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Harris et al.

[11] **4,333,537**

[45] **Jun. 8, 1982**

[54] **IMPACT DRILLING TOOL HAVING IMPROVED VALVING**

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Related U.S. Application Data

[63] Continuation of Ser. No. 963,221, Nov. 24, 1978, abandoned.

[51] **Int. Cl.**³ **B25D 9/12;** F01L 21/02

[52] **U.S. Cl.** **173/17;** 173/78; 173/80; 91/234

[58] **Field of Search** 173/17, 73, 78, 80, 173/136; 91/234

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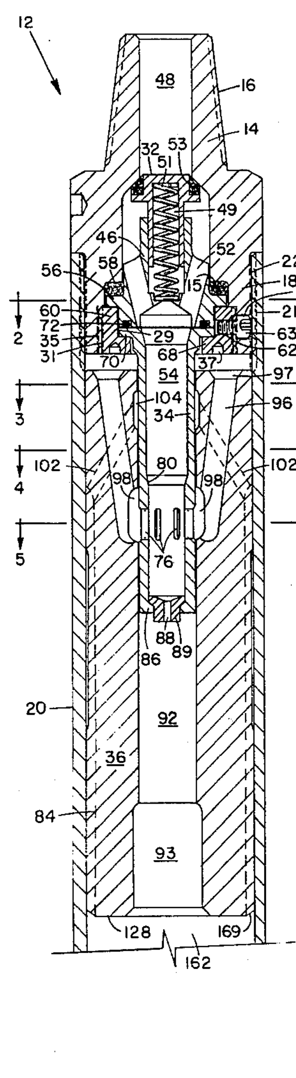
Primary Examiner—Wm. Carter Reynolds
Attorney, Agent, or Firm—Gunn, Lee & Jackson

[57] **ABSTRACT**

The device described contains a pneumatically operated hammer, a feeder controlling the flow of pneumatic fluid, an anvil which is struck repeatedly by the hammer, a drill bit attached to or integral with the lower end of the anvil, and an outer casing. The device is typically used as a down hole tool in rotary drilling operations and normally utilizes pressurized air as its pneumatic fluid. The pneumatic fluid first lifts the hammer above the anvil and second pushes the hammer downward to impact against the anvil in a striking movement. Simultaneous with striking, the pneumatic fluid above the hammer is expelled through an exhauster retained in the anvil and out through the drill bit where it is utilized to transport the cuttings from the hole being drilled. The feeder operates in conjunction with the hammer to control pressurization above and below the hammer, while exhaust above the hammer is controlled by the lower end of said feeder tube.

4 Claims, 9 Drawing Figures



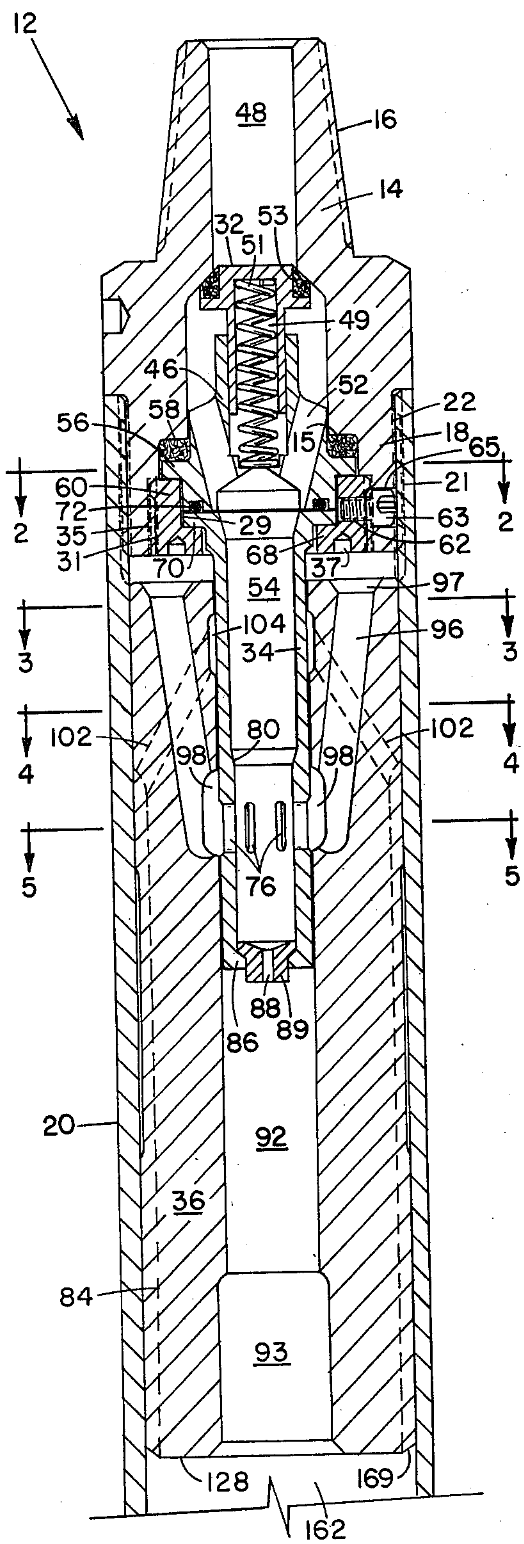

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FIG. 1a

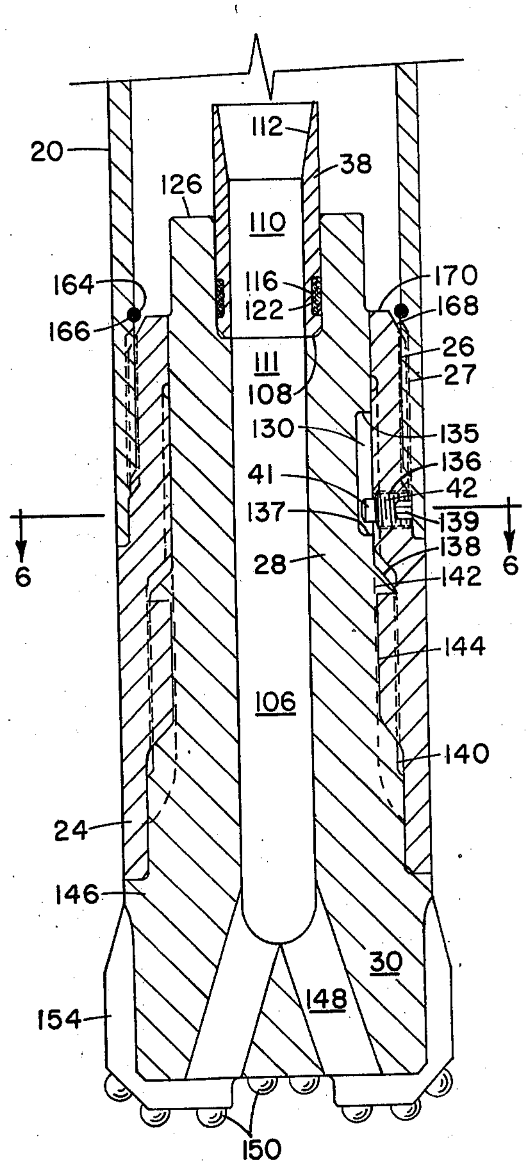
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FIG. 1b

