This invention is concerned with fluid-actuated, percussive devices utilized in earth borehole drilling. Fluid-actuated percussive devices are commonly composed of a power fluid inlet, a valving system for controlling passage of the power fluid through the power unit, a chamber section and a power fluid outlet. Mounted in the chamber section is a hammer which reciprocates longitudinally to impact an anvil member to which a drill bit is connected. Reciprocation of the hammer is accomplished by alternately applying power fluid to the ends of the hammer. When power fluid is applied to the lower end of the hammer between the anvil and hammer, the hammer is accelerated in an upward direction until entry of the power fluid no longer acts on the lower end of the hammer. The energy of the hammer is transmitted to fluid trapped above the hammer and the direction of movement of the hammer is reversed. When the hammer is near the peak of its upward or return stroke, the valving system switches flow of high pressure power fluid to the upper end of the hammer causing the hammer to accelerate downward to impact the anvil. The type of valving system affects the operation of the percussive unit in many ways. In general, prior valving systems have not been as reliable, sturdy, flexible and efficient as desired. For example, the timing of prior valves is often critically affected by natural changes in the system thereby causing great fluctuations in power fluid efficiency. In addition, most prior percussive units wherein the hammer is reciprocated many times per minutes are not suited to operation with incompressible fluids.

In percussive drills, it is desirable that all of the power fluid be discharged through the bit to cool and lubricate the bit and flush the cuttings out of the borehole. It is also desirable that contaminants in the incoming power fluid be removed before the power fluid enters the hammer chamber.

During drilling, there are periods during which it is desirable to cease drilling while maintaining fluid flow through the bit. In addition, it is always desirable to establish fluid circulation before commencing operation of the power unit. Moreover, there may be periods during drilling wherein the drill bit advances appreciably faster than the drill string. In all of these cases, if the hammer were reciprocated, the force or energy of the blows would be exerted on the bottom of the power unit chamber and damage the power tool. In such instances, it is highly desirable to have a percussional tool that automatically ceases operation without interruption of the flow of power fluid through the bit.

Accordingly, it is an object of this invention to provide an efficient, flexible and reliable valving system for a percussive tool used in earth borehole drilling. It is another object of this invention to provide a valving system for a percussive tool that is positive acting during any stage of the drilling process and that is relatively unaffected by fluid pressures thereby eliminating many of the disadvantages of many prior percussive drilling mechanisms.

Yet another object is to provide a valving system that facilitates removal of impurities or other contaminants from the incoming power fluid.

Still another object of this invention is to provide a novel inlet valving and a novel exhaust valving arrangement. Such valving arrangements permit ready adjustment of the percussion unit to changing operating conditions and to different sizes and types of percussive units.

Another object of this invention is to provide a valving and exhausting arrangement wherein the flow of power fluid may be continued until the hammer strikes the anvil.

Yet another object of this invention is to provide means for automatically ceasing hammer operation without momentarily ceasing the flow of power fluid.

Still another object of this invention is to provide a percussive unit of simplified design which operates with a minimum of down time while providing high power fluid efficiency.

Other advantages and objects of this invention will become apparent by reference to the accompanying drawings, appended claims and following specification.

In the drawings:

FIGURE 1 is an elevational, partial, cross-sectional view showing the internal construction of one embodiment of the percussive mechanism described herein.

FIGURE 2 is an elevational, partial, cross-sectional view taken at 2--2 in FIGURE 1 and showing one embodiment of governor means for the percussive mechanism.

FIGURE 3 is a top, cross-sectional view taken at 3--3 in FIGURE 2 and showing one embodiment of fluid-actuated rotary means for the percussive mechanism.

FIGURE 4 is a top cross-sectional view taken at 4--4 in FIGURE 1 and illustrating porting for passage of the power fluid to operate the percussive mechanism.

FIGURES 5a, b, c, and d illustrate four operating positions of the porting of FIGURES 1 and 4.

