

Let's Talk PNEUMATICS - FTOSP 1261

Lectures 1 & 2

Pneumatics is the study of air and gases and the relationship between volume, pressure and temperature of the air or gases. Initially used for carrying out simplest mechanical tasks but is playing an important role in the development in the development of pneumatic technology for automation.

Compressed air used for:

- ✓ The use of sensors to determine the status of processes
- ✓ Information processing
- ✓ Switching of actuators by means of final control elements
- ✓ Carrying out work

The pneumatic cylinder has a significant role as a linear drive unit due to its;

- ✓ Relatively low cost
- ✓ Ease of installation
- ✓ Simple and robust
- ✓ Ready availability in various sizes and lengths

Pneumatic components can perform the following types of motion;

- ✓ Linear
- ✓ Swivel
- ✓ Rotary

Some industrial applications of pneumatics;

- ❖ General methods of material handling
 - ✓ Clamping
 - ✓ Shifting
 - ✓ Positioning
 - ✓ Orienting

❖ General applications

- ✓ Packaging
- ✓ Feeding
- ✓ Metering
- ✓ Door control
- ✓ Transfer of materials
- ✓ Turning or inverting parts
- ✓ Sorting of parts
- ✓ Stocking of components
- ✓ Stamping or embossing of components

❖ Machining and working operations

- ✓ Drilling
- ✓ Turning
- ✓ Milling
- ✓ Sawing
- ✓ Forming
- ✓ Finishing
- ✓ Quality control

Advantages and distinguishing characteristics

- Availability – Air is available in unlimited quantity.
- Transport – Can be easily transported in pipelines even over long distances
- Storage – Compressor need not be in continuous operation. Even reservoir is transportable.
- Temperature- Compressed air is relatively insensitive to temperature fluctuations.
- Explosion proof- Compressed air offers minimum risk of explosion.
- Cleanliness- unlubricated exhaust air is clean
- Components- Components are relatively inexpensive.
- Speed- Compressed air is a very fast working medium.
- Adjustable- With compressed air, components speeds & forces are infinitely variable
- Overload safe- Pneumatic tools and operating components can be loaded to the point of stopping.

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Disadvantages:

- Preparation – Compressed air requires good preparation. Dirt and condensate should not be present.
- Compressible- Not always possible to achieve uniform and constant piston speeds with compressed air.
- Force requirement- Compressed air economical only up to a certain force requirement.
- Noise level- Exhaust air is loud
- Costs- Compressed air is a relatively expensive of conveying power.

A comparison with other forms of energy is essential.

Factors that must be considered if pneumatics is to be used as a control or working medium

- Work output requirements
- Preferred control methods
- Resources & expertise available to support project
- Systems currently installed which are to be integrated with the new project.

Choice of working media

- Electrics
- Hydraulics
- Pneumatics
- A combination of the above

Selection criteria for the working section

- Force, Stroke, Type of motion, Speed, Size
- Service life, Safety, Reliability
- Sensitivity, Controllability
- Energy Costs
- Handling, Storage

Choice of control media:

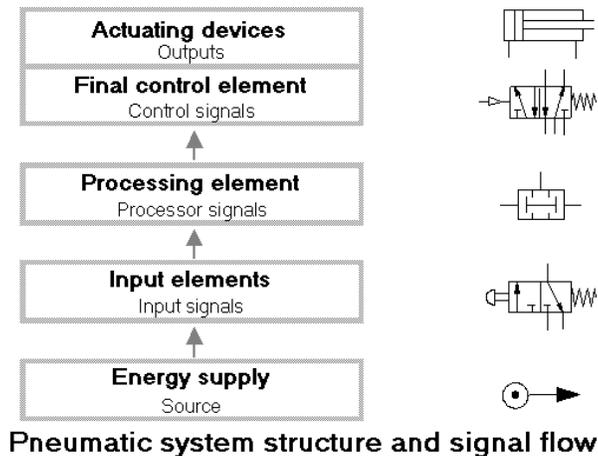
- Mechanical
- Electrical
- Electronic
- Pneumatic (normal pressure or high pressure)
- Hydraulic

Selection criteria for the control section;

- Reliability of components
- Sensitivity to environmental influences
- Ease of maintenance and repair
- Switching time of components
- Signal speed
- Space requirements
- Service life
- Training requirements of operators and maintainers
- Modification of the control system

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A pneumatic system can be broken down into a number of levels representing hardware and signal flow.



