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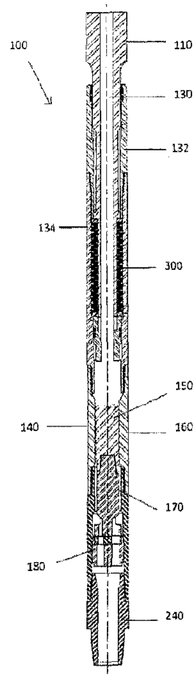
(54) **Titre : OUTIL DE FORAGE DIRECTIONNEL A CONTROLE DE FLUX**
(54) **Title: FLOW-CONTROLLING DIRECTIONAL DRILLING TOOL**



(57) **Abrégé/Abstract:**
A directional drilling tool provides a flow-controlling assembly for improving performance of a downhole drill. A motor contained in a housing on the drill string produces eccentric motion. An inverter disposed along the housing upstream from the motor, functions to expand and contract the central cavity in response to fluid pressure changes produced by the drilling fluid flow. A unique multi-port flow head-stationary nut assembly comprises a multi-port flow head which rotates with the rotor of the motor on a multi-port stationary nut to create an irregular pattern of pressure spikes within the central cavity as the ports of the flow head move into and out of alignment with the ports of the stationary nut, which in turn causes the central cavity to expand and contract arrhythmically.

ABSTRACT

A directional drilling tool provides a flow-controlling assembly for improving performance of a downhole drill. A motor contained in a housing on the drill string produces eccentric motion. An inverter disposed along the housing upstream from the motor, functions to expand and contract the central cavity in response to fluid pressure changes produced by the drilling fluid flow. A unique multi-port flow head-stationary nut assembly comprises a multi-port flow head which rotates with the rotor of the motor on a multi-port stationary nut to create an irregular pattern of pressure spikes within the central cavity as the ports of the flow head move into and out of alignment with the ports of the stationary nut, which in turn causes the central cavity to expand and contract arrhythmically.

FLOW-CONTROLLING DIRECTIONAL DRILLING TOOL

TECHNICAL FIELD

[001] The present invention relates to drilling tools, and in particular to down hole drilling assemblies for use in oil and gas recovery applications.

TECHNICAL BACKGROUND

[002] In oil and gas production and exploration, downhole drilling through rock can be accomplished with a downhole drill through which drilling fluid, conventionally referred to as drilling mud, is pumped. The drilling fluid assists in the drilling process by, for example, dislodging and removing drill cuttings, cooling the drill bit, and/or providing pressure to prevent formation fluids from entering the wellbore. The performance of the downhole drill can be improved by reducing the incidence of drill cuttings settling around the drill string, and reducing drag on the string as it advances downhole.

BRIEF DESCRIPTION OF THE DRAWINGS

[003] FIG. 1 is a side cross-sectional view of a drilling tool in accordance with one embodiment of the present invention.

[004] FIG. 2 is a side cross-sectional view of a segment of the drilling tool shown in FIG. 1.

[005] FIG. 3 is a side cross-sectional view of a multi-port flow head in accordance with one embodiment of the present invention.

[006] FIG. 4 is a top plan view of the multi-port flow head of FIG. 3.

[007] FIG. 5 is a side cross-sectional view of a stationary nut in accordance with one embodiment of the present invention.

[008] FIG. 6 is a top plan view of the stationary nut of FIG. 5.

[009] In the drawings, preferred embodiments of the invention are illustrated by way of example. It is to be expressly understood that the description and drawings are only for the

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purpose of illustration and as an aid to understanding, and are not intended as a definition of the limits of the invention.

DETAILED DESCRIPTION

[010] In one embodiment of the present invention, there is described a directional drilling tool forming part of a drill string. The drilling tool includes a mandrel, and a housing extending from the mandrel, to define a central cavity for enabling the transmission of drilling fluid through the drill string. A motor, such as a positive displacement motor or turbine driven assembly, is contained in the housing and includes a rotor-stator assembly in a multi-lobe arrangement, the motor for producing an eccentric motion of the rotor. An inverter is disposed along the drill string housing upstream from the motor and is capable of expanding and contracting the central cavity in response to fluid pressure changes produced by the drilling fluid flow. A unique multi-port flow head depends from the rotor. The flow head comprises a plurality of ports on a face thereof, the plurality of ports for permitting the transmission of drilling fluid therethrough, the flow head adapted to rotate as the rotor rotates. A stationary nut is affixed to the drill string housing downstream from the flow head and directly abutting the face of the flow head. The stationary nut itself has a unique multi-port arrangement which includes a plurality of ports extending through the stationary nut to permit transmission of drilling fluid therethrough. In operation, the rotation of the flow head on the stationary nut creates an arrhythmic pattern of pressure spikes within the central cavity as the ports of the flow head move into and out of alignment with the ports of the stationary nut, which in turn causes the inverter to expand and contract in an arrhythmic manner.

