June 25, 1963 E. A. MORI 3,095,046

HAMMER DRILL

Filed Sept. 15, 1961

2 Sheets-Sheet 1

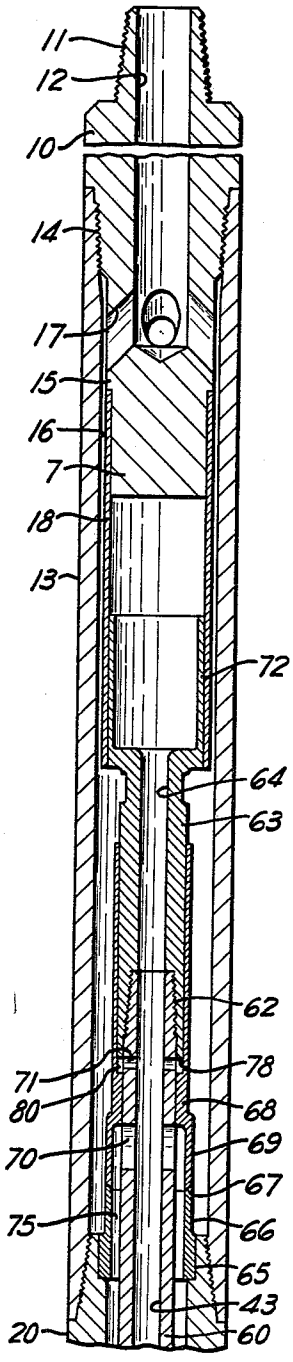


Fig. 1

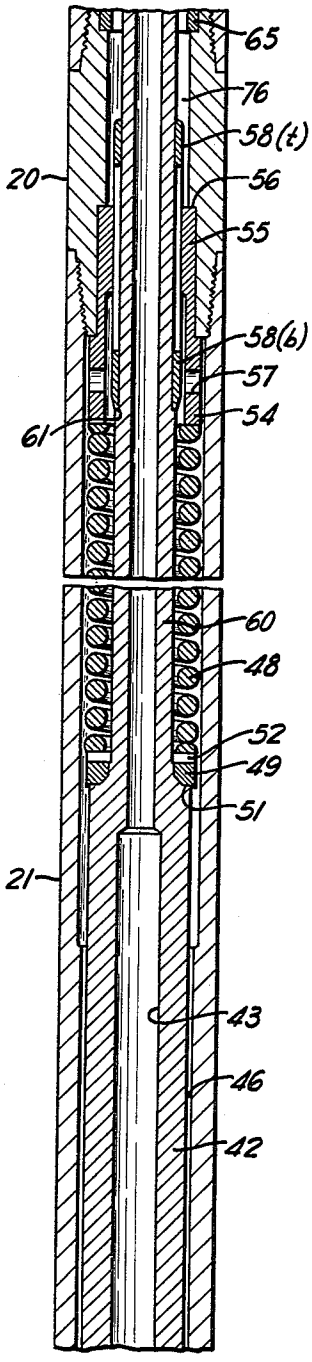


Fig. 2

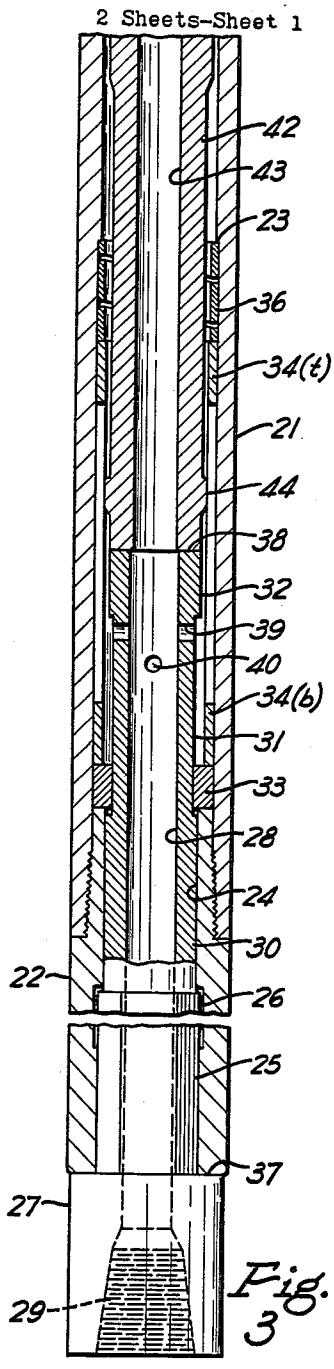


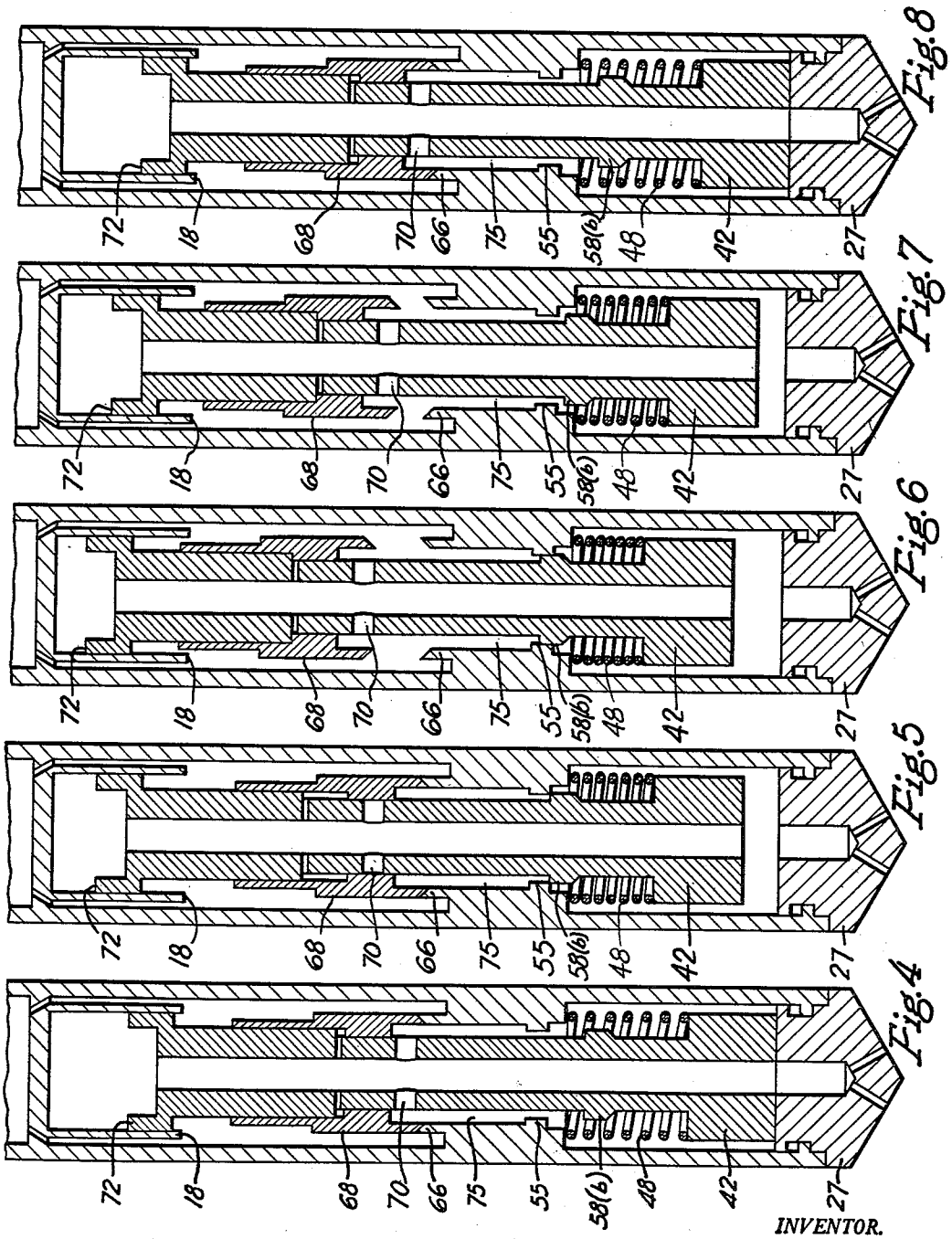
Fig. 3

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3,095,046

HAMMER DRILL

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This invention relates to rotary percussion drills and in particular concerns a rotary deep well drill having a fluid-actuated percussion mechanism of improved construction.

