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COMBINED ROTARY AND PERCUSSION DRILLING APPARATUS

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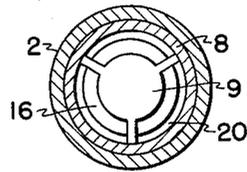
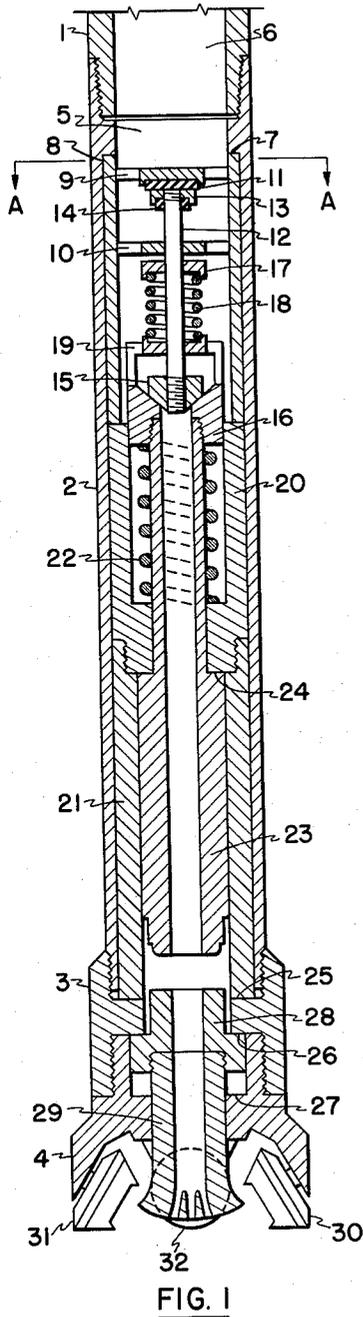


FIG. 2

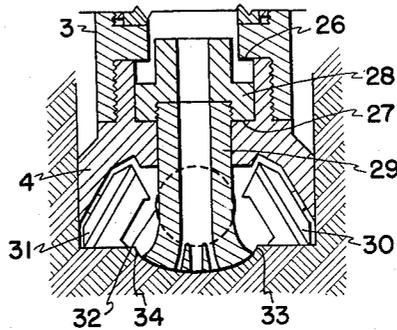


FIG. 3

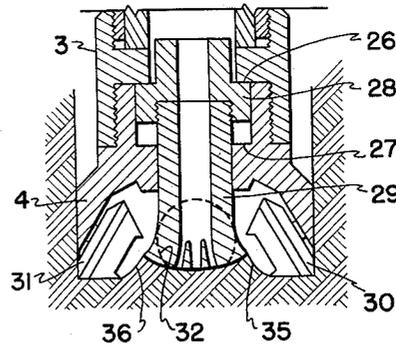


FIG. 4

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COMBINED ROTARY AND PERCUSSION DRILLING APPARATUS

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The present invention is concerned with an improved apparatus for drilling bore holes in the earth and is more particularly concerned with an improved drilling apparatus by means of which the center portion of a bore hole is drilled by a percussion bit while the outer portion of the hole is simultaneously drilled by a rotary bit, provision being made to automatically compensate for any differential in the drilling rates of the bits. The invention makes possible increased rates and longer bit life.

Rotary and percussion drilling are separately well known in the art. Each system has inherent features which limit its efficiency. In rotary drilling the linear velocity of the cutters of the drill bit varies from a maximum at the outer edge of the bit to zero at the center. Below a minimum linear velocity the cutters lose their ability to cut into the formation and therefore rotary drilling is relatively ineffective in the center portion of the bore hole. This ineffectiveness results in decreased drilling rates and excessive wear on the center portion of the bit. In addition, bearing failure in rotary cone bits is common because of the heavy stresses in the cantilever arms supporting the cones. Percussion bits are subjected to severe abrasion at their outer edges and failure through shear is common. Percussion bits are therefore most efficient in the center of the bore hole and relatively inefficient in the peripheral area.

