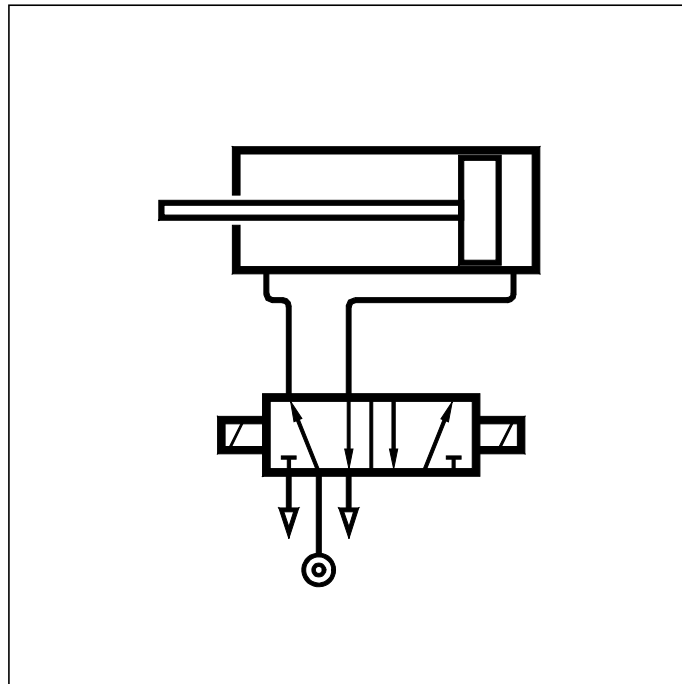


Textbook

Pneumatic system

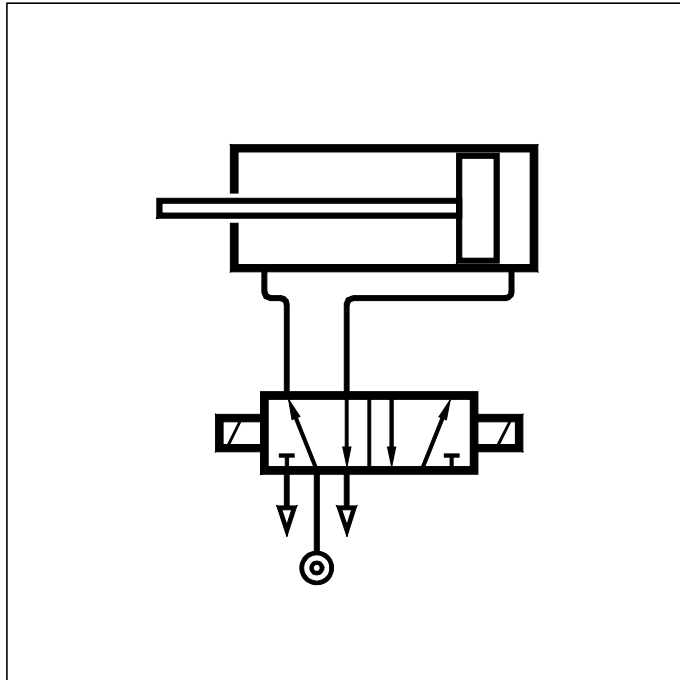


This textbook has been compiled by the Technical Training Centre in Lund.

Some of the pictures in the book are also available as OH pictures.

For further information on training material, please contact the Technical Training Centre.

Pneumatic system



Training Document

This Training Document is intended for Training purpose only, and must not be used for other purpose.

The Training Document is not replacing any instructions or procedures (e.g. OM, MM, TeM, IM, SPC) intended for specific equipment, and must not be used as such.

Note!

For safe and proper procedures, refer to the equipment specific documentation.

Contents

General	3
Components	4
Air conditioning units	4
Valves	5
Cylinders	14
Main air supply line	19
Function principle	20
Symbols	22

General

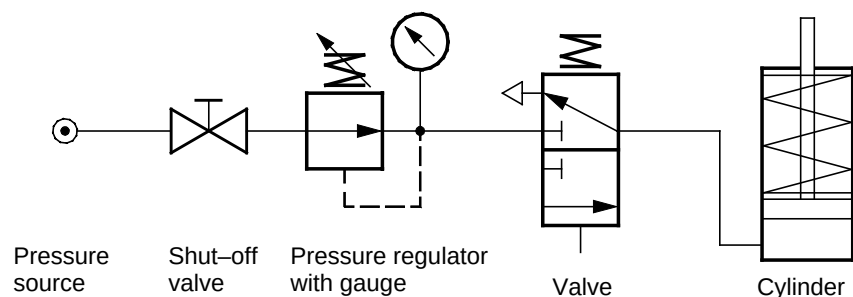
The technology of using compressed air to create movement is termed Pneumatics. In the Tetra Pak packaging machines and distribution equipment, compressed air is used to: make components move, operated by pneumatic cylinders

- make components move, operated by pneumatic cylinders
- control and operate valves
- create vacuum and supply air nozzles with air

The pneumatic system consists of two parts. One part is located external to the machine; in it, the required pressure is generated. The external pneumatics include compressor, air conditioning unit, main air supply line, etc. The other part is inside the machine and includes regulators, valves, cylinders, etc.

The air used in the pneumatic components must be clean and dry; pressure and flow rate must also be as required. The recommended values are specified in the installation manual (IM) for the machine concerned. In some systems, the components are factory prelubricated once and for all, requiring no further oil or grease; air for these components must be as free from oil as possible. However, if such a component is once mist lubricated, it must always be mist lubricated from then on.

The pneumatic system of each machine is documented in the form of a diagram. In order to simplify its construction and make the diagram easier to read, the various components are shown as symbols.

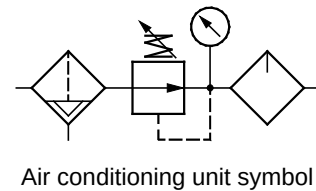
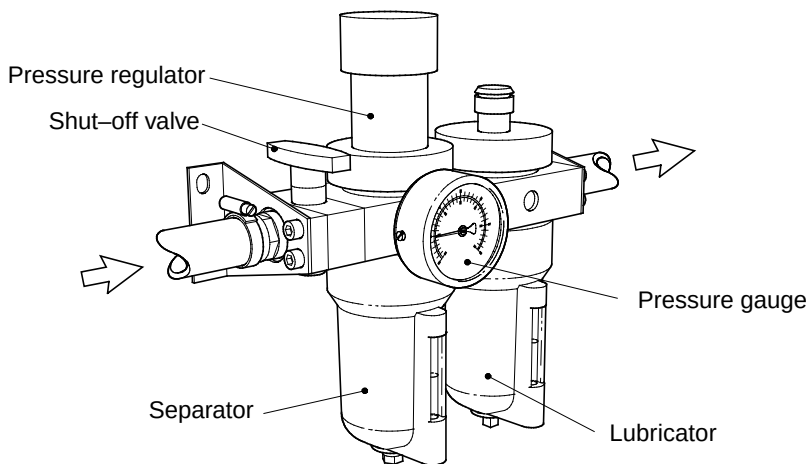


As there are many models and versions of machines, and some of them have been rebuilt or modified to differ from their original design, it is very important that the correct, up-dated, and currently valid pneumatic diagram is used when working with a particular machine.

Components

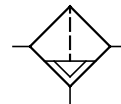
Air conditioning units

The first unit the air passes through on its way to the machine is the air conditioning unit. It consists of a separator, pressure regulator with pressure gauge, and, on some machines, lubricator. Normally, a shut-off valve is built into the conditioning unit.



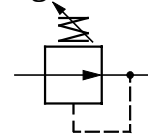
The purpose of the separator is to remove water and other pollutants that might be present in the compressed air. The separator consists of a filter element and a reservoir with a drain valve. The filter element may be made of sintered bronze. The input air is made to rotate, so that water drops and the larger solid particles are flung outwards against the inner surface of the reservoir. Condensated liquid runs down to the bottom of the reservoir, where it is removed through the drain valve when the input air is turned off.

Separator



The purpose of the pressure regulator is to provide air at a constant pressure, independent of the load on the system. It is a form of pressure reduction valve, and its function will be explained under the heading of Valves.

Pressure regulator



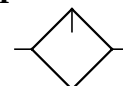
The pressure gauge indicates the pressure setting.

Pressure gauge



The lubricator (mist lubricator) provides the compressed air with oil. The injected amount of oil is proportional to the flow rate of the air and can be preset. In systems whose components are factory prelubricated, no oil must be added to the compressed air, as oil would wash out the grease in the prelubricated components.

