Sept. 21, 1971 | A. R. CURINGTON | 3,606,930

DOWN-HOLE DRILLING HAMMER

Filed Oct. 6, 1969 | 3 Sheets-Sheet 1

FIG. 1a.

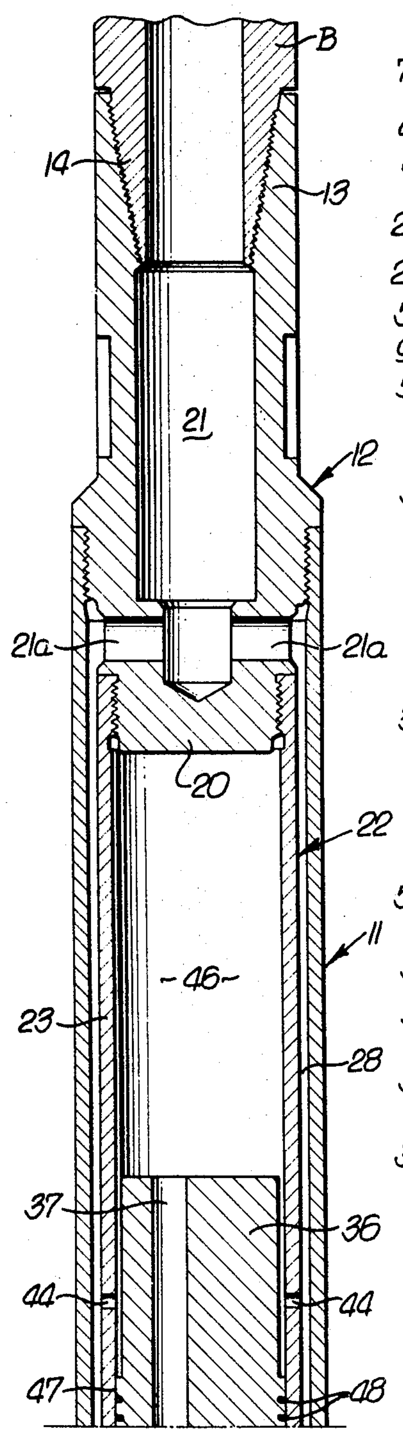

FIG. 1b.

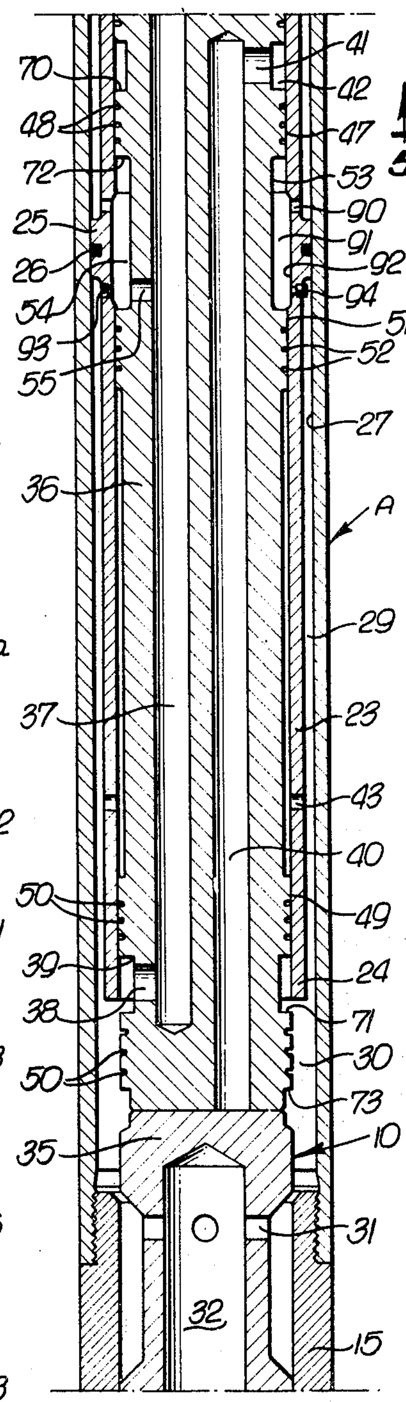

FIG. 1c.

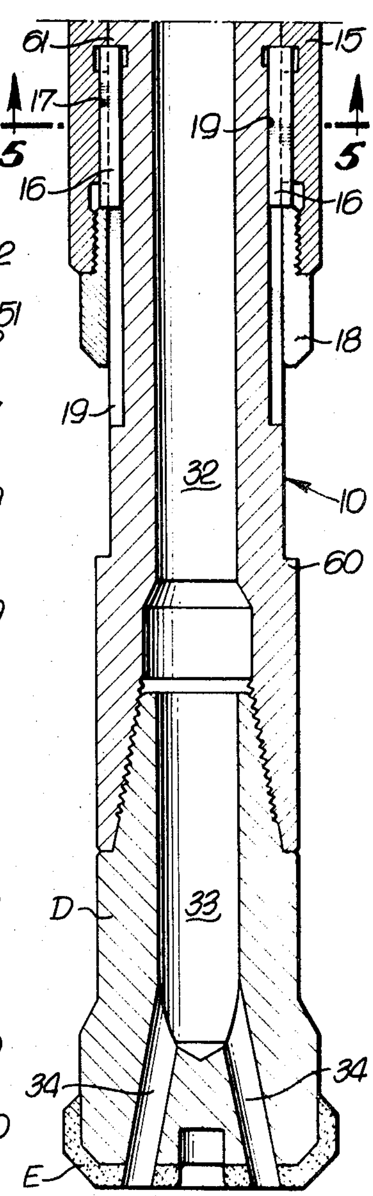

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FIG. 2a.

