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HYDRAULIC DRILLING DEVICE

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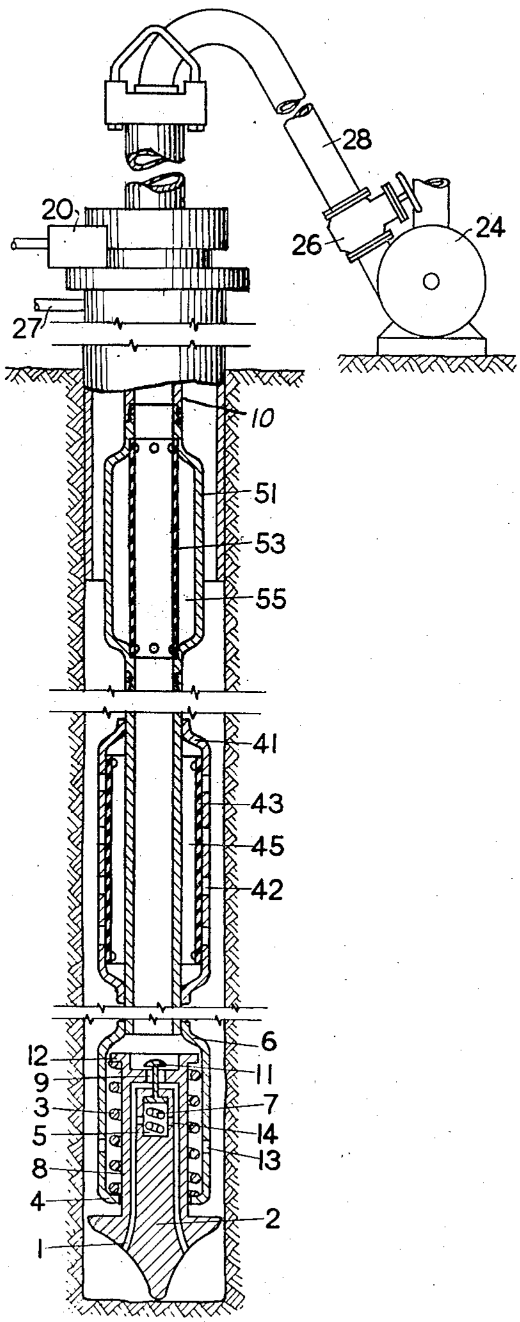

Fig. 1

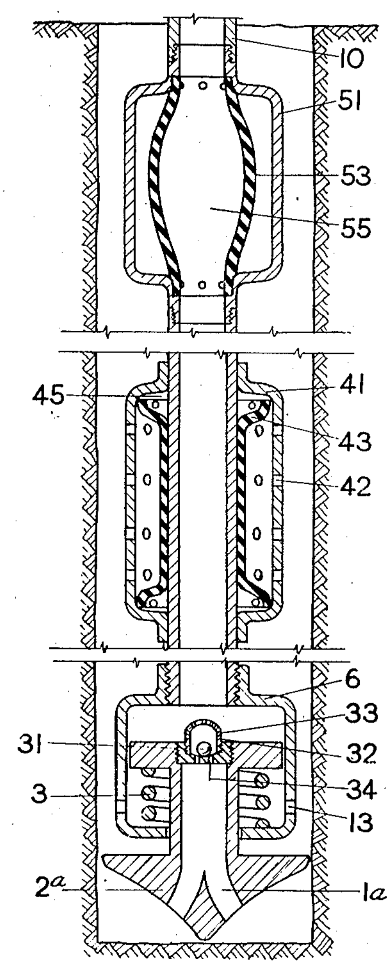

Fig. 2

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HYDRAULIC DRILLING DEVICE

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Original application September 27, 1940, Serial No. 358,585, now Patent No. 2,325,264, dated July 27, 1943. Divided and this application October 19, 1942, Serial No. 462,629

3 Claims. (Cl. 255—4.4)

This invention relates to hydraulically operated drilling devices, and pertains more particularly to a system wherein high pressures generated by the so-called water-hammer effect are utilized for drilling purposes, the present application being a division of a co-pending application Serial No. 358,585, filed September 27, 1940, now Patent No. 2,325,264, dated July 27, 1943.