Lubricator



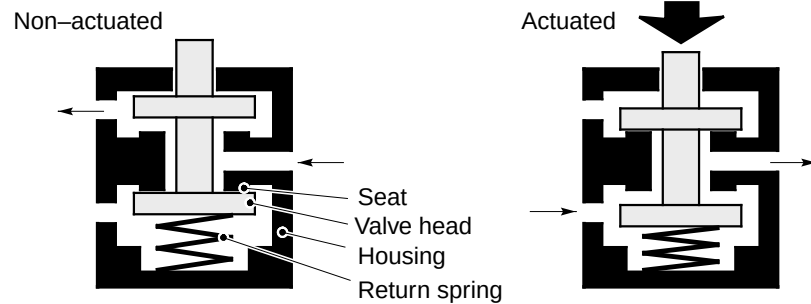
Valves

The purpose of valves is to regulate the flow rate and pressure of the compressed air and control its flow direction. The valves are controlled and operated either manually, by means of electrical signals from the PLC, or pneumatically by other valves.

Valves are subdivided into two groups – **seat valves** and **slide valves**. These groups differ in their design.

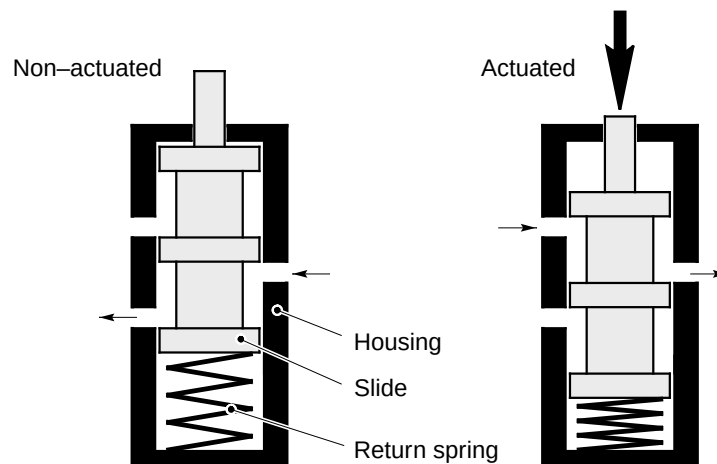
Seat valve

The seat valve controls the flow of air by means of its valve head and seat. The valve head only has to move a short distance to change over but needs considerable change-over force.



Slide valve

The slide valve controls the air flow by means of a movable slide. To change over, the slide has to move a relatively long distance, but the force needed for it is small.



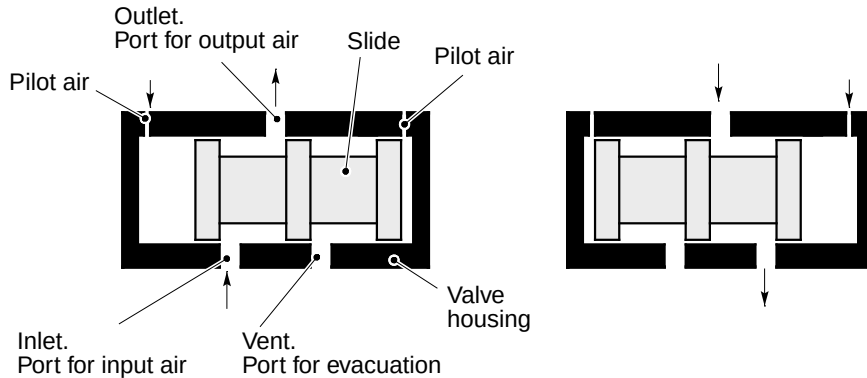
In respect of their purpose, valves are grouped as follows:

- **directional valves**, controlling the flow direction of the compressed air, for instance to operate the reciprocating movement of the piston in a pneumatic cylinder.
- **flow rate regulating valves**, controlling the amount of air per time unit, for instance to control the speed of the piston in a pneumatic cylinder.
- **pressure regulating valves**, controlling the pressure in the pneumatic system.

Before proceeding, we shall take a look at the symbols for the valves, and how they are constructed and function.

The valve symbols denote the function of the valves but not their design. This means that valves that look differently, due to the way they are designed and constructed but function in the same manner, are shown with the same symbol.

The illustration shows the working principle of a slide valve, which may be in either of two positions.



Position 1

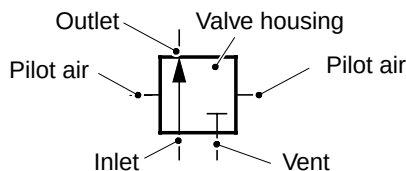
The valve has received pilot air on the lefthand side. The passage between inlet and outlet is open, and the vent is closed

Position 2

The valve has received pilot air on the righthand side. The inlet is closed, and the passage between outlet and vent is open.

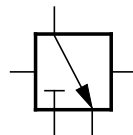
This valve can be shown simplified as a symbol.

The symbol consists of a square, with the ducts through which the air is able to pass shown as arrows. To the left and right of the square, the manner in which the valve is controlled is symbolised, for instance with a horizontal line for pneumatic control. The lines above and underneath the square represent the ports connected to the input and output air lines.



Position 1

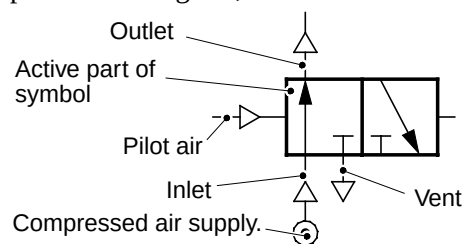
The valve symbol is shown with open passage between inlet and outlet, and closed vent.



Position 2

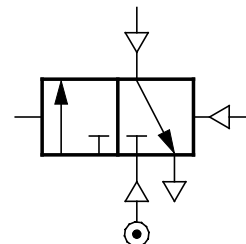
The valve symbol is shown with open passage between outlet and vent, and closed inlet.

The function of the valve is illustrated by means of symbols. Each position the slide may be in is shown as a symbol, and the symbols are drawn after one another. The ports are only shown on the symbol in active position in the pneumatic diagram, which is the starting position of the valve.



Position 1

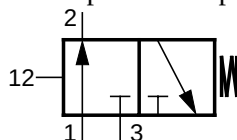
The pilot air is received on the lefthand side of the symbol, which means that the lefthand side of the symbol is active. Compressed air passes through the valve and can actuate a cylinder



Position 2

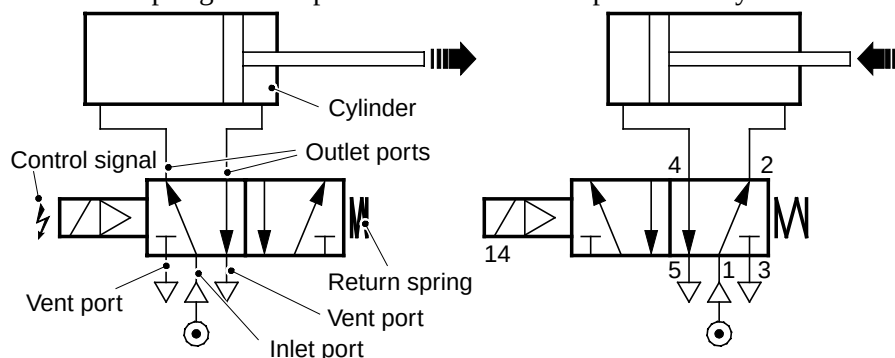
The pilot air is received on the righthand side of the symbol, which means that the righthand side of the symbol is active. The air in the cylinder can be evacuated.

To make it easier to identify them, the ports are numbered: input air port – No 1; output air port – No 2; vent port – No 3. The pneumatic signal ports take their numbers from the ports they provide passage between; for instance, port No 12 connects input and output air.



As the valve in the example has three ports and a slide which may be in two positions, it is termed a "3/2 valve". Similarly, a five-port valve with a three-position slide becomes a "5/3 valve".

The valve may be operated in several ways. Other than pneumatically, it can be operated manually, by a spring, or electrically. The different ways are shown as symbols. In the following example, an electrically operated 5/2 valve with spring return operates a double-action pneumatic cylinder.