[011] In this respect, before explaining at least one embodiment of the invention in detail, it is to be understood that the invention is not limited in its application to the details of construction and to the arrangements of the components set forth in the following description or illustrated in the drawings. The invention is capable of other embodiments and of being practiced and carried out in various ways. Also, it is to be understood that the phraseology and terminology employed herein are for the purpose of description and should not be regarded as limiting.

[012] All terms used herein are used in accordance with their ordinary meanings unless the context or definition clearly indicates otherwise. Also, unless indicated otherwise except within the claims the use of "or" includes "and" and vice-versa. Non-limiting terms are not to be construed as limiting unless expressly stated or the context clearly indicates otherwise (for example, "including", "having", "characterized by" and "comprising" typically indicate "including

without limitation"). Singular forms included in the claims such as "a", "an" and "the" include the plural reference unless expressly stated or the context clearly indicates otherwise. Further, it will be appreciated by those skilled in the art that other variations of the preferred embodiments described below may also be practiced without departing from the scope of the invention.

[013] Referring to Figure 1, there is shown a cross section of a drilling tool 100 in accordance with one embodiment of the present invention. The drilling tool 100 described herein forms part of a drill string, and is formed as a single unit, for use in down hole drilling applications, and in particular directional or horizontal well drilling, wherein the wells are laterally displaced from the surface drilling location. In drilling operations, fluid, such as drilling mud, is delivered through a flowbore of a drill string to a drill bit disposed at a distal end of the drill string. A mandrel 110 serves as the shaft on which the drill string is mounted. The upper end of the mandrel 110 may be coupled to a drill pipe (not shown), while the lower end of the mandrel 110 is received within the upper inverter housing 132 of the drill string. A cavity 130 contained within the mandrel 110 and upper inverter housing 132 receives the drilling fluid. The cavity 130 extends from the upper inverter housing 132 to the lower inverter housing 134 and into contact with a motor 140, such as a positive displacement motor or turbine driven assembly, the motor 140 essentially comprising a rotor 150 disposed within a stator housing 160, such that the rotor 150 rotates within the stator housing 160. As a positive displacement motor, the motor 140 uses the drilling fluid to create an eccentric motion within the power section of the motor 140, which motion is transferred as concentric power to a drill bit (not shown) disposed distally on the drill string. Each of the rotor 150 and stator housing 160 are arranged in a multi-lobe configuration, and preferably in a 7:8 lobe ratio. In order to ensure staggered eccentric motion of the rotor 150 vis-a-vis the stator housing 160, the rotor 150 and stator housing 160 must maintain an unequal lobe arrangement.

[014] An inverter 300 is positioned within the drill string housing downstream from the mandrel 110 and upstream from the motor 140. In the embodiment shown in Figure 1, the inverter 300 is depicted as an annular shaped conduit which surrounds a portion of the cavity 130. The inverter 300 is disposed in fluid communication with the motor 140 and is capable of expanding and contracting the volume of the cavity 130 in response to fluid pressure changes exerted on the inverter 300 by operation of the motor 140, as explained in greater detail below. A spring assembly (or equivalent means) associated with the inverter 300 functions to store energy in response to an increase in fluid pressure within cavity 130 and release the stored energy into the cavity in response to a decrease in fluid pressure within the cavity 130.