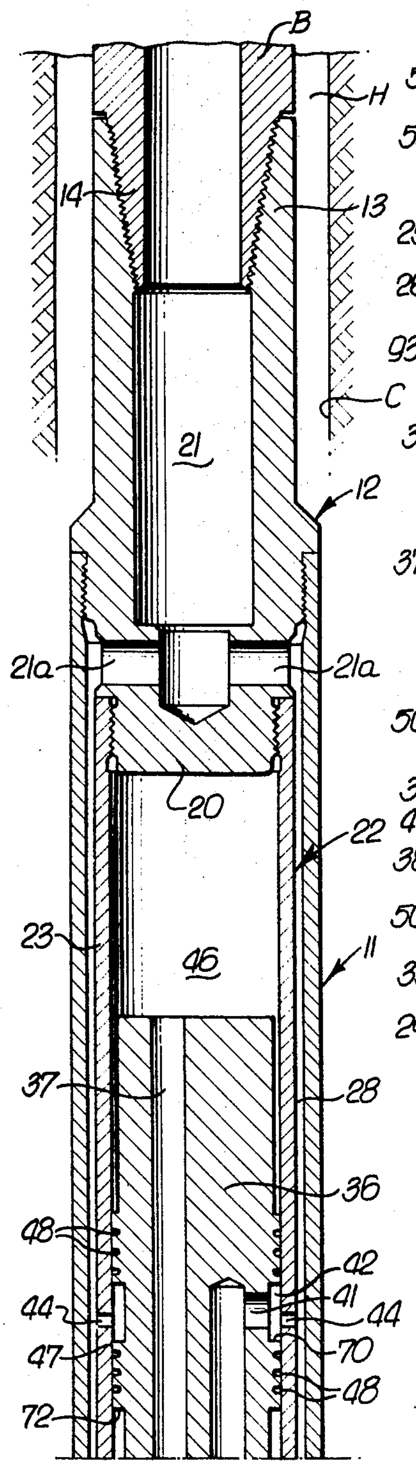

FIG. 2b.

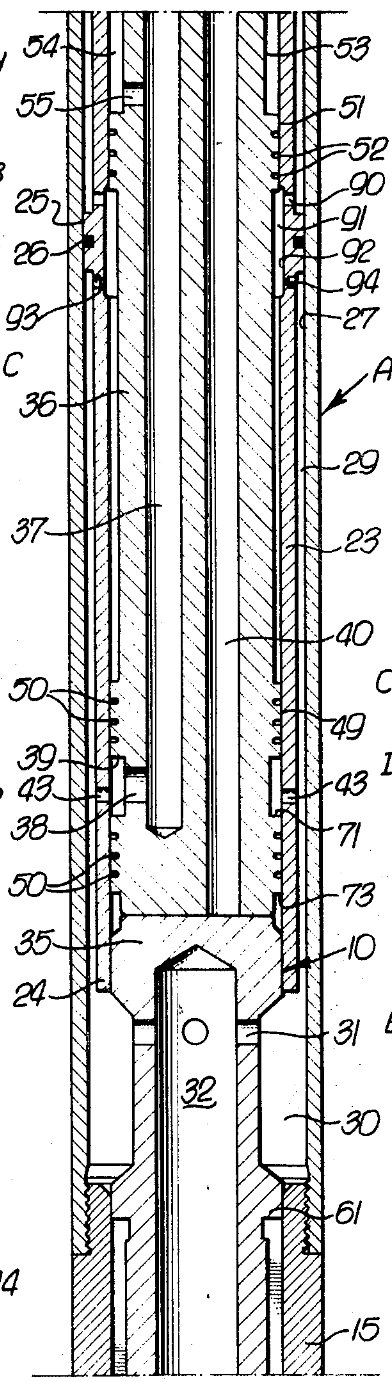

FIG. 2c.

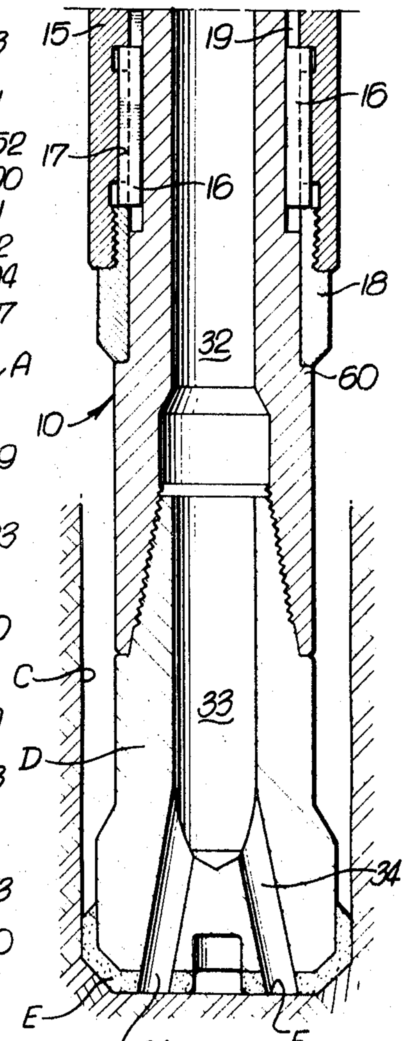

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FIG. 3a.