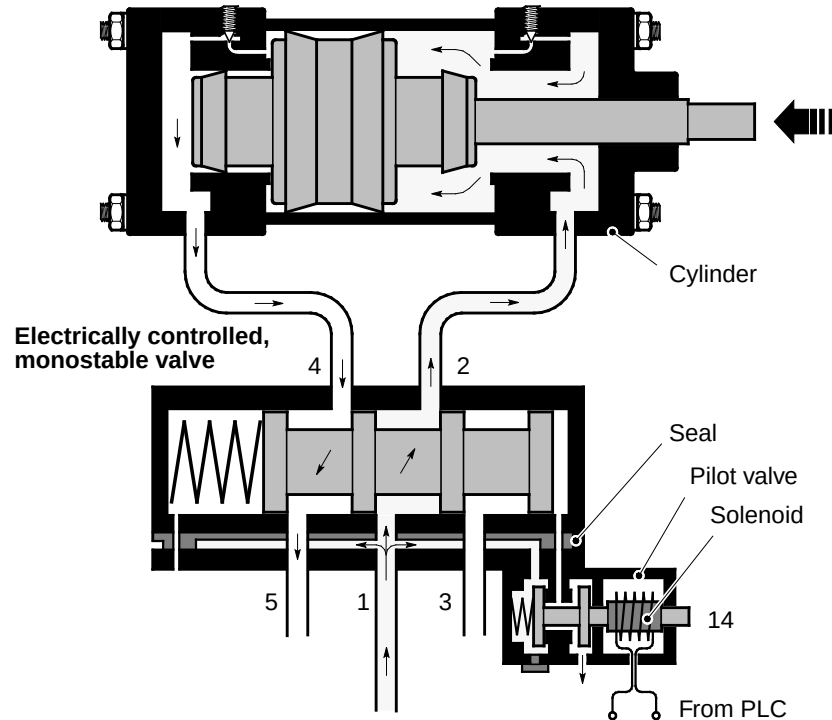
The control signal is received on the lefthand side of the symbol. Compressed air passes through the valve and into the plus compartment of the cylinder, while its minus compartment is vented.

The control signal is discontinued, and the return spring moves the slide. The compressed air is now directed to the minus compartment of the cylinder, while its plus compartment is vented.

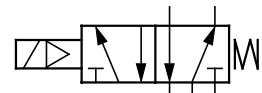
The various forms of valve symbols used in our pneumatic diagrams are explained in greater detail in the section of this text where the function of the valves is described.

The monostable valve features spring return, i.e. in idle position, the slide is always in the same position. One advantage of this type of valve is that it is possible to operate a cylinder in both direction with only one control signal output from the PLC.

Electrically controlled, monostable valves are used extensively in Tetra Pak machines. The pilot air is controlled by means of an solenoid, powered by 24 or 48 V DC from a PLC output. The pilot air system is an integral part of the directional valve.



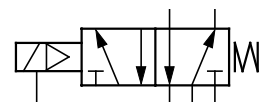
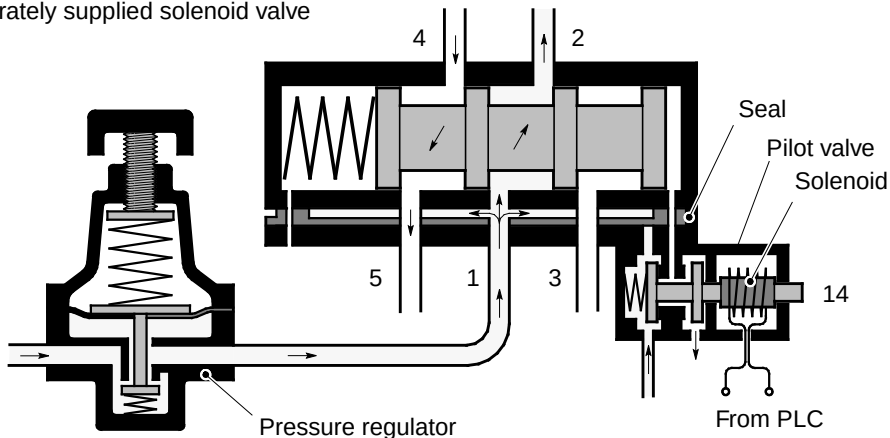
Monostable directional valve



Electrically controlled, monostable directional valve.

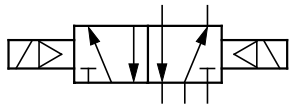
In those cases where the valve receives air with a reduced pressure, which is lower than the change-over pressure of the valve, the pilot valve can be supplied separately with air from the pneumatic system. On some valves, for instance Mecman Series 581, change-over is effected by turning the seal between the valve proper section and the control section upside down. Then control port No 14 in the connection plate is connected directly to the compressed air system.

Electrically controlled, monostable valve with separately supplied solenoid valve



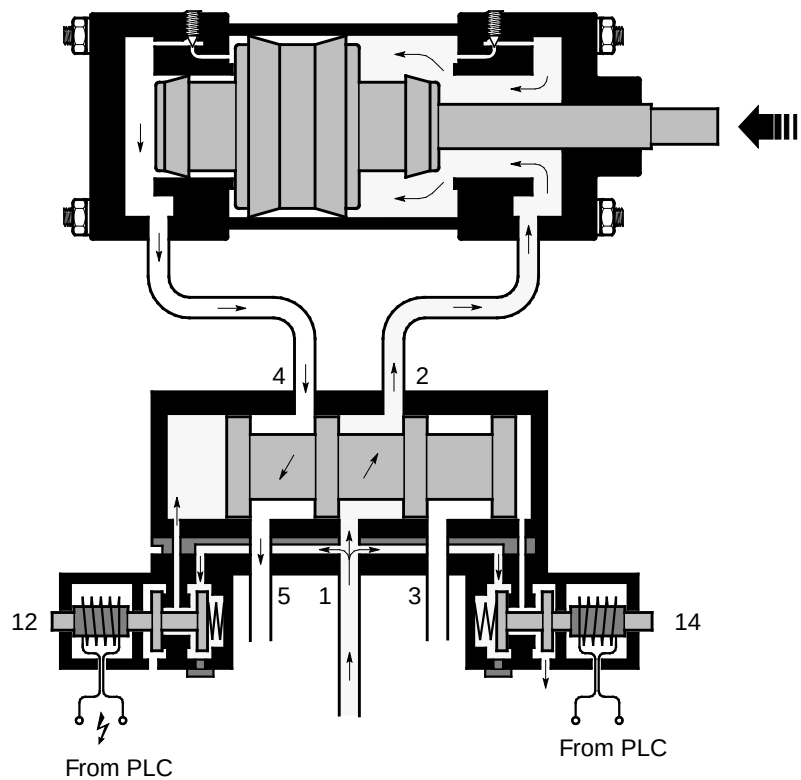
Electrically controlled, monostable directional valve with separate air supply to pilot valve.

Bistable directinal valve



Electrically controlled,
bistable directional valve

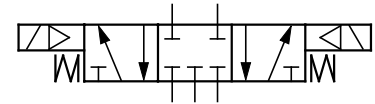
The valve has no spring return, and thus the slide can be in either of two idle positions, depending on which one of the two solenoids was most recently activated. Consequently, two outputs from the PLC are always required to control a bistable valve.



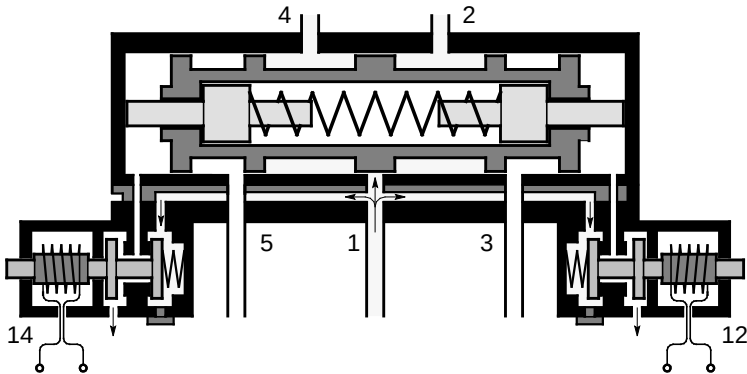
Valves of the bistable type are used if, for instance, it is desirable that the cylinder is to remain in the position it moved to as a result of the most recent valve operation, even if the the output signal is discontinued. The same standard principle for numbering the ports applies to this kind of valve. Pilot air at port No 12 connects ports No 1 and No 2, pilot air at port No 14 connects ports No 1 and No 4, in both cases admitting passage of input air.

This valve type is used, for instance when a cylinder is to remain in position at an emergency stop. Below, an electrically controlled 5/3 valve is illustrated.

