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(54) **CONTROLLED FULL FLOW PRESSURE PULSER FOR MEASUREMENT WHILE DRILLING (MWD) DEVICE**

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Description

FIELD OF DISCLOSURE

[0001] The current invention includes an apparatus and a method for creating a pulse within the drilling fluid, generally known as drilling mud, that is generated by selectively initiating flow driven bidirectional pulses within a bore pipe. Features of the device include operating a flow throttling device (FTD) that operates without a centrally located valve guide within a newly designed annular flow channel, such that the annular flow channel provides an increased area for the flow of the drilling fluid and also allows for the addition of an intelligent computerized control system using a combination of hardware and software tools with downlink capability. The downlink tools may be located above or below a positive displacement motor. The intelligent control system provides and maintains several parameters that effect drilling or other down-hole activity efficiency (i.e. Weight on Bit, Rate of Penetration, Pulse Amplitude, Axial Vibration, Borehole Pressure, etc.) by utilizing a feedback control loop such that the pressure differentials within the collar and associated annulus of the FTD inside a bore pipe provide information for properly controlled, reproducible pressure pulses that exhibit little or no associated signal noise. The pulse received "up hole" from the tool down hole includes a series of dynamic pressure changes that provide pressure signals which can be used to interpret inclination, azimuth, gamma ray counts per second, etc. by oilfield personnel. These dynamic pressure changes and resulting signals are utilized to further increase yield in oilfield operations. The system according to the preamble part of claim 1 is disclosed in US 2005/0260089 A1.

BACKGROUND

[0002] Current pulser technology utilizes pulsers that are sensitive to different fluid pump down hole pressures, and flow rates, and require field adjustments to pulse properly so that meaningful signals from these pulses can be received and interpreted uphole.

[0003] US 2005/0260089 A1 discloses a method of transmitting pressure pulses from a downhole location through a flowing fluid in a wellbore. A linear actuator is used to controllably move a reciprocating member axially back and forth between a first position and a second position to at least partially obstruct flow of the flowing fluid to generate the pressure pulses. A reciprocating pulser for generating pressure pulses in a fluid flowing in a wellbore, comprises a fluid passage that allows flow of the fluid through the pulser, and a reciprocating member. A linear actuator is coupled to the reciprocating member, such that the linear actuator moves the reciprocating member in a first axial direction and then in a reverse direction to at least partially obstruct flow of the fluid through the pulser to generate pressure pulses in the flowing fluid.

[0004] An important advantage of the present disclosure and the associated embodiments is that it decreases sensitivity to fluid flow rate or pressure within easily achievable limits, does not require field adjustment, and is capable of creating recognizable, repeatable, reproducible, yet controlled, clean (i.e. noise free) fluid pulse signals using minimum power due to a unique flow throttling device (FTD) with a pulser that requires no guide, guide pole or other guidance system to operate the main valve, thus reducing wear, clogging and capital investment of unnecessary equipment as well as increasing longevity and dependability in the down hole portion of the MWD tool. This MWD tool still utilizes battery, magneto-electric and/or turbine generated energy. The mostly unobstructed main flow in the main flow area enters with full flow into the cone without altering the main flow pattern. The increased flow rate and change in pressure produces a very efficient pilot valve response and associated energy pulses. Specifically, as the pilot valve closes faster (than in any known previous designs) this produces large pressure spike similar to a "water hammer" effect much like that is heard when shutting off a water faucet extremely quickly. The faster flow and corresponding larger pressure differential also moves the pilot valve into an open and closed position more rapidly. The faster the closure, the more pronounced the water hammer effect and the larger the pulse and associated measured spike associated with the pulse. These high energy pulses are also attributed to the position and integrity of the pilot channel seals (240) which ensure rapid and complete closure while maintaining complete stoppage of flow through the channel. The controllability of the pulser is also significantly enhanced in that the shape of the pressure wave generated by the energy pulse can be more precisely predetermined. The pulse rise and fall time is sharp and swift - much more so than with conventional devices utilizing guide pole designs. These more easily controlled and better defined energy pulses are easily distinguished from the background noise associated with MWD tools. Distinguishing from the "background" noise leading to ease of decoding signals occurring on an oil or gas rig offers tremendous advantages over current tools. By implementing the feedback control by utilizing sensors to detect pulse responses, the pulser can be programmed to operate intelligently responding based on measured sensor parameters using preprogrammed logic. Being able to control and determine pulse size, timing, and shape without ambiguity provides the user with reproducible, reliable data that results in reduced time on the rig for analysis and more reliable and efficient drilling.

[0005] US Patents 7,180,826 and US Application Number 2007/0104030A1 to Kusko, et. al., disclose a fully functional pulser system that requires the use of a pulser guide pole to guide and define the movement of the main valve together with a different hydraulic channel designs than that of the present application and associated invention.

SUMMARY

[0006] The present disclosure involves the placement of a Measurement-While-Drilling (MWD) pulser device including a flow throttling device located within a bore pipe in a wellbore incorporating drilling fluids for directional and intelligent drilling. In the design, the pilot channel location is very different than in any prior application in that the channel is now located on the outside annulus. Features of the device include operating a flow throttling device (FTD) that operates without a centrally located valve guide within a newly designed annular flow channel, such that the annular flow channel provides an increased area for the flow of the drilling fluid and also allows for the addition of an intelligent computerized control system using a combination of hardware and software tools with downlink capability. The downlink tools may be located above or below a positive displacement motor. The intelligent control system provides and maintains several parameters that effect drilling or other downhole activity efficiency (i.e. Weight on Bit, Rate of Penetration, Pulse Amplitude, Axial Vibration, Borehole Pressure, etc.) by utilizing a feedback control loop such that the pressure differentials within the collar and associated annulus of the FTD inside a bore pipe provide information for properly guided, reproducible pressure pulses that exhibit little or no associated signal noise. The pulse received "up hole" from the tool down hole includes a series of dynamic pressure changes that provide pressure signals which can be used to interpret inclination, azimuth, gamma ray counts per second, etc. by oilfield personnel. These dynamic pressure changes and resulting signals are utilized to further increase yield in oilfield operations. The present invention also discloses a novel device for creating pulses in drilling fluid media flowing through a drill string. Past devices, currently in use, require springs or solenoids to assist in creating pulses and are primarily located in the main drilling fluid flow channel. US Patents 7,180,826 and US Application Number 2007/0104030A1 to Kusko, et. al., disclose a fully functional pulser system that requires the use of a pulser guide pole to guide and define the movement of the main valve together with a different hydraulic channel designs than that of the present application and associated invention. The pilot flow for the present invention without the guide pole allows for more efficient repair and maintenance processes and also allows for quickly replacing the newly designed apparatus of the present disclosure on the well site as there is at least a 15-20 percent reduction in capital costs and the costs on the maintenance side are drastically reduced. In the previous designs, guide pole failures accounted for 60-70 percent of the downhole problems associated with the older versions of the MWD. With the guide pole elimination, reliability and longer term downhole usage increases substantially, providing a more robust tool and much more desirable MWD experience.

[0007] Additionally, previous devices also required on-site adjustment of the flow throttling device (FTD) pulser

according to the flow volume and fluid pressure and require higher energy consumption due to resistance of the fluid flow as it flows through an opened and throttled position in the drill collar.

[0008] The elimination of the centralized guide pole and pilot channel allows, in the current design, larger pressure differential to be created between the pilot flow and the main flow at the main valve thus increasing the control and calibration and operation of the pulser. The ability to precisely control the pulser and thus the pressure pulse signals is directly related to cleaner, more distinguishable and more defined signals that can be easier detected and decoded up hole.

