June 23, 1964 H. C. BRIDWELL 3,138,214

BIT FORCE APPLICATOR

Filed Oct. 2, 1961 2 Sheets-Sheet 1

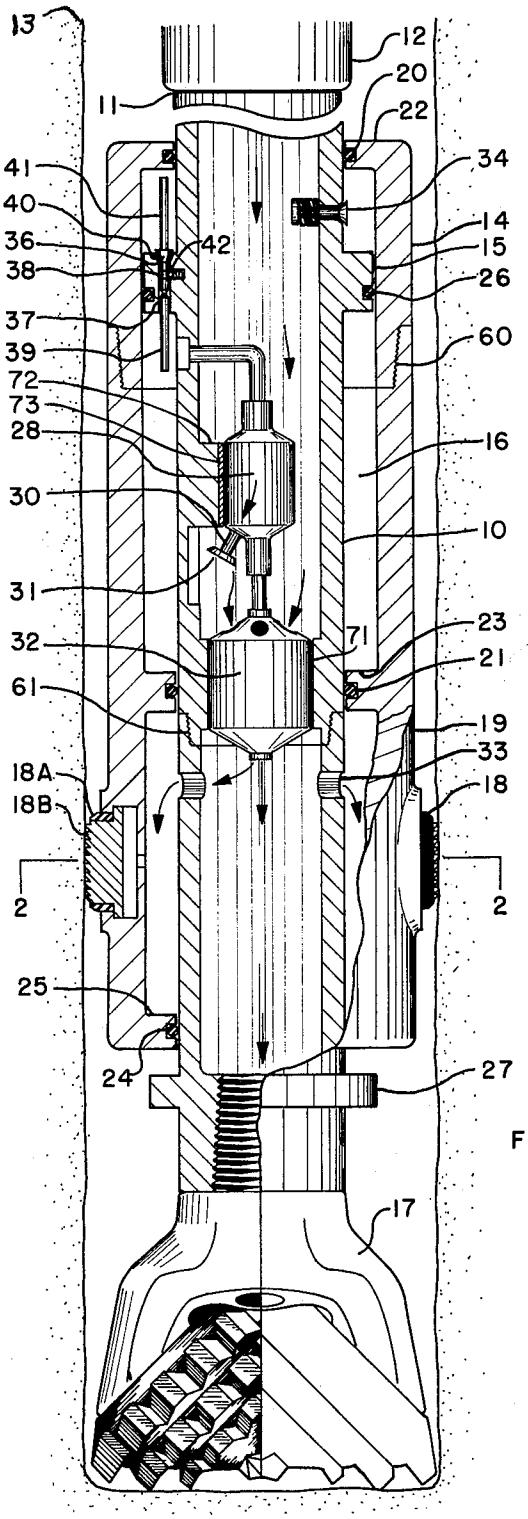

FIG. 1

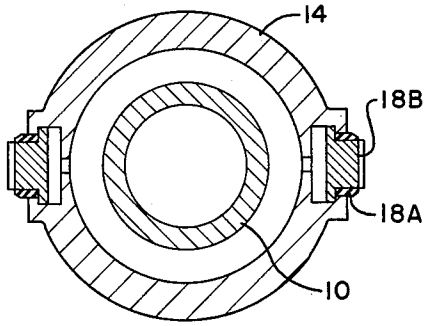

FIG. 2

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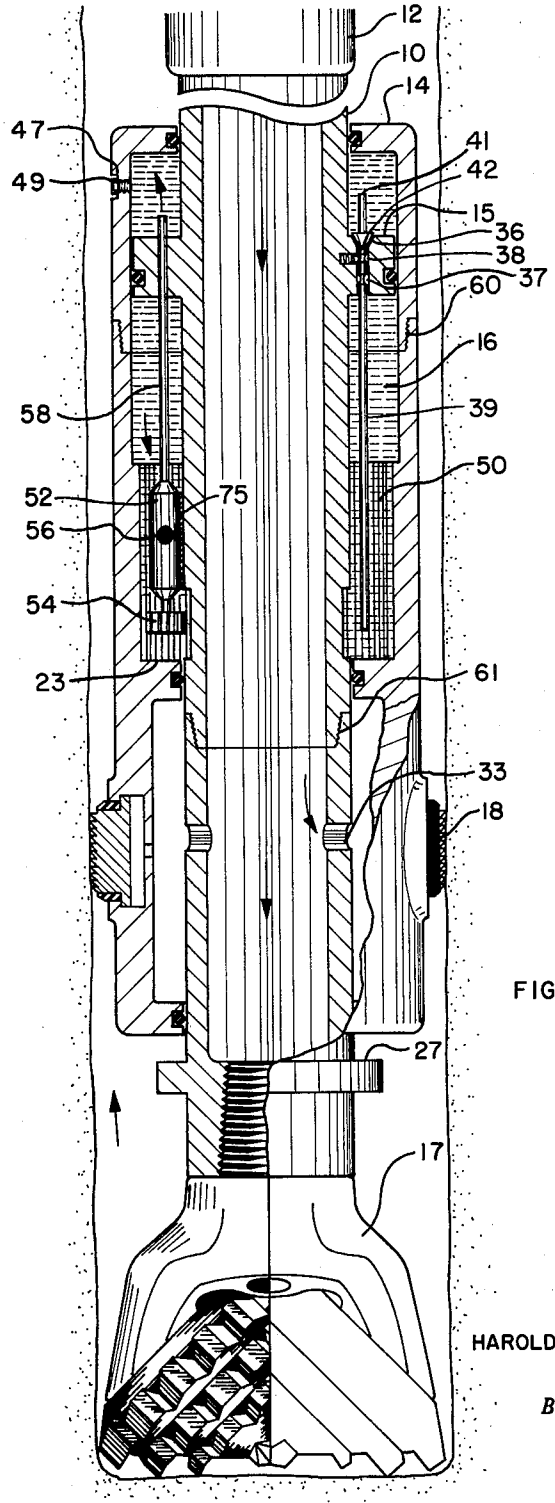

FIG. 3

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BIT FORCE APPLICATOR

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9 Claims. (Cl. 175—230)

This invention concerns the drilling of boreholes, oil wells, and the like. It relates in general to a system for forcing a bit against the bottom of a borehole. It relates especially to a hydraulic system for forcing a bit against the bottom of a borehole.

The rotary drilling system is the most commonly used method in the art of drilling wells for the production of oil and gas. In this system a drill bit is suspended at the lower end of a string of drill pipe which is supported from the surface of the earth. A drilling fluid is forced down through the drill string, through the drill bit, and back up to the surface through the annulus between the drill pipe and the walls of the borehole. While the drilling fluid serves primarily to carry the rock cuttings from the drill bit to the surface, it also serves to lubricate and cool the drill bit. The drill bit obtains its rotary motion from the drill pipe which is rotated from the surface. It is known that the rate of penetration of a drill bit can be increased by increasing the force of the drill bit on the bottom of the borehole.

A usual method for increasing the pressure of the bit on the bottom of the borehole which has been tried with some success is by the addition of several heavy drill collars between the drill bit and the drill string. This method, however, has not been completely satisfactory. While the addition of drill collars aids the penetration rate, this advantage is partially offset by the need for heavier surface equipment. The borehole also tends to deviate considerably from the vertical during drilling. Again, many horsepower and much "rig time" are required in pulling the drill pipe, drill collars, and drill bit during normal operations of drilling such as are required when the drill bit becomes worn and needs replacing.

In the broad aspect, this invention comprises means for forcing a bit against the bottom of a borehole. In a preferred embodiment this includes an arbor attachable at its lower end to a bit and at its upper end to a drill string. The arbor is rotatable with respect to the housing which surrounds it. In a preferred embodiment an annular piston is supported by the arbor. The upper part of the housing forms a cylindrical cylinder with the arbor that is adapted to receive the piston. Differential pressure across the piston forces the arbor downwardly in the direction of the bit. Anchor means are provided in the housing and are of a character such that when actuated, engage the borehole wall and transfer the reaction thrust of the downward force to the borehole wall.

