Functional Mechanical Design

Actuators for automatic machines (2/2)

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Pneumatic actuators for automatic machines

Introduction

Pneumatic actuators are profitably used in automatic machine due to:

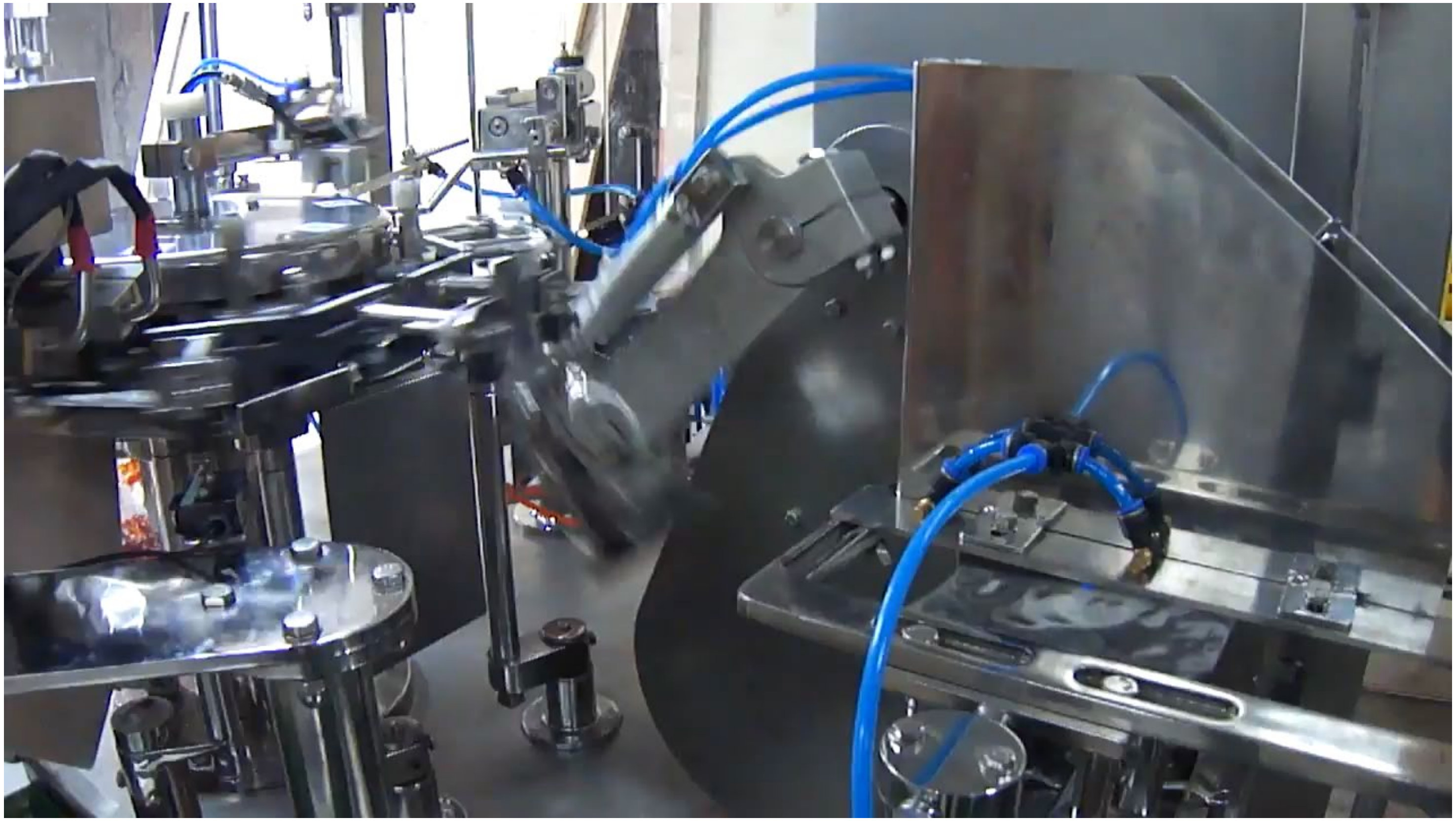
- High exertable forces. Moreover force can easily controlled by regulating pressure
- Large strokes
- Small cost (compared to other actuators)
- Lightweight
- No need for heat dissipation
- Reliability and limited maintenance
- Cleanness and absence of electric contacts that make them usable in a lot of applications (eg. Explosive environments, food and beverage industry, etc.)

However these devices have strong limitations due to air compressibility:

- Position control is unrealistic, while speed control is very hard.
- Vibrations may occurr

Introduction

For this reason, pneumatic actuators are exploited to generate simple motions without restriction related to the precision of movement.



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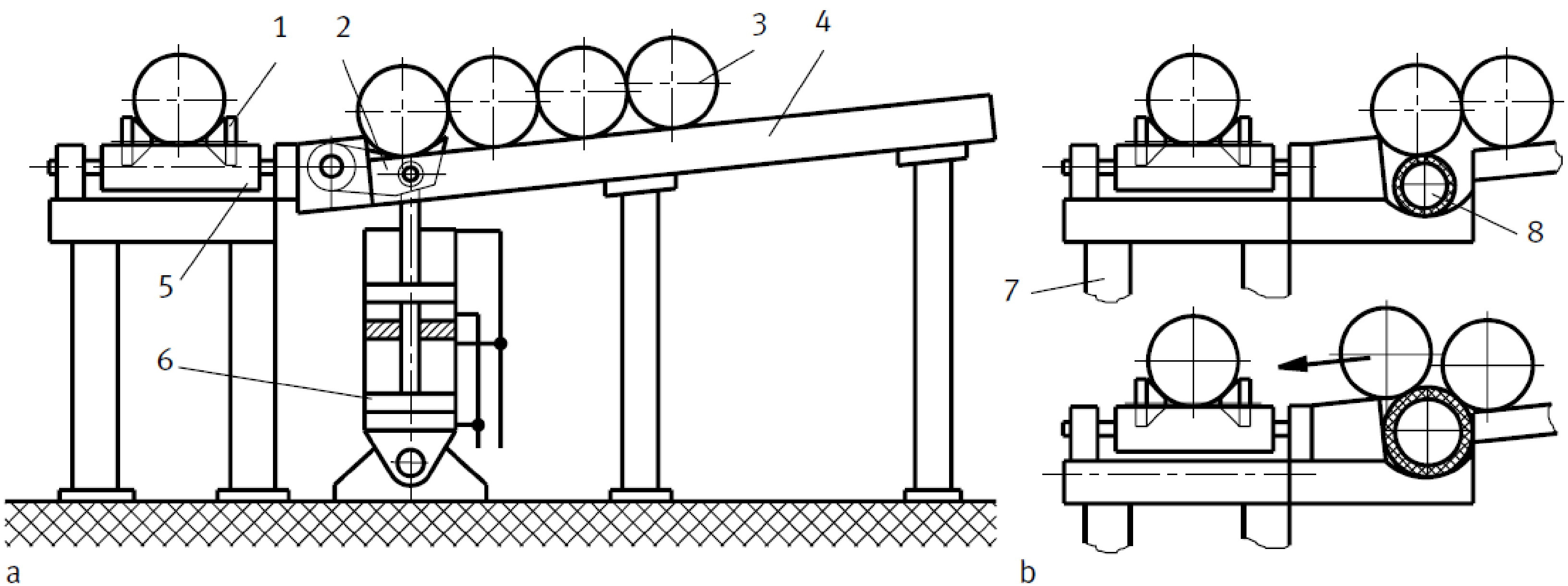
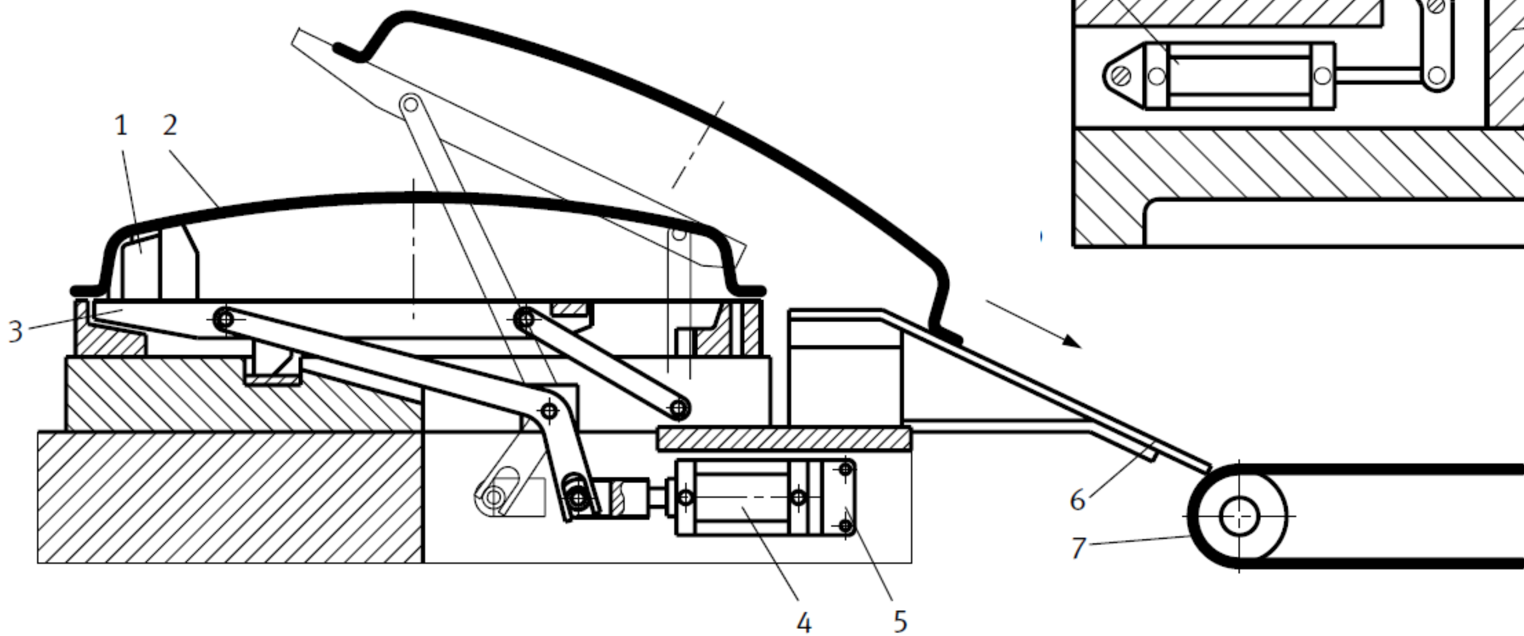
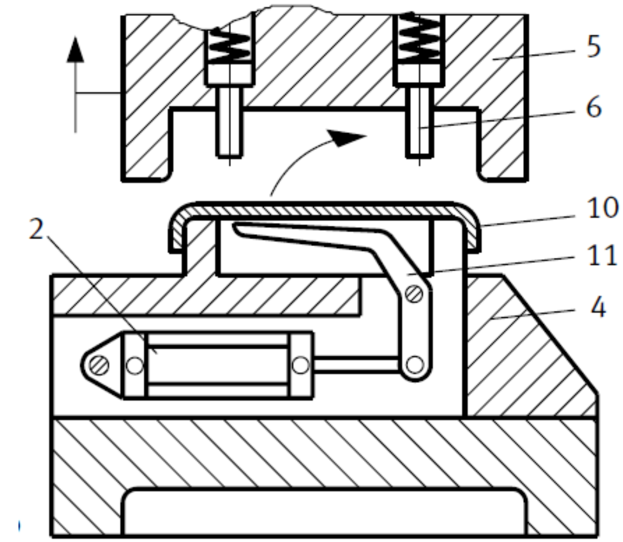


