

- [54] **BORE HOLE HAMMER DRILL**
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- [73] Assignee: **Bakerdrill, Inc.**, Spartanburg, S.C.
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- [52] U.S. Cl. .... **173/17; 173/66; 173/80; 173/131**
- [51] Int. Cl. .... **E21b 5/00; E21c 7/00**
- [58] Field of Search ..... **173/64-73, 173/78, 80, 136, 17**

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[57] **ABSTRACT**

An air hammer embodying an outer housing structure connectable to a rotatable drill pipe string through which compressed air is conducted. A hammer piston reciprocates in the housing structure, compressed air being directed alternately to the upper and lower ends of the piston to effect its reciprocation in the structure, each downward stroke inflicting an impact blow upon the anvil portion of an anvil bit extending upwardly within the lower portion of the housing structure. The flow of air to the upper and lower ends of the hammer piston is controlled by valve passages formed in the piston and a relatively stationary air supply tube which closes the passage to the lower end of the piston when the outer housing structure is lifted by the drill pipe string to allow the bit to hang down from the housing during the circulation of air for flushing cuttings from the bore hole.

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19 Claims, 10 Drawing Figures

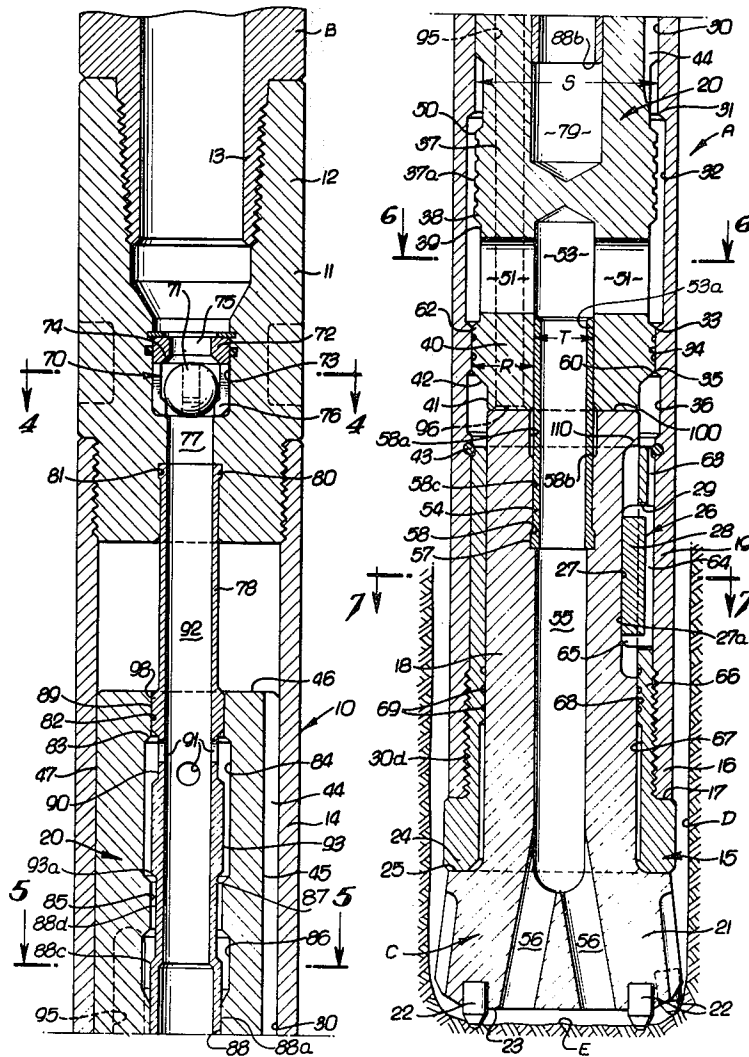


FIG. 1a.

FIG. 1b.

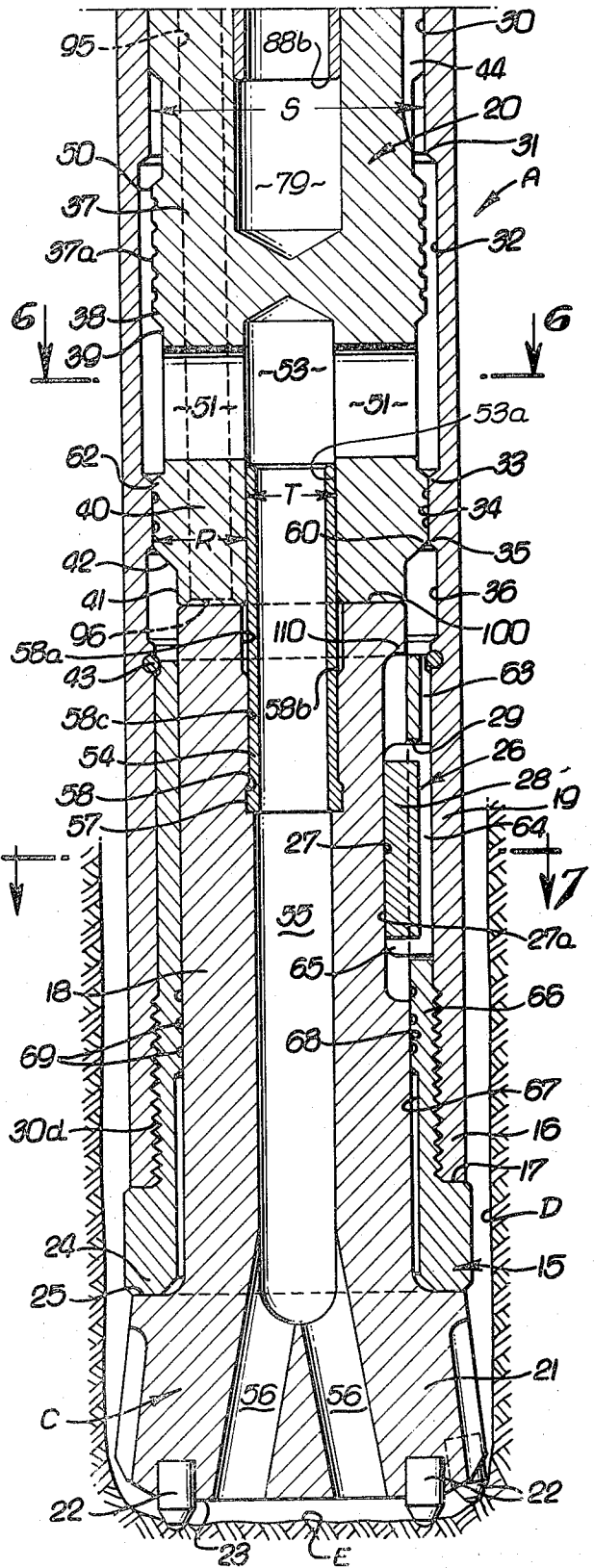
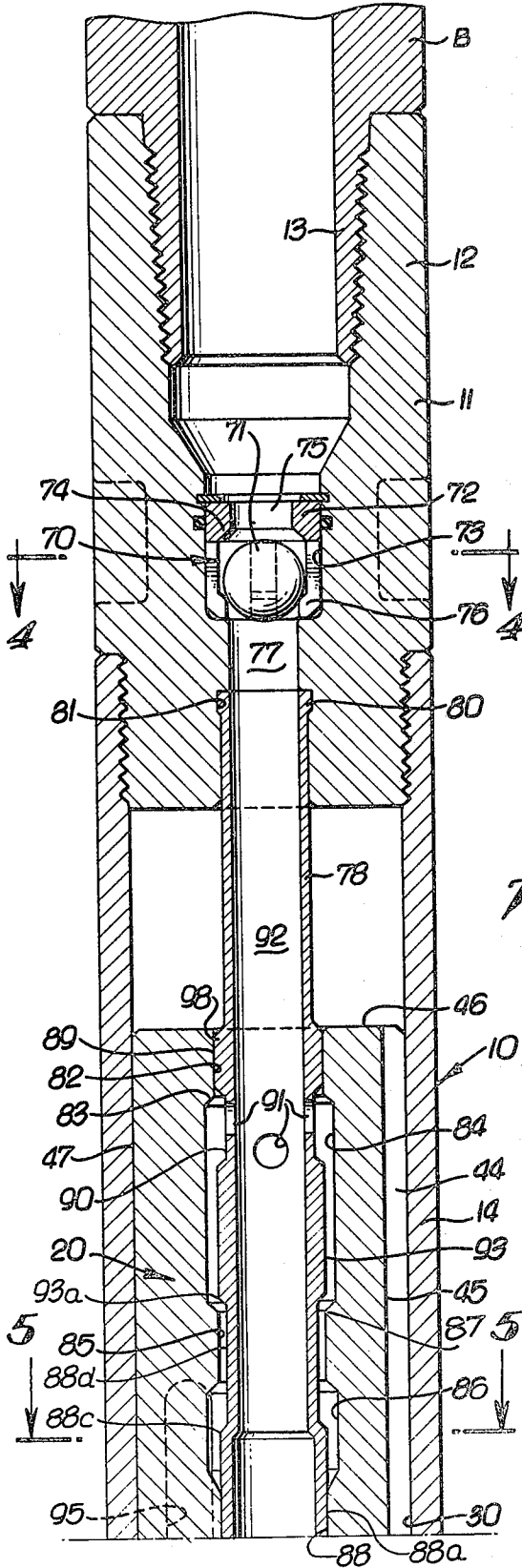


