July 30, 1957 E. A. MORI 2,800,884

POSITIVE DISPLACEMENT-TYPE HAMMER DRILL

Filed Feb. 24, 1956 2 Sheets-Sheet 1

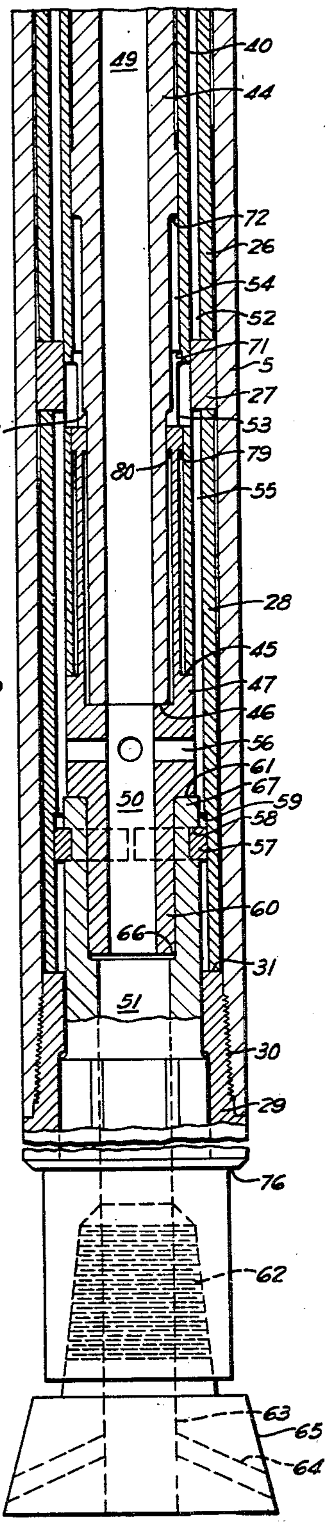

Fig.2

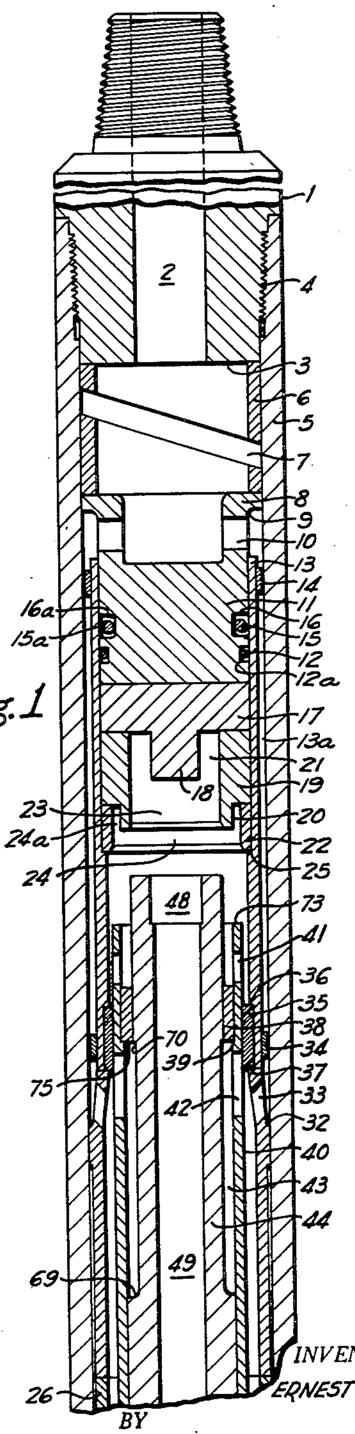

Fig.1

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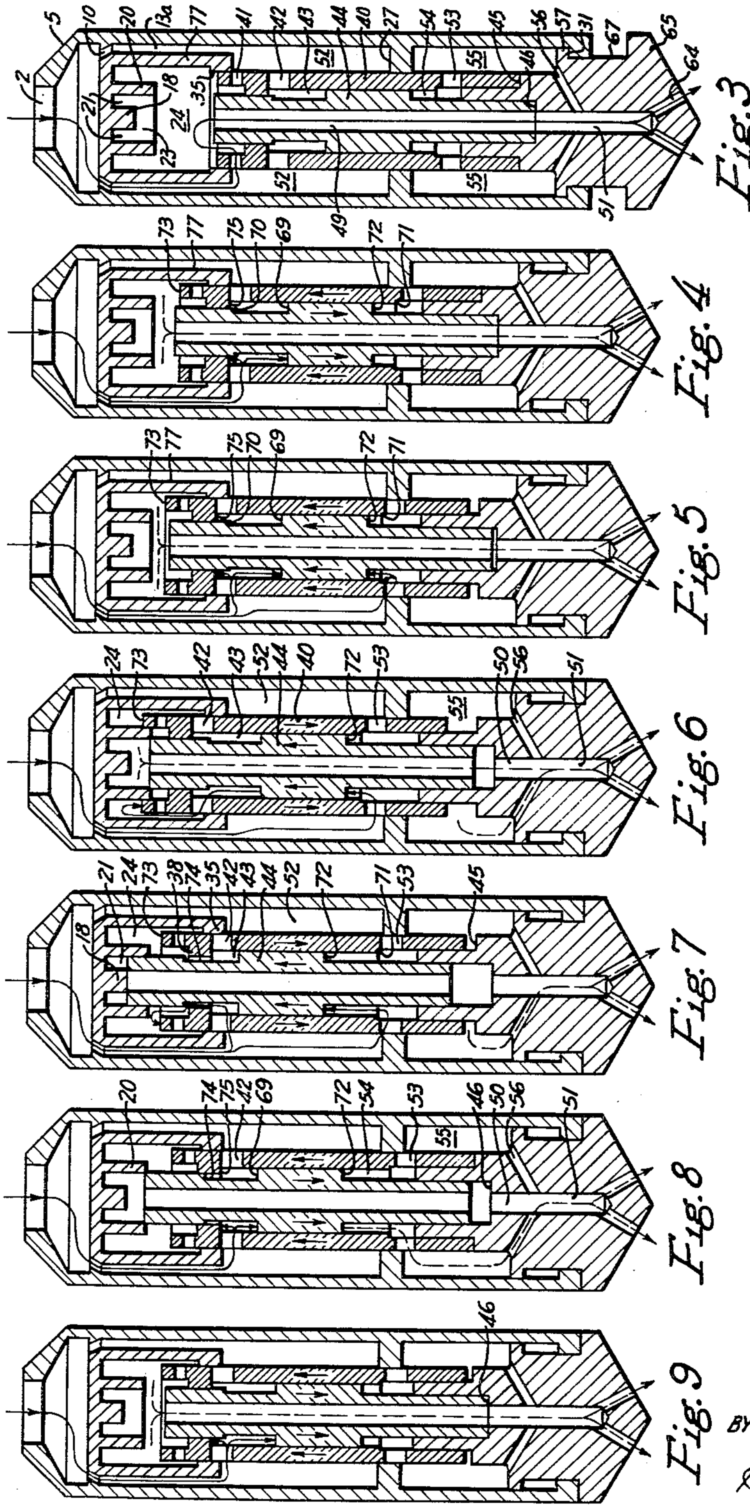

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POSITIVE DISPLACEMENT-TYPE HAMMER DRILL

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9 Claims. (Cl. 121—15)

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

One of the advantages of my invention is the provision of a hammer drill in which the two reciprocating hammers are the only moving parts. These reciprocatng parts may be made of comparable weight so as to impart separate percussive blows of equal force. Both hammers of my invention strike the anvil directly and at different times with approximately the same force.

