May 29, 1962 D. S. ROWLEY 3,036,645

BOTTOM-HOLE TURBOGENERATOR DRILLING UNIT

Filed Dec. 15, 1958 4 Sheets-Sheet 1

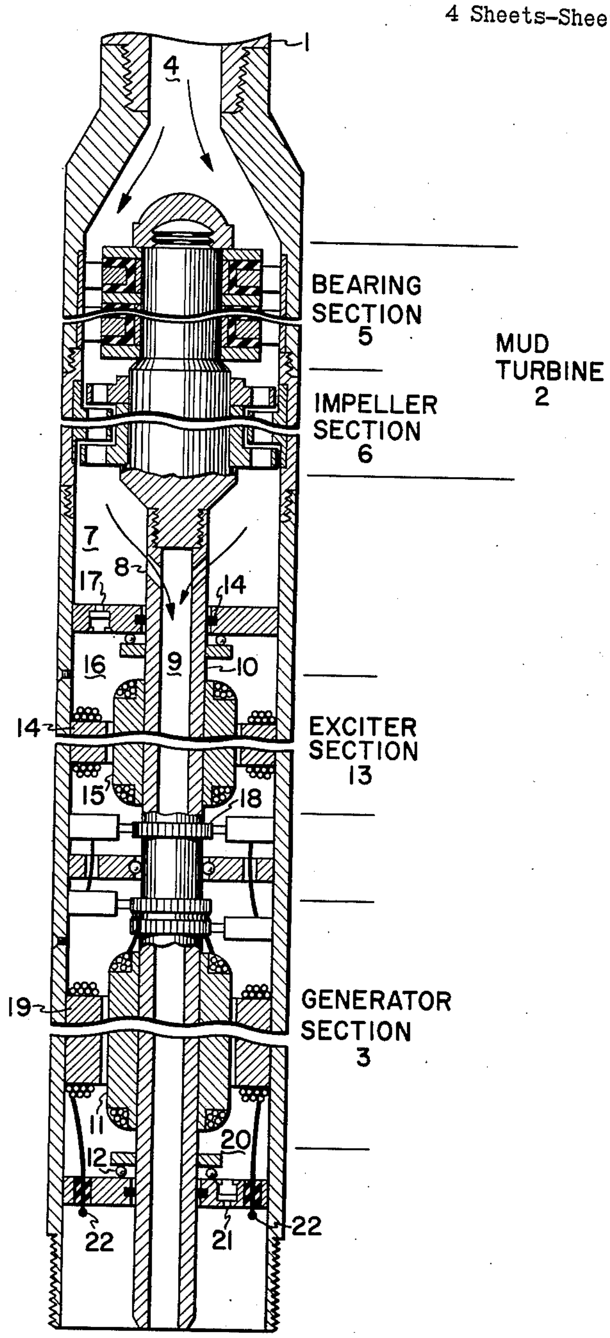

Fig. I

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4 Sheets-Sheet 2

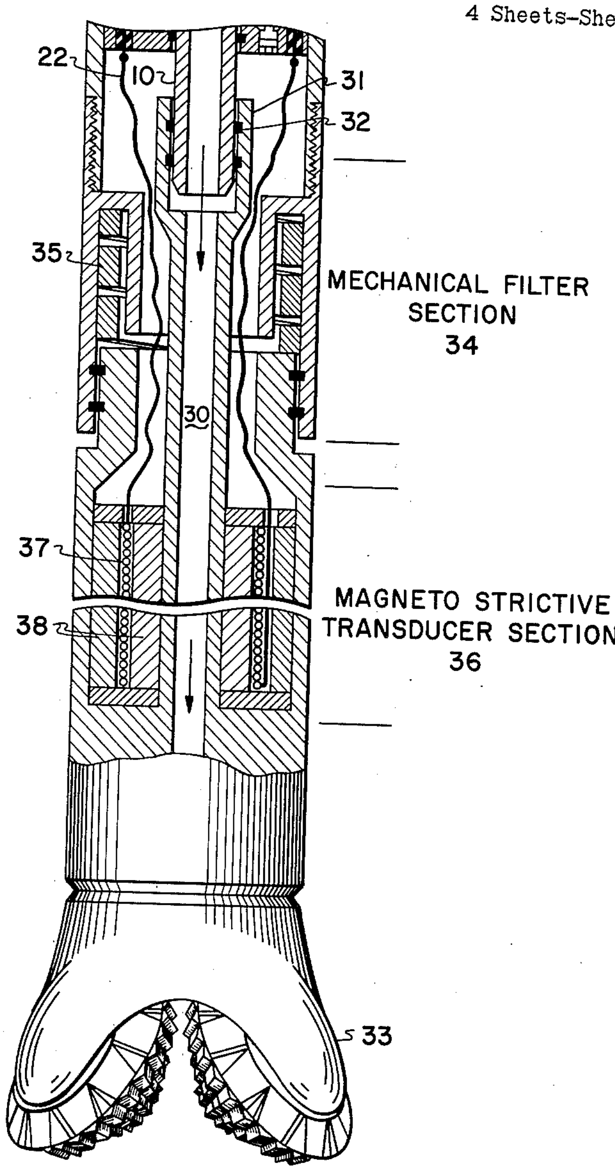

Fig. 2

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4 Sheets-Sheet 3

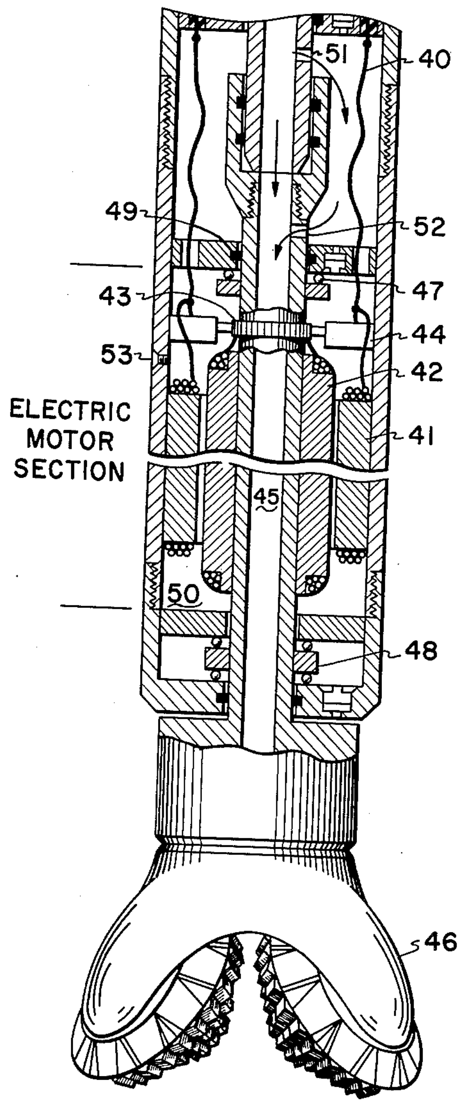