Briefly, this invention concerns a fluid pressure operated percussive unit of a rotary earth percussive drilling system wherein the percussive unit and a drilling means are rotated at time spaced intervals the drilling means is impacted against the earth formation by a reciprocating hammer means. The hammer means is reciprocated by applying the fluid pressure to at least one movable surface. Flow of the power fluid to or from, or to and from the at least one movable surface is at least partially controlled by porting rotated by flow of the power fluid through the percussive unit. The porting rotates independently of rotation of the percussive unit and the drilling means. In a preferred embodiment, the direction of rotation of the porting is opposite to the direction of rotation of the percussive unit and drilling means. In a more specific embodiment, the hammer means is reciprocated by applying the fluid pressure to a first movable surface to move the hammer means in a first direction and then applying the fluid pressure to a second movable surface to move the hammer means in a second direction different from the first direction.

The fluid pressure is applied alternately to the first and second surfaces by way of an inlet port and the fluid pressure is removed from the first and second surfaces by way of an exhaust port. Flow of the fluid rotators the inlet port and exhaust port independently of the percussive unit and drilling means. The ports open and close upon rotation, thereby conducting fluid pressure to and from the movable surfaces. In still a more specific embodiment, the inlet and exhaust ports are part of a rotatable fluid passage means extending centrally through the power chamber of the percussive unit. In the fluid passage means between the inlet port and the exhaust port is flow restrictive means so that fluid will...
pass from inside fluid passage means to the movable surfaces by way of the inlet port and from the movable surfaces by way of the exhaust port. The fluid passage is adapted to be rotated independently of rotation of the percussion unit and driving means. Preferably, the tubular passage means is rotated by fluid operated rotary drive means and the speed of rotation is controlled by governor means.

Referring specifically to FIGURE 1, there is shown a percussive unit built in accordance with the present invention and designed to be rotated in a clockwise direction when viewed from the top of the borehole. The percussive unit includes casing 11 whose upper end is removably connected to a rotary drill string (not shown) which conducts power fluid to the percussive unit.

Slideably telescoping into the lower end of casing 11 is a bit-anvil unit which is capable of limited longitudinal movement therein. The bit-anvil unit is formed of a drill bit (not shown), shank 13 and anvil surface 15. Longitudinally traversing shank 13 is a central, bit-anvil bore passage whose lower end (not shown) communicates in the usual fashion with fluid discharge passages in the drill bit. Shank 13 is designed to rotate with casing 11 and rotate the drill bit.

In casing 11 above shank 13 is hammer means 17 which is preferably mounted within casing 11 to undergo reciprocating longitudinal movement and periodicaly impact anvil surface 15. The lower portion of hammer means 17 is of smaller diameter than the upper portion thereby forming shoulder 19 at a point intermediate of the ends of the hammer means.

Longitudinally traversing hammer means 17 is a central bore. Fluidly connecting the underside of shoulder 19 with this central bore is fluid escape passage 21 which prevents capture of fluid under shoulder 19 as hereinbefore described.

As shown in FIGURES 1 and 4, near the top face surface of hammer means 17, one side of the central bore passage is recessed to form upper hammer opening 23 which communicates with the interior of casing 11 above hammer means 17 and which during operation of the percussive unit conducts fluid to and from the cylinder volume above the hammer means as set forth hereinafter.

As shown, aligned just below upper hammer opening 23 and on the opposite side of the central bore passage through hammer means 17 is a similar recess forming lower hammer opening 25 which during operation of the percussive unit conducts fluid to and from the cylinder volume below the hammer means.

Extending longitudinally through the central bore in hammer means 17 and into the central bore of the shank 13 is a rotatable fluid passage means which as illustrated is formed by tubular passage means 27 which is open at both ends for egress and ingress of power fluid and which is free to rotate independently of casing 11, shank 13 and hammer means 17.

Near the top or first end of tubular passage means 27 is bypass port 29 which is opened and closed by a governor means. Just below this bypass port is rotary drive means 31 which is rigidly connected to tubular passage means 27. Both the governor means and rotary drive means will be hereinafter described in more detail.

At the lower or second end of tubular passage means 27 is bearing surface 33 which forms a rotatable fluid seal with the wall of the central bore of shank 13.

Above the lower end of tubular passage means 27 and below rotary drive means 31 is a first opening through the wall of tubular passage 27 which opening forms power fluid inlet port 35 which is on the bottom and when rotated independently of the drill bit, alternately communicates with the cylinder volume above the top face surface and the cylinder volume below the underside face surfaces of hammer means 17 by way of the upper and lower hammer openings, previously described, to conduct power fluid to and below the hammer means.

