

3,018,834

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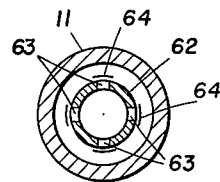


FIG. 3.

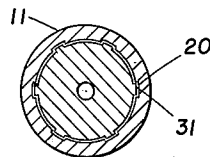


FIG. 4.

FIG. 1.

FIG. 2.

EVIN L. COOK
INVENTOR.

BY *H. Mathews Garland*
ATTORNEY

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3,018,834

FLUID-ACTUATED PERCUSSION DRILL

Evin L. Cook, Dallas, Tex., assignor to Socony Mobil Oil Company, Inc., a corporation of New York
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8 Claims. (Cl. 175-92)

Generally, this invention relates to drilling devices. Specifically, this invention relates to a fluid-actuated drilling device which utilizes an impulse developed by interrupting the flow of a column of liquid to obtain percussive action.

In the art of drilling wells, particularly oil wells, the devices and methods which presently are most commonly employed generally may be referred to under the term "rotary drilling." In rotary drilling, a drill bit is secured to the lower end of an assembly of pipe sections called drill collars which in turn are connected to lighter weight pipe known as the drill string which extends to the surface. As the drill string is rotated by equipment located at the top of the well on the surface of the earth, drilling fluid, commonly referred to as drilling mud, is pumped downwardly through the drill string assembly and outwardly through passages provided in the drill bit. The drilling fluid functions to cool the bit, flush cuttings from the area of drilling upwardly to the surface through the annulus around the drill string, and provide a hydrostatic head on the formation being drilled to prevent the invasion of formation fluid into the well during drilling. A roller type drill bit is the form of cutting tool most often used in conventional rotary drilling operations. The roller type drill bit is provided with several conical-shaped members which roll into contact with the formation as the bit is rotated. Each of these conical-shaped members has a number of tooth-like portions which effect chipping action with the rock being drilled. Each of these tooth-like portions behaves as cogs on the hard rock in the formation and impart a vertical component of movement which may be said to be a form of percussive action. Because of certain inherent acute limitations of roller type bits, other methods of combining rotary and percussion actions have been sought. Among those methods and devices which have been proposed for the purpose of combining rotary and percussion actions have been drilling tools which employ reciprocating liquid-actuated hammer devices and those which utilize sudden interruptions of drilling fluid flow to cause a "water hammer" effect or high pressure impulse which results in a quick downward movement of the bit into the rock being cut.

One of the numerous problems encountered in using the high pressure impulse effect in percussion drilling is that of the transmission of shock waves through the drill string to the surface equipment. Among the suggestions for controlling the frequency of the impulse and minimizing the transmission of the shock waves to the surface equipment have been drilling devices which utilize either a highly compressible sleeved section in the drill string, or a gas-filled pocket provided in the drill string. Such shock minimizing and frequency controlling devices are not only troublesome in operation, but also expensive and complicated to construct. Another factor in the design of drilling tools utilizing the fluid impulse effect is the fact that the magnitude of the pressure increase developed is dependent upon the velocity of the flow of fluid which is interrupted in order to obtain the impulse. Increasing the velocity of fluid flow requires reduction in tubing cross-sectional area which, of course, leads to a reduction in the total force available. This is true because the tool surface on which this fluid impulse must act to develop a driving force is also reduced.

It is an object of this invention to provide a fluid-actuated drilling tool. It is another object of this invention

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to provide a drilling tool in which both rotary and percussion types of action are combined. It is another object of this invention to provide a rotary type drilling tool in which percussion action is achieved by utilizing the fluid impulse effect. It is a further object of this invention to provide a rotary-percussion type drilling device in which the shock waves incident to the percussion action are minimized insofar as their transmission to the surface equipment is concerned. It is a further object of this invention to provide a percussion type drilling device actuated by fluid impulse in which the velocity of the fluid actuating the device is in excess of the velocity of the same fluid as it flows through the drill string to the device. It is a further object of this invention to provide a percussion type drilling device actuated by the fluid impulse effect which utilizes a pressure intensifying means to achieve maximum percussive force from minimum size tubing diameter. These, and further objects of the invention, will be evident from a reading of the following specification in conjunction with the drawings.

