Percussion drilling system

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10 Claims

ABSTRACT OF THE DISCLOSURE

A tool for imparting percussive energy to a subterranean formation at the bottom of a borehole which includes an elongated housing containing an annular cylinder and a gas reservoir communicating with the cylinder, a hollow mandrel that extends through the cylinder and projects from the lower end of the housing, an annular piston which is attached to the mandrel within the cylinder and in its uppermost position prevents communication between the reservoir and cylinder, and an elongated actuating member that extends downwardly through the mandrel from a cap at its upper end.

BACKGROUND OF THE INVENTION

Field of the invention

This invention relates to a percussive tool for use in drilling oil wells, gas wells, and similar boreholes.

Description of the prior art

The use of percussion tools has often been suggested as a means for obtaining higher penetration rates in hard formations during oil field drilling operations. The most successful tools of this type have been fluid-actuated devices containing a hammer, an anvil which the hammer strikes to transmit percussive energy to a bit at the lower end of the tool, and a valve mechanism for controlling movement of the hammer in response to the flow of drilling fluid. Experience has shown that certain of these tools are reasonably effective in operations where compressed air or natural gas is used as the drilling fluid but that they are seldom satisfactory in systems using drilling muds or similar liquids. For this reason, percussive tools have been used to only a limited extent.

SUMMARY OF THE INVENTION

This invention provides an improved tool for imparting percussive energy to the formation at the bottom of a borehole that avoids many of the difficulties encountered with tools available in the past. The apparatus of the invention includes an elongated outer housing which is connected to the lower end of a drill string extending downwardly in the borehole from the earth's surface. The housing contains a reservoir of pressure nitrogen or a similar gas and an annular cylinder into the upper part of which the gas can be introduced. A hollow mandrel extends through the cylinder and is connected to a percussion bit or similar device below the housing. An annular piston is attached to the outer surface of the mandrel for operation within the cylinder. In its uppermost position, this piston acts as a valve to prevent the entry of gas from the reservoir into the cylinder. The portion of the cylinder below the piston is evacuated to increase the differential pressure acting on the upper surface of the piston. An elongated actuating member fitted with a cap at its upper end extends through the mandrel and bit.

The device of the invention is actuated by first lowering the tool against the bottom of the borehole so that the housing moves downwardly about the mandrel. This forces gas in the cylinder above the piston into the reservoir. Flow between the cylinder and reservoir is shut off when the upper end of the cylinder reaches the piston. The entire tool is then lifted from the surface until the actuating member clears the formation and the cap at its upper end closes off the opening through the mandrel. This interrupts the flow of drilling fluid through the apparatus and results in an increase in hydraulic pressure against the cap and upper end of the mandrel. In response to this increase in pressure, the reservoir and mandrel are forced downwardly with respect to the housing.

High pressure gas from the reservoir expands into the cylinder and drives the piston downwardly until the bit strikes the formation. The tool is then reset by again lowering the apparatus from the surface. A hydraulic cylinder containing a piston supported by high pressure gas can be used at the earth's surface to facilitate the resetting operation.

Studies have shown that the apparatus of the invention provides significantly greater power outputs than are generally obtained with conventional rotary drilling systems and that this in turn may result in substantially higher penetration rates than might be secured otherwise. This advantage, coupled with the simplicity of the system and the fact that it can be used with either liquid or gaseous drilling fluids, makes the tool useful under a variety of different drilling conditions and often permits drilling at costs well below those incurred with conventional systems.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 in the drawing is a partial elevation of an oil field drilling rig provided with the apparatus of the invention, FIGS. 2A and 2B is a detailed vertical section through the percussion tool and bit depicted schematically in FIG. 1, and FIGS. 3, 4, and 5 are schematic diagrams illustrating the operation of the tool of FIGS. 2A and 2B.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 in the drawing depicts an oil field drilling rig and auxiliary equipment for carrying out the invention. The apparatus shown includes a conventional derrick 10 provided with a draw works 11 and a rotary table 12. The upper part of the derrick, the crown block, and the dead line have been omitted to simplify the drawing. Lines 13 extending from the crown block support traveling block 14. A hydraulic cylinder 15 is suspended from the traveling block by means of hook 16. The cylinder contains an internal piston 17 to which rod 18 is connected. The rod extends downwardly through a sealed opening in the lower end of the cylinder and is provided with a hook 19. Hose 20 and rigid line 21 extend between the lower end of the cylinder and a high pressure gas reservoir 22. The reservoir is filled with nitrogen gas maintained at a pressure sufficient to lift the drill string connected to the rod and piston assembly. The pressure required will depend upon the area of the piston and the effective weight of the drill string but will normally be on the order of 5,000 pounds per square inch or higher. Hose 23 and line 24 extend between the upper end of the cylinder and a three way valve 25. This valve is connected through discharge line 26 to a hydraulic fluid reservoir 27 and through line 28 to a high pressure hydraulic pump 29. A line not shown in the drawing connects the inlet side of the pump and the lower part of the reservoir. By pumping hydraulic fluid from reservoir 27 into the upper end of the cylinder above the piston, the piston and rod assembly can be forced downwardly to lower the drill string in the borehole. By switching valve 25 so that fluid from the upper end of the cylinder flows into reservoir 27, the drill string can be raised.
This provides a relatively inexpensive means for raising and lowering the string without the necessity for using the draw works.