Fig. 3

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4 Sheets-Sheet 4

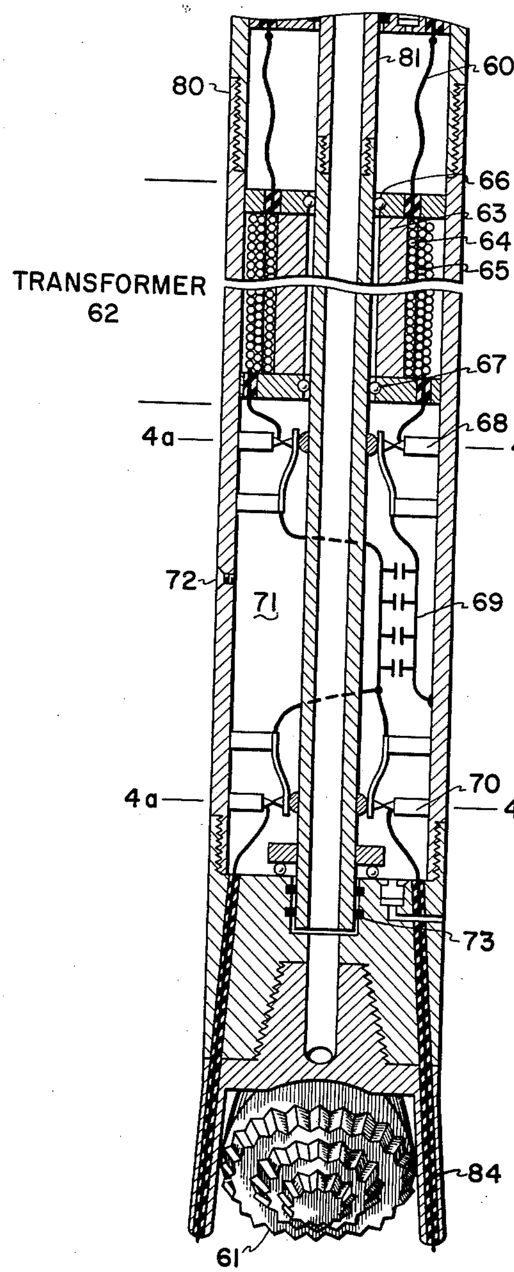

Fig. 4

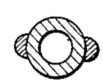

Fig. 4a

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3,036,645
BOTTOM-HOLE TURBOGENERATOR DRILLING UNIT

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Filed Dec. 15, 1958, Ser. No. 780,412
1 Claim. (Cl. 175—93)

