

United States Patent

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[54] FASTENER DRIVING TOOL
20 Claims, 12 Drawing Figs.

[52] U.S. Cl. 91/252,
91/308, 91/309, 91/318, 91/399

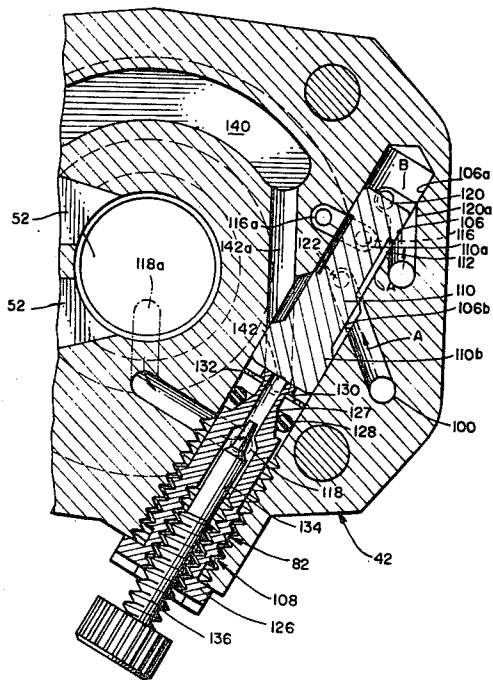
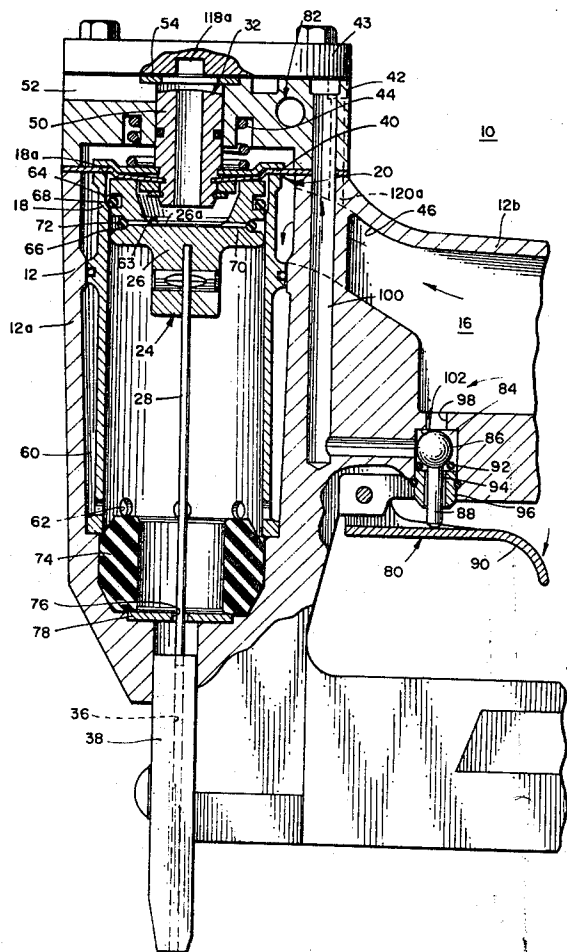
[51] Int. Cl..... F011 31/00,
F011 25/06

[50] **Field of Search**..... 91/(card),
220, 252, 308, 309

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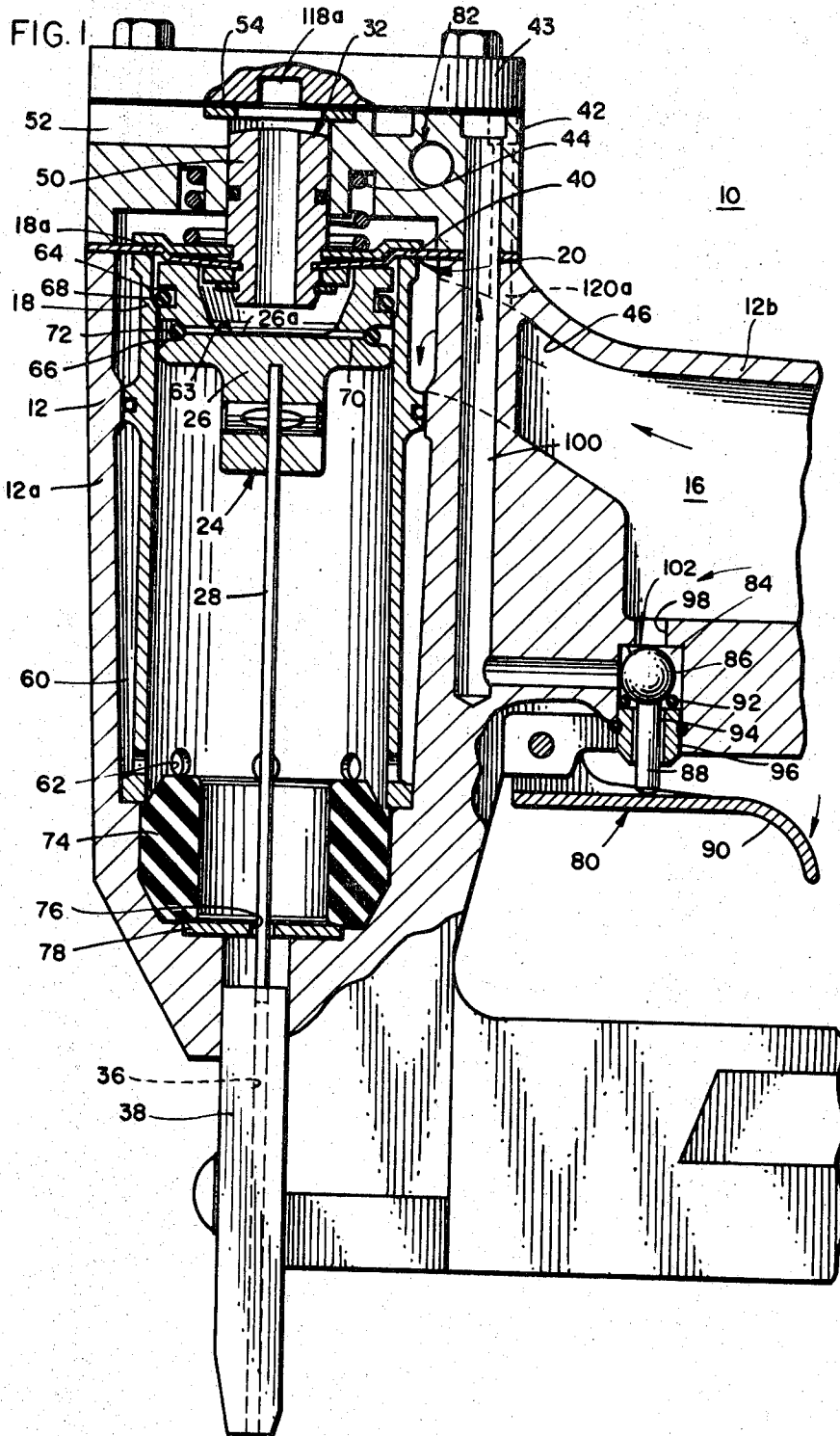
ABSTRACT: A pneumatically operated automatically cycling fastener driving tool includes a housing having a cavity defining a fluid reservoir. A cylinder is provided in the housing for slideably receiving a piston therein. A cylinder valve is provided for controlling the admission of fluid to and the exhaustion of fluid from one end of the cylinder. A suitable trigger arrangement is effective when depressed to exhaust the cylinder valve to atmosphere, and when released to connect the cylinder valve to the reservoir. An automatic cycling valve controls such admission to and discharge from the cylinder valve and is responsive to the pressure buildup in the upper end of the cylinder at the end of the driving stroke to switch the cylinder valve from exhaust to the reservoir to effect closing of the cylinder valve and the return stroke of the piston.



