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Wilson et al.

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[54] **FASTENER DRIVING TOOL WITH IMPROVED VALVE**

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[52] **U.S. Cl.** **227/130,** 251/61.1, 251/75, 251/25

[51] **Int. Cl.** **B25c 1/04**

[58] **Field of Search** .... 251/25, 75, 61.1; 91/417, 91/417 A, 461, 468; 173/169; 227/130

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[57] **ABSTRACT**

A snap-action valve for a fluid motor that includes a cylinder and a piston reciprocably mounted therein. The snap-action valve is located at the upper cylinder end and includes a diaphragm supported about its periphery with one surface facing the upper cylinder end and movable between a position spaced from that end and a position adjacent thereto. The diaphragm divides a housing into an upper chamber and a lower chamber, the latter continually provided with pressurized air. A resilient flat disc is secured at its center to the surface of the diaphragm facing the cylinder. A control valve admits pressurized air to the upper chamber to drive down the diaphragm to its cylinder-adjacent position against the force exerted by the pressurized lower chamber to carry the disc into sealing engagement with the cylinder end. After the control valve begins to release the upper chamber air, the pressurized air in the lower chamber moves the diaphragm upwardly away from the cylinder end but initially maintains the disc in sealing engagement with the cylinder. After a predetermined movement of the diaphragm, the disc snaps upwardly against the diaphragm back to its flat configuration to instantaneously provide a large opening at the upper cylinder end thereby minimizing the pressure drop of the high-pressure air being admitted into the cylinder. The pressurized air from the lower chamber upon entering the cylinder then drives down the piston, whereafter the control valve resupplies the upper chamber with pressurized air to again seal off the cylinder in preparation for subsequent cycles.

8 Claims, 3 Drawing Figures

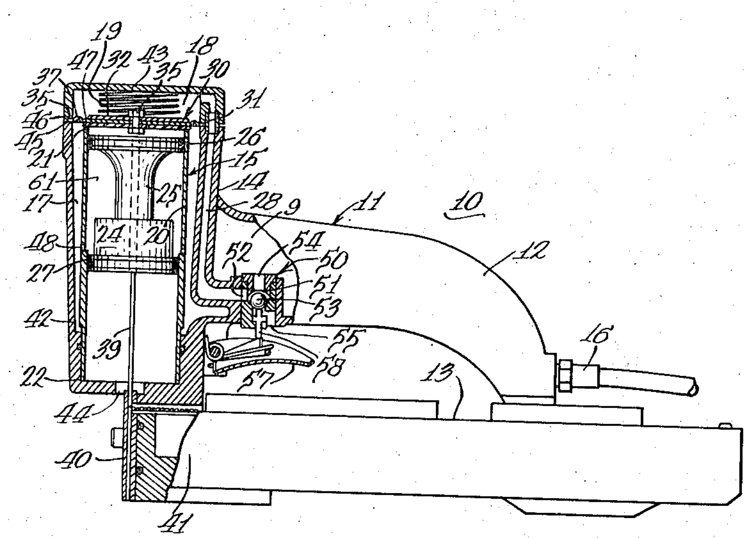

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Fig. 1.

