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Varley

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[54] **HYDRAULICALLY ENHANCED WELL DRILLING TECHNIQUE**

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[51] **Int. Cl.** **E21b 3/00**

[58] **Field of Search** 175/57, 61, 65, 321

[56] **References Cited**

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FOREIGN PATENTS OR APPLICATIONS

1,009,128	5/1957	Germany	175/321

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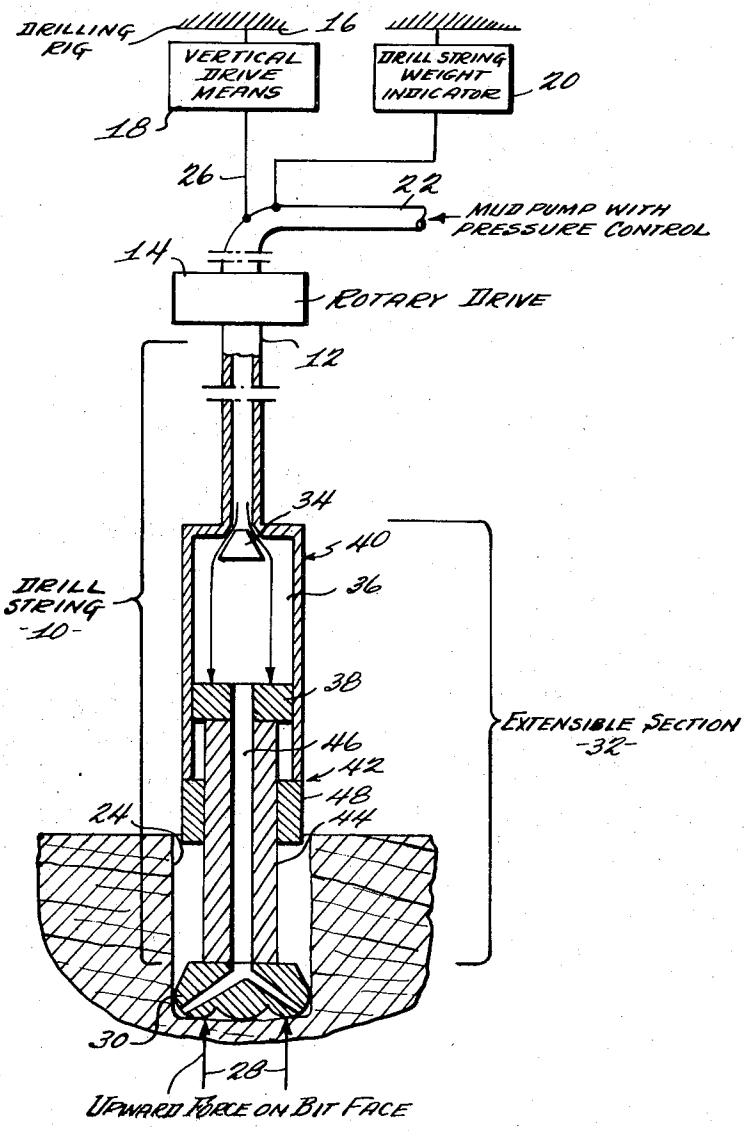
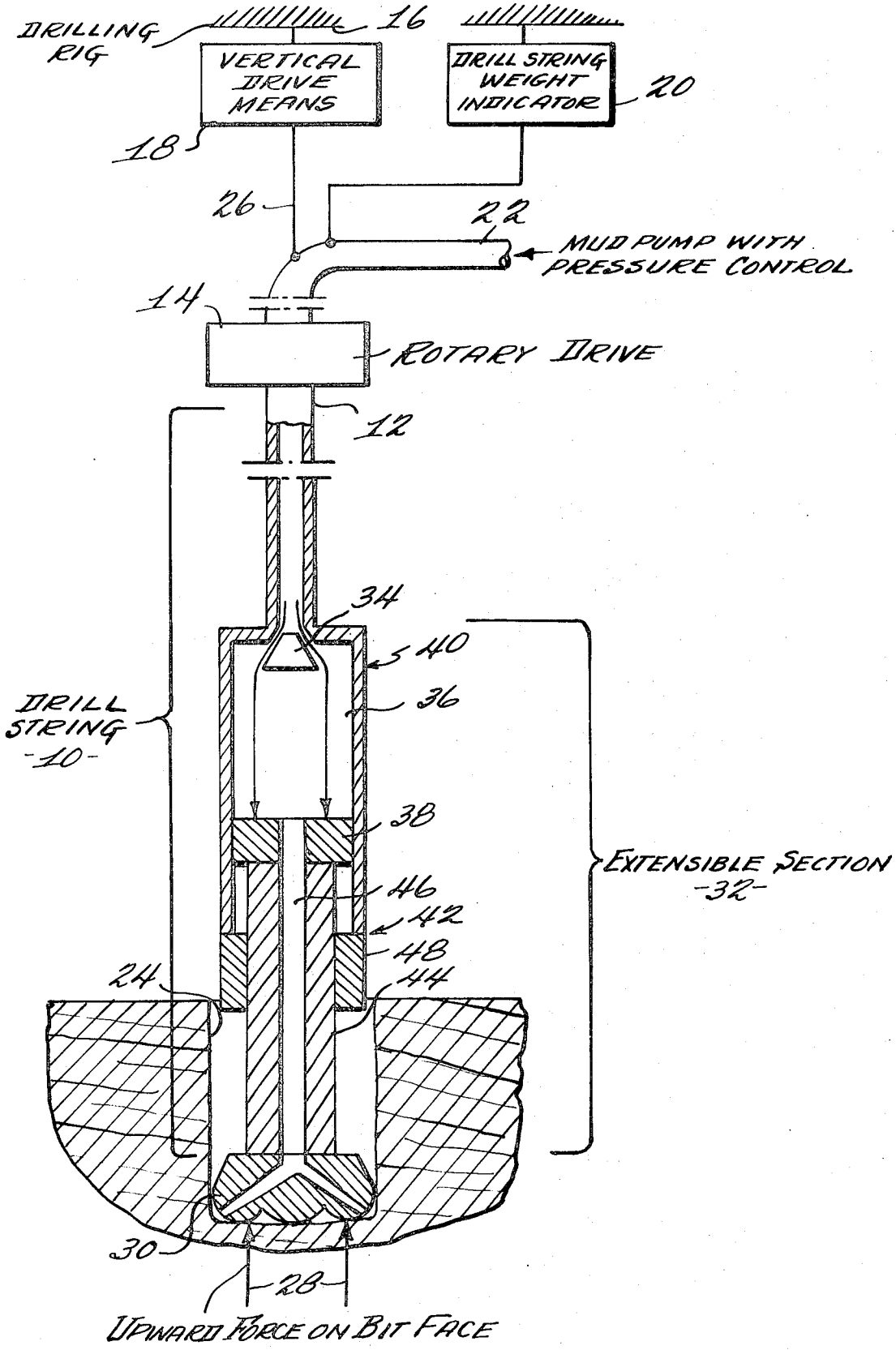
[57] **ABSTRACT**

