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Curington

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[54] DOWN-HOLE AIR HAMMER

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[52] **U.S. Cl.** **173/78,** 173/137

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

[58] **Field of Search** 173/78, 134–138

[56] **References Cited**

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[57] **ABSTRACT**

A down-hole air hammer embodying an outer housing structure connectible to a string of rotatable drill pipe through which compressed air is conducted. Upper and lower cylinder sleeves within the housing structure define an upper high pressure air annulus and a lower low or exhaust pressure annulus, the cylinder sleeves being longitudinally spaced from each other. A hammer piston reciprocates in the sleeves, having an enlarged intermediate portion slidable along the housing structure between the cylinder sleeves, there being small diameter upper and lower pistons slidable along the upper and lower cylinder sleeves, respectively, to provide a large intermediate piston area over which high pressure air can act to increase the impact force of the piston on a companion anvil secured to the drill bit rotatable by the housing structure. The high pressure air exhausts through the housing structure above the bit to provide sufficient air volume for carrying the cuttings upwardly through the annulus surrounding the drill pipe to the top of the hole being drilled.

17 Claims, 8 Drawing Figures

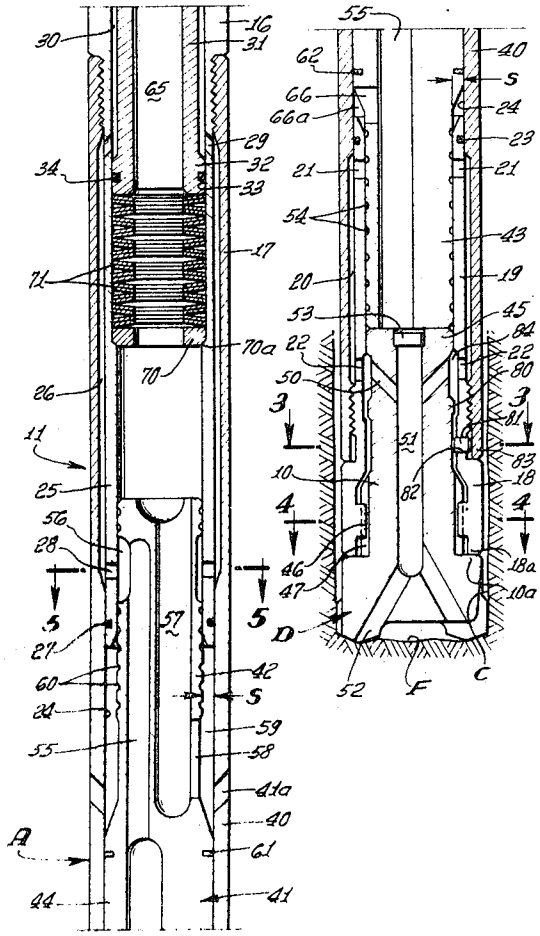


FIG. 1a.

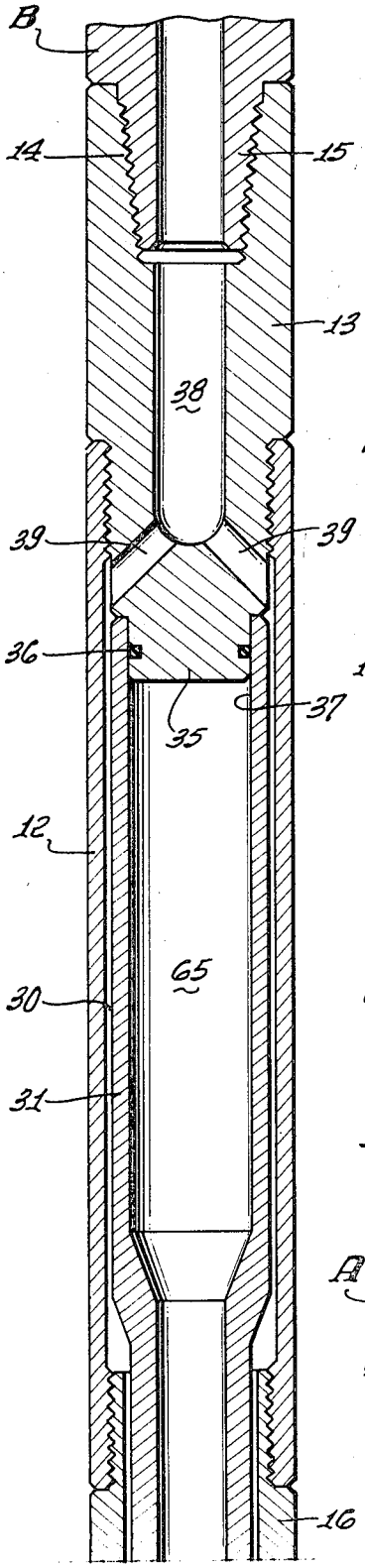


FIG. 1b.