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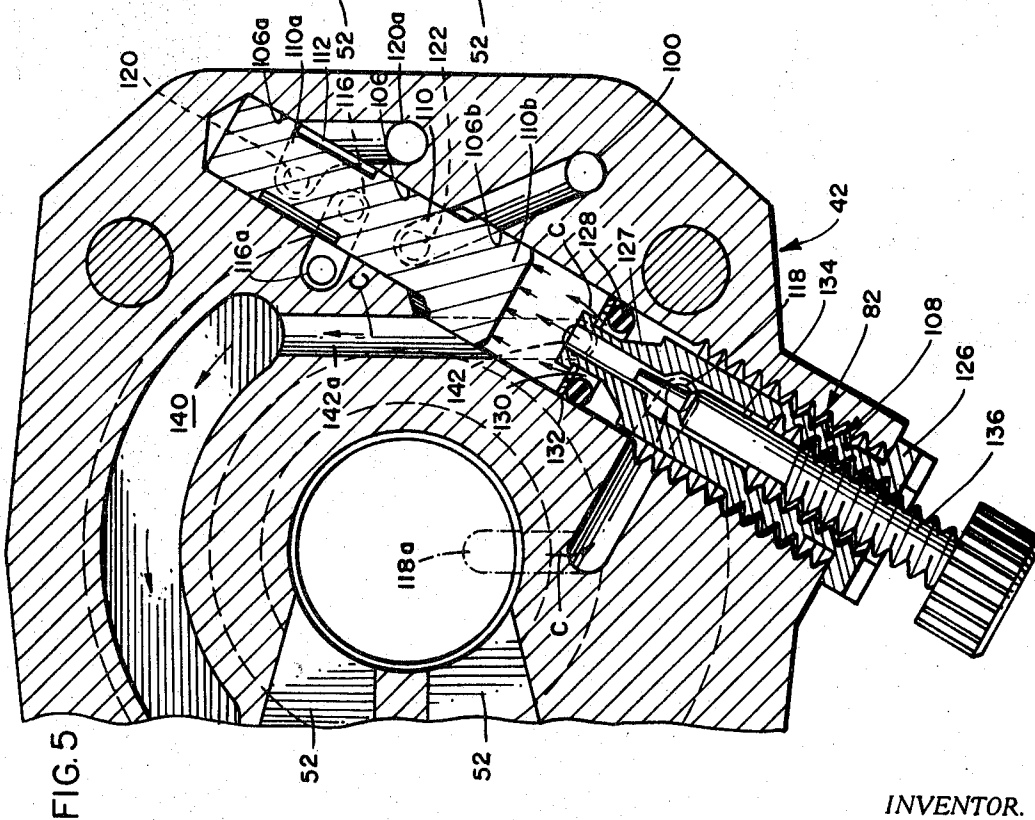
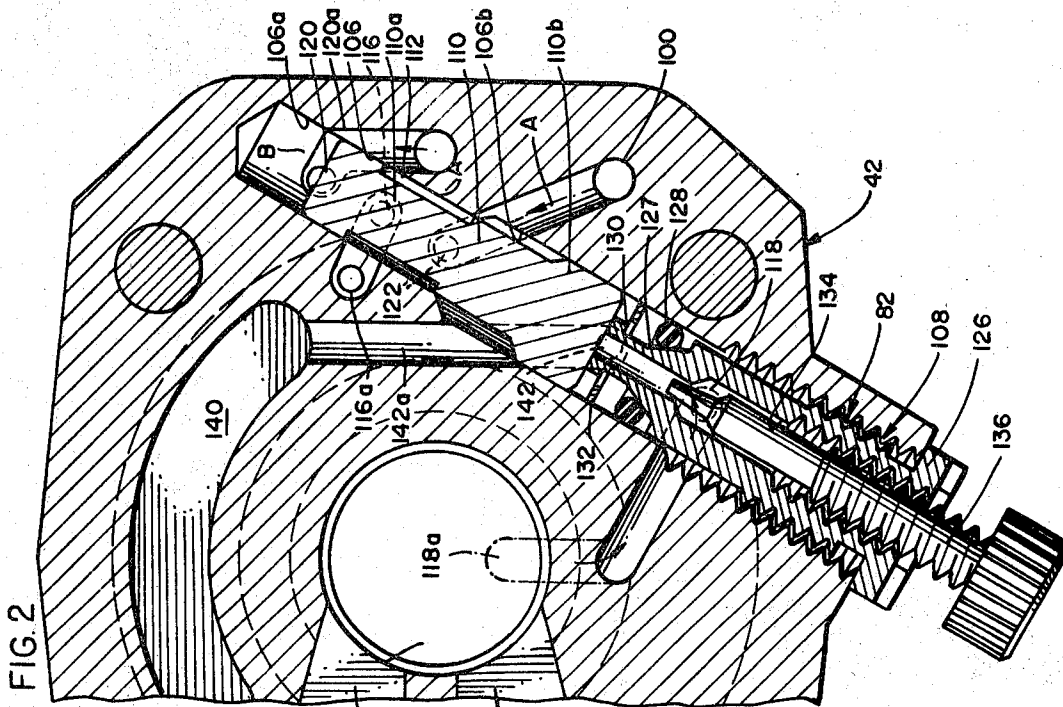
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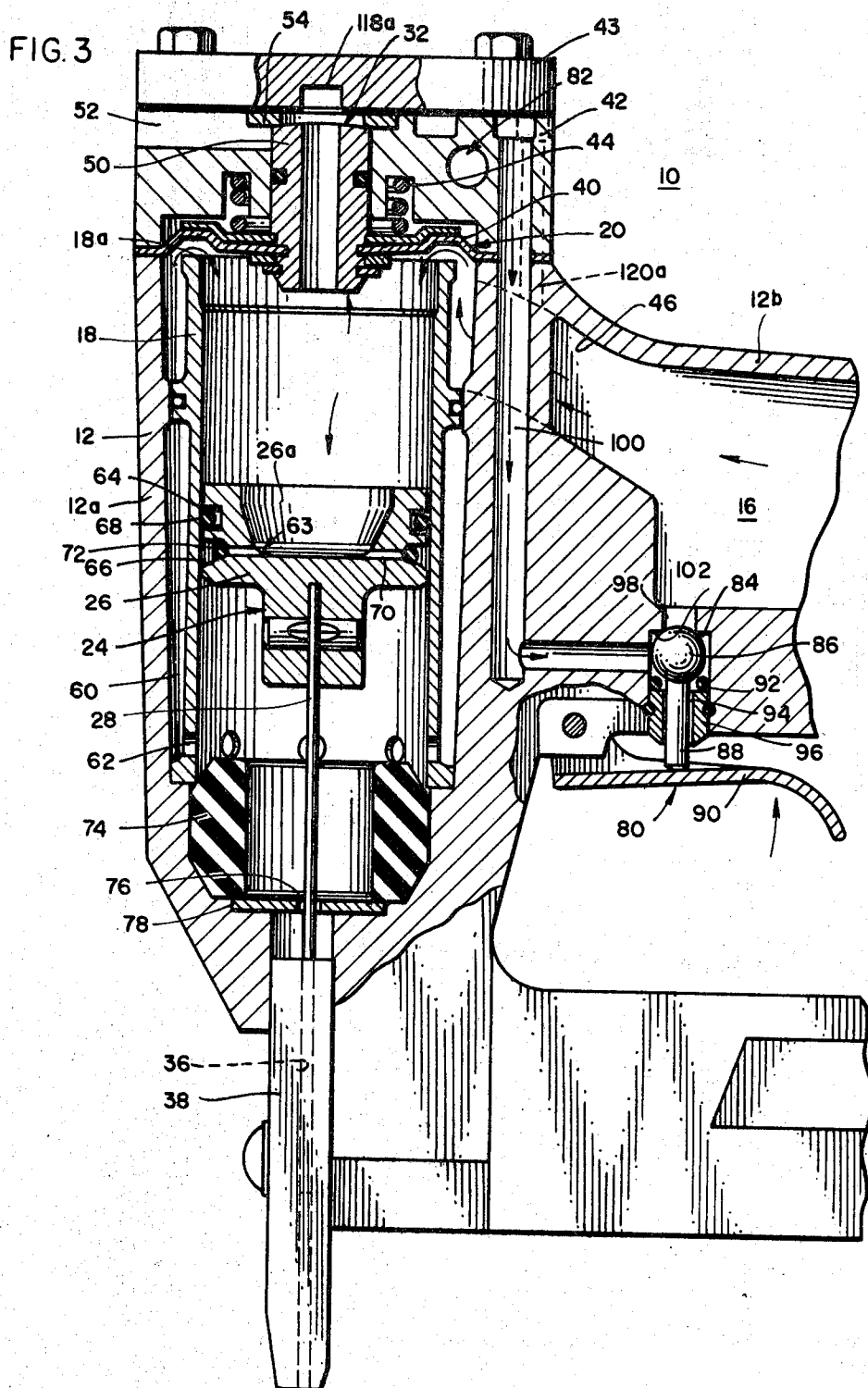
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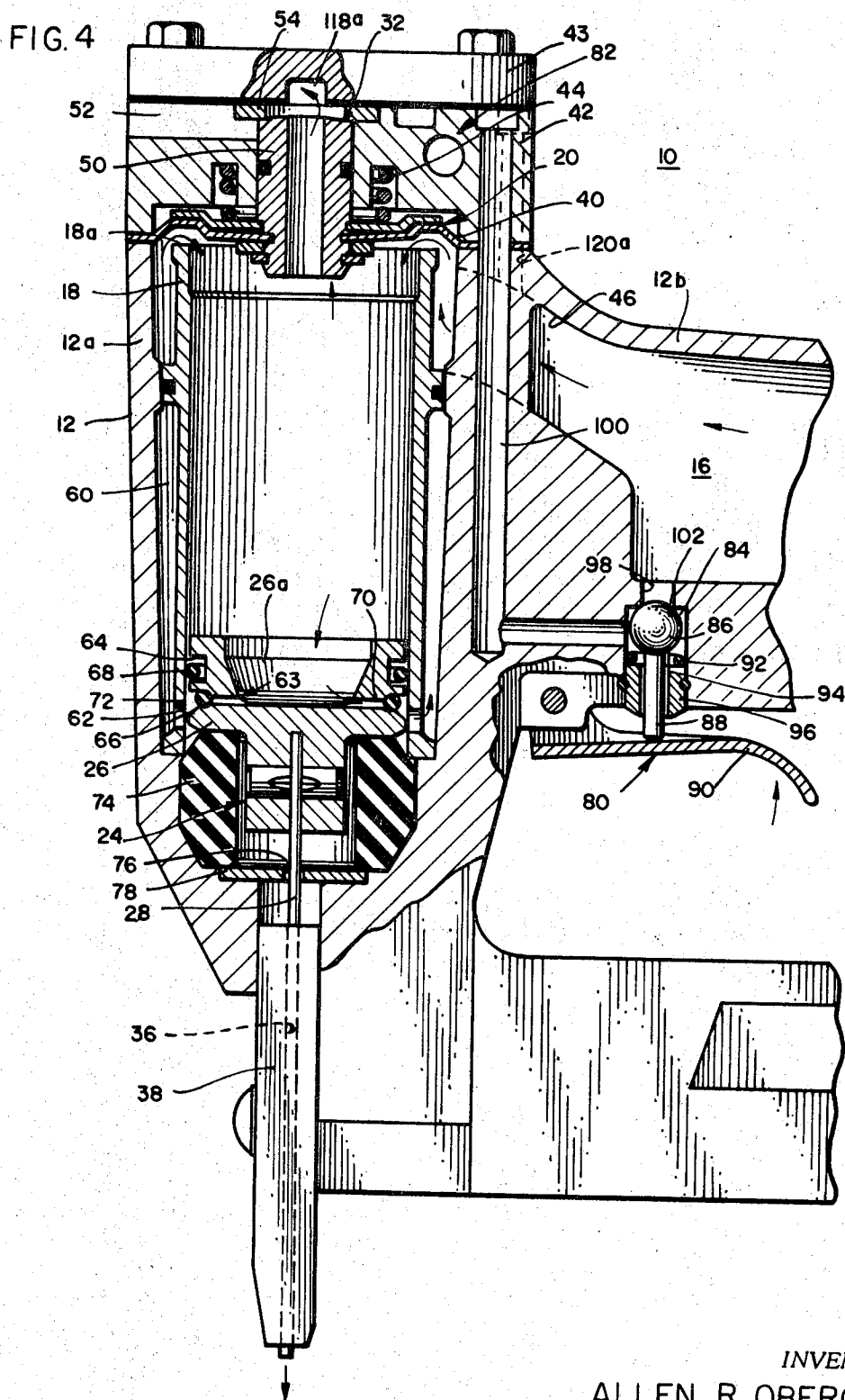
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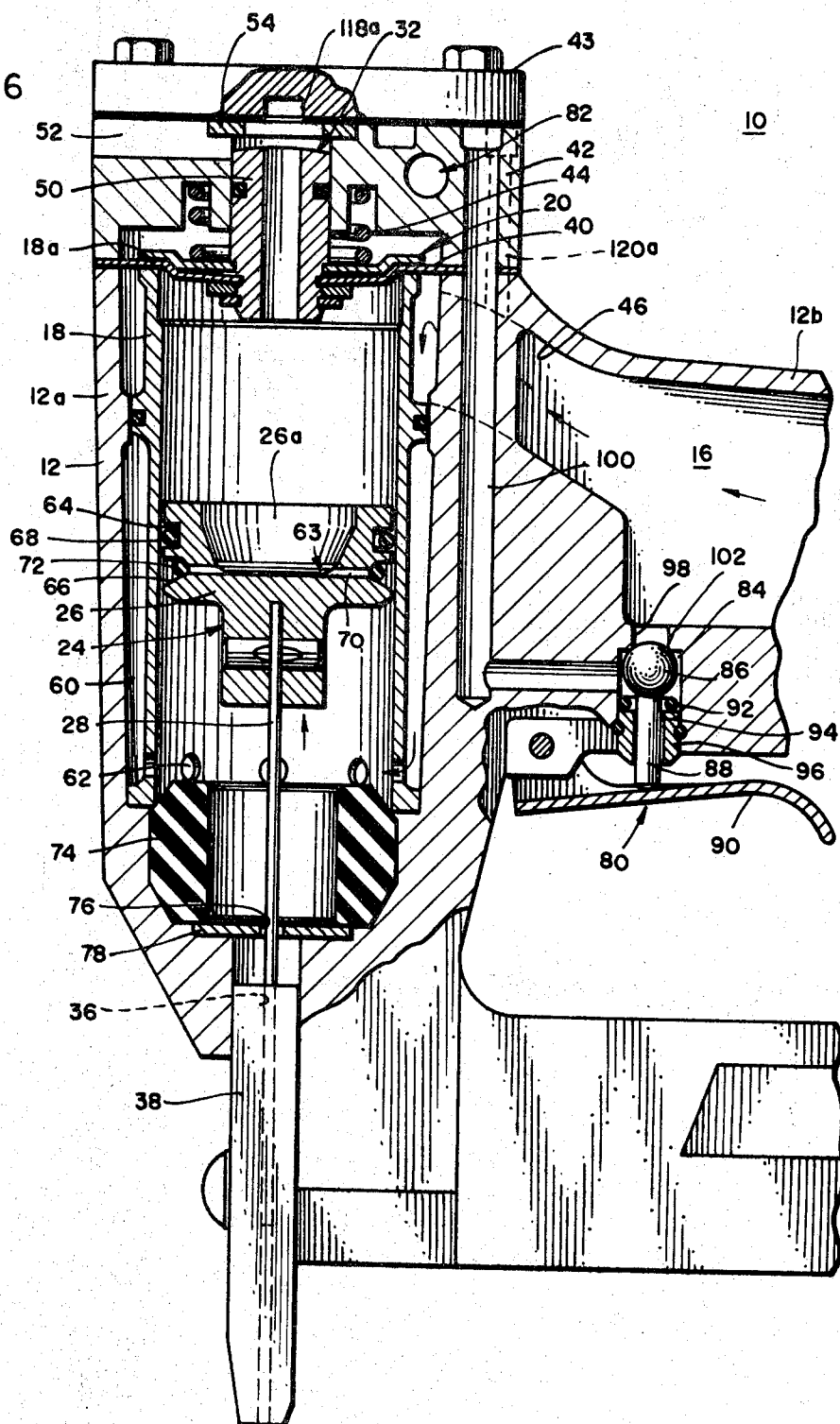