FIG. 2a.

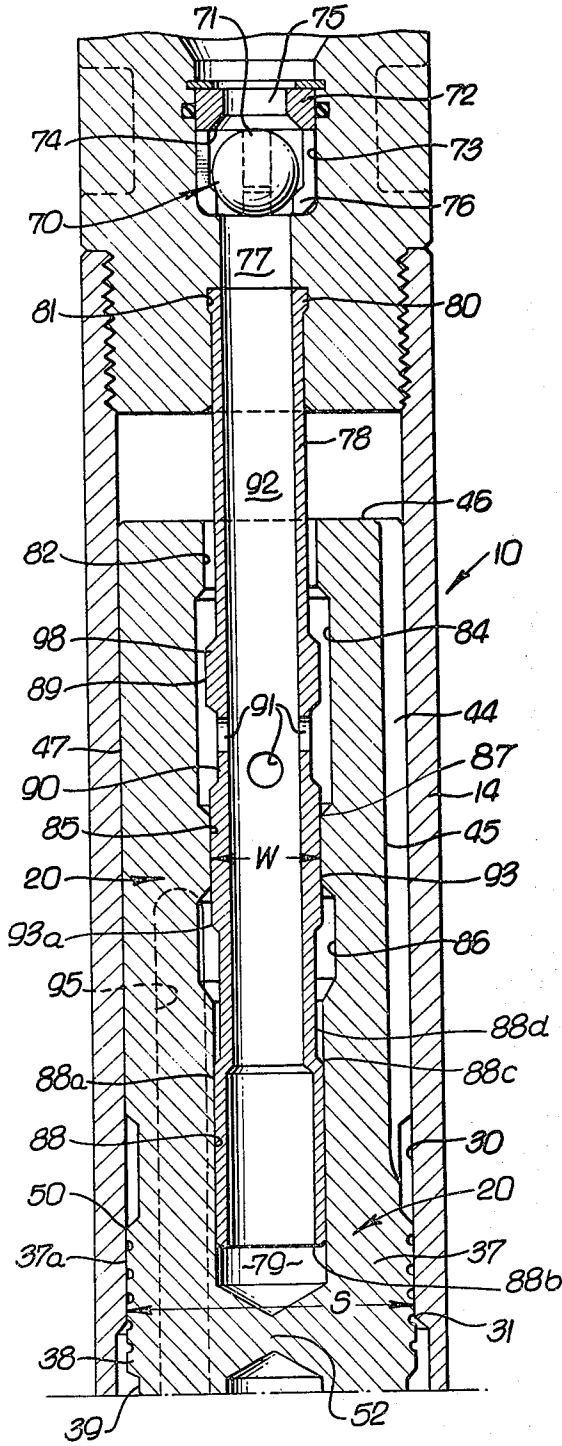


FIG. 2b.

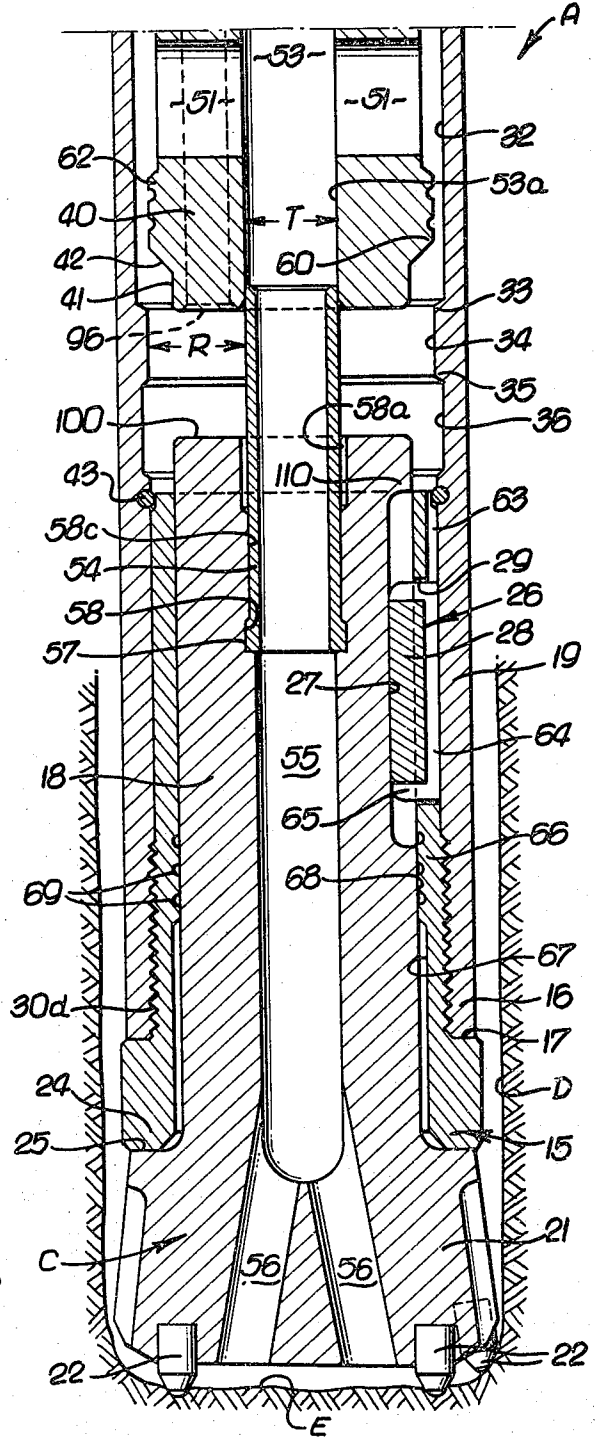


FIG. 3a.