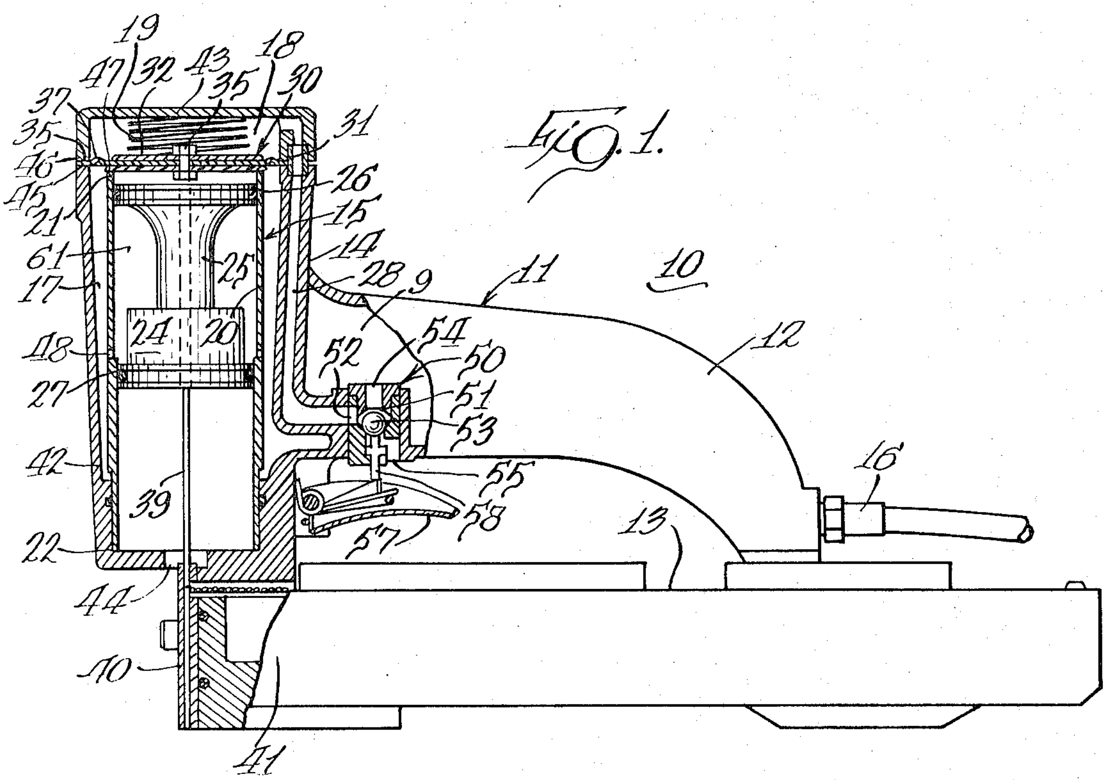


Fig. 2.

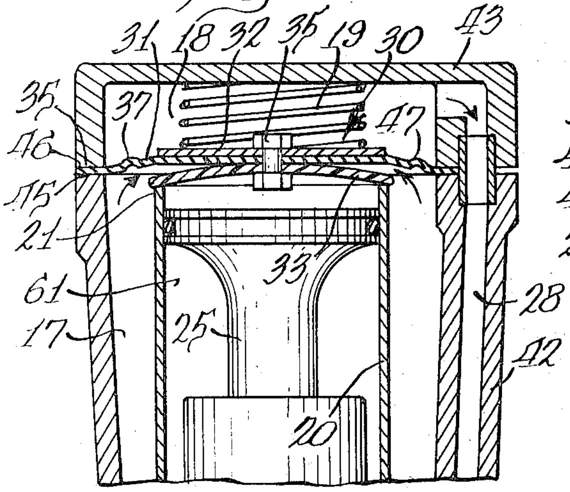
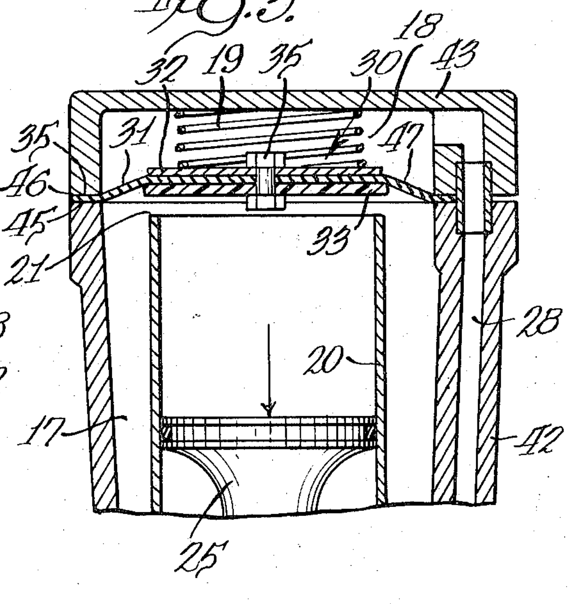


Fig. 3.