Through the wall of tubular passage means 27 opposite and below power fluid inlet port 35 is a second opening which forms power fluid exhaust port 37 which, when the drill bit is on bottom and when rotated independently of the drill bit, alternately communicates with the cylinder volume above the top face surface and the cylinder volume below the underside face surfaces of hammer means 17 to conduct power fluid from above and below the hammer means.

In tubular passage means 27 between power fluid inlet port 35 and power fluid exhaust port 37 is flow restrictive means 39 which effectively divides the tubular means into two sections with the section above the flow restrictive means being a power fluid inlet section and the section below the flow restrictor being a power fluid exhaust section. As shown, preferably, flow restrictive means 39 has bleed port 41 which permits a small amount of power fluid to escape thence for the fluid foot supplied inlets of the side of the flow restrictive means to the exhaust side thereby assuring a continuous stream of fluid for cleaning and flushing the drill bit and for removing impurities from the incoming power fluid.

Through the wall of tubular passage means 27 above power fluid exhaust port 37 above the second port 35 and below rotary drive means 31 are slit-like openings 43 which communicate with power fluid passage 45 in casing 11 which conduct power fluid from rotary drive means 31 back to tubular means 27 as hereinafter disclosed.

Just above slit-like openings 43 is bearing 47 which circumscribes and supports tubular means 27 and permits easy rotation thereof. Preferably bearing 47 will be a ball, thrust bearing.

Below power fluid exhaust port 37, tubular means 27 is of reduced outside diameter thereby creating an annulus between the walls of the central bore of hammer means 17 and tubular passage means 27. This annular space forms lower hammer passage 49 which communicates with the underside face surfaces of the hammer means. Above this passage, no appreciable amount of power fluid may flow between tubular passage means 27 and hammer means 17 except by way of lower hammer power fluid opening 55 and upper hammer opening 23 as the tubular passage means fits snugly into the central bore of the hammer means.

Returning now to rotary drive means 31, this rotary drive may be any form of fluid-actuated rotary device or fluid reaction motor connected to and suitable for rotating tubular passage means 27 and could be an integral part thereof. As shown in FIGURES 1 through 3, rotary drive means 31 is of the jet type and includes hollow cylinder 51 extending cross-like through tubular passage means 27 in such manner as to prevent fluid flow directly through the tubular passage means. Cylinder 51 is locked in place by fastener means 53, which for simplicity is shown as a rivet and which extends through the cylinder and tubular passage means.

Located centrally in the top of cylinder 51 is power fluid entry 55 which is aligned with and communicates with the upper end of tubular passage means 27.

At its two ends, as shown in FIGURE 3, cylinder 51 is bounded to fit the contour of the inside of casing 11 and form a tubular seal therein except for jet openings 57 and 59 in opposite sides of the cylinder and located on opposite ends thereof so that fluid emitting from these openings will cause cylinder 51 to rotate rotary drive means 31 counterclockwise as viewed from the top of the borehole. Preferably, the direction of rotation should be clockwise on the drill bit, casing 11 and shank 13, which as shown will be counterclockwise as viewed from the top of the borehole.

The speed of rotation of rotary drive means 31 and thus tubular passage means 27 is controlled by governor
means. One form of suitable governor means is illustrated in FIGURES 2 and 3 where bypass port 29 is opened by spring member 61. Spring member 61 is pretensioned to close bypass port 29. When the speed of rotation of tubular passage means 27 exceeds a preset value centrifugal force will cause spring member 61 to pull away from tubular passage means 27 just enough to keep the speed of rotation of the tubular passage means relatively constant. Spring member 61 is, therefore, quite sensitive to small changes in r.p.m.

Consider now the operation of the percussive unit which is best understood by reference to all of the drawings and in particular to FIGURES 5a, b, c, and d, which illustrate four stages in the passage of power fluid through the percussive unit.

At the outset, attention must be drawn to the fact that power fluid inlet port 35 and power fluid exhaust port 37 are rotated with the inlet port slightly above the exhaust port. In FIGURE 5, these ports are cross-hatched and the corresponding motion depicted by arrows. By comparing the relative vertical distances that each port extends above a dashed reference ellipse shown in each figure, the fact that the inlet port is slightly higher than the exhaust port may be noted. This will also aid in following each port through its circular path.