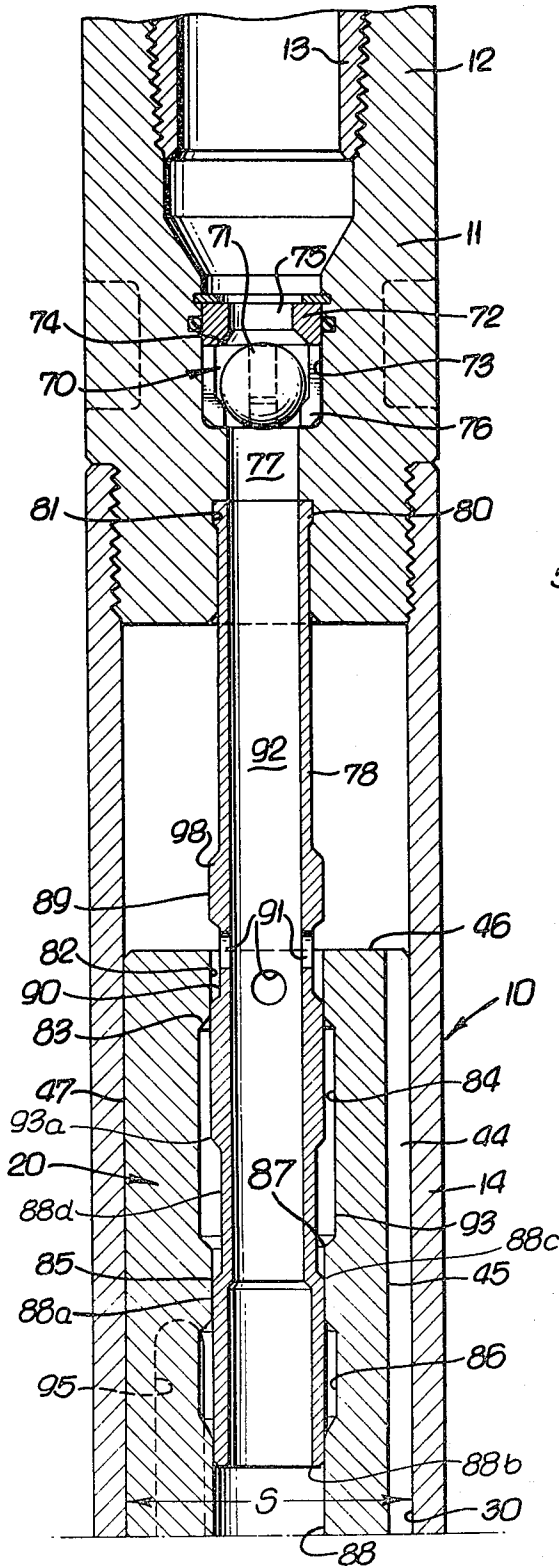


FIG. 3b.

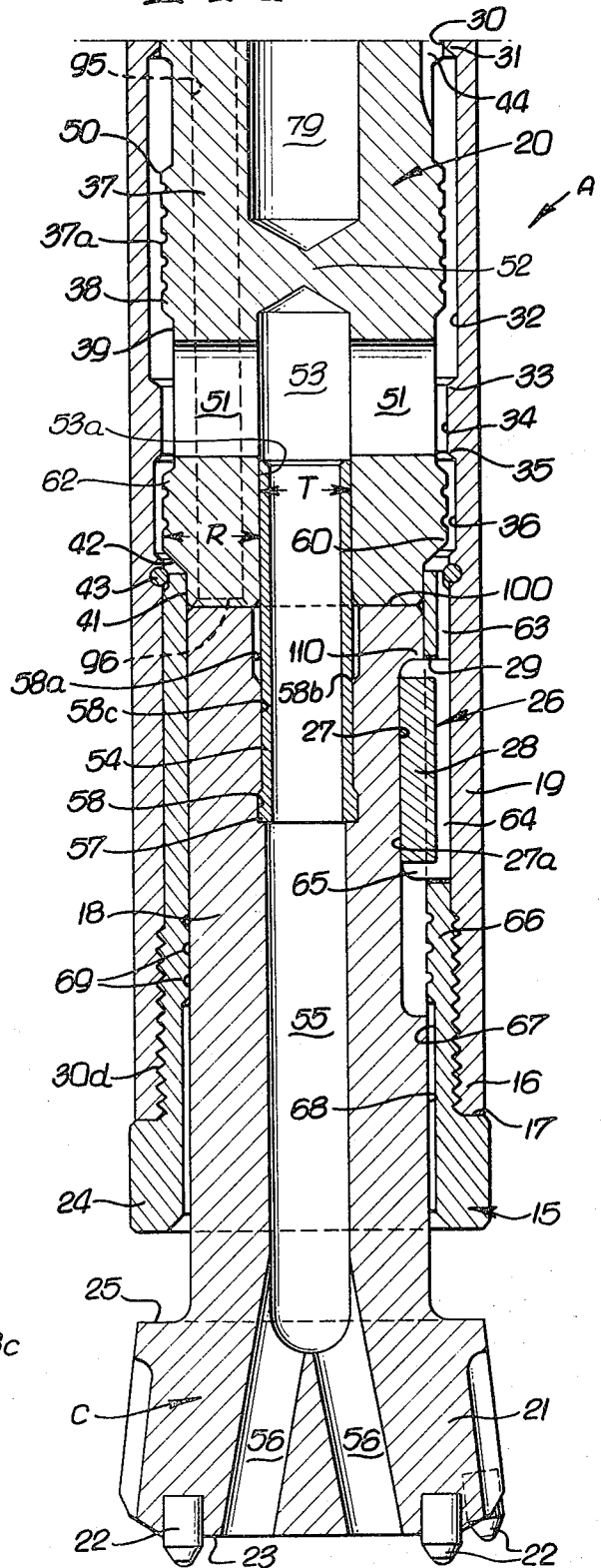


FIG. 4.

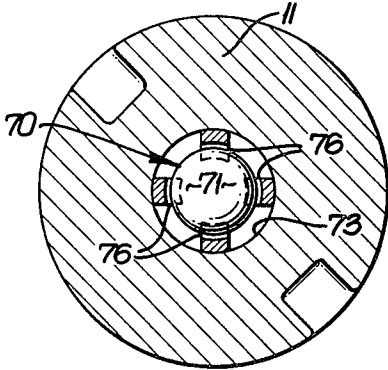


FIG. 5.