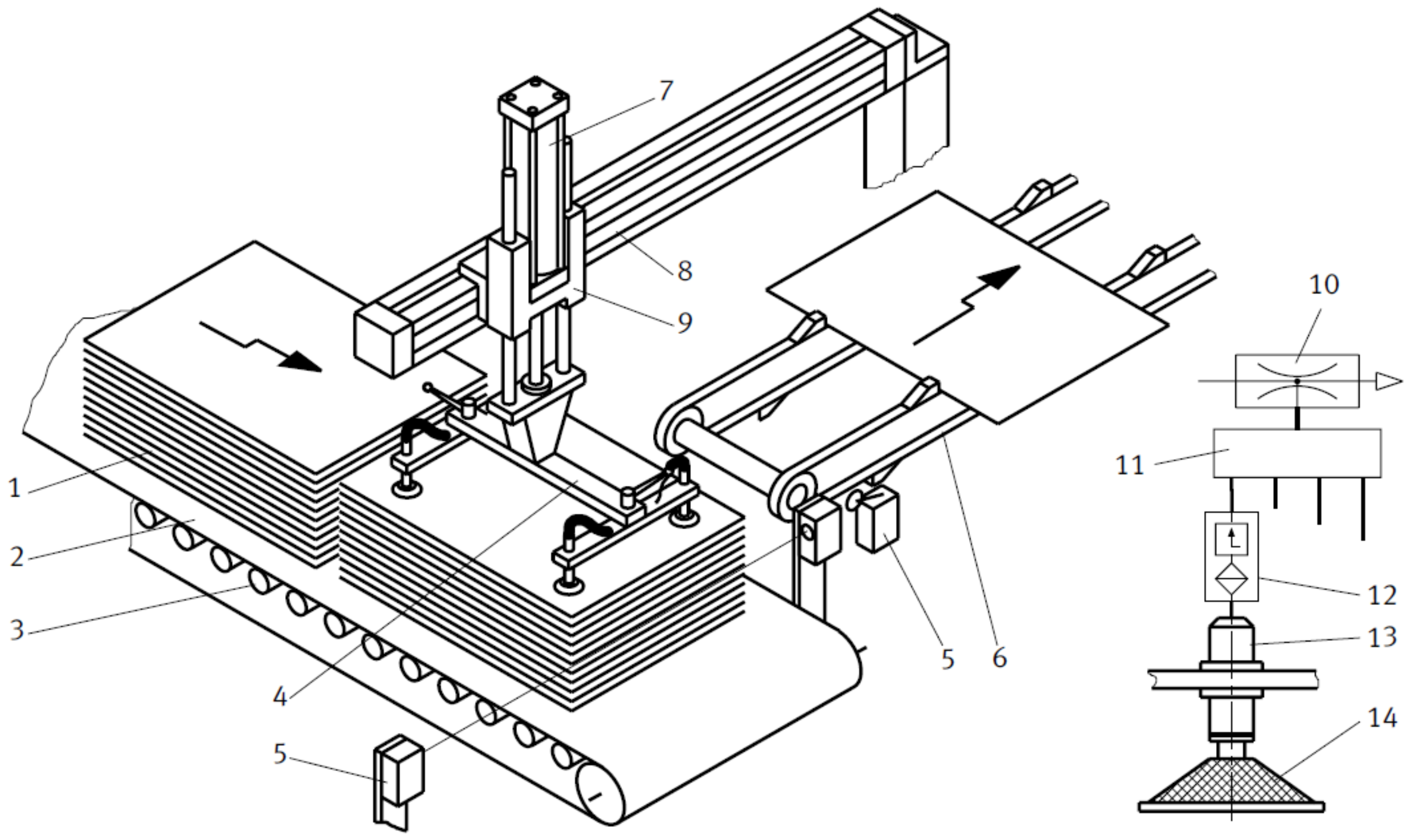
Applications

Ejection



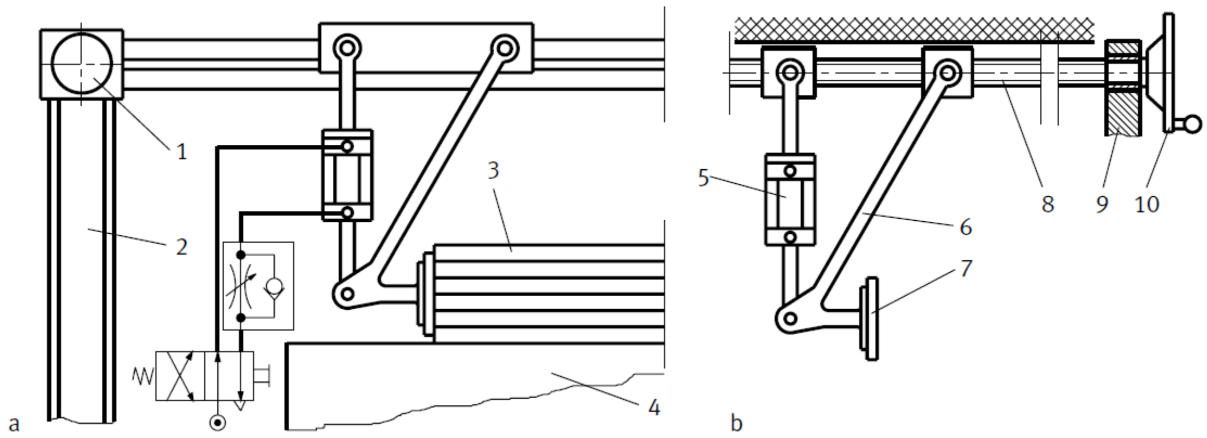


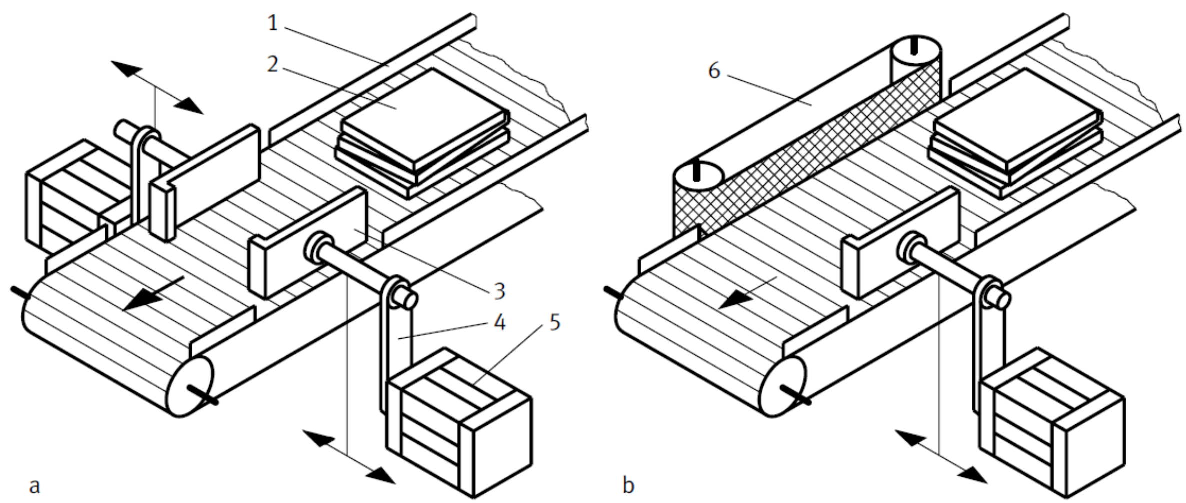
Destacking



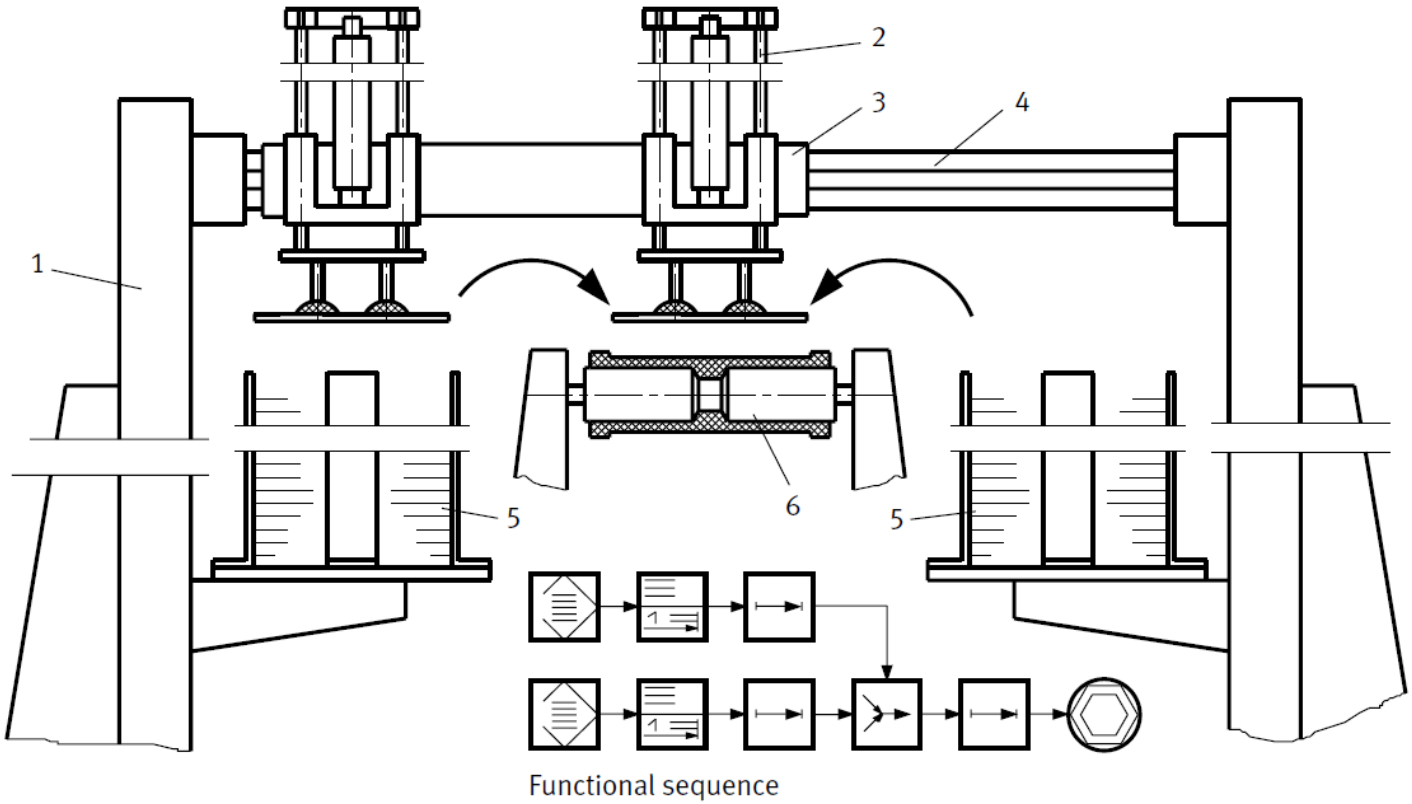
Applications

Aligning

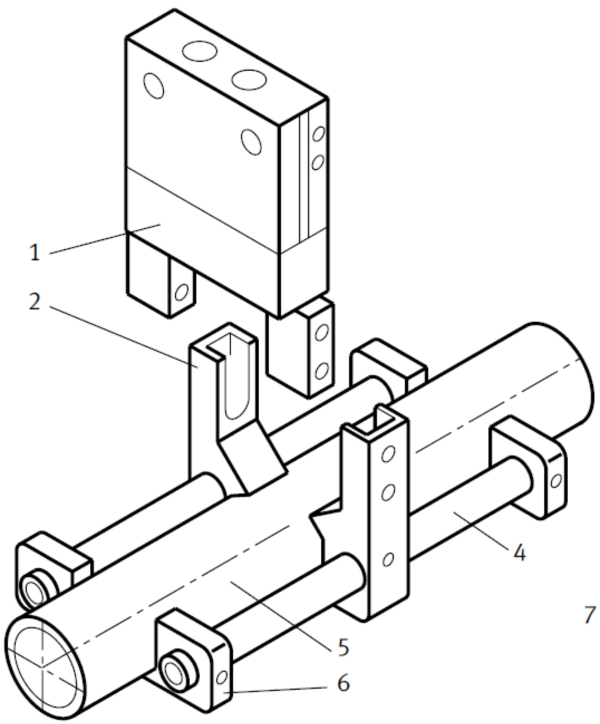




