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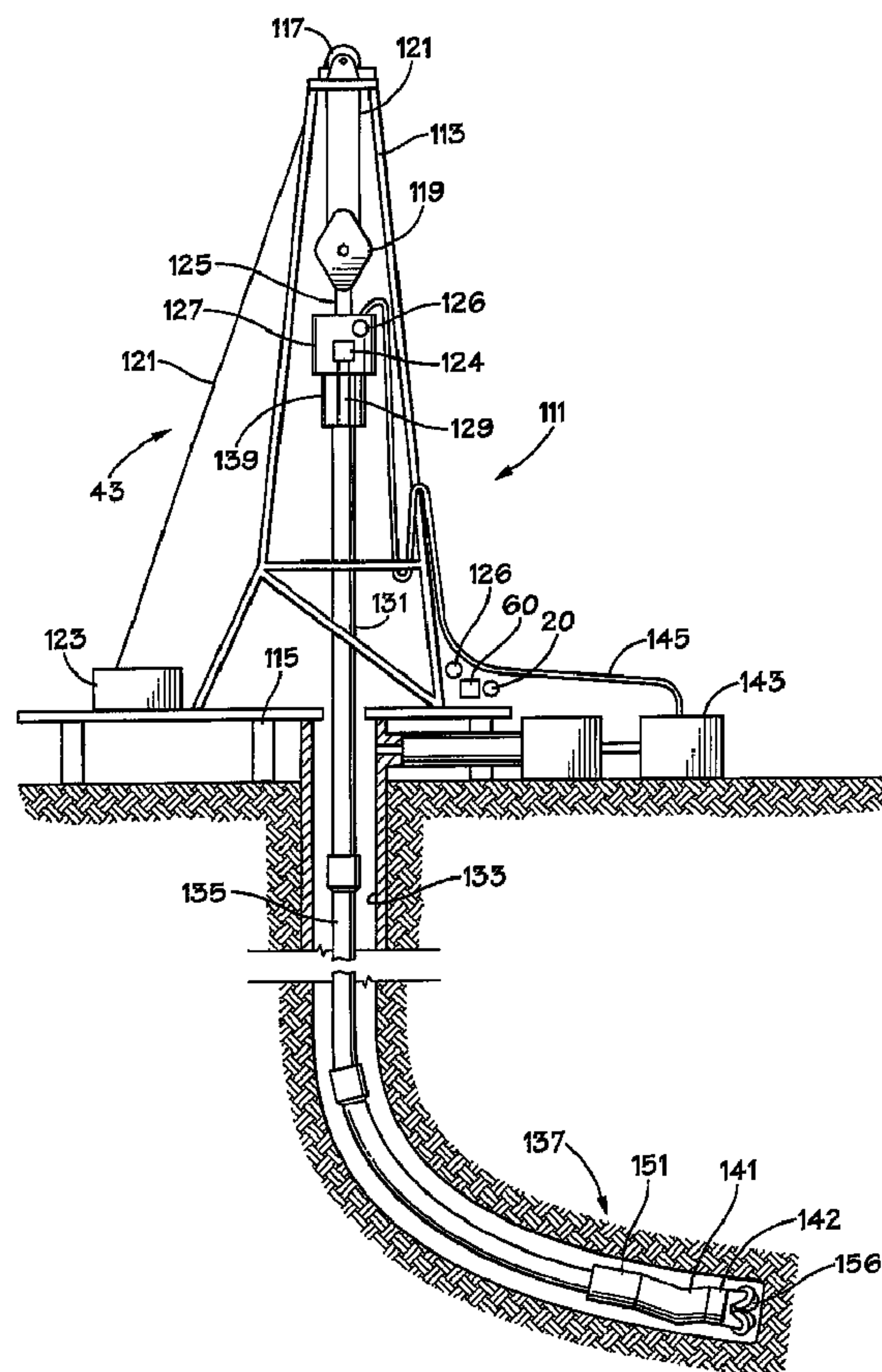
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A method of oscillating a drill string (135), which method comprises the steps of : (a) rotating said drill string (135) in a first direction until a first limit is reached; and (b) rotating said drill string (135) in a second direction until a second limit is reached; characterised in that said first and second limits are based upon the amount of energy expended during rotation .

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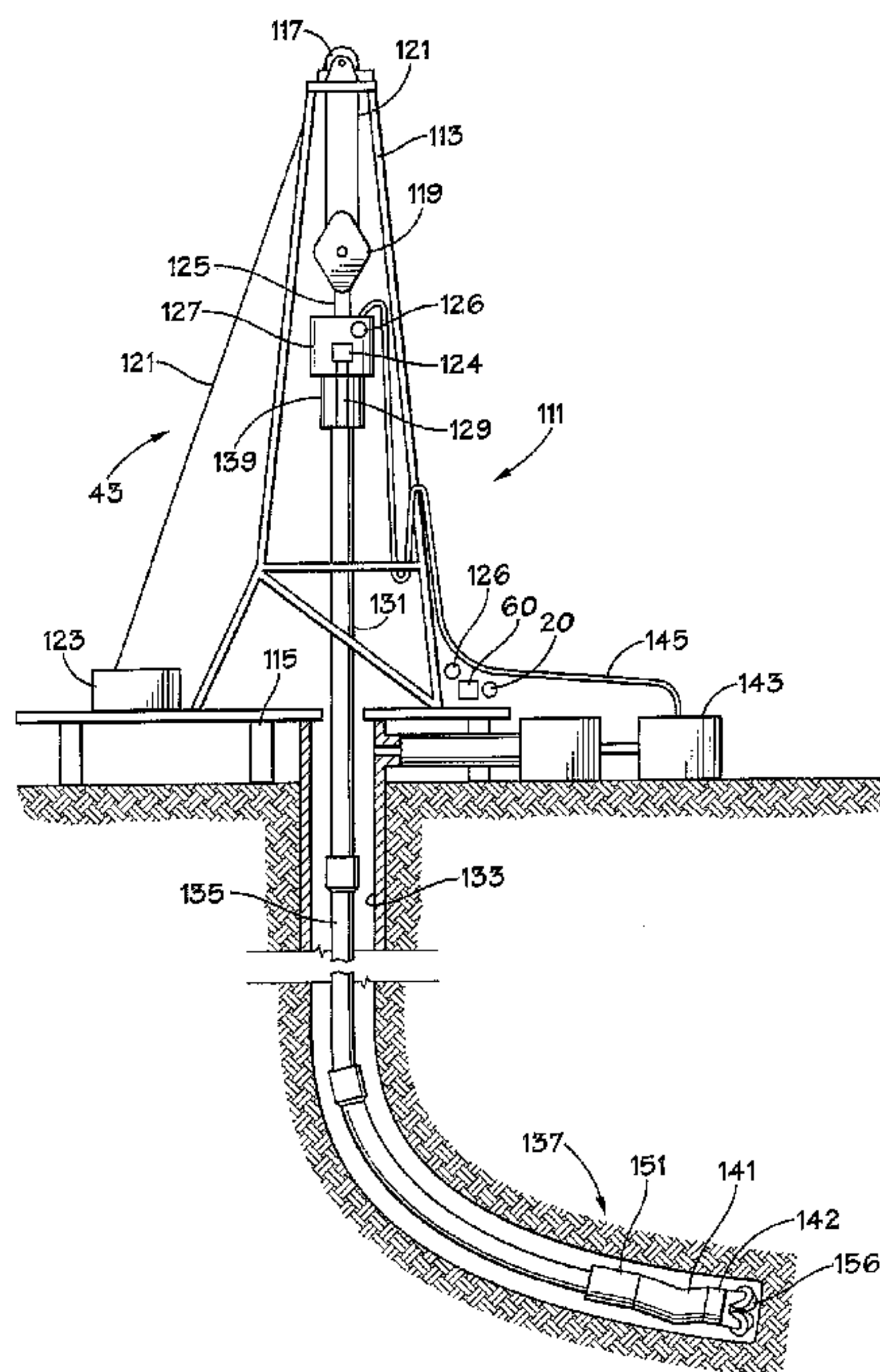
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(54) Title: METHOD AND APPARATUS FOR OSCILLATING A DRILL STRING



