

March 18, 1958

J. G. SCOTT ET AL
WELL DRILLING EQUIPMENT

2,827,263

Filed Aug. 27, 1954

7 Sheets-Sheet 1

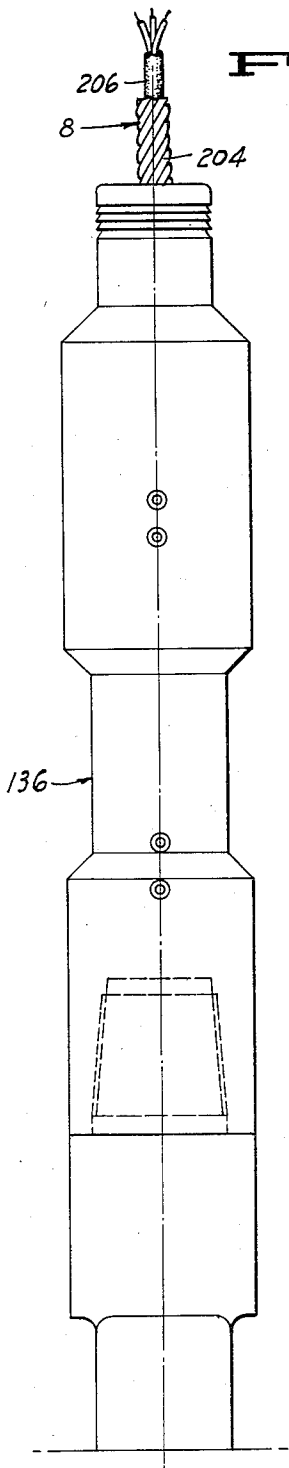
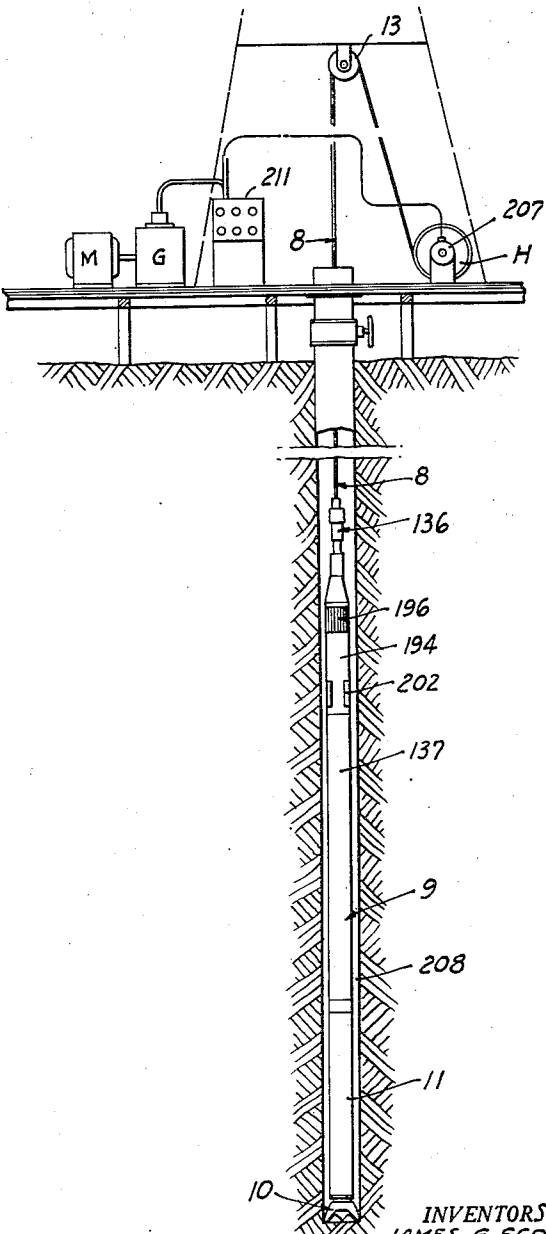


FIG. 2A-
FIG. 1--



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FIG. 2C.

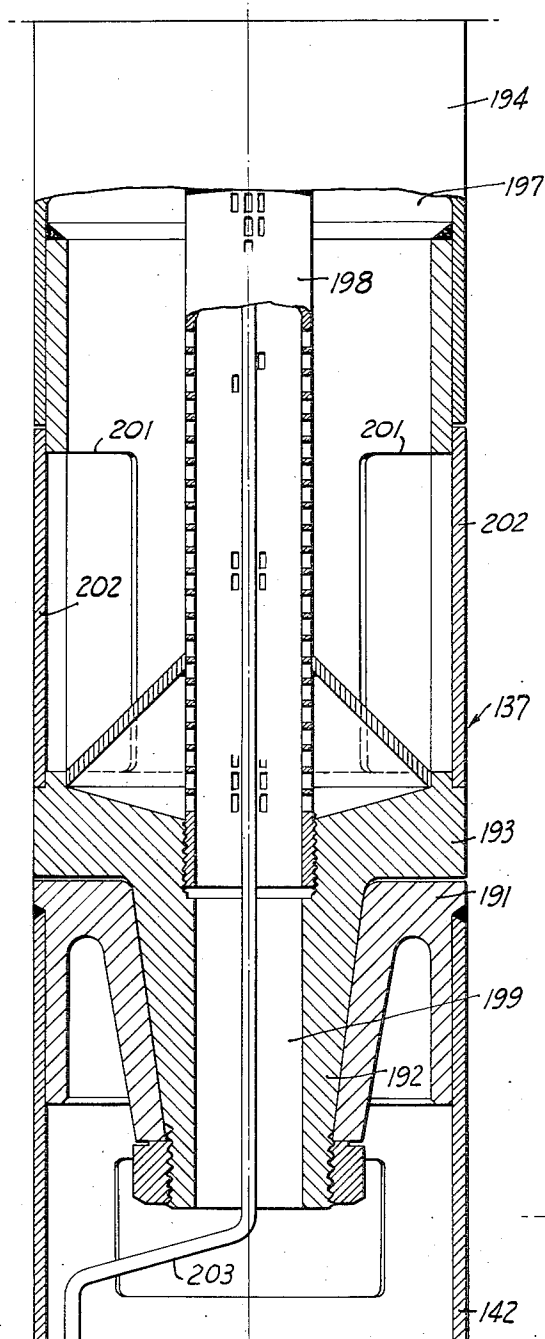
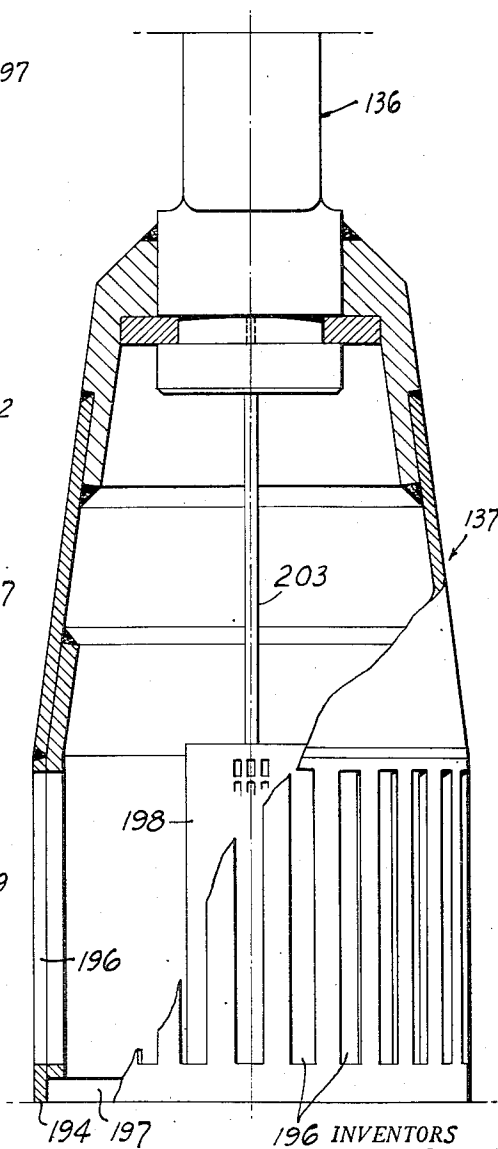


