

Dec. 2, 1952

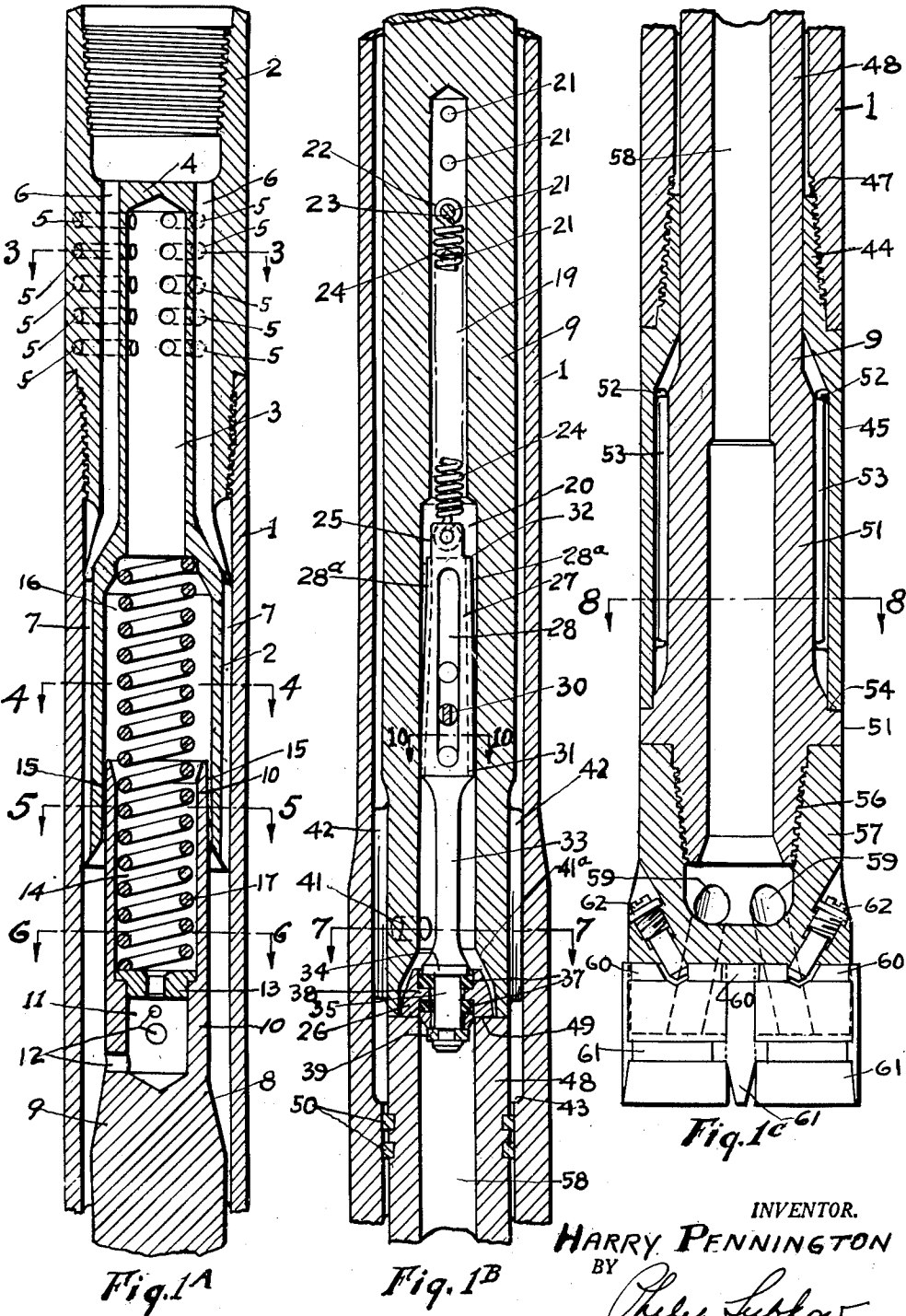
H. PENNINGTON

2,620,162

HAMMER TYPE ROTARY ROCK-DRILLING BIT

Filed Nov. 16, 1946

3 Sheets-Sheet 1



INVENTOR.
HARRY PENNINGTON
BY
Chely Lubkow
ATTORNEY

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H. PENNINGTON

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HAMMER TYPE ROTARY ROCK-DRILLING BIT