At the hammer means position shown in FIGURE 5, the hammer means 17 and, as far as the over-all operation of the percussive unit is concerned, they do not rotate. These openings in the hammer means are illustrated in FIGURE 5 without cross-hatching and their up movement is shown in FIGURES 5a and 5b and their down movement in FIGURES 5c and 5d. Again, by referring to the reference ellipse, it can be seen that upper hammer opening 23 is above lower hammer opening 25. In FIGURE 5, when an opening in the hammer means communicates with a port in the tubular means, the communicating areas are represented by the blackened portion of the port and opening. For example, in FIGURE 5a, power fluid inlet port 35 communicates with lower hammer opening 25 and power fluid exhaust port 37 communicates with upper hammer opening 23.

Return now to the over-all operation of the percussive unit. Power fluid enters the top of tubular means 27 passing downward into rotary drive means 31 and outlet openings 57 and 59 causing tubular passage means 27 to rotate. The power fluid continues downward back into the passage means where it is conducted to power fluid inlet port 35. As shown, in FIGURE 5a, power fluid inlet port 35 communicates with lower hammer opening 25 which is the position of the hammer means 17 shown in FIGURE 1, where lower hammer opening 25 in turn communicates with the underside surface of the hammer means by way of lower hammer passage 49. The power fluid pressure acting on the underside surface of the hammer means causes the hammer to accelerate upward in its return stroke. At the same time, fluid above the hammer means is exhausted through upper hammer opening 23 and power fluid exhaust port 37 into tubular passage means 27 where the exhausted fluid is conducted through the drill bit.

Hammer means 17 continues to accelerate upward in its return stroke as long as power fluid may pass from inlet port 35 to the underside of the hammer means. If the power fluid is highly compressible, e.g., air, before the power fluid is shut off from the underside of the hammer means, upper hammer opening 23 may no longer communicate with exhaust port 37 as shown in FIGURE 5b. The fluid thus trapped above the hammer means begins to compress.

As the hammer means moves upward, power fluid inlet port 35 rotates ceasing communication with the underside of the hammer means. The hammer means continues to travel upward compressing fluid trapped above the hammer means until upward momentum of the hammer is absorbed by this fluid. At this point, the compressed fluid reverses the direction of the hammer means and starts the hammer downward in its power stroke.

As shown in FIGURE 5c, exhaust port 37 has rotated into communication with lower hammer opening 25 thereby allowing fluid under hammer to be exhausted through tubular passage means 27. Very quickly thereafter power fluid inlet port 35 communicates with upper hammer opening 23 and accelerates the hammer means downward to impact anvil surface 15 driving shank 13 downward to force the drill bit against the formation being drilled and completing one cycle of the hammer means.

In order to obtain maximum impact energy, it is preferred that power fluid act on the upper face of the hammer until impact and that all of the fluid below the hammer be allowed to escape to exhaust port 37. This is shown in FIGURE 5d. In addition, fluid escape passage 21 prevents any fluid from being trapped under shoulder 19 as the hammer means anvil surface 15.

From the above description, it should be evident that the relative positions and shapes of the ports and openings of this invention may be varied to fit the particular percussive unit being used and the nature of the power fluid which may be either compressible or incompressible. Moreover, the speed of rotation of the rotatable passage means may be similarly varied.

During the above described mode of operating the percussive unit the drill bit was on bottom of the borehole. As mentioned in the introduction, there are moments when it is desirable to circulate power fluid through the percussive unit without reciprocating the hammer means. As stated previously, shank 13 may undergo limited longitudinal movement within casing 11. When shank 13 moves downward beyond its normal operating position, hammer means 17 also drops exposing power fluid inlet port 35 to power fluid exhaust port 37 so that the power fluid passes through the percussive unit without reciprocating the hammer means.

While the invention has been described in connection with certain specific embodiments thereof, it will now be understood that further modifications will suggest themselves to those skilled in the art and it is intended to cover such modifications as fall within the scope of the foregoing description and appended claims.

