The present invention relates to impact tools of the type employing a pneumatically operable piston and cylinder assembly for powering the driver ordinarily associated with such tools. The invention has particular reference to a novel means for returning the piston of such an assembly to its retracted position after the piston has delivered its power stroke.

Insofar as piston return means are concerned, pneumatically operable piston and cylinder assemblies may, broadly, be divided into two groups. In one group the piston is returned by spring pressure and in the other group the piston is returned by air pressure. It is to this latter class of piston and cylinder assemblies that the present invention pertains.

Piston and cylinder assemblies which rely solely upon spring pressure for return of the piston to its retracted position are possessed of numerous limitations that render the same unsuitable for use where an extremely fast power stroke, terminating in maximum power delivery at the time of impact, is desired. Principal among these is the inability of the spring to uniformly absorb the compression exerted upon it by the fast moving piston during the power stroke. Due to the inertia of the spring, particularly if it is comprised of a large number of convolutions, the quick movement of the piston will not displace the entire length of the spring, only the first few spring convolutions in the vicinity of the piston becoming compressed and the remainder thereof remaining static. Stated otherwise, the piston initially delivers an impact to the adjacent end of the spring which creates a shock wave that does not have time to traverse the entire length of the spring before the piston is at the end of its power stroke. This causes the first several convolutions of the spring to go solid while the remainder of the spring is not compressed. Then, at such time as air pressure is relieved on the side of the piston remote from the spring, the spring is not immediately effective to return the piston inasmuch as the compressed convolutions of the spring cannot find reaction support and must distribute their potential expansive force to the uncompronsed portions of the spring before the entire spring can become effective to return the piston. This results in an undesirable delayed piston return. Such a spring action not only delays the piston return, but it also damages the spring due to repeated impact between adjacent spring convolutions which go solid during each power stroke of the piston.

A further limitation in connection with the use of a spring for returning the piston resides in the relatively great counter-thrust which is offered to the piston by the spring during its power stroke, this counter-thrust increasing progressively and being at its maximum at the time of impact by the driver, thus detracting from the total power delivered.

In an effort to obviate the above-noted limitations that are attendant upon the use of spring-actuated piston return systems, numerous air return systems have been devised. Such systems likewise are possessed of limitations, and furthermore they require the use of relatively complicated valve mechanisms and cylinder porting arrangements. Principal among the limitations associated with certain air return systems currently in use is the large volume of air that must be expended when live air is employed for driving the piston in both directions. An additional limitation resides in the fact that unrestricted expulsion of air on either side of the piston is not always available due to the necessity of employing relatively small area air inlet and outlet ports at the ends of the cylinder commensurate with the particular valve system employed, thus resulting in a dash pot action when the air is expelled.

In an effort to overcome the above-noted limitations that are attendant upon the use of such conventional air return systems, it has been proposed that all, or at least, a limited portion, of the air which is expelled from the cylinder during the power stroke of the piston be collected in a fixed pressure chamber and compressed therefrom by the compressive action of the piston during its power stroke. After the piston has completed its power stroke, this stored and compressed air is returned to the cylinder and caused, by expansion thereof, to return the piston to its retracted position. While such systems conserve an appreciable amount of compressed air, the placement of the pressure chamber entails difficulty in cylinder design. Placement of the pressure chamber at the end of the cylinder on the driver side of the piston requires a cylinder of undue length, while placement of the pressure chamber at one side of or concentric with the cylinder involves the use of complicated and unreliable valve porting and valve arrangements, as well as increasing the overall bulk of the system. Regardless of the position of the fixed pressure chamber, the total volume of air collected in the chamber during the power stroke of the piston must be sufficient in mass to effectively fill the cylinder when the piston is completely returned and maintain an appreciable degree of return pressure upon the piston to hold it in its retracted position until the next succeeding power stroke thereof. Where such a large volume of air is employed for return of the piston by expansion of the air, the problem of large total air displacement during the power stroke and of counter-thrust during such power stroke, as heretofore described in connection with spring return systems, remains prevalent. Small porting areas for large air displacements also present difficulties that have not been overcome by such air expansion piston return systems. Finally, the use of fixed pressure chambers for piston return purposes results in undesirable accelerated and rapid piston return due largely to the application of high pressure return air to large piston surface areas at the commencement of the return stroke and the necessity of maintaining relatively high return pressure on the piston during its entire return stroke so that the expansive force of the return air will not be expended before the piston reaches its fully retracted position.

The present invention is designed to overcome the above-noted limitations that are attendant upon the construction and operation of conventional piston return systems, whether the same be of the spring return or the air return type. Accordingly the invention contemplates the provision of a novel air return system wherein the piston, after it has completed its effective power stroke and delivered its impact, is returned to its retracted position gradually and uniformly with sufficient rapidity to satisfy the requirements of the particular tool involved or service required, yet at a rate which is not excessive.

Briefly, in carrying out the invention, it is contemplated that the cylinder wall be of tapering design, the wall tapering in the direction of movement of the piston during its power stroke and on a small slant angle. The piston, which is reciprocable axially within the cylinder, is provided with an outwardly facing continuous annular recess therein which opposes the tapered wall of the cylinder and, in combination therewith, defines a variable volume annular pressure chamber or air reservoir which surrounds the piston and the capacity of which...
decreases during the power stroke of the piston and increases during the return stroke thereof. The pressure chamber is sealed from both the large and the small ends of the cylinder. The pressure chamber communicates through an air passage in the body of the piston with the large end of the cylinder and a check valve disposed in said passage is effective to admit air to the pressure chamber when air pressure in the large end of the cylinder exceeds the air pressure in the chamber and to prevent air from escaping from the chamber when the reverse is true. The small end of the cylinder is bled to the atmosphere and at no time has communication with the pressure chamber.