The hydraulic cylinder and associated apparatus of FIG. 1 supports an oil field swivel 30 to which a conventional Kelly 31 is connected. Hose 32 and line 33 extend from the swivel to a pump or compressor, not shown, which is used to pump drilling fluid to the system. The fluid employed may be a drilling mud or similar liquid or a gas such as compressed air or natural gas. The Kelly extends through the rotary table 12 and is connected to a string of drill pipe 34 which in turn extends through a conventional blowout preventer 35 and wellhead 36. Below the wellhead, the borehole 37 has been provided with a string of casing 38 which is surrounded by cement 39. A string of drill collars, not shown, a percussion tool 40, and a percussion bit 41 are connected in place at the lower end of the drill pipe. The percussion tool and bit are shown in greater detail in FIG. 2 of the drawing. Drilling fluid circulated in the borehole 37 downwardly through the drill pipe, drill collars, percussion tool, and bit is returned to the surface through an annulus surrounding the drill string. The returning fluid is discharged through line 42 to a mud pit or other facility not shown.

FIGS. 2A and 2B is a detailed drawing of the percussion tool 40 shown schematically in FIG. 1. This tool includes an outer housing provided with an API tool joint box connection at its upper end. The housing is preferably arranged in sections as shown to facilitate its construction and assembly. In the embodiment depicted, the upper section 43 is provided with internal threads 44 at its upper end. Below this upper section are an inner sleeve 45 and an outer sleeve 46. The outer sleeve is connected to upper section 43 by means of threads 47 and is provided with a seal ring 48. The inner sleeve extends into the upper section below the threads 44 through seal ring 49. An intermediate member 50 is connected to the lower ends of the two sleeves by threads 51 and 52 below seals 53 and 54. This provides an annular reservoir 55 which surrounds a drilling fluid passageway 56 through the inner sleeve. An inlet 57 containing a check valve 58 is provided in the upper section to permit the charging of this reservoir with high pressure gas. Nitrogen or a similar inert gas normally can be used. The gas is discharged from the reservoir through longitudinal passageways 59 and 60 in the intermediate member. Only two passageways appear in the drawing but a greater number will normally be provided in order to reduce the pressure drop.

The housing also includes a second inner sleeve 61 and an outer sleeve 62 which engage the lower end of intermediate member 50. The outer sleeve is held in place by threads 63 above seal ring 64. The inner sleeve slips into the lower end of member 50 and is surrounded by seal ring 65. The two sleeves are connected at their lower ends, by threads 67 and 68 below seals 69 and 70, to a second intermediate member 66 containing longitudinal passageways 71 and 72. Again, more than two passageways will normally be provided. This provides a second annular reservoir 73 which communicates with the first through passageways 59 and 60. This particular arrangement has advantages from the standpoint of constructing and assembling the tool but it will be apparent that a single large reservoir could be used in place of the two interconnecting reservoirs shown. As will be pointed out hereinafter, the volume of the reservoirs is determined in part by the desired stroke of the tool and the gas pressure employed.

