United States Patent

[11] 3,568,783

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[54] FLUID-ACTUATED IMPACT APPARATUS

27 Claims, 8 Drawing Figs.

[52] U.S. Cl. 175/92, 175/296
[51] Int. Cl. E21b 1/00, F21b 5/00
[50] Field of Search 175/296, 92

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ABSTRACT: A fluid-actuated hammer drill for drilling well bores and connected to a drill pipe string through which drilling fluid is pumped, which passes through a pair of shock passages controlled at their lower portions by one or more valves, the valves being switched by the flowing fluid to alternately close each shock passage, creating a high-pressure pulse in each passage when closed which acts upon and reciprocates a hammer to rapidly impact upon a companion anvil connected to a drill bit, the fluid flowing through the bit to convey the cuttings to the top of the well bore.

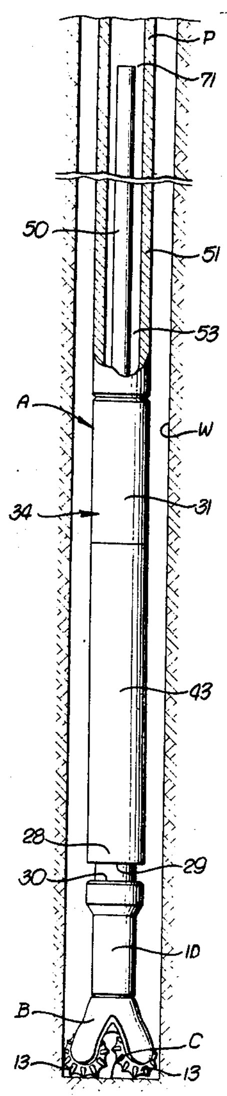

FIG. 1.

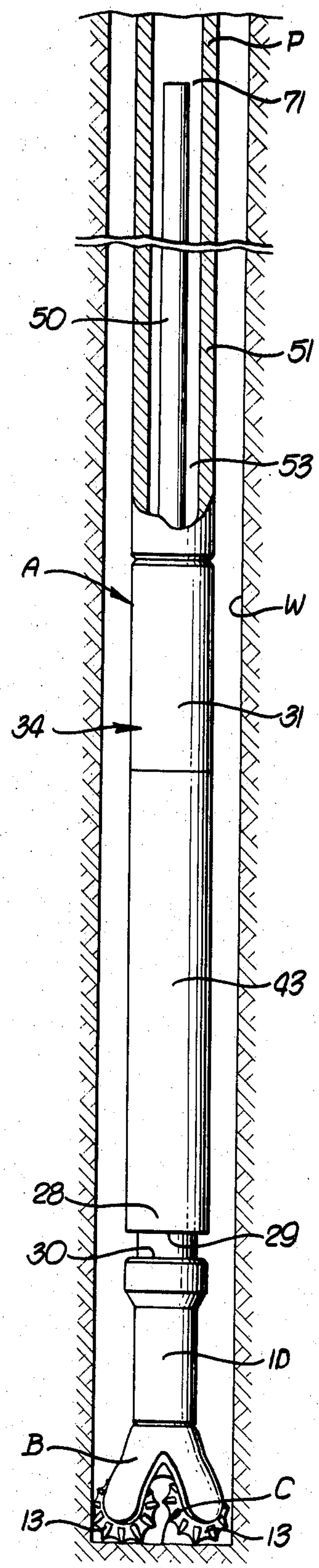

FIG. 2a.

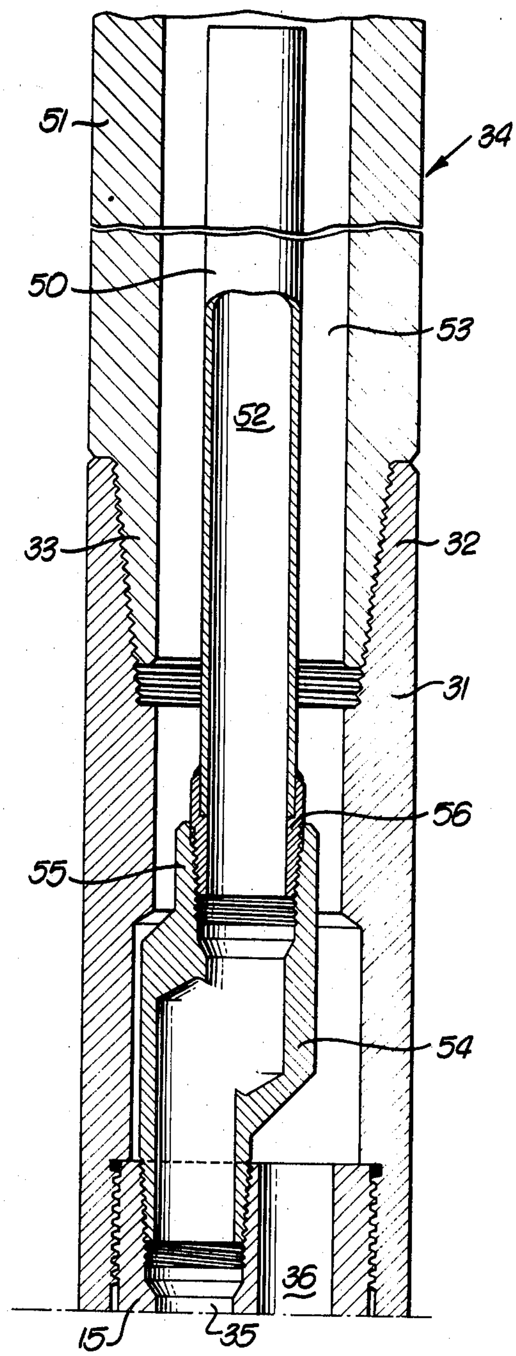

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FIG. 2b.