Various proposals have been made heretofore for combining rotary and percussion drilling and thereby securing longer bit life and increased drilling rates. The most successful combination units have utilized a center percussion bit coupled with an annular rotary bit. In such units the percussion bit continuously leads the rotary bit and is intended to fracture the entire formation at the bottom of the bore hole, the rotary bit serving merely to crush and abrade the rock thus fractured. These units have not proved completely satisfactory for a number of reasons. It has been found that the power requirements for the percussion bit in order to break up and fracture the formation are high and that the life of the percussion bit is comparatively short. Full advantage is not taken of the cutting action of the rotary bit and therefore maximum overall drilling rates are not obtained. Moreover, the drilling rates of the two component bits vary appreciably in some formations and therefore the overall drilling rate is impeded by the slower bit.

It is therefore an object of the present invention to provide an improved combination rotary and percussion drilling apparatus wherein the rotary and percussion bits coact to produce higher drilling rates than can be achieved with conventional combination units.

A further object of the invention is to provide an improved combination rotary and percussion drilling apparatus wherein any differential in the drilling rates of the rotary and percussion bits is automatically compensated for in order to permit higher overall drilling rates.

A still further object is to provide an improved combination drilling apparatus by means of which percus-

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sive force may be applied to the rotary bit or additional weight may be applied to the percussion bit in order to achieve higher overall drilling rates.

Other objects will be apparent from the description of the invention.

The nature of the invention can perhaps be best understood by reference to the attached drawings, in which:

Figure 1 is a sectional elevation of a drilling tool embodying the invention;

Figure 2 is a cross-sectional view of the drilling tool taken about the line A—A;

Figure 3 is a sectional elevation of the lower portion of the drilling tool showing the percussion bit leading the rotary bit, and;

Figure 4 is a sectional elevation of the lower portion of the drilling tool showing the rotary bit leading the percussion bit.

Referring now to Figure 1, reference numeral 1 designates a drill collar positioned at the lower end of a string of drill pipe located in a bore hole. Connected to the lower end of drill collar 1 is main housing 2, which extends downward and is connected to a locking collar 3. Unless otherwise stated, all connections are threaded connections. Collar 3 is in turn connected to the stem of rotary bit 4, which is shown as an annular bit having truncated conical cutters, although a diamond bit may be used. The bore 5 of main housing 2 decreases in diameter at the upper end of the housing to align with the bore 6 of drill collar 1. This decrease in diameter forms internal shoulder 7, below which is positioned valve housing 8. Fixed within valve housing 8 are valve retainer 9 and valve guide 10. Valve retainer 9 is a disk supported by radial members affixed to the inner wall of the valve housing and contains a circular recess in its lower face in which is fixed rubber disk 11. Valve guide 10 is a ring supported by radial members affixed to the walls of valve housing 8 below valve retainer 9. Valve stem 12 slideably extends through the opening in valve guide 10 and is connected at its upper end to cap 13. The under side of cap 13 contains an annular recess in which is affixed rubber ring 14. In the uppermost position of valve stem 12, cap 13 contacts rubber disk 11 and in its lowermost position rubber ring 14 contacts valve guide 10. The lower end of valve stem 12 is connected to tapered valve plug 15, which seats in valve seat 16 to form a tight closure. Below valve guide 10, valve stem 12 is secured within or made integral with an annular flange 17 which has an annular recess in its lower surface to retain the upper end of a helical valve spring 18. Valve spring 18 is retained at its lower end by a ring 19 supported by radial members affixed to the upper surface of valve seat 16 outside the seating surface contacting valve plug 15.

Valve housing 8 is supported in main housing 2 by spring housing 20 which is connected to liner 21. These members are held in position within main housing 2 by locking collar 3. The upper bore of spring housing 20 has an increased diameter over the lower part of the bore and a helical compression spring 22 is positioned therein. Valve seat 16 is slideably positioned in the upper bore of spring housing 20 above spring 22 and is supported by spring 22, being free to slide downward as spring 22 is compressed. Valve seat 16 fits closely against the inner wall of spring housing 20 above spring 22 to prevent the flow of fluid around the valve seat. An annular recess in valve seat 16 fitted with a ring of felt, plastic, rubber or similar material may be provided to secure a better seal between the walls of the spring housing and the valve seat. Connected to valve seat 16 and extending slidably downward in the bore of spring housing 20 and liner 21 through helical spring 22 is a

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tubular hammer member 23. The lower section of hammer 23 has an increased outer diameter and this forms a shoulder 24 which engages the bottom of spring housing 20 when hammer 23 is in its uppermost position.