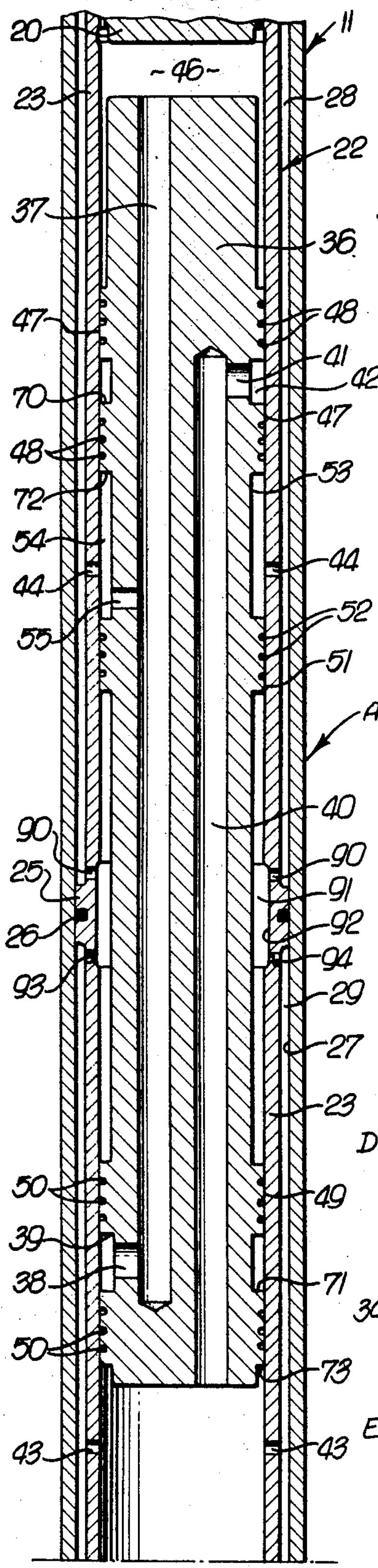


FIG. 3b.

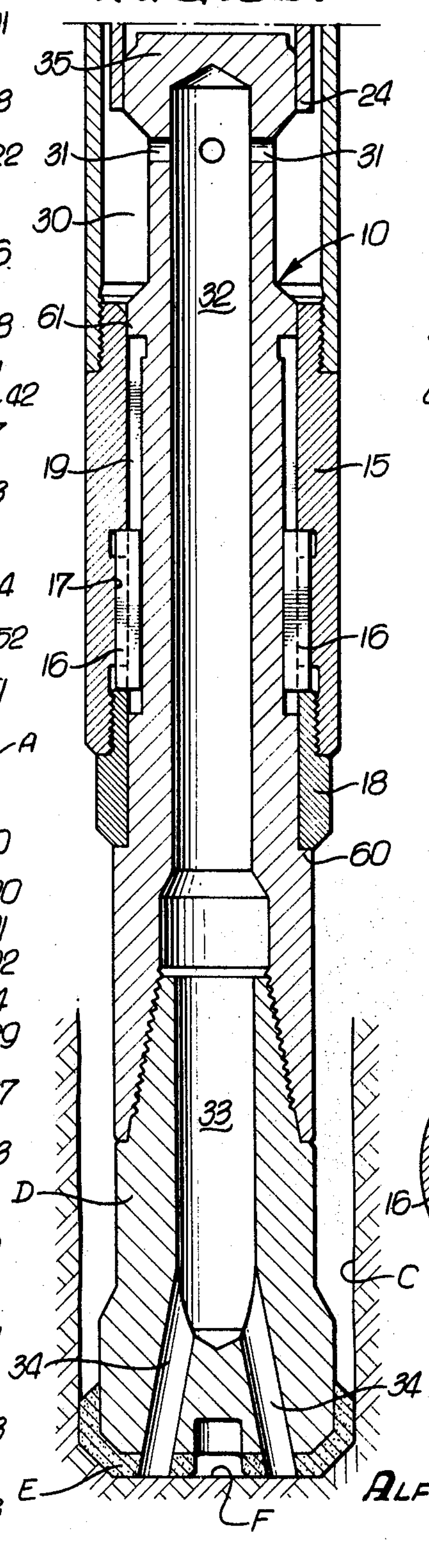


FIG. 4.

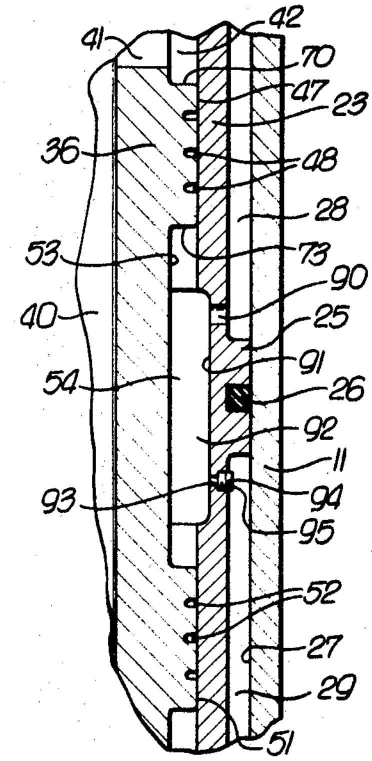
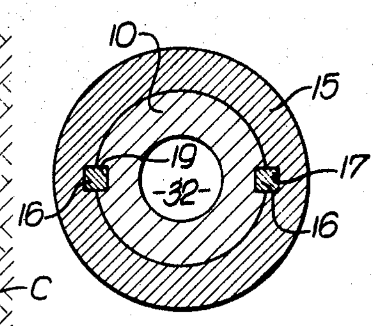


FIG. 5.



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3,606,930
DOWN-HOLE DRILLING HAMMER

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Int. Cl. E21b *1/06*
U.S. Cl. 173—73 22 Claims

ABSTRACT OF THE DISCLOSURE

A down-hole drilling hammer embodying an outer housing structure connectible to a string of rotatable drill pipe through which compressed air is pumped. A cylinder sleeve within the housing structure defines a high pressure air annulus and a low air pressure annulus therewith. A hammer piston reciprocates in the cylinder sleeve, the piston and cylinder sleeve having ports and passages to alternately communicate the high pressure and low pressure annuli with the cylinder sleeve first above and below the piston and then below and above the piston to reciprocate the piston and cause it to impact repeatedly upon an anvil connected to or integral with a bit rotatable by the drill string, the low pressure air exhausting through the bit to convey the cuttings upwardly around the drilling hammer and drill pipe to the drilling rig.

The present invention relates to drill bit apparatus for drilling a hole in a formation, and more particularly to pneumatically operated bottom-hole drilling apparatus that imparts a percussive action to a drill bit, during which time the bit is preferably rotated.