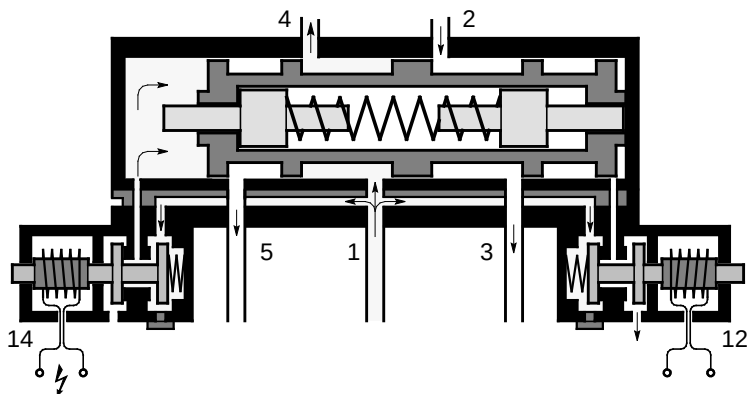
3-positioned directional valve



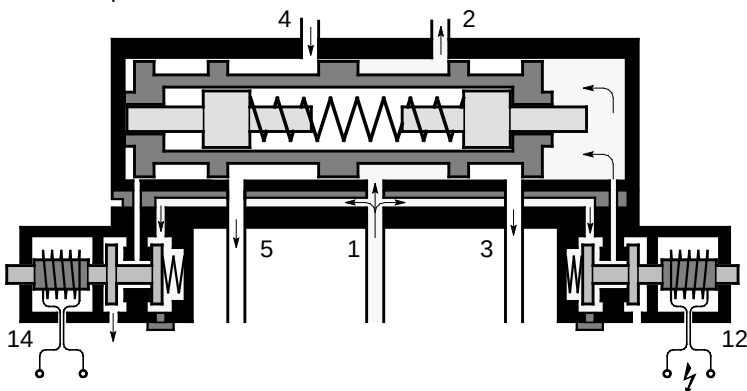
Electrically controlled, 3-positions directional valve with closed middle position.



No control signal to ports No 12 and No 14 means that the return spring positions the slide in the middle; all ports closed.



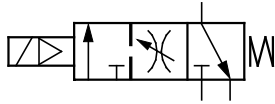
On port No 14 receiving a control signal, the slide moves to the right in the picture. This means that port No 1 is connected to port No 4, and port No 2 to port No 3.



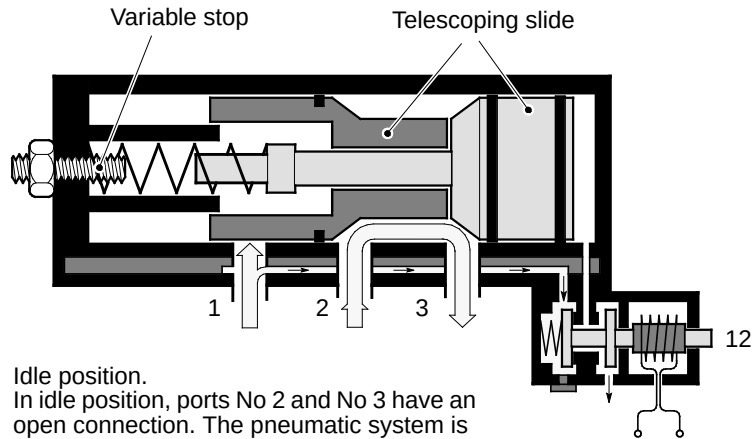
On port No 12 receiving a control signal, the slide moves to the left in the picture. This means that port No 1 is connected to port No 2, and port No 4 to port No 5.

The valve can be in three positions. In addition to the two positions of a 2-position valve, the 3-position valve has a middle position with all ports closed (as exemplified above) or open for venting. Two PLC outputs are required to control the valve. If there is no signal when the system is depressurised, the return spring puts the valve in its middle position.

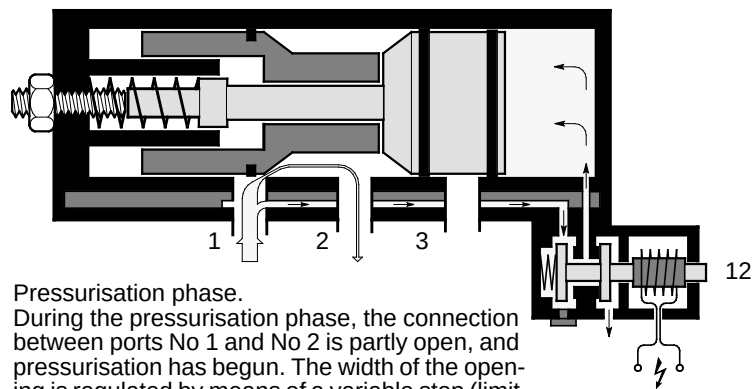
Soft-start valve



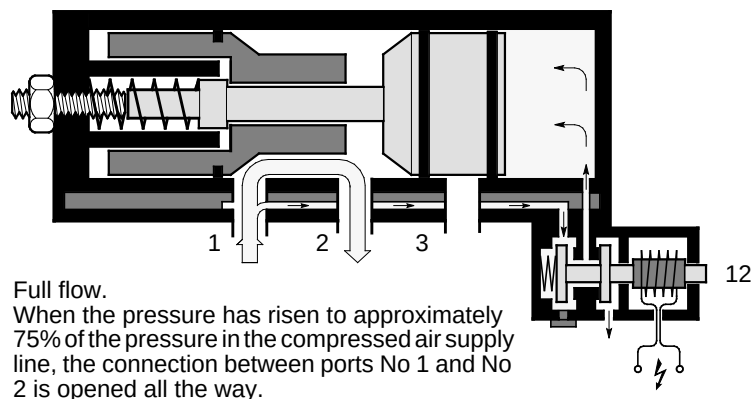
This type of valve is used in order to make pressurisation of the pneumatic system soft and smooth.



Idle position.
In idle position, ports No 2 and No 3 have an open connection. The pneumatic system is depressurised.



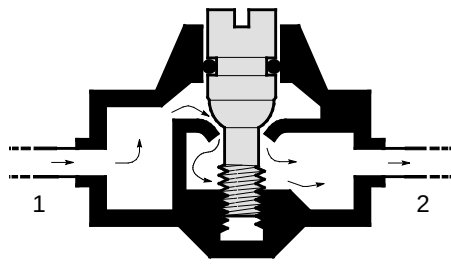
Pressurisation phase.
During the pressurisation phase, the connection between ports No 1 and No 2 is partly open, and pressurisation has begun. The width of the opening is regulated by means of a variable stop (limit screw).



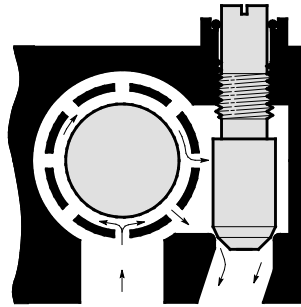
Full flow.
When the pressure has risen to approximately 75% of the pressure in the compressed air supply line, the connection between ports No 1 and No 2 is opened all the way.

The three positions of the telescoping slide are illustrated, somewhat simplified. When the control signal is received, the slide moves up against the variable stop, opening a narrow connection between ports No 1 and No 2 (pressurisation phase). When the pressure has risen to approximately 75% of the pressure in the compressed air supply line, the valve opens all the way. On depressurisation or at an emergency stop, the valve provides full flow directly between ports No 2 and No 3 (depressurisation).

This kind of valve is used to regulate the flow of air, which is restricted equally much in both directions.



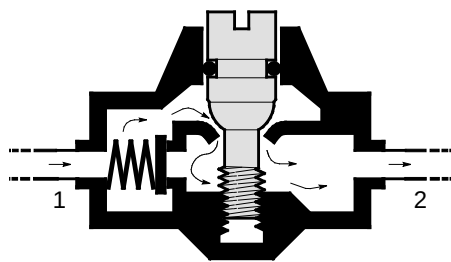
Throttle valve



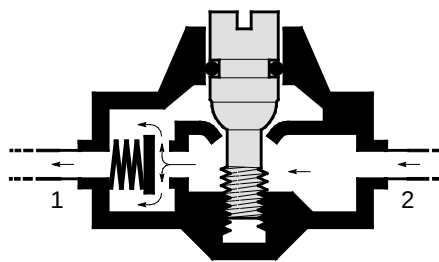
Throttle fitted in directional valve

If throttles are incorporated in a directional valve, they are fitted in the outlet ports and consist of brass screws. Normally, such throttles are factory fitted in most of our directional valves. Normally, they provide adequate speed regulation accuracy.

This kind of valve is used when the air is to be regulated in one flow direction only.