Another advantage of my invention is the provision of a hammer drill in which each of the hammers acts as a valving element as well as imparting a useful percussive blow at the end of its downward travel. In my invention ports for fluid passage are incorporated in the outer hammer, and the central passage of the inner hammer also acts intermittently as a passage for fluid, so that both hammers function as valving elements.

A further advantage of my invention is in providing a fluid operated mechanism for delivering percussive blows to the drill bit without interrupting the downward flow of fluid through the drill pipe and bit. My invention provides for continuous flow of fluid through the mechanism in that the fluid flow is never completely shut off by the hammers at any point in their reciprocating motion. My invention is a positive displacement-type drill and there are no openings or passages that permit fluid to bypass the unit during the operating cycle so that all fluid supplied to the unit is utilized except for a minimal amount of leakage. Conversely since all of the flow supplied to the unit is effective, the drill will operate with a minimum of flow.

Still another advantage of my invention is the provision of a hammer drill in which both hammers are hydraulically driven in both directions so that the force and frequency of the blows applied to the anvil by the hammers are direct functions of the flow rate of fluid through the drill mechanism.

Because of the fact that both hammers of my invention are hydraulically driven in both directions and the operation of the mechanism is not therefore dependent on the force of gravity aided by spring action to move the hammers downward, my drill is not limited to operation in a vertical position such as is normally used in well drilling but will function in any plane inclined to the vertical or in a horizontal position or in an inverted position.

A further advantage of my invention is the provision of a percussion drill which will operate with relatively light weight on the formation being drilled.

Another advantage of my invention is the provision of a positive displacement-type hammer drill in which both hammers operate continuously. When either of the hammers strikes the anvil or has reached its maximum elevation on the up-stroke and is momentarily stopped, the other hammer is in motion. In this manner intermittent flow, which is a principal factor in causing pressure surges, is prevented, so that fluid pressure surges caused by the hammer portion of the drill mechanism are practically eliminated. Furthermore, the upward movement of both hammers is arrested by hydraulic cushion action which is also effective in preventing hydraulic hammer and consequent fluid pressure surges.

A still further advantage of my invention is the provision of a hammer drill of simplified design such that all parts may be made large, heavy and strong whereby breakage of parts and shutdown of the drill for repairs is substantially eliminated.

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

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

Figure 2 is a longitudinal section taken through the lower portion of the drill of Figure 1 showing the drill bit attached thereto; and

Figures 3 to 9 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 Figure 1 adaptor **1** serves to connect the drill assembly with the drill string (not shown), the latter having a central passage as is conventional for supplying drilling fluid. Adaptor **1** is provided with a central passage **2** for the purpose of supplying drilling fluid under pressure to the drill mechanism. Adaptor **1** is screwed into the drill housing **5** by threads **4**. Immediately below adaptor **1** and fitting snugly within housing **5** is a short circular section of flat spacer spring **6** provided with a space **7** between spirals which permits limited compression of the spring. The purpose of this spring will be described later.

Below spacer spring **6** is positioned a manifold **8** which fits snugly within housing **5**, against the lower surface of spring **6**. The upper portion of manifold **8** is hollow to receive the downward flow of fluid from passage **2** of the adaptor. Below the upper end of manifold **8** is a portion of reduced external diameter as at **9** which is provided at this point with a series of ports **10** spaced about its circumference, through which the downward flow fluid is laterally diverted by the solid lower portion **11** of manifold **8**. The solid lower portion **11** of manifold **8** fits snugly within cylinder **13**, being sealed to the inside of cylinder **13** by O-ring **12** which is seated in a groove **12*a***. Cylinder **13** is concentrically positioned within housing **5** by lugs **14** of which there are three or more circumferentially spaced therearound and which may be welded to the outer surface of cylinder **13** to serve as guides, sliding freely on the inner surface of housing **5** during assembly or adjustment of the parts but allowing circulation of fluid between lugs. Manifold **8** is held in place abutting the lower surface of spacer spring **6** by two parallel pins **15** and **15*a*** which are inserted through the wall of cylinder **13** from the outside thereof and which engage slots **16** and **16*a*** in manifold **8**. Both ends of pins **15** and **15*a*** extend beyond the cylinder sufficiently so that housing **5** will prevent them from being displaced while the assembly is inside of the housing. The pins **15** and **15*a*** are easily removed when the inner assembly is withdrawn from the housing **5** if repair or replacement of parts becomes necessary. Slots **16** and **16*a*** are of sufficient longitudinal dimension to permit limited longitudinal movement of manifold **8**, the purpose of which will be explained later.

Abutting the lower surface of manifold **8** and fitting snugly within the cylinder **13** is a solid cylindrical member **17** provided with a downwardly projecting central boss

18. Fitting snugly within cylinder 13, an annular member 19 abuts the lower side of cylindrical member 17, defining the annular space 21 which, in conjunction with boss 18 and the hydraulic fluid, acts as a dash-pot to hydraulically cushion and terminate the upward movement of the inner hammer when it approaches the limit of its upward travel. The lower end of annular member 19 has a portion of reduced external diameter as at 20 and positioned partly within the annular space defined between the portion of reduced diameter 20 and cylinder 13 is a small annular member 22. The small annular member 22 fits snugly within cylinder 13 and extends below the lowermost part of the portion of reduced external diameter 20 of annular member 19. The lower end of the small annular member 22 fits against a shoulder 25 in the inner surface of cylinder 13. At its lower end cylinder 13 in turn abuts liner 26 which also fits closely within housing 5. Liner 26 at its lower end fits against lower valve ring 27 and below lower valve ring 27 is still another liner 28, each of these members fitting closely within housing 5.

The lower end of housing 5 is threaded as at 30 for a bushing 29 which has a smaller internal diameter than housing 5 so that the various liners, valve ring, etc. are firmly clamped between shoulder 31 of bushing 29 and shoulder 3 of adaptor 1 when the bushing 29 is screwed up tightly into housing 5. Thus bushing 29 holds in place, within housing 5, liner 28, lower valve ring 27, liner 26, cylinder 13 and cylindrical member 17, annular members 19 and 22, manifold 8 and spacer spring 6, the latter abutting against shoulder 3 of adaptor 1. The purpose of spacer spring 6 with space 7 for compression thereof and the longitudinal space in slots 16 and 16*a*, permitting limited longitudinal movement of pins 15 and 15*a* relative to manifold 8 can now be explained. All of the parts enumerated are clamped tightly between the shoulder 31 of bushing 29 and the lower shoulder 3 of adaptor 1, with spacer spring 6 taking up any slack that might accumulate in assembly of these parts due to the machining tolerances required. The longitudinal space in slots 16 and 16*a* permits limited longitudinal movement of manifold 8 to adjust to position with respect to cylinder 13 and spacer spring 6 in taking up slack as described.

Manifold 8 also acts as a sealing head for cylinder 13. By use of this construction, including spacer spring 6, the need for machining a special spacer for each hammer drill is eliminated so that drill parts are interchangeable. Furthermore, the upper surfaces of manifold 8 are always subject to fluid pressure which is higher at all times than the fluid pressure on the lower side of the manifold and the area of the surfaces on the upper side of manifold 8 which is exposed to such higher fluid pressure is also larger so that a downward thrust is maintained at all times on the assembled parts. In addition to the fluid pressure holding these parts clamped tightly down against shoulder 31 of bushing 29 the parts are assembled with an initial pressure loading against spacer spring 6. With this downward thrust maintained at all times any chance of these parts moving up and down during high speed, high pressure operation and peening their ends is eliminated.

