



- (51) **International Patent Classification:**
E21B 10/42 (2006.01) *E21B 17/00* (2006.01)
E21B 10/26 (2006.01)
- (21) **International Application Number:**
PCT/US2015/029923
- (22) **International Filing Date:**
8 May 2015 (08.05.2015)
- (25) **Filing Language:** English
- (26) **Publication Language:** English
- (71) **Applicant:** HALLIBURTON ENERGY SERVICES, INC. [US/US]; 3000 N. Sam Houston Parkway E., Houston, TX 77032-3219 (US).
- (72) **Inventors:** GREENWOOD, Jeremy, Alexander; 1910 C Huldy Street, Houston, TX 77019 (US). MARLAND, Christopher, Neil; 9307 Memorial Manor Drive, Spring, TX 77379 (US).
- (74) **Agents:** MORICO, Paul et al.; Baker Botts LLP, 910 Louisiana Street, Houston, TX 77002 (US).

- (81) **Designated States** (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.
- (84) **Designated States** (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

[Continued on next page]

(54) **Title:** APPARATUS AND METHOD OF ALLEVIATING SPIRALING IN BOREHOLES

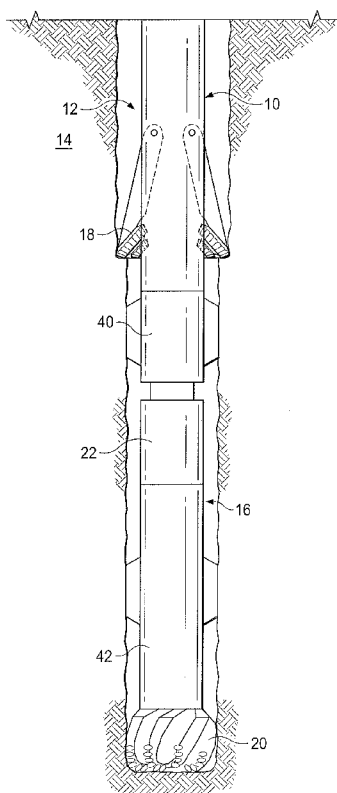


FIG. 2

(57) **Abstract:** An apparatus and method for alleviating spiraling in boreholes is disclosed. The apparatus includes a sub, which adjusts the length of the bottom-hole assembly in response to tension/compression, flexural bending and/or torque measurements made above and below the reamer so that the drill bit and the reamer cut at the same depth rate. The sub is connected between the drill bit and the reamer. The apparatus further includes measurement devices disposed on the bottom-hole assembly above and below the reamer, which are capable of measuring the tension/compression, flexural bending and torque in the bottom-hole assembly. The method includes use of a data processor, which determines which operational output signals to supply to the sub in order to adjust its length and thereby accomplish the desired drilling rates.



Declarations under Rule 4.17:

— *of inventorship (Rule 4.17(iv))*

Published:

— *with international search report (Art. 21(3))*

APPARATUS AND METHOD OF ALLEVIATING SPIRALING IN BOREHOLES

TECHNICAL FIELD

5 The present disclosure relates generally to bottom hole assemblies (BHAs) used in drilling wellbores in subterranean formations, and more particularly, to an apparatus and method of alleviating spiraling in boreholes, which can occur in some applications with BHAs having a hole enlargement device such as an underreamer.

BACKGROUND

10 Hydrocarbons, such as oil and gas, are commonly obtained from subterranean formations that may be located onshore or offshore. The development of subterranean operations and the processes involved in removing hydrocarbons from a subterranean formation typically include a number of different steps such as, for example, drilling a wellbore from a surface location to a desired target in the reservoir, treating the wellbore to
15 optimize production of hydrocarbons, and performing the necessary steps to produce and process the hydrocarbons from the subterranean formation.

 The drilling part of completing a well can present many challenges, especially in those formations, which are difficult to drill, such as highly interbedded formation, hard formations or complicated geological structures. Those formations, which require access
20 through complex angles such as is required with directional drilling can also present many challenges as can those formations having many differing structures throughout their depth.

 In some drilling applications, it is necessary to enlarge the wellbore to a greater diameter than the drill bit and/or the pass-through diameter of the previous casing string. This can be required for different reasons, the main one being to reduce the circulating
25 pressure of drilling fluid or cement in the wellbore.

 Such an operation is commonly known as reaming. This is often accomplished using a device known as a reamer or underreamer. A reamer is included as part of the BHA and attached above the drill bit assembly. The reamer is a secondary drilling apparatus having cutters, which remain retracted within the BHA until it is desired to drill the enlarged hole
30 above the drill bit assembly. There are many mechanisms used to expand and retract the reamer from the BHA, which are well known within the art.

 In some applications, especially those involving formations having inter-beds of

different strength or structures that intersect the wellbore at different angles, which vary from region to region, the reamer can cut at a different speed than the drill bit, cutting their respective formations at differing depths per unit of time, faster or slower depending on the rock strength. This change in loading between the two cutting structures causes different levels of compression and tension within the BHA above the bit and below the reamer and also above the reamer. This variation in load can cause the borehole to become spiraled as the orientation of the cutting faces is altered as the compression or tension bends the drill collars between the two cutting structures by varying amounts. Different amounts of wear are also induced on the cutting structures by failing to balance the load causing a greater difference in the rates at which the reamer and bit will drill.

If the spiraling is severe enough it is possible for the BHA to become lodged in the wellbore. Spiraling builds up torque on the stabilizers or other down-hole equipment in contact with the formation. This can adversely affect the drilling operation by reducing the rate of penetration, causing premature wear to the cutting structures, increasing the difficulty of moving cuttings out of the wellbore as it becomes spiraled and potentially causing the BHA to become stuck either through the mechanical creation of ledges or excessive cuttings build up. Thus, there remains a need in the art for minimizing spiraling of the borehole in an effort to prevent the BHA from becoming stuck in the borehole during back reaming and to improve overall drilling performance.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present disclosure and its features and advantages,
reference is **now** made to the following description, taken in conjunction with the
5 accompanying drawings, in which:

FIG. 1 is a schematic diagram illustrating a bottom-hole assembly in accordance with
the present disclosure installed in a wellbore illustrating a sub capable of altering the length
of the bottom-hole assembly in a compressed position;

FIG. 2 is a schematic diagram of the bottom-hole assembly shown in FIG. 1
10 illustrating the sub in an expanded position;

FIG. 3 is a schematic diagram of one embodiment of the sub shown in FIGs. 1 and 2;

FIG. 4 is a schematic diagram illustrating the control system which communicates
with the sub shown in FIGs. 1 and 2;

FIG. 5 is a schematic diagram of an alternate embodiment of the sub shown in FIGS.
15 1 whereby the sub is expanded or contracted by action of a hydraulically-activated ram; and

FIG. 6 is a schematic diagram of an alternate embodiment of the sub shown in FIGS.
1 and 2 whereby the sub is expanded or contracted by action of a grub screw compressed
plate and spring; and

FIG. 7 is a schematic diagram of an alternate embodiment of the sub shown in FIGS.
20 1 and 2 whereby the sub is expanded or contracted by action of a plunger which moves in
response to a rheologically-activated fluid which changes its viscosity in the presence of a
changing magnetic field.