Percussive types of drilling apparatus are known for lowering in a well bore for the purpose of drilling the hole as a result of a hammering action imposed upon a suitable bit connected to the apparatus. Prior devices are rather complex, having an arrangement of parts that limits the mass of the hammer piston which effects repeated impact blows on a coacting anvil to which the drill bit is secured or with which it is integral. The relatively light impacting pistons have a very short stroke, operating at a very high frequency. Such high frequencies produce very small cuttings, which are almost powders in consistency. The light reciprocating hammer pistons apparently are incapable of striking the anvil hard enough to break the hard formation into relatively large pieces. The prior pneumatically operated drilling apparatus require close fitting pistons and cylinders, and this fact, coupled with the extensive manufacturing operations involved in their designs, results in comparatively high manufacturing costs.

By virtue of the present invention, a pneumatically operated drilling apparatus is provided of simpler design; comparatively inexpensive to manufacture. A hammer piston is provided of greater mass than in prior devices. It has a longer stroke, thereby reducing its frequency of operation. The resulting heavier piston hammer delivers higher impact forces, and despite its lower frequency of operation achieves faster formation penetration rates. It is known that a hard formation can withstand a very high impulse load if the impulse time is very short, but the same formation will fracture at a much lower impulse force if the impulse time is increased only slightly. Thus, by virtue of the present invention, the use of a piston of greater mass having an increased impulse time effects an increase in the penetration rate, producing much larger cuttings than resulted from the use of prior impact drilling apparatus.

With an apparatus embodying the present invention, the impact piston strikes an associated anvil during its power stroke, but it is prevented from striking any other portion of the tool during its return stroke. The parts are so arranged that the hammer piston is brought to rest against an air cushion, thereby preventing it from impacting upon an associated top sub, or the like. If the piston hammer were permitted to impact against such top sub, its frequency of operation would be increased, but such impacting would result in excessive tightening of threaded joints in the tool as the latter is rotated by an associated string of drill pipe during the reciprocation of the hammer piston toward and from its associated anvil.

The present invention involves a pneumatically operated down-hole percussion drill used with conventional rotary rigs equipped for air drilling medium-hard to hard formations in quarry, construction, mining and exploration operations, and in drilling bore holes generally. The drilling hammer is of comparatively simple design, is more rugged, and is capable of drilling at much higher rates.

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:

FIGS. 1*a*, 1*b* and 1*c* together constitute a longitudinal section through an apparatus embodying the invention with parts in their relative position for moving the apparatus longitudinally in a bore hole, FIGS. 1*b* and 1*c* being lower continuations of FIGS. 1*a* and 1*b* (respectively;

FIGS. 2*a*, 2*b* and 2*c* are views corresponding to FIGS. 1*a*, 1*b* and 1*c*, with the apparatus in condition for performing an impacting action against the bottom of the bore hole and with the hammer piston in its lower position, FIGS. 2*b* and 2*c* being lower continuations of FIGS. 2*a* and 2*b*, respectively;

FIGS. 3*a* and 3*b* are views corresponding to FIGS. 2*a*–2*c*, with the hammer piston in its upper position, FIG. 3*b* being a lower continuation of FIG. 3*a*;

FIG. 4 is an enlarged, fragmentary, longitudinal section through the fluid bypass portion of the apparatus; and

FIG. 5 is a cross-section taken along the line **5—5** on FIG. 1*c*.

The down-hole drilling hammer A illustrated in the drawings is connected to the lower end of a string of drill pipe B extending to a drilling rig (not shown) at the top of a bore hole C, and by means of which the apparatus and a drill bit D connected to its lower end are rotated while compressed air or any other suitable fluid medium is pumped down the drill pipe for operating the apparatus. The drill bit D is of any suitable type, and may have its end face tipped with tungsten carbide inserts E for impacting against the bottom F of the bore hole while the apparatus A and bit D are being rotated, so as to impart a drilling action against the full area of the bottom of the hole as a result of an impacting action imparted to an anvil **10** integral with the drill bit or threadedly connected thereto.

The drilling hammer apparatus A includes an outer elongate housing **11**, the upper end of which is threadedly connected to an upper sub **12** having an upper threaded box **13** for attachment to the lower pin **14** of an adjacent drill pipe section B. The lower end of the tubular housing is threadedly secured to a lower sub **15** surrounding the upper portion of the anvil **10**. This sub has drive keys **16** fitting in sub grooves **17** secured to the sub by a nut **18** threaded into the lower end of the lower sub, the keys fitting within elongate keyways **19** in the anvil **10**. Accordingly, turning effort or drilling torque can be transmitted from the drill pipe B through the upper sub **12** and housing **11** to the lower sub **15**, and from the lower sub to the anvil **10** which can move longitudinally within and relative to the lower sub and housing **11**, as described hereinbelow.

The upper sub **12** terminates in a head **20** closing the lower end of a central passage **21** through the upper sub, and which forms the upper head of a cylinder **22** that includes a cylinder sleeve **23**, the upper end of which is threadedly secured to the head **20**, and which extends downwardly in the housing, its lower end **24** terminating a predetermined distance above the upper end of the lower sub **15**. This cylinder sleeve has an intermediate external flange or head **25** fitting closely within the housing, this flange carrying a suitable side seal ring **26** sealingly engaging the inner wall **27** of the housing. The cylinder sleeve has a reduced diameter above and below the flange, providing an upper high pressure annular passage **28** between it and the housing, and also a lower low pressure annular passage **29** between the lower portion of the cylinder sleeve and the inner wall of the housing. This low pressure passage **29** opens into the space **30** below the sleeve **23**, communicating through inlet ports **31** in the anvil with a central passage **32** in the latter that communicates with a companion passage **33** in the drill bit. The air or other fluid in the passage **33** is capable of passing through the bit passages or nozzles **34**, jetting against the bottom of the hole, so as to clean the hole bottom F, as well as the bit itself, of cuttings, and to flush the cuttings upwardly around the bit D and drilling apparatus A and through the annular space H between the drill pipe and wall of the bore hole to the top of the latter.