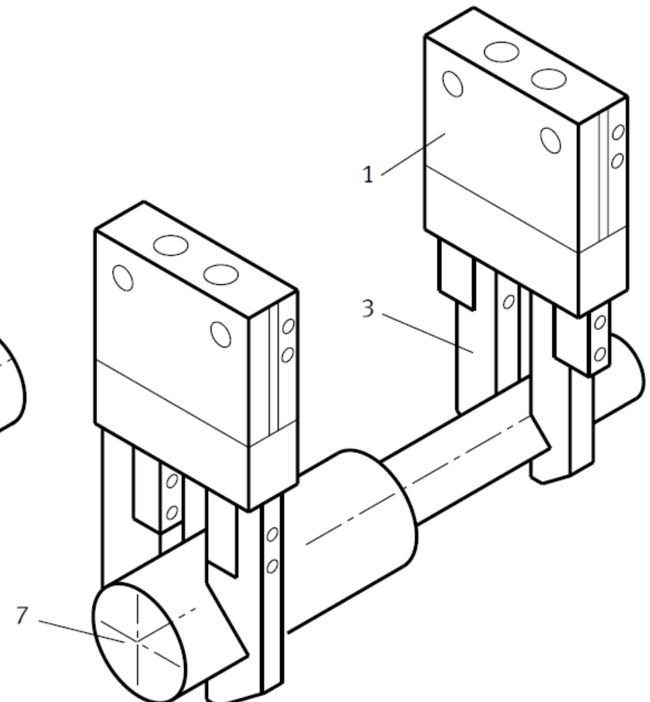
Feeding



Gripping



a



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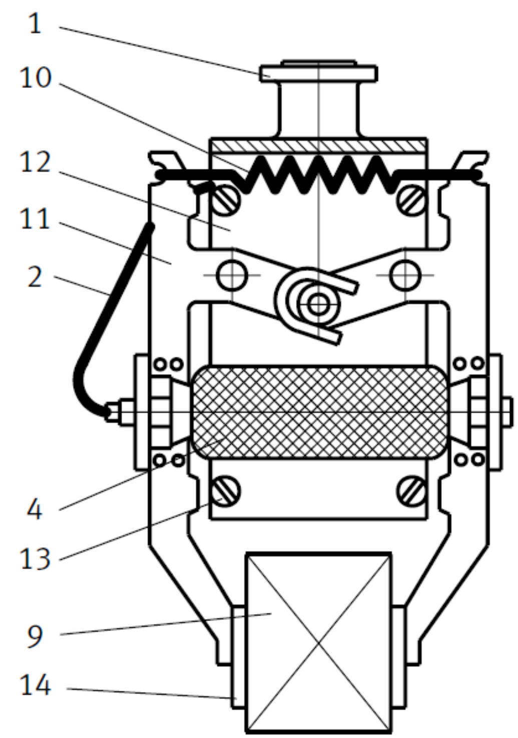
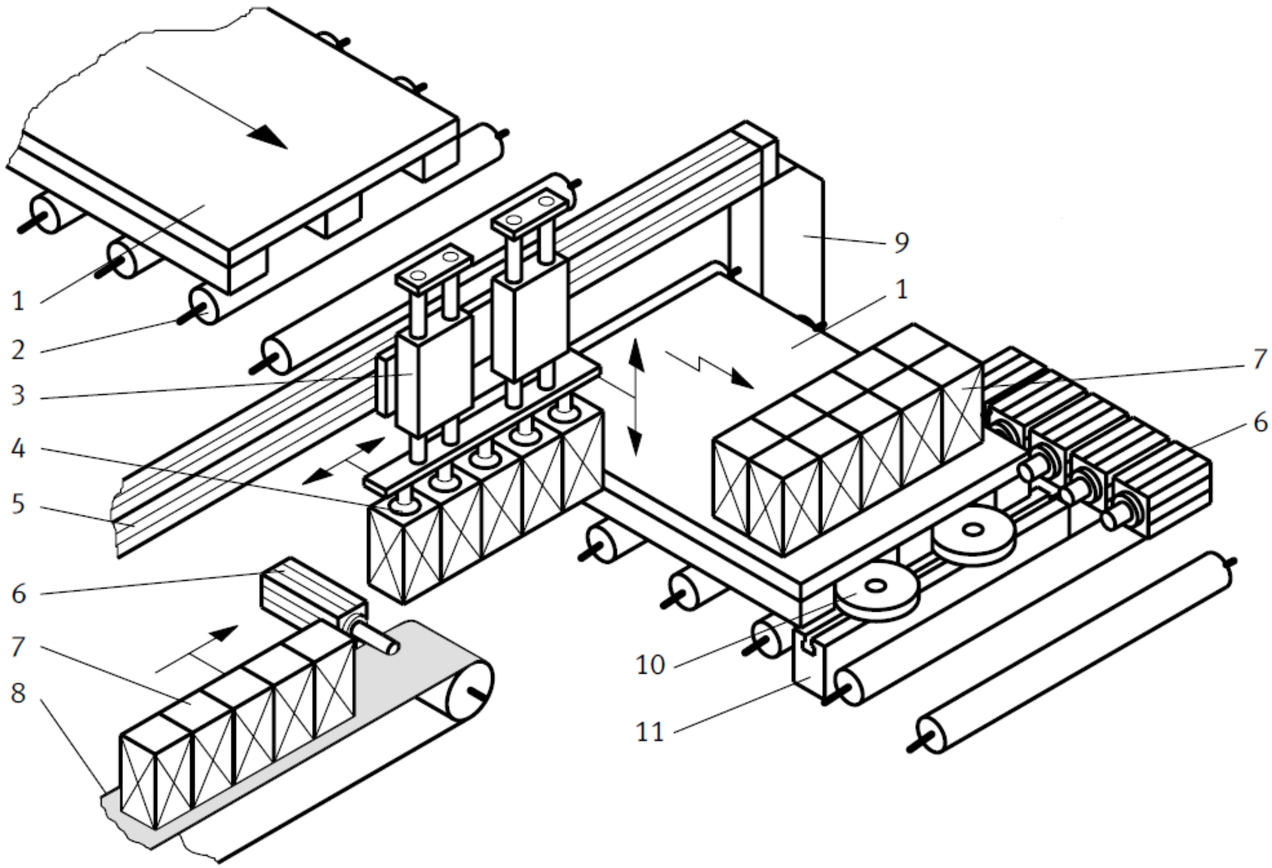
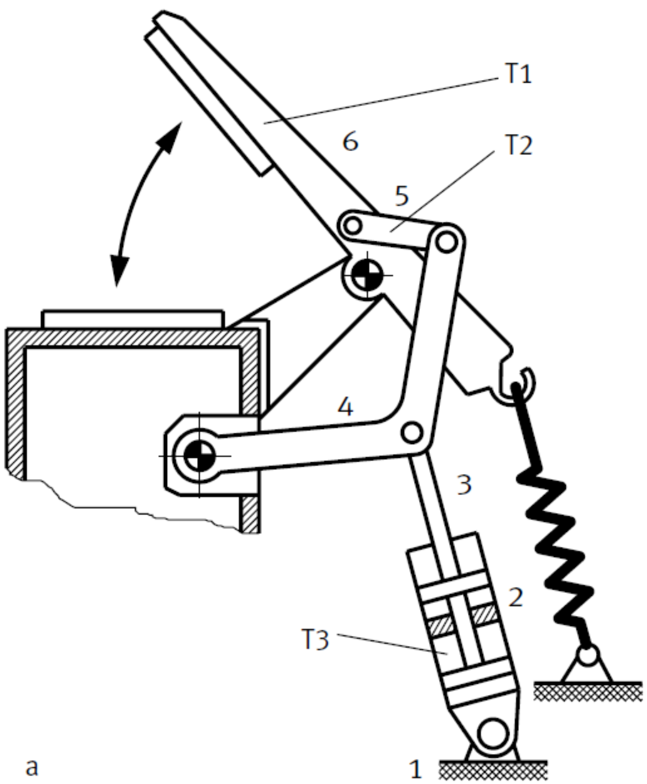