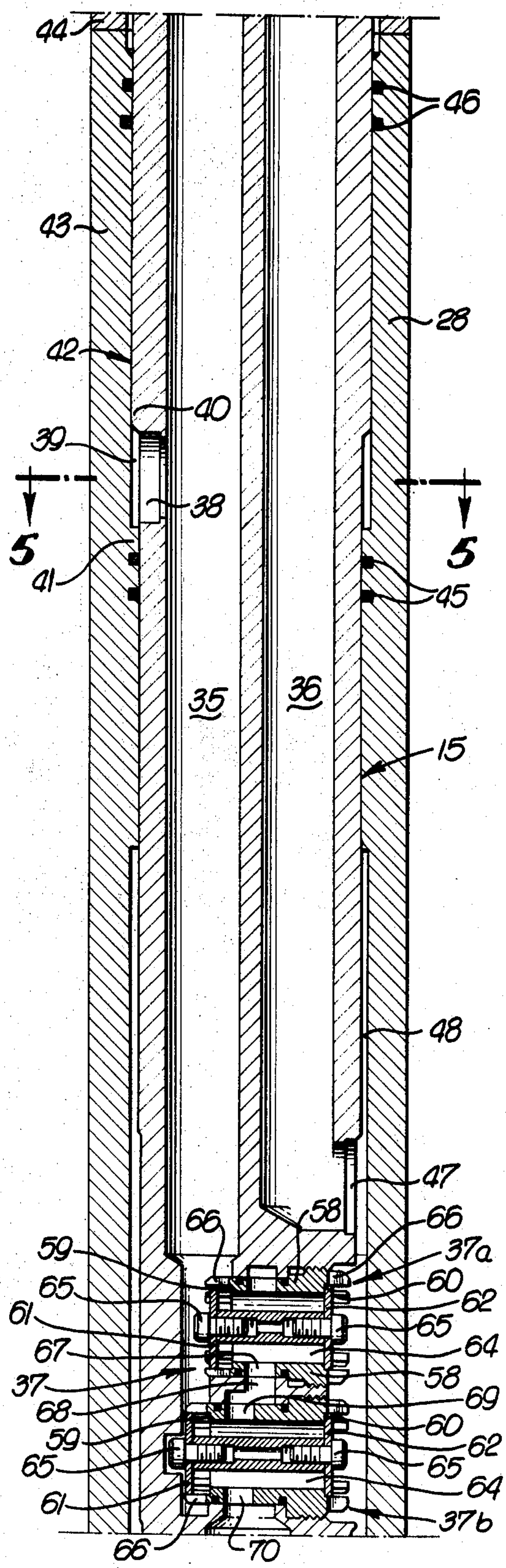

FIG. 2c.

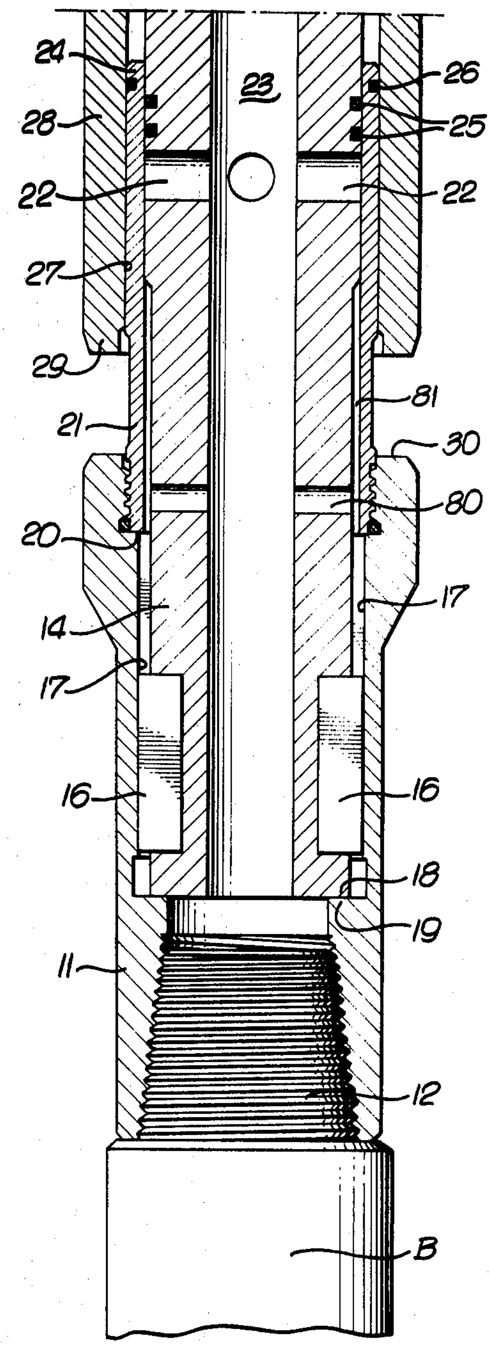

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FIG. 3a.