The anvil **10** terminates in an upper imperforate impact head **35** fitting snugly, but slidably, within the lower end of the cylinder sleeve **23**. The impact head of the anvil is adapted to be struck by an elongate hammer piston **36** reciprocable within the cylinder sleeve **23**, this piston having a longitudinal impact passage **37** opening through its upper end and communicating through a lower exhaust port **38** with an external circumferential exhaust piston groove **39**. The piston also is provided with a hammer return longitudinal passage **40**, opening through its lower end and communicating at the upper portion of the piston with an inlet port **41** opening into an external peripheral piston groove **42**.

The cylinder sleeve **23** has one or more lower exhaust ports **43** extending between the low pressure annular passage **29** and the lower interior portion of the cylinder sleeve, and also with one or more inlet ports **44** in the upper portion of the cylinder sleeve establishing communication between the high pressure annular passage **28** and the upper portion of the interior of the cylinder sleeve. The longitudinal distance between the lower piston exhaust port **38** and the upper piston inlet port **41** is equal to the longitudinal distance between the inlet ports **44** and the exhaust ports **43**. The exhaust ports **43** are so related to the upper end of the anvil **10** when the anvil is fully telescoped upwardly within the housing **11** that the lower end of the hammer piston **36** is engaging the anvil when the inlet ports **44** are aligned with the upper piston groove **42** and the exhaust ports **43** are aligned with the exhaust groove **39** at the lower portion of the piston, as disclosed in FIGS. 2*a*, 2*b* and 2*c*. With the piston **36** in this lower position, high pressure air can flow from the high pressure annulus **28** through the cylinder ports **44**, groove **42** and piston inlet port **41** into the hammer return passage **40**, passing to the lower end of the piston and exerting an upward force on the piston to shift it upwardly toward the upper cylinder head **20**. At the same time, the air in the cylinder space **46** above the piston can pass

through the impact passage **37** and through the exhaust port **38**, exhaust groove **39** and cylinder exhaust ports **43** into the low pressure annular passage **29**, flowing downwardly therearound and through the anvil inlet ports **31** into its central passage **32** for discharge through the bit D.

The upper peripheral groove **42** is formed in an upper land **47** of the piston that makes a close sliding fit with the inner wall of the cylinder sleeve **23**. On opposite sides of the groove **42**, the land is provided with a plurality of circumferential labyrinth seal grooves **48** to inhibit leakage of fluid between the periphery of the land and the inner wall of the cylinder sleeve. Similarly, the lower exhaust groove **39** is provided in a lower land **49** that makes a close sliding fit with the inner wall of the cylinder sleeve **23**, this land also having labyrinth seal grooves **50** on opposite sides of the exhaust groove **39** for minimizing leakage of fluid between the lower land and the inner wall of the cylinder sleeve. The piston has an intermediate land **51** slidably and sealingly engaging the inner wall of the cylinder and also provided with labyrinth seal grooves **52** in its periphery to prevent leakage of fluid between the land **51** and the cylinder wall. The piston also has a reduced diameter portion **53** between the upper and intermediate lands **47**, **51**, to define with the cylinder wall an elongate high pressure circumferential groove **54** communicating with a side port **55** in the piston that extends from the lower portion of the groove **54** to the impact passage **37**. When the piston **36** is in an elevated position, as disclosed in FIG. 3*a*, the high pressure groove **54** is in communication with the inlet ports **44** through the cylinder sleeve, so that high pressure air can flow through the sleeve ports **44** and high pressure groove **54** through the inlet port **55** into the impact passage **37** and into the cylinder space **46** above the piston for the purpose of driving the hammer piston **36** downwardly to strike an impact blow upon the lower anvil **10**, as described hereinbelow.

The drilling hammer A is rendered inoperable unless the bit D is resting upon the bottom F of the hole C, with a required amount of drilling weight imposed upon it by the drill pipe B, acting through the upper sub **12**, housing **11**, lower sub **15** and nut **18**, which then engages an upwardly facing shoulder **60** on the anvil **10**. When the drill pipe B is elevated to raise the bit from the bottom of the hole, the anvil **10** and bit D drop downwardly, as permitted by the telescoping of the anvil within the lower sub **15**, until an external anvil flange **61** engages the drive keys **16**, as disclosed in FIGS. 1*a*, 1*b* and 1*c*. Such lower position of the anvil **10** permits the piston **36** to drop downwardly within the cylinder sleeve **23** and expose the piston exhaust port **38** below the lower end of the cylinder sleeve, so that compressed air being pumped through the apparatus merely passes through the inlet ports **44** and the impact passage **37** for flow through the exhaust port **38** into the housing space **30** below the sleeve **23**, the air flowing through the anvil ports **31** into its central passage **32** and then through the bit passage **33** and its nozzles **34** into the open hole. When in this position, the inlet port **41** in the upper part of the piston, communicating with the hammer return passage **40**, is out of communication with the high pressure inlet ports **44**, so that there is no tendency to elevate the piston within the cylinder sleeve **23**. With the parts in this position, compressed air can be pumped through the apparatus to clean bit D of cuttings and impart a circulating action upwardly through the annulus H around the drill pipe B to the top of the well bore. It is only when drilling weight is imparted to the drill bit D, with the housing **11** and cylinder sleeve **23** telescoped downwardly over the anvil **10** to hold the drill bit against the bottom of the bore hole, that the apparatus becomes operative.

