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(54) **Position sensor for determining operational condition of downhole tool**

(57) Downhole tools, such as a sliding sleeve or an openhole type packer, include position indicators. The position indicators can include one or more magnets disposed in predetermined positions in the outer housing and the insert of the sliding sleeve. A casing collar locator (CCL) can be used to detect the magnets and determine the relative positions of the housing magnets and insert magnets. The relative positions of the magnets can be used to determine the operational condition of the downhole tool, *i.e.*, whether a sliding sleeve is open or closed or how much a sealing element of an openhole type packer had to expand to seal an annulus.

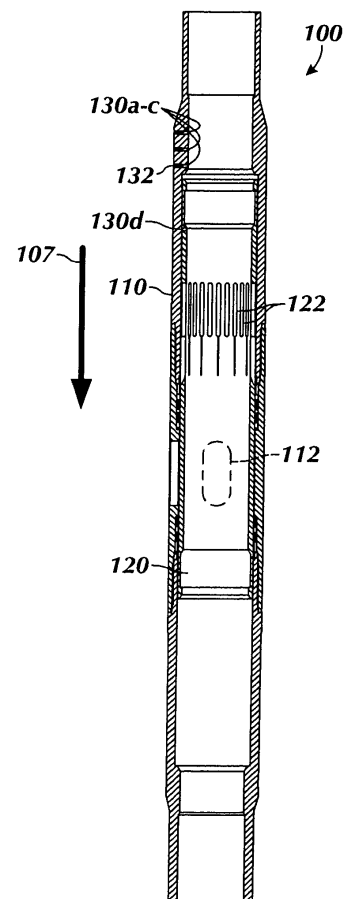


FIG. 1A

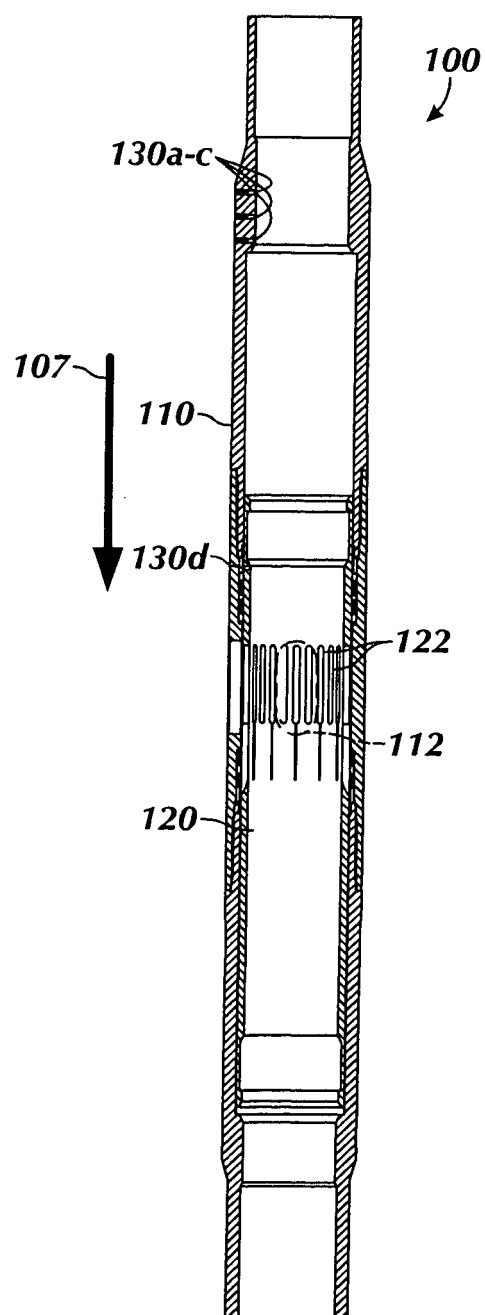


FIG. 1B

Description

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This is a non-provisional of U.S. Provisional Application Ser. No. 60/908,616, entitled "Position Sensor for a Downhole Tool," filed 28 March 2007, which is incorporated herein by reference in its entirety and to which priority is claimed.

