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(54) **Title:** COILED TUBING APPLICATIONS AND MEASUREMENT TOOL

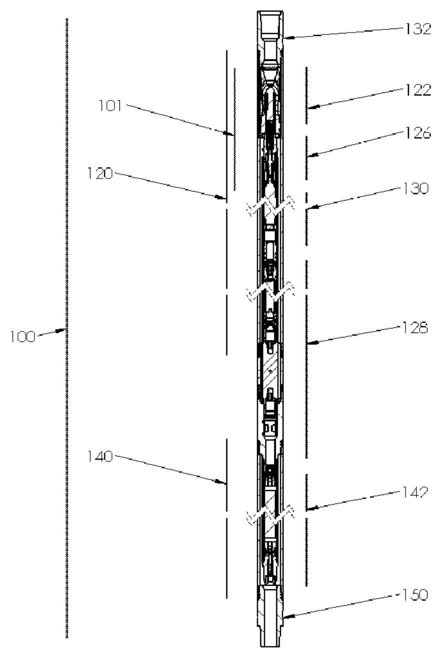

FIG. 1

(57) **Abstract:** An apparatus and system for generating pressure pulses and gathering down-hole sensory information for enhancing and completing a well bore within a coiled tubing operation including: a valve longitudinally and axially positioned within the center of a pulser section and electronics to transmit and record down-hole sensory information. The main fluid flow is interrupted by the main valve which is operated by the controlled pilot fluid stream. The main fluid flow proceeds toward one or more pressure sensors to measure the fluid flow pressure with sensors that send signals to a Digital Signal Processor (DSP) that controls a valve which generates controllable and measurable energy pulses. Recorded downhole sensory information such as temperature, fluid bore and annulus pressure, weight/axial force, torque, vibration, shock, gravity tool-face, casing collar locator, gamma, flow and battery condition can be transmitted in real-time via pressure pulses to the surface with pulser or downloaded for analysis.

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Coiled Tubing Applications and Measurement Tool

PRIORITY

This application is an international PCT fling of US application number15/721,083, filed September 29, 2017, which is a continuation-in-part of and claims priority under 35 USC 120 to US Patent Application 15/465,814 filed March 22, 2017 which is a divisional of and claims priority to US Patent Application 14/255,763 filed April 17, 2014, and granted as US Patent 9,702,204 on July 11, 2017, both entitled "Controlled Pressure Pulser for Coiled Tubing Measurement While Drilling Applications".

FIELD OF DISCLOSURE

The current invention includes a coiled tubing application improvement tool that enhances coil tubing (CT) operations and includes electronics with sensor memory and/or a controlled pressure pulser, herein referred to as "the Tool", that can be used in CT operations including but not limited to intervention and completion. The Tool creates controlled pulses within the drilling fluid or drilling mud that travels along the internal portion of a CT string. The pulse is normally generated by the use of a dual-function pulser, selectively initiating flow driven bi-directional pulses due to proper geometric mechanical designs within a pulser, while creating coded pressure pulses which transmit sensor readings to the surface. At the same or nearly the same time, measured downhole sensor data is also recorded and stored in the memory download after the job is completed. The Tool also can be used only in memory mode so that all required down-hole sensor data is logged without utilizing the axial agitation created by the pulser.

A telemetric pulse signal is received at the surface from the use of the Tool down-hole and includes information necessary for the field personnel during the well operation. At the same time, the telemetric pulses produced by the pulser also create momentary axial loads on the bottom-hole assembly (BHA) and along the CT string, thus reducing friction and enhancing extended reach (ER) within the wellbore.

BACKGROUND

This invention relates to new and improved methods and devices for completion, deepening, fracturing, fishing, cleanout, reentering and plug milling of the wellbore. This invention finds particular utility in the completion of horizontal wells. Notwithstanding previous attempts at obtaining cost effective and workable horizontal well completions, there continues to be a need for increasing horizontal well departure to increase, for example, unconventional shale plays – which are wells exhibiting low permeability and therefore requiring horizontal laterals increasing in length to maximize reservoir contact. With increased lateral length, the number of zones fractured increases proportionally.

Most of these wells are fractured using the "Plug and Perf" method which requires perforating the stage nearest the toe of the horizontal section, fracturing that stage and then placing a composite plug followed by perforating the next stage. The process is repeated numerous times until all the required zones are stimulated. Upon completing the fracturing operation, the plugs are removed with a mill/bit on the end of a down-hole positive displacement motor (PDM) that is connected to the coiled tubing (CT) string. As the lateral length increases, milling with CT becomes less efficient, leading to the use of jointed pipe for removing plugs.

Two related reasons cause this reduction in efficiency of the CT. First, as the depth increases, the effective maximum weight on bit (WOB) decreases. Second, at increased lateral depths, the coiled tubing is typically in a stable helical spiral in the wellbore. The operator sending the additional coiled tubing (and weight from the surface) will have to overcome greater static loads leading to a longer and inconsistent transmission of load to the bit. The onset of these two effects is controlled by several factors including; CT wall thickness, wellbore deviation and build angle, completion size, CT/completion contact friction drag, fluid drag, debris, and bottom hole assembly (BHA) weight and size. CT with an outer diameter less than 4 inches tends to buckle due to easier helical spiraling, thus increasing the friction caused by increased contact surface area along the wall of the bore hole. CT outer diameters greater than 4 inches are impractical due to weight and friction limitations. Friction drag is a function of CT wall thickness and diameter, leaving end loads as one of the variables most studied for manipulation to achieve better well completion.

In fracturing application milling out frac-plugs with coiled tubing can be challenging, especially in longer laterals. Vibration or water hammer type of extended reach (ER) tools included in the BHA can extend the coiled tubing unit's reach to the deepest plugs, but well-site operators still encounter slow drilling, motor stalls, debris build-up and coil lock up, which can cause delays and require frequent short trips.

Similarly, while running CT into horizontal wells to perform annular fracturing or workover operations, an extended reach (ER) tool may be needed to reach the toe of the well, but operators may still encounter hang ups or tight spots. Continuous operation of vibration tools in these applications can complicate operations.

In most CT operations in horizontal wells, operators have no direct measurement of weight on bit or bottom-hole pressure, and addressing problems involves trial and error while applying imprecise rules of thumb.

These problems could be prevented or resolved quickly if operators had real-time downhole measurements of weight-on-bit and other key parameters. The Tool described herein combines an axial thruster with downhole sensors and mud pulse telemetry that wirelessly transmits real-time data to the surface.

Horizontal wellbores around the world are getting longer, leading to more demand for coiled tubing (CT) extended-reach (ER) tools. Current ER tools that create vibration and take no down-hole measurements provide inconsistent, unquantified results. A more powerful mechanical agitation feature is needed to carry coiled-tubing strings to deeper total depth (TD). In coil-frac applications, TDs are reached without the need to pump down annulus with frac pumps, which is operationally complex, and could inadvertently shift a frac sleeve.

The present disclosure relates to the Tool that provides for extended lateral reach due to reduced friction forces, improved operational decisions leading to increased efficiency, improved weight transfer to BHA while providing real-time downhole information to the operator. Downhole weight-on-bit and differential pressure measurements eliminate costly actions based on the inference and guesswork inherent with using surface measurements without downhole data

Improved weight transfer is a cost effective solution for CT operations. With real-time weight control on bit, CT trips downhole can be reduced. Axial agitation at will is independent of the real-time data transfer. A reduced number of trips down hole also translate into reduced fatigue of the coil and extension of the coil for further reach. Real-time measurements and surface display of downhole weight-on-bit improves the ability to time-drill plugs and generate smaller cuttings that are easier to circulate out of the hole.

Coiled tubing string replacement is one of the highest costs for CT operators in unconventional well completions. Because coil life is a function of its reeling and unreeling, excessive coil movement can create premature fatigue and shorten the life of the coil. The Tool provided herein enables downhole measurements that enable drill-outs and hole-cleaning with a minimum number of short trips, extension coil life and saving money for CT providers and oil company operators.

Pulsing technology incorporated within the Tool acts to reduce friction along the length of the coil whilst providing real-time and recorded parameters needed to enable continuous operational control. There parameters also serve in the development of better future practices within the industry.

Current pulser technology utilizes pulsers that are sensitive to different fluid properties, 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 using Coiled Tubing (CT) technology. Newer technology incorporated with CT has included the use of water hammer devices producing a force when the drilling fluid is suddenly stopped or interrupted by the sudden closing of a valve. This axial force created by the sudden closing and opening of the valve can be used to pull the coiled tubing deeper into the wellbore. The pull into the wellbore is increased by the axial stress in the coiled tubing and straightening the tubing due to momentary higher fluid pressure inside the tubing and thus reducing the frictional drag. This task – generating the force by opening and closing valves - can be accomplished in many ways – and is also the partial subject of the present disclosure.

SUMMARY

The need to effectively overcome these challenges regarding both lateral reach and improved plug milling efficiency has led to the development of the Tool of the present disclosure. This Tool allows for improved methods that provide better well completions, achieving extended reach, communicating real-time operational information, better rate and direction of penetration with proper WOB, as well as providing for controlled pulsing on an as-needed (on demand) manner. Downloaded memory sensor data also allows post-job analysis. More specifically

Current pulser technology utilizes pulsers that are sensitive to different fluid properties, 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 using Coiled Tubing (CT) technology. Newer technology incorporated with CT has included the use of water hammer devices producing a force when the drilling fluid is suddenly stopped or interrupted by the sudden closing of a valve. This axial force created by the sudden closing and opening of the valve can be used to pull the coiled tubing deeper into the wellbore. The pull into the wellbore is increased by the axial stress in the coiled tubing and straightening the tubing due to momentary higher fluid pressure inside the tubing and thus reducing the frictional drag. This task – generating the force by opening and closing valves - can be accomplished in many ways – and is also the partial subject of the present disclosure.