[0009] Additional featured benefits of the present inventive device and associated methods include having a pulser tool above and/or below the PDM (positive displacement motor) allowing for intelligence gathering and transmitting of real time data by using the pulser above the motor and as an efficient drilling tool with data being stored in memory below the motor with monitored borehole pressure, acceleration, as well as downhole WOB control, among other drilling parameters. Drilling parameter control is accomplished by using a set point and threshold for the given parameter and adjusting based on effects provided by the shock wave generated using the FTD. Master control is provided uphole or downhole with a feedback loop from the surface of the well or from intelligent programming incorporated in the pulsing device in the BHA above and/or below the PDM. The device provided by the current invention allows for the use of a flow throttling device that moves from an initial position to an intermediate and final position in both the upward and downward direction corresponding to the direction of the fluid flow. The present invention still avoids the use of springs, the use of which are described in U.S. Pat. No's 3,958,217, 4,901,290, and 5,040,155.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010]

Figure 1 is an overview of the full flow MWD with feedback control.

Figure 2 is a close up of the pilot flow screen assembly

Figure 3 is a detailed cross section of the main valve actuator assembly including the seals.

Figure 4 shows the lower portion of the pilot actuator assembly, drive shaft and motor.

Figure 5 is a pulser feedback control flow diagram.

DETAILED DESCRIPTION OF THE DRAWINGS

[0011] With reference now to Figure 1, the pulser assembly 400 device illustrated produces pressure pulses in drilling fluid main flow 110 flowing through a tubular hang-off collar 120 and includes a pilot flow upper annulus 160. The flow cone 170 is secured to the inner diam-

eter of the hang off collar 120. Major assemblies of the MWD are shown as provided including aligned within the bore hole the pilot flow screen assembly 135 and main valve actuator assembly 229 and pilot actuator assembly 335.

[0012] In Figure 1, starting from an outside position and moving toward the center of the main valve actuator assembly 226 comprising a main valve 190, a main valve pressure chamber 200, a main valve support block 350, main valve seals 225 and flow guide seal 240. The same figure shows the main valve feed channel 220, the pilot orifice 250, pilot valve 260, pilot flow shield 270, bellows 280 and the anti-rotation block 290, as well as a cylindrical support shoulder 325 and tool face alignment key 295 that exists below the pilot flow shield 270 for keeping the pulser assembly centered within the bore hole. This figure also shows the passage of the main flow 110 past the pilot flow screen 130 through the main flow entrance 150, into the flow cone 170, through the main orifice 180 into and around the main valve 190, past the main valve pressure chamber 200, past the main valve seals 225 through the main valve support block 350, after which it combines with the pilot exit flow 320 to become the main exit flow 340. The pilot flow 100 flows through the pilot flow screen 130 into the pilot flow screen chamber 140, through the pilot flow upper annulus 160, through the pilot flow lower annulus 210 and into the pilot flow inlet channel 230, where it then flows up into the main valve feed channel 220 until it reaches the main valve pressure chamber 200 where it flows back down the main valve feed channel 220, through the pilot flow exit channel 360, through the pilot orifice 250, past the pilot valve 260 where the pilot exit flow 320 flows over the pilot flow shield 270 where it combines with the main flow 110 to become the main exit flow 340 as it exits the pilot valve support block 330 and flows on either side of the rotary magnetic coupling 300, past the drive shaft and the motor 310.

[0013] The pilot actuator assembly 335 includes a magnetic pressure cup 370, and encompasses the rotary magnetic coupling 300. The magnetic pressure cup 370 and the rotary magnetic coupling 300 may comprise several magnets, or one or more components of magnetic or ceramic material exhibiting several magnetic poles within a single component. The magnets are located and positioned in such a manner that the rotary movement or the magnetic pressure cup 370 linearly and axially moves the pilot valve 260. The rotary magnetic coupling 300 is actuated by the adjacent drive shaft 305.

[0014] Figure 2 provides details of the pulser assembly in the open position; the pilot flow 100 and main flow 110 both flow through the pilot flow screen assembly 135 and pilot flow screen 130 where a portion of the main flow 110 flows through the pilot flow screen 130. The pilot flow 100 flows through the pilot flow screen chamber 140 and into the pilot flow upper annulus 160. Pilot flow 100 and main flow 110 within the pilot flow screen assembly 135 flows through the main flow entrance 150 and through the flow cone 170 and into the main orifice 180 to allow

for flow within the main valve feed channel 220.

[0015] Figure 3 describes the main valve actuator assembly 229 and illustrates the flow of the pilot flow 100 and main flow 110 areas with the main valve 190 in open position.

[0016] The main flow 110 passes through openings in the main valve support block 350 while the pilot flow 100 flows through the pilot flow lower annulus 210, into the pilot flow inlet channel 230 and into the main valve feed channel 220 which puts pressure on the main valve pressure chamber 200 when the pilot valve 260 is in closed position. The pilot flow 100 then flows out through the pilot flow exit channel 360, through the pilot orifice 250 and over the pilot valve 260. Also shown are the seals 225, 226, 227, 228 & 240 of the main valve actuator assembly.

[0017] When pilot valve 260 closes, pressure increases through the main valve feed channel 220 into the main valve pressure chamber 200. The upper outer seal 227, upper inner seal 225, lower inner seal 226, lower outer seal 228 and flow guide seal 240 keep the pilot flow 100 pressure constrained and equal to the pressure that exists in main flow entrance 150 area.

[0018] Upper outer seal 227 and lower outer seal 228 exclude large particulates from entering into the space where the upper inner seal 225 and lower inner seal 226 reside. The upper outer seal 227 and lower outer seal 228 do not support a pressure load and allow a small amount of pilot flow 100 to bypass while excluding particulates from entering the area around the upper inner seal 225 and lower inner seal 226. This eliminates pressure locking between the inner seals 225, 226 and the outer seals 227, 228. By excluding the particulates from entering into the space where the inner seals reside 225, 226 the seals are protected and the clearances of the inner seals 225, 226 can be reduced to support high pressure loads. Very small particulates can bypass the outer seals 227, 228, but the particulates must be very small in relative to the clearances of the inner seals 225, 226 to penetrate the space between the outer seals 227, 228 and inner seals 225, 226.

[0019] Referring to Figure 4, an embodiment of the rotary magnetic coupling 300 and motor 310 is shown. The Main exit flow 340 flows parallel along each side of the rotary magnetic coupling 300 which is contained within the magnetic pressure cup 370, past the drive shaft and parallel along each side of the motor 310 down toward the cylindrical support shoulder 325 that includes a tool face alignment key 295 below the pilot flow shield 270. The magnetic pressure cup 370 is comprised of a non-magnetic material, and is encompassed by the outer magnets 302. The outer magnets 302 may comprise several magnets, or one or more components of magnetic or ceramic material exhibiting several magnetic poles within a single component. The outer magnets 302 are housed in an outer magnet housing 303 that is attached to the drive shaft. Within the magnetic pressure cup 370 are housed the inner magnets 301 which are permanent-

ly connected to the pilot valve 260.

[0020] The outer magnets 302 and the inner magnets 301 are placed so that the magnetic polar regions interact, attracting and repelling as the outer magnets 302 are moved about the inner magnets 301. The relational combination of magnetic poles of the moving outer magnets 302 and inner magnets 301, causes the inner magnets 301 to move the pilot valve 260 linearly and inter-actively without rotating. The use of outer magnets 302 and inner magnets 301 to provide movement from rotational motion to linear motion also allows the motor 310 to be located in an air atmospheric environment in lieu of a lubricating fluid environment. This also allows for a decrease in the cost of the motor 310, decreased energy consumption and subsequently decreased cost of the actual MWD device. It also alleviates the possibility of flooding the sensor area of the tool with the drilling fluid like in the use of a moving mechanical seal.