It is apparent that cylinder 13, liners 26 and 28, lower valve ring 27 and annular members 17, 19 and 22 could be made integral with housing 5, the inside of the housing being bored to the several internal diameters and shoulders as required. The equivalent construction shown is more convenient to manufacture because the housing 5 can be bored with a single internal diameter. The separate parts 27, 13, 17, 22, 26 and 28 are more easily finished separately to close dimensions and to better surface finish, and they provide the necessary shoulders or differences in diameter for assembly. In addition any of these smaller parts may easily be replaced if they become worn.

Cylinder 13 has a shoulder 32 on its external circumference, cylinder 13 being of such diameter below shoulder 32 as to fit snugly within housing 5 and above shoulder 32 being of a reduced diameter such as to permit passage of drilling fluid through annular space 13*a* between housing 5 and the outer surface of cylinder 13. Immediately above shoulder 32, cylinder 13 is provided with a series of ports 33 spaced about its circumference. By means of these ports downwardly flowing drilling fluid is permitted to pass from space 13*a* outside of cylinder 13 to its interior. Above ports 33 are lugs 34 of which there are three or more circumferentially spaced equi-distant from each other and welded to the outer surface of cylinder 13 to hold it concentric within housing 5 but permitting fluid to flow freely between the lugs. Lugs 34 fit snugly within housing 5 sliding freely on the inner surface of the latter during assembly and/or adjustment of the parts against the tension of spacer spring 6, similarly to lugs 14.

Within cylinder 13 immediately above ports 33 and opposite lugs 34 is a constriction comprising an upper valve ring 35 seated between upper and lower shoulders 36 and 37 in the inner surface of cylinder 13 and forming a sliding seal about outer hammer 40.

Upper valve ring 35 is non-moving and is essentially a part of cylinder 13. While it is shown in Figure 1 as a separate element it will be understood that it may be made integral with cylinder 13. It is advantageously made and inserted as a separate element in order that it may be more easily replaced as it is subject to wear from sliding contact with outer hammer 40 during the high-speed reciprocating movement of the latter while the hammer drill is in operation. Also it will be noted that upper valve ring 35 constitutes the lower end of the structure comprising outer cylinder 77 as shown in the schematic drawings 3 to 9 inclusive defining outer cylinder chamber 24.

Outer hammer 40 is an elongate hollow, substantially cylindrically shaped element provided with by-pass ports 41 which are spaced about the circumference of hammer 40 immediately adjacent its upper end and a short distance below by-pass ports 41 are upper ports 42 which are also spaced about the circumference of hammer 40. Between ports 41 and 42, on the inner circumference of hammer 40 is a sealing ring 38 seated at its lower end in a shoulder 39 in the inner surface of hammer 40 and forming a sliding seal about inner hammer 44.

The wall thickness of outer hammer 40 is uniform through its central portion, which wall thickness continues upward to shoulder 39 on the inner surface of the hammer. From shoulder 39 upward to the upper end of the hammer the wall thickness of the hammer is decreased by the dimension of the shoulder. Sealing ring 38 is essentially a part of outer hammer 40. It will be understood that while it is shown as a separate element in Figure 1 it may be made an integral part of outer hammer 40. Like upper valve ring 35, it is advantageously constructed as a separate element in order to be more easily replaceable as it is subject to wear in the reciprocating movement of the hammers.

Ports 33 in cylinder 13 afford access between passage 13*a* and an annular shaped upper housing chamber 52 which is situated below ports 33 within the lower portion of cylinder 13. Below ports 33 cylinder 13 is of enlarged diameter and constitutes a liner, fitting snugly within housing 5. Abutting the lower end of cylinder 13 is a liner 26 also fitting snugly within housing 5. A constriction in the housing comprising a lower valve ring 27 abuts the lower end of liner 26. A lower housing chamber 55 is formed below lower valve ring 27. Adjacent the lower end of outer hammer 40 a series of ports 53 is spaced about the circumference of the hammer. Ports 53 afford lower fluid course chamber 54 access alternately to upper and lower housing chambers 52 and 55 respectively.

As has been stated, the wall thickness of outer hammer 40 is uniform through the central portion of the hammer. This uniform wall thickness is continued downward to a point just above the lower ports 53. At this point the wall thickness of hammer 40 is decreased by a small amount on its inner surface thereby providing a narrow, downwardly facing shoulder 71, the purpose of which will be discussed later. The decreased wall thickness of hammer 40 is continued from shoulder 71 to the lower end of the hammer. Below lower valve ring 27 an annular shaped lower housing chamber 55 is defined by the valve ring 27, liner 28, the outer surface of outer hammer 40, the outer surface of anvil 47 and the upper end of bit stem 67 including split ring 57 sealing bit stem 67 to liner 28. It will be noted that chamber 55 is always open to the outside of the drill housing by way of passages 56, 50, 51, 63 and 64.

Starting now at the lower end of Figure 2 there is shown a bit stem 67 which has a central passage 51 through which drilling fluid reaches the bit. A conventional drilling bit 65 may be screwed into the bit stem 67 by means of threads 62. The drill bit 65 has a central passage 63 and is further provided with jetting passages 64 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 bit stem 67 is hexagonally shaped and the bushing 29 is hexagonally shaped internally to match the shape of the bit stem so that torque may be transmitted from the bushing 29 to the bit stem and bit. Instead of using hexagonally shaped facings on the bushing and bit stem, square or other equivalent shapes may be used or the rotary driving engagement between bushing 29 and bit stem 67 may be accomplished by grooves in the bushing and mating splines on the bit stem which engage the grooves.

Accordingly, during drilling the entire assembly may be rotated from the surface of the ground by means of a conventional drill string (not shown) and this will rotate the bit 65. The bit stem 67 fits slidably within bushing 29 permitting a limited amount of longitudinal movement. The upper end of bit stem 67 extends above bushing 29 and is provided with a split ring 57 rigidly mounted in groove 58. Split ring 57 is slidably sealed to the inner surface of liner 28. The downward movement of bit stem 67 is limited by split ring 57 so that when bit stem 67 is in its lowermost position, split ring 57 abuts against shoulder 31 of bushing 29. The upward movement of bit stem 67 is also limited, so that when it is in its uppermost position the split ring 57 abuts against a shoulder 59 within liner 28 and external shoulder 76 on the lower end of bit stem 67 abuts against the lower end of bushing 29.

Inner hammer 44 is a substantially cylindrical member longitudinally positioned concentrically within outer hammer 40 and is provided with a central passage 49 which is of increased internal diameter within its upper end as at 48. The increased internal diameter of passage 49 at 48 is in order to accommodate boss 18 at the limit of the upward motion of inner hammer 44 and at the same time to permit the escape of entrapped drilling fluid in a dash-pot type of operation, to avoid hydraulic hammer. The external diameter of inner hammer 44 at its upper end is such that it fits closely within sealing ring 38 of outer hammer 40. A short distance below the upper end of inner hammer 44 the external diameter is decreased, providing a narrow downwardly facing shoulder 70, the purpose of which will be explained later. The portion of hammer 44 of decreased external diameter continues downward from shoulder 70 to shoulder 69. At shoulder 69 the external diameter of hammer 44 is substantially increased so that inner hammer 44 forms a snug sliding fit within outer hammer 40. The portion of inner hammer 44 which is of increased external diameter extends from shoulder 69 downward to shoulder 72 where the exterior diameter is decreased to approximately the same dimension as that portion of the hammer, above described, between shoulders 69 and 70. The reduction in external diameter of hammer 44 extends downward from shoulder 72 to a point a short distance above the upper end of anvil 47 when inner hammer 44 is in its lowermost position relative to the anvil, as shown in Figure 2. At this point the external diameter of hammer 44 is still further reduced to form a downwardly facing shoulder 78 on the outer surface of hammer 44. This reduction in external diameter extends downward from shoulder 78 to the lower end of hammer 44. This last described reduction in external diameter of hammer 44 serves to conveniently fit hammer 44 within anvil 47. The function of shoulders 69 and 72 will be explained later.