FASTENER DRIVING TOOL WITH IMPROVED VALVE

BACKGROUND OF THE INVENTION

This invention relates to an improvement in fluid-driven motors of the type including a piston reciprocable in a cylinder under the influence of pressurized fluid. More particularly, it relates to an improved valve for such a motor and an improved pneumatically-driven fastener driving tool utilizing an air-driven motor.

Fluid motor driven tools of many types, including pneumatic tools driven by pressurized air, have received wide acceptance in the art. For convenience of description the following will be confined to the pneumatic context, it being understood that the invention is equally applicable to fluids other than air. A particular useful example of such tools have been those utilized for driving fasteners such as staples, T-nails, and the like, into relatively pierceable materials, one example being described in U.S. Pat. No. 3,106,136 to A. Langas for "Fastener Driving Tool," which patent is assigned to assignee of the present invention. To the extent that the disclosure of this patent is not inconsistent with that of the present invention, it is incorporated by reference herein.

Although highly satisfactory, such tools have not utilized the storage fluid or air pressure driving the tool with maximum efficiency. It has been found that the pressure of the air driving the piston of the pneumatic motor is lower than that of the pressurized air before entering the cylinder. This condition is accentuated due to the relative slowness with which even relatively fast acting valves of conventional design admit pressurized air to the cylinder.

The substantial reduction of such a valve opening gradient must be achieved before optimum pressure transferral to the piston and an improvement in efficiency can be obtained.

A fastener driving tool with such advantages would exhibit a distinct improvement in speed of operation and driving force brought to bear on the staple, nail, or other fastener.

SUMMARY OF THE INVENTION

The present invention provides a novel snap-acting valve assembly for controlling the flow of fluid under pressure into a chamber, particularly one containing a fluid motor. The valve comprises a valve support member movably supported adjacent an entrance to the chamber and having a first surface for closing the chamber and defining an area outwardly of the chamber exposed to the fluid under pressure. The valve support member also defines a second surface opposite the first surface. The first surface area is subjected to a first force due to the fluid pressure tending to bias the first surface away from the entrance. The second surface is subjected to a second force counteracting the first biasing force to bias the member toward the entrance. This second biasing force may also be supplied by means of fluid pressure acting over the second surface.

Also included in the valve assembly is a flexible disc secured to the first support surface inwardly of at least one portion of the disc periphery whereby the disc is movable relative to the first support surface. The support member biases the disc into sealing engagement with the chamber entrance while the second biasing force opposes the first biasing force. When the first biasing force is reduced, however, the support member begins to move away from the chamber entrance. At the same time the disc initially continues in sealed relationship with the chamber entrance under the influence of the pressurized fluid, which then flows between the disc and the first surface of the valve support member. The fluid pressure biases the periphery of the disc against the chamber entrance despite the movement of an inward portion of the disc upwardly with the valve support member. Finally, the valve support member reaches a position spaced from the chamber entrance and the disc finally snaps away from the entrance against the first surface of the support member, thereby instantaneously opening a large aperture to the chamber entrance to allow the pressurized fluid to enter the chamber without the pressure loss normally occurring when the fluid enters a chamber controlled by a conventional valve initially presenting a small opening to the pressurized fluid. Thus, the full available air pressure is utilized by the fluid motor for a substantial improvement in the speed of operation of the motor for a given fluid pressure, as well as a substantial improvement in power and efficiency because of the fluid pressure conserved.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

FIG. 1 is a side elevational view showing a fastener driving tool, with a pneumatic motor and improved snap-action valve in cross section;

FIG. 2 is a detail of the valve and motor of FIG. 1, showing the valve as it is about to open; and

FIG. 3 is a detail of the valve and motor of FIG. 1, showing the valve in its open attitude, and the piston of the motor in a driven attitude.

