A liquid actuated percussion tool contains a case which surrounds the moving parts, an anvil mounted in the lower part of this case, a reciprocating hollow piston or hammer mounted above the anvil within the case and a valve system for applying pressure alternately to the two ends of the piston to reciprocate it in the case and cause it to strike the anvil. This in turn causes the anvil to apply axial reciprocating forces to a drill bit mounted on the lower portion of the anvil.

One or more ports are provided in the upper part of the case, permitting communication between the region outside of the case and a part of the top of the hammer. As the piston reciprocates, the volume within the case adjacent to such port changes size and can, therefore, be called a variable volume. Liquid from outside the case moves through the port to occupy space in the variable volume in a cyclic manner with each reciprocation of the hammer.

The particular improvement of this invention comprises forming an axially oriented enclosed channel extending downward from each port along the case, the port being otherwise blanked off, so that the cyclic movement of liquid into and out of the variable volume occurs through this downward oriented enclosed channel which extends a substantial distance below the port. This furnishes a disengaging space tending to prevent vertical motion of solids incorporated in the liquid outside the case up into the variable volume, which could otherwise jam the hammer and stop operation of the tool.
ROTARY PERCUSSION DRILLING MOTOR

CROSS REFERENCES TO RELATED APPLICATIONS

This application is a continuation-in-part of co-pending application Ser. No. 747,234, now abandoned entitled "Rotary Percussion Drilling Motor," filed July 24, 1968, René P. Vincent and Lawrence B. Wilder, inventors.

A very similar tool without the channel arrangement claimed in this invention is disclosed and claimed in Ser. No. 738,923, now U.S. Pat. No. 3,491,838 filed June 21, 1968, by René P. Vincent and Lawrence B. Wilder.

BACKGROUND OF THE INVENTION

1. Field of the Invention

A number of fluid actuators percussion drilling tools have been patented over the years. Generally, those that have been successfully applied in commercial drilling have been actuated by a gas such as a compressed air, natural gas or the like. On the other hand, until recently, successful commercial tools have not been actuated by liquid such as drilling mud or the like. This situation has changed recently with the development of liquid actuated tools using relatively lighter hammers than employed in the past, and axially mounted adjacent but separate to the anvil. In such tools a stepped piston or hammer is used, having an upper end of smaller area exposed to the liquid than that at the bottom end and reciprocally mounted within a cylindrical case above a so-called anvil. The anvil is slideably mounted within and splined to the case in such a fashion that bottom vertical force on the case can be transmitted to the anvil, and similarly rotary torque applied to the case can be transmitted to the anvil. The axial separate valve is reciprocally mounted between the hammer and anvil and serves to apply liquid pressure part of the time to the bottom surface of the hammer. Because of its increased bottom area, the hammer in such case rises until the valve cuts off fluid pressure from the bottom of the hammer, at which point liquid pressure on top of the hammer drives it into impact with the anvil. This occurs cyclically.

The tool is mounted at the lower end of a string of drill pipe which may include drill collars. A rotary bit is attached at the bottom of the anvil where it may rotate against the rock formation being drilled. Percussive action applied during the rotation of the drill bit increases considerably the rate at which the bit can be driven into the formation compared with that involved in rotary drilling alone.

Ordinary drilling mud is employed in such a tool, being circulated down through the drill string and up in the annulus between the motor or drill string, and the wall of the well. Such drilling fluid may incorporate clay, weighting agents, or other materials, and certainly in the region of the annulus above the bit will also include rock particles or cuttings removed by the bit.

The percussion tool ordinarily will have a variable volume between a stepped part of the hammer and the associated part of the case. This volume changes as the hammer reciprocates up and down in the case. The variable volume ordinarily communicates with the liquid in the region around the tool by one or more ports through the case. Accordingly, liquid from outside the case rushes into this variable volume during each downward stroke of the hammer and is in turn forced out of this volume through the ports on each upward stroke. If any of the liquid entering this variable volume contains drill cuttings or the like, there is a very substantial possibility that such solids may be deposited within the variable volume, where they interfere with the general performance of the tool and, in fact, may in some instances cause it to jam and become unoperable. While screens may be employed across the opening of any such port, I have found that a much better solution can be provided, which essentially increases the length of the channel defined by the port in a vertical downward direction, so that cuttings or other solids being carried by the fluid outside of the tool settle out in a disengaging space and are not deposited in the variable volume.