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3 Sheets-Sheet 2

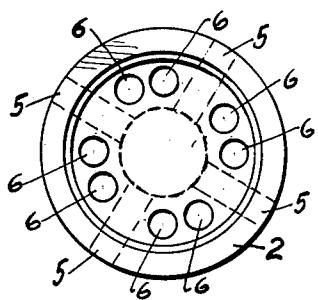


Fig. 2

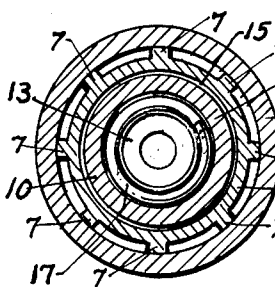


Fig. 5

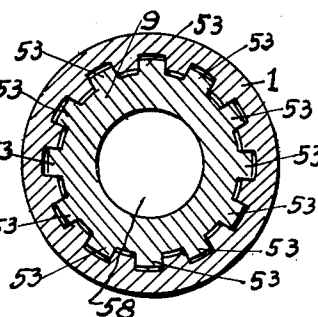


Fig. 8

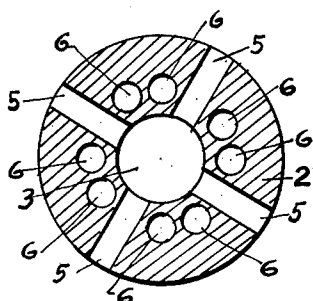


Fig. 3

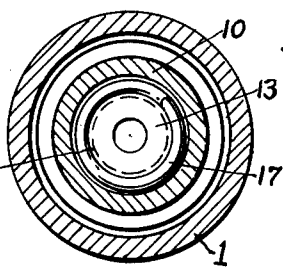


Fig. 6

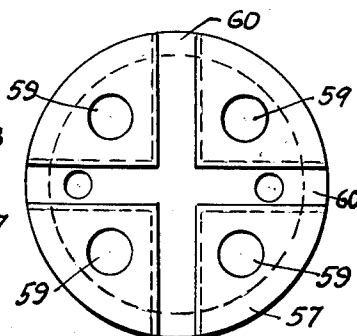


Fig. 9

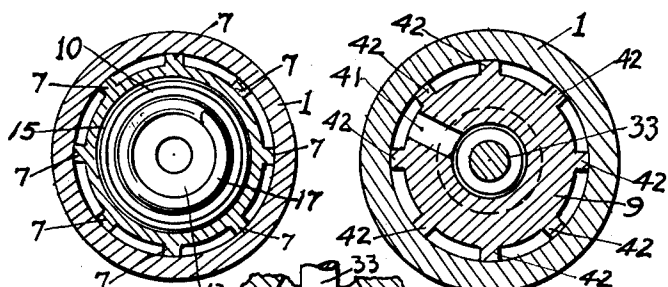


Fig. 4

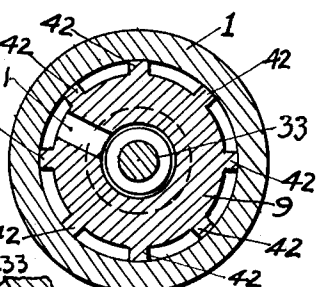


Fig. 7

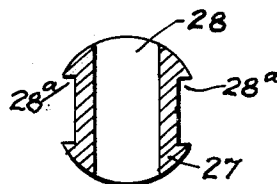


Fig. 10

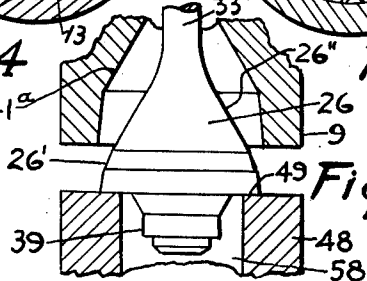


Fig. 16

INVENTOR.
HARRY PENNINGTON
BY
Phily Lubow
ATTORNEY

Dec. 2, 1952

H. PENNINGTON

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3 Sheets-Sheet 3

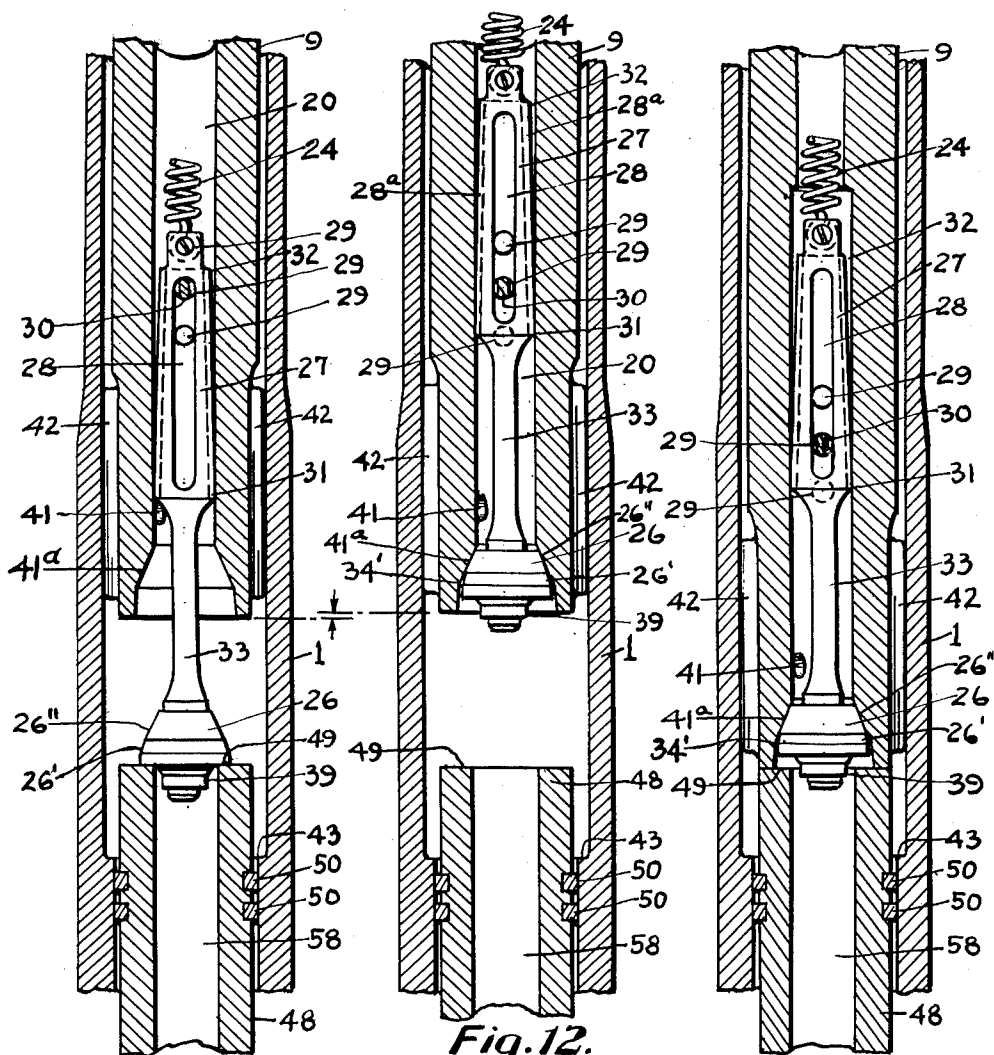


Fig. 11.

Fig. 12.

Fig. 13.

