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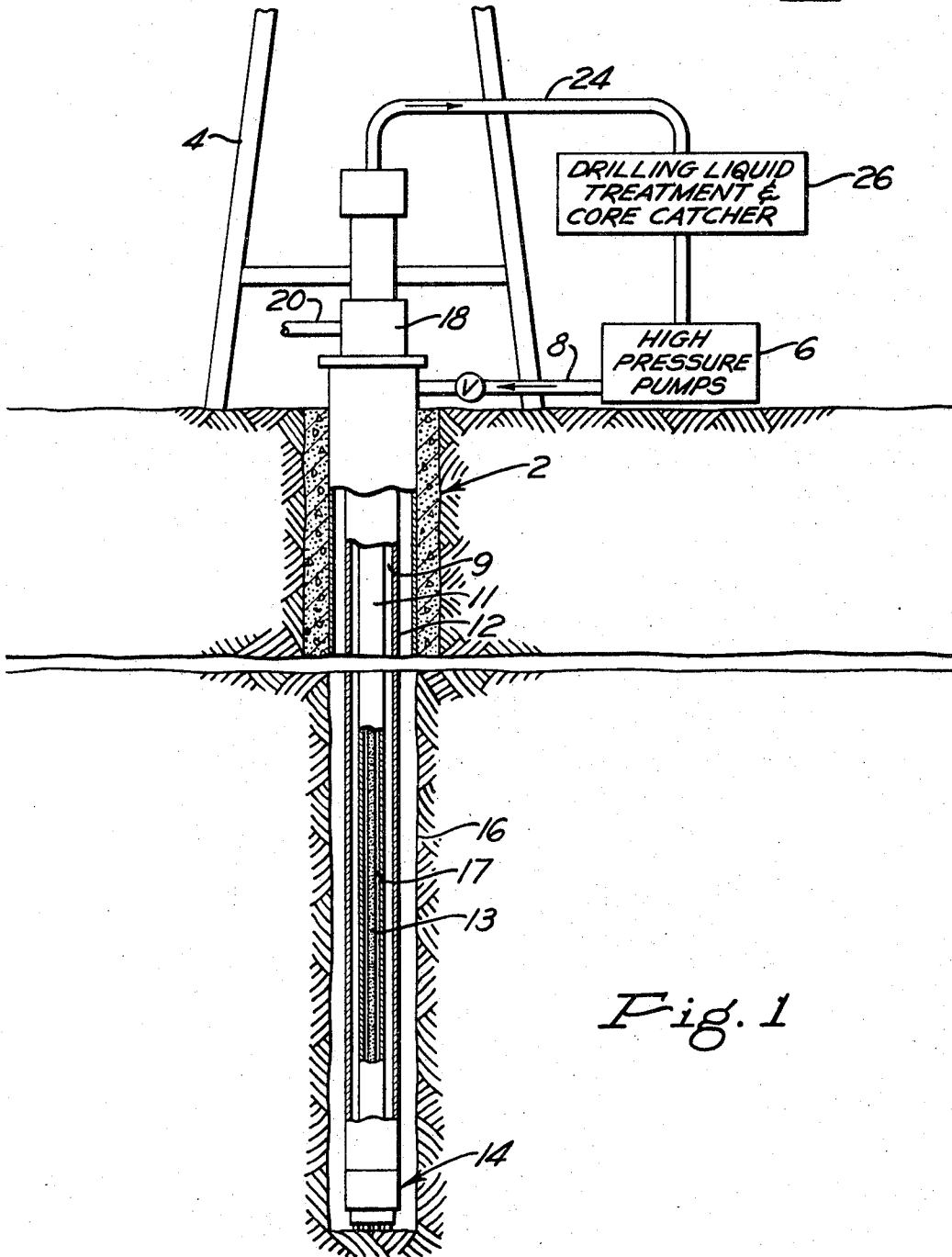
E. A. MORI ET AL

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CONTINUOUS CORING JET BIT

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Sheet 1 of 3



INVENTORS.
ERNEST A. MORI
PAUL W. SCHAUB

1

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CONTINUOUS CORING JET BIT

Ernest A. Mori, Glenshaw, and Paul W. Schaub, Verona, Pa., assignors to Gulf Research & Development Company, Pittsburgh, Pa., a corporation of Delaware

