Dec. 3, 1963 R. A. BOBO 3,112,800

METHOD OF DRILLING WITH HIGH VELOCITY JET CUTTER ROCK BIT

Filed Aug. 28, 1959 3 Sheets-Sheet 1

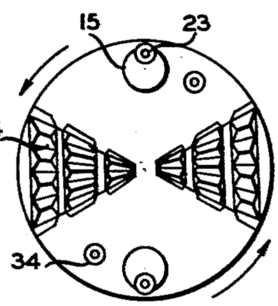

FIG. 1

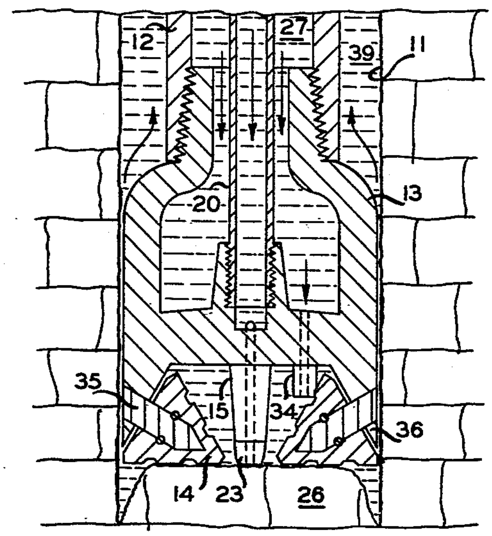

FIG. 3

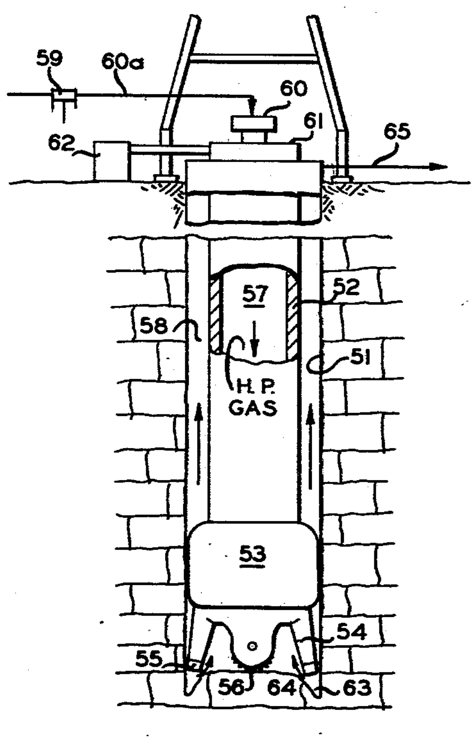

FIG. 4

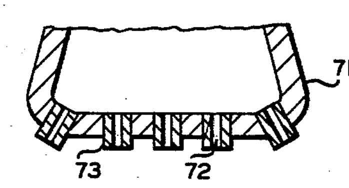

FIG. 5