The present invention is concerned with the production of oil from subterranean reservoirs. The invention is more particularly directed toward an improved down-hole turbogenerator which comprises an axial flow turbine, an exciter and an electrical generator. The current generated down-hole may be used to drive an electrical motor to actuate a bit or may be employed to furnish power for an electromechanical unit, particularly a magnetostrictive unit, to superimpose vibratory forces upon a rotating bit.

In the production of oil from subterranean reservoirs, it is well known in the art to drill wells or boreholes from the earth's surface into the substrata by various means. One of the most widely employed techniques is to use various types of drill bits such as drag bits, roller type rock bits, and the like and to attach these bits to the lower end of relatively heavy pipe sections known as drill collars which in turn are connected to other sections of pipe as the borehole goes deeper. These connected pipe sections are conventionally known as the drill string. The drilling of the borehole is usually secured by rotating the pipe string from the surface by suitable actuating means, thus causing the drill bit to rotate. Cuttings are usually removed by circulating a drilling mud downwardly usually within the pipe string and upwardly usually in the annulus between the drill string and the borehole wall. This drilling fluid comprises various types of so-called drilling muds.

While this method of drilling boreholes into the earth's substrata has been generally satisfactory, several disadvantages are apparent. One great disadvantage is that, as the pipe string is extended from 5,000 to 10,000 feet into the earth's subsurface or even deeper, the frictional loss of power incurred between the rotating pipe string and the circulating mud carrying the cuttings to the surface becomes excessive. Another disadvantage of rotating the bit from the surface by rotating the drill string is that, in order to secure the necessary mechanical strength when drilling very deep wells, it is necessary to increase the weight of the pipe sections. Otherwise, winding up and failure of the drill string occurs. This represents an appreciable portion of the cost of drilling any particular borehole.

Suggestions have been made in the past for overcoming some of these disadvantages, at least to some extent. For example, it is conventional to interpose heavy pipe sections known as drill collars between the bit and the relatively lighter weight pipe sections or string. In effect, this keeps the string in tension, while at the same time permitting a predetermined amount of downward thrust to be exerted by the bit as it is being rotated. It has also been suggested that necessary power for rotating the drilling bit be generated at the bottom of the borehole, preferably between the drill collars and the bit. One suggestion has been that an electric motor provide the driving force for the bit and be positioned adjacent the bit. One such suggestion is covered in U.S. Patent 2,643,-087, issued June 23, 1953, H. J. Ogorzaly et al. It is to be noted that the foregoing mentioned patent covers an apparatus and a procedure wherein the electrical power necessary to run the motor is supplied by suitable storage batteries positioned near the motor.

It is also known to directly connect an axial flow mud

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turbine to the drill bit. This combination is commonly known as the turbodrill. Because of the hydraulic characteristics of the mud turbines used in the turbodrills however, it is usual for the turbines to rotate at high rotary speeds, nominally between 600 and 1,000 revolutions per minute. These speeds are required in order that the turbine produce maximum rotary power to the bit. Maximum power occurs when the turbine rotor torque decreases from its starting value at stall, or zero speed, to about one-half that value of rotor torque at some very high rotary speed of the turbine rotor. At these high rotary speeds, it is well known that abrasion and wear of the drill bit take place rapidly. In fact, wear of the drill bit is often so rapid and excessive at these high speeds that the most desirable economic aspect of turbodrilling, which is high penetration rate, is completely offset, or more than offset, on a cost basis by a corresponding decrease in the life of the bit.

Thus, to provide more economical drilling, one embodiment of the present invention involves the use of an electric motor and a turbogenerator to drive the drill bit. In this manner, the more desirable torque and speed characteristics of an electric motor can be used to advantage. Such apparatus has the added advantages of, first, having no rotary power losses in rotation of the drill string from the surface, as previously explained, and, secondly, not requiring an electric power cable from the surface to the bottom-hole electric motor. Experience in the drilling art has shown conclusively that such surface to bottom conductors are impractical due to costly insulation and connection breakdowns which interrupt the flow of current and stop drilling operations.