FIG. 2B.



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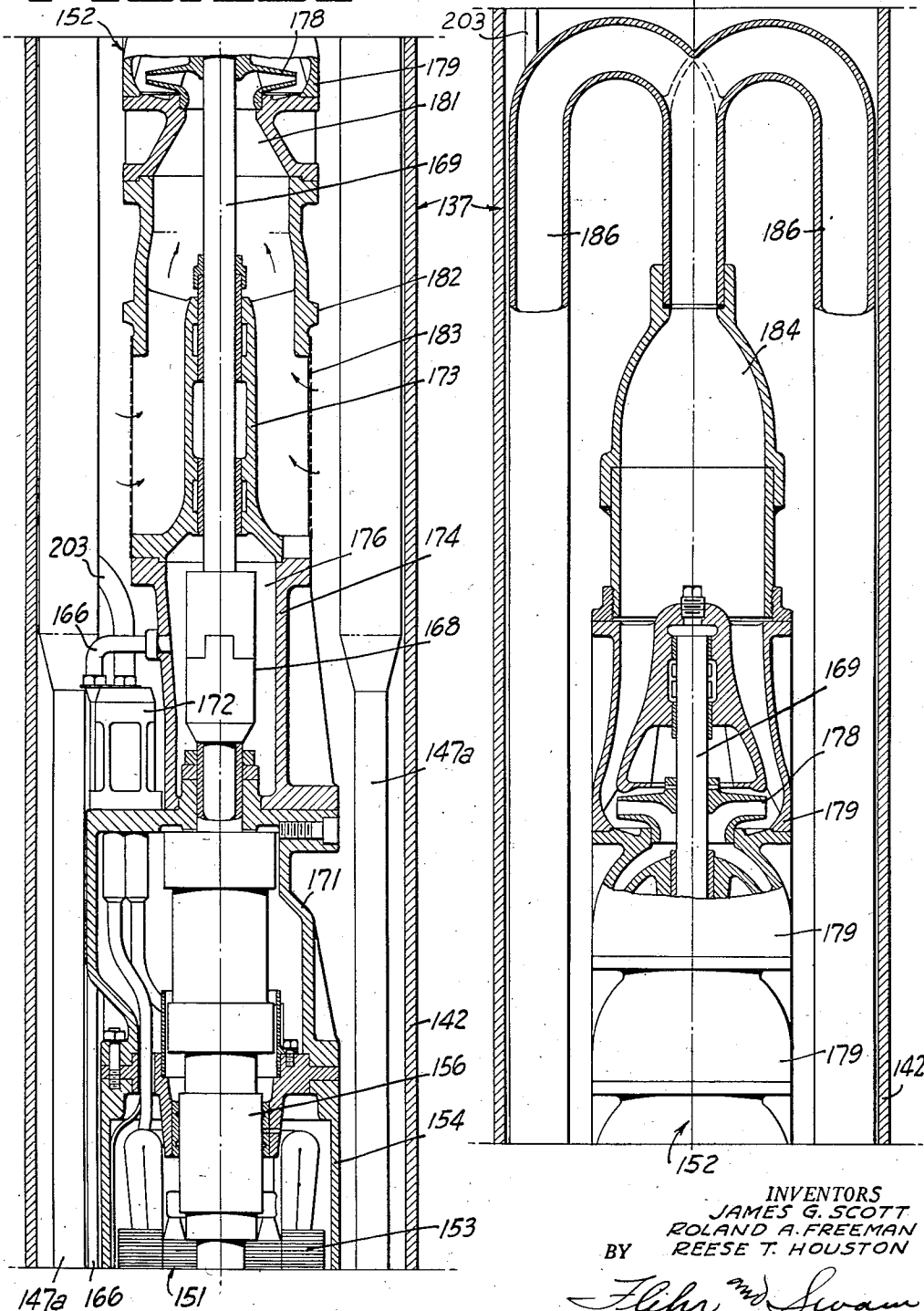
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FIG. 2E