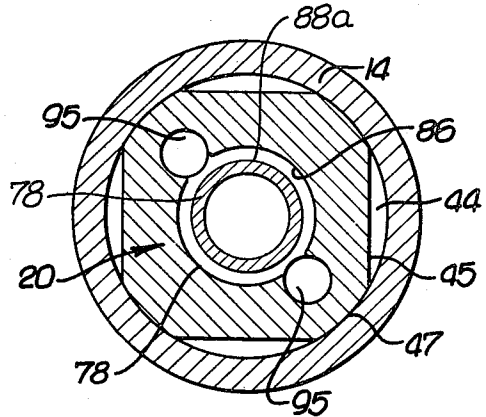


FIG. 6.

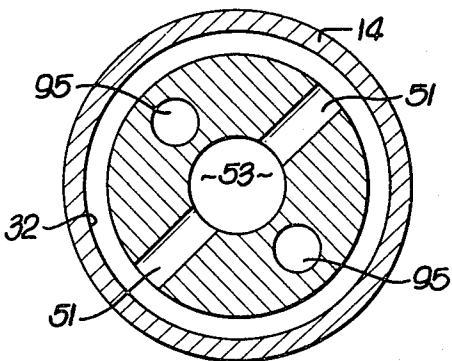
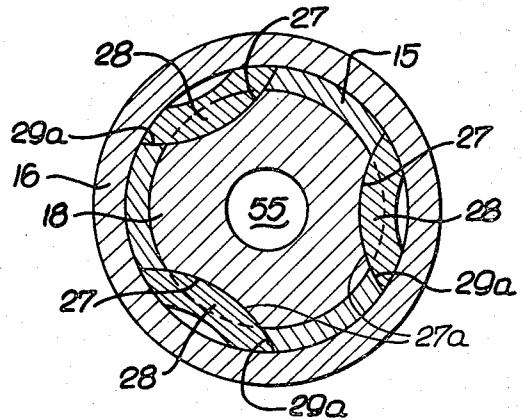


FIG. 7.



## BORE HOLE HAMMER DRILL

## BACKGROUND OF THE INVENTION

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 being rotated, in order that the bit may cover substantially the full area of the bore hole bottom.

As disclosed in the pending application for letters Patent of the United States, Ser. No. 246,837, filed Apr. 24, 1972, in the name of Alfred R. Curington, an air hammer is disclosed wherein the housing structure in which the hammer piston is reciprocable is of a simple design and is economical to manufacture. The reciprocating hammer piston coacts with the housing structure in such a manner as to alternately direct compressed air into the housing structure at the upper and lower ends of the piston, and alternately effects exhaust of the air from the upper and lower portions of the housing structure. The compressed air on the power stroke of the hammer piston acts over its full cross-sectional area, which is the full cross-sectional area of the inner wall of the housing structure itself, such area having a maximum value. After traversing the major portion of its power or downward stroke, the hammer piston shifts to an exhaust condition. During the downward shifting of the hammer piston on its power stroke, the air therebelow is compressed to some extent, but despite the presence of such compressed air, which remains after the hammer piston opens its exhaust passage before the piston impacts upon the anvil, a continuing supply of inlet air pressure acts over a portion of the hammer piston area to assist in driving the hammer piston downwardly against the anvil and against the resistance of the air compressed below the hammer piston. Accordingly, a greater blow is struck against the anvil than in prior devices.

In the use of the aforesaid air hammer drill, it sometimes is necessary or desirable to circulate air down the drill pipe string, from the lower end of the apparatus, and then upwardly in the bore hole, while the drilling is interrupted. The prior air control valve means for alternately directing air to the upper and lower ends of the piston is such that when the hammer drill housing is lifted by the drill pipe string and the bit hangs downwardly from the housing, the air can flow downwardly between the piston and the housing and between the anvil bit or drill and the housing into the bore hole. However, the cooperative air supply tube or valve tube and the piston passages are such that during circulation, as just described above, air also has access to the bottom of the piston, and reciprocation of the piston can result, causing undesired impacts of the piston on the bit while the bit is off of the bottom of the bore hole.

## SUMMARY OF THE INVENTION

The present invention involves a hammer drill or air hammer of the type referred to above which incorporates an improved air valve cooperative with the hammer piston to close off the passage leading to the bottom of the hammer piston during circulation of air when the housing is lifted upwardly by the drill pipe string to allow the anvil bit or drill to hang downwardly from the housing.

More particularly, the air supply tube has a lower cylindrical sealing section which closes the fluid passage or opening, through which air flows to the bottom of the piston during hammer strokes of the piston, when the piston moves downwardly and rests upon the anvil of the bit upon elevation of the housing prior to circulation of the air down the drill pipe, from the lower end of the apparatus and upwardly in the bore hole.

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. A 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. 1a and 1b together constitute a longitudinal section through an apparatus embodying the invention, with parts in their relative positions for drilling and in which the hammer piston has completed delivering an impact blow against the companion anvil bit, FIG. 1b being a lower continuation of FIG. 1a;

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

FIGS. 3a and 3b are views similar to FIGS. 1a and 1b, illustrating the relationship of parts when the drill bit has been elevated from the bottom of the hole, allowing air to be circulated through the apparatus, FIG. 3b being a lower continuation of FIG. 3a;

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

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

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

FIG. 7 is a cross-section taken along the line 7—7 on FIG. 1b.

## DESCRIPTION OF THE PREFERRED EMBODIMENT

As shown in the drawings an air hammer apparatus A is provided that is secured to the lower end of a string of drill pipe B, by means of which the apparatus is rotated to correspondingly rotate an impact anvil bit C used for drilling a bore hole D, the apparatus delivering repeated impact blows upon the anvil bit when compressed air is forced down the drill pipe for actuating the apparatus and for cleaning the cuttings from the bottom E of the hole. The apparatus is relatively simple, consisting of an elongate housing structure 10 that includes an upper sub 11 having an upper threaded box 12 (or threaded pin, not shown) for threaded attachment to the lower end 13 of the string of drill pipe, that extends to the drilling rig (not shown) at the top of the bore hole D. This sub is threadedly secured to the upper portion of an elongate housing section 14, which can be of one piece, the lower end of which is threadedly secured to a lower housing head or drive member 15, the lower end 16 of the housing section bearing against an upwardly facing shoulder 17 formed on the head.

An elongate anvil portion 18 of the anvil bit C is piloted upwardly within the drive member 15 and lower portion 19 of the housing section 14, a hammer piston

20 being reciprocable in the housing section above the anvil 18 to deliver repeated impact blows thereagainst. The anvil is preferably formed integrally with the drill bit portion 21 of the anvil bit, and which has suitable cutting elements 22 (such as sintered carbide buttons 22) mounted in its drilling face 23 for impacting against the bottom E of the bore hole, to produce cuttings therein, the cutting elements 22 also acting against the side of the bore hole adjacent to its bottom to insure the production of a bore hole D of the desired diameter.

During the reciprocation of the hammer piston 20 in the housing to deliver impact blows upon the anvil bit, the drill pipe string B and housing structure 10 are rotated at a desired speed, such as 20 r.p.m., to correspondingly rotate the anvil bit C and insure an impacting action of the cutting members 22 over substantially the entire cross-sectional area of the bottom E of the hole. During the impacting action, suitable drilling weight is imposed on the anvil bit through the drill pipe string B and the housing structure 10, such drilling weight being transferred from the lower end 24 of the housing head or drive member 15 to an upwardly facing shoulder 25 of the bit 21. The rotary drive itself is transferred from the housing structure 10 to the anvil 18 through a slidable spline type of connection 26, which can assume several different forms, the particular drive connection illustrated constituting no portion of the present invention. The specific drive connection is illustrated in the application of Alfred R. Curington and Archer W. Kammerer, Jr., for "Bore Hole Air Hammer Drive Mechanism", Ser. No. 239,047, filed Mar. 29, 1972, now U.S. Pat. No. 3,804,181 to which attention is directed.