In the drawings:

FIGURE 1 is a longitudinal cross-sectional view of one embodiment of the invention.

FIGURE 2 is a longitudinal cross-sectional view of another embodiment of the invention.

FIGURE 3 is a cross-sectional view taken along the line 3-3 of FIGURE 2.

FIGURE 4 is a cross-sectional view taken along the lines 4-4 of FIGURES 1 and 2.

The embodiments of the invention illustrated in FIGURES 1 and 2 are identical in mode of operation and differ in structure only with respect to the form of valve and anvil employed. For purposes of simplicity, therefore, identical reference numerals are used in both FIGURES 1 and 2 for all parts except those which relate to the valve and anvil structure.

Referring to the drawings, drill string 8, which is formed of sections of conventional drill pipe, functions to rotate a drill bit and convey drill fluid or mud from the surface to the bit for the purposes previously described. The entire length of drill string 8 is provided with a uniform internal diameter. Threadedly engaged to the lower end of drill string 8 is a section of drill collar 9 which is provided with a small bore 10. Drill collar 9 may be an assembly formed of several sections of conventional, small-bore collar. Bore 10 functions to increase the velocity of the flow of drilling fluid through the drill collar 9 from the drill string to the drilling tool. The cross-sectional area of bore 10 is smaller than the cross-sectional area of the drill string and preferably is designed to effect a fluid velocity in range of about 2 to about 20 times the fluid velocity through the drill string. The boundary between drill string 8 and drill collar 9, that is, the point of connection between the drill string and the drill collar, also serves as an acoustical reflector, as will be explained later. Threadedly connected to the lower end of drill collar 9 is a tubular housing 11 which is provided with an upper small bore 12 and a lower large bore 13, a portion of which functions as a pressure intensifying chamber. Small bore 12 terminates at and connects into the upper end of large bore 13 which provides a reflecting surface 14 at the upper end of the large bore. The shape and contour of surface 14 may be varied as desired to alter the reflection wave forms that will be developed shortly after the stoppage of fluid flow by valve closure. The relationship between the relative diameters of small bore 12 and large bore 13, together with the function of reflecting surface 14, will be explained in more detail in connection with the operation of the apparatus of the invention. Cut into the internal surface of the lower end of housing 11 are a plurality of axially extending grooves or slots 20 which are evenly spaced around the

lower inside of the housing. Slots 20 are all open at the lower end of the housing and extend upwardly into the housing equal distances from the lower end thereof. Slots 20 are substantially rectangular in cross section, though it will be recognized from an understanding of their function that they may be satisfactorily formed with other cross-sectional shapes. The cross-sectional shapes of slots 20 and their distribution may be best observed by reference to FIGURE 4. Threadedly engaged to the lower end of housing 11 is a collar or stop member 21 which is provided with a smooth bore having a diameter substantially equal to diameter of enlarged bore 13 of the drill collar. The external diameter of collar member 21 is substantially equivalent to the outside diameter of housing 11. The upper end of collar member 21 functions to provide a stop or closure at the lower end of each of the slots 20 in housing 11.

Positioned within the lower end of housing 11 within the lower portion of enlarged bore 13 is an anvil and valve body 30 which is provided with a plurality of axially extending integral splines 31 which are equally spaced around the anvil to register with slots 20 in the housing. The cross-sectional dimensions of splines 31 are sufficiently less than the cross-sectional dimensions of slots 20 that there may be sliding relative motion between the anvil and the housing. The relation between the cross-sectional dimensions of the splines and the cross-sectional dimensions of the slots should be such that the play between the anvil and the anvil and the housing will be at a minimum in order to reduce the possibility of shearing the splines off the anvil. The length of the splines 31 should be less than the length of slots 20 in order to permit longitudinal movement of the anvil with respect to housing 11. The lower end of splines 31 contact the upper end of collar member 21 to prevent the anvil from coming out of the drill collar at the times when the anvil is at the lowermost point in its path of longitudinal travel within the drill collar. Anvil 30 is provided with a centrally located, axially positioned cylindrical bore 32. At its upper end, bore 32 terminates in a valve chamber 33 which is formed in the upper end of the anvil. Secured within valve chamber 33 is a valve 34 which is supported on a spring member 35. The upper end of valve chamber 33 is provided with an inclined surface or valve seat 40 which cooperates with valve 34 to control flow of drilling fluid through the valve chamber and the bore of the anvil.