The present disclosure and associated embodiments allow for providing a pulser system within coiled tubing string such that the pulse amplitude increases with flow rate or overall fluid pressure within easily achievable limits, does not require field adjustment, and is capable of creating recognizable, repeatable, reproducible, clean [i.e. noise free] fluid pulse signals using minimum power due to a unique design feature. The Tool utilizes battery, magneto-electric and/or turbine generated energy to provide real time down-hole sensory information through telemetric pulsing, as well as controlled rate of penetration (ROP) capabilities, extended reach (ER) and axial agitation within the CT using the Tool of the present disclosure.

Additional featured benefits of the present device and associated methods include using a pulser tool above the down-hole PDM (positive displacement motor) allowing for intelligence gathering, transmitting and storing of real time data in memory such as bore and annular pressure, acceleration, temperature, torque and weight-on-bit (WOB) controls. The

WOB is controlled by using a set point and threshold for the axial force provided by the shock wave generated by the pulser. Master control could be provided from the surface via downlinking to the Tool, or with a feedback loop pre-programmed into the Tool to automatically adjust its settings for specific conditions.

The coiled tubing industry continues to be one of the fastest growing segments of the oilfield services sector, and for good reason. Growth has been driven by attractive economics, continual advances in technology, and utilization of CT to perform an ever-growing list of field operations. The economic advantages of the present invention include; pulse only when needed (on demand) and with as much amplitude as needed, increased efficiency of milling times of the plugs by intelligent down-hole assessments, extended reach of the CT to the end of the run, allowing for reduction of time on the well and more efficient well production, reduced coiled fatigue by eliminating or reducing CT cycling (insertion and removal of the CT from the well), high pressure pulses with little or no kinking and less friction as the pulses are fully controlled, and a lower overall power budget due to the use of the intelligent pulser.

More specifically, this disclosure describes an apparatus that generates pressure pulses in a drilling fluid within a well bore that exists within a coiled tubing assembly, the apparatus comprising: a tool within which exists a valve portion longitudinally and axially positioned within a center portion of a main valve assembly, the assembly including a main valve, a main valve pressure chamber, and a main valve orifice with the main valve, such that as the drilling fluid flows downward along the well bore the drilling fluid splits into both an inlet main fluid stream and a pilot fluid stream, wherein the pilot fluid stream flows through a pilot flow annulus and into a pilot flow inlet channel, wherein the pilot fluid stream then flows into a main valve fluid feed channel until it reaches the main valve pressure chamber and through a pilot valve section that functions as a pulser generating portion of the tool that further comprises a pilot valve housing, a pilot shaft positioned in a central axial position within the tool supported by thrust bearings, a seal carrier, upper and lower rotary seals, and a pilot inlet cam and a pilot outlet cam such that the pilot shaft can rotate the pilot inlet cam and pilot outlet cam inside a pilot sleeve with matching orifices so that the pilot fluid stream is controlled by movement of the pilot inlet cam and the pilot outlet cam and wherein the pilot fluid stream fluid flows into and through a pilot flow outlet channel such that the pilot fluid stream fluid recombines with a main fluid flow to become a main exit fluid flow.

Here the upper and lower rotary seals exist within an oil filled pressure chamber and act to separate a portion of the pilot fluid stream fluid above or in front of the upper rotary seal from a portion exposed to atmospheric pressure that exists below or behind the lower rotary seal so that a drive shaft, a motor, and additional sections below the upper and lower rotary seals prevent pilot fluid stream fluid from entering and damaging the motor and associated electronics.

Further, the pilot shaft is rotated by an electrical motor which is connected to the drive shaft and wherein the pilot inlet cam and the pilot outlet cam are positioned on the shaft so that both cams can rotate and so that when the pilot inlet cam is in an open position it allows the pilot fluid stream fluid to enter the main valve and simultaneously the pilot outlet cam maintains a closed position that prevents the pilot fluid stream fluid to exit through a reverse flow check valve.
The reverse flow check valve allows reverse fluid flow through said tool.

The resultant reverse fluid flow is does not cause pulsing of fluid while operation of a normal pulsing mode exists during a forward flow condition.

Further, the frequency of opening and closing of a pilot inlet cam and a pilot outlet cam directly influences and determines one or more frequencies of the main valve opening and closing to create pressure pulses in a main fluid column above or in front of the main valve orifice.
Upon a controlled signal the motor rotates the pilot shaft to position the pilot inlet cam to open and closed positions and wherein when the pilot inlet cam is a closed position the pilot outlet cam is in an open position the pilot fluid stream fluid behind or below the main valve to allowed escape through the reverse flow check valve and to join the main fluid flow.

The reverse flow check valve allows pilot fluid stream fluid to exit the main valve so that the pilot fluid stream fluid can return to a rear or lower position with respect to the main valve orifice.

Further, the check valve prevents fluid flow back into said tool by not allowing fluid to enter said pilot flow outlet channel which ensures blockage of fluid flow in a reverse direction through said tool and also allows closure of said main valve, thereby stopping further fluid flow.

The present disclosure also provides for a system that generates pressure pulses in a drilling fluid within a well bore that exists within a coiled tubing assembly, the system comprising: a tool within which exists a valve portion longitudinally and axially positioned within a center portion of a main valve assembly, the assembly including a main valve, a main valve pressure chamber, and a main valve orifice with the main valve, such that as the drilling fluid flows downward along the well bore the drilling fluid splits into both an inlet main fluid stream and a pilot fluid stream, wherein the pilot fluid stream flows through a pilot flow annulus and into a pilot flow inlet channel, wherein the pilot fluid stream then flows into a main valve fluid feed channel until it reaches the main valve pressure chamber and through a pilot valve section that functions as a pulser generating portion of the tool that further comprises a pilot valve housing, a pilot shaft positioned in a central axial position within the tool supported by thrust bearings, a seal carrier, upper and lower rotary seals, and a pilot inlet cam and a pilot outlet cam such that the pilot shaft can rotate said pilot inlet cam and pilot outlet cam inside a pilot sleeve with matching orifices so that the pilot fluid stream is controlled by movement of the pilot inlet cam and the pilot outlet cam and wherein the pilot fluid stream fluid flows into and through a pilot flow outlet channel such that the pilot fluid stream fluid recombines with a main fluid flow to become a main exit fluid flow.

The present disclosure also provides for a method for generating pressure pulses in a drilling fluid within a well bore that exists within a coiled tubing assembly, the method comprising: a tool within which exists a valve portion longitudinally and axially positioned within a center portion of a main valve assembly, the assembly including a main valve, a main valve pressure chamber, and a main valve orifice with the main valve, such that as the drilling fluid flows is flowing downward along the well bore the drilling fluid splitting into both an inlet main fluid stream and a pilot fluid stream, wherein the pilot fluid stream is flowing through a pilot flow annulus and into a pilot flow inlet channel, wherein the pilot fluid stream then continues to flow into a main valve fluid feed channel until it reaches the main valve pressure chamber and continues through a pilot valve section that functions as a pulser generating portion of the tool further comprising a pilot valve housing, a pilot shaft positioned in a central axial position within the tool supported by thrust bearings, a seal carrier, upper and lower rotary seals, and a pilot inlet cam and a pilot outlet cam such that the pilot shaft can be rotating the pilot inlet cam and pilot outlet cam inside a pilot sleeve with matching orifices so that the pilot fluid stream is being controlled by movement of the pilot inlet cam and the pilot outlet cam and wherein the pilot fluid stream fluid continues flowing into and through a pilot flow outlet channel such that the pilot fluid stream fluid recombines with a main fluid flow for becoming a main exit fluid flow.

Further, a mating area for electrical wiring of the annular pressure sensors exist within annular pressure ports and wherein the ports are sealed off insuring that the annular pressure sensors within the sensor sub assembly receive and sense only the annular pressure within the annular pressure ports.

In some cases the mating area for electrical wiring for the bore pressure sensors exist within bore pressure ports and wherein the ports are sealed off insuring that the bore pressure sensors within the sensor sub assembly receive and sense only bore pressure within the bore pressure ports.

The mating area for electrical wiring for weight-on-bit/axial force sensors exist within force sensing region wherein the force sensors are sealed off, insuring that the force sensors within the weight sensor sub assembly receive and sense only a force within the force sensor.

The mating area for electrical wiring for torque sensors exist within torque sensing region wherein the torque sensors are sealed off, insuring that the torque sensors within the weight sensor sub assembly receive and sense only torque within the torque sensor.

The electrical wiring for the annular pressure sensors are sealed off from flow of the main fluid flow and wherein the wiring is routed to and connected to an electrical connector.

The electrical wiring of the bore pressure sensors are sealed off from the flow of the main fluid flow and wherein the wiring is routed to and connected to an electrical connector.

The electrical wiring of the weight-on-bit/force sensors are sealed off from the main fluid flow and wherein the wires are routed to and connected to an electrical connector.

The electrical wiring of the torque sensors are sealed off from the flow of the main fluid flow and wherein the wires are routed to and connected to an electrical connector.

In an additional embodiment, a pilot valve actuator assembly is provided. The pilot valve actuator assembly is any one or more from the group consisting of; a pilot valve housing, a pilot shaft, rotary seals, a seal carrier, pilot cams, a pilot sleeve, oil chamber, thrust bearings and reverse flow check valve.

Further, a motor is connected to the pilot shaft that has pilot cams attached to the shaft and rotate the pilot cams. The pilot cams are sized and oriented within the pilot sleeve in order to allow for the pilot shaft to move in a bi-directional rotary motion in order to seal or open pilot outlet or pilot inlet port.

Rotational motion of a motor connected to a rotating pilot shaft that is connected to and moves the pilot cams, causes channeling of the pilot fluid toward the main valve. This channeling of the fluid causes the main valve to close and also allows for the pilot fluid to move the main valve. Consequently, the motor can reverse rotational direction. The pilot shaft subsequently reverses the position of the pilot cams and the main valve opens, therefore returning to its original (open) position causing an end to the single positive pulse so that the entire process can begin again.

In this case, the apparatus generates fluid pulses such that the Tool using the pilot shaft rotation provides either unidirectional or bi-directional rotary movement of the pilot shaft within the pilot valve housing.

Further, the apparatus provides a flow path allowing flow of the pilot fluid through the pilot valve that channels the pilot fluid toward the main valve resulting in operation of the main valve bi-directionally along the moving axis.

