

**AN APPARATUS FOR REDUCING THE CONSUMPTION
OF COMPRESSED AIR IN PNEUMATIC MACHINES**

The present invention relates to an apparatus for effectively utilizing compressed air in reciprocable pneumatic machines, in particular pneumatic machines of the type which provide a strong primary working movement and a relatively weak return movement, or one or more secondary, stepwise weaker and weaker movements, and which machines therefore need a stronger compressed air force in one direction of movement than in the opposite direction.

The invention is useful both for axially operating pneumatic machines, generally referred to as piston-cylinder units, and for rotary machines of reciprocable type.

In many types of pneumatic piston-cylinder machines, which can be referred to as "single acting" cylinders compressed air power is used only in one direction of movement, which is called the working stroke of the motor, whereas the return stroke is made under the actuation of a return spring while the cylinder, at the former working side, is evacuated from compressed air. This involves several different disadvantages and problems:

- for making it possible to return the piston, this is made by means of a return spring, the pressure of the working chamber has to be unloaded, and this has until now been made in that the active working chamber has been opened to the ambient, whereby the compressed air remained in the working chamber gets lost;

- a certain power is needed for exceeding the power of the return spring which is compressed during the working stroke of the piston, and such power has to be added to the power of compressed air which is necessary for the work of the piston;

- when the compressed air from the working chamber, which is pressurized until the moment of changing direction, is let out there is obtained a compressed air blow which is apprehended as an annoying bang;

- at the moment that the working chamber is opened to the ambient the piston is stopped by a heavy braking, and this may lead to strong movements in the apparatus which is actuated during the working stroke of the piston.

The loss of power which depends both on the evacuation of compressed air at the end of the working stroke of the piston and also on the

excess of compressed air which is necessary for exceeding the counter force from the return spring involves rather considerable costs for providing more compressed air.

The object of the invention is to solve the problem of eliminating the above mentioned lacks and disadvantages in pneumatic, reciprocable machines providing a strong working stroke and a less strong return stroke and this is provided by a machine providing a strong primary movement by a pressure in a working chamber and a less strong return movement by a pressure in a return chamber, or by one or more secondary, stepwise softer movements, and in which the primary movement demands a stronger compressed air force than the return movement, and which pneumatic machine comprises a piston operating in a cylinder and which defines a working chamber and a return chamber, a valve formed with three or more functional positions for providing the different functional steps, and in which the valve, in a first position, provides a full pressurization of the working chamber and an evacuation of the return chamber, in a second position provides an equalization of compressed air between the working chamber and the return chamber, and in a third position provides a return stroke by means of the equalized compressed air remained in the return chamber and an evacuation of the working chamber.

The machine is characterized in that the valve is enclosed in an end of the cylinder and comprises an inlet channel for pressurization of the working chamber and a bypass channel for evacuation of the return chamber at the same time as the working chamber is pressurized, and a cross channel for providing an interconnection of the working chamber and the return chamber thereby equalizing the pressure of the two chambers at the same time as the inlet and the outlet is blocked by the valve piston, and in that the return chamber communicates with the valve of the cylinder end over a channel (bore) extending axially in the cylinder wall.

It is possible to utilize the same principle as mentioned above in several steps, whereby the equalization of pressure between the two piston chambers is made in two or more successive steps, as illustrated in the 7-stage process which is diagrammatically illustrated in figures 2a-g, in which a first pressure equalization and a succeeding unloading of the former working chamber is made as a first step (figure 2b) at the end of a first working stroke, thereafter in a second step (figure 2d) at the end of a first

return stroke, and thereafter in a third step (figure 2f) by a reduced force at the end of a second working stroke. The working strokes thereby are executed in four reciprocal steps, with full pressure in a first step, with about 50% force in a second step (1st return step), with only about 25% in a third step (2nd working step) and with about 12.5% in a fourth step (2nd return step).