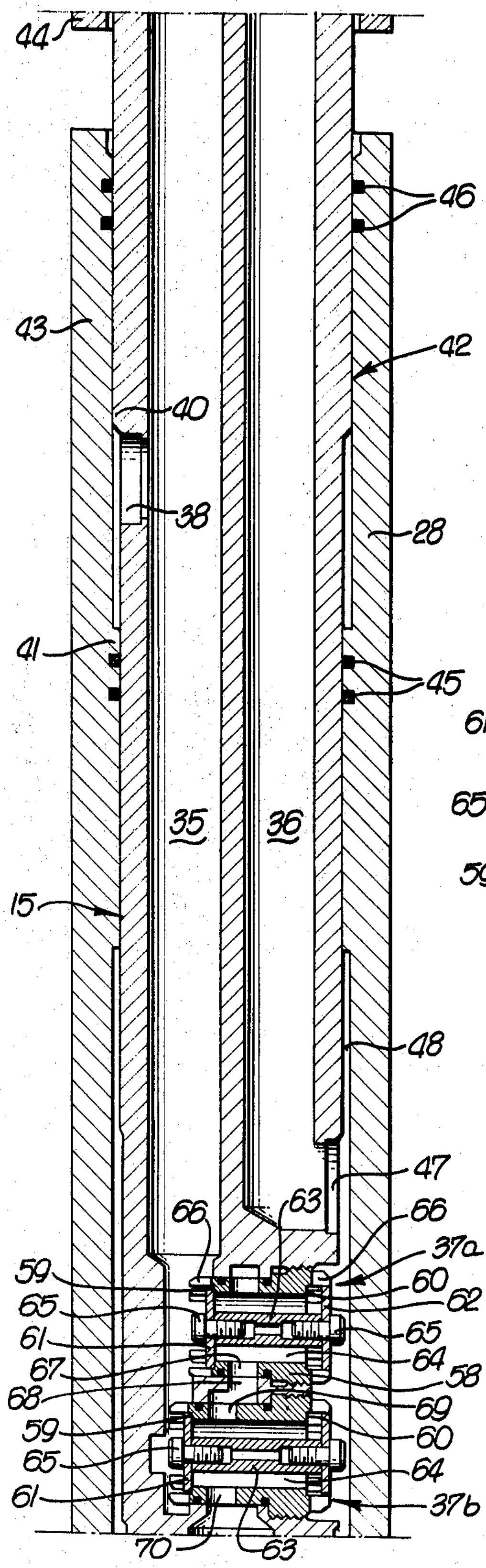


FIG. 3b.

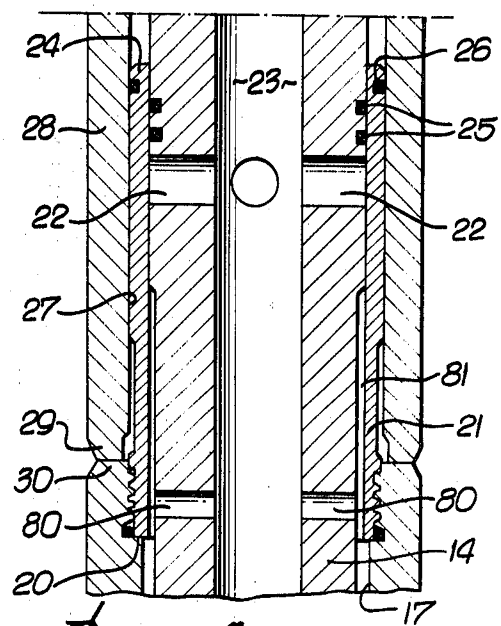


FIG. 4.

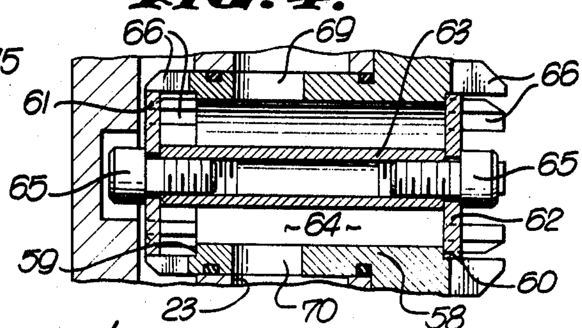
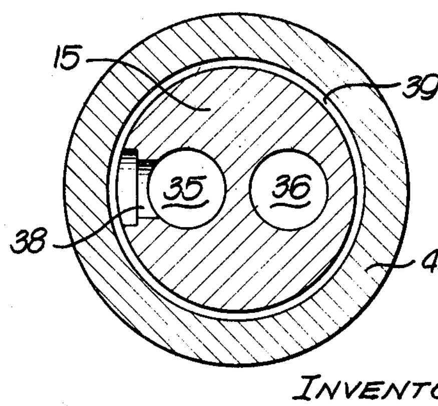


FIG. 5.



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FLUID-ACTUATED IMPACT APPARATUS

The present invention relates to fluid-actuated impact apparatus, and more particularly to apparatus use in drilling oil, gas, water and similar well bores.

In the drilling of well bores, impact tools have been used in the drilling of hard formations. Impact percussion or hammer drilling enables a sufficient force to be generated and applied through the bit to the formation for the purpose of causing rock failure with a minimum of drill collar weight. As is usual in the drilling of well bores, the drill bit is connected, directly or indirectly, to a string of drill collars and drill pipe. Since it is desirable to maintain the drilling string in tension, it is usually only relaxed sufficiently to cause the relatively stiff drill collars to impose an appropriate force or weight upon the drill bit. Convention rotary drilling in hard formations may require the imposition of a drilling weight of the order of 8,000 to 10,000 lb. per inch of bit diameter. For example, in drilling a 9⅝inch hole, the drilling weight imposed upon the bit may be of the order of about 90,000 lb. Such drilling weights are excessive in the achievement of optimum penetration rates because the tendency is for a deviated well bore to be produced. The extent of deviation is considerably reduced, or even eliminated, when drilling with an impact bit since the drilling weight need not all be provided by the drill collars to cause rock failure, the dynamic forces generated by the impact drill causing the rock failure. As a result, the string of drill collars and drill pipe thereabove need not be placed in compression, but can be maintained substantially entirely in tension, all of which is productive of the drilling of a straight hole.

Pneumatic hammers or percussion drills are commercially available, but it is not economically possible to drill many wells with air or gas, which would afford economies because of faster penetration rates. The difficulties are due to water encroachment, as well as other factors. Attempts have been made to develop a hydraulic impact drill through which hydraulic fluid or mud would be circulated from the rotary rig through a string of drill pipe and drill bit for the purpose of conveying the cuttings upwardly around the string of drill pipe to the rotary rig. However, such prior hydraulic impact drills have not been successful.