In general, the upper portion of the anvil has circumferentially spaced elongate chordal surfaces 27 (FIG. 7), which are preferably concave in shape, against which correspondingly shaped segments 28 bear, these segments being carried in circumferentially spaced windows 29 in the drive member 15. The chordal surfaces 27 are substantially longer than the length of the segments 28, permitting relative longitudinal movement of the anvil bit C with respect to the housing structure 10. The rotary effort is transferred from the housing section 19 to the drive member 15 by virtue of the threaded connection 30d, and from the sides 29a of the opening or windows 29 of the segments 28, from where the turning effort is transmitted through the abutting segment surfaces 27a on the segments 28 and anvil surfaces 27 to the anvil 18 of the bit C.

The housing section 14 includes an elongate upper inner cylindrical housing wall 30, the lower end 31 of which constitutes an upper housing flow control corner at the upper end of an elongate internal circumferential exhaust groove 32 of a substantially larger internal diameter than the diameter of the inner cylindrical housing wall 30. Below the lower end 33 of the exhaust groove 32, the housing section 19 is provided with a lower inner cylindrical housing wall 34, which may be of the same internal diameter as the upper housing wall 30, the upper end of the lower wall being the housing lower flow control corner 33. The lower end 35 of the lower inner cylindrical housing wall 34 provides a bypass corner at the upper end of an enlarged internal diameter circumferential by-pass groove 36.

The elongate hammer piston 20 includes an upper piston portion 37 having an external diameter 37a con-

forming to the diameter of the upper inner cylindrical housing 30, this upper piston portion terminating at the upper end 38 of an external circumferential exhaust groove 39 of a lesser external diameter than the upper piston portion 37. This external exhaust groove terminates at a lower piston portion 40 having an external diameter conforming to the internal diameter of the lower inner cylindrical housing wall 34. Below its lower piston portion 40, the hammer is of a reduced external diameter 41, providing a downwardly facing shoulder 42 which may, upon removal of the anvil bit C from the housing 10, engage a limit ring 43 mounted in the housing section 14, to prevent the piston 20 from inadvertently dropping out of the housing structure. The hammer piston extends upwardly to a substantial distance above its upper piston portion 37, having a plurality of circumferentially spaced relief spaces 44 (FIG. 5) which may be formed by elongate chords 45 in the hammer portion extending from the upper piston portion 37 to the upper end 46 of the latter, there being circumferentially spaced elongate arcuate sections 47 between the chords 45 having the same external diameter as the upper piston portion 37 and assisting in guiding the hammer piston 20 in its reciprocation within the housing section 14.

As described hereinbelow, when the hammer piston 20 is at the lower end of its stroke, as shown in FIGS. 1a, 1b, a flow control piston corner 50 at the upper end of the piston portion 37 is spaced below the upper housing flow control corner 31, allowing air in the housing above the piston 20 to flow down through the passages 44 and into the internal circumferential exhaust groove 32, around the upper piston portion 37, then into radial exhaust ports 51, formed through the hammer piston below its intermediate piston wall 52, that communicate with an elongate central piston cavity 53 into which an exhaust tube 54 extends upwardly from the anvil 18, the tube forming a continuation of the exhaust passage 53 and communicating with an exhaust passage 55 through the anvil and through one or a plurality of exhaust passages 56 extending downwardly through the bit 21 and opening outwardly thereof for the purpose of enabling the drilling fluid to flow into the bore hole D for removing the cuttings from the bottom E of the hole. The tube 54 makes a slidable seal with the wall 53a of the piston cavity 53, being secured to the anvil 18 by a lower outwardly extending tube flange 57 being received within an inner circumferential groove 58 in the anvil. The tube may be made of an elastic material, such as Delrin, which permits it to be inserted within the anvil passage, the flange 57 contracting sufficiently until it is opposite the circumferential groove 58, whereupon the tube flange can snap outwardly into the groove 58 and thereby lock the tube 54 to the anvil 18.

When the piston 20 is shifted upwardly within the housing on its return stroke, the return air corner 60 at the lower end of the lower piston portion 40 will be disposed above the housing lower flow control corner 33 (FIGS. 2a, 2b), whereupon the compressed air below the piston can exhaust into the internal circumferential housing groove 32 and flow through the exhaust ports 51 and exhaust passages 53, 55, 56 to the bottom E of the bore hole. At this time, the upper flow control piston corner 50 will be disposed above the upper housing flow control corner 31, which will seal the upper piston portion 37 against the upper inner cylindrical housing

wall 30, whereupon compressed air can drive the piston 20 downwardly on its hammer or power stroke. When the return air corner 60 moves below the housing lower flow control corner 33, the air below the piston and within the housing, which remains after the lower piston portion 40 is closed within the lower end of the cylindrical housing wall 34, is subject to compression, but such air will be at a relatively low pressure.

As described hereinbelow, in the event the apparatus is elevated to raise the bit 21 from the bottom E of the hole, the latter will drop downwardly until its upper anvil head flange 110 engages the upper ends of the segments or keys 28. This will allow the upper piston by-pass corner 62 to shift below the housing by-pass corner 35 at the lower end of the lower inner cylindrical housing wall 34, the upper flow control piston corner being well below the upper housing flow control corner (FIGS. 3a, 3b). Accordingly, compressed air above the piston can flow through the passages 44 and the internal circumferential exhaust groove 32 into the air by-pass groove 36 below the lower housing wall 34, the air passing downwardly through the passages 63 in the upper portion of the anvil rotary drive member 15 and into the by-pass passages 64 between the segments and the surrounding housing wall, flowing through the lower slots 65 in the segments and into the concave cavities 27 in the anvil 18, the air flowing past a head sealing portion 66 within the drive member 15 and into elongate relief groove 67 extending downwardly through the lower end of the drive member 15. When the anvil 18 is in its upper position within the housing and with the bit shoulder 25 engaging the lower end 24 of the drive member 15, the head sealing portion 66 seals against the periphery 68 of the anvil below its elongate grooves 27 in which the segments or keys 28 are positioned. To facilitate such sealing, the head portion 66 may have a plurality of longitudinally spaced internal labyrinth seal grooves 69 formed therein.

Compressed air for reciprocating the hammer piston 20 passes downwardly through the string of drill pipe B and into the upper housing sub 11, flowing past a downwardly opening check valve 70 which may be in the form of a ball 71 received within a valve body 72 mounted in a counterbore 73 in the sub, the ball being movable upwardly to engage a companion seat 74 surrounding a central passage 75 through the body, the downward movement of the ball being limited by its engagement with circumferentially spaced feet 76 extending inwardly from the body. With air being pumped downwardly through the apparatus, the ball 71 engages the feet 76 and the air can flow around the ball and between the feet and into a central passage 77 in the housing sub.