Means are provided for selectively admitting air under working pressure to the large end of the cylinder to drive the piston during its power stroke and for bleeding the large end of the cylinder to the atmosphere during the return stroke of the piston. When air thus enters the large end of the cylinder it is admitted to the pressure chamber by the check valve and places the chamber under full working air pressure. Substantially simultaneously with the entry of air into the pressure chamber the piston is driven forwardly to commence the power stroke thereof. As the piston moves forwardly towards the small end of the cylinder, the volume of air in the pressure chamber progressively decreases, as heretofore set forth, due to the tapered wall of the cylinder. This causes the pressure of air within the chamber to increase progressively so that it exceeds the working pressure, the check valve preventing escape of air from the chamber. By the time the piston reaches the end of its power stroke and assumes a position at the small end of the cylinder, the pressure of air within the pressure chamber is appreciably above working pressure.

Return of the piston to its normal position at the large end of the cylinder is effected automatically by discontinuing the application of air to the large end of the cylinder and bleeding such end to the atmosphere. Due to the existence of air within the pressure chamber under relatively high pressure, the normal tendency for the piston is to move toward the large end of the cylinder under the expansive influence of the air within the pressure chamber. Considering the cylinder to be disposed vertically, the physical phenomena involved may roughly be described as a circumferential camming action wherein the air within the pressure chamber, which has been highly compressed during descent of the piston, seeks to expand to its initial volume and, in so doing, exerts a circumferential outward pressure on the tapered wall of the cylinder. The inward taper of the cylinder wall below the piston opposes any tendency for downward movement of the piston but the outward taper of the cylinder wall above the piston offers no such opposition to upward movement of the piston and the latter is constrained to move uniformly and gradually upwardly within the cylinder. The expansive pressure of air within the pressure chamber constitutes the sole motivating means for moving the piston upwardly with the cylinder, air pressure on opposite ends of the piston being equalized since both ends of the cylinder are in communication with the atmosphere. As will be described in greater detail subsequently, the specific slant angle of the frusto-conical wall of the cylinder, the slant height of the cylinder, the capacity of the pressure chamber and the anti-friction characteristics of the sealing means whereby the pressure chamber is sealed to the tapered wall of the cylinder, are selected according to engineering expediencies so that when the piston is in its fully advanced position its power stroke air is disposed at the small end of the cylinder, the pressure of air within the pressure chamber will be sufficiently great as to exert an expansive action on the cylinder wall throughout the entire return stroke of the piston with sufficient residual air pressure remaining within the pressure chamber to retain the piston in its retracted or non-mal position preparatory to the next succeeding power stroke thereof. By reason of the fact that, unlike conventional piston return systems which rely upon the expansive power of air for retracting the piston, only a small portion of the air which is admitted to the cylinder for driving the piston during its working stroke is entrapped within the pressure chamber, and especially by reason of the fact that the entrapped air is raised to a pressure appreciably higher than the working pressure of air admitted to the cylinder, the pressure drop within the pressure chamber as the piston returns to its retracted position may be regulated to vary the rate of piston return.

The improved piston return system of the present invention as briefly outlined above has been designed for use primarily in connection with portable impact tools such as magazine fed stapling and nailing machines, and other devices which rely for their action upon the pressure stroke of a driver. It is to be distinctly understood however that the invention is not necessarily limited to such use and piston and cylinder assemblies constructed in accordance with the principles of the invention may, with or without suitable modification, as required, be employed in numerous other applications. Irrespective however of the particular use to which the invention may be put, the essential features thereof are at all times preserved.

The piston return system of the present invention has been illustrated herein for exemplary purposes as being operatively embodied in a portable impact tool in the form of a nailing machine which, in itself, is possessed of certain novel features relating principally to a pneumatic control whereby working air pressure may selectively be applied to and exhausted from the large end of the cylinder in association with the piston return system. The provision of a novel piston return system such as has briefly been outlined above constitutes the principal object of the invention but other objects relating to the construction and operation of the impact tool also are present.

Accordingly, it is a further object of the invention to provide a novel impact tool having associated therewith the improved piston return system, together with novel valve means whereby, upon application of moderate manual pressure to a trigger control element, air under full working pressure will automatically be applied to the cylinder to initiate the working stroke of the piston, after which release of such manual pressure on the trigger element will automatically discontinue such application of air to the cylinder and cause the latter to be bled to the atmosphere to the end that the piston return system may become effective to restore the piston to its initial or normal retracted position.

The provision of an impact tool which is extremely simple in its construction and which therefore may be manufactured at a low cost; one which is comprised of a minimum number of parts, especially moving parts, and which therefore is unlikely to get out of order; one which is rugged and durable and which therefore will withstand rough usage; one which is capable of easy assembly and disassembly for purposes of inspection of parts, replacement or repair thereof; and one which, otherwise, is well adapted to perform the services required of it, are further desirable features which have been borne in mind in the production and development of the present invention.

In the accompanying two sheets of drawings forming a part of this specification, two illustrative forms of the invention have been illustrated, both schematically and in operative embodiments thereof.

In these drawings:

FIG. 1 is a sectional view, somewhat schematic in its representation, taken substantially centrally and vertically through a piston and cylinder assembly embodying the novel piston return system of the present invention, the
piston being shown in its normal or retracted position; FIG. 2 is a sectional view similar to FIG. 1, showing the piston during its power stroke and at approximately 5° in the machine cycle; FIG. 3 is a sectional view similar to FIG. 1, showing the piston during its power stroke and at approximately 30° in the machine cycle; FIG. 4 is a sectional view similar to FIG. 1, showing the piston during its power stroke and at approximately 180° in the machine cycle; FIG. 5 is a sectional view similar to FIG. 1, showing the piston at the completion of its power stroke and at 180° in the machine cycle; FIG. 6 is a sectional view similar to FIG. 1, showing the piston during its return stroke and at approximately 270° in the machine cycle; FIG. 7 is a sectional view taken substantially centrally and longitudinally through a portable nailing machine constructed according to the present invention and embodying the novel piston return system thereof; FIG. 8 is a sectional view taken substantially along the line—line 9—9 of FIG. 7; FIG. 9 is a sectional view taken substantially along the line 9—9 of FIG. 7; FIG. 10 is an enlarged fragmentary detail sectional view of a portion of the structure shown in FIG. 1 and in the vicinity of a check valve controlled air passage employed in connection with the air return system of the present invention; and FIG. 11 is a fragmentary sectional view taken substantially along the line 11—11 of FIG. 8 but showing a slightly modified form of piston operatively installed within the cylinder.