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FIG. 6



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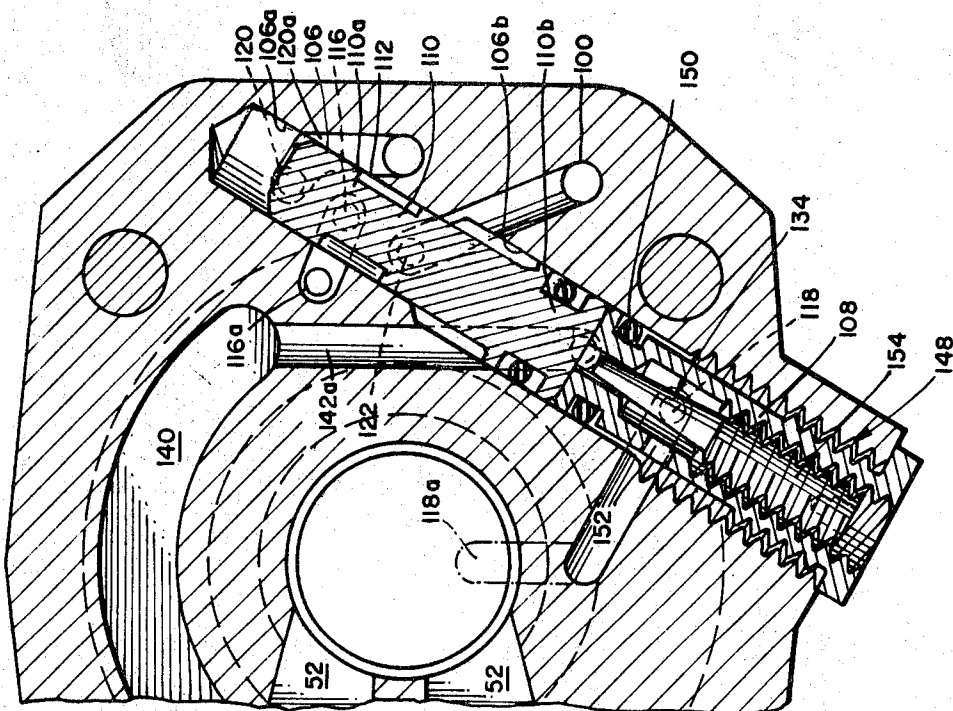


