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Curington

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[54] BORE HOLE AIR HAMMER

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[73] Assignee: **Baker Oil Tools, Inc.,** Los Angeles, Calif.

[22] Filed: **May 5, 1971**

[21] Appl. No.: **140,515**

[52] **U.S. Cl.** **173/78,** 173/80, 173/133, 173/136

[51] **Int. Cl.** **E21b 1/06**

[58] **Field of Search**.....175/92, 305, 321, 175/214; 173/136, 138, 133, 80, 78

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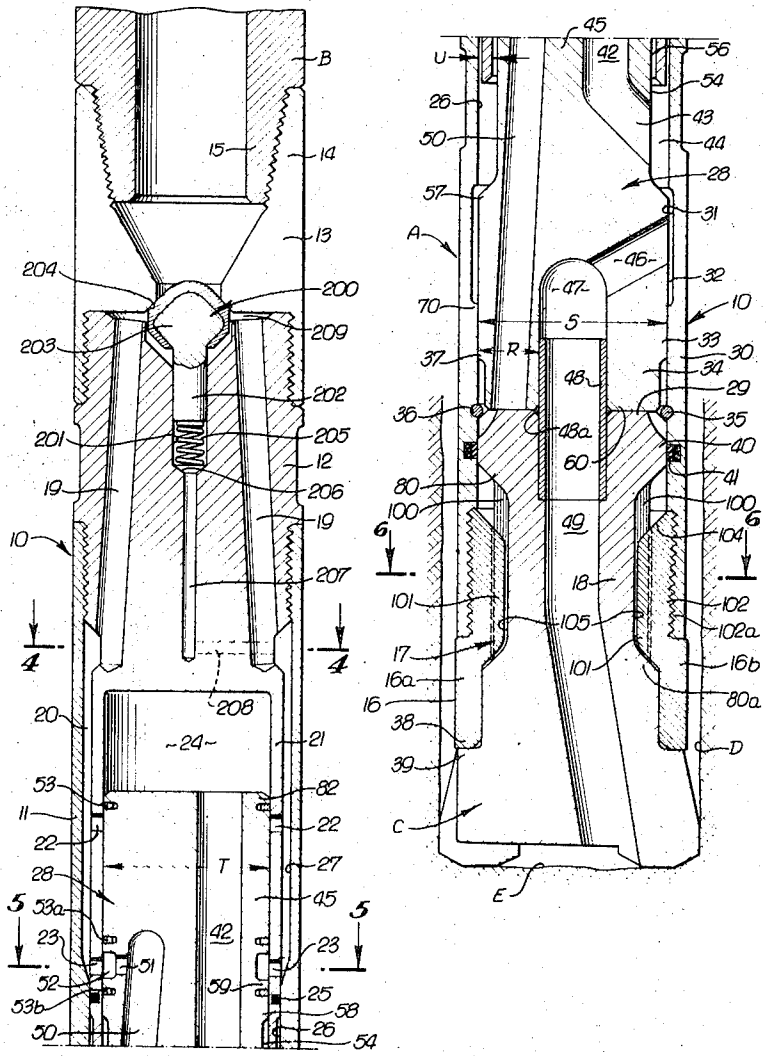
Attorney—Bernard Kriegel and Kendrick, Subkow & Kriegel

[57] **ABSTRACT**

An air hammer embodying an outer housing structure connectible to a rotatable drill pipe string through which compressed air is conducted. An upper cylinder sleeve in the housing structure defines an annular air inlet passage therewith, a hammer piston reciprocating in the housing structure with an upper smaller diameter portion slidable in this sleeve and a larger diameter portion in the housing structure below this sleeve, such that high pressure acts over the full cross-sectional area of the larger diameter piston portion in driving the piston downwardly against a companion anvil affixed to a drill bit rotatable by the drill pipe string and housing structure, compressed air acting over a smaller diameter piston area and returning the piston upwardly in the housing structure, all of the air being caused to exhaust through the anvil and bit to clean the bit and the bottom of the bore hole of cuttings.

18 Claims, 9 Drawing Figures



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SHEET 1 OF 3

FIG. 1a.

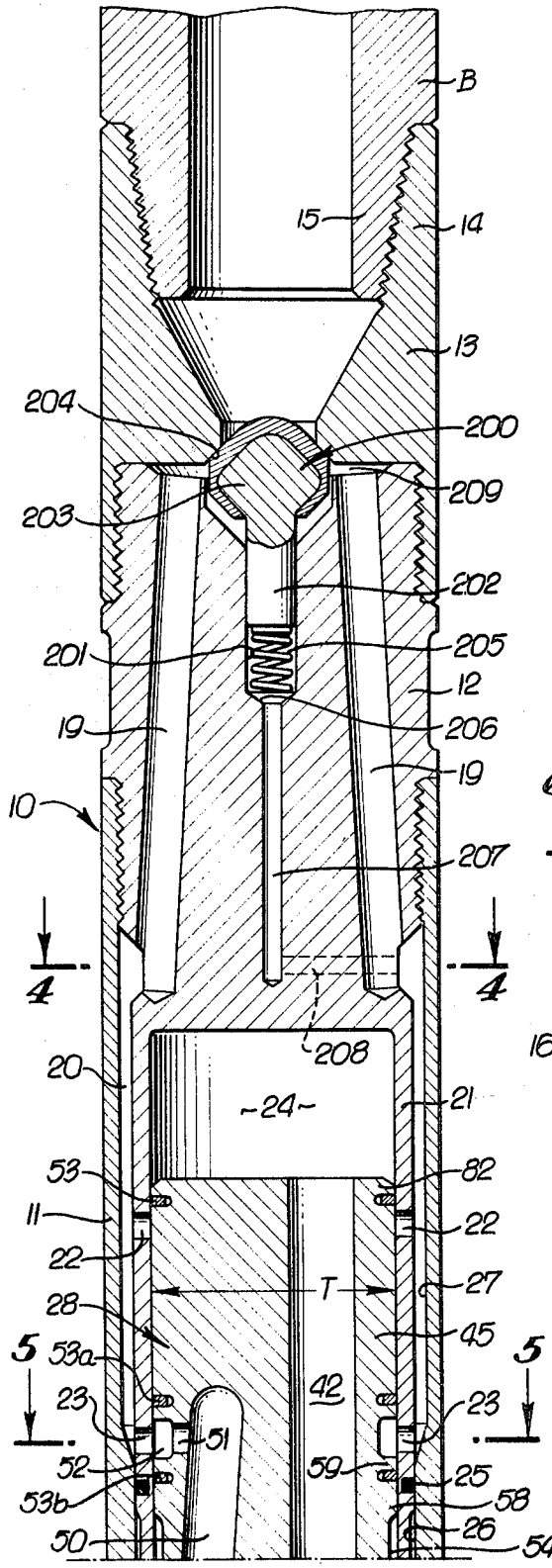

FIG. 1b.