FIG. 2D



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FIG. 26

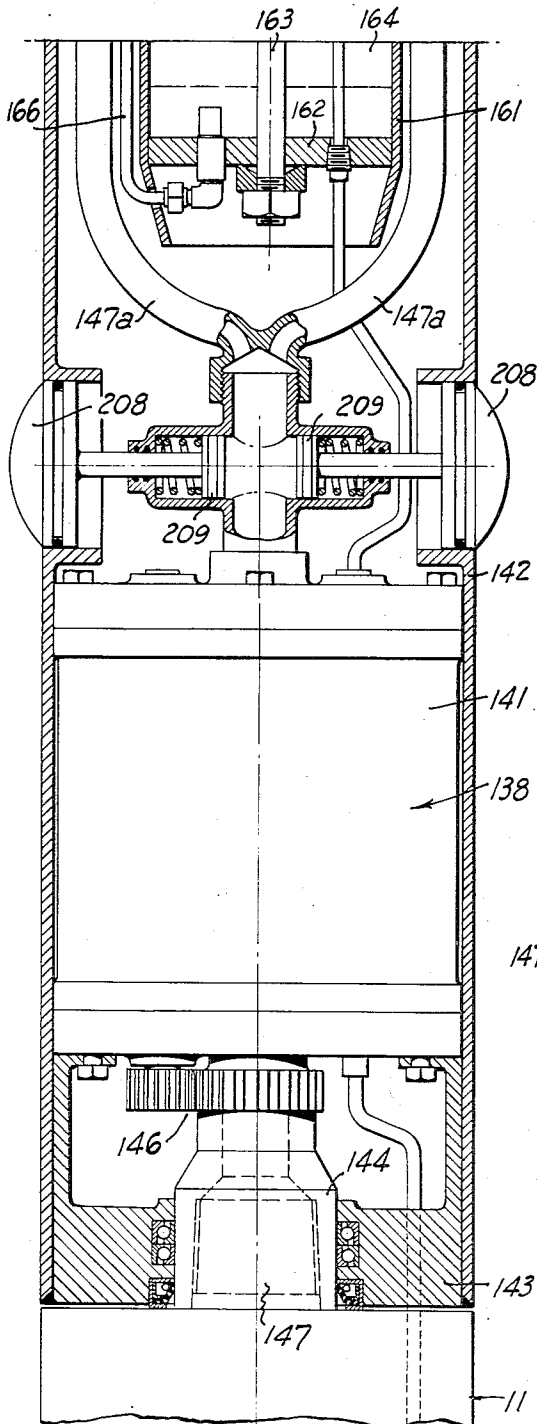
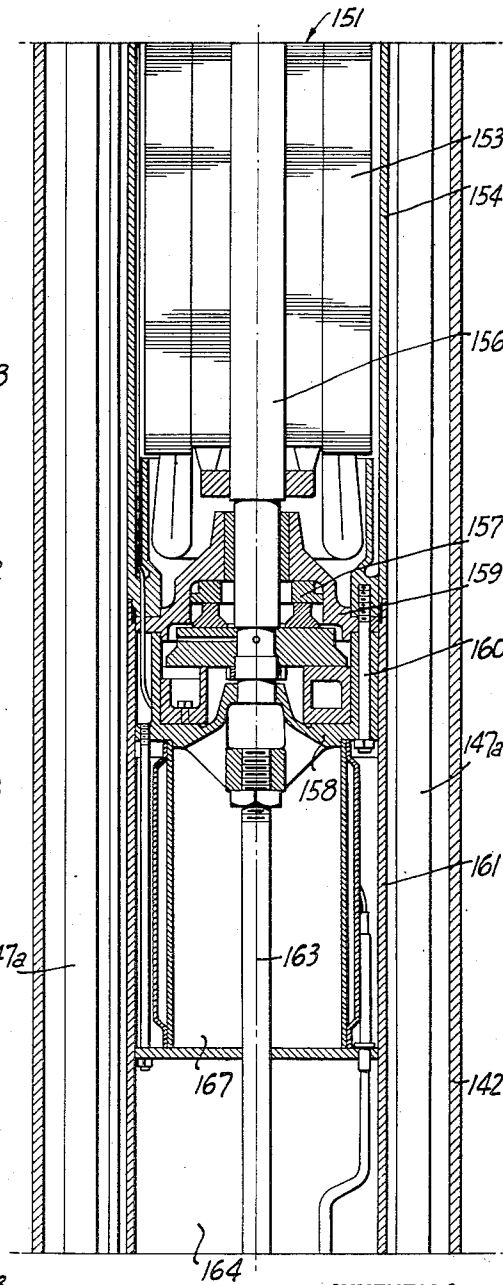


FIG. 2F



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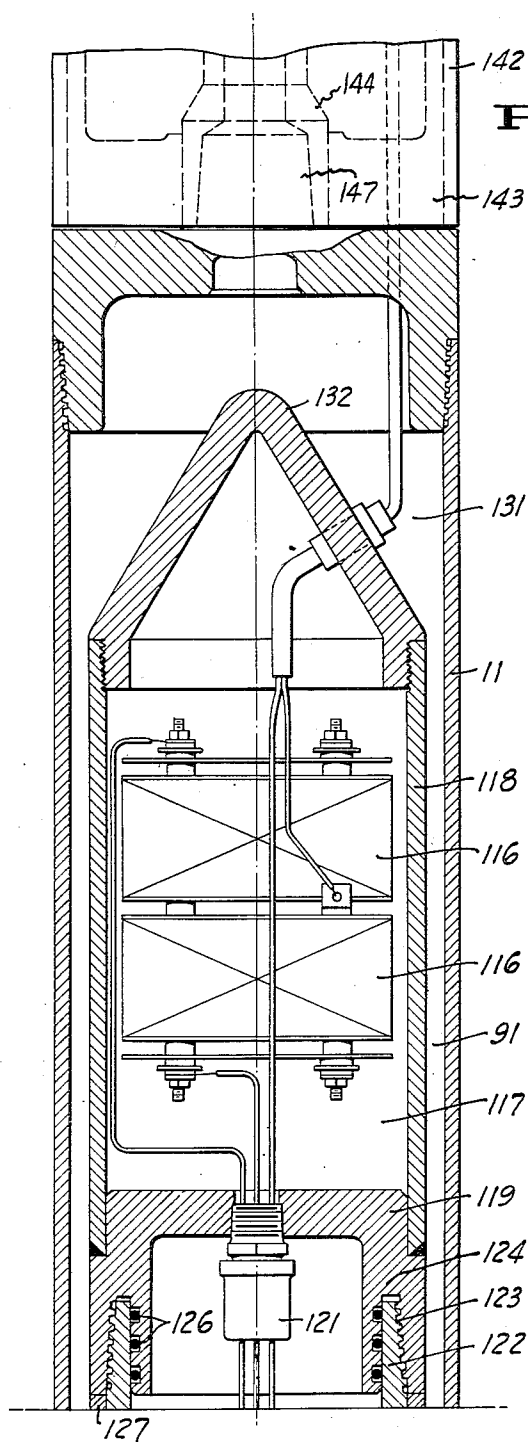