2. Description of the Prior Art

A modern tool of the type referred to above is shown in U.S. Pat. 3,277,790 Vincent-Wilder, and a similar tool is shown in U.S. Pat. No. 3,307,639 Wilder-Blenkarn. These patents, together with their references, furnish the best description of the prior art currently known to the inventors. In the specifications of each of these patents variable volumes of the type mentioned above are shown, ported to the region immediately surrounding the tool. Cross reference has also been made above to a related patent application.

SUMMARY OF THE INVENTION

The improvement incorporated in a liquid actuated percussion tool of the type described above comprises extending ports in the case connecting the variable volume within the tool to the region immediately outside the case in a downward direction, and blanking off all other communication between the port and the outside region, so that liquid entering into and out of the variable volume must travel, vertically an appreciable distance in an enclosed channel in the case between the point of entry of such liquid and the variable volume. This enclosed extension of the channel can be considered to furnish a dis-engaging volume in which solid particles such as drill cuttings entrained in the liquid entering the channel separate from the liquid, so that the liquid entering the variable volume is essentially free of such solids. The size of the channels can be expressed in terms of the variable volume. The volume of the enclosed channels should exceed the maximum variable volume. Preferably, the volume of all of the enclosed channels is desirably at least 1.5 times this volume, and can be, for example, twice this volume. With such arrangement, there is ample disengaging space in the essentially vertically enclosed channels to separate out by gravity the solid particles from the liquid surging into the variable volume.

BRIEF DESCRIPTION OF THE DRAWINGS

The attached drawings form a part of the specification and are to be read in conjunction therewith.

FIG. I shows, partially in cross section, the upper part of a percussion tool of the type described in the prior art (specifically in the related application mentioned above), showing a plurality of vertical, enclosed channels connecting the port with openings a considerable distance below in the case to provide suitable disengaging space.
FIG. 2 shows, partially in cross section, the lower part of such a percussion tool.

DESCRIPTION OF THE PREFERRED EMBODIMENT

A view partly in cross section of the upper portion of a liquid actuated percussion tool is shown in the attached figure. This includes a case 11 through which there are one or more ports 12. The upper part of the case 10 is shaped in the form of the conventional pin for standard threaded attachment to a drill pipe or drill collar (not shown). A center valve tube 14 is held in place at the upper end of the tool by having the top of this valve tube provided with a ball portion 15 which is centralized and mates with an upper retainer ring 16, and a second lower ball surface 17 which mates with a lower retainer ring 18. A plurality of web-type guide means 19 (only one shown) are mounted on the outer surface of the center valve tube 14 to centralize this tube axially in the tool. A spacer ring 20 above a cylindrical seal 21 holds the lower retainer ring 18 in place.

Only a part of the hammer (or piston) 22 is shown in FIG. 1. Hammer 22 has a longitudinal passage therethrough. The upper end of this hammer 22 is stepped by use of an extension 23 screwed or otherwise fastened to the hammer 22 so that the top portion 24 of the hammer exposed to the well fluid in chamber 25 is less in area than the lower part of this hammer. Some of the drilling fluid flowing through the bore 26 at the top of the tool is deflected through ports 27 into the chamber 25 to exert pressure on the upper or rearward face 24 of the hammer. The seal 21 minimizes leakage of fluid between the extension 23 and the case 11, so that the pressure of the liquid in chamber 25 is not exerted on the step face 28 of hammer 22.