The variations in external diameter of inner hammer 44 create two elongate annular spaces between the inner and outer hammers which are designated as upper and lower fluid course chambers, the functions of which will be explained. Upper fluid course chamber 43 is defined by shoulders 69 and 70 and the outer surface of hammer 44 between them and the inner surface of hammer 40 from a lower point adjacent shoulder 69 on the inner hammer to the shoulder 75 formed by the lower side of sealing ring 38 where it abuts shoulder 39 in outer hammer 40, and including that portion of the inner periphery of outer hammer 40 provided with upper ports 42. Lower fluid course chamber 54 is defined by the outer surface of inner hammer 44 from shoulder 72 downward to the upper end of anvil 47 which abuts hammer 44, and the inner surface of outer hammer 40 from a point adjacent shoulder 72 on the inner hammer, downward to a point adjacent the upper end of anvil 47 which also abuts hammer 40, including that portion of the inner periphery of outer hammer 40 provided with lower ports 53 and shoulder 71, and the upper end of anvil 47. It will be understood that during the reciprocating motion of the hammers those portions of the inner surface of outer hammer 40 which define portions of upper and lower fluid course chambers 43 and 54 will vary. Also when the inner hammer is elevated with respect to the outer hammer, as shown in Figures 7 and 8, sealing ring 38 is not in contact with the outer surface of the inner hammer but forms a narrow passage 74 between the ring 38 and the surface of inner hammer 44 where it is of reduced diameter below shoulder 70.

Anvil 47 is an elongated substantially cylindrically shaped element with a longitudinal passage 50 through the center. Anvil 47 is positioned concentrically within housing 5, below and in the path of hammers 40 and 44 and extends upward between them above the highest point of upward movement of the lower end of either of the hammers. At its upper end the anvil 47 forms a close sliding fit between the inner and outer hammers 44 and 40 respectively and serves as a guide to direct the vertical reciprocating movement of the hammers to their respective seats. The external diameter of anvil 47 is increased at a point below its upper end providing a shoulder 45 on which outer hammer 40 seats and delivers its percussive blows. The outer surface of anvil 47 is recessed from shoulder 45 upward to a point, 79, above the highest point of elevation of the lower end of outer hammer 40, in order to provide clearance for any peening which may develop on the lower end of hammer 40 during operation. The width of shoulder 45 is therefore slightly greater than the wall thickness of outer hammer 40 at this point. Hammer 40 above and anvil 47 below present a uniform exterior diameter. The increased external diameter of anvil 47 continues downward to the point at which it abuts the upper end of bit stem 67. At this point the exterior diameter of anvil 47 is reduced as at 60 to form a sliding fit within bit stem 67, the reduction in diameter providing a downwardly facing shoulder 61 on the exterior surface of anvil 47 which abuts the upper end of the bit stem 67. The internal diameter of anvil 47 is increased at a point below its upper end to provide a shoulder 46 on which inner hammer 44 seats and delivers its percussive blows. The inner surface of anvil 47 is recessed from shoulder 46 upward to a point, 80, above the highest point of elevation of the lower end of inner hammer 44, in order to provide clearance for any peening which may develop on the lower end of inner hammer 44 during operation. Shoulder 46 is therefore slightly greater in width than the wall thickness of that portion of inner hammer 44 adjacent anvil 47. The interior surface of inner hammer 44 and anvil 47 which constitute passages 49 and 50 respectively are of uniform internal diameter. Inner hammer 44 seats on and delivers its percussive blows to shoulder 46. Shoulders 45 and 46 therefore constitute anvil faces. The lower end of the anvil is seated on a shoulder 66 in the interior surface of bit stem 67. Central passage 50 within anvil 47 is in register with central passage 49 of inner hammer 44 and with central passage 51 of bit stem 67 all being of the same internal diameter and forming a continuous smooth surfaced conduit. Passage 51 in turn connects with passages 63 and 64 of bit 65, and through these is connected to the outside of housing 5.

A short distance below the top of outer hammer 40 there are provided a series of by-pass ports 41. When outer hammer 40 is in its lowermost position it still partially penetrates outer cylinder 77 as shown in Figure 3 and the tip of its upper end is still within upper valve ring 35 but ports 41 are not covered by the ring. This permits drilling fluid to be circulated through the drill without activating the hammers. The purpose of this is to permit drilling-off (as will be described in more detail later), and to facilitate drilling-in by permitting the drill to be run into or out of the bore hole with the drill rotating and with fluid flowing through the drill assembly but without activating the hammer mechanism. When by-pass ports 41 are above upper valve ring 35 the free circulation of drilling fluid through the drill assembly is cut off; fluid pressure begins to build up and the hammer mechanism becomes activated by the increased fluid pressure. However, once the hammer mechanism has been started its continuous operation assures an uninterrupted flow of fluid through the drill.

While the length of the various elements of my drill are not conveniently indicated in Figures 1 and 2 of the accompanying drawings, it is believed clear to those skilled in the art that the length of inner hammer 44 and outer hammer 40 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 67 is in its lowermost position, i. e. with split ring 57 resting on shoulder 31 of bushing 29, anvil 47 resting in turn on shoulders 61 and 66 and hammers 40 and 44 resting on anvil faces 45 and 46 the lengths of the parts are made so that the top of outer hammer 40 penetrates upper valve ring 35 a short distance but leaving by-pass ports 41 fully uncovered.

The operation of my above-described drill will now be explained. Reference is made to the diagrams of Figures 3 to 9 showing the various phases during the operation of my drill and in which diagrams the numerals indicate the same elements as in Figures 1 and 2 previously described.

The entire unit will be suspended vertically in the well bore with ordinary rotary drill string (not shown) attached to adaptor 1, means being provided at the surface for supplying drilling fluid under pressure to the central passage of the drill string as is well known in the art. Starting with the drill bit 65 several feet above the bottom of the hole, bit stem 67 and the other parts will be in their lowermost positions as described above. The configuration of parts will be as shown in Figure 3.

It is usually desirable to "rotate in" when a new bit has been attached to the drill in order to insure that the bore hole 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 botttom of the well bore. During this "rotating in" process, drilling fluid will be circulated through the drill, using by-pass ports 41, and returning up the hole outside of the drill housing 5. Thus hammering will not take place to endanger the drill pipe or other parts as the drill is lowered into the hole.

With the unit suspended in the well bore the weight of the hammers 40 and 44 and the weight of the anvil 47 plus the weight of the bit 65 and bit stem 67 will force all of these parts downward to their lowermost position as shown in Figure 3. In this position split ring 57 on the bit stem comes in contact with the upper shoulder 31 of bushing 29, and by-pass ports 41 at the upper end of outer hammer 40 are below upper valve ring 35. Drilling fluid flowing down through the drill string enters the adaptor through the central passage 2 therein, passes through the open center of spacer spring 6 to manifold 8 and is laterally diverted through manifold ports 10 down annular space 13a between cylinder 13 and housing 5 into upper housing chamber 52. The fluid is free to flow through by-pass ports 41 in outer hammer 40 into outer cylinder chamber 24, down central passages 49, 50 and 51 of inner hammer, anvil and bit stem and out of the drill through central passage 63 and jetting holes 64 in bit 65. Thus the free flow of fluid is maintained for flushing out the well bore. The upper fluid course chamber 43 is open to upper housing chamber 52 via upper ports 42 in outer hammer 40. The lower fluid course chamber 54 is open, via lower ports 53 in outer hammer 40, to lower housing chamber 55, which in turn is always open to the outside of the drill through passages 56, 50, 51, 63, and 64. Thus all chambers are in open connection and fluid pressures are substantially the same throughout the mechanism so that no forces are present to cause movement of the hammers.