It is an object of this invention to provide a drilling system comprising a valve capable of suddenly stopping the fluid flow in a conduit to generate high-pressure water-hammer effects.

It is also an object of this invention to provide a hydraulic impact drilling system comprising flow equalizers for controlling the frequency of the bit impacts and for absorbing shocks and minimizing the shattering effects of water-hammer pressure on the equipment.

These and other objects of the present invention will be understood from the following description taken with reference to the attached drawing, wherein:

Fig. 1 is a diagrammatic vertical cross-section view showing an embodiment of the impact bit and valve of the present invention, together with the supporting tubing, flow equalizers and tubing head equipment; and

Fig. 2 is another view of the present drill string provided for purposes of illustration, with a somewhat different type of impact bit and valve, showing the diaphragms of the flow equalizers in distended position.

Referring to Fig. 1, numeral 2 indicates a drill bit which may be of any desirable type and shape. The bit is attached to the lower end of a string of drill pipe or tubing 10 which extends to the surface. Means for imparting to the string 10 a rotational motion either manually or by power machinery, as, for example, through a rotary table, are diagrammatically shown at 20. A pump 24 is used to circulate a liquid such as water, brine or a suitable drilling fluid through the tubing 10, and is connected thereto by means of a conduit 28 provided with a valve 26, while a conduit 27 is used to withdraw the liquid returned up the borehole.

The bit 2 is affixed for axial motion within the enlarged lower cylindrical member 6 of the tubing 10, which member is provided with a bottom flange 4. The bit 2 has a cylindrical portion 8 provided at its upper end with a top flange 12 adapted to fit slidably within the cylindrical member 6. A powerful spring 3 is wound around the cylindrical portion 8 of the bit, and is held between the flanges 12 and 4, whereby the motion of the bit relative to the tubing string is limited, and the bit is normally held in a raised position with regard to said tubing string. Openings 13 are provided to prevent any liquid leaking past flanges 4 and 12 into the housing of the spring 3 from exerting any hydraulic effect opposing the compression of said spring.

Liquid communication between the inside of the string 10 and the borehole is effected through passages 1 in the bit 2 of which any desired number may be provided, and an orifice 9, forming the seat of a valve 11, which closes said passage by seating axially against the action of a relatively weak spring 7, opposing the downward motion of the stem of valve 11 in a chamber 5. A passage 14 may be provided between chamber 5 and, for example, passage 1 to prevent incompressible liquid leaking into chamber 5 around the stem of the valve 11 from interfering with the operation of the valve.

When the circulation of the liquid down the tubing 10 and up the borehole is established by starting the pump 24 and opening the valve 26, a certain pressure differential is created by the flow of the liquid through the relatively restricted orifice 9, between the space within tubing 10 above said orifice, and the space within passages 1 below said orifice, said pressure differential being a function of the rate of flow in passages 10 and 9, respectively.

The spring 7 is selected of a compressive strength such that it will permit the valve 11 to close suddenly the orifice 9 when this pressure differential reaches a value corresponding to a predetermined fluid velocity in tubing 10 delivered by the pump 24, for example, 20 ft. per second, the valve 11 being in general adapted to close in a time period smaller than $2\,L/u$, wherein L is the length of the conduits between the flow equalizers, to be described below, and the valve 11, and u is the velocity of transmission of pressure waves in the liquid, which for water is in practice about 4200 feet per second.

It is known from hydraulics that when, under these circumstances, the flow of the circulation liquid is abruptly stopped by the closure of the valve 11, its kinetic energy is transformed into static pressure energy. The high pressure which is thus generated, and which is additional to the working pressure developed by the pump, produces the so-called water-hammer effect, and may be expressed by the following formula derived from the equation of conservation of energy:

$$P=\frac{vuw}{g}$$

wherein P is the maximum additional unit pressure produced by the closure of the valve 11, v is the velocity of liquid in the tubing, u is the velocity of transmission of pressure waves in the liquid, w is the weight of a unit volume of the liquid, and g is the gravitational acceleration constant.

When P and w are in pounds, and v and u in feet per second, the above formula gives, taking into consideration the elasticity of the water and of the tubing, as well as various losses, about 600 to 1200 lbs. per sq. inch for the device of the present invention at working pump pressures of from about 60 to 100 lbs. per sq. inch.