(57) Abstract: A method of oscillating a drill string (135), which method comprises the steps of: (a) rotating said drill string (135) in a first direction until a first limit is reached; and (b) rotating said drill string (135) in a second direction until a second limit is reached; characterised in that said first and second limits are based upon the amount of energy expended during rotation.

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Method and Apparatus for Oscillating a Drill String

The present invention relates to a method for oscillating a drill string, to a method of directional drilling, to an apparatus for performing the oscillation method, and to a driller's cabin comprising the apparatus.

In directional drilling target formations may be spaced laterally thousands of feet from a well's surface location requiring penetration to depth and also laterally through soil, rock, and formations. The bit is rotated by a mud motor located downhole near to the bit.

In directional drilling a substantial length of the drill string is in frictional contact with and supported by the borehole. Since the drill string is not rotating, it is difficult to overcome the friction. Problems in overcoming the friction makes it difficult for the driller to apply sufficient weight to the bit to achieve an optimal rate of penetration. The drill string exhibits stick/slip friction such that when a sufficient amount of weight is applied to overcome the friction, the weight on bit tends to overshoot the optimum magnitude.

The mud motor produces a reactive torque on the drill string. In some circumstances the reactive torque that would be transmitted from the bit to the surface through drill string, if the hole were straight, is absorbed by the friction between the drill string and the borehole. In other circumstances (e.g. if the horizontal or non-vertical section is short) some or all of the reactive torque may reach the surface. Thus, during drilling, there may or may not be a reactive torque at the surface. The presence or otherwise of such reactive torque can complicate overcoming of the friction between the drill string and the borehole.

One of the challenges for directional drilling is preventing the horizontal portions of the string from

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binding with the surrounding rock formation and reducing sliding friction as the bit progresses through the formation. To do this it is desirable to keep as much of the horizontal portion of the string moving as fast as possible without affecting or changing the bit face orientation. The process of rotating the string alternating in direction without moving the bit is known in the art as "wagging the dog."

In one prior method the frictional engagement between the drill string and the borehole is reduced by rocking the drill string back and forth between a first angle and a second angle. By rocking the string, the stick/slip friction is reduced, thereby making it easier for the driller to control the weight on bit and make appropriate face angle corrections. In another prior method a motor's shaft is rotated at a fixed speed for a specified time in each direction, effectively rotating the shaft a fixed distance. However, one problem with both of these methods is that, as the drill string gets longer, it becomes increasingly difficult to determine accurately the number of turns (or analogously the fixed speed and time) required to move rotate the drill string, but not the bit.

Another prior method reduces the friction between the drill string and the well bore by rocking the drill string back and forth between first and second torque magnitudes. A downhole drilling motor is connected to the surface by a drill string. The drilling motor is oriented at a selected tool face angle. The drill string is rotated at the surface location in a first direction until a first torque magnitude is reached, without changing the tool face angle. The drill string is then rotated in the opposite direction until a second torque magnitude is reached, again without changing the tool face angle. However, the accuracy of this method is

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greatly reduced when the reactive torque from the mud motor reaches the surface i.e. is not absorbed by friction
5 between the horizontal section of the drill string and the borehole. In that case, there is a torque bias at the surface and rotation of the drill string in one sense is helped by the torque from the mud motor. This leads to a constant torque output from the drilling motor at the
10 surface and so the torque limit is not reached resulting in unwanted re-orientation of the bit. Rotation in the other sense is against the torque bias and results in the torque limit being reached prematurely.

There is a need for an improved method of rocking or
15 oscillating a drill string in which the aforementioned disadvantages are mitigated.

According to the present invention there is provided a method of oscillating or rocking a drill string, which method comprises the steps of:

20 (a) rotating said drill string in a first direction until a first limit is reached; and

(b) rotating said drill string in a second direction until a second limit is reached;

characterised in that said first and second limits
25 are based upon the amount of energy expended during rotation. The energy expended may be in terms of that by a motor at the surface acting on the drill string, or by the drill string on the motor).

According to another aspect of the present invention
30 there is provided an apparatus for oscillating or rocking a drill string, which apparatus comprises a controller connectable to a motive apparatus for rotating said drill string, said controller comprising a memory storing computer executable instructions for performing the

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method steps set out above.