DETAILED DESCRIPTION

While this invention is susceptible of embodiment in many different forms, there is shown in the drawings and will herein be described in detail a preferred embodiment of the invention with the understanding that the present disclosure is to be considered as an exemplification of the principles of the invention and is not intended to limit the invention to the embodiments illustrated. The scope of the invention will be pointed out in the appended claims.

FIG. 1 illustrates a fastener driving tool **10** having a pneumatic motor assembly **15** which includes a cylinder **20** and a piston **25** slidably mounted within the cylinder. A novel snap-action valve assembly **30** as described therein is used for controlling the motor assembly **15.** Although the invention is described as embodied in an improved fastener tool, it is to be understood that the motor assembly and valve are equally adaptable to many other applications; also, the described fastener tool is exemplary of other tools with which the present invention can be used.

Fastener driving tool **10** includes a hollow housing **11** having a graspable elongated chamber portion **12** mounted on a base **13** at one end of portion **12.** The housing portion **12** defines therein a storage chamber **9.** Housing **11** also includes an upright generally cylindrical portion **14** at the other end thereof comprised of a lower body portion **42** that is closed at its lower end except for a central port **44,** and a cap **43** for closing the upper end of the body portion **42.** The storage chamber 9 is adaptable to contain pressurized air and is coupled to any suitable source of such air at the end adjacent base 13 through a hose and coupling means 16.

Open-ended motor cylinder 20 is of a smaller diameter and length than housing portion 14 and is centrally disposed therein so that an annular chamber 17 is defined between the outer wall of cylinder 20 and the inner wall of housing portion 14. The lower edge 22 of cylinder 20 is closed by the closed lower end of housing portion 42 except for port 44. The annular chamber 17 is filled with pressurized air by being in direct communication with storage chamber 9. Cylinder 20 is of a height such that its upper edge 21 is positioned just below the upper end of housing portion 42 when installed. Housing portion 42 is flanged to provide an annular rim surface 45 adjacent cylinder edge 21.

Slidably mounted within cylinder 20 is piston 25 having upper and lower ends 26 and 27 and movable between cylinder ends 21 and 22. Piston 25 may be biased upwardly toward end 21 by any suitable means such as a spring. Preferably, however, the piston 25 and cylinder 20 are constructed so as to define chamber 61 supplied with pressurized air from chamber 17 via ports 48 in cylinder 20. The exposed area of the piston upper end 26 in chamber 61 is greater than that of piston lower end 27 in chamber 61 resulting in an unbalanced upper force thereon. For more particular details of such a piston bias means, reference should be made to the above-referenced Langas patent. Piston 25 is moved downwardly to cylinder end 22 in opposition to its bias force by pressurized air from chamber 17, and is further provided with an axial passage-way 24 extending between ends to exhaust such air through port 44 after completion of the downward cycle, to allow the piston bias to return the piston to its upward position.

Carried at the lower end 27 of the piston is an elongated staple driver 39 that extends vertically through the central port 44 and guide 40, that is part of the staple magazine assembly 41 secured to base 13 below cylinder 20 and portion 12 at one side thereof. Magazine assembly 41 holds staples in a row transversely to the path of driver 39 and supplies staples serially under driver 39 into guide 40 to be driven when piston 25 with driver 39 descends toward the lower edge 22 of cylinder 20. For further details of a fastener driving tool, reference should be made to the above-referenced Langas patent.