Threadedly engaged into the lower end of anvil 30 is a bit connecting member 50 which is provided with an axial bore 51 positioned to register with bore 32 in anvil 30. Threadedly engaged to the lower end of bit connecting member 50 is a drill bit 55 which is provided with passages 56 and 57 through which drilling fluid flows to the formation being drilled.

The embodiment of the invention illustrated in FIGURE 2 differs from that shown in FIGURE 1 only in the form of construction of the upper end of the anvil and the type of valve which is employed. Anvil 60, as shown in FIGURE 2, is identical with anvil 30 of FIGURE 1 except that central bore 61, which is provided through anvil 60, extends substantially the entire length of the anvil. Secured into the upper end of anvil 60 is a valve body 62 which is provided with a plurality of axially extending slots 63 which permit the flow of drilling fluid through the valve body into bore 61 of the anvil. Secured around the upper external surface of and depending from the upper end of valve body 62 are a plurality of relatively thin, flexible strips 64. Strips 64 may be secured by any desired means to valve body 62. For example, strips 64 may be spot welded at their upper ends to body 62. Also, strips 64 may be secured to body 62 by screws extending through each of the strips into the body. Strips 64 are larger than slots 63 in order that they may move horizontally to engage the side of valve body 62 over the slots to provide a complete stoppage of the flow of drilling fluid through the slots into the bore of the anvil. Stated otherwise, strips

64 coact with valve body 62 over slots 63 to provide valve action. Strips 64 are thin strips of material, such as spring steel, which are of sufficient strength and resilience that they will permit the flow of drilling fluid until the drilling fluid reaches a predetermined velocity at which time the strips seat against the side of the valve body to block the flow of drilling fluid. In cross section, strips 64 have a slight curvature, as shown in FIGURE 3, so that they will conform to the curvature of the valve body over the slots. Valve body 62 may be formed integrally with anvil 60, but preferably it is constructed separately and threadedly engaged into the upper end of the anvil, as shown in FIGURE 2.

While two specific forms of valve design have been disclosed, a vertically oscillating valve as shown in FIGURE 1 and a valve having certain horizontally operating members as shown in FIGURE 2, it is to be understood that other forms of valves possessing the required characteristics may be employed. In addition to the ability to close abruptly at the desired fluid velocity through the tool, a primary consideration in the design of the valve assembly is that the fundamental frequency of the valve assembly operating in the fluid flowing through the tool should be greater than the frequency of the impulses to be delivered by the tool in order that the characteristic frequency of the valve assembly will not interfere with the timing of these impulses. In other words, the valve assembly for satisfactory operation should be of such design that it can complete its movements in less time than the period between impacts as established by the sum of the lengths of bores 10 and 12. Among the characteristics of a valve which are factors affecting the natural frequency of the valve are the stiffness of the spring members employed and the masses of the various moving parts of the valve.

The apparatus of the invention is employed in the drilling of a well in the same manner as conventional rotary drilling equipment. After the valve and anvil, the bit connecting member, and the bit are assembled in the lower end of housing 11, the housing is threadedly engaged to the lower end of the lowermost section of drill collar 9 which is secured to a string of drill pipe 8. Drilling is commenced in a conventional manner with drilling fluid flowing through the drill string, through small bore 10 in drill collar 9, through small bore 12 of the housing into chamber 13 from where it flows around the valve and through the anvil and then outwardly into contact with the formation through the passages in drill bit. The drilling fluid functions in the conventional manner to assist in keeping the bit cool, to flush the cuttings from the hole, and to provide a hydrostatic head on the formation being drilled to prevent invasion of the well bore by formation fluids during the actual drilling. It is to be understood that the drill string, drill collar, and drilling tool of the invention are constantly rotated during operation.