Upon continuing to lower and rotate the mechanism, including bit stem 67 and bit 65, 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 longitudinal position of housing 5 and the parts carried thereon relative to the internal parts 67, 47, 40 and 44. With the drill bit resting on bottom, the housing 5 with bushing 29 attached continues downward until the lower end of bushing 29 rests on external bit stem shoulder 76 as shown in Figure 4.

It will be noted that in the diagrammatic representations comprising Figures 3 through 9 inclusive, the outer cylinder designated by the numeral 77 is composed of several parts which are shown as separate elements in Figure 1; namely, annular members 17, 19 and 22 at the top, upper valve ring 35 at the bottom and the wall of cylinder 13 between these parts joining the elements into substantially a single unit.

The function of shoulders 71 and 75 on outer hammer 40, and shoulders 69, 70 and 72 on inner hammer 44 can now be described. These shoulders present surfaces which are acted upon by the pressure drilling fluid introduced intermittently, by valving action, into the upper and lower fluid course chambers of the drill through upper and lower ports 42 and 53 thereby producing reciprocating motion of the hammers as will be explained. Shoulders 71, 75, 69, 70 and 72 therefore constitute primary and secondary lifting areas, and down driving areas on the respective hammers and they are so designated hereinafter. Area 73 on the upper end of outer hammer 40 is also a down driving area and is designated as such.

After the drill bit contacts the bottom of the bore hole, continued lowering of the drill string with attached housing 5 and the non-moving parts of the drill contained therein, including upper valve ring 35, moves these elements downward with respect to bit 65 and the other moving parts of the hammer drill mechanism, namely, bit stem 67, anvil 47 and hammers 40 and 44, so that by-pass ports 41 in outer hammer 40 are closed off by upper valve ring 35 which is fixed within cylinder 13 in housing 5, thus interrupting the free flow of fluid through the drill. The parts will then be essentially in the position as shown diagrammatically in Figure 4. Due to the fact that there is no immediate outlet for the fluid being supplied under pressure from the surface of the ground, fluid pressure will build up within annular passage 2, manifold 8, through ports 10, annular space 13*a* and ports 33 into upper housing chamber 52 and through upper ports 42 in outer hammer 40 into upper fluid course chamber 43 between the inner and outer hammers. The increased fluid pressure acts simultaneously on both hammers. The force exerted by the fluid pressure on primary lifting area 75 of outer hammer 40 starts it moving upward. A force is also exerted by the fluid pressure acting on primary lifting area 70 of inner hammer 44. However the force exerted on primary lifting area 70 is more than counterbalanced by the downward force exerted by the fluid on down driving area 69 of inner hammer 44, holding hammer 44 down on the anvil.

When the outer hammer 40 has been raised to a point where lower valve ring 27 has closed lower ports 53 in outer hammer 40 from lower housing chamber 55 and slightly opened lower ports 53 to upper housing chamber 52, fluid pressure is transmitted from chamber 52 through ports 53 into lower fluid course chamber 54 between the inner and outer hammers. When fluid pressure is transmitted into lower fluid course chamber 54 it acts on secondary lifting area 71 of outer hammer 40 boosting its upward motion. This fluid pressure also acts on the secondary lifting area 72 of inner hammer 44 exerting a force which is equal to or slightly larger than that exerted on down driving area 69 of inner hammer 44, whereby the downward force on inner hammer 44, (previously holding it down on the anvil) is cancelled. This leaves the force exerted on primary lifting area 70 the only effective force being exerted on inner hammer 44, so that hammer 44 then starts to move upward. Fluid displaced by the upward-moving inner hammer 44 in cylinder chamber 24 escapes through central passage 49 in inner hammer 44 which is always open via passages 50, 51, 63 and the bit jetting holes 64 to the lower pressure outside of the drill. This stage of the operation is illustrated in Figure 5 of the schematic drawings.

The overlap of operation of upper and lower ports 42 and 53 determines the location of outer hammer 40 when inner hammer 44 starts upward, and also regulates the speed and impact of the outer hammer on its downward travel. The amount of overlap depends on the location of lower valve ring 27 which can be adjusted by means of different spacer lengths in the finished drill.

At the start of operation of the hammer mechanism, inner hammer 44 is held down against anvil seat 46 while outer hammer 40 starts moving upward under the impetus of fluid pressure. After outer hammer 40 is moving upward, inner hammer 44 starts its upward travel as described above. When outer hammer 40 approaches its maximum elevation, inner hammer 44 is entering inner cylinder 20 sealing off inner cylinder chamber 23 from outer cylinder chamber 24 and thereby sealing off the escape of fluid from chamber 24 (by means of passage 49 in inner hammer 44. Fluid entrapped in outer cylinder chamber 24 acts as a hydraulic stop for the upward movement of outer hammer 40.

As inner hammer 44 continues its upward stroke to maximum elevation, fluid is also entrapped by it in annular space 21 between annular member 20 and boss 18, and acts as a hydraulic stop for the upward movement of inner hammer 44. This operation will be described in more detail below. It will be understood that outer cylinder chamber 24 of Figure 6 is the same as chamber 24 in Figure 1 which is defined at its upper end by annular member 22, at its lower end by upper valve ring 35 and on its outer periphery by cylinder 13.

As shown in Figure 6, upper ports 42 are closed to upper housing chamber 52 and open to outer cylinder chamber 24 connecting chamber 24 with upper fluid course chamber 43 between the inner and outer hammers. Inner hammer 44 continues to travel upward, under the pressure transmitted through lower ports 53 and acting on secondary lifting area 72 of inner hammer 44. This upward movement of inner hammer 44 displaces fluid from upper fluid course chamber 43 which moves out through upper ports 42 into outer cylinder chamber 24 and there exerts force on the top area 73 of outer hammer 40 driving it downward. Fluid displaced in lower housing chamber 55 by the lower end of outer hammer 40 moving downward escapes through anvil passages 56 and 50 and bit stem passage 51 which, as stated, are always open to the lower pressure outside of the drill.

As shown in Figure 7, when inner hammer 44 reaches its maximum elevation it engages boss 18 forming annular chamber 21 in which fluid is trapped. However, the internal diameter of the longitudinal passage 49 through inner hammer 44 is increased as at 48 so that fluid trapped in chamber 21 can escape between the boss and the inner circumference of the hammer down passage 49 in hammer 44. Thus chamber 21 and boss 18 function as a dashpot for hammer 44 and stop its upward movement gradually, operating as a hydraulic cylinder, thereby avoiding a sudden stop and resulting hydraulic hammer. At this point outer hammer 40 has moved downward sufficiently so that upper ports 42 are below upper valve ring 35 opening upper fluid course chamber 43 to high fluid pressure from upper housing chamber 52. Also sealing ring 38 of outer hammer 40 is no longer sealed to the outer surface of inner hammer 44 but faces upper fluid course chamber 43 forming a passage 74 between sealing ring 38 and inner hammer 44. High fluid pressure is therefore transmitted from upper housing chamber 52 through ports 42 into upper fluid course chamber 43, through passage 74 and into outer cylinder chamber 24 where it exerts a force on the top area 73 of outer hammer 40 accelerating its downward movement. Lower ports 53 are almost closed to upper housing chamber 52 and when closed upward pressure on secondary lifting area 71 of outer hammer 40 and secondary lifting area 72 of inner hammer 44 will be cut off.