[0021] The information flow on the Pulser Control Flow Diagram in Fig. 5 details the controllable pulser operation sequence. The drilling fluid pump, known as the mud pump 500 is creating the flow with a certain base line pressure. That fluid pressure is contained in the entirety of the interior 510 of the drill string, known as the bore pressure. The bore pipe pressure sensor 420 is sensing this pressure increase when the pumps turn on, and send that information to the Digital Signal Processor (DSP) 540 which interprets it. The DSP 540 also receives information from the annulus pressure sensor 470 which senses the drilling fluid (mud) pressure 520 as it returns to the pump 500 in the annulus 520 (outside) of the drill pipe. Based on the pre-programmed logic 530 in the software of the DSP 540, and on the input of the two pressure sensors 420, 470 the DSP 540 determines the correct pulser operation settings and sends that information to the pulser motor controller 550. The pulser motor controller 550 adjusts the stepper motor 310 current draw, response time, acceleration, duration, revolution, etc. to correspond to the pre-programmed pulser settings 530 from the DSP 540. The stepper motor 310 driven by the pulser motor controller 550 operates the pilot actuator assembly 335 from Fig. 1. The pilot actuator assembly 335, responding exactly to the pulser motor controller 550, opens and closes the main valve 190, from Fig. 1, in the very sequence as dictated by the DSP 540. The main valve 190 opening and closing creates pressure variations of the fluid pressure in the drill string on top of the bore pressure which is created by the mud pump 500. The main valve 190 opening and closing also creates pressure variations of the fluid pressure in the annulus 520 of the drill string on top of the base line annulus pressure because the fluid movement restricted by the main valve 190 affects the fluid pressure downstream of the pulser assembly 400 through the drill it jets into the annulus 520 of the bore hole. Both the annulus pressure sensor 470 and the bore pipe pressure sensor 420 detecting the pressure variation due to the pulsing and the pump base line pressure sends that information to the

DSP 540 which determines the necessary action to be taken to adjust the pulser operation based on the pre-programmed logic.

5 **Operation - operational pilot flow - all when the pilot is in the closed position;**

[0022] The motor 310 rotates the rotary magnetic coupling 300 which transfers the rotary motion to linear motion of the pilot valve 260 by using an anti-rotation block 290. The mechanism of the rotary magnetic coupling 300 is immersed in oil and is protected from the drilling fluid flow by a bellows 280 and a pilot flow shield 270. When the motor 310 moves the pilot valve 260 forward (upward in Figure 1) into the pilot orifice 250, the pilot fluid flow is blocked and backs up as the pilot fluid in the pilot flow exit channel 360, pilot flow inlet channel 230 and in the pilot flow upper annulus 160 all the way back to the pilot flow screen 130 which is located in the lower velocity flow area due to the larger flow area of the main flow 110 and pilot flow 100 where the pilot flow fluid pressure is higher than the fluid flow through the main orifice 180. The pilot fluid flow 100 in the pilot flow exit channel 360 also backs up through the main valve feed channel 220 and into the main valve pressure chamber 200. The fluid pressure in the main valve pressure chamber 200 is equal to the main flow 110 pressure, but this pressure is higher relative to the pressure of the main fluid flow in the main orifice 180 in front portion of the main valve 190. This differential pressure between the pilot flow flow in the main valve pressure chamber 200 area and the main flow through the main orifice 180 into the main orifice 180 causes the main valve 190 to act like a piston and to move toward closure still upward in Figure 1 causing the main orifice 180 to stop the flow of the main fluid flow 110 through the main orifice 180. As the drilling fluid main flow 110 stops at the main valve 190 its pressure increases. Since the pilot flow lower annulus 210 extends to the bore pipe pressure inlet 410 located in the pilot valve support block 330 the pressure change in the pilot fluid flow reaches the bore pipe pressure sensor 420 which transmits that information through the electrical connector 440 to the pulser control electronics DSP 450. The pulser controlling electronics DSP 450 together with pressure data from the annulus pressure sensor 470 adjusts the pilot valve operation based on pre-programmed logic to achieve the desired pulse characteristics.

50 **Opening operation**

[0023] When the motor 310 moves the pilot valve 260 away downward in Figure 1 from the pilot orifice 250 allowing the fluid to exit the pilot exit flow 320 and pass from the pilot flow exit channel 360 relieving the higher pressure in the main valve pressure chamber 200 this causes the fluid pressure to be reduced and the fluid flow to escape. In this instance, the main fluid flow 110 is

forced to flow through the main orifice 180 to push open (downward in Figure 1) the main valve 190, thus allowing the main fluid 110 to bypass the main valve 190 and to flow unencumbered through the remainder of the tool.

Pilot Valve in the Open Position

[0024] As the main flow 110 and the pilot flow 100 enter the main flow entrance 150 and combined flow through into the flow cone area 170, by geometry (decreased cross-sectional area), the velocity of the fluid flow increases. When the fluid reaches the main orifice 180 the fluid flow velocity is increased (reducing the pressure and increasing the velocity) and the pressure of the fluid is decreased relative to the entrance flows (main area vs. the orifice area) 180. When the pilot valve 260 is in the opened position, the main valve 190 is also in the opened position and allows the fluid to pass through the main orifice 180 and around the main valve 190, through the openings in the main valve support block 350 through the pilot valve support block 330 and subsequently into the main exit flow 340.

[0025] The information flow on the Pulsar Control Flow Diagram in Fig. 5 details the controllable pulser operation sequence. The drilling fluid pump, known as the mud pump 500 is creating the flow with a certain base line pressure. That fluid pressure is contained in the entirety of the interior 510 of the drill string, known as the bore pressure. The bore pipe pressure sensor 420 is sensing this pressure increase when the pumps turn on, and sends that information to the Digital Signal Processor (DSP) 540 which interprets it. The DSP 540 also receives information from the annulus pressure sensor 470 which senses the drilling fluid (mud) pressure as it returns to the pump 500 in the annulus 520 (outside) of the drill pipe. Based on the pre-programmed logic 530 in the software of the DSP 540, and on the input of the two pressure sensors 420, 470 the DSP 540 determines the correct pulser operation settings and sends that information to the pulser motor controller 550. The pulser motor controller 550 adjusts the stepper motor 310 current draw, response time, acceleration, duration, revolution, etc. to correspond to the pre-programmed pulser settings 530 from the DSP 540. The stepper motor 310 driven by the pulser motor controller 550 operates the pilot actuator assembly 335 as shown in Fig. 1. The pilot actuator assembly 335, responds directly to the pulser motor controller 550, and opens and closes the main valve 190, again shown in Fig. 1, in the sequence dictated by the DSP 540. The main valve 190 opening and closing creates pressure variations of the fluid pressure in the drill string in addition to the bore pressure which is created by the mud pump 500. The main valve 190 opening and closing also creates pressure variations or fluctuations of the fluid pressure in the annulus 520 of the drill string in addition to the base line annulus pressure because the fluid movement restricted by the main valve 190 affects the fluid pressure downstream of the pulser assembly

bly 400 through the drill as the fluid jets into the annulus 520 of the bore hole. Both the annulus pressure sensor 470 and the bore pipe pressure sensor 420 detect the pressure variations exhibited by the pulsing pressures and the pump base line pressure. These variations provide signals that are sent as data information to the DSP 540 that determines the necessary action to be taken to adjust the pulser operation based on any pre-programmed logic provided.

DETAILED DESCRIPTION

[0026] The present invention will now be described in greater detail and with reference to the accompanying drawings. With reference now to Figure 1, the device illustrated produces pressure pulses for pulsing of the pulser within a main valve actuator assembly of the flow throttling device (FTD) in the vertical upward and downward direction using drilling fluid that flows through a tubular rental collar and an upper annulus which houses the pilot flow. There is a flow cone secured to the inner diameter of a hang off collar with major assemblies of the MWD that include a pilot flow screen assembly, a main valve actuator assembly, and a pilot actuator assembly.

[0027] To enable the pulser to move in a pulsing upward and downward direction, the passage of the main flow of the drilling fluid flows through the pilot flow screen into the main flow entrance then into the flow cone section and through the main orifice and main valve past the main valve pressure chamber, past the seals, and finally into and through the main valve support block with the flow seal guide.