In an additional embodiment, differential pressure is maximized by using a flow cone in the main valve section. The flow cone provides for increasing the velocity of the drilling fluid through the orifice of the main valve section. This increase in velocity causes an increase in the pressure differential and also allows for utilization and better control of the energy pulses created by opening and closing of the main valve by using the pilot valve.

In a related embodiment, a system comprising an intelligent pulser operation sequence within a coiled tubing apparatus for enhanced well bore completion within a well bore comprising;

(i) a fluid drilling pump creating fluid flow at a predetermined base line bore pressure contained entirely within a drill string containing a bore pipe pressure sensor for sensing pressure increases of the fluid flow;

(ii) an annular pressure sensor located on the outer annular portion of the main pipe, a bore pressure sensor within an interior flow area of the main pipe, and an axial force sensor measuring weight-on-bit load, torque sensor, casing collar locator, gamma and other sensors wherein all sensors are located within the Tool and are sending information to a digital signal processor (DSP), with information being sent to the DSP before, during or after pulser operation.

For this embodiment, pre-programmed logic embedded in computer software controlling DSP based upon an input signal from sensors determines via processing correct pulser operation settings and sends information to a pulser motor controller that controls adjustment of a motor current draw, response time, acceleration, duration, and revolutions to correspond with pre-programmed flow pulser settings from the DSP. Pre-programmed logic embedded in computer software is controlling the DSP based upon an input signal to the DSP from sensors that determine via signal processing, pulser operational settings and wherein settings are manipulated by the DSP when it sends signals to a pulser motor controller that controls adjustment of the motor parameters according to values generated by the group consisting of motor current draw, motor response time, motor acceleration, pressure pulse duration, and motor shaft revolutions.

Flow pulses are developed using a pilot valve responding exactly to a motor that operates opening and closing of a main valve located within the wellbore thereby controlling fluid flow through the pilot valve section by a sequence dictated by computer software working with said DSP, thereby creating positive pressure variations of fluid pressure.

In applying this system, an annulus pressure sensor and bore pressure sensor detect pressure variations due to pulsing flow within coiled tubing apparatus that is compared with pump base line pressure and sends pressure variation information to the DSP to adjust pulser operation and avoid excessive water hammer.

Force sensors and torque sensors detect load variations due to pulsing flow within the coiled tubing apparatus that is compared with base line load and sends load variation information to the DSP for determining actions to adjust pulser operations and avoid excessive water hammer.

Here, the DSP collects, records, and stores data in a computer memory device located within or remote from the DSP during operation and wherein the DSP allows for downloading and analyzing the data.

Intelligent pulser operation sequences within the coiled tubing Tool controlling apparatus also provides axial agitation allowing for friction reduction while logging sensor data into the computer memory device.

In addition, a logging tool for data logging is provided wherein the data is down-hole sensing data when no pulsing is occurring, thereby allowing for real time telemetry or when axial friction reduction agitation is required.

The Tool includes three modular sections which when combined provide a downhole tool which measures from 5 to 12 feet in length depending on memory only, pulser or additional sensors in the configuration, with an outside diameter in the range of 2-3/8 to 3-1/8 inches.

Batteries provide up to 80 hours of continuous pulsing operation, with partial pulsing operations providing extended hours of use. The Tool is made up in the BHA directly above the down-hole PDM motor during plug milling operations, so measurements are taken as close as possible to the bit, while allowing ball drop-activated tools above the Tool to be operated in the normal fashion.

Advanced electronics are utilized within the Tool in order to withstand the high temperature and high pressure associated with downhole environments. The electronics within the Tool are rated to 175^{0}C.

The Tool employs downhole sensors that include and continuously record tubing bore pressure, annulus pressure, weight-on-bit, temperature, gravity tool-face, vibration, inclination, gamma, casing collar locator and battery condition. The downhole Tool can be programmed to transmit measurement data from any or all the sensors at specified sequences and levels. Pulse signals can be reliably transmitted and decoded in CT strings up to 30,000 ft. All data is stored and available for download within the Tool's memory for post-well analysis.

Pulse technology employed within the tool enables axial oscillation which reduces friction and increases reach in CT applications. The tool can be installed into the CT-BHA where its water hammer-style pulsing action is utilized to advance the CT string deep into the wellbore. The water hammer-style ER tool uses pressure pulse amplitude to dictate how much force will be applied to the CT-BHA. The pulser portion of the tool performs the dual functions of developing force to advance the CT and creating coded pressure pulses to transmit sensor readings to the surface. The rapid operation of the tool pulser portion generates pressure signals and delivers axial thrust, advancing the BHA in the horizontal section of the well while simultaneously propagating a pressure wave to the surface, significantly increasing reach.

A unique ability to adjust pulse amplitude is imparted without tripping out of the hole. Tripping pipe (or "tripping out of the hole") is the physical act of pulling the drill string out of the wellbore and then running it back in. A pipe trip is usually performed because the bit has dulled or has otherwise ceased to drill efficiently and must be replaced. The pulse amplitude can be adjusted "on-the-fly", providing the force needed to reach TD, and the pulses can also be decoded into real-time downhole measurements, creating a combined reach and telemetry system.

In annular frac applications, the Tool provides reverse circulation capability in the event of a screen-out. A "screen-out" is when the fracing propellant clogs the perforation holes causing increased pump pressure. The operation is thus stopped in order to clean the well bore. A reverse flow check valve prevents the pilot valve actuating the main valve in case the flow in the CT is reversed. The down-hole tool is compliant with the use of hydrochloric (HCl) and hydrofluoric (HF) acids and allows for sand-jet perforating.

The present disclosure and associate inventiveness can be described as a system that utilizes pulse technology to improve weight transfer in horizontal wells by modulating flow, pressure and weight on the bit. The system can be used to overcome coiled tubing (CT) drill out challenges by overcoming friction forces that impede the downhole reach, providing the downhole weight applied while milling occurs, and identifying downhole tool performance issues without tripping out of the hole.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 provides a cross-sectional view of the Tool.

Fig. 2 is an enlarged cross-sectional view of the main valve section.

Fig. 3A is an enlarged cross-sectional view of the pilot valve section in relation to the main valve section.

Fig. 3B is a more complete cross-sectional view of the pilot valve section.

Fig. 4A is a cross-sectional view of the electronics located within the electronics section.

Fig. 4B is a cross-sectional view of the sensor subs located within the electronics section

Fig. 5 is an illustrated view of the power section of the Tool.

Fig. 6 provides graphical data from a CT field well intervention simulation.

Fig. 7 provides a representation of change in pulse amplitude to dynamically change force on an end of a coiled tubing string

DETAILED DESCRIPTION OF DRAWINGS

The present invention will now be described in greater detail and with reference to the accompanying drawings.

Figure 1 shows the complete modular down-hole Tool [100] in its entirety. The Tool [100] has three major sections: the Pulser Section [101] that houses the main valve section [122] and pilot valve section [126], the electronics section [128] including the motor [130] and sensors described herein, and the power unit or the battery section [142] including the battery [502] as shown in Figure 5.

The fluid enters the tool at the top where the tool is connected to the coil tubing by the Upper String connection [132] also referred to in the industry as a top crossover connection. Respectively the fluid exits the tool at the bottom through the Lower String connection [150], also referred to in the industry as a bottom crossover connection, where the Tool [100] is connected to the downhole motor or other Bottom Hole Assembly (BHA) (not shown). The fluid flows through the tool on the inside of the Upper Pipe Portion [120] and Lower Pipe Portion [140] in the opening around the Motor [130], electronics [404], and battery [502] including the battery switch [601], as shown in Figure 5.

Figure 2 shows the main valve section [122] of the pulser section [101]. The fluid enters the tool through the Upper String connection [132] into the Fluid Inlet Cone [202] and also through the Pilot Flow Take Off ports [214] into the Pilot Flow upper Annulus [260] to the Pilot Flow Inlet Channel [320], bypassing the Main Valve Orifice [204]. The Pilot Flow upper Annulus [260] is created by the concentric Pulser Pipe [270] inside the Upper Pipe Portion [120] connecting the Fluid Inlet Cone [202] with the Main Valve Housing [210]. Radial apertures [211] are located along the circumferential area of the Flow Inlet Cone [202]. The main fluid flow in the center of the tool goes through the Main Valve Orifice [204] and around the Main Valve [206] in the open position, continuing around the internal parts of the entire Tool [100] until it exits through the Lower String Connection [150].

The Main Valve [206] in the closed position moves upward, or forward, into the Main Valve Orifice [204] restricting the main fluid flow and thus creating a backpressure in the fluid column upstream of the Main Valve Orifice [204]. The forward closing movement of the Main Valve [206] is activated by the pilot fluid which enters the Main Valve Housing [210] through the Pilot Flow Inlet Channel [320]. The Pilot Inlet Cam [316] in the open position allows the pilot fluid to enter the rear part of the Main Valve [206] and the higher pressure of the pilot fluid causes the Main Valve [206] to move forward against the Main Valve Orifice [204] which is smaller in diameter with less pressure across it. The Main Valve Plunger [208] provides a complete seal for the pilot fluid to allow full pressure to act on the Main Valve [206]. When the Pilot Inlet Cam [316] closes off the incoming pilot fluid to the rear of the Main Valve [206], the main fluid flow through the Main Valve Orifice [204] assisted by the Valve Spring [207] returns the Main Valve [206] to its rear, open position allowing the main fluid to flow through the tool.

Figure 3A shows the Pulser Section [101 including the Main Valve Section [122] and the Pilot Valve Section [126] in relation to each other with their major internal components. The main fluid flow enters the Tool at the top into the Fluid Inlet Cone [202] and flows around the Main Valve [206] and around the Pilot Valve Housing [302].