When outer hammer 40 delivers its blow to anvil face 45 inner hammer 44 is moving downward under the impetus of fluid pressure on downward driving area 69 exerted through upper ports 42 and upper fluid course chamber 43. Fluid displaced in lower fluid course chamber 54 by the lower end of inner hammer 44 moving downward escapes through lower ports 53, which are open at this point to lower housing chamber 55. As shown in Figure 8 of the drawings, at this stage of the operation inner hammer 44 is moving downward, leaving inner cylinder 20, and sealing ring 38 of outer hammer 40 is seating against inner hammer 44 closing passage 74. With passage 74 closed, fluid pressure is exerted on primary lifting area 75 of outer hammer 40 to start it moving upward again on its next stroke.

After outer hammer 40 delivers its blow to anvil face 45 and starts upward for its next stroke, inner hammer 44 delivers its blow to anvil face 46. Although outer hammer 40 is moving upward, lower ports 53 are still open to lower housing chamber 55 which, as has been pointed out, is always open to the outside of the drill housing by way of passages 56, 50, 51, 63 and 64, so that no fluid pressure is exerted on secondary lifting area 72 of inner hammer 44. A downward force is exerted by the fluid pressure acting through upper ports 42 on down driving area 69 of inner hammer 44 holding it down on anvil face 46. This stage of the operation of the drill is illustrated in Figure 9 of the diagrammatic drawings.

This completes the operating cycle which starts over again beginning as shown in Figure 5. It will be noted that after the drill action starts, both hammers are never in contact with the anvil at the same time and are always moving relative to each other, thereby maintaining an uninterrupted flow of drilling fluid. In the operation of this hammer drill an operating speed of six hundred cycles per minute was achieved, making a total of twelve hundred blows per minute delivered to the anvil by the hammers.

While the above described hammer represents a preferred embodiment of my invention an alternative type of construction may be used in which either hammer constitutes the sole effective percussive element and the other hammer acts only as a valving element. In such an alternative embodiment of my invention the hammer constituting the valving element would be of much lighter construction. For example, it could be made of much lesser wall thickness, or of a lighter material such as aluminum, or both.

As previously stated, my hammer drill is not limited to operation in a vertical position, since it is not dependent on the force of gravity to assist the hammers in imparting percussive blows to the anvil. In the description of the parts of my drill both in this specification and in the appended claims the terms up, down, above, below, upwardly, downwardly, etc., have been used in a relative sense, that is, the words up, above, and upwardly refer to a direction toward adaptor 1 from which the pressurized operating fluid flows, while below, down, and downwardly refer to a direction toward the bit stem and bit at the opposite end of the hammer drill assembly, i. e. the direction in which the pressurized operating fluid is discharged.

It will be apparent that other modifications and variations may be made in the above described structure and its method of operation, without departing from the scope and spirit of the present invention, therefore only such limitations should be imposed as are indicated in the appended claims.

I claim:

1. A fluid operated positive displacement type hammer mechanism comprising a tubular housing, an elongate hollow outer hammer provided with upper and lower ports therein adjacent the respective upper and lower ends thereof, said outer hammer being longitudinally disposed within said housing, an elongate inner hammer longitudinally disposed within and slidably sealed to the inner surface of said outer hammer, said inner hammer being provided with a longitudinal passage therethrough, a cylinder closed at its upper end disposed within the upper end of said housing and with the upper ends of said hammers extending within said cylinder, an anvil disposed within said housing below and in the path of said hammers, said anvil being provided with a longitudinal passage therethrough in register with the passage in said inner hammer, a constriction within said cylinder slidably sealed about the upper end of said outer hammer, a constriction within said housing slidably sealed about the lower end of said outer hammer, means introducing pressurized operating fluid into said housing below said cylinder, an upper fluid course chamber formed between the upper portion of the inner hammer and the upper portion of the outer hammer, said upper fluid course chamber being adapted to cooperate with said upper ports in said outer hammer and said constriction in said cylinder to effect longitudinal reciprocating movement of said inner and outer hammers under the force of the pressurized operating fluid, a lower fluid course chamber formed between the lower portion of the inner hammer and the lower portion of the outer hammer, said lower fluid course chamber being adapted to cooperate with said lower ports in said outer hammer and said constriction in said housing to assist in effecting

longitudinal reciprocating movement of said inner and outer hammers under the force of the pressurized operating fluid.

2. A fluid operated positive displacement type hammer mechanism comprising a tubular housing, an elongate hollow outer hammer positioned longitudinally within said housing, said outer hammer being provided with upper and lower ports adjacent the respective upper and lower ends thereof and being adapted for longitudinal reciprocating movement, an elongate inner hammer provided with a longitudinal passage therethrough, said inner hammer being longitudinally disposed within and slidably sealed to the inner surface of said outer hammer and adapted for longitudinal reciprocating movement, a cylinder closed at its upper end disposed within the upper end of said housing and with the upper ends of said hammers extending within said cylinder, an anvil disposed within said housing below and in the path of said hammers, said anvil being provided with faces for seating said inner and outer hammers and for receiving percussive blows therefrom and being provided with a longitudinal passage therethrough in register with the longitudinal passage in said inner hammer, a constriction within said cylinder slidably sealed about the upper end of said outer hammer adjacent the upper ports therein, a constriction in said housing slidably sealed about the lower end of said outer hammer adjacent the lower ports therein, means introducing pressurized operating fluid into said housing below the lower end of said cylinder and affording said pressurized operating fluid intermittent access to the upper and lower ports in said outer hammer, an upper fluid course chamber formed between the upper portion of the inner hammer and the upper portion of the outer hammer, a lower fluid course chamber formed between the lower portion of the inner hammer and the lower portion of the outer hammer, said upper fluid course chamber being adapted to cooperate with said upper ports in said outer hammer and said constriction in said cylinder to effect longitudinal reciprocating movement of said inner and outer hammers under the force of the pressurized operating fluid, said lower fluid course chamber being adapted to cooperate with said lower ports in said outer hammer and said constriction in said housing to assist in effecting longitudinal reciprocating movement of said inner and outer hammers under the force of the pressurized operating fluid.

3. A fluid operated positive displacement type hammer mechanism comprising a tubular housing, an elongate hollow outer hammer provided with upper and lower ports adjacent the respective upper and lower ends thereof, said outer hammer being disposed longitudinally within said housing, an elongate inner hammer longitudinally disposed within and slidably sealed to the inner surface of said outer hammer and provided with a longitudinal passage therethrough, a cylinder closed at its upper end disposed within the upper end of said housing and with the upper ends of said hammers extending within said cylinder, a downwardly projecting annular boss and a downwardly extending annular flange surrounding said boss disposed within the upper end of said cylinder, an anvil disposed within said housing below and in the path of said hammers, said anvil being provided with a longitudinal passage therethrough in register with the longitudinal passage in said inner hammer, a constriction within said cylinder slidably sealed about the upper end of said outer hammer adjacent the upper ports therein, a constriction within said housing slidably sealed about the lower end of said outer hammer adjacent the lower ports therein, means introducing pressurized operating fluid into said housing below said cylinder, an upper fluid course chamber formed between the upper portion of the inner hammer and the upper portion of the outer hammer, a lower fluid course chamber formed between the lower portion of the inner hammer and the lower portion of the outer hammer, said upper fluid course chamber being adapted to cooperate

with said upper ports in said outer hammer and said constriction in said cylinder to effect longitudinal reciprocating movement of said inner and outer hammers under the force of the pressurized operating fluid, said lower fluid course chamber being adapted to cooperate with said lower ports in said outer hammer and said constriction in said housing to assist in effecting longitudinal reciprocating movement of said inner and outer hammers under the force of the pressurized operating fluid, said reciprocating movement of said outer hammer being substantially between an upper position defined by closure of said upper ports in said outer hammer by said constriction in said cylinder and a lower position contacting said anvil, and said reciprocating movement of said inner hammer being substantially between an upper position defined by engagement of the upper end of said inner hammer with said downwardly projecting boss and annular flange surrounding said boss within the upper end of said cylinder and a lower position contacting said anvil.