BACKGROUND

[0002] Downhole tools, such as sliding sleeves, are widely used in a variety of hydrocarbon production systems. A sliding sleeve typically includes a tubular outer housing having threaded connections at one or both ends for connection to a tubing string. The outer housing also includes one or more flow ports therethrough. Inside the housing, a sleeve mechanism, also known as an insert, is arranged to slide longitudinally within the outer housing. The insert may have one or more flow ports there-through. The insert can be positioned to align the flow ports in the sleeve with the flow ports in the housing, which will allow fluid flow (either from inside out or outside in). Alternatively, the insert can be positioned so that the flow ports are not aligned, thereby preventing fluid flow. Many variations of this basic concept are known to those skilled in the art, and will not be discussed in detail here. For example, in some embodiments, the insert may not have flow ports, but may be arranged to either block the flow ports in the outer housing or not, thereby permitting flow or not.

[0003] In many applications, it is desired to determine the condition (*i.e.*, whether open or closed) of one or more sliding sleeves in a tubing string. Historically, this has been done by running a shifting tool to see if it engages the open or closed mechanism, thereby indicating whether the sliding sleeve is open or closed. Additionally, other mechanical tools have been developed that feel for the gap behind the insert to determine if the sliding sleeve is open or closed. A problem with these approaches is that the relatively subtle "feel" of these approaches, which takes the form of mechanical feedback, can, in many cases, be difficult to detect and/or properly interpret.

SUMMARY

[0004] A variety of downhole tools are disclosed herein. In some embodiments, the tool is a sliding sleeve having one or more magnets affixed to an outer housing and one or more magnets affixed to an insert. A casing collar locator (CCL) or other instrument can be used to detect the relative positions of the housing magnets and the insert magnets. The relative position of the magnets can then be used to ascertain the position of the insert within the housing, and thus whether the sliding sleeve is in the open or closed condition. In other embodiments, instead of magnets, other position indicators or signal inducing

devices may be used. Examples of such devices include RFID devices, radioactive pills, ferromagnetic components, etc.

[0005] Additional details and information regarding the disclosed subject matter can be found in the following description and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

10 [0006] FIG. 1A shows a closed sliding sleeve having position indicators as described herein.

[0007] FIG. 1B shows an open sliding sleeve having position indicators as described herein.

15 [0008] FIG. 2 shows an output signal of a casing collar locator (CCL) when run past a sliding sleeve having position indicators as described herein.

[0009] FIGS. 3A-3B shows a downhole apparatus in two operational conditions and having position indicators as described herein.

DETAILED DESCRIPTION

20 [0010] In the disclosure that follows, in the interest of clarity, not all features of actual implementations are described. It will of course be appreciated that in the development of any such actual implementation, as in any such project, numerous engineering and technical decisions must be made to achieve the developers' specific goals and sub goals (*e.g.*, compliance with system and technical constraints), which will vary from one implementation to another. Moreover, attention will necessarily be paid to proper engineering and programming practices for the environment in question. 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 relevant fields.

25 [0011] An exemplary sliding sleeve 100 is illustrated in FIGS. 1A-1B. The closed condition of sliding sleeve 100 is illustrated in FIG. 1A, while the open condition is illustrated in FIG. 1B. Sliding sleeve 100 includes an outer housing 110 and a sleeve mechanism or insert 120 disposed therein. The outer housing 110 may be comprised of upper and lower sections and an intermediate section all coupled together. A plurality of flow ports 112/122 are disposed in the housing 110 and the insert 120. (It will be appreciated by those skilled in the art that the flow ports in insert 120 are not strictly necessary, depending on the design of the sliding sleeve.)

30 [0012] As shown in FIG. 1A, the sliding sleeve 100 may be closed by moving insert 120 longitudinally within housing 110 so that the flow ports 112/122 are not aligned (as shown). Similarly, as illustrated in FIG. 1B, the sliding sleeve 100 may be opened by moving insert 120 longitudinally within housing 110 to align flow ports 112/122. Exemplary sliding sleeve types include the OptiSleeve™ family of sliding sleeves available from Weatherford International Ltd., although other sliding sleeve types may also be used.

[0013] As noted above, it is often desired to ascertain the sliding sleeve's condition (*i.e.*, opened or closed). This can be facilitated by magnets disposed in predetermined positions on sliding sleeve 100 to allow casing collar locator (CCL) tools or other magnetically-sensitive instruments, such as a simple wire coil, Hall effect sensor, GMR (giant magnetoresistive effect) device, etc., to determine whether sliding sleeve 100 is open or closed. Casing collar locator (CCL) tools are well known in the art. However, their basic operation may be understood as described below.

