

Dec. 8, 1953

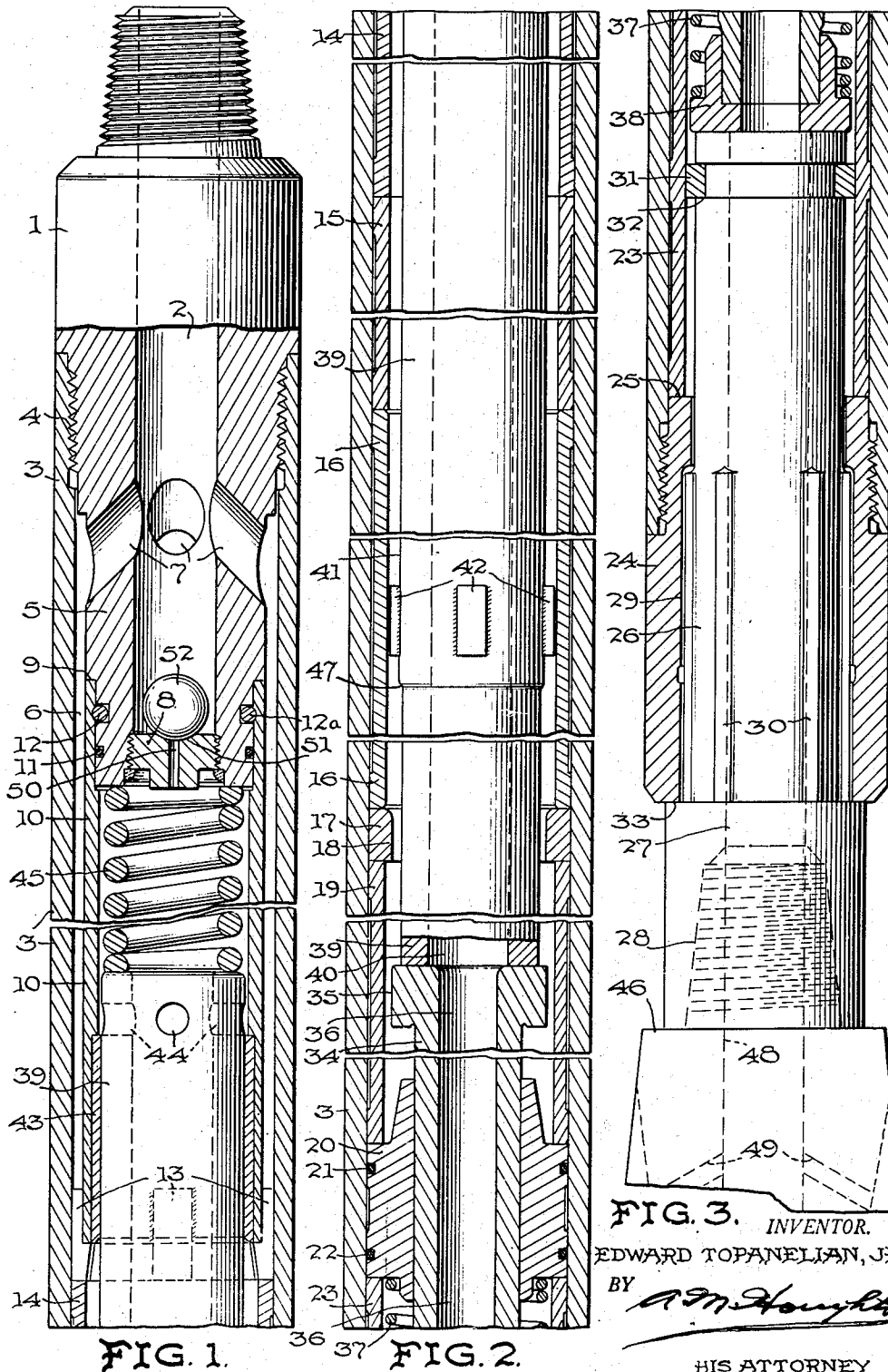
E. TOPANELIAN, JR

2,661,928

HAMMER DRILL

Filed Feb. 9, 1952

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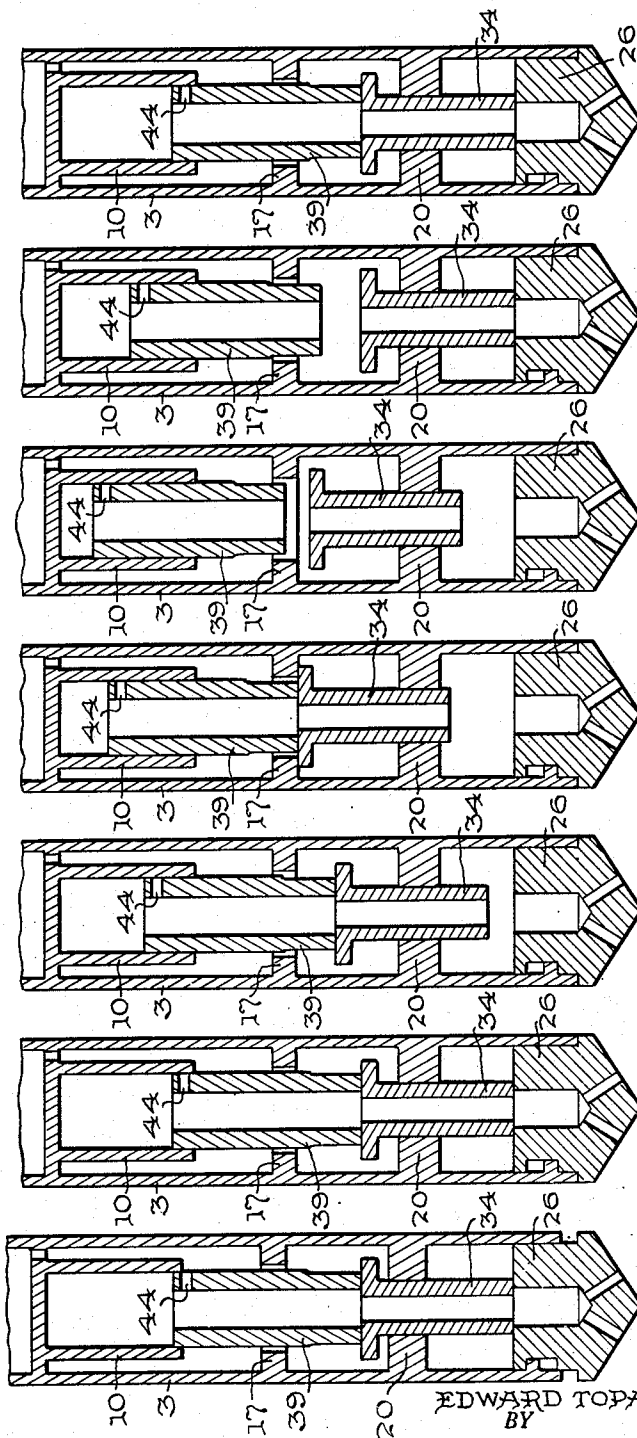
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FIG. 4. FIG. 5. FIG. 6. FIG. 7. FIG. 8. FIG. 9. FIG. 10.



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HAMMER DRILL

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Application February 9, 1952, Serial No. 270,807

3 Claims. (Cl. 255-4.4)

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This invention relates to well drills and more particularly to a deep-well drill combining the advantageous features of rotary and percussion drill mechanisms.