The lower end of intermediate member 66 defines the upper end of an annular cylinder 74 in the housing wall. An elongated sleeve 75 which is attached to member 66 by threads 76 above seal ring 77 forms the outer cylinder wall. Passageways 78 and 79 extend longitudinally in the upper part of sleeve 75 to permit the introduction of gas into the upper part of the cylinder through ports 80 and 81. At its lower end, sleeve 75 is connected by threads 82 to a lower housing section 83. The upper end of this member serves as the bottom of the cylinder 74. Seal rings 84 and 85 are provided to prevent leakage between the two members. The bottom of the lower housing section is provided with projections 86 which extend downwardly between the blades of the percussion bit 41. The bit depicted is provided with three blades and hence these projections on the lower end of the housing are spaced 120° apart. If a two-bladed or four-bladed bit is employed, the spacing of the projections will be modified accordingly.

Extending downwardly through the housing of the tool is an elongated mandrel 87. This member is of circular cross section and is hollow over its entire length. The inner wall is tapered at the upper end to form an annular seat 88. An annular piston 89 is mounted on the outer surface of the mandrel within cylinder 74. The piston is held in place by a ring 90 set in a groove in the mandrel wall. The ring and piston are welded or brazed to one another. The cross-sectional area of the mandrel below the piston is slightly larger than that of the mandrel above the piston. The outer surface of the piston contains a circumferential recess 91 bounded by seal rings 92 and 93. A check valve 94 is installed in the upper surface of the piston and the circumferential groove to permit the entry of gas into the piston recess from the upper part of the cylinder. A similar check valve 95 between the piston recess and the lower face of the piston permits the entry of gas into the recess from the outside of the piston. Seal rings 96, 97, 98, and 99 provide a seal between the mandrel and the inner wall of the housing above and below cylinder 74. Percussion bit 41 is connected to the lower end of the piston by threaded joint 100. The length of the mandrel is such that the bit is located adjacent the lower end of the housing when the piston is in the upper end of cylinder 79 as shown in FIG. 2. The upper end of the mandrel extends a sufficient distance above the piston to maintain a seal between the mandrel and housing when the piston is at the lower end of the cylinder. The distance between the upper end of the mandrel and the lower end of intermediate member 60 should be approximately the same as the length of the cylinder.

The bit 41 contains an axial passageway having essentially the same diameter as the passageway extending through the hollow mandrel. An actuating member 101 extends downwardly through the opening in the mandrel and bit. At its upper end this member is fitted with a cap 102 that extends into an opening in the end of the member and is held in place by a coil spring 103. The opening is of sufficient length to permit longitudinal movement of the cap with respect to the actuating member. Above the spring, the undersides of the cap are tapered to seat against tapered seat 88 at the upper end of the mandrel.

The length of the actuating member is such that it will project below the bottom of the bit a distance approximately equal to the length of cylinder 74 when the mandrel is in its uppermost position in the housing and the cap is seated at the upper end of the mandrel.

The operation of the tool of FIGS. 2A and 2B can best be understood by referring to FIGS. 3, 4, and 5 in the drawing. FIG. 3 is a schematic diagram showing the tool in position at the bottom of the borehole following impact of the bit against the formation. In this position, the bit 41 and actuating member 101 rest against the formation. Piston 89 is at the lower end of the cylinder and the portion of the cylinder above the piston is filled with high pressure gas. The housing is suspended by the drill string in an upward position with respect to the mandrel. Cap 102 at the upper end of the actuating member extends above the upper end of the mandrel a distance approximately equal to the length of cylinder 74. The tool shown schematically in FIG. 3 is reset by
lowering the drill string from the surface so that the housing moves downwardly around the mandrel and actuating member. This is done by pumping hydraulic fluid from reservoir 27 through line 28 and hose 23 until sufficient pressure is built up in the upper end of cylinder 15 above piston 17 to overcome the gas pressure on the underside of the piston and cause the rod 18 to move downwardly. As the drill string is lowered, the housing moves downwardly about the mandrel and actuating member. When the upper end of the cylinder 74 reaches the top of piston 89. Gas between the upper end of the cylinder and the piston is forced out of the cylinder through ports 80 and 81 and back into the gas reservoirs 55 and 73. The last traces of gas escape through check valve 94 into recess 91 in the outer piston wall. Check valve 95 remains closed during this period so that a vacuum is created in the portion of the cylinder below the piston.