[0028] At this point, the initial drilling fluid combines with the pilot exit fluid and together results in the exit flow of the main fluid. The pilot fluid flow continues flowing through the pilot flow screen and into the pilot flow screen chamber then through the pilot flow upper annulus section, the pilot flow lower annulus section and into the pilot flow inlet channel where the fluid flows upward into the main valve feed channel until it reaches the main valve pressure chamber causing upward motion of the pulser. There, the fluid flows back down the main valve feed channel through the pilot flow exit channel and through the pilot orifice and pilot valve at which point the fluid exits the pilot area where it flows over the pilot flow shield and combines with the main flow to comprise the main exit flow as it exits the pilot valve support block and flows down both sides of the rotary magnetic coupling, outside the magnetic pressure cup and eventually past the drive shaft and the motor.

[0029] In operation to accomplish the task of providing for the pilot to attain the closed position, the motor rotates the rotary magnetic coupling transfers rotary motion to linear motion of the pilot valve by using an anti-rotation block. The mechanism of the rotary magnetic coupling is protected from the fluid flow by the use of a bellows and a pilot flow shield. When the motor moves the pilot

valve forward - upward into the pilot orifice -the pilot valve blocks and backs up the pilot fluid in the pilot flow exit channel, the pilot flow inlet channel, and in the pilot flow upper annulus, such that the fluid back up and reaches all the way back to the pilot flow screen (which is located in the lower velocity flow area due to the geometry of the larger flow area of the main flow and pilot flow sections such that the pilot flow fluid pressure is higher than the fluid flow through the main orifice).

[0030] The pilot fluid flow in the pilot flow exit channel also backs up through the main valve feed channel and into the main valve pressure chamber. The fluid pressure in the main valve pressure chamber is now equal to the main flow pressure but the fluid pressure is higher relative to the pressure of the main fluid flow in the main orifice in the front portion of the main valve. The differential pressure between the pilot flow and the main flow through the main orifice causes the main valve to act like a piston and moves toward closure of the main orifice (upward direction in the Figures provided), thereby causing the main valve to provide a stoppage of the flow of the main fluid flow within the main orifice.

[0031] In another embodiment, the MWD device utilizes a turbine residing near and within the proximity of a flow diverter. The flow diverter diverts drilling mud in an annular flow channel into and away from the turbine blades such that the force of the drilling mud causes the turbine blades and turbine to rotationally spin around an induction coil. The induction coil generates electrical power for operating the motor and other instrumentation mentioned previously. The motor is connected to the pilot actuator assembly via a drive shaft. The pilot actuator assembly comprises a magnetic coupling and pilot assembly. The magnetic coupling comprises outer magnets placed in direct relation to inner magnets located within the magnetic pressure cup or magnetic coupling bulkhead. The magnetic coupling translates the rotational motion of the motor, via the outer magnets to linear motion of the inner magnets via magnetic polar interaction. The linear motion of the inner magnets moves the pilot assembly, comprising the pilot shaft, and pilot valve, linearly moving the pilot into the pilot seat. This action allows for closing the pilot seat, pressurizing the flow throttling device, closing the flow throttling device orifice, thereby generating a pressure pulse. Further rotation of the motor, drive shaft, via the magnetic coupling, moves the pilot assembly and pilot away from the pilot seat, depressurizing the flow throttling device sliding pressure chamber and opening the flow throttling device and completing the pressure pulse. Identical operation of the pilot into and out of the pilot seat orifice can also be accomplished via linear to linear and also rotation to rotation motions of the outer magnets in relation to the inner magnets such that, for example, rotating the outer magnet to rotate the inner magnet to rotate a (rotating) pilot valve causing changes in the pilot pressure, thereby pushing the FTD (flow throttling device) up or down.

[0032] Unique features of the pulser include the com-

bination of middle and lower inner flow channels, flow throttling device, bellows, and upper and lower flow connecting channels possessing angled outlet openings that helps create signals transitioning from both the sealed (closed) and unsealed (open) positions. Additional unique features include a flow cone for transitional flow and a sliding pressure chamber designed to allow for generation of the pressure pulses. The flow throttling device slides axially on a pulser guide pole being pushed by the pressure generated in the sliding pressure chamber when the pilot is in the seated position. Additional data (and increased bit rate) is generated by allowing the fluid to quickly back flow through the unique connecting channel openings when the pilot is in the open position. Bi-directional axial movement of the poppet assembly is generated by rotating the motor causing magnets to convert the rotational motion to linear motion which opens and closes the pilot valve. The signal generated provides higher data rate in comparison with conventional pulsers because of the bi-directional pulse feature. Cleaner signals are transmitted because the pulse is developed in near-laminar flow within the uniquely designed flow channels and a water hammer effect due to the small amount of time required to close the flow throttling device.

[0033] The method for generating pressure pulses in a drilling fluid flowing downward within a drill string includes starting at an initial first position wherein a pilot (that can seat within a pilot seat which resides at the bottom of the middle inner flow channel) within a lower inner flow channel is not initially engaged with the pilot seat. The pilot is held in this position with the magnetic coupling. The next step involves rotating the motor causing the magnetic fields of the outer and inner magnets to move the pilot actuator assembly thereby moving the pilot into an engaged position with the pilot seat. This motion seals a lower inner flow channel from the middle inner flow channel and forces the inner fluid into a pair of upper connecting flow channels, expanding the sliding pressure chamber, causing a flow throttling device to move up toward a middle annular flow channel and stopping before the orifice seat, thereby causing a flow restriction. The flow restriction causes a pressure pulse or pressure increase transmitted uphole. At the same time, fluid remains in the exterior of the lower connecting flow channels, thus reducing the pressure drop across the, pilot seat. This allows for minimal force requirements for holding the pilot in the closed position. In the final position, the pilot moves back to the original or first position away from the pilot orifice while allowing fluid to flow through the second set of lower connecting flow channels within the lower inner flow channel. This results in evacuating the sliding pressure chamber as fluid flows out of the chamber and back down the upper flow connecting channels into the middle inner flow channel and eventually into the lower inner flow channel. As this occurs, the flow throttling device moves in a downward direction to open along the same direction as the flowing drilling fluid until motionless. This decreases the FTD created pressure

restriction of the main drilling fluid flow past the flow throttling device orifice completing the pulse.

[0034] An alternative embodiment includes the motor connected to a drive shaft through a mechanical device such as a worm gear, barrel cam face cam or other mechanical means for converting the rotational motion of the motor into linear motion to propel the pilot actuator assembly.

Opening operation

[0035] When the pilot valve moves away (downward in the vertical direction) into the pilot orifice allowing the fluid to flow through the pilot exit and pass from the pilot flow exit channel causing relief of the higher pressure in the main valve pressure chamber. This allows for the pressure to be reduced and the fluid to escape the chamber. The fluid is then allowed to flow into the main fluid flow and flow through the main orifice pushing open (downward) or opening the main valve, thus allowing the main fluid to by pass the main valve and to flow unencumbered through the remainder of the tool.

[0036] When the main flow and pilot flow enters the main flow entrance and flows through into the flow cone area where the velocity of the fluid flow increases such that the fluid reaches the main orifice and the fluid flow velocity is increased (reducing the pressure and increasing the velocity of the fluid). The pressure of the fluid is decreased relative to the entrance flows (main area vs. the orifice area). When the pilot valve is in the opened position, the main valve is also in the open position and allows the fluid to pass through the main orifice and around the main valve and through the openings in the main valve support block allowing for the fluid to flow through the opening of the pilot and through the pilot valve support block. Subsequently the fluid flows into the main exit flow channel.

[0037] With reference now to Figure 1, the device illustrated produces pressure pulses in drilling fluid flowing through a tubular drill collar and upper annular drill collar flow channel. The flow cone is secured to the inner diameter of the drill collar. The centralizer secures the lower portion of the pulse generating device and is comprised of a non-magnetic, rigid, wear resistant material with outer flow channels. These conditions provide generation of pulses as the flow throttling device reaches both the closed and opened positions. The present invention allows for several sized FTD's to be placed in a drilling collar, thereby allowing for different flow restrictions and/or frequencies which will cause an exponential increase in the data rate that can be transmitted up hole.

[0038] Positioning of the main valve actuator assembly within the drill collar and utilizing the flow cone significantly decreases the turbulence of the fluid and provides essentially all laminar fluid flow. The linear motion of the flow throttling device axially is both up and down (along a vertical axial and radial direction without the use of a guide pole).