Locking collar 3, connecting main housing 2 and rotary bit 4, contains an internal shoulder having an upper face 25 which abuts against the bottom of liner 21 and having a lower face 26. The center bore of collar 3 is aligned with the bore of liner 21. The bore of rotary bit 4 is enlarged in the upper portion of the stem to form an internal flange 27. Positioned slideably within this enlarged upper bore is anvil member 28, which has a neck portion, decreased in diameter, extending upward into the bore of collar 3. The anvil contains an axial passage therethrough. Vertical movement of the anvil in an upward direction is limited by lower face 26 of collar 3 and downward movement is limited by flange 27 of rotary bit 4. A hollow percussion bit 29 is connected to the lower end of anvil 28 and extends downward through the bore of rotary bit 4. The length of bit 29 is such that the lower end thereof extends downward to the cutting plane of rotary bit 4 when anvil 28 is centrally positioned within the enlarged bore of rotary bit 4. When the anvil is in its lowermost position against flange 27, percussion bit 29 extends below the cutting plane of rotary bit 4 and when the anvil is in its uppermost position against face 26, percussion bit 29 extends downward to a point above the cutting plane of rotary bit 4. The lower end of the percussion bit is flared outwardly to cover the central portion of the bore hole bottom between the cutters of the rotary bit. The bore of the percussion bit opens into a plurality of fluid passages in the lower end thereof in order to achieve efficient distribution of the drilling fluid circulated therein.

Rotary bit 4 has mounted thereon cutters designated by the numerals 30, 31 and 32. A fourth cutter disposed toward the viewer is not shown. It will be understood that the invention is not limited to the use of four cutters and that a greater or lesser number may be used. These cutters, in contrast to those of the conventional core bit, are truncated conical cutters disposed upon axles extending at a downward angle from the outer edge of the bit toward the center bore. The use of relatively large diameter truncated conical cutters permits more efficient rotary drilling and longer bit life than is possible with a conventional core bit. The truncated cutters have a shorter cantilever length than conventional cone cutters and therefore there are lower stresses under maximum load than with the conventional rotary bit. This results in fewer bearing and shank failures. At the same time, a greater unit pressure is exerted upon the formation under maximum load conditions by the rotary bit because of the smaller area covered by the cutters and thus higher drilling rates are possible.

In drilling with the apparatus of the present invention, the entire drill assembly is rotated by rotating the drill pipe at the earth's surface means of conventional rotary drilling equipment which is well known in the art and which need not be described. The cutters of the rotary bit are thus caused to rotate against the peripheral section of the bore hole bottom, advancing this section of the hole. Drilling mud is continuously supplied under pressure to the drilling apparatus through the tubular drill string. This drilling mud may be any of the conventional drilling fluids, including various suspensions of clay in a water or hydrogen base. Drilling mud supplied through bore 6 of drill pipe 1 enters bore 5 of main housing 2 and passes downward within valve housing 8. Hydraulic pressure is exerted against the upper surfaces of valve plug 15 and valve seat 16. Under the influence of this pressure, the valve plug and seat are forced downward, causing hammer 23 to move downward against the resistance of spring 22. The downward moving hammer strikes the upper surface of anvil 28, driving percussion

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bit 29 against the formation at the bottom of the bore hole.

Valve stem 12 and plug 15 move downward with valve seat 16 and hammer 23 in response to hydraulic pressure until rubber ring 14 on the under side of cap 13 strikes the upper surface of valve guide 10. At this instant further movement of valve stem 12 and plug 15 is inhibited and therefore the valve is opened and valve spring 18 is placed in tension as valve seat 16 and hammer 23 move downward against anvil 28. The drilling fluid flows through the opening in valve seat 16, downward through hammer 23 and anvil 28, and through percussion bit 29 to the cutting area at the bottom of the bore hole. The opening of valve seat 16 releases the pressure on the upper surface thereof and, due to compression of spring 22, tension in valve spring 18 and recoil of the hammer upon striking anvil 28, the hammer and valve seat move upward. The upward moving valve seat 16 engages valve plug 15, closing the valve and shutting off the flow of drilling fluid. This upward movement continues until simultaneously cap 13 strikes rubber disk 11 and shoulder 24 on the hammer engages the lower end of spring housing 20, preventing further upward motion. At this point the entire mechanism is in its uppermost position with the valve closed and therefore hydraulic pressure is again exerted against the valve plug and seat and the action is repeated.