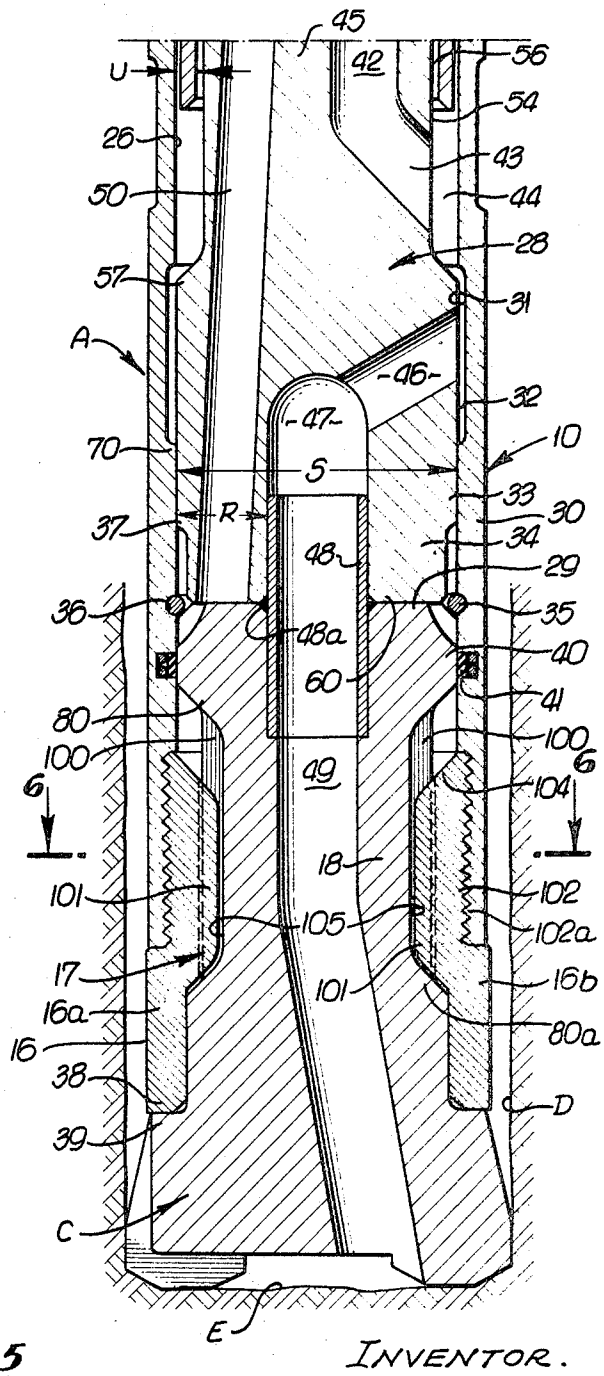

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FIG. 2a.

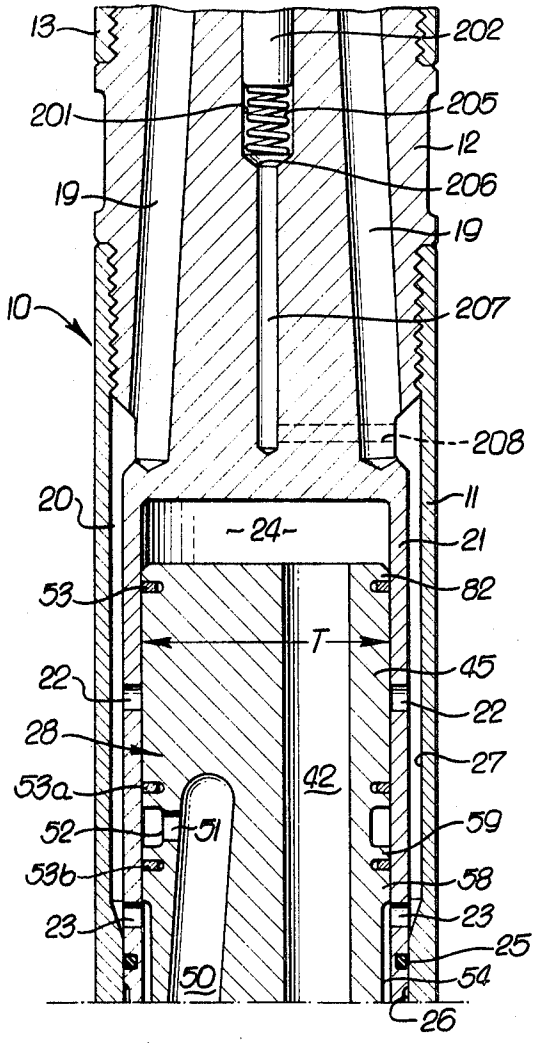

FIG. 2b.