[0039] Conventional pulsers require adjustments to provide a consistent pulse at different pressures and flow rates. The signal provided in conventional technology is by a pulse that can be received up hole by use of a pressure transducer that is able to differentiate pressure pulses (generated downhole). These uphole pulses are then converted into useful signals providing information for the oilfield operators, such as gamma ray counts per second, azimuth, etc. Another advantage of the present invention is the ability to create a clean (essentially free of noise) pulse signal that is essentially independent of the fluid flow rate or pressure within the drill collar. The present invention thereby allows for pulses of varying amplitudes (in pressure) and frequencies to significantly increase the bit rate.

[0040] An additional embodiment of the present invention includes a system comprising a controllable pulser that operates sequentially within a downhole assembly such as a drill pipe, that enhances operational efficiency in the removal of hydrocarbon deposits, where the system comprises; a fluid, fluid flow, and a fluid drilling pump which when combined creates fluid flow into a bore pipe annulus such that a base line bore pipe pressure is created and such that fluid flow and bore pipe pressure is contained entirely within a drill string and wherein bore pipe pressure increases and is measured with one or more pressure sensors for sensing bore pipe pressure such that pressure sensor(s) send information to a digital signal processor (DSP) that receives information in the form of digital data from said pressure sensor(s), and wherein pulser utilize computerized instructional software and hardware components included in the digital signal processor (DSP) so that controllable sequential operation of the pulser is obtained utilizing one or more pressure sensors located within a bore pipe annulus located within an outer annular portion of the drill pipe. The pre-programmed logic is embedded within the software components of the DSP such that the input data supplied to the DSP by one or more pressure sensors correctly determines pulser operation settings allowing for the sending of data that is subsequently received and interpreted by the DSP for controlling a pulser motor controller, wherein the motor controller controls adjustment of a stepper motor's current draw, response time, acceleration, duration, and revolutions corresponding with pre-programmed pulser settings provided by the software components of the DSP and wherein pulses are developed with a pilot actuator assembly that identically match the pulses of the pulser motor controller and operates the opening and closing of a main valve in a sequence dictated by the DSP, thereby creating pressure variations of the fluid pressure resulting from fluid flowing within the drill string and within the bore pipe.

[0041] The main valve opens and closes, thereby creating pressure variations of the fluid pressure in the annulus of the drill string in addition to the base line bore pipe pressure due to fluid flow movement restricted by the main valve, wherein the fluid pressure is also affected

downstream of the pulser assembly as the fluid flows through a drill bit and jets within said bore hole pipe annulus.

Claims

1. A system comprising a controllable pulser that operates sequentially within a downhole assembly within a drill string of a drill pipe, that enhances operational efficiency in the removal of hydrocarbon deposits, said system comprising; a drilling fluid, fluid flow, a main valve (190) and a mud pump (500), said features when combined create a fluid flow into a bore pipe annulus (520) within said downhole assembly such that a base line bore pressure is created wherein said fluid flow and bore pressure is contained in the entirety of the interior (510) of said drill string and
 wherein said bore pipe pressure is sensed via a sensor (420) located within said controllable pulser sensing a pressure increase when said mud pump (500) is operating such that said sensor (420) sends information to a Digital Signal Processor-DSP-(540) also located within said controllable pulser that interprets said information and
 wherein said DSP (540) also receives information from an annulus pressure sensor (470) that senses drilling fluid pressure as it returns to said pump in an annular outside portion of said drill pipe such said DSP (540) recognizes pressure variation inputs obtained from said annulus pressure sensor (470) and said bore pipe pressure sensor (420) and detects pressure variation exhibited between pulsing pressures and a pump base line pressure, thereby providing signals that are sent as data information to said DSP (540) such that said DSP (540) determines required action to properly adjust controllable pulser operation settings and subsequently sends information to a pulser motor controller (550) that adjusts a stepper motor current draw, response time, acceleration, duration, and number of revolutions corresponding to any pre-programmed pulser settings provided by said DSP (540)
characterized in that
 opening and closing said main valve (190) creates pressure variations of said fluid pressure in said drill string in addition to a bore pressure,
 wherein said bore pressure is created by said mud pump (500) and
 wherein opening and closing said main valve (190) also creates pressure variations or fluctuations of a fluid pressure in an annulus of said drill string in addition to a base line annulus pressure due to fluid movement restricted by said main valve (190) which directly affects fluid pressure downstream of said controllable pulser assembly (400) extending through a drill bit as said fluid jets into said bore hole

pipe annulus.

2. The system of claim 1, wherein pre-programmed logic (530) is embedded within software components of said DSP (540) such that the input data supplied to said DSP (540) by one or more pressure sensors correctly provides information that determines settings that define the pulser operation in terms of number of pulses, amplitude of pulses, duration for pulses and timing of pulses allowing for the sending of output data that is subsequently received and interpreted by said DSP (540) for precisely controlling said pulser motor controller (550), using a stepper motor (310) driven by said pulser motor controller (550) that operates a pilot actuator assembly (335), said assembly responding directly to said pulser motor controller (550) by opening and closing said main valve (190) of said controllable pulser in a sequence dictated by said DSP (540).
3. The system of one of the preceding claims, wherein said annulus pressure sensor (470) and said bore pipe pressure sensor detect pressure variations due to pulsing in comparison with a pump base line pressure wherein said pressure variations provide information signals to said DSP (540) to ensure required actions for adjustment of continued pulser operation that also avoids excessive water hammer during opening and closing of said main valve (190).

Patentansprüche

1. Ein System mit einem steuerbaren Druckimpulsgeber, der fortlaufend innerhalb einer Bohrlochanordnung innerhalb eines Bohrstrangs eines Bohrrohrs arbeitet, das die Betriebseffizienz beim Entfernen von Kohlenwasserstofflagerstätten erhöht, wobei das System folgendes umfasst: eine Bohrflüssigkeit, Flüssigkeitsströmung, ein Hauptventil (190) und eine Spülpumpe (500), wobei diese Merkmale, wenn sie kombiniert werden, eine Flüssigkeitsströmung in einem Bohrröhring (520) innerhalb der Bohrlochanordnung erzeugen, so dass ein Nulllinien-Bohrdruck erzeugt wird,
 wobei die Flüssigkeitsströmung und der Bohrdruck im gesamten Inneren (510) des Bohrstrangs enthalten sind und
 wobei der Bohrröhrdruck über einen Sensor (420), der sich innerhalb des steuerbaren Druckimpulsgebers befindet, eine Druckzunahme erfasst, wenn die Spülpumpe (500) arbeitet, so dass der Sensor (420) Information zu einem digitalen Signalverarbeiter - DSP - (540) sendet, der sich ebenfalls innerhalb des steuerbaren Druckimpulsgebers befindet, der die Informationen deutet und
 wobei der DSP (540) ebenfalls Information von einem Ringdrucksensor (470) empfängt, der den

Druck der Bohrflüssigkeit erfasst, wenn diese zur Pumpe in einem ringförmigen Außenabschnitt des Bohrrohrs zurückfließt, so dass der DSP (540) Druckabweichungseingaben erkennt, die er von dem ringförmigen Drucksensor (470) und dem Bohrrohrdrucksensor (420) erhalten hat und Druckabweichung erkennt, die sich zwischen Impulsdrücken und einem Pumpen-Nullliniendruck zeigt, wobei dabei Signale geliefert werden, die als Dateninformation zum DSP (540) gesendet werden, so dass der DSP die erforderliche Aktion bestimmt, um korrekt die steuerbaren Impulsoperationseinstellungen einzustellen und im Anschluss Informationen zu einer Impulsantriebssteuerung (550) sendet, die eine Schrittmotorstromaufnahme, Reaktionszeit, Beschleunigung, Dauer und Anzahl der Umdrehungen, die den vorprogrammierten Druckimpulsgebeeinstellungen entsprechen, die vom DSP (540) geliefert werden, abstimmt

dadurch gekennzeichnet, dass

Öffnen und Schließen des Hauptventils (190) Druckabweichungen des Flüssigkeitsdrucks in dem Bohrstrang zusätzlich zu einem Bohrdruck verursacht, wobei der Bohrdruck durch die Spülpumpe (500) verursacht wird und

wobei das Öffnen und Schließen des Hauptventils (190) ebenfalls Druckabweichungen oder -schwankungen eines Flüssigkeitsdrucks in einem Ring des Bohrstrangs verursacht, zusätzlich zu einem Nulllinien-Ringdruck aufgrund zur Flüssigkeitsbewegung, die durch das Hauptventil (190) begrenzt wird, was direkt den Flüssigkeitsdruck in Strömungsrichtung nach der steuerbaren Druckimpulsgebervorrichtung (400) beeinflusst, die sich durch einen Bohrmeißel erstreckt, wenn die Flüssigkeit in den Bohrlochrohring strömt.