Use of the turbogenerator and electric motor drive unit to rotate the bit permits high power output of the turbine to the generator and at the same time allows the drill bit to be rotated at reduced speeds and high rotary power. This can be done because the torque output of the electric motor is relatively constant at full load through a desirably wide range of rotary speeds, in contrast with the characteristics of the ordinary, direct-coupled turbodrill unit.

Another embodiment of the present invention involves the use of a turbogenerator in conjunction with electrodes at the hole bottom. The drilling art has shown that rapidly developed electrical sparks, generated close to the hole bottom between suitable electrodes in the drilling fluid, create water hammer and hydraulic impact shock stresses in the rock, sufficient to cause rapid failure of the rock. The present invention provides means for generating the required electrical power at the hole bottom, thus eliminating the need for troublesome conductors from the surface to the hole bottom. These conductors, as mentioned before, make such operations costly due to frequent breakdowns.

Another adaptation of the present invention comprises an improved combination of an axial flow turbine, an exciter, an electrical generator and a magnetostrictive transducer to supply the necessary power for actuating the bit. Such a unit may also be used to superimpose vibratory forces upon a rotating bit.

In other possible embodiments of this invention the power output of the turbogenerator unit is used to generate heat or to provide magnetic fields of special characteristics for various uses in the art of drilling oil wells. The method and apparatus of the present invention may be readily understood by reference to the drawings illustrating specific embodiments of the same.

FIG. 1 illustrates the apparatus of the present invention showing particularly the turbine section, the exciter section and the generator section.

FIG. 2 illustrates the use of the power generated in the apparatus of FIG. 1 to activate a magnetostrictive transducer section in conjunction with a frusto-conical rock bit.

FIG. 3 shows the use of the electrical power generated in the apparatus of FIG. 1 to activate an electric motor which in turn rotates a frusto-conical rock bit.

FIG. 4 illustrates the use of the power generated in the apparatus of FIG. 1 to activate the sparking of high voltage electrodes.

Referring specifically to FIG. 1, the assembly is shown positioned in a borehole (not shown) and attached to the lower end of a drill collar assembly 1 which in turn is attached to the lower end of a pipe string extending downwardly from the earth's surface. The assembly comprises an axial flow mud turbine section 2, an exciter section 13 and a generator section 3. In operation, mud flows downwardly through passageway 4 around the bearing section 5 and into impeller section 6. In this section, the mud impinges on impeller blades and causes the turbine to rotate. The mud then flows into area 7, through fluid passageways or ports 8 and into area 9 within shaft 10. The impeller blades in the impeller section 6 are mounted on shaft 10, as is the armature 15 in exciter section 13 and the field winding 11 in generator section 3. Thus, the mud turbine section, the exciter section and the generator section have a common shaft, namely, element 10 which is hollow in the exciter section and the generator section so as to permit the passage of downflowing mud. Shaft 10 is suitably supported by means of an upper bearing section 5 and a lower thrust section 12. Passage of mud into the exciter section 13 is prevented by suitable sealing means 14.

The exciter section 13 comprises a suitable field winding 14 and an armature element 15 mounted on shaft 10. Area 16 of the exciter section 13 is filled with a suitable gas or inert fluid. An equalizer piston 17 is designed so as to prevent the flow of fluid from area 16 to without the same. A conventional commutator 18 is employed so as to provide exciter current. The rotation of shaft 10 motivated by the impellers of the impeller section causes a current to be generated in generator section 3. Generator section 3 comprises a suitably wound armature coil 19 and a field winding 11 mounted as described hereinbefore on shaft 10. Area 20 in the generator section 3 is filled with a suitable inert gas or fluid. An equalizer piston 21 prevents the flow of fluid from area 20 to without the same. Electrical connecters 22 are provided so as to pass the current to power units as hereinafter described with respect to FIGS. 2, 3 and 4.

Referring specifically to FIG. 2, mud flows downwardly within shaft 10 into mud passageway 30. Shaft 10 is suitably mounted in a bearing assembly 31 and sealed by means of seals 32. The mud flows downwardly through passageway 30 into suitable passageways in the conical bit 33 and thence upwardly in the annular area between the pipe string and the borehole wall. The apparatus illustrated in FIG. 2 comprises a mechanical filter section 34 which in essence consists of a filter spring 35. The mechanical filter may be any suitable shielding or buffing device whereby the vibratory action of the bit is not imparted to the drill string above. The power current supplied by means of connecters 22 causes the magnetostrictive unit 36 to expand and contract longitudinally in a manner known to the art and as described, for example, in "Ultrasonic News," page 22, volume I, No. 4, November 1957, published by Ultrasonic News, Inc., 5800 North Marvine Street, Philadelphia 41, Pennsylvania. In essence, the magnetostrictive transducer comprises a coil 37 and a core as, for example, nickel 38. The off and on flow of current causes the nickel core to expand and contract, thereby causing the bit to vibrate longitudinally. This greatly aids in securing rapid penetration of the formation being drilled.