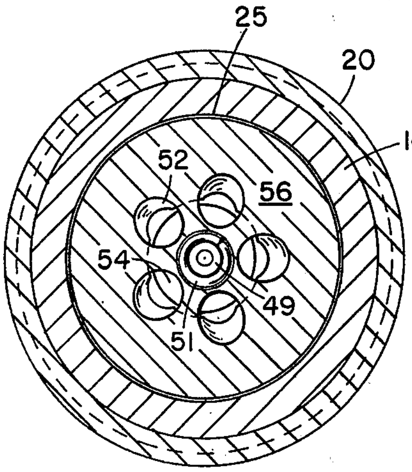

FIG. 2

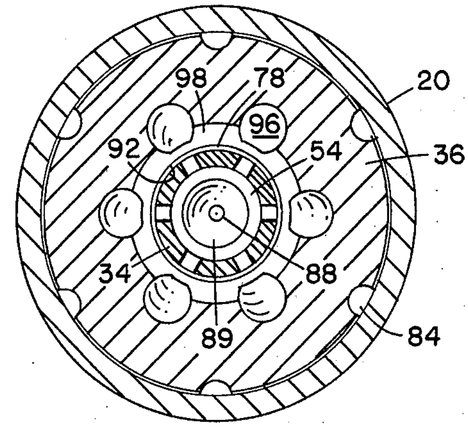

FIG. 5

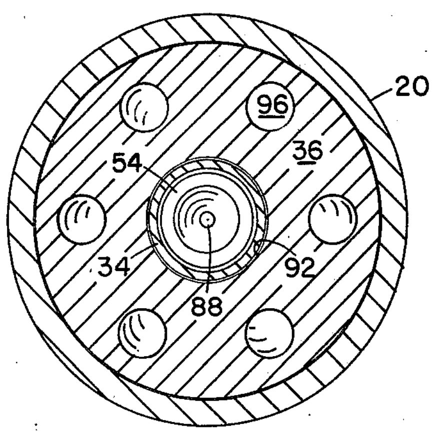

FIG. 3

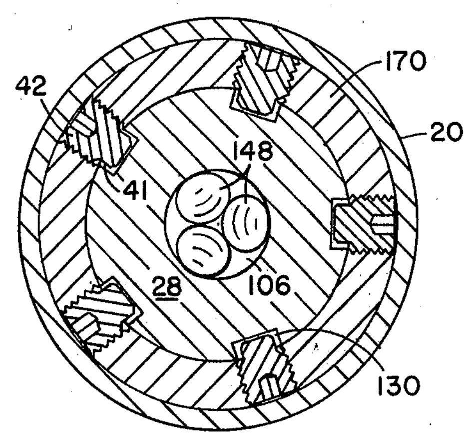

FIG. 6

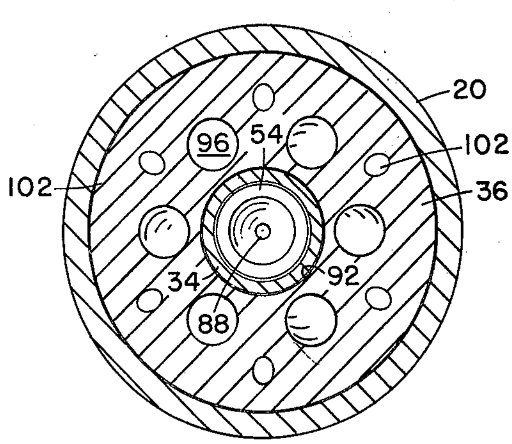

FIG. 4

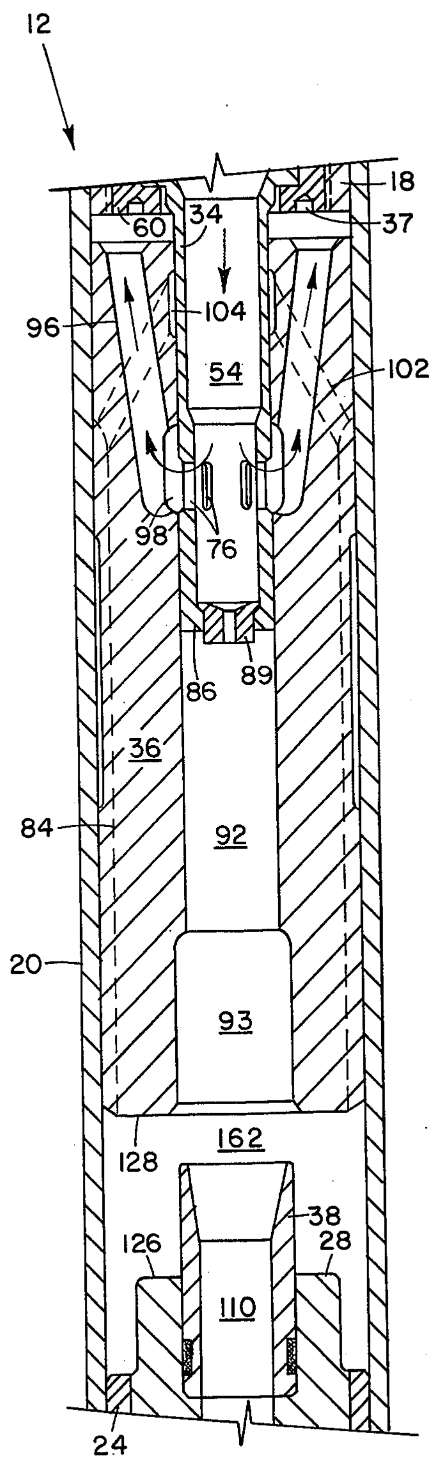
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FIG. 7

