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3,158,207

COMBINATION ROLLER CONE AND SPARK DISCHARGE DRILL BIT

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2 Sheets-Sheet 1

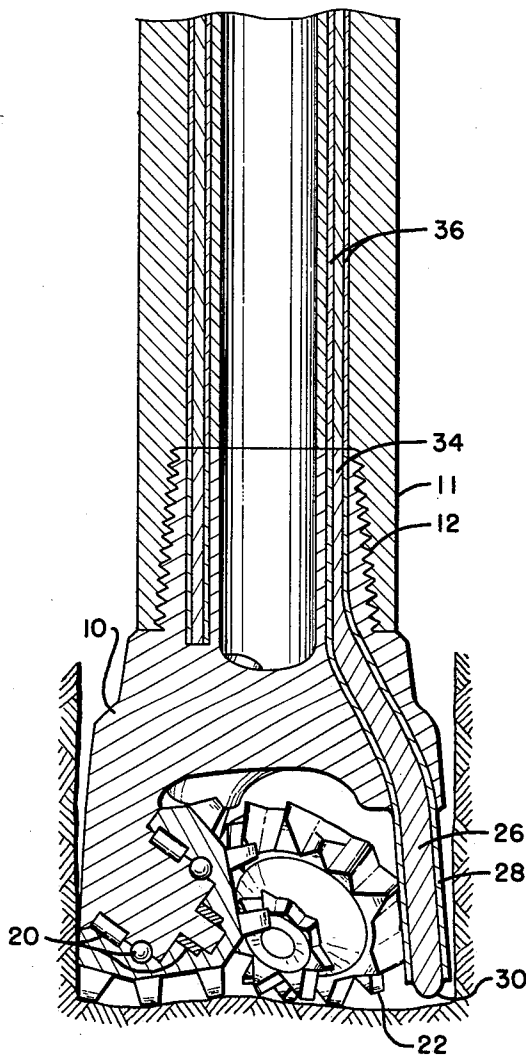


FIG. 2

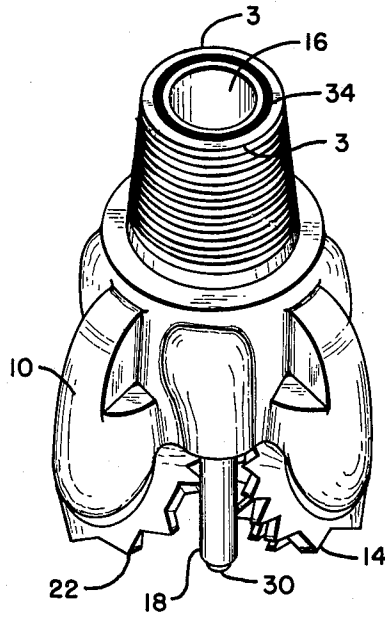


FIG. 1

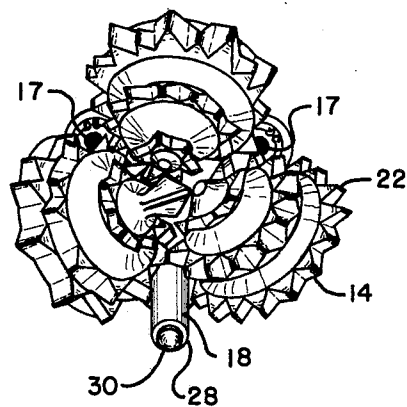


FIG. 3

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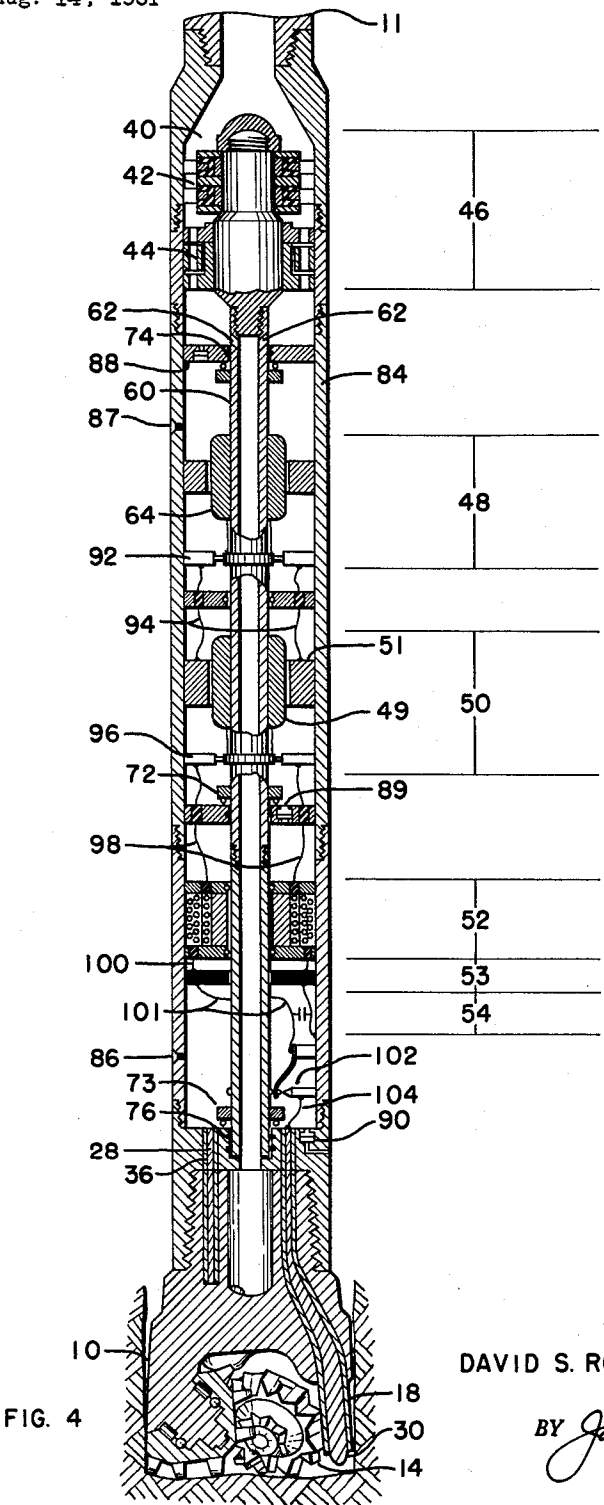
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3 Claims. (Cl. 175-16)

This invention relates to a method and apparatus for drilling wells. More particularly, the invention relates to a type of drill bit adaptable for use in conjunction with rotary drilling systems having means to effect a shock wave at or near the bit to improve the penetration rate of the drill bit in hard formations.

This application is a continuation-in-part of Serial No. 780,412, now Patent No. 3,036,645, entitled "Bottom-Hole Turbogenerator Drilling Unit," filed December 15, 1958, for David S. Rowley.

The drilling of oil wells has always presented the expensive and difficult problem of penetrating hard rock formations. The rotary method of drilling wells decreased the problem to some extent. Rotary drilling basically includes the use of a drill pipe rotated at the surface and having a drill bit at its lower end. Drilling fluids of the water and/or oil base type are circulated downward through the pipe and bit and thence upward in the annulus between pipe and borehole wall to the surface, where cuttings are separated out to permit recirculation of the mud. Even with modern, improved metallurgy as utilized in present day drill bits, the life of such bits is sometimes relatively short when used to penetrate hard rock formations. In addition, the trend toward deeper drilling with increased borehole temperatures and pressures has further reduced the footage life capacity of present day bits. Time and great expense are required making trips in and out of the hole with drill pipe and collars to change a drill bit, especially in such deep drilling operations.