FIG. 8

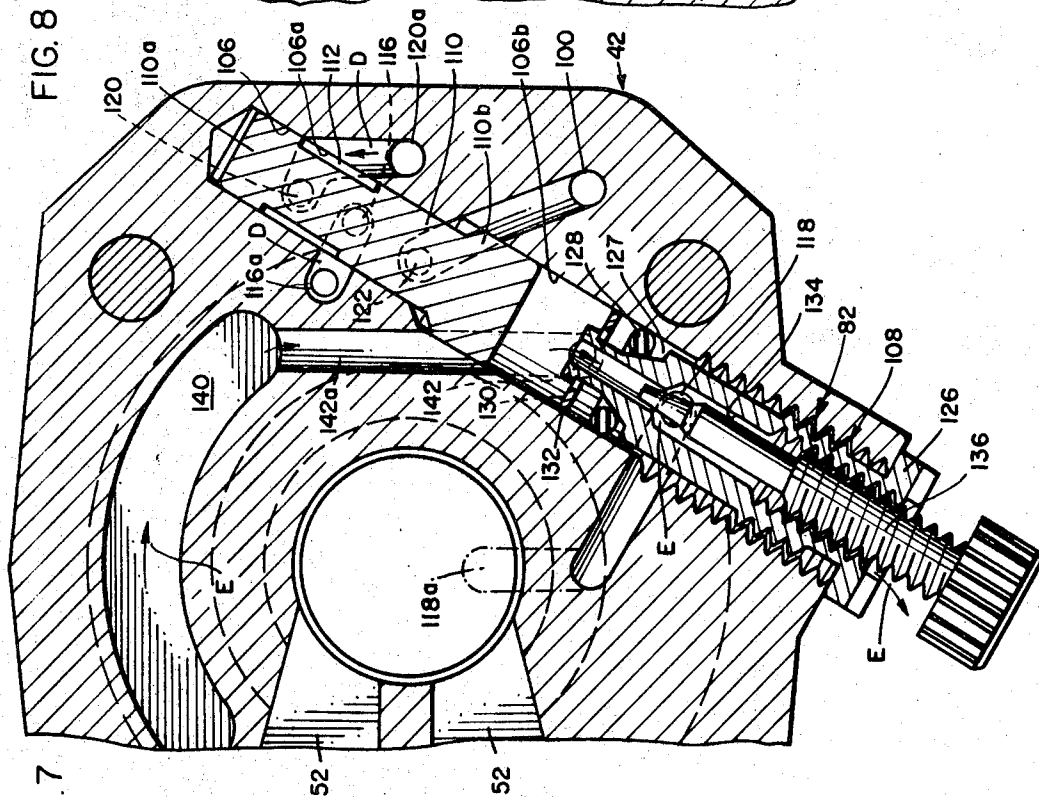


FIG. 7

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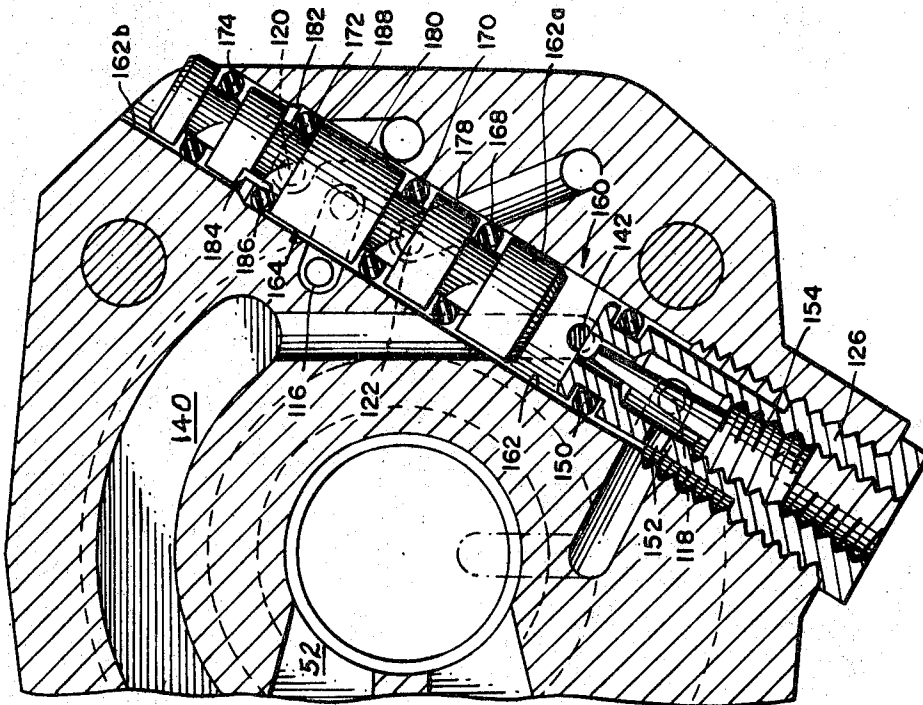


FIG. 10

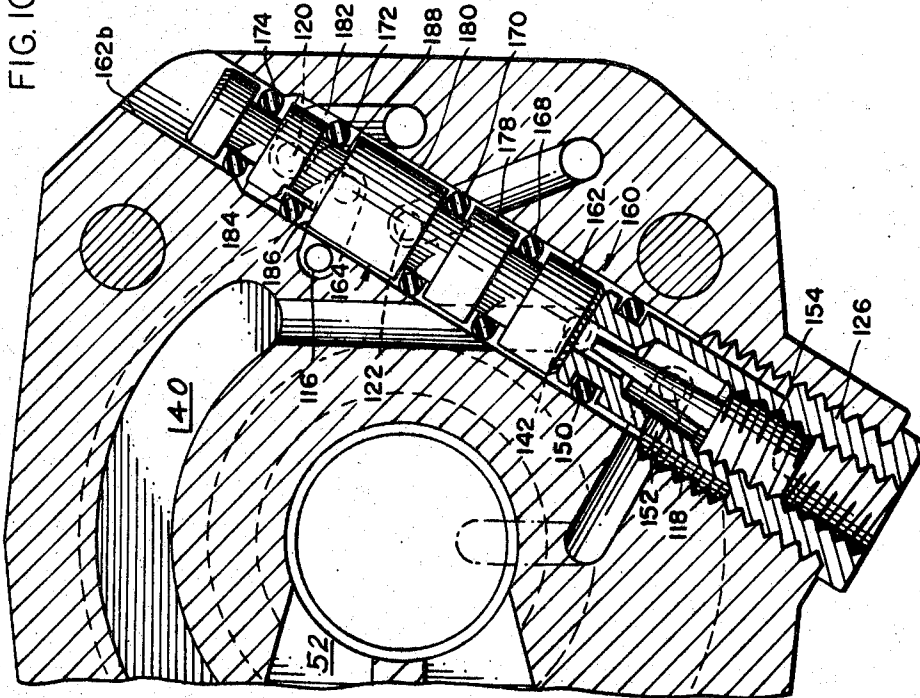


FIG. 9

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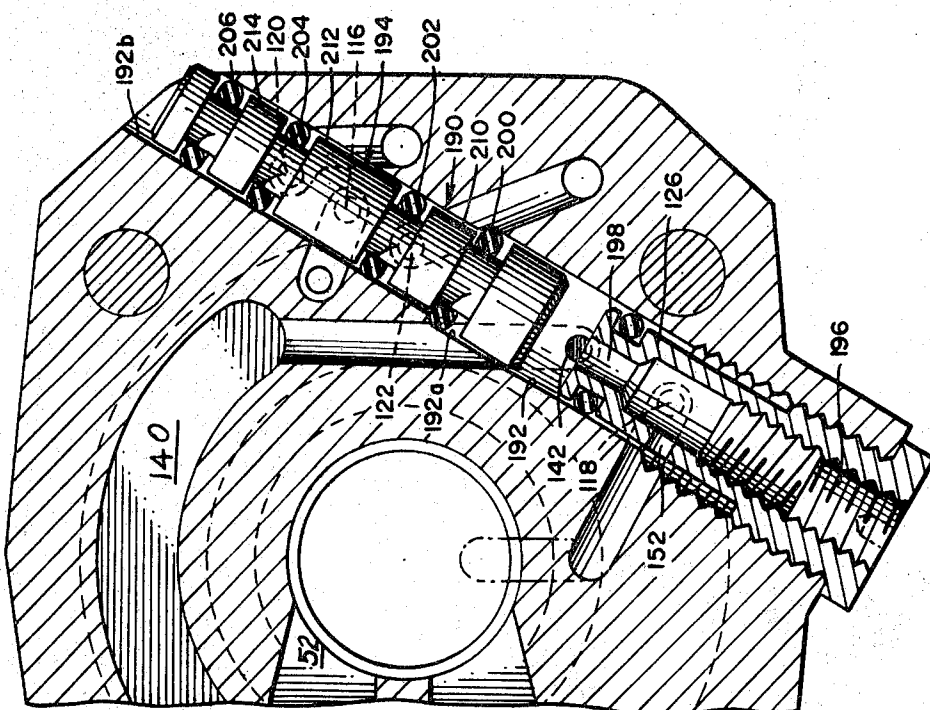


FIG. 12

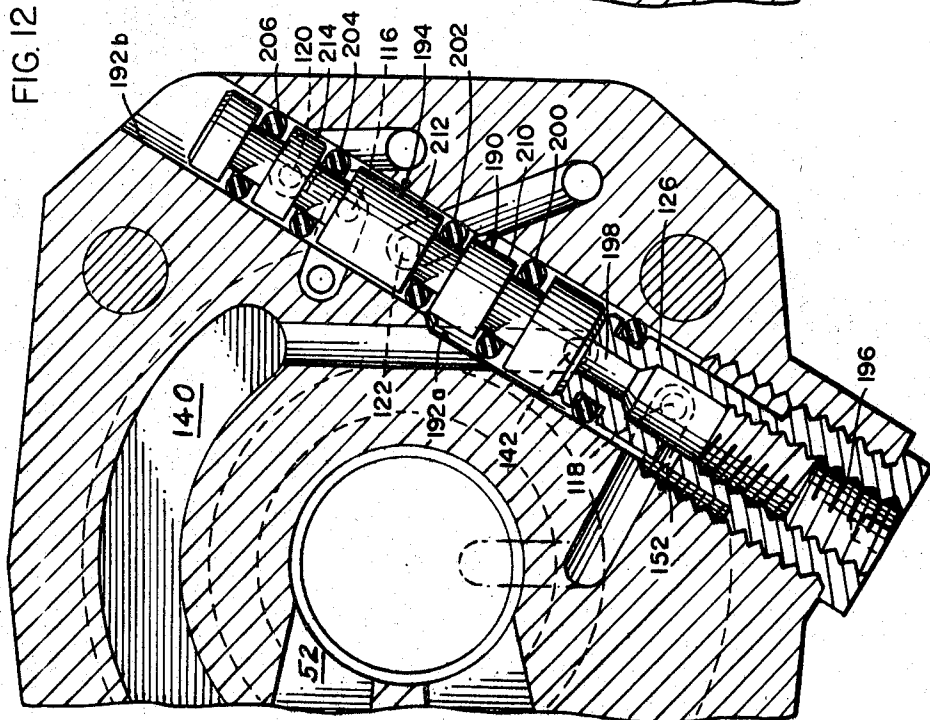


FIG. 11

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FASTENER DRIVING TOOL

This invention relates to a fastener driving tool and, more particularly, to a fastener driving tool including new and improved control means providing for successive or repetitive fastener driving operations upon a single depression of the tool trigger.