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METHOD OF DRILLING WITH HIGH VELOCITY JET CUTTER ROCK BIT

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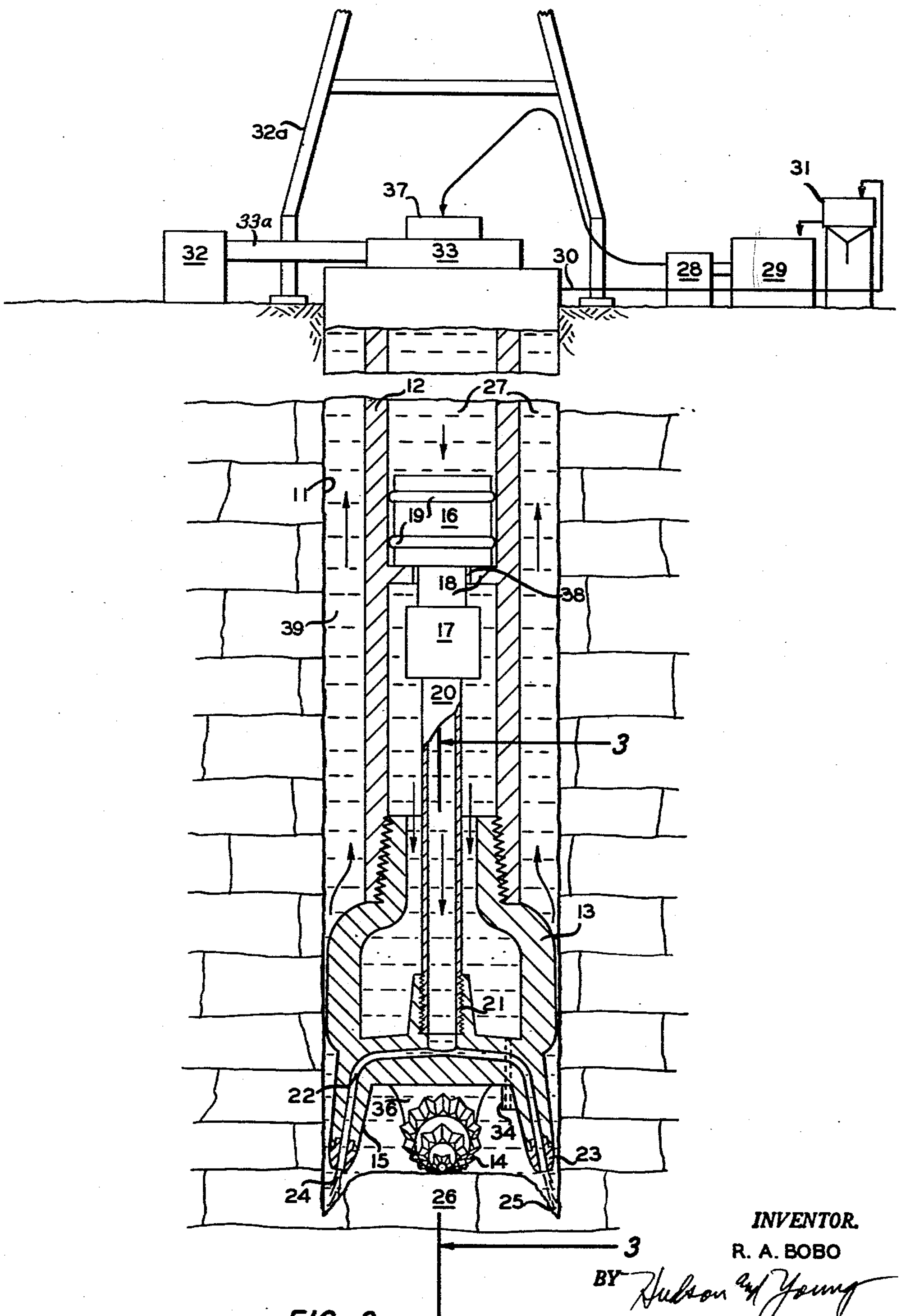

FIG. 2

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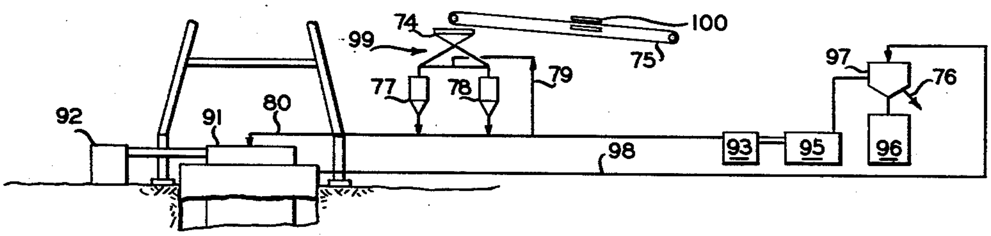
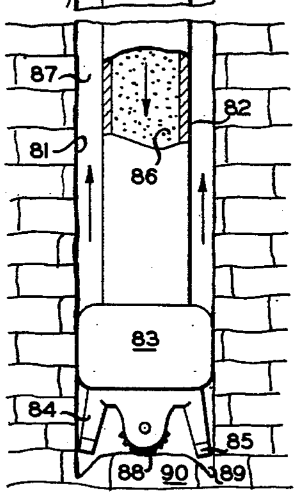