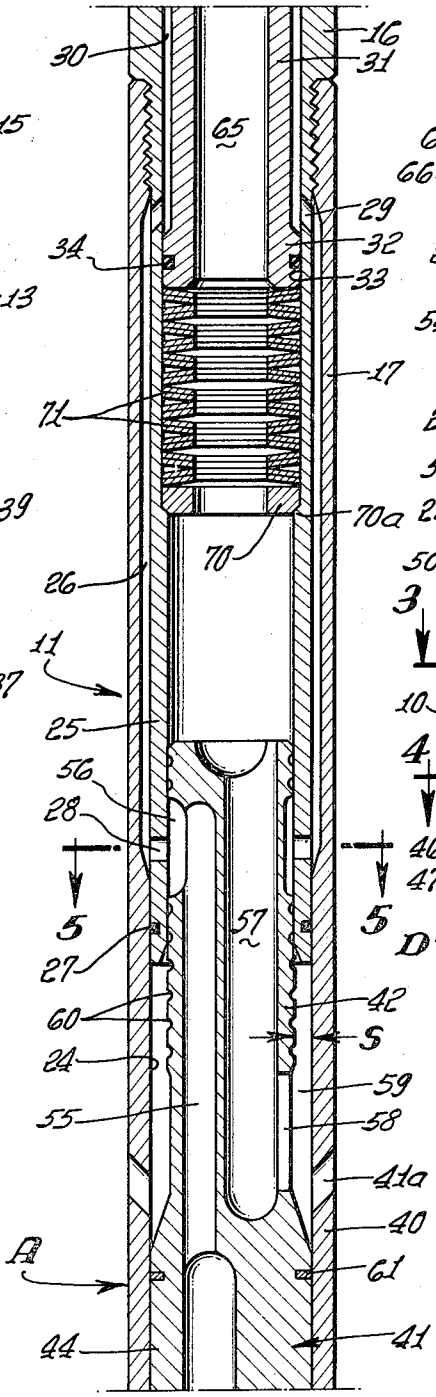
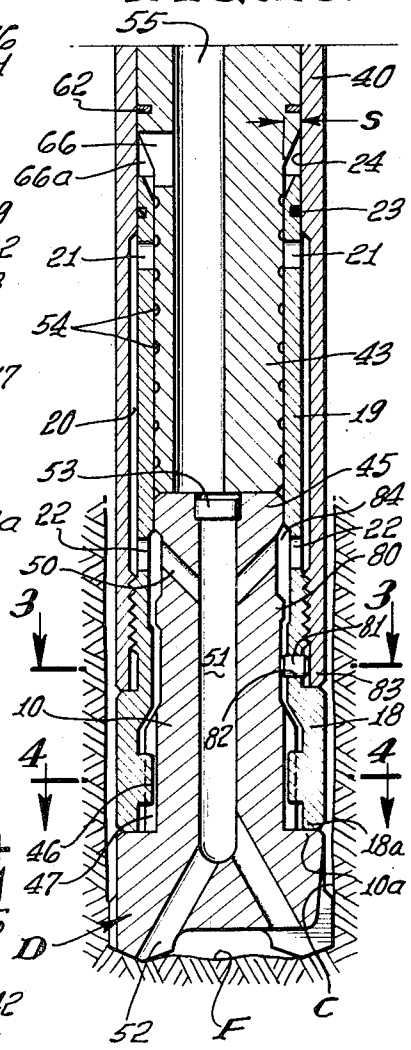


FIG. 1c.



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FIG. 2a.

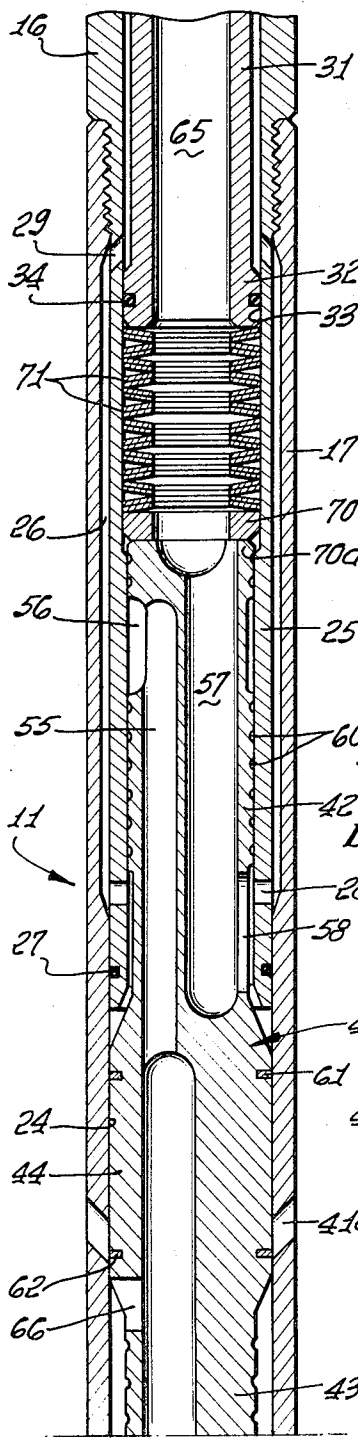


FIG. 2b.