FIG. 2H

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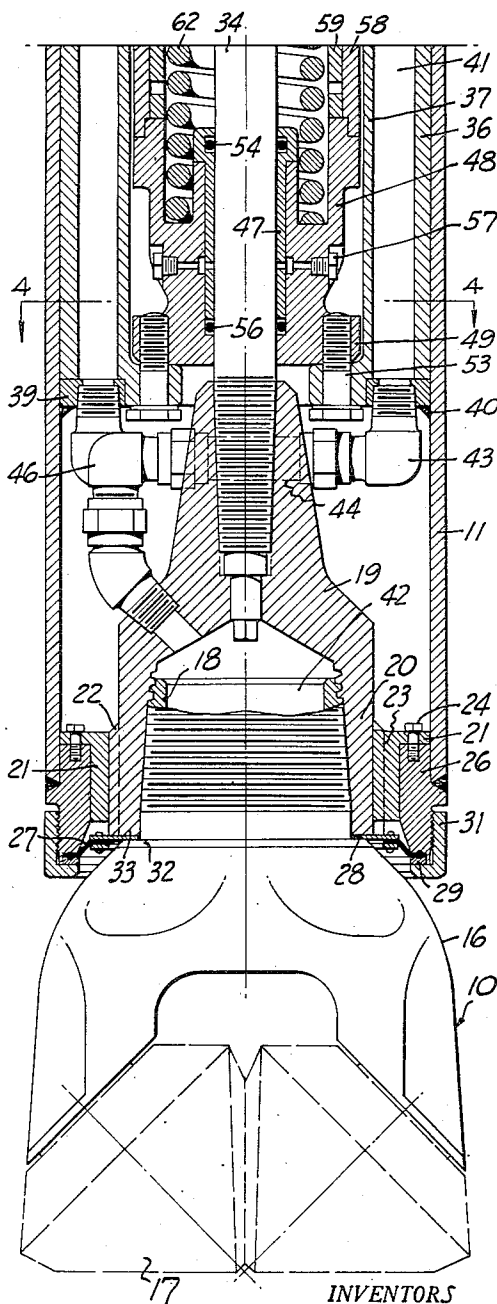
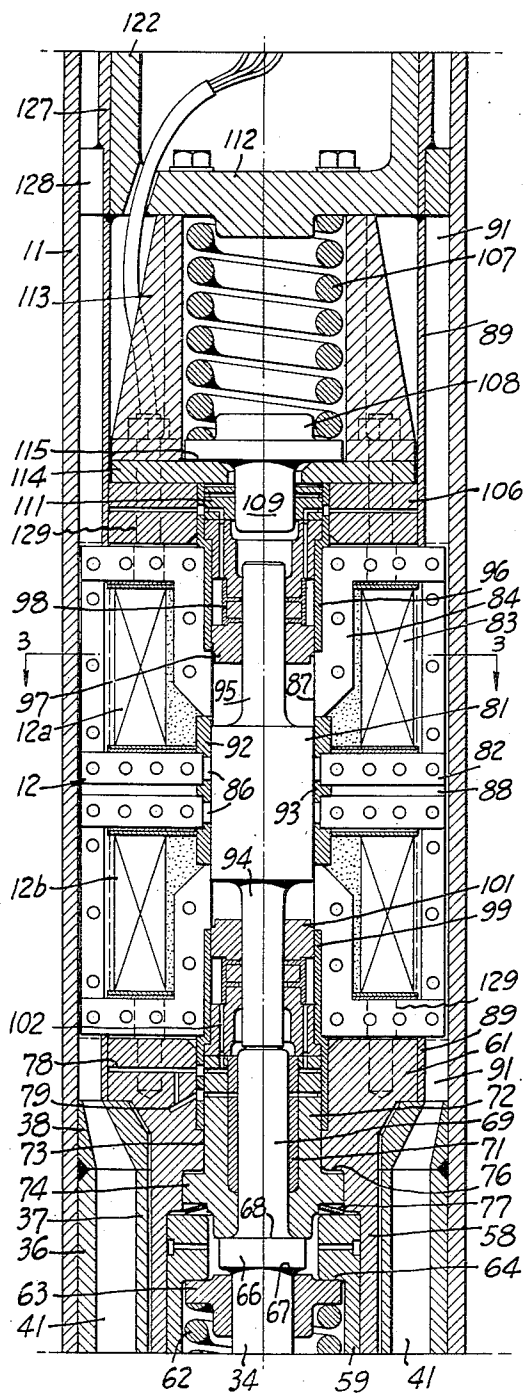
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FIG. 21

FIG. 22



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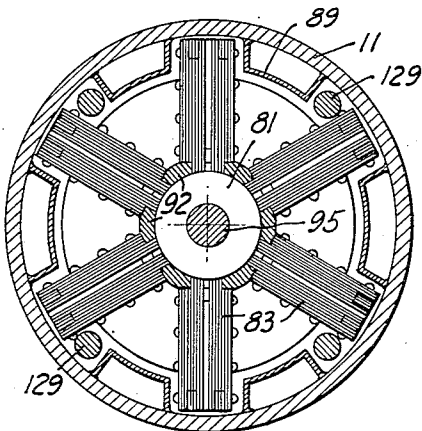


FIG. 3

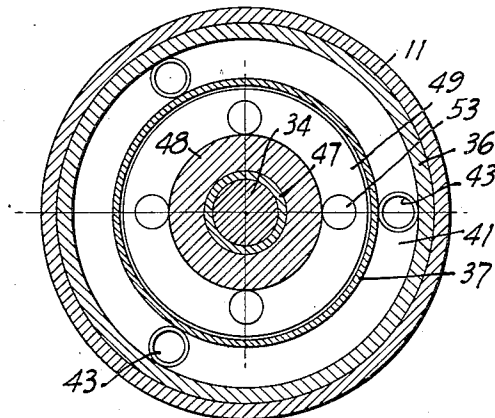


FIG. 4

FIG. 5

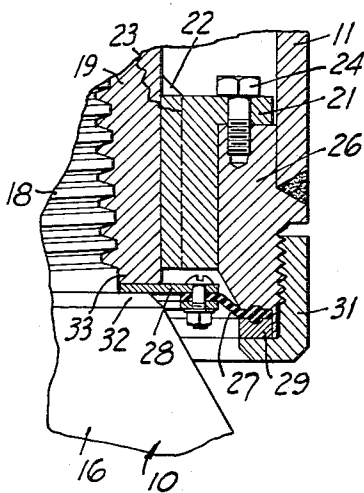
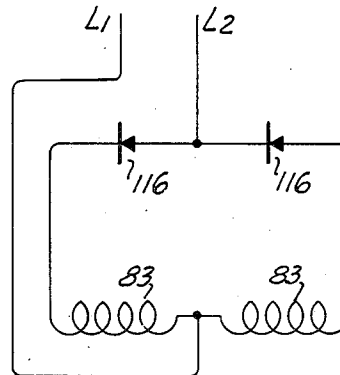


FIG. 6



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WELL DRILLING EQUIPMENT

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Application August 27, 1954, Serial No. 452,522

7 Claims. (Cl. 255—4.4)

This invention relates generally to the drilling of oil, gas, water or like earth wells, and to equipment for such drilling operation.

In our co-pending application Serial No. 445,666, filed July 26, 1954, and entitled Well Drilling Equipment and Method, there is disclosed drilling equipment employing a rotary drill head and an electrical actuator adapted to apply impact to the head at a constant frequency. The housing which carries the rotary head and mounts the actuating means is adapted to be attached to the lower end of a rotary drill stem. In operation the drill stem is rotated in accordance with conventional rotary earth drilling practice, the actuator is energized to apply impacts to the drill head to thereby effect percussion drilling, and at the same time rotary mud is circulated through the head for the removal of cuttings. In some instances it is not desirable to employ a conventional drill stem, together with other parts of a conventional rotary drilling equipment, including the table at the surface of the well for turning the stem.

It is an object of the present invention to provide a drilling equipment and method making use of the invention disclosed in said copending application, but which incorporates all of the operating parts in an assembly which can be lowered into a well by a cable.

Another object of the invention is to provide novel equipment of the above character which provides for the circulation of rotary drilling mud within the well.