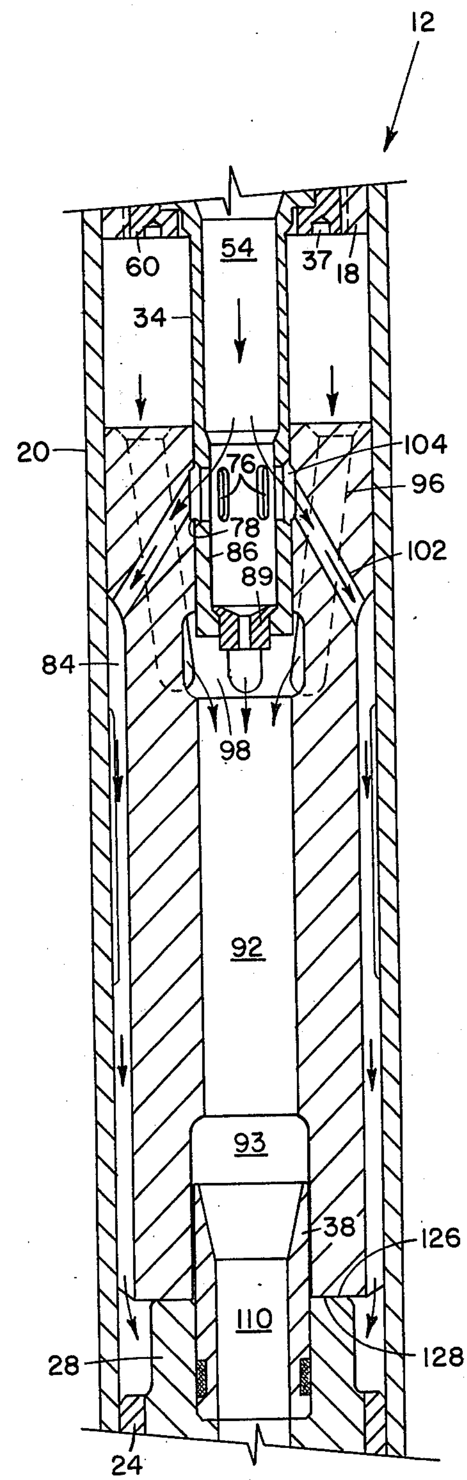
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FIG. 8

IMPACT DRILLING TOOL HAVING IMPROVED VALVING

This is a continuation, of application Ser. No. 963,221 filed Nov. 24, 1978 now abandoned.

BACKGROUND OF THE INVENTION

This invention relates to pneumatically operated impact drilling tools for rotary drilling having an improved system of valving.

There are currently many pneumatic impact drilling tools used in the field. A typical such device is disclosed in U.S. Pat. No. 3,964,551 which patent is hereby incorporated by reference.

The importance of simplicity and durability of construction in a pneumatic impact drilling tool cannot be overemphasized. The expenses involved in maintaining drilling rigs, paying skilled crews, and other time-related expenses, make it mandatory that "down-time" be held to an absolute minimum. A second essential consideration in drilling tool design is drilling rate (feet of hole drilled per unit time). This is basically related to the force of each individual hammer impact, and the frequency with which they occur.

Another prospect for time savings lies in the area of maintenance procedures; tool design should eliminate maintenance wherever possible. Required procedures, such as changing worn out drilling bits, need to be simple and fast.

Manufacturing cost is also important to a designer of down hole drilling tools, in that use of exotic materials and/or manufacturing procedures might price an otherwise satisfactory tool out of the market.

There is a constant need in the impact drilling industry for improvement in any or all of the aforementioned areas (reliability, drilling rate, maintenance, cost). Significant contributions in one or more will improve the performance of the industry and help in the economic utilization of our natural resources.

BRIEF DESCRIPTION OF THE PRIOR ART

In the incorporated reference, the prior art was discussed in great detail. Therefore, the present description of the prior art will be limited to that not covered in the incorporated reference.

The chief objective in pneumatic impact drilling tools is to provide high intensity impacts upon the drill bit while maximizing the frequency of such impacts. Normally, a hammer and anvil type of arrangement is used, the anvil being connected to the drill bit and the hammer being first lifted upward and then pushed downward by a pressurized fluid. Means for increasing impact against the drill bit include increasing the upper surface area of the hammer so that the pressurized fluid acts against more area and/or increasing the effective stroke length. This must be done within the cross-sectional area limited by the size of hole being drilled.

An example of such a pneumatically operated drill bit is shown in the incorporated U.S. Pat. No. 3,964,551. The device disclosed therein has a central feeder element around which a reciprocating hammer is located. The hammer also serves as a slidable valve means to close passages from the feeder element. This valving action controls the pressurized fluid for pressurization above the hammer, pressurization below the hammer, and exhaust from above the hammer. Exhaust from below the hammer is controlled by a slidable valve means consisting of the hammer slidably receiving an exhauster located in the anvil into a center bore of the hammer.

The feeder element of the device disclosed in U.S. Pat. No. 3,964,551 extends from a point above the hammer down to a point just above the anvil. This is necessary to accommodate separate passages within the feeder element for valving. Because the feeder element is extremely long and has thin cross-sectional areas, stresses which are created within the feeder element during the impact drilling operation may eventually cause metal fatigue and failure of the feeder element. The feeder element of the incorporated reference is expensive to manufacture because the tolerances for such a feeder element are very precise, and also because of the complexity of the many different cuts and bores therethrough.

A major problem with any type of "downhole" tool is that of limited space. The device must be capable of performing within the confines of the internal radius of the casing within which the device is enclosed. In U.S. Pat. No. 3,964,551, the feeder element must be wide enough to accommodate at least two longitudinal bores within the feeder element, one for pressurization and one for exhaust. Further, it must be sturdy enough to withstand the stresses caused in part by the length of the feeder element as discussed above. The large diameter thus required for the feeder element reduces the space available within the casing for the hammer. This reduced size of the hammer directly results in less impact being delivered against the anvil by the hammer during operation. Loss of impact occurs partly because the hammer is lighter than it would be if it had a greater cross-sectional area; but more importantly, because the reduced space available for the hammer reduces the upper surface area of the hammer available for generating force by means of pressure from the pressurized fluid.

The feeder element merely transfers the pressurized fluid to the proper cavities above and below the hammer. It is the hammer which is the real working element of the drilling impact tool. Thus, due to the reduced space available for the hammer, the device disclosed in the incorporated reference is less efficient than the device as described herein, which provides a hammer with a greater cross-sectional area.

