AUTOMATIC DRILLING SYSTEM

Filed Feb. 5, 1968 3 Sheets-Sheet 1

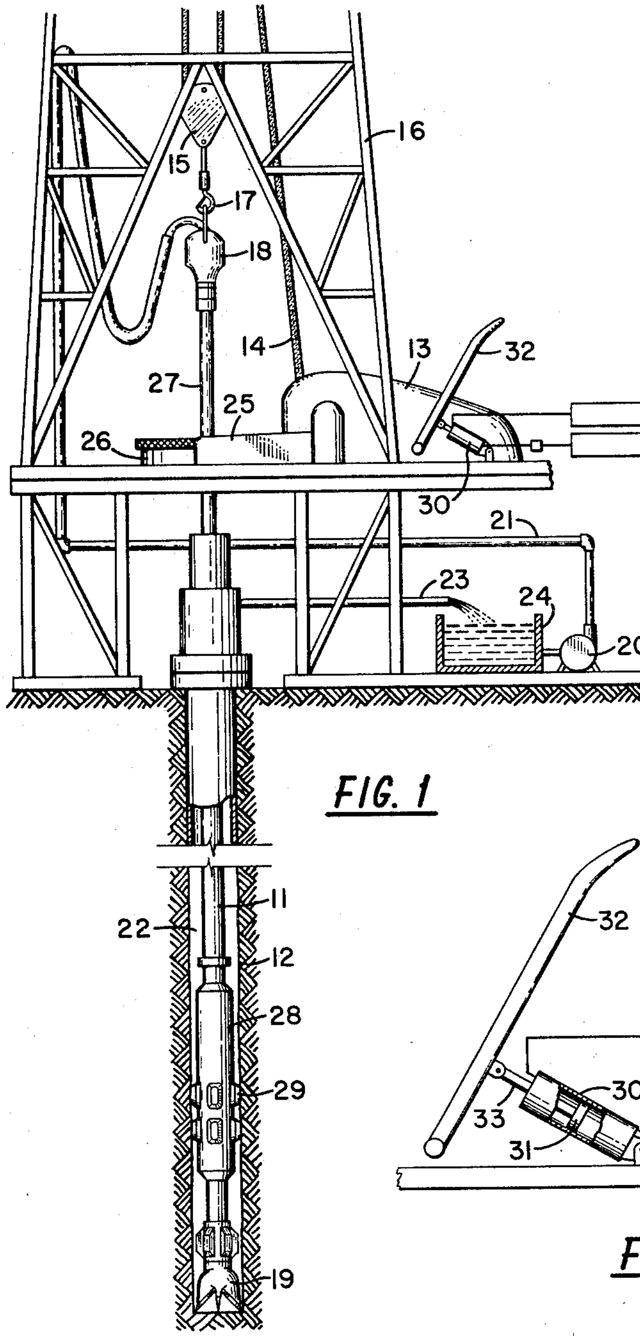

FIG. 1

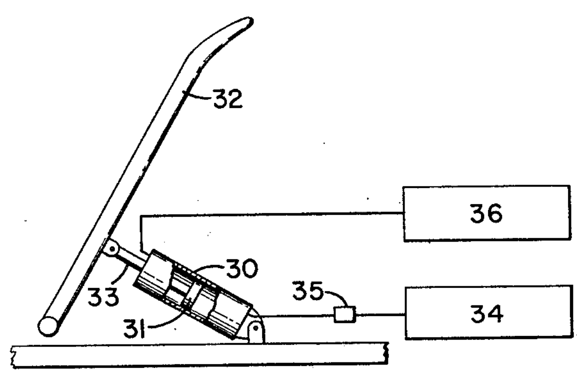

FIG. 2

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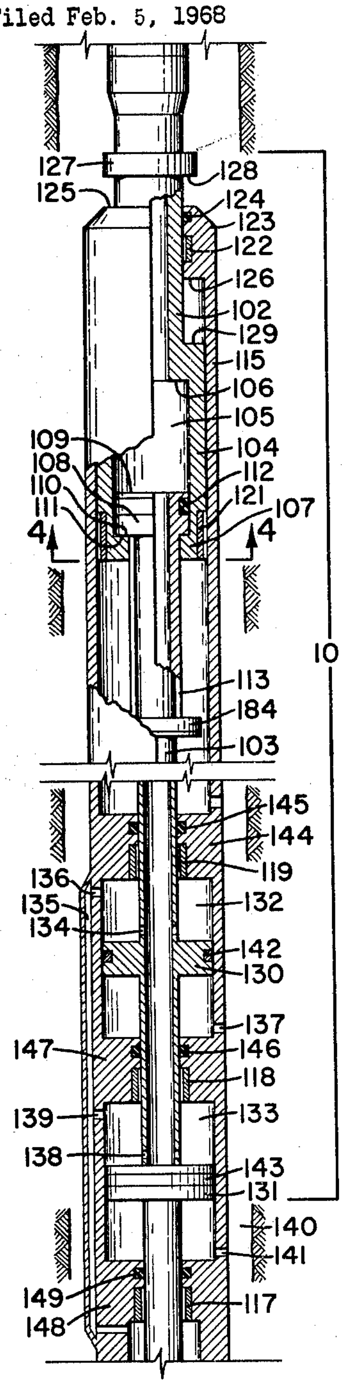