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ABSTRACT OF THE DISCLOSURE

A method and apparatus for drilling the borehole of a well in which a core is removed from the well. Nozzles are pivotally and eccentrically mounted in a nozzle holder seated in a downwardly tapering annulus between rotating concentric drill pipe and conduit. An abrasive-laden liquid is pumped down the annulus under a high pressure which swings the nozzles into position to cut a groove having an outer diameter larger than the diameter of the drill string and an inner diameter smaller than the diameter of the conduit. Reversal of the direction of flow of the drilling liquid allows circulation of the nozzle holder from the well for replacement of nozzles.

This invention relates to a hydraulic jet method and apparatus for drilling wells.

A recent development for drilling formations is to utilize abrasive-laden liquid as a drilling fluid and bombard the bottom of the borehole with this liquid by passing it through nozzles at extremely high velocities of at least 500 feet per second. In the operation of heretofore employed jet bits the outlet of the nozzles is maintained within a close and carefully controlled distance from the bottom of the borehole to prevent dissipation of the impact energy in the high velocity stream of abrasive-laden liquid discharge from the nozzle and to reduce erosion at the bit by back splash of the abrasive-laden liquid against the bottom of the bit. The drill string is rotated to rotate the bit and cause the impact points of the high velocity streams to travel over the bottom of the borehole to cut a borehole of the desired diameter. Drilling liquid downwardly discharged from the nozzles cut, substantially by impact, overlapping or contiguous grooves. Virtually the entire removal of rock from the bottom of the hole is thereby accomplished by the initial bombardment by the streams of drilling liquid.

Other jet bits have been designed whose nozzles cut a plurality of concentric vertical grooves separated by intervening annular ridges. The proper interval of separation between a nozzle outlet and the formation is maintained by standoff bars mounted on the bottom of the jet bit. The leading edge of the standoff bars is employed to mechanically break the intervening ridges.

These heretofore employed bits utilize the advantages of jet drilling bombardment but experience reduced penetration rates because all of the rock removed from the hole must be cut by either breaking ridges or complete removal by the fluid jet cutting action.

This invention resides in an improved hydraulic jet drilling method and apparatus in which nozzles are pivotally mounted in a core bit to swing outwardly and cut a groove having an outer diameter substantially the same as the borehole diameter and other nozzles are mounted to pivot inwardly to cut a groove leaving a central core which can be continuously moved upwardly through the core bit. The nozzles are mounted in a ring-shaped nozzle holder that can be circulated upward to the well head and replaced without pulling drill pipe from the well. A borehead of desired diameter is thereby created without providing the horsepower necessary to cut, mechanically

2

break or abrade, the entire volume of rock. Worn or damaged nozzles may also be replaced in a bit of this invention without pulling the drill pipe from the well bore.

FIGURE 1 is a diagrammatic view partially in cross section of a derrick, treating equipment, drilling equipment and a bit of this invention for hydraulically jet drilling a well by this method.

FIGURE 2 is a cross sectional view taken along section line II—II of FIGURE 3 of a drill bit of this invention.

FIGURE 3 is a horizontal sectional view taken along section line III—III in FIGURE 2 showing the nozzle holder and nozzles.

FIGURE 4 is a bottom view of the bit illustrated in FIGURE 2.

FIGURE 5 is a diagrammatic view, partially in section, showing a bit, the formation matrix and the pattern of grooves and ridges formed by the operation of a bit of this invention.

Referring to FIGURE 1, a well, indicated generally by reference numeral 2, is illustrated with a derrick 4 positioned above it. An abrasive-laden drilling liquid is discharge from high pressure pumps 6 through delivery line 8 into the annulus 9 formed by a conduit 11 and drill string 12. Mounted on the lower end of the drill string 12 and the conduit 11 is a drill bit, indicated generally by reference numeral 14. The abrasive drilling liquid is discharged through nozzles in the drill bit at high velocities of at least 500 feet per second, preferably 800 feet per second against the formation at the bottom of the borehole 16. Drill string 12 and conduit 11 are rotated in the borehole by engagement of the drill string 12 with a rotary drill table 18, driven through a shaft 20 by a suitable power source, not shown.