While the valve of the apparatus remains open, the flow of drilling fluid continues relatively unimpeded through the tool, and the anvil is held at the upper end of its travel path since the bit is urging it upwardly to the upper ends of slots 20. The spring 35, which holds valve 34 in the embodiment illustrated in FIGURE 1, and valve strips 64, shown in the embodiment illustrated in FIGURE 2, are so designed that they will close when a predetermined desired velocity of the drilling fluid is reached through the tool. Until this predetermined velocity of the drilling fluid is reached, the valve in each of the embodiments of the invention remains in an open position, permitting continuous flow of drilling fluid through the tool. When the flow rate of the drilling fluid reaches the velocity at which the valves are designed to close, the valves will close abruptly, stopping the flow of drilling fluid through the tool which results in the generation of a fluid impulse. The pressure rise accompanying this impulse is very large and acts upon the upper end of the anvil, that is, anvil 30 in the embodiment shown in FIGURE 1 and anvil 60 in the embodi-

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ment shown in FIGURE 2, which results in an abrupt downward movement of the drill bit, driving it into the formation being drilled.

The general principles concerning computation of the magnitude of the pressure impulse and the force available therefrom are as follows. The pressure rise accompanying the compressional wave which is generated upon abrupt stoppage of the flow of drilling fluid may be determined in accordance with the following expression:

$$\Delta P = \frac{\rho c \Delta V}{g}$$

where

ΔP = the pressure rise,

ρ = the density of the drilling fluid,

c = the velocity of sound in the drilling fluid,

ΔV = the change in velocity of the drilling fluid (the change in velocity is equal to the maximum velocity around the valve since after valve closure the velocity is zero), and

g = gravitational constant.

The actual force being exerted on the anvil and, consequently, the bit is determined by the expression

$$F = \Delta P \frac{\pi D^2}{4}$$

where D = the diameter of the anvil being employed.

Combining these expressions, it may be found that the impulse force acting on the anvil is expressed by the formula

$$F = \frac{\rho c \Delta V}{g} \frac{\pi D^2}{4}$$

Specific application of the above principles to the device of the invention and their variations due to provision of the pressure intensifying chamber is made hereinafter.

If provisions were not made for the opening of the valve, the valve once closed would remain closed as the pressure wave would travel up the entire length of the drill string and be finally substantially absorbed in the surface equipment. The present invention provides means for effecting the opening of the valve, along with means for controlling the frequency of the operation of the valve and, consequently, frequency of the impacts delivered by the drill bit. A pressure wave, or a water hammer wave, passing through a tube may be caused to reflect at an opening or enlargement in the path of the pressure wave. By causing a pressure wave to pass through a relatively small bore leading to an enlarged bore, a portion of the wave will reflect from the point of entry of the small bore into the large bore, that is, the point in the path of the wave where the small bore joins the large bore. The amount of the original pressure wave which is reflected is governed by the ratio of the cross sections of the large and the small bores employed. Assuming rigid pipe, the magnitude of the reflected pressure wave is in accordance with the expression

$$\Delta P_R = -\Delta P \frac{1-M}{1+M}$$

where

ΔP_R = the pressure of the reflected wave,

ΔP = the increase or rise in pressure initially created by the fluid impulse, and

$$M = \frac{A_S}{A_L}$$

where

A_S = the area of the small bore, and

A_L = the area of the large bore.

In the instance of the present invention, the small bore referred to in the above expressions consists of bores 10

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and 12, while the large bore is the bore of drill string 8. The reflection of the pressure wave in the present invention occurs at the boundary between small bore 10 and drill string 8, that is, the point where bore 10 and the bore of drill string 8 interconnect. It is seen that the sign of the reflected pressure wave is minus (—) and thus the pressure during the reflection period is below normal, that is, it is less than the pressure in the drilling fluid at a time just prior to the closure of the valve. With the resultant rarefied pressure in the reflected wave, the valve in the apparatus of the invention is permitted to once again open. With the valve again open, flow of the drilling fluid is again initiated and it continues to increase in rate until the velocity is obtained which is required to once again shut the valve. Upon the valve closure, the pressure impulse again is created and the cycle repeats itself. Thus there is provided an apparatus which will deliver repetitive percussive blows against a formation being drilled with the tool.