In the drilling of deep wells it is recognized that the addition of a percussive action at the drill bit increases the penetration rate of a rotary drill, particularly when drilling in hard formations, such as chert or limestone. It is also known that substantially the same or greater penetration rates can be attained with a rotary drill that includes percussive action but with reduced weight on the drill bit, and experience has shown this to result in a straighter hole. The latter characteristic is particularly important when drilling in steeply dipping hard formations which tend to deflect the drill down dip unless the weight on the bit is kept to a minimum. On the other hand, percussion drill mechanisms necessarily have moving parts that tend to wear and this wear is aggravated if the drilling fluid contains sand or grit as is often the case when drilling hard formations. Furthermore when the drilling fluid is laden with grit it tends to cut out ports. In prior-art devices the valve ports that successively open and close in the course of the operating cycle of the percussive mechanism are particularly susceptible to such sand cutting with the result that the valve soon fails to seat properly and the tool becomes inoperative.

It is the purpose of this invention to provide a rotary percussion mechanism that is particularly adaptable to use with drilling fluid laden with abrasive particles and that continues to operate even though substantial sand cutting has taken place. Experience has shown that in the drill of this invention the valve face and valve seat may cut away to a substantial extent and the valve nevertheless continues to function properly, and only when the valve face or the valve seat are substantially completely dissipated does the tool cease to function properly. The structure of this invention therefore extends the useful life of the mechanism before it needs to be pulled from the well and repaired or replaced.

This invention is illustrated in the accompanying drawings that form a part of this specification, and in which,

FIGURE 1 is a longitudinal section taken through the upper portion of a preferred embodiment of the drill of this invention;

FIGURE 2 is a longitudinal section taken through the intermediate portion of the drill;

FIGURE 3 is a longitudinal section taken through the lower portion of the drill; and

FIGURES 4 to 8 are diagrammatical representations illustrating successive phases in the cyclic operation of the drill of this invention.

Reference is made to the drawings in which like numerals indicate the same element in the various views and diagrams.

Referring to FIGURES 1, 2, and 3, adapter **10** serves to connect the drill assembly of this invention to the conventional drill stem (not shown) by means of conventional drill-collar threads **11**. The drill stem has a central passageway as is conventional for supplying drilling fluid to the drill bit and adapter **10** is also provided with a central passage **12** for the purpose of admitting the pressurized drilling fluid from the drill stem to the drill mechanism. A cylindrical upper housing **13** is fastened by threads **14** to adapter **10**. A portion **15** of the adapter

is of reduced diameter and extends into the upper housing **13** with an annular clearance **16**. The annular clearance **16** is sufficiently large to permit free flow of drilling fluid between the portion **15** of the adapter and the inside of upper housing **13**, the area of the clearance **16** being preferably substantially the same as that of passage **12**. Diagonal openings **17** permit pressurized drilling fluid to pass from passage **12** into annular clearance **16**.

The lower end **7** of the adapter is further reduced in diameter and an open ended cylinder **18** is pressed and shrunk thereon. The outside diameter of cylinder **18** is substantially the same as that of portion **15** of the adapter so as to continue the annular space **16** substantially unchanged. The cylinder **18** thus forms an inverted cup-like downward extension of adapter **10** and the annular clearance **16** permits the pressurized drilling fluid access to below the cylinder **18**.

The cylindrical upper housing **13** is screwed to an intermediate housing portion **20** (FIGURE 2) to which there is screwed a lower housing **21** whose lower end (FIGURE 3) is internally threaded to be screwed to bit-stem retainer **22** as shown. The form and function of the intermediate housing portion **20** will be described later. The lower housing **21** is substantially cylindrical but has a downward-facing shoulder **23** whose function will become evident. Elements **10, 13, 20, 21,** and **22** all have substantially the same outside diameter.