The frequency with which percussion bit 29 operates to impact the formation will depend upon the force required to compress spring 22 and expand valve spring 18, the weight of hammer 23, and the pressure at which drilling fluid is supplied to the apparatus. Frequencies of 40 strokes per second or more can be obtained by using a valve spring of about 60 pounds per inch and a return spring of about 245 pounds per inch with a 30 pound hammer and a drilling fluid pressure of about 400 p. s. i. g. It will be understood that these are not limiting values and are intended to be merely illustrative.

The drilling fluid supplied to the cutting area through the openings in the lower surface of percussion bit 29 serves to cool and lubricate the cutters of rotary bit 4 and to entrain cuttings produced by the two bits. The high pressure of the drilling fluid prevents clogging of the openings in percussion bit 29. The drilling fluid and entrained cuttings pass upward around rotary bit 4 and are forced to the surface of the earth through the annular space between the drill string and the bore hole wall.

During normal drilling operations anvil 28 is centrally disposed within the enlarged upper bore of rotary bit 4 and percussion bit 29 extends downward to the cutting plane of the rotary bit, impacting the formation on that plane. The pressure exerted by the rotary bit and drill string upon the peripheral area at the bottom of the bore hole creates high stresses in that area. These stresses lessen the compressive stresses which afford lateral support to the rock at the center of the bore hole bottom and the rock can therefore be readily crushed by the impactions of the percussion bit. The action of the percussion bit is thus similar to that of a pestle, rather than being a deep, chisel-like action as in the case of the normal percussion bit. It has been found that under these conditions very low horsepower is required for efficient percussion drilling and that the life of the percussion bit is extended considerably. The improved performance of the percussion bit permits higher overall drilling rates than can be obtained with equipment wherein the percussion bit leads the rotary bit.

As is apparent from the foregoing, it is necessary that the two bits contact the formation upon substantially the same plane if maximum drilling rates are to be obtained. Under certain conditions the percussion bit may tend to advance at a faster rate than the rotary bit. When this occurs, there will be an unsupported area, designated by the numerals 33 and 34 in Figure 3, be-

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neath the lagging rotary bit. This unsupported area will offer less resistance to the advance of the rotary bit and the rotary bit will tend to overtake the percussion bit. If the percussion bit 29 continues to advance at a rate faster than that of the rotary bit, the anvil and percussion bit will gradually move downward until the anvil 28 bears upon flange 27 in the rotary bit 4, as shown in Figure 3. At this point percussive force imparted to the anvil 28 by hammer 23 will be transferred to rotary bit 4, further increasing the drilling rate of the rotary bit and bringing the two bits together.

If the drilling rate of rotary bit 4 exceeds that of percussion bit 29, an unsupported area, designated by numerals 35 and 36 in Figure 4, develops beneath percussion bit 29. This unsupported area offers less resistance to the advance of the percussion bit and therefore the drilling rates tend to equalize. If the rotary bit 4 continues to advance faster than percussion bit 29, rotary bit 4 moves downward around anvil 28 until face 26 of locking collar 3 bears upon anvil 28, as shown in Figure 4. At this point the weight of the drill string is imparted to anvil 28 and percussion bit 29 in addition to the percussive force imparted by hammer 23. The rate of the percussion bit will thus be accelerated until the two bits are advancing at the same rate on the same plane.

It is thus apparent that the present invention permits the acceleration of the drilling rate of either the percussion bit or the rotary bit to compensate for any differential in the drilling rates. This permits substantially improved overall drilling rates with no increase in power requirements or drill pipe stresses. The invention makes possible more uniform drilling rates under varying drilling conditions and leads to better overall drilling efficiency. Bit life is prolonged and thus shut down time required for withdrawing the drill string and changing bits is decreased.