FIG. 3A

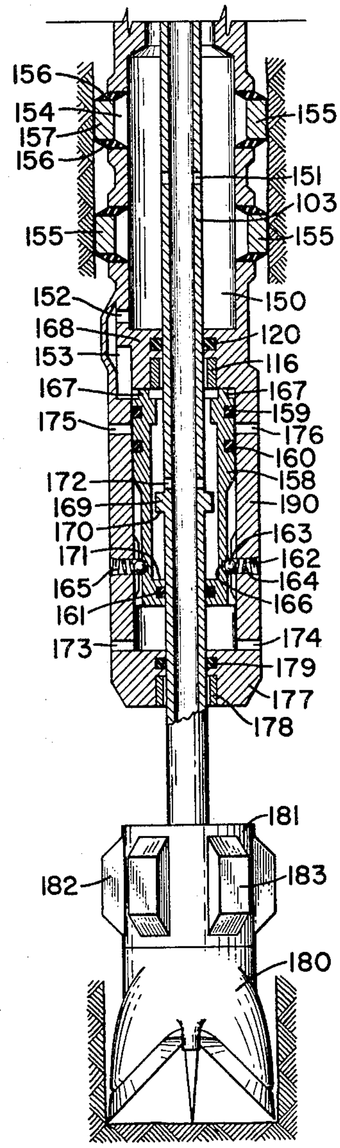

FIG. 3B

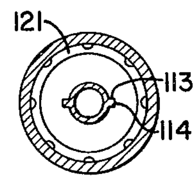

FIG. 4

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Filed Feb. 5, 1968 3 Sheets-Sheet 3

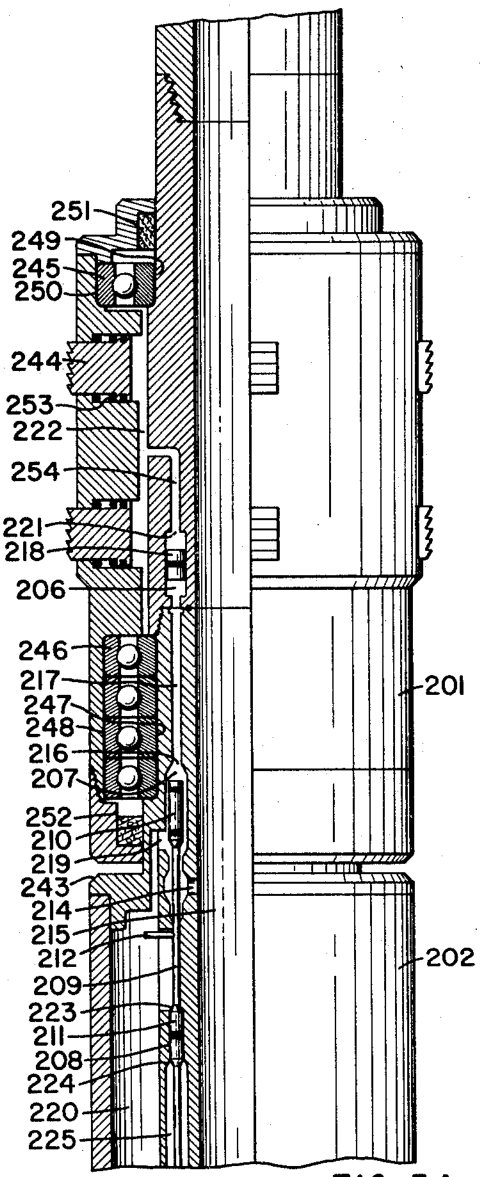

FIG. 5A

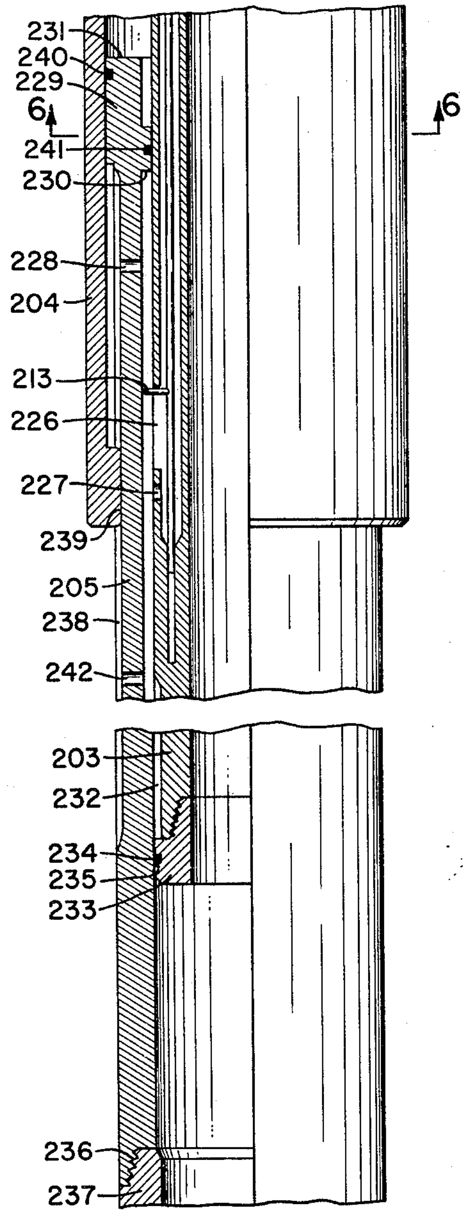

FIG. 5B

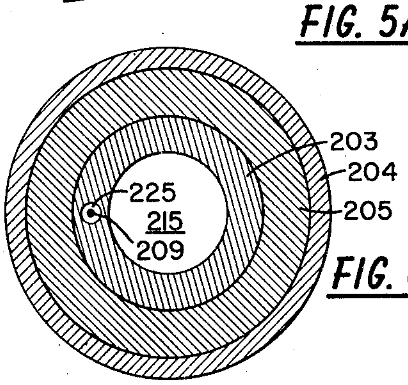

FIG. 6

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United States Patent Office

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AUTOMATIC DRILLING SYSTEM

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Int. Cl. E21c *15/00*
U.S. Cl. 175—27 6 Claims