Another object of the invention is to provide equipment of the above character in the form of a self-contained assembly adapted to be lowered into a well to carry out efficient and rapid cutting by impact percussion action, while at the same time including means for rotating the head upon the formation, for circulating drilling mud, and for the continual removal of cuttings from the area of the drill head.

Additional objects and features of the invention will appear from the following description in which the preferred embodiment has been set forth in detail in conjunction with the accompanying drawing.

Referring to the drawing:

Figure 1 is a side elevational view partly in section, schematically illustrating an earth well with our equipment being employed for drilling operations.

Figures 2A to 2J, inclusive, taken together, form a side elevational view in section illustrating the upper part of a complete assembly which is lowered into the well for drilling operations.

Figures 3 and 4 are cross sectional details taken along the lines 3—3 and 4—4 respectively, of Figures 2I and 2J.

Figure 5 is a detail in section showing the spline connection between the assembly housing and the drill head.

Figure 6 is a circuit diagram showing connections to the windings of the electrical actuator.

In Figure 1 we have schematically illustrated our equipment applied to an earth well for drilling operations. The equipment forms a complete assembly 9 which op-

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erates at the bottom of the well, and which carries a drill head 10. The assembly 9 is carried at the lower end of a cable 8, which extends down from the surface of the well, and which at the well surface is passed over suitable means such as the conventional crown block 13 of a well derrick, and wound on a drum H.

Assembly 9 is illustrated in Figures 2A—2J taken together. Referring first to Figure 2H, 2I and 2J, they illustrate equipment as disclosed in our aforementioned copending application. The drilling head 10 in this instance consists generally of a body 16 carrying a plurality of toothed rotary cutter assemblies 17. Such drilling heads are well known to those familiar with oil and gas drilling methods, and are manufactured in various types and sizes for different kinds of drilling conditions. The threaded shank 18 of the head is engaged with the head mounting member 19, which in turn is located within the lower part of the tubular housing 11. The lower annular portion 20 of member 19 is slidably received in the bushing 21, which can be made of suitable material, such as bronze. A suitable torque transmitting connection is formed between these parts, and may consist of a plurality of splines 22 formed on the member 19 and slidably engaging slots 23 formed in the bushing 21. The bushing 21 is attached by suitable means such as the screws 24 to the ring 26, the latter being suitably secured, as by welding, to the lower end of the housing 11.

A suitable seal is formed between the head and the ring 26 to prevent entrance of mud or cuttings. For this purpose we have shown a diaphragm 27 of flexible material such as fabric reinforced natural or synthetic rubber, having its inner peripheral edge clamped to a gasket ring 28, and its outer margin clamped between the end piece of the ring 26 and the annular washer 29. The clamping washer 29 is held in place by the ring 31, which is internally threaded and engaged with the threaded exterior of ring 26. The inner margin of the gasket ring 28 is tightly clamped between the shoulder 32 on the head and the opposed end face 33 of member 19.

The upper end of the member 19 is attached to the impact transmitting bar 34 which extends concentric with the axis of the housing 11. As will be presently explained it is the upper end of this bar that receives impacts from the electrical actuator.

Interposed between the member 19 and the electrical actuator there is a structure including guide means for the bar 34, and a recoil spring. As shown particularly in Figures 2I and 2J this structure consists of concentric tubes 36 and 37, which have their upper ends attached to a mounting ring 38, and their lower ends attached to a similar member 39. These tubes are fixed to the housing 11 as by means of the weld connection 40. The space 41 between these tubes serves to conduct drilling mud and is connected with the mud receiving space 42 in the shank 18 of the drill head. For this purpose, space 41 is shown communicating with a plurality of pipe fittings 43, which in turn are connected by the flexible hose sections 44 with pipe fittings 45. The latter fittings directly connect through the member 19 to deliver mud into the space 42. In accordance with customary practice the cutter head is provided with ducts (not shown) which conduct the mud to the area being drilled, whereby chips or cuttings are removed.

The bar 34 is slidably fitted within the bushing 47, which in turn is fitted within the end casting 48. This casting has a lower flange 49 which is clamped to the flange 51 on the lower end of tube 37, by suitable means such as the screws 53. Suitable lubricant sealing means such as the resilient O-ring seals 54 and 55, can be provided at the upper and lower ends of the bushing 47. Also suitable fittings 57 can be provided for the introduction of lubricant.

The lower end casting 48 seats an upper annular body

58, and the latter is bored and fitted with the bushing 59. The upper end of body 58 is provided with a flange 61 that overlies the ring 38.

The members 48 and 59 provide space for accommodating the loaded recoil spring 62. One end of this spring seats upon member 48, and the other upper end seats upon the collar 63, which is loosely fitted about the bar 34. Collar 63 normally engages the annular shoulder 64 on the upper end of bushing 59 to resist the normal loading of the spring. Immediately above the collar 63 the rod 34 has an enlarged annular portion 66 to form the abutment shoulders 67 and 68. When no loading is being applied to the drill head, shoulder 67 is urged against the opposed face of the collar 63, by the force of the loaded spring 62.

The upper part 69 of the rod 34 forms what can be referred to as an anvil portion. It is slidably fitted within a bushing 71 that is carried by the sleeve 72. The sleeve 72 is assembled within a bore 73 formed in the upper part of member 58, and is provided with a flange 74 adapted to seat upon the cooperating shoulder face 76. The flange 74 is urged against the shoulder face 76 by suitable means such as a Belleville washer 77. A suitable arrangement of ducts 78 and 79 can be provided for introducing lubricant to the area between the bushing 71 and the anvil portion 69.

The electrical actuator is preferably constructed as follows: It employs a field comprising two electromagnet assemblies 12a and 12b, which serve to operate a central piston-like core 81. The assemblies 12a and 12b can each consist of laminated cores 82 disposed radially about the axis of the central core, and provided with windings 83. The pole pieces 84 and 86 of each laminated core terminate at the boundary of a cylindrical passage 87, within which the central core 81 operates. The two sets of laminated cores are shown separated by the mounting plate 88, and have their outer portions set interposed between the channels 89. The passages 91 formed by these channels permit passage of mud. This arrangement brings the drilling mud into heat exchange relation with the magnetic cores and windings, thus providing for dissipation of heat. The lower ends of channels 89 are sealed with respect to ring 38, and passages 91 have their lower ends in free communication with the passage 41 between the tubes 36 and 37. Filler rings 92 and 93 are interposed between the pole pieces 84 and 86 of each electromagnet assembly, and the filler ring 93 is interposed between the two sets of pole pieces 86.