It is well known that a reduction in the bottom-hole pressure in a well bore tends to improve the drillability of the formation being cut. Another unique feature of the apparatus of the invention is that during its operation there is the creation of a rarefied pressure period under the closed valve which passes on through the bit to the bottom of the hole and up the annulus between the drill string and the side walls of the well bore, with the rarefied pressure wave being created below the valve coincident with its abrupt closure. Thus the rarefied pressure period at the bottom of the hole exists at the same time that the bit delivers its percussive blow to the bottom of the hole. This condition greatly amplifies the destructive effect of the bit on the rock at the bottom of the hole. Further, the fluid pressure opposing the movement of the anvil and bit is reduced with the reduction in pressure below the valve being additive to the increased pressure above the valve, the sum of the reduction in pressure below the valve and the increased pressure above the valve comprising the force which drives the anvil and the bit downwardly during the percussive stroke.

It has been stated above that the frequency of the cycle of operation of the tool may be controlled. The length of the small bore section of the tool, that is, bores 10 and 12, is determined by the desired frequency of water hammer recurrence or the frequency of the impacts desired to be delivered by the bit. The frequency of this cycle is inversely proportional to the length of the sum of small bores 10 and 12 and is described by the following relation:

$$f = \frac{c}{4l}$$

where

f = the frequency of the cycle,

l = the length of small bores 10 and 12 of the collar 11, and

c = the velocity of sound through the drilling fluid in the small bore.

For example, for a value of c = 5,000 feet per second and a desired frequency of 10 cycles per second, the length of the sum of small bores 10 and 12 would be

$$l = \frac{5,000}{4 \times 10} = 125 \text{ feet}$$

As a practical matter, the length of 125 feet as shown in this example would be roughly equivalent to 4 drill collars which ordinarily are approximately 30 feet in length each. A device or tool in accordance with the invention could, therefore, be assembled by employing regular large bore drilling pipe for drill string 8 and connecting four small bore drill collars between drill string 8 and the tool, with housing 11 having a bore 12 of about 5 feet in length, to provide a small bore which would give approximately a frequency of 10 cycles

per second. Any other desired frequency could be similarly attained.

It will be noted by reference to FIGURES 1 and 2, and as previously described, the housing 11 contains enlarged bore 13, the upper end of which connects with the small bore 12 with reflecting surface 14 being present at the boundary between large bore 13 and small bore 12. The presence of large bore 13 immediately above the valve provides another unique feature of the invention. The presence of enlarged bore 13 connecting with small bore 12 actually causes a reduction in the velocity of the drilling fluid as it enters the large bore inasmuch as the same quantity of drilling fluid will be flowing through the large bore as flowed through small bore 12. It has previously been pointed out that the change in velocity of the drilling fluid effected by the abrupt closure of the valve directly affects the force exerted on the anvil and drill bit, and it would, therefore, appear that this reduction of velocity by virtue of entry of the fluid into large bore 13 would result in a lower pressure rise due to the fluid impulse effect. It has been found, however, that by maintaining the length of enlarged bore 13, that is, the distance within the bore between reflecting surface 14 and the upper end of the anvil, at a minimum as compared with the length of the sum of small bores 10 and 12, the pressure due to the fluid impulse effect within the large bore will increase to substantially the same level as that which develops in the small bore. Though the initial increase in pressure upon abrupt valve closure is less within bore 13 than within bores 10 and 12, it has been found that the presence of reflecting surface 14 at the point of juncture of small bore 12 and large bore 13 results in a large number of short duration reflections between the upper end of the anvil and the reflecting surface 14 within bore 13 which causes the pressure within the large bore to increase to substantially the same level as that within the small bore. This increase in pressure within the large bore occurs within a very short period. The length of the pressure intensifying chamber, that is, that portion of large bore 13 above the valve, preferably ranges from about one half of one percent (½%) to about ten percent (10%) of the length of the sum of bores 10 and 12.

The velocity of the fluid flowing within large bore 13 may be determined from the expression

$$V = \frac{4Q}{\pi D^2}$$

where

V = the velocity of the drilling fluid,
 Q = the quantity of drilling fluid flowing, and
 D = the diameter of large bore 13.