ABSTRACT OF THE DISCLOSURE

Apparatus for drilling a borehole in the earth including a drill string, a bit-weight applicator including extensible members for anchoring the drill string to the borehole wall and a reciprocating piston for forcing a drill bit against the bottom of the borehole, means for transmitting a signal to the surface when the piston reaches the end of its stroke, and means for lowering the drill string and resetting the piston in response to the signal to permit continued drilling.

BACKGROUND OF THE INVENTION

Field of the invention

This invention pertains to the drilling of boreholes in the earth and is particularly concerned with an automatically resettable bit-weight applicator for use in rotary drilling operations.

Description of the prior art

In conventional rotary drilling systems the penetration rate of the drill bit through the subsurface formation is to some degree proportional to the weight applied to the bit. Such systems generally include a string of heavy drill collars which are placed in the drill string just above the bit to increase the downward force or "weight" acting on it. Bit-weight applicators have been developed to supplant the drill collars and provide the same force at the bit by means of a hydraulically actuated piston. These devices alleviate certain undesirable features associated with the use of drill collars, such as the requirement for heavier equipment at the surface and the necessity for more horsepower and rig time to lift the drill pipe, drill collars, and drill bit from the well. The use of bit-weight applicators thus offers certain advantages over the use of drill collars.

Apparatus for lowering the drill pipe, drill collars, and drill bit in response to weight changes at the surface caused by penetration of the drill bit is commercially available for use with conventional rotary drilling systems. Drilling with a constant weight on the bit can thus be carried out more or less continuously. Existing bit-weight applicators also apply a constant force to the bottom of the hole throughout the stroke of the hydraulic piston. This force is opposed by a wall anchor which transfers the reacting force to the borehole wall. There is therefore no change in weight at the surface when the piston reaches the lower end of its stroke. Since there is thus no weight reduction to which a conventional continuous drilling device can respond, continuous drilling operations are not feasible with most bit weight applicators. Instead, the period of time for the drilling of one stroke length must be estimated, circulation periodically stopped, and the drill pipe lowered to reset the tool. This manual monitoring of the operation is often unreliable, is generally time-consuming, and is usually expensive.

SUMMARY OF THE INVENTION

The automatic drilling system of this invention permits continuous drilling with a hydraulic bit-weight applicator. The apparatus of the invention includes a string of drill pipe or a similar conduit, a bit-weight applicator including extensible shoes and a hydraulically actuated piston for anchoring the lower end of the string to the borehole wall, means for transmitting a signal to the upper end of the string when the piston reaches the end of its stroke, and means responsive to this signal for lowering the drill string and resetting the piston to permit continued drilling.

The bit-weight applicator utilized in carrying out the invention will normally be mounted in the drill string just above the bit and will include an outer housing containing extensible shoes which are actuated hydraulically in response to a differential pressure between the interior of the drill string and the annulus. A telescoping shaft assembly linking the drill string and bit is free to rotate within this outer housing. Differential pressure acting on one or more pistons attached to the shaft causes it to move downwardly and thus exert force through the bit on the bottom of the borehole. At the end of its stroke, the piston mechanically opens a port between the drill string and annulus which permits fluid within the string to rush into the low-pressure annulus. This results in a reduction in pressure within the drill string. The extensible shoes are released in response to the pressure reduction. A hoist control at the surface which causes the drill string to be lowered the length of a piston stroke is simultaneously actuated. The pressure relief port is closed and the string is lowered permitting pressure to build up within the drill string and reset the hydraulic wall anchor. Lowering the string also resets the piston to the beginning of its stroke, so that drilling can continue.

The apparatus of the invention has the advantage that the drilling operation can be carried out on a substantially continuous basis while using a bit-weight applicator. The necessity for manual supervision of the drilling, inherent in conventional operations utilizing a bit-weight applicator, is eliminated. It is also advantageous in that the heavy string of drill collars used in existing automatic drilling systems can be eliminated. This makes possible a reduction in the size of the hoisting equipment and in the amount of rig horsepower necessary. The system of the invention thus offers distinct advantages over automatic drilling systems available in the past.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic illustration of the automatic drilling system of the invention. FIG. 2 shows schematically a pressure-responsive hoist controller suitable for use with the system of FIG. 1. FIGS 3A and 3B are cross-sectional views of bit-weight applicator that may be employed in the system depicted in FIG. 1. FIG. 4 is a detail section of the bit-weight applicator of FIG. 3 taken along line 4—4. FIGS 5A and 5B are cross-sections of an alternate bit-weight applicator useful in the system of FIG. 1. FIG. 6 is a detail section of the bit-weight applicator of FIG. 5B taken along line **6—6**.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The automatic drilling system of the invention, as depicted in FIG. 1, includes a string of drill pipe or a similar conduit **11** suspended in borehole **12**. The drill pipe can be raised or lowered by hoist **13** acting on drilling line **14** which suspends traveling block **15** from the crown block, not shown, of derrick **16**. Hook **17** is attached to the lower part of the traveling block and carries swivel **18** from which kelly **27** and drill pipe **11** are suspended. Mounted at the bottom of the drill pipe is drill bit **19**.