The central piston-like core 81 is provided with lower and upper axial extensions 94 and 95 of reduced diameter which form impact or hammer elements. The hammer element 94 delivers impacts to the anvil portion 69 of the bar 34. A bearing assembly for element 95 can consist of a sleeve 96 which is mounted upon the laminated cores for the upper electromagnet assembly, and which serves to mount the bushing 97. This bushing is bored to receive the element 95, and is also provided with suitable means such as ducts 98, for introducing lubricant. A similar bearing assembly is formed for the lower element 94. It consists of a sleeve 99 (corresponding to sleeve 96) serving to mount the bushing 101 (corresponding to bushing 97). Here again the bushing can be provided with lubricant receiving ducts 102. At its lower end face the bushing 101 is in direct engagement with the upper end face of the sleeve 72. Also the lubricant ducts 102 can be in communication with ducts 78.

Overlying the upper electromagnet assembly 12a there is an annular plate 106 that is fitted within the channels 89. Above this plate there is a second recoil spring 107 and mounting means for the same. The lower end of spring 107 seats upon the impact receiving member 108, which has its end face 109 aligned with and opposed to the end face of the impact element 95. The member 108 is guided by the bushing ring 111 which is fitted in the upper portion of the sleeve 96. The upper end of the spring 107 seats upon a member 112, which is maintained

in spaced relationship with the plate 106 by the tubular shroud 113 and the interposed plate 114. The inner margin of the plate 114 forms an abutment shoulder 115 for the thrust receiving member 108.

As will be presently explained the windings of the electromagnet assemblies are energized by current pulsations whereby the central core 81 is caused to reciprocate a predetermined number of complete strokes per minute. The weight of the moving parts, the strength and pre-loading of the recoil springs, and the frequency of excitation of the windings is such that the core reciprocates at a constant frequency. When no downward force is being applied to the drill head, the force of the downward stroke of the core is absorbed by the lower recoil spring 62. However as the load is applied to the head an increasing amount of the impact energy is transmitted through the bar 34 to the head and to the formation, until a maximum optimum loading is reached, which is equal to the force of the loaded spring 62. By way of example this may be of the order of 30,000 pounds.

A suitable circuit arrangement for exciting the windings of the electromagnet assemblies is shown in Figure 6. The lines L1 and L2 are connected to a suitable source of alternating current, such as 150 volts at 30 cycles at the surface of the well. The power is delivered to the lines through an electrical cable which extends concentric with the cable 8 through the assembly, the mud motor 13, and either member 143 or 147 (the latter portion of the path not shown in the drawing). The windings 83 have a common point of connection which connects with one line L1. The other terminals of the windings 83 connect with the rectifiers 116, which have a common point of connection to the other line L2. With this arrangement rectifying pulses are supplied alternately to the two sets of windings, whereby for a current frequency of 30 cycles per second, the central core 81 is reciprocated at a frequency of 3600 complete strokes per minute, thus delivering 1800 impacts per minute. The rectifiers 116 may be of the dry selenium type, the mercury vapor type, or any other type suitable for the current carrying capacity required.

Referring again to Figures 2H and 2I, rectifier units 116 of the dry selenium type are shown disposed within a space 117 provided for this purpose. This space is formed within a tubular housing 118 that is disposed in the upper portion of the main tubular housing 11. The lower closure 119 for the housing 118 can be provided with a sealed fitting 121 to accommodate the conducting wires leading to the windings of the electromagnet assemblies. Also the end member 119 has a rigid sealed connection with the member 112. Thus member 112 has an upwardly extending cylindrical portion 122, which has a threaded engagement 123 with a depending cylindrical portion 124 of the end closure 119. Suitable means such as the O-ring seals 126 provide a fluid tight seal between these parts. The upper ends of channels 89 are attached to the lower edge of a tubular section 127 that surrounds the tubular portion 122, and which abuts the lower end face of the tubular portion 124. Also a ported seating ring 128 can be provided about the tubular section 127, and against which this section may seat.

To maintain the parts of the electrical actuator in assembled relation, we have shown a plurality of tie bolts 129, which at one end engage the member 113, and at the other end engage the member 58.

By reference to Figure 2I it will be seen that the angular passage 91 for circulating mud continues upwardly past the closed housing 118 to the space 131 which overlies the upper end 132 of the housing 118. Space 131 communicates with the lower end of that part of the complete assembly illustrated in Figures 2A-2G, inclusive.

Referring now to Figures 2A-2G, inclusive, they show an upper coupler part 136 for making connection with

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the suspending cable, a bailer 137 for the removal of cuttings, a pump 152 for the circulation of drilling mud, and a mud motor 138 for driving the lower part of the equipment, namely that part illustrated in Figures 2H-2J, inclusive.

Referring particularly to that part of the assembly illustrated in Figure 2G, the drive means 138 consists of a suitable fluid pressure operated motor 141 which is mounted within the tubular housing 142. This motor can be one of the positive displacement type, suitable for operation on drilling mud. At the lower end of the housing 142 there is a closure 143 which serves to journal the central rotatable shaft 144. This shaft is operably connected to the drive shaft of the motor 141, as by means of suitable speed reduction gearing 146. The shaft is internally threaded as illustrated in Figure 2G, thereby enabling it to be coupled upon the male coupling part 147, formed at the upper end of the assembly shown in Figure 2H. The upper end of the motor is coupled to the mud piping 147a, whereby drilling mud is delivered to the motor from the pumping means presently described. At the other end of the motor there is a direct coupling from the motor discharge ports to the passage through the shaft 144, whereby the mud is delivered into the space 131 of that part of the assembly illustrated in Figure 2H.

The pumping means 137 illustrated particularly in Figures 2D, 2E and 2F consists of an electrical motor 151, together with a multistage centrifugal pump 152. The electric motor can be of any suitable construction but should be designed to provide the necessary power together with compactness. The stator 153 of the motor is enclosed within the housing shell 154. At its lower end the motor shaft 156 is carried by a suitable thrust bearing 157. This assembly is carried by the casting 158, which is attached to the end casting 159 of the motor housing by suitable means such as the threaded rods 160. A depending extension 161 of the motor housing shell has its lower end closed by plate 162, and is retained by the central tie bar 163. The chamber 164 formed by the housing extension 161, has its lower end connected to tube 166, and also serves to enclose the oil reservoir 167.

At its upper end the motor shaft 156 is connected by coupling 168 to the shaft 169 of the centrifugal pump 152. Adjacent the coupling 168 the motor housing 154 is terminated by the closed casting 171, which may serve to mount the terminal connector 172. The leads to the stator winding of the motor connect with the terminal device 172.

The lower end of the pump shaft 169 is carried by the journal 173, which in turn is mounted upon the casting 174. The space 176 enclosed by the casting 174, encloses the coupling 168. The pressure equalizing tube 166 makes connection with space 176.

The centrifugal pump consists of a multistage centrifugal impeller 178 (Figure 2D) which is carried by the shaft 169, and which operates within the cooperating pump housing 179. The inlet passage 181 at the lower end of the housing (Figure 2E) communicates with the interior of the strainer 182. The strainer is provided with screened openings 183, through which mud may flow for delivery upwardly into the inlet passage 181 of the pump.