When the air flows from port No 1 to port No 2, it must pass through the throttle and can thus be regulated.



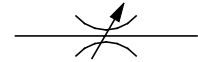
If, on the other hand, the air flows from port No 2 to port No 1, it passes through the check valve without being regulated.

In order to achieve better accuracy in speed regulation, throttle check valves can be used, for instance fitted in the end sections of the cylinders. This is done when the cylinder is located remote from the directional valve. If throttle check valves are being used, the throttles integral with the directional valves must be fully open; adjustment must only be made by means of the throttle check valves.

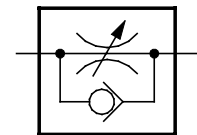
This is a manually operated ball valve, used to shut the supply of air to the entire pneumatic system. Normally, it is built into the air conditioning unit.

The pressure switch triggers an alarm to the control system, if the pressure drops below a preset value. This value can be adjusted.

Throttle valve



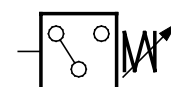
Throttle check valve



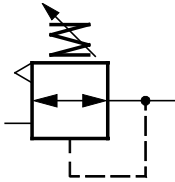
Shut-off valve



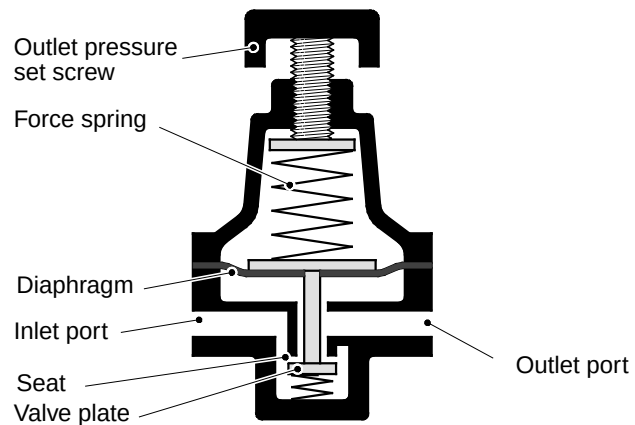
Pressure switch



Pressure regulator



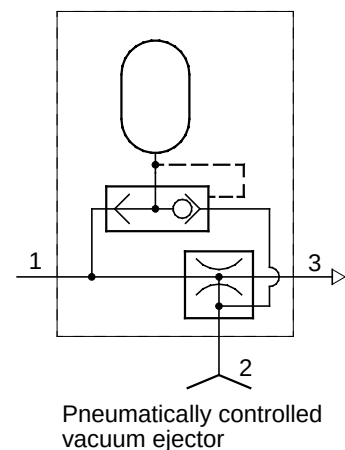
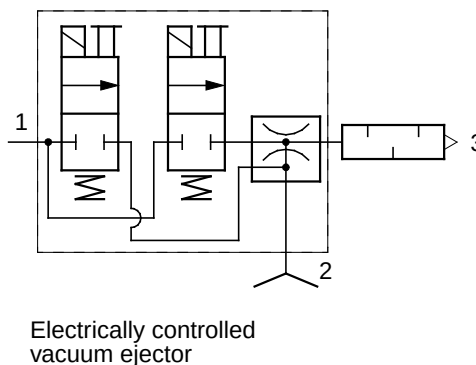
Correctly set pressure is a condition of correct speed control and correct force. For this reason, a pressure regulator is always fitted in the air conditioning unit. To enable the pressure regulator to function well, there must be a pressure difference between input and output air of not less than 0.8 bar. Some machines have an extra pressure regulator within the pneumatic system for the purpose of allowing the reduction of the air pressure to some of the cylinders.



The valve plate of the seat valve is operated by the diaphragm, which in its turn is actuated by the outlet pressure of the pressure regulator. The force created by this pressure is balanced by the spring force on the other side of the diaphragm. By increasing the spring force by turning the set screw, the seat valve is opened and is kept open until the outlet pressure exceeds the spring force. Thus the diaphragm and the spring force together maintain a constant, preset outlet pressure. If the pressure on the outlet side drops, for instance due to air used in moving a cylinder, the seat valve opens again.

Vacuum ejector with valve

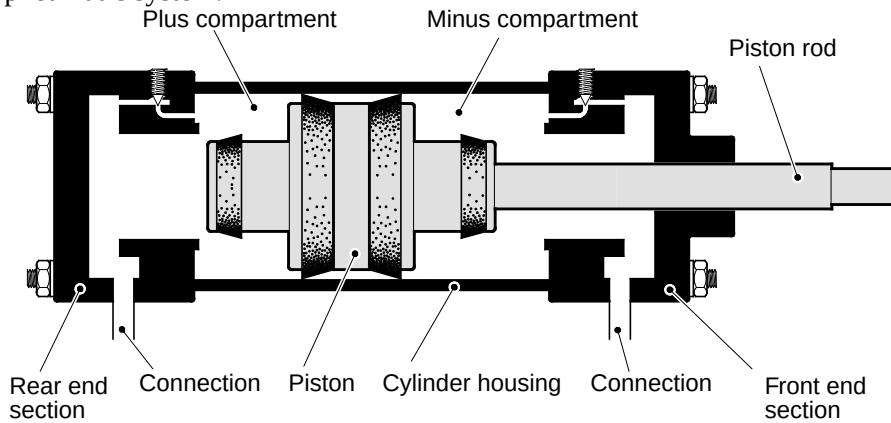
This valve generates underpressure through its ejector effect. It is used, as an example, to supply a vacuum to suction cups. There are two types of vacuum valves. One type which is electrically controlled and generates a release pulse when the direction of flow is reversed. The other type is entirely pneumatic and generates the release pulse by means of a built-in accumulator.



Cylinders

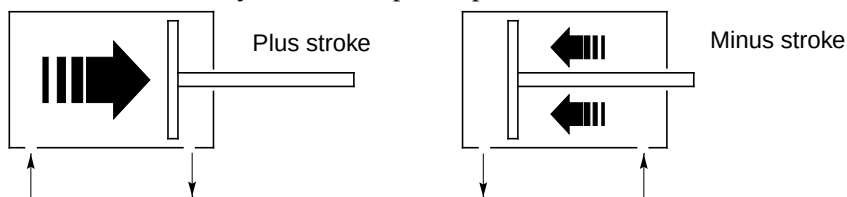
The purpose of a pneumatic cylinder is to perform a movement, powered by compressed air.

In simple terms, the pneumatic cylinder consists of a cylinder housing with two end sections, a piston with piston rod, and two connections to the pneumatic system.



The piston is provided with seal-rings, separating the two compartments. The front end section has a piston rod guide and seal.

When compressed air is admitted into the plus compartment (pressurisation), and the air in the minus compartment is vented, or evacuated (depressurisation), the piston rod extends out of the cylinder – the piston performs a plus stroke. If the flows of air are reversed, the piston rod is withdrawn into the cylinder – the piston performs a minus stroke.

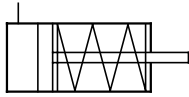


The cylinder described above is a double-action cylinder with single-side piston rod. This means that both the plus stroke and the minus stroke are performed powered by compressed air, and that there is a piston rod at one end only.

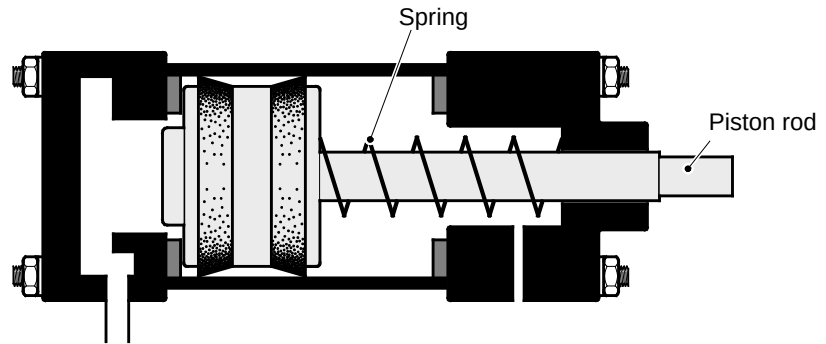
Double-action cylinder



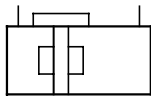
Single-action cylinder



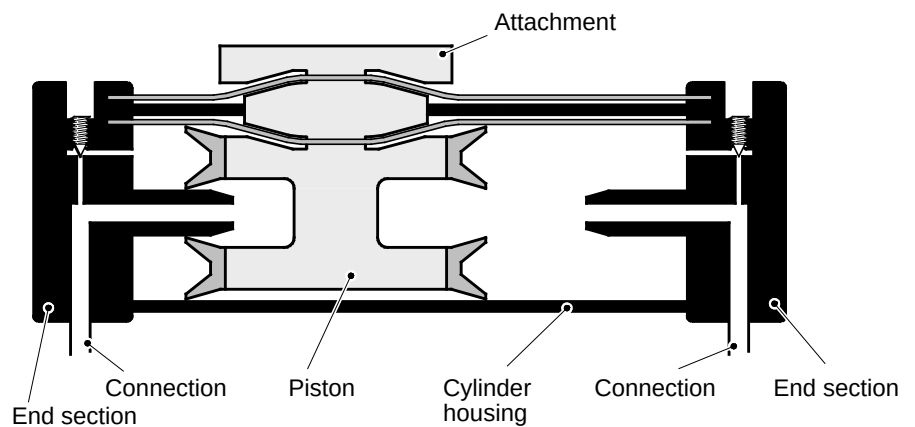
In the single-action cylinder, a spring effects the minus stroke.