The inlet air under pressure is caused to flow alternately into the housing below the piston 20 and the housing above the piston, to effect reciprocation of the hammer piston. A housing inlet and valve tube 78 is mounted in the sub passage 77, projecting downwardly from the sub or head 11 and into an upper elongate central piston cavity or chamber 79 above the intermediate piston wall 52, which separates the upper chamber 79 from the lower chamber 53. The tube 78 is secured in the sub by an upper external flange 80 on the tube fitting within a companion internal circumferential groove 81 in the sub. The inlet tube is made of a flexible material, such as Delrin, which permits the upper portion of the tube to be deflected inwardly of

the sub passage 77 below the circumferential groove 81, and when the flange 80 becomes aligned with the groove, the latter inherently expands outwardly into the groove to secure the tube to the sub 11. The elastic nature of the tube is such that it also provides a slidable seal with the inner walls of the piston 20, as explained hereinbelow.

The piston has an elongate upper cylindrical surface 82 opening through its upper end 46 and terminating at an inner, upper flow control piston corner 83, which is the upper end portion of an elongate internal circumferential impact passage groove 84 having a substantially larger internal diameter than the inside diameter of the upper piston portion 82. The circumferential impact passage groove 84 terminates at an intermediate inner cylindrical piston wall 85, which may have the same internal diameter as the upper cylindrical piston wall 82, the intermediate wall terminating at an internal circumferential return passage groove 86 formed in the piston and terminating at a lower flow control piston corner 87, which is the upper end of a lower internal piston seal wall portion 88 and forms a bore extending between the intermediate piston wall 52 and the corner 87. The inlet tube 78 has an upper external cylindrical sealing surface 89 relatively slidably sealable with the upper piston wall 82 and terminating in an external circumferential inlet groove 90 communicating with radial inlet ports 91 that open to the central inlet passage 92 through the tube. Below this circumferential inlet groove 90, the tube is formed with an intermediate cylindrical sealing surface section 93 slidably and sealingly engageable with the intermediate inner cylindrical piston wall 85 and also with the lower piston wall 88. In accordance with the invention and as distinguished from the structure of the aforementioned application Ser. No. 246,837, the tube and valve member 78 has a lower sealing section 88a which is of elongated cylindrical form and slidably fits in the lower bore wall 88 and in the cylindrical piston wall 85. This valve or tube section 88a has a length between its lower end 88b and an upper corner 88c greater than the axial dimension of the return groove 86. Between the corner 88c on the tube or valve section 88a and the intermediate sealing section 93, the tube has an annular groove 88d which is a return flow groove.

When the piston 20 is in its lowermost operative position, with the drill bit 21 pressed against the bottom E of the bore hole D, compressed air can flow downwardly through the inlet passage 92, discharging through ports 91, groove 84 and groove 88d, into the circumferential return passage 86 that communicates with the upper portion of one or more longitudinal return passages 95 extending downwardly through the hammer piston and opening outwardly through its lower end 96. When the hammer piston 20 moves upwardly within the housing 10 and along the inlet tube 78, the lower flow control piston corner 87 shifts upwardly over the lower flow control housing tube corner 93a to interrupt communication between the inlet passage 92 and the return passages 95, continued upward movement of the piston then placing the inner upper flow control piston corner 83 above the upper flow control piston corner 83 above the upper flow control housing tube corner 98, which then allows compressed air to flow from the inlet passage 92 through the ports 91 into the circumferential inlet groove 90 into the internal circumferential impact passage groove 84 and



thence into the housing above the upper end 46 of the piston (FIGS. 2a, 2b). At this time, the upper piston portion 50 will have moved partially above the upper housing flow control corner 31, so that the air under pressure between the upper end 46 of the piston and the housing sub or head 11 can act downwardly on the piston, urging it in a downward direction. As also seen in FIGS. 2a and 2b, the intermediate portion 93 of the tube 78 seals in the sealing wall 85 and the sealing section 88a is sealingly engaged in the bore wall 88 with the portion 88d of the tube 78 bridging the return passage 86 to prevent air from flowing through the return passages 95 to the lower end of the piston.

The piston 20 will be shifted downwardly, from the position of FIGS. 2a and 2b, until the upper flow control piston corner 83 moves below the flow control housing tube corner 98, which shuts off air pressure into the housing above the piston, the piston continuing to move downwardly, as the compressed air expands, until the outer upper flow control piston corner 50 moves below the upper housing flow control corner 31, which then permits air above the piston to pass through the passages 44 into the internal circumferential exhaust grooves 32, and through the exhaust ports 51 and exhaust passages 53, 55, 56 to the bottom of the hole below the drill bit, the hammer piston being driven against the upper face 100 of the anvil to deliver an impact blow to the impact bit C. As the piston nears the end of its downward stroke, the lower flow control piston corner 87 will move below the lower flow control housing tube corner 93a, thereby allowing the compressed air to flow from the inlet passage 92 into the upper piston cavity 79 and internal circumferential return passage groove 86, passing downwardly through the longitudinal return passages 95 to the lower end of the piston, such air then moving the piston in an upward direction, until the lower flow control piston corner 87 passes upwardly beyond the lower flow control housing tube corner 91a, once again, to shut off the flow of air into the return passages 95. When this occurs, the outer upper flow control piston corner 50 moves above the upper housing flow control corner 31 to shut off the exhaust of air from the housing region above the piston 20, the compressed air below the piston expanding and driving the hammer piston upwardly toward the head 11 of the housing. Before reaching the head 11, the inner upper flow control piston corner 83 will have shifted upwardly along the tube 78 to a position above the upper flow control housing tube corner 98, allowing air under pressure to pass from the inlet passage 92 through the impact passage grooves 90, 84 to a position in the housing above the piston 20.

The upward travel of the piston 20 is cushioned by the compression of the air remaining in the housing above the piston. However, the piston will still move upwardly sufficiently to place the lower corner 60 of the lower piston portion 40 above the housing lower flow control corner 33, which then permits the compressed air below the piston to travel into the internal circumferential exhaust groove 32 and through the exhaust ports 51 into the exhaust passages 53, 55, 56 for discharge from the drill bit. The compressed air in the housing structure above the piston then expands to drive the piston downwardly, and the foregoing cycle of operation is repeated, the piston reciprocating to deliver repeated impact blows against the anvil portion 18 of the anvil bit C, while the drill string B and the entire

apparatus A is being rotated, to insure that the drilling or cutting elements 22 will cover substantially the entire cross-sectional area of the bore hole bottom E.

When circulation of fluid to flush cuttings from the bore hole is desired, while the drill bit 21 is off bottom, elevation of the apparatus A, as seen in FIGS. 3a and 3b, will cause the impact bit C to drop downwardly along the housing until the upper anvil head 110 engages the upper ends of the keys 28. The piston 20 will also drop downwardly until its by-pass corner 62 is below the by-pass corner 35 of the housing 10, the upper corner 62 of the piston being disposed below the upper end of the internal circumferential groove 36. Accordingly, compressed air flowing downwardly through the drill string B and into the inlet passage 92 can pass through the inlet ports 91 and upwardly between the tubing and the upper seal portion 82 to a position above the piston, then flowing downwardly through the passages 44 and into the internal circumferential exhaust groove 32, flowing between the external circumferential exhaust groove 39 in the piston and the opposed lower inner cylindrical housing wall 34 into the enlarged diameter groove 36 below the inner cylindrical housing wall, then passing through the passages 63, 64, 65, 67 to the exterior of the bit 21. Since the path just described is open, and since the sealing section 88a of the tube valve 78 closes off the passage 86 which leads to the return ports 95, compressed air cannot find access below the piston 20, which might otherwise tend to cause the piston to continue reciprocating and cycling in the housing 10. It is also evident that the compressed air being pumped through the apparatus will also flow through the exhaust ports 51 and the exhaust passages 53, 55, 56 and downwardly through the anvil bit C.