Now the invention is to be described more in detail with reference to the accompanying drawings. In the drawings figures 1a-c diagrammatically illustrate the method according to the invention in a 3-step method including equalization of the pressure preceding the return stroke. Figures 2a-2g correspondingly illustrate a 7-step method comprising three successive pressure equalization steps (2b, 2d, 2f). Figure 3 shows the markings which are used for explanatory purposes in figures 1 and 2. Figure 4 shows a piston-cylinder unit according to the invention having means for accurately indicating the position of the piston in the cylinder. Figure 5 shows an axial cross section through a piston-cylinder unit which is suited for use in the methods according to figures 1 and 2. Figure 6 is a cross section view, in an enlarged scale, along line VI-VI of figure 5. Figure 7 is an enlarged scale view of the left hand part of the cylinder of figure 5. Figure 8 is a cross section view along line VIII-VIII of figure 5. Figure 9 diagrammatically shows a valve structure for use in a pneumatic machine according to the invention and arranged for being mounted in an end of the piston cylinder unit. Figures 10a-10d show four different functional positions of the valve of figure 9. Figures 11, 12 and 13 show a detail, in three different functional positions, of an alternate embodiment of a valve means for a piston-cylinder unit according to the invention, likewise mounted in an end of a cylinder-piston unit.

Figures 1a-1c show a pneumatic machine comprising a cylinder 1 in which a piston 2 is displaceable. The piston has a piston rod 3 projecting out from the cylinder. As conventional the cylinder is formed with a connection 4 for compressed air entering a working chamber 5 of the pneumatic machine, and a second connection 6 leading to a return chamber 7 thereof. The two connections 4 and 6 are connected to a step valve 8 which can take three different positions of function, which are illustrated in figures 1a-1c, respectively. As conventional the valve 8 is connected to a source of compressed air. The valve may be of linear type, but in the drawings the

valve is shown as a rotary valve. It is evident that the working chamber in the position according to figure 1a is under full pressure, whereas the return chamber 7 is evacuated.

When the piston 2 approaches the end position of its working stroke the valve 7 is rotated by 120° to the position shown in figure 1b. In this position the supply of compressed air is broken, and the working chamber 5 and the return chamber 7 are connected to each other over a shunt conduit 9, whereby the air pressures of the two chambers are being equalized. By a rough approximation it can be said that the pressure is distributed by 50% in each of the two chambers 5 and 7.

Immediately following the pressure equalization the valve is rotated another 120° to the position shown in figure 1c, whereby the working chamber 5 is evacuated. The pressure of the compressed air in the return chamber 7 is remained. Said pressure is quite sufficient for forcing the piston 2 back to its initial position. The return stroke thereby is made solely by means of the reduced pressure present in the return chamber 7.

In figures 2a-2g an alternative method is shown, whereby the valve 8' is formed as a 7-step valve. The function with the pressure equalization between the working chamber 5 and the return chamber 7 is basically the same as that of figures 1a-1c, but the function comprises three successive pressure equalization steps, which are shown in figure 2b (to about 50%), 2d (to about 25%) and 2f (to about 12.5%).

In figure 2a the piston 2 is pressed by full force in a first working stroke in the working chamber 5; in figure 2b there is provided a first pressure equalization between the working chamber 5 and the return chamber 7; in figure 2c there is shown a first return stroke by means of the about 50% pressure which is remained in the return chamber 7; in figure 2d a second pressure equalization is obtained to about 25% pressure; in figure 2e there is obtained a second working stroke or damping stroke by means of the 25% the air pressure remained in the working chamber 5; in figure 2f there is obtained a third pressure equalization to about 12.5% of the original pressure; and in figure 2g there is shown a second return stroke by means of the presently strongly reduced air pressure.

It is of importance that the piston is displaced an accurately predetermined distance before it is turned to execute its return stroke, or it starts its working stroke, respectively. To this end the piston-cylinder unit

shown in figure 4 is formed with a positioning means for the piston, which is directly connected to a step feeding means (not shown in figure 4) for the step valve 7. In this case the cylinder 1 is star-formed having eight star tops 10, all having axially through bores 11. Four of said bores are used for
5 through mounting bolts, and one or more of the remaining bores are used for transmitting compressed air axially through the cylinder, in particular in the cylinder of the type shown in figure 5, in which case there is only a single connection for compressed air provided at one end of the pneumatic machine. The right hand end 12 of the cylinder shown in figure 4 has an end
10 bore for the piston rod 3 and it is also formed with a cavity 13 over which the return chamber 7 directly communicates with the uppermost air bore. The left hand cylinder end 14 has a corresponding cavity 15 through which it communicates with the bore 11.

