March 7, 1967 L. B. WILDER ET AL 3,307,639

VALVE SYSTEM FOR PERCUSSION DRILL MOTOR

Filed Nov. 23, 1964

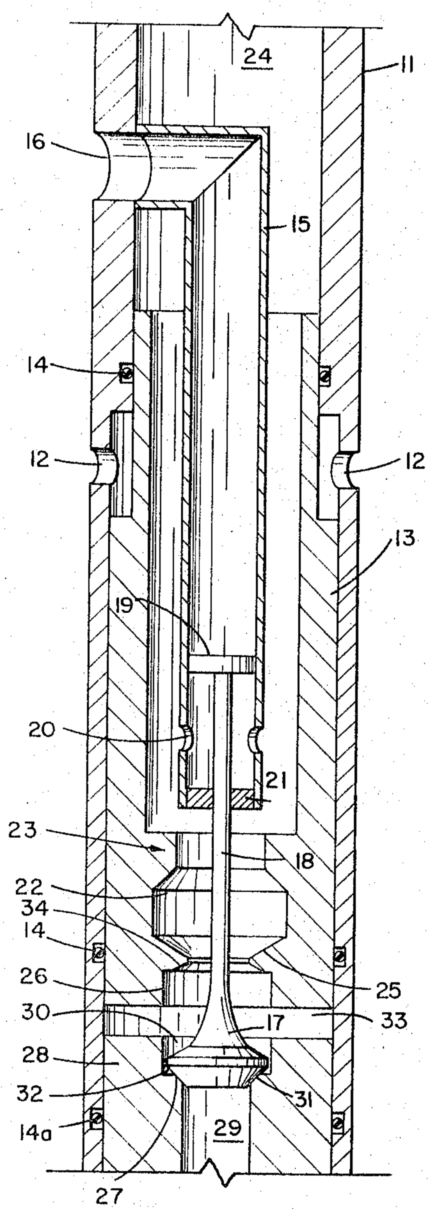

FIG. -1

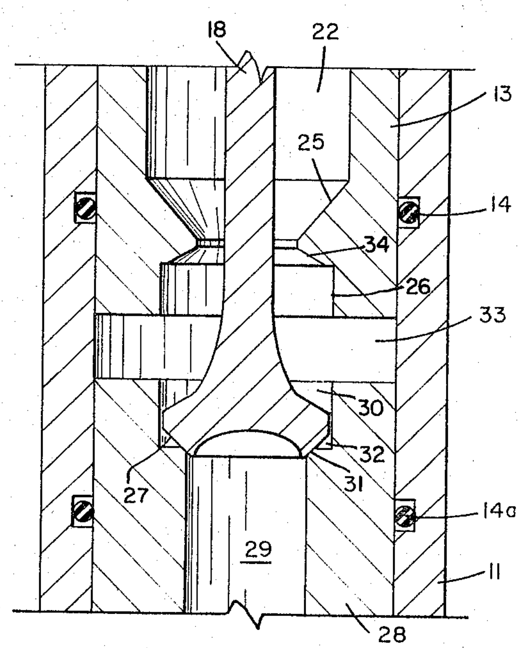

FIG. -2

LAWRENCE B. WILDER
KENNETH A. BLENKARN

INVENTORS.

BY Paul F. Hawley

ATTORNEY.

United States Patent Office

3,307,639
Patented Mar. 7, 1967

3,307,639

VALVE SYSTEM FOR PERCUSSION DRILL MOTOR

Lawrence B. Wilder and Kenneth A. Blenkarn, Tulsa, Okla., assignors to Pan American Petroleum Corporation, Tulsa, Okla., a corporation of Delaware

Filed Nov. 23, 1964, Ser. No. 413,023
2 Claims. (Cl. 173—136)