In normal drilling operations there is a considerable pressure drop resulting when the drilling fluid passes through the drill bit. Thus, the pressure of the drilling fluid within the arbor is considerably greater than that on the exterior of the tool. Thus, the pressure differential between the drilling fluid in the arbor and that in the annulus between the drill pipe and the borehole can be used to actuate the pushdown piston, thus forcing the arbor and the bit downwardly. There is an optimum rate of pumping drilling fluid through a drilling bit in order to obtain optimum drilling conditions. This optimum rate then normally results in a certain pressure drop across the bit. If the downward force is not sufficient, additional pushdown units can be placed in tandem in the borehole. This will, of course, greatly increase the length of the tool in the borehole and the downward force is not

as concentrated near the bit as desired. However, this problem is not present in the instant invention. Pumping means are provided which positively increases the pressure differential across the pushdown piston. The pumping means can be actuated in various means such as by a hydraulic motor or can be gear driven by mating gears between gears on the pump which can be attached in a preferred embodiment to the arbor and with driving gears thereon which mate with gears on the housing which is locked to the borehole wall when in operation. In a preferred embodiment, the cylinder below the piston is not in fluid communication with the exterior of the apparatus. Rather, a pump is provided such that the inlet of the pump is in fluid communication with the cylinder below the piston. Operation of the pump removes fluid from beneath the piston and provides a large pressure differential across the piston; the pressure differential being nearly equal to the pressure of the fluid in the arbor. Various objects and a better understanding of the invention will be had from the following description taken in conjunction with the drawing in which:

FIG. 1 illustrates the preferred embodiment of this invention;

FIG. 2 illustrates a sectional view taken along the line 2—2 of FIG. 1; and

FIG. 3 illustrates another embodiment of this invention.

Attention is directed to the drawing and toward FIG. 1 in particular which illustrates an embodiment of a fluid operated bit loading device in which means are provided to increase the downward force exerted on a piston which is connected to a sub or arbor section which "pushes" against a bit. Numeral **10** indicates a hollow sub or arbor which is connectable at **11** to a string of drill pipe. Drill pipe **12** is suspended from the surface in a conventional manner in borehole **13**. Arbor **10** extends through outer case or housing **14** and is rotatable with respect to housing **14**. A pushdown or thrust piston **15** which is attached to arbor **10** is disposed in annular cylinder **16** which is formed in the annulus between housing **14** and arbor **10**. A drill bit **17** is attached to the lower end of arbor **10**. Thus in the drawing shown, arbor **10** provides a rigid connection between bit **17** and drill string **12**.

Below annular cylinder **16** is a wall anchor or hold down section which includes hold down anchor shoes or blocks **18**. Hydraulically expansible hold down anchor blocks **18** are disposed in the wall of housing **14** and are of a type that, when actuated, rigidly hold the outer case in a fixed position against the wall of the borehole. The individual anchor blocks, of which there may be any selected number, are normally preferably composed of expansible material such as rubber **18A** molded around a metal core **18B**. Rubber elements **18A** can be similar to those shown in U.S. Patent No. 3,088,532. When actuated by a pressure between the interior of arbor **10** and outer frame **19** which is a part of housing **14**, the anchor blocks are expanded outwardly to contact and firmly grip the wall of the hole.

Anchor blocks **18** are spaced one from the other so that circulating fluid may pass upwardly through the annulus between the outer housing and the borehole wall through the plates between the anchor blocks. In other words, the anchor blocks do not block the annular passageway.

Suitable seals are provided. These include seals **20** and **21**, sealing chamber **16** between the outer wall of sub **10** and internal shoulders **22** and **23** respectively of housing **14**. The lower end of housing **14** has seals **24** to form a sealing contact between lower shoulder member **25** and the exterior wall of sub **10**. Piston **15** is also provided with seals **26**. Seals **24** and **26** can be O-ring seals for example. A stop **27** is provided on the lower end

of arbor 10 beneath housing 14 so as to limit the downward movement of housing 14 with respect to the sub. For ease of assembly, housing 14 has a threaded joint means 60 connecting an upper section of the housing to a lower section. Likewise, as illustrated, arbor 10 has a threaded joint means 61 connecting an upper section and a lower section.

The amount of force exerted downwardly on piston 15 is proportional to the differential pressure across the piston. One way of accomplishing an increase in differential pressure is shown in FIG. 1. A suction pump 28 is provided such that its inlet or suction side is connected to cylinder 16 below piston 15. The discharge line 30 of pump 28 is connected through valve 31 to the interior of arbor 10. Pump 28 is held to shoulder 72 of arbor 10 by weld 73 for example. Preferably valve 31 is a pressure operated valve that opens only after the pressure in the pump 28 has built up to a predetermined level. This prevents the fluid in cylinder 16 below piston 15 from escaping before the anchor section 18 has had a chance to become anchored.