Drilling liquid circulated up through the annulus 17, formed between conduit 11 and the formation core 13 is discharged at the surface and delivered through line 24 to apparatus 26 for treating the drilling liquid and recovering the core. The treating generally consists of removal of large cuttings from the drilling liquid, removal of fines which tend to increase the density of the drilling liquid, cooling the drilling liquid to the desired temperature and incorporating additional abrasive particles to replace those that are broken into fine particles and are removed with the fines. The drilling liquid may also be treated to maintain other properties such as viscosity, density, etc. in the desired range.

Referring to FIGURE 2, the drill bit 14 is formed of an inner housing 28 positioned inside of an outer housing 30. The inner housing 28 of the bit is attached to the lower end of the conduit 11. The outer housing 30 is attached to the lower end of the drill string 12. As preferred in this illustration, the lower end of the outer housing 30 is tapered inward to form a nozzle holder seat 32 and cause drilling fluid, which is pumped down the annulus formed between the conduit 11 and the drill string 12, to pass through the plurality of nozzles formed through the nozzle holder 34. The proper nozzle standoff is maintained by a series of short concentrically placed inner and outer standoff bars, indicated by numerals 36 and 38 respectively, mounted on the bottom of the nozzle holder 34.

Outwardly extending swing nozzles, generally indicated by numeral 40, with nozzle inserts 42 are mounted on the nozzle holders 34 and eccentrically installed through rotatable nozzle supports 43. Inwardly extending swing nozzles, generally indicated by numeral 44, are mounted on the nozzle holder 34 and eccentrically installed through rotatable nozzle supports 43.

FIGURE 3 illustrates the placement through the nozzle holder 34 of outer swing nozzles 40, inner swing nozzles 44 and, as preferred in this illustration, downwardly

directed stationary nozzles 46. The inlet of these nozzles are positioned in a groove 47 formed concentrically around the top of the nozzle holder, generally indicated by numeral 34.

FIGURE 4 illustrates the placement of the inner standoff bars 36 and the outer standoff bars 38 in relation to the plurality of nozzles. These standoff bars are concentrically positioned on the nozzle holder 34 to travel, during rotation, within the grooves cut by the inner swing nozzles 44 and the outer swing nozzles 40. Nozzle passages 45 are formed through the nozzle holder 34 to allow the swing nozzles 40, 44 to extend during drilling operations. The bottom of the outer and inner housing 30, 28, nozzle holder 34 and standoff bars 36, 38 are protected from abrasion by mounting a hard abrasive-resistant material, such as tungsten carbide, on these lower surfaces.

FIGURE 5 shows the formation core 13 formed by the operation of the bit of this invention. The concentric outer groove 48 is cut by the abrasive-laden fluid discharged from the outer swing nozzles. The concentric inner groove 50 is formed by the cutting action of the abrasive-laden liquid discharged from the inner swing nozzles. The inner groove, as preferred in this illustration, is formed by the liquid discharged from the stationary nozzles.

In the drilling process of this invention, an abrasive-laden drilling liquid is delivered by high pressure pumps 6 into the annulus 9, formed between the drill string 12 and the conduit 11, and to the drill bit 14. The particular size of the abrasive material suspended in the drilling liquid will depend in part on the size of the orifice in the drill bit. If the nozzle orifices have a diameter of $\frac{1}{8}$ inch, abrasive particles ranging in size from 7 to about 80 mesh can be used. Nozzles having an orifice diameter of $\frac{3}{32}$ to $\frac{1}{4}$ inch can be used in the hydraulic jet drilling process. Larger nozzles require excessive pump capacity to deliver the drilling liquid at the required high velocity. Smaller nozzle orifices reduce the rate of penetration because of the limitation that is put on the size of the abrasive particles. One of the abrasive materials that can be used advantageously, because of its availability and low cost, is sand. Sand particles having a size in the range of 20 to 40 mesh are suitable for use in drilling by the process of this invention with nozzle orifices $\frac{1}{8}$ inch in diameter.