For providing an exact indication of the position of the piston 2 a
15 longitudinally extending reinforced belt 16, for instance a rack belt, is connected between the two ends of the piston 2 and it extends over pulleys 17 at the two cylinder ends 12 and 14. The belt extends, well protected, through one of the bores 11 of the cylinder 1. One of the pulleys 17 may be
20 a tooth gear which can be mounted on a shaft which at the free end thereof has a positioning means having a great many bars, magnetic code dots or similar marking which can be read by a position reader which in figure 4 is marked as a reader pin extending out through the left end 14. Said position reader thereby very accurately gives the position of the piston and can, as mentioned above, be connected to the valve thereby making the piston turn
25 direction at very accurate positions in the cylinder.

The piston-cylinder unit shown in figure 5 has a compressed air connection 18 only at one end thereof, which connection enters the left hand end of the cylinder, in which a several step valve 19 is housed. Said valve may be of the type shown in figures 9 and 10. The compressed air enters the
30 working chamber 5 over one of the axial bores of the cylinder and through a cross bore 20 in the inner cylinder wall of the cylinder. Said axial bore is plugged so as to avoid escaping of air therefrom. Another one of said axial bores 44 is formed as a connection between the return chamber 7 and the valve 19, and at the left end of the cylinder said bore is connected to the
35 valve 19 over a channel or bore 21. At the right end the axial bore 44 is connected to the return chamber 7 over a cross bore 22 in the inner cylinder

wall. In the illustrated case the pneumatic machine can operate over only one compressed air connection 18, which makes it possible to use the machine in narrow spaces where it has until now often not been possible to make use of pneumatic machines.

- 5 As shown in figure 5 the piston is, at both ends inside the cylinder, formed with damping pistons co-operating with damping cavities in the cylinder ends.

The rotary valve 19 at the left end of the piston-cylinder unit of figure 5 is more closely described in connection to figure 9. The valve is a specific
10 function valve 23 arranged for controlling the function of a single acting pneumatic machine according to the invention - without the need of using a return spring or another type of similar means.

The valve 23 preferably is mounted at one end of the cylinder and it is formed with two valve discs, a lower valve disc 24 which is stationary
15 mounted, and an upper valve disc 25 which is rotatable on the stationary valve disc 24 operated by a pin 26. The stationary disc 24 is formed with four connections, a compressed air connection 27, an evacuation connection 28, a connection 29 leading to the working chamber of the cylinder, and a connection 30 to the return chamber of the cylinder. The upper valve disc 25
20 is likewise formed with four connections 31, 32, 33 and 34 which are arranged like in the bottom disc 24. Between the connections 31 and 32 there is a first bypass channel 35, and between the connections 33 and 34 there is a second bypass channel 36. The compressed air connection 27 is formed with a one way valve 37 which allows a flow of air only into said
25 connection 27. In the bypass channel 35 there is also a one way valve 38 allowing a flow of air only in the direction from 31 to 32; in the bypass channel 36 there is likewise a one way valve 39 allowing flow of air only from 33 to 34; also there is a first bypass channel 40 between the working chamber connection 29 of the lower disc 24 and the connection 31 of the
30 upper disc 25 and a second bypass channel 41 between the connections 28 and 32.

The valve makes it possible to utilize the equalization pressure as a power for the return stroke of the piston.

In figure 9 the valve 23 is shown in its closed position. The
35 compressed air connection 27 is closed, the return chamber connection 30 is closed and the working chamber connection 29 is evacuated over channels

29-40-38-41-28.

Figure 10a shows the working stroke of the cylinder, in which case the upper valve disc 25 is rotated by 45°. Compressed air is supplied to the working chamber over the connections 27-33-39-34-29, and the return chamber is evacuated over 30-31-35-32-28.

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Figure 10b shown an intermediate position, in which the upper disc 25 temporarily has been rotated 90° in relation to the lower disc 24. The piston movement is damped in the cylinder chambers depending on the compressibility of the air and by means of the damping pistons indicated for instance in figure 5.

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Figure 10c shows a position in which the upper disc 25 is rotated another 45° (135° in total) and in which position the pressures of the cylinder chambers 5 and 7 are equalized over 29-33-36-30-34. The compressed air connection 28 is closed by the non return valve 38.

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In figure 10d the return stroke is made in that the working chamber 5 is evacuated by 29-40-31-35-32-41-28. Thereby a complete working cycle has come to an end, and a new cycle is started according to figures 10a-10d.