The pump discharges into a chamber 184 at its upper end, and this chamber in turn connects with the pipes 186. These pipes are bent to extend downwardly about the pump housing, below which they connect with the pipes 147a. It will be evident that these pipes are accommodated within the space between the pump and motor housings and the outer tubular housing 142.

With the arrangement described above, the pump delivers mud to the fluid pressure operated motor 141, thus causing this motor to supply sufficient torque for rotation of the drill head through the gearing 146. At

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the same time the mud discharged from the motor 141 is delivered downwardly through the passages of the drill head.

Mud is caused to flow through the bailer or cuttings separator 137 before entering the strainer and the pump. Thus referring to Figure 2C, the upper end of the outer tubular housing 142 mounts a closure 191 that is provided with a tapered central bore. This bore seats the tapered extension 192 from the casting 193, the latter forming the lower end of the bailer 137, and being attached to the bailer housing 194. The upper end of the bailer housing 194 is provided with slots 196 for inflow of mud from the well, whereby such mud flows downwardly through the housing 194, and particularly through the space 197 between the housing and the inner perforated strainer conduit 198. The lower end of conduit 198 communicates with the passage 199 in the casting 193, and this in turn discharges the mud into the outer tubular housing 142 which surrounds the pump and the electric motor, whereby such mud fills the spaces between the pump and motor housings and the outer housings 142, and is delivered to the screened openings 183 and to the inlet passage 181 of the pump.

The lower part of the bailer housing 194 is preferably provided with openings 201 normally closed by the gates 202. In operation cuttings which are too coarse to pass through the openings in the perforated conduit 198 accumulate in the lower portion of the housing 194. However, when the assembly is raised to the surface of the well, such cuttings can be flushed out by opening the closures 202.

The terminal device 172 for the electric motor is connected to a cable 203 (Figure 2E) which must be supplied with current from a suitable current supply or generator at the surface of the well. In practice the cable 203 can be extended upwardly through various parts of the equipment, to ultimately extend through the coupling device 136. The cable 204 for suspending the entire assembly can consist of a hollow wire cable of sufficient strength to support the load, together with a central core 206 which forms in effect an extension of the cable 203, and which includes the requisite number of electrical conductors. At the top of the well the cable can connect with a suitable device 207 which makes connections with the various conductors, and which permits them to connect with the various sources of current supply. As previously explained, the actuator for applying impacts to the drill head can be supplied with 30 cycle alternating current at a suitable voltage. The electric motor can be supplied with current of the same frequency, and from the same supply circuit, although if desired it can be supplied with a separate circuit at a frequency of, say, 60 cycles per second.

At some convenient point along the assembly suitable means is provided to engage the side walls of the well and prevent rotation of the assembly. As shown in Figure 2G, said means can consist of arcuate shoes 208 for engaging the side walls of the well and urged outwardly by the pressure of the mud on the pistons 209.

It will be noted that to simplify the drawing, portions of the assembly have been omitted which would otherwise appear between the several Figures 2A-J inclusive. By way of example, in practice the over-all height of the assembly shown in Figures 2H-2J can be of the order of ten feet, and the over-all height of the complete assembly comprising Figures 2A-2J, inclusive, can be of the order of forty feet. The weight of the parts comprising the assembly can be such as to provide (when immersed in mud) a downward force upon the drill head sufficient for proper loading and for most efficient transfer of impact energy to the formation. Assuming an actuator operating with 1800 impacts per minute, this load may, for example, be of the order of 30,000 pounds.

In Figure 1 it is assumed that both the electrical actuator and the motor are being supplied with current from

a common generator G. This generator can be driven by suitable means such as an engine M of the internal combustion type. The current supply connections from the generator to the device 207 have been shown through a suitable control panel 211, which may indicate current, voltage, frequency and like data.

Over-all operation of the equipment described above is as follows: The entire assembly 9 is lowered into a well until the drilling head 10 comes to rest on the bottom formation. It will be understood that in this process it may be desirable to provide a suspending cable in sections, which can be coupled together to provide a cable of the requisite length. The various couplings can be provided with means for making connections between the electrical conductors. Sufficient drilling mud of proper consistency is introduced into the well to completely submerge the equipment. Power is now supplied to the electrical motor and the electrical actuator, whereby the motor delivers mud at a relatively high pressure to the fluid pressure operated motor 138, thereby operating this motor to drive the drill head at speed comparable to ordinary rotary drilling. Energization of the electrical actuator applies impacts to the drill head at a constant frequency to effect percussion drilling. The drilling mud circulates through the ducts in the drill head, and then flows upwardly around the housing 142 with the cuttings, ultimately to be delivered into the bailer 137. Here coarse cuttings are removed and the mud permitted to return to the intake side of the pump. After a period of drilling the assembly can be raised to the surface of the well and the cuttings removed by uncovering the openings 201.

In general, the present invention has all of the attributes of the equipment and method described in the above mentioned copending application. Assuming that the drill head is operated upon a relatively hard rock formation, the rate of drilling with the actuator in operation is many times the rate for the same equipment operating under the same conditions, but without operation of the actuator. By way of example, where the drilling rate in a rock formation is of the order of 1 inch per hour, with the actuator in operation the drilling rate is of the order of 10 feet or more per hour. This remarkable increase in drilling speed is obtained without excess power consumption. No great amount of power is required for turning the drill head, because with the present assembly it is not necessary to turn a long drill stem extending down through the casing. Furthermore, the impact actuation of the drill head reduces the torque requirements for turning the head relative to the rest of the assembly.

The wear upon the cutters of the drill head is not proportional to the increase in drilling speed attained. It appears that for a given amount of effective drilling, the wear upon the cutting teeth using our invention is substantially less than for conventional rotary drilling.

A further advantage of the drilling equipment and method described herein is that it is highly effective in drilling through difficult formations, which otherwise might make it necessary to abandon a well. Although faulting presents serious difficulty for conventional drilling rigs, with our invention faulting has little if any effect upon drilling efficiency, and the drill head proceeds along the desired direction without tending to cause breakage of the cutters or drill head, and with little if any tendency toward deviation.

Another advantage pointed out in said copending application is that conventional rotary equipment is frequently susceptible to uneven or contoured drilling patterns upon the bottom formations, which greatly decrease drilling efficiency, and which cause excessive wear and possible drill breakage. Here again our equipment is remarkably effective under such conditions. Where a formation is encountered which, under normal conditions, would develop such an uneven or contoured pattern, with our method and apparatus such a pattern does not develop,

and at all times the pattern remains even and for minimum possibility of drill breakage. This result is obtained without the use of expensive cutterheads such as have been developed for use in conventional rotary drilling, to minimize development of such patterns.