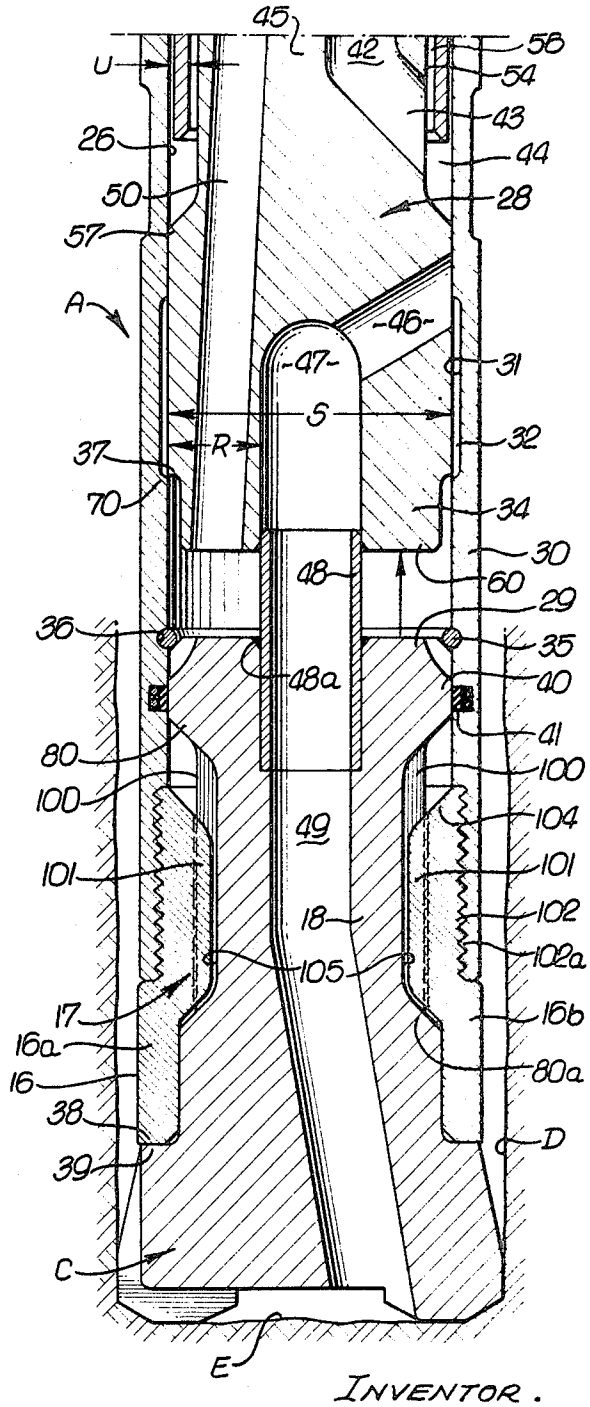

FIG. 4.

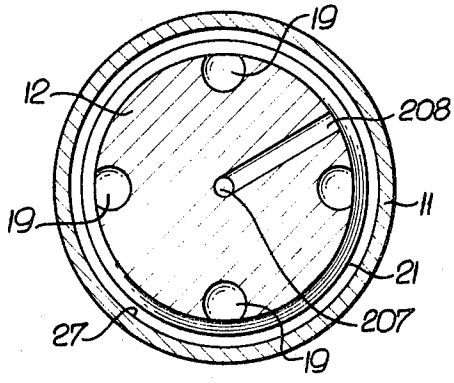

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FIG. 3a.

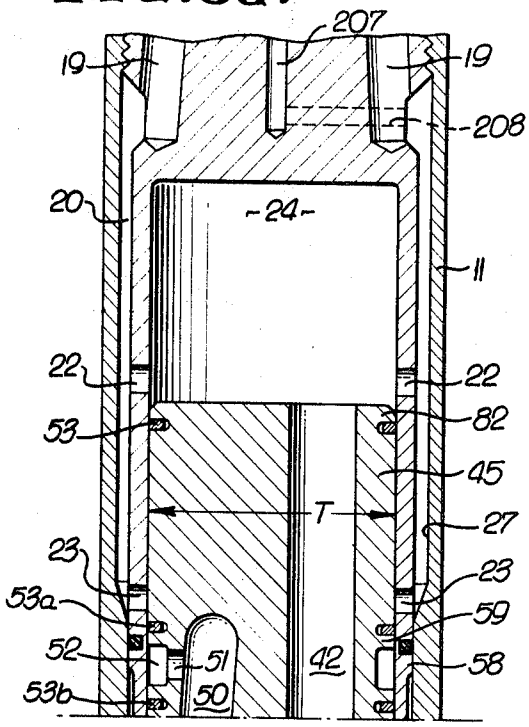


FIG. 3b.

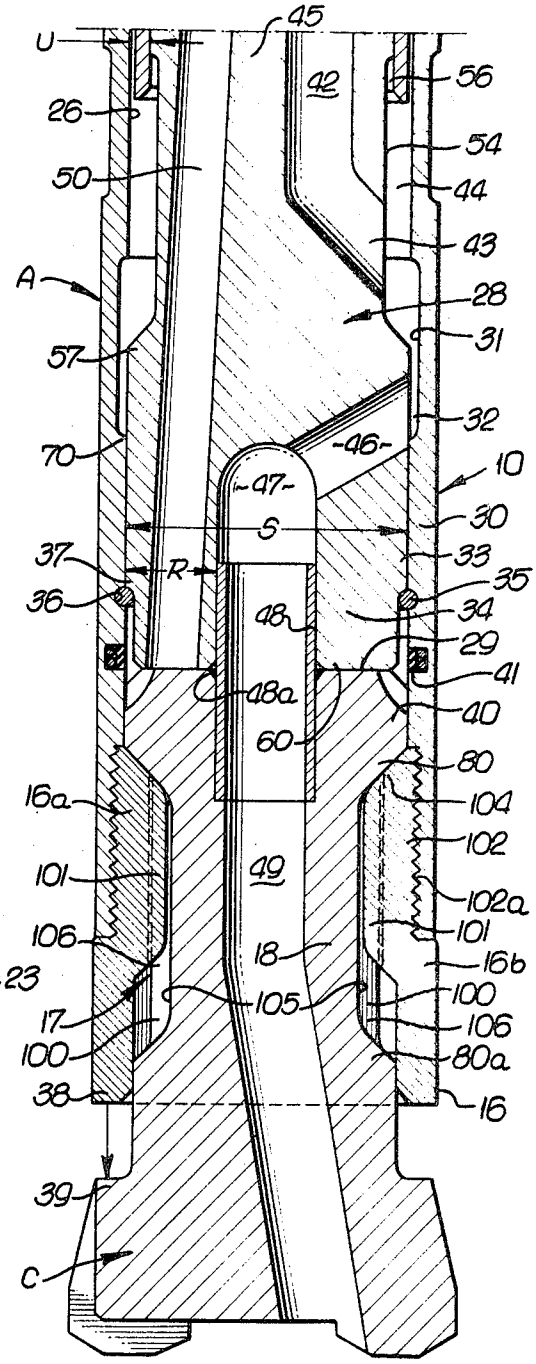


FIG. 5.