Further, the method of retaining the anvil in U.S. Pat. No. 3,964,551 is awkward in many respects. Five separate components—two retainer ring halves, an O-ring, a lower sub, and an anvil guide—are used to retain the anvil. There is a need to simplify the drilling tool at this point both because the many separate small parts complicate servicing the drilling tool, and because the violent jarring of the anvil may cause such delicate parts to wear and eventually to fail under downhole conditions. Also, due to the limited extension of the lower sub within the casing, requiring the use of a separate part (the anvil guide ring) to position the top of the anvil, this design does not allow the anvil and its mating parts to develop either strength or alignment to the fullest.

SUMMARY OF THE INVENTION

A hammer is slidably located about a central feeder element, both of which are retained within a casing. Due to pressure created by a pressurized fluid below the hammer, the hammer is pushed upward. Thereafter, due to pressure created by a pressurized fluid above the hammer, the hammer is pushed downward so that the hammer strikes an anvil. Since the anvil is attached to a drill bit, the reciprocating motion of the hammer provides for repeated sharp blows by the drill bit against the medium being drilled. The pressurized fluid alternately utilized below and then above the hammer is conducted through or around the feeder element and through hammer passages to the respective cavities above and below the hammer. The feeder element contains only one central flow passage, with a single level of openings in its side wall. Thus, even though it has a significantly reduced cross-section with respect to the referenced patent, its capacity to deliver pressurized fluid is greater.

Control of the flow of pressurized fluid to the upper and lower hammer actuating areas is provided by slidable valve means consisting of the single feeder side-port passage and hammer passages which, due to the slidable relationship of the feeder element and the hammer, are opened and closed by the reciprocation of the hammer. Exhaust of pressurized fluid from above the hammer is also controlled by slide-valve action of the feeder, exhaust from the hammer passage occuring entirely below the lowermost end of the feeder.

The presently disclosed invention utilizes a feeder element which is shorter, narrower, simpler and sturdier than prior feeder elements. As a result, stress effects upon the feeder element are less severe, more room for the hammer is provided, the expense of manufacturing the device is lessened, and down hole failure minimized.

The present invention also offers a unique method of joining the anvil, a lower sub, and the casing in a combination such that the elements cooperate to provide maximum structural support for each other.

It is an object of the present invention to provide a pneumatically actuated impact tool for rotary drilling that provides the maximum space possible for a hammer contained therein.

It is another object of the present invention to provide the maximum upper cross-sectional area for the hammer in order to allow for the greatest possible force to be generated by the pressurized fluid against the hammer element.

It is yet another object of the present invention to provide a pneumatically actuated tool at a minimum expense of production due to utilizing fewer and simpler parts, which parts may be manufactured within greater tolerance limits than previous designs have allowed.

It is yet another object of the present invention to provide a pneumatically actuated tool which is structurally designed to endure for a maximum period of time under downhole working conditions.

It is yet another object of the present invention to provide the maximum impact upon a drill bit with a maximum frequency of such impacts.

It is yet another object of the present invention to provide a pneumatically actuated tool which may be easily serviced and returned quickly to operation.

It is yet another object of the invention to join the anvil to the remainder of the impact drilling tool such that a maximum amount of structural support is provided to the tool.

In the present invention, a shortened and simplified central feeder is combined with a novel arrangement of passages within the hammer element and feeder element to produce all of the above desired results. Further, a novel method of attaching the lower sub to the casing allows for increased durability and easier servicing of the impact tool.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1***a* and FIG. **1***b* are elevated sectional views taken along the longitudinal axis of the present invention.

FIG. **2** is a sectional view of FIG. **1***a* taken along section line **2—2**.

FIG. **3** is a sectional view of FIG. **1***a* taken along section line **3—3**.

FIG. **4** is a sectional view of FIG. **1***a* taken along section line **4—4**.

FIG. **5** is a sectional view of FIG. **1***a* taken along section line **5—5**.

FIG. **6** is a sectional view of FIG. **1***b* taken along section line **6—6**.

FIGS. **7** and **8** are simplified elevated sectional views showing pictorial illustrations of the different phases of operation of the impact drilling tool.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to FIGS. **1***a* and **1***b* in combination there is shown an elongated cross-sectional view of the present invention wherein reference numeral **12** represents the pneumatic impact drilling tool. The present invention is designed for connection in a string of drill pipe immediately above a drill bit. The pneumatic impact drilling tool **12** has an upper sub **14** that is connected by means of upper threads **16** to the drill pipe (not shown). To the lower portion **18** of the upper sub **14** threadably engages a casing **20** by means of lower threads **22** of the upper sub **14** and upper threads **21** of the casing **20**. The internal portion of the casing **20** which incorporates the present invention will be described in more detail subsequently. The lower portion of the casing **20** connects to a lower sub **24** by means of threads **26** of the lower sub **24** and lower threads **27** of the casing **20**. Inside of lower sub **24** is retained an anvil **28** with a drill bit **30** being integrally formed therewith.

It is to be understood that throughout the description of the preferred embodiment that "vertical" shall refer to a direction parallel to the elongated axis of the drilling tool **12** and that "horizontal" shall refer to a direction perpendicular to the elongated axis of the drilling tool **12**. It is further understood that "upper" shall refer to the object closest to the drill string and that "lower" shall refer to the object closest to the drill bit **30**.

Enclosed within the casing **20** is located a check valve **32** which allows pneumatic fluid to flow from the string of drill pipe, through the impact drilling tool **12**, to the drill bit **30**, but not vice versa. This prevents cuttings from the drill bit **30** from being drawn into the impact drilling tool **12**. Below the check valve **32** is located a feeder element **34** which controls many of the valving functions of the pneumatic impact drilling tool **12**. The check valve **32**, feeder element **34**, and the passages and structures thereof are collectively referred to as "feeder means". Around the feeder element **34** is located an axially slideable hammer **36**, which in operation repeatedly strikes the striking surface **126** of the anvil **28**. Between the hammer **36** and the anvil **28** is located an exhauster **38** which controls at least one of the exhaust functions of the pneumatic impact drilling tool **12**. For assembly purposes, at least one screw **42** retains the anvil **28** within lower sub **24**, and at least one screw **63** assists in holding a feeder retainer **60** in upper sub **14**.

Before describing a method of operation of the present invention, a detailed description of the structure will be given in the following paragraphs. Pneumatic fluid is communicated through the string of drill pipe to the impact drilling tool **12** where it is further communicated through a large orifice **48** located in the upper sub **14**, and through sloping passages **52** located in valve retaining block **46** and into the feeder **34** of the impact drilling tool **12**. The check valve **32** is located between the valve retaining block **46** and the large orifice **48** upper sub **14**.