DETAILED DESCRIPTION

Illustrative embodiments of the present disclosure are described in detail herein. In the interest of clarity, not all features of an actual implementation are described in this specification. It will of course be appreciated that in the development of any such actual
5 embodiment, numerous implementation specific decisions must be made to achieve developers' specific goals, such as compliance with system related and business related constraints, which will vary from one implementation to another. Moreover, it will be appreciated that such a development effort might be complex and time consuming, but would nevertheless be a routine undertaking for those of ordinary skill in the art having the benefit
10 of the present disclosure. Furthermore, in no way should the following examples be read to limit, or define, the scope of the disclosure.

To maintain the correct load on the cutting structures and prevent spiraling a sub can be installed on the drill string in accordance with the present disclosure. The sub may not only maintain a certain level of force on the cutting tool but also relieves some of the axial
15 length as the drill string is torqued upward. The sub may be positioned on the drill string between the two cutting structures, above the reamer or in both positions. The sub relieves a portion of the axial contraction or increases the amount of axial contraction to balance the load on the cutting structures while still allowing for torsional force to be translated through the string and down to the BHA and bit.

The cutting structure when drilling and reaming has a force applied to the cutters by reducing the tension in the drill string above the cutting structures to apply load. The tension required at the top of the drill string is the required weight minus the surface load. Which is the sum of the buoyant weight of the drill string from the top of the drill string to the cutting structure, plus any drag exerted on the drill pipe from contact with the wellbore wall as the
20 string is rotated and moved axially, plus the required force at the cutting structure to drill the rock, plus the buoyant weight of the BHA below the cutting structure, plus any drag of the BHA below the cutting structure from contact with the wellbore wall as the string is rotated and moved axially.

The factors that cause variation in the force being applied to the cutting structure
30 assuming a constant tension is maintained at the surface are as follows:

1) The speed at which one cutting structure drills relative to the other. If the drill bit penetrates the rock faster, the load on the reamer is increased as less of the BHA is in compression below the reamer and more force is applied to the reamer. If the drill bit penetrates slower, the load on the reamer is decreased as there is more of the BHA in compression below the reamer lessening the force applied.

2) The shortening of the drill string above the cutting structure, increasing the force, caused by the torque applied to turn the cutting structure causing elastic deformation of the drill string in a torsional mode. The force applied to the cutting structures and the strength of the rock that is being cut will control the amount of torque required to cut the formation and hence the change in drill string length through torsional deformation.

3) The variation in drag of the BHA below the cutting structure, decreasing the force, as the BHA is moved through the enlarged hole below the cutting structure which will be a factor of the size of the hole enlargement and the BHA length and the hole angle which will determine how much of the BHA is in contact with the wellbore wall. Variations in the drag are also influenced by the differential pressure inside and outside the drill string caused by changes in the mud flow rate changing the stiffness of the drill string.

To establish the force being applied to the bit cutting structure, a device that measures axial and torsional loads is positioned between the bit and reamer cutting structures within the BHA. To establish the force being applied to the reamer cutting structures a second device that measures axial and torsional loads is positioned above the reamer cutting structures. Both the actual loads on the bit and reamer cutting structures and the differential loads across the reamer cutting structure are measured. A third device, such as a sub, is placed above the drill bit that is able to shorten or elongate a defined amount to reduce or increase the force applied to the cutting structures of the reamer by compensating for the amount of shortening or elongation of the BHA through variation in tension and compression below the reamer. The distance that the sub elongates or shortens is governed by the information on the actual loads derived from the devices measuring the force being applied. With the objective of maintaining a constant torque at the cutting structure, the value of the constant torque will be established by a calculation in the tool that examines the average torque being applied over a fixed window to allow for changes in torque demand caused by variations in the formation strength.

The device for controlling the amount of elongation or shortening of the sub within the drill string can take the form of a number of different embodiments, including but not limited to:

1) A hydraulic ram where the amount of extension can be adjusted by pumping fluid in and out of a chamber, which actuates the ram. This embodiment is shown in FIG. 5.

2) A spring with a retaining plate that is moved on a grub screw. This embodiment is shown in FIG. 6. The spring passes through the retaining plate and as the plate is turned it varies the length of the spring that can elastically deform below the plate by compressing the part of the string above the retaining plate. The grub screw may be controlled by a motor, which can be controlled by the tool electronics. Power to the motor may be supplied by a hydraulic pump, which in turn is powered by circulation of the drilling mud.

3) A cylinder with a plunger. This embodiment is shown in FIG. 7. The difference between this embodiment and the first embodiment is that the cylinder may be filled with a magneto-rheological fluid whose viscosity can be varied in response to changes in a magnetic field. Changes in the viscosity of the fluid in turn cause the plunger to move, as opposed to increases in the fluid pressure caused by a pumping action, which in turn translates into a lengthening or shortening of the length of the BHA.

The device can be controlled in several ways in order to elongate or shorten the sub to ensure the balance between tension and compression of the two cutting structures is managed in such a way to avoid borehole spiraling. The device can be programmed to ensure a fixed load balance is maintained on each of the cutting structures when reaming is activated. This will ensure that when the reamer is activated and a set weight is applied to the bottom-hole assembly the sub controls the elongation of the drill string to ensure that the slacked off weight is distributed evenly across the cutting structures of the drill bit and reamer.