Referring now to the drawings in detail and in particular to FIGS. 1 to 6 inclusive wherein the piston return system of the present invention has been schematically illustrated, a pneumatic piston and cylinder assembly has been designated in its entirety at 10 and includes a cylinder 12 within which a piston is axially reciprocable. The cylinder 12 is of open-ended tubular construction and the opposite ends thereof are closed by upper and lower circular heads or end walls 16 and 18 respectively. The lower end wall is provided with a bleeder passage 19 therein. The inner working surface or wall 20 of the cylinder 12 is of tapered or frusto-conical configuration, the cone having a small slant angle and a slant height commensurate with the desired stroke of the piston 14. The specific slant angle of the frusto-conical cylinder wall 20 is not critical, the particular angle selected for illustration being on the order of 30°. However, greater or lesser slant angles are contemplated.

The piston 14 is generally of cylindrical design and is provided with a shallow annular recess 22 in the otherwise cylindrical side surface thereof. Immediately above the recess 22 are expansible and contractible sealing elements, preferably, but not necessarily, in the form of an elastomeric or other resilient O-ring 24, axially and floatingly confined within an annular groove 26, makes sliding sealing contact with the tapered wall 20 of the cylinder 12. Immediately below the recess 22, a similar sealing element 28, confined within an annular groove 30, likewise makes sliding sealing contact with the wall 20. The bottom or inner wall of the annular recess 22 is spaced from the tapered wall 20 of the cylinder and thus the recess, in combination with a limited vertical span of the cylinder wall, establishes a closed normally hermetically sealed pressure chamber 22 which travels or shifts bodily with the reciprocating movement of the latter. When the piston is in its normally retracted position at the top of its stroke as shown in FIG. 1, the O-rings 24 and 28 are disposed outwardly in the grooves 26 and 30 respectively and make sealing contact with the wall 20. When the piston is in its fully advanced position at the bottom of its stroke as shown in FIG. 5, these two O-rings are compressed deep within their respective grooves. In any given intermediate position of the piston, the two O-rings assume corresponding intermediate positions within their respective grooves. In all instances however, the annular pressure chamber 32 remains sealed by the O-rings from the outside.

The piston 14 is guided in its movements by means of a plunger 34, the upper end of which is fixedly secured to the piston and which projects outwardly from the cylinder 10 through a guide bushing or sleeve 36 suitably secured in the lower end wall 18. The plunger 34 thus serves to center the piston within the cylinder in the event of any angular misalignment of the piston and cylinder, or lateral shifting of the piston within the cylinder. Stated otherwise, the plunger serves to maintain the piston 14 and cylinder 12 in coaxial relationship at all times.

Means are provided for selectively admitting air pressure under the upper end of the cylinder 12 and bleeding air from the upper end thereof to the atmosphere, such means in the schematic illustration of FIGS. 1 to 6 inclusive comprising the form of a three-way valve V having one leg 40 thereof in communication with the upper end of the cylinder 12 through the end wall 18. A second leg 42 of the valve V is adapted to be connected to a source of air under pressure (not shown), while a third leg 44 communicates with the atmosphere. The valve V is further provided with a rotatable valve body or core 46 which is manually operable under the control of a handle 48 either to establish communication between the two legs 40 and 44 when the handle is in the right hand full line position in which it is shown in FIG. 1, or to establish communication between the two legs 40 and 42 when the handle is in its left hand dotted line position. When the handle is in its full line position, air under pressure will be conducted from the source to the upper end of the cylinder 12 through the valve V. When the handle is in its dotted line position, the upper end of the cylinder will be bled to the atmosphere. The upper end face of the piston is provided with a large diameter shallow recess or socket 49 therein to establish wide pressure distribution on the piston at the commencement of its power stroke.

The piston 14 is formed with an air passage 50 therein, the passage establishing communication between the upper end of the cylinder 12 and the annular pressure chamber 32. Although the passage 50 is shown as being generally of L-shape configuration, this passage may be linearly straight or of other configuration. A check valve in the form of a spring-pressed ball 52, having a spring 53 associated therewith is disposed within the passage 50 and is normally maintained in sealing relation with a downwardly facing valve seat 54, the arrangement being such that when the pressure of air in the upper end of the cylinder exceeds the pressure in the pressure chamber 32, air will be conducted through the passage 50 from the upper end of the cylinder to the pressure chamber. Conversely, when the pressure of air within the pressure chamber 32 exceeds the pressure of air in the upper end of the cylinder, the ball 52 will move into sealing engagement with the valve seat 54 and prevent escape of air from the pressure chamber. The spring employed in connection with the ball 52 is of relatively light construction and it exerts little force on the ball 52 other than to normally maintain the same seated. Its effect on the pneumatic behavior of the ball may, for all practical purposes, be disregarded, the ball moving relative to the seat 54 almost entirely under the influence of pneumatic pressure.