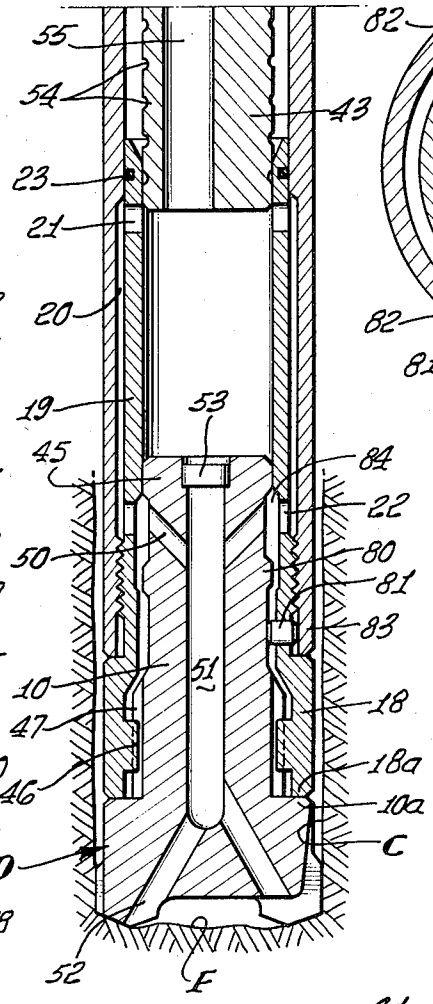


FIG. 3.

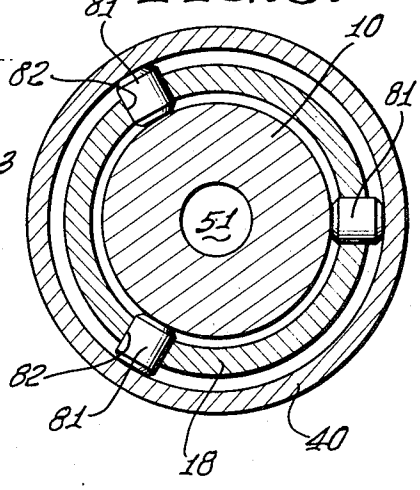


FIG. 4.

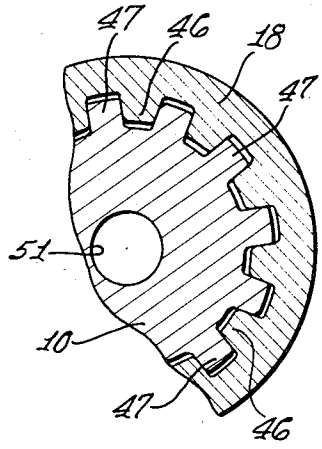
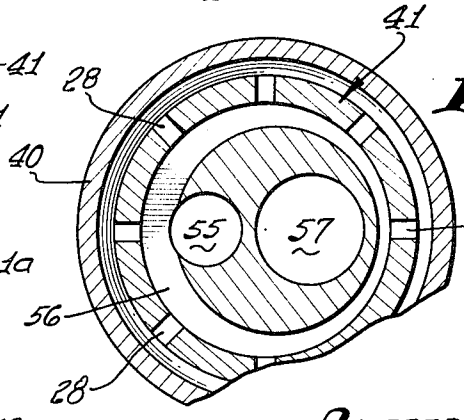


FIG. 5.



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DOWN-HOLE AIR HAMMER

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

Percussive types of drilling apparatus are known for lowering in a well bore for the purpose of drilling the hole as a result of a hammering action imposed upon a suitable bit connected to the apparatus. An improved type of drilling apparatus is illustrated in United States patent application Ser. No. 863,988, filed Oct. 6, 1969, for "Down-Hole Drilling Hammer". In drilling small diameter holes, the down-hole drilling apparatus itself must be of correspondingly small external diameter. The piston area available in such small diameter apparatus has been limited to the point that it is difficult for the apparatus to perform effectively, particularly when only relatively low air pressures are available.

Moreover, the air for effecting reciprocation of the hammer piston that impacts upon an anvil secured to the drill bit is required to pursue a circuitous path in exhausting from the apparatus, for the purpose of carrying the cuttings upwardly through the annulus surrounding the drill pipe string to which the apparatus is secured. Regardless of the path followed, the air available for each cycle of operation of the hammer piston is of restricted volume because of the relatively small area of the piston on which the compressed air acts.