The sub can be designed to also be controlled through communication commands from surface computers. This downlink command and control is well known in the art. Control of the sub in this fashion can be done to ensure the tension and compression of the bottom-hole assembly is balanced to ensure torque and cutting structure depth of cut are optimal for the geological formation being drilled. As previously described different

formations may have differing rock strength, therefore the load applied to the cutting structure needs to be varied to optimize the relative penetration rate of each structure. As a new formation is entered a different weight distribution can be sent through downlink command to the sub in order to balance the loads as required.

5 The sub can be designed to automatically control the load distribution for tension, compression and torque on each cutting structure. In a similar manner to that previously described, the sub can manage the load distribution based on known geological conditions. In this example the sub would be programmed at the surface with the required load distribution for each geological formation and for each transition between formations if
10 applicable. As the drilling assembly drills the borehole the load is managed according to this pre-programmed set of conditions. Regular updates via downlink or other command from surface will update the sub to the current depth and therefore what loads to apply. The pre-programmed models can be updated to account for geological uncertainty in formation depth and to account for changes in geological conditions that may require different load balancing.

15 Further details of the present disclosure will now be provided with reference to the figures. A drill string having a bottom-hole assembly in accordance the present invention is shown generally in FIG. 1 by reference numeral 10. The drill string 10 is disposed in a wellbore 12 formed in a subterranean formation 14. As those of ordinary skill in the art will appreciate, the subterranean formation 14 may located below the subsea floor or be located
20 on-shore. The drill string 10 includes a bottom-hole assembly 16. Bottom-hole assembly 16 includes a reamer 18 and a drill bit 20. The drill bit 20 is the primary cutting means for forming the wellbore 12 in the subterranean formation 14. The reamer 18 widens the wellbore just above the section of the wellbore being drilled by the drill bit 20.

 The bottom-hole assembly 16 includes a sub 22, which is located between the reamer
25 18 and the drill bit 20. The sub 22 is capable of extending from a contracted position (shown in FIG. 1) to an expanded position (shown in FIG. 2). The sub 22 is shown in FIG. 3 in more detail. It is formed into two main sections, an upper sub 24 and a lower sub 26. The upper sub 24 connects via a threaded connection to a stablizer 40 (shown in FIGs. 1 and 2), which in turn is connected to the reamer 18. The lower sub 26, connects via a threaded connection
30 to a stabilizer 42 (shown in FIGs. 1 and 2), which in turn is connected to the drill bit 20. The upper sub 24 is defined by an upper section 28 and a lower section 30. The lower section 30

of the upper sub 24 is capable of sliding relative to the upper section 28 of the upper sub 26 in a telescoping fashion. It is the telescoping movement of the upper section 28 relative to the lower section 30 of the upper sub 24 which enables the sub 22 to move from a contracted or closed position (as shown in FIG. 1) to an extended or open position (as shown in FIG. 2).

5 The upper section 28 of the upper sub 24 has a main body 32, which is generally cylindrical shaped and disposed within the lower section 30. The main body 32 slides relative to the lower section 30 by operation of an actuation mechanism 34. As those of ordinary skill in the art will appreciate, there are a number of suitable actuation mechanisms 34 that can be employed in the sub 22. Non-limiting examples of such mechanisms include a
10 hydraulically-activated ram which moves laterally in response to differential fluid pressures created by a pump, a fluid-activated plunger which moves in response to changes in the viscosity of the fluid, which in turn is caused by changes in a magnetic field, a spring with a retaining plate that is moved on a motor-driven grub screw, as well as other known devices for altering the length of an object.

15 The sub 22 further includes an electronics module 36, which in one embodiment is disposed between the main body 32 and the lower section 30 of the upper sub 24 and which communicates with, and activates, the actuation mechanism 28. In one embodiment, the electronics module 36 may have the processing capability built into it, thereby making the sub 22 a smart sub. In another embodiment, the processing capability is at the surface (as
20 shown in FIG. 4), such that the electronics module simply passes commands from the surface to the actuation mechanism 28 via telemetry, a wired-connection, acoustics, fiber optics or other known communication means.

Turning to FIG. 4, the electronics system which determines the conditions under which the sub 22 needs to be activated will now be described. The electronics system
25 includes a first measurement device 50, which is capable of measuring axial and torsional loads in the BHA below the reamer 18. The first measurement device 50 is placed on the bottom-hole assembly 16 between the reamer 18 and the drill bit 20. The electronics system also includes a second measurement device 52, which is placed on the drill pipe 10 just above the reamer 18. The second measurement device 52 is capable of measuring the axial and
30 torsional loads on the drill string 10 proximate the reamer 18. Both the actual loads on the bit 20 and reamer 18 cutting structures and the differential loads across the reamer cutting

structure are measured. The first and second measurement devices 50 and 52 may be transducers or other known measurement devices. The first and second measurement devices 50 and 52 communicate with a signal processor, which may be located in the electronics module 36 within the sub 22 (shown in FIG. 3) or alternatively in a stand-alone device 54 at the surface, as shown in FIG. 4. The signals from the measurement devices 50 and 52 may be transmitted via wires 56 and 58 or via wireless transmission, such as telemetry, acoustic transmission or fiber optics. The axial and load signals are analyzed in the processor 54 to determine the distance that the sub 22 needs to elongate or shorten. As noted above, the objective is to maintain a constant torque at the cutting structures 18, 20. The value of the constant torque will be established by a calculation in the tool that examines the average torque being applied over a fixed window to allow for changes in torque demand caused by variations in the formation strength. The processor 54 makes this determination and then sends a decoded signal to the electronics module 36, which in turn activates the actuation mechanism 34, as may be necessary.

Turning to FIGS. 5-7, the various described mechanisms for expanding and contracting the sub are shown. FIG. 5 shows the embodiment of a hydraulically-activated ram 500 which moves the main body 32 of the sub 22 relative to the lower section 30. The ram 500 is attached to the main body 32. The ram 500 is disposed in a chamber 502 which is filled on one side with a hydraulically-activated fluid. The hydraulically-activated fluid is supplied to the chamber 502 by a pump 504, which is shown in FIG. 5 at the surface, but which may be disposed in the sub 22 or elsewhere down hole. The pump 504 is controlled by processor 54 based on the calculations processor 54 has made to determine how much the sub 22 should be expanded or contracted to achieve the desired operational parameters for the reamer 18 and drill bit 20.