A method for drilling a well bore hole using a drill string which includes an extensible hydraulic cylinder and piston section located above the drill bit. The drill string is positioned such that the extensible section is in less than a fully extended condition while pressurized fluid is pumped into the extensible section to produce hydraulic forces tending to extend that section. The hydraulic force thus generated within the extensible section influences the effective drill string weight applied to the drill bit and thus controls the force actually exerted between the drill bit and the bottom of the bore hole.

9 Claims, 1 Drawing Figure




DRILLING RIG
16
VERTICAL DRIVE MEANS
DRILL STRING WEIGHT INDICATOR
20
18
26
22
MUD PUMP WITH PRESSURE CONTROL
14
ROTARY DRIVE
12
34
40
36
DRILL STRING -10-
38
EXTENSIBLE SECTION -32-
46
42
48
24
44
30
28
UPWARD FORCE ON BIT FACE

HYDRAULICALLY ENHANCED WELL DRILLING TECHNIQUE

This invention generally relates to the drilling of well bore holes such as in the drilling of oil wells. More specifically, it relates to a method for drilling such holes by utilizing hydraulic forces in an extensible section of the drill string to control the force with which the drill bit is urged against the bottom of a bore hole during a drilling operation.

In my prior U.S. Pat. No. 3,599,733 issued Aug. 17, 1971, I have described a method for enhanced directional jet drilling utilizing a reciprocatable in-hole mud pump located relatively adjacent to a directional jetting bit in the drill string. In essence, this in-hole mud pump comprises an extensible cylinder and piston section having a back pressure operated fluid valve at the top thereof. In the technique described in my prior patent, this extensible section is first fully extended to fill the cylinder with mud after which the drill string is lowered thus trapping the cylinder full of mud behind the back pressure valve, thereafter compressing the mud and forcing it out of the jet drilling bit at an increased velocity.

It has now been discovered that basically this same drill string structure may be utilized in other methods for even further enhancing either directional jet drilling, drilling out, angle building, straight forward and/or other drilling operations.

In the past, the effective force with which the drill bit is forced against the bottom of a bore hole has been controlled to some extent by controlling the portion of the drill string weight which is supported by the drilling rig. That is, by slacking off some of the supporting force, more drill string weight is permitted to act in forcing the drill bit against the bottom of the bore hole. Conversely, by increasing the lifting force on the drill string, less force (from the drill string weight) is effectively transmitted to the drilling bit.

However, this technique of controlling the force on the drilling bit is less than perfect especially when long lengths of drill pipe or drill string, significant frictional forces, etc., are involved. Furthermore, when performing offshore drilling on a floating rig, normal vertical wave motion of the rig makes it virtually impossible to maintain the desired force between the drill bit and the bottom of the drill bore hole. This problem is generally recognized and one attempted solution involving the use of multiple bumper subs and drill collars is described in "Turbodrilling from Floating Rigs" by L. Dicky, Petroleum Engineer, June, 1972.

The hydraulically enhanced drilling operations encompassed within the newly discovered method of this invention represents a substantial improvement over past techniques of controlling the force between the drill bit and the bottom of a bore hole.

In the method of this invention, the drill string is constructed to include an extensible hydraulic cylinder and piston section located above a drill bit in a manner similar to that disclosed in my prior U.S. Pat. No. 3,599,733. However, the drill bit positioned at the bottom of the drill string in this invention may comprise any kind of conventional jetting and/or other drilling bit. The extensible section is positioned in a partially retracted or less than fully extended position such that substantially the whole force urging the drill bit against the bottom of the bore hole comprises the hydraulic force generated within the extensible hydraulic cylinder and piston section when pressurized fluid is admitted into that section. That is, pressurized fluid exerts a force against the piston tending to extend the extensible section and force the drill bit against the bottom of the bore hole with exactly this amount of force. Accordingly, by controlling the hydraulic fluid pressure and hence the hydraulic force exerted upon the piston of said extensible section, the force with which the drill bit is urged against the bottom of the bore hole may be accurately controlled.

In particular, so long as the hydraulic fluid pressure is maintained substantially constant (and possible frictional side effects are minimized by rotating drill string), the force with which the drill bit is urged against the bottom of the bore hole will also remain substantially constant so long as the extensible section is somewhere within the extremes of its normal travel. That is, so long as the extensible section is not fully extended or fully retracted, the force with which the drill bit is urged against the bottom of the bore hole will be substantially determined by the pressurized fluid pressure acting to produce hydraulic forces within the extensible cylinder and piston section of the drill string. Accordingly, so long as the available travel in the extensible section is of sufficient magnitude, even the wave motion of floating drilling rigs will not substantially alter the force with which the drill bit is urged against the bottom of a bore hole. Furthermore, even in straight forward drilling operations, a substantially constant drill bit force may be obtained by periodically repositioning the drill string to insure that the extensible section is always somewhere between the two extremes or limits of travel.