FIG. 6

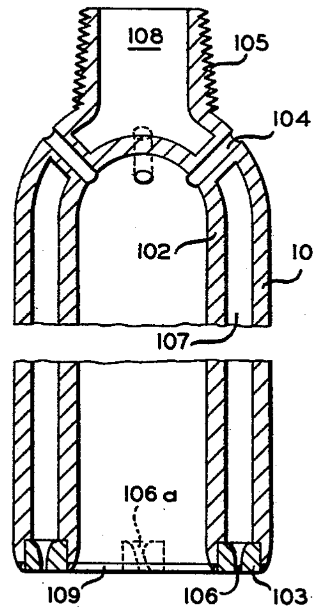

FIG. 7

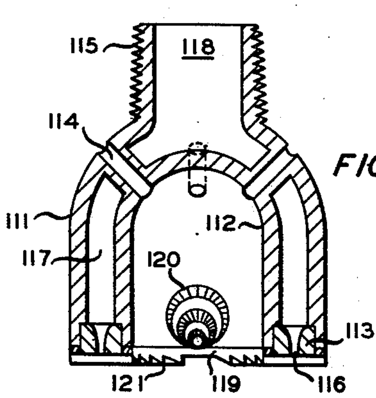

FIG. 9

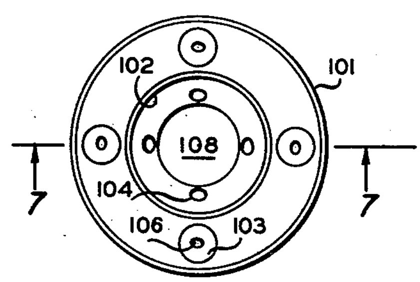

FIG. 8

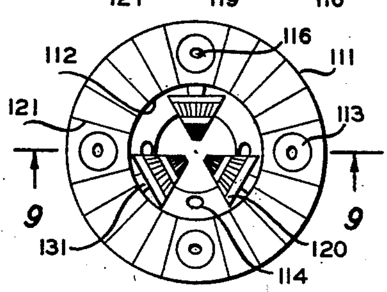

FIG. 10

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METHOD OF DRILLING WITH HIGH VELOCITY JET CUTTER ROCK BIT

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8 Claims. (Cl. 175—67)

This invention relates to high velocity jet cutters for use with rotary rock bits for drilling wells.

In drilling deep wells, rock formations are frequently encountered which are extremely hard and slow to drill even with the most modern rotary drill equipment. In using rotary drill bits it is noted that the teeth on the gage and the outside periphery of the bit cone always show greater wear than the teeth nearer the center of the hole. The reason for this greater wear on the teeth near the periphery of the borehole is that the overburden stress acts downward at the wall of the hole while the downward stress at the center of the hole, due to the pull of gravity of overlying strata, has been removed. This latter condition occurs when the borehole is free from all liquids. For this reason with an empty borehole as far as liquid is concerned and without solid overburden to compress the rock in the bottom of the hole, the bottom drills much easier than that portion of the hole near the wall. It is known that when drilling with circulating gas as a means for removing cuttings the drilling rate is more rapid than when drilling in the presence of a column of drilling mud. Under the latter condition the pressure on the bottom of the hole may be several thousand pounds per square inch tending to compress the rock at the bottom of the hole and more energy is required to drill away the rock under this condition.

According to this invention an annular groove is cut downward around the periphery of the well bore leaving a core of rock in the center of the hole. After cutting such a groove all lateral forces tending to compress the central portion of the rock or core are removed and removal of this core is then merely a matter of crushing the core of rock. According to this invention, there is employed a fluid jetted under extremely high pressure through a small nozzle which operates as a cutting means. By placing suitable nozzles on a drill head and near the outer periphery thereof, and orienting them to eject fluid in a downward direction in a well, then upon forcing fluid, either liquid or gas, under sufficiently high pressure therethrough and rotating the drill head, an annular groove is cut. As mentioned, a gas can be used, such as air, natural gas, or gas evolved by chemical reaction, such as oxygen evolved upon the catalytic decomposition of hydrogen peroxide, or gases of combustion formed by the burning of, for example, such an easily combustible material as a propellant composition normally used in the propulsion of missiles. A catalyst suitable for the rapid decomposition of hydrogen peroxide is fully described in U.S. Patent 2,680,487. These catalysts are finely divided silver, finely divided platinum, the alkali metal permanganates, the alkaline earth metal permanganates and manganese dioxide. The combustion of a hydrocarbon fuel with free oxygen liberated from hydrogen peroxide by these catalysts also provides large volumes of gases, and when injected under high pressure through a suitable nozzle directed in a generally downward direction, these gases erode the formation at the bottom of the drill hole according to this invention. As mentioned above, upon rotation of such a nozzle around the periphery of the borehole, an annular groove is formed surrounding a core of rock.