By virtue of the present invention, a down-hole air hammer apparatus is provided in which the piston area on which the compressed air acts is of a much greater diameter than was heretofore available, thereby correspondingly increasing the force delivered by the piston against the anvil on its power stroke. Such increase in piston area is provided without increasing the outside diameter of the apparatus itself. Accordingly, a larger piston area is available in comparatively small diameter sizes of apparatus, making such apparatus perform more effectively, particularly under conditions in which only relatively low air pressure is available.

The apparatus also has a relatively large volume air chamber at its upper end, which permits the introduction of more high pressure air imposed on the hammer piston for its downstroke, thereby enabling more power to be developed. The use of a large diameter expansion chamber also provides more air to be exhausted from the apparatus, thereby insuring sufficient air volume to carry the cuttings upwardly out of the bore hole being drilled. In addition, a comparatively large quantity of air is exhausted directly into the bore hole annulus surrounding the apparatus, and without the necessity for passing through the anvil and out the drill bit, which avoids the necessity for the air to traverse a tortuous path before venting through the bit. Since the air can escape more readily on the downstroke of the hammer piston, a lesser quantity of air is trapped in the air chamber on the upstroke, resulting in the reduction in the air pressure trapped in the chamber on the upstroke of the hammer piston.

In general, the intermediate or center portion of the hammer piston is enlarged to slidably seal against the outer housing or cylinder of the apparatus, the upper and lower portions of the hammer piston being of smaller diameter and controlling the flow of air to opposite ends of the hammer piston in effecting its reciprocation. The power air exerted on the piston on its downstroke acts on the enlarged intermediate portion of the piston to cause the piston to impact on the anvil of the apparatus therebelow with a much greater force. The power air also exhausts directly through the enlarged outer housing into the annulus surrounding the apparatus, permitting its ready escape and minimizing the amount of air trapped above the piston on its upstroke, as noted above.

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

Referring to the drawings:

FIGS. 1*a*, 1*b* and 1*c* together constitute a longitudinal section through an apparatus embodying the invention, with parts in their relative position after the hammer piston has completed delivering an impact blow against its companion anvil and the drill bit secured thereto, FIGS. 1*b* and 1*c* being lower continuations of FIGS. 1*a* and 1*b*, respectively;

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

FIG. 3 is an enlarged cross-section taken along the line 3—3 on FIG. 1*c*;

FIG. 4 is an enlarged partial cross-section taken along the line 4—4 on FIG. 1*c*;

FIG. 5 is an enlarged cross-section taken along the line 5—5 on FIG. 1*b*.

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

The drilling hammer apparatus A includes an outer elongate housing structure **11** made of several sections or components, including an upper section **12** threadedly secured to an upper sub **13** having an upper threaded box **14** for attachment to the lower pin **15** of an adjacent drill pipe section B. The lower end of the upper section **12** is threadedly secured to an intermediate coupling section **16** which is, in turn, threadedly attached to a lower housing section **17**, the lower end of which is threadedly secured to a lower sub **18** integral with a lower cylinder sleeve **19** extending upwardly therefrom and spaced laterally from the housing to form an annular exhaust passage **20**

therewith. Upper radial exhaust ports **21** extend through the upper portion of the cylinder sleeve, establishing communication between the interior of the sleeve and the exhaust passage **20**; whereas, lower generally radial exhaust ports **22** extend through the sleeve, establishing communication between the exhaust passage **20** and the interior of the sleeve **19**. The upper portion of the lower sleeve carries a suitable side seal ring **23** thereon sealing against the inner wall **24** of the lower housing section **17** immediately above the annular exhaust passage **20**.

An upper cylinder sleeve **25** is integral with an extends downwardly from the intermediate coupling section **16** within the lower housing section **17**, being laterally spaced therefrom to provide a high pressure annular air passage **26** therebetween. The lower end of this sleeve **25** carries a suitable side seal ring **27** sealing against the wall **24** of the lower housing section, the cylinder sleeve having a plurality of lower radial inlet ports **28** establishing communication between the high pressure air passage **26** and the interior of the upper sleeve, and also having upper ports **29** establishing communication between the upper end of the annular passage **26** and the lower end of an annular inlet passage **30** formed between an inner tubular member or sleeve **31** having a head **32** engaging the inner wall **33** of the upper sleeve below its ports **29**, and sealed thereagainst by a suitable elastomer head seal **34** also engaging the wall of the sleeve **25**. The tubular member **31** is elongate, extending upwardly through the coupling **16** and to the upper portion of the upper housing section **12**, encompassing a lower head **35** of the upper sub **13**, against which it is sealed by a suitable elastomer side seal member **36** on the head engaging the wall **37** of the inner tubular member **31**.

Compressed air pumped downwardly through the tubular string B can enter a central passage **38** through the upper sub, which communicates with side ports **39** in the sub opening into the upper end of the annular inlet passage **30**, such air being capable of passing through the upper ports **29** in the upper cylinder sleeve **25** into the high pressure passage **26**, and then through the inlet ports **28** at the lower portion of the sleeve **25**.