In order to periodically admit pressurized air to drive the piston 25 downwardly, novel snap-action valve assembly 30 is provided at the upper edge of the cylinder 20. Unlike prior valve expedients, valve assembly 30 at once opens fully in a completely novel snap manner which provides an instantaneous large opening at cylinder end 21, so that pressurized air enters into the cylinder without the loss of pressure, and consequently of piston driving power and efficiency, which is inevitable without the novel valve assembly. The valve assembly is supported by housing cylindrical portion 14 and includes a thin circular diaphragm 31 having a diameter at least equal to that of the rim surface 45 of cylindrical body portion 42. The diaphragm carries a rigid circular back-up plate 32 on one side, of a diameter equal to, or greater than the outside diameter of cylinder 20. A resilient flexible circular disc 33 of a diameter equal to or preferably somewhat greater than the outside diameter of cylinder 20 is carried on the other side of diaphragm 31. Preferably, disc 33 is of a plastic material, although other resilient materials will also serve. This element is highly important to the "snap" operation of the valve to create instantaneously a large opening at the cylinder end. Specifically, the disc is used to maintain a seal at cylinder end 21 while diaphragm 31 begins to move away from end 21 until finally "snapping" away to present a large opening, as will be described in greater detail. Both plate 32 and disc 33 are secured to diaphragm 31 by a nut and bolt assembly 35 passed through the center of each member. In this manner the periphery of disc 33 is not itself bound to diaphragm 31, a fact which is important for the "snap" operation of disc 33, as will later be described.

Neither cylinder 20 together with piston 25, nor valve assembly 30, need necessarily be of a round configuration; instead, for example, cylinder 20 could well be a tubular member with a square or rectangular cross section, and valve assembly 30 together with disc 33 of similar square or rectangular cross section. Furthermore, it is not necessary in either the round or rectangular configurations that the disc be fastened at its center to the diaphragm 31, as long as the disc is fastened inwardly from at least one portion of the disc periphery and the disc may be moved relative to the diaphragm.

The valve assembly 30 is placed over the annular rim surface 45 of the flanged end of portion 42 and with disc 33 overlapping and seating on edge 21. In this position, an outer generally annular portion 36 of diaphragm 31 overlies rim surface 45. The open end of cap 43 is also flanged to provide a second matching annular rim surface 46 adaptable to be placed in registration over surface 45. Assembly 30 is secured with end housing portion 14 by clamping annular disc portion 36 between cap 43 and housing portion 42, with the respective rims and annular portion having their centers in registration.

When thus properly positioned over cylinder edge 21 and secured within housing portion 44, the valve assembly divides the annular chamber region 17 from an upper chamber 18 within cap 43 and above plate 32. An intermediate annular portion 47 of diaphragm 31 bridges annular chamber 17 between cylinder 20 and housing portion 14 and is provided with an annular, upwardly bulging convex bend 37, to allow the portion of diaphragm overlying its cylinder 20 to be moved upwardly away from edge 21 from its normal first position adjacent cylinder edge 21 to a second position spaced therefrom, as is illustrated in FIG. 2.

It should be noted that the diaphragm 31 could instead be replaced by a different movable valve support member, for example, a piston or rigid plate slidably and sealingly mounted within housing portion 14 and similarly creating a chamber such as upper chamber 18 above such movable support member and an annular chamber such as chamber 17 below it. Just as in the case of diaphragm 31, the member would be movable between a position adjacent edge 21 to a position spaced therefrom. The resilient disc 33 similarly would be attached to one surface of the member to seal the cylinder at its upper end 21.

A downwardly acting biasing force must be provided for biasing valve assembly 30 toward the cylinder 20, and disc 33 into sealing engagement with cylinder end 21, so that cylinder 20 is properly sealed off from the pressurized air until the moment when piston 25 is to be driven. Such a biasing force could be accomplished by use of various expedients, such as a spring and release mechanism bearing on back-up plate 32 from above, or creating an area difference between the upper and lower diaphragm surfaces exposed to pressurized air. Preferably, however, the downward biasing is provided by means of air pressure within chamber 18, supplied from storage chamber 9 through a control valve 50 and a conduit 28 plus a relatively light compression spring 19 in chamber 18 to insure that after the driver 39 is driven and high-pressure air is introduced to chamber 18, the valve assembly 30 will be returned to sealing relationship with the cylinder end 21. The conduit 28 is incorporated within a portion of the wall of both cap 43 and housing portion 42 and extends generally vertically adjacent housing portion 12. At its upper end, the conduit opens into chamber 18, while at its lower end, it opens into control valve 50, which is secured within housing portion 12 at a lower surface thereof and adjacent cylindrical housing portion 14.