As shown in FIG. 2, slideably mounted for limited axial movement in the lower end of casing or case 11 is anvil 40. At the lower end, anvil 40 is provided with means for transmitting torque from housing or case 11 to a drill bit (not shown) which is attachable to the lower end thereof in a conventional manner such as by threads 41. Various modifications of torque transmission arrangements can be used. One form is shown in FIG. 2 in which the lowermost part of the housing contains a plurality of vertical ridges 42 between each two of which are splines or grooves. These ridges 42 engage equivalent splines or grooves cut into, or otherwise provided on, the outer periphery of the lower portion of anvil 40. The lower portion 40A of anvil 40 is enlarged to approximately the same diameter as that of case 11. Upper surface 102 of anvil portion 40A is designed to receive lower end 100 of case 11 so that a portion of the weight of the drill string above may be applied to the bit, thus improving its effectiveness in drilling. The splines in both the anvil 40 and the case 11 are longer than the corresponding or mating ridges so that until the drill bit touches bottom, there is a vertical distance that anvil 40 can move between the position shown in FIG. 2 and a lower position in which adjacent splines and ridges are in top contact. Suitable means, not specifically described, are provided to limit this vertical downward movement, typically from about one to about three inches. Full extension renders the hammer inactive when liquid is being circulated through the tool.

Anvil 40 is provided with an exhaust duct or central bore 44. The top surface 36 of anvil 28 mates with the bottom surface 38 of hammer 22. Surface 36 is provided with a plurality of grooves 46. Also provided within anvil 40 are a plurality of conduits 48 which extend from surface 36 to within bore 44. Grooves 46 are intercepted by or otherwise are in fluid communication with conduits 48. The grooves 46 should be inclined to conduct fluid from the edge of the case to the center of the anvil and bore 44. These various grooves and conduits, singly or in combination, permit the liquid between the hammer and anvil to be quickly evacuated so as not to cushion impact between the two.

Center valve tube 14 is provided for use in controlling movement of the valve assembly. Tube 14 is preferably a thin-walled pipe of uniform diameter, concentrically mounted in case 11. The upper end of valve tube 14 is in direct fluid communication with fluid from the drill string. The upper end of valve guide tube 14 is provided with a plurality of ports which are of sufficient size and number so that there is very little pressure drop between the pressure of the fluid in the drill string and fluid channel 55 which is the annular space between the exterior of valve tube 14 and the interior of hammer 22. Fluid channel 55 is an extension of chamber 25.

A main valve assembly is provided for the lower end of valve tube 14 and includes a valve stem 54, a valve piston 56 and a loose ring-shaped valve head 58 having an upper valve surface 58A and a lower valve surface 58B. Valve piston 56 is sealingly fitted within the lower end of valve tube guide 14. Ring valve head 58 is slideably mounted on the lower end of valve stem 54 and is prevented from falling off by shoulder 59 which is an enlarged portion of the lower end of valve stem 54. When assembling the valve assembly, valve head 58 is lowered down over the upper end of valve stem 54, followed by hammer seat 88 and guide nut member 60. Valve piston 56 is then attached on the upper end of the stem. This can be accomplished, for example, by silver brazing the piston to the valve stem. The melting temperature of the silver braze material and the heat treating temperature of the piston material are selected so that both fastening and the hardening of the piston can be done in one operation.

Valve head 58 has a lower interior configuration which complements and mates with the outer portion 59A of enlarged shoulder 59 of the valve stem 54. During normal operation valve head 58, as explained more fully later, is held in position by the differential pressure which exists across this valve head. The advantages of such a system over rigidly attaching the valve head to the valve stem is discussed in co-pending patent application Ser. No. 738,923 supra.

Valve stem 54 slidingsly extends in a sealing relationship through end member 60 of valve tube 14. Just above end member 60 are a plurality of ports 62 in the wall of valve tube 14. Valve stem 54 is of a sufficient length that when the moving parts of the tool are in the position shown in FIG. 2 of the drawing, there is a cavity 64 within valve tube 14 below valve piston 56. When piston 56 is above ports 62, cavity 64 has substantially the same pressure as the pressure Ps in annulus 55 between valve tube 14 and hammer 22. This pressure acts against an area A, which is the horizontal com-
ponent of the area of the lower side of valve piston 56 which is in communication with cavity 64. Mounted within valve tube 14 above valve piston 56 is a fluid restriction means which is shown in the drawing as being a nozzle or choke 66. This nozzle functions so that the pressure $P_1$ within the interior 45 of valve guide tube 46, between piston 56 and nozzle 66, is always substantially less than pressure $P_2$ in the annulus between the valve tube 14 and the hammer with an exception when ports 62 are in communication with interior 45. In other words, this arrangement provides a reduced pressure to act downwardly against the effective horizontal component $A_{hp}$ of the valve piston 56. Nozzle 66 should be a sufficient distance above piston 56 so that no appreciable jetting action is imparted to the valve piston.