Drilling fluid is circulated in the system of FIG. 1 by means of a pump **20** which discharges through line **21** to swivel **18**, connected to the upper end of the kelly. Fluid passes down the kelly and drill pipe, through the drill bit, and returns through annulus 22 and return line 23 to fluid tank 24.

The apparatus of FIG. 1 also includes a drive mechanism, not shown, within housing 25 for applying torque to rotary table 26. The rotary table imparts rotary motion to kelly 27 which is coupled at its lower end to the drill string. In lieu of a rotary table, kelly and rigid string of drill pipe as shown, the invention can also be carried out with a flexible drill string connected to a turbodrill or similar downhole drive system.

Force is applied to the pit in FIG. 1 py bit-weight applicator 28 which includes extensible anchor shoes 29 and a hydraulic piston which is not shown. The construction of the bit-weight applicator is discussed in greater detail below in connection with FIGS. 3 through 6. In the device shown schematically in FIG. 1, hydraulic pressure is applied to the piston to force the drill bit downwardly against the bottom of the borehole. Pressure applied to the extensible shoes forces them outwardly against the borehole wall and thus prevents movement of the apparatus upwardly in the borehole.

A signal is transmitted to the upper end of the drill string when the piston reaches the lower end of its stroke. This can be accomplished by means of a mechanically actuated valve that is opened when the piston reaches the lower end of its stroke. The opening of the valve causes fluid within the drill string to be vented to the low-pressure annulus, thus reducing the fluid pressure within the drill pipe and causing a drop in pressure at the surface. The construction of such a valve is discussed in connection with the bit-weight applicators of FIGS. 3 through 6 below. Other signaling means such as an electric or acoustic system could also be used to create a detectable signal.

The apparatus responsive to the signal for lowering the drill pipe and resetting the piston for continuous drilling is illustrated in FIG. 2. This apparatus includes a cylinder 30 within which is a slidable piston 31. The piston is connected to hoist brake arm 32 by connecting rod 33. A packing gland, not shown, maintains a pressure-tight seal between the connecting rod and end of the cylinder. A pressure source 34 and a pressure regulator 35 control the pressure on the lower end of the piston. The pressure on the upper side of the piston 36 is that exerted by the drilling fluid. These two pressures are balanced by regulator 35 so that as the bit-weight applicator piston reaches the end of its stroke and the drilling fluid pressure drops in response to opening of the valve, the higher pressure on the under side of the piston forces the connecting rod 33 to move outwardly from hydraulic cylinder 30 and release the brake. The hoist then lowers the drill string the length of the weight-applicator piston stroke. This automatically closes the relief valve in the bit-weight applicator, causing pressure to build up within the drill string. The pressure buildup resets the extensible shoes and brake and actuates the hydraulic weight applicator piston so that drilling can be continued. It should be noted, however, that when the specific drilling operations undertaken require precise control of the progress of the bit within the borehole, it may be advisable to manually operate the hoist control instead of utilizing the apparatus illustrated in FIG. 2.

A bit-weight applicator suitable for use in the automatic drilling system of this invention is shown in FIG. 3. A hollow, telescoping power transmission shaft 101 is divided into an upper section 102 and a lower section 103. These are connected by a telescoping joint 104. The inner diameter of the upper section is enlarged near the lower end thereof to form an internal recess 105 bounded by a downwardly facing shoulder 106 and an upwardly facing shoulder 107. The upper end of lower section 103 includes an enlarged section 108 which fits within recess 105. Enlarged section 108 has an upwardly facing surface 109 which, when section 108 is in its uppermost position in recess 105, contacts shoulder 106. When section 108 is in its lowermost position, a downwardly facing shoulder 110 contacts upwardly facing shoulder 111 in recess 105. As is seen more clearly in the section shown in FIG. 4, splines 113 on lower shaft section 103 fit or interlock within matching recesses 114 of upper shaft section 102.

Outer housing 115 is mounted about telescoping shaft assembly 101. The lower part of the housing surrounds and is supported on lower section 103 by bearings 178 at the lower end of the housing and by intermediate bearings 116, 117, 118, and 119. A seal 179 is provided between housing 115 and shaft 103 just above bearings 178. Housing 115 surrounds surrounds and is supported on upper shaft section 102 by lower bearing 121 and upper bearing 122. The upper end of housing 155, designated by reference numeral 123, supports bearing 122 and wiper 124. The housing includes an external upwardly facing surface 125 and an internal downwardly facing shoulder 126. A resetting collar 127 having a downwardly facing surface 128 is provided on upper shaft section 102 above housing 115. Surface 128 is arranged to contact surface 125 on housing 115 when the shaft moves downwardly with respect to the housing. Upper shaft section 102 has an upwardly facing shoulder 129 just above annular recess 105. When shaft 101 is raised with respect to the housing, shoulder 129 engages shoulder 126 in the housing and supports it.