Figure 3B shows the Pilot Valve Section [126] of the Pulser Section [101]. The main fluid flows around the Pilot Valve Housing [302] inside the Upper Pipe Portion [120]. The Pilot Valve Section [126] consists of the Pilot Valve Housing [302], the Pilot Shaft [304] which is positioned centrally and axially located and supported by Thrust Bearings [306], a Seal Carrier [308], Upper and Lower Rotary Seals [310, 311], and Pilot Inlet Cam [316] and Pilot Outlet Cam [314] . The Pilot Shaft [304] rotates the Pilot Inlet Cam [216] and the Pilot Outlet Cam [314] inside the Pilot Sleeve [318] which has matching holes to allow the pilot fluid flow to be controlled by the cams. The Upper and Lower Rotary Seals [310, 311] in the Oil Filled Chamber [326] separate the pilot fluid side above or in front of the upper Rotary Seal [310] from the air side below the lower Rotary Seal [311] housing the Drive Shaft [305], Motor [130] and below, thus preventing the pilot fluid from entering and damaging the Motor [130] and the Electronics [404]. The Pilot Shaft [304] is rotated by the electric Motor [130] which is connected to it with a Drive Shaft [305]. The Pilot Inlet Cam [316] and the Pilot Outlet Cam [314] are positioned on the shaft rotationally so that when the Pilot Inlet Cam [316] is in open position it allows pilot fluid to enter the Main Valve [206]. At the same time the Pilot Outlet Cam [314] is in closed position preventing the fluid to exit through the Reverse Flow Check Valve [325]. Upon a controlled signal the Motor [130] rotates the Pilot Shaft [304] to position the Pilot Inlet Cam [316] to open and closed positions. When the Pilot Inlet Cam [316] is in closed position, the Pilot Outlet Cam [314] is in open position allowing the pilot fluid behind the Main Valve [206] to escape through the Reverse Flow Check Valve [325] to join the main fluid flow. The Reverse Flow Check Valve [325] allows the pilot fluid to exit the Main Valve [206] thus allowing it to return to the rear position away from the Main Valve Orifice [204]. Without the Reverse Flow Check Valve [325] in the case when the fluid may flow backward in the tool, the incoming fluid coming up from the lower part of the tool would enter the Pilot Flow Outlet Channel [322], which is an opening closed by a check valve, and would push the Main Valve [206] forward into the Main Valve Orifice [204] and thus blocking the fluid flow in the reverse direction through the tool. To prevent such case, the Reverse Flow Check Valve [325] prevents the fluid flow coming up the tool from below from entering the Pilot Flow Outlet Channel [322] to cause the Main Valve [206] to close to stop the fluid flow. With the Reverse Flow Check Valve [325] in place the tool can allow reverse fluid flow through the tool, although not pulsing the fluid, but still operating in normal pulsing mode in forward flow condition. The frequency of opening and closing the Pilot Inlet and Pilot Outlet Cams [316, 314] determines the frequency of the Main Valve [206] closing and opening and creating pressure pulses in the main fluid column in front of the Main Valve Orifice [204].

Figure 4A shows the Electronics Section [128] of the tool located in the Pressure Housing [408] inside the upper pipe portion [120], is downstream of the Pulser Section [101] and before the Power unit or the battery Section [142]. The Electronics [404] control the Motor [130] and Pilot Shaft [304] rotation which drives the Main Valve [206] to create positive pressure pulses in the main fluid. The Electronics [404] not only control the Motor [130] but also collect continuous data from all sensors on board and auxiliary, and monitors power. Sensors may include temperature, fluid bore and annulus pressure, weight/axial force, torque, vibration, shock, gravity tool-face, casing collar locator, gamma, flow and others.

Figure 4B shows the Pressure Sensor Sub [411] and Weight Sensor Sub [415] of the Electronics Section [128]. The Pressure Sensor Sub [411] is directly connected to the Upper Pipe Portion [120] and also to the Electronics [404] inside the center of the concentric Pressure Housing [408]. The Weight Sensor Sub [415] is directly connected to the Pressure Sensor Sub [411] and the Lower Pipe Portion [140] below. The main fluid between the Upper Pipe Portion [120] and the Pressure Housing [408] continues into the Flow Through Channels [410] through the Pressure Sensor Sub [411] and the Weight Sensor Sub [415]. The Pressure Sensor Sub [411] houses the Bore Pressure Sensor [409] measuring the main fluid pressure inside the Tool [100] in front of the Pressure Sensor Sub [411]. The Annulus Pressure Sensor [413] measures the fluid pressure in the annulus, on the outside of the Upper Pipe Portion [120]. The Communication Port [412] is accessible from the outside of the Tool [100] and it is sealed to the fluid and pressure in the annulus (not shown). The Communication Port [412] allows programing of the Tool and downloading of memory data when the Tool [100] is assembled. The Pressure Sensor Sub [411] may also contain another Bore Pressure Sensor [409] downstream of the Flow Through Channels [410] to measure fluid flow.

The Weight Sensor Sub [415] houses the Weight and Torque Sensors [414] measure axial force and torque on the Tool [100]. The measurement of the torque is essential to monitor the performance of the down-hole motor [130] and its operation. The torque on the sub is created by the Lower Pipe Portion [140] below the Weight Sensor Sub [415] and the Upper Pipe

Portion [120] above the Pressure Sensor Sub [411]. Wiring from the Power unit or the battery Section [142] below and the wiring of the Weight Sensor Sub [415] run through the Pressure Sensor Sub [411] to the Electronics [404]. The main fluid flow goes through the Weight Sensor Sub [415] similar to the Pressure Sensor Sub [411], in the Flow Through Channels [410] between the outside wall of the Weight Sensor Sub [415] and the center concentric opening where the Weight and Torque Sensors [414] are located.

Figure 5 shows the lower end of the Power Unit or the Battery Section [142] of the Tool [100] which houses the Battery [502] and the Battery Switch [601]. The main fluid coming from the Weight Sensor Sub [415] above the Battery [502] flows between the Lower Pipe Portion [140] and the Battery Pressure Housing [603]. The fluid converges passed the Battery Switch Centralizer [608] to the center flow area of the Lower String Connection [150] where it exits the Tool [100] to the down-hole motor or BHA (not shown). The Battery Switch [601] holds the Battery [502] in the Battery Pressure Housing [603] and seals the Battery [502] from the main fluid. The Battery [502] is pressed against the Battery Switch Plunger [604] by the Battery Spring [503]. The Battery Switch Screw [606] allows a limited rotation in and out which moves the Battery Switch plunger [604]. This allows the Battery [502] to move to or away from the connection to the Weight Sensor Sub [415], thus connecting or disconnecting power to the Electronics Section [128]. When the Battery Switch Screw [606] is rotated in the forward position, the Battery Switch Plunger [604] pushes the Battery [502] forward to engage with the connector in the Weight Sensor Sub [415] and thereby powering the Tool [100] and the Electronics [404]. The Battery Switch [601] also has a safety feature built in by the Battery Switch Safety Lock [607]. When the Battery Switch Screw [606] is screwed in and the Battery [502] is engaged and powering the Electronics [404], the spring loaded Battery Switch Safety Lock [607] are pushed by springs in the way of the Battery Switch Screw [606] preventing it from accidentally unscrewing and allowing the Battery [502] to disengage during Tool [100] operation. A supplied special tool inserted through the center of the Battery Switch Centralizer [608] is required to push the Battery Switch Safety Lock [607] out of the way so the Battery Switch Screw [606] can be unscrewed to disengage the Battery [502]. When the Tool [100] is in operation, the Battery Switch Centralizer [608] prevents the Battery Pressure Housing [603] from radial vibration and holds the Tool [100] in compression in the axial direction from the Lower String Connection [150].

<u>WORKING EXAMPLE 1:</u>

Location: West Texas, USA
Application: Coil-frac
Well Depth (TVD): 11,000 ft. (3,350 m)
Lateral Length: 8,000 ft. (2,450 m)
Sliding Sleeves: 80

Figure 6 provides data on a well intervention simulation for CT. Pre-job modeling shows that RIH surface weight would not be sufficient to convey the coil to TD, indicating the need for an extended-reach tool. Figure 6A provides actual data on a CT operation with the Tool [100] of the present disclosure.

Results of the Tool [100] CT operation show that the TD was successfully reached without assistance from frac pumps tied into the annulus. A pound force measurement of 20,000 lbf (1 lbf = 4.448222 N) on surface weight was maintained, indicating the transfer of weight to BHA (as graphically shown in [680]), advancing across 80 sleeves to TD, as graphically shown in [690]. The operator concluded that an even deeper reach could have been achieved with the Tool.

WORKING EXAMPLE 2:

Location: North Dakota, USA
Application: Coil tubing
Well Depth (TVD): 11,000 ft. (3,350 m)
Lateral Length: 8,000 ft. (2,450 m)
Sliding Sleeves: 80

The Tool [100] provides a water hammer-style ER tool with a known and adjustable force setting which optimizes the lateral reach of the CT and more closely matches pre-run simulation models. The data telemetry of the Tool [100] system reduced risk and the thruster provides consistent axial pull for deeper, faster coiled tubing runs. Obtaining real-time downhole pulse amplitude data during extended reach operations is provided in Figure 7. The Tool [100] system allows the operator to know exactly what size force the tool will generate. The water hammer pulses of 1,000 psi generate an average of 4,000 lbf pull on the end of the CT string at BHA.

CLAIMS

We claim:

1. An apparatus that generates pressure pulses in a drilling fluid within a well bore that exists within a coiled tubing assembly, said apparatus comprising: a tool within which exists a valve portion longitudinally and axially positioned within a center portion of a main valve assembly, said assembly including a main valve, a main valve pressure chamber, and a main valve orifice with said main valve, such that as said drilling fluid flows downward along said well bore said drilling fluid splits into both an inlet main fluid stream and a pilot fluid stream, wherein said pilot fluid stream flows through a pilot flow annulus and into a pilot flow inlet channel, wherein said pilot fluid stream then flows into a main valve fluid feed channel until it reaches said main valve pressure chamber and through a pilot valve section that functions as a pulser generating portion of said tool that further comprises a pilot valve housing, a pilot shaft positioned in a central axial position within said tool supported by thrust bearings, a seal carrier, upper and lower rotary seals, and a pilot inlet cam and a pilot outlet cam such that said pilot shaft can rotate said pilot inlet cam and pilot outlet cam inside a pilot sleeve with matching orifices so that said pilot fluid stream is controlled by movement of said pilot inlet cam and said pilot outlet cam and wherein said pilot fluid stream fluid flows into and through a pilot flow outlet channel such that said pilot fluid stream fluid recombines with a main fluid flow to become a main exit fluid flow.