[0014] The CCL tool is a magnetic device that is sensitive to the increased mass of metal located at a casing or tubing collar in a well. The CCL may be run through tubing on an electric line ("E-line"), in which it is connected to the surface by a cable including one or more electrical conductors that power the device and provide a communication path for the signals generated by the device. Alternatively, CCLs may be run as memory tools on slick-line or coiled tubing. A memory tool is self-contained and battery-operated. The tool records data as it is run through the well, and this data may be extracted by retrieving the tool and reading the data on the surface.

[0015] As the CCL tool is passed through tubing, the magnetic flux lines of the transducer interact with the tubing. The disruption of these flux lines by the increased thickness of material at the collars creates a current (or voltage) spike as the CCL tool passes the collar. The depth at which these spikes occur are therefore indicative of the location of the various collars, etc. In the present embodiment, magnets 130a-d located in or on the sliding sleeve 100 also interact with the magnetic sensing of a CCL tool. This interaction is then used to determine the opened or closed condition of the sliding sleeve 100 as described in greater detail below.

[0016] Sliding sleeve 100 illustrated in FIGS. 1A-1B illustrates one embodiment in which three magnets 130a-c are disposed in outer housing 110 and another magnet 130d disposed in insert 120. The first magnets 130a-c in the outer housing 110 are preferably disposed at a known, predetermined distance from one another. Thus, when a CCL tool is run past the tool (*e.g.*, in the direction indicated by arrow 107 but the opposite direction may also be possible) an output signal 200, as illustrated in FIG. 2, is generated. Output signal 200 has three peaks 203a-c induced by these three magnets 130a-c. Each of these three peaks 203a-c will appear separated by a time interval 210 that is a function of the known distance between the magnets 130a-c and the speed of the CCL tool through the sleeve 100.

[0017] Because the distance between the magnets 130a-c and the time interval 210 are both known, the speed of the CCL tool can then be inferred. By inferring the speed of the CCL and measuring a subsequent time interval 211 from the last of the three peaks 203c to a later peak 204 induced by insert's magnet 130d, the position of the insert 120 can be determined with relatively high precision, for example within about 0.1 inches. This

determined position of the insert 120 then indicates whether the sliding sleeve 100 has a closed condition (FIG. 1A) or an opened condition (FIG. 1B).

[0018] As noted above, the known spacing of the three magnets 130a-c can be used to determine the speed of the CCL with relatively high precision as it moves through the sliding sleeve 100, and this speed can then be used to determine the position of the insert 120. However, it is not strictly necessary for the magnets 130a-d to be arranged as shown. For example, only a single magnet may be used in the outer housing 110 if the speed of the CCL can be determined sufficiently accurately through other means. Alternatively, two, four, or other numbers of magnets can also be used. In other variations, multiple magnets could be included in the insert 120, with only a single magnet in the outer housing 110.

[0019] The magnets used in sliding sleeve 100 may take a variety of forms. In some embodiments, the magnets may be permanent magnets, such as rare earth magnets. Alternatively, other types of permanent magnets or electromagnets could be used. The strength of the magnets should be selected so that a distinct signal peak for each magnet will be detected by the CCL. If the magnets are too strong, the distinct peaks may appear as one wide peak, reducing or eliminating the precision of the position measurement.

[0020] The magnets in sliding sleeve 100 may be affixed to or embedded in outer housing 110 and insert 120 in a variety of ways. In the illustrated embodiment, for example, magnets 130a-c for the housing 110 are positioned in recesses machined into the outer housing 110 and retained by set screws 132. Other retention mechanisms, such as adhesives, welded plugs, etc. are also possible. In the case of insert 120, its magnet 140 is positioned in a machined recess and retained/covered with a welded plug, although, as with the outer housing 110, other retention mechanisms may also be used.

[0021] Variations of these concepts are possible in which the position of the inner housing 120 is indicated by signal inducing devices other than magnets. For example, Radio Frequency Identification (RFID) devices could be affixed to the sliding sleeve 100 similarly to the magnets 130a-d described above. An RFID reader could then be passed through the sleeve 100 to detect signals from the RFID devices and to use the detected signals in much the same way described above. A potential added advantage of such an arrangement is that the RFID devices could include additional information, such as a unique identification (*e.g.*, serial number) of the particular sliding sleeve, for example.