Power for driving pump 28, as illustrated, is a hydraulic motor 32 which is supported from arbor 10 and is driven by the downward flow of hydraulic fluid. Motor 32 can be supported for example as illustrated by being press fitted into annular shoulders 71 of arbor 10. Ports 33 are provided in arbor 10 to provide fluid communication between the interior of arbor 10 and the interior of the anchor section so as to provide fluid pressure against anchor shoes 18. A valve 34 is provided in arbor 10 above piston 15. This valve is a pressure valve and opens only after the pressure in arbor 10 has reached a predetermined minimum. This minimum is greater than the amount required for anchor shoes 18 to become anchored. Thus the device is securely anchored to the wall before fluid pressure forces piston 15 downwardly with respect to the housing 14.

Means will now be described for permitting fluid from below piston 15 within annular cylinder 16 to escape so that the outer housing, when anchor shoes 18 are not actuated, is lowered by gravity downwardly against stop 27 connected to arbor 10. This includes a valve 36 in a vertical passage through piston 15. Valve 36 has a lower recess 37 and an upper recess 38 in stem 39 which extends downwardly from valve seat 40 through the piston. An upper stem 41 extends upwardly from the valve proper in piston 15. A spring loaded ball 42 holds the valve in either a closed position when ball 42 is in upper recess 38 as shown, or in an open position when in the lower detent 37.

In operation the device of FIG. 1 is inserted in the drill string and lowered to the bottom of the borehole. The weight of the housing 14 will lower itself downward against stop 27 and thus close valve 36 as stem 41 is forced downwardly by the weight of the case 14. When valve stem 39 is lowered to its lower position, spring loaded ball 42 is in upper recess 38 such that the valve is closed, that is the portion of cylinder 16 above piston 15 is not in fluid communication with that portion of the cylinder below the piston. When the bit 17 is on the bottom of the borehole, drilling fluid under pressure is inserted downwardly through drill string 12 which inflates anchor shoes 18 securely against the borehole wall before valve 34 opens permitting fluid to enter cylinder 16 above piston 15. Hydraulic fluid operates hydraulic motor 32 which starts operating pump 28 which removes the fluid from beneath piston 15. The discharge pressure of pump 28 must reach a predetermined setting to force fluid through discharge pressure operated valve 31. By properly selecting the pressure at which valves 34 and 31 open, anchorage of anchor 18 is obtained before any substantial downward force is created on piston 15. The differential pressure across piston 15 then is seen to be very great as the pressure below piston 15 is reduced to a very small amount approaching less than one atmosphere of pressure or zero p.s.i. As an example of the differential pressure, at 5000 ft. depth and using a drilling mud of 10 lb./gal., the static pressure alone is approximately 2500 p.s.i. If the area of piston 15 is 10 sq. in. the downward force exerted is in excess of 25,000 p.s.i. When the dynamic pressure is considered the downward force is found to be even greater. The rotation of the drill string is then commenced and drilling proceeds with the force of the fluid on piston 15 being transmitted through the arbor 10 to bit 17. When the bit advances the length of the stroke of piston 15, the device is ready to be reset. Stem 39, in coming into contact with shoulder 23 pushes the valve to an open position which is held there inasmuch as ball 42 is forced into the lower recess 37. Drilling fluid is then shut off and the weight of the housing 14 causes the tool to lower itself down to stop 27. When the drilling fluid pumps are shut off, the pressure within mandrel 10 equalizes with that in the borehole annulus exterior housing 14. With this equalized pressure, the resilience of rubber 18A returns the anchors to their normal retracted position. When housing 14 reaches stop 27, it will be seen that valve 36 is closed as stem 41 is forced downwardly, thus forcing valve 36 into its closed position. At this time drilling fluid is again started circulating down through the arbor 10 and rotation of the drill bit is subsequently started as described above.

Attention will now be directed to FIG. 3 which is a modification of the device of FIG. 1. In FIG. 1 a hydraulic motor is illustrated to drive a pump, whereas in FIG. 3 the pump is driven by a mechanical motor. In the system of FIG. 1 the pump is used to decrease the pressure below piston 15. In FIG. 3 the pump is also used to decrease pressure below piston 15 but is further used to increase the pressure above piston 15, i.e. the intake to the pump is below piston 15 and the discharge is above piston 15. A port 47 having plug 49 is provided in the wall of housing 14. Fluid for pump 52 is supplied through this port.