These high additional pressures act to compress the spring 5 and to impact the bit 2 sharply against the formation to be drilled. Since, however, a water-hammer cycle consists of a high pressure period followed by a sub-normal pressure period, both the spring 3 and the spring 7 expand again during this latter period, thereby returning the bit 2 to its original position and opening the valve 11, after which the cycle is repeated.

While the bit is being reciprocated against the formation, the drill string may be caused to rotate by means of the apparatus 20, whereby the cutting blade or blades of the bit are rotatably displaced with regard to the formation substantially only during periods between successive impacts, and a better rate of penetration may be obtained.

Fig. 2 shows another embodiment of the valve 9—11, which has given excellent results in combination with the flow equalizers of the present invention. The arrangement of the drilling apparatus, tubing, bit, etc., is substantially equivalent to that of Fig. 1. Instead of a stem valve 11 passing through the orifice 9, however, this orifice 9 is closed by a resilient ball valve. For example, this may be effected by screwing or otherwise positioning therein a valve cage 32 provided with perforations 33 and 34 for the flow of the liquid from the tubing to the passage 1a in the bit 2a. The valve cage 32 contains a ball valve 31, made of rubber or other suitable resilient material. When the pressure differential generated by the liquid flow at the operating pump pressure reaches a predetermined value, the elastic ball valve 31 is flattened or deformed and pressed against the bottom and walls of the valve cage, thus stopping the flow of the liquid and causing the water-hammer effect as explained above. The hardness and resiliency and the size of the ball valve 31 are selected with consideration to the working pressure at which it is desired to operate the pump 24 to give an operative closure time for the valve structure.

As shown at 55 and 45, in Figs. 1 and 2, the drill pipe or tubing 10 is provided at any desired level above the bit with a plurality of internal and external flow equalizers for the liquid circulating in the tubing and the borehole.

When the present system is operated for protracted periods of time and at high frequency, the air in the air-cushion spaces such as provided in conventional cup or funnel-shaped air chambers or flow equalizers may become dissolved in the water which is constantly and violently agitated in contact therewith, whereby the effectiveness of these conventional flow equalizers may be impaired.

According to the present invention, external flow equalizers comprise, therefore, a closed annular air chamber 45 formed by suitably affixing to the tubing 10, for example, by welding, a cylindrical member 41 provided with perforations 42. These perforations are closed on the inside, as shown in Fig. 1, by means of a cylindrical sleeve 43 made of rubber or other resilient water- and air-impervious material. The violent pressure surges in the borehole will flex the rubber sleeve 43 to a position shown in Fig. 2, whereby the air in the chamber 45 is compressed and exerts its shock-absorbing effect without being permitted to dissolve in the water by intermingling therewith.

Internal flow equalizers are made by inserting between two stands of the tubing 10 to a joint 51 having a relatively enlarged diameter. Affixed with the joint 51 is a cylindrical resilient sleeve 53 of a diameter substantially equal to the inside diameter of the tubing 10, whereby an annular air chamber 55 is formed between the sleeve 53 and the member 51. Water-hammer pressure surges within the tubing 10 distend the sleeve 53 to a position such as shown in Fig. 2, whereby the same shock-absorbing effect is obtained as described above with regard to the external flow-equalizer.

It is known that flow equalizers or air chambers are very effective as shock absorbers for water-hammer pressures in that part of the equipment which lies between an air chamber and the point of flow origin, without affecting said pressures in that part of the equipment which lies between the air chamber and the point of flow closure. The flow equalizers shown at 45 and 55 are, therefore, desirable for protecting the surface equipment, permitting the pump to work smoothly and thereby raising its efficiency, and for controlling the frequency of the water-hammer cycles by limiting the amount of liquid which is accelerated.