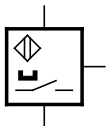
Rod-less cylinder



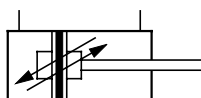
Such a cylinder is double-acting, but its piston rod has been replaced by an attachment sliding along the outside of the cylinder shell. The movement may be transferred to the attachment mechanically or by means of magnets.



Magnetic piston sensor

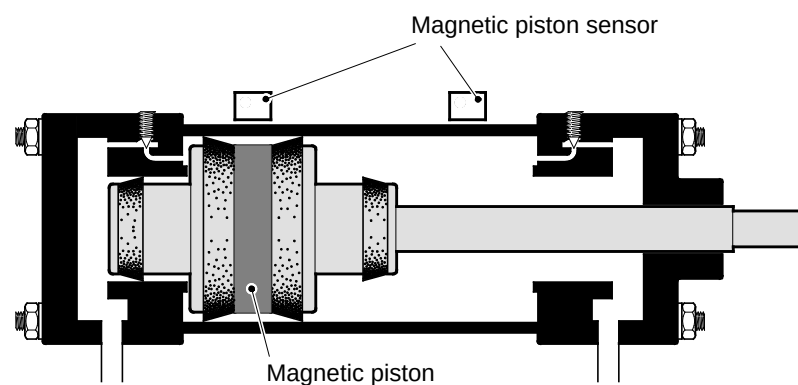


Fully electronic magnetic piston sensor; when the magnetic field of the piston alters the resistance in a semiconductor element inside the sensor, an output signal is transmitted to the PLC; the sensor has a switch-off delay of 20–30 ms.



Double-action cylinder with magnetic piston

A magnetic piston sensor is fitted on the cylinder for the purpose of giving the PLC information on the current piston position. This information is then utilised by the PLC as a precondition of, for instance, the changing over a directional valve etc.

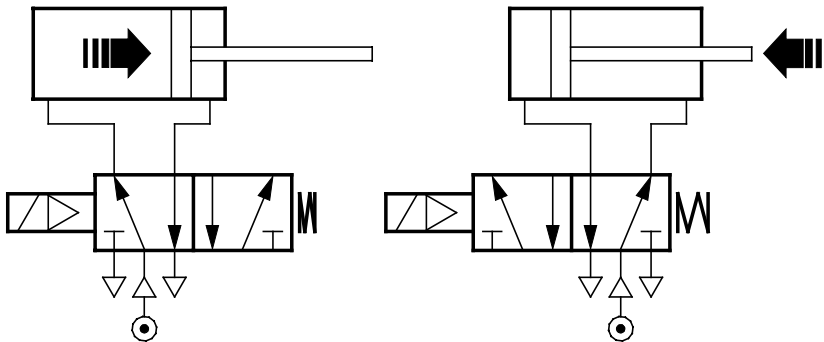


When replacing a cylinder with a magnetic piston, it is important that the replacement cylinder also has a magnetic piston. A cylinder with the correct length of stroke and diameter, but without magnetic piston, will not actuate the magnetic piston sensors.

The direction, force, and speed of movement of the **piston rod** can be controlled. To ensure that the piston rod stops moving softly and smoothly, there are also end position dampers. The various functions are explained in the following.

The direction of movement is controlled by directional valves..

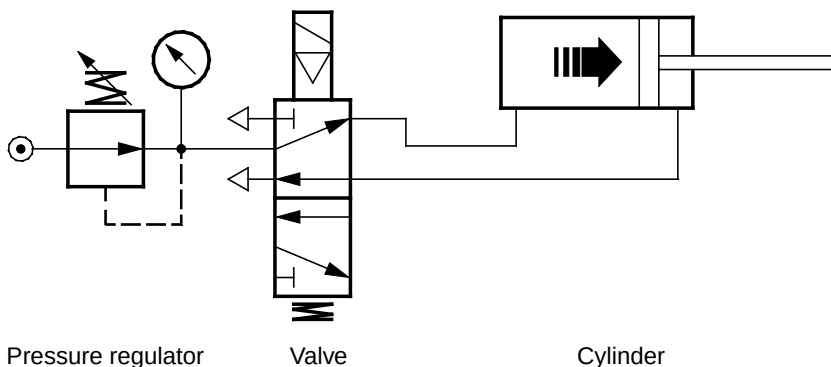
Direction of movement



In order to control the movements of a double-action cylinder, a five-port valve is required. As the valve is actuated by a control signal, its slide changes over, and the compressed air is led to the plus compartment of the cylinder, while the minus compartment is vented. The piston performs a plus stroke. If the control signal is discontinued, the return spring of the valve moves the slide back again, and the flow of air reverses direction; the minus compartment is filled with air, the plus compartment is vented, and the piston makes a minus stroke.

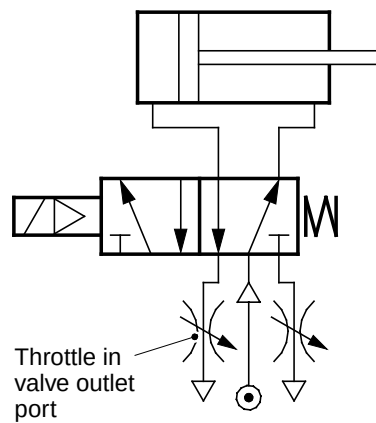
The force which the piston rod exerts on the load, is regulated by varying the pressure of the air – reducing the pressure decreases the force. The pressure is controlled by means of a pressure regulator.

Force

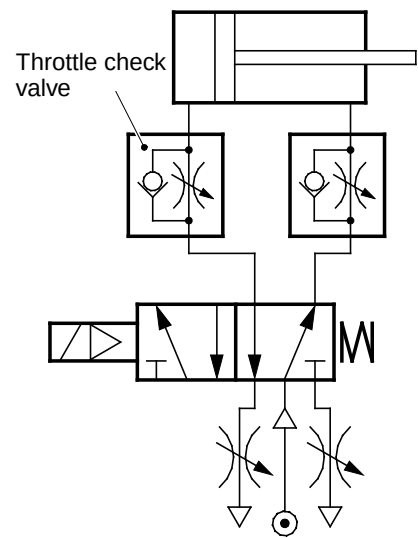


Speed

The speed of the piston is regulated by varying the flow of air on the return side in the cylinder. This is done by means of the throttles in the valve, or with throttle check valves fitted in the line between the valve and cylinder.

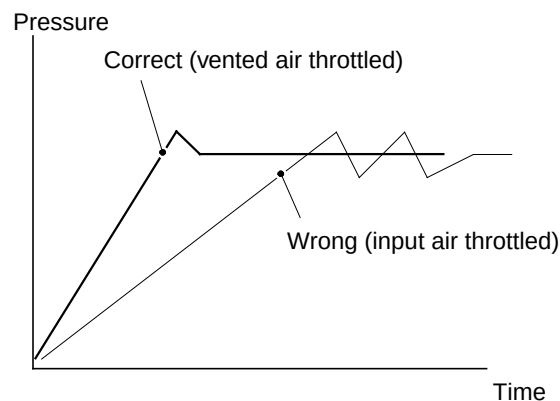


Speed regulation by means of throttles in valve



Speed regulation by means of throttle check valves; throttles in valve to be fully open

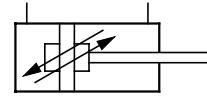
The reason why throttling is done on the return side of the cylinder is to make the movement smooth.