2. The tool of claim 1, wherein said upper and lower rotary seals exist within an oil filled pressure chamber and act to separate a portion of said pilot fluid stream fluid above or in front of said upper rotary seal from a portion exposed to atmospheric pressure that exists below or behind said lower rotary seal so that a drive shaft, a motor, and additional sections below said upper and lower rotary seals prevent pilot fluid stream fluid from entering and damaging said motor and associated electronics.

3. The tool of claim 1, wherein said pilot shaft is rotated by an electrical motor which is connected to said drive shaft and wherein said pilot inlet cam and said pilot outlet cam are positioned on said shaft so that both cams can rotate and so that when said pilot inlet cam is in an open position it allows said pilot fluid stream fluid to enter said main valve and simultaneously said pilot outlet cam maintains a closed position that prevents said pilot fluid stream fluid to exit through a reverse flow check valve.

4. The reverse flow check valve of claim 3, wherein said reverse flow check valve allows reverse fluid flow through said tool.

5. The reverse check valve and reverse fluid flow of claim 4, wherein resultant reverse fluid flow is does not cause pulsing of fluid while operation of a normal pulsing mode exists during a forward flow condition.

6. The tool of claim 1, wherein a frequency of opening and closing of a pilot inlet cam and a pilot outlet cam directly influences and determines one or more frequencies of said main valve opening and closing to create pressure pulses in a main fluid column above or in front of said main valve orifice.

7. The pilot flow check valve of claim 3, wherein upon a controlled signal said motor rotates said pilot shaft to position said pilot inlet cam to open and closed positions and wherein when said pilot inlet cam is a closed position said pilot outlet cam is in an open position said pilot fluid stream fluid behind or below said main valve to allowed escape through said reverse flow check valve and to join said main fluid flow.

8. The pilot flow check valve of claim 7, wherein said reverse flow check valve allows pilot fluid stream fluid to exit said main valve so that said pilot fluid stream fluid can return to a rear or lower position with respect to said main valve orifice.

9. The reverse flow check valve and reverse fluid flow of claim 5, wherein said check valve prevents fluid flow back into said tool by not allowing fluid to enter said pilot flow outlet channel which ensures blockage of fluid flow in a reverse direction through said tool and also allows closure of said main valve, thereby stopping further fluid flow.

10. The tool of claim 1, wherein a coupling mechanism toward a motor housing and wherein one or more annular pressure sensors measuring a pressure of flowing fluid is located inside a sensor sub assembly with sensors that send signals to a Digital Signal Processor (DSP) that controls tools and multiple sensors in real time while continuing to generate controllable, large, measurable, rapid energy pulses, improvement of weight on bit and an ability to time drill plugs allows for generation of small cuttings that are easily removed from downhole

and also adjustment of pulse amplitude at any time without removing said tool from any coiled tubing downhole completion and/or drilling applications.

11. A system that generates pressure pulses in a drilling fluid within a well bore that exists within a coiled tubing assembly, said system comprising: a tool within which exists a valve portion longitudinally and axially positioned within a center portion of a main valve assembly, said assembly including a main valve, a main valve pressure chamber, and a main valve orifice with said main valve, such that as said drilling fluid flows downward along said well bore said drilling fluid splits into both an inlet main fluid stream and a pilot fluid stream, wherein said pilot fluid stream flows through a pilot flow annulus and into a pilot flow inlet channel, wherein said pilot fluid stream then flows into a main valve fluid feed channel until it reaches said main valve pressure chamber and through a pilot valve section that functions as a pulser generating portion of said tool that further comprises a pilot valve housing, a pilot shaft positioned in a central axial position within said tool supported by thrust bearings, a seal carrier, upper and lower rotary seals, and a pilot inlet cam and a pilot outlet cam such that said pilot shaft can rotate said pilot inlet cam and pilot outlet cam inside a pilot sleeve with matching orifices so that said pilot fluid stream is controlled by movement of said pilot inlet cam and said pilot outlet cam and wherein said pilot fluid stream fluid flows into and through a pilot flow outlet channel such that said pilot fluid stream fluid recombines with a main fluid flow to become a main exit fluid flow.

12. A method for generating pressure pulses in a drilling fluid within a well bore that exists within a coiled tubing assembly, said method comprising: a tool within which exists a valve portion longitudinally and axially positioned within a center portion of a main valve assembly, said assembly including a main valve, a main valve pressure chamber, and a main valve orifice with said main valve, such that as said drilling fluid flows is flowing downward along said well bore said drilling fluid splitting into both an inlet main fluid stream and a pilot fluid stream, wherein said pilot fluid stream is flowing through a pilot flow annulus and into a pilot flow inlet channel, wherein said pilot fluid stream then continues to flow into a main valve fluid feed channel until it reaches said main valve pressure chamber and continues through a pilot valve section that functions as a pulser generating portion of said tool further comprising a pilot valve housing, a pilot shaft positioned in a central axial position within said tool supported by thrust bearings, a seal carrier, upper and lower rotary seals, and a pilot inlet cam and a pilot outlet cam such that said pilot shaft can be rotating said pilot inlet cam

and pilot outlet cam inside a pilot sleeve with matching orifices so that said pilot fluid stream is being controlled by movement of said pilot inlet cam and said pilot outlet cam and wherein said pilot fluid stream fluid continues flowing into and through a pilot flow outlet channel such that said pilot fluid stream fluid recombines with a main fluid flow for becoming a main exit fluid flow.