When the piston 20 is on its power stroke, air will be compressed below the piston, as pointed out above, because of the sealing of the lower piston portion 40 against the lower inner cylindrical housing wall 34 and the sealing of the head portion 66 against the periphery of the anvil 18. However, air under pressure is always present within the upper central piston cavity or chamber 79, acting over the cross-sectional area W of such chamber, and continuing to exert its force to overcome the pressure acting upwardly over the piston and tending to elevate it (FIGS. 1a, 1b). Thus, the hammer piston 20 will strike its impact blow upon the upper end 100 of the anvil with a greater force, in view of the overcoming of a portion of the resisting force offered by the compressed air acting upwardly over the cross-sectional area R across the lower portion of the piston, such area existing between the periphery of the exhaust tube 54 and the lower inner cylindrical housing wall 34.

On its power stroke, the compressed air acts over the full cross-sectional area S of the upper piston portion, which is the same area as the area across the inner cylindrical housing wall 30. It is acting downwardly over the cross-sectional area of the piston between the periphery of the upper flow control tube and the upper inner cylindrical housing wall 30, and also over the area W across the central piston cavity or chamber 79. During the return stroke, the compressed air is acting upwardly over the piston over the area R, which is less than the full cross-sectional area S, but such full area is not needed for the purpose of returning the piston under comparatively little load toward the upper end of its stroke.

As described above, the exhaust tube or sleeve 54 is made of an elastic material, which is a suitable synthetic resin such as Delrin. This sleeve must make a slidable seal with the wall 53a of the piston cavity 53 to prevent or minimize leakage of air between the tube and the wall 53a. Because of manufacturing tolerances, a perfect alignment between the hammer piston 20 and the anvil 18 may not exist. Accordingly, as the piston approaches the anvil and impacts thereagainst, it imposes a lateral force on the exhaust sleeve 54. If the exhaust tube made a close fit with the wall 58c of the anvil downwardly from its upper face 100, even a small amount of misalignment between the piston 20 and the anvil would cause a high shearing stress to be imposed on the exhaust tube 54, resulting in fatigue failure of the exhaust tube after a relatively short period of use of the apparatus.

The above difficulty is overcome in the apparatus illustrated by providing relief between the exterior of the exhaust tube or sleeve 54 and the wall 58c of the anvil 18, such relief extending downwardly from the upper anvil face 100. As shown, a counterbore 58a is provided in the anvil that extends downwardly from its upper face 100 to a substantial extent, which, by way of example, is of the order of about 1 inch. In view of the counterbore, any misalignments between the piston 20 and the anvil 18 will prevent the high shearing stresses from occurring on the tube substantially in the plane of the upper face 100 of the anvil. Instead, the exhaust sleeve 54 can readily flex or bend about the base 58b of the counterbore, which acts as a fulcrum point, particularly in view of the elastic material from which the exhaust sleeve 54 is made. The bending stresses to which the tube 54 is subjected as a result of misalignment between the piston 20 and the anvil 18 are maintained at a comparatively low value, which prevents the exhaust sleeve 54 from fatigue failure.

I claim:

1. In percussion drilling apparatus: a housing structure connectable to a drill string; an anvil in the lower portion of said housing structure and operatively connectable to a drill bit; said anvil having an exhaust passage; a hammer piston reciprocable in said housing structure for intermittently impacting against said anvil, said piston having an upper passage; inlet means for directing a fluid medium under pressure into said upper passage; first passage means for directing the fluid medium from said upper passage into said housing structure above said piston upon upward movement of said piston in said housing structure for driving said hammer piston downwardly toward said anvil; second passage means for directing the fluid medium from said upper passage into said housing structure below said piston upon downward movement of said piston in said housing structure; means for alternately exhausting the fluid medium from the housing structure above and below said piston; stop means for supporting said anvil in a lower position in said housing upon elevation of said housing; means defining a fluid circulating path from the interior of said inlet means to the exterior of said housing structure when said anvil is supported by said stop means; said circulating path including the region of said housing structure around said inlet means above said piston and also said anvil exhaust passage; and valve means for closing off said second passage means when said anvil is supported by said stop means to prevent flow of the fluid medium from said upper passage

into said second passage means and into said housing structure below said piston.

2. In percussion drilling apparatus: a housing structure connectable to a drill string; an anvil in the lower portion of said housing structure and operatively connectable to a drill bit; a hammer piston reciprocable in said housing structure for intermittently impacting against said anvil, said piston having an upper passage; inlet means for directing a fluid medium under pressure into said passage; first passage means for directing the fluid medium from said passage into said housing structure above said piston upon upward movement of said piston in said housing structure for driving said hammer piston downwardly toward said anvil; second passage means for directing the fluid medium from said passage into said housing structure below said piston upon downward movement of said piston in said housing structure for elevating said piston in said housing structure; means for alternately exhausting the fluid medium from the housing structure above and below said piston; stop means for supporting said anvil in a lower position in said housing upon elevation of said housing; means defining a fluid circulating path from the interior to the exterior of said housing when said anvil is supported by said stop means; and valve means for closing off said second passage means when said anvil is supported by said stop means to prevent flow of the fluid medium from said upper passage into said second passage means and into said housing structure below said piston; the lower portion of said passage being substantially closed, whereby the fluid medium under pressure acts over substantially the full cross-sectional area of said piston in driving said piston downwardly toward said anvil.

3. In apparatus as defined in claim 1; said inlet means and piston having coengaging valve means thereon opening said first passage means and closing said second passage means upon upward movement of said piston in said housing structure and closing said first passage means and opening said second passage means upon downward movement of said piston in said housing structure.

4. In apparatus as defined in claim 1; said inlet means and piston having coengaging valve means thereon opening said first passage means and closing said second passage means upon upward movement of said piston in said housing structure and closing said first passage means and opening said second passage means upon downward movement of said piston in said housing structure; said inlet means and said piston also having said valve means for closing off said second passage means when said anvil is supported by said stop means.

5. In apparatus as defined in claim 2; said inlet means and piston having coengaging valve means thereon opening said first passage means and closing said second passage means upon upward movement of said piston in said housing structure and closing said first passage means and opening said second passage means upon downward movement of said piston in said housing structure.

6. In apparatus as defined in claim 1; said inlet means and piston having coengaging valve means thereon opening said first passage means and closing said second passage means upon upward movement of said piston in said housing structure and closing said first passage means and opening said second passage means upon downward movement of said piston in said hous-

ing structure; said exhausting means including exhaust passage means through which the exhaust fluid medium passes alternately from said housing structure above and below said hammer piston, said exhausting means further including co-engaging valve means on said piston and housing structure for controlling said alternate passage of the exhaust fluid medium.

