April 27, 1965 **R. P. VINCENT** 3,180,434

FLUID-DRIVEN PERCUSSION TOOL

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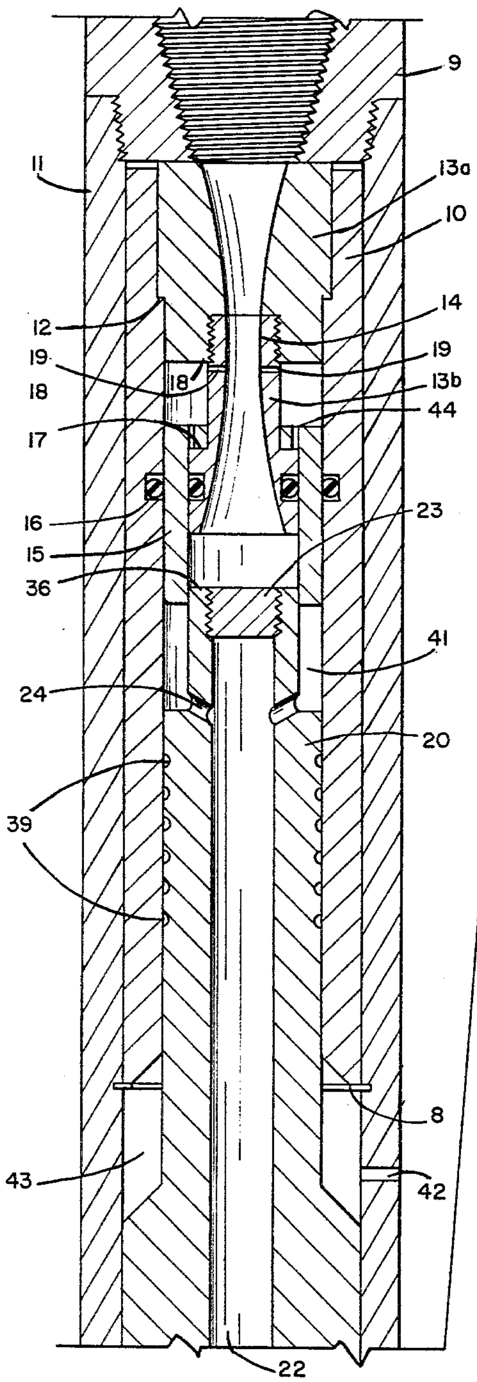

FIG.-1

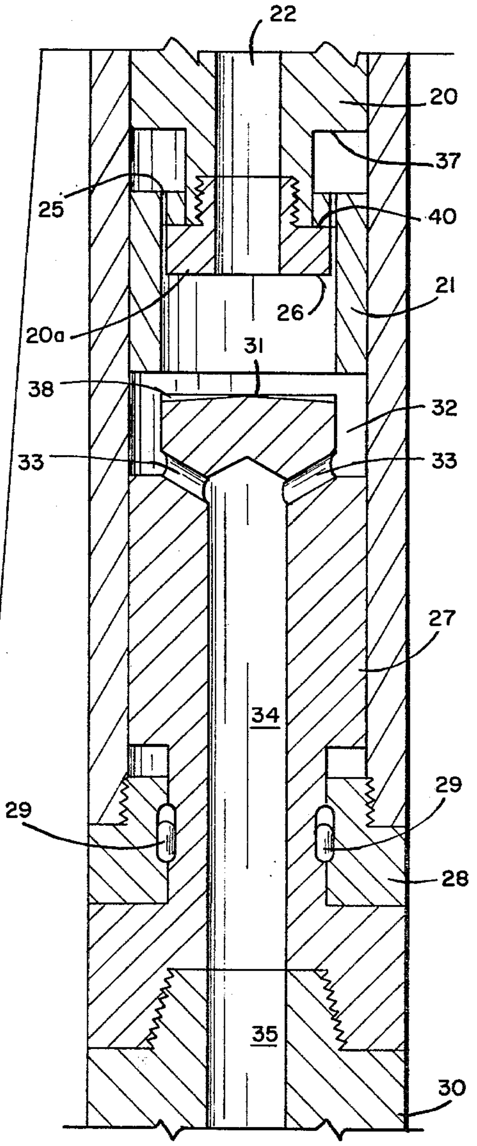

FIG.-2

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FLUID-DRIVEN PERCUSSION TOOL

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This invention relates to a fluid-actuated percussion motor. Such a motor is particularly adapted for use in rotary drilling apparatus in which the drill bit is both rotated and vibrated against the formation for increasing speed of drilling.