According to this invention when using extremely high pressure gas or liquids under high pressure, even the hard-

est of rock can be relatively rapidly eroded or ground away thereby permitting rapid drilling of deep wells.

An object of this invention is to provide a method and apparatus for drilling deep wells at a more rapid rate than is presently possible.

Another object of this invention is to provide a method and apparatus for drilling deep wells which is less costly than present apparatus and methods.

Still other objects and advantages of this invention will be realized upon reading the following description which, taken with the attached drawing, forms a part of this specification.

In the drawing,

FIGURE 1 is a view looking at the underside of a drill bit of this invention.

FIGURE 2 is an elevational view, partly in section, of one embodiment of apparatus of this invention.

FIGURE 3 is an elevational view, in section, taken on the line 3—3 of FIGURE 2.

FIGURE 4 is an elevational view, partly in section, of another embodiment of this invention.

FIGURE 5 is a sectional view of another embodiment of the drill bit of this invention.

FIGURE 6 is an elevational view, partly in section, of another embodiment of this invention.

FIGURE 7 is a sectional view of another embodiment of drill bit of this invention.

FIGURE 8 is a bottom view of FIGURE 7.

FIGURE 9 is a sectional view of still another embodiment of drill bit.

FIGURE 10 is a bottom view of the apparatus of FIGURE 9.

In the drawing, and particularly in FIGURES 2 and 3, a borehole into the earth is identified by reference numeral 11. Derrick 32*a* supports a draw works or hoist, not shown, the latter being provided for lowering and raising the equipment into and from, respectively, the well bore. Disposed within this borehole is a drill tubing 12 at the bottom end of which is threaded or otherwise suitably attached a drill bit 13. This drill bit is provided with one or more rotary drill cones 14 similar to those used in conventional rotary drill bits. These cones are supported by shafts 35 which, in turn, are supported by support arms 36 extending downward from the main body of the drill bit. In this embodiment there are two drill cones 14 placed opposite each other. At 90 degrees from each drill cone is positioned nozzle bases 15. These nozzle bases or supports 15 are so constructed that upon insertion of nozzle inserts 23, fluid flows in a generally downward direction. By arranging these nozzles so that one follows the other in rotation of the bit, cutting of the groove is quite rapid. It is found that upon cutting such a groove as even the narrow groove 25 the remaining core is relatively easily crushed and the rock fragments disintegrated for easy removal by either circulating drilling mud or gas.

As illustrated in FIGURES 2 and 3, drilling mud 27 is pumped by a surface pump 28 through drive head 33 into the drill tubing 12 and up the annulus outside drill tubing 12. It is intended that the mud pump 28 exert a more or less conventional mud circulating pressure. However, under some conditions it is desired that pump 28 exert a pressure several hundred pounds more than that required for the normal circulation of the drilling mud. A pressure considerably greater than that stated relative to pump 28 is required for the operation of the drill bits of this invention. As illustrated in FIGURE 2, a suitable pressure multiplying motor-pump assembly is provided down hole in the drill tubing. This assembly includes a fluid motor 16 resting upon a flange 18 in tubing 12. One or more O-ring seals 19 are provided to prevent leakage of fluid between the motor and the inner wall of the tubing. Operatively attached to the lower end of motor 16 is a pressure multiplying pump 17. This pressure multiplying pump operates on the principle of employing a small fluid pressure against a piston of large diameter with the total force on the large diameter piston being transferred to a small diameter piston which then provides a much greater pressure. Such pressure increasing pumps are well known and are commercially available from equipment supply houses. A fluid motor-pump combination which is suitable for use as motor 16 and pump 17 in the apparatus of FIGURE 2 is illustrated and described on page 2896, Composite Catalog of Oil Field Equipment and Services, 1957, published by World Oil, Houston, Texas. The drilling mud is exhausted from the lower side of the fluid motor 16 through an annulus 38. A small portion of the mud enters the pump 17 and is exhausted therefrom through a pressure pipe 20 under high pressure. The remainder of the mud flows on downward around pump 17. This mud from pipe 20, under an extremely high pressure, passes on through conduits 22 to the nozzles 23 for impinging at high velocity around the periphery of the borehole. Reference numeral 24 identifies the high pressure fluid jets from nozzles 23. The drilling mud which emerges from nozzles 23, then entrains cuttings and flows upward through annulus 39 between the drill tubing 12 and the walls of the borehole. The drilling mud not entering the pump 17 bypasses the pump and flows on downward and through one or more conventional jets 34. This added volume of drilling mud, along with the mud emerging from the two high pressure nozzles, carries all of the cuttings, that is, those produced by the high pressure liquid jets and the cuttings produced by the drill cones, upward through annulus 39. The mud with the entrained cuttings leaves the annulus 39 and flows through a pipe 30 into a separator 31 which removes the cuttings from the drilling mud. Separator 31 can, if desired, be suitable centrifuge. Mud free or substantially free from cuttings flows from the centrifuge into tank 29 from which mud pump 28 takes suction for recirculation of the mud. Reference numeral 37 identifies a swivel such as is used for connecting a rotating conduit to one which does not rotate. Pressure pipe 20 is attached by threads 21, or other suitable means, to the body of drill bit 13.