This invention relates to a particular valve and seat arrangement, collectively called a valve system, for use in a percussion drilling tool or drilling motor. Such a tool, or motor, is attached to the lower end of a drill string and is actuated by the drilling fluid (gas or liquid) to impart a repetitive or oscillating force to a drill bit in the course of rotary drilling earth formations, thus increasing the penetration rate of the bit. Such equipment, particularly when employing gas as the drilling fluid, have been employed successfully in drilling wells at a much more rapid rate than is possible with conventional drilling apparatus. However, particularly when a liquid is employed as the drilling fluid, the valve systems used to direct the forces inside of the tool are of a critical nature since successful actuation of the tool depends very definitely on the proper seating and unseating of the valve, or valves, in the seats provided. Again, particularly in the case where liquid drilling fluid is employed, but occasionally when gas is used, it is found that there is a distinct tendency of the valve to "chatter," that is, rapidly open and close for a short period after initial seating. This results in a considerable decrease in effectiveness of the tool in that it both decreases the magnitude of impact imparted to the drill bit and decreases the number of cycles per unit time, resulting in decreased drilling rate. The valve system used in our invention has been found to overcome this chattering difficulty and to provide maximum effectiveness of the percussion motor.

The cause of the erratic closing or seating of the valve has on analysis resulted when the pressure surge, which occurs on seating of the valve, is reflected from discontinuities in the tool or associated equipment. Such a phenomenon is frequently referred to as "water hammer," though it occurs in a lesser degree in gas actuated systems. It is known that wherever there is a change in acoustic impedance of the fluid column through which the pressure surge is traveling, there is an echo or reflection of the pressure surge which then returns to the original source. The surge is reflected out of phase, which means that there is a decrease in seating pressure applied by the fluid to the valve, tending to dislodge the valve from its seat. Erratic unseating of the valve can also result from shock wave reflections from the drilling string or from the formations being drilled arriving at the valve seat with sufficient vibratory energy to dislodge the valve from its seat. We have found it is possible to design the valve system in such a way that the unseating, or chattering, tendency of the valve on its seat in a percussion drilling tool is minimized and is usually completely absent.

It is accordingly an object of this invention to provide a valve system for a fluid actuated percussion drill motor which minimizes tendencies to unseat the valve due to pressure variations in the actuating fluid on the valve or to vibrations of the seat. Further object of the invention will be apparent from this specification.

In order to illustrate this invention, certain drawings have been attached hereto and made a part hereof. In these drawings the same reference numeral in different views refers to the same or corresponding part.

In the drawings:

FIGURE 1 shows in diagrammatical form a cross section of one type of drilling motor employing a valve system designed in accordance with this invention.

FIGURE 2 shows in cross section the valve system in an enlarged view.

While it is useful in other mechanisms, our invention particularly finds application in percussion drilling motors, and particularly those actuated by liquid. Such motors have been described a number of times, so no detailed description is believed warranted. Reference is made to co-pending U.S. application 404,046 filed October 15, 1964 in the names of Renic P. Vincent and Lawrence B. Wilder, and to U.S. Letters Patent 3,101,796 Stall et al., for examples of liquid and gas actuated percussion drilling motors. Such motors are attached to the end of a string of drill pipe and supplied with a stream of high pressure actuating fluid through the pipe. The motors incorporate an axially oscillating hammer, the movement of which is controlled by one or more valve systems. Below the hammer there is an anvil slideably supported in the lower end of the motor housing and coupled to the housing in such a way that axial torque supplied through the string to the housing is applied to this anvil. The lower end of the anvil protrudes through the housing and is attached to a drill bit. Suitable passages and ports in the motor, including the anvil, permit the actuating fluid ultimately to escape through the hollow anvil and through the bit so that circulation is maintained, suitable hydraulic pressure is applied to the formations of the well, and drill cuttings are forced to the surface.