The lower side **70** of the upper peripheral groove **42** will shut off fluid flow through the ports **44** and into the hammer return passage **40** at the same time that the lower side **71** of the lower peripheral exhaust groove **39** shuts off the lower exhaust ports **43**. When this occurs, high pressure air can no longer flow through the hammer return passage **40** to the lower end of the cylinder sleeve to elevate the piston **36**, nor can any further air in the cylinder above the piston flow through the impact passage **37** and exhaust ports **38, 43**. In addition, the lower end **72** of the upper land **47** at the upper end of the elongate high pressure piston groove **54** will open the inlet ports **44** at the same time that the lower end **73** of the lower land **49** opens the exhaust ports **43** as a result of elevation of the piston in the cylinder sleeve. Thus, there will be communication of high pressure air with the high pressure groove **54** communicating with the impact passage **37** simultaneously with communication of the air under pressure below the piston **36** with the cylinder sleeve exhaust ports **43**.

From the foregoing description, it will be noted that the upper inlet ports **44** and the lower exhaust ports **43** are simultaneously shut off from communication with the hammer return passage **40** and the impact passage **37**, and that they are brought into simultaneous communication with the impact passage **37** and the hammer return passage **40** during upward travel of the piston **36** in the cylinder **22**. The piston can continue travelling upwardly in the cylinder sleeve **23**, but in view of the elongate high pressure passage **54** surrounding the piston, and the disposition of the lower end of the piston above the exhaust ports **43**, the introduction of high pressure air into the cylinder space **46** above the piston and the exhaust of air from below the piston to the low pressure annular passage **29** continues.

In the operation of the drilling hammer, a suitable drill bit D is secured to its lower end and the drill pipe B to its upper end, whereupon it is lowered in the bore hole C. During such lowering action, the anvil is in its extended position, as shown in FIGS. 1*a*, 1*b*, 1*c*, so that, if desired, compressed air can be pumped down the drill pipe B and through the apparatus A for discharge through the lower end of the drill bit D. When the drill bit contacts the bottom F of the hole, it comes to rest and the apparatus A is shifted downwardly along the anvil **10** until the nut **18** engages the anvil shoulder **60**, permitting a suitable amount of drilling weight to be imposed upon the apparatus and the bit to retain the latter in contact with the hole bottom. The drill pipe B is then rotated to rotate the bit D and compressed air at an appropriate pressure pumped down the drill pipe and into the apparatus A. At the beginning of the impacting operation of the apparatus, the hammer piston **36** will be disposed in its lower position, as illustrated in FIGS. 2*a*, 2*b*, 2*c*, resting upon the upper end **35** of the anvil **10** which is then disposed in sealing relation within the lower end of the cylinder sleeve **23**. With the piston in this position the impact passage **37** communicates with the exhaust ports **43**; whereas, the hammer return or elevating passage **40** communicates with the high pressure ports **44**. Air under pressure then flows from the sub passage **21** through its side ports **21*a*** into the high pressure annulus **28** and the piston return passage **40** to the lower end of the piston, acting upon the full cross-sectional area of the piston to shift it upwardly within the cylinder sleeve **23**. As the piston is moved upwardly by the compressed air, the upper land **47** and its shoulder **70** shut off flow of the fluid through the inlet ports **44** to the return passage **40** simultaneously with the shutting off of flow of fluid by the lower land **49** and its shoulder **71** from the cylinder space **46** above the piston **36** through the impact passage **37** and through the exhaust ports **43**. At this time, the high pressure air or other gas below the piston **36** has imparted a certain amount of kinetic energy to the piston, the high pressure air below the piston expanding to continue the upward movement of the piston within the cylinder sleeve **23** and compressing the low pressure air in the cylinder space **46** above the piston. The piston will continue to rise

in the cylinder as a result of expansion of the high pressure air therebelow until the lower end **73** of the lower piston land **49** opens the exhaust ports **43**, the inlet ports **44** being opened at the same instant, by movement of the shoulder **72** above the ports **44**, to communication with the high pressure piston groove **54** that communicates with the impact passage **37**. During expansion of the high pressure gas below the piston, additional kinetic energy is imparted to the piston, the high pressure air below the piston then exhausting from below the piston through the exhaust ports **43** into the low pressure annulus passage **29**, from which it can flow through the anvil ports **31** and through the central anvil passage **32** and through the drill bit to flush the cuttings from the bottom of the hole and upwardly around the bit and the annulus surrounding the drill pipe to the top of the bore hole. The piston **36** continues moving upwardly in the cylinder until its kinetic energy is overcome by the high pressure air flowing through the impact passage **37** and into the cylinder space **46** above the piston. The air trapped above the piston will have been compressed by the upward travel of the piston in the cylinder **22**, but on the return or down stroke of the piston under the influence of high pressure air in the upper portion **46** of the cylinder, the energy in the trapped air will be released and assist in propelling the piston downwardly within the cylinder. Such downward or power stroke of the piston will commence when the compressed air in the cylinder above the piston equals the kinetic energy of the ascending piston, reducing the kinetic energy and the velocity of the piston to zero at the top of the stroke. At this time, the piston will still be a short distance away from the upper cylinder head **20** and will be prevented from impacting thereagainst.

The high pressure air being fed into the cylinder space **46** above the piston **36** then drives the piston downwardly on its power stroke, such high pressure air being fed into the upper portion of the cylinder until the lower end **72** of the upper land **47** closes the inlet ports **44**, which action will occur simultaneously with closing of the exhaust ports **43** by the lower end **73** of the lower land. However, the air pressure in the cylinder below the piston **36** is then at the low value of that existing in the low pressure annular passage **29**, so that the piston can continue moving downwardly at high velocity to impact against the upper end **35** of the anvil **10**.

When the piston hammer **36** strikes the anvil, the exhaust ports **43** again communicate with the impact passage **37** (FIGS. 2*a*, 2*b*, 2*c*), allowing the compressed air in the cylinder space above the piston to exhaust into the low pressure annular passage **29** and then through the ports **31**, anvil passage **32** and drill bit passage **33, 34** into the bore hole C. At the same time, the inlet ports **44** in the sleeve **23** are again communicating with the piston return passage **40** so that high pressure air is again conducted through such passage into the cylinder sleeve **23** below the piston to again elevate the piston **36**, resulting in repetition of the cycle of operation of the equipment.