[0022] In another alternative, radioactive pills could be used for the signal inducing devices instead of magnets, and a radiation detector could be used in place of the CCL tool or other magnetic sensor. Various nuclear devices are often used in the oilfield environment so much of the infrastructure necessary for dealing with nuclear materials is already in place. In yet another variation, which may find particular application in sliding sleeves

manufactured from non-magnetic materials, ferromagnetic components, *e.g.*, bolts, plugs, or the like, can be positioned within the sliding sleeve 100 in much the same way as the magnets described above. The presence of the ferromagnetic components in the otherwise non-ferromagnetic sliding sleeve 100 will cause a detectable change in a CCL tool or other magnetically sensitive device.

[0023] In the embodiment of FIGS. 1A-1B, the position of an inset within an outer housing of a sliding sleeve has been determined to infer whether the sliding sleeve is either open or closed. With the benefit of the present disclosure, however, it will be appreciated that the signal inducing devices and position sensing techniques disclosed herein are applicable to various downhole apparatus, including, but not limited to, sliding sleeves, packers, plugs, and any other downhole tools having a fixed and a movable member.

[0024] FIGS. 3A-3B schematically illustrates one example of a downhole tool 300 having a fixed member 310 that couples to tubing (not shown) and having a movable member 320 on the tool 300 that is movable relative to the fixed member 310. For example, the fixed member 310 may be the housing of an openhole type packer, and the movable member 320 may be the movable piston on the packer for actuating a sealing element 330. When the movable member 320 is actuated, it compresses the sealing element 330, which expands outward to seal against an annulus between the tool 300 and an outer casing (not shown).

[0025] To determine the position of the movable member 320 and infer the operational condition of the downhole tool 300, signal inducing devices 130a-c are positioned a predetermined distance from one another and at a defined location on the movable member 320. Likewise, another signal inducing device 130d is positioned at a defined location on the fixed member 310. Using the same techniques discussed previously, the position of the movable member 320 relative to the fixed member 310 is determined based on an analysis of signals detected from the devices 130a-d by a detection tool passing through the tool 300. From this determined position, the operational condition of the tool 300 is inferred. For example, in the openhole type packer, the movable piston (*e.g.*, 310) may be moved from a first unactuated position to a second actuated position that is anywhere up to 20-inches from the first position, for example. Using the devices 130a-d and determining the position of the piston (*e.g.*, 320) relative to the housing (*e.g.*, 310), the condition of the packer (*i.e.*, whether the packer is fully or partially actuated or how much the sealing element 330 had to expand to seal in the openhole) can be inferred. This information can then be used for various purposes.

[0026] Although specific embodiments and variations of the invention have been disclosed herein in some detail, this has been done solely for the purposes of describing various features and aspects of the invention,

and is not intended to be limiting with respect to the scope of the invention. It is contemplated that various substitutions, alterations, and/or modifications, including but not limited to those implementation variations that may have been suggested in the present disclosure, may be made to the disclosed embodiments without departing from the scope of the invention as defined by the appended claims. The foregoing description and drawings are, accordingly, to be regarded in an illustrative rather than a restrictive sense.

Claims

1. A downhole apparatus, comprising:

a fixed member coupled to tubing and having one or more first signal inducing devices affixed thereto in one or more first predetermined locations; and

a movable member moveable relative to the fixed member, the movable member having one or more second signal inducing devices affixed thereto in one or more second predetermined locations, and

wherein the first and second devices induce signals indicative of their positions relative to one another from which the position of the movable member relative to the fixed member is determined.

2. The apparatus of claim 1, wherein the downhole apparatus comprises a packer having a housing for the fixed member and having a piston for the movable member.

3. The apparatus of claim 1 or 2, wherein the downhole apparatus comprises a sliding sleeve having an outer housing for the fixed member and having an insert for the movable member.

4. The apparatus of claim 3, wherein the outer housing has a plurality of first openings, and wherein the insert has a plurality of second openings, the second openings aligning with the first openings when the insert has a first position within the outer housing.

5. The apparatus of claim 3 or 4, wherein an open or closed condition of the sliding sleeve is inferred from the determined position of the insert relative to the outer housing.

6. The apparatus of any of the preceding claims, wherein the first and second signal inducing devices are selected from the group consisting of magnets, radio frequency identification devices, radioactive pills, and ferromagnetic components.