One suitable percussion motor in accordance with the above is shown in FIGURE 1. The connection of the cylindrical housing **11** to a drill string (not shown) is not given. It could be, for example, as shown in the Stall et al. patent mentioned above. The housing **11** has an upper portion which is thick walled and has a relative small internal diameter attached to, or made in integral with, a lower portion of thinner wall and greater internal diameter. At or adjacent the point of diametral change is located one or more ports **12** radially communicating between the inside and outside of the housing. A stepped piston-type hammer **13**, the outer upper and lower diameters of which fit closely, respectively, the upper and lower diameters of housing **11** is slideably mounted within the housing so that it can oscillate axially. Seals **14** are mounted on either the outer surface of hammer or the inner surface of the housing to provide fluid shut-off between the hammer and the housing.

A cylindrical center tube **15** substantially coaxial for the majority of its length with housing **11** is attached at its upper end to the housing at a port **16**. Thus, the interior of tube **15** communicates with the fluid outside the housing. A valve assembly including a poppet valve **17**, a connecting rod **18**, and a piston **19** are substantially coaxially mounted within the hammer; piston **19** is within and closely fitting the internal diameter of the center tube **15**. This valve assembly is axially symmetric. Center tube **15** also includes one or more ports **20** in the wall, below which there is a fluid seal or partition **21** closely surrounding the connecting rod **18** of the valve assembly and extending from wall to wall of the center tube **15** so that there is substantially no fluid pressure transference from the lower part of center tube **15** into the annular space **22**. An annular valve member **23**, which is integral with the hammer **13**, forms one valve system for this motor, with the aid of the lower end of center tube **15**. The minimum inside diameter of this annular member slightly exceeds the outer diameter of center tube **15** and the two are aligned so that when the hammer **13** rises, the flow of fluid from the hollow opening **24** in the upper part of the housing **11** into the annular space **22** is definitely minimized and may be substantially shut off. Below this annular member **23** a second annular member **25** also extends into the annular space **22**. The minimum diameter of this annular member (also integral with hammer **13**) is less than the inside diameter of center tube **15**, and is provided with a seat **34** for the upper surface of poppet valve **17**. Preferably a cylindrical recess **26** is provided in hammer **13** below the second annular member **25** of sufficient diameter and length to accommodate the outermost diameter of valve **17** without striking.

The lower surface **27** of poppet valve **17** is beveled inwardly as shown in FIGURES 1 and 2. The region of maximum diameter is axially of short length—for example about ⅛ inch to ½ inch, though this not not critical.

A hollow cylindrical anvil **28** is slideably mounted, as discussed above, in housing **11** below the hammer **13**. The hollow portion includes an axial exhaust passageway **29** through which the actuating fluid exhausts. A fluid seal **14***a* is employed between the anvil **28** and housing **11**. The top of the anvil **28** has a coaxial recessed right circular cylindrical portion **30** aligned with valve **17** and of just slightly larger diameter than the maximum diameter of valve **17**. This produces an annular step in the top part of the anvil **28**. The top of the step is machined to form a seat **31** for the lower surface **27** of valve **17**. The axial length of the recessed portion **30** of the exhaust passageway is sufficient so that when the valve **17** is seated on the lower seat **31** the region of maximum valve diameter is within or below the top of the anvil **28**. Under this condition, there is an annular chamber **32** below the point of maximum diameter of valve **17** and above the lower seat **31**, which has only minimal fluid communication with variable space **33** between the hammer **13** and the anvil **28**.