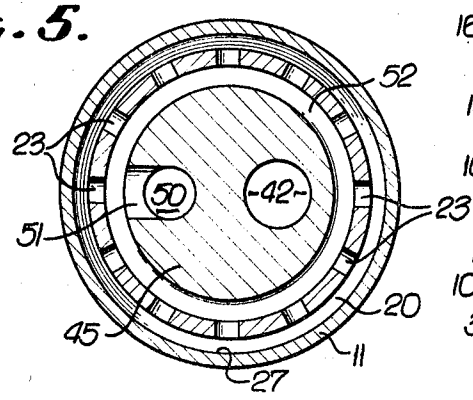
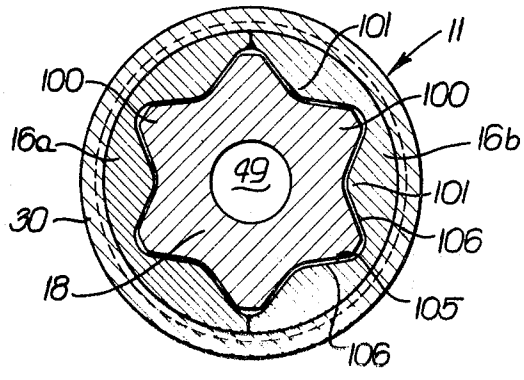


FIG. 6.



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BORE HOLE AIR HAMMER

The present invention relates to drill pipe apparatus for drilling a bore hole in a formation, and more particularly to pneumatically operated apparatus that imparts a percussive action to a drill bit while the latter is preferably rotated.

Prior air hammers are of the type having a relatively thick housing to feed compressed air through external side ports into the housing for reciprocating a hammer piston therein, which, because of the restricted internal diameter of the housing, is relatively small in diameter. Another type of prior air hammer has air inlet porting through the center of the piston, again reducing the effective area of the piston. In both cases, the reduced effective area of the piston results in a reduction of the impact blow deliverable by the piston to a companion anvil for the same inlet air pressure.

In my United States patent application for "Down-Hole Air Hammer," Ser. No. 100,848, filed Dec. 23, 1970, a relatively large diameter hammer piston is provided on which compressed air will act, despite the feeding of the compressed air through side ports into the housing, but only a portion of the air used in reciprocating the piston is exhausted through the drill bit connected to the anvil against which the piston impacts. As a result, assurance is not had that the cuttings are cleaned completely from the bottom of the hole and from the bit.

By virtue of the present invention, a larger outside diameter piston can be used for the same outside diameter of confining housing structure, the compressed air acting over the entire cross-sectional area of the piston on its power stroke, thereby enabling the piston to deliver a maximum impact blow against the anvil secured to the drill bit. The larger piston area allows a heavier piston to be used, which is accelerated over a shorter stroke to achieve a desired impact velocity in less time and with lower air consumption, the kinetic energy for each piston blow being greater. The shorter stroke causes the piston to reciprocate at a substantially greater frequency and results in a much greater horsepower being delivered. In addition, all of the compressed air for reciprocating the piston is exhausted through the bit secured to the anvil against which the piston impacts, to insure effective removal of the cuttings from the bottom of the hole and their conveyance around the apparatus and the drill pipe string connected thereto to the top of the bore hole, the exhaust air also maintaining the bit in a clean and cool condition.

Moreover, the invention has for its objective the provision of an integral anvil and bit combination splined to the housing structure of the air hammer, in which the spline connection is more economical to manufacture and is relatively simple in construction, facilitating assembly of the bit and anvil with respect to the housing structure.

This invention possesses many other advantages, and has other objects 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 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* and 1*b* together constitute a longitudinal section through an apparatus embodying the invention, with parts in their relative positions in which the hammer piston has completed delivering an impact blow against its companion anvil and the drill bit secured thereto, FIG. 1*b* being a lower continuation of FIG. 1*a*;

FIGS. 2*a* and 2*b* are views similar to FIGS. 1*a* and 1*b*, with the hammer piston approaching its upper position, FIG. 2*b* being a lower continuation of FIG. 2*a*;

FIGS. 3*a* and 3*b* are views similar to FIGS. 1*a* and 1*b*, illustrating the relationship of the parts with the bit off the bottom of the hole, allowing air to be circulated through the apparatus, FIG. 3*b* being a lower continuation of FIG. 3*a*;

FIG. 4 is a cross-section taken along the line 4—4 on FIG. 1*a*;

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

FIG. 6 is a cross-section taken along the line 6—6 on FIG. 1*b*.

As illustrated in the drawings, an air hammer apparatus A is provided which is secured to the lower end of a string of drill pipe B by means of which the apparatus is rotated to correspondingly rotate a drill bit C used for drilling a bore hole D while the apparatus delivers repeated impact blows upon the drill bit, compressed air being forced down the drill pipe for actuating the apparatus and to cleaning the cuttings from the bottom of the hole. The apparatus includes an elongate housing structure **10** consisting of a plurality of parts. A main central section **11** of the housing structure has its upper end threadedly secured to an upper head **12**, which, in turn, is threadedly secured to a sub **13** having a box **14** threadedly attached to the pin **15** at the lower end of an adjacent drill pipe section B. The lower end of the intermediate housing section is threadedly attached to a lower head **16** having a spline connection **17** with an anvil **18** integral with the impact drill bit C of any suitable form, against which impact blows will be directed while the drill pipe string B and apparatus A are being rotated, to insure that the cutting portions of the drill bit will cover the entire cross-sectional area of the hole bottom E.

The upper housing head **12** has one or a plurality of inlet passages **19** opening through its upper end, their lower ends communicating with an annular inlet passage **20** between the outer housing section **11** and a cylinder sleeve **21** integral with and depending from the housing head. This cylinder sleeve has upper inlet ports **22** and lower inlet ports **23** communicating with the annular inlet passage and adapted to be placed in communication with the cylinder space **24** within the cylinder sleeve. Below the lower inlet ports **23**, the cylinder sleeve **21** carries a suitable seal ring **25** for sealing against a wall **26** of the housing section **11**, which is of smaller internal diameter than the wall **27** of the housing section portion surrounding the annular inlet passage **20**.