7. The apparatus of any of the preceding claims, wherein the one or more first signal inducing devices comprise a plurality of first signal inducing devices positioned a predetermined distance from one another along a longitudinal axis of the fixed member. 5
8. The apparatus of claim 7, wherein a speed of a detection tool passing through the downhole apparatus is determined using the predetermined distance between the plurality of first signal inducing devices and using a time interval between signals induced from the first signal inducing devices. 10
9. The apparatus of claim 8, wherein the detection tool comprises a collar locator tool, a magnetically sensitive device, a radio frequency identification device reader, or a radiation detector. 15
10. The apparatus of any of the preceding claims, wherein a variable distance between at least one of the one or more first signal inducing devices and at least one of the one or more second signal inducing devices is determined using a speed of a detection tool passing through the downhole apparatus and using a time interval between signals induced from the at least one first and second signal inducing devices. 20 25
11. A downhole sliding sleeve, comprising:
- an outer housing having one or more first signal inducing devices affixed thereto in one or more first predetermined locations; and
an insert disposed and longitudinally moveable within the outer housing, the insert having one or more second signal inducing devices affixed thereto in one or more second predetermined locations, 30 35
- wherein the first and second devices induce signals indicative of their positions relative to one another from which the position of the insert within the housing is inferred. 40
12. The sleeve of claim 11, wherein the outer housing has a plurality of first openings, and wherein the insert has a plurality of second openings, the second openings aligning with the first openings when the insert has a first position within the outer housing. 45
13. The sleeve of claim 11 or 12, wherein the first and second signal inducing devices are selected from the group consisting of magnets, radio frequency identification devices, radioactive pills, and ferromagnetic components. 50
14. The sleeve of claim 11, 12 or 13, wherein the one or more first signal inducing devices comprise a plurality of first signal inducing devices positioned a predetermined distance from one another along a longitudinal axis of the outer housing. 55
15. The sleeve of claim 14, wherein a speed of a detection tool passing through the apparatus is determined using the predetermined distance between the plurality of first signal inducing devices and using a time interval between signals induced from the first signal inducing devices.
16. The sleeve of claim 15, wherein the detection tool comprises a collar locator tool, a magnetically sensitive device, a radio frequency identification device reader, or a radiation detector.
17. The sleeve of any of claims 11 to 16, wherein a variable distance between at least one of the one or more first signal inducing devices and at least one of the one or more second signal inducing devices is determined using a speed of a detection tool passing through the apparatus and using a time interval between signals induced from the at least one first and second signal inducing devices.
18. The sleeve of claim 17, wherein an open or closed condition of the sliding sleeve is inferred from the determined variable distance.
19. A downhole apparatus, comprising:
- a fixed member coupled to tubing;
a movable member movable relative to the fixed member;
first means affixed to the fixed member for inducing signals indicative of position;
second means affixed to the movable member for inducing signals indicative of position; and
means for determining the position of the movable member relative to the fixed member based on the relative positions of the first and second means for indicating position.
20. The apparatus of claim 19, wherein the first or second means for inducing signals indicative of position comprises means for inducing a plurality of signals along a longitudinal axis of the apparatus.
21. The apparatus of claim 20, wherein the means for determining the position comprising means for determining a speed of a detection tool passing through the apparatus from the plurality of signals.
22. The apparatus of claim 19, 20 or 21, wherein the means for determining position comprises means for detecting signals induced by the first and second means.
23. The apparatus of any of claims 19 to 22, wherein the

means for determining the position comprising means for inferring an open or closed condition of the apparatus based on the determined position of the movable member relative to the fixed member.

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- 24.** A downhole position determining method, comprising:

detecting one or more first devices affixed to a fixed member of a downhole apparatus in one or more first predetermined locations;

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detecting one or more second devices affixed to a movable member of the downhole apparatus in one or more second predetermined locations; and

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determining the position of the movable member relative to the fixed member from the relative positions of the first and second devices.

- 25.** The method of claim 24, further comprising inferring an operational condition of the downhole apparatus based on the determined position of the movable member relative to the fixed member.