I claim:

1. A fluid pressure-operated percussive unit of a rotary percussive drilling system, having a hammer means and a drilling means wherein the percussive unit and the drilling means are rotated and the drilling means is impacted against the earth by fluid reciprocating of the hammer means, an improved valving system comprising:
   (a) a tubular rotatable valve having at least one inlet port located in said valve in a position to alternately pass power fluid from a power fluid supply passage to opposite ends of said hammer means as said valve is rotated, and at least one outlet port located in said valve in a position to alternately pass power fluid from said outer opposite ends of said hammer means to a power fluid exhaust passage as said valve is rotated, and
   (b) rotary drive means connected to said valve to rotate said valve independently of the rotation of said percussive unit and said drilling means.

2. A valving system in accordance with claim 1 wherein the inlay port of the valve passes power fluid continuously from the power fluid supply passage to the power fluid exhaust passage when the hammer means over-travels downwardly beyond its normal operating position.

3. A valving system in accordance with claim 1 wherein the valve is rotated in a direction opposite to the direction of rotation of the percussive unit and the drilling means.
4. A valving system in accordance with claim 1 wherein the rotary drive means is a fluid-actuated rotary drive means operable by the power fluid.

5. A valving system in accordance with claim 1 wherein the rotary drive means is operable for a period of time prior to the passage of power fluid to the ends of the hammer means.

6. A valving system in accordance with claim 1 wherein the speed of rotation of the rotary drive means is controlled by a governor means.

7. In a fluid pressure-operated percussive unit of a rotary percussive drilling system, having a hammer means and a drilling means, and wherein the percussive unit and drilling means are rotated and the drilling means is impacted against the earth by fluid reciprocation of the hammer means, an improved valving system comprising:

(a) a tubular, rotatable valve having at least one inlet port located in said valve in a position to alternately pass power fluid from a power fluid supply passage to opposite ends of said hammer means as said valve is rotated, and at least one outlet port located in said valve in a position to alternately pass power fluid from said opposite ends of said hammer means to a power fluid exhaust passage as said valve is rotated.

(b) rotary drive means connected to said valve to rotate said valve independently of the rotation of said percussive unit and said drilling means, and

(c) a flow restrictive means in said valve between said inlet port and said exhaust port to continuously pass a small amount of power fluid from the upper inlet section to the lower outlet section of said valve.

8. A valving system in accordance with claim 7 wherein the inlet port of the valve passes power fluid continuously from the power fluid supply passage to the power fluid exhaust passage when the hammer means over-travels downwardly beyond its normal operating position.

9. A valving system in accordance with claim 7 wherein the valve is rotated in a direction opposite to the direction of rotation of the percussive unit and the drilling means.

10. A valving system in accordance with claim 7 wherein the rotary drive means is a fluid-actuated rotary drive means operable by the power fluid.

11. A valving system in accordance with claim 7 wherein the rotary drive means is operable for a period of time prior to the passage of power fluid to the ends of the hammer means.

12. A valving system in accordance with claim 7 wherein the speed of rotation of the rotary drive means is controlled by a governor means.

13. In a fluid pressure-operated percussive unit of a rotary percussive drilling system, having a hammer means and a drilling means wherein the percussive unit and the drilling means are rotated and the drilling means is impacted against the earth by fluid reciprocation of the hammer means, an improved valving system comprising:

(a) a tubular, rotatable valve passing through the center of said hammer means, said valve having power fluid inlet passages located adjacent its upper end to pass power fluid to the interior of said valve, a power fluid inlet port located in the side of said valve near the center of said valve to alternately pass power fluid from the interior of the upper section of said valve to opposite ends of said hammer means as said valve is rotated, and a power fluid outlet port located in the side of said valve, opposite to and slightly below said power fluid inlet port, to alternately pass power fluid from said opposite ends of said hammer means to the interior of the lower section of said valve,

(b) an angularly disposed flow-restrictive plate dividing the interior of said valve near its center to form an upper power fluid inlet section including said inlet port and a lower power fluid outlet section including said outlet port, said flow-restrictive plate having a small portion therein to continuously pass a small amount of power fluid from the upper power fluid inlet section to the lower power fluid outlet section,

(c) a fluid-actuated rotary drive means operable by the power fluid and connected to said valve in a manner to rotate said valve independently of the rotation of said percussive unit and said drilling means, and

(d) a governor means connected to said rotary drive means to control the speed of rotation of the rotary drive means irrespective of the rate of flow of power fluid.

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