By virtue of the drilling hammer illustrated and described, the mass of the piston **36** can be made large since it fills the entire cross-sectional area of the inner wall of the cylinder sleeve **23**. There is only a slight reduction in mass due to the relatively small passages **37, 40** and ports **38, 41, 55** provided in the piston. In view of its greater mass, the piston will have a greater kinetic energy when it impacts against the anvil **10**, and will, therefore, strike a greater blow against the bit D and the bottom F of the bore hole C. Because of its greater mass, the frequency of reciprocation of the piston **36** in the cylinder sleeve **23** will be lower than is associated with a lighter hammer piston. Such lower operational frequency is of advantage since rock fractures at a much lower impulse force if the impulse time is increased only slightly. The frequency of operation is further reduced by preventing the piston from impacting against the upper cylinder head **20** because of the cushioning action of the entrapped air above the piston on its return stroke, the energy imparted to such trapped air being recovered during the downstroke of the piston.

The piston **36** is of relatively simple design, the only close fitting parts being between the piston and the cylinder wall. No valves or other parts are used, as in prior devices. The piston and cylinder can be manufactured through use of turning and drilling equipment, the cost of manufacture being relatively low.

If the quantity of air required for reciprocating the anvil piston is deemed insufficient for also exhausting through the apparatus for the purpose of removing the cuttings and maintaining the drill in a relatively cool and clean condition, some of the compressed air pumped down through the drill pipe B can be caused to by-pass the piston **36**, so that the chips produced by the bit D can be blown from the bottom of the hole and then upwardly towards the drilling rig. As specifically disclosed in the drawings (see FIG. 4), by-pass ports **90** are provided in the cylinder sleeve **23** immediately above its intermediate head or flange **25**, which communicate with an elongate, enlarged internal diameter portion **91** in the cylinder sleeve defining an elongate circumferential groove **92** with the exterior of the piston which extends from a position above the flange **25** to a position below the flange, where the groove communicates with a plurality of choke orifices **93** of an appropriate size or sizes in the sleeve **23** communicating with the low pressure passage **29**, which will control the amount of compressed air by-passing around the flange **25** and into the low pressure annular passage, from where the compressed air will flow through the anvil ports **31** and then through the passages **32**, **33**, **34** through the anvil **10** and bit *d* to the bottom of the bore hole. Any or all of the orifices that are not needed can be rendered ineffective by threaded set screws or plugs **94** into the threaded holes **95** in the sleeve **23** extending outwardly from the orifices.

I claim:

1. In percussion drilling apparatus: an outer housing connectible to a drill string; an anvil reciprocable in the lower portion of said housing and connectible to a drill bit; a cylinder in said housing; a hammer piston reciprocable in said cylinder for intermittently impacting against said anvil; means for directing a fluid medium under pressure into said cylinder alternately at one end of said piston and then at the opposite end of said piston to reciprocate said piston in said cylinder, comprising passage means between said cylinder and housing; and means for alternately exhausting the fluid medium in said cylinder at opposite ends of said piston, including passage means in said anvil through which the fluid medium from said cylinder at one or more ends of said piston is adapted to exhaust into a fluid passage in the drill bit.

2. In apparatus as defined in claim **1**; said piston shifting in said cylinder to alternately control flow of the fluid medium to said cylinder at one end of said piston and then at the opposite end of said piston.

3. In apparatus as defined in claim **1**; said piston shifting in said cylinder to alternately control flow of the fluid medium to said cylinder at one end of said piston and then at the opposite end of said piston; said piston shifting in said cylinder to alternately control exhaust of the fluid medium in said cylinder first from one end of said piston and then from the opposite end of said piston.

4. In apparatus as defined in claim **1**; said means for directing a fluid medium further including a passage in said piston communicable with said passage means.

5. In apparatus as defined in claim **1**; said means for directing a fluid medium further including a first passage in said piston communicable with said passage means to direct the fluid medium into said cylinder at one end of said piston and a second passage in said piston communicable with said passage means to direct the fluid medium into said cylinder at the opposite end of said piston.

6. In apparatus as defined in claim **1**; said means for directing a fluid medium further including a first passage in said piston communicable with said passage means to direct the fluid medium into said cylinder at one end of said piston and a second passage in said piston communicable with said passage means to direct the fluid medium into said cylinder at the opposite end of said piston; said exhausting means being communicable with at least one of said passages.

7. In percussion drilling apparatus: an outer housing structure connectible to a drill string; a cylinder sleeve in said housing structure and spaced therefrom to form therewith an upper high fluid pressure passage and a lower fluid pressure passage separate from said upper passage; an upper cylinder head closing the upper portion of said cylinder sleeve; means for conducting high pressure fluid to said upper passage; an anvil extending into the lower portion of said cylinder sleeve to close the same; a hammer piston reciprocable in said cylinder sleeve for intermittently impacting against said anvil; said cylinder sleeve having an inlet port through which fluid may flow from said upper passage into said cylinder sleeve; said cylinder sleeve having an exhaust port through which fluid may flow from said cylinder sleeve to said lower passage; said piston having a longitudinal impact passage communicating with said cylinder sleeve above said piston and communicable with said inlet port and exhaust port; said piston having a longitudinal piston return passage communicating with said cylinder sleeve below said piston and communicable with said inlet port; said piston being reciprocable in said cylinder sleeve between a first position communicating said piston return passage with said inlet port while said impact passage communicates with said exhaust port, at which first position said piston shuts off communication between said piston return passage and exhaust port and between said impact passage and inlet port, and a second position communicating said impact passage with said inlet port while said cylinder sleeve below said piston communicates with said exhaust port, at which second position said piston shuts off communication between said piston return passage and inlet port and between said impact passage and exhaust port.