The large orifice **48** is restricted by the check valve **32** pressing against the lower surface of the large orifice, which check valve acts to prevent the reverse flow of pneumatic fluid therethrough. The check valve **32** consists of a spring loaded dart **49** with a resilient sealing material **53** (normally rubber) sealing against the base of the large orifice. Inside the dart is a coil spring **51** for urging the dart **49** into the closed position as shown in FIG. **1***a*. The coil spring **51** has a small compression force exerted thereon by the dart **49** and valve retaining block **46**. The pressure drop across check valve **32** is normally very small when compared to the working pressure of the fluid flowing through the tool **12**.

The valve retaining block **46** is maintained in position by means of valve retaining block flange **56** that is wedged between a makeup ring **58** and feeder retainer **60**. The makeup ring **58** is located beneath a first shoulder **15** of upper sub **14**, and is formed from an oil resistant elastomer to provide a firm downward force on retaining block **46** against feeder retainer **60** when all said parts are in place. The lower portion of the feeder retainer **60** has an inward shoulder **68**, which mates against outward flange **70** of feeder element **34**. The outer radius of outward flange **70** of feeder element **34** is somewhat smaller than the inner radius of feeder retainer **60** with horizontal adjustment space **29** allowing the feeder element **34** a degree of lateral flexibility. O-ring seal **72** is located within a lower cavity of the valve retaining block **46** and pressed against the top of outward flange **70** of the feeder element **34** to insure against leakage of pneumatic fluid around the feeder element **34**. Due to use of the elastomer makeup ring **58** and the O-ring seal **74** no substantial pressure may be developed below feeder retainer **60** without passing through the center bore **54** of the feeder element **34**.

Further, the use in combination of the horizontal adjustment space **29**, elastomer makeup ring **58**, and O-ring seal **74** provides for the feeder means to harmlessly adjust its position. The flexible seals cushion the inevitable vibration, and also provide a continuous seal against the pressurized fluid.

To assemble the above parts, the feeder retainer **60** is threadably engaged within the upper sub **14** by threads **31** of the feeder retainer **60** and inner threads **35** of the upper sub **14**. At least two "spanner-type" sockets **37** are located in the lower surface of the feeder retainer **60**. The upper sub **14** also contains at least one upper sub retaining aperture **65** and the feeder retainer **60** contains at least one corresponding feeder retainer threaded aperture **62**. A second retaining threaded screw **63** is placed through the upper sub retaining aperture **65** and threadably engages the feeder retainer threaded aperture **62**.

Thus in operation, after the feeder retainer **60** has been threadably engaged and "seated" within the upper sub **14**, the second retaining screw **63** is threaded into the feeder retainer **60** threaded aperture **62** to prevent the feeder retainer **60** from backing out of its intended position. Further, when the upper sub **14** is subsequently screwed into the upper threads **21** of the casing **20**, it is seen that the casing **20** overlaps the second retaining threaded screw **63** and prevents the second retaining threaded screw **63** from backing out of the feeder retainer threaded aperture **62**. Because the drill string and impact drilling tool **12** are only rotated in a clockwise direction while the impact drilling tool **12** is in use, the upper sub **14** is also prevented from backing out of the casing **20**.

The feeder means additionally consists of a feeder element **34** as shown in FIG. **1***a*. The feeder element **34** basically consists of a hollow tube enclosing a center bore **54** and is located along the elongated central axis of the impact drilling tool **12**.

The first openings from the center bore **54** of the feeder element **34** are cross slots **76** that connect to annulus **78**. The annulus **78** is a shallow undercut in the outer surface of feeder element **34**. A better understanding of the construction of feeder element **34**, cross slots **76** and annulus **78** can be obtained by referring to the cross-sectional view as shown in FIG. **1** and FIG. **5**. As shown in FIG. **1***a*, the cross slots **76** are all located at an equal distance from the upper end of the feeder element **34**, and all of the cross slots **76** connect the center bore **54** to annulus **78**.

The diameter of the center bore **54** of feeder element **34** decreases slightly in the lower section thereof by means of inward slope **80**. The outer diameter of the feeder element, however, is approximately constant throughout the entire length of the feeder element **34**. At the bottom of the center bore **54** of the feeder element **34** is located a nozzle **89** with a restrictive orifice **88** that will allow a small amount of pneumatic fluid to continually flow through the feeder element **34** and into the center chamber **162** located below. The nozzle **89** is retained within the feeder element **34** by means of shoulder **86**, which consists of an inward rim projecting from the inner wall of the feeder element **34** and located at the lower end of the feeder element **34**. The restrictive orifice **88** cannot accomodate the high volume of pneumatic fluid (air) that is necessary in rotary drilling operations, and is used mainly to insure that the full capacity of a compressor (not shown) that supplies the air may be utilized. The nozzle **89** may be interchanged with other like nozzles to accomodate different compressor capacities. A second useful feature of the nozzle aperture **88** is that it is positioned to achieve maximum separation of water or other material heavier than air that may enter the tool with the pressurized fluid.

Referring now to the hammer **36**, it is basically an elongated annular device that fills the annular space between feeder element **34** and casing **20**. The hammer **36** has a center bore **92** that slidably receives the feeder element **34** in a close abutting relationship to form a good metal-to-metal seal therebetween. Oil grooves and oil (not shown) may be used to aid this metal-to-metal seal and also a corresponding metal-to-metal seal with the inner surface of casing **20**.

At the top of the hammer **36**, hammer openings **97** are connected by slanting bores **96** within the hammer **36** to a first hammer undercut **98** which is located in center bore **92**. The location of the slanting bores **96** in the hammer **36** can best be seen in FIGS. **1***a*, **3**, **4**, and **5**. As many slanting bores 96 as are necessary for the proper operation of the impact drilling tool 12 may be utilized.

From the bottom of the hammer 36 along the outside of the hammer 36 in a longitudinal direction, slots 84 are cut parallel to the elongated axis of the hammer 36. These slots 84 form vertical passages between the casing 20 and the hammer 36 and extend approximately two-thirds to three-fourths the length of the hammer 36. The location of the slots 84 may be viewed in FIGS. 1*a*, and 5. Slanting holes 102 intersect the upper portion of the slots 84 and connect the slots 84 to a second hammer undercut 104. The location of the slanting holes 102 may be viewed in FIGS. 1*a* and 4. The second hammer undercut 104 is located in center bore 92 of hammer 36 and is positioned at a point above the first hammer undercut 98. As many slots 84 and slanting holes 102 may be cut as are necessary for the proper functioning of the impact drilling tool 12. FIG. 1*a* shows a full length view of the slanting holes 102 and slots 84 while FIG. 4 shows a radial cross-sectional view of the slanting holes 102.

