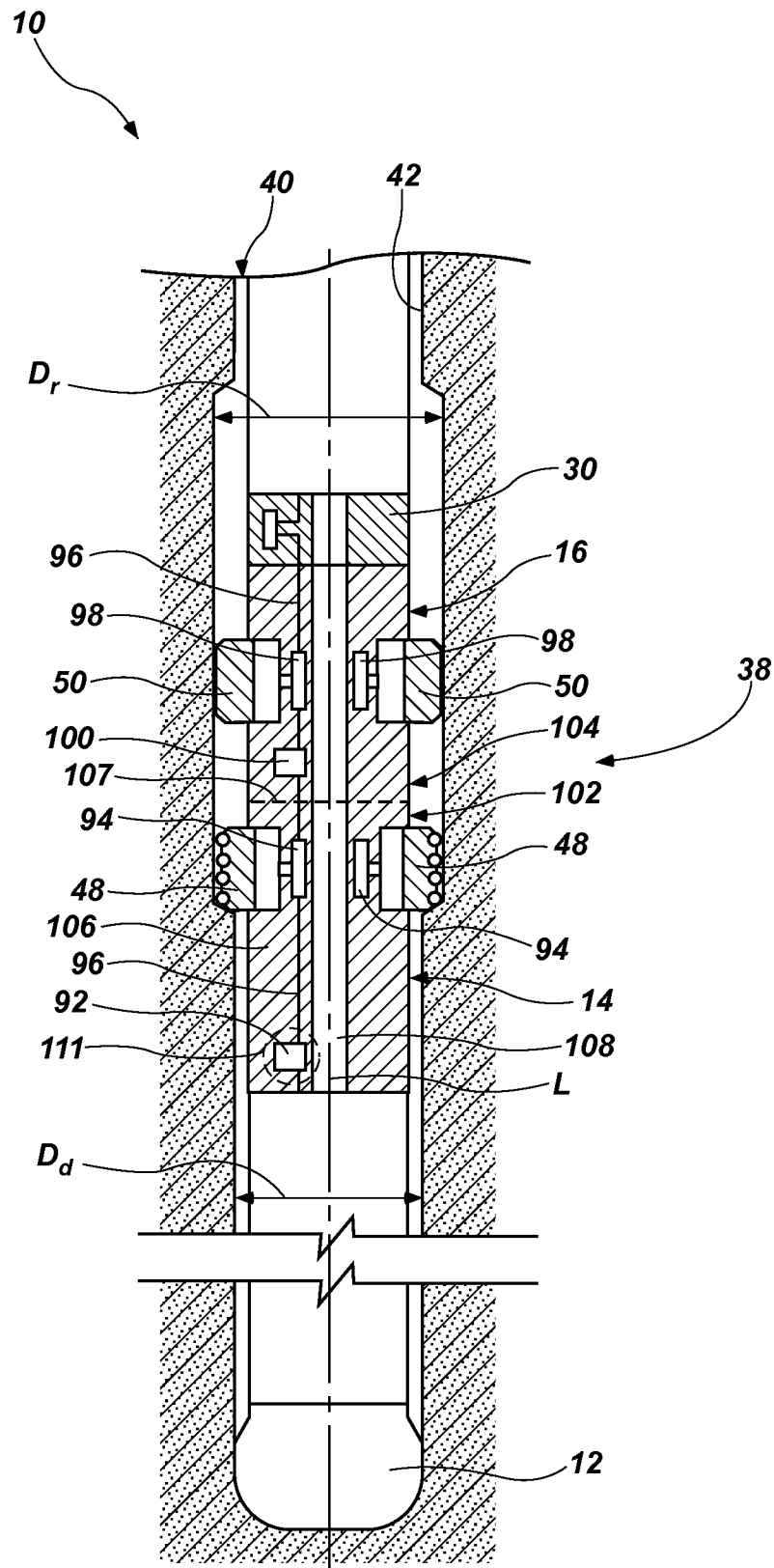


FIG. 6