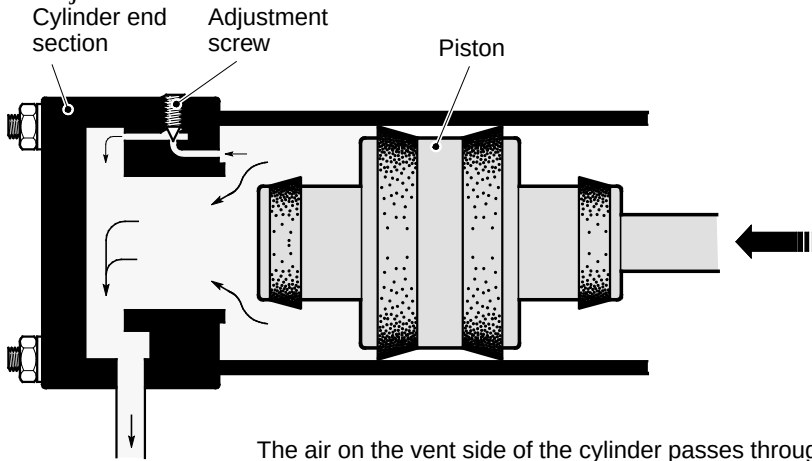
If the cylinders used are small, or the air lines between cylinder and valve are long, the alternative of employing throttle check valves offers better speed regulation accuracy; the valve throttles must in this case always be fully open.

The movement of the piston is dampened at both end positions by built-in dampers in the cylinder end sections. The dampening effect is regulated with adjustment screws. The purpose of the dampers is to decelerate, i.e. slow down and stop, the piston smoothly. In this way, damage to the cylinders, caused by the piston striking the cylinder end section with some force, is eliminated. Dampening also reduces vibrations in the machine. If, on the other hand, the dampening effect is too great, the piston may bounce back and come to a stop with a jerk.

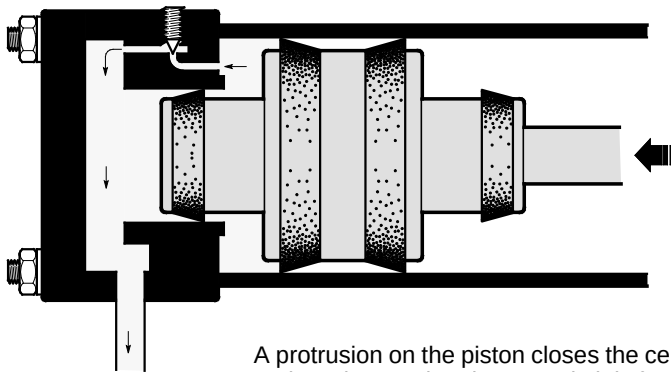
Dampening



Double-action cylinder with variable end position dampening

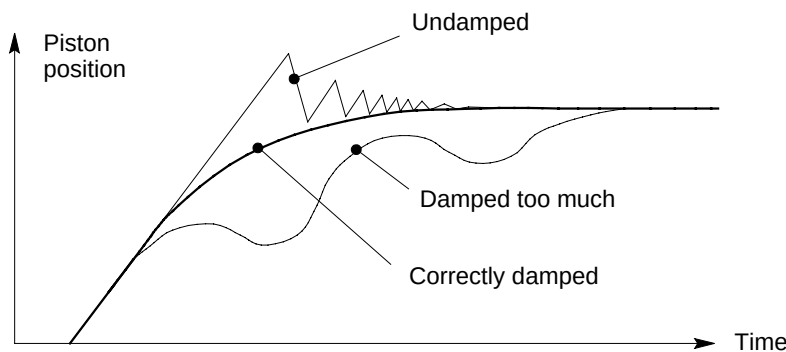


The air on the vent side of the cylinder passes through the large, central opening in the cylinder end section

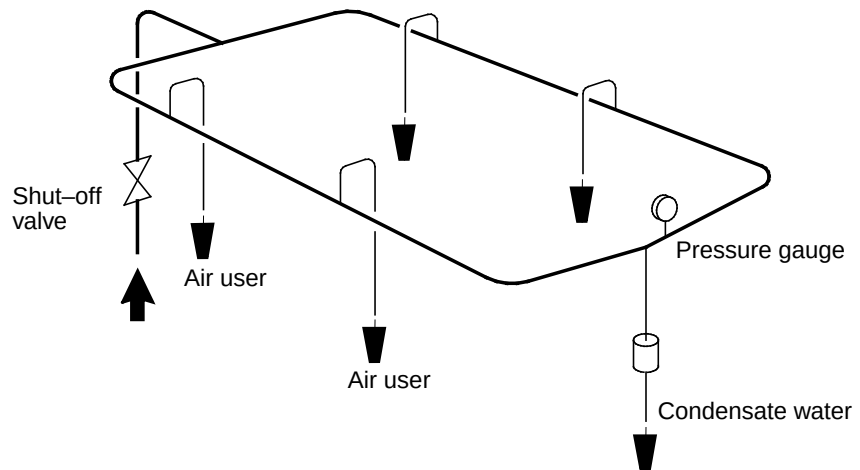


A protrusion on the piston closes the central opening in the end section, so that the vented air is forced through the narrow duct, in which the adjustment screw enables the flow, and thus dampening effect on the piston, to be regulated.

In order to successfully set both speed and dampening, it is important first to make sure that the pressure in the system is correct. Thereafter, the cylinder speed can be set, and lastly, the dampening effect.



Main air supply line



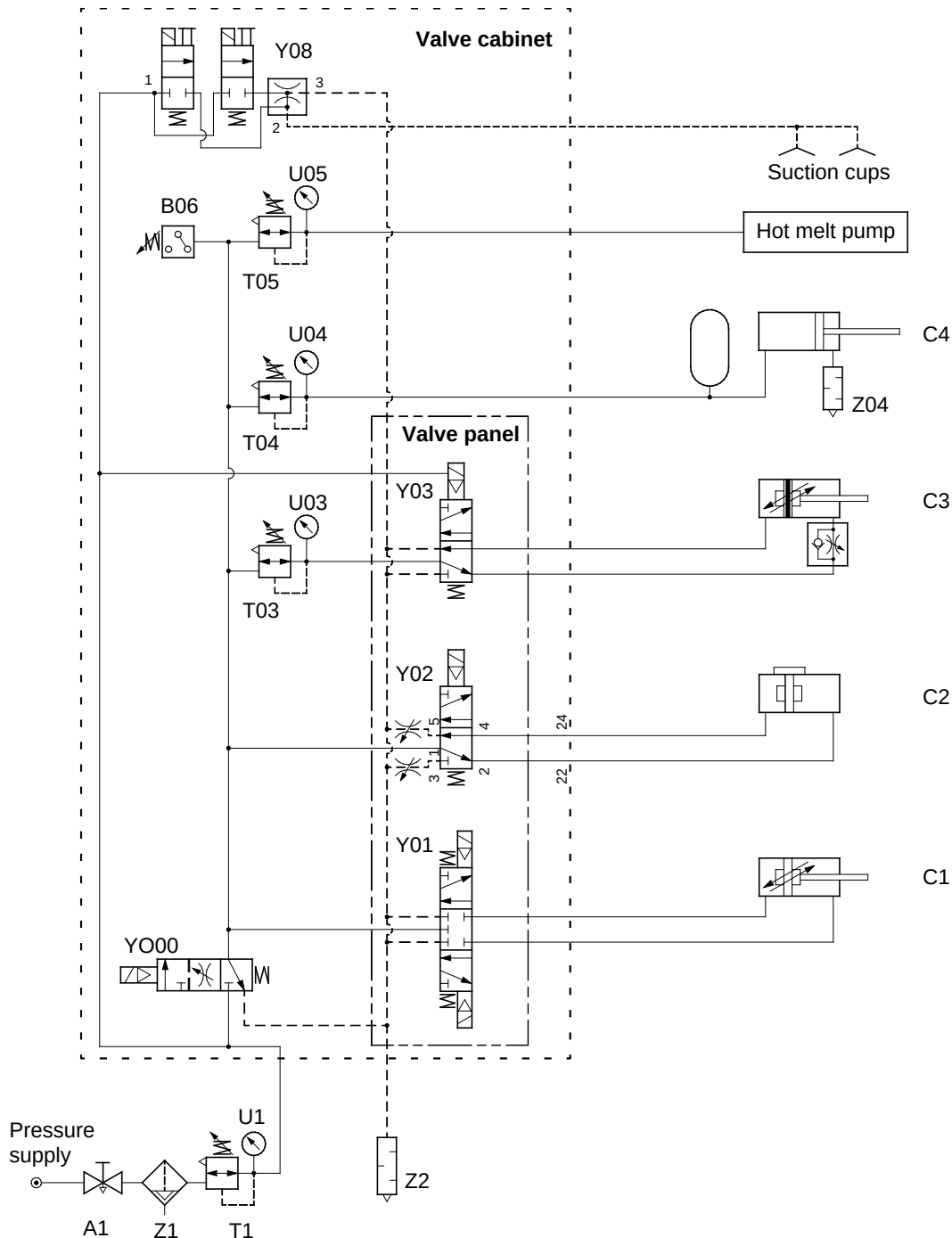
The main air supply line should form a ring main line through the premises; this will allow the users of air to receive it from two directions. There should be a drop of 5–10 mm per metre in the direction of flow. Underneath the lowest point in the ring line, a condensate drain cock is to be fitted. The output connections to the users should be fitted on the top side of the main line piping; this will keep condensate water and dirt from following the air into the user device. There should also be a pressure gauge to make it possible to check that correct air pressure is being maintained.