These and other objects of the invention will be more fully explained in the following detailed description and in the accompanying drawing which schematically depicts an exemplary drill string and bore hole as it might appear in practicing this invention.

As shown in the drawing, the drill string **10** is normally connected to a Kelly bar **12** which passes through a rotary drive mechanism **14.** The drill string is suspended from a drilling rig **16** through a vertical drive means **18** and usually attached to some form of drill string weight indicator **20.** Pressurized mud is pumped into the drill string at **22** as will be appreciated by those in the art. While the drilling rig **16** has been shown as fixed in the drawing, it should be appreciated that the drilling rig may in fact be on a floating platform in offshore operations and therefore not necessarily fixed with respect to the bore hole **24.**

In simplistic terms, for purposes of explanation, the drill string **10** may be thought of as a weight suspended by the vertical drive means **18.** If an absolute slack is permitted in suspension line **26,** then the drill string weight indicator **20** would indicate the weight of the drill string minus the upward force **28** (if any) exerted by the bottom of the bore hole on the drill bit **30** as shown in the drawing. Accordingly, if the drill bit **30** is not yet in contact with the bottom of the bore hole, the drill string weight indicator would indicate the total weight of the drill string. On the other hand, if the drill bit is in contact with the bottom of the bore hole and the vertical drive means **18** completely slacks off suspension line **26,** the entire weight of the drill string would be supported by the force **28** thus causing the drill string weight indicator **20** to indicate zero.

As shown in the drawing, near the lower end of the drill string **10,** an extensible section **32** is included just above the drill bit **30.** A back pressure valve **34** may be included for in-hole mud pumping operations as explained in my prior U.S. Pat. No. 3,599,733. The extensible section **32** comprises a cylinder portion **36** and a piston portion **38.** As shown in the drawing, the extensible section **32** is slightly more than half-way extended with the piston **38** being somewhere between the fully retracted position **40** and a fully extended position **42** as should now be apparent. The piston **38** is connected with a mandrel **44** to which the drill bit **30** is attached at the bottom end thereof. A fluid conduit **46** permits pressurized fluid entering the cylinder **36** to also pass through the conduit **46** into jetting and/or lubricating conduits as shown schematically in the drill bit **30.** A hex drive sub **48** cooperates with the outside hexagonal shape of the mandrel **44** to transmit rotary motion to the bit **30** if such rotary motion is imparted to the drill string through rotary drive means **14** as will be appreciated by those in the art.

Accordingly, when mud is pumped into the cylinder **36,** the piston **38** will be forced downwardly to extend the extensible section **32** if the total force on the face of the piston **38** from the mud pressure (hydraulic) is greater than the opposing upward force **28** exerted on the face of the bit.

For enhanced jet directional drilling as described in my prior U.S. Pat. No. 3,599,733, the drill bit **30** would, of course, be a directional type of jetting bit and, after desired orientation of this bit, the tool would be operated by raising the drill string sufficiently to permit the extensible section **32** to fully extend. At this point, the piston or cylinder chamber **36** would be filled with mud. The drill string would then be quickly slacked off and lowered until the bit touches the bottom, the back pressure valve would then close thus permitting the travelling weight of the drill string to force the extensible section **32** into its retracted position and thus force the mud out through the passage **46** and the jet directional bit **30** at a velocity which is much greater than the normal velocity which can be attained by surface mud pumps alone. This reciprocating procedure is then repeated according to my previous invention until a pocket has been formed to result in a desired angle or change of angle in the drilled bore hole.

It has now been discovered that even after the jet directional operation according to my previous patent has been completed, the extensible section **32** may be left at the end of the drill string to further enhance a "drilling out" operation. During the "drilling out" operation, the drill bit is rotated while simultaneously lowering the bit **30** to drill a new section of the bore hole at the new angle. In this operation, after the directional jetting operation has been completed, the tool is left closed with the bit **30** located at the bottom of the bore hole. Mud pressure is then held down to permit this closing of the extensible section or tool **32.** The actual weight or fore **28** on the bit face is then adjusted as desired by raising or lowering the drill string from the rig **4,** and rotation of the drill string and bit is begun for the drilling out process.