According to another aspect of the invention there is provided a driller's cabin comprising an apparatus as aforesaid. The apparatus may be installed in the cabin
5 either at point of manufacture or may be retrofit in existing cabins. In one aspect a controller (e.g. computer) in a driller's cabin may have software installed (e.g. from a remote location via satellite link, or on site) to enable it to control and perform the
10 functions described herein.

The present invention discloses, in certain aspects, systems and methods for moving a bit efficiently and effectively through a formation while inhibiting or preventing binding of the drill string on the formation
15 and maintaining a desired bit face orientation during drilling. In certain aspects, such systems and methods reduce sliding friction of the drill string with respect to the formation.

The present invention, in certain aspects, discloses
20 a method for oscillating a drill string, the drill string extending into the earth, the drill string having a drill bit on a lower end thereof, the drill string connected to a motive apparatus (e.g. a rotary system, power swivel, top drive system) for rotating the drill string, the
25 motive apparatus having a power output associated with rotating the drill string, the method including: determining a first amount of energy and a second amount of energy (of different or equal values), said determining based on the power output of the motive
30 apparatus; applying the first amount of energy to the drill string in a first rotational direction; applying the second amount of energy to the drilling in a second rotational direction, the second rotational direction opposite to the first rotational direction; and the
35 application of both the first amount of energy and the

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second amount of energy not moving the bit.

In certain embodiments of the present invention a system is provided for moving a drill string, particular non-vertical portions of a drill string, through a formation by imparting a certain desired amount of energy to the string with a top drive motor, with a rotary table, or with a power swivel to rotate the string in a first direction and then imparting a certain desired amount of energy to the string to rotate it in an opposite second direction, thereby reducing sliding friction of the string and binding of the string on the formation. As needed, continuous oscillation in one direction then the other is repeated.

The present invention, in certain aspects, discloses a system for cyclically rotating a drill string, the drill string having a bit at a lower end of a drill string, the system including: motive apparatus for rotating a drill string and a bit, the bit connected to an end of the drill string, the drill string in a wellbore, the wellbore extending from an earth surface into the earth, the bit at a location beneath the earth surface; a control system in communication with the motive apparatus, the control system for controlling the motive apparatus to rotate the drill string in a first rotational direction applying a first amount of energy to the drill string and then in a second rotational direction applying a second amount of energy to the drill string; and said amounts of energy applied to the drill string without moving the bit.

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For a better understanding of the present invention, reference will now be made, by way of example only, to the accompanying drawings, in which:

Fig. 1 is a schematic side view, partly in cross section, of a drilling rig comprising an apparatus according to the present invention;

Fig. 2 is a schematic block diagram of an apparatus according to the present invention and relevant parts of the drilling rig of Fig. 1;

Fig. 3 is a flow diagram of operation of the apparatus of Fig. 2; and

Fig. 4 is a schematic front view of an operator touch screen employed to operate the control apparatus of Figs. 1 and 2.

Referring now to Fig. 1, a drilling rig 111 is depicted schematically as a land rig, but other rigs (e.g., offshore rigs, jack up rigs, semi-submersibles, drill ships, and the like) are within the scope of the present invention. In conjunction with an operator interface, e.g. an interface 20, a control system 60 as described below controls certain operations of the rig. The rig 111 includes a derrick 113 that is supported on the ground above a rig floor 115. The rig 111 includes lifting gear, which includes a crown block 117 mounted to derrick 113 and a travelling block 119. A crown block 117 and a travelling block 119 are interconnected by a cable 121 that is driven by drawworks 123 to control the upward and downward movement of the travelling block 119. Travelling block 119 carries a hook 125 from which is suspended a top drive system 127 which includes a variable frequency drive controller 126, a motor (or motors) 124 and a drive shaft 129. The top drive system 127 rotates a drill string 131 to which the drive shaft 129 is connected in a wellbore 133. The top drive system 127 can be operated to rotate the drill string 131 in

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either direction. According to an embodiment of the present invention, the drill string 131 is coupled to the top drive system 127 through an instrumented sub 139 which includes sensors that provide information, e.g.,
5 drill string torque information.

The drill string 131 may be any typical drill string and, in one aspect, includes a plurality of interconnected sections of drill pipe 135 a bottom hole assembly (BHA) 137, which includes stabilizers, drill
10 collars, and/or an apparatus or device, in one aspect, a suite of measurement while drilling (MWD) instruments including a steering tool 151 to provide bit face angle information. Optionally a bent sub 141 is used with a downhole or mud motor 142 and a bit 156, connected to the
15 BHA 137. As is well known, the face angle of the bit 156 is controlled in azimuth and pitch during drilling.

Drilling fluid is delivered to the drill string 131 by mud pumps 143 through a mud hose 145. During rotary drilling, drill string 131 is rotated within bore hole
20 133 by the top drive system 127 which, in one aspect, is slidably mounted on parallel vertically extending rails (not shown) to resist rotation as torque is applied to the drill string 131. During sliding drilling, the drill string 131 is held in place by top drive system 127 while
25 the bit 156 is rotated by the mud motor 142, which is supplied with drilling fluid by the mud pumps 143. The driller can operate top drive system 127 to change the face angle of the bit 156.

Although a top drive rig is illustrated, it is
30 within the scope of the present invention for the present invention to be used in connection with systems in which a rotary table and kelly are used to apply torque to the drill string.

The cuttings produced as the bit drills into the
35 earth are carried out of bore hole 133 by drilling mud

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supplied by the mud pumps 143.

As shown in Fig. 2, a system 10 according to the present invention has an operator interface 20 (e.g., but not limited to, a driller's console and/or one, two, 5 three or more touch screens and/or joystick(s), slider (s) or knob(s) with an optional adjustable encoder 30 for rotating a main shaft 41 of a top drive system 40 (like the system 127, Fig. 1). The adjustable encoder 30 has adjustable apparatus 31 (e.g. a rotatable knob or a 10 movable slider), which, when moved or rotated by the driller or other personnel results in a corresponding movement of the main shaft 41 (like the shaft 129, Fig. 1) of the top drive system 40 and, therefore, of the drill string and attached bit (as in Fig. 1).