An object accomplished by my invention is the provision of a well drill which combines in a novel manner the more desirable features of rotary and percussion types of drills. A further object accomplished by my invention is the provision of a well drill having increased effectiveness against hard rock formations. Another object accomplished by my invention is the provision of a drill of the character described, having incorporated therein a fluid-operated mechanism for delivering percussive blows to the drill bit without substantially interrupting the flow of fluid through the bit. A still further object accomplished by my invention is the provision of a well drill of such design that the effect of hydraulic hammer is diminished, but advantageously used in some degree to actuate a hammer mechanism which strikes percussive blows to the drill bit. A still further object accomplished by my invention is the provision of a hydraulically-actuated hammer drill having improved hydraulic balance. A still further object accomplished by my invention is the provision of a hammer drill in which the reciprocating parts may be made of comparable weight so as to separately impart effective percussive blows to the drill bit. A still further object of my invention is the provision of a hammer drill in which the valving element itself may act as a ram and impart percussive blows to the drill bit. A still further object accomplished by my invention is the provision of a hammer drill in which upward motion of the valving element is arrested by hydraulic action and in which the valving element strikes a useful blow at the end of its downward travel. Still another object accomplished by my invention is the provision of a percussion drill which will operate with relatively light weight on the formation being drilled. Still another object accomplished by my invention is the provision of a rotary-percussion type well drill having improved tendency to drill straight hole and having hole-straightening properties. Still another object accomplished by my invention is the provision of a rotary-percussion type well drill of extremely simple design. A still further object accomplished by my invention is the provision of a hammer drill mechanism of such design that all parts may be made large, heavy, simple, and rugged, whereby breakage of parts and shutdown of the drill for this reason is substantially eliminated.

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My invention is illustrated in the drawings accompanying this specification and forming a part thereof, and in which

Fig. 1 is a longitudinal section taken through the upper portion of a preferred embodiment of my drill;

Fig. 2 is a longitudinal section taken through the intermediate portion of the drill of Fig. 1;

Fig. 3 is a longitudinal section taken through the lower portion of the drill of Figs. 1 and 2 showing the drill bit attached thereto; and

Figs. 4 to 10 inclusive are diagrammatic representations illustrating various phases during the operation of my drill.

Reference is made to the drawings in which like numerals indicate the same element in the various views and diagrams. In Fig. 1, adapter 1 serves to connect the drill assembly with a drill pipe (not shown), the latter having a central passage as is conventional for supplying drilling fluid. Adapter 1 is provided with a central passage 2 for the purpose of supplying drilling fluid under pressure into the drill mechanism. Adapter 1 is screwed into the drill housing 3 by threads 4 and a portion of the adapter of reduced diameter 5 extends into the housing 3 with an annular clearance 6 between them. Openings 7 permit drilling fluid to pass from the passage 2 into the annular space 6. The lower end of passage 2 is plugged, the plug 8 being either screwed or welded in place and having a relatively small orifice 50 and spherical depression 51 on its upper surface. A rubber or steel ball 52 may rest in the spherical depression 51 and serve to close the orifice 50. The function of the ball and orifice will be explained later.

The extreme lower end of adapter 1 is further reduced in diameter as at 9, and carries thereon a tube 10 against which a tight seal is provided by O-ring 11. The tube 10 is held in place abutting the shoulder 9 by two parallel pins 12 and 12-a which are inserted through the wall of tube 10 from the outside thereof and which engage grooves in adapter 1. Both ends of pins 12 and 12-a extend beyond the tube 10 sufficiently so that the outer housing 3 will prevent their coming out while the assembly is inside the housing. The pins 12 and 12-a are easily removed when the inner assembly is withdrawn from the housing 3 if replacement or repair of tube 10 becomes necessary. The tube 10 at its outside lower end has fingers 13 welded to it and these rest on a liner 14. The liner 14 in turn rests on liner 15, and this on liner 16. Liners 14, 15, and 16 have snug fits in housing 3. These liners receive wear

and may be conveniently replaced when necessary.

Below liner 16 there is a stop ring 17 also fitting snugly in housing 3, but having a smaller inside diameter 18 than the liner 16. A spacer 19 lies below the stop ring 17, and below this is a guide 20 which is sealed to the inside of the housing 3 by O-rings 21 and 22 and which has a much smaller inside diameter than that of stop ring 17. The guide 20 rests on spacer 23.