In FIG. 3 the lower interior of annular chamber 16 is arranged to define drive gear 50. The longitudinal length of the drive gear 50 is approximately the same length as the length of the stroke of piston 15. Suction pump 52 is carried from and supported by arbor 10 such as by weld 75. A pump drive gear 54 is supported from pump 52 and is arranged such as to mesh with drive gear 50. Inlet 56 of pump 52 is in fluid communication with chamber 16 below piston 15. The discharge of pump 52 is in fluid communication with cylinder 16 above piston 15 through conduit means 58. Pump 52 is operative upon rotation of arbor 10 after anchor shoe 18 has anchored case 14 to the borehole wall.

In operation the tool shown in FIG. 3 is attached to the lower end of a string of drill pipe and is lowered into a drill hole. The weight of the apparatus causes the outer housing and its accompanying parts to be lowered with respect to arbor 10 and come to rest on stop 27. When this occurs, stem 41 has been struck or contacted by the upper part of housing 14 and shoved down so as to close valve 36 by forcing it downwardly such that ball 42 is held by upper recess 38 and the valve is thus held in its closed position. When the tool has been lowered to the bottom of the borehole, the pressure of the drilling fluid in arbor section 10 is then increased and the anchor shoes are forced outwardly against the borehole wall by fluid acting through ports 33. After the anchor section has been securely anchored to the borehole wall, rotation of the drill pipe is commenced. The rotation of the drill pipe causes pump 42 to take fluid from beneath piston 15 and pump it under high pressure into the chamber 16 above piston 15. This results in a large differential pressure across piston 15 thus forcing piston 15 downwardly. Piston 15, being rigidly attached to bit 17, thus forces the bit downwardly against the bottom of the borehole. The reaction thrust

is conveyed through housing 14 to the anchor section 18 where it is transferred to the borehole wall.

As drilling continues and the borehole advances, piston 15 approaches the lower end of its stroke. As this happens, stem 39 pushes valve 36 into its open position where it is held by ball 42 being held by lower recess 37. At this point the drilling fluid pressure is reduced and anchor shoes 18 become relaxed and the tool is no longer anchored to the borehole wall. The weight of housing 14 causes it to move downwardly so that the cycle can be repeated.

While there are above disclosed but a limited number of embodiments of the structure and system of the invention herein presented, it is possible to produce still other embodiments without departing from the inventive concept herein disclosed. It is therefore desired that only such limitations be imposed on the appended claims as are stated therein.

What is claimed is:

1. An apparatus attachable to the lower end of a string of drill pipe for forcing a bit against the bottom of a borehole comprising in combination: a hollow arbor rigidly attaching said bit to said string of drill pipe, a piston fixed to the exterior of said arbor; a housing surrounding said arbor in a slidable, rotatable and sealing relationship therewith and defining a cylinder for said piston, said cylinder adapted to contain a fluid, said piston being disposed intermediate the ends of the cylinder to define an upper and a lower chamber; means including a pump having its inlet in fluid communication with said lower chamber operable to discharge fluid from said lower chamber to said upper chamber; wall anchor means mounted on said housing and operable to anchor said housing to the wall of the borehole; a passage through said piston establishing fluid communication between said chambers; a valve in said passage; and means operative to close said valve when said housing is moved to a predetetermined lower position with respect to said piston and to open said valve when the housing is moved to a predetermined upper position with respect to said piston.

2. An apparatus attachable to the lower end of a string of drill pipe for forcing a bit against the bottom of a borehole comprising in combination: a hollow arbor rigidly attaching said bit to said string of drill pipe, a piston attached to said arbor; a housing means surrounding said arbor in a slidable rotatable and sealing relationship therewith and defining therewith (*a*) a cylinder for said piston and (*b*) a pressure chamber between said arbor and said housing means, said pressure chamber being longitudinally spaced from said cylinder; means for supplying fluid to said cylinder; anchor shoes resiliently mounted in that part of the wall of said housing means defining said pressure chamber and operable upon fluid actuation to expand against the wall of the borehole; port means in said arbor establishing fluid communication between the interior of said arbor and the pressure chamber; a pump supported by said arbor and mounted within said cylinder, the inlet of said pump being in fluid communication with the cylinder below said piston; a pump driving gear mounted on said pump and operable upon rotation to drive said pump; a drive gear on the lower internal surface of said cylinder and arranged to mesh with said pump drive gear; conduit means establishing fluid communication between the discharge of said pump and the cylinder above said piston; a passage through said piston establishing fluid communication between said cylinder below said piston and that part of said cylinder above said piston; valve means in said passage; means operable to close said valve when said housing is in a lower position with respect to said piston and to open said valve when said housing is in an upper position with respect to said piston.