15 Control software 50 in a programmable medium of the control system 60, e.g., but not limited to, one, two, three or more on-site, or remote computers, PLC's, single board computer(s), CPU(s), finite state machine(s), microcontroller(s), controls the movement of the main 20 shaft 41 in response to the movement of the adjustable apparatus 31 (e.g. at a driller's console) so that the main shaft 41 is not moved too quickly and so that it and a drill string 62 (like the drill string 131, Fig. 1) and a bit 70 connected thereto (like the bit 156, Fig. 1) are 25 moved smoothly with a smoothly decreasing deceleration as a movement end point is approached. "On-site" may include e.g., but is not limited to, in a driller's cabin and/or in a control room or building adjacent a rig.

A motor 42 of the top drive system 40 rotates the 30 main shaft 41 (which is connected to the drill string 62) with the drill bit 70 at its end. A VFD controller 80 (like the controller 126, Fig. 1) controls the motor 42. A position encoder 43 (located adjacent the top drive motor) sends a signal indicative of the actual position 35 of the main shaft 41 to the VFD controller 80 and to the

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control system 60 where it is an input value for the control software 50.

From the operator interface 20, pre-selected limiting values for main shaft speed ("speed limit");
5 main shaft torque ("torque limit"); and a desired bit position or "Position Set Point" are input to the control system's control software 50. The control system 60 provides status data to the operator interface 20 which includes speed, torque, shaft orientation, and position
10 of the apparatus 31.

The control software 50 sends commands to the VFD controller 80 which include speed commands and torque commands (torque limit). The VFD controller 80 provides feedback to the control software 50 which includes values
15 for actual speed of the main shaft 41 and the actual torque (the torque applied to the drill string by the top drive motor).

Fig. 3 illustrates functioning of the system 10.

As shown in Fig. 3, the control system 60 then
20 adjusts the speed of the top drive motor and controls the torque applied to the drill string so that the main shaft of the top drive stops at a desired point. The control system conveys to the control software data values (e.g. fifty per second) for the amount of torque actually
25 applied to the string; and, regarding actual speed, the amount of actual rotation of the string (in degrees or radians). The position encoder 43 has provided position information and velocity information to the VFD controller 80. The control software 50 receives
30 information regarding position from the encoder 43 and/or from the VFD controller 80 or, optionally, through a direct input/output apparatus (e.g. an I/O device in communication with the encoder) controlled by the software 50. The VFD controller 80 constantly uses the
35 position from the encoder 43 to control outputs of the

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top drive motor to achieve the desired commanded speed and to maintain torque within the torque limit imposed by the control software 50.

5 The operator using the operator controls on the control interface 20 inputs to the VFD controller 80 a limitation on the torque that is to be applied to the string ("Torque Limit") and a limitation on the speed at which the main shaft 41 of the top drive system 40 is to be rotated ("Speed Limit").

10 Using the Speed Limit, the actual position of the main shaft, the last speed at which the main drive shaft was rotating ("Last Speed"), the speed commanded by the control system 60 to the VFD controller 80 from the previous control iteration), the maximum allowable
15 acceleration ("Max Accel"), and the cycle time for sending speed commands to the VFD controller 80 (cycle time is provided by a hardware clock, a clock in a CPU, or a clock in the control system 60), the control software 50 calculates a speed command ("Speed Command")
20 which is sent to the VFD controller 80 which, in turn, controls the rotation of the main shaft 41 so that the drill string is rotated at the desired speed. To re-orient a bit, it is desirable to rotate the string at such a speed that the bit neither overshoots nor
25 undershoots a desired position (orientation) and this is achieved by rotating as quickly as possible; but as the bit approaches the desired position, it is important to decelerate so that overshoot does not occur. Thus, the control software 50 calculates desired speed for the
30 entire period of bit movement and desired speed changes as the bit approaches a desired position. A final speed is such a calculated speed for rotation of the string as the bit nears the desired position.

35 The VFD controller 80 receives commands from the operator interface 20 so that the VFD controller follows

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(performs correspondingly to) the adjustable encoder 30. The change of position of the adjustable encoder 30 is monitored by the control software 50 and the difference between the two positions is calculated resulting in an amount to move the encoder 30 ("Position Error"). The difference between the two positions is given by the position indicated by encoder 30 minus the position indicated by the encoder 43. Before being used in this calculation the position of the encoder 43 may need to be adjusted according to the gear ratio of the top drive, that is the ratio between the rotation of the drill motor to the rotation of the shaft, e.g., but not limited to 10:1. For example, with a gear ratio of 10:1 the encoder 43 moves ten times as much as the encoder 30. The square root of the position error times a gain factor ("gain") yields a "Target Speed" which is further processed to determine the lesser of the speed limit and the target speed, to yield a momentary speed ("Limit Speed") of rotation of the drill string to arrive quickly and smoothly at a desired bit orientation/location.

The Last Speed is subtracted from the lesser of the Target Speed and an operator-entered speed limit and the resulting difference is divided by the cycle time to give the needed shaft acceleration. The lesser of this calculated acceleration and the acceleration limit (parameter) is multiplied by the cycle time to give a differential speed which is then added to the Last Speed and sent to the VFD controller 80 as the new speed command.

Fig. 4 shows an operator's console, e.g. a touch screen, according to the present invention useful with a control system as described above; e.g., for operating in a bump mode, an encoder-follow mode, or a "wag-the-dog" mode for oscillating ("rocking") a drill string according to methods of the present invention. But for the

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"buttons" or areas to be activated by an operator on the touch screen within the dotted line, including the button labelled "Directional Drilling," the screen would be a screen as used in a prior art console used, e.g., in a prior art AMPHION (trademark) system commercially available from National Oilwell Varco. After pushing the "Directional" button, when the "Directional Drilling" button is pushed, the remainder of the buttons within the dotted line appear and an operator can then select to stop - "Stop" - rotation of the drill string; to move the drill string (and, therefore, the bit) in bump - "Bump" - mode; to move the drill string in correspondence to operator movement of a control member (e.g. knob or slider) - "Follow" mode; or to oscillate part of the drill string to inhibit binding of the drill string - in "Rocking" mode. Optionally, instead of a single "Bump" button, two buttons may be used - one for "Bump" clockwise and one for "Bump" counter clockwise.