The portion of the apparatus utilized for applying force to the bit includes an upper piston 130 and a lower piston 131. These pistons may be, but are not necessarily, an integral part of lower shaft section 103. Internal recesses 132 and 133 in the housing 115 serve as cylinders for pistons 130 and 131 respectively. The upper portion of cylinder 132 above piston 130 communicates with the interior shaft 103 through port 134 and with longitudinal passageway 135 in the housing wall through port 136. The lower part of cylinder 132 communicates with the borehole annulus 140 through port 137 in the wall of the housing. The upper part of cylinder 133 above piston 131 communicates with the interior of shaft section 103 through port 138 and with passageway 135 through port 139. The portion of cylinder 133 below piston 131 communicates with the annulus 140 through port 141 in the wall of the housing. Pistons 130 and 131 are each provided with seals 142 and 143 respectively to prevent fluid from bypassing the pistons.

Intermediate bearing 119 and seal 145 are supported by the housing above cylinder 132. Below cylinder 132 are intermediate bearing 118 and seal 146. Bearing 117 and seal 149 are located below cylinder 133 Seals 120, 149, 146, 145, 112, and 124 can all be similar and are preferably lipped or V-ring seals.

Below the load developing section is an anchor section. This includes a pressure chamber 150 extending between the outer part of the lower shaft section 103 and the inner wall of housing 115. A port 151 in the wall of the lower shaft section provides fluid communication between the hollow shaft and pressure chamber. Port 152 in the wall of the housing leads to passageway 153. The wall of lower housing 115 adjacent pressure chamber 150 contains a series of openings 154 in which a plurality of anchor shoes 155 are mounted. These shoes preferably include a rubber member 156 which is molded to or otherwise sealed in contact with the walls of the openings 154. A hard metal core 157 is supported within the rubber material 156. The elasticity of the rubber member is such the core 157 is forced outwardly against the borehole wall when pressure is exerted in pressure chamber 150 but, when the pressure is released, the core is retracted by the rubber member. The lower portion of the anchor section, indicated by reference numeral 168, contains a bearing 116 and a seal 120 between the interior surface of the housing and the exterior of shaft section 103.

A stroke limit indicator section 190 is located below the anchor section in the apparatus of FIGS. 3 and 4. This includes a cylindrical piston 158 which slides in contact with inner walls of housing 115. Sealing is provided by upper seal rings 159 and 160 and lower seal ring 161. The piston is held against the uppermost end of the annular chamber formed by shaft 103 and housing 115 by a ball detent assembly 162 which includes a ball 163 and a spring 164 mounted in port 165 in the wall of the housing. Concave surface 166 on the lower skirt of the piston accepts the ball.

Stops 167 separate the piston from the housing above it. Shaft section 103 is enlarged to provide an intermediate flange 169. The lower edge 170 of the flange contacts surface 171 on the piston when the thrust pistons 130 and 131 reach the end of their stroke.

Port 172 provides communication between the drill string and the upper side of piston 158. Ports 173 and 174 through wall of housing 115 provide fluid communication between the borehole annulus and the underside of cylindrical piston 158. Ports 175 and 176 in the housing wall communicate with the annulus above the lower most position of the piston. The lower end of the stroke limit indication section 190, indicated by reference numeral 177, contains bearing 178 and seal 179.

A drill bit 180 is mounted at the lower end of lower shaft 103. Just above the drill bit is a spiraling preventer 181 which can be made an integral part of lower shaft section 103. The spiraling preventer includes a series of shoes 182 spaced about the circumference of the shaft. The face 183 of each shoe is preferably hard-surfaced. The diameter is approximately equal to or slightly greater than the relaxed diameter of the anchor shoes and less than the gage diameter of the bit. A spiraling preventer of this type stops or reduces spiraling and prevents substantial reduction of "drift" diameter of the hole. This permits rapid advancement of the outer case or housing 115 while resetting the tool.

A hardened steel stop 184 is provided on lower shaft section 103 above cylinder 132. This prevents pistons 130 and 131 from striking the packing glands housed within shoulder members 147 and 148 respectively. This stop is especially useful in drilling off; that is, when the bit has drilled nearly the full length of stroke of piston 130. Before pistons 130 and 131 strike the bottom of their respective cylinders 132 and 133, stop 184 comes in contact with annular shoulder 144 which is also hardened. This avoids severe damage to the piston packing and shaft seals.

In operation, the apparatus is assembled as shown in the drawing and is then lowered into the borehole until it reaches bottom. Drilling fluid is then pumped downwardly under pressure through the drill pipe and telescoping shaft 101 to drill bit 180. The drilling fluid expands anchor shoes 155 against the borehole, securely anchoring housing 115 against longitudinal or rotational movement. Fluid also flows through ports 134 and 138 to the upper side of push-down or thrust pistons 130 and 131. Ports 134 and 138 can be designed with respect to port 151 so that anchor shoes 155 will firmly anchor before pistons 130 and 131 move substantially with respect to housing 115. Other means for preventing premature movement can also be used. The drill string is rotated, thus causing bit 180 to advance. The force on the bit is supplied primarily by the downward thrust on pistons 130 and 131. The lower sides of these thrust pistons are in fluid communication with the relatively lower pressure in the annulus.