A hammer piston **28** is reciprocable within the housing structure **10** and its cylinder sleeve **21**, this piston being adapted to deliver an impact blow against the upper end **29** of the anvil **18** splined to the lower head **16** and extending upwardly into the lower portion **30** of the housing section **11**, this lower portion and its inner wall **26** having a substantially greater internal diameter S than the internal diameter T of the cylinder sleeve **21**.

In fact, the internal diameter S of the cylinder section is greater than that of the cylinder sleeve from the location of the cylinder sleeve seal ring **25** to the upper end of the lower head **16.** An elongate circumferential internal groove **31** in the housing wall will function as an annular exhaust passage **32,** as described hereinbelow.

The piston **28** has an enlarged outside diameter portion **33** reciprocable along the greater diameter wall **26** of the housing structure, the lower part **34** of this piston portion having a reduced external diameter so as to clear a limit ring **35** fitting within an internal circumferential groove **36** in the housing section, and on which a downwardly facing piston shoulder **37** is adapted to rest when the drill bit has been removed. When the drill bit C is in engagement with the bottom of the bore hole, it is held thereagainst by the lower end **38** of the lower head bearing against an upwardly facing drill bit or anvil shoulder **39,** at which time the periphery of an upper head **40** of the anvil within the housing section **11** engages a seal ring **41** mounted in such housing section.

The hammer piston **28** has a longitudinal impact passage **42** opening through its upper end and having a lower lateral branch **43** communicating with the annular space or passage **44** between an upper, smaller diameter piston portion **45** and the enlarged diameter wall **26** of the housing section below the housing sleeve **21.** The lower end of this annular passage **44** is adapted to communicate with the annular exhaust passage **32** which is in communication with a lateral exhaust port **46** extending from a central exhaust passage **47** in the lower portion of the piston to the periphery of the enlarged piston portion. This central passage **47** receives the upper portion of a sleeve valve member **48** piloted within a central air exhaust passage **49** extending through the anvil, being secured to the anvil in any suitable manner, as by welding material **48***a.* The exhaust passage **49** extends downwardly through the anvil **18** and drill bit C, discharging from the latter against the bottom E of the hole to clean the latter and the drill bit of cuttings, conveying the cuttings upwardly around the housing **10** and the drill pipe B to the top of the bore hole.

The hammer piston or impacting member also has a longitudinal return passage **50** opening through its lower end, its upper portion communicating with a port **51** opening into an annular inlet groove **52** in the smaller diameter portion **45** of the piston adapted to communicate with the lower inlet ports **23** when the air hammer is in its lower position engaging the anvil, as disclosed in FIGS. **1***a* and **1***b.* At this time, the upper inlet ports **22** are closed by the piston. Suitable piston rings **53, 53***a,* **53***b* may be mounted on the piston for preventing leakage therealong. As disclosed, an upper piston ring **53** occupies a position above the upper inlet ports **22** during the drilling operation, intermediate and lower piston rings **53***a,* **53***b* straddling the lower inlet ports **51** when the hammer piston **28** engages the anvil **18.**

The smaller diameter piston portion **45** has a further reduced diameter portion **54** below the lower piston ring **53***b,* which defines an annular air inlet passage **56** with the cylinder sleeve **21,** so that upon elevation of the piston in the housing structure and its cylinder sleeve, the annular inlet passage **56** will be placed in communication with the lower inlet ports **23** to permit compressed air to flow from the latter through the annular passage and into the lower end **43** of the impact passage **42,** such compressed air then passing into the cylinder **24** above the piston **28** for the purpose of forcing the latter downwardly and strike an impact blow against the anvil **18.** During the early portion of upward movement of the piston, the upper end **57** of its enlarged piston portion engages the cylinder wall **26** above the annular exhaust groove **32** to shut off communication between the impact passage **42** and exhaust port **32.** Additional upward movement of the piston will then place the annular inlet passage **56** in communication with the lower inlet ports **23** to feed compressed air into the impact passage **42,** as described above.

As the piston moves downwardly, the lower end **58** of the upper piston portion of smaller diameter will move across the lower inlet ports **23** to close them from communication with the annular inlet passage **20,** further downward movement then moving the shut-off corner **57** into the annular exhaust passage **32,** allowing the compressed air above the piston and in the impact passage **42** to exhaust through the exhaust port **46,** central exhaust passage **47,** inner valve sleeve **48,** and exhaust air passage **49** to the bottom of the hole, the energy imparted to the piston **28** by the compressed air driving it downwardly to impact it against the anvil **18.** Just before impact occurs, the annular inlet groove **52** is placed in communication with the lower inlet ports **23,** compressed air flowing therethrough and through the return passage **50** to the lower end of the piston, such air acting on the piston to drive it back toward its upper position. A relatively short upward travel again places the piston portion **59** below the grove **52** across the lower inlet ports **23** to shut off communication between them and the return passage **50,** the air below the piston expanding and driving the piston upwardly, once again compressing the air in the cylinder space **24** above the piston, the piston reaching the upper end of its stroke with the lower end **60** of the piston moving off the valve sleeve **48,** permitting the compressed air in the return passage **50** and below the piston to exhaust through the central exhaust passage **47,** valve sleeve **48** and exhaust air passage **49** into the bottom of the bore hole.

Another manner of exhausting the piston return air into the anvil is to lengthen the sleeve **48** so that it always remains slidably secured within the piston passage **47.** As the return air drives the piston upwardly, its lower shoulder **37** will move above the lower end **70** of the exhaust groove **32,** allowing the return air to exhaust from below the piston around the reduced diameter portion **34** into the exhaust groove **32,** from where it flows through the passages **46, 47, 48** and **49** to the bottom of the bore hole D.