During directional drilling the mud motor supplies the torque that turns the bit 156 against the formation. The mud motor is mounted on the bent sub 141 and in order to steer the bit 156 in the desired direction it is necessary to maintain the correct orientation of the bent sub 141 whilst the mud motor is in operation. The mud motor induces a reactive torque into the drill string 135 that is usually (but not always) absorbed by friction between a substantially horizontal portion of the drill string and the formation. This reactive can cause the bit to wander from the desired drilling direction. Whether or not such reactive torque is absorbed by friction normally depends on the length of the horizontal section and on the amount of contact between the drill string 135 and that section.

As the substantially horizontal section gets longer, an increasing proportion of drill string 135 rests on the

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formation creating significant static friction therebetween. Although this friction can be overcome by pushing the drill string from the surface, it then becomes difficult to determine weight-on-bit (WOB) accurately, and overshoot can occur.

The aim of rocking the drill string between different angular positions is to reduce the effect caused by static friction as the drill string is pushed. Ideally however, the rocking should not rotate the bit at the same time; in this way the desired drilling direction may be maintained more accurately. In other words the rocking should overcome enough of the static friction to rock a section of the drill string down to or near the bottom hole assembly, but without rocking the bottom hole assembly itself.

Feedback from MWD tools enables the driller to monitor directional drilling progress. It is usual that every 3-6m or so the MWD tools will indicate that the bit needs to be re-oriented. The mud motor will be stopped and the top drive used to back the bit off the formation. The top drive is then used to rotate or wind-up the drill string (possibly through several revolutions) to the point at which further rotation of the drill string results in rotation of the bent sub by the desired amount and thereby of the orientation of the bit. The drill string is then unwound to a neutral position and the mud motor re-started to continue drilling. Re-orienting the bit in this way significantly reduces rate of penetration (ROP).

There are two scenarios when rocking or oscillating a drill string during directional drilling:

(1) the reactive torque of the mud motor is wholly absorbed by the drill string; or

(2) the reactive torque of the mud motor is only partially absorbed by the drill string and therefore a

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reactive torque is measured at the surface.

In order to proceed in a "Rocking" mode, an operator first defines a reference value (a start value) from which energy applied to the drill string is measured. To
5 do this, the "Set Reference" button is pushed which causes the control system to zero the calculated applied energy stored in memory. Typically the reference value will be a position approximately where there is no wind-up of the drill string in either direction (i.e. a
10 neutral position), although this is not essential. The control system also stores a physical location at that point of the drill string and, therefore, of the bit, as indicated by the encoder apparatus (e.g. like the encoder apparatus 43 described above).

15 The operator then rotates the drill string (using normal controls and rotating normally; in "Bump" mode; or in "Follow" mode) in a first direction to a first position as compared to the reference position. This new first position may be several revolutions of the drill
20 string (e.g. six) from the reference position and may be just before the point at which further turning of the drill string would result in rotation of the bent sub 141. Accordingly this new first position may be determined on the basis of the number of revolutions of
25 the drill string required before the bent sub starts re-orientation as described above. The control system's computer functions calculate how much energy was applied to the drill string to reach the first position (e.g. by integrating the torque applied by the motor 124 between
30 the reference position and the new first position of the drill string 135). This amount of energy is displayed as "Current Energy." The operator then pushes the "Use as Set Point" button to store the "Current Energy" as the energy set point value (the amount of energy to be
35 applied to rotate the drill string in a second direction

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opposite to the first direction). Then the operator pushes the "Rocking" button and the control system initiates rotational movement of the drill string in the second direction back to the reference position. From the
5 reference position the control system initiates movement in the second direction and sums the energy applied to the drill string and compares the sum with the set point value. When the applied energy is substantially equal to the energy set point value, the control system stops the
10 rotation and then again rotates back to the reference position.

This cycle is repeated to rock the drill string back and forth in a desired oscillatory mode on the basis of the energy required to cause re-orientation of the bit.
15 In particular, during re-orientation of the bit 156 an energy limit is discovered, which limit represents the amount of energy required to start rotation the bent sub 141 and thereby re-orient the bit 156. By rocking the drill string on the basis of this limit, the portion of
20 the length of the drill string that is rocked can be increased or maximised, and thereby reduce or minimise the effect of static friction substantially without rocking the bit at the same time. The energy set point value can be determined manually by the operator as
25 described above, or could be performed automatically by measuring the energy required to just start re-orienting the bit and then setting the energy set point value at some percentage of the re-orienting energy (e.g. between 90% and 99%).

30 Rotating back to the reference position after rotating to the energy set point value helps to ensure that there is no overall drift of the reference value over a large number of iterations, which might otherwise be caused by a systematic bias or noise for example.

35 In scenario (1) above (i.e. where there is no

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reactive torque from the mud motor 142 at the surface), applying a certain amount of energy in turning the drill string 135 in either direction is likely to result in substantially the same amount of turn at the surface
5 (e.g. measured in degrees or number of revolutions) in either rotational direction.

In scenario (2) there is a reactive torque from mud motor 142 at the surface. This is effectively a torque bias on the drill string in one rotational direction.
10 Accordingly when the drill motor 124 rotates the drill string from the reference position in one sense work is done against the torque bias and energy is input into the drill string. However, when the drill motor 124 rotates the drill string from the reference position in the
15 opposite sense the torque bias helps the drill motor 124 and energy is taken out of the string. In the latter case, the torque output from the drill motor 124 may not change during rotation. In that case, monitoring the torque output from the drill motor 124 does not indicate
20 when a sufficient number of turns have been made to overcome the static friction, but not so much as to start rotation of the bent sub 141. It has been known to address this problem by rotating the drill string for a fixed number of turns in either direction. However, the
25 problem with this is that as the drill string gets longer, it is very difficult to know exactly how many turns are required to overcome the static frictional forces. In contrast setting limits of rotation on the basis of input energy helps to overcome both of these
30 problems simultaneously since no position-based limit is required and, whether or not torque output from the drill motor 124 remains constant, the energy input can be measured accurately.

Once both drilling and rocking are underway, MWD
35 results may indicate that the bit requires re-orienting.