With the present invention, a fluid-actuated impact apparatus has been developed which is comparatively simple in construction and manufacturing cost, relatively easy to service, and which has a comparatively long life. The invention can be used for imparting impact blows generally, but the form specifically disclosed in the present application has been designed specifically for use in the drilling of well bores. In general, fluid is circulated down through a string of drill pipe and through the apparatus to which a suitable drill bit can be secured, the fluid flowing through the apparatus causing a hammer or other impact device to deliver its impacting force to the drill bit, the reciprocation of the hammer and the kinetic energy for delivering the impact blow being developed as a result of the fluid circulating down through the drill pipe and the apparatus, such circulating fluid discharging through the drill bit for the purpose of maintaining the latter in a clean and cool condition and to comingle with the cuttings and deliver them upwardly around the apparatus and the drill string to the top of the well bore. Because of the fact that the impact blows delivered are quite considerable, a minimum of drilling weight need be imposed by the drilling string on the bit, since the hammer blows effect rock failure. The result is the maintenance of the drilling string in tension and the drilling of a straight or vertical hole. The force necessary for imparting the kinetic energy to the hammer or impacting member of the apparatus is generated as a result of suddenly arresting fluid flowing through a shock tube, which creates a positive high-pressure pulse that drives the hammer against an anvil or other member connected to the drill bit. The hammer is elevated and raised in a very rapid manner without rotation of the drill string being required, but purely as a matter of pumping the drilling fluid or liquid, such as drilling mud, downwardly through the drill string and the apparatus. The rotary drill string may be rotated during the impacting operation, such that the full bottom of the hole being drilled upon can be covered by the cutting tool as a result of rotating the drilling string, impacting apparatus, and drill bit, and also as a result of creating the rather rapid impacting or hammer blows upon the cutting elements of the drill bit.

A further feature of the invention is that fluid can be circulated through the drill string and the apparatus without the hammering effect being permitted to occur. Thus, circulation can be established through the drill pipe and apparatus in an unimpeded manner, until the hammering action is required. Moreover, the drill pipe is permitted to fill with the drilling fluid while the apparatus is being lowered therewithin in a comparatively unrestricted manner. During elevation of the drilling string and apparatus through the drilling mud or other fluids in the well bore, the drill pipe and drill collars can drain freely, thereby preventing the pulling of a "wet job" when the drilling apparatus and drill bit are being withdrawn from the well bore.

This invention possesses many other advantages, and has other purposes which may be made more clearly apparent from a consideration of a form in which it may be embodied. This form is shown in the drawings accompanying and forming part of the present specification. It will now be described in detail, for the purpose of illustrating the general principles of the invention; but it is to be understood that such detailed description is not to be taken in a limiting sense.

Referring to the drawings:

FIG. 1 is a side elevational view, with a portion in longitudinal section, of an apparatus embodying the invention, disclosed within a well bore in combination with a drilling string and drill bit;

FIGS. 2*a*, 2*b*, and 2*c* together constitute a longitudinal section through the apparatus, FIGS. 2*b* and 2*c* being lower continuations of FIGS. 2*a* and 2*b*, respectively;

FIGS. 3*a* and 3*b* illustrate the lower portion of the apparatus with the control valve switched over to an opposite position from that illustrated in FIG. 2*b*, FIG. 3*b* being a lower continuation of (FIG. 3*a*;

FIG. 4 is an enlarged fragmentary longitudinal section through one of the switching valves in the position illustrated in FIG. 2*b*; and

FIG. 5 is a cross section taken along the line 5–5 on FIG. 2*b*.

The impacting apparatus A illustrated in the drawings is adapted to be connected to a string of pipe P and also to a suitable drill bit B, illustrated as being of the toothed roller type, the combination being disposed in a well bore W so that the drill or drill bit can act upon the formation at the bottom C of the latter, as a result of rotating the drill pipe P, impacting apparatus A and drill bit B and simultaneously delivering hammerlike blows to the latter in a rapid manner.

The impacting apparatus includes a lower anvil **10** having a threaded box **11** adapted to threadedly receive the pin **12** of the drill bit, which has the toothed roller cutters **13**. Although not shown, and as is well known in the art, the drill bit has circulation posts or nozzles for delivering drilling mud or other fluid downwardly against the bottom of the hole, or cutters, or both, for the purpose of cleaning and cooling the cutters and flushing the cuttings around the bit, the apparatus, and the string of drill pipe to the top of the hole, the drill pipe string extending to the rotary rig with its kelly (not shown) passing through a rotary table (not shown) in the usual manner, by which it can be rotated at the desired speed.

The anvil **10** is telescoped over the lower portion **14** of the main elongate body **15** of the impacting apparatus, torque being transmittable from the body to the anvil by a spline connection therebetween. As specifically disclosed, such spline connection is in the form of keys **16** secured to the body **15** and slidable relatively longitudinally in internal longitudinal keyways **17** in the anvil. The lower end **18** of the body is engageable with an upwardly facing shoulder **19** in the anvil immediately above the threaded box **11**, the anvil and drill bit being capable of lowering relatively with respect to the body because of the spline connection, to the extent limited by engagement with the keys **16** of the lower end **20** of a bypass sleeve valve member **21** threadedly secured to the upper end of the anvil **10**. The sleeve valve **21** extends upwardly, being adapted to close bypass ports **22** extending between the exterior of the body and a central flow passage **23** therein, communicating with the central passage (not shown) in the drill bit.

When the drill bit B and anvil **10** are allowed to shift to a lower position, so that the lower end **20** of the bypass sleeve **21** engages the keys **16**, the upper end **24** of the bypass sleeve is disposed below the ports **22**, which are then in an open condition to permit circulation therethrough, as hereinafter described. One or more seals **25** are provided on the body above the bypass ports in engagement with the interior of the sleeve valve **21**, the sleeve valve having a seal **26** on its periphery slidably sealingly engaging the inner surface **27** of a hammer or impacting sleeve **28** surrounding the body and reciprocable therealong to impact its lower hammerhead **29** against the upwardly facing impacting surface **30** of the anvil **10**.