It is to be noted that the upper and lower cylinder sleeves **25**, **19** are longitudinally spaced from one another to a substantial extent, allowing a cylinder portion **40** of the lower housing section to be provided therebetween of a substantially greater inside diameter than the inside diameters of the upper and lower cylinder sleeves, discharge or exhaust ports **41a** extending through the larger diameter cylinder **40** and establishing communication between its interior and the exterior of the housing **11**.

A hammer piston **41** is reciprocable within the upper and lower cylinders **25**, **19** and the intermediate, larger diameter cylinder member **40** therebetween. This piston includes an upper piston portion **42** slidable longitudinally in the upper cylinder sleeve **25**, a lower piston portion **43** slidable longitudinally in the lower cylinder sleeve **19**, and an enlarged intermediate piston portion **44** integral with such upper and lower piston portions and slidable along the inner wall **24** of the enlarged cylinder. The piston **41** is adapted to be shifted downwardly to deliver an impact blow against the upper impact head **45** of the anvil **10** mounted within the lower cylinder sleeve **19** and lower sub **18**, this anvil being integral with the drill bit D, or other wise suitably secured thereto. The anvil makes a spline connection with the lower sub **18**, to permit longitudinal movement of the anvil and bit with respect to the lower sub **18**, and also to enable the rotary motion of the drill pipe B to be transmitted through the upper sub **13** and housing **11** to the lower housing sub **18**, and then to the anvil **10** and drill bit D. As specifically shown, the anvil connection is provided by inwardly extending circumferentially spaced splines **46** on the lower sub slidably meshing with companion splines **47** on the anvil.

When the drill bit D engages the bottom F of the hole and the housing **11** and its lower sub **18** are disposed in a downward position with respect to the anvil and bit, as determined by engagement of the lower end **18***a* of the lower sub with an upwardly facing shoulder **10***a* on the anvil, the impact head **45** is disposed within the lower cylinder sleeve **19** above its ports **22**, making a close fit therewith. At this time, when the piston **41** has been disposed in its uppermost position within the housing and sleeves **25**, **19** (FIGS. **2***a*, **2***b*), compressed air can exhaust through the upper ports **21** into the exhaust annulus **20**, and then through the lower ports **22** to the interior of the sleeve **19**, such air continuing to flow through inlet ports **50** in the upper portion of the anvil into its central passage **51**, discharging through lower nozzles or passages **52** in the drill bit against the bottom F of the bore hole C to clean the bottom of cuttings, clean the bit D, and convey such cuttings around the drill bit and upwardly through the annulus surrounding the housing **11**, and the annulus surrounding the drill pipe B to the top of the bore hole. The upper end of the central passage **51** is closed by a suitable plug **53**.

The lower piston portion **43** has suitable seal means on its periphery for sealing against the inner wall of the lower cylinder sleeve. As illustrated, such seal means may take the form of a labyrinth seal provided by a series of circumferential external grooves **54** in the piston in which air will be trapped. When the piston is in its lowermost position against the impact head, the seals **54** extend from a location above the lower exhaust ports **22** to a location above the upper exhaust ports **21**. The piston has a longitudinal hammer return passage **55** extending therewithin from its lower end and into communication with an upper annular inlet groove **56**, which will be in registry with the inlet ports **28** when the hammer piston is in its lowermost position (FIGS. **1***a*–**1***c*). The piston also has a longitudinal impact passage **57** in its upper small diameter portion extending from the upper end of the piston and communicating with an elongate lower side port **58** which opens into the annular space **59** between the small diameter piston **42** and the enlarged cylinder **40** when the piston is in its lower position. The small diameter upper piston portion **42** has suitable seal means **60** thereon on opposite sides of its inlet groove **56** which can assume any desirable form. As shown, labyrinth seal grooves **60** are provided capable of trapping air and sealing against the inner wall of the upper cylinder sleeve **25**.

The enlarged intermediate piston portion **44** slidably seals against the wall **24** of the enlarged cylinder **40**. This intermediate piston portion carries an upper seal ring **61**, such as a piston ring, therein near its upper

portion and a lower piston ring **62** at its lower portion, so as to prevent leakage along the enlarged hammer piston portion **44**.