In the drilling of a well in the earth it is important that the hole be properly gauged. That is, the diameter of the hole must be substantially uniform to permit the passage of tools, bits, casing and other apparatus desired to be inserted into the well. In addition, it is important that the hole be maintained substantially straight; that is, without severe changes in hole inclination and usually without too great an overall inclination from vertical.

Accordingly, it is an object of this invention to provide a method and apparatus of drilling wells wherein the above problems are diminished.

It is another object of this invention to provide methods and apparatus for the rotary drilling of wells wherein the mechanical cutting action of the bit is assisted by a shock wave reaction created by an electrical spark discharge at or near the bit.

Another object of this invention is to provide a drill bit for use in drilling boreholes in the earth including means of utilizing electrical discharge to improve the penetration rate of the drill bit and having means whereby the well will be accurately gauged in diameter.

A still further object of this invention is to provide apparatus including a bottom-hole turbogenerator and an electrical discharge circuit in combination with a rotary drill bit having an insulated electrode which forms one leg of the circuit separated by a gap near the lower part of the bit which forms the other leg of the circuit.

It is another object of this invention to provide a

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means of conducting electrical energy through the drill bit to an electrode whereby a spark discharge may be utilized in conjunction with the drilling process.

These and other objects and a better understanding of the invention may be had from the following description and claims taken in conjunction with the attached drawings in which:

FIGURE 1 is an isometric view of a roller cone type rotary drill bit utilizing the principles of this invention.