Engine 32 is illustrated as being the prime mover for rotation of a drive shaft 33*a* which is provided with a pinion gear, not shown. This gear meshes with a rack, also not shown, integral with the drivehead 33 for rotation of the drill tubing and drill bit.

In FIGURE 3 the position of the drill cones with respect to one another is illustrated. There is also illustrated in this figure positioning of the conventional jets 34 through which the major portion of the drilling mud passes.

In FIGURE 4 is illustrated an embodiment of this invention in which the cutting fluid is a gas, such as air. In this embodiment a compressor 59 compresses air to an extremely high pressure and the air passes through a conduit 60*a*, a swivel 60, into drill tubing 52. High pressure air or gas in this tubing is identified by reference numeral 57. This high pressure gas passes down the tubing into the body of drill bit 53 and through nozzles 55 which are positioned or oriented in the same manner as described above relative to FIGURE 2. These nozzles are supported by nozzle bases 54. Drill cones 56 are provided for drilling or crushing the core remaining in the center of the well bore. The gas emerging from nozzles 55 entrains the cuttings produced by the air emerging from the nozzles and the cuttings produced by the drill cone, and carries the cuttings up annlus 58 for exhaust through pipe 65. Reference numeral 51 identifies the well bore while reference numerals 61 and 62 identify, respectively, the drivehead and the engine. The groove cut by the high pressure gas in the bottom of the well is identified by reference numeral 63.

The gas pressure suitable for such a drilling operation

is of the order from 5,000 to 50,000 (pounds per square inch gage) at the inlet to the nozzles.

The embodiment of drill bit illustrated in FIGURE 5 is provided with several nozzle inserts 73 which are provided with nozzle openings 72 for covering the entire diameter of the borehole. This drill bit 71 is not provided with drill cones because the several jets of gas are intended to do the entire drilling job. Pressures of gas for drilling with the bit 71 are the same as mentioned above for use in the embodiment of apparatus illustrated in FIGURE 4.

In FIGURE 6 is illustrated an embodiment of this invention in which solid pellets are entrained in the high pressure drilling mud to increase the drilling rate over that possible when using drilling mud alone. In this embodiment the drilling is carried out in a well bore 81 under a mud pressure of 5,000 to 20,000 pounds per square inch gage or more at the inlet of the nozzles. The high pressure mud pump 93 discharges the mud into a conduit 80 for passage to drill tubing 82. A portion of the mud from conduit 80 is by passed therefrom through a conduit 79 which communicates with means 99 for adding pellets into the high pressure mud stream. The operation of this means 99 is relatively simple and merely involves operating the valves to provide communication from pipe 79 through tank 77 or through tank 78 to pipe 80 again. For example, with tank 78 previously filled with pellets to be added to the high pressure drilling mud, the valves are regulated for providing communication from pipe 79 by way of tank 77 to conduit 80, with the valves for use with tank 78 being closed. Upon admission of drilling mud from pipe 79 to tank 77, pressure is equalized therein and pellets then flow by gravity into conduit 80 at any desired rate. While pellets are being transferred from tank 77 to conduit 80, the valves above tank 78 are opened and the tank is filled with pellets from a hopper 74 disposed thereabove. Drilling mud containing pellets in suspension within drill tubing 82 is identified by reference numeral 86 and this pellet-laden mud flows on downward and through nozzles 85 for cutting annular groove 89. Engine 92 by way of drivehead 91 rotates the tubing and drill bit 83. Upon rotation of this drill bit, the pellet-laden mud cuts the groove 89 while the drill cone or cones 88 drill or crush the core from the center of the borehole. The cuttings produced in the drilling operation and the pellets are carried upward by the mud in annulus 87. The mud, cuttings and pellets pass from the top of the annulus through conduit 98 to a pellet and cutting separator 97 from which the cuttings emerge through a conduit 76 for such disposal as desired and the pellets pass into pellet receiver 96. From this pellet receiver 96 the pellets are transferred by means not shown to a belt 75 for addition into hopper 74. A magnet 100 is provided for removing any iron separated with the pellets. The drilling mud, free or substantially free from cuttings and free from pellets, is discharged from the separator 97 into a mud tank 95 from which the pump 93 takes suction.