As an alternative of the above described stepwise rotatable valve the cylinder can be formed with an axially operating valve which is enclosed in one end of the cylinder, as shown in figures 11-13. Also in this case the cylinder is formed with only a single compressed air connection 42, and the piston-cylinder unit is formed with a valve enclosed in one end 45 of the apparatus, which valve connects and disconnects the compressed air, respectively.

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Figures 11-13 are fragmentary axial cross section views through one end of a piston-cylinder unit giving a strong working stroke actuated from the working chamber 5 and a softer return stroke actuated from the return chamber 7. In the illustrated apparatus both the compressed air inlet 42 and the compressed air outlet 43 are formed in the same cylinder end. The flow of air from the working chamber 5 to the return chamber 7 goes through one of the axial bores 44 of the cylinder. The end 45 of the cylinder is formed with a valve piston 46 and with a system of channels 47, 48 which both allow a supply of compressed air to the working chamber 5 through the inlet 42 and an evacuation of the return chamber 7 through the outlet 43.

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The cylinder end 45 is formed with a first channel 47 connecting the compressed air inlet 42 to the working chamber 5 and a second channel 48

connecting the return chamber 7 to the outlet 43 via the cylinder bore 44. The valve piston 46 is slideable in the a valve chamber 49 in the end of the cylinder, and said valve piston can take two main positions, namely a pressure position which is shown in figure 11 and an evacuation position
5 which is shown in figure 13. The valve piston is pressed towards a non-pressurized position by a spring 50. The valve piston also is formed with a transverse channel 51 which, in an intermediate position of the valve piston, interconnects the working chamber 5 with the return chamber 7, as shown in figure 12, whereby the pressure is equalized between said two chambers 5
10 and 7. In said intermediate position the valve piston 46 blocks the pressure channel 47. This intermediate position is taken under only a very short moment of the return stroke of the valve piston. The valve piston 46 also is formed with a bypass channel 52 allowing an evacuation of the return chamber 7 while the valve piston is in pressurized condition.

15 In figure 11 the compressed air inlet 42 is shown pressurized, whereby the compressed air forces the valve piston 46 to the right (as shown in the drawings), and compressed air is thereby supplied to working chamber 5; at the same time the return chamber 7 is evacuated over the cylinder bore 44 and the bypass channel 52, and the working piston can be moved freely to
20 the right during its working stroke, as shown in figure 11.

When the working piston 2 approaches its actual end position a signal is obtained (for instance from the position reading means mentioned in connection to figure 4), which signal provides a stop of supply of compressed air to the inlet 42. The spring 40 thereby forces the valve piston 46 back
25 (left) to its original position. While the piston 46 moves to the left the cross channel 51, for a short moment, interconnects the working chamber 5 and the return chamber 7, as shown in figure 12. The air pressure in the working chamber 5 thereby is balanced to the air pressure of the return chamber 7 over the transverse channel 51 and the cylinder bore 44. In this position both
30 the inlet 42 and the outlet 43 are blocked by the valve piston 46.

When the valve piston 46 has returned to its original (left) position shown in figure 11 the air in the working chamber 5 is evacuated through the channel 47, the cross channel 51 and the outlet 43. The "balanced" pressure which is still present in the return chamber 7 is sufficient for softly starting a
35 return movement of the working piston 2 to its initial position adjacent the cylinder end 45. Thereby a complete working cycle has come to an end.

REFERENCE NUMERALS

	1	cylinder	31	connection
	2	piston	32	connection
	3	piston rod	33	connection
5	4	1st connection	34	connection
	5	working chamber	35	bypass channel
	6	2nd connection	36	bypass channel
	7	return chamber	37	one way valve
	8	step valve	38	one way valve
10	9	shunt conduit	39	one way valve
	10	star top	40	bypass channel
	11	bore	41	bypass channel
	12	right hand cylinder end	42	compressed air inlet
	13	cavity	43	compressed air outlet
15	14	left hand cylinder end	44	axial bore
	15	cavity	45	cylinder end
	16	belt	46	valve piston
	17	pulleys	47	channel system
	18	compressed air connection	48	channel system
20	19	step valve	49	valve chamber
	20	cross bore	50	spring
	21	bore	51	cross channel
	22	cross bore	52	bypass channel
	23	function valve		
25	24	valve disc, stationary		
	25	valve disc, rotatable		
	26	pin		
	27	compressed air connection		
	28	evacuation connection		
30	29	connection		
	30	connection		