It will be understood by those skilled in the art that various changes and modifications may be made in the apparatus without departing from the spirit of the invention. Thus, an annular diamond bit may be used in place of the truncated conical rotary bit; a portion of the drilling fluid may be circulated past the valve mechanism to provide a continuous flow of drilling fluid; and the anvil or percussion bit may be splined to cause rotation of the percussive drilling element. It is intended to cover all such modifications as fall within the scope of the claims.

The nature and objects of the invention having thus been fully described and illustrated, what is claimed is:

1. Apparatus for drilling bore holes comprising in combination a main housing adapted to be connected to a rotary drill string; a collar member connected to said housing and having an internal shoulder; an annular rotary drill bit having an axial bore and connected to said collar and containing an internal flange in the bore thereof; an anvil member slideable vertically in the bore of said rotary bit above said flange and of a character to be retained therein by said flange and said shoulder, and having a fluid passage therethrough, movement of said anvil being limited by said shoulder of said collar and said flange; a percussion drill bit connected to said anvil and extending downward through said flange, said percussion bit having a fluid passage therethrough and being of a character to impact the formation on the cutting plane of said rotary bit when said anvil is disposed at an intermediate position; a tubular hammer slideable axially in said housing and adapted to impact said anvil; a valve; a slideable stem axially aligned with said hammer and connected to said valve; the valve being biased to close the bore of said hammer whereby said hammer moves downward responsive to a pressure of drilling fluid in said housing; means for limiting downward movement of said stem whereby said valve is

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opened as said hammer moves downward; and means for normally biasing said hammer upwardly.

2. Apparatus for drilling bore holes comprising in combination a main housing adapted to be connected to a rotary drill string; a collar member connected to said housing and having an internal shoulder; an annular rotary drill bit being characterized by having truncated conical cutters and an axial opening therethrough, said bit being connected to said collar and containing an internal flange in the lower bore thereof with said flange spaced from said shoulder; an anvil member slideable vertically in the bore of said rotary bit above said flange and of a character to be retained therein by said flange and said shoulder and having a fluid passage therethrough, axial movement of said anvil being limited by said shoulder of said collar and said flange; a percussion drill bit connected to said anvil and extending downward through said flange, said percussion bit having a fluid passage therethrough and being adapted to impact the formation on the cutting plane of said rotary bit when said anvil is disposed at an intermediate position; a tubular hammer slideable axially in said housing above said anvil and of a character to impact said anvil; a valve seat connected to the upper end of said hammer; a slideable valve stem positioned in said housing above said hammer and axially aligned with said hammer; a valve plug positioned on the lower end of said stem; means for normally biasing said plug against said seat; means for limiting the downward movement of said stem and said plug whereby said valve is opened as said hammer moves downward responsive to pressure of a drilling fluid in said housing; and means for normally biasing said hammer and seat upwardly.

3. Apparatus for the drilling of bore holes comprising in combination a main housing adapted to be connected to a rotary drill string; a reciprocating hammer member slideable axially in said housing and having an axial opening therethrough; a valve seat attached to the upper end of said hammer; a valve plug adapted to seat in said valve seat whereby the bore of said hammer is closed and said hammer moves downwardly responsive to pressure of a drilling fluid in said housing; a valve stem supporting said plug; means slidably supporting said stem with the axis of said stem aligned with the axis of said hammer; means for limiting downward movement of said stem and plug whereby the bore of said hammer is opened as said hammer moves downwardly; means normally biasing said hammer upwardly; means normally biasing said plug against said seat; a collar member having an internal shoulder therein and connected to the lower end of said housing; an annular rotary drill bit connected to said collar and having an internal flange in the bore thereof; an anvil member axially aligned with the axis of said hammer and axially slideably positioned within the bore of said rotary bit above said flange and of a character to be retained therein by said shoulder and disposed in the path of the downward movement of said hammer and adapted to receive the impact from said hammer, said anvil containing an axial opening therethrough; and a percussion bit having an axial opening therethrough connected to said anvil and extending downward to the cutting plane of said rotary bit when said anvil is centrally disposed between said flange and said shoulder; with said percussion bit being above said cutting plane of said rotary bit when said anvil is in its uppermost position and below said cutting plane when said anvil is in its lowermost position.