3. An apparatus as defined in claim 2 including a stop on the exterior of said arbor below said housing to limit the lower travel of said housing with respect to said arbor.

4. An apparatus attachable to the lower end of a string of drill pipe for forcing a bit against the bottom of a borehole comprising in combination: an arbor rigidly attaching said bit to said string of drill pipe, said arbor having a longitudinal passageway therethrough; a piston rigidly fixed to the exterior of said arbor; a housing surrounding said arbor in a slidable, rotatable and sealing relationship therewith and defining a cylinder for said piston; means including a pump having its inlet in fluid communication with said cylinder beneath said piston and operable to pump fluid from beneath said piston to said cylinder to above said piston; wall anchor means mounted on said housing and operable to anchor said housing to the wall of the borehole; and means operable to establish fluid communication between that part of said cylinder above said piston with that part below said piston when said housing is in its uppermost position with respect to said piston.

5. In a rotary drilling system for drilling a borehole, including a drill string and a bit, the improvement which comprises: an arbor rigidly connecting said drill string to said bit adapted to convey fluid from said drill string to said bit; a piston attached to said arbor; a housing surrounding said arbor in a rotatable, longitudinally slidable, and sealing relationship therewith and defining a cylinder for said piston; port means in said arbor to provide fluid communication between said arbor and said cylinder above said piston; pumping means having its inlet in fluid communication with said cylinder beneath said piston, said pumping means being supported by said arbor and operable to remove fluid from said cylinder beneath said piston; and wall anchor beans mounted on said housing and operable to anchor said housing to the wall of the borehole.

6. An apparatus as defined in claim 5 including a pressure valve in said port in said arbor operable to open upon the pressure in said arbor reaching a predetermined selected amount.

7. An apparatus attachable to the lower end of a string of drill pipe for forcing a bit against the bottom of a borehole comprising in combination: an arbor connecting said drill pipe to said bit and adapted to convey fluid from said drill pipe to said bit; a piston attached to said arbor; a housing means surrounding said arbor in a slidable rotatable and sealing relationship and defining a cylinder for said piston; means including a pump having its inlet in fluid communication with said cylinder beneath said piston for selectively applying fluid under pressure above the piston and for withdrawing fluid from below the piston; and wall anchor means mounted on said housing means and operable to anchor said housing means to the wall of the borehole.

8. An apparatus attacheable to the lower end of a string of drill pipe for forcing a bit against the bottom of a borehole comprising in combination: a hollow arbor rigidly attaching said bit to said string of drill pipe; a piston fixed to and mounted about said arbor; a housing means surrounding said arbor in a slidable, rotatable and sealing relationship therewith and defining a cylinder for said piston; port means in said arbor to provide fluid communication between said arbor and said cylinder above said piston; pumping means supported by said arbor, the inlet to said pumping means being in fluid communication with the said cylinder below said piston and the discharge of said pumping means being the interior of said arbor; wall anchor means mounted on said housing means and operable to anchor said housing means to the wall of the borehole; and means to prevent longitudinal movement between said arbor and said housing means while said anchor means is being secured to the borehole wall.

9. In a rotary drilling system for drilling a borehole including a drill string and a bit, the improvement which comprises: an arbor of a character to rigidly connect said drill string to said bit and adapted to convey fluid from

said drill string to said bit; a piston fixed to the exterior of said arbors; a housing surrounding said arbor in a rotatable and longitudinally slidable relationship therewith and defining a cylinder for said piston; pump means, the intake to said pump being fluidly connected to the cylinder below said piston and the outlet from said pump being to the cylinder above said piston; drive means interconnecting said arbor and said pump means such that said pump means is actuated by the rotation of said arbor and wall anchor means mounted on said housing and operable to anchor said housing to the wall of the borehole.

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