The initial pressure increase occurring within large bore 13 upon closure of the valve is expressed by the formula

$$\Delta P_1 = \frac{\rho c}{g} \left(\frac{4Q}{\pi D^2} \right)$$

where

ΔP_1 = the initial pressure increase,
 ρ = the density of the drilling fluid,
 c = the velocity of sound in the drilling fluid, and
 g = gravitational constant.

Since the final pressure obtainable within large bore 13 due to the numerous short reflections occurring within the bore will approach the pressure within small bore 12, the final effective pressure available for driving the anvil and bit downwardly is stated by the expression

$$\Delta P_1 = \frac{\rho c}{g} \left(\frac{4Q}{\pi d^2} \right)$$

where the definitions of the various terms are the same

as for the formula for ΔP_1 except that d = the diameter of small bore 12.

It will be appreciated that the actual force driving the anvil and bit downwardly is dependent upon the final pressure available within large bore 13 and the effective area of the top of the anvil. Since the top of the anvil is of substantially the same diameter as the internal diameter of large bore 13, the driving force upon the anvil is stated by the formula

$$F = \Delta P_1 \left(\frac{\pi D^2}{4} \right)$$

where ΔP_1 is the same as defined above and D is the diameter of large bore 13. Thus the provision of a large bore which is short in length at the lower end of an elongated small bore provides a force intensifier or pressure intensifying chamber which develops the pressure available in a small bore and applies that pressure to a large area to produce a large driving force on an anvil and bit to effect maximum cutting of the formation being drilled.

It will be recognized that the pressure intensifying chamber may be eliminated by reduction of the diameter of the valve and the upper end of the anvil to the diameter of bore 12 and extension of bore 12 downwardly to a point just above the top of the anvil. Such a device would be operable in accordance with the above discussed principles though it will be understood that the impulse force would be proportionally reduced and thus the impact deliverable by the bit reduced.

While the invention has been described in the light of the specific embodiments illustrated, it will be understood that other design features will occur to those skilled in the art, and it is intended that the invention shall be limited only within the scope of the appended claims.

I claim:

1. In a fluid-actuated drilling device the combination which comprises a tubular housing, bit securing means including a fluid flow path therethrough positioned in the lower end of said housing, means interconnecting said bit securing means and said housing to permit said bit securing means to be rotated by and slidable longitudinally relative to said housing, valve means supported by said bit securing means adapted to abruptly close when fluid flowing through said device exceeds a predetermined velocity, and connecting means for securing said housing to a drilling string, said connecting means including an elongated flow path having a cross-sectional area less than the cross-sectional area of the flow passage through said drilling string to conduct fluid to said drilling device at a velocity in excess of the fluid velocity in said drilling string.

2. In a fluid-actuated drilling device the combination which comprises a tubular housing adapted for suspension from a drilling string, bit supporting means provided with a fluid flow passage therethrough movably secured at one end of said housing, means interconnecting said housing and said bit supporting means to permit said bit supporting means to be rotated by and reciprocated relative to said housing valve means secured to said bit supporting means and adapted to effect sudden stoppage of fluid flow through said drilling device at a predetermined fluid velocity, and connecting means for securing said housing to a drilling string, said connecting means including an elongated fluid flow path having a cross-sectional area less than the cross-sectional area of the flow passage through said drilling string to conduct fluid to said housing at a velocity in excess of the fluid velocity in said drill string, the difference in cross-sectional areas of said fluid flow passage in said bit supporting means and said flow passage in said drilling string at the upper end of said fluid flow path providing an interface in flowing fluid for the reflection of acoustical impulses generated in said flowing fluid by closure of said valve means, the distance between said interface and said valve means being

determined in accordance with the desired frequency of operation of said valve means.