8. In apparatus as defined in claim **7**; said impact passage opening through the upper end of said piston and including an exhaust port in the lower portion of said piston communicable with said sleeve exhaust port and an inlet port in the upper portion of said piston communicating with said sleeve inlet port; said piston return passage opening through the lower end of said piston and including an upper inlet port communicating with said sleeve inlet port.

9. In apparatus as defined in claim **7**; said impact passage opening through the upper end of said piston and including an exhaust port in the lower portion of said piston communicable with said sleeve exhaust port and an inlet port in the upper portion of said piston communicating with said sleeve inlet port; said piston return passage opening through the lower end of said piston and including an upper inlet port communicating with said sleeve inlet port; said return passage inlet port being located substantially above said impact passage inlet port.

10. In apparatus as defined in claim **7**; said impact passage opening through the upper end of said piston and including an exhaust port in the lower portion of said piston communicable with said sleeve exhaust port and an inlet port in the upper portion of said piston communicating with an elongate external piston groove communicable with said sleeve inlet port; said piston return passage opening through the lower end of said piston and including an upper inlet port communicating with said sleeve inlet port; said return passage inlet port being located above said elongate external piston groove.

11. In apparatus as defined in claim **7**; said piston being so constructed and arranged that it moves upwardly in said cylinder sleeve to simultaneously shut off communication between said impact passage and exhaust port and between said return passage and inlet port.

12. In apparatus as defined in claim 7; said piston being so constructed and arranged that it moves downwardly in said cylinder sleeve to simultaneously shut off communication between said impact passage and inlet port and between said exhaust port and cylinder sleeve below said piston.

13. In apparatus as defined in claim 7; said piston being so constructed and arranged that it moves upwardly in said cylinder sleeve to simultaneously shut off communication between said impact passage and exhaust port and between said return passage and inlet port; said piston being so constructed and arranged that it moves downwardly in said cylinder sleeve to simultaneously shut off communication between said impact passage and inlet port and between said exhaust port and cylinder sleeve below said piston.

14. In apparatus as defined in claim 7; and means providing a fluid by-pass passage between said high and low pressure passages.

15. In apparatus as defined in claim 7; said impact passage opening through the upper end of said piston and including an exhaust port in the lower portion of said piston communicable with said sleeve exhaust port and an inlet port in the upper portion of said piston communicating with an elongate external piston groove communicable with said sleeve inlet port; said piston return passage opening through the lower end of said piston and including an upper inlet port communicating with said sleeve inlet port; said return passage inlet port being located above said elongate external piston groove; said piston being so constructed and arranged that it moves upwardly in said cylinder sleeve to simultaneously shut off communication between said impact passage and exhaust port and between said return passage and inlet port.

16. In apparatus as defined in claim 7; said impact passage opening through the upper end of said piston and including an exhaust port in the lower portion of said piston communicable with said sleeve exhaust port and an inlet port in the upper portion of said piston communicating with an elongate external piston groove communicable with said sleeve inlet port; said piston return passage opening through the lower end of said piston and including an upper inlet port communicating with said sleeve inlet port; said return passage inlet port being located above said elongate external piston groove; said piston being so constructed and arranged that it moves downwardly in said cylinder sleeve to simultaneously shut off communication between said impact passage and external piston groove and between said exhaust port and cylinder sleeve below said piston.

17. In apparatus as defined in claim 7; said impact passage opening through the upper end of said piston and including an exhaust port in the lower portion of said piston communicable with said sleeve exhaust port and an inlet port in the upper portion of said piston communicating with an elongate external piston groove communicable with said sleeve inlet port; said piston return passage opening through the lower end of said piston and including an upper inlet port communicating with said sleeve inlet port; said return passage inlet port being located above said elongate external piston groove; said piston being so constructed and arranged that it moves upwardly in said cylinder sleeve to simultaneously shut off communication between said impact passage and exhaust port and between said return passage and inlet port;

said piston being so constructed and arranged that it moves downwardly in said cylinder sleeve to simultaneously shut off communication between said impact passage and external piston groove and between said exhaust port and cylinder sleeve below said piston.

18. In apparatus as defined in claim 7; said anvil being movable from the lower portion of said cylinder sleeve to permit said piston to drop to a position in said cylinder sleeve in which the lower end of said piston is out of said cylinder sleeve and the lower portion of said impact passage is below said cylinder sleeve.

19. In percussion drilling apparatus: a housing structure having an upper connector member for securing said structure to a tubular drill string through which a fluid medium under pressure can be conducted; cylinder sleeve means having upper and lower sleeve portions in said housing structure spaced therefrom to form therewith an upper high fluid pressure passage communicable with the tubular string and a lower fluid pressure passage separate from said upper passage; an anvil extending into said lower sleeve portion and having an exhaust fluid passage communicable with said lower fluid pressure passage; a hammer piston reciprocable in said upper and lower sleeve portions for intermittently impacting against said anvil; said piston having an impact passage communicating with said upper sleeve portion above said piston and with said upper high fluid pressure passage; said piston having a return passage communicating with said lower sleeve portion below said piston and with said upper high fluid pressure passage; said piston being reciprocable in said sleeve portions to alternately control flow of fluid from said high pressure passage into said impact passage and return passage; and passage means communicating with said lower fluid pressure passage and controlled by said piston for exhausting the fluid medium from at least one of said sleeve portions to said lower fluid pressure passage.

20. In apparatus as defined in claim 19; said passage means establishing communication between said lower sleeve portion below said piston and said lower fluid pressure passage upon upward movement of said piston in said upper and lower sleeve portions.

21. In apparatus as defined in claim 19; said passage means establishing communication between said upper sleeve portion above said piston and said lower fluid pressure passage upon downward movement of said piston in said upper and lower sleeve portions.

22. In apparatus as defined in claim 19; said passage means establishing communication alternately between said upper and lower sleeve portions and said lower fluid pressure passage upon reciprocation of said piston in said upper and lower sleeve portions.

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