In operation, when the valve **17** of the valve assembly seats on the lower seat **31**, the pressure of the drilling fluid in the hollow opening **24** of housing **11** is axially applied substantially equally against the top and bottom areas of the stepped hammer **13**. Since the bottom area is the larger, a net upward force causes the hammer **13** to rise within the housing, until the top of the annular valve member **23** is adjacent the bottom of the center tube **15**, minimizing fluid flow into space **33**. The downward pressure on the top of hammer **13** continues; since the hammer is rising the upward pressure in space **33** on the bottom of the hammer **13** rapidly decreases and the hammer will stop and commence to descend. The minimum diameter of the lower seat **31** of valve **17** is greater than the diameter of the center tube **15**. The pressure in space **33** has considerably decreased so the downward seating force (hydraulic pressure in area **33** multiplied by the area corresponding approximately to the largest diameter of seat **31**) has correspondingly decreased. The bottom surface of piston **19** is exposed to the fluid pressure in opening **24** in housing **11** through ports **20**. The downward force on the top of piston **19**, due to the exhaust pressure at the port **16**, is considerably less and accordingly there is a net upward force on the valve assembly which rapidly impels this assembly upward until valve **17** seats against the upper seat **34** in the annular member **25**. As poppet valve **17** approaches the seat in the second annular member **25**, the largest diameter of the valve **17** enters the substantially similar diameter annular chamber **26**. The fluid trapped in annular chamber **26** between the poppet valve **17** and the second annular hammer member **25**, must therefore be expelled past the seat of said member **25**. The annular orifice area rapidly decreases as the valve **17** nears said seat, impeding the fluid flow from annular chamber **26**, and thus hydraulically decelerates the motion of the valve **17** and reduces the force of the valve **17** against said seat. Also, if there is not complete shut off between tube **15** and annular member **23**, some pressure will be applied against the larger diameter of valve **17** acting as a piston in recess **26**, applying a downward force which further decelerates the valve **17**. Exhaust passageway **29** is now opened to permit rapid drainage of the fluid in space **33**. There is, accordingly, a net downward force on hammer **13** which accelerates the hammer until it impacts against the anvil **28** and transfers a large part of its momentum to the anvil **28** and hence to its attached drill bit. Until the hammer **13** strikes the anvil **28**, the net upward force on piston **19** is greater than the downward force on the upper surface of valve **17** above and the upper seat **34** in annular member **25** and, accordingly, the valve assembly is held against the annular seat until the impact of hammer and anvil. The inertia force on the valve assembly at this instant of impact drives it down against the lower seat **31** immediately after the impact. As soon as the upper surface of valve **17** leaves the seat in second annular member **35**, the largest diameter of valve **17** (of greater area than the piston **19**) is exposed to the pressure in chamber **22**; the valve **17** acts as a piston in recess **26**, and the valve is also hydraulically expelled toward the anvil seat **31**. This further aids in preventing the tool from stalling, if in the start-up cycle the hammer hits a lighter than normal impact.

It is to be noted that the exhaust passageway **29** is kept open until the hammer and anvil impact. This is important. Due to this arrangement there is no liquid cushion in space **33** tending to minimize the sharpness of the blow of the hammer on the anvil. Also, since the deceleration is extremely rapid, the valve assembly by inertia is very rapidly displaced downward against the lower seat **31**, tending to give minimum fluid leakage (which decreases hydraulic efficiency) and makes the tool work most effectively. However, a seeming disadvantage of this arrangement is that there is accordingly a tendency of the valve assembly to chatter on seat **31**. However, by use of our invention, which involves the beveled lower surface **27** of valve **17**, the maximum cylindrical diameter of this valve **17**, and the recess **30** prevents or greatly minimizes possibility of such motion.

Particularly referring to FIGURE 2, it is seen that since the outer diameter of valve **17** very nearly matches the inside diameter of cylindrical recess **30** there is very limited fluid access from space **33** to annular chamber **32**. If valve **17** temporarily raises from the lower seat **31**, annular chamber **32** is in immediate fluid communication with the lower pressure in exhaust passageway **29** and, therefore, relatively there is an increased downward force on the upper face of valve **17** tending to restore it immediately to its seat. On the other hand, the higher fluid pressure in space **33** is applied across the upper face of valve **17**, and since there is very limited fluid communication between space **33** and annular chamber **32**, there is a marked pressure drop from space **33** to chamber **32** and little tendency of the high pressure fluid in space **33** to lift the valve. Accordingly, the pressure in space **33** has a maximum downward or re-seating effect. In practice, with this arrangement it is found that the clearance between the maximum diameter of valve **17** and the diameter of the annular recessed **30** should be the minimum without physical interference. The effectiveness is of course dependent in some degree to the viscosity of the fluid, greater effective viscosity permitting greater clearance. To be effective, the annular orifice area between valve and recess must be substantially less than the inclined orifice area between the seat **31** and the lower bevel of valve **17**, which depends on how far up the valve has moved from seat **31**. As the valve moves up, the inclined orifice area increases very fast, but the annular orifice between valve and recess becomes shorter in length and thus less effective. In one tool tested, the valve was 2.500" diameter and the recess was 2.505" diameter. When the combined clearance due to wear was .025", the pocket was noticeably less effective. With minimum clearance, there is virtually no tendency of the valve **17** to chatter on the lower seat **31**, even in the presence of water hammer, and the percussion drill motor works with maximum effectiveness.