The primary levels in a pneumatic system are

- Energy supply
- Input elements (Sensors)
- Processing elements (Processors)
- Actuating devices (Actuators)

Aspects to be considered in the preparation of service air:

- ✓ Quantity of air required to meet the demands of the system
- ✓ Type of compressor to be used to produce the quantity required
- ✓ Storage required
- ✓ Requirements for air cleanliness
- ✓ Acceptable humidity levels to reduce corrosion and sticky operation
- ✓ Lubrication requirements, if necessary
- ✓ Low temp. of the air and effects on the system
- ✓ Pressure requirements
- ✓ Line sizes and valve sizes to meet demand
- ✓ Material selection and system requirements for the environment
- ✓ Drainage points and exhaust outlets in the distribution system
- ✓ Layout of the distribution system to meet demand

PNEUMATIC GASES

QUALITIES

The ideal fluid medium for a pneumatic system is a readily available gas that is nonpoisonous (nontoxic), chemically stable, free from any acids that cause corrosion of system components, and nonflammable. It also will not support combustion of other elements.

Gases that have these desired qualities may not have the required lubricating power. Therefore, lubrication of the components of some pneumatic systems must be arranged by other means. For example, some air compressors are provided with a lubricating system, some components are lubricated upon installation or, in some cases, lubrication

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is introduced into the air supply line. Two gases meeting these qualities and most commonly used in pneumatic systems are compressed air and nitrogen.

COMPRESSED AIR

Compressed air is a mixture of all gases contained in the atmosphere. The unlimited supply of air and the ease of compression make compressed air the most widely used fluid for pneumatic systems. Although moisture and solid particles must be removed from the air, it does not require the extensive distillation or separation process required in the production of other gases.

Compressed air has most of the desired properties and characteristics of a gas for pneumatic systems. It is nonpoisonous and nonflammable but does contain oxygen, which supports combustion. One of the most undesirable qualities of compressed air as a fluid medium for pneumatic systems is moisture content. The atmosphere contains varying amounts of moisture in vapor form. Changes in the temperature of compressed air will cause condensation of moisture in the pneumatic system. This condensed moisture can be very harmful to the system, as it increases corrosion, dilutes lubricants, and may freeze in lines and components during cold weather. Moisture separators and air driers (dehydrators) are installed in the compressed air lines to minimize or eliminate moisture in systems where moisture would deteriorate system performance.

The supply of compressed air at the required volume and pressure is provided by an air compressor. In most systems the compressor is part of the system with distribution lines leading from the compressor to the devices to be operated. In these systems a receiver is installed in-line between the compressor and the device to be operated to help eliminate pulsations in the compressor discharge line, to act as a storage tank during intervals when the demand for air exceeds the compressor's capacity, and to enable the compressor to shut down during periods of light load. Other systems receive their supply from cylinders which must be filled at a centrally located air compressor and then connected to the system. Compressed air systems are categorized by their operating pressures as follows: high-pressure (HP) air, medium-pressure (MP) air, and low-pressure (LP) air.

High-Pressure Air Systems

HP air systems provide compressed air at a nominal operating pressure of 3000 psi or 5000 psi and are installed whenever pressure in excess and high flow rates of compressed air by the addition of HP storage flasks to the system. An example of such a system is one that provides air for starting diesel and gas turbine engines. Reduction in pressure, if required, is done by using specially designed pressure-reducing stations.

Medium-Pressure Air

MP air systems provide compressed air at a nominal operating pressure of 151 psi to 1000 psi. These pressures are provided either by an MP air compressor or by the HP air system supplying air through an air bank and pressure-reducing stations.

Low-Pressure Air

LP air systems provide compressed air at a nominal operating pressure of 150 psi and below. The LP air system is supplied with LP air by LP air compressors or by the HP air system supplying air through an air bank and pressure-reducing stations. LP air is the most extensive and varied air system used in the Navy, In addition to being used for various pneumatic applications, LP and HP compressed air are used in the production of nitrogen.

NITROGEN

For all practical purposes, nitrogen is considered to be an inert gas. It is nonflammable, does not form explosive Mixtures with air or oxygen, and does not cause rust or decay. Due to these qualities, its use is preferred over compressed air in many pneumatic systems, especially aircraft and missile systems, and wherever an inert gas blanket is required. Nitrogen is obtained by the fractional distillation of air. Oxygen/nitrogen-producing plants expand compressed air until its temperature decreases to -196°C (-320°F), the boiling point of nitrogen at atmospheric pressure. The liquid nitrogen is then directed to a storage tank. A liquid nitrogen pump pumps the low-pressure liquid nitrogen from the storage tank and discharges it as a high-pressure (5000 psi) liquid to the vaporizer where it is converted to a gas at 5000 psi.