It will be noted that immediately before the piston **28** impacts against the anvil **18,** the shut-off corner **57** moves off the cylinder wall **26** above the exhaust groove **32,** permitting the compressed air that has driven the piston downwardly to exhaust through the passages **46, 47, 48 49** into the bottom of the hole. Such exhaust action takes place after the piston shoulder **58** has moved below the lower inlet ports **23.** Shortly before the piston impacts against the upper end of the anvil, the annular inlet groove **52** is placed in communication with the lower inlet ports **23,** allowing the compressed air to flow through the return passage **50** in order to drive the piston **28** back upwardly. The

shut-off corner 57 moves above the exhaust groove 31 shortly before the piston portion 59 below the annular inlet groove 52 moves across the lower inlet ports 52 to shut off air flow into the return passage 50, the air below the piston expanding and driving the hammer piston upwardly, compressing the air in the cylinder space 24 above the piston. Near the upper end of the piston stroke, the shoulder 58 moves above the lower inlet ports 23 to feed compressed air through the impact passage 42 to the upper end of the piston, the compressed air driving the piston downwardly.

It will be noted that the compressed air that drives the piston downwardly acts over the full cross-sectional area S of the piston, which is the area of the enlarged piston portion 33. This piston area can be made quite large since the enlarged piston portion slides along the inner wall 26 of the housing section. There are no restrictions in the housing that can reduce the piston diameter over which the compressed air acts, such as the restriction in the housing imposed by the cylinder sleeve 21. Thus, the area S over which the compressed air is acting on the power stroke of the hammer piston is the sum of the cross-sectional area T of the smaller diameter piston plus the annular area U which is the annular area between the periphery of the smaller diameter piston portion and the periphery of the enlarged piston portion. The compressed air for returning the hammer piston acts across the annular area R between the periphery of the enlarged piston portion and the inner wall of the exhaust passage 47 in the lower portion of the piston. However, such area R need not be large, since the compressed air flowing through the return air passage 50 need only return the piston to the upper end of its stroke, compressing the air in the cylinder space 24 above the piston so that it will not impact against the cylinder head 12. However, the energy required to compress the air is recovered when the air later expands in driving the piston downwardly on its power stroke.

It is to be noted that all of the compressed air entering the apparatus exhausts through the lower end of the bit, insuring that the bottom of the bore hole will be swept free of cuttings, and insuring the maximum penetration of the cutting elements of the bit into the formation.

With the bit C elevated from the bottom E of the bore hole, air can be circulated through it relatively freely. With the bit off bottom (FIGS. 3*a*, 3*b*), it will drop downwardly of the housing structure, moving its anvil portion 18 downwardly until its downwardly facing shoulder 80 engages the upper end of the lower head 16, at which time the head 40 moves off its seal ring 41. The piston 28 moves downwardly to the extent limited by engagement of its lower end with the upper end of the anvil, the upper end 82 of the piston then being disposed below the upper inlet circulating ports 22. At this time, the shut-off corner 57 at the upper portion of the enlarged diameter of the piston is disposed well within the exhaust groove 31. Accordingly, compressed air can flow from the drill pipe B through the sub 13 and the inlet passages 19 into the annular inlet passage 20, proceeding through the inlet circulating ports 22 into the cylinder sleeve 21, and then passing through the impact passage 42, 43 to the exterior of the piston, flowing through the groove 31 and into the exhaust port 46, continuing to flow into the central exhaust piston passage 47, inner sleeve 48 and through the exhaust air passage 49 from the lower end of the bit.

In FIGS. 1*a* and 1*b*, the apparatus is illustrated with the bit C resting against the bottom E of the hole and the hammer piston 28 having just delivered its blow to the anvil 18. The air in the cylinder above the piston has exhausted through the impact passage 42 and the groove 31 into the exhaust port 46, continuing to exhaust through the passages 47, 48, 49 from the bit and against the bottom of the bore hole. The compressed air flows through the return passage 50 to the bottom 60 of the hammer piston, acting in an upward direction over the annular area R of the piston to drive it upwardly. Initially, the shut-off corner 57 moves above the exhaust groove 31 to close it from the impact passage 42, whereupon the piston 59 below the annular groove shuts off the lower inlet ports 23, the expanding air below the piston continuing to drive upwardly and compressing the air that remains in the cylinder space 24 above the piston, providing an air cushion to prevent the piston from impacting against the cylinder head 12. The downwardly facing piston shoulder 58 has now moved above the lowermost ends of the lower inlet ports 23, permitting compressed air to flow from the inlet ports 23 into the annular inlet passage 56, and through the impact passage 43, 42 to the upper portion of the piston (FIGS. 2*a* and 2*b*), which then causes the compressed air to drive the piston 28 downwardly and deliver an impact blow against the anvil. Near the limit of its downstroke, the shut-off corner 57 moves into the region of the exhaust groove 31, permitting the compressed air to exhaust through the bit, as described above, the return passage 50 again being placed in communication with the lower inlet ports 23, the piston impacting against the anvil, and the foregoing cycle of operation repeated.

During the reciprocation of the piston 28 within the housing structure 10 to deliver repeated impact blows against the anvil 18, the drill pipe string B and apparatus A are being rotated while suitable downweight is imposed on the drill pipe and housing structure, the lower end 38 of the head 16 continually bearing against the bit or anvil shoulder 39, holding it against the bottom E of the bore hole. Rotary motion is transmitted from the housing structure 10 through the spline connection 17 to the anvil 18. As disclosed (FIGS. 1*b*, 2*b*, 3*b*, 6), the spline connection includes circumferentially spaced external splines or teeth 100 on the exterior of the mandrel that mesh with companion internal splines 101 on the lower head member 16. This lower head member has an externally threaded portion 102 for threaded connection to the lower end of the housing section 11. However, it is made in two parts or halves 16*a*, 16*b*. It is to be noted that the outside diameter of the external splines 100 is within the periphery of the anvil portion on opposite sides thereof, the upper and lower ends of these splines terminating in upper and lower shoulders 80, 80*a*, the upper shoulder 80 diverging in an upward direction and being adapted to engage a companion upward facing shoulder 104 on the lower head 16, as disclosed in FIGS. 3*a*, 3*b*, when air is being circulated through the apparatus.