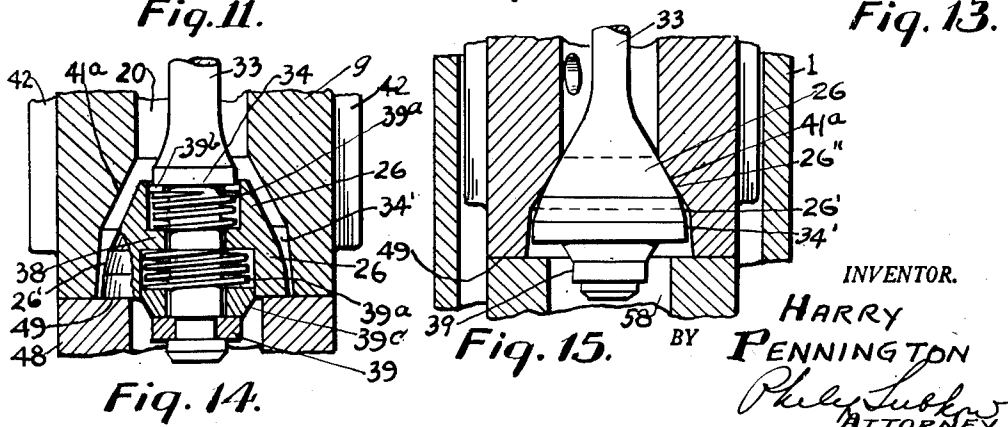


Fig. 14.

Fig. 15.

INVENTOR.

HARRY

PENNINGTON

BY *Phily Lusk*
ATTORNEY.

UNITED STATES PATENT OFFICE

2,620,162

HAMMER TYPE ROTARY ROCK-DRILLING
BIT

Harry Pennington, San Antonio, Tex.

Application November 16, 1946, Serial No. 710,356

8 Claims. (Cl. 255—3)

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This invention relates to a hammer type rotary rock drilling bit for the drilling of bore holes for oil and gas wells, for example, which has proved to be successful in use and has resulted in reduced cost of drilling and the drilling of deep bore holes through rock formation without twist-offs or fishing jobs.

The invention is an improvement of the hammer rock bit forming the subject matter of my Patent No. 1,892,517, patented December 27, 1932.

It is an object of my invention to improve the construction and operation of the hammer of said patent.

It is one of the objects of my invention to provide an auxiliary circulation of flushing fluid in addition to that employed in reciprocating the hammer by imposing a fluid pressure on the interior of the hammer case to cause a discharge of said fluid through auxiliary discharge ports in addition to the flushing fluid employed to operate the hammer and discharge through the nozzles of the cutter.

Another object of my invention is to provide means for selectively regulating the volume of such by-passed fluid discharge for the augmentation of the volume of the fluid circulating through the hammer and the nozzle of the cutter to provide the fluid desirable for elevation of the cuttings in the annular space outside the hammer case.

It is another object of my invention to improve the construction of the valve mechanism of the hammer.

It is a further object of my invention to cause the closing of the port through the chuck by means of the valve and to cause the motion of said valve to close said port to be caused by imparting a downward movement to said valve by means of said hammer and to seat said valve to shut off the flow of fluid through the nozzles by the inertia of said valve resulting from the downward motion of said valve caused by said motion of said hammer.

It is a further object of my invention to provide means in said hammer to control the length of stroke of said hammer.

It is a further object of my invention to control the stroke of said hammer by providing for the unseating of said valve from its seat upon a predetermined length of stroke of said hammer, and to provide for the retraction of said valve by means of a spring with means for regulating the tension of the spring for the purpose of regulating accurately the length of stroke and the speed of striking of said hammer.

It is a further object of my invention to pro-

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vide for sufficient flexibility in the valve stem to permit said valve to seat properly upon the chuck to shut off the passage of fluid through the cutter nozzles irrespective of variation in the axial alignment of said hammer and said chuck.

It is a further object of my invention to provide for a resilient seat for said valve upon said chuck to limit the shock of the striking of said valve against said chuck and said hammer upon the reciprocation of the hammer.

These and other objects of my invention will be understood from the further description of this invention by reference to the drawings, in which

Figs. 1a, 1b, and 1c are vertical sections taken through consecutive longitudinal portions of said hammer chuck and bit;

Fig. 2 is a top view of Fig. 1a;

Fig. 3 is a section taken along line 3—3 of Fig. 1a;

Fig. 4 is a section taken along line 4—4 of Fig. 1a;

Fig. 5 is a section taken along the line 5—5 of Fig. 1a;

Fig. 6 is a section taken along the line 6—6 of Fig. 1a;

Fig. 7 is a section taken along the line 7—7 of Fig. 1b;

Fig. 8 is a section taken along the line 8—8 of Fig. 1c;

Fig. 9 is a bottom view of Fig. 1c with cutters removed;

Fig. 10 is a section taken on the line 10—10 of Fig. 1b;

Fig. 11 is a fragmentary sectional view similar to Fig. 1b, but showing the hammer elevated and the valve seated on the chuck;

Fig. 12 is a view similar to Fig. 11 but with the valve retracted;

Fig. 13 is a view similar to Fig. 11 with the hammer seated and valve unseated;

Fig. 14 is fragmentary in part section of a modified valve construction;

Fig. 15 is a fragmentary illustrative view of the valve on its seat; and

Fig. 16 is an illustrative view showing the hammer just starting upward.

In Figs. 1a, 1b and 1c, numeral 1 designates the hammer case which at its head 4 is formed into a box tool joint 2 adapted to be attached to the lower end of a string of rotary drill tubing through which flushing fluid is pumped downwardly. The case head is provided with a concentric bore 3 the lower end 16 of which is enlarged and serves as a hammer cylinder. The bore is closed at its top except for the ports 6

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which connect the interior thereof with the annular space between the case and the bore of the well. The case has a central tubular section forming a central chamber 8 and in this chamber the hammer 9 reciprocates. The hammer at its top is reduced in diameter forming a head 10 which operates as a piston in hammer cylinder 16. A slight clearance 15 is provided between hammer head and the wall of the cylinder. The hammer head is provided with a vertical fluid passageway 14 for flushing fluid which through ports 12 is connected with the central chamber 8 of the case and serves as a bypass to pass flushing fluid from said chamber upwardly through the head of the hammer, through the bore 3 and then through ports 5 into the annular space between the case and the bore of the well. Owing to the fact, that the ports 5 connect with the well bore in which the pressure of flushing fluid is always lower than that in the central chamber 8, the pressure in the bore 3 is also lower than that in chamber 8. This differential pressure is what causes the hammer to be raised during its reciprocation, as will be explained below. The lower end 11 of the fluid passageway 14 is separated from the main body of the passageway by means of a replaceable bushing or choke 13 which serves as a convenient means to control the amount of flushing fluid flowing through the passageway. A compression spring 17 is mounted in the lower end 16 of bore 3 and abuts against the choke 13. This spring tends to move the hammer downwardly.