Preferred abrasive materials, because of the faster cutting rate that they cause, are ferrous abrasives which may be either cast iron or steel and may be in the form of either shot or angular grit. Ferrous abrasive particles in size from 10 to 80 mesh may be used effectively through nozzles $\frac{1}{8}$ inch in diameter. Aluminum oxide provides a high rate of cutting of rock formations, but has the important disadvantages of causing severe nozzle erosion and having a relatively high rate of breakup. Concentration of ferrous particles in the drilling liquid of $\frac{1}{2}$ to 4 percent by volume are preferred, while higher concentrations of sand, for example 5 to 15 percent, obtain optimum drilling rates for that abrasive.

The drilling liquid used will depend in part upon the abrasive used. Because of the higher density of the ferrous abrasive particles that can be suspended in the drilling liquid, a drilling liquid possessing a relatively high viscosity and gel strength should be employed to prevent excessive settling of the abrasive from the drilling liquid. A suitable drilling liquid for suspending abrasives is an invert emulsion of water and diesel oil containing approximately 40 percent diesel oil stabilized with a suitable emulsifier such as sulfurized calcium soap of tall oil. A six percent suspension of bentonite and water is suitable as a drilling liquid for utilizing sand as the abrasive.

The drilling liquid is delivered through the annulus 17 formed between the conduit 11 and the drilling string 12 and from the nozzles of the bit 14 at a rate of at least 500

feet per second resulting in a pressure drop through the nozzles of the drill bit of the order of at least 2000 pounds per square inch to impart the desired high velocity to the drilling liquid discharged from the nozzles. Owing to the eccentric positioning of the nozzle inserts through the pivotal mounted nozzle supports, fluid pressure exerted on top of the nozzle support will cause the nozzle supports to swing either outwardly or inwardly depending upon their particular construction. When pressure is released from the top of the nozzle supports they will swing back to a vertical position. By constructing the bit of this invention with swing nozzles the operator is able to remove and recover the nozzles without pulling the drill pipe.

During drilling operations the swing nozzles will extend to a position which will maintain a proper nozzle standoff distance between the formation and the outlet of the nozzles as the bit is rotated. In the extended position the outwardly extending swing nozzles will cut a concentric groove whose outer diameter is substantially the diameter of the desired borehole and the inwardly extending swing nozzles will cut a concentric groove whose inner diameter is smaller than the inside diameter of the conduit. As preferred in this illustration, a plurality of downwardly directed nozzles will cut a concentric groove which is separated by thin intervening ridges from the grooves cut by the swing jets. The cutting of the middle groove by downwardly extending jets is merely the preferred illustration of this invention and all fluid cutting may however be accomplished by the inwardly and outwardly swing nozzles.

As the bit is rotated the normal wobble of the bit in the borehole will deliver lateral impact forces through the standoff bars to the intervening ridges. The impact delivered to the ridges will cause the tops of the ridges to shear in tension toward the inner groove.

A continuous formation core will be formed upwardly through the conduit as drilling proceeds to greater depths. This core is termed continuous owing to the fact that the core, as recovered at the surface, is a sample of each and every subterranean formation penetrated by the drill bit of this design.

This continuous formation core will be abraded by the discharged fluid washing over the core on its path out of the well through the conduit. The lateral movement created by rotation of these two concentric strings of pipe will also break the core. As drilling is continued large chunks and long intervals of the core will be recovered and removed from the well at the surface.

When the nozzle inserts become worn they may be recovered and replaced by bumping the bit downward to unseat the nozzle holder and reverse circulating the nozzle holder out of the hole by pumping fluid down the annulus formed by the drill string and the borehole of the well. The nozzle holder replacement will be installed by placing the holder in the annulus formed between the drill string and the conduit and pumping it down the well until it seats into the bit body.

In the drilling method and apparatus of this invention, penetration is accomplished by the high-velocity streams of abrasive-laden liquid. This method and apparatus for drilling wells is more efficient than operations heretofore employed owing to the method of changing bits without pulling the drill string and the ability to drill a borehole without cutting and abrading the entire volume of rock desired to be removed.