2. Das System gemäß Anspruch 1, wobei vorprogrammierte Logik (530) innerhalb von Softwarekomponenten des DSP (540) eingebettet ist, so dass die Eingabedaten, die dem DSP (540) durch einen oder mehrere Drucksensoren geliefert werden, Informationen korrekt liefern, die die Einstellungen bestimmen, die den Druckimpulsgeberbetrieb hinsichtlich einer Anzahl von Impulsen, Amplitude von Impulsen, Dauer von Impulsen und Takt von Impulsen bestimmen, wobei das Senden der Ausgabedaten ermöglicht wird, die durch den DSP (540) zum präzisen Steuern der Druckimpulsgebermotorsteuerung (550) später empfangen und interpretiert werden, wobei ein Schrittmotor (310) verwendet wird, der durch die Druckimpulsgebermotorsteuerung (550) angetrieben wird, der eine Steuerungsantriebsvorrichtung (335) tätigt, wobei die Vorrichtung direkt auf die Druckimpulsgebermotorsteuerung (550) durch Öffnen und Schließen des Hauptventils (190) des steuerbaren Druckimpulsgebers in einer Abfolge reagiert, die durch den DSP (540) vorgegeben wird.

3. Das System gemäß einem der vorangehenden Ansprüche, wobei der Ringdrucksensor (470) und der Bohrrohrdrucksensor Druckabweichungen aufgrund von Impulsen im Vergleich zu einem Pumpen-nullliniendruck erfassen, wobei die Druckabweichungen Informationssignale zum DSP (540) liefern, um erforderliche Aktionen zur Abstimmung des weiteren Druckimpulsbetriebs sicherzustellen, die außerdem überhöhten Wasserschlag während des Öffnens und Schließens des Hauptventils (190) vermeiden.

Revendications

1. Système comprenant un générateur d'impulsions commandable qui fonctionne séquentiellement à l'intérieur d'une installation de fond à l'intérieur d'une colonne de forage d'une tige de forage, qui améliore l'efficacité opérationnelle de l'extraction de dépôts d'hydrocarbure, ledit système comprenant : un fluide de forage, un écoulement de fluide, une valve principale (190) et une pompe à boue (500), lesdites caractéristiques lorsqu'elles sont combinées créent un écoulement de fluide dans un espace annulaire (520) de tige de forage à l'intérieur de ladite installation de fond de façon à créer une pression de tige de forage de ligne de base, ledit écoulement de fluide et ladite pression de forage étant contenus dans la globalité dans l'intérieur (510) de ladite colonne de forage et ladite pression de tige de forage étant détectée via un capteur (420) positionné à l'intérieur dudit générateur d'impulsions commandable détectant une augmentation de pression lorsque ladite pompe à boue (500) est actionnée de telle sorte que ledit capteur (420) envoie l'information à un processeur de signal numérique - DSP - (540) également positionné à l'intérieur dudit générateur d'impulsions commandable qui interprète ladite information et ledit processeur DSP (540) recevant également l'information provenant d'un capteur de pression d'espace annulaire (470) qui détecte la pression de fluide de forage lorsqu'elle revient de ladite pompe dans une partie extérieure annulaire de ladite tige de forage de sorte que ledit processeur DSP (540) reconnaisse les entrées de variation de pression obtenues par ledit capteur de pression d'espace annulaire (470) et ledit capteur de pression de tige de forage (420) et détecte la variation de pression existant entre les pressions pulsées et une pression de ligne de base de pompe, fournissant ainsi des signaux envoyés sous la forme d'informations de données audit processeur DSP de sorte que ledit processeur DSP détermine l'action requise pour régler de façon adéquate les paramètres opérationnels du générateur d'impulsions commandable et envoie ensuite l'information à un contrôleur de moteur de généra-

teur d'impulsions (550) qui règle un appel de courant de moteur pas-à-pas, le temps de réponse, l'accélération, la durée et le nombre de tours correspondant à n'importe quels réglages de générateur d'impulsions préprogrammés fournis par ledit processeur DSP (540) ;

caractérisé par :

l'ouverture et la fermeture de ladite valve principale (190) qui crée des variations de pression de ladite pression de fluide dans ladite colonne de forage en plus d'une pression de forage, ladite pression de forage étant créée par ladite pompe à boue (500) et

l'ouverture et la fermeture de ladite valve principale (190) créant également des variations de pression ou des fluctuations d'une pression de fluide dans un espace annulaire de ladite colonne de forage en plus d'une pression d'espace annulaire de ligne de base due au mouvement de fluide limité par ladite valve principale (190) qui affecte directement la pression de fluide en aval dudit ensemble générateur d'impulsions commandable (400) s'étendant à travers un trépan lorsque ledit fluide gicle dans ledit espace annulaire de colonne de forage.

processeur DSP (540) pour assurer les actions requises pour régler l'exploitation du générateur d'impulsions en continu qui évite un coup de bélier excessif pendant l'ouverture et la fermeture de ladite valve principale (190).

2. Système selon la revendication 1, dans lequel la logique préprogrammée (530) est encastrée à l'intérieur des composants logiciels dudit processeur DSP (540) de telle sorte que les données d'entrée amenées audit processeur DSP (540) par un ou plusieurs capteurs de pression fournissent correctement des informations qui déterminent les paramètres définissant l'exploitation du générateur d'impulsions en termes de nombre d'impulsions, d'amplitude d'impulsions, de durée des impulsions et de séquençage des impulsions permettant l'envoi de données de sortie ensuite reçues et interprétées par ledit processeur DSP pour commander précisément ledit contrôleur de moteur de générateur d'impulsions (550), utilisant un moteur pas-à-pas (310) entraîné par ledit contrôleur de moteur de générateur d'impulsions (550) qui actionne un ensemble actionneur piloté (335), ledit ensemble répondant directement audit contrôleur de moteur de générateur d'impulsions (550) par l'ouverture et la fermeture de ladite valve principale (190) dudit générateur d'impulsions commandable selon une séquence dictée par ledit processeur DSP (540).
3. Système selon l'une quelconque des revendications précédentes, dans lequel ledit capteur de pression d'espace annulaire (470) et ledit capteur de pression de tige de forage détectent des variations de pression dues aux pulsations par rapport à une pression de ligne de base de pompe où lesdites variations de pression fournissent des signaux d'information audit