Commercially available pneumatic fastener driving tools in the past have frequently provided for a single fastener driving stroke upon each depression of the tool trigger. In order to provide rapid operation of the tool, it has been proposed to cycle the tool through a drive and return stroke upon a single depression of the trigger. Moreover situations have arisen where it is desirable to drive a plurality of fasteners in successive fastener driving operations and suitable short intervals upon a single depression of the tool trigger. It is frequently desirable that such autofire fastener driving tools be adaptable for single-stroke operation, or for operation in a repetitive manner upon a single depression of the tool trigger. Commercially available automatically firing tools commonly require switching from high speed repetitive operation to the single-fire mode before a single fastener can be driven. Most desirably such control of the tool should preferably be accomplished without manual selection of the mode of operation and with a minimum effort by the operator.

An object of the present invention therefore is to provide a new and improved pneumatically actuated fastener driving tool of the type to continuously and repetitively operate through its working cycle so long as the trigger thereof is depressed.

Another object of the present invention is to provide a fastener driving apparatus having new and improved control means.

Yet a further object of the present invention is the provision of the fastener driving tool of the type wherein the tool will repetitively and continuously operate through its working cycle so long as the trigger member is depressed, and wherein the rate of recycling of the tool may readily be varied.

Yet a further object of the present invention is the provision of a fastener driving tool of the type which may be conveniently actuated as a single-stroke tool or operated to continuously and repetitively operate through its working cycle so long as the trigger thereof is depressed.

Yet a further object is to provide a new and improved single-cycle or snap-acting fastener driving tool wherein the tool cycles through both a drive stroke and a return stroke upon depression of the trigger without the delay of releasing the trigger.

Further objects and advantages of the present invention will become apparent as the following description proceeds and the features of novelty which characterize the invention will be pointed out with particularity in the claims annexed to and forming a part of this specification.

In accordance with these and other objects there is provided a new and improved automatically cycling fastener driving tool. A known type of commercially available fastener driving tool includes a housing having a cavity defining a fluid reservoir and containing a cylinder in the housing slideably receiving a piston therein. A cylinder valve is provided for controlling the admission of fluid to and the exhaustion of fluid from one end of the cylinder. A return fluid chamber in the housing communicates with the cylinder and is effective to move the piston to its return stroke. In accordance with the present invention control means are provided for automatically recycling the fastener driving tool in response to the pressure buildup above the piston at the completion of its driving stroke. Such fluid under pressure above the piston is effective to shift a valve element in a cycling valve to provide for the return stroke of the drive piston. Subsequent bleeding of this fluid from the cycling valve will be effective to reset the valve and initiate a second drive stroke of the drive piston. In a preferred embodiment of the invention, a timing chamber communicates with the recycling valve which delays the pressure buildup to the cycling valve element after the first drive

stroke following depression of the tool trigger, thus causing a delay in the recycling of the tool after the first drive stroke. Such delay permits the operator selectively to operate the tool as a single-stroke tool, or by maintaining the trigger depressed, the operator may readily use the tool for repetitive operation. Subsequent firing of the tool after the initial stroke will be at a faster or set rate.

Advantageously the present recycling control structure may be incorporated into an existing commercial line of single-stroke tools by the mere replacement of the prior cylinder cap with a cap containing the improved cycling valve, and drilling of an additional passageway in the housing. Thus the tools may be most economically produced with a minimum inventory of replacement parts.

Many other objects and advantages of the present invention will become apparent from considering the following detailed description in conjunction with the drawings in which:

FIG. 1 is a fragmentary cross-sectional view of a fastener driving tool incorporating the present invention and illustrating the drive piston in its static or at rest position;

FIG. 2 is a cross-sectional view of the fastener driving tool of FIG. 1, illustrating the control valve arrangement;

FIG. 3 is a fragmentary cross-sectional view of the fastener driving tool of FIG. 1, illustrated during its drive stroke;

FIG. 4 is a fragmentary cross-sectional view of the fastener driving tool of FIG. 1, illustrated with the drive piston at the bottom of its drive stroke;

FIG. 5 is a cross-sectional plan view of the control mechanism, illustrated in the position of FIG. 4;

FIG. 6 is a fragmentary cross-sectional view of the fastener driving tool of FIG. 1, illustrated with the piston in its return stroke;

FIG. 7 is a fragmentary cross-sectional plan view of the control mechanism of the fastener driving tool, illustrated in the same position as FIG. 6;

FIG. 8 is a fragmentary cross-sectional plan of a control mechanism for a fastener driving tool according to another embodiment of the present invention;

FIG. 9 is a fragmentary sectional view of a control valve assembly forming another embodiment of the invention shown in a normal position;

FIG. 10 is a fragmentary sectional view of the valve assembly of FIG. 9 shown in an operated position;

FIG. 11 is a fragmentary sectional view of a control valve assembly forming another embodiment of the invention shown in a normal position; and

FIG. 12 is a fragmentary sectional view illustrating the valve assembly of FIG. 11 in an operated position.

Referring now to the drawings, there is fragmentarily illustrated a fastener driving tool generally as 10, which embodies a cycling valve assembly to provide for autofire of the tool according to the present invention. The tool 10 may be of generally known construction and, as illustrated, is similar to that described in the copending application Ser. No. 602,728, filed Dec. 19, 1966, by Richard H. Doyle and assigned to the same assignee as the present invention. The tool 10 comprises a housing 12 including a generally vertically extending head or forward portion 12a and a rearwardly extending hollow handle portion 12b defining a fluid reservoir 16. Pressurized fluid such as compressed air is supplied to the fluid reservoir of the tool 10 by a suitable flexible line. The drive system for the tool 10 includes a main or power cylinder 18 mounted within the head portion 12a having an open upper end 18a that is adapted to be selectively connected to the reservoir 16. The open upper end of the cylinder 18 is in engagement with a diaphragm type main or cylinder valve assembly 20, here shown of the poppet type, under the control of a control or trigger valve assembly and a cycling valve assembly according to the present invention. A fastener driving assembly 24 slideably mounted within the cylinder 18 includes a work or drive piston 26 and has connected thereto a depending driver blade member 28. The fastener driving assembly 24 is normally biased to a position with the piston 26 adjacent the

cylinder valve assembly 20, as illustrated in FIG. 1. An exhaust valve assembly indicated generally as 32 is provided for controlling the selective connection of the upper end of the cylinder 18 to the atmosphere.

When the tool 10 is to be operated, compressed fluid from the reservoir 16 enters the upper open end 18a of the cylinder 18 and drives the fastener driving assembly 24 downwardly to engage and set a fastener or nail supplied to a drive tract 36 in a nosepiece and nosepiece structure 38. The flow of compressed fluid into the upper end of the cylinder 18 is controlled by the cylinder valve assembly 20, which includes a diaphragm 40, the periphery of which is clamped between a cap 42 and a cover plate 43 against the head portion 12a of the housing 12 and which seats against the upper edge 18a of the cylinder 18. The diaphragm 40 is resiliently biased against the upper edge surface 18a by a spring 44 located between the cap 42 and the diaphragm 40. The cylinder side of the diaphragm 40 is continuously in communication with the fluid reservoir 16 through a suitable passageway 46 so that pressurized fluid continuously acts against the cylinder side of the diaphragm 40 tending to displace the diaphragm 40 from the edge 18a of the cylinder 18. However pressurized fluid is also introduced to the opposite side of the diaphragm 40 while the fastener driving tool is in a static or at rest position. The pressure acting above the diaphragm 40 is effective to maintain the diaphragm 40 in a closed position, as illustrated in FIG. 1. However if the pressurized fluid above the diaphragm 40 is discharged, the pressurized fluid through the passageway 46 is effective to unseat the diaphragm 40 from the edge 18a of the cylinder 18 to dump pressurized fluid into the top of the main cylinder 18 and to drive the drive piston 26 through a drive stroke.

When the fastener driving tool is at rest, or when the drive piston is in its return stroke, the open upper end of the cylinder 18 is exhausted to the atmosphere through the exhaust valve assembly 32. In the illustrated embodiment the exhaust valve assembly 32 comprises a hollow valve stem 50 which is secured to the diaphragm and which connects the upper end of the cylinder to the atmosphere through a plurality of suitable exhaust passages 52. However when the drive piston is operated through a fire or drive stroke, it is necessary for the upper end of the cylinder 18 to be closed, and to this end there is provided a valve seat 54 disposed adjacent the end of the valve stem 50 remote from the cylinder 18 and adapted to be engaged by the valve stem 50 when the diaphragm 40 is raised at the initiation of a drive stroke, thereby closing off the upper end of the cylinder 18 to the atmosphere.

To provide for the return drive of the fastener driving assembly 24, there is provided an air return chamber 60 communicating with the lower end of the cylinder 18 through a plurality of ports 62. Moreover the drive piston 26 is provided with suitable one way valve means 63. To this end the piston 26 is provided with spaced peripheral grooves 64 and 66, the upper one of which serves as a sealing groove while the lower one 66 functions as the one way valve means 63 to provide for the bypass of pressurized fluid to the air return chamber 60. An O-ring 68 provided in the upper one of the grooves 64 functions as a sealing member effecting a pneumatic seal between the piston 26 and the inner wall of the cylinder 18. To bypass around the groove 64 and O-ring 68, there is provided a plurality of air passageways 70 extending from the lower one 66 of the grooves and communicating with a central cavity 26a in the piston 26. An O-ring 72 defining a valve element is positioned within the lower one 66 of the grooves. The O-ring 72 is expandable upon a selected pressure differential between the upper and lower ends of the cylinder to the piston 26 so as to unseat from the ports of the air passageways 70 to provide for fluid to bypass through the piston 26 around the O-ring 72 and to supply air to the return chamber 60.