Control valve 50 includes a central control chamber 51 into which conduit 28 opens through its lower opening 52 and which houses a ball 53. Also included is an inlet port 54 and an exhaust port 55 extending generally vertically and respectively above and below control chamber 51, with port 54 communicating with storage chamber 9, and exhaust port 55 communicating with the outside atmosphere. A trigger assembly 57 operates a valve plunger 58 having an end bearing on ball 53 to move the ball vertically from a first position wherein ball 53 seals exhaust port 55 and opens inlet port 54, to a second position, wherein ball 53 seals inlet port 53 and opens exhaust port 55.

Normally ball 53 is at rest in the lower part of the chamber 51 in its first position. In this position, upper chamber 18 through conduit 28 and valve 50 is in communication with storage chamber 9 and thus is supplied with pressurized air. It will be remembered that the annular lower chamber 17 is in constant communication with the storage chamber 9 and is therefore constantly supplied with the same pressurized air. Thus, the pressurized air in both upper and lower chambers 18 and 17 acts respectively on the upper and lower surfaces of valve assembly 30, setting up opposed downwardly and upwardly acting forces upon the assembly. However, the air of the upper chamber 18 acts over the entire top surface of the valve assembly, while the air in the lower chamber 17 acts only over the annular portion 47 of diaphragm 30, since this is the only portion of the lower surface of the valve which is exposed to pressurized air in chamber 17. The pressure due to the air in chamber 18 then acts over a much larger area than the pressure due to chamber 17, thereby providing a large resulting downward force acting to force valve assembly 30 towards a cylinder 20 and bias disc 33 into sealing engagement with upper edge 21 of cylinder 20, as well as isolate cylinder 20 from chamber 17. This is the position of the valve assembly 30 which is illustrated in FIG. 1.

It should be noted that a resulting downward force could also be produced even in the absence of a differential area in favor of the upper surface of valve assembly 30 by simply supplying chamber 18 with air of correspondingly higher pressure, or even as previously indicated, by a relatively strong spring and release mechanism.

The tool may then be operated by upwardly moving trigger assembly 57 to drive plunger 58 and move ball 53 upwardly and preferably only momentarily to seal port 54 and open exhaust port 55, to vent chamber 18 through conduit 28 and port 55 to the atmosphere. As the air pressure in chamber 18 decreases, the resulting force on the annular portion 47 of the diaphragm becomes essentially that due to the air pressure in chamber 17, which moves the diaphragm 31 upwardly to its spaced second position. Although such air pressure reduction in chamber 18 appears to be instantaneous insofar as operation of the tool is concerned, it actually exhibits a finite time gradient which enables the air pressure in chamber 17 to act between disc 33 and diaphragm 31 to bias the periphery of the disc 33 downwardly into sealing engagement with the cylinder edge 21, even as diaphragm 31 is being moved upwardly to its spaced position. In this manner, the opening of cylinder 20 to pressurized air is delayed until diaphragm 31 (or other valve support member) is moved upwardly to its spaced second position.

Thus, before the seal between disc 31 and cylinder 20 is finally broken, the remainder of the valve assembly has had time to become well-separated from cylinder 20, so that the opening to the cylinder for the pressurized air when finally effected will be a substantial one. Equally importantly, the opening is made instantaneously by the disc finally snapping away from cylinder 20 to a position flat against diaphragm 31 as will be described. It is important to note that such disc operation only may be achieved if the manner of fastening disc 33 not only permits it to move relative to diaphragm 31, but also leaves at least much of the periphery of the disc unfastened so that the air pressure in chamber 17 may act to bias this periphery against edge 21. The reason for the requirement that the disc be fastened inwardly of at least one portion of its periphery, and preferably at its center, should now be clear.