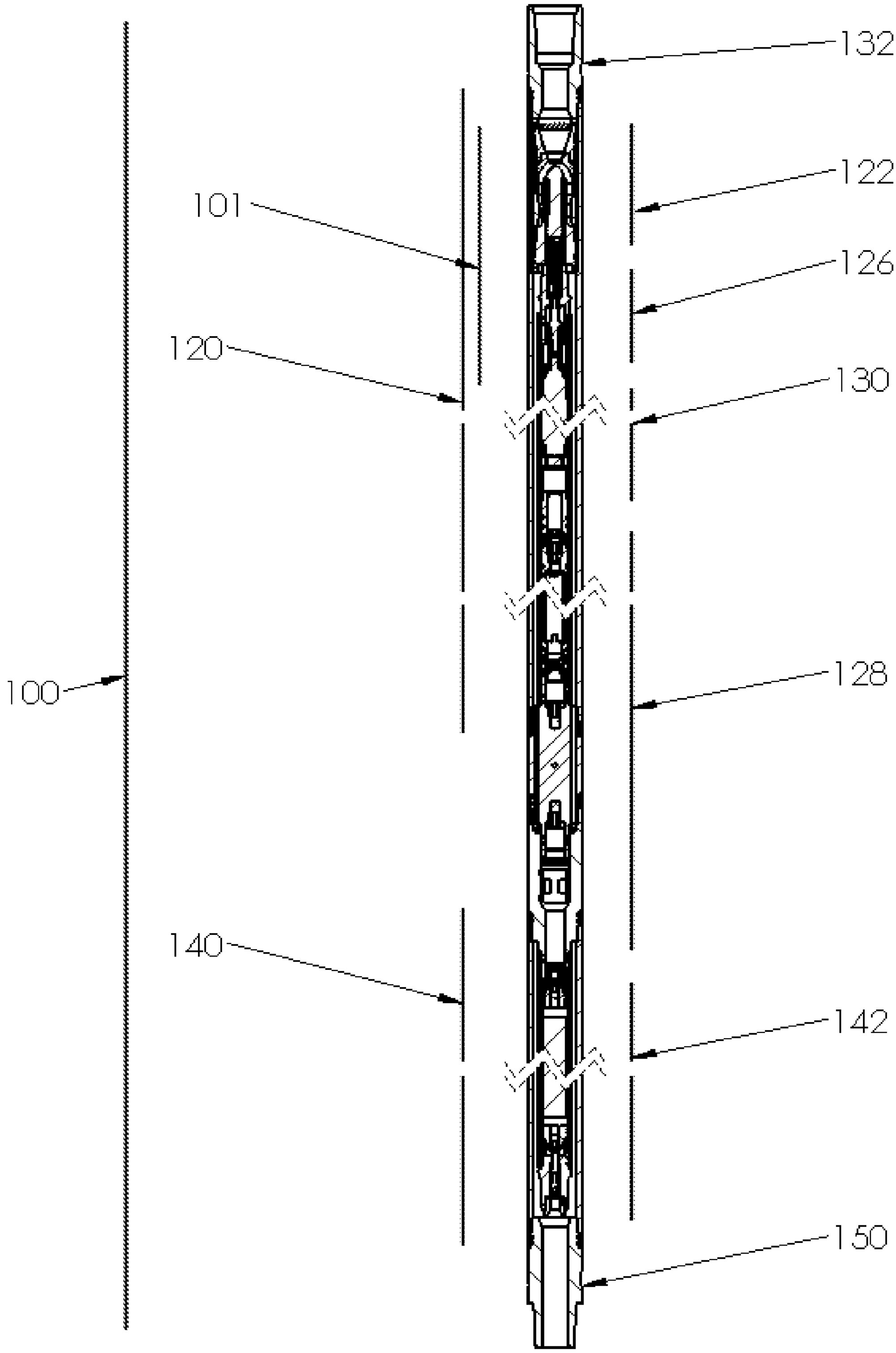


FIG. 1

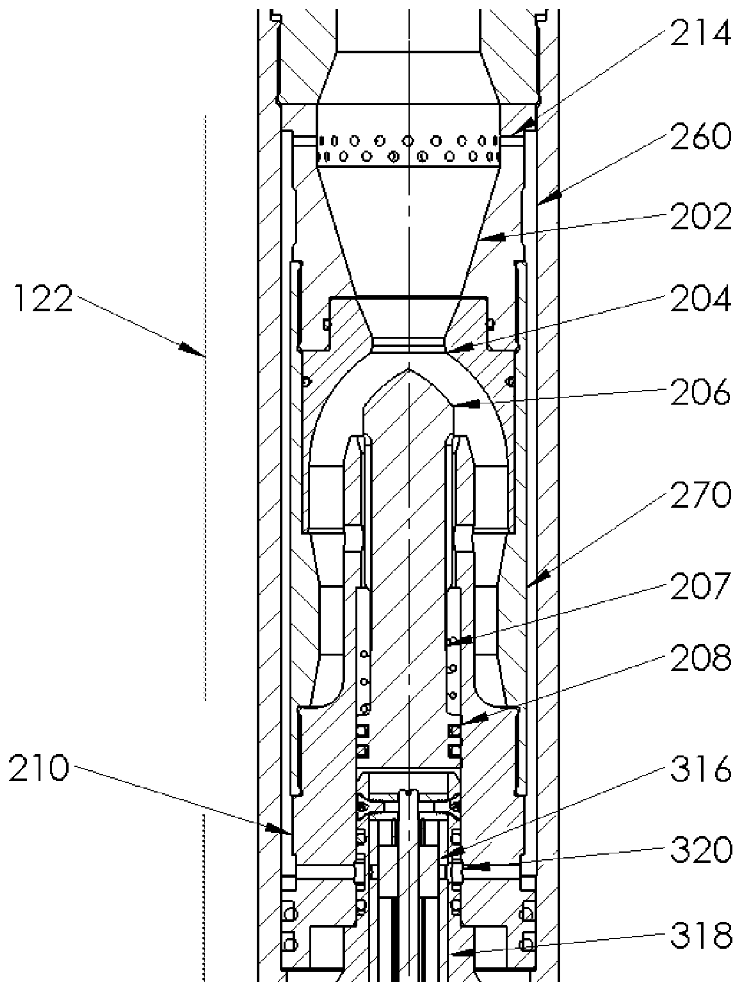


FIG. 2

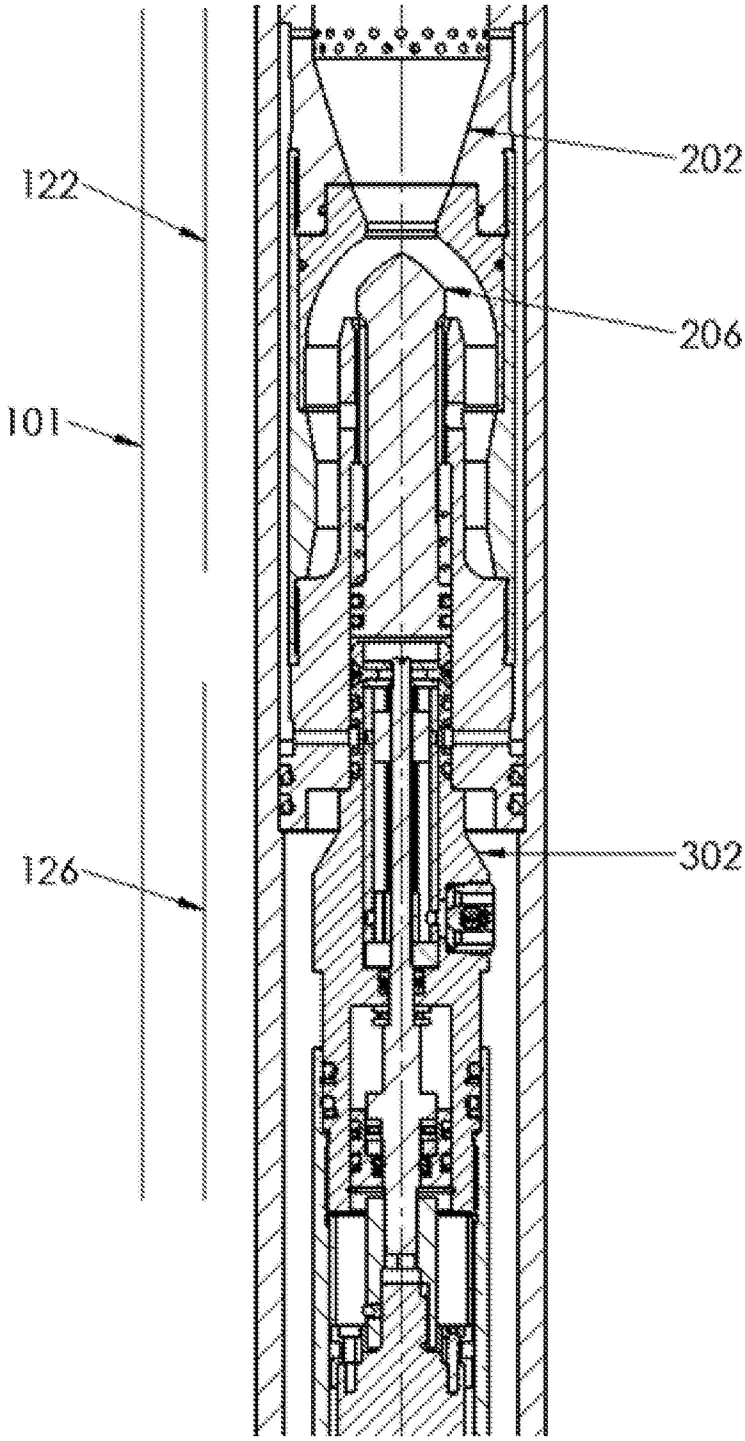


FIG. 3A

5

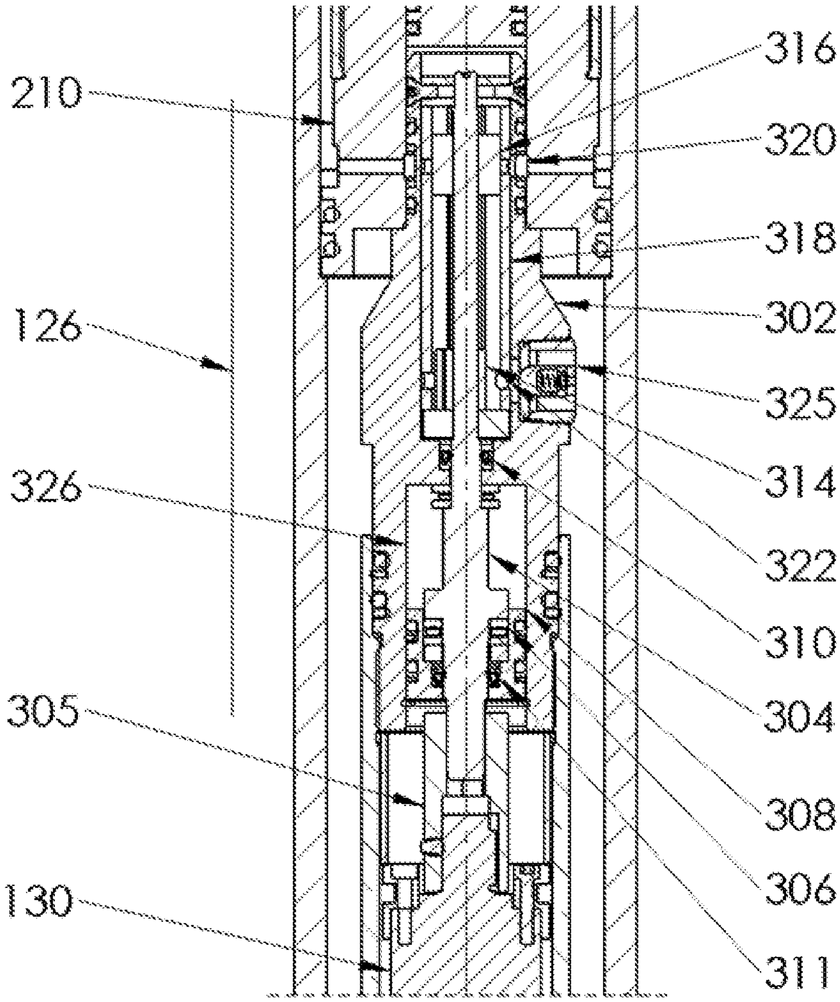

210
126
326
305
130
316
320
318
302
325
314
322
310
304
308
306
311

FIG. 3B

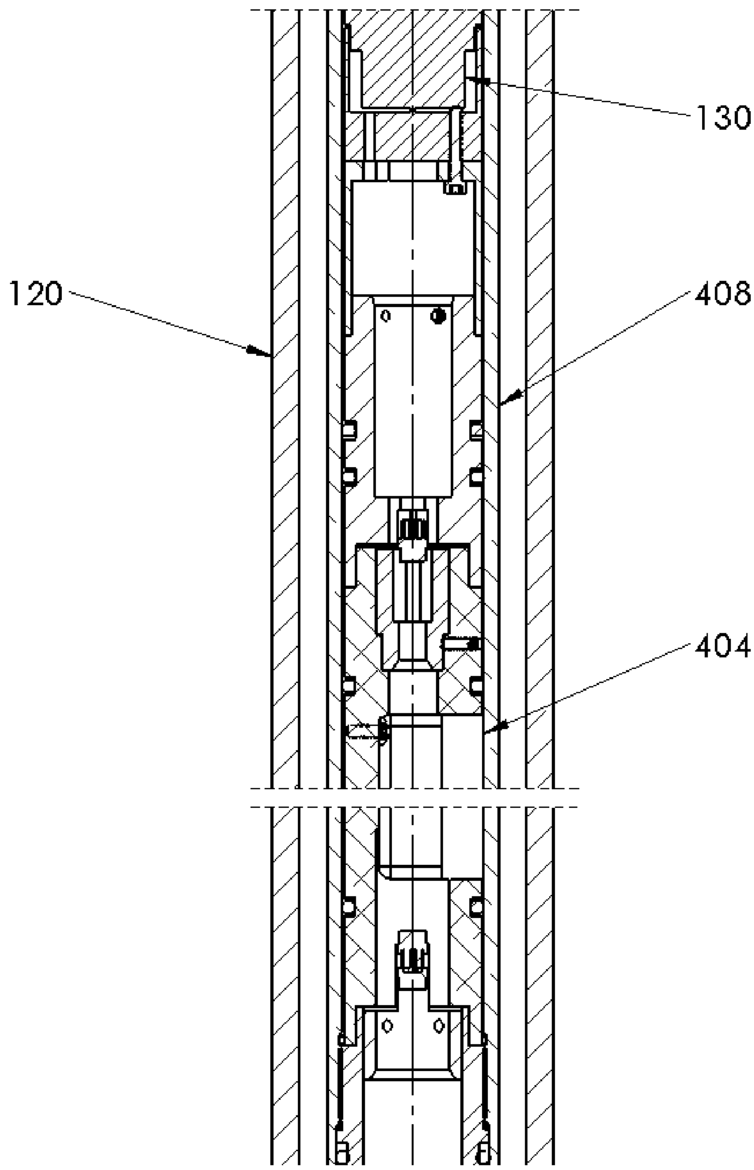


FIG. 4A

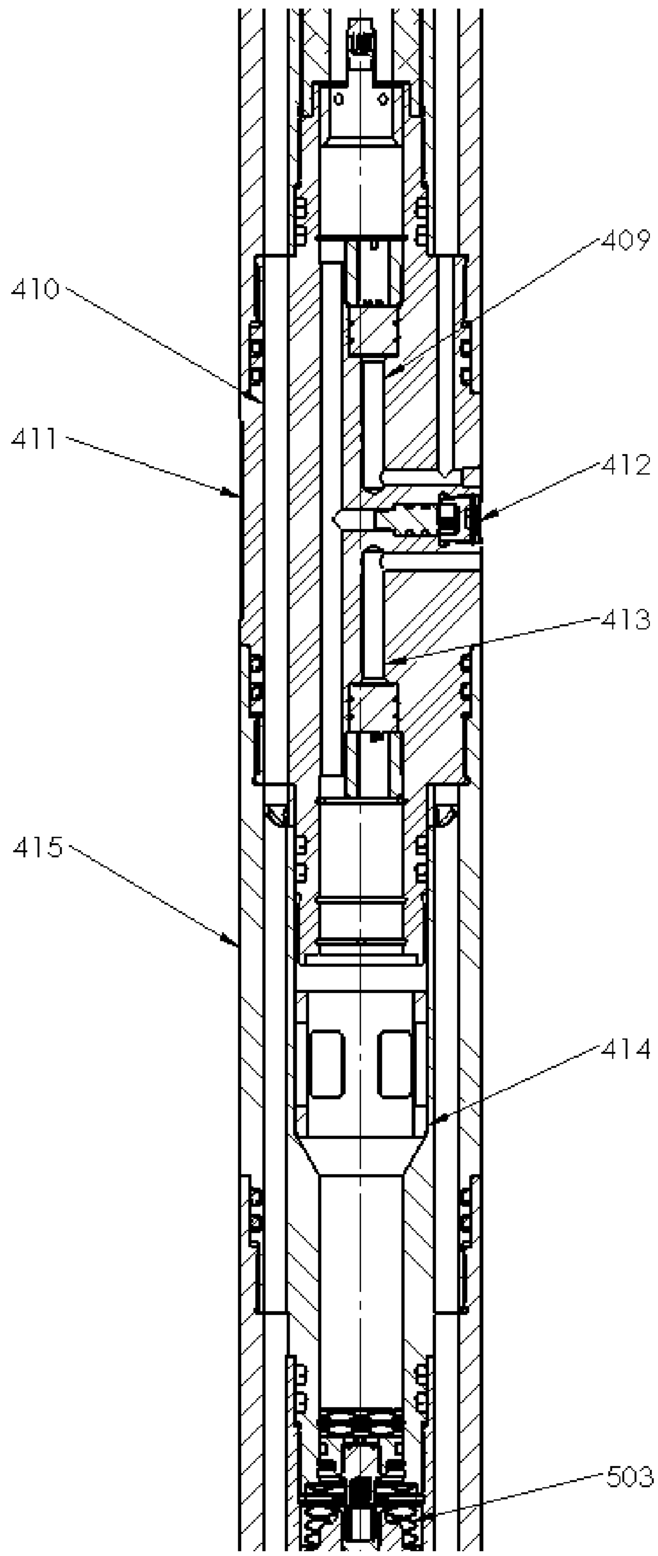


FIG. 4B

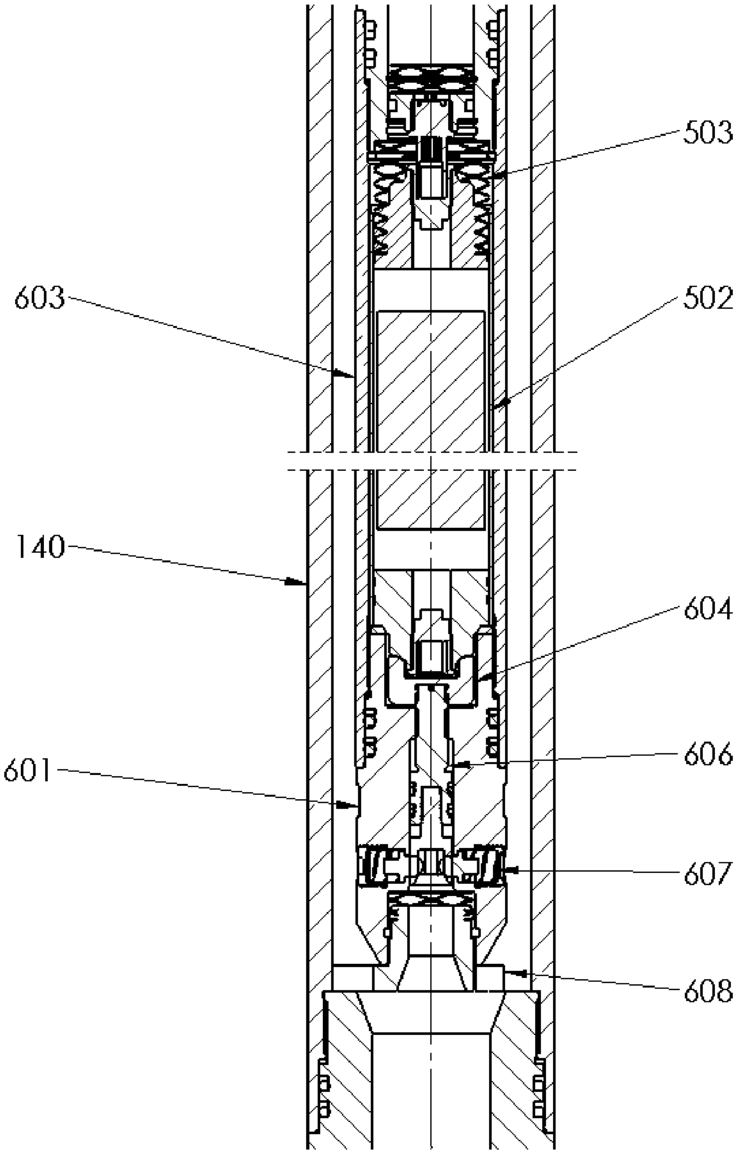


FIG. 5

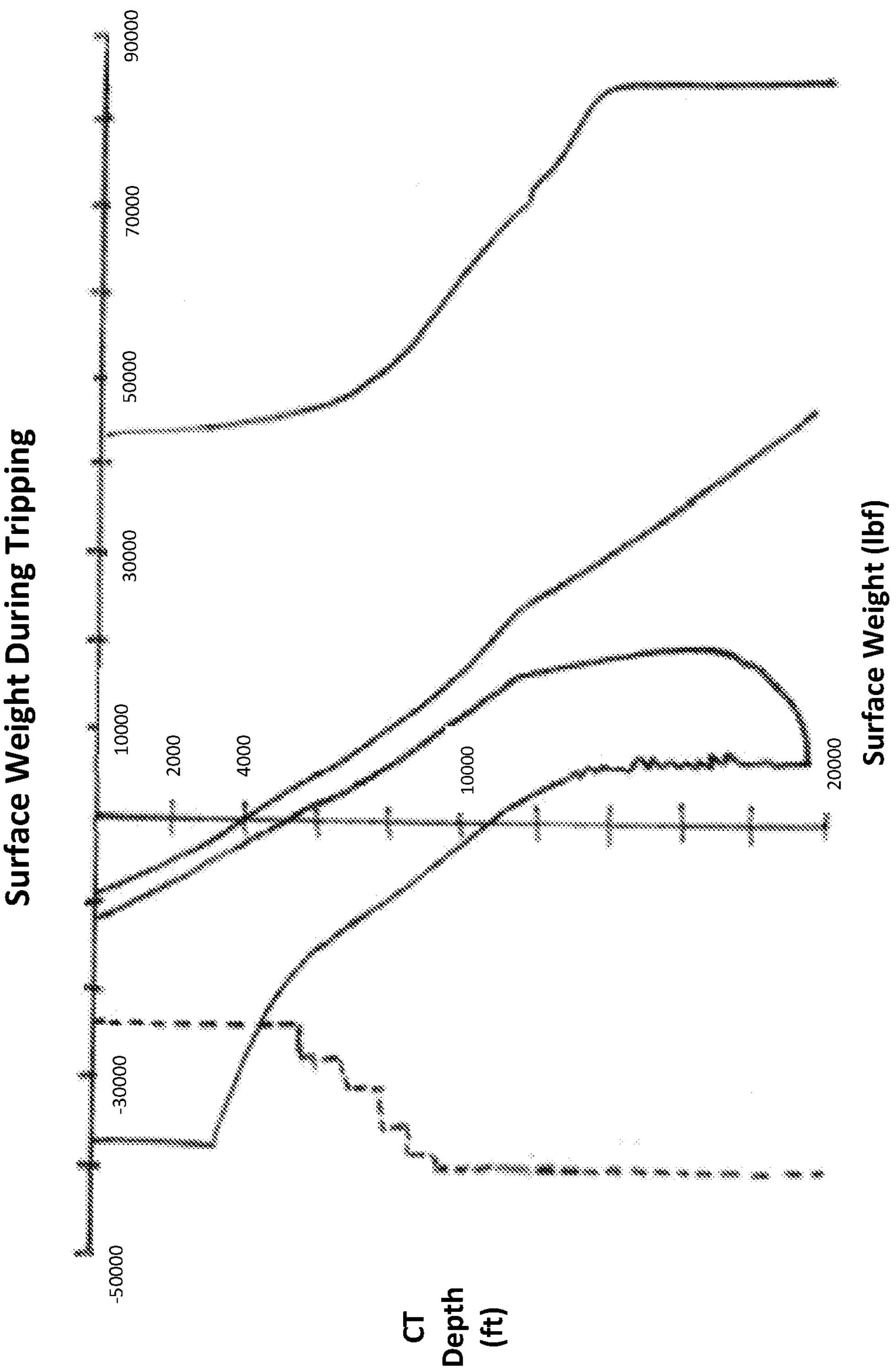
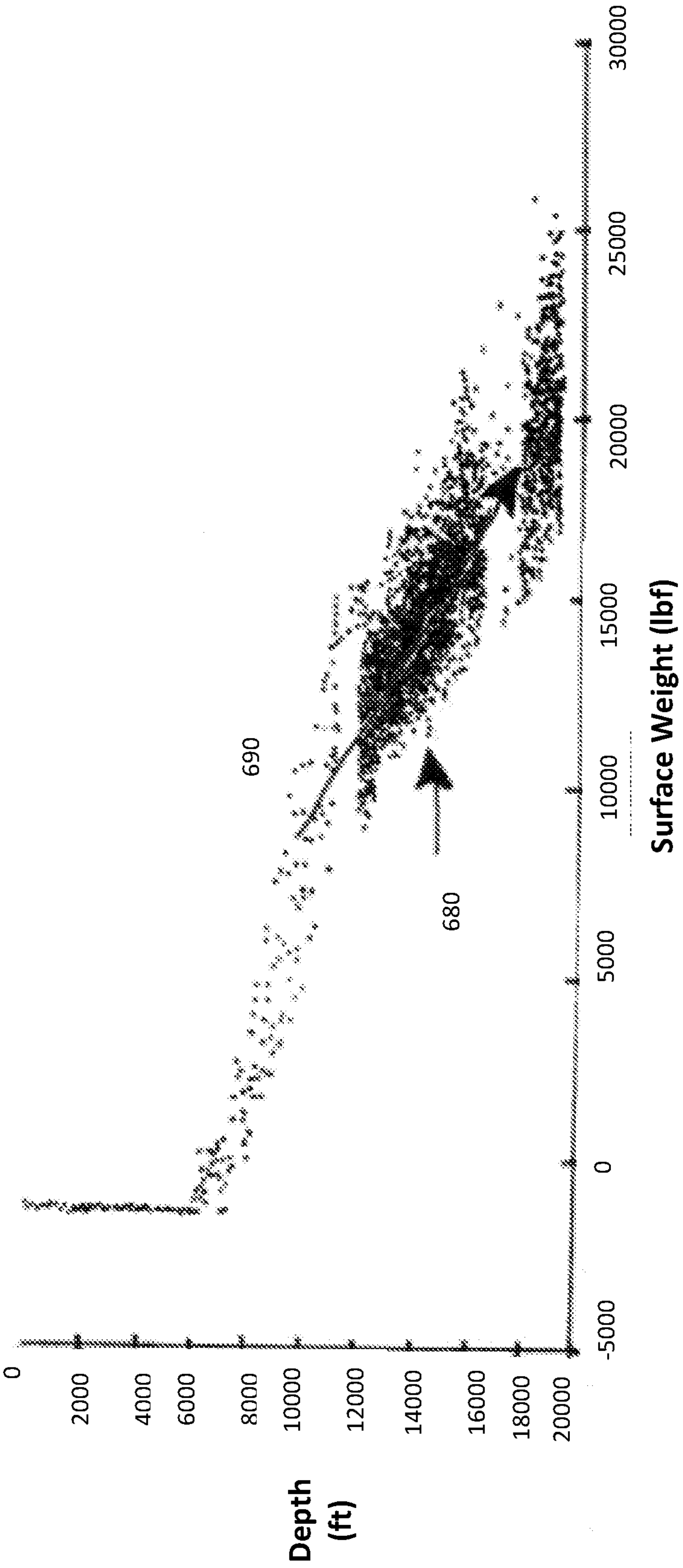

Surface Weight During Tripping
-50000
-30000
10000
30000
50000
70000
90000
2000
4000
10000
20000
Surface Weight (lbf)
CT
Depth
(ft)

FIG. 6



Depth (ft)
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
-5000
0
5000
10000
15000
20000
25000
30000
Surface Weight (lbf)
690
680

FIG. 6A

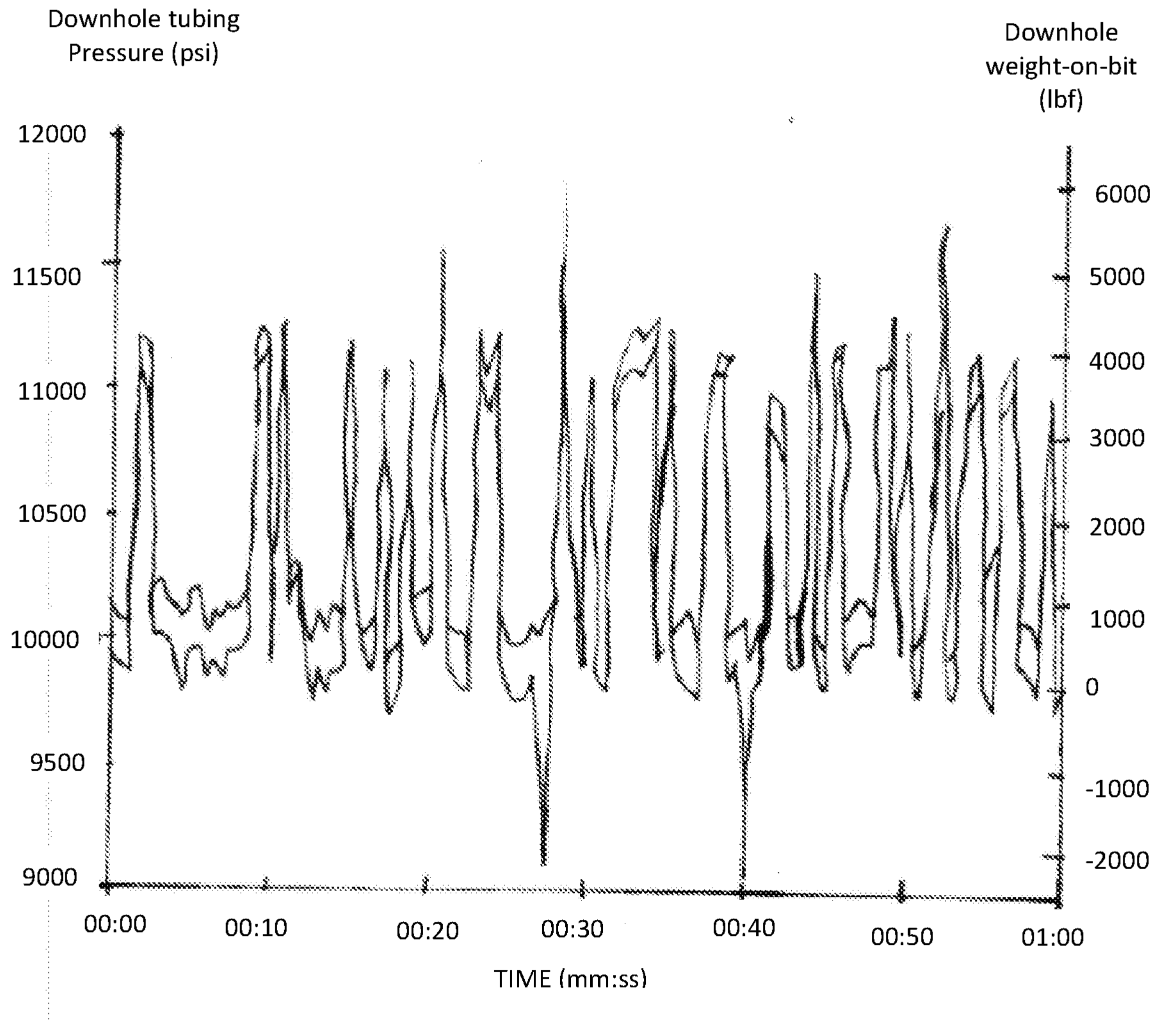