The upper end of the main body member is threadedly secured (FIG. 2*a*) to an extension **31** of the body member, which is an adapter sub having an upper threaded box **32** receiving the threaded pin **33** of a section of drill collar or drill pipe **34** extending upwardly and forming part of the drilling string P. The main body member has parallel first and second passages **35**, **36** extending from its upper end down to a switching valve portion **37** of the apparatus that determines the flow of fluid from the lower end of one passage **35** into the central flow passage **23** in the lower end of the body, or from the other passage **36** into such central flow passage. The first passage **35** has a side port **38** communicating with an annular cylinder space **39** provided between an annular piston portion **40** of the main body and a cylinder head **41** therebelow forming part of a cylinder portion **42** of the hammer or impacting sleeve **28**. The upper portion of such sleeve constitutes an outer cylinder consisting of the aforementioned cylinder head **41** and an upper cylinder skirt **43**, the upper end of which is engageable with the lower end **44** of the adapter sub **31**, which limits its upward travel along the body **15**. The cylinder head **41** carries one or more seal rings **45** slidably and sealingly engaging the periphery of the body below the port **38**, and the cylinder skirt has one or a plurality of seal rings **46** slidably and sealingly engaging the larger diameter portion of the body above the port **38**. Fluid under pressure from the first passage **35** will pass through its side port **38** into the annular cylinder space **39** and act upon the cylinder head **41** to drive the hammer or impacting sleeve **28** in a downward direction, impacting its hammerhead **29** upon the upper end **30** of the anvil.

A discharge port **47** from the second passage **36** opens into an annular cylinder space **48** defined between the impacting sleeve **28** and body below the cylinder head **41**, fluid under pressure in such annular cylinder space acting upwardly on the cylinder head **41** to drive the hammer or impacting sleeve upwardly along the body **15** to the extent limited by its engagement with the lower end **44** of the adapter sub.

The impacting apparatus comprises a pair of shock tubes **50**, **51** that provide shock passages **52**, **53**, each shock passage communicating with one of the first and second passages **35**, **36** in the main body member **15**. Thus, a sub **54** is threadedly secured to the upper end of the body in communication with the first passage **35** and has an upwardly facing threaded box **55** disposed centrally of the adapter sub and to which is threaded and adapter **56** welded, or otherwise secured, to the shock tube **50** extending centrally and upwardly through the drill collar to the desired extent. This inner shock tube **50** may have a suitable length, for example, 30 feet, and is open at its upper end so that it can receive fluid pumped downwardly through the drill pipe P. The second shock passage **53** is defined between the inner shock tube **50** and the drill collar portion **51** itself, communicating with the second passage **36**. Its cross-sectional area is equal or unequal to the area of the inner shock tube passage **52**. Thus, the inner and outer shock tube or shock passage arrangement effects economy of manufacture, since it is unnecessary to provide a pair of separate shock tubes, one of which communicates with the first body passage **35** and the other of which communicates with the second body passage **36**.

Assuming that the switching valve mechanism **37** were not present for controlling the flow of fluid from the lower ends of the first and second passages **35**, **36**, fluid would merely circulate freely through such parallel passages and into the central flow passage **23** of the body and then downwardly through the drill bit B. However, the downward flow of fluid through one passage is suddenly arrested, while fluid is permitted to flow through the other passage, to introduce a shock wave in the closed passage **35** or **36** which creates a high-pressure pulse that passes through one port **38** or **47** for action on the cylinder head **41** in one direction. The opening of such closed passage to flow of fluid, and the sudden closing of the other passage to the flow of fluid, causes the shock pressure wave to be generated in the second passage for action upon the cylinder head of the hammer in the opposite direction. Thus, by alternately suddenly stopping the flow of fluid through each passage, a pressure boost or increase in such passage is generated that acts upon the hammer and shifts it in one direction or the other.

The switching valve **37** for controlling the flow of fluid downwardly through the first and second passages and into the flow passage **23** therebelow is disclosed as a pair of valves, to provide adequate combined flow area therethrough. Thus, upper and lower switching valves **37*a***, **37*b*** are illustrated. An upper valve body **58** is threadedly secured transversly into the main body **15** of the apparatus, this valve body having first and second valve seats **59**, **60** adapted to be engaged by first and second valve heads **61**, **62**, respectively, that reciprocate transversely of the body to alternately bring the valve heads into engagement with their seats, and thereby prevent fluid from flowing from one passage into the valve body **58** and thence therethrough into the flow passage **23**, or to prevent fluid from flowing from the other passage into the valve body and then into the central flow passage **23**. When one valve head engages its seat, the other is disengaged from its seat, the valve heads moving together. Thus, the valve heads **61**, **62** are separated by a sleeve **63** defining an annular space **64** with the valve body, each valve head being clamped against an end of the sleeve by a screw **65** threaded into the sleeve and with its head bearing against the valve head. The screws **65**, sleeve **63** and valve heads **61**, **62** move as a unit transversely of the main body **15** of the apparatus and axially of the upper valve body **58**, being guided in such movement by a plurality of circumferentially spaced body fingers **66**.

The lower switching valve **37*b*** comprises the same parts and arrangement as the upper switching valve, merely being a duplicate of the other. Specifically, the fluid can flow simultaneously from one passage, as **35**, to the interiors **64** of the upper and lower valve bodies, the fluid from the upper valve body passing through a port **67** into an intercommunicating passage **68** in the main body of the apparatus and thence through an upper port **69** in the lower valve body to its interior, from where the combined flow of fluid passing into both the upper and lower valve bodies passes through a lower port **70** in the lower valve body into the lower flow passage **23** of the main body of the apparatus, which communicates with the passage and nozzles (not shown) of the drill bit B threadedly secured to the anvil **10**. When the upper and lower switching valves **37*a***, **37*b*** are in the position opening the other passage, as **36**, then fluid will still flow from such other passage into the annular space between the hammer **28** and the main body **15** into the upper and lower valve bodies, from where they pass into the main body flow passage **23**.