It will be understood that in the operation of the basic tool the piston 26 and associated driver blade member 28 are driven downwardly through a drive stroke by the connection of the upper end 18a of the cylinder 18 with the reservoir 16.

Since there is no significant restraint to the piston during its downward movement, the pressure above the piston 26 will not build up sufficiently to unseat the O-ring 72 until the piston 26 approaches the bottom of its drive stroke. At this point the pressure above the piston 26 will continue to build up until it approaches the pressure in the reservoir 16 and the O-ring 72, functioning as a valve element, will be unseated from the ports of the air passageways 70, thereby providing a source of pressurized fluid to the air return chamber 60 through the air passageway 62.

To cushion the drive stroke of the piston 26, and to seal the lower end of the housing 12a when the piston 26 is at its lowermost position, there is provided a resilient annular bumper 74 at the lower end of the cylinder 18 which is engageable by the piston 26 as it is at the end of its drive stroke. Fluid such as compressed air from the lower end of the cylinder normally vents through a blade opening 76 in a washer 78 at the lower end of the bumper 74. However when the piston 26 engages the bumper 74 as illustrated in FIG. 4, pressurized fluid which passes around the O-ring 72 cannot vent to atmosphere through the blade opening 76. Upon exhaustion of the open upper end 18a of the cylinder 18 to the atmosphere, the pressurized fluid in the air return chamber 60 will reenter the lower end of the cylinder 18 through the ports 62 and will drive the piston 26 back to its normal or at rest position. Leakage of air around the blade opening 76 is not rapid enough to prevent the return of the piston 26.

The operation of the tool 10 is under the control of a trigger valve assembly 80 and a cycling valve assembly 82 incorporated into the cap 42. Referring first to the trigger valve assembly, which is of a known type, there is provided a valve chamber 84 within the housing 12 containing a valve element in the form of a valve ball 86 operable by a valve pin 88 upon depression or release of the trigger 90. The trigger valve assembly 80 functions as a three way valve, so that when the trigger 90 is released, the valve ball 86 seats against an O-ring 92 defining a valve seat and closes off an exhaust passageway 94 extending from the valve chamber 84 and defined between the valve pin 88 and a valve retainer 96. With the valve ball 86 in this normal position, a reservoir passageway 98 is placed in communication with the valve chamber 84 and pressurized fluid from the reservoir 16 is supplied to a trigger passageway 100 which also opens into the valve chamber 84.

Depression of the trigger 90 however is effective to unseat the valve ball 86 from the valve seat 92 and to seat the valve ball 86 against a confronting edge 102 of the passageway 98 also defining a valve seat. Thus the trigger passageway 100 is closed from communication with the reservoir 16, and is simultaneously exhausted to the atmosphere through the valve chamber 84 and the exhaust passageway 94.

For controlling the automatic cycling of the tool 10, as best illustrated in FIGS. 2, 5 and 7, there is provided the cycling valve assembly 82 within the cap 42 of the tool 10 which is effective, after firing of the tool, to initiate recycling thereof in response to the pressure buildup in the cylinder 18 above the piston 26. Specifically the head 42 forms a valve body defining a valve cylinder 106 of the differential type, having a small diameter portion 106a and a large diameter portion 106b. The cylinder 106 is open at the large diameter end and the cylinder threading receives a needle valve assembly 108. A spool type valve element 110 of the differential diameter type is shiftably positioned within the cylinder 106 for movement from a normal position, as illustrated in FIG. 2, to an operated position, as illustrated in FIGS. 5 and 7. The valve element 110 is provided with a small diameter part 110a and a large diameter part 110b. An annular groove 112 defined in the small diameter part 110a intermediate the length thereof defines a fluid passageway. A first port 116 opens within the fluid passageway 112 and communicates with the cylinder valve assembly 20 through a passageway 116a. A second port 118 opens into the large diameter portion 106b of the valve cylinder 106 and communicates with the closed end of the cylinder through a passageway 118a opening in the top of the

valve seat 54. A third port 120 opens into the small diameter portion 106a of the valve cylinder 106 intermediate the stroke of the valve element 110 so as to communicate with the fluid passageway 112 when the valve element 110 is in its operated position, as illustrated in FIGS. 5 and 7, but opens into the small end of the valve cylinder 106 when the valve element 110 is in its normal position as indicated in FIG. 2. The third port 120 communicates with the reservoir through a suitable passageway 120a. A fourth port 122 opens into the fluid passageway 112 when the valve element is in a normal position, as illustrated in FIG. 2, to a position blocked by the valve element 110 when the valve element 110 is in an operated position, as illustrated in FIGS. 5 and 7. The fourth port 122 communicates with the trigger valve assembly 80 through the passageway 110.

In operation the valve element 110 is held in its normal position illustrated in FIG. 2 by the fluid pressure from the reservoir 16 acting through the port 120. The valve element 110 is moved to its operated position, as illustrated in FIGS. 5 and 7, by the buildup of fluid pressure within the cylinder 18 acting through the port 118 and against the large diameter end of the valve element 110. The valve element 110 will shift from its normal position to its operated position when the pressure acting on the large end thereof is sufficiently great to overcome the return bias of the reservoir pressure acting on the smaller end thereof. Moreover the valve element 110 will return to its normal position and recycle the tool as soon as the fluid pressure acting on the large diameter end 110b of the valve element 110 is bled off sufficiently to permit return of the valve.

To adjustably control the rate of recycling of the tool, there is provided the needle valve assembly 108 which restricts the exhaust of the fluid from the open end of the large diameter portion 106b of the valve cylinder 106. As therein illustrated, the needle valve assembly 108 includes a needle valve body 126 in the form of a sleeve threaded into the large diameter portion 106b of the valve cylinder 106. The needle valve body has a generally inwardly tapered point 127 against which an O-ring 128 can seat to define a check valve which will unseat to permit fluid flow from the port 118 toward the large diameter portion 110b of the valve element 110 and around ports 130 in a retaining ring 132, as illustrated in FIG. 5. However the check valve element 128 will seat between the valve seat 127 and the inner wall of the valve cylinder 106 to prevent reverse flow of the fluid, as illustrated in FIG. 7. The needle valve body 126 is provided with a longitudinal opening 134 adjustably receiving a needle element 136 serving to throttle or meter the escape flow of fluid from the large diameter portion 106b of the valve cylinder. The rate of bleeding air from the large diameter portion 106b will, of course, determine the recycling time of the tool.

To provide for single firing of the tool 10 without having to manually set or adjust the tool, a time delay is provided between the first and second driving strokes after initial actuation of the trigger. The time delay is accomplished through a timing chamber 140 communicating with the valve cylinder 106 through a port 142 opening into the large diameter portion of the valve cylinder 106b and a passageway 142. The timing chamber 140 is effective to cause a delay in the pressure buildup after the first stroke, but is not effective on succeeding strokes in the same burst or depression of the trigger. Thus the tool has a very important advantage of being easily used as a single shot tool or an autofire tool with no adjustment necessary by the operator.

From the above detailed description of the improved fastener driving tool, its operation is believed to be clear. However, briefly, it will be understood that the drive piston 26 is actuated through a drive stroke by the unseating of the diaphragm 40 from the upper end 18a of the cylinder, and is returned through a return stroke upon reseating of the diaphragm 40 and opening of the exhaust valve assembly 32 to atmosphere through the exhaust passageway 52. The position of the diaphragm 40 is controlled by the provision of pressurized fluid above the diaphragm, or the exhaustion thereof

to the atmosphere. Thus when the tool 10 is at rest, with the spool valve 110 in its normal position as illustrated in FIG. 2, fluid is supplied to the cylinder valve 20 through the passageway 100, ports 122 and 116 around the fluid passageway 112, and to the passageway 116a, as indicated by the arrows A in FIG. 2. At the same time the valve element 110 is held in its at rest position by the pressure of the fluid from the reservoir acting through the passageway 120a and port 120 against the small diameter end of the valve element 110, as illustrated by the arrows B in FIG. 2. The remaining ports of the cycling control valve assembly 80 are at atmospheric pressure.

Upon depression of the trigger, the cylinder valve 20 is exhausted to atmosphere through the passageway 116a, ports 116 and 122, around the fluid passageway 112, through the passageway 110, and into the trigger valve chamber 84 and the exhaust passageway 94. With the exhaustion of fluid from above the diaphragm 40, the cylinder valve 20 will snap open, dumping pressurized fluid above the piston 26 and driving the piston 26 through a drive stroke, as illustrated in FIG. 3. The pressure buildup above the cylinder during the drive stroke of the piston 26 is not sufficiently great to affect the position of the valve element 110. However as soon as the piston 26 reaches the end of its drive stroke, as illustrated in FIG. 4, pressure will begin to build up in the cylinder 18 above the piston 26. This buildup of pressure will result in an unseating of the O-ring 72 to permit fluid to pass through the one way valve means 63 into the air return chamber 60. At the same time the buildup of pressure will be effective to act through the opening in the hollow valve stem 50 and through the passageway 118a and port 118, to unseat the check valve 128 and act against the large diameter part 110b of the valve element 110. As soon as the pressure acting against the large diameter part 110 is sufficient to overcome the return force of the reservoir pressure acting against the small diameter portion 110a of the valve element 110 the valve element 110 will shift to the position illustrated in FIG. 5. However due to the volume of air which must enter the reserve chamber 140, there will be a short time delay in the buildup of pressure and accordingly the valve element 110 will not shift immediately. The size of the chamber 110 and connecting passageway 142a will, of course, determine the time delay. The flow of this signal fluid from the cylinder 18 will follow along the path of the arrows indicated as C, FIG. 5.