Within the anvil 28 is located an anvil center bore 106. The anvil center bore 106 consists of a larger diameter upper anvil center bore 110 and a smaller diameter lower anvil center bore 111. Inner anvil shoulder 108 separates the upper anvil center bore 110 from lower anvil center bore 111. Within the upper anvil center bore 110 is located an exhauster 38, which basically consists of an open ended tube and may be formed from any suitable substance, such as plastic or aluminum. The outer diameter of the exhauster 38 is in a close slidable relationship with the lower center cavity 93 of the hammer 36 and forms a slideable seal therewith. An outward tapering of the inner upper surface of the exhauster 112 aids in the dynamic flow of the pneumatic fluid through the exhauster 38. The outer diameter of the exhauster 38 fits snugly inside of the larger upper diameter anvil center bore 110 which is constructed to securely receive the exhauster 38. The outer diameter of the lower portion of the exhauster 38 has an undercut 116 located thereon. The space within the undercut 116 is filled with a resilient material 122. In the preferred embodiment of the present invention, the resilient material 122 is a rubber base substance that is formed on the exhauster 38. Upon assembly of the impact drilling tool 12, the exhauster 38 is pressed into position inside of the anvil 28 with the resilient material holding exhauster 38 in position. The inner diameter of the exhauster 38 is approximately the same as the smaller diameter of lower anvil center bore 110.

Below the striking face 126 of the anvil 28 and on the outer surface of the anvil 28 are located milled pockets 130. The lower sub 24 contains threaded apertures 136 within the lower sub 24 for threadably engaging threaded screws 42. The threaded apertures 136 and screws 42 are appropriately tapered so engagement of the screws within the threaded apertures may be wrench-tight, thereby eliminating all relative vibration between the screws and the lower sub. The threaded screws 42 are spaced radially about the lower sub 24. Each threaded screw 42 projects a rounded end 41 into the anvil 28 milled pockets 130. The threaded screws 42 prevent the anvil from falling out of the lower sub 24 if the tool 12 is picked up off the bottom of the hole being drilled.

When screws 42 are in place within the threaded aperture 136, the outer ends of the retaining threaded screws 42 are either flush with or slightly within the outer surface of the lower sub 24. This slightly recessed or flush position makes it possible to screw the lower sub 24 into position within the casing 20 without the threaded screws 42 blocking such action.

Once in position, the casing 20 prevents the threaded screws 42 from backing out from the threaded apertures 136. This retaining function of the casing 20 is necessary due to the tremendous vibrational forces which occur during operation of the impact drilling tool 12. The sole purpose of the threaded screws 42 is to retain the anvil 28 within the impact drilling tool 12 when the tool is lifted from the bottom of the hole. This will be explained in more detail later, but it should be understood that during operation of the impact drilling tool 12, the lower movement of the anvil 28 will be halted by the bottom of the hole being drilled and that the downward pressure from the drill string upon the tool 12 will be communicated by the lower end of the lower sub 24 abutting outward flange 146 of anvil 28.

The lower sub 24, commonly called a drive sub, is threadably connected to casing 20 by threads 26 of the lower sub 24 threadably engaged with corresponding threads 27 of the casing 20. Therefore, in final alignment, the anvil 28 is firmly held inside of casing 20 by means of the lower sub 24 and retaining screws 42.

Referring now to the lower portion of FIG. 1*b*, it can be seen that anvil 28 and lower sub 24 are assembled into a splined relationship with respect to each other. Grooves 138 of lower sub 24 receive vertical ridges 140 of anvil 28 and vice versa for grooves 142 of anvil 28 and vertical ridges 144 of lower sub 24. It should be realized that the mating of grooves 138 and 142 and vertical ridges 140 and 144, respectively, between anvil 28 and lower sub 24 allows free elongated axial movement but does not allow radial movement between the anvil 28 and the lower sub 24. This splined relationship between the grooves prevents the drill bit 30, which is formed intergral with the anvil 28, from rotating except as turned by casing 20. The upper portion 170 of the lower sub 24, located above the threaded screws 42, provides additional lateral support for the anvil 28.

A snap ring 164 is set within a shallow casing indentation 166 located within the casing and immediately adjacent to the upper end 170 of the lower sub 24, and partially within a lower sub snap ring cut 168. The lower sub snap ring cut 168 is an inward angling of the outer surface of the lower sub 24 about the outer edge of the upper portion 170 of the lower sub 24. This is done in such a manner that upon final installation, the uppermost portion of the lower sub 24 is in an approximately equal vertical position as is the snap ring 164 but, due to the lower sub snap ring cut 168, does not contact the snap ring 164. Further, a hammer snap ring cut 169 is located upon the lower outer surface and bottom surface of the hammer 36 in a manner corresponding to that of the lower sub 24 snap ring cut. The hammer 36 snap ring cut 169 is an inward angling of the outer surface of the hammer 36 about the outer edge of the lower end of the hammer 36. When the impact drilling tool 12 is lifted from the bottom of the hole being drilled, the drill bit 30 and anvil 28 are no longer supported by the bottom of the hole. The anvil 28 will drop through the lower sub 14 until the upper end 135 of the anvil undercut 130 abuts the threaded bolts 42. The dropping of anvil 28 removes the anvil 28 as a support for the hammer 36. The hammer 36 also drops down until it is halted by the upper end of the lower sub 24. At this point, the snap ring 164 is non-functional, being contained within the space formed by the concurrence of the hammer snap ring cut **169** and the lower sub snap ring cut **168**.

When the hammer **36** follows the anvil **28** as the impact drilling tool **12** is raised from the bottom of the hole, the top of the hammer **36** slides below the cross slots **76** of the feeder element **34**. Therefore, the flow of pneumatic fluid is directed through the cross slots **76** of the feeder element **34**, across the top of the hammer **36**, into the hammer opening **97** located upon the upper surface of the hammer, through the downward slanting bore **96** of the hammer, the center bore **92**, exhauster **38** and thence out through the drill bit **30**. This allows for continued circulation of pneumatic fluid through the impact drilling tool **12** without damaging the impact drilling tool **12** when it is lifted from the bottom of the hole. This is necessary in order to clean the hole of cuttings prior to pulling the impact drilling tool **12** from the hole.