In order to supply flushing fluid to the central chamber 8 of the case ports 6 are provided in the case head which pass downwardly around the bore 3 as shown in Figs. 1a, 2 and 3 of the drawing, the fluid then passing between splines 7 which separate the hammer cylinder from the case wall, see Fig. 4.

The hammer 9 is slidably mounted in case 1 with sufficient clearance throughout its length to provide for circulation of fluid in the annular space between the hammer 9 and case 1. It is guided at its lower end by means of wings or splines 42 on the exterior wall of the hammer 9 below the tapered portion of the hammer at the lower end thereof. The splines are of such diameter as to contact the walls of the case 1 and to provide circulation of fluid between the said splines. The hammer is provided at its lower end with a central bore 19 which connects with a central bore 20 of larger diameter both of which are axially disposed in the hammer 9.

At the upper end of the bore 19 is provided a plurality of cross bores 21, shown as four in number, through which pin 23 may be passed selectively as desired. Thus pin 23 may be introduced into any of the bores 21. The pin 23 passes through an eye 22 connected to a spring 24 which is in turn connected at its lower end to the top of the valve stem 25 slidably mounted in the bore 20. The pin 23 and bores 21 serve as an adjustable fastening means for the upper end of the spring. The bore 19 thus forms a spring recess or chamber and the bore 20 forms a valve stem recess or chamber. A reciprocating valve 26 is mounted at the bottom of bore 20. The valve stem 25 is composed of a yoke 27 formed with a slot 28, as shown, carrying external grooves 28a formed throughout the length of the yoke. The yoke 27 is connected to a cylindrical section 33 of reduced diameter which in turn is connected to the valve 26.

As will be observed the yoke is tapered with

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its widest point at 31 in slidable contact with the walls of the valve recess 20 and the narrowest portion of the taper 32 at the top of the yoke. Owing to the tapered construction of the valve stem the valve has a limited oscillatory motion about the point 31 of maximum diameter serving as a pivot. The end of the valve stem is formed with a shoulder 34 and a section of reduced diameter 35 and carries two resilient rings 37, such as rubber rings, between which the shoulder 36 of the valve 26 is held and locked in position by lock ring 39. The face of the valve body is tapered beginning at its lower face. Midway the angularity of the taper increases at 26', and then increases again at 26'' to form the seating section of the valve body.

An alternative construction is shown in Fig. 14 wherein the rubber rings, shown in Fig. 1b, are replaced by springs 39a. The washer 39b slidably abuts the shoulder 34 and is pressed against the shoulder by the spring 39a which rests on the internal shoulder 38. The second washer 39c seats on the lock ring 39 and abuts the lower spring 39a.

In both forms the valve body 26 is free to float on the resilient mountings whether they be the rubber rings or the metallic springs. In the case of the metallic springs, the washers, seating against the upper shoulder 34 and making a close but sliding fit with the valve body 26, prevent any leak past the valve.

Cross bores 29, shown as three in number, are formed in the wall of the hammer with centers upon the center line of the bore 20. A pin 30 may be passed through any of the bores 29 to pass across the slot 28. This pin 30 and bores 29 serve as an adjustable means for limiting the downward motion of the valve and its stem relative to the hammer.

The lower end of the hammer 9 carries an enlarged bore which has an internal tapered surface 41a to form a valve seat for the valve 26. The taper of surface 41a is parallel to the upper tapered surface 26' of the valve body portion 26. Thus, an annular chamber 34' is formed between the tapered surface 41a and the lower tapered surface of the valve body. The port 41 is provided in the lower end of the hammer 9 above the valve 26, connecting the chambers 19 and 20 with the annular space between the case 1 and the hammer 9.

The hammer 9 seats upon a chuck 48 positioned within the case 1 the top of which serves as an anvil. The chuck 48 carries a central bore or port 58 of smaller diameter than the valve chamber to form a seat 49 for the valve 26 on top of the chuck 48. The inner diameter of case 1 is less, contiguous to the chuck, than the internal diameter of the case 1 at the hammer, thus forming a seat 43 the purpose of which will be described below.

The case 1 is screwed by a box and pin tool joint connection 44 to the driving section 45. The end of the pin forms a seat 47 for rings 50 for purposes later described. The driving section carries splines 52 which engage with splines 53 formed upon the exterior wall of the enlarged portion 51 of the chuck 48. These splines serve as means providing relative longitudinal movement between the case and the chuck to rotate the chuck and hence the bit or cutter head 57. The chuck carries rings 50 positioned in suitable recesses and making a sliding contact with the wall of case 1. The ends of the driving section 45 abut against the shoulder 54 formed on the

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enlarged portion 51 of the chuck 48. The cutter head 57 is connected to the chuck by means of a box and pin screw connection 56. This cutter head carries the nozzles 59 and cutters 61 removably mounted in T slots 60 and secured by bolts 62 positioned on each of the separately removable cutters 61. The cutter head does not form a portion of this invention and is further described and claimed in my co-pending application Serial No. 710,357, filed November 16, 1946.