FIGURE 2 is a sectional view taken along the line 3-3 of FIGURE 1 showing the construction of the drill bit of this invention.

FIGURE 3 is an end view of the drill bit of this invention showing the relative positioning of the drilling cones, the drilling fluid jet openings, and the electrode.

FIGURE 4 is a sectional view showing in combination a bottom-hole axial flow turbogenerator, an electrical discharge circuit, and the drill bit shown in FIGURE 1.

Referring now to the drawings and first to FIGURE 1, the drill bit of this invention is shown in an isometric view and is indicated generally by the numeral 10. The bit is affixed to an upward extending drill pipe or drill collar 11 (FIGURE 2), by which rotary energy is applied to the bit by means of threaded connection 12. The usual drilling work is performed by bit cones 14 which are rotatably supported to the bottom of the bit for engagement with the bottom of the well. Passage 16 communicates with the interior of the drill collar for the circulation of drilling fluid pumped from the surface through the drill pipe and collars and thence into the drill bit 10. Jet openings 17, best shown in FIGURE 3, are provided in the drill bit 10 to create a high velocity discharge of the drilling fluid adjacent the cutting teeth 14 and impinging on the bottom of the borehole.

According to this invention, the effectiveness of drill bit 10 in penetrating hard rock formations is increased by the intermittent discharge of an electrical spark device, indicated generally by the numeral 18. In a typical rotary drill bit three jet openings are provided in the bit, whereby drilling fluid is discharged downwardly to clean and cool the bit and to flush the formation, washing out and carrying rock cuttings to the surface. In the preferred embodiment, the device 18 is positioned approximately in the area ordinarily utilized for a jet opening.

The device is best shown in FIGURE 2 and is adapted to discharge a high intensity electrical spark within the drilling fluid and adjacent the formation being drilled. An electrode portion 26 includes an insulating jacket 28 which extends around the electrode and terminates adjacent the lower end leaving the exposed tip 30. A high intensity electrical potential causes a spark discharge across the gap existing between exposed electrode tip 30 and the drill bit 10 such as an adjacent cutting member 14.

The roller cone cutting members 14 are ordinarily supported to the body portion 10 by suitable bearings 20. Although many various arrangements of drill bits 10 have been made, the most common utilizes three rolling cones 14 spaced 120° apart. Typically, the cutting members 14 are provided with teeth 22 which may interlock with the rows of teeth of the adjacent cones, providing a self-cleaning action and providing a greater volume of steel, to obtain improved bearing strength and longer wear surfaces.

FIGURE 3 illustrates a bottom view of the drill bit 10. As shown, the position of discharge device 18 and/or exposed electrode tip 30 is such that the spark discharge

takes place adjacent the lower end of the drill bit 10 and slightly within the limits circumscribed by the rotation of the drill bit 10, i.e., its peripheral diameter.

FIGURE 4 shows another adaptation of the present invention comprising in combination an axial flow turbine 46—which includes a bearing section 42 and a mud turbine section 44—an exciter 48, a generator 50, a transformer 52, a rectifier 53 and a capacitor 54 to supply the necessary power for the electrical discharge device 18.

The assembly of FIGURE 4 is shown as it would be positioned in a borehole and attached to the lower end of drill pipe 11 extending downwardly from the earth's surface. In operation of the assembly, mud flows downwardly through passageway 40 around bearing section 42 and into impeller section 44. The mud impinges on the impeller blades and causes the turbine to rotate. The mud then flows through the fluid passageways or ports 62 into the hollow shaft 60 which is connected to the rotor of the mud turbine 46.

Further, shaft 60 is suitably supported by means of an upper bearing section 42 and lower thrust bearings 72 and 73. An annular space is created by shaft 60 and outer case 84 in which electrical power parts and electrical circuit means for supplying electrical power to device 18 are contained. The annular space is sealed by sealable means 74 and 76 from drilling fluid which circulates through shaft 60 to drill bit 10. The annular space is filled with a satisfactory non-electrical conducting fluid, such as transformer oil or inert gas, through filler plugs 86 and 87. Equalizer pistons 88, 89 and 90 are designed to equalize the pressure between the drilling fluid outside the tool and the fluid in the annular space inside the tool.

Also connected to the outer periphery of shaft 60 is armature 64 of exciter 48 and a first conventional commutator 92 employed to supply exciter current to the field winding 51 of generator 50 through electrical conductors 94. Likewise, armature 49 of generator 50 is attached to shaft 60. Rotation of shaft 60 motivated by the impellers of the axial flow turbine 46 causes current to be generated in both exciter 48 and generator 50.