The lower end of housing 3 is threaded for a bushing 24 which has a smaller internal diameter than housing 3, so that the various liners, spacers, etc. are firmly clamped between shoulder 25 of bushing 24 and shoulder 9 of adapter 1 when the bushing 24 is screwed up tightly into the housing 3. Thus bushing 24 holds in place spacer 23, guide 20, spacer 19, stop ring 17, liner 16, liner 15, liner 14, fingers 13, and tube 10, the latter abutting against shoulder 9 of adapter 1.

It is apparent that liners 14, 15, 16, and spacers 19 and 23, as well as the stop ring 17, could be made integral with housing 3, the inside of housing 3 being bored to the several internal diameters and shoulders as required. The construction shown is more convenient to manufacture because the housing 3 can be bored with a single internal diameter. The separate parts 14, 15, 16, 17, 19, and 23 are easily finished to close dimensions and better surface finish and they provide the necessary shoulders or differences in diameter for the assembly. In addition, any one of these smaller parts may easily be replaced if it becomes worn.

Starting now at the lower end of Fig. 3 there is shown a bit stem 26 which has a central passage 27 through which drilling fluid reaches the bit. A conventional drilling bit 46 may be screwed on to the bit stem 27 by means of threads 28. The drill bit 46 has a central passage 48 and is further provided with passages 49 connecting the central passage with the well bore to facilitate the removal of cuttings and chips therefrom by means of flushing action of the drilling fluid. While a fish-tail type of bit is shown, the drill bit per se forms no part of my invention and any type of bit may be used, including rock bits having rolling cutters. The bushing 24 is grooved at 29, and mating splines 30 on bit stem 26 engage the grooves 29 so that torque may be transmitted from the bushing 24 to the bit stem and bit. Instead of using splines and grooves, the rotary driving engagement between bushing 24 and bit stem 26 may have square, hexagonal or other equivalent shape. Accordingly, during drilling the entire assembly may be rotated from the surface of the ground by means of the conventional drill pipe (not shown) and this will rotate the bit 46. The bit stem 26 may slide in the bushing 24, the amount of longitudinal motion being limited by a split ring 31 mounted in a groove 32 in the upper end of the bit stem. When the bit stem 26 is at its lowermost position, the ring 31 abuts against internal shoulder 25. When the bit stem 26 is in its uppermost position an external shoulder 33 on the bit stem abuts against the lower end of bushing 24.

Situated above the bit stem 26 is an annular lower arm 34 whose outer diameter is a close sliding fit in guide 20. Lower ram 34 functions as a valve as will be explained. In my drill it may be made quite heavy and it functions as well as a blow-imparting means, in that its reciprocation adds to the percussive action of the drill

as will become evident. The upper end or head of lower ram 34 is enlarged in diameter as at 35, the diameter 35 being larger than the opening 18 in stop ring 17. The purpose of this relationship will also be explained later. The lower ram 34 has a central passage 36 to permit discharge of drilling fluid therethrough. The passage 36 is made small enough so that it functions as an elongated orifice in the fluid stream whereby the velocity change sets up a pressure drop across the lower ram 34. In this way a substantial downward pressure differential is caused to act on the lower ram 34 whenever the drilling fluid discharges through it.

While it is not necessary for the operation of my drill, under certain conditions of operation it is advantageous to place a spring 37 around the lower ram 34, the spring 37 abutting against the lower end of guide 20 and against a shoe 38 which is carried on the lower end of ram 34. The shoe 38 may be shrunk onto the ram 34, or be held thereon by other means, and is conveniently made replaceable as it receives considerable pounding during operation of the drill. The ram 34, being of considerable mass, normally moves downward by its own weight plus the pressure differential of fluid flowing downward in its passage 36, but the downward impetus of ram 34 may be further augmented by the use of spring 37.