The configuration of the valve assembly just prior to the instant when it opens is illustrated by FIG. 2. Of course, since disc 33 is attached at its center to diaphragm 31, the center of the disc is moved upwardly with diaphragm 31 even as the periphery of the disc is being forced downward against edge 21. The disc thereby becomes distorted into a convex or cone-like configuration, illustrated by FIG. 2. Due to the resiliency of the disc, a restoring force is built up within the disc as the distortion of the disc increases, which tends to cause the disc to return to its normally flat shape. Finally, as the air pressure in the chamber 18 becomes atmospheric pressure and the diaphragm under the influence of chamber 17 air pressure reaches its second position spaced from cylinder edge 21, the restoring force due to the resiliency of the disc overcomes the force of air pressure acting downwardly on the disc periphery. The disc snaps away from the cylinder to its original flat shape against the lower surface of the diaphragm 31 (see FIG. 3), which is in its spaced second position away from cylinder 20. A large annular opening between cylinder 20 and pressurized chamber 17 is thus instantaneously created, allowing the highly pressurized air of chamber 17 to rush inside cylinder 20 substantially with a minimum drop of pressure. The air acting upon the upper surface of piston 25 overcomes the upward bias of the piston to drive it instantaneously downward, along with driver 26 and an associated staple supplied by magazine assembly **41** to guide **40** immediately therebelow.

In the meantime, as trigger assembly **57** is moved to the end of its upward stroke, it allows plunger **58** and ball **53** to descend to their original positions, wherein ball **53** closes off exhaust port **55** and opens input port **54**, the trigger assembly thereafter returning to its original position upon being released by the operator. With the opening of port **54**, pressurized air from storage chamber **9** then again passes through opening **52** and conduit **28** into upper chamber **18**, so that along with the spring **19**, there exists a net downward force on valve assembly **30**. The resultant downward force biases diaphragm **31** to its former cylinder-adjacent first position while carrying disc **33** into sealing engagement with cylinder edge **22** to cut off pressurized air to cylinder **20**. It should be obvious at this point that any alternative control valve and conduit arrangement which also selectively supplied pressurized air to upper chamber **18**, as well as releasing it upon command, would also serve and that control valve **50** and conduit **28** are merely exemplary.

The pressurized air in the cylinder escapes through axial passageway **24** in piston **25** and port **44** at the lower end of housing portion **42**. A wide choice of other means of exhausting such air may alternatively be used, since the action of the valve assembly **30** is so rapid in subjecting piston **25** to the full pressure of the air in chamber **17** that the loss of driving power through any of such exhaust expedients is negligible. Once cylinder **20** is again sealed by valve assembly **30**, the piston **25** is restored to its normal upper position adjacent cylinder edge **21** as described above to await the next driving cycle of the tool.

It will be appreciated that the improved valve assembly for the fluid motor provides a substantial increase in efficiency, driving force, and speed of operation at any given operating air pressure in comparison with prior-art expedients. This is because the cylinder is kept sealed against the air pressure for driving the piston even as some elements of the valve assembly begin to move away from the cylinder, until the sealing disc is able to snap at once to a position spaced well away from the cylinder. Thereupon a large opening is instantaneously available for the passage of pressurized air into the cylinder, and thus the maximum available air pressure is brought to bear to drive the piston with a minimum loss of available air pressure. Consumption of air by devices such as the fastener tool is lowered, and their power is increased, with staples being driven more forcefully for improved penetration. Of course, as was earlier stated, the improved motor and valve may be used in any related tool application, or indeed in any application calling for the use of such a motor. Neither is the invention limited to air powered applications, since it is also adaptable to work with other appropriate fluids.