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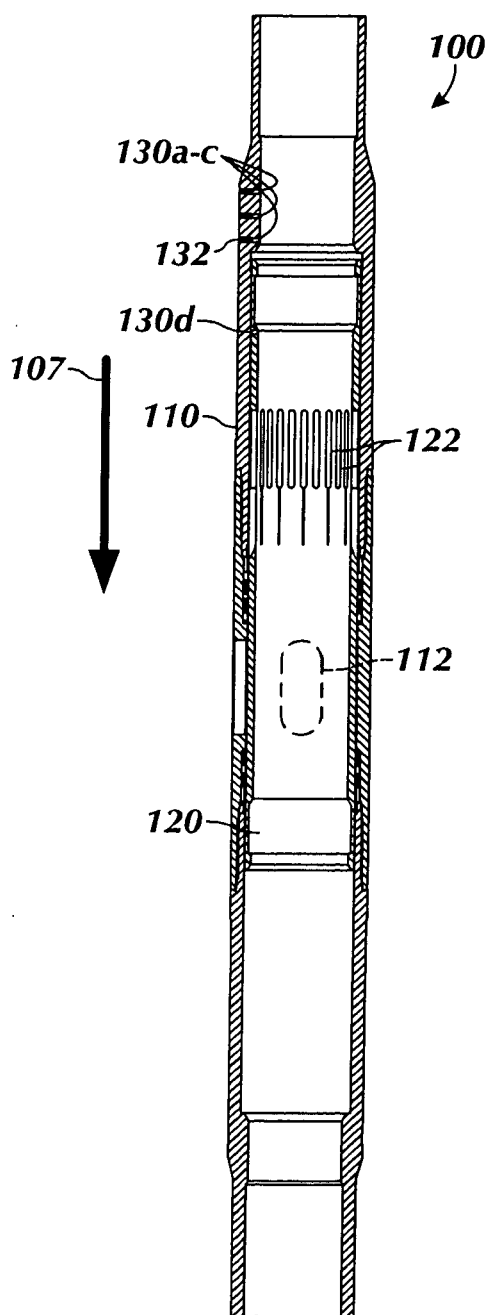