When the hammer piston **41** is in its lowermost position, as illustrated in FIGS. **1***b* and **1***c*, the lower piston portion **43** closes the upper exhaust ports **21**, but its upper annular groove **56** is aligned with the inlet ports **28**, its labyrinth seals **60** being disposed on opposite sides of the latter. The enlarged piston portion **44** seals against the enlarged cylinder **40** below the discharge ports **41***a*. When the piston is in the position illustrated in FIGS. **1***b* and **1***c*, air in the cylinder space or chamber **65** within the upper tubular member **31** and in the upper cylinder sleeve **25** above the piston will have exhausted through the impact passage **57** and its side port **58** into the enlarged cylinder **40**, and through its discharge or exhaust ports **41***a* into the bore hole surrounding the apparatus. At this time, compressed air can pass from the inlet ports **28** into the annular groove **56**, and then into the hammer return passage **55** to its lower end, acting upon the lower end area of the smaller diameter piston **43** to shift the piston **41** upwardly in the housing and the cylinder sleeve away from the anvil **10**. Such air under pressure can also pass through a side port **66** communicating with the return hammer passage **55** into the annular space **66***a* above the lower cylinder sleeve **19** and below the enlarged piston portion **44**, acting on the annular area S of the hammer piston and assisting in shifting the piston to its upper position.

The hammer piston moves only a short distance on its upward or return stroke before the labyrinth seals **60** below its annular groove **56** close the inlet ports **28**, the compressed air introduced through the hammer return passage **55** continuing to expand, driving the hammer piston **41** upwardly until its upper end impacts against a lower spring seat **70** engaged by a plurality of spring discs **71**, such as Belleville springs, the upper end of which bear against the lower head **32** of the upper tubular member **31**, which functions as an upper spring seat. The kinetic energy in the hammer piston **41** is transferred to the springs **71**, and also to the air trapped in the chamber **65** above the piston, which it is compressing.

Near the top of the hammer piston stroke, the impact passage side port **58** is placed in communication with the inlet ports **28**, the seal ring **61** on the enlarged piston portion **44** sealing against the enlarged cylinder wall **24** above the discharge ports **41***a* and the labyrinth seals **60** above the side port **58** sealingly engaging the upper cylinder sleeve **25** above the inlet ports **28** (FIG. **2***a*). As a result, compressed air flows from the annular passage **30** through the ports **28** into the impact passage **57** to the upper end of the piston **41**, forcing the piston downwardly, aided by the energy stored in the Belleville springs **71** and the compressed air in the cylinder space **65**. Because of the large length and volume of the cylinder space, a large quantity of air under pressure is introduced through the impact passage **57** into the chamber **65**, such compressed air shifting the hammer piston **41** downwardly, the inlet ports **28** being closed off after a relatively short downward movement of the piston, because of the sealing action of the labyrinth seals **60** against the wall of the upper cylinder sleeve **25** below the inlet ports **28**. However, the compressed air above the piston expands and propels the hammer piston **41** downwardly, causing it to impact against the anvil head **45**, such impact blow being delivered through the drill bit D to the bottom F of the bore hole. During the downstroke of the hammer piston **41**, when the upper seal **61** on the enlarged hammer piston portion **44** moves below the discharge ports **41***a*, the air above the impact piston can exhaust through the impact passage **57**, its side port **58**, and the housing discharge ports **41***a* into the annulus surrounding the housing **11**, to convey the cuttings upwardly around the apparatus and through the annulus surrounding the string of drill pipe B to the top of the bore hole.

Immediately prior to the hammer piston impacting against the anvil head **45**, the annular piston groove **56** moves into communication with the inlet ports **28**, the compressed air passing through the return passage **55** to the bottom of the piston and into the annular space below the enlarged piston portion **44**, to return the piston **41** to its upper position. The foregoing cycle is then repeated.

It should be noted that when the hammer piston **41** is at the upper end of its stroke, its lower end is disposed above the upper exhaust ports **21** in the lower cylinder sleeves **19** (FIG. **2***a* **2***b*), allowing the compressed air in the lower cylinder sleeve **19** below the piston and in the annular space **66***a* to pass through the upper exhaust ports **21** into the annular exhaust passage **20**, from where the air will flow through the lower ports **22** into the anvil passage **50**, **51**, and then out through the bit nozzles **52** to clean the bottom F of cuttings and to maintain the drill bit in a clean and cool condition.

The area available over which the compressed air acts on the downstroke or power stroke of the piston is the full cross-sectional area of the small diameter upper piston portion **42** plus the annular area S of the intermediate piston portion **44** between the small diameter piston portion and the wall **24** of the large cylinder **40**. In other words, the annular area available for delivery on the power stroke is the full cross-sectional area of the enlarged intermediate piston portion **44**, or the area across the inner wall **24** of the larger cylinder. A corresponding area is available for propelling the hammer piston **41** upwardly on its return stroke. The large areas over which compressed air can act is much greater than would be available if the hammer piston were made of a uniform diameter throughout its length, in view of the restrictions imposed within the housing by the upper and lower cylinder sleeves **25**, **19**. Because of the availability of the much greater piston area on which the compressed air can act, more power is imparted to the piston, such that even when relatively low air pressures only are available, sufficient kinetic energy can be imparted to the piston to cause it to deliver an effective impact blow upon the anvil **10** and the bit D attached thereto. In addition to the larger piston area that is provided in the apparatus, the large volume of the cylinder space or chamber **65** above the piston permits the introduction of more high pressure air into the apparatus for action upon the piston on its downstroke, permitting more power to be developed, since the compressed air does not reduce in pressure to as great an extent during the downstroke of the hammer piston and before the air can exhaust through the ports **41***a*.