7. In apparatus as defined in claim 1; said inlet means and piston having coengaging valve means thereon opening said first passage means and closing said second passage means upon upward movement of said piston in said housing structure and closing said first passage means and opening said second passage means upon downward movement of said piston in said housing structure; said exhausting means including exhaust passage means through which the exhaust fluid medium passes alternately from said housing structure above and below said hammer piston, said exhausting means further including coengaging valve means on said piston and housing structure for controlling said alternate passage of the exhaust fluid medium; said inlet means and said piston also having said valve means for closing off said second passage means when said anvil is supported by said stop means.

8. In apparatus as defined in claim 2; said inlet means and piston having coengaging valve means thereon opening said first passage means and closing said second passage means upon upward movement of said piston in said housing structure and closing said first passage means and opening said second passage means upon downward movement of said piston in said housing structure; said exhausting means including exhaust passage means through which the exhaust fluid medium passes alternately from said housing structure above and below said hammer piston, said exhausting means further including coengaging valve means on said piston and housing structure for controlling said alternate passage of the exhaust fluid medium; said inlet means and said piston also having said valve means for closing off said second passage means when said anvil is supported by said stop means.

9. In percussion drilling apparatus: a housing structure connectable to a drill string; an anvil in the lower portion of said housing structure and operatively connectable to a drill bit; said anvil having an exhaust passage; a hammer piston reciprocable in said housing structure for intermittently impacting against said anvil, said piston having a central upper chamber therein; an inlet tube piloted in said chamber and adapted to receive a fluid medium under pressure from the drill string and direct such fluid medium into said chamber; first passage means for directing the fluid medium from said upper chamber into said housing structure above said piston; second passage means for directing the fluid medium from said upper chamber into said housing structure below said piston; coengaging valve means on said tube and piston wall of said chamber opening said first passage means and closing said second passage means upon upward movement of said piston in said housing structure and closing said first passage means and opening said second passage means upon downward movement of said piston in said housing structure; means for alternately exhausting the fluid medium from the housing structure above and below said piston; stop means for supporting said anvil in a lower position in said housing upon elevation of said housing; means defining a fluid circulating path from

the interior of said inlet tube to the exterior of said housing structure when said anvil is supported by said stop means; said circulating path including the region of said housing structure around said inlet tube above said piston and also said exhaust passage; and valve means for closing off said second passage means when said anvil is supported by said drop means to prevent flow of the fluid medium from said upper chamber into said second passage means and into said housing structure below said piston.

10. In percussion drilling apparatus: a housing structure connectable to a drill string; an anvil in the lower portion of said housing structure and operatively connectable to a drill bit; a hammer piston reciprocable in said housing structure for intermittently impacting against said anvil, said piston having a central upper chamber therein; an inlet tube piloted in said chamber and adapted to receive a fluid medium under pressure from the drill string and direct such fluid medium into said chamber; first passage means for directing the fluid medium from said chamber into said housing structure above said piston; second passage means for directing the fluid medium from said chamber into said housing structure below said piston; coengaging valve means on said tube and piston wall of said chamber opening said first passage means and closing said second passage means upon upward movement of said piston in said housing structure and closing said first passage means and opening said second passage means upon downward movement of said piston in said housing structure; means for alternately exhausting the fluid medium from the housing structure above and below said piston; stop means for supporting said anvil in a lower position in said housing upon elevation of said housing; means defining a fluid circulating path from the interior to the exterior of said housing when said anvil is supported by said stop means; and valve means for closing off said second passage means when said anvil is supported by said stop means to prevent flow of the fluid medium from said upper chamber into said second passage means and into said housing structure below said piston; the lower portion of said chamber being substantially closed, whereby the fluid medium under pressure acts over substantially the full cross-sectional area of said piston in driving said piston downwardly toward said anvil.

11. In apparatus as defined in claim 9; the last-mentioned valve means including a valve section on said inlet tube for closing said second passage means.

12. In apparatus as defined in claim 9; said exhausting means including exhaust passage means through which the exhaust fluid medium passes alternately from said housing structure above and below said hammer piston, said exhausting means further including coengaging valve means on said piston and housing structure for controlling said alternate passage of the exhaust fluid medium; said valve means for closing said second passage means when said anvil is supported by said stop means including a valve section on said inlet tube.

13. In apparatus as defined in claim 10; said exhausting means including exhaust passage means through which the exhaust fluid medium passes alternately from said housing structure above and below said hammer piston, said exhausting means further including coengaging valve means on said piston and housing structure for controlling said alternate passage of the ex-

haust fluid medium; said valve means for closing said second passage means when said anvil is supported by said stop means including a valve section on said inlet tube.

14. In apparatus as defined in claim 9; said exhausting means including exhaust passage means through which the exhaust fluid medium passes alternately from said housing structure above and below said hammer piston, said exhausting means further including coengaging valve means on said piston and housing structure for controlling said alternate passage of the exhaust fluid medium; said exhausting means further including said anvil passage which communicates with an exhaust passage in the lower portion of said piston and communicable with said exhaust passage means under the control of said valve means on said piston and housing structure; said valve means for closing said second passage means when said anvil is supported by said stop means including a valve section on said inlet tube.

15. In an air hammer: an elongated housing, a hammer piston reciprocable in said housing, an anvil carried by said housing and having an exhaust passage, said anvil and said housing having abutment means coengageable to limit movement of said anvil inwardly with respect to said housing and stop means for limiting movement of said anvil outwardly with respect to said housing, air inlet means including a valve tube connected to said housing, said hammer piston having a bore receiving said valve tube, said hammer piston having passage means alternately opened and closed by said valve tube upon reciprocation of said hammer piston to supply and exhaust air to said housing at opposite ends of said hammer piston, said housing and said hammer piston defining therebetween an exhaust pas-

sage communicating with said housing at one end of said hammer piston, additional valve means on said tube and said hammer piston when said anvil is limited by said stop means against outward movement with respect to said housing, means defining a fluid circulation path from the interior of said valve tube to the exterior of said housing when said anvil is limited by said stop means against outward movement with respect to said housing, said circulation path including the region of said housing around said valve tube above said hammer piston and also said anvil exhaust passage.

16. In an air hammer as defined in claim 15; said valve tube having longitudinally spaced cylindrical valve sections thereon, said hammer piston having axially spaced cylindrical walls separating said passage means and sealingly engageable with said cylindrical valve section to open and close said passage means in said hammer piston.

17. In an air hammer as defined in claim 15; spline type drive means between said housing and said anvil for transmitting rotation from said housing to said anvil while allowing relative axial movement thereof.

18. In apparatus as defined in claim 1; said first passage means being provided between said inlet means and upper piston passage and opening centrally through the upper end of said upper passage into said housing structure above said piston.

19. In apparatus as defined in claim 9; said first passage means being provided between said inlet tube and upper chamber and opening centrally through the upper end of said upper chamber into said housing structure above said piston.

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UNITED STATES PATENT OFFICE  
CERTIFICATE OF CORRECTION

PATENT NO. : 3,896,886  
DATED : July 29, 1975  
INVENTOR(S) : THEODORE J. ROSCOE, JR.

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

Column 7, line 39: change "91a" to --93a--.

Column 12, line 7: change "drop" to --stop--.

Column 14, line 3: after "piston" insert --closing off the  
flow of air to the other end of said  
hammer piston--.

Signed and Sealed this  
twenty-fifth Day of November 1975

[SEAL]

*Attest:*

RUTH C. MASON  
*Attesting Officer*

C. MARSHALL DANN  
*Commissioner of Patents and Trademarks*