Therefore we claim:

1. A hydraulic jet method for drilling the borehole of a well comprising rotating in the borehole drill pipe and conduit having a bit secured at its lower end, pumping abrasive-laden liquid down the annulus formed between the drill pipe and the conduit and through the drill bit at a velocity of at least 500 feet per second, discharging a series of first streams of the abrasive-laden liquid inwardly against the bottom of the borehole to cut a groove whose inner diameter is smaller than the inner diameter of the conduit, discharging a series of second streams of abra-

5

6

sive-laden liquid, downwardly and outwardly to cut in the bottom of the borehole a groove whose outer diameter is larger than the outer diameter of the drill pipe, discharging a series of third streams of abrasive-laden liquid substantially downwardly against the bottom of the borehole to cut a groove separated from the inner and outer grooves by thin intervening ridges, urging the bit downward to break the intervening ridges toward the middle groove, circulating cuttings and broken particles of the formation upward through the conduit and recovering an uncut core at the surface.

2. A method as set forth in claim 1 wherein the intervening ridges have a width $\frac{1}{8}$ to $\frac{1}{2}$ inch.

3. A method as set forth in claim 1 wherein the drilling liquid contains $\frac{1}{2}$ to 6 percent by volume of ferrous abrasive particles having a size in the range of 7 to 80 mesh and in which the nozzles have a discharge diameter of $\frac{3}{32}$ to $\frac{1}{4}$ inch.

4. In apparatus for the continuous hydraulic jet drilling of wells by discharging a suspension of abrasive particles in liquids from nozzles at a high velocity against the bottom of the borehole of a well, a core bit comprising a core bit body, said core bit body having an outer tubular housing concentric with an inner tubular housing, one of said inner and outer housings having a greater thickness at its lower end than at its upper end to form an annular seat, an annular nozzle holder resting on the seat in the annulus between the inner and outer members, a nozzle pivotally mounted in the nozzle holder adapted to pivot to a downwardly and outwardly extending position adapted to cut a groove in the bottom of the borehole having a diameter larger than the diameter of the outer bit housing, and a nozzle pivotally mounted in the nozzle holder adapted to pivot to a downwardly and inwardly extending position adapted to cut a groove in the bottom of the borehole having a diameter smaller than the inner diameter of the inner bit body.

5. An apparatus as set forth in claim 4 in which the nozzles are eccentrically positioned in rotatable nozzle supports.

6. An apparatus as set forth in claim 4 in which stand-off bars extend downwardly from the lower end of the nozzle holder in position to ride in the grooves cut by jet streams discharged from the pivotally mounted nozzles.

7. An apparatus as set forth in claim 4 in which the nozzle body may be recovered and repositioned in the bit body without pulling the bit.

8. In apparatus for the hydraulic jet drilling of wells by discharging suspension of abrasive particles in liquids

from nozzles at a high velocity against the bottom of the borehole of a well, means for forming a continuous core by cutting concentric grooves, separated by intervening ridges, comprising two concentric hollow bit housings, a nozzle holder seat formed on the inner surface of the outer bit body, a nozzle holder seated in the annulus formed between the concentric bit bodies, a plurality of outwardly extending swing nozzles mounted through the nozzle holder, a plurality of inwardly extending swing nozzles mounted through the nozzle holder, a series of downwardly directed stationary nozzles mounted through the nozzle holder and concentrically positioned standoff bars mounted on the bottom of the nozzle holder.

9. An apparatus as set forth in claim 8 in which the nozzles are positioned and adapted to form ridges $\frac{1}{8}$ to $\frac{1}{2}$ inch wide.

10. An apparatus as set forth in claim 8 in which the outwardly extending differential area swing jets cut a groove having an outer diameter slightly larger than the outer diameter of the bit and in which the inwardly extending swing jets cut a groove having an inner diameter slightly smaller than the inner diameter of the bit.

11. An apparatus as set forth in claim 8 in which the nozzle body may be recovered and repositioned in the bit body without pulling the bit.

12. An apparatus as set forth in claim 8 in which the nozzles are eccentrically positioned in rotatable nozzle supports.

13. An apparatus as set forth in claim 8 in which stand-off bars extend downwardly from the lower end of the nozzle holder in position to ride in the grooves cut by jet streams discharged from the pivotally mounted nozzles.

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JAMES A. LEPPINK, *Primary Examiner.*

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