The operation of the above-described piston and cylinder assembly has been progressively and schematically illustrated in FIGS. 1 to 6 inclusive wherein one full pressure stroke of the piston 12 and one full return stroke thereof have been portrayed and regarded as constituting one full machine cycle of 360° duration. In FIG. 1, the piston 12 is shown as being in its fully retracted posi-
tion at 0° in the cycle. The valve body 46 of the valve V is shown as assuming a position wherein the upper end of the cylinder 12 is bled to the atmosphere through the legs 40 and 44, the handle 48 being in its full line position. Upon movement of the handle 48 to the dotted line position of FIG. 1, air under pressure will be admitted to the upper end of the cylinder 14 through the legs 42 and 40, thus driving the piston 14 downwardly within the cylinder and evacuating the lower end of the cylinder through the passage 19 in the end wall 18, in the usual manner of piston operation.

The initial rush of air into the upper end of the cylinder will serve to unseat the ball 52 from the valve seat 54 and cause air to enter the pressure chamber 32 through the air passage 50 as shown in FIG. 2. The inertia of the piston 14 and its attached plunger 54 will allow sufficient air pressure to build up within the upper end of the cylinder and the pressure chamber 32 that substantially full working pressure of air within these spaces will obtain before any appreciable downward displacement of the piston will take place. In FIG. 2 the piston is shown in the position which it assumes at 5° in the cycle and, in this position, the ball 53 remains unseated, thus permitting the pressure chamber 32 and pressure to build up therein. At 10° in the cycle as shown in FIG. 3 where the piston 14 has moved still further downwardly within the cylinder 12, the ball 52 remains unseated but at such point in the cycle it may be assumed that the pressure of air within the pressure chamber 32 now approaches closely working pressure.

As the piston 14 continues downwardly, a time factor is involved wherein full working pressure will exist within the pressure chamber 32. To date, no precise mathematical formulae have been developed to ascertain the precise position which the piston 14 will assume when the pressure of air within the working chamber 32 equals the working pressure in the upper end of the cylinder 12 but, for purposes of discussion it may be assumed that it takes place immediately after the 10° point in the cycle. At whatever point in the cycle such a condition exists, the spring associated with the ball 52 will restore the ball to its seated position and thereafter until the piston has completed its full power stroke, the air within the pressure chamber 32 will be entrapped therein by the O-rings 24 and 28 against escape into either the upper or lower ends of the cylinder. The disclosure of FIG. 4 wherein the piston is disposed in the position it assumes at 30° in the cycle is illustrative of such entrapment of air within the pressure chamber, the ball 52 being seated on the valve seat 54 and the O-rings being in sealing sliding contact with the tapered cylinder wall 20.

As shown in FIG. 5 wherein the piston 14 is at the end of its power stroke and in contact with the lower end wall 18, the ball 52 still remains seated and the piston is forced hard against this end wall under the influence of working pressure in the upper end of the cylinder. In moving downwardly in the cylinder 12 from the position wherein the ball 52 first became seated and air became entrapped in the pressure chamber 32, the volume of the pressure chamber diminished due to the tapering wall 20 of the cylinder 12 and the fact that the bottom wall of the annular recess 22 moved closer to this wall 20. Since, at the time that the ball first became seated, full working pressure was attained in the pressure chamber 32, and since the volume of the pressure chamber is now diminished, the pressure of air within the pressure chamber will now be appreciably above working pressure, this higher degree of pressure being progressively attained as the piston moved downwardly. The static condition of the piston illustrated in FIG. 5 wherein full working pressure exists in the upper region of the piston and a pressure appreciably higher than working pressure exists in the pressure chamber 32 will remain effective as long as air at working pressure is admitted to the cylinder.

Although a higher air pressure will obtain in the pressure chamber than in the upper end of the cylinder, the resultant pressure differential acting on the piston will exert a downward force upon the piston tending to maintain the same in its lowest position by reason of certain pressure area differences and vectorial considerations that will become clear presently.

The return or upward stroke of the piston 14 is initiated by moving the handle of the valve V from the full line position thereof shown in FIG. 5 to the dotted line position thereof, whereupon communication will be established between the legs 40 and 42 of the valve and air pressure will be relieved in the upper end of the cylinder 12. Pressure of air within the pressure chamber 32 at this time will be at a maximum since the piston 14 is at the bottom of its stroke and consequently occupies a position wherein the volume of entrapped air within the pressure chamber is at a minimum. Since the total area presented by the upper side wall of the annular recess 22 (including the portion of the O-ring 24 which is exposed between the piston 14 and tapered wall 20) is greater than the total area presented by the lower side wall of the recess (including the portion of the O-ring 28), the vectoral sum of the forces tending on the piston in an upward direction will exceed the vectoral sum of the forces acting in a downward direction, and thus the piston will be constrained to move upwardly under the yielding influence of the expansive action of the air entrapped within the pressure chamber 32. As the piston 14 continues upwardly within the cylinder 12 as shown in FIG. 6, the volume of the pressure chamber 32 will increase and thus, according to Boyle's law of thermodinamics, the pressure of the entrapped air within the pressure chamber will gradually decrease. Such progressive decrease in pressure as the piston 14 moves within the cylinder 12 will offset or counteract any tendency for the piston to accelerate during its return stroke. By a judicious selection of the working pressure of the air admitted to the upper end of the cylinder, the over-all diameter of the upper end face of the piston, the slant angle and slant height of the cylinder wall 20, the mass (and consequently the inertia) of the piston and its seals, as well as of the plunger 34, the gravitational force, if any, acting on the piston and plunger, the coefficient of sliding friction between the O-rings 24, 28 and the cylinder wall 20, and certain other factors, the piston 14 may be caused to perform its return stroke with substantially constant linear velocity. Moreover, it is contemplated that the above-mentioned factors shall be so chosen that an upward thrust is applied to the piston in all return positions thereof or, in other words, an over-all increase of air within the pressure chamber 32 shall not be fully dissipated before the piston has been fully returned to the large end of the cylinder. It is to be noted at this point that during the entire return stroke of the piston 14, the ball 52 remains seated upon the valve seat 54 so that pressure will be maintained within the pressure chamber. Thus, at 270° in the cycle when the piston is at the mid-point of its return stroke as illustrated in FIG. 6, the ball 52 is shown as being seated. Even after the piston 14 has been returned to its fully retracted position at 360° in the cycle as shown in FIG. 1, the air pressure within the pressure chamber 32 will not be entirely dissipated and sufficient residual pressure will be present to maintain the piston retracted preparatory to the next power stroke of the piston.