On top of the lower ram 34 rests an elongate annular upper ram 39, having a central passage 40. The latter may be larger in diameter than the passage 36 through the lower ram 34 in order to permit free flow of fluid through the passage 40. The outside diameter of upper ram 39 is smaller than the opening 18 of stop ring 17 in order to permit circulation of fluid through the annular space between them. Although it is not necessary for the operation of my drill, it has been found desirable to have the upper part 41 of ram 39 made slightly larger in diameter than the lower end thus providing a slight shoulder 47. The shoulder 47 provides a differential area between the bottom and top of ram 39 so as to afford the fluid a lifting effect on ram 39, which lifting effect should however be insufficient to overcome the weight of ram 39.

An annular space is provided between the outside of upper ram 39 and the liners 16 and 15 to provide adequate circulation of fluid. Lugs 42, three or more in number, may be welded to the outside of ram 39 and serve as guides sliding freely on the inner surface of liner 16 but allowing circulation of fluid between lugs. The lugs 42 serve to center the upper ram 39 in liner 16. The upper end of ram 39 penetrates the lower end of tube 10 and is of such diameter to slide freely into tube 10. A wear sleeve 43 may be pressed into tube 10 and have a slightly smaller inside diameter than tube 10. The upper end 41 of ram 39 is of proper diameter to form a sliding seal in the sleeve 43.

A short distance below the top of ram 39, there are provided one or more radial openings 44 from the outside of the ram to the passage 40. When the ram 39 is in its lowermost position, it still partially penetrates the tube 10, but the openings 44 are no longer covered by the sleeve 43 of tube 10, and fluid communication is established between the annular space 6 and the passages 40 and 36. The purpose of this is to permit drilling-off as will become evident later. The openings 44 also permit circulation of drilling fluid through the drill without activating the mechanism while the drill is being run into or out of the hole.

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Thus drilling-in may be accomplished with the drill rotating and with circulation of drilling fluid, but without activating the rams.

While it is not necessary for the operation of my drill, under certain conditions of operation it is desirable to place a spring 45 above the upper ram 39, i. e., between the top of ram 39 and the bottom of adapter 5. The ram 39 being of considerable mass normally moves downward by its own weight, but the spring 45 serves to decelerate the ram 39 when it has been elevated and also serves to give additional downward impetus to the ram 39.

While the length of the various elements of my drill are not conveniently indicated in Figs. 1 to 3 of the accompanying drawings, it is believed clear to those skilled in the art that the length of lower ram 34 and upper ram 39 may be made such as to provide the necessary mass for these parts, and that the length of other parts may be adjusted accordingly. When the bit stem 26 is in its lowermost position, i. e. with ring 31 against shoulder 25, and lower ram 34 is in its lowermost position against the top of the bit stem and with upper ram 39 resting on top of ram 34, the lengths of the parts are made so that the top 41 of the upper ram penetrates tube 10 a short distance but with the openings 44 fully uncovered. Because of the extreme simplicity of my drill the masses of lower ram 34 and of upper ram 39 may be made comparable whereby the mechanism imparts a double blow to the drill bit for each cycle of operation of the drill.

For proper operation of the mechanism the diameter of the lower ram 34 should be smaller than the diameter of the upper end 41 of upper ram 39. The diameter of the upper ram 39 below the shoulder 47 may be slightly smaller than the diameter 41 of the top of the ram 39 in order to facilitate separation of the upper ram 39 from the lower ram 34 when the upward motion of the latter is arrested at stop ring 17, but the difference between these diameters should not be so large as to cause premature separation of these elements. A satisfactory seal is normally maintained between the top surface of ram 34 and the bottom surface of ram 39 by contact between these surfaces under the residual forces not compensated by upward force of fluid on shoulder 47. Inasmuch as contact is made between these elements by a percussive blow of the upper ram, any foreign particles between them are crushed and the efficacy of the seal is thus automatically maintained.

The operation of my above-described drill will now be explained. Reference may be made to the diagrams of Figs. 4 to 10 showing the various phases during the operation of my drill, and in which diagrams the numerals indicate the same elements as in Figs. 1 to 3 previously described.