The operation of the hammer bit is as follows:

The cutter is rotated by the drill tubing from the surface, employing the turntable conventional in oil well drilling, and drives the cutter through the splines 52 and 53. It will be observed that during the rotation of the drill chuck through the splines and during the reciprocation of the hammer, the weight of the string of drill tubing, or so much thereof as the driller desires to impose on the drill, is imposed on the drill, since the drill string and case rest on the shoulder 54. Mud or other drilling fluid is continuously pumped down the drill pipe, as is conventional in drilling practice. The circulation of drilling fluid is down the drill pipe through 2, via conduits 6, and annular space between the hammer 9 and the case wall.

Since the port or bore 58 is in communication with the annulus between the drill and bore hole wall through the nozzles 59 and chamber 3 is in communication with the said annulus through the ports 5, the static pressure at the nozzles 59 and chamber 3 is substantially the static pressure of the fluid in the bore hole.

The drill pipe is connected to the hammer case 1 at 2, and the pressure in the drill pipe generated by the mud pump is communicated to the interior of the case 1 via ports 6. With the valve off the seat 49, the static pressure inside the case and the bore of the chuck is thus also that existing in the annulus. With the hammer (see Fig. 1b) seated on the chuck 48 and the valve seated on the seat 49, the fluid pressure inside the case 1 exerted by the mud pump down the drill pipe is transmitted via port 41 inside the bores 19 and 20. Venting of this pressure via nozzles 59 is prevented by the sealing rings 50. The pressure is also exerted via port 12 via the choke 13 and the restricted channel 15 into 16 which, however, is in turn vented to the annulus via ports 5. Thus the static pressure of the annulus is exerted on top of the hammer and the higher pump pressure within the drill pipe and bit is exerted inside the hammer in bores 19 and 20. The fluid pressure exerted down the drill pipe into case 1 thus elevates the hammer, the pressure in the case 1, with valve 26 seated on seat 49 during the lifting of the hammer, being higher than the static pressure in the annulus, while the pressure in the chamber 3 remains at substantially the static pressure in the annulus due to the ports 5.

The pressure of the fluid inside the drill pipe and exerted above the valve in the recess 20 is greater than the pressure in the bore hole and in the bore 58 underneath the valve. The seated valve and the rings 50 close communication between the drill pipe and port 6 and the bore 58. The pump pressure is thus exerted on top of the valve 26. The pump's pressure rising causes an elevation of the hammer as the pressure increases inside the recesses 19 and 20, and the valve remains seated on its seat 49 on the chuck

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while the hammer is elevated. The hammer thus rises over the valve stem, lifting the pin 30 until it engages the upper end of the slot 28 (see Fig. 11).

During all this time pressure in the case 1 is maintained by fluid flow down the drill pipe. When the pin engages the top of the slot the continued upward motion of the hammer lifts the valve stem and the valve is lifted from its seat on the chuck. The valve having been unseated communication is established between the port 58 and the fluid circulating down the case 1 discharges through port 58 and nozzles 59. Pressure thus falls in the annulus between the hammer and the case 1. The pressure in the recesses 20 and 19 is vented through 41 into the annulus. There being a pressure equalization between the fluid inside the case and under the hammer and in chambers 19 and 20, the valve is retracted by the spring 24 against its seat 41a (see Fig. 12). The hammer drops under the influence of gravity and the spring effort of spring 17 to strike a blow on the head of the chuck 48 (see Fig. 13).

The valve, due to its inertia, and also under the influence of pressure in 20, continues downward to seat on its seat 49 on top of the chuck 48 (see Fig. 1a), thus completing the cycle.

When the cutter head 57 and cutters 61 are off bottom by elevation of the drill tubing, the chuck 48 slides downward in the case 1 until the lower ring 50 seats on the seat 47 formed by the pin 44. The hammer 9 slides downward until the splines 42 seat on the shoulder 43, the splines 52 and 53 remaining in engagement. The distance between the shoulders and pin is such that the bottom of the hammer is above the top of the chuck. The valve is thus not seated on its seat on the chuck and pressure in the case is vented through the port 58. The hammer is thus not operated by fluid pressure within the drill tube and case during such time as the cutter is off bottom.

When the hammer and valve are seated upon the chuck 48 the spring effort of spring 24 is insufficient to unseat the valve due to the fact that the pressure in the chamber 20 is greater than the pressure in the port 58 plus the spring effort of the spring 24. During the upstroke of the hammer the valve remains seated on its seat 49 in the chuck, notwithstanding the spring is elongated by reason of the upward movement of the hammer 9. It remains seated until the pin 30 has reached its upward limit of travel in slot 28 and when it contacts the top of the slot the continued upward motion unseats the valve mechanically by lifting the valve stem. As soon as this pin has lifted the valve sufficiently to discharge the pressure in case 1 through port 58 to a pressure somewhat less than the pressure originally present in the case when the hammer is seated on the chuck the spring immediately lifts the stem into the recess 20 and snaps the valve 26 against its seat 41a, thus closing the recess 20. Immediately thereafter the valve is unseated by the pin, the pressure in the chambers 19 and 20 and in the case 1 is equalized, through the ports 58 and 59, with the pressure in the annulus between the case and the bore hole wall whereupon the hammer immediately descends to strike.

As the hammer descends the valve descends with the hammer, due to its mechanical connection to the hammer, the valve remaining seated against its seat 41a during the descent because of the tension of the spring 24. When

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the hammer 9 strikes the top of chuck 40 and is thus arrested in its motion, the valve and valve stem continue to descend under the influence of their inertial force until the valve is seated on its seat on the chuck, thus closing off the port 58. The cycle is thus completed. Connection between the port 58 and case 1 being cut off, pressure rises in case 1 and the hammer may repeat its upward motion as described above. While the hammer thus repeatedly strikes the chuck to cause hammer blows on the cutter 61, the drill pipe rotates case 1. By reason of the screw connection 44, case 1 rotates the driving section 45 and through the medium of the splines rotates the chuck and thus also rotates the cutter. The cutter thus not only cuts by hammer blows but also rotates and cuts by rotation, which is simultaneously caused by the operation of the rotary turntable and the circulation of flushing fluid.