In FIGS. 7 to 10 inclusive, the above-described system of piston return has been shown as being operatively embodied in a portable gun-type percussion or impact tool in the form of an air operated, magazine fed, nailing machine which has been designated in its entirety at 100. The impact tool 100 involves in its general organization a composite tool casing 101 including a generally tubular body portion 102 having inturned upper and lower retaining flanges 104 and 105 within which there is press...
fitted or otherwise secured a piston and cylinder assembly 110 constructed according to the principles set forth in connection with the previously described piston and cylinder assembly 10 and having the novel piston return system of the present invention embodied therein. Basically, the piston and cylinder assembly 110 is identical with the piston and cylinder assembly 10 and therefore, in order to avoid needless repetition of description, similar characters of reference but of a higher order have been applied to the corresponding parts as between the disclosures of FIGS. 7 to 10 inclusive, and FIGS. 1 to 6 inclusive respectively.

The upper end of the plunger 134 is threadedly received as at 160 in the piston 114 and is secured in position therein by a nut and washer assembly 162 disposed within the shallow recess 149. The plunger 134 constitutes the driver or hammer of the tool 100 and its lower end is guided in an upwarding boss 164 formed on the lower end wall 118. This end wall 118 is established by the provision of a nose piece 166 suitably secured to the lower open end of the tubular casing 102 and having a magazine assembly 168 operatively secured in position thereon for feeding a series of nails 170, one at a time, into operative position beneath the driver or hammer 134 for ejection from the magazine through a driver slot 171 in the usual manner of operation of conventional nailing machines of the type under consideration.

A bumper 172 fits within a recess 174 formed on the underside of the piston 114, surrounds the driver 134 and is designed for engagement with the lower end wall 118 at the end of the power stroke of the piston 114.

The upper end wall 116 of the tapered cylinder 112 is established by reason of the provision of an upper closure member or cap 176 of hollow construction and which is suitably secured to the upper open end of the tubular body portion 102 of the casing. A gasket 178 is interposed between the closure member 176 and the upper rim of the body portion 102 in sealing relationship. The casing is further provided with a lateral extension or handle portion 180, the outer end of which is adapted to be connected by a suitable handle fitting 182 to a flexible conduit 184 leading to a source of air under pressure (not shown).

The end wall 116 overhangs the upper rim of the cylinder wall 120 as at 186 and this overhanging portion divides the interior of the casing into an upper chamber 188 and a lower chamber 199. The upper chamber 188 communicates with the upper end of the cylinder 112 through the port 190. The two chambers 188 and 199 communicate with each other through a port 194.

An elongated valve spool 196 projects through the port 194 and has an enlarged lower end 195 guided in a socket 200 provided internally in the handle portion 180 and sealed to the wall of the socket by an O-ring 204. The upper end of the valve spool 196 is provided with an enlargement 206 which is guided in a socket 208 provided internally in the closure member 176. The medial region of the valve spool 196 is formed with a third enlargement 210 which constitutes a closure valve for the port 194.

The socket 200 normally communicates through an air passage 212 with the chamber 190 and a ball check valve assembly 214 is adapted upon actuation of a pivoted trigger element 215 to become closed and prevent such communication between the socket 200 and chamber 190. The socket 200 communicates through a passage 210 with the atmosphere and through a port 220 with the chamber 188. An O-ring 222 encompasses the port 220 and is designed for sealing engagement with the enlargement 206 when the valve spool 196 is in its lowermost position.

When the valve spool is in its uppermost position, the chamber 188 is bled through the port 220 and passage 218 to the atmosphere.

The check valve assembly 214 includes a ball valve element 224 which normally rests upon a valve seat 226 associated with a passage 228 in communication with the atmosphere. The ball valve element 224 opposes a second downwardly facing valve seat 230 associated with the passage 212. A thrust pin 232 is slidably disposed within the passage 228 and operates to displace the valve element 224 when the trigger element 215 is actuated.

In the operation of the above-described impact tool 100, the spool valve 196 will normally be maintained in its uppermost position since air pressure within the chamber 190 will be effective through the passage 212 to maintain full working pressure upon the underside of the enlargement 188, as well as to maintain pressure upon the closure valve 210. The enlargement or closure valve 210 will therefore close the port 194 and pressure within the upper end of the cylinder 112 will be bled to the atmosphere through the port 210 and passage 218. The pressure of residual air within the pressure chamber 132 will thus maintain the piston 114 in its fully retracted position due to considerations which have previously been set forth in detail in connection with the piston and cylinder assembly 10.

Upon depression of the trigger element 216, the ball valve element 214 will become dislodged from the valve seat 226, thus bleeding the socket 200 to the atmosphere through the passage 228. The ball valve element 214 will engage the valve seat 230 and close the passage 212 so that air at working pressure within the chamber 190 will act upon the enlargement 206 and cause the spool valve 196 to move downwardly, thereby opening the port 194 and at the same time causing the enlargement 206 to make sealing engagement with the O-ring 222, thus closing the port 220.

At this time working pressure within the chamber 190 will be transmitted through the port 194 to the chamber 188, from whence it will be applied through the port 192 to the upper end of the cylinder 112, thus forcing the piston 114 downwardly, while at the same time unseating the ball 152 from the valve seat 154 and filling the pressure chamber 132 with air at full working pressure as previously described in connection with the piston 14. If there is sufficient residual air within the pressure chamber 132 from a previous operation, the piston 114 may be driven through its power stroke without unseating the ball 152. It is contemplated that the ball 152 shall become unseated only for the purpose of supplying replacement air pressure to the pressure chamber 132 when such pressure has fallen below the working pressure of air due to seal leakage or other factors.