A number of varieties of such percussion motors have been proposed in the past. Up to the present, the only commercial varieties have been actuated by a gas such as compressed air, natural gas, or the like. There are several reasons for the major difficulties encountered when trying to design liquid-actuated percussion motors. Liquids are much less compressible than gases. They also possess very high inertia per unit volume as compared with gases. As a result, it is particularly difficult to cause an oscillating mass, or hammer, on its down stroke to impact on a bit, or an anvil above the bit, with the velocity the hammer had at, say, two-thirds of its down stroke. Any liquid ahead of the hammer must be removed rapidly if adequate impact is to result.

Another problem that occurs is due to water hammer. It is necessary to close valves in a percussion motor rapidly, particularly when it is realized that speeds of up to 2000 impacts per minute (or more) are desirable. When using relatively inealastic liquids, an abrupt change in flow rate as the valve quickly closes causes a pronounced pressure variation, or water hammer, which considerably changes operating conditions in the tool and minimizes its effectiveness.

Still a third major problem when liquids are employed lies in the fact that the liquids must be recirculated. Accordingly, there is a considerable tendency for recirculation of particles of rock that have been already removed from the formation. This means that the liquid frequently is not clear but is laden with abrasive particles. Such a liquid, in flowing past the various parts of a percussion tool, tend to cause it to wear rapidly and the necessary close clearances to be lost.

It is an object of this invention to provide for a percussion motor or tool, which can be actuated by a liquid and which can also be used with a compressed gas. It is a further object to provide such a motor adapted to be used at the lower end of a drill pipe to impart vertical oscillation to a drilling bit in addition to the rotary motion associated with rotary drilling practices. A further object of this invention is to provide improved valves for such a motor. Further objects and advantages of this tool will be apparent from the following description.

Reference is made to the accompanying two drawings in which:

FIGURE 1 shows a cross-sectional view of the upper part of a percussion motor with the hammer near the upper end of its stroke.

FIGURE 2 shows in cross section the lower part of the same percussion motor.

Referring now to FIGURE 1, the percussion motor is connected to the lower end of a drill pipe (not shown) through a short sub 9. This, in turn, is threaded into the outer casing 11. Within this casing 11, resting on a step 12 in a bushing 10, is a Venturi bushing (made of parts 13*a* and 13*b*) 13 with a throat section 14. The cylindrical bushing 10 is supported on an expansion ring 8 mounted in a groove in casing 11. The outer surface of the lower part of Venturi bushing 13 has been grooved to provide an opening in which is mounted slidably an upper sleeve valve 15. Both bushing 10 and Venturi bushing 13 are provided with packing 16 to make a fluid-tight seal on both the inner and outer surfaces of the upper sleeve valve 15. The top portion of the sleeve valve is enlarged, as shown, to fit within an enlarged part of the goove in the Venturi bushing. This defines between faces 17 and 18 (which act as stops) the vertical limits of travel of the upper sleeve valve 15. A plurality of ports 19 connect the top part of the groove in the bushing adjacent face 18 with the throat of the Venturi bushing 13.

Slidably disposed below the bushing 13 and the upper sleeve valve 15 is the hammer 20, which is generally cylindrical, with a small upper diameter fitting snugly within bushing 10 and a lower, larger diameter portion snugly fitting casing 11. The hammer 20 contains a lower piece 20*a* which forms with 20 grooves to accommodate the lower end of upper sleeve valve 15 and the upper part of lower sleeve valve 21. There is a fluid passage 22 extending axially upward from the bottom of the hammer 20. At the top of the hammer, this fluid passage is closed off by a plug 23 or the like. At the top of the hammer 20 the outside diameter of hammer 20 has been suitably reduced so that the hammer makes a close sliding fit with the inner diameter of the upper sleeve valve 15, as shown. Side ports 24 connect the reduced diameter portion of the top of the hammer with the fluid passage 22. Preferably this portion contains some type of packing, or a plurality of grooves 39 to form a labyrinth seal with bushing 10. Also, a plurality of ports 42 is provided in the casing to connect the variable volume 43 to a zone of low fluid pressure so that liquid can freely flow into and out of volume 43.