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As explained above, usually this would require the drilling and rocking to be stopped so that the re-orientation can be made. However, the present invention enables a re-orientation attempt to be made during drilling and rocking. The "Bump Distance" buttons in Fig. 4 enable the driller to adjust the reference position set for the rocking process. By using the up and down arrows the driller can set the amount of rotation in degrees that the bit should be rotated. The control system simply increases or decreases the reference position stored in memory by the amount of the "Bump Distance". In this way the energy input to the drill string by the drill motor 124 is measured from a new reference position. Assuming that the energy set point value is close to the energy required to just start turning the bent sub 141, any adjustment of the reference value will result in corresponding rotation of the bent sub 141 and thereby of the bit 156. After inputting a "Bump Distance" the driller may monitor the MWD results and make any further adjustments to the "Bump Distance" as necessary.

During this re-orientation process the control system may monitor the MWD results to ascertain when re-orientation started so that the energy set point value may be adjusted if necessary.

For the purposes of rocking the drill string 135 the drill motor 124 may simply be commanded by the control system to move from one position to another (the latter based on the input energy as described above).

The energy imparted to/from the drill string may be calculated by integrating the power output of the drill

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motor over time. In particular,

$$Power = \omega \tau$$

where ω is angular velocity and τ is torque; and

5

$$Energy = \int \omega \tau dt$$

Alternatively the energy imparted may be calculated as:

$$Energy = \tau \Delta \theta$$

10 where $\Delta \theta$ is the change in angular position of the drill string and τ is the torque applied (by the motor or drill string) during that change. The control system may perform this calculation at regular intervals (e.g. every clock cycle or over some number of clock cycles), store the result and then sum all previous results to determine
15 a running energy total. This total may be compared to the energy set point value to determine whether or not the limit has been reached.

In order to allow the top drive motor to ramp its speeds properly and ensure that its drive shaft stops and
20 reverses direction exactly when the energy limit has been reached, an angular stop position is calculated and the energy expended in stopping added to the running energy total before comparison with the set point value. To do this, the angular distance required to stop the shaft at
25 its maximum deceleration is calculated by:

$$\theta = \omega^2 / a_{\max}$$

where $a_{\max}$ is the acceleration limit used in the speed ramp function and θ is the angular distance (amount of shaft rotation) and ω is the current angular velocity of
30 the shaft (and, therefore, of the drill string). The energy added to the string during this ramp down is estimated by using a smoothed torque value (digitally filtered) and multiplying it by this angular distance. It is then determined when to begin ramping down the

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speed by keeping a running integral of the energy delivered to the shaft and when it is within the estimated stopping energy of the limit ramping the speed of the shaft to zero and reversing direction.

5 The present invention, therefore, in at least one or certain embodiments provides a method for oscillating a drill string, the drill string extending into the earth, the drill string having a bit on a lower end thereof, the bit for drilling into the earth, the drill string
10 connected to a motive apparatus, the motive apparatus for rotating the drill string, the motive apparatus having a power output associated with rotating the drill string, the method including: determining a first amount of energy and a second amount of energy, said determining
15 based on the power output of the motive apparatus; applying the first amount of energy to the drill string in a first rotational direction; applying the second amount of energy to the drilling in a second rotational direction, the second rotational direction opposite to
20 the first rotational direction; the application of both the first amount of energy and the second amount of energy not moving the bit. Such a method may include one or some, in any possible combination, of the following: wherein the motive apparatus is a top drive system, a
25 power swivel, or a rotary system for rotating the drill string; continuously oscillating the drill string cyclically in the first rotational direction then in the second rotational direction by applying amounts of energy to the drill string, said applications of amounts of
30 energy to the drill string not moving the bit; wherein the top drive system has a top drive shaft and is driven by a variable frequency drive, and a control system in communication with the top drive system and the variable frequency drive controls the variable frequency drive,
35 the variable frequency drive providing feedback to the

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control system regarding angular velocity of the top drive shaft and torque applied to the top drive shaft by the top drive system, the method further including the control system calculating amounts of energy imparted to the drill string by the top drive system based on the feedback from the variable frequency drive; wherein a control system in communication with and controlling the motive apparatus controls the motive apparatus to rotate the drill string; wherein the control system includes control apparatus containing programmable media, the control apparatus from the group consisting of computer, programmable logic controller, single board computer, central processing unit, microcontroller, and finite state machine; wherein the control system is in communication with an operator interface for an operator to initiate the control system calculating an amount of energy applied to the drill string by the motive apparatus to move the drill string in a first rotational direction to a first position, the method further including initiating calculation of the amount of energy applied to the drill string to move it to the first position, rotating the drill string from the first position in a second rotational direction to a second position, calculating an amount of energy applied to move the drill string to the second position, and applying a new amount of energy to the drill string to move in the first rotational direction the drill string to a third position; wherein the drill string includes a mud motor for rotating the bit, the method further including rotating the bit with the mud motor; determining a start reference value for energy applied to the drill string prior to application of the first amount of energy, and determining a reference position which is the position of the drill string prior to application of the first amount of energy to the drill string; calculating a new applied

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energy applied to the drill string following each application of an amount of energy applied to the drill string, and based on said new applied energy, applying a further amount of energy to the drill string in a direction opposite to the direction in which the new amount of energy was applied to the drill string; stopping rotation of the drill string in the first rotational direction when the first amount of energy has been applied to the drill string; stopping rotation of the drill string in the rotational direction in which it is rotating following application of the new amount of energy to the drill string; wherein the amounts of energy are applied by a rotary system; and/or wherein the amounts of energy are applied by a power swivel.

15 The present invention, therefore, in at least one or certain embodiments provides a method for oscillating a drill string with a top drive system, the drill string extending into the earth, the drill string having a bit on a lower end thereof, the bit for drilling into the earth, the method including: applying the first amount of energy to the drill string in a first rotational direction; applying the second amount of energy to the drilling in a second rotational direction, the second rotational direction opposite to the first rotational direction; the application of both the first amount of energy and the second amount of energy not moving the bit; continuously oscillating the drill string cyclically in the first rotational direction then in the second rotational direction by applying additional amounts of energy to the drill string, said applications of additional amounts of energy to the drill string not moving the bit; wherein the top drive system has a top drive shaft and is driven by a variable frequency drive, and a control system in communication with the top drive system and the variable frequency drive controls the

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variable frequency drive, the variable frequency drive providing feedback to the control system regarding angular velocity of the top drive shaft and torque applied to the top drive shaft by the top drive system;

5 the control system calculating amounts of energy imparted to the drill string by the top drive system based on the feedback from the variable frequency drive; and wherein the control system includes control apparatus containing programmable media, the control apparatus from the group

10 consisting of computer, programmable logic controller, single board computer, central processing unit, microcontroller, and finite state machine. Such a method may include one or some, in any possible combination, of the following: determining a start reference value for

15 energy applied to the drill string prior to application of the first amount of energy, and determining a reference position which is the position of the drill string prior to application of the first amount of energy to the drill string; calculating a further amount energy

20 to be applied to the drill string following each application of an amount of energy applied to the drill string, and applying the further amount of energy to the drill string in a direction opposite to the direction in which a previous amount of energy was applied to the

25 drill string; and/or stopping rotation of the drill string in the rotational direction in which it is rotating following application of each further amount of energy to the drill string.