Attention will now be directed toward means for stopping the upward movement of valve assembly (54, 56, 58). This can, in effect, be considered a dashpot stop. The upper end of valve piston 56 includes an interior cavity 56C. The interior of valve guide tube 14 above piston 56 has a downwardly facing cavity 37. This cavity 37 is annular in shape and the size of cavity 37 is such as to slideably receive the upper end of valve head 56 which forms cylindrical cavity 56C. The entrapment of fluids in cavity 37 when the upper end of valve head 56 reaches the lower surface 14A of the valve tube guide causes a very effective dashpot type stopping of the upward movement of the valve assembly.

Both the upper 58A and lower 58B surfaces of valve head 58 function as valves. Attention will first be directed toward a consideration of the seat assembly for the lower side of valve head 58 or the reciprocating main valve assembly. A cylindrical anvil valve seat 76 which is in effect an enlargement of anvil bore 44 is provided in the upper end of anvil 40. The upthrust facing surface 78A of valve seat 76 is shaped to conform to the lower surface 58A of the valve head 58. A second surface 78B, in the starting process, mates with the lower seat 59B of enlargement 59 of the valve stem 54 to stop the downward movement of the valve stem. To provide for proper differential areas, the largest (or seating) diameter of valve head 58 is greater than the diameter of piston 56. Seat 78 can be mounted directly in recess 79 without use of a shock absorbing means inasmuch as the valve head 58 is hydraulically held in place.

Valve head 58, when closed against anvil seat 78A, prevents flow of fluid from annulus 55 and its extension annulus 87 to bore 44 within anvil 40. Annulus 55 is that space between the outer wall of valve guide 14 and the inner wall of hammer 22. As can be seen in the drawings, drilling fluid flows freely from the drill pipe down through ports 27 and into annulus 55.

Valve head 58 includes a carefully machined upper surface 58A. We shall now consider how this cooperates with the annular valve sleeve in the hammer. Near the bottom of stepped hammer 22, the bore of the hammer is decreased and an annular sleeve valve member 88 is provided, forming a hammer valve pocket. An annular valve seat 90 is provided in annular member 88 for the upper surface 58A of valve head 58. The bore 91 of valve member 88 is eccentric to the bore of stepped hammer 22.

Attention will now be directed toward the secondary or annular valve. This includes an annular ring valve 82 mounted on the interior of the lower end of hammer 22 above annular member 88. Valve 82 preferably is provided with hard facing 84. The lower slightly tapered portion 86A of lower member 60 of valve guide 14 is preferably a hard metal, such as sprayed-on tungsten carbide, and is carefully machined as is the interior of the hard facing 84 of the ring valve 82 so that the hammer 14 moves upward, ring valve 82 cooperates with the lower portion 86A to stop substantially all of the flow of fluid downwardly from annulus 55. There will still be flow from annulus 55 to cavity 64 (beneath piston 56 within valve guide 46) while the valve assembly 54, 56, 58 is moving upward.

Although not needed for an understanding of this invention, for a more complete discussion of the valving arrangement and how it operates to reciprocate the hammer, attention is directed to our co-pending application Ser. No. 739,923 supra.

The port 12 and the volume above the face 28 of hammer 22 form a variable volume 29, since it is apparent that as the hammer 22 reciprocates up and down axially and in the course of operation of the tool the annular volume must necessarily change, being a minimum when the hammer 22 is at the top of its stroke and a maximum when it is at the bottom of the stroke. Since this variable volume is in liquid communication with the region immediately outside of the case 11, it is seen that liquid will flow in and out of this variable volume as the hammer 22 moves up and down. It is the inward surge of liquid through port 12 as the hammer 22 moves down which, in tools of this sort before my invention, could cause solid particles to be deposited in the annular volume 29 which could crush and jam the hammer 22 in place and thus inactivate the tool.