The functionality of the snap ring **164** occurs when the impact drilling tool has been completely pulled from the hole. At this point, it is often necessary to replace the old worn bit **30** with a new bit. Because the bit **30** is formed integrally upon the anvil **28**, the anvil **28** and lower sub **24** are removed in order to replace the bit. When this entire lower portion of the impact drilling tool **12** is removed, the lower sub **24** no longer serves to support the hammer **36**. At this point, the snap ring **164** becomes functional as the hammer **36** slides down and is halted by the snap ring **164** from sliding from the casing **20** of impact drilling tool **12**.

The advantages of the above type of structure over previously patented structures are numerous. The present invention allows the worn drill bit to be quickly exchanged for a new drill bit simply by unscrewing and removing the old lower sub **28** containing the worn drill bit **30**, and replacing it with a new lower sub **28** containing a new drill bit **30**. Thus, an exchange of bits is made possible without the necessity of completely disassembling the impact drilling tool **12**. The presence of the snap ring **164** as located and the threaded screws **42** as located are each necessary to prevent the hammer **36** and anvil **28**, respectively, from sliding out of the impact drilling tool. Bits will be resharpened for reuse in the tool without disassembly from lower sub **28**. However, when an anvil-bit is completely worn out, screws **42** may be removed and the lower sub remated to a different anvil. The fact that a single structural unit (the lower sub **24**) is utilized to support and guide the anvil **28**, engage the casing **20**, retain the hammer and provide hold-down pressure upon the drill bit **30**, rather than employing a plurality of structures to perform those functions, enables the present impact drilling tool **12** to be considerably more durable than current drilling tools and to be more economically manufactured.

When drilling, the lower portion of the lower sub **24** abuts against an outward flange **146** of the anvil **28** to force the anvil **28** and drill bit **30** downward. As the anvil **28** center bore **106** approaches the lower end of the anvil **28**, the anvil **28** center bore **106** converts into slanting passages **148** that communicate the pressurized fluid through the drill bit **30**. A cutter portion composed of specially hardened inserts **150**, is formed on to the lower end of the drill bit **30**. The hardened inserts **150** are located about its outer edge by an outer support **154**. The outer circumference of the outer support **154** of the drill bit **30** and of the hardened inserts **150** is slightly larger than that of the casing **20**. This is necessary in order to drill a hole having a larger diameter than the outer diameter of the casing **20** so that exhausted air and drill cuttings may have an open annulus to the surface.

Although the present invention is shown in conjunction with a solid head type of bit, a roller cone type of bit may be utilized by a proper adjustment of the downward impact force.

By combining the various elements of the impact drilling tool **12**, as described above, speedy replacement of the anvil **28** and drill bit **30** is facilitated and because this entire portion of the drilling tool **12** (lower sub **24**, anvil **28** and drill bit **30**) can be removed as a unit, the difficulty, time, and skill involved in removing and replacing these elements when they become worn is greatly reduced. Further, the unit is structurally well adapted to perform under rigorous down hole conditions.

METHOD OF OPERATION

As the pneumatic fluid (air) flows through the large orifice **48**, the check valve **32** is subjected to high pressure. This high pressure forces the check valve **32** open and the pneumatic fluid flows through the slanting passages **52** of the valve retaining block **46** and into the center bore **54** of the feeder element **34**. At the bottom of the center bore **54** of the feeder element **34**, a small amount of the air continually flows through the nozzle **89** of the restrictive orifice **88**. The majority of the air, however, flows outward through cross slots **76** of the feeder element **34**.

Referring now to FIGS. **7** and **8**, there are shown pictorial schematic views of the impact drilling tool **12** to illustrate the sequential positions of the hammer **36** and the air flow through the impact drilling tool **12**. Like numbers will be used to designate like parts as previously described in conjunction with FIGS. **1–6**.

In FIG. **8**, the hammer **36** has just struck the anvil **28**. Air flows through the center bore **54** of feeder element **34**, cross slots **76** and annulus **78** into the second hammer undercut **104**, through the downward slanting holes **102** and connecting slots **84** to below the hammer **36**. The pressurized air thus transferred to underneath the hammer **36** creates an upward pressure upon the hammer **36** as it attempts to expand. This upward pressure upon the base of the hammer **36** causes the hammer **36** to begin moving upward.

As the hammer **36** moves upward, the flow of air through the cross bores **76** of the feeder element **34** is terminated as the second hammer undercut **104** of the hammer **36** moves upward and past the uppermost portion of annulus **78** of the feeder element **34**. The air trapped between the bottom of the hammer **36**, the top of the anvil **28**, the outer diameter of the exhauster **38** and the inner surface of the casing **20**, continues to expand, however, and continues to force the hammer **36** upward.

Further, the upward momentum of the hammer **36**, resulting from the initial burst of highly pressurized air upon the bottom of the hammer **36**, as described above, continues to propel the hammer **36** upward. As the hammer **36** is thus being driven upward, the first hammer undercut **98** of the hammer **36** moves into alignment with the annulus **78** of the feeder element **34**. A flow relationship is thus created by the highly pressured air in the center bore **54** of the feeder element **34**, through the cross slots **76** and annulus **78**, into the first hammer undercut **98**, through the slanting bores **96**, and hammer openings **97** to above the hammer **36**.

The continually expanding trapped air from below the hammer **36** and the upward momentum of the hammer **36** maintain the upward movement of the hammer **36** until the downward force of the pressurized air communicated to above the hammer **36** overcomes those upward forces and the upward movement is halted. Also, at a given point in the upward movement of the hammer **36**, the bottom of the lower center cavity **93** of the hammer **36** moves above the uppermost portion of the exhauster **38** and releases the pressurized air which had been trapped below the hammer **36**. The released air escapes across the top of and through the exhauster **38** and is ultimately ejected through the drill bit **30**.

FIG. **7** shows the hammer **36** in its uppermost position. By utilizing an oversized first hammer undercut **98**, a large slanting bore **96** and annulus **78** of the feeder element **34**, a very rapid pressurization is completed above the hammer **36** when the first hammer undercut **98** moves adjacent to the cross slots **76** of the feeder element **34**. The air pressure below the hammer **36** has at this point dissipated across the top of the exhauster **38**, into center chamber **162** and through the exhauster **38** because the hammer **36** and exhauster **38** are no longer in a close slidable relationship. The upward momentum of the hammer **36** has been overcome by the highly pressurized air that has suddenly been injected into the space immediately above the hammer **36**. This cushion or stop means of highly pressurized air above the hammer **36** prevents the hammer **36** from striking the feeder retainer **60** and upper sub **14**. This is necessary in order to prevent the hammer **36** from damaging the upper portion of the impact drilling tool **12**.