One of the primary purposes for the use of drilling fluid is to clear the cuttings away from the cutter head and to elevate them to the surface. In order to obtain these desired ends it is necessary to have a certain velocity of the fluid through the cutter nozzles and a certain rate of flow of fluid in the annular space between the drilling tool and the bore hole wall. This requirement is well understood in the drilling art.

In ordinary drilling practice, it is sufficient to establish the upward velocity of the drilling fluid in the annulus between the drill string and the bore hole by regulating the total pressure of the fluid entering the drill pipe, since the nozzle velocity thus obtained will be sufficient both to clear the cutters and to elevate the cuttings.

In the reciprocating hammer bits of my invention the discharge of fluid through the nozzles such as shown at 59 of Fig. 1c, for any given hammer, depends on the length of stroke and the rate of reciprocation of the hammer, since this determines the length of time during which the port 58 is in communication with the interior of the case 1 and the pumping effect of the hammer. The fluid discharges through the nozzles 59 intermittently in spurts during the period when the hammer is falling. In some sizes of hammers and some depths of bores, and depending on other conditions of drilling operations, this intermittent discharge may give a sufficient rate of flow of fluid in the annulus to elevate the detritus. However, under other conditions and for other sizes of hammers and gauge of bores, it is found that this will give an insufficient rate of flow of drilling fluid to efficiently elevate the cuttings. In order to increase the velocity of the drilling fluid in the annulus between the tool and the bore hole wall without interfering with the operation of the hammer, I have provided an auxiliary circulation of drilling fluid which is substantially independent of the operation of the hammer. The fluid pressure inside the case 1 being at all times higher than the pressure in the annulus between the tool and the bore hole wall, fluid flows through ports 12 into the chamber 11 and through the chambers 14 and 16, chamber 3, through the ports 5 into said annulus outside the case. However, except when the hammer is elevated, the pressure inside case 1 is only slightly higher than the pressure in the annulus between the tool and the bore hole wall, the pressure being substantially equalized through the ports 58 and 59. When the hammer and the valve are seated

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on the chuck and the hammer is elevated this differential pressure rises. The flow through ports 12 into chamber 11, through 14 and 16, 3, and ports 5, thus increases as the hammer is elevated. The rate of flow is adjusted by the proper selection of the size of the port openings to give the additionally desired rate of flow. Additional flexibility is provided to adjust this rate of discharge to varying conditions of operation by the provision of a replaceable choke 13 which may be changed by disassembly of the tool and the introduction of a choke of proper opening into its seat, as shown in Fig. 1.

It will be observed that this auxiliary fluid flow is by-passed away from the port 58. Since this fluid discharge, which is in addition to the fluid flow incident to the operations of the hammer, does not flow through the port 58 and the nozzles 59, it does not interfere with the discharge of the fluid used to operate the hammer and thus will not affect the rate of hammer reciprocation.

The circulation of fluid through the ports 5 has the additional advantage of preventing the intrusion of cuttings from the bore hole into the hammer through such breather ports 5. Due to the fact that the section 10 rises and falls in the chamber 16, a pumping action is occasioned. The absence of ports such as 12 would produce inside the chambers 16 and 3, upon the descent of the hammer, a pressure lower than the pressure in the annulus outside the case because upon the descent of the section 10 inside the chamber 16 a lowering of pressure in the chamber 16 results and thus cuttings may intrude by a back flow of fluid through the ports 5 into the chambers 3 and 16. The continuous upward circulation of fluid through 58 prevents this intrusion of cuttings by maintaining a slightly higher pressure in chambers 16 and 3 than in the annulus. This is aided by the circulation of fluid between the walls of the section 10 and the walls of the chamber 16 due to the clearance 15. This circulation has the additional effect of clearing this annulus and chambers 16 and 3 of any possible detritus and preventing wear between the sliding surfaces of 10 and 16.

Thus this auxiliary flow prevents wear and aids in increasing the volume of flow of fluid to supplement the fluid discharge through the nozzles 59 and gives the desired upward velocity of fluid in annulus between the tool and the bore hole wall.

In order to avoid any shock transmitted to the depending hammer cylinder 16 produced by any deviation from verticality of the hammer which could in some circumstances cause rupture of the connection between the cylinder and the casing, I have provided guides for the hammer as illustrated by splines 42. These guide the lower end of the hammer in the case 1. I have also provided splines 7 positioned between the casing and the chamber 16. Thus, the hammer is constrained to move substantially concentrically of the case 1 except as deviation may be occasioned by the clearances which manufacturing tolerances require for the fit of the splines 47 and by the clearances provided for at 15. Any deviation from verticality of the hammer thus remaining and resulting in any component of force against the walls of the cylinder 16 which results in shock blows is minimized and made harmless by reason of the splines 7 which thus constrain and hold the cylinder 16 in the case 1 by a close fit therein to reduce and make harmless any such shocks.

As will be seen from Figs. 1b, and 11 and 12, no portion of the valve or valve stem when the hammer and valve are off the chuck projects into the bore 58. Thus upon the elevation of the hammer and the withdrawal of the valve from its seat upon the chuck the pressure may be immediately discharged through the port without any restriction being imposed upon its flow into the port 58. As will be seen from Figs. 1b, 11 to 15, inclusive, as the hammer starts rising, the valve remaining on its seat 49, the clearance between the seat 41a and 26 becomes immediately enlarged, thus avoiding frictional contact between the seat 41a and the valve body 26. When the hammer has reached its limit of upward travel the pressure is sufficiently dissipated so that it may fall immediately. For many bore hole sizes the space restrictions, imposed by the requirement that the annulus between the bore hole wall and the tool be sufficiently large to permit the desired volume of flow of fluid, impose severe restrictions upon the sizes of the parts and the port 58. The freeing of this port to permit the maximum rate of discharge of fluid from the case 1 through the port 59 is thus of importance.

In order to insure this result the valve has been designed so that the valve stem is entirely within the recess provided therefor in the hammer, to wit, recess 20, and the valve spring is positioned above the valve in recess 19.