The lower part of hammer 20 is grooved rather like the bushing 13 to define the motion of the lower sleeve valve 21. As in the case of the upper sleeve valve, the lower sleeve valve contains an enlarged top portion fitting into the bottom groove in the hammer; however, the lower sleeve valve 21 fits only loosely within the hammer 20 and in fact, may be provided with ports 25 to insure that the fluid pressure above the top of the lower slide valve 21 is substantially equal at all times to that immediately below the lower face 26 of hammer 20. The faces 37 and 40 of the grooves in hammer 20 serve as stops to limit the axial motion of lower sleeve valve 21 with respect to the hammer 20.

An anvil 27 is supported with some axial freedom of motion in the lower end of the motor housing. Thus, a split nut 28 may be screwed into casing 11 and the lower portion of the anvil 27 is machined to accommodate the inner diameter of this split nut. A plurality of keys, or drive pins 29, is placed in corresponding elongated grooves in the anvil 27 and split nut 28. This provides a kind of splined joint for rotating the anvil with the casing 11 (and hence the drill pipe) and also to provide longitudinally for lost motion between the casing 11 and the anvil. The lower end of the anvil 27 is machined for coupling to a drill bit 30. The split nut arrangement allows any desired downward force to be applied through the casing 11 to the drilling bit 30 during drilling without restricting movement of the anvil 27 and the bit 30 when the anvil is struck by the hammer 20.

In the position of the hammer 20 shown in FIGURES 1 and 2, i.e., at or near the upper end of the stroke of this hammer, the lower sleeve valve 21 has been raised by the hammer so that there is a fluid path past the top face 31 of anvil 27 into the annular groove 32 and through ports 33 in the anvil, into a fluid passage 34 which extends down through the anvil and connects with the similar fluid conduit 35 in bit 30. Accordingly, liquid in the volume between face 26 of hammer 20 and face 31 of anvil

27 can freely escape through ports 33 and passages 34 and 35 as the hammer descends.

At this point the upper sleeve valve 15 is in its lower position, thus closing the annular groove 41 and preventing passage of drilling fluid into the fluid passage 22. Accordingly, the entire fluid pressure on the top face 36 of hammer 20 accelerates the hammer downward, until the top face 36 is below the bottom of the upper sleeve valve 15. By this time the hammer has reached almost its maximum velocity, driving the drilling fluid below the face 26 through the fluid passages 34 and 35. Since the pressure on the upper and lower faces of the lower slide valve 21 are substantially the same, this valve tends to remain in the position shown as the hammer is forced downward past the valve. Of course, ultimately the top face or stop 37 of the groove in the hammer 20 carrying the lower slide valve, contacts the top face of slide valve 21 and forces it down at the same speed as the hammer. The top face 31 of the anvil contains, preferably, a plurality of relatively small, outwardly sloping radial grooves 38 which permits drainage of the last drilling fluid from the anvil 27 just before impact of the hammer on the anvil. With this arrangement, tests show that the anvil is struck by the hammer at peak hammer velocity and, therefore, maximum momentum. This causes the anvil to strike a sharp percussive blow on the drill bit 31, even when the drilling fluid is a liquid, and accordingly, gives a high additional force on the bottom of the bit 30 to cause it more actively to remove rock cuttings.

As soon as drilling fluid resumes substantial flow through the throat 14 of the Venturi bushing 13, the pressure in the throat at ports 19 drops, decreasing pressure on upper face of the upper sleeve valve 15 and making it lower than that on the lower face of this valve. Accordingly, the valve 15 rapidly retracts to its upper position. Passages 44 are provided to permit fluid to fill the volume above stop 17 as upper valve 15 rises. This arrangement also allows this volume to empty when the valve 15 falls. When valve 15 is raised, it clears the ports 24 for fluid passage, ordinarily just before the hammer 20 has struck the anvil 27. It should be added that this valve 15 will remain in the upper position until the top of hammer 20 enters the valve, at which point the fluid pressure above the valve is greater than that below it (since the fluid below is leaving through passage 22), causing the valve to be driven rapidly to its lower position against stop 17, as shown in FIGURE 1. As the hammer 20 rises, it will continue to ascend until upper sleeve valve 15 closes the fluid flow through ports 24 or lower sleeve valve 21 is pulled up by the hammer 20 to expose ports 33 to fluid flow. It is obvious that in the design of this tool, both valve actions mentioned immediately above take place substantially simultaneously.