CLAIMS

1. A reciprocable pneumatic machine of piston-cylinder type arranged for effectively making use of compressed air by providing a strong
5 primary movement actuated from a working chamber (5) and a soft return movement actuated from a return chamber (7), or one or more secondary, stepwise softer movements, and in which the primary movements demands a greater force of compressed air than that of the return movement, which pneumatic machine comprises a piston (2) which is operable in a cylinder (1)
10 and which defines a working chamber (5) and a return chamber (7), and a valve (8; 8'; 23) which is formed with three or more functional positions for providing the different functional steps, and which valve, in a first position, provides a full pressurization of the working chamber (5) and an evacuation of the return chamber (7), in a second position provides an equalization of
15 pressure between working chamber (5) and the return chamber (7), and in a third position provides a return stroke by means of the equalized pressure which is remained in the return chamber and an evacuation of the working chamber, characterized

in that the valve is enclosed in an end of the cylinder (1),
20 in that the valve comprises a first means (27; 47) for pressurizing the working chamber (5), a second means (35; 52) for evacuation of the return chamber (7) at the same time as the working chamber is pressurized (39; 47) and a third means (36; 51) for interconnecting the working chamber (5) and the return chamber (7) thereby providing an equalization of the pressure of
25 said two chambers (5, 7) at the same time as the inlet (27; 42) and the outlet (28; 43) are choked by the valve piston (25; 46),

and in that the return chamber (7) communicates with the valve at the cylinder end (19; 45) via a bore (44) extending axially through the cylinder wall.

30 2. A pneumatic machine according to claim 1, characterized in that said first means is an inlet channel (27; 47) which in one position of the valve is directly connected to the working chamber (5), in that said second means is a bypass channel (35; 52) in the valve piston (46) connecting the return chamber (7) to the ambient, and in that said third means is a
35 transverse channel (36; 51) which in an intermediate position of the valve piston (46) interconnects the working chamber 5 and the return chamber (7).



3. A pneumatic machine according to claim 1 or 2, characterized in that the valve (19; 45) has one single compressed air inlet (18; 27; 42) which is connected to a source of compressed air having means for connecting and disconnecting, respectively, said compressed air to the valve (19; 45).

4. A pneumatic machine according to any of the preceding claims, characterized in that the valve ((8'; 19; 23) has several positions for providing a multiple function whereby the pressure is reduced in several steps by alternately actuating the working chamber (5) and the return chamber (7).

5. A pneumatic machine according to any of the preceding claims, characterized in that the valve comprises two valve discs (24, 25) placed on top of each other and consisting of a stationary valve disc (24) having connections (18; 27) for supplying compressed air, for evacuation (21; 28) the working chamber (5) and the return chamber (7), and having connections (29, 30; 47, 48) to the working chamber (5) and to the return chamber (7), respectively.

6. A pneumatic machine according to claim 5, characterized in that valve disc (24) having said connections is stationary and co-operates with a rotatable valve disc (25) having two pairs of connections (31-32 and 33-34) and between each said pair of connection extending bypass channels (35, 36) each having a non-return valve (38, 39). (Figure 9 and 10)

7. A pneumatic machine according to claim 5 or 6, characterized in that there are bypass channels (40, 41) between the two valve discs (24, 25) for evacuating the working chamber (5) of the pneumatic machine in an intermediate position of the rotatable valve disc (25). (Figure 10d)

8. A pneumatic machine according to any of the preceding claims, characterized in that the valve is an automatically operating valve comprising a valve piston (46) which is slideable in a valve chamber, said valve piston (46) having a series of channels (47, 48, 51, 52) arranged to perform the different functions of the pneumatic machine in that the valve piston (46) is actuated by compressed air during the working stroke, whereas the piston is returned to a blocking position by a spring (50) during the return stroke. (Figures 11-13)

9. A pneumatic machine according to any of the preceding claims, characterized in that the machine comprises a positioning apparatus (16)



arranged to give signal at an accurately predetermined position of both strokes of the pneumatic machine thereby providing a change of position of the valve thereby providing a working stroke, a pressure equalization and a return stroke. (Figure 4)

- 5 10. A pneumatic machine according to any of the preceding claims, characterized in that the machine is formed with a single pressure supply connection (18; 42) and a single evacuation connection (28; 43), both connections provided at one end of the cylinder.