Referring specifically to FIG. 3, the electrical power generated in accordance with the present invention is utilized to drive a down-hole motor which in turn drives a bit as, for example, a frusto-conical bit. The power is passed from the prime mover or generator by means of leads 40. The motor comprises conventional field windings 41 and armature windings 42. The commutator 43 and brush elements 44 are positioned as shown. Drilling mud is passed downwardly from the pipe string through passageway 45 within the armature and into mud passageways positioned within bit 46. The mud then flows upwardly in the annular area between the motor assembly and the borehole wall. The armature is supported by an upper thrust bearing 47 and a lower thrust bearing 48. Satisfactory seals 49 are provided to prevent the flow of mud into the electrical field or armature area 50. The mud in passing downwardly, passes through ports 51 and 52 to within the hollow cylindrical armature which rotates, and in turn rotates the bit 46. The area 50 is filled with a satisfactory fluid which can be introduced through filter plug 53. Thus, in accordance with this concept of the invention only the bit is rotated along with the armature positioned in the electrical motor section. The pipe string above the bit is rotated only at a rate sufficient to prevent freezing. Thus, an appreciable amount of energy which otherwise would be lost to the mud column, can be used for more effective and efficient drilling.

Another concept of the present invention is illustrated in FIG. 4 wherein the electrical power generated in accordance with the concept of the present invention is utilized to induce high voltage sparking, thus causing fatigue and breakdown of the substrata being drilled. The electrical power is passed into the transformer section from the generator by means of electrical lead 60. In accordance with this concept of the present invention, a bit 61 is rotated from the surface by means of the pipe string. The electrical power of the generator of the prime mover is passed into a transformer section 62 comprising a core 63, a primary coil 64 and a secondary coil 65. This transformer is supported by means of bearing 66 and 67. High voltage is built up which is passed through a mechanical rectifier 68 and a condenser bank 69. A conventional commutator 70 is employed to control the sparking. The area 71 is filled with satisfactory fluid as, for example, oil which may be introduced through filler plug 72. Passage of fluid from this area to without is prevented by means of seal 73.

In operation, the pipe string 80 and bit 61 rotate at a relatively slower rate as compared to mud passageway 81. Thus, as a high voltage is built up in a secondary coil, the mechanical rectifier 68 will periodically make contact and pass the electric charge to the condenser bank. The timing of the rectifier 68 is adjusted so as to prevent the discharge of the condenser bank backwardly. The timing of commutator 70 is adjusted to take the charge off the condenser and to pass the charge to the electrodes 84, thus causing a spark across the same. FIG. 4A is a top view of the mechanical rectifier 68 showing the method of making contact.

What is claimed is:

An improved drilling tool comprising a cylindrical housing attachable to the lower end of a drill string; a rotatable shaft concentrically mounted in said housing, said shaft containing an axial passage extending downwardly from a lateral port intermediate the ends thereof; impeller elements mounted on said shaft above said port for imparting torque to the shaft in response to downward flow of drilling fluid in said housing; an upper baffle disposed in fluid-tight relationship between said shaft and housing below said port; an exciter positioned in said housing below said upper baffle, said exciter including exciter field windings mounted on the inner wall of said housing and exciter armature windings mounted on said shaft adjacent said exciter field windings; a generator positioned within said housing below said baffle, said generator including generator field windings mounted on the inner surface of said housing and generator armature windings mounted on said shaft adjacent said generator field windings; means for transmitting electric current induced in said exciter armature windings to said generator field windings; a lower baffle disposed below said generator in fluid-tight relationship between said shaft and housing; terminals within said housing beneath said lower baffle; a second shaft rotatable with respect to said housing concentrically mounted in said housing below said lower baffle, said second shaft containing an axial passage communicating with said passage in said first shaft and being independently rotatable with respect to said first shaft; motor armature windings mounted on said second shaft below said lower baffle; motor field windings mounted on the inner wall of said housing adjacent said motor armature windings; means electrically connecting said motor armature and field windings to

said generator armature windings; and a drill bit containing a passage for the downward discharge of drilling fluid attached to the lower end of said second shaft, said passage in said bit communicating with said passage in said second shaft.

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