The diameter of the main line piping depends on its length as well as the number of pipe bends and elbows, connections, and valves in the line. The larger the number of such components that the air must pass, the bigger the pipe diameter must be to prevent excessive pressure drop up to the points where the air is used.

The pipe-lines should be installed so that they are easily accessible for checking that they are tight.

Function principle

This is an example of a principle diagram of a pneumatic system:



The input compressed air passes through manual valve A1, water separation filter Z1, and pressure regulator T1; pressure gauge U1 indicate the pressure. If the pressure drops below a preset value, pressure switch B06 indicates a warning by lighting a signal lamp on the control panel. The pressure switch should be connected as the last component in the system in order to sense the pressure drops created by the other components.

A manual valve
 B cylinder
 C cylinder
 T pressure regulator
 U pressure gauge
 Y electrically controlled valve
 YO pressurisation valve
 Z filter

————— Pressurisation
 ————— Control line
 - - - - - Depressurisation
 - - - - - Vacuum line
 - - - - - Valve panel
 - - - - - Valve cabinet

Pressurisation valve YO00 is used to make pressurisation of the system slow in order to allow cylinders in wrong positions to return smoothly to their correct idle positions. The pressurisation time can be adjusted by means of an adjustment screw in this valve. Valve YO00 also has a safety function, for instance if an emergency stop requires the system to be instantly depressurised.

Valve Y01 is a 3-position valve with closed middle position. If, for instance, the machine is emergency stopped, the valve moves to the middle position, and cylinder C1 remains in the position it was in at the stop.

Valve Y02 is monostable and electrically controlled. It has throttles in its outlet ports for regulating the speed of cylinder C2.

Valve Y03 is also monostable and electrically controlled, but its pilot valve is supplied with air separately from a line, connected before soft-start valve YO00. This means that valve Y03 does not have to wait for the slow build-up of pressure via the soft-start valve but changes over instantly as soon as valve A1 opens. The separate supply of air also allows valve Y03 to be supplied with air at a reduced pressure, for instance to limit the force of cylinder C3.

Pressure regulator T04 regulates the pressure to cylinder C4. This cylinder acts as an air spring, and for this reason, an accumulator is connected to the air line.

Pressure regulator T05 regulates the pressure to the hot melt pump and thus controls the amount of hot melt adhesive to be extruded.

Y08 consists of a vacuum ejector and two valves. When the righthand valve is activated, compressed air flows from port 1 to port 3 and, due to the ejector effect, a vacuum is generated at port 2, to which the suction cups are connected. When the lefthand valve is activated, compressed air is supplied directly to the suction cups, which thus receive a blast of air, releasing their suction and blowing their ducts clear.

Silencer Z2 is common to the whole pneumatic system.

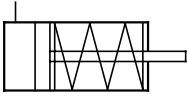
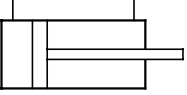
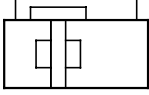
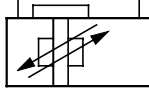
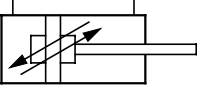
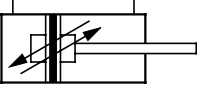
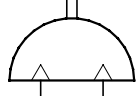
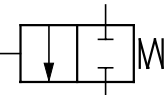
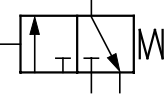
The designations in the diagram follow a certain system, usually consisting of a letter and a number. The components which the compressed air comes to first are given the same number, in this case 1, but different letters to denote their functions: A for manual valve, Z for filter, and T for pressure regulator. The number of a valve, for instance Y02, determines the numbers of the following components. The output lines from the valve are given numbers beginning with 2, followed by the number of the outlet port, i.e. numbers 22 and 24. The cylinder is designated C2.

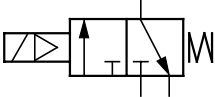
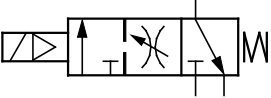
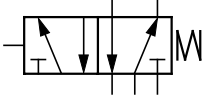
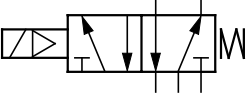
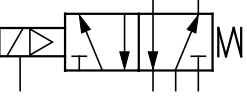
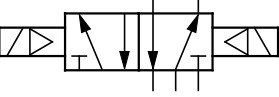
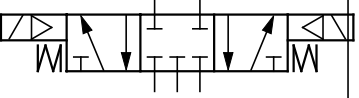
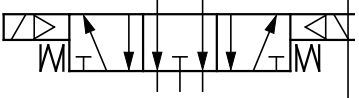
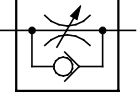
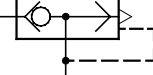
Whenever setting is done in the pneumatic system, it is important to do it in the right order:

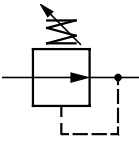
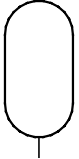
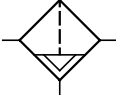
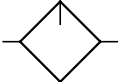
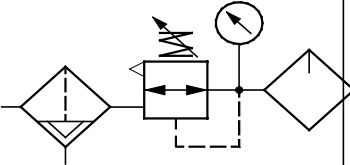
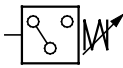
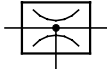
- 1input pressure
- 2speed (throttle check valves or valve throttles)
- 3dampening (end position dampers in cylinders)

Symbols

The following table, which is an excerpt from the Tetra Pak Standards (DS 208.35), lists the symbols that are normally used in our pneumatic diagrams.

Symbol	Meaning
	Single-action cylinder with return stroke by spring.
	<i>Double-action cylinder with single-ended piston rod.</i>
	Double-action cylinder without piston rod.
	Double-action cylinder without piston rod, with variable dampening at both end positions.
	<i>Double-action cylinder with variable dampening at both end positions.</i>
	<i>Double-action cylinder with variable dampening at both end positions and magnetic piston.</i>
	Torque cylinder.
	<i>2/2 directional control valve, controlled by pressure acting against return spring.</i>
	<i>3/2 directional control valve, controlled by pressure acting against return spring.</i>

	<i>3/2 directional control valve, controlled by solenoid with return spring.</i>
	<i>3/3 soft-start valve.</i>
	<i>5/2 directional control valve, controlled by pressure acting against return spring.</i>
	<i>5/2 directional control valve, controlled by solenoid with return spring.</i>
	<i>5/2 directional control valve, controlled by solenoid valve with separate air supply.</i>
	<i>5/2 directional control valve, controlled by solenoid in both directions.</i>
	<i>5/3 directional control valve, closed in middle position, controlled by solenoid and return spring.</i>
	<i>5/3 directional control valve, open in middle position, controlled by solenoid and return spring.</i>
	<i>Variable throttle valve.</i>
	<i>Non-return valve with variable throttle check.</i>
	<i>Rapid-exhaust avlve.</i>

	<i>Pressure regulator with relief port, spring controlled. Adjustable spring force.</i>
	<i>Shut-off valve with exhaust port.</i>
	<i>Silencer</i>
	<i>Accumulator</i>
	<i>Separator with water trap and automatic drain.</i>
	<i>Lubricator.</i>
	<i>Air conditioning unit, consisting of filter, pressure regulator, pressure gauge, and lubricator.</i>
	<i>Pressure gauge.</i>
	<i>Electric pressure switch with change-over contact and variable pressure setting.</i>
	<i>Magnetic piston sensor.</i>
	<i>Ejector.</i>