Thereafter, the mud pressure is again increased. This hydraulic pressure tends to extend the piston and cylinder or extensible section **32,** which extension can only result in one of two things happening. Namely, the drill string will either be lifted or the mandrel **42** with the attached bit **30** will begin to drop which is, of course, equivalent to a successful "drilling out" operation. By maintaining a constant mud pressure, the force on the bit will thus remain constant until the tool is finally fully extended, if friction effects are disregarded. The process just described can be cyclically repeated after the tool is again closed by momentarily reducing mud pressure and slacking off on the vertical drive means as should now be apparent.

For instance, in a typical example, the weight of an entire string might be indicated as 200,000 pounds when the bit is on the bottom of the bore hole and the tool or extensible section **32** is half closed. With the pump started, the drill string is put into rotation to make sure that it is completely free within the bore hole. As the pump pressure is increased, the weight indication on the floor shows 165,000 pounds, a decrease of some 35,000 pounds. Of course, this decrease in weight is directly attributable to the upward force **28** acting at the bottom of the string which is, in turn, caused by the hydraulic action of the extensible section **32.** That is, the 35,000 pound decrease on the weight indicator **20** means that the bit is in fact loaded by a force of 35,000 pounds.

This result can perhaps be better understood by mentally envisioning a set of spring scales from which a 10 pound weight is suspended. Now further envision a hydraulic cylinder extending between the floor and the bottom of the 10 pound weight. When no fluid pressure is supplied to the hydraulic cylinder, the scale will read the full **10** pounds, However, when sufficient pressure is applied to the hydraulic cylinder to lift 5 pounds of the weight, the scale will read **5** pounds instead of **10.** As should now be appreciated, if the change in opposing upward force at the bottom of the hydraulic cylinder were to be measured, it would exactly equal the weight loss of 5 pounds as indicated on the scales.

This usage of the extensible section **32** for "drilling out" after directional jetting operations greatly enhances the process of changing the angle of the drilled bore hole because of the constant bit pressure as well as because of the greater flexibility of the hexagonal mandrel **24** as compared to a standard drill pipe or collar due to its smaller outside diameter and dimensional tolerances resulting in natural "play" or motion between the hex drive **48** and the mandrel **44** as the tool is extended. This flexibility allows a greater degree of angle change or deviation to be accomplished than if the tool were left closed or not used at all.

In soft formations, the drilling out procedure may still be performed with the tool fully retracted if desired since all the advantages accruing from the use as stated above might not be needed. However, in medium formations, the advantages of the above discussed method will begin to become important. Here, the bit should be pulled free of the bottom and then the drill string slacked off slowly until the bit touches the bottom and the tool is closed at least partially. At this point, the vertical drive means **18** should be stopped while the pump pressure should be adjusted to increase the mud pressure and the bit should be rotated. As the bit starts to rotate, the drill string should be further slacked off until the drilling weight and pump pressure have been re-established as desired after which the drilling operations detailed above can be continued.

In harder formations, the tool should be picked up until the bit is free of the bottom. With the full pump

pressure on, the string should be rotated slowly and drilled into the pocket with the tool fully extended. After the bit has broken free the drill string should be slacked off fast enough to partially close the tool after which it should be further slacked off slowly to the bottom until the tool is fully retracted (adding the drilling weight to the indicator) before the drilling process as described above is continued.

In exceedingly hard or deep formations, it may become necessary to jet four or five times on a single joint in order to turn a hole as desired. In this type of jetting and drilling, it is essential that the rotary table and rotary bushings be correctly marked and that all makeup is out of the drill pipe and that the drilling torque be worked out of the drill string before jetting in order to stay correctly oriented.

In ordinary drilling situations where angle building problems have been encountered, the tool described above will build angle at the rate of 1¼° to 2° per **100** feet. In exceedingly difficult situations or where the rate of build required exceeds the ordinary building rate, the following procedure has been found to be advantageous.