Provision is also made to insure that any shocks imposed by the hammer upon the valve stem will not cause a fracturing thereof.

It will be recognized that ordinary manufacturing clearances between the splines 42 and the case and the clearances which are provided at 45 may permit the hammer to cant or move axially to one side or the other of the chuck center line. If the bore hole is not exactly vertical, as is usually the case, the splines 42, on reciprocation in case 1, will, on rotation of the drill pipe, permit the hammer to cant or shift to the low side of the hole due to the vertical angle of deviation of the bore hole. The degree of cant will be emphasized by the increase in clearance resulting from wear on continued use.

The spring tension will tend to keep the valve stem coaxial with the hammer recess. If the valve had on its previous descent not been seated coaxially with the port 58 a bend will be imposed on the valve stem. The hammer will upon the descent kick the valve over to be coaxial with the center line of the valve recess. If the hammer cants, the hammer and the valve on their descent may strike the chuck with the center lines of the chuck and hammer at a slight angle to each other. As a result of the above circumstances severe bending forces are imposed on the valve stem. This bending may be sufficient, unless provisions are made therefor, to cause a fracture of the valve stem. In order to avoid this I have provided for the following features in the valve stem construction.

The upper slotted portion of the valve stem is tapered as previously described. The tapered portion 32 provides for a greater clearance at the upper part of the valve stem than at 31 where it is in sliding contact. The other provision is a section of reduced diameter shown at 33. This portion is relatively more flexible than the more rigid yoke portion. The tapered portion of the valve stem permits the upper portion of the valve stem to have a limited lateral movement while maintaining normal sliding contact

at 31. This will reduce flexure in the valve stem. There is provided sufficient flexibility in the valve stem, particularly because of the reduced cross-sectional area 33, to permit some flexure. As a result of this construction also the valve may seat on the chuck at an acute angle thereto without damage.

The tapers provided on the valve body 26 and the seat 41a permit of the elevation of the hammer while the valve is on its seat 49 without friction between the seat and the valve. As the valve enters the seat 41a, the upper frusto-conical valve shoulder guides the valve to its correct concentric position with the hammer valve recesses 19 and 20 seating centrally of the seat 41a, as shown in Figs. 1b, 12, and 13.

As has been previously described, as the hammer strikes the chuck at high speeds it is accelerated both by gravity and the hammer spring. The valve is carried downwardly with the hammer at the speed of the hammer and when the hammer strikes the chuck the valve is projected downwardly due to the inertia of the valve and valve stem and the pressure in chamber 20. The valve therefore strikes its seat 49 with considerable force. Also when the valve is retracted to its seat 41a it strikes this seat with great force. I provide a cushioning effect to prevent damage to the valve by reason of the blow thus struck. A blow struck by the valve either on its seating on the chuck at 49 or on its seat 41a is cushioned by the resiliency of the rubber ring 37. Instead of rubber rings I may use any other resilient means such as flat coil springs as illustrated in Fig. 14.

An additional hydraulic cushion is obtained to reduce the shock on the seating of the valve 26 on its seat 41a. The seating of the valve occurs while the valve and hammer are both moving. The recesses 19 and 20 furnish a chamber for entrapment of fluid. The fluid is forced out as the valve body is eased quickly to its seat on 41a. This is a form of hydraulic shock absorber.

The response of the hammer, that is, the speed of striking and the force of blow of the hammer, for any given hammer design, depends upon the speed of response of the valve. It is essential that when the valve is unseated by the arrival of the pin 30 at the top of the slot 28 the spring have sufficient tension to immediately retract the valve in the recess to seat the valve against the frusto-conical seat 41a. If the tension is too small the valve will have insufficient average vertical acceleration and the valve will not be seated in its frusto-conical seat 41a at the time the hammer is ready to make its descent. The result will be that the valve will be out of phase with the motion of the hammer. This may not only reduce the speed of reciprocation of the hammer, but may cause damage to the valve. If the tension of the spring is too great the hammer on the upstroke unseats the valve before the hammer reaches top stroke, that is, the tension of the spring may be sufficient to unseat the valve against the fluid pressure before the pin 30 has reached the uppermost position in the slot 28. This will have a tendency to shorten the stroke of the hammer.

By using an extension type spring instead of a compression type and by pinning the upper end of the valve stem to the lower end of the valve spring and the upper end of the spring to the hammer by pins 30, as described above, and by the provision of valve seat 41a as described above, I am able to fix the initial spring tension

to a definite value commensurate with the weight of the valve and valve stem.

I can so fix the final tension of the spring when the hammer is elevated to overcome the pressure of the fluid exerted through port 41 and prevent the valve from being pumped downwardly during the descent of the hammer prior to the seating of the hammer.

When, as previously described, the valve 26 is seated on its seat on chuck 48, the spring is designed so that this initial tension and the tension of the spring during its extension are not sufficient to unseat the valve until the pin 30 has reached its uppermost point of travel. Since the fluid pressure exerted through port 41 is known and can be controlled by regulating the mud pump pressure at the top of the well, and since the dimensions of the various ports and other parts of this hammer are known, a spring may be designed by regulating the diameter of the wire and the number of coils so that the spring may have the desirable final and initial tensions previously described.

During the portion of the travel of the hammer when the valve 26 is on its seat on the chuck 48, the valve stem is retracted from the recesses 20 and 19, thus creating a zone of lower pressure. This pressure is relieved and pressure maintained in the valve chamber by means of the port 41 which permits fluid to enter from the higher pressure zone in the annulus of the case 1 into the chambers 20 and 19. This is necessary in order to maintain the pressure in the chambers 19 and 20 to hold the valve on its seat on the chuck until the pin 30 reaches its uppermost travel in the slot 28. In like manner when the valve stem is retracted by the spring 24, excess fluid is discharged through the port 41 into the annulus of the case as a result of the pumping action of this valve stem. The bores 29 act as additional ports for the same purpose. The slots 28a provided in the yoke of the valve stem permits fluid to pass between the valve stem and the walls of the recess and are made of sufficient diameter to pass any beet pulp, bagasse, hay, cellophane, mud or other materials used in drilling fluids in oil field practice.