When the hammer 20 strikes the anvil 27, the momentum of the valve 21 carries it downward, closing the exhaust passage around the anvil 27. Valve 21 cannot, accordingly, close until impact of hammer 20 on anvil 27. This immediately raises the pressure in the fluid between the hammer and anvil. It is to be remembered that the top valve 15 is open at this point and drilling fluid flowing through the fluid passage 22 to the faces 26 and 31 in substantial contact. The force on the bottom face 26 of hammer 20 is now greater than that on its top face 36, due to the difference in area of these two faces and the approximately equal fluid pressure at both points. Accordingly, the hammer starts to rise from its lowermost position, and the cycle repeats.

It is to be noted in connection with the action of the lower sleeve valve 21 that solids in the circulating fluid cannot interfere with the working of this valve since the full force of the hammer moves the valve. As far as the upper sleeve valve 15 is concerned, it is substantially out of the path of solid particles in the drilling fluid.

The design of this particular tool is readily adaptable to making large the ports through which drilling fluid flows, so that relatively low fluid velocities can be obtained. This is another factor tending to minimize effects of solids in the drilling fluid on action of the percussion tool.

It is particularly important to notice that the lower sleeve valve 21 does not close until after impact of the hammer 20 on the anvil 27. Accordingly, by this relatively simple arrangement, maximum impact, or transfer of kinetic energy from hammer to anvil, is achieved.

Under test conditions, a percussion motor of this type with an outer casing diameter of 6.5 inches, a stroke of 1 to 1.25 inches, a hammer weighing approximately 100 pounds and using water as the drilling fluid with a pressure drop through the drilling tool of approximately 500 p.s.i. gave operation for a period of about 100 hours. Percussive rates up to approximately 2000 strokes per minute and a peak force on the drilling bit of approximately 100,000 pounds were achieved. As far as I know, these conditions have never been previously obtained using any type of liquid actuation and have only been approached when using, for example, compressed air. Incidentally, this design of percussion motor works well when actuated by a high-pressure gas stream.

It is apparent that modifications may be made within the spirit of the appended claims which serve to define my invention.

I claim:

1. In a percussion motor containing a cylindrical hammer reciprocatingly mounted within a casing above an anvil,

a lower sleeve valve surrounding the lower end of said hammer and slidably carried between stops on said hammer so that said valve has a predetermined axial travel between said stops, said valve being shaped and adapted to be moved axially only by motion of said stops of said hammer,

said hammer and said anvil being shaped to define at least one fluid passage through said motor, one portion of said passage adjacent the top end of said anvil being adapted for closure by said valve when in its lowermost position,

the upper of said stops on said hammer being so located with respect to the length of said valve that the lower end of said valve cannot close off fluid flow through said passage at the instant said hammer contacts said anvil,

an upper valve adjacent the upper end of said hammer and slidably carried between upper and lower stops in a support stationary with respect to said casing so that said valve admits fluid to said fluid passage intermittently, during the upward travel of said hammer, and so that said valve has a predetermined axial travel between said stops,

said support being shaped to define a flow passage for the actuating fluid of said motor,

said hammer being so shaped at the upper end thereof so that with

said upper valve closed and said hammer at the top end of its stroke, fluid flow is substantially cut off through said fluid passage in said hammer.