Downhole tubing Pressure (psi)
Downhole weight-on-bit (lbf)
12000
11500
11000
10500
10000
9500
9000
6000
5000
4000
3000
2000
1000
0
-1000
-2000
00:00
00:10
00:20
00:30
00:40
00:50
01:00
TIME (mm:ss)

FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 2018/053735

A. CLASSIFICATION OF SUBJECT MATTER

E21B 47/20 *(2012.01)*

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

E21B47/00, E21B47/06, E21B47/12, E21B47/14, E21B47/18, E21B47/20, E21B47/22, E21B47/24, H04B1/00, H04B13/00, H04B13/02

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

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

RUPTO, PatSearch, DWPI, Espasenet

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2015/300153 A1 (TELEDRILL INC.,) 22.10.2015, abstract, [0005]-[0012], [0046]-[0053]	1, 6, 10-12
Y		2-5, 7-9
Y	US 2009/133930 A1 (SCHLUMBERGER TECHNOLOGY CORP.) 28.05.2009, [0024], [0028]	2, 3, 7, 8
Y	US 2016/0215590 A1 (NCS MULTISTAGE INC.,) 28.07.2016, [0107], [0124]-[0126]	4, 5, 9

☐ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

* Special categories of cited documents:

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

“E” earlier document but published on or after the international filing date

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

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

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

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

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

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

“&” document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
17 January 2019 (17.01.2019)	24 January 2019 (24.01.2019)

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