The bit-stem retainer **22** has a central cylindrical bore **24** that is enlarged to have a hexagonal cross section at **25**, the upper part of the hexagonal portion being relieved slightly as shown at **26**. The bit stem **27** has a central passageway **28** and the lower end is provided with female threads **29** that are conventional for attaching any desired type of drill bit (not shown). The bit stem **27** is provided with a hexagonal section that is a sliding fit in the hexagonal portion **25** of the bit-stem retainer. The hexagonal arrangement **25** serves to transmit torque from the tool to the bit through the bit stem **27**. Immediately above the hexagonal portion **25** the bit stem has a cylindrical portion **30** that is a sliding fit in the cylindrical bore **24** of the bit-stem retainer. Above this the bit stem has a region of reduced diameter **31**, and above this the diameter is again enlarged at **32** to a diameter that is no larger than that of cylindrical portion **30**. Before the bit-stem retainer **22** is screwed onto the lower end of lower housing **21**, the bit stem is inserted in the retainer and the two halves of a split ring **33** are placed around the region **31** of the bit stem, the inside diameter of the split ring **33** being a sliding fit on **31** and the outside diameter of the split ring being such as to slide into the lower end of lower housing **21**.

Above the split ring **33** there is located in the housing **21** a guide cage **34** whose top and bottom rings are marked **34***t* and **34***b* respectively in FIGURE 3, and between which there are connecting longitudinal legs separated by longitudinal slots. The outside diameter of the legs and rings of guide cage **34** is such as to fit into the lower end of lower housing **21**, and its inside diameter is somewhat larger than the diameter of portion **32** of the bit stem. Above the guide cage **34** is a stiff spiral clamping spring **36** whose upper end bears against the previously mentioned shoulder **23** of the lower housing **21**. The axial dimensions of elements **33, 34,** and **36** are made such that when these parts are assembled as shown and the bit-stem retainer **22** is tightened in the lower housing, the clamping spring **36** will be compressed so as to hold the split ring **33** tightly against the upper end of the bit-stem retainer.

It will be evident that the bit stem **27** will be allowed a limited amount of longitudinal motion to the extent that the axial length of portion **31** of the bit stem exceeds the axial length of split ring **33**. The axial length of the

hexagonal region 25 of the bit stem is slightly less than the mating portion of the bit-stem retainer in order that when weight is applied to the bit, the force is transmitted through the shoulder 37 rather than through the split ring 33 or the shoulder at the top of the hexagonal joint 25. The axial length of each of portions 24 and 25 of the bit stem is of course greater than the longitudinal freedom of the bit stem in its retainer. The upper end 38 of the bit stem forms an anvil upon which the hammer pounds and it may be appropriately heat treated for such service. A plurality of transverse holes 39 and 40 are drilled in the bit stem just below its head for the purpose of permitting free flow of fluid from outside the bit stem to its central passage 28, the holes being staggered so as to minimize any detrimental effect of the holes on the strength of the bit stem.

Above the bit stem there is located an elongate annular hammer 42 having a central passageway 43. The lower end of hammer 42 strikes the anvil surface 38 upon impact and may be appropriately heat treated to withstand such service. A short way above the lower end of the hammer the outside surface of the hammer is provided with a cylindrical enlargement 44 whose outside diameter is a sliding fit in the guide cage 34. The construction serves to guide the lower end of the hammer and at the same time fluid may bypass the enlargement 44 through the slots of the guide cage 34. It should be noted however, that when the hammer is raised to a point where the enlargement 44 engages the top ring 34*t* of the cage 34 such fluid bypass is cut off, and the purpose of this will be explained later. The top ring 34*t* forms an annular ledge on the inside surface of the housing, and as will become evident later this ledge coacts with the enlargement 44 to provide a hydraulic stop at the top of the upward stroke of the hammer. The body of hammer 42 extending upward and above the enlargement 44 has an outside diameter that is smaller than the inside diameter of lower housing 21 so as to allow an annular space 46 between the hammer and the housing to permit flow of fluid longitudinally past the outside of the hammer. At the upwardly facing shoulder 51 (FIGURE 2) the hammer is reduced in diameter to form hammer stem 60 whose upper portion (FIGURE 1) is threaded at 62.