The drilling bit should be placed on the bottom of the bore hole. With full mud pump pressure, the drill string should be rotated while the tool is closed at least partially. Then, with the rotary motion temporarily stopped, the tool should be closed completely as indicated by the added drill collar weight on the weight indicator. Then, the rotating motion should be started again but without slacking off on the vertical drive. That is, the upper portion of the drill string **10** down to and including the cylinder **40** is effectively suspended or held in a position just indicated. Thereafter, the hydraulic pressure will force the bit against the bottom of the bore hole and as drilling proceeds, the extensible section **32** will extend after the mandrel **44** has extended some predetermined distance less than the total travel of the extensible section. Then the vertical drive means **18** should be slacked off until the drill string weight begins to appear again on the indicator **20** thus indicating that the extensible section **32** has again been retracted. Thereafter, the same sequence will be repeated with the hydraulic forces forcing the bit **30** against the bottom of the bore hole and with the extensible section **32** extending as the drilling proceeds.

While only a few embodiments of this invention have been described in detail, those in the art will recognize that many modifications may be made in the exemplary embodiments without materially departing from the advantages of this invention.

What is claimed is:

1. A method for drilling a well bore hole using a drill string which includes an extensible unanchored hydraulic cylinder and piston section above a drill bit, said method comprising:

positioning said extensible section in a less than fully extended condition without anchoring any portion thereof to the bore hole, and

pumping pressurized fluid into said extensible section thereby producing hydraulic forces reacting against the drill string weight and tending to extend said extensible section thus influencing the effective force applied to said drill bit.

2. A method as in claim **1** wherein said positioning step comprises:

lowering said drill string into said bore hole until indicated drill string weight begins to decrease and then further lowering said drill string by a predetermined amount.

3. A method as in claim **1** further comprising the step of rotating said drill string simultaneously with said pumping step.

4. A method as in claim **1** further comprising the step of controlling the pressure of said pressurized fluid to achieve a substantially constant force between said drill bit and the bottom of said bore hole.

5. A method as in claim **1** wherein said positioning step comprises:

lowering said drill string into said bore hole to a first point until said extensible section is substantially retracted,

holding the upper portion of said drill string located above said extensible section at said first point while permitting the extensible section to extend, and cyclically repeating said lowering and holding steps.

6. A method as in claim **1** wherein said positioning and pumping steps comprise:

rotating said drill string while fluid pressure is applied to partially extend said extensible section,

stopping the rotary motion,

slacking off said drill string to completely retract said extensible section, and then

restarting said rotary motion without further slacking off said drill string.

7. A method as in claim **6** wherein said stopping, slacking and restarting steps are cyclically repeated.

8. A method for drilling a well bore hole using a drill string which includes an extensible hydraulic cylinder and piston section above a drill bit, said method comprising:

positioning said extensible section in a less than fully extended condition, and

pumping pressurized fluid into said extensible section thereby producing hydraulic forces tending to extend said extensible section and thus influence the effective force applied to said drill bit,

wherein said positioning and pumping steps comprise;

pulling the bit free of the bottom of said bore hole,

slacking off said drill string until the bit touches the bottom of said bore hole and said extensible section is at least partially closed,

holding said drill string,

increasing the fluid pressure in said extensible section,

rotating said drill string, and then further slacking off said drill string until a desired drilling force is achieved.

9. A method for drilling a well bore hole using a drill string which includes an extensible hydraulic cylinder and piston section above a drill bit, said method comprising:

positioning said extensible section in a less than fully extended condition, and

pumping pressurized fluid into said extensible section thereby producing hydraulic forces tending to extend said extensible section and thus influence the effective force applied to said drill bit,

wherein said positioning and pumping steps comprise:

pulling the bit free of the bore hole bottom,

rotating said drill string with sufficient applied fluid pressure to fully extend said extensible section, and

slacking off the drill string to partially close said extensible section.

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