The present invention, therefore, in at least one or

30 certain embodiments provides a system for cyclically rotating a drill string, the drill string having a bit at a lower end of a drill string, the system including: motive apparatus for rotating a drill string and a bit, the bit connected to an end of the drill string, the

35 drill string in a wellbore, the wellbore extending from

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an earth surface into the earth, the bit at a location
beneath the earth surface; a control system in
communication with the motive apparatus, the control
system for controlling the motive apparatus to rotate the
5 drill string in a first rotational direction applying a
first amount of energy to the drill string and then in a
second rotational direction applying a second amount of
energy to the drill string; and said amounts of energy
applied to the drill string without moving the bit.

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Claims:

1. A method of oscillating a drill string, which method comprises the steps of:

(a) rotating said drill string in a first direction until a first limit is reached; and

(b) rotating said drill string in a second direction until a second limit is reached;

characterised in that said first and second limits are each an amount of energy expended during rotation in said first and second directions respectively.

2. The method according to claim 1, further comprising the step of determining an amount of energy expended during said rotation step and comparing said amount to said first or said second limit according to the direction of rotation.

3. The method according to claim 2, further comprising the step of substantially continuously determining said amount and comparing during rotation of said drill string.

4. The method according to claim 2 or 3, wherein said determining step comprises integrating torque applied to or from said drill string with respect to a change in angular position of said drill string.

5. The method according to claim 2, 3 or 4, further comprising the steps of storing an angular reference position of said drill string, and determining said amount as said drill string is rotated from said angular reference position in either direction.

6. The method according to claim 5, further comprising the step of rotating said drill string back to said angular reference position once said first or second

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energy limit is reached irrespective of the energy required to reach said angular reference position, whereby drift of said angular reference position is inhibited.

7. The method according to claim 5 or 6, further comprising the step of changing said angular reference position during oscillation of said drill string whereby the orientation of a bit located at the lower end of said drill string may be adjusted to facilitate directional drilling.

8. The method according to any one of claims 1 to 7, further comprising the steps of determining the energy required in rotating the drill string from a neutral position to a position in which the bit may be re-oriented, and determining and storing a memory said first and second limits based on said energy.

9. The method according to claim 8, where said determination of said first and second limits comprises calculating and storing a fraction less than one of said energy.

10. The method according to any one of claims 1 to 9, wherein said first and second limits are substantially the same.

11. The method according to claim 10, wherein said first and second limits are the same and only one limit is stored in electronic memory for use in either direction.

12. The method according to any one of claims 1 to 11, further comprising the step of drilling whilst oscillating.

13. The method according to any one of claims 1 to 12, wherein said amount of energy for comparison with said

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first and second limits is either that amount input to said drill string or that amount output from said drill string.

14. The method according to any one of claims 1 to 13, further comprising the steps of determining a stopping energy that would be imparted to said drill string in order to stop said drill string from its present angular speed, whereby said stopping energy may be taken into account so that first and second limits are not exceeded.

15. The method according to any one of claims 1 to 14, further comprising the step of performing said rotation steps with a top drive connected to said drill string.

16. The method according to claim 15, wherein said top drive comprises a top drive shaft and is driven by a variable frequency drive, there being a control system in communication with said top drive and said variable frequency drive, the method further comprising the steps of receiving at said control system feedback from said variable frequency drive regarding an angular velocity of said top drive shaft and a torque applied to said top drive shaft by said top drive, and said control system calculates amounts of energy imparted to said drill string by said top drive based on said feedback.

17. The method according to claim 1, wherein said rotation step is performed by a rotary system.

18. The method according to claim 1, wherein said rotation step is performed by a power swivel.

19. A method of directional drilling, which method comprises the steps of:

(a) drilling a non-vertical wellbore with a bit attached to one end of a drill string; and

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(b) oscillating said drill string in step (a) using a method according to any one of claims 1 to 18.