The head 16 can be placed in assembled relation with respect to the splines 100 of the anvil by forming the head in a plurality of pieces or sections, such as the two sections 16*a*, 16*b* illustrated in the drawings. This enables each section to be moved laterally inwardly to

place the internal splines **101** in mesh with the external splines **100.** The undulating groove configuration **105** of each head section **16***a*, **16***b* has its opposed walls **106** diverging in a lateral inward direction, which enables each head section to be appropriately shifted laterally to mesh the internal splines **101** with the external splines **100,** as shown in FIG. **6.** With the two halves of the head member mounted on and in splined relation to the anvil **18,** the anvil and head member can be inserted upwardly into the housing section **11** and the external threads **102** of the head member **16** threaded into the companion internal thread **102***a* of the housing member to its fullest extent. This secures the head members **16, 16***a* together and makes it function as a single head member.

The splines are readily manufactured, as by use of a milling tool, which will cut the grooves in the anvil to produce the external splines **100.** Similarly, the internal splines **101** can be produced through use of a suitable machine tool, such as a milling machine.

The spline connection illustrated and described is much simpler than prior spline arrangements found in air hammers. It is more economical to manufacture. It reduces the cost of an integral anvil and bit considerably.

The apparatus disclosed in the drawings also includes a water check valve device **200** (FIG. **1***a*). As shown, the upper housing head **12** has a guide bore **201** opening through its upper end and receiving a valve stem **202** terminating in an upper valve head **203** adapted to engage a central valve seat **204** on the upper sub. The valve stem and its head are urged upwardly to place the head **203** in engagement with its companion seat **204** by a helical compression spring **205** bearing against the lower end of the valve stem and against the base **206** of the guide bore. A bleeder passage **207** is provided in the upper housing head, its upper end communicating with the guide bore **201** and its lower end with a lateral bleeder port **208,** to avoid trapping of fluid in the bore and its potential interference with the movement of the valve head.

Compressed air pumped down through the drill pipe string B will shift the valve head **203** downwardly from engagement with its seat **204,** enabling the compressed air to flow into an upper recess **209** in the upper head through which the inlet passages **19** open. Any tendency for water or other liquid to flow upwardly into the apparatus is precluded by the upward seating of the valve head **203** against its seat **204.**

It will be apparent that an air hammer has been provided in which a larger piston area is available over which compressed air can act in delivering the impact blow to the companion anvil. The piston can be made heavier, its larger area enabling it to be accelerated to a desired velocity at impact. Moreover, such impact velocity can be achieved with the piston having a shorter stroke, resulting in a much higher frequency of operation of the piston in reciprocating within the housing structure. Thus, the increased weight of the piston and its higher frequency of reciprocation with the same impact velocity results in a greatly increased horsepower delivered by the piston to the anvil and bit. It is found that such increased horsepower is achieved with the consumption of substantially less air. By way of example, it is found that 47 percent more horsepower has been developed with a consumption of 21 percent less air, a 10 percent higher energy blow being delivered with approximately the same impact velocity as a well known prior air hammer. Despite the lower air consumption, the increased horsepower results from the use of a heavier piston having a shorter stroke operating at a much higher frequency, for example, a 34 percent higher frequency.

I claim:

I. In percussion drilling apparatus: a housing structure connectible to a drill string; an anvil in the lower portion of said housing structure and operatively connectible to a drill bit, said anvil having an exhaust passage; said housing structure including a first cylinder portion and a second cylinder portion therebelow of greater internal diameter than the internal diameter of said first cylinder portion, a hammer piston reciprocable in said cylinder portions for intermittently impacting against said anvil, said piston having an upper portion slidably reciprocable in said first cylinder portion and in sealed relation thereto, and a lower portion of greater diameter than said upper portion slidably reciprocable in said second cylinder portion and in sealed relation thereto; said upper piston portion having an effective cross-sectional area substantially equal to the internal cross-sectional area of said first cylinder portion; first means for directing a fluid medium under pressure into said first cylinder portion above said upper piston portion for action upon the full effective cross-section area of said upper piston portion, and into said second cylinder portion above said lower piston portion, for driving said hammer piston downwardly toward said mandrel; second means for directing the fluid medium under pressure into a lower portion of said housing structure for action upon said hammer piston to elevate said hammer piston in said housing structure; and exhaust passage means for exhausting substantially all of the fluid medium from said cylinder portions above said upper and lower piston portions and from said lower portion of said housing structure into said exhaust passage of said anvil.

2. In apparatus as defined in claim **1**; said first directing means including an inlet passage in said housing structure opening into said first cylinder portion through a side wall thereof.

3. In apparatus as defined in claim **1**; said exhaust passage means including an exhaust passageway in an inner side wall of said second cylinder portion placed in communication by said hammer piston with the interior of said housing structure above said lower piston portion upon downward movement of said hammer piston in said housing structure.

4. In percussion drilling apparatus: a housing structure connectible to a drill string; an anvil in the lower portion of said housing structure and operatively connectible to a drill bit, said anvil having an exhaust passage; said housing structure including a first cylinder portion and a second cylinder portion therebelow of greater internal diameter than the internal diameter of said first cylinder portion, a hammer piston reciprocable in said cylinder portions for intermittently impacting against said anvil, said piston having an upper portion slidably reciprocable in said first cylinder portion and in sealed relation thereto, and a lower portion of greater diameter than said upper portion slidably reciprocable in said second cylinder portion and in sealed relation thereto; first means for directing a fluid medium under pressure into said first cylinder portion above said upper piston portion and into said second

cylinder portion above said lower piston portion for driving said hammer piston downwardly toward said mandrel; second means for directing the fluid medium under pressure into a lower portion of said housing structure for action upon said hammer piston to elevate said hammer piston in said housing structure; and exhaust passage means for exhausting substantially all of the fluid medium from said cylinder portions above said upper and lower piston portions and from said lower portion of said housing structure into said exhaust passage of said anvil; said exhaust passage means including an exhaust passageway in an inner side wall of said second cylinder portion placed in communication by said hammer piston with the interior of said housing structure above said lower piston portion upon downward movement of said hammer piston in said housing structure, said exhaust passage means further including an exhaust passage in said hammer piston communicating with said exhaust passageway and said anvil exhaust passage.