Upon release of the trigger element 216, the ball valve element 214 will be returned to the position 226, thus returning the spool valve 196 to its uppermost position and bleeding the upper end of the cylinder 112 to the atmosphere through the port 220 and passage 218, whereupon the piston 112 will perform its return stroke under the influence of expansion of air within the pressure chamber 132 in the manner previously described in connection with the piston and cylinder assembly 10.

It has previously been pointed out that during the return stroke of the piston 114 the upward thrust exerted thereon by the expansive action of air within the pressure chamber 132 is maintained throughout the entire return stroke of the piston so that the expansive force of air within the pressure chamber will at no time be completely dissipated. Thus, if at any time a nail 170 or other element undergoing impacting should encounter an obstruction which prevents it from being driven to its home position so that the piston 114 will not perform its full power stroke, return of the piston is assured from whatever region of the cylinder 112 it occupies at the time of its arrested motion.

In the modified form of percussion tool fragmentarily illustrated in FIG. 11, a slightly modified form of piston 214 has been substituted for the piston 114 of FIG. 7. Otherwise the various parts of the impact tool remain
substantially the same. Again, due to the similarity of parts, and in order to avoid needless repetition of description, similar reference numerals but of a still higher order have been applied to the corresponding parts as between the disclosures of FIGS. 7 and 11.

In FIG. 11, the piston 314 remains substantially the same as the piston 114, the only difference being in a slightly different shape characteristic. Whereas the piston 114 is generally of cylindrical design, the piston 314 is generally of frusto-conical design and has a slant angle commensurate with the slant angle of the tapering cylinder wall 320. This results in a more equal displacement of the two annular grooves 326 and 328 from the tapered wall 320 so that when the piston is in its fully advanced position and is disposed near the small end of the tapered wall 320, both grooves are in close proximity to the wall. The net result of this is to lessen the extent of inward and outward radial expansion of the upper O-ring 324 during piston travel. Otherwise, the construction and operation of the tool associated with the piston and cylinder assembly 310 remains substantially the same as has previously been described in connection with the form of tool shown in FIG. 7.

The invention is not to be limited to the exact arrangement of parts shown in the accompanying drawings or described in this specification as various changes in the details of construction may be resorted to without departing from the spirit of the invention. For example, whereas in the foregoing description the motive fluid for actuating the piston 114, 114 or 314, as the case may be, has been referred to as air, obviously other gaseous media may be employed if desired. Furthermore, the piston return system of the present invention is not necessarily limited to pneumatic operation inasmuch as under certain circumstances hydraulic operation is contemplated, utilizing a liquid for the motive fluid or a compound system wherein both a liquid and a gaseous media are employed. While the use of elastomeric O-rings for sealing the piston to the cylinder wall provides an effective seal for the pressure chamber, other sealing means such as Teflon or other molded plastic rings, whether continuous or of the split type, with or without overlapping ends, may be employed. Under certain circumstances, metal piston rings may be desirable. Finally, the pressure chamber need not necessarily directly oppose and be adjacent to the tapered cylinder wall. If desired, the pressure chamber may be formed deep in the body of the piston and the entrapped air therein may be caused to exert its expansive influence on the tapered wall of the cylinder by the interpositioning of mechanical thrust means which cooperate with the cylinder wall. Therefore, only insofar as the invention has particularly been pointed out in the accompanying claims is the same to be limited.

Having thus described the invention, what I claim and desire to secure by Letters Patent is:

1. In a fluid-actuated device, a cylinder having a tapered frusto-conical internal working surface of small slant angle, an axially reciprocable piston in said cylinder and moveable between a retracted position wherein it is disposed adjacent the large end of the cylinder and an advanced position wherein it is disposed adjacent the small end of the cylinder, an end wall closing the large end of the cylinder, means for selectively admitting a fluid under pressure to the large end of the cylinder to drive the piston forwardly from its retracted position to its advanced position and for releasing such fluid pressure to allow the piston to return to its retracted position, a pair of axially spaced expansible and contractible sealing rings carried by the piston and in sliding engagement with said frusto-conical working surface, the outer side surface of the piston between said sealing rings opposing said frusto-conical working surface and, in combination therewith and with said sealing rings, establishing a variable-volume fluid pressure chamber which travels with the piston and the volume of which consequently is a function of the axial displacement of the piston within the cylinder, there being a fluid passage in said piston establishing communication between said pressure chamber and the large end of the cylinder, and a check valve disposed in said fluid passage effective to admit fluid to the pressure chamber when the pressure of fluid in the large end of the cylinder exceeds the pressure of fluid in the pressure chamber and to prevent passage of fluid from the pressure chamber to the large end of the cylinder when the pressure of fluid in the pressure chamber exceeds the pressure of fluid in the large end of the cylinder, whereby fluid under pressure admitted to the large end of the cylinder when the piston is in its retracted position will enter said pressure chamber through said passage, the fluid thus admitted to the pressure chamber will become progressively compressed during movement of the piston toward its advanced position due to the progressive decrease in the volume of the pressure chamber, and the expansive force of the thus compressed fluid within the pressure chamber will be effective to return the piston to its retracted position when the pressure of fluid in the large end of the cylinder is relieved.

2. In a fluid-actuated device, the combination set forth in claim 1 and including, additionally, guide means independent of said frusto-conical working surface for maintaining said piston in coaxial relationship with respect to the working surface.

3. In a fluid-actuating device, the combination set forth in claim 1 and including, additionally, an end wall extending across the small end of said cylinder, and a plunger fixedly secured to said piston and projecting through said end wall in guided relationship whereby the piston is maintained in coaxial relationship with respect to said frusto-conical working surface.

4. In a fluid-actuating device, the combination set forth in claim 1, wherein said axially spaced expansible and contractible sealing rings are in the form of continuous elastomeric sealing rings, the outer side surface of the piston being formed with continuous annular grooves therearound and within which grooves the sealing rings are axially confined.