What is claimed is:

1. A valve system for controlling the flow of fluid under pressure to a fluid motor located in a tubular member, said system comprising: a housing, a tubular member positioned in said housing; a fluid motor located in said tubular member; a diaphragm valve support member movably supported in said housing adjacent an open end of the tubular member and having a first surface for moving toward said open end and defining an area outwardly of such end exposed to said fluid contained under pressure in said housing, said support member also defining a second surface opposite said first surface, said first surface outer area being subjected to a first biasing force due to said pressurized fluid in said housing tending to bias said support member away from the open end of the tubular member, said second surface being subjected to a second biasing force acting in opposition to said first biasing force; a resilient disc positioned in said housing to overlie and to close said open end, said disc terminating inwardly of the peripheral edge of said support member; means securing said disc to said first support surface inwardly of at least a portion of the disc periphery whereby said disc periphery is movable relative to said first support surface and relative to the portion of said disc secured to said first support surface, said support member biasing said disc into sealing engagement with said open end of said tubular member due to said second biasing force; and control means operable for releasing at least a portion of said second biasing force to allow said pressurized fluid in said housing to move said first support surface away from said open end while initially maintaining said resilient disc in sealing engagement with said open end, said resilient disc finally snapping away from said open end when the support member has become spaced from said tubular member, thereby instantaneously opening a large aperture to said open end of said tubular member to expose the tubular member to said pressurized fluid in said housing whereby said pressurized fluid may enter said tubular member through said open end to drive said fluid motor.

2. A valve system as in claim **1** in which said second surface is exposed to said fluid under pressure, and said control means for releasing at least a portion of said second biasing force includes a control valve controlling the application of said pressurized fluid to said second surface.

3. A valve system as in claim **1** in which said support member is supported upon an inner wall of said housing and divides said housing into a first chamber confronting said second surface and a second chamber about said tubular member said second chamber being continuously supplied with said pressurized fluid to furnish said first biasing force.

4. A valve system as in claim **3** in which said first chamber is also supplied with pressurized fluid to subject said second surface to pressure and thereby to provide at least a portion of said second biasing force and said control means is operable to cut off said pressurized fluid to said first chamber to thereby release at least a portion of said second biasing force.

5. A valve system as in claim **4** in which said fluid is air, and said control means includes a valve selectively connecting said first chamber to the atmosphere for releasing said pressurized air therein, and to a source of pressurized air for again supplying pressurized air to said first chamber.

6. A valve system as in claim **4** in which said first surface outer area extends between the inner wall of said housing and the outer wall of said tubular member and is generally annular in configuration.

7. A valve system as in claim **4** in which said resilient disc is substantially congruent with the open end of said tubular member.

8. A pneumatically operated fastener driving tool comprising: a housing adapted to contain air under pressure; a tubular member disposed within said housing and having an open end for exposure to said pressurized air; a piston slidably mounted within the tubular member and normally biased toward said open end, said piston being provided with a fastener driver on one side thereof opposite the side facing said open end; a closure member supported within said housing and positioned to extend across said open end and having a periphery engaging said housing, said closure member being movable between an open position spaced from said open end and a closed position adjacent said open end, said closure member having a first surface facing towards said open end and an opposite surface facing away from said open end, said closure member dividing said housing into a storage chamber on said first surface side maintaining pressurized air over said first surface, and an operating chamber on said opposite surface side, a compression spring in said operating chamber acting on said opposite surface, said storage chamber containing pressurized air providing a first force upon said first surface tending to move said closure member away from said open end; a resilient disc secured to said first closure member surface at a location inwardly of the periphery of said disc and sealingly engageable with said cylinder open end; control means for selectively admitting and exhausting pressurized air to said operating chamber, said air upon admittance providing a second force acting in conjunction with said compression spring to overcome said first force to bias said closure member toward said closed position and said disc into sealing engagement with said open end, said means thereafter exhausting said operating chamber to allow said closure member to move from said closed position to said open position under the influence of said first force, with said resilient disc initially maintaining sealing engagement with said open end under the influence of pressurized air admitted between said disc and said support member from said storage chamber, said disc finally snapping away from said open end against and toward said one closure member surface, thereby instantaneously opening said open end to said storage chamber pressurized air to drive said piston together with said fastener driver, said means thereafter again admitting pressurized air to said operating chamber to again seal said open end; and means for venting the air confined between said resilient disc and said piston when said disc is restored to sealing engagement with said open end, allowing said piston bias to return said piston to its original position near said open end.

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