FIG. 6 illustrates an alternate embodiment of the actuation mechanism 34. This figure illustrates an embodiment whereby actuation mechanism includes a spring 600 attached to retaining plate 602, which in turn is moved on a grub screw 604. The spring 600 passes through the retaining plate 602 and as the plate is turned it varies the length of the spring that can elastically deform below the plate by compressing the part of the string above the retaining plate. The spring 600 is attached to the main body 32, so that upon activation it can slide relative to the lower section 30. The grub screw 604 may be controlled by a motor 606, which can be controlled by the tool electronics, which as noted above can either be at the

surface or in the sub 22. Power to the motor 606 may be supplied by a hydraulic pump (not shown), which in turn is powered by circulation of the drilling mud.

FIG. 7 illustrates another alternate embodiment of the actuation mechanism 34. In this embodiment, the sub 22 is expanded and contracted by action of a plunger 700 which
5 under the influence of a rheologically-activated fluid, which is disposed within a chamber 702. The fluid changes viscosity in response to a changing magnetic field, which may be generated by an inductor 704 controlled by tool electronics, which as noted above can either
10 by at the surface or in the sub 22. The plunger 700 is attached to the main body 32 of the sub 22, so that upon activation it can slide relative to the lower section 30 thereby expanding or contracting the sub 22 and in turn varying its length.

Although the present disclosure and its advantages have been described in detail, it should be understood that various changes, substitutions and alterations can be made herein without departing from the spirit and scope of the disclosure as defined by the following claims.

WHAT IS CLAIMED IS:

1. A bottom-hole assembly, comprising:
a generally cylindrical main body having an upper section and a lower section;
a drill bit attached to an end of the lower section of the main body;
5 a reamer attached to the upper section of the main body;
a sub connected between the upper and lower sections which is capable of
expanding and retracting which changes the length of the bottom-hole assembly;
a first measurement device attached to the main body above the reamer; and
a second measurement device attached to the main body below the reamer.

2. The bottom-hole assembly according to claim 1, wherein the sub includes a
hydraulic ram which can move between a first compressed position, which corresponds to a
first length of the main body of the bottom-hole assembly and a second extended position,
which corresponds to a second length of the main body, the second length being greater than
15 the first length.

3. The bottom-hole assembly according to claim 2, wherein the movement of the
ram is actuated by the pumping of fluid in and out of a chamber which acts on the ram.

4. The bottom-hole assembly according to claim 1, wherein the sub includes a
spring which passes through a retaining plate which is moved laterally by a grub screw such
that as the plate is turned by the grub screw the length of the spring can elastically deform
below the plate by compressing a part of the spring above the retaining plate, which in turn
alters the length of the main body.

5. The bottom-hole assembly according to claim 4, further comprising a motor
which controls rotation of the grub screw and a hydraulic pump which supplies power to the
motor via mud circulation.

6. The bottom-hole assembly according to claim 1, wherein the sub comprises a cylinder having a plunger and wherein the cylinder is filled with a magneto-rheological fluid whose viscosity can be varied in response to a changing magnetic field, such that changes in the viscosity translates into movement of the plunger and in turn lengthening or shortening of the main body of the bottom-hole assembly.

7. The bottom-hole assembly according to claim 1, wherein the first and second measurement devices are capable of obtaining data, which includes one or more of a tension, compression, flexural bending and torque measurement of the main body during operation of the bottom-hole assembly.

8. The bottom-hole assembly according to claim 7, further comprising a device for communicating to a data processing device which is capable of processing said data to determine whether the bottom-hole assembly should be shortened or lengthened to alleviate down-hole spiraling of a drill string comprising the bottom-hole assembly, said data processing device further capable of sending operational commands to the sub in order to activate the sub to alter its length to prevent said condition from occurring.

9. The bottom-hole assembly according to claim 8, wherein the data processing device is located on the sub or at the surface.

10. The bottom-hole assembly according to claim 8, wherein the communicating device comprises a device selected from the group consisting of wires, a down-hole telemetry system, a down-hole acoustic system, fiber optic communication and combinations thereof.

11. The bottom-hole assembly according to claim 1, wherein the first and second measurement devices are selected from the group consisting of transducers, strain gauges, gyroscopes, magnetometers, and combinations thereof mounted in such a way as to measure axial strain, tension, torque, bending moment, rotational speed and/or changes in velocity.

12. A method of alleviating down-hole spiraling of a drill string having a bottom-hole assembly defined by a main body having a reamer and drill bit during a drilling operation, comprising:

gathering data which includes one or more of a tension, compression, flexural bending and torque measurement of the main body;
determining a depths-of-cut rate by the drill bit and the reamer based on the data;

extending or shortening a longitudinal length of the main body of the bottom-hole assembly under the condition where the depth-of-cut rate by the drill bit is not substantially the same as the depth-of-cut rate of the reamer.

13. The method according to claim 12, further comprising gathering the data from locations above and below the reamer.

14. The method according to claim 13, wherein gathering data includes measuring one or more tension, compression, flexural bending and torque of the main body above and below the reamer using one or more transducers, strain gauges, gyroscopes, magnetometers, and combinations thereof mounted in such a way as to measure axial strain, tension, torque, bending moment, rotational speed and/or changes in velocity.

15. The method according to claim 12, wherein the longitudinal length of a main body is extended or shortened using a sub disposed in the main body between the drill bit and the reamer and wherein the sub includes a hydraulic ram which can move between a first compressed position, which corresponds to a first length of the main body of the bottom-hole assembly and a second extended position, which corresponds to a second length of the main body, the second length being greater than the first length.

16. The method according to claim 12, wherein the longitudinal length of a main body is extended or shortened using a sub disposed in the main body between the drill bit and the reamer and wherein the sub includes a spring which passes through a retaining plate which is moved laterally by a grub screw such that as the plate is turned by the grub screw the length of the spring can elastically deform below the plate by compressing a part of the spring above the retaining plate, which in turn alters the length of the main body.

17. The method according to claim 12, wherein the longitudinal length of the main body is extended or shortened using a sub disposed in the main body between the drill bit and the reamer and wherein the sub comprises a cylinder having a plunger and wherein the
5 cylinder is filled with a magneto-rheological fluid whose viscosity can be varied in response to a changing magnetic field, such that changes in the viscosity translates into movement of the plunger and in turn lengthening or shortening of the main body.

18. The method according to claim 12, wherein gathering data comprises using a
10 device which communicates to a data processing device which is capable of processing said data to determine whether down-hole spiraling of a drill string is occurring based on said data, said data processing device further capable of sending operational commands to the sub in order to activate the sub to alter its length to prevent said condition from occurring.