As drilling continues, pistons 130 and 131 move downwardly toward the cylinders. Just before the pistons strike the bottoms of the cylinders, stop 184 comes to rest. The lower edge 170 of flange 169 contacts piston 158. Continued drilling forces the flange downwardly against the piston until the restraining force of ball detent assembly 162 is overcome. Since passageway 153 and port 172 introduce fluid that is at drill string pressure to the upper side of piston 158 and since the underside of piston 158 is in communication with the annulus through ports 173 and 174, a differential pressure exists across the piston that will force it down against the bottom of the housing as soon as the ball detent is released. This opens ports 175 and 176, which are in communication with the annulus, to the upper chamber of the stroke limit indicator section between shaft 103 and housing 115. High-pressure fluid above pistons 130 and 131 flows through passageway 135 to pressure chamber 150, which communicates through passageway 153 with the stroke limit indicator section. The drill string communicates with the stroke limit indicator section through port 172. When the ports 175 and 176 are opened, the pressure within the tool and that in the annulus are equalized.

The reduction of pressure within the drill pipe allows anchor shoes 155 to retract Reduced pressure at the surface activates the automatic hoist control to lower the drill pipe the length of the piston stroke. This in turn forces collar 127 downwardly against shoulder 125 on the housing 115. The housing is thus pushed downwardly until pistons 130 and 131 are in the uppermost part of the cylinders 132 and 133 respectively. Flange 169 pushes piston 158 back into its uppermost position and the ball detent assembly 162 is re-engaged. During this operation, the lower shaft section 103 remains stationary with bit 180 on the bottom of the borehole. The upper shaft section 102, therefore, slides downwardly in telescoping joint 104. The "stroke" of the telescoping joint, the distance between upper surface 109 on the lower shaft section and the downwardly facing shoulder 106 on the upper shaft section 102 is approximately equal to the stroke of pistons 130 and 131. This permits complete resetting of the pistons. There is no danger of the pistons being jammed against the upper ends of the cylinders because stop 184 will limit relative upward movement of lower shaft section 103. In other words, the distance between stop 184 and the lower portion of upper shaft section 102 is approximately equal to the desired stroke of piston 130. The distance between upper shoulder 125 on the housing and resetting collar 128 is approximately equal to the distance between stop 184 and the housing beneath it. When the tool has been reset, fluid pressure again builds up in the drill pipe and the drilling operation continues as described before.

An important feature of telescoping joint 104 is that lower shaft section 103 can be "picked up" and upward force applied thereto through upper shaft section 102 and the drill string from the surface. This permits the force on bit 180 to be regulated from the surface in certain operations such as reaming where it is desired that a reduced force be applied to the bit. By lifting up on the drill string during drilling, the necessity for reducing the pressure of the fluid in the drill string to regulate the force on the bit can be eliminated. This permits variations in the circulating fluid pressure and volume without corresponding variations in the downward force on drill bit 180.

When it is desired to come out of the hole with the tool of FIGS. 3 and 4, the circulation of drilling fluid is interrupted so that anchor shoes 155 are retracted. The drill pipe is then lifted, causing upper shaft section 102 to move upwardly until shoulder 129 contacts shoulder 126 on the housing. Further upward movement of the drill pipe then moves housing 115 upwardly. Shoulder 108 on the lower shaft section contacts the shoulder 107 on the upper shaft section and thus the lower shaft section 102 and bit 180 are raised. The drill pipe is lifted until the tool has been removed from the borehole.

An alternate bit-weight applicator which is also suitable for use in the system of this invention is shown in FIG. 5. The apparatus depicted includes an upper barrel 201 including means for anchoring the device to the borehole wall and an inner telescoping power shaft 202, both of which are mounted near the lower end of the drill string. The telescoping assembly includes an inner tubular member **203**, a lower barrel **204**, and an extensible piston member **205**, all of which rotate with respect to the upper barrel. The piston member rotates and moves longitudinally with respect to the upper barrel. It also moves longitudinally with respect to the inner tubular member and the lower barrel. The interrelationship between these three is illustrated in cross-section in FIG. 6. The inner tubular member as shown includes three threaded joints, although it will be apparent that other methods of assembly would be suitable. Fluid passageways extending longitudinally in this member include chambers **206**, **207**, and **208** containing piston **218**, upper valve **210**, and lower valve **211** respectively. Positioned in the lower part of these passageways is a push-rod valve assembly. Rod **209** has an upper valve **210** and a lower valve **211** accurately spaced along its length and includes an upper valve actuator peg **212** and a lower valve actuator peg **213**. Each valve has sealing rings mounted circumferentially about it. The individual components of the push-rod valve assembly can be welded, threaded, or joined in some other fashion.

Upper valve chamber **207** contains a port **214** communicating with interior conduit **215** which contains drilling fluid. A second port **216** leads to an upper passageway **217** beneath sealing piston **218**. The third port, designated as **219**, leads to thrust piston chamber **220**. In its uppermost, open position, the upper valve **210** permits the passage of drilling fluid from the interior conduit **215** to both the sealing piston **218** and the thrust piston chamber **220**. In its lowermost position, this valve prevents the passage of fluid from the interior conduit to either the sealing valve or the piston chamber.

Sealing piston chamber **206** has two ports. The upper port **221** leads to wall-anchor fluid chamber **222**. The lower port opens into fluid passageway **217**, which is in communication through port **216** with the upper valve chamber. The sealing piston ports are always open, since the function of this piston is to maintain segregation between drilling fluid and hydraulic fluid and yet transmit drilling fluid pressure to hydraulic fluid contained within the wall-anchor fluid chamber.

Lower valve chamber **208** contains an upper port **223** that leads to thrust piston chamber **220** and a lower port **224** that opens into lower passageway **225**. This is open through slot **226** and ports **227** and **228** to the annulus when the piston is at the end of its stroke. With push rod **209** in its uppermost position, the lower valve is closed, isolating the thrust piston chamber from the annulus. The lower valve is open when the push rod is in its lowermost position and allows pressure to equalize between the annulus and the thrust piston chamber.