Above the shoulder 23 the lower housing 21 extends upward with substantially uniform inside diameter but is enlarged somewhat in its upper portion to provide some additional interior space for a helical compression spring 48. The lower end of spring 48 abuts a collar 49 that is pressed onto the hammer against the shoulder 51. The upper surface of the collar 49 has a plurality of radial slots 52 milled therein and the spring 48 rests on the intervening lands. This construction permits free flow of fluid from inside the spring 48 to the annular space 46 around the hammer even though the spring 48 be tightly compressed as may occur at some phase of the operating cycle. The collar 49 may be somewhat larger in outside diameter than the hammer in order to provide a better supporting surface for the lower end of spring 48, but the outside diameter of collar 49 is less than the inside diameter of lower housing 21 to permit fluid flow past the collar.

The upper end of spring 48 abuts the skirt 54 of a wear sleeve 55 shaped substantially as shown in FIGURE 2 and whose upper end is pressed and shrunk into the intermediate housing 20 against a downwardly facing shoulder 56 as shown. The upper portion of wear sleeve 55 forms an annular ledge on the inside surface of the housing, and as will become evident this ledge coacts with a ledge 58*b* on the hammer stem to shut off the annular space 76 when the hammer approaches its upward limit of travel. The outside diameter of the skirt 54 of the wear sleeve is less than the internal diameter of lower casing 21, and the skirt is perforated by a plurality of holes 57 whose purpose is to permit fluid to have access to both sides of spring 48.

A wear cage 58 is shrunk on the hammer stem 60, being pressed against a slight upwardly facing shoulder 61. The wear cage 58 comprises top and bottom rings identified in FIGURE 2 by the numerals 58*t* and 58*b* respectively, the rings 58*t* and 58*b* being connected by a plurality of legs separated by longitudinal slots. The outside diameter of the legs and rings of wear cage 58 forms a sliding fit in the upper portion of wear sleeve 55. Thus whenever either of the parts 55 or 58 become excessively worn the part may easily be replaced. The inside diameter of the wear sleeve skirt 54 is larger in diameter than the outside diameter of wear cage 58 in order to permit flow of fluid between them even though the bottom wear cage ring 58*b* be opposite the skirt 54. The holes 57 thus form communication between the annular spaces on the two sides of the skirt 54.

The upper end of hammer stem 60 is threaded (FIGURE 1) at 62 and screwed to a piston carrier 63. The piston carrier 63 is somewhat larger in diameter than the diameter of hammer stem 60 so as to form a downwardly facing shoulder 78. The upper end of piston carrier 63 is enlarged to form a piston 72 that is a sliding fit in cylinder 18. The piston 72 and piston carrier 63 are provided with a central passageway 64.

The internal diameter of intermediate housing portion 20 is larger than the outside diameter of the wear cage 58 to provide an annular clearance between them. At the upper end of housing portion 20 (see FIGURE 1) the internal bore is enlarged at 65 and a replaceable valve seat 66 is pressed and shrunk into it as shown. The valve seat 66 forms an annular ledge on the inside surface of the housing and its upper portion serves to coact with the lower end of an annular valve member 68 to form an annular seal at 67. The internal diameter of the valve seat 66 is larger than the outside diameter of wear cage 58 in order to provide annular clearance between the inside of valve seat 66 and the top ring 58*t* of the wear cage 58. Thus when the hammer is raised the top ring 58*t* of the wear sleeve may enter the valve seat 66 with clearance between these elements. The valve surface 67 at the upper end of valve seat 66 is frusto-conical in shape with the apex of the cone pointing downward. The valve seat 66 is easily replaced in the housing portion 20 when it becomes worn or damaged.

An annular valve member 68 is a sliding fit on the upper end of hammer stem 60. The upper end of the valve member 68 is bored out larger and makes a sliding fit on the lower portion of the piston carrier 63. The end of skirt 69 of valve element 68 has a frusto-conical shape that mates with the valve seat 66 at the valve surface 67. The internal diameter of the valve skirt 69 is larger than the outside of wear cage 58. A plurality of longitudinal slots 70 are milled in the hammer stem 60 in order to provide fluid communication between the annular space 75 around the hammer stem and its central passageway 43. Also a plurality of holes 71 are drilled in the hammer stem 60 directly below the shoulder 78 formed by the lower end of the piston carrier for the purpose of preventing fluid from being trapped between the valve element and the hammer stem.