2. In a percussion motor containing a cylindrical hammer reciprocatingly mounted within a casing above an anvil,

a lower sleeve valve surrounding the lower end of said hammer and slidably carried between stops on said hammer so that said valve has a predetermined axial travel between said stops, said valve being shaped and adapted to be moved axially only by motion of said stops of said hammer,

said hammer and said anvil being shaped to define at least one fluid passage through said motor, one portion of said passage adjacent the top end of said anvil being adapted for closure by said valve when in its lowermost position,

the upper of said stops on said hammer being so located with respect to the length of said valve that the lower end of said valve cannot close off fluid flow through said passage at the instant said hammer contacts said anvil,

an upper sleeve valve adjacent the upper end of said hammer and slidably carried between upper and lower stops in a support stationary with respect to said casing so that said valve has a predetermined axial travel between said stops,

said support being shaped to define a flow passage for the actuating fluid of said motor, said passage having lesser cross-sectional area adjacent said upper stop than at the botom end of said passage, and said support further being shaped to define at least one port from said passage at the region of said lesser cross-sectional area to said upper stop,

sealing means for preventing flow of fluid past the inner and outer surfaces of said upper sleeve valve,

said hammer being so shaped at the upper end thereof so that with said upper sleeve valve against the lower stop of said support and said hammer at the top end of its stroke fluid flow is substantially cut off through said fluid passage in said hammer.

3. A fluid-actuated percussion motor for drilling including:

a cylindrical casing, portions being of two different diameters,

an anvil slidably mounted on the lower, larger diameter part of said casing for limited axial motion thereto, said anvil containing coupling means at the lower end for attaching a drill bit, and at least one fluid passage,

a hammer slidably mounted in said casing above said anvil, said hammer having a lower part of larger diameter than the upper part, both of said lower and upper parts closely fitting corresponding parts of said casing, said hammer containing at least one fluid passage,

an upper slide valve adjacent the upper end of said hammer and slidably carried between upper and lower stops in a support stationary with respect to said casing, said upper valve being so shaped and adapted that it closes the fluid passage through said hammer when said hammer is near the top of its stroke, whereupon said upper valve moves against the lower stop of said support,

said upper valve support containing a fluid passage with a constricted throat region intermediate the ends of said support and at least one passage connecting said throat region with said upper stop in said support,

sealing means for preventing flow of fluid past the inner and outer surfaces of said upper sleeve valve, and

a lower slide valve slidably mounted between upper and lower stops in and adjacent the lower end of said hammer with sufficient clearance so that fluid pressure on top and bottom of said valve is approximately the same, said lower valve being so shaped and adapted so as to stop flow of fluid through said anvil at the lowermost position of said lower valve while permitting such flow at the topmost position thereof, and the length of said lower valve relative to said upper stop in said hammer being such that flow of fluid through said anvil upon downward motion of said hammer from the top of its stroke cannot be stopped by said lower valve until impact of said hammer on said anvil.

4. A fluid-actuated percussion motor for drilling which may be driven with a liquid under pressure comprising:

a cylindrical casing, portions being of two different diameters,

an anvil slidably mounted on said casing for limited axial motion thereto, said anvil containing coupling means at the lower end for attaching a drill bit, and at least one fluid passage,

a hammer slidably mounted in said casing above said anvil, said hammer having a lower part of larger diameter than the upper part, both of said lower and upper parts closely fitting corresponding parts of said casing, said hammer containing at least one fluid passage,

a support above said hammer and stationary with respect to said casing, said support containing an axial fluid passage therethrough with a Venturi throat,

a cylindrical upper slide valve adjacent the upper end of said hammer and slidably carried between upper and lower stops in said support, upon the outer periphery of said support, said upper valve being so shaped and adapted that it closes the fluid passage through said hammer when said hammer is at the top of its stroke and said upper valve is against the lower stop of said support,

said support containing at least one passage for applying fluid pressure at said Venturi throat to the top of said upper valve,

sealing means for preventing flow of fluid past the inner and outer surfaces of said upper sleeve valve, and

a cylindrical lower slide valve slidably mounted around the lower end of said hammer between upper and lower stops but with sufficient fluid clearance to said hammer so that fluid pressure on top and bottom of said valve is approximately the same, said lower valve being so shaped and adapted so as to stop flow of fluid through said anvil at the lowermost position of said lower valve while permitting such flow at the topmost position thereof, and the length of said lower valve relative to said upper stop in said hammer being such that flow of fluid through said anvil upon downward motion of said hammer from the top of its stroke is first stopped on each downward stroke of said hammer only after said hammer has contacted said anvil.

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