19. The method according to claim 18, wherein the data processing device is
15 located on the sub or at the surface.

20. The method according to claim 18, wherein the communicating device is
20 selected from the group consisting of a wired connection, down-hole telemetry, acoustics, fiber optics and combinations thereof.

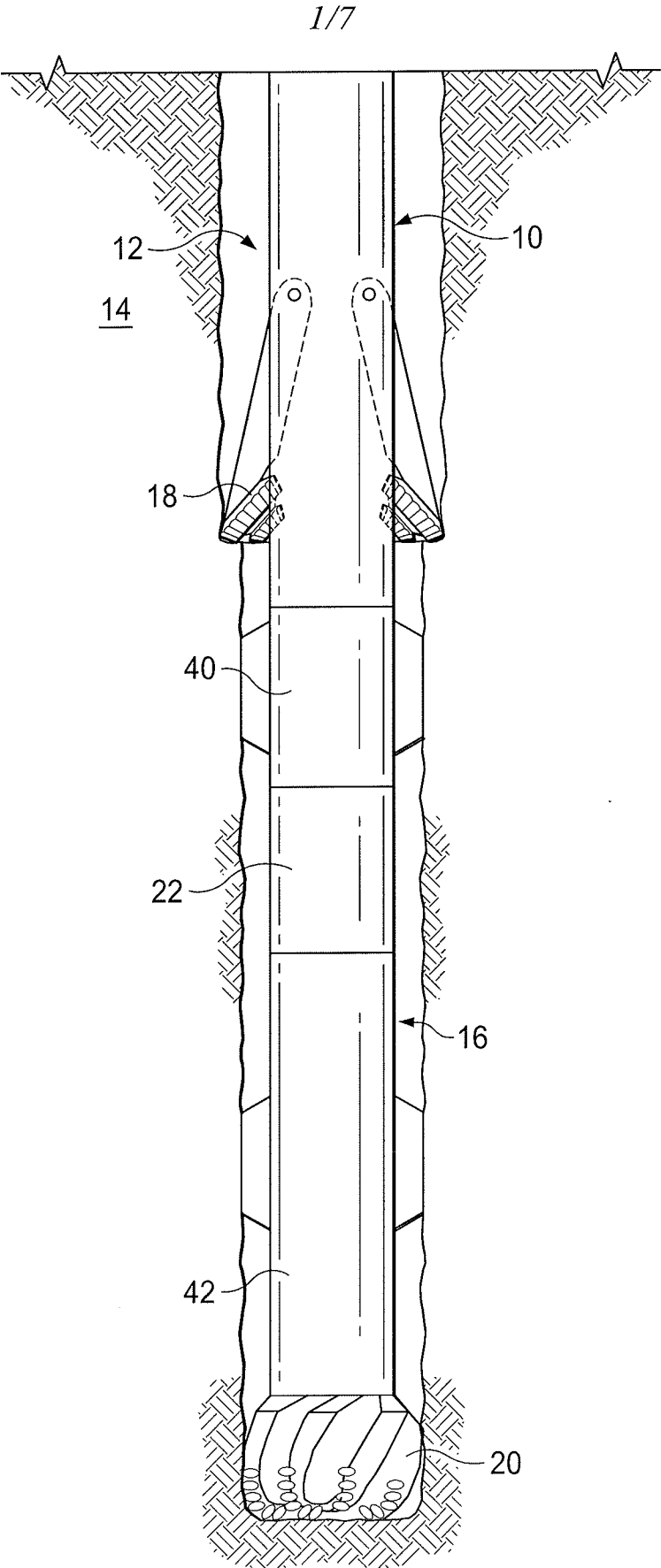


FIG. 1

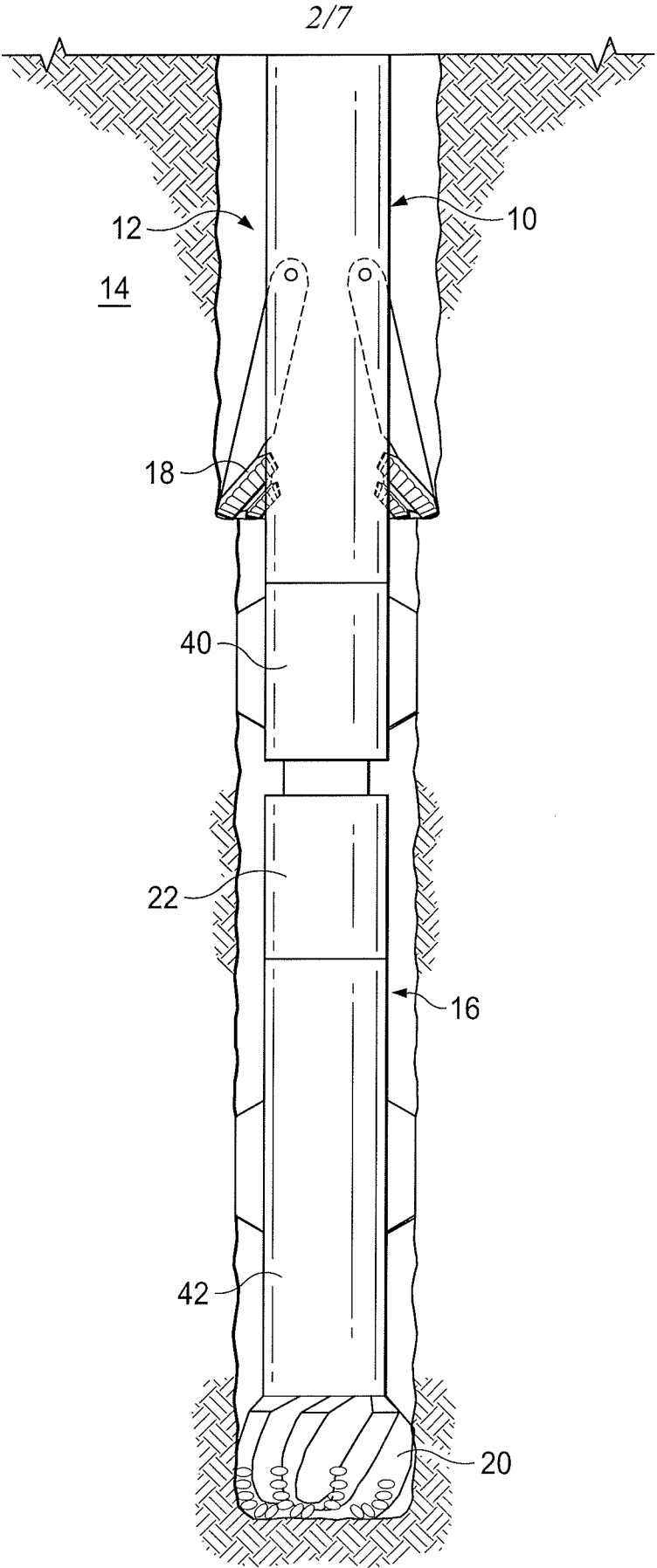


FIG. 2

3/7

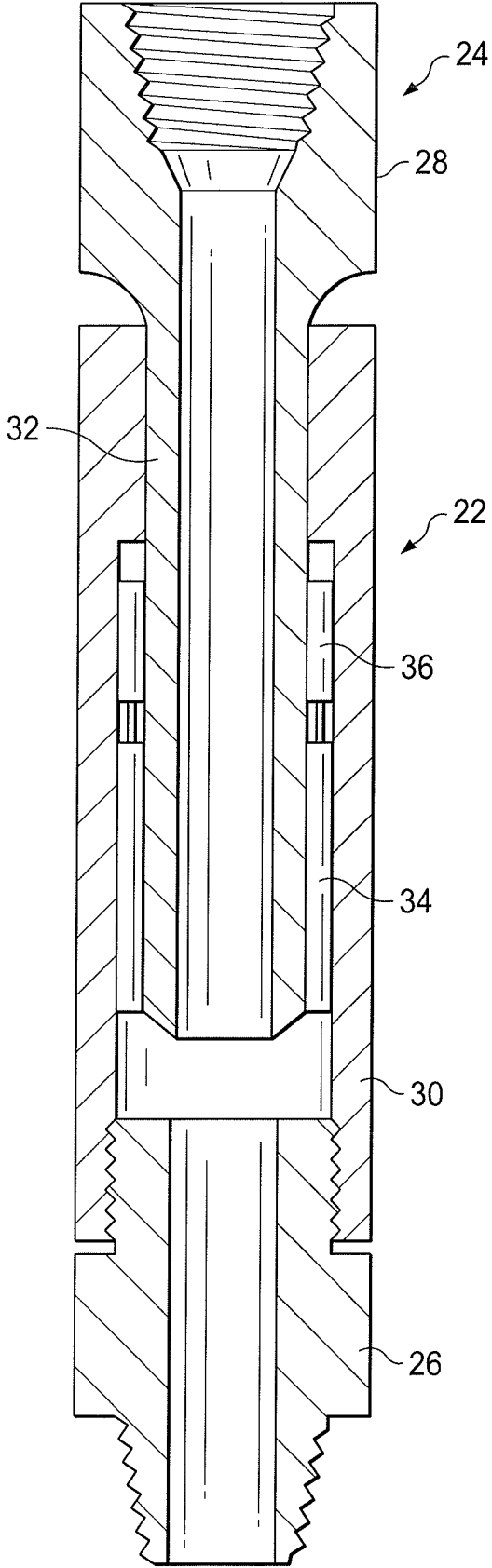
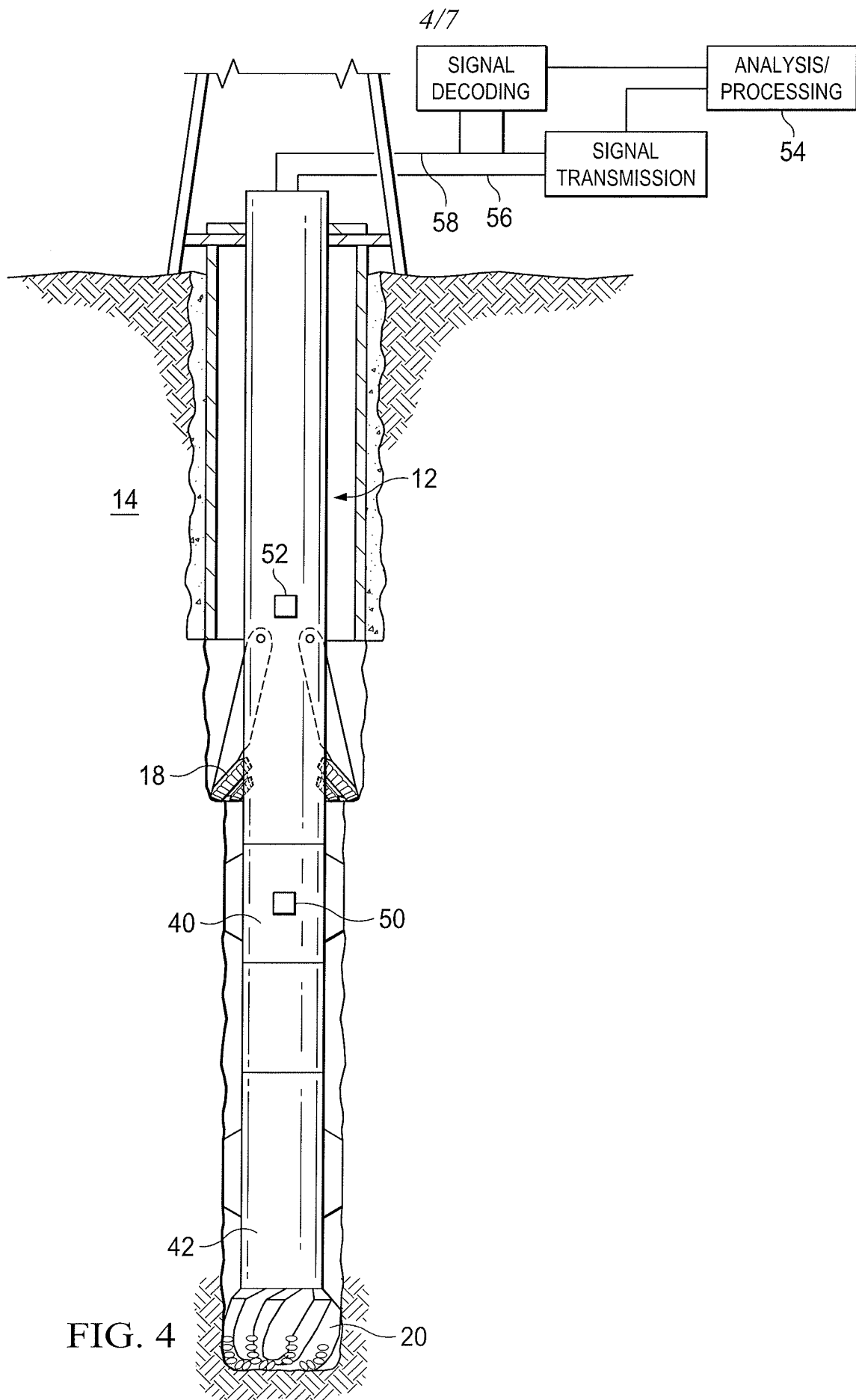