The internal diameter of the cylinder 18 must be larger than the diameter of the piston stem 63 in order that when the mechanism is in the configuration illustrated in FIGURES 1, 2, and 3 a lifting force will be exerted on the piston 72 by fluid pressure in the annular space 16 inside housing 13 thereby to raise the hammer against the compression of spring 48. The outside diameter of the valve and valve seat is made larger than the inside diameter of the hammer stem and this gives rise to a downward hydraulic force on valve 68 causing it to remain seated on the valve surface 67 as the hammer starts to lift.

At the beginning of the operating cycle, the hammer will lift until the bottom ring 58*b* of wear sleeve 58, which forms a collar on the hammer stem 60, enters upper por-

tion of wear sleeve **55** and this traps fluid in the annular spaces **75** and **76** because the slots **70** will have moved above the valve and will no longer communicate with the annular space **75** and **76**. Accordingly, the upward force on the hammer is transferred to the trapped fluid in the annular space **75** and **76** and this hydraulic pressure lifts the valve **68** off its seat at the valve surface **67**. The longitudinal dimensions of the parts are such that near the top of the hammer stroke the bottom ring **58***b* of the wear cage **58** enters the upper portion of wear sleeve **55**, thereby to kick the valve off its seat hydraulically. When the valve is thus hydraulically opened, the pressurized fluid is momentarily shut off and exerts a lifting force on the valve **68** causing it to move upward to full opening. The upper surface of ring **58***b* is made substantially flat and horizontal in order that the hydraulic valve kick-off be sudden so as to quickly lift the valve. As soon as the seal at valve surface **67** is broken, the pressure lifting the hammer is relieved and the hammer decelerates, subsequently falling under the combined action of gravity and of spring **48**. Near the end of the upward stroke of the hammer the shoulder **78** of the hammer catches the valve **68** and the valve is forcibly carried down with the hammer. The longitudinal dimensions of the respective various parts are such that with the tool resting on the bit stem shoulder **37** as shown in FIGURES 1 to 3, the bottom of the hammer will impact the anvil surface **38** (FIGURE 3) before the valve seats at **67**. Valve clearance **80** is provided for this purpose, and this insures that the hammer blow will not be absorbed by the valve. During operation of the tool with abrasive fluids, the valve clearance **80** gradually increases as the valve and its seat are worn away, but this does not hinder operation of the tool. The hammer stops suddenly upon impact on the anvil surface **38**, but the downward momentum of the valve serves to carry the valve downward the extent of the valve clearance to strike its seat and close at the valve surface **67**. The cycle then repeats itself so long as the tool rests on the bit-stem shoulder **37** and pressurized fluid is supplied through the drill pipe.

An important advantage of the invention resides in the fact that at the top of its stroke the upward motion of the hammer is hydraulically arrested. This feature of the invention materially increases the frequency of impact. The hydraulic stop for upward motion of the hammer is effected when the hammer enlargement **44** (FIGURE 3) enters the top ring **34***t* of the guide cage **34**. The longitudinal dimensions of the respective parts are such that the enlargement **44** enters the ring **34***t* a short time after the bottom ring **58***b* of the wear cage **58** has entered the wear sleeve **55**. Thus when the latter of these seals occurs, fluid is trapped in the annular space around the hammer and its stem above the enlargement **44** and below the ring **58***b*. Due to the fact that the outside diameter of enlargement **44** is larger than that of ring **58***b* any further upward movement of the hammer is arrested by compression of fluid trapped in this annular space. The result is that the upward motion of the hammer assembly is very effectively stopped by hydraulic action, and the hammer quickly reverses and descends. The quick hydraulic reversal of hammer motion at the top of its stroke prevents a dwell at this point and thus increases the cyclic frequency of the percussive action of the drill.