At the position shown in FIG. **7**, the hammer **36** is, for an instant motionless. Highly pressurized air above the hammer **36** exerts a large downward force upon the hammer **36**. Due to the force of the pressurized air above the hammer **36** and the lack of resistance below the hammer, the hammer begins to accelerate very rapidly as it moves downward. Furthermore, due to the large mass of the hammer **36**, a large momentum is thus attained.

The flow relationship from the center bore **54** of the feeder element **34** to the space above the hammer **36** is terminated due to the first hammer undercut **98** of the hammer **36** sliding out of communication with the cross bore annulus **78** of the feeder element **34**. Further, as the lower end of the first hammer undercut **98** of the hammer **36** moves below the lower end of the feeder element **34**, the highly pressurized air trapped above the hammer **36** begins to flow through the slanting bores **96** of the hammer **36** and into the upper center cavity **92** of the hammer **36**, thus relieving the hammer **36** of any appreciable air pressure above it. In other words, the lower end of the feeding means in conjunction with the first duct means in the hammer means provides a second slidable valve means for exhaust above the hammer means to the center chamber.

Thus, after the hammer **36** is stopped in its upward motion and begins its downward motion by highly pressurized air above the hammer **36**, the highly pressurized air above the hammer **36** is dissipated through the upper center cavity **92** of the hammer **36** and into the center chamber **162**. The sliding valve relationship of the first hammer undercut **98** of the hammer **36** with the end of the feeder element **34** permits this dissipation to be effected very rapidly.

Further, as the hammer **36** moves downward, a flow relationship is established between the center bore **54** of the feeder element **34** and the space below the hammer **36** as was previously shown in FIG. **7**. This is accomplished when the second hammer undercut **104** of the hammer **36** slidably moves adjacent to the annulus **78** of the feeder element **34**. The highly pressurized air is communicated from the center bore **54** of the feeder element **34** through the cross slots **76**, annulus **78**, the second hammer undercut **104**, slanting holes **102**, and slots **84** to the space below the lower face of the hammer **36**. Thus, immediately prior to the impact of the hammer **36** upon the anvil **28** pressurized air begins to build up in the space below the hammer **36**. As the hammer **36** moves downward, the lower center cavity **93** of the hammer **36** engages in a slidable mating relationship with the outer radial surface of the exhauster **38** thus providing a sealed cavity within which the highly pressurized air is trapped below the hammer **36**. Because the anvil **28** projects above the top of the lower sub **24**, the pressurized air is forced from between the striking hammer **36** and anvil **28** and into the space beneath the hammer **36** and to the outside of the upper portion of the anvil **28**. Thus, the pressurized air below the hammer **36** does not prevent a solid striking of the hammer **36** upon the anvil **28** as it had stopped the hammer **36** from striking the feeder retainer **60** and upper sub **14** in the earlier upward portion of the cycle. The impact of the hammer **36** striking the anvil **28** is conducted through the anvil **28** to the drill bit **30** where the work function of the impact drilling tool **12** is performed.

The hammer **36** both bounces upward from the top of the anvil **28** which it has struck and is lifted by the pressurized air which is being conducted to beneath it. The position of the parts of the impact drilling tool **12** are now in place for another cycle as described above and as shown in previously described FIG. **8**. Due to the reciprocating nature of the device, FIGS. **7** and **8** are each descriptive of more than one point of the complete cycle. FIG. **7**, for example, describes the position of the hammer **36** both as it is ascending and descending.

The downward momentum of the hammer is determined by integrating the force of the highly pressurized air over the hammer **36**, less the instantaneous pressure existing below the hammer **36**, times the cross-sectional area of hammer **36**, throughout its entire stroke length. Effects of friction and gravity and minimal. Use of a single passage center feed (feeder element **34**) as described in the present invention, provides a larger surface area against which the pressurized air can act to drive the hammer than when either a multiple passage center feeder or "through-the-casing" feed system is employed. Further, valving and feeding pneumatic fluid to the hammer by means of passages within the casing often entails a substantial weakening of the casing itself. It is clear, therefore, that the large upper and lower surface areas of the hammer **36** provided in the present invention result in maximum forces, accelerations, and repetition rates for a given diameter of hole being drilled.

What is claimed is:

1. An impact drilling tool for connection in a string of drilling pipe, said tool comprising:
- an upper sub for connection to said drilling pipe;
- a casing with an upper end connected to said upper sub;
- anvil means slideably received in a lower end of said casing, said anvil means being connected to bit means;

hammer means carried in said casing above said anvil means, said hammer means reciprocating along an elongated axis of said tool for striking said anvil means during each cycle;

means for feeding pressurized pneumatic fluid from said drilling pipe through a center portion of said hammer means, said feeder means having a lengthwise passage and a set of radial passages, a lower end of said feeder means terminating within said center portion of said hammer means;

cross passages in said hammer means with a first set terminating at an upper end above said hammer means and a second set terminating at a lower end below said hammer means, a lower end of said first set of cross passages terminating in said center portion below an upper end of said second set of cross passages which also terminate in said center portion;

said set of radial passages slideably connecting with said lower end of said first set of cross passages and said upper end of said second set of cross passages to respectively pressurize above and below said hammer means during each cycle thereof, said lower end of said feeder means slideably connecting with said lower end of said first set of cross passages to exhaust pressure above said hammer means during each cycle thereof;

exhaust means carried by said anvil means and located between said hammer means and said anvil means for exhausting pressure below said hammer means during each cycle thereof.

2. The impact drilling tool for connection in a string of drilling pipe as given in claim **1** wherein said feeder means includes a first annulus thereon connecting said radial passages, said hammer means having a first undercut therein connecting said lower end of said first set of cross passages and a second undercut therein connecting said upper end of said second set of cross passages, said first annulus slideably connecting to said first undercut and said second undercut, respectively.

3. The impact drilling tool for connection in a string of drilling pipe as given in claim **2** wherein said first and second sets of said cross passages include slanting bores through said hammer means, said second set of slanting bores connecting to downwardly extending slots in an outer perimeter of said hammer means, said slots terminating at a lower end below said hammer means.

4. The impact drilling tool for connection in a string of drilling pipe as given in claims **2** or **3** wherein said lower end of said feeder means slideably connects with said first undercut to exhaust pressure above said hammer means during each cycle thereof.

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