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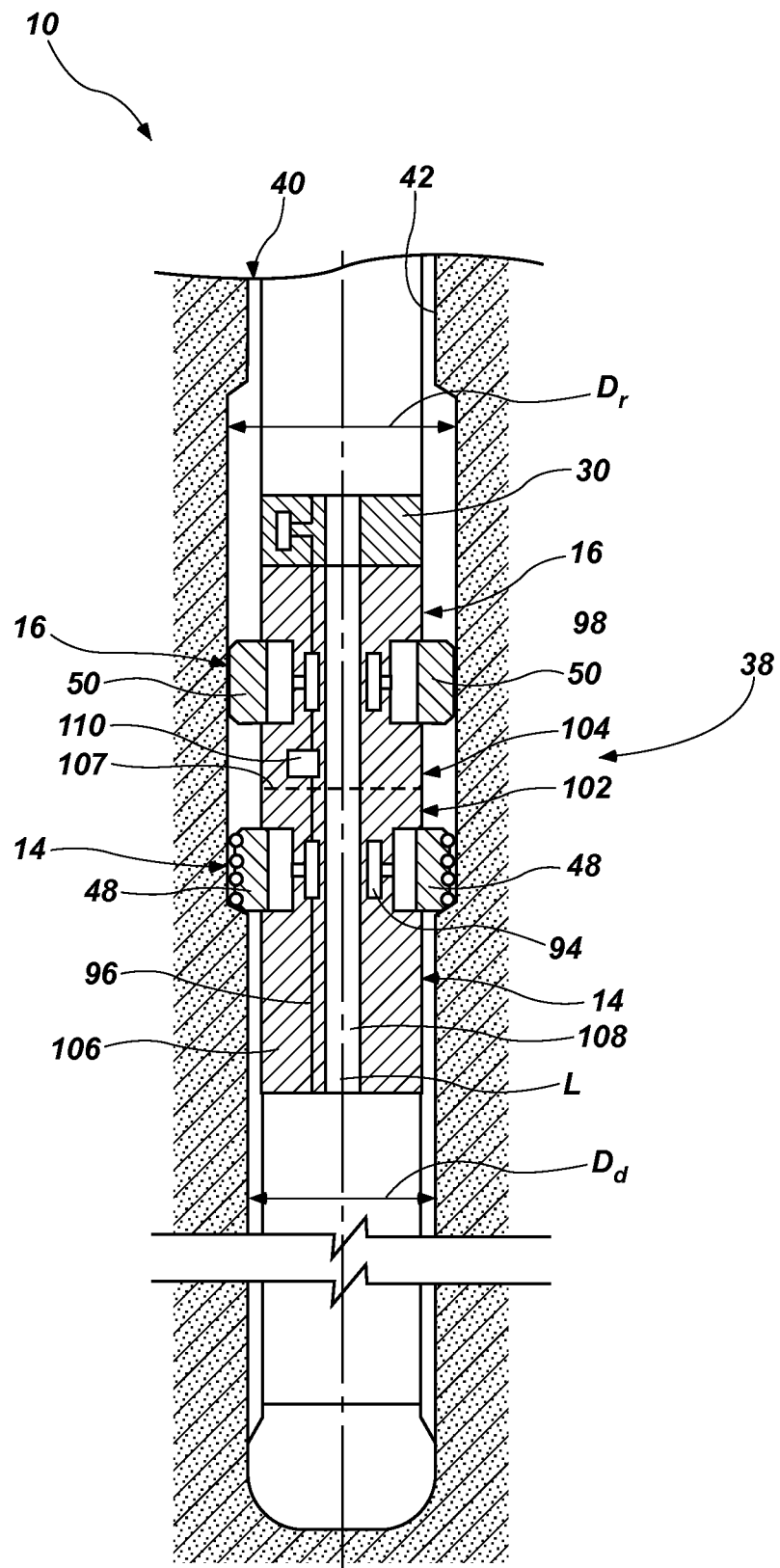