Upon shifting of the valve element 110 to its operated position, as illustrated in FIG. 7, fluid will now be directed from the reservoir 16 through the passageway 120a, ports 120 and 116, around the fluid passageway 112, and through the passageway 116a to the top of the cylinder valve 20 as illustrated by arrows D, FIG. 7, whereupon the cylinder valve 20 will close by having the diaphragm 40 thereof seat against the upper edge 18a of the cylinder 18. The closing of the cylinder valve 20 will be effective to unseat the hollow valve stem 50 from the valve seat 54 and to exhaust the upper end of the cylinder 18 to atmosphere through the exhaust passageway 52. Fluid will bleed from the timing chamber 140 around the needle valve 136, as indicated by the arrows E, FIG. 7. The check valve 128 will, of course, seat between the tapered portion 127 and the inner wall of the valve cylinder 106b to prevent return flow of the fluid from the timing chamber 140 to the upper end of the piston 18. As soon as the pressure acting on the large diameter part 110b drops sufficiently to permit reshifting of the valve element 110 to its normal position, the valve element 110 will shift, exhausting the cylinder valve 20 and recycling the tool. Such recycling will continue so long as the trigger 90 remains depressed.

Since only a portion of the pressure from the timing chamber 140 has had time to bleed out, repetitive cycling of the tool will occur more rapidly than took place following the first cycle of operation.

It has been found that very accurate speed control is obtainable by metering the signal air through the needle valve in both directions. An arrangement which accomplishes such

metering is illustrated in FIG. 8. Similar components in the embodiments of FIG. 8 and FIGS. 1 through 7 are identified by the same reference numerals. As therein shown, there is provided a cycling valve assembly 148, similar to the cycling assembly 82 heretofore described, but having a sealing O-ring 150 that replaces the check valve 128. The cycling valve assembly 148 is further provided with a port 152 which extends through the side of the needle valve body 126 so as to place the signal air from the port 118 into communication with the longitudinal opening of the needle valve. Thus the signal air during the buildup of pressure in the timing reservoir 140 must be metered past a needle valve 154. If desired, the needle valve 154 could be identical with the needle valve 136 previously described. Similarly the fluid from the reservoir 140 must be metered past the needle valve 154 during its discharge to atmosphere. Such discharge to atmosphere will now take place through the port 118, the chamber 134, the port 152, the signal passageway 118, and through the exhaust passageway 52.

FIGS. 9 and 10 illustrate an embodiment of the invention which provides very accurate recycling of the tool by utilizing a bleed from the reservoir to return the cycle valve. Similar components of the embodiment of FIGS. 9 and 10 and of the prior embodiments are identified by the same reference numerals. As therein shown, there is provided a cycling valve assembly 160, similar to the cycling assembly 82 heretofore described, but using sealing O-rings on the spool valve rather than metal to metal engagement with subsequent seepage for the return force. More specifically, the cycling valve assembly 160 includes a valve cylinder 162 open at both ends having a spool type valve element 164 slideably received therein, as well as the needle valve assembly including the needle valve body 126 and the needle valve 154. As heretofore described, the port 152 extends through the side of the needle valve body 126 so as to place the signal air from the port 118 into communication with the longitudinal opening of the needle valve. Thus the signal air during the buildup of pressure in the timing reservoir 140 must be metered past the needle valve 154 in the manner heretofore described. Similarly the fluid from the air reservoir 140 must be metered past the needle valve 154 during its discharge to the atmosphere.

Referring now to the spool type valve element 164 in accordance with the present embodiment, the spool valve element 164 is of the differential diameter type, having a plurality of spaced O-rings 168, 170 and 172, each defining piston means on the valve element 164 slideably received within a large diameter portion 162a of the valve cylinder 162, and additionally includes an additional O-ring 174 also defining piston means on the valve element 164 and slideably received within a reduced diameter portion 162b of the valve cylinder 162. Intermediate the O-rings, the valve element 164 is of slightly reduced diameter to provide annular passageways 178, 180 and 182. Moreover a bleed passageway 184 is provided around the O-ring 172 and, along with the O-ring 172, acts as a check valve so that when the pressure buildup on the left of the O-ring 172, as viewed in FIGS. 9 and 10, is greater than the pressure to the right thereof, fluid will be bled through the bleed passageway 184, around the O-ring 172; however, when the pressure to the right of the O-ring 172 is greater, the O-ring 172 will be driven against a shoulder 186 in an elongated O-ring groove 188 to block the return flow of fluid around the O-ring 172.

From the above description of the embodiment of FIGS. 9 and 10, the operation of the improved control valve is believed clear. However, briefly, it will be understood that with the absence of signal air from the port 118, the valve element 164 is biased to the left by the reservoir pressure entering port 120 and acting on the effective differential diameters between the piston means defined by the O-rings 172 and 174. The main or cylinder valve is connected to the reservoir pressure through the trigger control valve. When the trigger is depressed the control valve is now opened to the atmosphere, thus venting the cylinder valve through the passageway 116,

180, and 122. The cylinder valve will now open, allowing the reservoir pressure to drive the drive piston downwardly to complete the work stroke. Pressure builds up in the main cylinder of the tool and exhaust passageways thus creating a signal pressure to the cycling valve assembly 160 entering through the passageway 118. After filling the delay chamber 140 of the cycling valve assembly, the signal fluid is effective to bias the valve element 164 to the right, to the position illustrated in FIG. 10. This shift is rapid since the only return bias is the trapped fluid between the O-rings 172 and 174 acting on the effective diameter differences of the O-rings. Shifting of the valve element 164 to the right connects the reservoir directly to the cylinder valve through the passageways 120, 180 and 116. The O-ring 170 has moved between the ports 116 and 122 to block the communication of the trigger from the reservoir. As the work cylinder pressure and the signal pressure are dissipated to the atmosphere, the trapped air between the O-rings 172 and 174 shift the valve element 164 to the left, starting the recycling of the tool, providing of course that the trigger has not yet been released. The shifting of the cycle valve to the left is now slow enough to allow full-line pressure to build up above the cylinder valve, insuring positive closure. This minimizes any unstable or erratic operation of the cylinder valve.

A tool according to the present invention may readily be converted for single-cycle operation. Such an embodiment is illustrated in FIGS. 11 and 12. Similar components in the embodiment of FIGS. 11 and 12 and the previous embodiments are identified by the same reference numerals. Referring now specifically to FIGS. 11 and 12, there is provided a single-cycle control valve assembly 190 including a valve cylinder 192 containing both a spool-type valve element 194 and a needle valve body 126, similar to that heretofore described, but provided with an end plug 196 rather than the conventional needle valve. The valve cylinder 192 is of the differential diameter type, having an enlarged portion 192a and a reduced diameter portion 192b. The port 152 is provided through the side of the needle valve body 126 so as to place signal air from the signal airport 118 into communication with the longitudinal opening 198 of the needle valve body.

Referring now to the construction of the valve element 194, the valve element is of the differential diameter type, slideably received within the valve cylinder 192. A first O-ring 200 defining piston means is contained on the valve element 194 slideably received within the large diameter portion 192a of the valve cylinder 192. Additional spaced O-rings 202, 204 and 206 are received on the spool-type valve element 194 slideably received within the reduced diameter portion 192b of the valve cylinder 192. The valve element 194 is formed with reduced diameter portions between the O-rings 200, 202, 204 and 206 so as to define annular passageways 210, 212 and 214.

From the above brief description, the operation of the single-cycle action valve is believed clear. In the static position illustrated in FIG. 11, the valve element 194 is positioned to the left with the cylinder valve of the tool being connected through the trigger to the reservoir, including the passageways 116, 212 and 122 of the control valve assembly 190. Direct reservoir pressure through the control valve assembly 190 is blocked by the O-rings 204 and 206. Moreover signal pressure through the signal passageway 118 is absent, as the exhaust of the tool is opened to the atmosphere.

When the trigger is depressed, shutting off the reservoir air to the cylinder valve, and allowing this pressure to vent to the atmosphere, the cylinder valve will open exposing the work piston to the full reservoir pressure. The work piston will then move downwardly through the drive stroke, and the cylinder exhaust valve will be closed causing a buildup of pressure in the main cylinder. Pressurized fluid from the main cylinder will pass through the signal passageway 118 to act on the effective diameter defined by the O-ring 200. As soon as sufficient force has built up on the O-ring diameter 200, the valve element 194 will shift to the right, to the position illustrated in

FIG. 12, in which position the element 194 connects the cylinder valve with the direct reservoir pressure through the passageways 120, 212 and 116 of the control valve assembly 119. The cylinder valve will close, which operation opens the exhaust valve, dissipates the signal, and allows the drive piston to return to the normal position. While the trigger is depressed, the trigger passage 122 is blocked by the O-rings 200 and 202. However as soon as the trigger is released, the reservoir pressure will be provided through the trigger and through the trigger passageway 122 to act on the differential diameter portions of the valve element 194 defined by the difference in the diameter of O-rings 200 and 202. The tool is now ready to go through another single-cycle stroke as soon as the trigger is again depressed.

I claim:

1. A pneumatically operated fastener driving tool including a housing having a cavity defining a fluid reservoir; a cylinder in said housing; a piston slideably mounted in the cylinder; cylinder valve means controlling admission of fluid to and the exhaustion of fluid from one end of the cylinder; cycling means for automatically cycling said piston to provide for multiple firing of said tool, said cycling means being connected with said reservoir, said one end of said cylinder, and said cylinder valve means; trigger valve means movable between an operated and an unoperated position to connect said cycling means selectively to exhaust and to said reservoir; and means establishing a delay only prior to the initiation of the second cycle of operation during each continued operation of said trigger valve.