4. An apparatus for drilling boreholes comprising in combination a main housing adapted to be connected to a rotary drill string; a collar member adapted to be connected to said housing and having an internal shoulder and having an axial opening therethrough; an annular rotary drill bit having an axial bore therethrough and adapted to be connected to said collar and also having an

internal flange in the bore thereof which is spaced from said internal shoulder of said collar when said collar is connected to said rotary bit; an anvil member having an axial passage therethrough and with at least a portion of said anvil member being of a greater diameter than the larger of the diameters of the bore formed by said internal shoulder and the diameter of the bore formed by said internal flange; said anvil being free to slide vertically in the bore of said rotary bit with its uppermost movement being limited by said internal shoulder and its lowermost movement being limited by said internal flange; a percussion drill bit attachable to said anvil and extending downward through said flange, said percussion bit having an axial fluid passageway therethrough and being of a character to intersect the cutting plane of said rotary bit when said anvil is in its uppermost position and with the lowermost portion of said percussion bit being above the cutting plane of said rotary bit when said anvil is in its uppermost position and with said lowermost portion of said percussion bit being below the cutting plane of said rotary bit when said anvil is in its lowermost position; a tubular hammer slidable vertically in said housing with said anvil limiting the lowermost movement of said hammer, the external diameter of said hammer being less than the internal diameter of said shoulder member of said collar; a valve seat connected to the upper end of said hammer with the valve seat sealingly engaging the inner periphery of the housing, a slidable valve stem positioned in said housing above said hammer with the axis of said stem aligned with the axis of said hammer, a valve plug positioned at the lower end of said stem; means for slidably suspending said valve stem in said housing; means for normally biasing said plug against said seat; means for limiting the downward movement of said stem and said plug whereby said valve is opened as said hammer moves downward responsive to pressure of a drilling fluid in said housing; and means for normally biasing said hammer and said seat upwardly.

5. An apparatus for drilling boreholes comprising in combination a main housing adapted to be connected to a rotary drill string; a collar member adapted to be connected to said housing and having an internal shoulder intermediate its end and having an axial opening therethrough; an annular rotary drill bit having an axial bore therethrough and adapted to be connected to said collar and also having an internal flange in the bore thereof which is spaced from said internal shoulder of said collar when said collar is connected to said rotary bit, with the internal diameter of said flange and said shoulder being substantially equal; an anvil member having an axial passage therethrough and with at least a portion of said anvil member being approximately equal to the

internal diameter of the bore of said rotary bit above said internal flange, said anvil being free to slide vertically in the bore of said rotary bit with its uppermost movement being limited by said internal shoulder and its lowermost movement being limited by said internal flange; a percussion drill bit attachable to said anvil and extending downwardly through said flange with the axis of said percussion bit being aligned with the axis of said housing, said percussion bit having an axial fluid passageway therethrough and being of a character to intersect the cutting plane of said rotary bit when said anvil is at an intermediate position and with the lowermost portion of said percussion bit being above the cutting plane of said rotary bit when said anvil is in its uppermost position and with said lowermost portion of said percussion bit being below the cutting plane of said drill bit when said anvil is in its lowermost position; a tubular hammer slidable vertically in said housing with the axis of said hammer aligned with the axis of said housing and the external diameter of said hammer being less than the internal diameter of said shoulder of said collar, said tubular hammer being disposed in said housing above said anvil with said anvil limiting the lowermost movement of said hammer; a valve seat connected to the upper end of said hammer and axially aligned therewith; sealing means to slidably seal the inner periphery of said housing with exterior of said hammer; slidable valve stem positioned in said housing above said hammer with the axis of said stem aligned with the axis of said hammer; a valve plug positioned at the lower end and attached to said stem; means for slidably suspending said valve stem in said housing; means for normally biasing said hammer upwardly; means for normally biasing said plug against said seat; means for limiting the downward movement of said stem and said plug whereby said valve is opened as said hammer moves downward responsive to pressure of a drilling fluid in said housing; means for limiting the upward movement of said valve stem whereby said valve is closed as said valve seat and said hammer moves upward responsive to said upward biasing means and the recoil of said hammer striking said anvil.

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