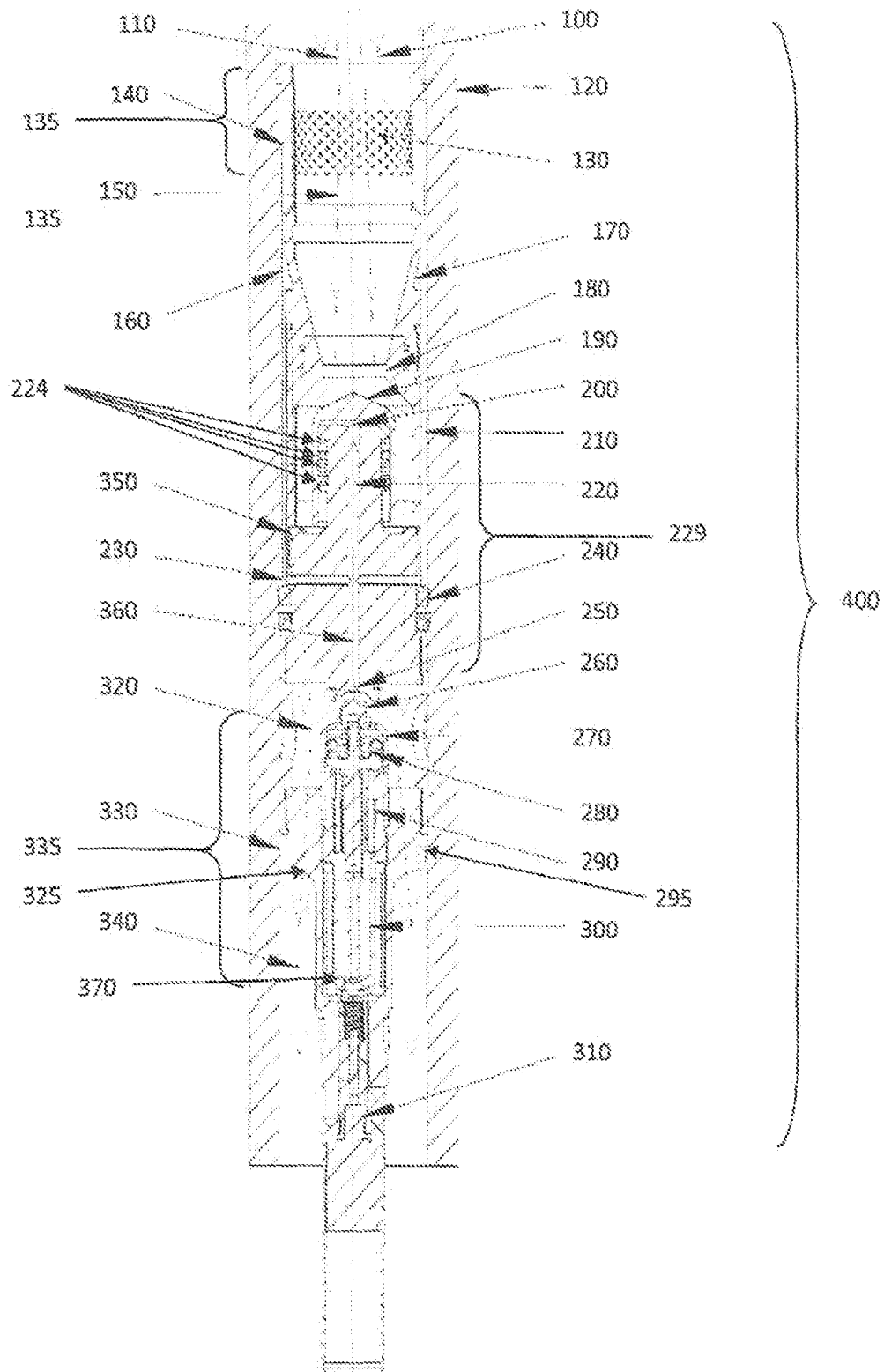


FIG. 1

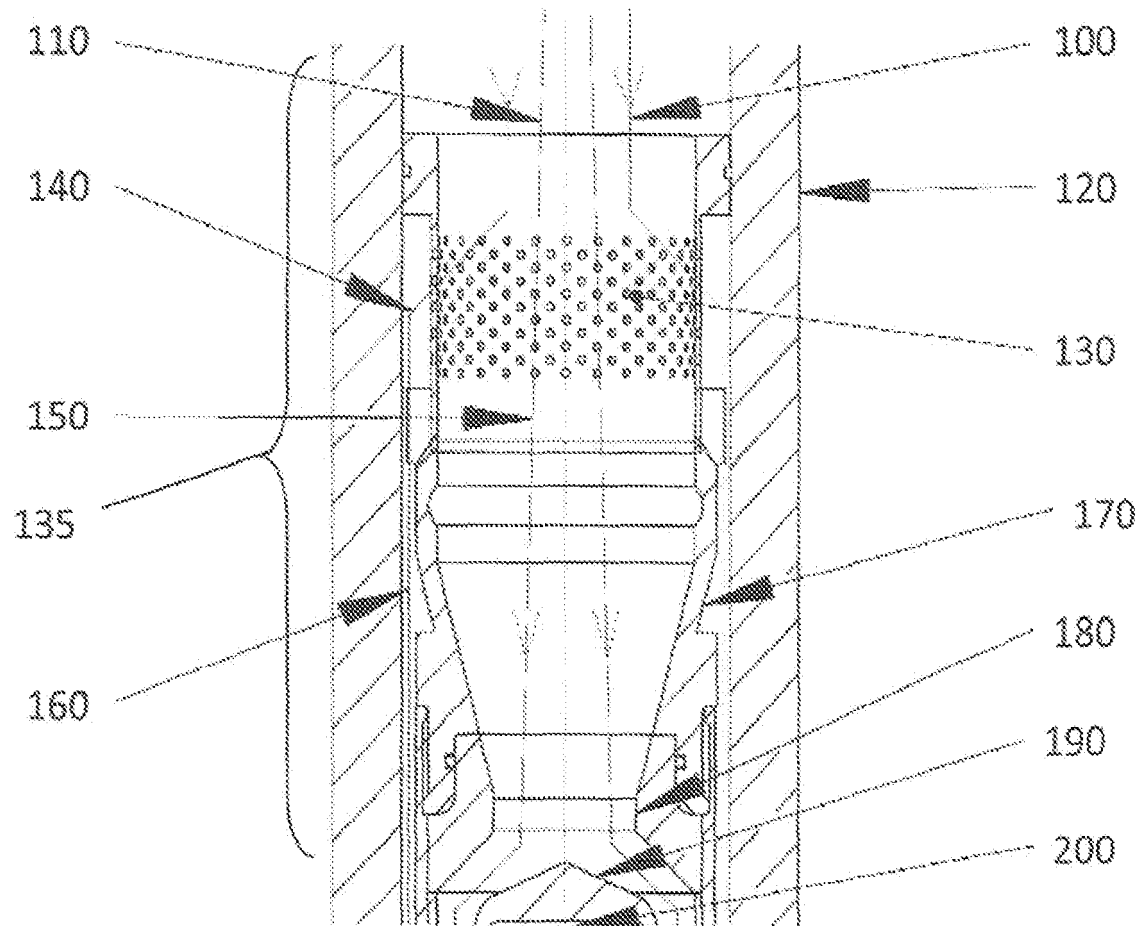


FIG. 2

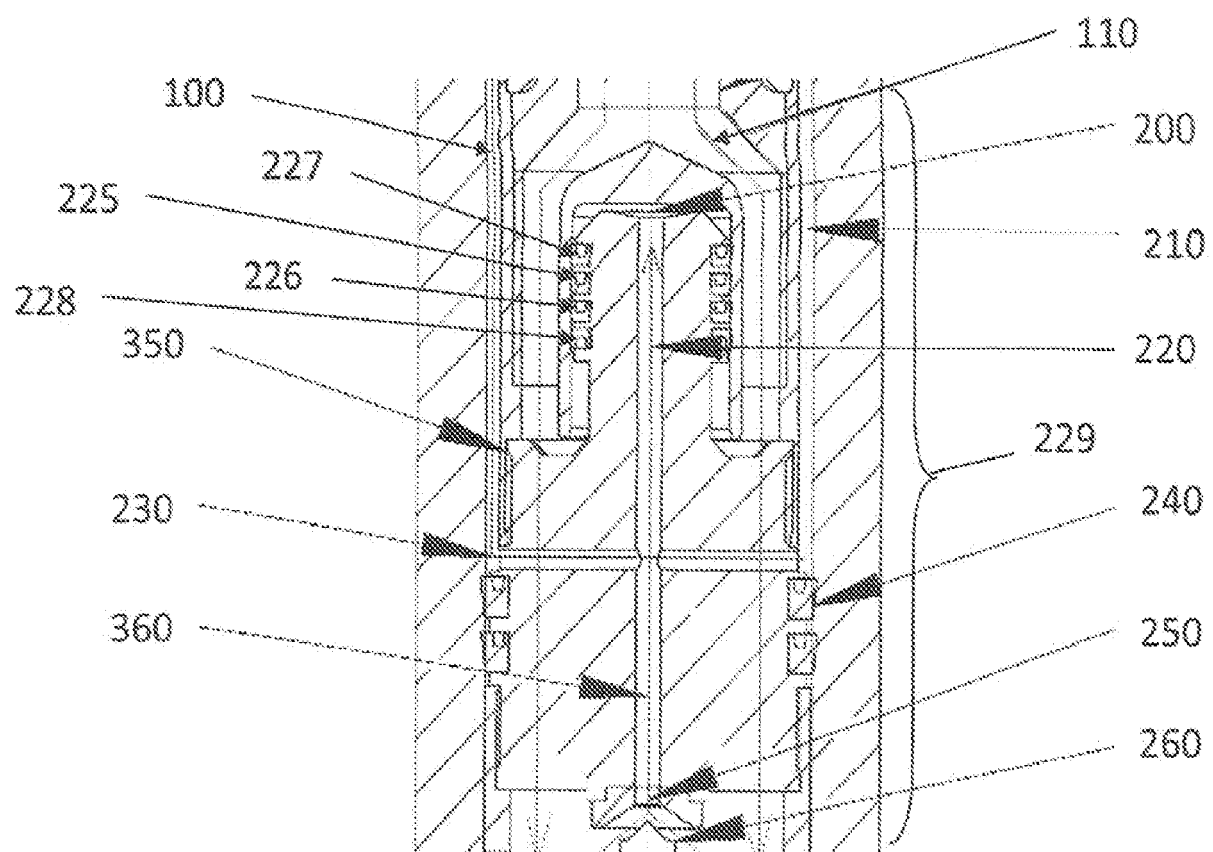


FIG. 3