[015] A unique multi-port flow head 170 is positioned within the drill string housing and secured to the rotor 150 at a first end 175 of the flow head 170, for example, by male/female engagement, or equivalent means. A plurality of ports 180 are disposed on a second end 185 of the flow head 170, which end is disposed remotely from the first end 175 and separated by a body portion 190. Figure 3 illustrates the flow head 170, in accordance with one embodiment of the present invention, as a stand-alone component. In Figure 3, it can be seen that the body portion 190 is separated from the second end 185 by a collar 200 the outer diameter of which is smaller than the outer diameter of both the body portion 190 and the second end 185, with the result that an annular chamber 210 is formed between the body portion 190 and the second end 185 of the flow head 170, the chamber 210 for receiving an amount of drilling fluid as same flows through each of the plurality of ports 180 on the flow head 170, and obviating the need for the ports to extend across the full length of the flow head 170. In the embodiments depicted in Figures 3 and 4, four ports 180 are shown on the second end of the flow head 170. While the number and size of the ports 180 can be varied, depending on fluid weight and/or desired pressure within the cavity 130, in order to ensure sufficient flow variation, it is preferable to utilize at least two ports 180 of at least two different sizes. The ports 180 are preferably substantially cylindrically, or otherwise curvilinearly, shaped (such that a continuous interior wall is formed within each port) in order to facilitate fluid flow and discourage mud build-up on the interior port walls.

[016] Referring back to Figures 1 and 5, a stationary nut 220 is shown in direct abutment with the second end of the multi-port flow head 170. Figure 5 shows a portion of the second end 185 of the flow head 170 abutting a face of the stationary nut 220. The distal end of the drilling tool 100 (located downstream from the stationary nut 220 may be fitted with an adaptor 240 for ultimate connection to a drill bit (not shown). The stationary nut 220 is affixed to the interior wall of the drill string housing and downstream from the motor 140. In operation, as the flow head 170 rotates on the rotor 150, the faces of the flow head 170 and stationary nut 220 will rub together as the stationary nut 220 receives the thrust load generated by the motor 140. In the embodiment shown in Figures 5 and 6, the stationary nut 220 comprises a plurality of ports 230, and preferably at least two ports 230, each of which extend across the width of the stationary nut 220. As with the ports 180 of the flow head 170, where two ports 230 are disposed on the stationary nut 220, it is preferable to provide these ports 230 in two different sizes or diameters to sufficient fluid flow variation. In the embodiment shown in Figure 6, three ports 230 are shown, where two are substantially equal in diameter and a third is of a larger diameter. A forth port 230 of the stationary nut 220 is shown completely closed off by use of a plug (or hardened

insert). Again, depending on the weight of the drilling fluid used and/or the desired cavity pressure sought, the number and size of the ports 230 can be varied as described above, and with respect to the embodiment shown in Figure 6, the plug contained within the fourth port 230 could be removed. In the embodiments depicted in the drawings, the ports 180 and 230 range in diameter from approximately 9/16" to 13/16", though these stated diameters are exemplary and not meant to be limiting. In an optimal embodiment, the ports on both the flow head 170 and stationary nut 220 are radially spaced apart on each such component, however the ports of each such component are not in direct alignment with each other. Again, while both the flow head ports 180 and stationary nut ports 230 are illustrated as having a substantially cylindrical cross-section, persons of skill in the art will appreciate that ports having different shaped cross-sections may be employed.

[017] In the embodiment described above, four ports are positioned on the flow head 170 and three are positioned on the stationary nut 220 (4:3 ratio). Combined with the 7:8 lobe ratio between the rotor 150 and stator housing 160, a unique eccentric, irregular motion of the drilling tool 100 is achieved, whereby every turn of the rotor 150 results in a different flow head-stationary nut facing with no discernible pattern. Further, by maintaining unequal ratios between both the lobes on the rotor and stator, and the ports on the flow head and stationary nut, a compounding of fluid flow variation is achieved, whereby fluid flow is varied along each of the rotor-stator combination and the flow head-stationary nut facing.

[018] In operation, drilling fluid passes through the mandrel 110 and on through the multi-lobe motor 140. This turns the rotor 150 in an eccentric clockwise motion. The rotor 150 is directly connected to the multi-port flow head 170 which rotates in an eccentric manner on the multi-port stationary nut 220. This in turn creates a unique arrhythmic pattern of multi-pressure spikes per revolution of the rotor 150 which causes the inverter 300 to extend and retract in a unique irregular motion, wherein every eccentric revolution of the rotor 150 results in a different arrangement between the ports the flow head 170 and stationary nut 220, again owing to the use of multiple ports of at least two different sizes on each component. When a port of the flow head 170 is in substantial alignment with a port of the stationary nut 220, then fluid flow through the drilling tool 100 will not be constrained. In contrast, when a port of the flow head 170 rotates out of alignment with a port of the stationary nut 220, then fluid flow will be restricted at that port location.