Palleting



Applications

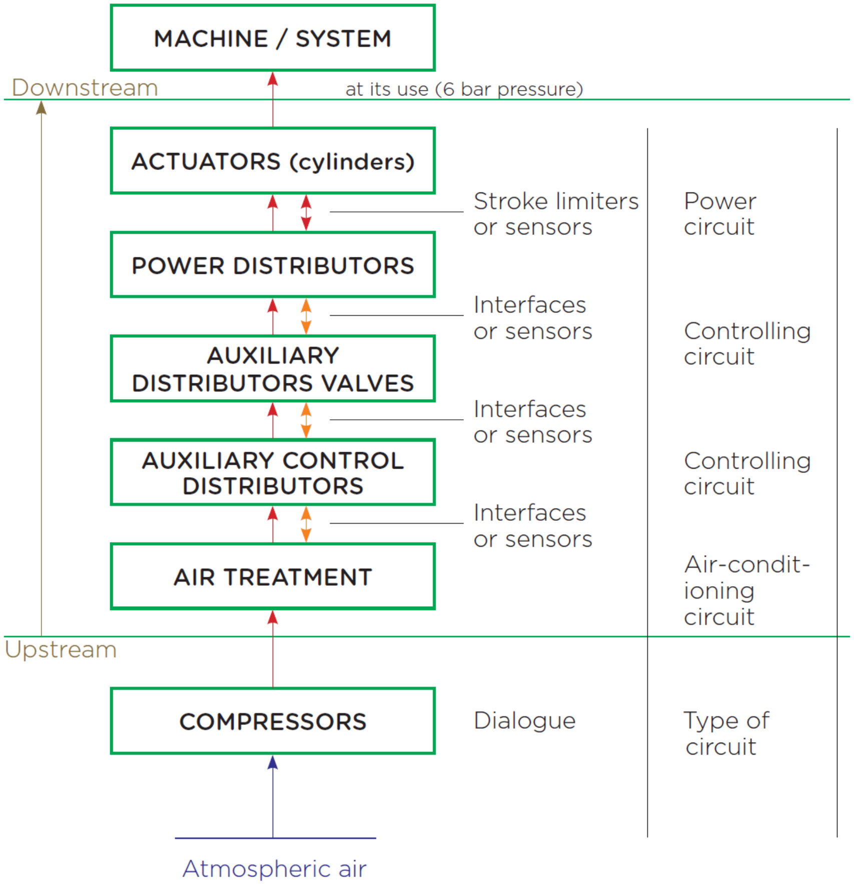
Pressing



Pneumatic automation circuit structures

The diagram describes the circuit structure of a pneumatic automation system, from the source of compressed air to the operating connections of the different components and their respective dialogues with their interfacing elements.

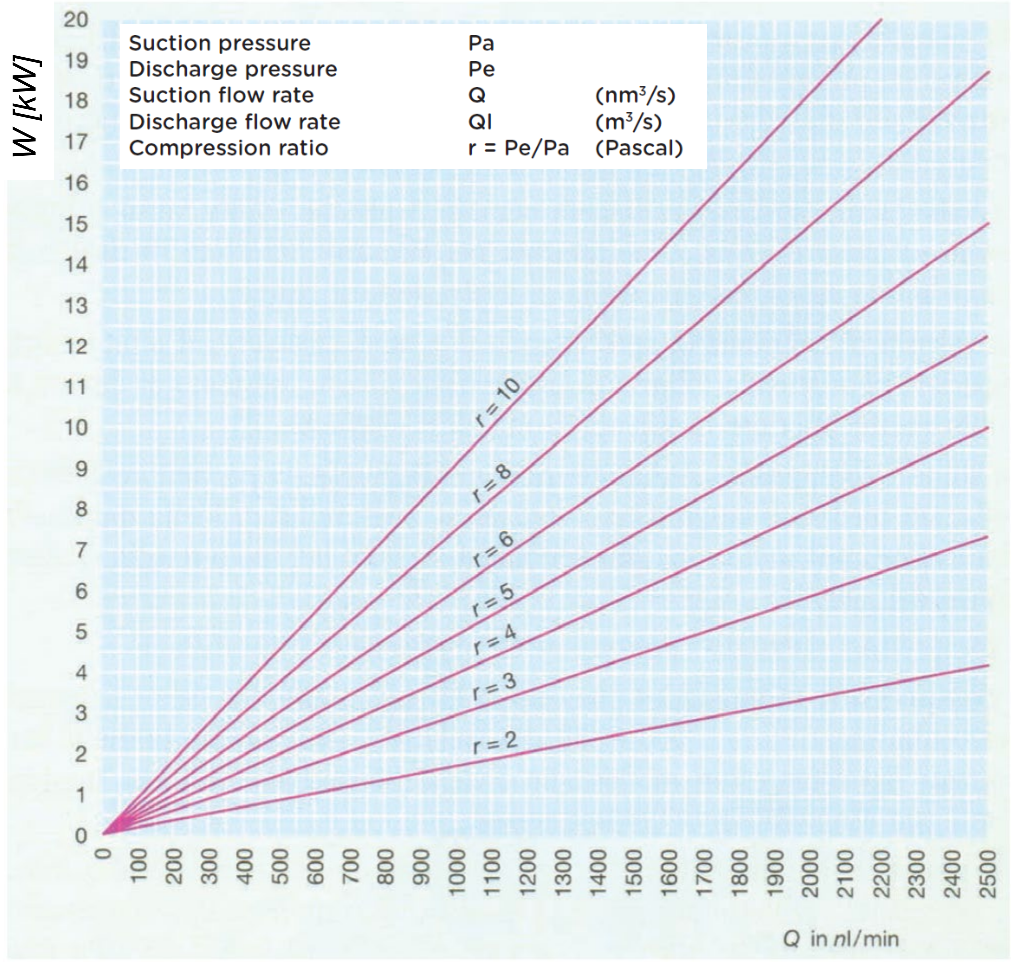
In this structure diagram we notice the entire sequence made by the fluid in order to start-up and activate a system, a machine or an automatic device.



Pneumatic automation circuit structures: compressors

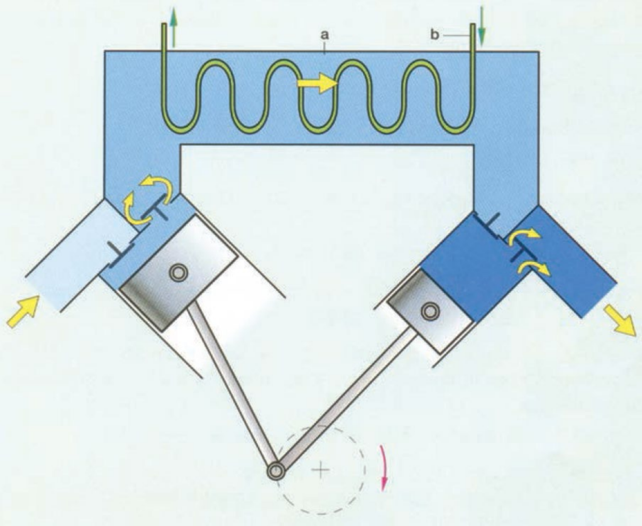
The machines that produce air are known as **compressors** that, activated by engines, capture the atmospheric air and, once it has been compressed, transfer it to the users.

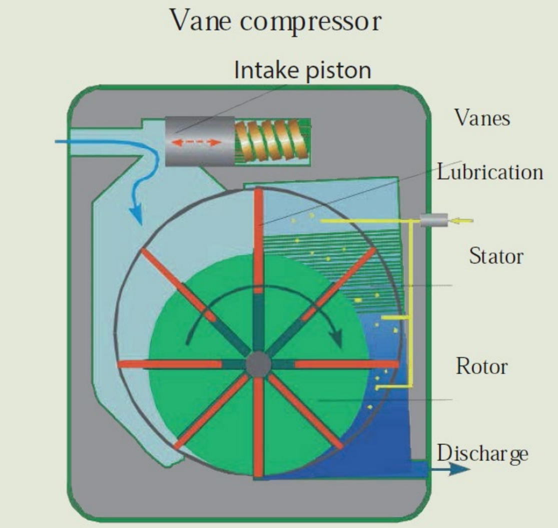
The graph shows the power *W* needed to compress a gas for different compression ratios (*r*) as a function of the volumetric flow rate *Q* during suction.