Positioning of the upper and lower valves occurs in response to the movement of thrust piston **229**. As the piston reaches the end of its stroke, beveled edge **230** contacts valve actuator peg **213** and pushes it down. When the piston is reset for another stroke, upper edge **231** of the thrust piston pushes valve actuator peg **212** up and forces the push rod into its uppermost position.

The lower portion of the inner tubular member is slotted as indicated by reference numeral **232** to accommodate a spline, not shown, on the thrust piston. The splined connection between the inner tubular member and the thrust piston compels the piston to rotate with the inner tubular member, but permits the piston to move longitudinally relative to the inner tubular member. A threaded pipe sub **233** forms the lower extremity of the inner tubular member. Packing **234** located in groove **235** in the sub forms a slidable seal with the extensible thrust piston member.

The extensible piston member is shown in FIG. 5 as an integral member with a threaded connection **236** at its lower end which is coupled to the shank **237** of a drill bit, the remainder of which is not shown. This member could also be constructed of several segments. To insure that the piston member and the lower barrel will rotate with the inner tubular member and the piston will slide longitudinally with respect to the other two members, the three are splined together. The piston includes a spline, not shown, which fits into groove **232** in the inner tubular member and a groove **238** which accepts spline **239** on the lower barrel.

The upper end of the piston member is slidably disposed within thrust piston chamber **220**. The exterior surfaces of the piston that contact the walls of the piston chamber are grooved for and contain sealing elements **240** and **241**.

Upper port **228** and lower port **242** allow fluid to pass through the cylindrical piston member. Port **228** is necessary to release fluid from the thrust piston chamber at the end of the piston stroke so that the wall anchor will release. Port **242** allows fluid within the drill string to escape to the annulus at the end of the piston stroke, thus equalizing pressure within and without the drill string and providing an ascertainable surface indication that the piston has completed its stroke.

The lower barrel **204** is splined to the extensible piston member at its lower end and attached at its upper end to outwardly flared upper portion **243** of the inner tubular member. The inner surface of the lower barrel forms the exterior surface of thrust piston chamber **220**. The upper barrel **201** contains wall anchor shoes **244** which lock it to the walls of the borehole. This barrel remains stationary during the drilling of each piston stroke, while permitting rotation of the inner telescoping power shaft within it.

The barrel is connected to the inner tubular member of the telescoping power shaft by means of bearings **245** and **246**. The lower set of four bearings **246** is mounted in groove **247** of the inner tubular member and groove **248** of the upper barrel, while upper bearing **245** is mounted in groove **249** of the inner tubular member and groove **250** of the upper barrel. These bearings both permit rotation of the inner power shaft and transmit force from the inner shaft to the walls of the borehole by means of the wall anchor shoes. Packing between the upper barrel and the rotating inner shaft is contained in upper groove **251** and lower groove **252** of the upper barrel.

Wall anchor fluid chamber **222** is in communication with wall anchor shoes and with sealing piston **218** through passageway **254**. Pressure of the hydraulic fluid is controlled by the pressure of the fluid in the drill pipe, which is in communication with the underside of the sealing piston. Wall anchor shoes **244** have teeth on their outer surface to better grip the walls of the borehole. Return springs **253** bias each of the shoes so that in their normal position they are retracted. As pressure builds up within the wall anchor fluid chamber, the shoes extend outwardly and dig into the borehole wall.

In operation, the tool with a drill bit attached to its lower end is lowered into the borehole on the end of a string of drill pipe or other suitable conduit. Drilling fluid is directed down the interior of the conduit, and, as a result of the pressure drop across the bit, pressure in excess of that within the annulus rapidly builds up within the drill pipe.

Setting the tool on bottom prior to any pressure buildup within the drill string collapses the telescoping power shaft and forces the thrust piston to its uppermost position within the piston chamber. This causes upper beveled edge **231** of the piston to push valve actuator peg **212** up positioning the push-rod valve assembly in its uppermost position as it is shown in FIG. 5.

Pressurized drilling fluid enters port **214** and flows toward the sealing piston and the thrust piston. The differential pressure between the drill string and the annulus causes wall anchor shoes **244** to overcome the force of return springs, extend, and engage the borehole wall. Since drilling fluid enters thrust piston chamber **220** through port **219** of the upper valve chamber, differential pressure is exerted on the thrust piston. The downward resultant of this force drives the bit against the bottom of the borehole. An opposing resultant force is, of course, transmitted to the borehole wall through the wall anchor shoes.

As the drill bit advances, the extensible thrust piston moves downwardly. The push-rod valve assembly does not move, however, until the piston reaches the end of its stroke. Near the end of the piston stroke, the lower beveled edge **230** of the thrust piston contacts valve actuator peg **213** and forces it and the whole push-rod assembly to their lowermost positions. This closes the upper valve and opens the lower valve. With the upper valve closed, no more pressurized drilling fluid can enter the thrust piston chamber or the sealing piston cylinder. Opening of the lower valve permits pressurized drilling fluid to escape from the thrust piston chamber through passageway **225**, slot **226**, port **227**, and port **228** into the annulus. This terminates the application of force on the bit and also allows the return springs to retract the wall anchor shoes, thus releasing the tool. At the same time, port **242** located in the extensible piston member moves past packing element **234** located at the lower extremity of the inner tubular member. This allows drilling fluid within the drill string to pass through port **242** to the annulus and so bypass the drill bit. Pressure between the drill pipe and the annulus equalizes.