It is desirable, because of the variable hardness of the formation which must be drilled, to regulate the force of the blow of the hammer to be greater for harder formations and less for formations which are not as tough or are more brittle, as the case may be. By lengthening the stroke of the hammer I can increase the force of the blow and by diminishing the length of the stroke of the hammer I can reduce the force of the blow.

I have provided for this purpose a simple expedient for altering the stroke of the hammer by changing the position of the pin 30 in the bores 29. The hammer stroke may thus be increased in length or diminished in length. The force of the blow may therefore be predetermined before the hammer is run to bottom for cutting of a hole in the formation. Thus by placing the pin 30 in an upper bore 29 the stroke of the hammer may be lengthened and by placing the pin 30 in a lower bore 29 the hammer stroke may be shortened.

I have also provided means for controlling the initial and final spring tension of the spring 24 to be adjusted to the variation in the stroke length imposed by the positioning of the pin 30 as previously described. Thus, as will be seen from what has been said before, it is necessary

to assure that the proper spring tensions exist at both ends of the stroke of the hammer in order to operate the valve properly. When the stroke is shortened, the initial spring tension, when the hammer is elevated, may not be sufficient to retract the valve into the recess 20 when the pin 30 reaches its uppermost position against the top of the slot 28. In such case when the pin 30 is elevated to an upper bore 29 the pin 23 is removed from the bore 21 at the top of the recess 19 and moved to a higher bore hole in order to increase the tension of the spring so that when the pin 30 reaches its topmost point of travel there will be sufficient tension in the spring to raise the valve. In like manner when the stroke is lengthened by moving the pin 30 to a lower bore 29, the tension in the spring 24 caused by the upward movement of the hammer while the valve is seated on the chuck may create a tension in the spring sufficient to unseat the valve before the hammer has reached its uppermost point of travel and the pin 30 has reached its uppermost position in the slot 28. In such case the pin 23 is moved to a lower bore 21 in order to reduce the tension on the spring so that the tension be not sufficient to unseat the valve until the pin 30 has reached the uppermost point of travel.

While I have described a particular embodiment of my invention for the purpose of illustration, it should be understood that various modifications and adaptations thereof may be made within the spirit of the invention as set forth in the appended claims.

I claim:

1. A hammer type rotary rock drilling apparatus which comprises in combination a hammer case having at its head a joint adapted to be attached to the end of a string of rotary drill tubing through which flushing fluid is pumped downwardly, a hammer mounted for vertical reciprocation within a central tubular section forming a chamber inside said case, said hammer having at its top a head of reduced diameter, the head of said case having a bore open at the bottom and closed at its top except for ports connecting the interior thereof with the annular space between the case and the bore of the well; said bore forming a cylinder in which the reduced head of the hammer reciprocates with the latter acting as a piston, a compression spring mounted in said bore bearing against said reduced head and tending to push said head downwardly in the tube, a passageway for flushing fluid in said head leading into said head at a point beneath said depending tube and then upwardly through said head into said bore, whereby the flushing fluid can pass from the central chamber of the case through the hammer head, through the bore and outwardly into the space between the case and the well bore, conduit means for passing flushing fluid from the drill tubing around said bore and into the central chamber of the case, the said hammer having sufficient clearance in said chamber to pass said fluid downwardly between the hammer and the case wall, a central bore at the bottom of said hammer, a reciprocating valve mounted at the bottom of said bore having a valve stem leading upwardly into said hammer bore, an extension spring attached between the top of the valve stem and an adjustable fastening means at the top of the hammer bore whereby the spring tends to pull the valve stem upwardly into said bore, means for limiting the downward motion of said valve

stem in said bore relative to the hammer, a chuck slidably mounted in the bottom of the case the top of which forms an anvil to receive blows from said hammer, a cutting head attached to the lower end of the chuck, the chuck having a central bore connecting with ports in said cutter head to supply flushing fluid from the central chamber of the case to said cutting head, the top of the chuck forming a valve seat for said valve which when seated closes the central bore of said chuck and means providing relative longitudinal movement connecting the case and the chuck to rotate the chuck and hence the cutter head as the case is rotated by the rotation of the drill tubing; said valve and hammer being so constructed and arranged that when said valve closes the central bore of the chuck the pressure of the flushing fluid in said central chamber forces the hammer upwardly off the chuck while the valve remains seated until said means for limiting the downward motion of the valve stem becomes operative, whereby the valve is then lifted and the resulting decrease in the pressure of the flushing fluid in the central chamber due to its flow through the central bore of the chuck coupled with the downward pressure of said compression spring at the top of the hammer causes the hammer to descend and to strike the chuck whereby the valve again becomes seated.

2. The drilling apparatus of claim 1 wherein the valve stem has an upper tapered section the lowest point of which makes a sliding fit with the bore of said hammer so as to provide limited oscillatory motion of the valve about said lowest point serving as a pivot.

3. The drilling apparatus of claim 2 wherein the valve stem is of reduced diameter between the lowest point of the tapered section and the valve to make the stem flexible.

4. The drilling apparatus of claim 1 wherein splines are provided between the lower end of the hammer and the wall of the case to guide the hammer in its reciprocating motion.

5. The drilling apparatus of claim 1 wherein means are provided for adjustably restricting the fluid passageway leading through the head of the hammer into said bore and from thence to the annular space between the case and the bore of the well.

6. The drilling apparatus of claim 1 wherein said means for limiting the downward motion of the valve stem relative to the hammer is adjustable vertically to provide valve strokes of adjustable length downwardly.

7. The drilling apparatus of claim 6 wherein the extension spring at the top of the valve stem is provided with an adjustable upper fastening means to change the tension on the spring and thereby to change the stroke of the hammer.

8. The drilling apparatus of claim 1 wherein the valve stem is connected to the valve body through resilient means which absorb the shocks caused by the valve striking its seat.

HARRY PENNINGTON.

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