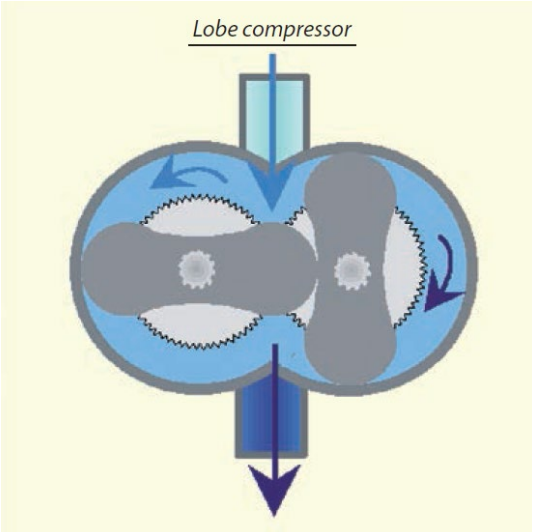


Pneumatic automation circuit structures: compressors

Reciprocating piston compressors	Rotary vane & screw compressors	Lobe compressors



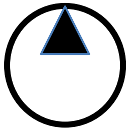




Up to 1 bar mono stage
Up to 15 bar 2 stages
Over 15 bar 3+ stages

Up to 10 bar

Up to 3 bar

Symbol used: 

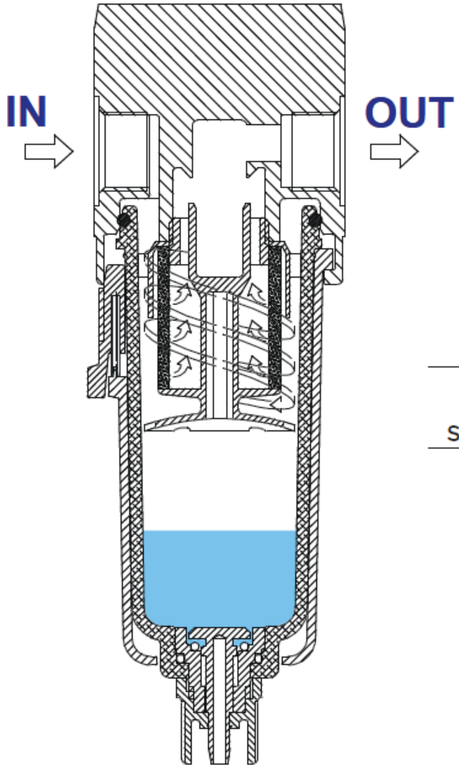
Pneumatic automation circuit structures: air treatment

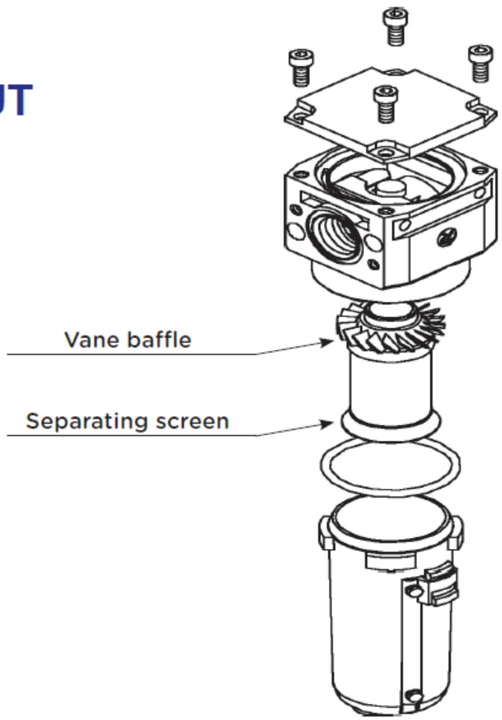
Once the compressed air is distributed, it needs further treatment in order to be adequate to the pneumatic equipment it will supply with air. This means to remove any foreign particles suspended in the air with suitable **filtration** and to reduce and **stabilize the pressure**, which in networks is variable, at a lower and constant value than the one existing in the distribution system. Whenever necessary, lubricant mist and micro-mist oil shall be supplied to the moving parts of the devices.

The structure of an air treatment device is:

- Filter
- Pressure regulator and manometer
- Lubricator (whenever necessary)

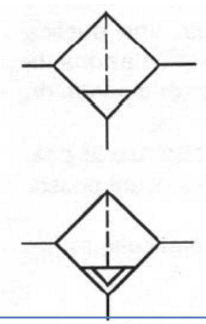
Pneumatic automation circuit structures: air treatment



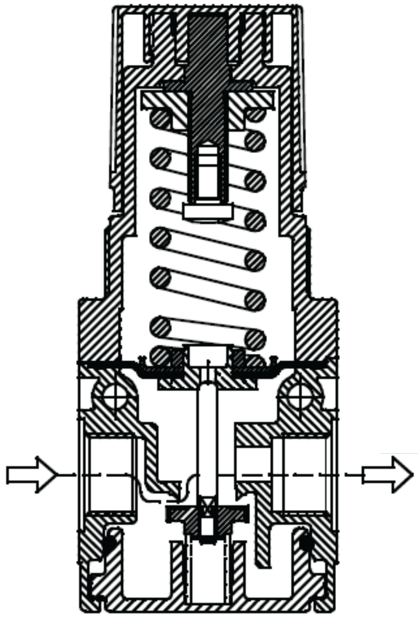


It is known that air does not contain only water vapor, but also solid particles and degraded oil vapors produced by the compressor, etc. The task of any filter, at the user's point, is to **clean the air** completely from the moment it is placed in-line, after the suction and line filters have carried out the first rough filtering.

Symbol used:



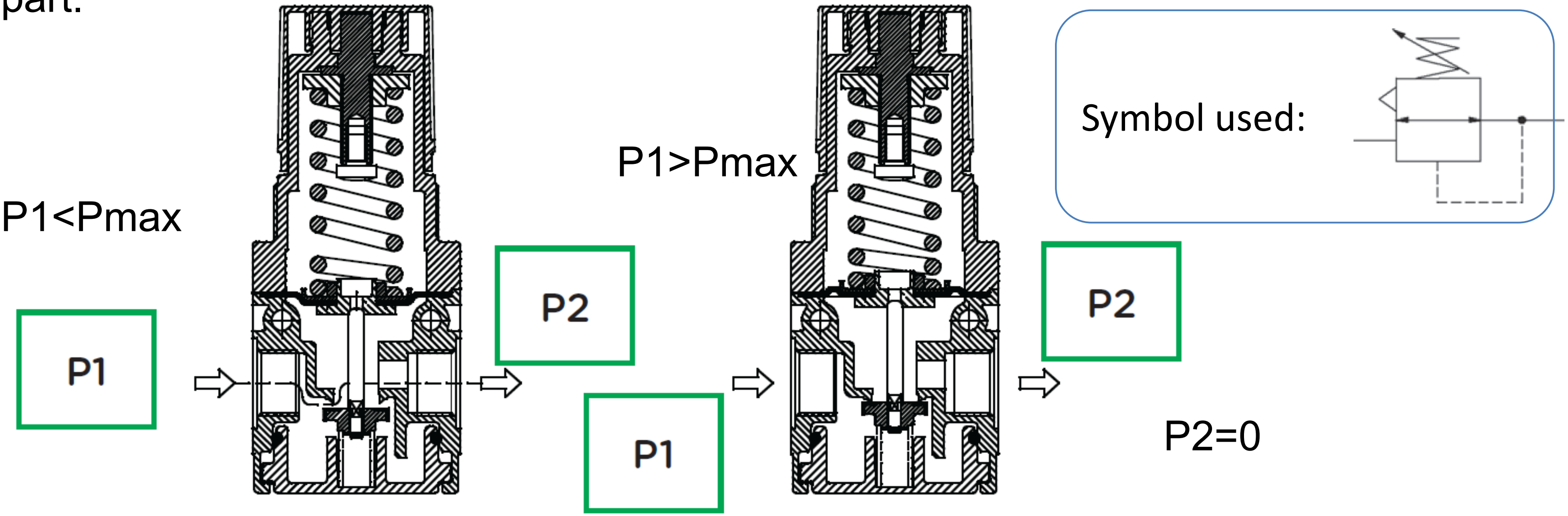
A **pressure regulator** is a device that allows reducing and stabilizing the air pressure available in the system. It works according to the proportionality principle of supplying a pressure at its outlet that is proportional to a reference signal. Its employment is always necessary to supply the correct downstream pressure in order for the equipment to function properly.



In order to set up a secondary pressure that shall be mandatorily lower than the operating pressure, we must act on a screw that loads the regulating spring, which, acting on a membrane, pushes a shaft integrated to a shutter. This action allows opening an air passage from the entrance toward the outlet.

Pneumatic automation circuit structures

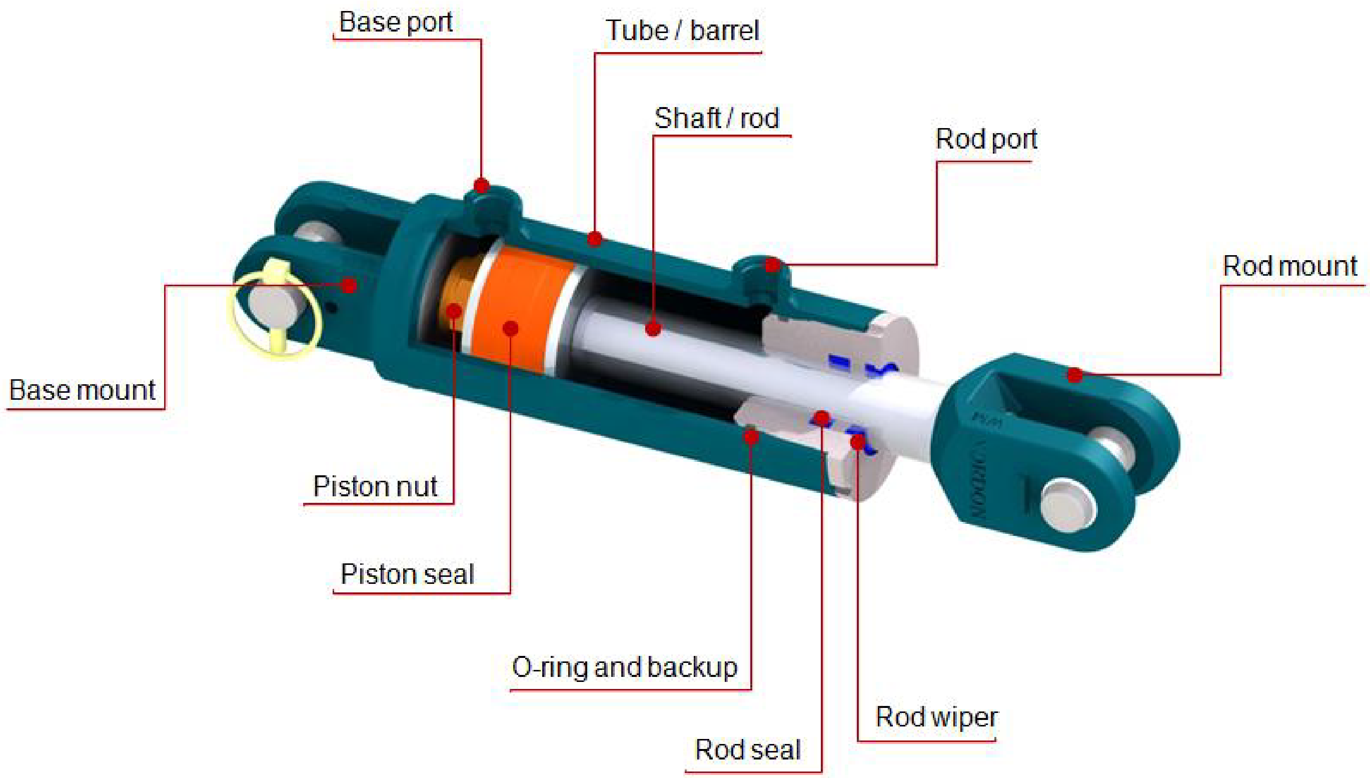
P2, that feeds the equipment downstream, rises and starts to react on the lower surface of the membrane contrasting the force of the spring that acts on the upper part.