FIGURES 4 to 8 inclusive are diagrammatical illustrations of various phases in the cyclic operation of the tool. FIGURE 4 shows the configuration of the various elements at the begining of the operating cycle, the hammer **42** and valve **68** being in their lowermost positions. The valve is closed and the pressurized fluid from the drill pipe exerts a lift on piston **72** which lifts the hammer against compression of spring **48**. When the hammer has reached the configuration shown in FIGURE 5, the ring **58***b* enters the sleeve **55** whereupon fluid is trapped in the annular space **75**. Upward momentum of the hammer against the trapped fluid kicks the valve **68** off its seat **66**. As soon as the valve opens, the pressurized fluid acting on the lower surface of the valve exerts a lifting force on the valve and the valve quickly reaches its full-open position as shown in FIGURE 6. Upward motion of the hammer is subsequently arrested hydraulically as previously explained (but not shown in FIGURES 4 to 8) and the hammer starts to descend. FIGURE 7 shows the hammer **42** falling under the action of gravity and spring **48**, and carrying the valve **68** with it. At the bottom of its stroke the hammer strikes the bit stem **27** imparting a percussive blow. The valve continues downward and closes on its seat, so that at the end of the stroke as shown in FIGURE 8 the mechanism is again in condition to repeat the cycle.

Provision for bypassing the percussion action for purposes of maintaining fluid circulation while running in and out of the hole is not shown in the figures, since such may be conventional, as for example a pressure controlled bypass in a drill-string sub above the percussion mechanism or a conventional shut off controlled by a ball dropped through the drill pipe from the surface.

Operational tests made on the drill of this invention under conditions of sand-laden fluid have shown that the valve skirt **69** and the valve seat extension **66** (FIGURE 1) are both abraded at the valve surface **67** but the valve surface remains smooth and a tight seal is maintained even though considerable wear of the mating parts takes place. It is believed that due to the rotation of the drill a certain degree of relative rotation of the parts and the fluid stream takes place and this is sufficient to effect uniform circumferential wear observed to take place at the valve surface **67**. It has further been found that considerable wear of both the valve seat **66** and the valve skirt **69** may take place without materially affecting the operating efficiency of this drill.

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 the top of said housing, means affording operating fluid access to the interior of said housing below said cylinder, an elongate annular hammer smaller in diameter than the inside diameter of said housing and slidably disposed in and sealed against the inside of said cylinder, said hammer having a longitudinal central passage therethrough, an annular valve slidably disposed on and sealed against the outside surface of said hammer, the inside diameter of said valve being less than the inside diameter of said cylinder, a passageway leading from said longitudinal central passage of said hammer to a point outside said hammer proximately below said valve, a first annular ledge on the inside surface of said housing below said valve, the lower end of said valve being adapted to seat on the upper portion of said first ledge to form an annular seal, a stop on said hammer limiting upward movement of said valve on said hammer, a second annular ledge in said housing below said valve, a collar on said hammer below said second ledge adapted to penetrate said second ledge and form a sliding seal therewith, and a bit stem slidably disposed in and sealed against said housing below said hammer and having a longitudinal central passage, the upper end of said bit stem being disposed to be struck by the lower end of said hammer.

2. A fluid-operated well-drilling mechanism comprising a tubular housing, an inverted cup-like cylinder longitudinally mounted in the top of said housing, means affording operating fluid access to the interior of said housing below said cylinder, an elongate annular hammer smaller in diameter than the inside diameter of said housing and slidably disposed in and sealed against the inside of said cylinder, said hammer having a longitudinal central passage therethrough, an annular valve slidably disposed on and sealed against the outside surface of said hammer, the inside diameter of said valve being less than

the inside diameter of said cylinder, a first annular ledge on the inside surface of said housing below said valve, the lower end of said valve being adapted to seat on the upper portion of said first ledge to form an annular seal, a stop on said hammer limiting upward movement of said valve on said hammer, a second annular ledge in said housing below said valve, a collar on said hammer below said second ledge adapted to penetrate said second ledge and form a sliding seal therewith, a third annular ledge in said housing below said second annular ledge, an enlargement on said hammer below said third ledge adapted to penetrate said third ledge and form a sliding seal therewith, the longitudinal distance between said third ledge and said enlargement being greater than the longitudinal distance between said second ledge and said

collar, a bit stem slidably disposed in and sealed against said housing below said hammer and having a longitudinal central passageway, the upper end of said bit stem being disposed to be struck by the lower end of said hammer, and a passageway leading from said longitudinal central passage of said hammer to a point outside said hammer proximately below said valve.

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