4. A fluid operated positive displacement type hammer mechanism comprising a tubular housing, inner and outer hammers longitudinally disposed within said housing and adapted for longitudinal reciprocating movement, said outer hammer comprising an elongate hollow element provided with upper and lower ports therein adjacent the respective upper and lower ends thereof, said inner hammer comprising an elongate element longitudinally disposed within and slidably sealed to the inner surface of said outer hammer and being provided with a longitudinal passage therethrough, a cylinder closed at its upper end disposed within the upper end of said housing and with the upper ends of said hammers extending within said cylinder, a downwardly projecting annular boss and a downwardly extending annular flange surrounding said boss disposed within the upper end of said cylinder, an anvil disposed within said housing below and in the path of said hammers, said anvil being provided with faces for seating said inner and outer hammers and for receiving percussive blows therefrom and being provided with a longitudinal passage therethrough in register with the longitudinal passage in said inner hammer, a constriction within said cylinder slidably sealed about the upper end of said outer hammer adjacent the upper ports therein, a constriction within said housing slidably sealed about the lower end of said outer hammer adjacent the lower ports therein, means introducing pressurized operating fluid into said housing below said cylinder, shoulders on the outer surface of said inner hammer adjacent the upper end thereof cooperating with a shoulder on the inner surface of said outer hammer adjacent the upper end thereof to form an upper fluid course chamber adapted to receive a flow of said pressurized operating fluid, said upper ports in said outer hammer cooperating with said constriction in said cylinder to intermittently interrupt said flow of pressurized operating fluid to said upper fluid course chamber to effect longitudinal reciprocating movement of said inner and outer hammers, a shoulder on the outer surface of said inner hammer adjacent the lower end thereof cooperating with a shoulder on the inner surface of said outer hammer adjacent the lower end thereof and said anvil to form a lower fluid course chamber adapted to receive a flow of said pressurized operating fluid, said lower ports in said outer hammer cooperating with said constriction in said housing to intermittently interrupt said flow of pressurized operating fluid to said lower fluid course chamber to assist the operation of said upper fluid course chamber in effecting longitudinal reciprocating movement of said inner and outer hammers, said reciprocating movement of said outer hammer being substantially between an upper position defined by closure of said upper ports in said outer hammer by said constriction in said cylinder and a lower position contacting said anvil, and said reciprocating movement of said inner hammer being substantially between an upper position defined by engagement of the upper end of said inner hammer with said downwardly projecting boss and said annular flange surrounding said boss within the upper end of said cylinder and a lower position contacting said anvil.

5. A fluid operated positive displacement type hammer drill comprising a tubular housing, an elongate hollow outer hammer provided with upper and lower ports therein adjacent the respective upper and lower ends thereof, said outer hammer being disposed longitudinally within said housing, an elongate inner hammer longitudinally disposed within and slidably sealed to the inner surface of said outer hammer and provided with a longitudinal passage therethrough, a cylinder closed at its upper end disposed within the upper end of said housing and with the upper ends of said hammers extending within said cylinder, a downwardly projecting annular boss and a downwardly extending annular flange surrounding said boss disposed within the upper end of said cylinder, an anvil disposed within said housing below and in the path of said hammers, said anvil being provided with faces for seating said inner and outer hammers and for receiving percussive blows therefrom and being provided with a longitudinal passage therethrough in register with the longitudinal passage in said inner hammer, means introducing pressurized operating fluid into said housing below said cylinder, a constriction within said cylinder slidably sealed about the upper end of said outer hammer adjacent the upper ports therein, a constriction within said housing slidably sealed about the lower end of said outer hammer adjacent the lower ports therein, an upper fluid course chamber formed between the upper portion of the inner hammer and the upper portion of the outer hammer, a lower fluid course chamber formed between the lower portion of the inner hammer and the lower portion of the outer hammer, said upper fluid course chamber being adapted to cooperate with said upper ports in said outer hammer and said constriction in said cylinder to effect longitudinal reciprocating movement of said inner and outer hammers under the force of the pressurized operating fluid, said lower fluid course chamber being adapted to cooperate with said lower ports in said outer hammer and said constriction in said housing to assist in effecting longitudinal reciprocating movement of said inner and outer hammers under the force of the pressurized operating fluid, said reciprocating movement of said outer hammer being substantially between an upper position defined by closure of said upper ports in said outer hammer by said constriction in said cylinder and a lower position contacting said anvil, said reciprocating movement of said inner hammer being substantially between an upper position defined by engagement of the upper end of said inner hammer with said downwardly projecting boss and annular flange surrounding said boss within the upper end of said cylinder and a lower position contacting said anvil, and a bit stem slidably sealed within the lower end of said housing below said anvil, said bit stem being adapted for carrying a drilling tool and being provided with a longitudinal passage therethrough in register with the longitudinal passage in said anvil.

6. A fluid operated positive displacement type hammer drill comprising a tubular housing an elongate hollow outer hammer provided with upper and lower ports therein adjacent the respective upper and lower ends thereof, said outer hammer being disposed longitudinally within said housing, an elongate inner hammer longitudinally disposed within and slidably sealed to the inner surface of said outer hammer and provided with a longitudinal passage therethrough, said inner hammer being approximately equal in length and mass to said outer hammer, a cylinder closed at its upper end disposed within the upper end of said housing and with the upper ends of said hammers extending within said cylinder, a downwardly projecting annular boss and a downwardly extending annular flange surrounding said boss disposed within the upper end of said cylinder, a constriction within said

cylinder slidably sealed about the upper end of said outer hammer adjacent the upper ports therein, a constriction within said housing slidably sealed about the lower end of said outer hammer adjacent the lower ports therein, an anvil disposed within said housing below and in the path of said hammers, said anvil being provided with faces for seating said inner and outer hammers and for receiving percussive blows therefrom and being provided with a longitudinal passage therethrough in register with the longitudinal passage in said inner hammer, said anvil also being provided with a lateral passageway connecting the longitudinal passage therein with the interior of said housing below said constriction therein exterior of said anvil and said outer hammer, means introducing pressurized operating fluid into said housing below the lower end of said cylinder, an upper fluid course chamber formed between the upper portion of the inner hammer and the upper portion of the outer hammer, a lower fluid course chamber formed between the lower portion of the inner hammer and the lower portion of the outer hammer, said constriction in said cylinder being adapted to cooperate with said upper ports in said outer hammer to afford said pressurized operating fluid intermittent access to said upper fluid course chamber to effect longitudinal reciprocating movement of said inner and outer hammers, said constriction in said housing being adapted to cooperate with said lower ports in said outer hammer to afford said pressurized operating fluid intermittent access to said lower fluid course chamber to assist in effecting longitudinal reciprocating movement of said inner and outer hammers, said reciprocating movement of said outer hammer being substantially between an upper position defined by closure of said upper ports in said outer hammer by said constriction in said cylinder and a lower position contacting said anvil, said reciprocating movement of said inner hammer being substantially between an upper position defined by engagement of the upper end of said inner hammer with said downwardly projecting boss and annular flange surrounding said boss within the upper end of said cylinder and a lower position contacting said anvil, and a bit stem slidably sealed within the lower end of said housing below said anvil, said bit stem being adapted for carrying a drilling tool and being provided with a longitudinal passage therethrough in register with the longitudinal passage in said anvil.