3. In a fluid-actuated drilling tool the combination which comprises a tubular housing provided with a fluid flow path leading from the upper end thereof, an anvil provided with a longitudinally extending fluid flow path positioned in the lower end of said tubular housing, means interconnecting said housing and said anvil to permit said anvil to be rotated by said housing and slidable longitudinally relative to said housing, means for securing a drill bit to the lower end of said anvil, valve means secured to the upper end of said anvil and adapted to suddenly close when a predetermined fluid velocity through said tool is exceeded, and a drill collar assembly provided with a fluid flow path therethrough secured to the upper end of said tubular housing and adapted to be secured to the lower end of a string of drill pipe, said fluid flow path through said drill collar assembly having substantially the same cross-sectional area as said fluid flow path leading into the upper end of said tubular housing, the cross-sectional area of said fluid flow paths through said drill collar assembly and leading into said tubular housing being less than the cross-sectional area of the fluid flow passage through said drill pipe so that the velocity of fluid flowing through said flow paths from said drill pipe will be in excess of the velocity of fluid flowing through said drill pipe, the combined lengths of said fluid flow paths being determined by the desired frequency of closures of said valve means.

4. The apparatus of claim 3 wherein the cross-sectional area of the fluid flow paths leading through said drill collar assembly and into said tubular housing is such that the velocity of fluid flowing through said flow paths will be from about 2 to about 20 times the velocity of said fluid flowing through a drill string secured to the upper end of said drill collar assembly.

5. In a fluid-actuated drilling device the combination which comprises a tubular housing provided with lower fluid pressure intensifying means and an upper fluid flow path connected with said pressure intensifying means, an anvil positioned within said housing below said pressure intensifying means, said anvil being provided with a fluid flow path therethrough, means interconnecting said anvil and said housing to permit said anvil to slide longitudinally relative to and be rotated by said housing, means for securing a drill bit to said anvil, valve means supported by said anvil to effect a sudden stoppage of fluid flow through said anvil at a predetermined fluid velocity, and drill collar means, including a fluid flow path, for securing said housing to a string of drill pipe, said upper fluid flow path in said housing and said fluid flow path in said drill collar means having substantially equivalent cross-sectional areas which are less than the cross-sectional area of the flow passage through said drill pipe to effect a uniform fluid velocity therethrough in excess of the fluid velocity through said drill pipe.

6. In a fluid-actuated drilling device the combination which comprises a string of drill pipe having an internal bore of substantially uniform diameter extending from the surface of the earth to the lower end thereof, an assembly comprising at least one drill collar secured to the lower end of said drill pipe and provided with an internal bore of substantially uniform diameter, the diameter of the internal bore of said drill pipe being so related to the diameter of the internal bore of said drill collar that the velocity of fluid through said drill collar will be approximately 2 to 20 times the velocity of fluid flowing through said drill pipe, a tubular elongated housing secured at the upper end thereof to the lower end of said drill collar assembly, said tubular housing being provided with an upper internal bore of substantially the same diameter as and interconnecting with said internal bore in said drill collar assembly, said tubular housing being further provided with a pressure intensifying chamber in the lower portion thereof and interconnected with said upper internal bore of said tubular housing, the length of said pressure intensifying chamber being approximately from one half percent to ten percent of the length of the total of said internal bores in said drill collar assembly and said tubular housing, an anvil provided with a fluid flow passage therethrough positioned in the lower end of said tubular housing at the bottom of said pressure intensifying chamber, means interconnecting said housing and said anvil to permit said anvil to be rotated with and slidable longitudinally relative to said tubular housing, valve means positioned at the upper end of said anvil to control flow of fluid from said pressure intensifying chamber through said anvil, said valve means being adapted to abruptly close responsive to a predetermined velocity of fluid flow from said pressure intensifying chamber into said anvil, and means for securing a drill bit to the lower end of said anvil.

7. The apparatus of claim 4 wherein said valve is of the vertically oscillating type.

8. The apparatus of claim 4 wherein said valve is provided with horizontally oscillating members.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,018,834

January 30, 1962

Evin L. Cook

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 2, line 39, for "drill", second occurrence, read -- drilling --; line 46, before "collar" insert -- drill --; column 3, line 29, strike out -- and the anvil --; line 34, for "end", first occurrence, read -- ends --; column 4, line 21, for "deisgn" read -- design --; column 6, line 14, for "required" read -- required --; column 8, line 60, after "housing" insert a comma.

Signed and sealed this 15th day of May 1962.

(SEAL)

Attest:

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