The discharge of the compressed air upon the downstroke of the hammer piston through the discharge ports **41***a* provides a direct travel path for the air into the bore hole for lifting the cuttings to the top of the hole, such air being provided in a comparatively large volume. Such air need not traverse a circuitous path, as is necessary for the compressed air below the piston **41** to follow at the end of the piston upstroke, which enhances the efficiency of the apparatus. Particularly in air hammers of small size, the direct exhaust of the power air into the annulus surrounding the apparatus insures a sufficient air volume for carrying the the cuttings out of the bore hole. The required volumes of air are difficult to provide in prior air hammers of small diameter. The elimination of the necessity for a large portion of the exhaust air to traverse a tortuous path insures a rapid escape of the power air and, therefore, results in less air being trapped in the cylinder **25** and chamber **65** above the piston upon its upstroke, so that the piston on its upstroke need perform less work in compressing air trapped thereabove.

The apparatus illustrates the Belleville or annular, tapered disc springs in which the energy of the hammer piston **41** is stored on its upstroke, and which returns the energy to the piston on its downstroke, the downward expansion of the stack of disc springs being limited by engagement of its lower seat **70** with an upwardly facing shoulder **70a** formed in the upper cylinder sleeve. Apparatus embodying the conical spring arrangement is both described and claimed in the application of Alfred R. Curington, Ser. No. 100,887, filed Dec. 23, 1970, for "High Frequency Pneumatically Actuated Drilling Hammer"

The apparatus is rendered inoperable unless the bit D is resting upon the bottom F of the hole C, with a required amount of drilling weight imposed upon it by the drill pipe B. When the drill pipe is elevated to raise the bit from the bottom of the hole, the anvil **10** and bit D drop downwardly, as permitted by the telescoping of the anvil **10** within the lower sub **18**, until an external anvil flange **80** engages a plurality of circumferentially spaced limit pins **81** extending through bores **82** in the lower sub **18** and held in an inward position by a depending skirt **83** of the lower housing section **17**. Such lower positioning of the anvil permits the piston to drop downwardly within the upper and lower cylinder sleeves **25, 19** and intermediate larger cylinder **40** to a position determined by engagement of the enlarged piston portion **44** with the upper end of the lower cylinder sleeve **19**, at which time the annular groove **56** of the piston still communicates with the inlet ports **28**, the impact head being disposed in an enlarged internal diameter portion **84** of the lower cylinder sleeve, such that compressed air can be pumped through the apparatus and through the hammer return passage **55**, discharging from the lower end of the piston and passing around the impact head **45** for continued flow through the ports **50** into the central passage **51** of the anvil and out through the bit nozzles **52**, With the parts in this position, compressed air can be pumped continuously through the apparatus to clean the bit D of cuttings and impart a circulating action upwardly through the annulus surrounding the apparatus A and the drill pipe B to the top of the bore hole. It is only when drilling weight is imparted to the drill bit, with the housing structure **11** telescoped downwardly over the anvil **10**, to hold the drill bit D against the bottom F of the bore hole, that the apparatus becomes operative.

I CLAIM:

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

2. In apparatus as defined in claim **1**; said structure having discharge ports communicating with the interior of said second cylinder through which fluid medium exhausts directly to the exterior of said structure after downward movement of said hammer piston along said first and second cylinders.

3. In apparatus as defined in claim **1**; said second cylinder having discharge ports controlled by said lower piston portion through which fluid medium in said first cylinder above said upper piston portion and fluid medium in said second cylinder exhaust after downward movement of said hammer piston along said first and second cylinders.

4. In apparatus as defined in claim **1**; said hammer piston shifting in said first and second cylinders to alternately control flow of the fluid medium into said lower portion of said housing structure and said first and second cylinders.

5. In apparatus as defined in claim **1**; said hammer piston shifting in said first and second cylinders to alternately control flow of the fluid medium into said first and second cylinders and said lower portion of said housing structure; and means for alternately exhausting the fluid medium from said first and second cylinders and said lower portion of said housing structure.

6. In apparatus as defined in claim **1**; said hammer piston shifting in said first and second cylinders to alternatively control flow of the fluid medium into said first and second cylinders and said lower portion of said housing structure; said housing structure having discharge ports communicating with the interior of said second cylinder through which fluid medium exhausts after downward movement of said hammer piston along said first and second cylinders; and means for exhausting the fluid medium from said lower portion of said housing structure after upward movement of said hammer piston in said housing structure.