FIG. 3



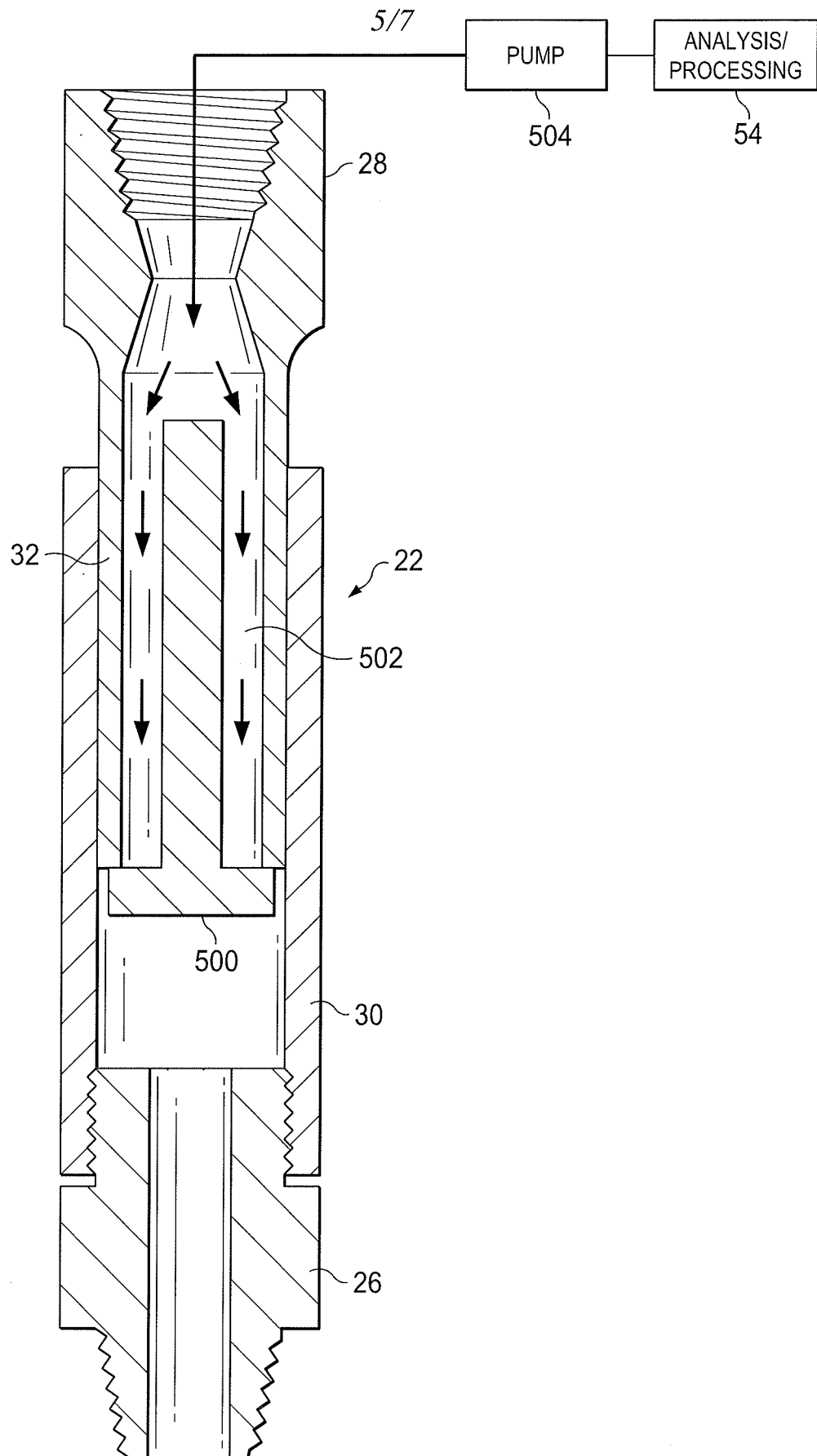


FIG. 5

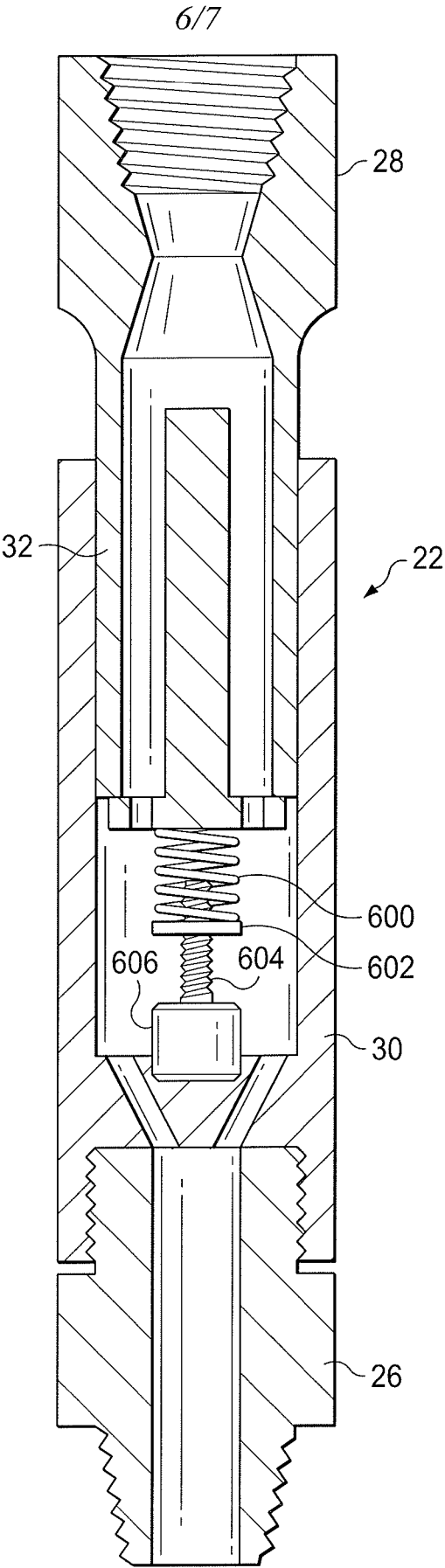


FIG. 6

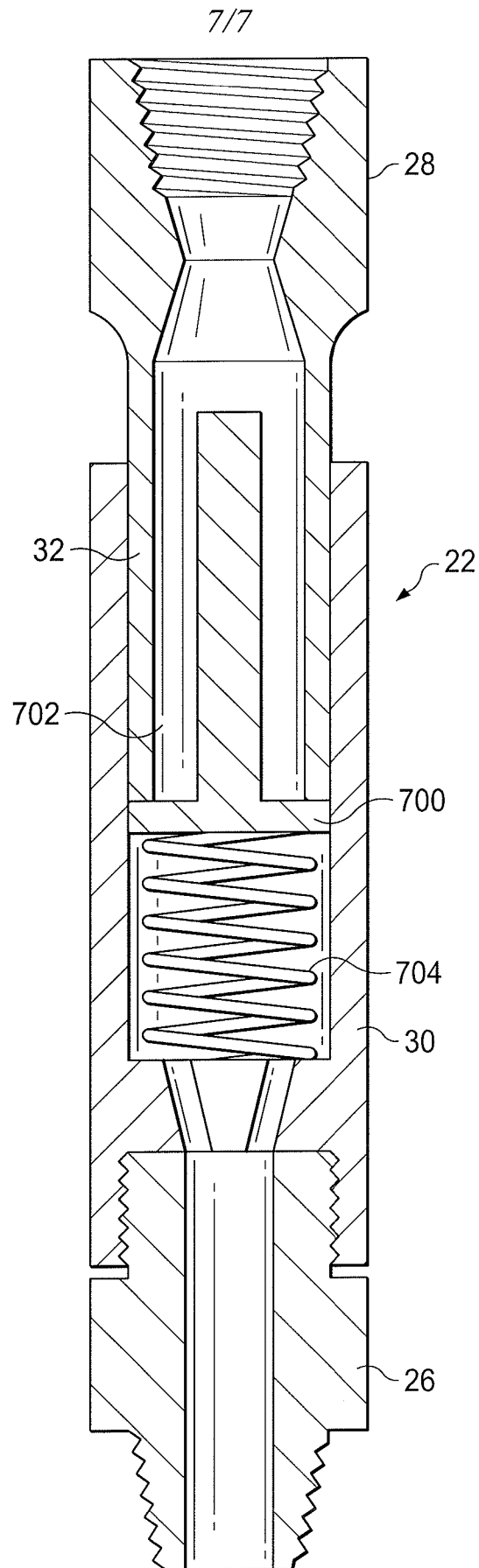


FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/029923**A. CLASSIFICATION OF SUBJECT MATTER****E21B 10/42(2006.01)i, E21B 10/26(2006.01)i, E21B 17/00(2006.01)i**

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

E21B 10/42; E21B 7/00; E21B 10/44; E21B 44/04; E21B 17/10; E21B 47/00; E21B 17/07; E21B 10/50; E21B 4/18; E21B 10/26; E21B 17/00

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) & Keywords: drill bit, reamer, measurement, bottom-hole assembly, expand, retract, change length, hydraulic, ram

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2014-105034 A1 (HALLIBURTON ENERGY SERVICES, INC.) 03 July 2014 See paragraphs [0007], [0020]-[0038] and figures 1-2.	1-20
A	US 2014-0182934 A1 (HALLIBURTON ENERGY SERVICES, INC.) 03 July 2014 See paragraphs [0019]-[0021], [0039] and figures 1, 3A-3B.	1-20
A	WO 2015-065410 A1 (HALLIBURTON ENERGY SERVICES, INC.) 07 May 2015 See paragraphs [0025]-[0028], [0052] and figures 1, 4A.	1-20
A	US 2005-0211470 A1 (JEFFRYES, BENJAMIN PETER) 29 September 2005 See paragraphs [0008]-[0010], [0065]-[0067] and figure 1.	1-20
A	US 2013-0220701 A1 (SMART STABILIZER SYSTEMS LIMITED) 29 August 2013 See paragraphs [0014]-[0016], [0066] and figures 1-3.	1-20



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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