5. In a fluid-actuated device, the combination set forth in claim 1, wherein the expansive force of compressed fluid in said pressure chamber constitutes the sole means for returning the piston from its advanced position to its retracted position.

6. In a pneumatically actuated device, in combination, a cylinder having a tapered frusto-conical internal working surface of small slant angle, an axially reciprocable piston movably disposed in said cylinder and moveable between a retracted position wherein it is disposed adjacent the large end of the cylinder and an advanced position wherein it is disposed adjacent the small end of the cylinder, an end wall closing the large end of the cylinder, valve means selectively operable to admit air at a predetermined working pressure to the large end of the cylinder to drive the piston forwardly from its retracted position to its advanced position and to relieve such working pressure to allow the piston to return to its retracted position, a pair of axially spaced expansible and contractible sealing rings carried by the piston and in sliding engagement with said frusto-conical working surface and, in combination therewith and with said sealing rings, establishing a variable-volume pressure chamber which travels with the piston and the volume of which consequently is a function of the axial displacement of the piston within the cylinder, there being an air passage in said piston establishing communication between said pressure chamber and the large end of the cylinder, a check valve disposed in said fluid passage effective to admit air to the pressure chamber when the air pressure in the pressure chamber falls below a predetermined level and to prevent fluid from entering the large end of the cylinder, and means independent of said frusto-conical working surface for guiding said piston in coaxial re-
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7. In a fluid-actuated device, a cylinder having a tapered frusto-conical internal working surface of small slant angle, an axially reciprocable piston in said cylinder being movable between a retracted position wherein it is disposed adjacent the large end of the cylinder and an advanced position wherein it is disposed adjacent the small end of the cylinder, an end wall closing the large end of the cylinder, means for selectively admitting a fluid under pressure to the large end of the cylinder to drive the piston forwardly from its retracted position to its advanced position and for relieving such fluid pressure to allow the piston to return to its retracted position, a pair of axially spaced expansible and contractible sealing rings carried by the piston during engagement with said frusto-conical working surface, the outer sealing ring between said sealing rings being formed with a continuous annular recess therearound, opposing said frusto-conical working surface, said annular recess, in combination with said frusto-conical working surface and said sealing rings, establishing an annular variable-volume fluid pressure chamber which travels with the piston and the volume of which consequent progressively decreases in volume as said piston approaches its advanced position, there being a fluid passage in said piston establishing communication between said pressure chamber and the large end of the cylinder, and a check valve disposed in said fluid passage and effective to admit fluid to the pressure chamber when the pressure of fluid in the large end of the cylinder exceeds the pressure of fluid in the pressure chamber and to prevent passage of fluid from the pressure chamber to the large end of the cylinder, whereby fluid under pressure admitted to the large end of the cylinder when the piston is in its retracted position will enter said pressure chamber through said passage, the fluid thus admitted to the pressure chamber will be progressively compressed during movement of the piston toward its advanced position due to the progressive decrease in the volume of the pressure chamber, and the expansive force of the thus compressed fluid within the pressure chamber will be effective to return the piston to its retracted position when the pressure of fluid in the large end of the cylinder is relieved.

8. In a fluid-actuated device, the combination set forth in claim 7, wherein said axially spaced expansible and contractible sealing rings are in the form of continuous elastomeric sealing rings, the outer side surface of said piston being formed with continuous annular grooves therearound within which grooves the sealing rings are floatingly confined.

9. In a pneumatically operable device, a cylinder having a tapered frusto-conical internal working surface of small slant angle, an axially reciprocable piston is said cylinder and movable between a retracted position where in it is disposed adjacent the large end of the cylinder and an advanced position wherein it is disposed adjacent the small end of the cylinder, the end region of the piston which opposes the large end of said working surface being of greater diameter than the end region of the piston which opposes the small end of the working surface whereby the piston is generally of tapered design and on a slant angle commensurate with the slant angle of said working surface, an end wall closing the large end of the cylinder, means for selectively admitting air at a predetermined working pressure to the large end of the cylinder to drive the piston forwardly from its retracted position to its advanced position and for relieving such working pressure to allow the piston to return to its retracted position, there being a continuous annular groove formed in each end region of the piston, an elastomeric O-ring disposed in each of said grooves and in sealing sliding engagement with said frusto-conical working surface, the outer side surface of the piston between said O-rings opposing the frusto-conical working surface and, in combination therewith and with the O-rings, defining a variable-volume air pressure chamber which travels with the piston and the volume of which consequent is a function of the axial displacement of the piston within the cylinder, there being a fluid passage in said piston establishing communication between said pressure chamber and the large end of the cylinder, and a check valve disposed in said fluid passage and effective to admit fluid to the pressure chamber when the pressure of fluid in the large end of the cylinder exceeds the pressure of fluid in the pressure chamber and to prevent passage of fluid from the pressure chamber to the large end of the cylinder when the pressure of fluid in the pressure chamber exceeds the pressure of fluid in the large end of the cylinder, whereby fluid under pressure admitted to the large end of the cylinder when the piston is in its retracted position will enter said pressure chamber through said passage, the fluid thus admitted to the pressure chamber will become progressively compressed during movement of the piston toward its advanced position due to the progressive decrease in the volume of the pressure chamber, and the expansive force of the thus compressed fluid within the pressure chamber will be effective to return the piston to its retracted position when the pressure of fluid in the large end of the cylinder is relieved.