5. In percussion drilling apparatus: a housing structure connectible to a drill string; an anvil in the lower portion of said housing structure and operatively connectible to a drill bit, said anvil having an exhaust passage; said housing structure including a first cylinder portion and a second cylinder portion therebelow of greater internal diameter than the internal diameter of said first cylinder portion, a hammer piston reciprocable in said cylinder portions for intermittently impacting against said anvil, said piston having an upper portion slidably reciprocable in said first cylinder portion and in sealed relation thereto, and a lower portion of greater diameter than said upper portion slidably reciprocable in said second cylinder portion and in sealed relation thereto; first means for directing a fluid medium under pressure into said first cylinder portion above said upper piston portion and into said second cylinder portion above said lower piston portion for driving said hammer piston downwardly toward said mandrel; second means for directing the fluid medium under pressure into a lower portion of said housing structure for action upon said hammer piston to elevate said hammer piston in said housing structure; and exhaust passage means for exhausting substantially all of the fluid medium from said cylinder portions above said upper and lower piston portions and from said lower portion of said housing structure into said exhaust passage of said anvil; said first directing means including an impact passage in said piston opening at its upper portion into said first cylinder portion above said upper piston portion and at its lower portion into said second cylinder portion above said lower piston portion, said first directing means further including an inlet passage in said housing structure opening into said first cylinder portion through a side wall thereof and communicating with the lower portion of said impact passage upon upward movement of said piston in said housing structure.

6. In apparatus as defined in claim 5; said exhaust passage means including an exhaust passageway in an inner side wall of said second cylinder portion placed in communication by said hammer piston with said lower portion of said impact passage upon downward movement of said hammer piston in said housing structure, said exhaust passage means further including an exhaust passage in said hammer piston communicating with said exhaust passageway and said anvil exhaust passage.

7. In apparatus as defined in claim 5; said second directing means further including a return passage in said piston opening at its lower portion into said lower portion of said housing structure below said piston and at its upper portion into said first cylinder portion in communication with said inlet passage upon downward movement of said piston in said housing structure.

8. In apparatus as defined in claim 5; said second directing means further including a return passage in said piston opening at its lower portion into said lower portion of said housing structure below said piston and at its upper portion into said first cylinder portion in communication with said inlet passage upon downward movement of said piston in said housing structure; said exhaust passage means including an exhaust passageway in an inner side wall of said second cylinder portion placed in communication by said hammer piston with said lower portion of said impact passage upon downward movement of said hammer piston in said housing structure, said exhaust passage means further including an exhaust passage in said hammer piston communicating with said exhaust passageway and said anvil exhaust passage and with said housing structure below said piston.

9. In percussion drilling apparatus: a housing structure connectible to a drill string and having an inner cylinder portion and an outer portion surrounding said inner portion and spaced laterally therefrom to provide an annular air inlet passage therebetween, said outer portion extending below the lower end of said inner portion and having an inside diameter substantially greater than the inside diameter of said inner portion to provide an outer cylinder portion of greater internal diameter than said inner portion; an anvil in the lower portion of said housing structure and having an exhaust passage; a hammer piston reciprocable in said housing structure for intermittently impacting against said anvil, said piston having an upper small diameter portion slidably reciprocable in said inner cylinder portion and a lower large diameter portion slidably reciprocable in said outer cylinder portion below said inner cylinder portion; said inner cylinder portion having one or more side ports communicating said annular passage with the interior of said inner cylinder portion; said outer cylinder portion having an exhaust passageway in its inner side wall below said inner cylinder portion; said piston having an impact passage opening at its upper end into said inner cylinder portion and at its lower end into said outer cylinder portion; said piston having a return passage opening at its lower end into said outer cylinder portion below said piston and at its upper end into said inner cylinder portion below the upper end of said piston; said piston having an exhaust passage communicating said exhaust passageway with said anvil exhaust passage, said piston having means thereon coacting with said housing structure to alternately communicate said impact passage with said one or more side ports and said exhaust passageway upon upward and downward movement, respectively, of said piston in said structure, said piston having means thereon coacting with said housing structure to alternately communicate said return passage with said one or more side ports and said piston exhaust passage upon downward and upward movement, respectively, of said piston in said structure.

10. In apparatus as defined in claim 9; and a sleeve in said anvil exhaust passage adapted to extend into said piston exhaust passage.

11. In apparatus as define in claim 9; and a sleeve in said anvil exhaust passage adapted to extend into said piston exhaust passage in sealing relation to said piston; said piston being movable off said sleeve upon elevation of said piston in said structure to permit air below aid piston to exhaust into said anvil passage.

12. In percussion drilling apparatus: a housing structure; an anvil extending into the lower portion of said housing structure; a hammer piston reciprocable in said structure above said anvil; means for reciprocating said piston in said housing structure for intermittently impacting said piston against said anvil; a connection between said housing structure and anvil including V-shaped external splines on said anvil, a member comprising a plurality of separate parts having V-shaped internal splines adapted to mesh with said external splines, said parts being movable laterally inwardly of said anvil toward each other to mesh said internal splines with said external splines, and means on said housing structure encompassing and retaining said separate parts in their lateral inward position.

13. In apparatus as defined in claim 12; said encompassing and retaining means including external threads on said parts meshing with companion internal threads in said housing structure.

14. In apparatus as defined in claim 12; the outer ends of said external splines lying on a circle of lesser diameter than the external diameter of said anvil above said splines.

15. In apparatus as defined in claim 12; said encompassing and retaining means including external threads on said parts meshing with companion internal threads in said housing structure, the outer ends of said external splines lying on a circle of lesser diameter than the external diameter of said anvil above said splines.

16. In apparatus as defined in claim 12; said separate parts consisting of two members each having an arcuate extent of about 180° and movable laterally inwardly of said anvil toward each other to mesh said internal splines fully with said external splines without interference from said external splines.

17. In apparatus as defined in claim 12; said external splines being circumferentially spaced uniformly from each other, said internal splines being circumferentially spaced uniformly from each other an movable laterally inwardly towards each other to mesh said internal splines fully with said external splines without interference from said external splines.

18. In apparatus as defined in claim 12; said external splines being circumferentially spaced uniformly from each other, said internal splines being circumferentially spaced uniformly from each other; said separate parts consisting of two members each having an arcuate extent of about 180° and movable laterally inwardly of said anvil toward each other to mesh said internal splines fully with said external splines without interference from said external splines.

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