We have built several tools in which the displacement of the hammer in variable volume 29 is less than the total volume of ports 12. However, in most instances, this did not prove satisfactory. Therefore, in order to minimize the possibility of liquid passing through port 12 carrying drill cuttings or the like into volume 29, we provide the outer part of the case 11 extending downward from the bottom of port 12 with a slot 30 milled or otherwise machined in the outer surface of case 11. Each such slot extends a considerable distance axially downward from port 12. The outer surface of case 11 is also reduced in diameter (for example, by turning) from a distance at least slightly above the top of port 12 to a point near but not completely to the bottom of any of the slots 30. A sleeve 31 is then attached as by welding or the like in the region where the diameter of the case has been reduced, completely blanking off the face of port 12 and enclosing the slot to form an axially oriented enclosed channel with an opening 32 at the bottom, preferably approximately of the same area as the area of port 12.

I have found by experimentation that the volume of these enclosed channels formed by the slots 30 and the sleeve 31 should preferably exceed the maximum variable volume 29. By this arrangement, there is a sufficient settling space in each enclosed channel so that drill cuttings or other solids present in the fluid entering the bottom of an enclosed channel during the time that the hammer 22 is moving downward will not be entrained
and rise to the top of this slot, i.e., to the bottom of port 12. The volume of all of the enclosed channels preferably should be at least 1¼ times the maximum variable volume 29 and desirably is approximately twice or more this volume.

It is not necessary that the enclosed channels provided in the case below the ports 12 be formed as described above. Any arrangement is satisfactory in which an enclosed channel is provided of the desired volume in such a way that the settling space is substantially vertical and extends downward from the ports 12. The main point is that this settling space be of sufficient length so that the entrained liquid will not cause the solid particles to rise the entire distance of this enclosed channel. The initial immersion of the tool in the hole ordinarily fills variable volume 29 with relatively grit-free well fluid which is substantially non-damaging to the hammer and housing.

I have found that while drilling with this tool in very heard formations with sharp particles in the cuttings that the operation of the tool continues without jamming or apparent abrasive effects formerly found in some cases when the ports 12 were directly open to the region around the case. This arrangement is considerably better than that provided by placing a screen over the entrance to each channel 12, since it is necessary to have sufficient openings in any such screen to allow ready flow of liquid through port 12 and the solid particles in the drilling mud can abrade this screen rapidly. Of course, the smaller abrasive particles can penetrate through the openings in the screen right from the start and pile up on top of face 27 where they are effective in scoring and, in some cases, jamming the hammer.

It will be apparent that this disclosure is addressed to those skilled in this art, and that it is possible to make other arrangements providing axially oriented enclosed channels extending downward from each port 12 along the case which will provide settling space for cuttings. Accordingly, the invention is not limited to the apparatus shown and described, but is best determined by the scope of the appended claims.

We claim:

1. In a liquid actuated percussion tool including a case, a reciprocating piston slideably mounted within said case, and a port in said case at the upper end of a variable volume above and adjacent only a part of the upper end of said hammer, said variable volume being fluidly isolated except for said port, the improvement comprising means defining at least one axially oriented enclosed channel extending downward from said port along said case and terminating in fluid communication with the outside of said case, said means further serving to blank off fluid communication other than by said channel between said port and the outside of said case, said channel having no fluid communication with the interior of said tool other than said port.

2. Apparatus in accordance with claim 1 in which said means includes a slot in said case and a thin cylindrical sleeve attached to said case and extending from above the top of said port down considerably below the bottom of said port.

3. Apparatus in accordance with claim 2 in which the volume of all of the enclosed channels exceeds the maximum value of that of said variable volume.

4. Apparatus in accordance with claim 3 in which the volume of all of said enclosed channels is at least 1¼ times the maximum value of that of said variable volume.