For purposes of control, the length of the tubing connected between flow equalizers and the bit may be varied, whereby the frequency of impacts is also varied. In general, the frequency of impacts is a function of several factors. Thus, the cycle of each impact may be divided into three parts: first, the time necessary to accelerate the fluid in tubing 10 to the velocity at which the valves 11 or 31 will close; second, the time during which the high pressure prevails on the bit and said valves remain closed; and third, the time necessary for the spring 3 to force the bit back to its normal position, driving the water which collected in the bit chamber either up into the flow equalizer, or out through the valve passage 9. The first period depends mainly on the pressure which the pump 24 can maintain in the flow equalizer, the amount of water between the internal and the external flow equalizers which has to be accelerated, the velocity to which it has to be accelerated before the valve 11 closes; and, finally, upon the size of orifice 9. The second period is short, and is equal to the distance between the internal flow equalizer and valve 11 divided by the velocity of the elastic wave in the fluid. The third period may be given a desired small value by selecting a powerful spring 3. During the latter two time periods, the pump supplies the flow equalizers with fluid while increasing the pressure therein. This fluid is forced out again where needed during the acceleration period of the cycle. A suitable operating frequency for the present system is, for example, 15 cycles per second.

I claim as my invention:

1. In a hydraulic drilling system, a pump, a tubing string adapted to be lowered into a bore-

hole, said tubing being in communication with the high pressure side of the pump, a piston adapted for limited displacement within the lower portion of the tubing, spring means opposing said displacement, a bit attached to said piston, a passage through said piston and said bit, whereby a liquid stream may be circulated by said pump down said tubing, through said bit, and up the borehole, normally open resilient valve means in said passage, said means being responsive to a predetermined flow pressure differential across said passage for suddenly closing said passage, whereby a high-pressure water-hammer impulse is generated to displace said piston against the action of said spring means, and means for controlling the frequency of said water-hammer impulses, said means comprising at least one air chamber carried by the tubing between said pump and said piston, said chamber comprising a rigid tubular member insertable between two stands of the tubing string, the diameter of said member being larger than that of the tubing, a tubular flexible diaphragm carried within said member, said diaphragm being substantially in axial register with the tubing when said member is inserted in the tubing string, and fluid-tight closure means between said member and said diaphragm, whereby an annular air chamber is formed between said member and said diaphragm.

2. In a hydraulic drilling system, a pump, a tubing string adapted to be lowered into a borehole, said tubing being in communication with the high-pressure side of the pump, a piston adapted for limited displacement within the lower portion of the tubing, spring means opposing said displacement, a bit attached to said piston, a passage through said piston and said bit, whereby a liquid stream may be circulated by said pump down said tubing, through said bit, and up the borehole, normally open resilient valve means in said passage, said means being responsive to a predetermined flow pressure differential across said passage for suddenly closing said passage, whereby a high-pressure water-hammer impulse is generated to displace said piston against the action of said spring means, and means for controlling the frequency of said water-hammer impulses, said means comprising at least one air chamber carried by the tubing between said pump and said piston, said chamber comprising a rigid tubular member insertable between two stands of the tubing string and in register for liquid communication therewith, a resilient tubular member surrounding said rigid member and concentrically spaced therefrom, and fluid-tight closure means affixing said resilient member to said rigid member, whereby a fluid-tight annular air-chamber surrounding said rigid member is formed between said two members.

3. In a hydraulic drilling system, a pump, a tubing string adapted to be lowered into a borehole, said tubing being in communication with the high-pressure side of the pump, a piston adapted for limited displacement within the lower portion of the tubing, spring means opposing said displacement, a bit attached to said piston, a passage through said piston and said bit, whereby a liquid stream may be circulated by said pump down said tubing through said bit, and up the borehole, normally open resilient valve means in said passage, said means being responsive to a predetermined flow pressure differential across said passage for suddenly closing said passage, whereby a high-pressure water-hammer impulse is generated to displace said piston against the action of said spring means, and means for controlling the frequency of said water hammer impulses, said means comprising an inner air-chamber carried by the tubing between said pump and said piston, said chamber comprising a rigid tubular member insertable into the tubing string, the diameter of said member being larger than that of the tubing, a tubular flexible diaphragm carried within said member, said diaphragm being substantially in axial register with the tubing when said member is inserted in the tubing string, and fluid-tight closure means between said member and said diaphragm, whereby an annular air-chamber is formed between said member and said diaphragm, and an outer air-chamber carried by the tubing between said pump and said tubing, said chamber comprising a rigid tubular member insertable into the tubing string and in register for liquid communication therewith, a resilient tubular member surrounding said rigid member and concentrically spaced therefrom, and fluid-tight closure means affixing said resilient member to said rigid member, whereby an annular air-chamber surrounding said rigid member is formed between said two members.

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