Once a balance between the two forces has been reached, the shutter valve returns to the closed position. When consumption is required, P2 decreases together with the opposing force on the lower part of the membrane. The shutter moves downward opening a passage that allows compensating the consumption.

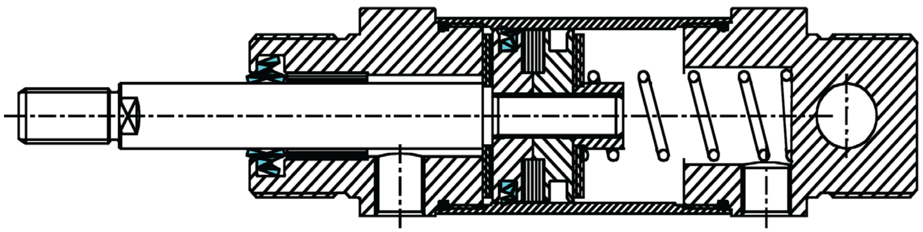
Pneumatic automation circuit structures: cylinders

The operating pneumatic elements (actuators) are the final bodies of a system that carry out mechanic work and perform many operations. The actuators that carry out displacements or rotations with alternative movements are called **cylinders**.



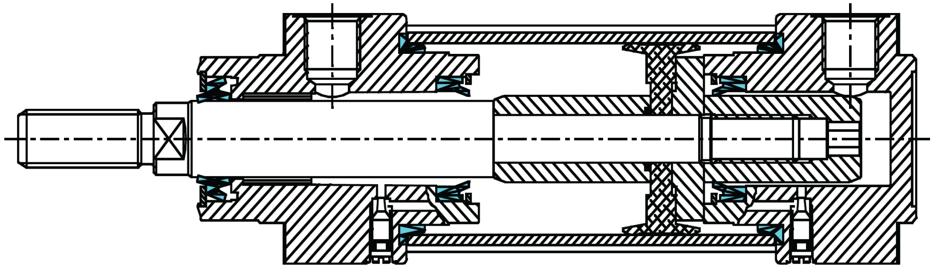
Pneumatic automation circuit structures: cylinders

A single-acting cylinder produces its thrust in only one direction. The rod places itself in the resting position due to a spring or to an external force.



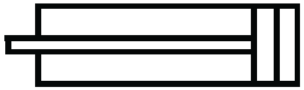
They are used for operations such as tightening, ejections, pressing, etc. that are performed without any loads anchored to the rod's thread

This type of actuator produces both thrust and tension forces sending pressure alternatively to the two sides of the piston.



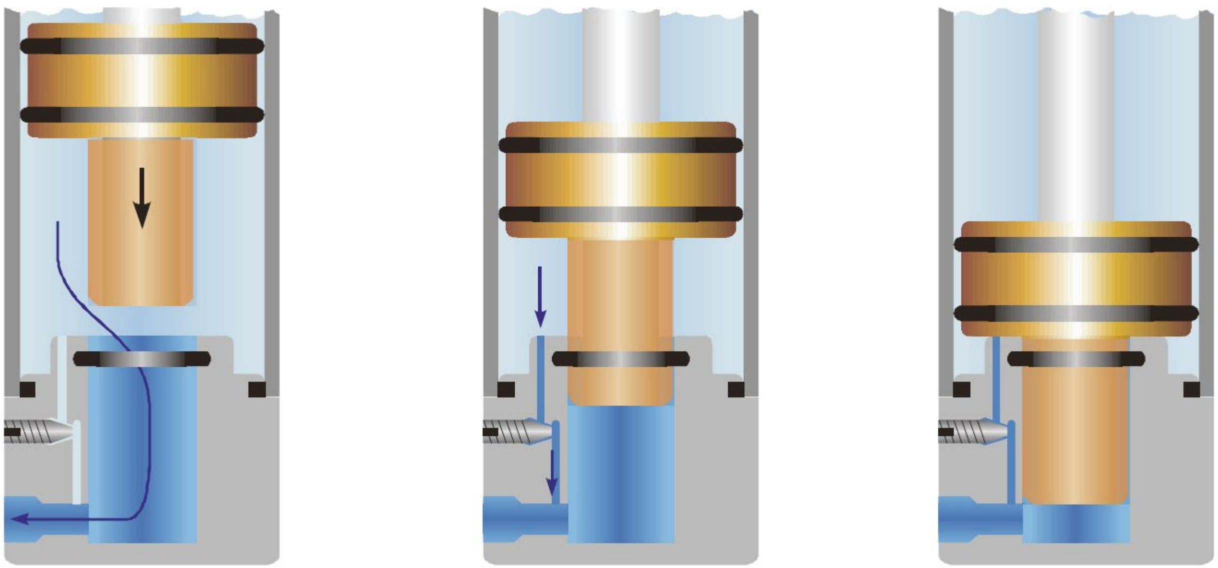
They carry out different kinds of operations and load may be bound to the rod.

Symbol used:



Pneumatic automation circuit structures: cylinders

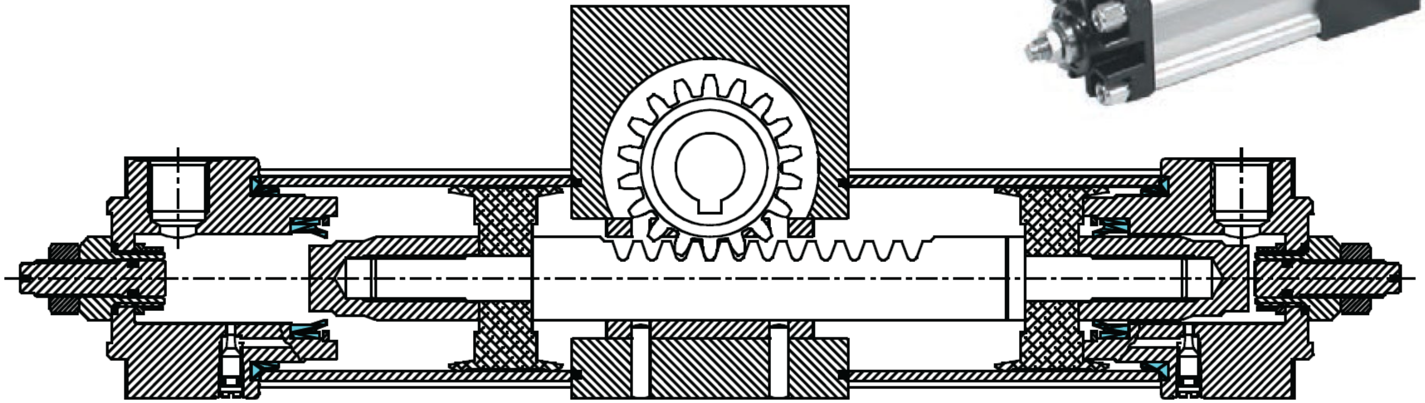
Pneumatic cylinders are able to produce high speeds, and therefore, the impact forces at stroke end may be considerable. The impact of the stroke limiter (adjuster) is tempered using an **air-cushion** that reduces piston speed near the end of the stroke.



When the ogive engages with the ring gasket placed on the head, free air discharges captured in the absorption chamber are prevented. In this chamber the air is compressed by the piston's motion and it is able to flow freely toward the discharge.

Pneumatic automation circuit structures: cylinders

A cylinder called **rotary actuator** is used instead, in order to allow greater rotation angles. There are devices equipped with pinion/rack mechanisms, as shown in the figure. The shaft that comes out from the central block is connected to a pinion that engages on a rack moved alternatively by two pistons. A torque is thus produced, whose magnitude depends on the actuator's size and on the operating pressure.



The theoretical piston force can be easily calculated as:

$$F_{th} = A \cdot p$$

Where A = useful piston area (m^2) and p = operating pressure (Pa)

For the effective piston force the frictional resistance should be taken into consideration. Under normal operating conditions (pressure range of 400 to 800 kPa / 4 to 8 bar) frictional force of approx. 10% of the theoretical piston force can be assumed.

Single-acting cylinders: $$F_{eff} = A \cdot p - (F_f + F_s)$$

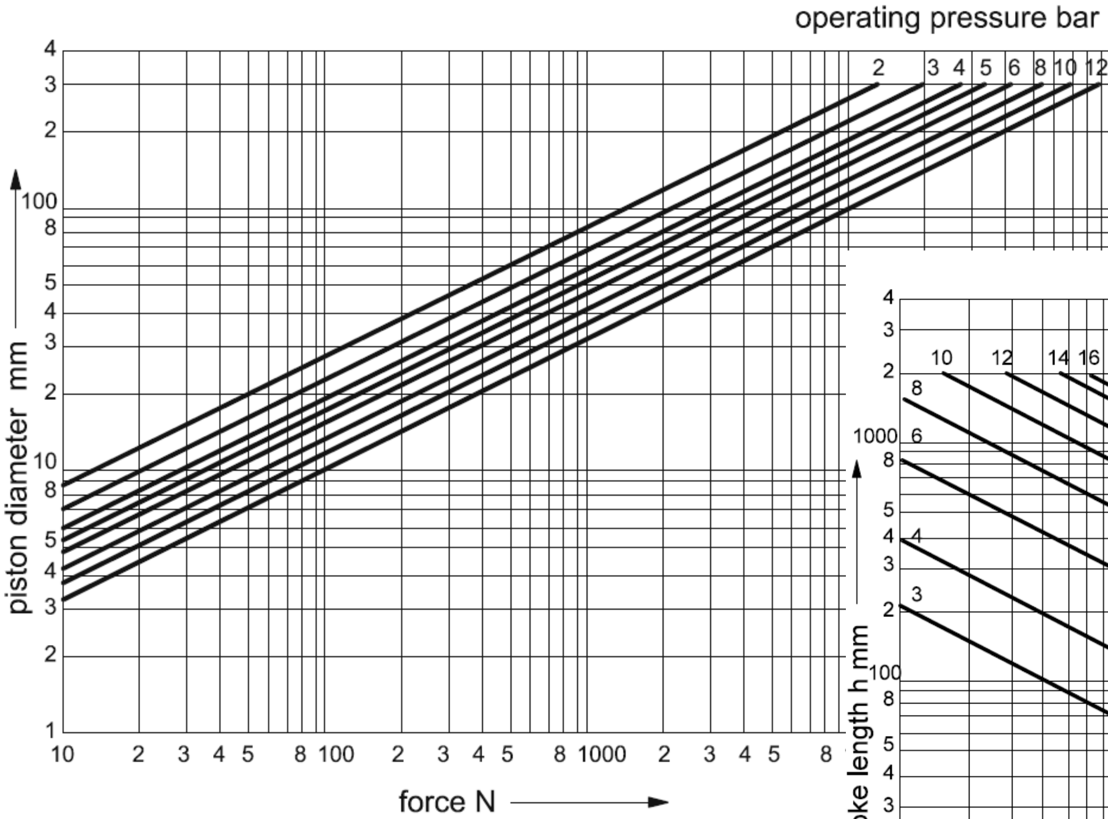
Double-acting cylinders:

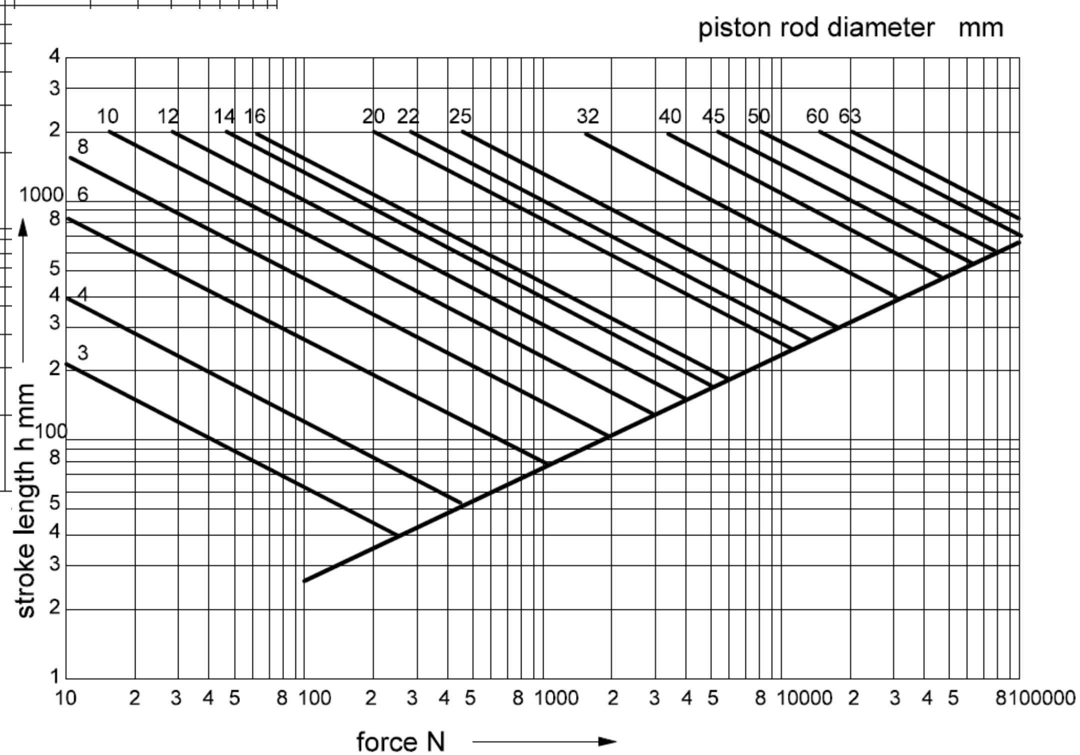
$$F_{eff} = A \cdot p - F_f$$ forward

$$F_{eff} = A' \cdot p - F_f$$ backward

Where A = useful piston surface $(D^2\pi/4)$; A' = useful annular surface $(D^2\text{-}d^2)\pi/4$;
p = working pressure; F_f= frictional force; F_s = return spring force; D = cylinder diameter; d = piston rod diameter

Pneumatic automation circuit structures: cylinders

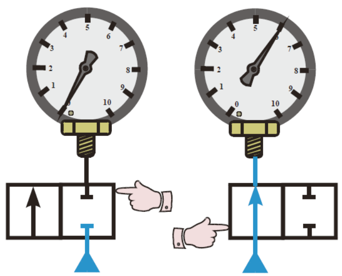




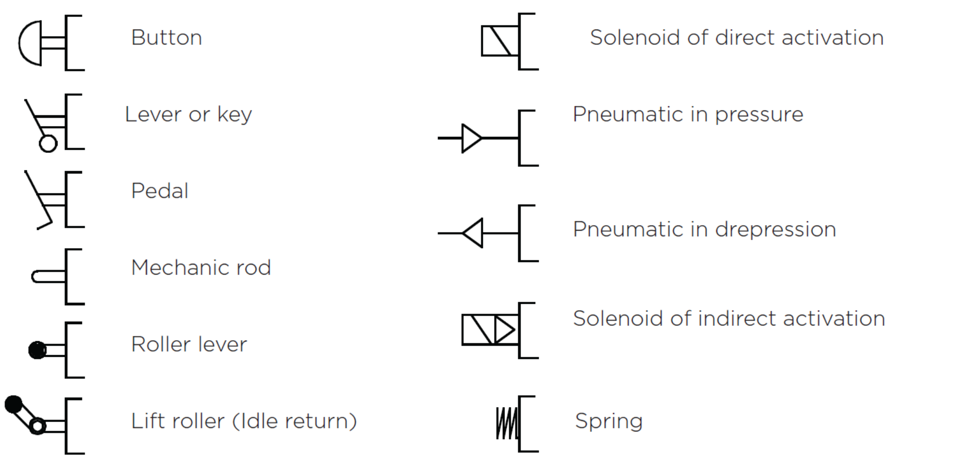
Pneumatic automation circuit structures: directional valves

Directional control valves deflect compressed air flow along the internal workings by means of external activations of controls. These valves are characterized by:

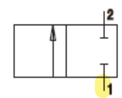
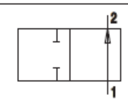
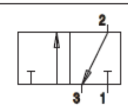
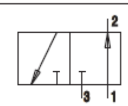
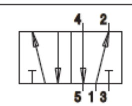
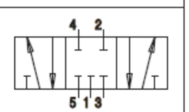
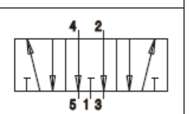
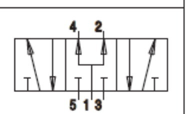
- Number of ways: may be identified very simply by counting the number of joints in its body, excluding those dedicated to controls.



- Number of positions: results from the positions that the valve may assume when it is activated by the controls, including the resting position.
- Type of activations: describes how the valve is moved.



Pneumatic automation circuit structures: directional valves

Way	Pos.	Function	Symbol
2	2	Normally closed	
2	2	Normally open	
3	2	Normally closed	
3	2	Normally open	
5	2	Separated exhaust connections	
5	3	Closed centres	
5	3	Open centres	
5	3	Pressured centres	

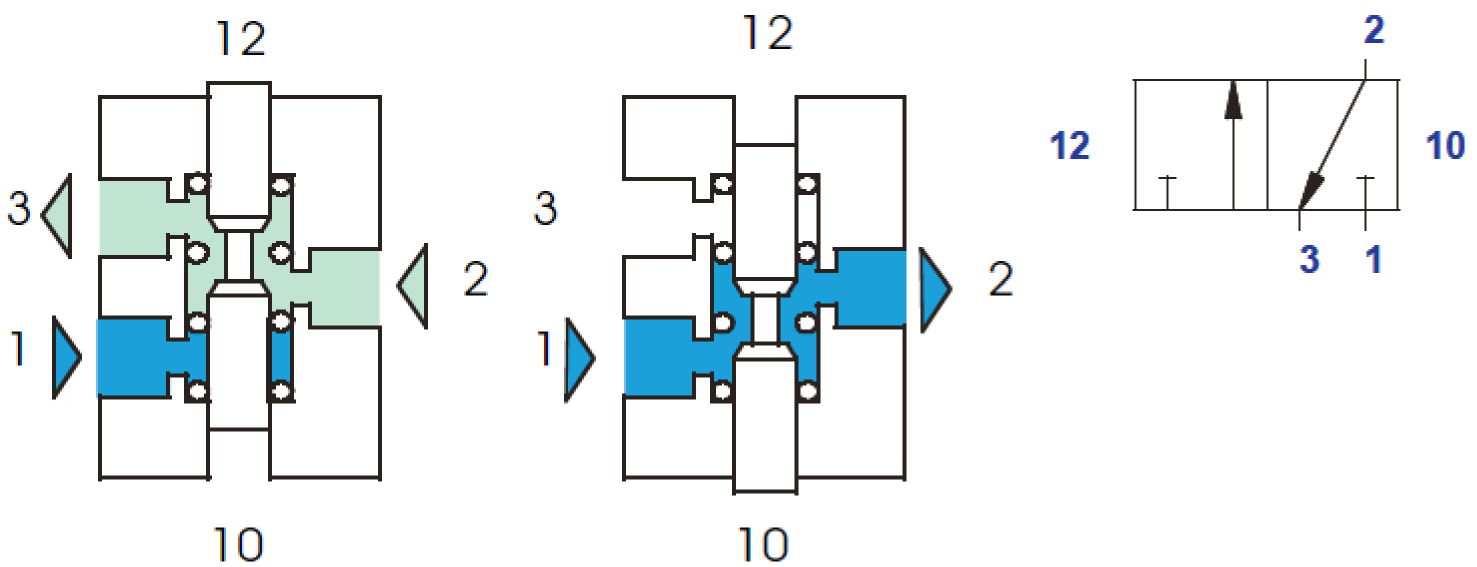
The working ports are usually labelled 2 and 4, the exhaust ports 3 and 5 and the supply 1; the control ports of pneumatically operated valves are not counted.

Numbers are placed in the resting position.