2. A pneumatically operated fastener driving tool including a housing having a cavity defining a fluid reservoir; a cylinder in said housing; a piston slideably mounted in the cylinder; cylinder valve means controlling admission of fluid to and the exhaustion of fluid from one end of the cylinder; a control passage; a trigger valve means for alternately connecting the control passage to the reservoir and the atmosphere; cycling means for automatically cycling said piston to provide for multiple firing of said tool, said cycling means being directly connected with said reservoir and being connected to said cylinder and said cylinder valve means, said cycling means including a spool valve with a first fluid surface connected to the fluid supplied to the cycling means by the reservoir to continuously bias the spool valve toward a first position placing said cylinder valve means in communication with said control passage, said spool valve having a second fluid surface supplied with the pressure in said cylinder to move the spool valve to a second position connecting the fluid continuously supplied to the cycling means from said reservoir to said cylinder valve means.

3. A fastener driving tool as set forth in claim 2 including a timing chamber, and metering means connecting said timing chamber to said cylinder to retard the pressure buildup acting on said spool valve upon initial cycling after operation of said trigger valve means.

4. A pneumatically operated fastener driving tool including a housing having a cavity defining a fluid reservoir; a cylinder in said housing; a piston slideably mounted in the cylinder; cylinder valve means controlling admission of fluid to and the exhaustion of fluid from one end of said cylinder in response to the exhaustion of fluid from said cylinder valve and the admission of fluid from said reservoir to said cylinder valve; a cycling control valve; first passage means connecting said cycling control valve to said cylinder valve means; second passage means connecting said cycling valve to said cylinder; third passage means continuously connecting said cycling valve to said reservoir; fourth passage means connected to said cycling valve; and a trigger valve connected to said cycling control valve through said fourth passage means effective when depressed to exhaust said cycling control valve and when released to connect said cycling control valve to the reservoir; said cycling valve including a spool valve element of the differential type having a small diameter end and a large diameter end, said reservoir communicating with said small

diameter end through said third passage means to continuously bias the spool valve toward a normal position connecting said first and fourth passage means, said cylinder communicating with said large diameter end through said second passage means and responsive to a fluid pressure buildup in the cylinder to shift the spool valve to an operated position connecting said first and third passage means.

5. A fastener driving tool as set forth in claim 4 including a timing chamber communicating with said second passage means to provide a delay in the first recycling stroke of said tool.

6. A fastener driving tool as set forth in claim 5 including exhaust means exhausting the large diameter end of said spool valve and said timing chamber to atmosphere.

7. A fastener driving tool as set forth in claim 6 including throttling means throttling said exhaust valve.

8. A fastener driving tool as set forth in claim 7 wherein said throttling means includes an adjustable needle valve for regulating the rate of recycling of said tool.

9. A fastener driving tool as set forth in claim 5 including check valve means in said second passage means intermediate said timing chamber and said one end of said cylinder preventing return flow from said timing chamber to said one end of said cylinder.

10. A pneumatically operated fastener driving tool including a housing having a cavity defining a fluid reservoir; a cylinder in said housing; a piston slideably mounted in the cylinder; cylinder valve means controlling admission of fluid to and the exhaustion of fluid from one end of the cylinder in response to the exhaustion of fluid from said cylinder valve and the admission of fluid from said reservoir to said cylinder valve, a cycling control valve including a valve body in said housing defining a valve cylinder of the differential type having a small diameter portion and a large diameter portion, said valve cylinder open at the large diameter end, a spool-type valve element of the differential diameter type shiftably positioned in said valve cylinder for movement between a normal and an operated position and having a small diameter part and a large diameter part, structure on said small diameter part defining a fluid passageway, first passage means opening in said fluid passageway and communicating with said cylinder valve means when said valve element is in both of the normal and operated positions; second passage means opening into said large diameter portion and communicating with said cylinder, third passage means opening into said small diameter portion of said valve cylinder intermediate the stroke of said valve element so as to communicate with said fluid passageway only when said valve element is in said operated position and communicating with said reservoir, fourth passage means opening into said fluid passageway only when said valve element is in a normal position; a trigger valve connected to said cycling control valve through said fourth passage means effective when depressed to exhaust said cycling control valve and when released to connect said cycling control valve to the reservoir; throttling means including an adjustable needle valve for restricting the exhaust of fluid from the open end of said large diameter portion; and check valve means in said second passage means permitting fluid flow only out of said one end of said cylinder.

11. A fastener driving tool as set forth in claim 10 including a timing chamber communicating with said large diameter portion of said valve cylinder.

12. A fastener driving tool including a housing having cylinder means; cycling means slideably mounted in the cylinder means; cycling means for automatically cycling said piston means to provide for multiple firing of said tool; control means operatively associated with said cycling means to initiate cycling thereof; and delay means operatively associated with said cycling means for providing a delay in the refiring of said tool between the first and second operations of said piston means after initiation of the cycling thereof.

13. A fastener driving tool as set forth in claim 12 wherein said housing includes a cavity defining a fluid reservoir, and

said cylinder means is operatively connected to said reservoir through said cycling means to provide for pneumatic firing of said tool.

14. A fastener driving tool as set forth in claim 12 wherein said control means is a manually operable trigger valve operable between an operated and an unoperated position for initiating cycling of said tool whereby said delay is provided after the first cycle of operation of said tool following movement of said trigger valve to an operated position.

15. A fastener driving tool including fastener driving means, control means for initiating automatic repetitive cycling of said fastener driving means, and delay means effective during continued operation of the control means for providing a delay in the recycling of said fastener driving means to cause the first cycle of the fastener driving means to take longer than the second and following cycles of the fastener driving means.

16. A pneumatically operated fastener driving tool including a housing having a cavity defining a fluid reservoir; a cylinder in said housing; a piston slideably mounted in the cylinder; cylinder valve means controlling admission of fluid to and the exhaustion of fluid from one end of the cylinder; cycling means for automatically cycling said piston through a drive and return stroke, said cycling means including a valve having a first fluid responsive surface supplied with fluid directly from said reservoir and continuously biased thereby to a normal position and a second fluid responsive surface continuously coupled to said cylinder and biased by pressure admitted to the cylinder to an operated position, an inlet passage, and an outlet passage continuously coupled to said cylinder valve means; and trigger valve means movable between an operated and an unoperated position and connected in said inlet passage to connect said cycling means selectively to exhaust and to said reservoir.

17. A pneumatically operated fastener driving tool including a housing having a cavity defining a fluid reservoir; a cylinder in said housing; a piston slideably mounted in the cylinder; cylinder valve means controlling admission of fluid to and the exhaustion of fluid from one end of said cylinder in response to the exhaustion of fluid from said cylinder valve and the admission of fluid from said reservoir to said cylinder valve, a cycling control valve including a valve body in said housing defining a valve cylinder of the differential type having a small diameter portion and a large diameter portion, said cylinder open at both ends, a spool-type element of the differential diameter type shiftably positioned in said cylinder for movement between a normal and an operated position having a small diameter part and a large diameter part, means defining first, second and third piston means on said valve element slideably received in said large diameter portion, and fourth piston means defining a seal slideably received in said small diameter portion, means on said large diameter part intermediate said first and second piston means defining a first fluid passageway, means on said large diameter part intermediate said second and third piston means defining a second fluid passageway; first passage means opening in said second fluid passageway and communicating with said cylinder valve means; second passage means opening into said valve cylinder

and communicating with said one end of said cylinder, third passage means opening into said large diameter portion of said valve cylinder intermediate the stroke of said third piston means so as to communicate with said second fluid passageway when said valve element is in said operated position and communicating with said reservoir, fourth passage means opening into said second fluid passageway when said valve element is in a normal position and intermediate the stroke of said second piston means; a trigger valve connected to said cycling control valve through said fourth passage means effective when depressed to exhaust said cycling control valve and when released to connect said cycling control valve to the reservoir; and throttling means restricting the exhaust of fluid from the open end of said large diameter portion.

18. A fastener driving tool as set forth in claim 17 including check valve bleeding means around said third piston means providing for fluid flow into the differential portion of said cylinder for return of said valve element to a normal position.

19. A fastener driving tool as set forth in claim 17 including a delay chamber communicating with said large diameter portion of said valve cylinder beyond the stroke of said first piston means.

20. A pneumatically operated fastener driving tool including a housing having a cavity defining a fluid reservoir; a cylinder in said housing; a piston slideably mounted in the cylinder; cylinder valve means controlling admission of fluid to and the exhaustion of fluid from one end of said cylinder in response to the exhaustion of fluid from said cylinder valve and the admission of fluid from said reservoir to said cylinder valve, a control valve including a valve body in said housing defining a valve cylinder of the differential type having a small diameter portion and a large diameter portion, said cylinder open at both ends, a spool-type valve element of the differential diameter type shiftably positioned in said cylinder for movement between a normal and an operated position having a small diameter part and a large diameter part, means defining first piston means on said valve element slideably received in said large diameter portion, and means defining second, third and fourth piston means on said valve element slideably received in said small diameter portion, first fluid passageway defined between said first and second piston means, second fluid passageway defined between said second and third piston means, and third fluid passageway defined between said third and fourth piston means; first passage means opening in said second fluid passage means and communicating with said cylinder valve means; second passage means opening into said valve cylinder and communicating with said one end of said cylinder, third passage means opening into said small diameter portion of said valve cylinder intermediate the stroke of said third piston and communicating with said reservoir, fourth passage means opening into said valve cylinder intermediate the stroke of said fourth piston means; and a trigger valve connected to said control valve through said fourth passage means effective when depressed to exhaust said control valve and when released to connect said control valve to the reservoir.

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