The switching valves **37** operate in concert, being shifted by the fluid under pressure in the first and second passages **35**, **36** and the shock tubes **50**, **51** into a position in which the second valve heads **62** engage their respective seats **60** to prevent flow of fluid from the second passage 36 into the main body flow passage 23, as disclosed in FIGS. 2*b* and 4, or to the position illustrated in FIG. 3*a*, in which the fluid flowing from the second passage 36 into the valve body is closed or prevented. When one flow passage is closed, the other is open so that fluid pumped down through the drill pipe is flowing alternately through the first passage 35 and the second passage 36, through the switching valves 37 and into the lower flow passage 23 of the apparatus. When it is flowing through one passage 35, the other 36 is closed, and when flow through the other passage 36 is closed by the switching valves 37, flow is permitted through the first-mentioned passage 35.

In the application of David V. Chenoweth, Ser. No. 810,536, filed Mar. 26, 1969, for "Fluid Shock Wave Oscillator and Fluidic Pump," a positive pressure pulse fluid pressure booster is disclosed and described, which takes advantage of sudden stopping of fluids through a passage to increase or boost the fluid pressure. In that apparatus, a pair of shock tubes of passages is illustrated having appropriate length, the alternate and sudden stopping of the flow of fluid through each tube increasing the fluid pressure therewithin in a time $T=2L/C$; in which T=time; L=length of shock passage, which will be the distance between the open end of the shock passage and the switching valve; and C=wave celerity, that is, the speed of sound through the fluid in the shock passage.

In the present case, assuming that the fluid being pumped through the drill pipe P and through the shock passages 52, 35 and 53, 36 effects closing of the second passage 53, 36, as illustrated in FIGS. 2*a* and 2*b*, the velocity energy of the fluid that had been flowing downwardly through the second passage 36 is converted into pressure, the pressure wave traveling upwardly from the switching valve 37 to the upper end 71 of the second passage 53, the upper end of such second passage effectively terminating at the upper end of the inner shock tube 50. The duration of such pressure wave is for the time that it takes the wave to travel from the closed switching valve 37 upwardly through the second shock passage 36, 53 to its upper end (the upper end of the inner shock tube) and then downwardly through such passage; that is, in the time $2L/C$. When the pressure pulse returns to the switching valve 37, it decreases in pressure below the pressure of the fluid flowing through the inner shock tube 50 and first passage 35, which then switches the valve over to the right (as seen in FIGS. 2*b* and 3*a*) to close the first passage 52, 35 to the flow of fluid and open the second passage 53, 36 to such flow. The sudden arresting of the fluid flowing at a particular velocity through the first passage causes an increase in the pressure in the first passage, the pulse wave travelling upwardly through the first passage and the inner shock tube 50 to the upper end of the latter and then back down again. When the pulse wave returns to the switching valves 37, it then is at a lower pressure than the pressure of the fluid flowing through the second passage 53, 36, the valve being switched back to its initial position illustrated in FIG. 2*b*, the cycle of operation being repeated.

During the time $T=2L/C$ that the high-pressure pulse is travelling through the second passage 53, 36, the pressure therein, the port 47, and in the annular space 48 below the cylinder head between the hammer 28 and the body 15 increases to drive the hammer or impacting sleeve 28 upwardly to the position illustrated in FIG. 2*b*, the fluid being pumped down the drill pipe through the first shock passage 52, 35 and through the open valves 37 into the flow passage 23, passing therefrom through the drill bit B into the well bore W. When the pulse wave in the second passage 53, 36 returns to the switching valves 37 and the pressure is of a decreased value, compared to the pressure of fluid flowing through the first passage 52, 35, the valve switches to the position illustrated in FIG. 3*a*, the high-pressure pulse in such passage then being imparted to the fluid in the port 38 and the annular space 39 below the piston 40 for action on the cylinder head 41 to drive the hammer 28 downwardly and impact its lower end 29 against the upper impacting surface 30 of the anvil 10, such blow or force being transmitted to the drill bit B and its cutters 13 to strike a blow by the cutters against the bottom C of the well bore, which can be of a sufficient force as to overcome the compressive strength of the rock or other formation, resulting in its failure. During the striking of such hammer blow and the closing of the first passage 52, 35, fluid is circulating downwardly through the second passage 53, 36 and through the switching or shuttle valves 37 into the central flow passage 23 in the lower portion of the body, flowing therefrom through the drill bit B into the well bore.

After the high-pressure pulse has travelled upwardly to the upper end of the inner shock tube 50, and then downwardly again to the switching valves 37, when it arrives at the latter point, it has a reduced pressure compared to the pressure in the second passage 53, 36, the valves 37 switching to their initial position, and the foregoing cycle of operation is repeated, the hammer or impacting sleeve 28 being reciprocated along the body and alternately driven upwardly and downwardly.

During the pumping of fluid through the drill string P and alternately through the pair of shock tubes 50, 51, the drill string and the apparatus are rotated, rotary effort being transmitted from the body 15 through the keys 16 to the anvil 10, and from the latter to the drill bit B, so that the cutters 13 are covering the entire area of the bottom C of the well bore. A desired amount of drilling weight is imposed by the drilling string on the drill bit to insure the retention of its contact with the bottom of the well bore, which enables the impact blows imparted thereto to be most effective in causing failure of the rock or other hard formation being operated upon. However, the drilling weight can be relatively small, for example, of the order of 2,000 lb., although, if desired, a greater or lesser weight can be imposed upon the bit. In an actual test of apparatus employing the shock tubes, with a 300 p.s.i. pressure differential, a force of impact blow of about 85,000 lb. was generated and imposed on the hammer 28 in driving it into contact with the anvil 10, which is in excess of the strength of many hard formations encountered in well bores. With the impact drill, a dynamic force generated to cause rock failure is applied near the bit, as distinguished from a force of a static nature heretofore required by imposing the weight of a long relatively limber drilling string in compression upon the bit. Accordingly, the drilling string P is almost entirely in tension throughout its length, resulting in the drilling of a straight hole, and because of the overcoming of the compressive strength of the rock, the hole is drilled at a much greater rate.