FIG. 7

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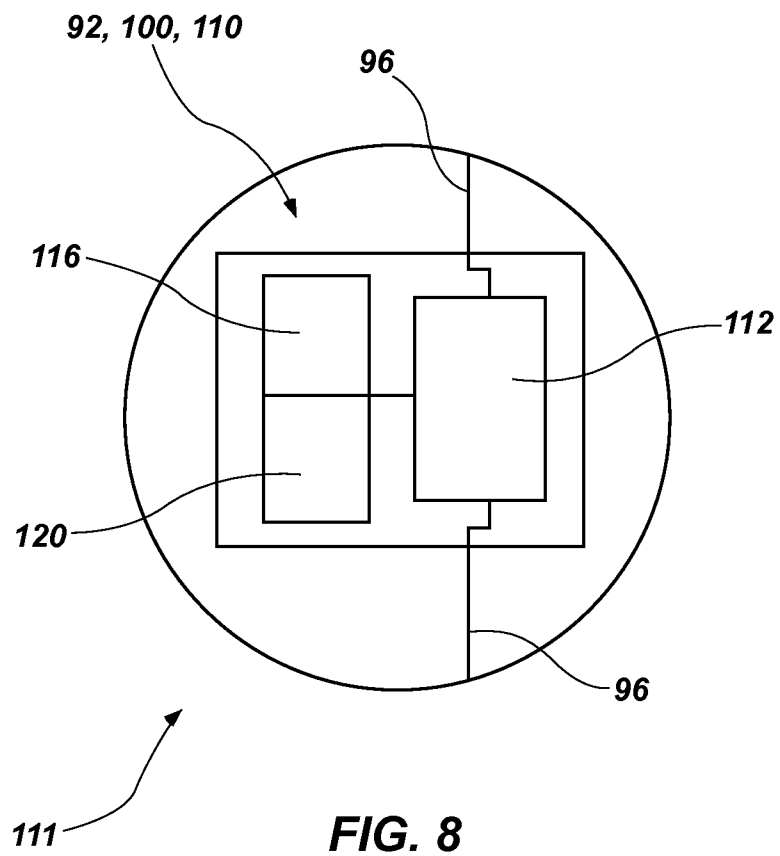


FIG. 8

A. CLASSIFICATION OF SUBJECT MATTER**E21B 10/30(2006.01)i, E21B 10/32(2006.01)i**

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

E21B 10/30; E21B 10/26; E21B 10/32; E21B 10/62; E21B 7/04; E21B 7/28

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) & Keywords:expandable reamer, expandable stabilizer, actuation, electrical device, signal, retracted position, and expanded position**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2009-135116 A2 (BAKER HUGHES INCORPORATED) 05 November 2009 See page 7, line 26 - page 9, line 29, page 12, line 12 - page 14, line 25, and figures 1-2.	1-6, 18-20
Y		7-12
Y	US 2010-0139981 A1 (MEISTER, MATTHIAS et al.) 10 June 2010 See paragraphs [0022], [0029], [0044], [0048] and figures 1-3, 5.	7-12
A	US 7513318 B2 (UNDERWOOD, LANCE D. et al.) 07 April 2009 See column 5, line 53 - column 6, line 28 and figure 5.	1-12, 18-20
A	US 8028767 B2 (RADFORD, STEVEN R. et al.) 04 October 2011 See column 7, line 32 - column 8, line 62 and figures 1-2.	1-12, 18-20
A	US 7493971 B2 (NEVLUD, KENNETH M. et al.) 24 February 2009 See column 7, line 41 - column 9, line 8 and figures 1-4.	1-12, 18-20



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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

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

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search

26 September 2013 (26.09.2013)

Date of mailing of the international search report

27 September 2013 (27.09.2013)

Name and mailing address of the ISA/KR

Korean Intellectual Property Office
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302-701, Republic of Korea

Facsimile No. +82-42-472-7140

Authorized officer

LEE Jong Kyung

Telephone No. +82-42-481-3360



INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2013/039480

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☒ Claims Nos.: 15,17
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
Claims 15 and 17 are unclear under PCT Article 6, because they are dependent on multiple dependent claims which do not comply with PCT Rule 6.4(a).

3. ☒ Claims Nos.: 13-14,16
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2013/039480

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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