The entire unit will be suspended vertically in the well bore with an ordinary rotary drill pipe (not shown) attached to adapter 1, means being provided at the surface for supplying drilling fluid to the central passage of the drill pipe as is well known in the art. Starting with the bottom of drill bit 46 several feet above the bottom of the hole, bit stem 26 will be in its lowermost position, with the ring 31 resting on the shoulder 25 of bushing 24. The lower ram 34 will rest on top of the bit stem with its head 35 some distance below stop ring 17 and just above guide 20. On top of ram 34 there will rest upper ram 39, and the length of the various liners and spacers are made so that the upper end of ram

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39, i. e., the end above the openings 44, extends into the tube 10 a short distance leaving openings 44 near the top of ram 39 uncovered. The configuration of parts will be as shown in Fig. 4.

It is usually desirable to "rotate in" when a new bit has been attached to the drill in order to insure that the borehole is to gauge, and to flush out sediment and cuttings which may have settled to the bottom of the hole while the drill pipe was out of the hole to change bits. This is accomplished by establishing circulation of drilling fluid downward through the central passage of the drill pipe and rotating the bit as it is lowered through the last few feet to the bottom of the well bore. During this "rotating in" process, fluid will be circulated through passages 2, 7, 6, 44, 40, 36, and 27 and out through passages 48 and 49 of the bit, returning up the hole outside of drill housing 3. Since there is free passage of fluid through the mechanism, no upward pressure differential exists, and accordingly rams 34 and 39 will not be actuated with the bit off bottom as shown in Fig. 5. Thus hammering will not take place to endanger the drill pipe or other parts as the drill is lowered into the hole.

Upon continuing to lower and rotate the mechanism including bit stem 26 and bit 46, the nose or cutting edge of the bit will eventually touch the bottom of the hole. Further lowering of the drill pipe and attached parts will then cause changes in the relative longitudinal positions between housing 3, together with the parts carried thereon, and the internal parts 26, 34, and 39. Since tube 10 is integral with housing 3, the top of upper ram 39 will eventually enter tube 10 a sufficient distance to close off openings 44 from fluid flow. The parts will then essentially be in the position as shown diagrammatically in Fig. 5. Due to the fact that there is no immediate outlet for the fluid being supplied under pressure from the surface, the pressure will build up within the annular passage 6, around the upper ram 39, and around the upper end of lower ram 34. The upper surface of the column comprising the rams 34 and 39 is exposed to a pressure substantially equivalent to the static head of the fluid in the well bore at the depth of the tool, because the upper surface of the ram 39 is afforded communication with the well bore through passages 40, 36, 27, 48, and 49. Since the diameter of lower ram 34 is less than the diameter of the upper ram 39, the application of sufficient pressure of fluid from the surface pumps will produce sufficient upward force to lift as a unit the ram 34 together with ram 39. This phase of the operation is shown in Fig. 6. The continued application of fluid pressure will continue to raise the two rams as a unit, the weight of the upper ram tending to seal the junction between them. Some lifting effort on the upper ram 39 also results from the pressure of fluid on the shoulder 47 but as previously stated the ram 39 effects sufficient remaining downward force to maintain a seal on top of the lower ram 34.

Eventually the head 35 of lower ram 34 approaches the lower edge of stop ring 17, and as the head 35 is larger than the opening 18 this approach tends to cut off the flow of fluid required to lift the lower ram 34. Actually the downward flow of fluid being cut off by the head of the ram 34 effects a hydraulic deceleration of this ram and its upward motion is arrested hydraulically so that the lower ram 34 does not strike the ring 17 with any appreciable impetus;

This phase of the operation is illustrated in Fig. 7.

As soon as upward motion of lower ram 34 is arrested, the pressure fluid tends to separate the two rams, and indeed the upward momentum of the upper ram 39 tends also to lift it off the top of the lower ram 34. The upper ram 39 may continue to move upward a short distance. However, as soon as the upper ram 39 breaks away from the lower ram 34, the pressure fluid may escape downward through the passage 36 in the latter. The consequent release of upward pressure on the lower ram 34 allows it to drop of its own weight, and furthermore, the downward rush of fluid through its passage 36 effects a pressure differential which gives it further downward impetus. Accordingly, the ram 34 moves rapidly downward as illustrated in Fig. 8.