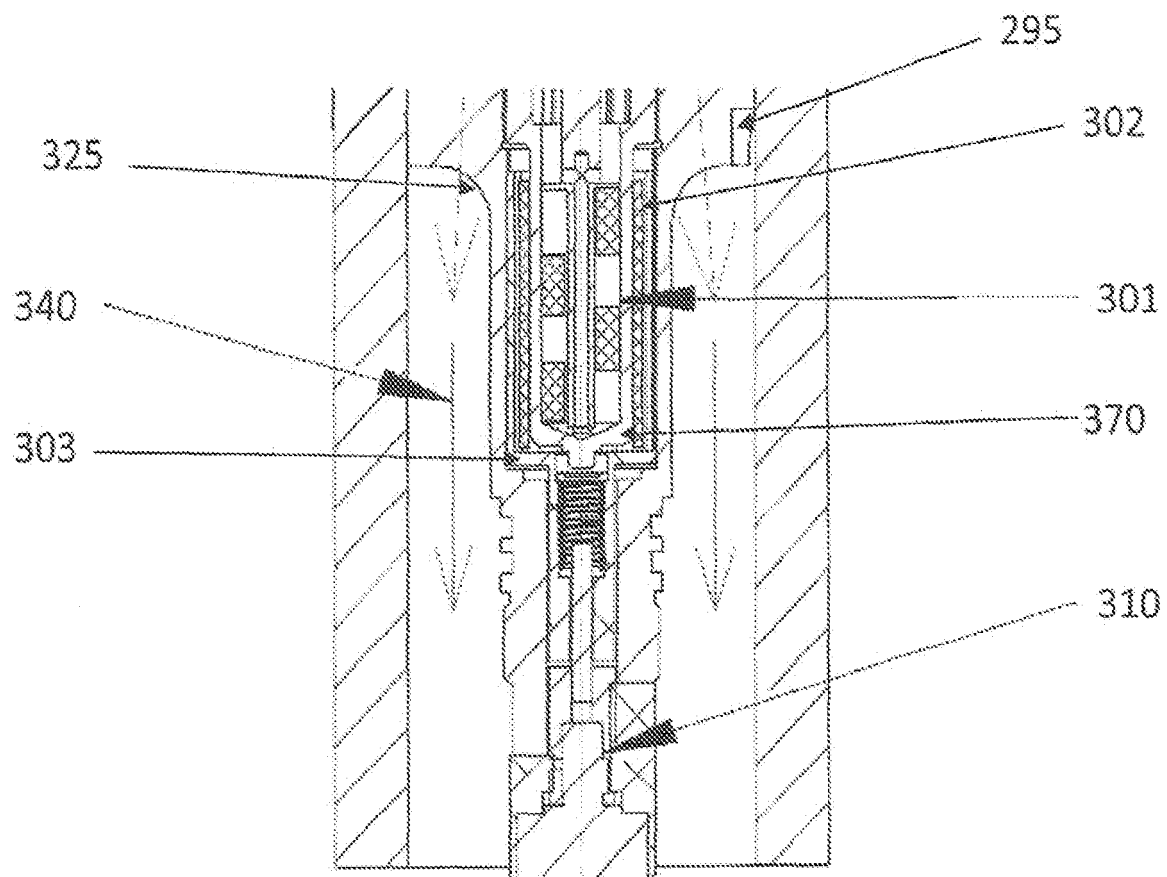


FIG. 4

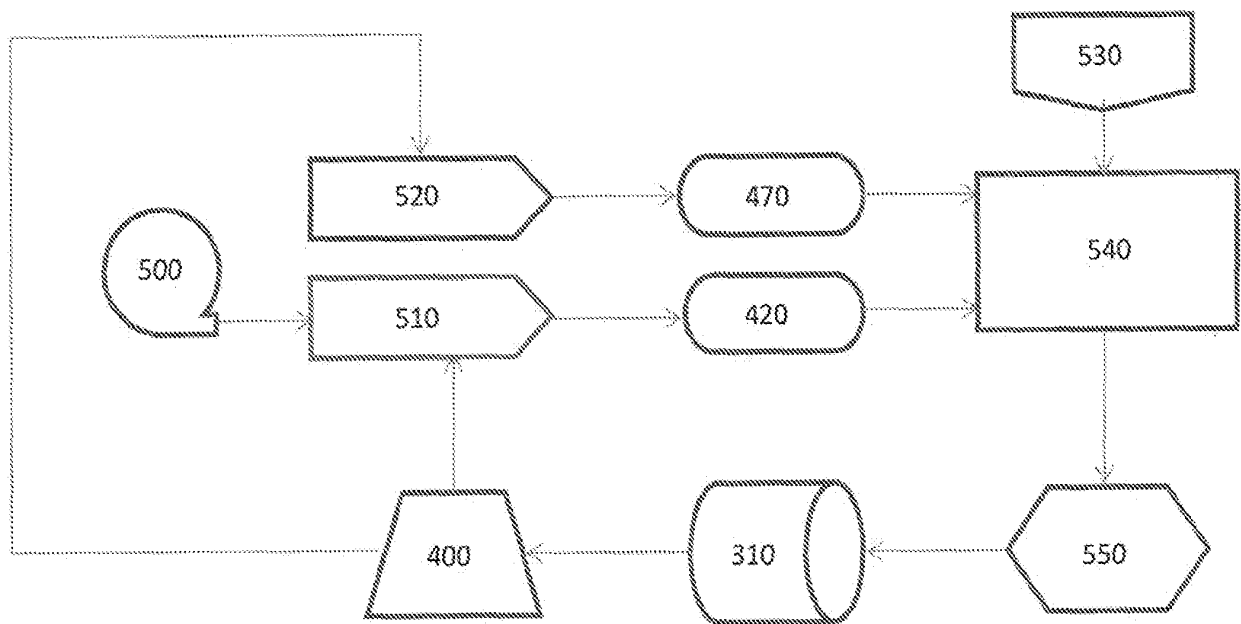


FIG. 5

REFERENCES CITED IN THE DESCRIPTION

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