Under some circumstances it may be desirable to correct an uneven or contoured drilling pattern, as for example where the pattern has been developed by use of conventional equipment. In such an event our invention can be applied to remove the unevenness. Suitable procedure is to slowly lower the drill head after initial light contact with the bottom formation. This is of course accompanied by rotation of the drill head, and operation of the electric actuator and mud circulating pump. The cutters gradually cut away the high areas of the pattern due to the percussion and chipping action of the head as the assembly is gradually lowered, and all unevenness has disappeared.

When drilling through clay, or other soft formations, the electrical actuator may or may not be put into operation, depending upon the choice of the operator. However, even under such conditions use of the actuator generally facilitates drilling, particularly in that it eliminates tendency towards balling adjacent to the drill head, and it generally makes possible a high drilling speed.

The frequency of impacts upon the bottom formation is independent of other factors, such as the operation of the mud circulating pump. Thus efficient drilling conditions can be maintained at all levels and independent of mud circulation.

Although in the foregoing we have referred to impacts frequency of the order of 1800 impacts per minute, it will be evident that this can be varied depending upon drilling conditions, the size of the equipment, and the like. We believe that in all instances it is desirable to keep this frequency above about 1000 impacts per minute. It is anticipated that in some applications it may be desirable to increase the frequency to, say, 2000 impacts per minute, or more.

We claim:

1. In well drilling equipment, mounting means adapted to be lowered into an earth well, a cutter head including mud circulating ducts carried at one end of the mounting means and adapted to operate on the bottom formation, electromagnetic means serving to apply impacts to the head at a substantially constant frequency, said means including an electromagnetic assembly carried by the mounting means and a piston-like core adapted to be actuated by said assembly to apply impacts to the head, a mud circulating pump having inlet and outlet passages carried by the mounting means, electrical motive means serving to operate said mud circulating pump, a mud passage communicating at one end with the exterior of said mounting means and at its other end with the inlet passage of said pump, motive means serving to rotate the head relative to the mounting means comprising a motor of the fluid pressure operated type having inlet and outlet passages, ducts connecting the outlet passage of said pump to the inlet passage of said motor, and ducts serving to connect the outlet passage of said motor to the mud circulating ducts formed in the head.

2. Equipment as in claim 1 in which the pumping means comprises a multi-stage centrifugal pump.

3. Equipment as in claim 2 together with a bailer carried by the mounting means and serving to remove cuttings from the mud delivered to the pump, said bailer having openings communicating with the exterior of said mounting means and connected to the mud passage, said bailer also including a plurality of gates which are adapted to be opened whereby accumulated cuttings can be flushed from the bailer when the equipment is raised to the surface.

4. In well drilling equipment, mounting means adapted to be lowered into a well, a cutter head including mud circulating ducts carried at one end of the mounting means

and adapted to operate on the bottom formation, electromagnetic means serving to apply impacts to the head at a substantially constant frequency, said means including an electromagnetic assembly carried by the mounting means and a piston-like core adapted to be actuated by said assembly to apply impacts to the head at a substantially constant frequency to effect percussion drilling, a mud circulating pump having inlet and outlet passages carried by the mounting means, electrical motive means serving to operate said mud circulating pump, a mud passage communicating at one end with the exterior of said mounting means and at its other end with the inlet passage of said pump, a motor of the fluid pressure operated type having inlet and outlet passages serving to rotate the head relative to the mounting means whereby the head is rotated against a formation simultaneously as impacts are applied thereto, ducts connecting the outlet passage of said pump to the inlet passage of said motor, and ducts serving to connect the outlet passage of said motor to the mud circulating ducts formed in the head.

5. In well drilling equipment, mounting means adapted to be lowered into a well, a cutter head including mud circulating ducts carried at one end of the mounting means and adapted to operate on the bottom formation, electromagnetic means serving to apply impacts to the head at a substantially constant frequency, said means including an electromagnetic assembly carried by the mounting means and a piston-like core adapted to be actuated by said assembly to apply impacts to the head at a substantially constant frequency to effect percussion drilling, a mud circulating pump having inlet and outlet passages carried by the mounting means, electrical motive means serving to operate said pump, means for engaging the side wall of the well to prevent rotation of the mounting means comprising fluid pressure operated shoes, said shoes including a piston in contact with the circulating mud and adapted to be urged outwardly by the pressure of the mud on the pistons, a motor of the fluid pressure type having inlet and outlet passages serving to rotate the head relative to the mounting means, a mud passage communicating at one end with the exterior of said mounting means and at its other end with the inlet passage to said pump, ducts communicating between the outlet passage of said pump and the inlet passage of said motor, said ducts having a portion in communication with said pistons, ducts serving to connect the outlet passage of said motor to the mud circulating ducts formed in the head, and a cable adapted to extend down into the well for supporting the equipment.

6. Apparatus as in claim 5 wherein said means serving to engage the side walls of the well to prevent rotation of the mounting means comprises a plurality of shoes serving to engage the side walls of the well, a piston

associated with each of said shoes, cylindrical openings in communication with the circulating mud and serving to slideably receive the pistons whereby the mud pressure urges the shoes outwardly against the side wall of the well.

7. In well drilling equipment, mounting means adapted to be lowered into an earth well, a cutter head including mud circulating ducts carried at one end of the mounting means and adapted to operate on the bottom formation, electromagnetic means serving to apply impacts to the head at a substantially constant frequency, said means including an electromagnetic assembly carried by the mounting means and a piston-like core adapted to be actuated by said electromagnetic assembly to apply impacts to the head at a substantially constant frequency to effect percussion drilling, a mud circulating pump having inlet and outlet passages carried by the mounting means, electrical motive means serving to operate said mud circulating pump, a bailer carried by the mounting means and serving to remove cuttings from the circulating mud, said bailer including a plurality of gates which are adapted to be opened whereby accumulated cuttings may be flushed from the bailer when the equipment is raised to the surface of the earth, said bailer communicating with the exterior of said mounting means, a mud passage communicating at one end with the bailer and at its other end with the inlet passage of said pump, means for engaging the side walls of the well to prevent rotation of the mounting means, said means comprising a plurality of shoes serving to engage the side walls and a piston associated with each of said shoes, cylindrical openings communicating with the circulating mud and serving to slideably receive the pistons whereby the mud pressure against the pistons urges the shoes outwardly against the side walls of the well, motive means comprising a motor of the fluid pressure type having inlet and outlet passages serving to rotate the head relative to the mounting means, ducts interconnecting the outlet passage of said pump, said cylindrical openings and the inlet side of said motor, and ducts serving to connect the outlet passage of said motor to the mud circulating ducts formed in the head.

References Cited in the file of this patent

UNITED STATES PATENTS

1,477,563	Hirschfeld et al.	Dec. 18, 1923
1,523,629	Bullock	Jan. 20, 1925
1,899,438	Grant	Feb. 28, 1933
1,983,287	Grennell	Dec. 4, 1934
2,609,182	Arutunoff	Sept. 2, 1952

FOREIGN PATENTS

2,443	Great Britain	Jan. 26, 1905
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