The increase in pressure alternately in the shock passages 52, 35 and 53, 36 is dependent upon the switching time of the switching valves 37 in shifting from one position to the other. The greater the switching time, the greater will be the pressure generated in each passage upon closing of its lower end, since the fluid circulating through such passage, when open, will have reached a greater velocity, resulting in a much greater pressure when the valve or valves 37 close such passage. This greater pressure boost results from the fact that the switching valves 37 have substantially a zero natural frequency of vibration, the frequency of shifting being dependent completely upon the time required for each pressure pulse to make its round trip through each shock passage and the time required to overcome the inertia of the movable valve members. The time for the high-pressure pulse wave to make its round trip through a shock passage is, of course, dependent upon the length of the shock passage. By way of example, if the effective length of the inner shock passage and outer shock passage is about 30 feet, it is found that the hammer 28 will reciprocate at a frequency of about 8 to 30 cycles per second. Thus, impact blows at a relatively high rate are being delivered to the anvil 10 and drill bit B, all of which is productive of drilling the well bore W in a comparatively rapid manner.

When the drill bit B is out of engagement with the bottom C of the well bore, as during the time that it has been elevated thereabove, or is being raised or lowered in the well bore, the weight of the drill bit B and anvil 10 pulls the bypass sleeve 21 downwardly of the body to a position limited by engagement of the lower end 20 of the bypass sleeve valve with the upper ends of the keys 16, which places the upper end of the bypass sleeve below the bypass ports 22. When in such position, fluid can be circulated down through the drill pipe P and through the impacting apparatus A without effecting switching of the valves 37 and the reciprocation of the hammer 28 along the body 15, inasmuch as fluid can pass through the second passage 36 into the space between the hammer 28 and body around the switching valves 37, and then inwardly through the bypass ports 22 to the central flow passage 23 in the lower portion of the body. If the shuttle or switching valves 37 are open to permit flow of fluid through the second passage 36, then the fluid can also pass through such open valves into the flow passage 23. If the switching valves have closed the lower end of the second passage 36, then the lower end of the first passage 35 is open and fluid can then flow from the drill pipe P through the first passage 52, 35 and its open valves 37 into the body central flow passage 23 simultaneously with the flow of fluid through the second passage 53, 36 and open bypass ports 22 into the body flow passage 23. The switching valves 37 will not reciprocate, as when the bypass ports 22 are closed.

Not only does the bypass valves permit fluid to be circulated down through the drill pipe P, but it will permit the fluid to fill the drill pipe automatically during lowering of the apparatus through the drilling mud, or other fluid, in the well bore, since the fluid can pass through the drill bit B into the central passage 23 and then through the bypass ports 22 into the annular space between the hammer 28 and body into the second passage 36, flowing upwardly through the second passage into the drill string P thereabove. If the switching valve 37 is in the position disclosed in FIG. 2*b*, such fluid can also flow through the switching valves 37 into the first passage 35, 52 and then into the drilling string P thereabove. Similarly, during elevation of the bit in the well bore towards the top of the hole, the bypass ports 22 are again open and fluid can drain from the drill string through the apparatus A and the bypass ports 22 into the central flow passage 23, flowing through the drill bit B into the well bore. To insure that there are no fluid locks to prevent movement of the anvil 10 and bypass sleeve 21 along the body 15 between its bypass port closing and opening positions, bleeder holes 80 are provided through the body between the central flow passage 23 and the exterior of a reduced diameter portion providing an annular space between the sleeve valve 21 and body.

We claim:

1. Impacting apparatus comprising a passageway including a shock passage through which fluid pumped through the passageway can flow, said shock passage having a fluid inlet and a fluid outlet, impacting means communicating with said shock passage and having a surface responsive to fluid pressure in said passage, and a shuttle valve device downstream of said surface and in the path of fluid flow through said shock passage and shiftable by the fluid flowing in said shock passage to a position closing said outlet to generate a positive fluid pressure pulse wave in said shock passage acting on said surface of said impacting means to force the same against a companion member.

2. Impacting apparatus as defined in claim 1; said positive pressure pulse wave travelling through said shock passage from said outlet to said inlet and then returning to said outlet as a negative pressure pulse wave enabling said shuttle valve device to shift to outlet opening position.

3. Impacting apparatus as defined in claim 1; said impacting means being spaced from the companion member before said outlet is closed and propelled toward and against the companion member upon closing of said outlet.

4. Impacting apparatus as defined in claim 1; said positive pressure pulse wave traveling through said shock passage from said outlet to said inlet and then returning to said outlet as a negative pressure pulse wave enabling said shuttle valve device to shift to outlet opening position, and means for shifting said shuttle valve to outlet opening position.

5. Impacting apparatus as defined in claim 1; said impacting means being spaced from the companion member before said outlet is closed and propelled toward and against the companion member upon closing of said outlet, and means returning said impacting means to its position spaced from the companion member.

6. Impacting apparatus as defined in claim 1; said positive pressure pulse wave travelling through said shock passage from said outlet to said inlet and then returning to said outlet as a negative pressure pulse wave enabling said shuttle valve device to shift to outlet opening position, said impacting means being spaced from the companion member before said outlet is closed and propelled toward and against the companion member upon closing said outlet, and means for returning said impacting means to its position spaced from the companion member.