[019] Expanding on the foregoing description, the drilling tool 100 of the present invention works on the principle that rotation of the flow head 170 within the drill string determines how

much fluid flow is restricted. When fluid flow is restricted, pressure within the cavity 130 increases, which in turn causes the inverter 300 to extend, thereby resulting in a push motion along the horizontal axis of the drill string. In contrast, when fluid flow is not restricted, pressure within the cavity 130 will decrease, which in turn causes the inverter 300 to retract, which in turn causes the drill string to retract along its horizontal axis. The unique arrhythmic motion of the drill string, as described above, prevents drill cuttings in the drilling fluid from settling around the drill string, which in turn results in less drag and easier penetration (with less force) of the drill string (i.e. rate of penetration increase), thereby allowing a greater drilling distance to be achieved with less exertion than would otherwise be required, and resulting in significant improvements in drilling time. Easier steering and controlling of the directional equipment and tool face will also result. In addition, the non-uniform inverter strokes achieved by the present invention have been demonstrated to reduce interference, including namely electronic interference, with measurement while drilling (MWD) or survey equipment compared to conventional directional drilling apparatuses, including other pulsing mechanisms. Such interference between the drilling tool and survey equipment can result in tool failure, which unnecessarily increases down time and can cause operating costs to spike. In an industry where operating costs can be significant, it is important to minimize drilling down time as much as possible. Notably, the beneficial aspects of the present invention, as described above, can be attained for both horizontal and vertical drilling operations.

[020] In summary, a directional drilling tool includes housing defining a central cavity for enabling the transmission of drilling fluid through the drill string. A motor contained in the housing includes a rotor-stator assembly, the motor for producing eccentric motion of the rotor. An inverter disposed along the housing upstream from the motor, functions to expand and contract the central cavity in response to fluid pressure changes produced by the drilling fluid flow. A unique multi-port flow head-stationary nut assembly comprises a multi-port flow head which rotates on a multi-port stationary nut to create an irregular pattern of pressure spikes within the central cavity as the ports of the flow head move into and out of alignment with the ports of the stationary nut, which in turn causes the central cavity, and by association the drill string itself, to expand and contract in a unique irregular pattern.

[021] While one or more embodiments of this invention have been illustrated in the accompanying drawings and described above, it will be evident to those skilled in the art that changes and modifications can be made therein without departing from the essence of this

invention. All such modifications are believed to be within the sphere and scope of the invention as defined by the claims appended hereto.

CLAIMS

1. A directional drilling tool forming part of a drill string, the drilling tool comprising:

a mandrel;

a housing extending from the mandrel, the housing defining a central cavity for enabling the transmission of drilling fluid through the drill string;

a motor having a rotor-stator assembly comprising a rotor and a stator, the motor for producing eccentric motion of the rotor;

an inverter disposed along the housing upstream from the motor, the inverter capable of expanding and contracting the central cavity in response to fluid pressure changes produced by the drilling fluid flow;

a flow head depending from the rotor, the flow head comprising a plurality of ports on a face thereof, the plurality of ports for permitting the transmission of drilling fluid therethrough, the flow head adapted to rotate with the rotor; and a stationary nut abutting the face of the flow head, the stationary nut itself comprising a plurality of ports, the plurality of ports on the stationary nut extending through the stationary nut to permit transmission of drilling fluid therethrough;

wherein the rotation of the flow head on the stationary nut creates an arrhythmic pattern of pressure spikes within the central cavity as the ports of the flow head move into and out of alignment with the ports of the stationary nut, which in turn causes the inverter to expand and contract in an arrhythmic manner.

2. The directional drilling tool of claim 1, wherein the flow head comprises a different number of ports than the stationary nut.

3. The directional drilling tool of either claim 1 or 2, wherein the flow head comprises ports of different sizes.

4. The directional drilling tool of any one of claims 1 to 3, wherein the stationary nut comprises ports of different sizes.

5. The directional drilling tool of any one of claims 1 to 4, wherein the plurality of ports comprised in the flow head have a cylindrical cross-section.

6. The directional drilling tool of any one of claims 1 to 5, wherein the plurality of ports comprised in the stationary nut have a cylindrical cross-section.