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

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

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search

26 January 2016 (26.01.2016)

Date of mailing of the international search report

26 January 2016 (26.01.2016)

Name and mailing address of the ISA/KR

International Application Division
Korean Intellectual Property Office
189 Cheongsu-ro, Seo-gu, Daejeon Metropolitan City, 35208,
Republic of Korea

Facsimile No. +82-42-472-7140

Authorized officer

HWANG, Chan Yoon

Telephone No. +82-42-481-3347



INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2015/029923

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2014-105034 A1	03/07/2014	AU 2012-397834 A1 CA 2888807 A1 CN 104781502 A EP 2938816 A1 US 2015-0322767 A1	07/05/2015 03/07/2014 15/07/2015 04/11/2015 12/11/2015
US 2014-0182934 A1	03/07/2014	AU 2012-397838 A1 CA 2889130 A1 CN 104870745 A EP 2917475 A1 WO 2014-105038 A1	30/04/2015 03/07/2014 26/08/2015 16/09/2015 03/07/2014
WO 2015-065410 A1	07/05/2015	None	
US 2005-0211470 A1	29/09/2005	BR PI0500981 A CA 2502165 A1 CA 2502165 C GB 2412388 A GB 2412388 B GB 2412392 A GB 2412392 B NO 327621 B1 US 7316277 B2	08/11/2005 27/09/2005 15/01/2013 28/09/2005 27/09/2006 28/09/2005 30/08/2006 07/09/2009 08/01/2008
US 2013-0220701 A1	29/08/2013	AU 2013-200873 A1 CA 2806742 A1 GB 2499895 A GB 2499895 B GB 2514880 A GB 2514880 B	12/09/2013 28/08/2013 04/09/2013 15/10/2014 10/12/2014 27/05/2015