7. Impacting apparatus comprising first and second shock passageways intercommunicating at one end and adapted to receive fluid from a source, said passageways having outlets at their opposite ends, impacting means communicating with said first passageway to be moved by fluid pressure therein in one direction and communicating with said second passageway to be moved by fluid pressure therein in the opposite direction, and a shuttle valve device at said outlets in the path of fluid flow through said passageways and outlets shiftable alternately across said openings to alternately close the same to alternately generate positive fluid pressure pulse waves in said shock passageways which act upon and move said impacting means in opposite directions to alternately force the same against and from a companion member.

8. In impacting apparatus as defined in claim 7; said impacting means being propelled between a position spaced from the companion member to a position striking against the companion member.

9. In impacting apparatus as defined in claim 7; and means providing a discharge passage into which fluid from said outlets can flow.

10. In impacting apparatus as defined in claim 7; wherein one of said passageways includes a shock tube surrounded by said other passageway.

11. Well bore drilling apparatus comprising a body adapted to be secured to a drill pipe string extending to the top of a well bore, an anvil operatively connected to said body and adapted to be secured to a drill bit, a hammer reciprocable along said body into and from impacting contact with said anvil, said body having a shock passageway open at its upper end to the entry of fluid pumped down the drill pipe string, said passageway having a lower outlet, said hammer being subject to fluid pressure in said passageway, and a shuttle valve device in the path of fluid flow through said passageway and shiftable by the fluid flowing in said passageway to a position closing said outlet to generate a positive fluid pressure pulse in said passageway acting on said hammer to propel said hammer in one direction relative to said anvil, and means for shifting said hammer in the opposite direction relative to said anvil.

12. Well drilling apparatus as defined in claim 11; wherein said positive pressure pulse propels said hammer toward said anvil.

13. Well drilling apparatus as defined in claim 11; wherein said positive pressure pulse propels said hammer away from said anvil.

14. Well drilling apparatus as defined in claim 11; said positive pressure pulse travelling through said shock passageway from said lower outlet to said upper end and then returning to said outlet as a negative pressure pulse enabling said shuttle valve device to shift to outlet opening position.

15. Well drilling apparatus as defined in claim 11; said anvil having a passage communicating with said outlet through which fluid can flow to the drill bit.

16. Well drilling apparatus as defined in claim 11; said hammer being reciprocable along the exterior of said body.

17. Well drilling apparatus comprising a body adapted to be secured to a drill pipe string extending to the top of a well bore, an anvil operatively connected to said body and adapted to be secured to a drill bit, a hammer reciprocable along said

body into and from impacting contact with said anvil, said body having first and second shock passageways intercommunicating at their upper ends and open to the entry of fluid pumped down the drill pipe string, said passageways having outlets at their lower ends, said hammer having a first pressure-actuatable surface subject to the pressure of fluid in said first passageway and movable thereby toward said anvil, said hammer having a second pressure-actuatable surface subject to the pressure of fluid in said second passageway and movable thereby away from said anvil, and a shuttle valve device at said outlets in the paths of fluid flow through said passageways and shiftable alternately across said outlets to alternately close the same to alternately generate positive fluid pressure pulses in said shock passageways to reciprocate said hammer along said body into and from impacting contact with said anvil.

18. Well bore drilling apparatus as defined in claim **17**; said anvil having a passage communicating with said outlets and through which fluid from said passageways can flow to the drill bit.

19. Well bore drilling apparatus as defined in claim **17**; said body being telescoped in said anvil, and means for transmitting rotary motion from said body to said anvil.

20. Well bore drilling apparatus as defined in claim **17**; said body being telescoped in said anvil, said body having a passage communicating with said outlets and through which fluid from said passageways can flow toward the drill bit.

21. Well bore drilling apparatus as defined in claim **17**; said body being telescoped in said anvil, said body having a passage communicating with said outlets and through which fluid from said passageways can flow toward the drill bit, said anvil having a passage for conducting fluid from said body passage to the drill bit.

22. Well bore drilling apparatus as defined in claim **17**; one of said passageways including a shock tube surrounded by said other passageway.

23. Well bore drilling apparatus as defined in claim **17**; bypass means for bypassing fluid from one of said passageways around said shuttle valve device, and valve means for opening and closing said bypass means.

24. Well bore drilling apparatus as defined in claim **17**; said body being telescoped in said anvil, said body having a passage communicating with said outlets and through which fluid from said passageways can flow toward the drill bit, bypass means for bypassing fluid from one of said passageways around said shuttle valve device, and valve means for opening and closing said bypass means.

25. Well bore drilling apparatus as defined in claim **17**; said body being telescoped in said anvil, said body having a passage communicating with said outlets and through which fluid from said passageways can flow toward the drill bit, bypass means for bypassing fluid from one of said passageways around said shuttle valve device to said body passage, and valve means secured to said anvil and closing said bypass means when said anvil is in an upper position on said body and opening said bypass means when said anvil is in a lower position on said body.

26. Well bore drilling apparatus as defined in claim **17**; said body being telescoped in said anvil, said body having a passage communicating with said outlets and through which fluid from said passageways can flow toward the drill bit, bypass means for bypassing fluid from one of said passageways around said shuttle valve device to said body passage, and valve means secured to said anvil and closing said bypass means when said anvil is in an upper position on said body and opening said bypass means when said anvil is in a lower position on said body, said hammer being reciprocable along the exterior of said body.

27. Impacting apparatus comprising a passageway including a shock passage through which fluid pumped through the passageway can flow, said shock passage having a fluid inlet and a fluid outlet, impacting means communicating with said shock passage and responsive to fluid pressure in said passage, and a shuttle valve device in the path of fluid flow through said shock passage and shiftable by the fluid flowing in said shock passage to a position closing said outlet to generate a positive fluid pressure pulse wave in said shock passage acting one said impacting means to force the same against a companion member, said shuttle valve device and said impacting means being free from contact with each other at all times.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. **3,568,783** Dated **March 9, 1971**

Inventor(s) **DAVID V. CHENOWETH ET AL**

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 10, line 36, "one" should read --on--.

Signed and sealed this 13th day of June 1972.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Pate