Power generated by generator 50 is conveyed by a second commutator 96 through electrical circuit means 98 to transformer 52. The power then passes from transformer 52 through electrical circuit means 100 to rectifier 53, through circuit means 101 and then to capacitor or condenser bank 54. High voltage passes from condenser 54 to a third commutator 102 which controls the flow of electrical power to device 18, through conductor 104 for generation of an electrical discharge between electrode tip 30 and an adjacent cutting member 14.

It is only recently that the submerged electrical discharge phenomenon has been investigated and its tremendous physical potential begun to be understood. One investigation using a 25,000 volt discharge from a 5.8 microfarad capacitor determined that at peak transient current of about 85,000 amps, and surrounding pressure in the vicinity of the spark of 8,300 times atmospheric pressure (122,000 p.s.i.), the instantaneous electrical power of the spark may exceed 390 megawatts. Static borehole fluid pressures, by contrast, rarely exceed 16,000 p.s.i. The energy created by the spark discharge action is dissipated as mechanical work in generating a shock wave which, although of short duration, has the capacity to crush and fracture hard rock formation in the vicinity of the electrical discharge.

The shock wave generated by the electrical discharge appears to be a result of the mechanical inertia of the fluid surrounding the discharge. When the discharge occurs, the fluid in the area of the spark is heated by the spark and tends to expand. The inertia of the fluid and its inherent incompressibility resist the expansion, resulting in the development of extremely high pressures. The electrical discharge lasts only approximately four micro-

seconds, with the peak energy occurring approximately two microseconds after initiation of the electrical discharge.

The electrical energy required to produce the high voltage under-water discharge is typically stored in a capacitor which may be positioned at the surface or which may be mounted adjacent the bit 10 within a portion of the drill pipe as shown in FIGURE 4. In this invention novel means of conducting electricity is provided by an annular or eccentric conductor member 34 which forms electrode 26 and one leg of the circuit. Conductor 34 extends within the threaded portion 12 of the bit 10 and is adaptable to engage a similarly constructed portion of drill pipe or drill collar 11 as shown in FIGURE 2. This conductor may extend to the earth's surface where it is connected to a capacitor at the surface. The conductor 34 is isolated from the metallic components of the bit 10 by insulation 36.

Since the electrical current must be large, even though occurring for only a few microseconds, it is important to provide relatively large volumes and low resistances in conductor 34 and electrode 26. The intensity of the shock wave produced and thus the effectiveness of the electrical discharge device 18 to improve drilling rates is substantially directly proportional to the intensity of the spark discharge.

This invention incorporates means wherein electrical discharges are used in conjunction with a mechanical drill bit, and wherein the characteristics of a mechanical drill bit to produce a uniformly cylindrical hole are retained. Electrical discharge device 18 is positioned adjacent the periphery of the drill bit 10 and slightly to the interior of the ultimate hole formed by the rotation of drill bit 10. In this manner, electrical discharge device 18 is in the area adjacent the gage corner of the borehole. Greater destructive power is needed here than in the center of the hole because the formation is supported not only in a horizontal plane, as it is in the hole bottom, but also in a vertical plane.

Although this invention has been described with a certain degree of particularity, it is manifest that many changes may be made in the details of construction and the arrangement of components without departing from the spirit and scope of this disclosure.

What is claimed is:

1. In a method of drilling a borehole in the earth by rotating a roller cone-type, multi-cutter drill bit against the bottom of the borehole while loading the bit and circulating a liquid drilling fluid within the borehole, the improvement which comprises generating electrical spark discharges intermittently around the periphery of the borehole and adjacent the lower end of said bit concurrently with said rotation and said loading.

2. In a rotary well drilling apparatus including a tubular drill string: a roller cone-type, multi-cutter drill bit attached to the lower end of said string, said drill bit having a body portion and a plurality of roller cone-type cutters journaled in said body portion, an electrode member supported by and insulated from said body portion, one end of said electrode member terminating in an exposed tip adjacent the lower end of said bit and slightly within the periphery of said bit so as to define a gap with said bit, an electrical power source positioned within said drill string above said drill bit, electrical circuit means connecting with said electrical power source and terminating at each side of said gap, a first leg of said circuit means including said body portion of said bit and a second leg of said circuit means including said electrode, said electrical power source and said electrical circuit means being of a character to generate an intermittent electrical spark discharge across said gap.

3. An apparatus as defined in claim 2 in which said first leg of said circuit means includes one of said roller cone-type cutters and said exposed tip of said electrode

member is arranged to define said gap with the roller cone-type cutter.

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