7. A fluid operated positive displacement type hammer drill comprising a tubular housing, an elongate hollow outer hammer positioned longitudinally within said housing, said outer hammer being provided with upper and lower ports adjacent the respective upper and lower ends thereof and being adapted for longitudinal reciprocating movement, an elongate inner hammer provided with a longitudinal passage therethrough, said inner hammer being disposed longitudinally within and slidably sealed to the inner surface of said outer hammer and adapted for longitudinal reciprocating movement, a cylinder closed at its upper end disposed within the upper end of said housing and with the upper ends of said hammers extending within said cylinder, a constriction in said cylinder slidably sealed about the upper end of said outer hammer adjacent the upper ports therein, a constriction in said housing slidably sealed about the lower end of said outer hammer adjacent the lower ports therein, an anvil disposed within said housing below and in the path of said hammers, said anvil being provided with faces for seating said inner and outer hammers and for receiving percussive blows therefrom and being provided with a longitudinal passage therethrough in register with the longitudinal passage in said inner hammer, said anvil also being provided with a lateral passageway connecting the longitudinal passage therein with the interior of said housing below said constriction therein exterior of said anvil and said outer hammer, means introducing pressurized operating fluid into said housing below the lower end of said cylinder and affording said pressurized operating fluid intermittent access to the upper and lower ports in said outer hammer, a sealing ring fixedly attached to the inner surface within the upper end of said outer hammer, said sealing ring being slidably sealed about the upper end of said inner hammer, the lower side of said sealing ring forming a downwardly facing annular shoulder on the inner surface of said outer hammer, a narrow downwardly facing annular shoulder on the inner surface of said outer hammer immediately above said lower ports therein, a narrow downwardly-facing annular shoulder on the outer surface of said inner hammer adjacent the upper end thereof, a wider upwardly facing annular shoulder spaced below said narrow downwardly facing shoulder on the outer surface of said inner hammer, a central portion of said inner hammer of increased external diameter slidably sealed to the inner surface of said outer hammer below said upwardly facing shoulder on said inner hammer, a downwardly facing annular shoulder below said central portion of said inner hammer at least equal in width to said upwardly facing shoulder, and a bit stem slidably sealed within the lower end of said housing below said anvil, said bit stem being provided with a downward extension adapted to carry a drilling tool and being provided with a longitudinal passage therethrough in register with the longitudinal passage in said anvil.

8. The apparatus of claim 7 wherein is provided a downwardly projecting annular boss and a downwardly extending annular flange surrounding said boss disposed within the upper end of said cylinder, said boss and flange being of such dimensions as to provide a downwardly opening annular space therebetween of sufficient width to closely engage said inner hammer at the top of its upward stroke thereby cushioning the termination of the upward movement of said inner hammer and whereby upward movement of said outer hammer is hydraulically cushioned upon closure of said upper ports as said outer hammer approaches maximum elevation on its upward stroke, and fluid pressure is exerted on the upper end thereof tending to drive said outer hammer downward.

9. A fluid operated positive displacement type hammer drill comprising a tubular housing, an elongate hollow outer hammer positioned longitudinally within said housing, said outer hammer being provided with by-pass ports adjacent its upper end, upper ports adjacent its upper end below said by-pass ports, and lower ports adjacent its lower end and being adapted for longitudinal reciprocating movement, an elongate inner hammer approximately equal in length and mass to said outer hammer and provided with a longitudinal passage therethrough, said inner hammer being longitudinally disposed within and slidably sealed to the inner surface of said outer hammer at its upper end and in its central portion and adapted for longitudinal reciprocating movement, a cylinder closed at its upper end disposed within the upper end of said housing and with the upper ends of said hammers extending within said cylinder, a constriction in said cylinder adjacent its lower end slidably sealed about the upper end of said outer hammer adjacent said by-pass ports and said upper ports in said outer hammer, a constriction in said housing slidably sealed about the lower end of said outer hammer adjacent the lower ports therein, an anvil disposed within said housing below and in the path of said hammers, said anvil being provided with faces for seating said inner and outer hammers and for receiving percussive blows therefrom and being provided with a longitudinal passage therethrough in register with the longitudinal passage in said inner hammer, said anvil also being provided with a lateral passageway connecting the longitudinal passage therein with the interior of said housing below said constriction therein exterior of said anvil and said outer hammer, means introducing pressurized operating fluid into said housing

below the lower end of said cylinder and affording said pressurized operating fluid intermittent access to said upper and lower ports in said outer hammer, a sealing ring on the inner surface of said outer hammer adjacent the upper end thereof, said sealing ring forming a sliding seal about the upper end of said inner hammer, an annular shaped upper fluid course chamber formed between the upper end of said inner hammer and the upper end of said outer hammer, said upper fluid course chamber being defined by a narrow downwardly facing annular shoulder on the outer surface of said inner hammer adjacent the upper end thereof, a wider upwardly facing annular shoulder spaced below said narrow downwardly facing shoulder on the outer surface of said inner hammer, the outer surface of said inner hammer between said shoulders, a downwardly facing shoulder formed by the lower side of said sealing ring on the inner surface of said outer hammer adjacent the upper end thereof, and the inner surface of said outer hammer downward from said shoulder to a point opposite said upwardly facing shoulder on said inner hammer, including that portion of the inner surface of said outer hammer in which said upper ports are located, a central portion of said inner hammer of increased external diameter below said last mentioned upwardly facing shoulder on said inner hammer slidably sealed to the inner surface of said outer hammer, an annular shaped lower fluid course chamber formed between the lower end of said inner hammer and the lower end of said outer hammer below said upper fluid course chamber, said lower fluid course chamber being defined at its upper end by a downwardly facing annular shoulder on the outer surface of said inner hammer below said central portion of said inner hammer, said downwardly facing shoulder being at least equal in width to said upwardly facing shoulder on said inner hammer, said lower fluid course chamber being defined at its lower end by the upper end of said anvil, on its inner periphery by the outer surface of said inner hammer between said last mentioned downwardly facing shoulder and said anvil, and on its outer periphery by the inner surface of said outer hammer from a point opposite said last mentioned downwardly facing shoulder on said inner hammer downward to the upper end of said anvil, including that portion of the inner surface of said outer hammer in which said lower ports are located, a narrow downwardly facing shoulder on the inner surface of said outer hammer immediately above said lower ports within said lower fluid course chamber, a bit stem slidably sealed within the lower end of said housing below said anvil, said bit stem being adapted to be rotated by rotation of said housing and being provided with a downward extension adapted to carry a drilling tool, and a longitudinal passage in said bit stem in register with the longitudinal passage in said anvil.

References Cited in the file of this patent

UNITED STATES PATENTS

1,110,067	MacDonald	Sept. 18, 1914
2,661,928	Topanelian	Dec. 8, 1953
2,673,713	Ringler	Mar. 30, 1954
2,714,370	Jeschke	Aug. 2, 1955