Equalization of the pressures creates a reduction in pressure at the surface which actuates the hoist control, causing it to lower the drill string the length of the piston stroke. This resets the piston to the top of its stroke and another cycle is initiated.

What is claimed is:

1. Apparatus for drilling a borehole in the earth comprising:

(a) a drill string;

(b) means operatively connected to said drill string near the lower end thereof for anchoring said string to the wall of a borehole and exerting a downward force against the bottom of said borehole, said means including a hydraulically actuated piston having a vertical stroke, a plurality of laterally extensible shoes, and a device for emitting a signal detectable at the earth's surface when said piston reaches the lower end of its stroke;

(c) means at the earth's surface for detecting said signal, said means operatively related to said signal emitting device; and

(d) means operatively connected to said drill string and responsive to said detecting means for lowering said drill string and resetting said piston to permit continued drilling.

2. An apparatus for drilling a borehole in the earth comprising:

(a) a drill string;

(b) means operatively connected to said drill string near the lower end thereof for anchoring the string to the borehole wall and for forcing a drill bit against the bottom of the borehole, said means including a hydraulically actuated piston and a hydraulically actuated wall anchor;

(c) means operatively connected to said anchoring means for substantially reducing the pressure of a drilling fluid within said drill string when said piston reaches the end of its stroke; and

(d) means at the earth's surface operatively connected to said drill string and responsive to said pressure change for lowering said drill string to reset the piston for continued drilling.

3. Apparatus for applying force to a drill bit comprising:

(a) a hollow cylindrical upper barrel provided with pressure-actuated means for anchoring said barrel to the walls of a borehole;

(b) a hollow cylindrical inner tubular member, the upper portion of which is rotatably affixed within said upper barrel and the lower portion of which extends downwardly therefrom, the interior of said hollow inner tubular member forming an inner conduit extending from the top to the bottom of said tubular member;

(c) a cylindrical lower barrel member having a substantially frusto-conical upper end which is attached to the lower part of said inner tubular member to form an annular piston chamber between said lower barrel and said tubular member;

(d) a cylindrical extensible piston member having said drill bit structurally connected to the lower end thereof, said piston member slidably disposed within said annular piston chamber and attached to said inner tubular member and said lower barrel member to rotate therewith;

(e) means operatively connected to said inner tubular member for admitting fluid from said internal conduit to the upper end of said piston chamber to force said extensible piston to slide downwardly in relation to said inner tubular member and said lower barrel member; and

(f) means operatively connected to said extensible piston member for discharging said fluid from the upper end of said piston chamber to the annulus between said piston member and said borehole whenever said piston reaches the end of its stroke.

4. Apparatus for applying force to a drill bit comprising:

(a) a hollow cylindrical outer housing having pressure actuated means for anchoring said housing to the walls of a borehole, said housing having a plurality of internal circular shoulders that form annular piston chambers therebetween;

(b) a substantially cylindrical upper shaft section having an enlarged lower portion that terminates in a circular shoulder and having an internal fluid passageway therethrough, said upper shaft section rotatable with respect to said outer housing and slidably received within the upper end thereof;

(c) a substantially cylindrical lower shaft section, the lower end thereof being operatively connected to said drilling bit, said lower shaft section having an internal conduit therethrough, having its upper end slidably received within said enlarged lower portion of said upper shaft section so that its travel relative thereto is limited by said circular shoulder of said upper shaft section and having affixed to its exterior a plurality of cylindrical pistons, said pistons being so positioned along said lower shaft section as to be slidably disposed within said annular piston chambers of said outer housing;

(d) means operatively connected to said internal conduit for admitting fluid from said internal conduit to the upper ends of said piston chambers so as to force said pistons and said lower shaft section downwardly in relation to said outer housing; and

(e) means operatively connected to said internal conduit for discharging fluid from the upper ends of said piston chambers and from said internal conduit into the annulus between said outer housing and said borehole whenever said pistons reach the ends of their strokes.

5. A method for drilling a borehole in the earth wherein a drill string, bit-weight applicator, and drill bit are suspending within a borehole comprising:

(a) forcing drilling fluid down said drill string and through said drill bit so as to anchor said bit-weight applicator against the borehole wall and so as to cause said bit-weight applicator to force said drill bit against the bottom of the borehole;

(b) rotating said drill bit while continuing to force drilling fluid down said drill string so as to continuously apply force to said drill bit until the combination of rotation and force causes the drill bit to extend the borehole within the earth a distance equal to the length of the stroke of a thrust piston integral within said bit-weight applicator; and

(c) lowering said drill string the length of the stroke of said piston in response to a surface-detectable signal emitted by said bit-weight applicator whenever said piston reaches the end of its stroke.

6. Apparatus as defined by claim **3** wherein said means for discharging fluid from the piston chamber is operatively connected to said lower barrel member.

References Cited

UNITED STATES PATENTS

2,937,007	5/1960	Whittle	175—321 X
3,088,532	5/1963	Kellner	175—321 X
3,138,214	6/1964	Bridwell	175—321 X
3,207,238	9/1965	Davidson	175—27 X
3,225,843	12/1965	Ortloff	175—321 X
3,233,689	2/1966	Whittle	175—27 X

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