FIG. 1A

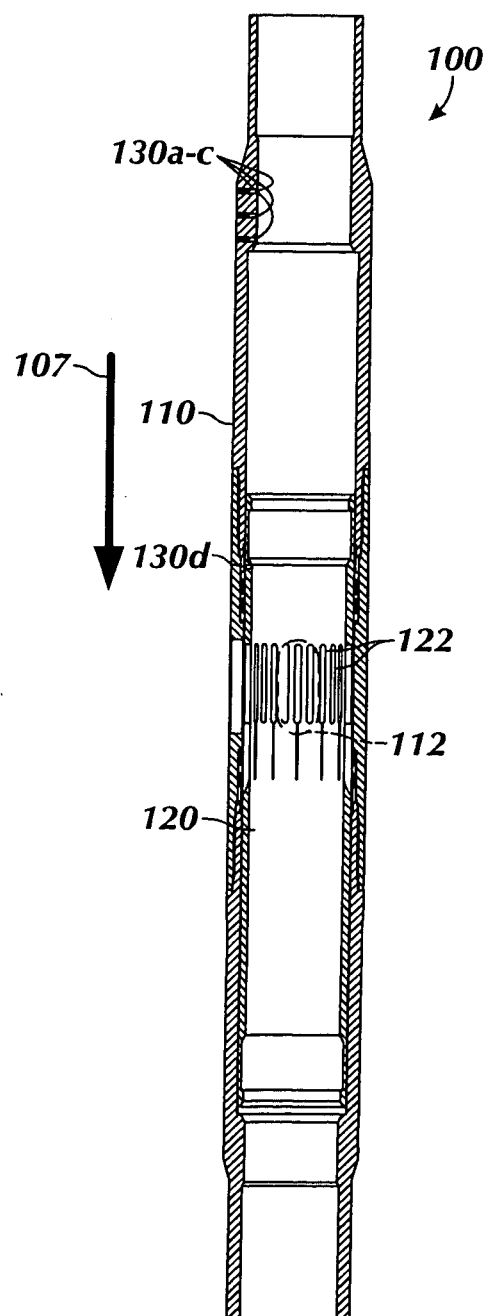
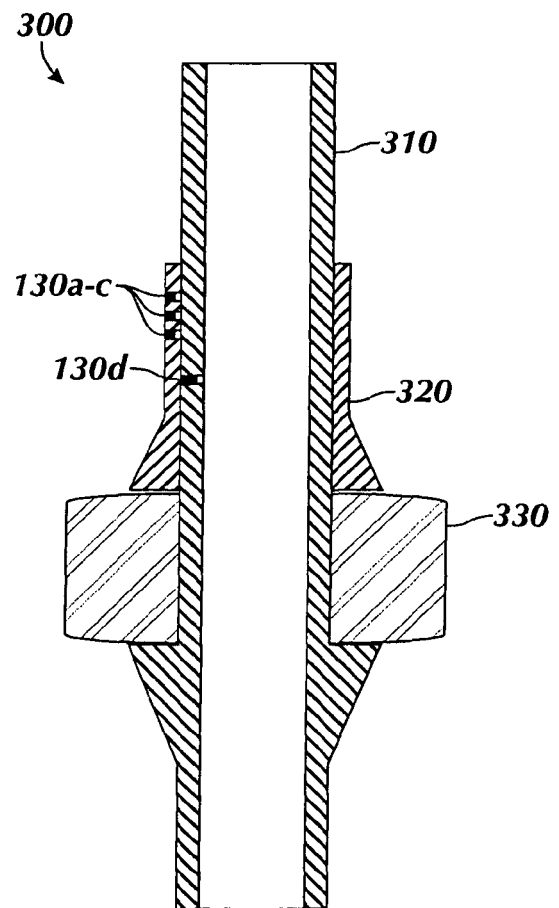
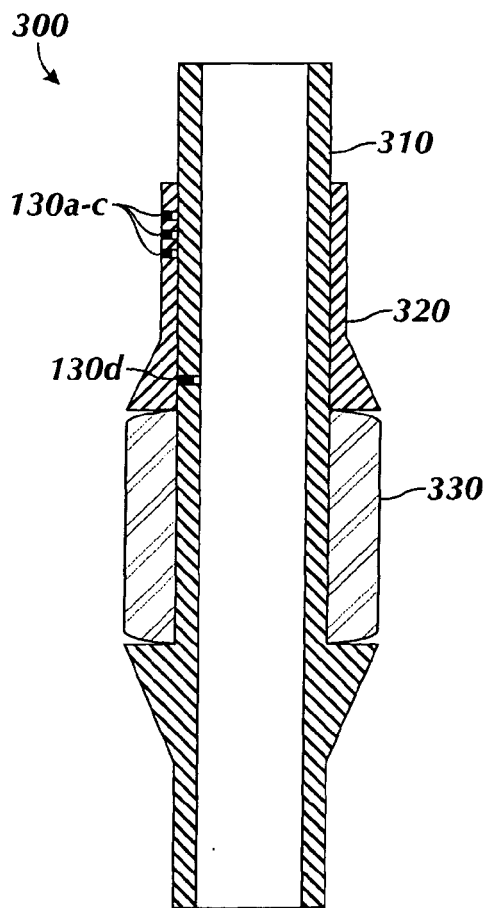
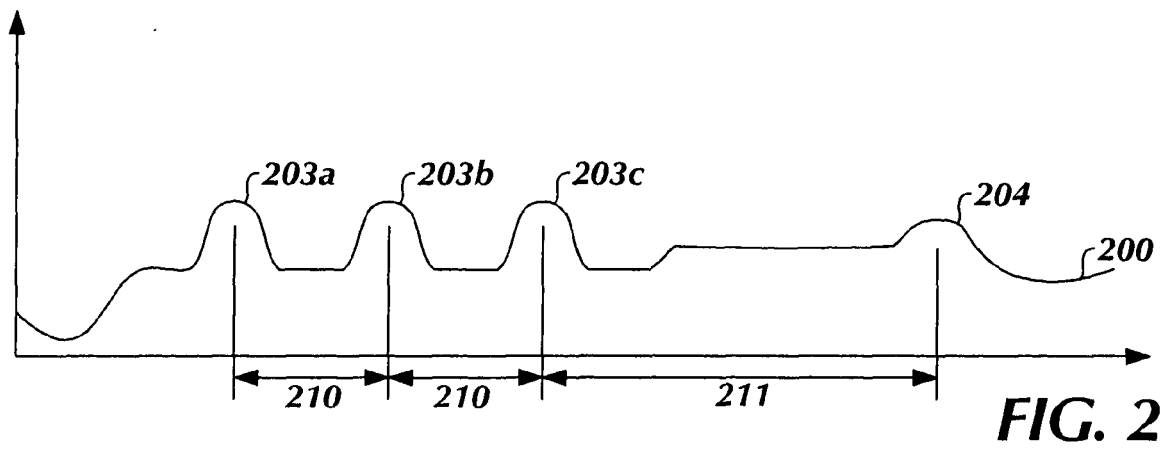


FIG. 1B



REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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