Pellets suitable for use in the embodiment of this invention can be small iron or steel balls or sand grains such as Ottawa sand. When iron or steel pellets are used, the magnet 100 is obviously not used.

When using iron or steel pellets, it is preferable to employ pellets of about $\frac{1}{16}$-inch to $\frac{1}{8}$-inch in diameter. From about one to 200 pounds of steel pellets per barrel of drilling mud can be used. When using pellets such as Ottawa sand, with grains of the sand being well rounded and from about $\frac{1}{32}$-inch to $\frac{1}{8}$-inch in diameter, about one to 100 pounds of sand per barrel of mud is used.

According to this invention it is preferable to use rounded pellets rather than sharp angular materials because sharp angular materials tend to abrade the conduits through which they pass and particularly to nozzles through which they are ejected at high velocity. The materials for making the nozzles for use according to this invention are selected from among those commercially available, taking into consideration resistance desired to abrasion by gas and by drilling mud containing suspended suspended solid pellets.

The principles of this invention are adaptable for drilling wells in which core samples are taken as well as drilling wells in which the core is drilled out by conventional drill cones as described hereinabove. A drill bit suitable for high pressure fluid drilling and taking a core is illustrated in FIGURE 7. Within the bit illustrated in FIGURE 7, a core barrel is used for recovery of a core. The use of core barrels is common and a core barrel is not illustrated in the drawing nor described herein. The need and the use of such equipment is well understood by those skilled in the art. The length of this drill bit will be controlled by the length of the core it is desired to take. The bit is composed of an outer cup-shaped shell 101 within which is inserted an inner or second cup-shaped shell 102. These two shells are positioned concentrically and are so spaced from one another as to provide an annular space 107 between them. This annular space is sealed at its bottom by an annular plate 109. The plate 109 is provided with one or more openings into which nozzles 103, containing nozzle openings 106, are inserted. Threads or other means 105 are provided for attaching this drill bit to the bottom end of a drill tubing, not shown. Conduit 108 is for passage of high pressure drilling mud or high pressure gas for injection through the nozzle openings 106. The fluid containing drill cuttings in suspension passes upward between the outer surface of the outer shell 101 and the walls of the borehole for passage up the annulus of the well. Obviously some high pressure fluid with cuttings in suspension passes upward between the inner wall of the inner shell 102 and the outer wall of a core, and conduits 104 are provided through this double shell drilling bit so that this latter mentioned fluid, with cuttings in suspension, can be ejected from the well. FIGURE 8 illustrates the appearance of the bottom of the drilling bit of FIGURE 7 The nozzles 106 in this particular case are oval or elliptical in cross section with the long axis being normal to the radius of the drill bit. The long axis of these nozzles being positioned in this manner increases the rate of drilling because the high pressure fluid is ejected against a particular point for a longer period of time during the rotation of the bit than if the nozzles were oriented in any other direction or were round in section. However, the nozzles can be round in cross section, if desired. The nozzles as illustrated in FIGURE 7 are so oriented that their longitudinal axis slopes in the direction of rotation, as illustrated by nozzle 106*a*. It is also preferable, in some instances, to slope two nozzles slightly toward the outer periphery and the other two nozzles, when four nozzles are used, toward the inner periphery of the drill bit of FIGURE 7. The nozzles in this case are so oriented in order to cut a groove sufficiently wide that the annular drill can advance downward therein.