We have tried a number of designs for the shape of the lower surface of valve **17** and the recess **30** and lower seat **31**. The design shown has proved to be better than any other arrangement given and, in fact, is the one design that has permitted this type of percussion motor to work for many hours uninterruptedly and without breakage of the valve **17**. It is to be noted that not only is the radially outer portion of the poppet valve beveled inwardly, but the center part of the lower valve surface is concave upward. This eliminates mass from the center part of the valve where it is of little benefit as far as strength is concerned and, accordingly, this arrangement gives the popet valve a greater stiffness for the total weight than would be possible if this concavity were missing.

It must be kept in mind that if a liquid is the actuating fluid, it is carrying small particles of solids, for example, parts of the drill cuttings and hence tends to produce definite erosional effects when valves are in the process of closing. These erosional effects are minimized if the valve closure is very rapid with deceleration or damping effect only at the last instant. This also is found in the design according to our invention, as discussed immediately above. Accordingly, we have found minimal erosional effects on the valve in the design shown.

The valve assembly is maintained coaxial with the lower seat **31** but there is no restriction to rotational movement of this valve as it oscillates back and forth. Accordingly, the valve **17** will not ordinarily re-seat in the same position relative to the lower seat **31**, stroke after stroke. This, therefore, causes the lower beveled surface **27** of the valve and the corresponding lower seat **31**, to be maintained in a uniform good seating relationship over a tremendous number of cycles of valve oscillation. Accordingly, we find that the valve system consisting of valve **17**, recess **30**, and lower seat **31**, are maintained in good mechanical closure relationships over the life of the percussion drill motor.

It is apparent that variations in the arrangement of our invention may be made without departing from the principle disclosed in this specification. Accordingly, the design is best defined by the attached claims.

We claim:

1. In a percussion drill motor including a housing, an axially hollow hammer slideably disposed within and closely fitting said housing, an axially hollow anvil slideably disposed within and closely fitting said housing adjacent one end of said hammer, said hammer being reciprocated by valve action on a stream of pressure fluid flowing in the axial hollow portions of said hammer and said anvil, the improvement comprising:

(1) an axially symmetric poppet valve coaxially and slideably mounted within said housing adjacent said anvil with an axially short section of maximum diameter and a lower beveled face extending inwardly from said section of maximum diameter,

(2) a recessed valve seat in the hollow portion of said anvil adjacent said hammer, said valve seat being beveled to correspond to said lower beveled face of said valve and axially aligned therewith, said seat being located below the top of said anvil by a substantial axial distance such that when said valve touches said seat said short section is below the top of said anvil, the recess above said seat being substantially a right circular cylinder the diameter of which is of only slightly greater diameter than the maximum diameter of said valve, and

(3) a recessed valve seat in the hollow portion of said hammer adjacent said anvil, said valve seat being beveled to correspond to the upper surface of said valve and axially aligned therewith, said seat being located above the bottom of said hammer by a substantial axial distance, the recess below said seat in said hammer being substantially a right circular cylinder the diameter of which is of only slightly greater diameter than the maximum diameter of said valve.

2. Apparatus in accordance with claim **1** in which the lower beveled face of said poppet valve extends inwardly only a portion of the total valve width and the remainder of the lower surface of said valve is concave upward.

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FRED C. MATTERN, Jr., *Primary Examiner*.

L. P. KESSLER, *Assistant Examiner*.