7. An assembly for use in a drill string, the assembly comprising:

a motor comprising a rotor-stator assembly;

a flow head connected to the rotor, the flow head being configured to rotate against a stationary nut when driven by the rotor, each of the flow head and the stationary nut comprising at least one port configured to enter into and out of alignment with each other when the flow head is driven by the rotor; and

an inverter in fluid communication with the motor, the inverter comprising a spring assembly for storing energy in response to an increase in fluid pressure within a cavity, and releasing the stored energy in response to a decrease in fluid pressure within the cavity, the cavity being disposed at least in part in the inverter.

8. The assembly of claim 7, wherein the flow head comprises a different number of ports than the stationary nut.

9. The assembly of either claim 7 or 8, wherein the flow head comprises ports of different sizes.

10. The assembly of any one of claims 7 to 9, wherein the stationary nut comprises ports of different sizes.

11. The assembly of any one of claims 7 to 10, wherein the at least one port comprised in the flow head has a cylindrical cross-section.

12. The assembly of any one of claims 7 to 11, wherein the at least one port comprised in the stationary nut has a cylindrical cross-section.

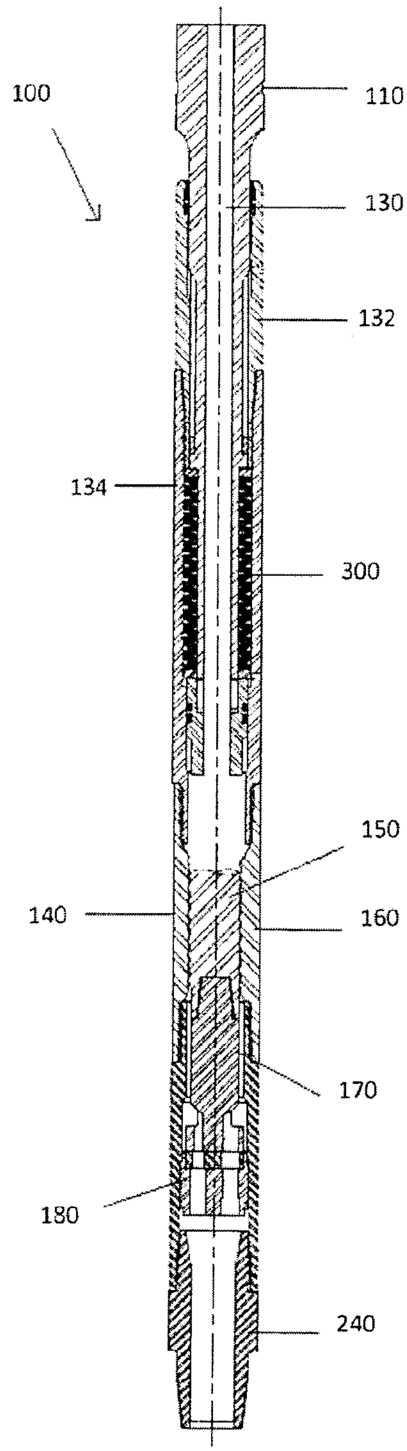


FIG. 1

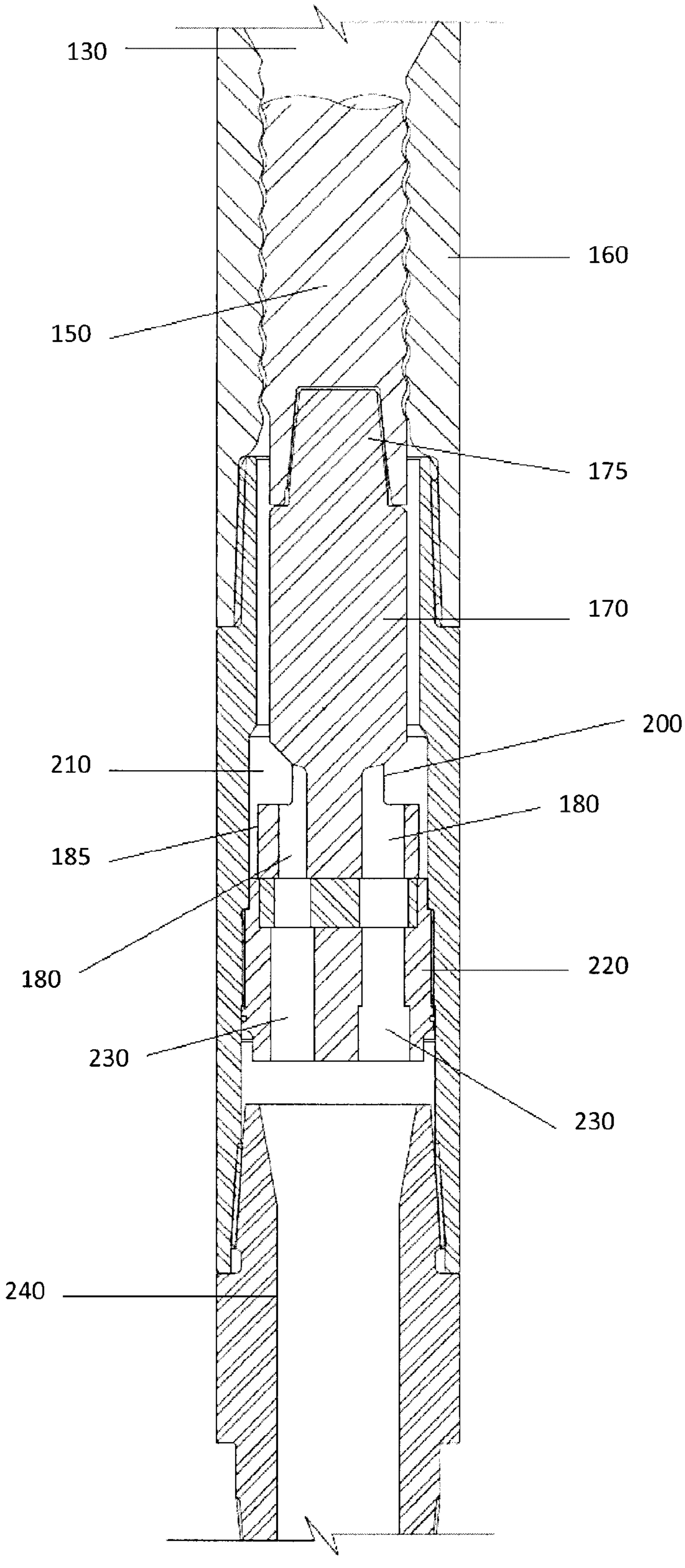


FIG. 2

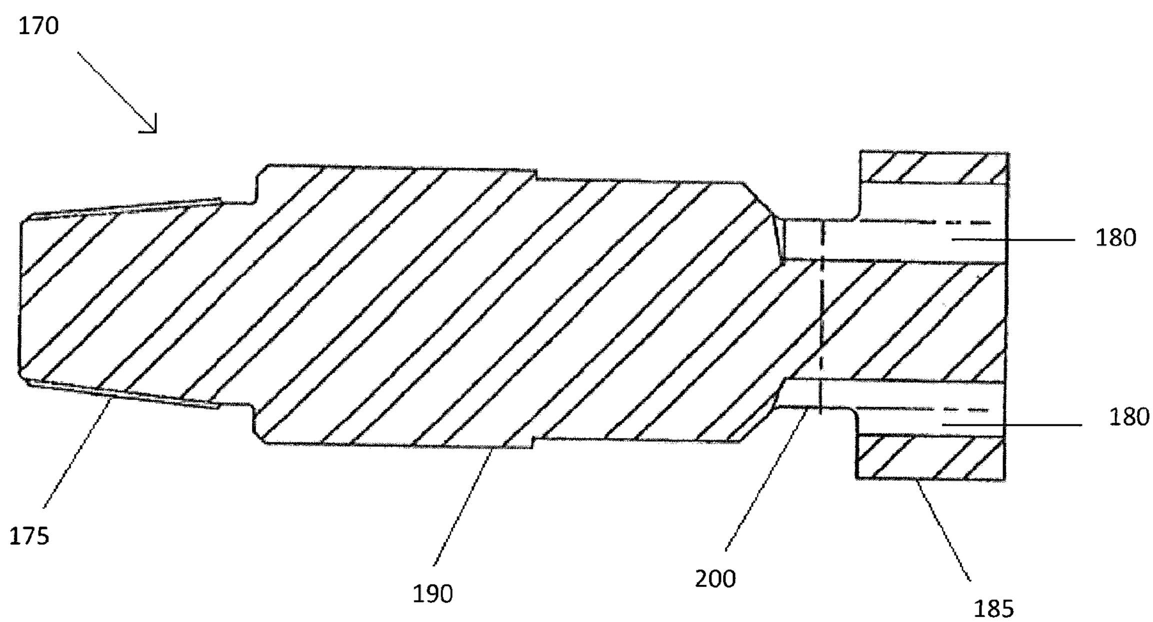


FIG. 3

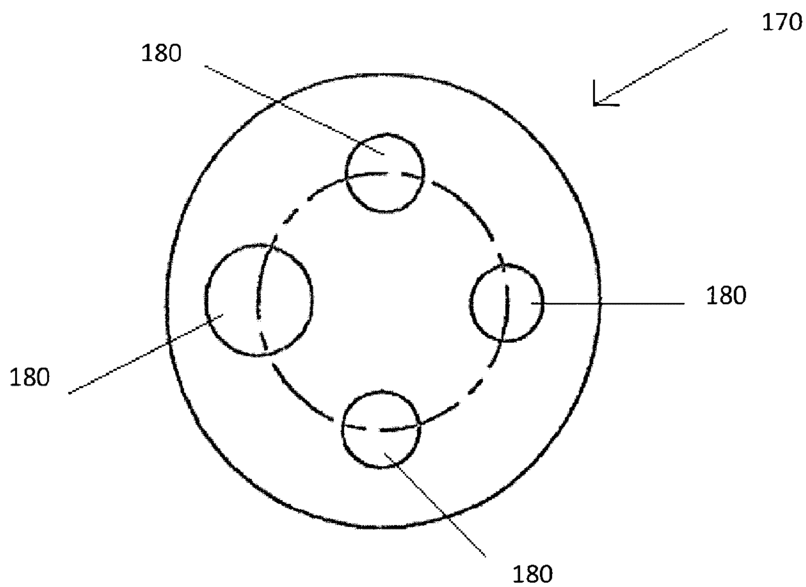


FIG. 4

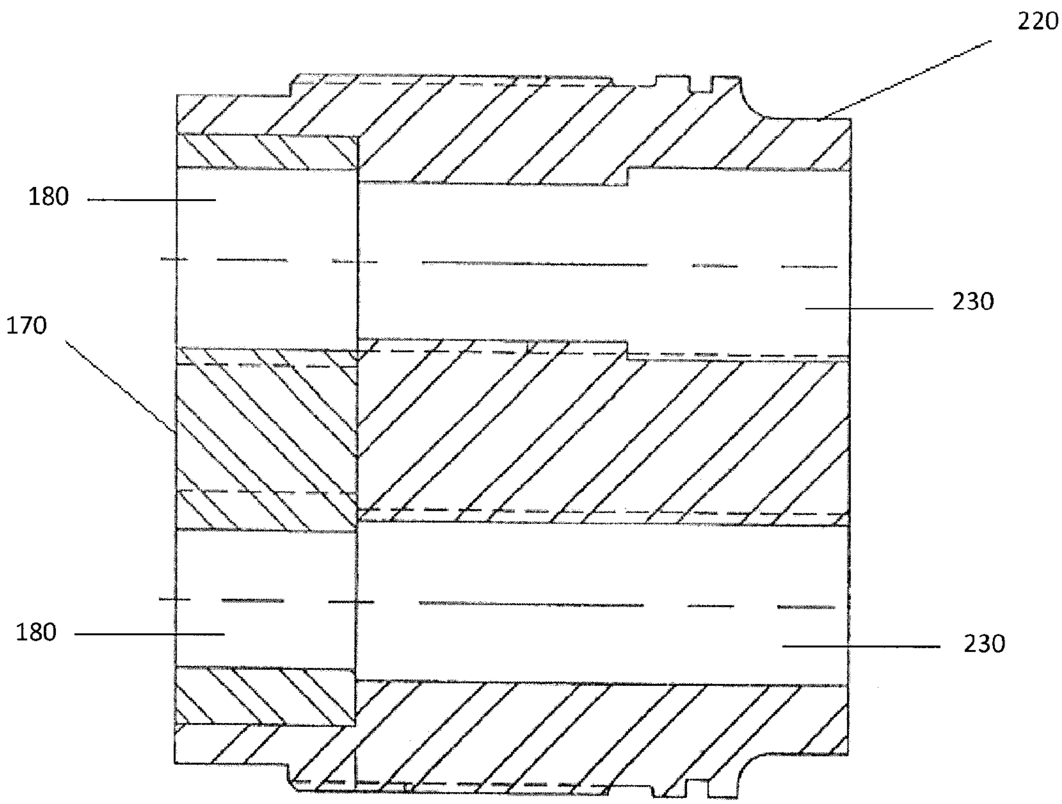


FIG. 5

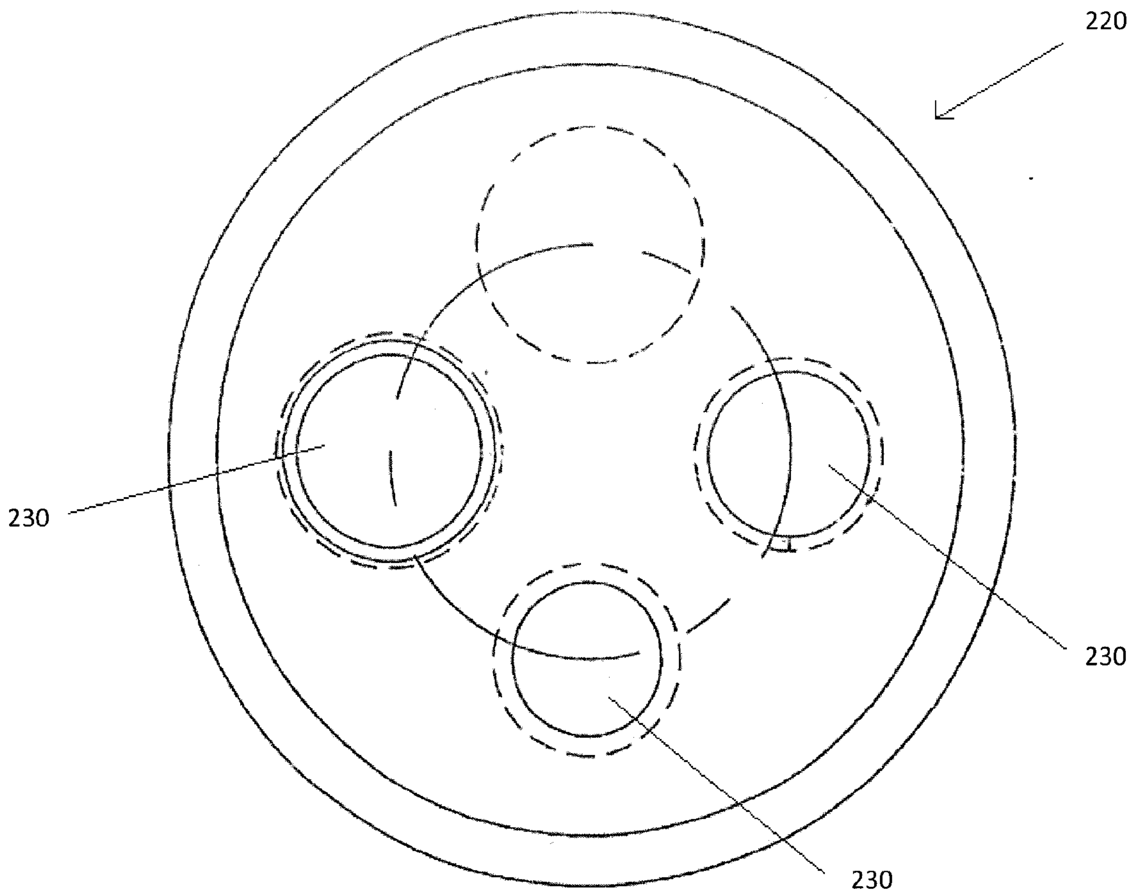
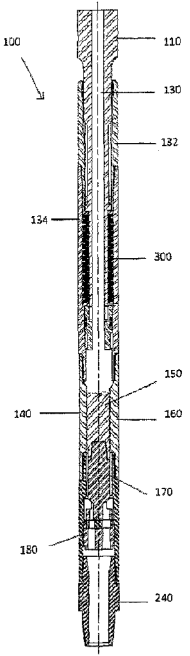


FIG. 6



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