10. In a pneumatic impact tool of the character described, in combination a cylinder having a frusto-conical wall of small slant angle, an axially reciprocable piston in said cylinder and movable between a retracted position wherein it is disposed adjacent the large end of the cylinder and an advanced position wherein it is disposed adjacent the small end of the cylinder, an end wall at each end of the cylinder, valve means for selectively admitting air at a predetermined working pressure to the large end of the cylinder to drive the piston forwardly from its retracted position to its advanced position and for bleeding said large end of the piston to the atmosphere to relieve such working pressure therein and permit return of the piston, a driven fixedly secured to the piston and projecting through the end wall at the small end of the cylinder in guided relationship, a pair of axially spaced radially expansible and contractible sealing rings carried by the piston and in sliding engagement with said frusto-conical wall, the outer side surface of the piston between said sealing rings opposing said frusto-conical wall and, in combination therewith and with said sealing rings, establishing an annular variable-volume pressure chamber being a function of the axial displacement of the piston within the cylinder, said piston being provided with an air passage therein establishing communication between said pressure chamber and the large end of the piston, a check valve disposed in said air passage and effective to admit air to the pressure chamber when the pressure in such chamber falls below the working pressure of air in the large end of the piston, the slant angle of said frusto-conical wall being sufficiently great that the sum of the vectorial forces acting upon the piston due to the expansive force of air entrapped within said pressure chamber will yieldingly urge the piston toward its retracted position in all intermediate positions of the piston when the large end of the piston is bled to the atmosphere by said valve means.

11. In a pneumatic impact tool of the character described, the combination set forth in claim 10, wherein said expansible and contractible sealing rings are in the form of elastomeric O-rings seated within respective annular grooves provided in the side surface of the piston.
12. In a fluid-actuated device, a cylinder having a tapered frusto-conical internal working surface of small slant angle, an axially reciprocable piston in said cylinder and movable between a retracted position wherein it is disposed adjacent the large end of the cylinder and an advanced position wherein it is disposed adjacent the small end of the cylinder, means for selectively admitting a fluid under pressure to the large end of the cylinder to drive the piston forwardly from its retracted position to its advanced position and for relieving such fluid pressure to allow the piston to return to its retracted position, means in the vicinity of said piston and movable bodily with the piston establishing a fluid pressure chamber, there being a fluid passage in said piston establishing communication between the large end of the cylinder and said pressure chamber, a check valve disposed in said passage and effective to admit fluid to the pressure chamber when the pressure therein falls below the pressure of fluid in said large end of the cylinder, the expansive force of fluid in said pressure chamber being effective in a generally radial direction against said frusto-conical wall and serving, by a circumferential camming action, yieldingly to urge the piston toward its retracted position when fluid pressure in the large end of the cylinder is relieved.

13. In a pneumatically operable device, a cylinder having a tapered working surface of small slant angle, a piston reciprocable in said cylinder and movable between a retracted position wherein it is disposed adjacent the large end of the cylinder and an advanced position wherein it is disposed adjacent the small end of the cylinder, means for admitting air to the large end of the cylinder to drive the piston toward its advanced position, and air pressure means interposed between an area of the piston and said tapered working surface and effective in any position of piston displacement to yieldingly urge the piston toward its retracted position.

14. In a fluid pressure actuated device, a cylinder having a downwardly and inwardly tapered substantially frusto-conical working surface of small slant angle, a piston axially reciprocable in said cylinder and movable between a retracted position adjacent the large upper end of the cylinder and an advanced position adjacent the small lower end thereof, means for admitting fluid under pressure to the large end of the cylinder to drive the piston downwardly toward its advanced position, said piston and tapered working surface defining therebetween a pressure chamber, means for admitting fluid under pressure to said pressure chamber for entrapping therein, said piston being subject to the force exerted thereon by entrapped fluid within said pressure chamber for return of the piston to its retracted position when fluid pressure in the large end of the cylinder is relieved.

15. In a pneumatically operable device, a cylinder having a downwardly and inwardly tapered substantially frusto-conical internal working surface of small slant angle, a piston axially reciprocable in said cylinder and movable between a retracted position adjacent the large upper end of the cylinder and an advanced position adjacent the small lower end of the cylinder, means for admitting air to the large end of the cylinder to drive the piston downwardly to its advanced position, said piston and tapered working surface defining therebetween a constant height, variable volume, pressure chamber the volume of which is a function of the axial displacement of the piston, within the cylinder, means for applying air under pressure to said pressure chamber for entrapping therein, said piston, in all positions thereof, being subject to the force exerted upon the piston by entrapped air within said pressure chamber for return thereof to its retracted position when air pressure in the large end of the cylinder is relieved.

16. In a pneumatically operable device, a cylinder having a downwardly and inwardly tapered substantially frusto-conical internal working surface of small slant angle, a piston axially reciprocable in said cylinder and movable between a retracted position adjacent the large upper end of the cylinder and an advanced position adjacent the small lower end of the cylinder, means for admitting air to the large end of the cylinder to drive the piston downwardly to its advanced position, sealing means effective between each end of the piston and the tapered working surface, said sealing means in combination with an area of the piston and an opposed area of the working surface, establishing a pressure chamber which moves bodily with the piston, means for admitting air under pressure to said pressure chamber for entrapping therein, said piston, in all positions thereof, being subject to the force exerted upon the piston by entrapped air within the pressure chamber for returning the piston to its retracted position when air pressure in the large end of the cylinder is relieved.

17. In a fastener-applying implement, a cylinder having a tapered internal working surface, a piston axially reciprocable in said cylinder and movable between a retracted position wherein it is disposed adjacent the large end of the cylinder and an advanced position wherein it is disposed adjacent the small end of the cylinder, valve means for selectively admitting air at a predetermined working pressure to the large end of the cylinder to drive the piston from its retracted position to its advanced position and for discharging air from said large end of the cylinder to permit return of the piston to its retracted position, air pressure means interposed between an area of the piston and said tapered working surface and effective in any position of piston displacement to yieldingly urge the piston toward its retracted position, a fastener magazine connected to the cylinder and extending radially therefrom, a throat at the end of the magazine for receiving fasteners therefrom, and a driver connected to the piston for driving fasteners through said throat to apply them to the work.

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