In FIGURE 9 is illustrated a drill bit quite similar to that of FIGURE 8 but this drill bit is provided with one or more drill cones 120 in such a manner that the core is drilled up and accordingly is not saved for inspection. In this embodiment the drill is composed of an outer cup-shaped shell 111 with an inner cup-shaped shell 112 so disposed as to provide an annular space 117 therebetween. An annular plate 119 seals this annulus at its bottom. Nozzle inserts 113, provided with elliptical or oval cross section nozzle openings are inserted through plate 119. Conduit or conduits 114 are provided for passage of drilling fluid with cuttings in suspension from within the inner shell 112 to the annulus between the drill tubing and the borehole wall. Threads 115 are provided for attaching this drill bit to the lower end of a drill tubing and conduit 118 is for passage of high pressure fluid from the drill tubing, not shown, into the drill bit. FIGURE 10 is a bottom end view of the drill bit of FIGURE 9. FIGURE 10 illustrates the positioning of the drill

cones 120 with respect to the inner wall of the inner shell 112. As shown in FIGURES 9 and 10, the bottom of the annular plate 119 is provided with teeth 121 more or less similar to the teeth provided in washover drill bits.

The pelletized fluid can be used with the drill bits illustrated in all of the figures excepting FIGURE 4, which uses a high pressure gas as the cutting fluid.

The high pressure mud driven motor 16 and pump 17 of FIGURE 2 can be either rotary or reciprocating equipment whichever is deemed most suitable for the problem at hand.

Such a drilling mud as one containing a bentonitic clay is suitable for use according to this invention. Such a drilling mud with sand or other pellets in suspension is used at pressures of 2500 p.s.i. and above or as high as 20,000 p.s.i., at the inlets to the nozzles, for drilling according to this invention.

Since the hereinbefore-mentioned high pressures are present only within the drill tubing and drill bit and upstream of the jetting orifices, those pressures are not present at any location in the well bore by which drilling apparatus could be ejected. Furthermore, the combined weights of drill bits, drill collars and drill tubings are many tons and such apparatus is just not blown from the wells by high pressure fluid within the drill tubing and collars.

While certain embodiments of the invention have been described for illustrative purposes, the invention obviously is not limited thereto.

I claim:

1. A method for drilling a well comprising impinging a stream of fluid at a pressure greater than conventional well fluid circulating pressure and at high velocity downwardly and directly against an earth formation at the bottom of said well and adjacent the wall of said well, moving the downwardly impinging stream of fluid around the wall of said well thereby cutting an annular groove around the periphery and below the bottom of said well and producing cuttings and leaving a centrally located core of said formation, crushing said core, passing additional fluid at bottom hole, circulating pressure into the crushed core and said cuttings, suspending the crushed core and said cuttings in the combined impinged fluid and said additional fluid, and exhausting the combined impinged fluid and additional fluid carrying the crushed core and cuttings in suspension from said well.

2. The method of claim 1 wherein said fluid is a gas.

3. The method of claim 1 wherein said fluid is a liquid.

4. The method of claim 1 wherein said fluid is a drilling mud.

5. The method of claim 1 wherein said fluid is a drilling mud containing solid, difficultly breakable pellets.

6. A method for drilling a well comprising pumping a stream of well fluid downwardly in a drill tubing in said well at conventional well fluid circulating pressure, dividing the well fluid into two portions, pumping one portion to a pressure higher than said circulating pressure, impinging this fluid of higher pressure at a high velocity downwardly and directly against an earth formation at the bottom of said well and adjacent the wall thereof, moving the downwardly impinging stream of fluid around the wall of said well thereby cutting an annular groove around the periphery and below the bottom of said well and producing cuttings and leaving a centrally located core of said formation, crushing said core, passing the remaining portion of fluid at bottom hole circulating pressure into the crushed core and said cuttings thereby suspending said cuttings and said crushed core in the combined portions of said fluid, and exhausting the combined portions of fluid carrying the cuttings and crushed core in suspension from the well.

7. The method of claim 6 wherein said well fluid is a drilling mud.

8. The method of claim 6 wherein said well fluid is a drilling mud containing solid, difficulty breakable pellets.

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