The valve in picture is a 3/2 valve

Resting position

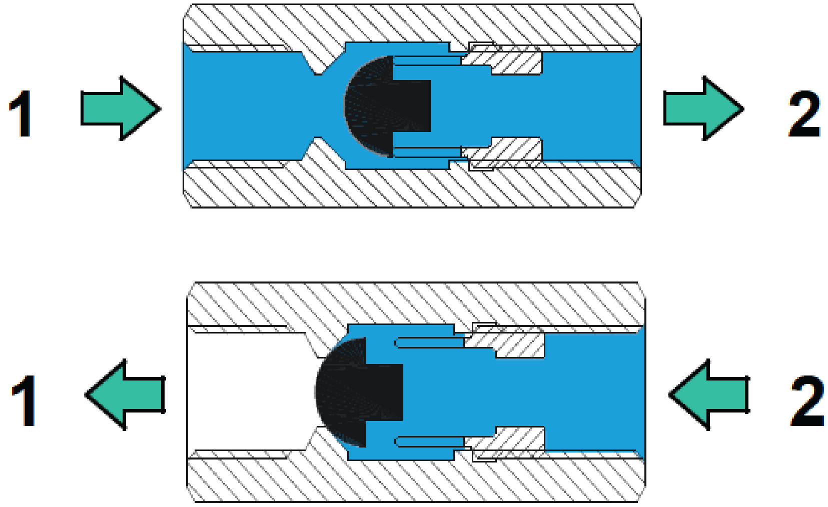
Activated



The spool moves along a direction orthogonal to the pressure, thus its control force is independent from the working condition

Pneumatic automation circuit structures: auxiliary valves

The function of the **non-return valve** is to make the air flow in a single direction and to prevent it from flowing in the opposite direction.



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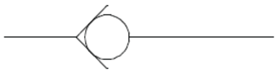
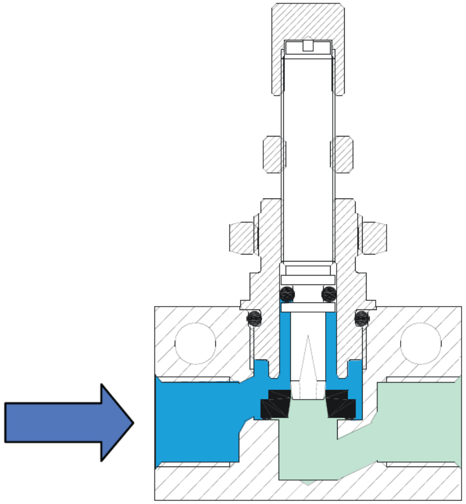
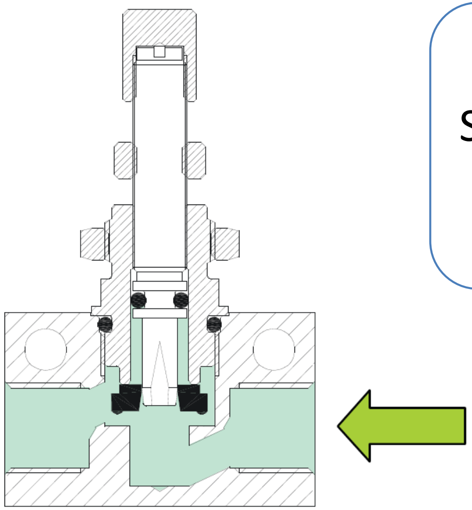


Flow control valves perform the task of regulating cylinder speeds. They are substantially constituted by a variable throttle regulated by a knob that combines with a screw that closes or opens the passage opening gradually.

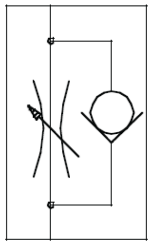


Regulated flow



Free flow

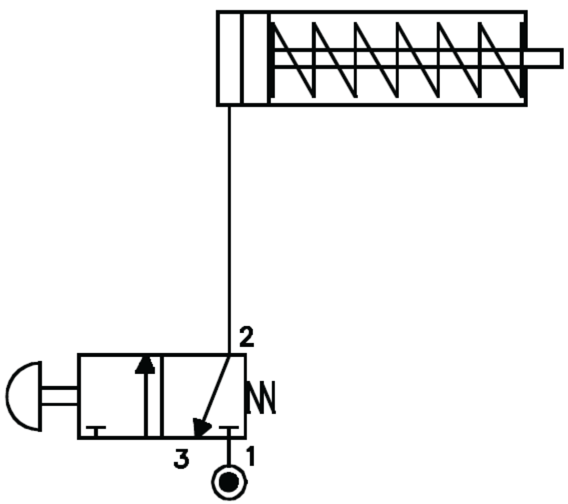
Symbol used:



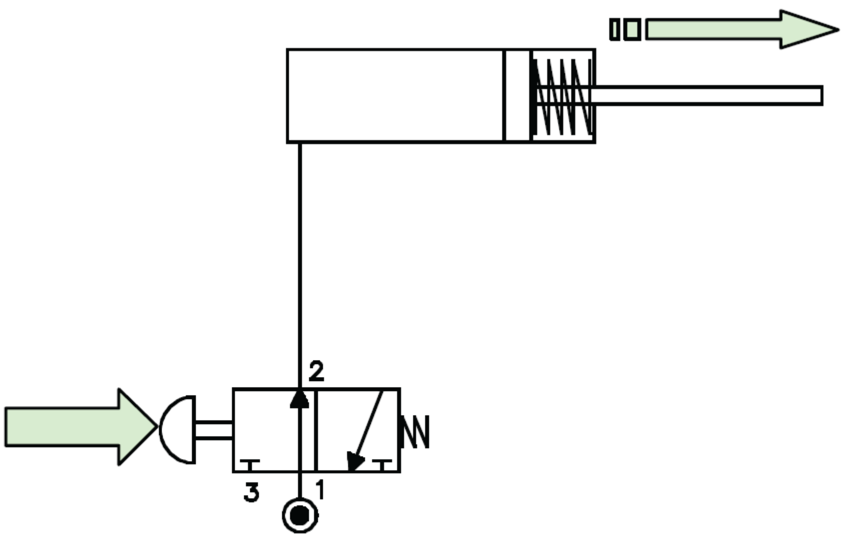
The flow is regulated in one direction, while in the opposite it raises the unidirectional valve and flows freely

Elementary circuits

The simplest circuit connection is represented by the direct control of a single acting cylinder.



At resting position

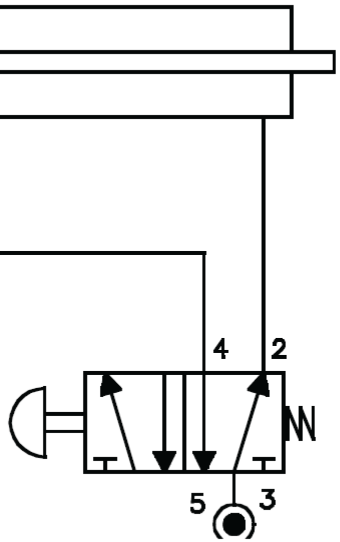


Active

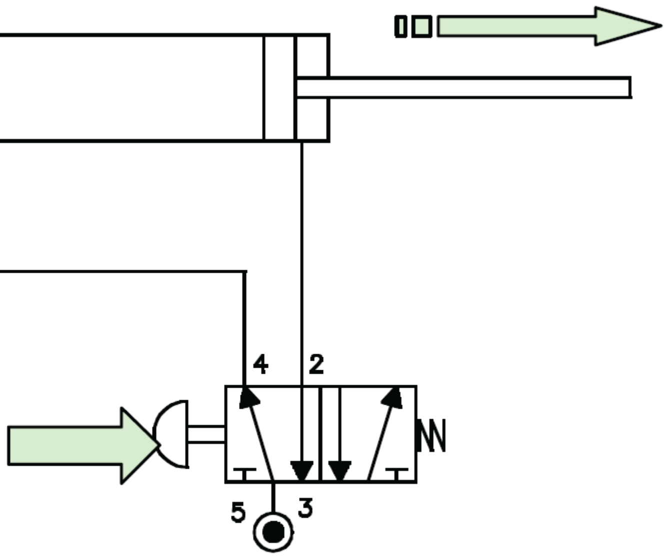
A 3/2 manual control valve activates the cylinder, connecting outlet 2 with the cylinder's inlet port directly.

Elementary circuits

This configuration is the simplest to control a double effect cylinder.



At resting position

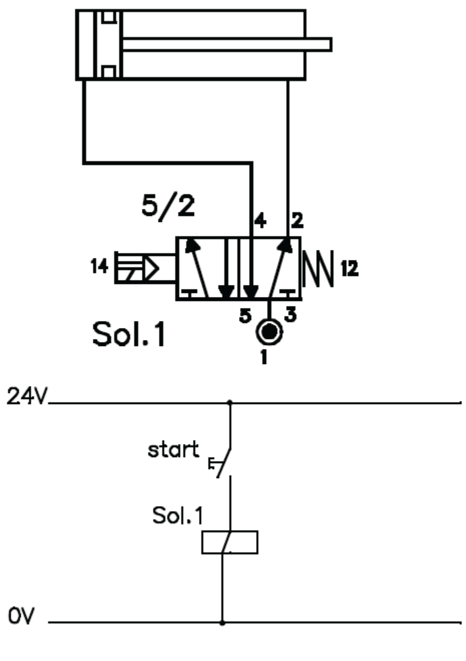


Active

In this case the cylinder's resting position is kept by the compressed air in the front chamber, instead by the spring.

Elementary circuits

In automatic machines, command signals are usually sent electrically…



At resting position

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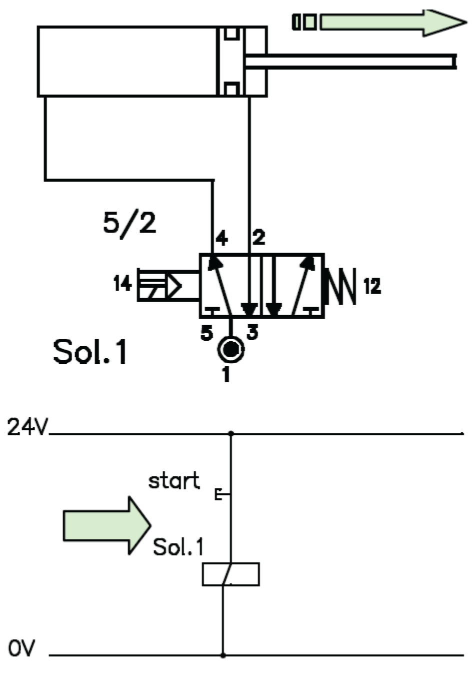

Active

… but the circuit remains the same