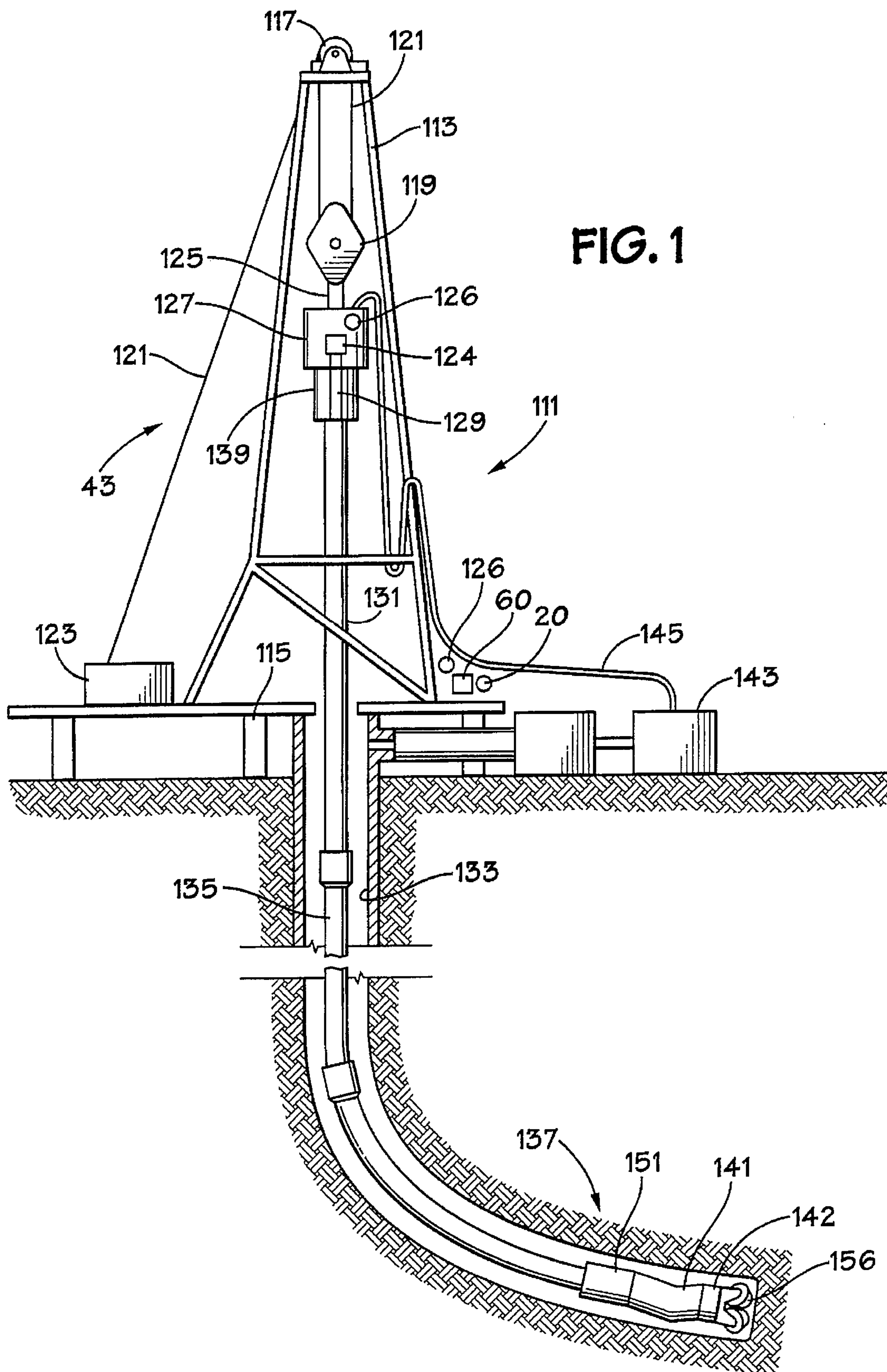
20. An apparatus for oscillating a drill string, which apparatus comprises a controller connectable to a motive apparatus for rotating said drill string in a first rotational direction until a first limit is reached and then in a second rotational direction until a second limit is reached, said controller comprising a physical memory storing computer executable instructions for controlling said motive apparatus to:

(a) rotate said drill string in a first direction until a first limit is reached; and

(b) rotate said drill string in a second direction until a second limit is reached;

wherein said first and second limits are each an amount of energy expended during rotation in said first and second directions respectively.

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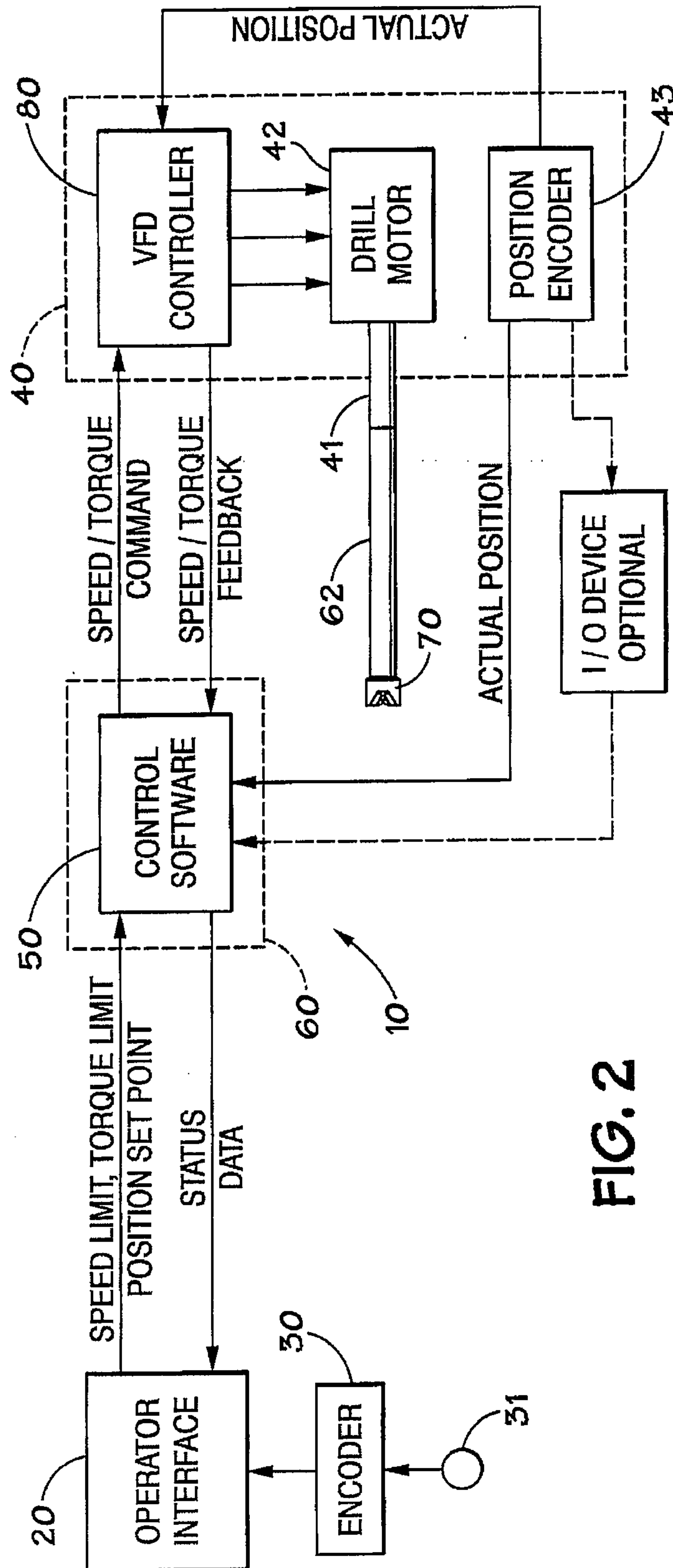


FIG. 2

FIG. 3