FIG. 4 in the drawing is a schematic representation of the apparatus of FIG. 3 after the tool has been set by lowering the housing around the mandrel and actuating member as described above. Once this has been done, the entire tool can be lifted from the surface by actuating check valve 25 so that hydraulic fluid above piston 17 in cylinder 15 flows through hose 23 and lines 24 and 26 into reservoir 27. In response to the pressure exerted on the underside of the piston by gas in the lower part of the cylinder, piston 17 and rod 18 move upwardly so that the drill string and percussion tool are lifted in the borehole. The differential pressure across the piston is sufficient to maintain the piston and mandrel in their uppermost position with respect to the housing. As the tool moves upwardly, the actuating member 101 remains in contact with the formation at the bottom of the borehole. The upward movement continues until the upper end of the mandrel reaches cap 102 and the flow of drilling fluid through the mandrel is interrupted. The length of the piston and rod in cylinder 15 are such that the housing continues to move upwardly a short distance after this point is reached. FIG. 5 shows the apparatus in its uppermost position. The interruption in fluid flow in the tool results in an increase in the downward force acting on the mandrel and actuating member cap. This causes the mandrel and actuating member to move downwardly. As the piston moves in the cylinder, ports 80 and 81 are uncovered and high pressure gas flows from the gas reservoirs into the upper part of the cylinder above the piston 89. This drives the mandrel 87 downwardly until the lower end of the percussion bit 41 strikes the formation. The force thus generated is sufficient to drive the bit assembly against the formation at speeds approaching 200 feet per second. The energy released is often sufficient to secure penetration of a quarter of an inch or more. If the apparatus is operated at a frequency of 10 cycles per minute, studies indicate that drilling rates well in excess of 100 feet per hour can be obtained.

The apparatus of the invention is shown in the drawing as being used in conjunction with a conventional rotary drilling rig. The rotary table thus provided can be used to rotate the drill string and bit at periodic intervals if desired. This can be done by lowering the housing until the projections 86 extend between and engage the blades of the bit. The torque transmitted to the drill string by the rotary table will then be imparted to the bit. Periodic rotation of the bit in this manner may permit higher overall drilling rates than can be obtained by percussion action alone, particularly in deep, high pressure formations. In many formations, however, satisfactory penetration rates can be obtained without such rotation.

I claim:

1. Apparatus for imparting percussive energy to a subterranean formation at the bottom of a borehole which comprises an elongated housing containing a cylindrical chamber and a gas reservoir communicating with said chamber; a hollow mandrel extending slidably through said chamber and projecting from the lower end of said housing; an annular piston attached to said mandrel within said chamber, said piston in its uppermost position in said chamber preventing the entry of gas into said chamber from said reservoir; and means in said housing for initiating downward movement of said piston and mandrel with respect to said housing from the earth's surface.

2. Apparatus as defined by claim 1 wherein said housing includes an inner sleeve and a concentric outer sleeve and said gas reservoir is located between said inner and outer sleeves.

3. Apparatus as defined by claim 1 wherein said housing includes a longitudinal passageway extending from said gas reservoir to an opening in the wall of said chamber near the upper end thereof.

4. Apparatus as defined by claim 1 wherein said piston includes a circumferential recess and a passageway containing a check valve extending between said recess and the upper surface of the piston.

5. Apparatus as defined by claim 1 wherein said piston includes a circumferential recess and a passageway containing a check valve extending between said recess and the lower surface of the piston.

6. Apparatus as defined by claim 1 wherein said means for initiating downward movement of said piston and mandrel includes an elongated actuating member extending slidably through the mandrel and a cap attached to the upper end of said member for closing off the upper end of said mandrel.

7. Apparatus as defined by claim 1 wherein said gas reservoir includes an upper section and a lower section connected to said upper section by a passageway in the housing wall.

8. Apparatus for drilling a borehole in the earth which comprises a conduit extending downwardly in said borehole from the earth's surface; a hydraulic cylinder connected to the upper end of said conduit for raising and lowering the conduit in said borehole; a percussive motor connected to the lower end of said conduit, said motor including a housing, a hollow mandrel, and an actuating member which extends below said mandrel for controlling the downward movement and resetting of said mandrel in response to movement of said conduit at the earth's surface; and a percussive bit connected to the lower end of said mandrel.

9. Apparatus as defined by claim 8 including means for supplying high pressure gas to one end of said hydraulic cylinder and hydraulic fluid to the other end of said cylinder.

10. Apparatus as defined by claim 8 wherein said percussive motor includes a high pressure gas reservoir, a piston attached to said mandrel, and means for discharging gas from said reservoir to drive said piston and mandrel downwardly with respect to said housing.

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