Shortly after lower ram 34 has started to move downward, the upper ram 39 also begins to move downward since there is no longer any pressure to raise it. Accordingly, the ram 34 and ram 39 both descend, though separated by some distance and with the lower ram 34 moving down somewhat faster than the upper ram 39 because of the aforementioned downward forces which act on the lower ram but not on the upper ram. Eventually, the lower ram 34 strikes the top of the bit stem 26 imparting a blow thereto which blow is transmitted to the drill bit 46. This phase is illustrated in Fig. 9. The upper ram 39 at this phase is still falling.

A short interval after the lower ram 34 has struck the bit stem 26, the upper ram 39 strikes the top of ram 34, and this blow is transmitted through ram 34 to the bit stem and thence to the drill bit 46. This represents the completion of a cycle of operation, as shown in Fig. 10.

The mechanism is now (Fig. 10) in the same configuration as it was in Fig. 5 and is therefore ready to repeat the cycle of operation. Each cycle results in two percussive blows being struck on the formation through the drill bit 46. Due to the fact that the entire drill assembly is continually also being slowly rotated, the various percussive blows exerted on the formation being drilled will be made at points angularly displaced from one another by several degrees, so that the drill bit will chip out the formation between successive points of impact. Fluid discharged from the mechanism will act as flushing agent and will be substantially continuously discharged from the bit 46 into the well bore and serves to carry the chips to the surface of the well. Continuous operation of the drill will therefore completely remove material from the bottom of the hole and result in advance of the drill through the formation.

As stated above my hammer drill will operate without the use of spring 37 and spring 45, but the use of these springs has been found to increase the frequency of operation. This is particularly desirable when hole conditions prescribe drilling with very heavy mud in which the mechanism tends to become sluggish. Successful operation with light to medium weight mud and without the use of the springs 37 and 45 results in longer tool life.

Fig. 1 shows a narrow passage 50 in the plug 8 at the lower end of the passage 2 of adaptor 5. The passage 50, together with the omission of ball 52, permits the drill to accommodate larger fluid circulation rates which are required when drilling certain types of formation. The flow of fluid through passage 50 by-passes the drill mechanism and is effective for flushing chips or

detritus out of the borehole in addition to the fluid normally discharged through the drill mechanism. It is apparent that the diameter of passage 50 may be of calculated size such that it acts as a by-pass orifice but does not seriously interfere with the operation of the drill mechanism. Whenever it is desired to close the passage 50, the ball 52 may be dropped from the surface to seal the opening without pulling the tool from the well. In this manner the circulation rate may be controlled. It has also been found desirable to start a new drill with the passage 50 open, and after the drill mechanism has become worn the ball 52 may be dropped to close passage 50 and in this way leakage caused by wear may be compensated.

As previously stated, one of the advantages of my hammer drill lies in the fact that the valving ram 34 as well as the upper ram 39 delivers a percussive blow and these are in rapid succession. By making use of the impetus of the valving ram 34 as well as that of the upper ram, my drill attains a higher degree of effectiveness than if one ram alone supplied the percussive action. The timing of the two blows may be adjusted by the size of the passage 36 through the lower ram 34, since the smaller this passage is made the faster the ram 34 is kicked down by the discharging fluid. Additional adjustment of the timing may be effected by adjusting the relative stiffnesses of springs 37 and 45 when these are used. My drill permits the two blows to be made comparable because the lower ram 34 may be made of a mass comparable to that of the upper ram 39.