7. In apparatus as defined in claim 1; said hammer piston shifting in said first and second cylinders to alternately control flow of the fluid medium into said lower portion of said housing structure and said first and second cylinders; said second cylinder having discharge ports controlled by said lower piston portion through which fluid medium in said first cylinder above said upper piston portion and fluid medium in said second cylinder exhaust after downward movement of said hammer piston along said first and second cylinders; and means for exhausting the fluid medium from said lower portion of said housing structure after upward movement of said hammer piston in said housing structure.

8. In percussion drilling apparatus: a housing structure connectible to a drill string; an anvil in the lower portion of said housing structure and connectible to a drill bit; said housing structure including an upper cylinder, a lower cylinder, and an intermediate cylinder therebetween of greater internal diameter than the diameters of said upper and lower cylinders; a hammer piston reciprocable in all of said cylinders for intermittently impacting against said anvil, said piston having upper and lower portions slidably reciprocable in said upper and lower cylinders, respectively, in sealed relation thereto to and an intermediate portion of greater diameter than said upper and lower piston portions slidably reciprocable in said intermediate cylinder in sealed relation thereto; said upper piston portion having an effective cross-sectional area substantially equal to the internal cross-sectional area of said upper cylinder; means for directing a fluid medium under pressure into said upper cylinder above said upper piston portion for action upon the full effective cross-sectional area of said upper piston portion and into said intermediate cylinder above said intermediate piston portion for driving said hammer piston downwardly toward said anvil, and 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.

9. In apparatus as defined in claim 8; said last-mentioned means directing the fluid medium under pressure into said lower cylinder below said lower piston portion.

10. In apparatus as defined in claim 8; said last-mentioned means directing the fluid medium under pressure into said lower cylinder below said lower piston portion and into said intermediate cylinder below said intermediate piston portion.

11. In apparatus as defined in claim 8; said intermediate cylinder having discharge ports controlled by said intermediate piston portion through which fluid medium in said upper cylinder above said upper portion and fluid medium in said intermediate cylinder exhaust after downward movement of said hammer piston along said upper, intermediate and lower cylinders.

12. In apparatus as defined in claim 8; said hammer piston shifting in said cylinders to alternately control flow of the fluid medium into said upper and intermediate cylinders and said lower portion of said housing structure.

13. In apparatus as defined in claim 8; said last-mentioned means directing the fluid medium under pressure into said lower cylinder below said lower piston portion; said hammer piston shifting in said cylinders to alternately control flow of the fluid medium into said upper and intermediate cylinders and lower cylinder.

14. In apparatus as defined in claim 8; said last-mentioned means directing the fluid medium under pressure into said lower cylinder below said lower piston portion; said hammer piston shifting in said cylinders to alternately control flow of the fluid medium into said upper and intermediate cylinders and lower cylinder; said intermediate cylinder having discharge ports controlled by said intermediate piston portion through which fluid medium in said upper cylinder above said upper piston portion and fluid medium in said intermediate cylinder exhaust after downward movement of said hammer piston along said upper, intermediate and lower cylinders; and means controlled by said lower piston portion for exhausting the fluid medium from said lower cylinder after upward movement of said hammer piston in said upper, intermediate and lower cylinders.

15. In percussion drilling apparatus: an outer housing structure connectible to a drill string; an upper cylinder in said housing structure and forming therewith an upper high fluid pressure passage; a lower cylinder in said housing structure spaced longitudinally below said upper cylinder and forming with said structure a lower fluid pressure passage; said housing structure providing an intermediate cylinder between said upper and lower cylinders of a substantially greater internal diameter than the internal diameters of said upper and lower cylinders; an anvil extending into the lower portion of said lower cylinder to close the same; a hammer piston reciprocable in all of said cylinders for intermittently impacting against said anvil; said upper cylinder having an inlet port through which fluid may flow from said upper passage into said upper cylinder; said lower cylinder having an exhaust port through which fluid may flow from said lower cylinder to said lower passage; said piston including upper and lower small diameter piston portions reciprocable in said upper and lower cylinders, respectively, and an intermediate large diameter piston portion reciprocable in said intermediate cylinder; said intermediate cylinder having discharge ports communicating the interior of said intermediate cylinder with the exterior of the housing structure; said piston having an impact passage communicating with said upper cylinder above said upper piston and intermediate cylinder and its discharge ports when said piston is in a lower position in said cylinders, said impact passage communicating with said upper cylinder above said upper piston and with said upper passage when said piston is in an upper position in said cylinders, at which time said intermediate portion closes said discharge ports; said piston having a return passage communicating with said lower cylinder below said lower piston portion and with said upper passage when said piston is in a lower position in said cylinder; said lower piston portion closing said lower passage when said piston is in a lower position in said cylinders and opening said lower passage to the interior of said lower cylinder when said piston is in an upper position in said cylinders.

16. In apparatus as defined in claim 15; said lower piston portion having a side port establishing fluid communication between said return passage and intermediate cylinder below said large piston portion.

17. In apparatus as defined in claim 15; and passage means in said anvil communicating with said lower passage to conduct fluid medium to the drill bit.

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