An important characteristic of my drill is the fact that it achieves hydraulic balance. By this I mean that the hydraulic actuating pressure is not exerted on the bit stem 26 or on the bit 46. Hence the percussive action will take place with comparatively little weight on the bit. The guide 20 serves as a restriction above which the fluid pressure is higher than below by an amount required to actuate the drill mechanism. The restriction 20 forms a housing-supported barrier between the high-pressure fluid required for hammer operation and the much lower fluid pressure required to circulate fluid through the ports in the drill bit. Therefore, there is but very little pressure tending to eject the bit stem 26 and bit 46 from the end of the housing 3, and accordingly the drill may be operated with the bit applying to the formation between percussive blows little more than the weight of the bit 46 and bit stem 26, all other weights and pressures being supported from the surface through the drill pipe and housing 3. This characteristic of my drill results in the ability to drill straight hole under adverse conditions which usually require that the bit be rotated with only light weight on the formation. On the other hand, by lowering the drill pipe from the surface so that a substantial part of the drill-pipe weight rests on the shoulder 33 (Fig. 3) any desired larger weight may be exerted on the formation. Furthermore, the percussive action of my drill is entirely independent of the weight which is carried on the formation.

A further advantage of my drill lies in the fact that when the drill is set on bottom the telescoping bit stem forces the lower ram upward out of any accumulation of sand, mud or other debris which may have packed around the top of the lower ram while the drill was inactive during the trip into the hole. This upward motion of the

lower ram breaks any such accumulation and permits the operating pressure to act on the lower ram so as to initiate the reciprocating action. As soon as the drill has completed a cycle or two of reciprocating action, any such accumulation will of course be flushed out and can no longer interfere with operation of the drill mechanism.

In the appending claims the term "cylinder" is used to designate tube 10, the term "lower ram" is used to designate valving element 34, and the term "upper ram" is used to designate the element 39, but it is to be understood that the names given these and other elements shown are descriptive and that other equivalent shapes may be given these elements and still remain within the scope of the claims.

What I claim as my invention is:

1. A fluid-operated well-drilling mechanism comprising a tubular housing, an inverted cup-like cylinder longitudinally mounted in said housing, means affording operating fluid access to the interior of said housing below said cylinder, an elongate annular upper ram slidably disposed in and sealed against the inside of said cylinder and having a longitudinal central passage, an internal constriction in said housing below said upper ram and of diameter smaller than said upper ram, an elongate annular lower ram slidably disposed in and sealed against said constriction and having a longitudinal central passage and having spring-retaining means on the lower end of said lower ram, a compression spring between the lower side of said constriction and said spring-retaining means, means affording operating fluid access to the upper end of said lower ram, and a bit stem slidably disposed in and sealed against said housing and having a longitudinal central passage.

2. A fluid-operated well-drilling mechanism comprising a tubular housing, an inverted cup-like cylinder longitudinally mounted in said housing, means affording operating fluid access to the interior of said housing below said cylinder, an elongate annular upper ram slidably disposed in and sealed against the inside of said

cylinder and having a longitudinal central passage, a compression spring inside said cylinder above said upper ram, an internal constriction in said housing below said upper ram and of diameter smaller than said upper ram, an elongate annular lower ram slidably disposed in and sealed against said constriction and having a longitudinal central passage and having spring-retaining means on the lower end of said lower ram, a compression spring between the lower side of said constriction and said spring-retaining means, means affording operating fluid access to the upper end of said lower ram, and a bit stem slidably disposed in and sealed against said housing and having a longitudinal central passage.

3. A fluid-operated well-drilling mechanism comprising a tubular housing, an inverted cup-like cylinder longitudinally mounted in said housing, means affording operating fluid access to the interior of said housing below said cylinder, an annular upper ram slidably disposed in and sealed against the inside of said cylinder and having a longitudinal passage, an internal constriction in said housing below said upper ram and of diameter smaller than said upper ram, an annular lower ram slidably disposed in and sealed against said constriction and having a longitudinal passage in register with the passage in said upper ram, said passage in said lower ram being of diameter to effect reduction of pressure of operating fluid in flowing therethrough, means affording operating fluid access to the upper end of said lower ram, means limiting the upward movement of said lower ram, and a bit stem slidably disposed in and sealed against said housing and having a longitudinal passage in register with the passage in said lower ram.

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