CONTAMINATION CONTROL

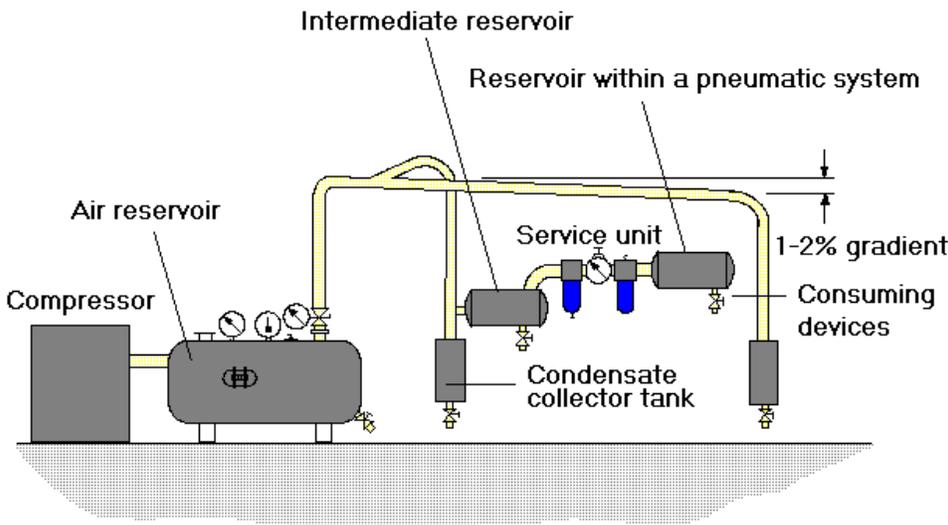
As in hydraulic systems, fluid contamination is also a leading cause of malfunctions in pneumatic systems. In addition to the solid particles of foreign matter which find a way to enter the system, there is also the problem of moisture. Most systems are equipped with one or more devices to remove this contamination. These include filters, water separators, air dehydrators, and chemical driers, which are discussed in chapter 9 of this manual. In addition, most systems contain drain valves at critical low points in the system. These valves are opened periodically to allow the escaping gas to purge a large percentage of the contaminants, both solids and moisture, from the system. In some systems these valves are opened and closed automatically, while in others they must be operated manually. Complete purging is done by removing lines from various components throughout the system and then attempting to pressurize the system, causing a high rate of airflow through the system. The airflow will cause the foreign matter to be dislodged and blown from the system.

NOTE: If an excessive amount of foreign matter, particularly oil, is blown from any one system, the lines and components should be removed and cleaned or replaced. In addition to monitoring the devices installed to remove contamination, it is your responsibility as a maintenance person or supervisor to control the contamination. You can do this by using the following maintenance practices:

- Keep all tools and the work area in a clean, dirt-free condition.
- Cap or plug all lines and fittings immediately after disconnecting them.
- Replace all packing and gaskets during assembly procedures.
- Connect all parts with care to avoid stripping metal slivers from threaded areas. Install and torque all fittings and lines according to applicable technical instructions.

Complete preventive maintenance as specified by MRCs. Also, you must take care to ensure that the proper cylinders are connected to systems being supplied from cylinders. Cylinders for compressed air are painted black.

Ring main should be laid out with a 1-2% gradient to allow drainage points for condensate from the compressor.



Compressed air supply: Delivery

Air drying equipment should be fitted if the amount of condensate is too much.

The air service unit consists of the following;

- Compressed air filter
- Compressed air regulator
- Compressed air lubricator

The correct combination, size and type of these elements are determined by the application and the control system demand.

Compressed air filter:

- ✓ Removing all contaminants from the compressed air
- ✓ Removing water which already condensed

Collected condensate must be drained before the level exceeds the maximum.

Compressed air regulator:

- ✓ To keep the operating pressure virtually constant regardless of fluctuations in the line pressure or air consumption.

Compressed air lubricator:

- ✓ To deliver a metered quantity of oil mist into a leg of the air distribution system when necessary for the use by pneumatic control and working components

VALVES : Valves can be divided into a number of groups according to their function in relation to

- Signal type
- Actuation method
- Construction

Primary function valves is to alter, generate or cancel signals for the purpose of sensing, processing and controlling.

Additionally the valve is used as a power valve for the supply of working air to the environment.

Therefore the following categories are relevant:

- **Directional control valves**
 - ⇒ Signalling elements
 - ⇒ Processing elements
 - ⇒ Power elements

DCV:

❖ As a signal element the DCV is operated by roller lever to detect the piston rod position of a cylinder. The signal element can be small in size and create a small air pulse. A signal pulse created will be at full operating pressure but have a small flow rate.

❖ As a processing element the DCV redirects, generates or cancels signals depending on the signal inputs received. It can be supplemented with additional elements such as the AND function and the OR function valves to create desired control conditions.

The processing element can be supplemented with additional elements such as the AND & OR function.

❖ As a power element the DCV must deliver the required quantity of air to match the actuator requirements and hence there is a need for larger volume rates and therefore larger sizes.

DCV can be of poppet or slide type.

The poppet type used for small flow rates and for generation of input and process signals

The slide type used for larger flow rates and hence lends itself to the power and actuator control valve

➤ **Non return valves and its derivatives:**

The non return valve allows a signal to flow through the device in one direction and in the other blocks the flow. There many variations in construction and size derived from the basic non return valve. Other derived valves utilise features of the non return valve by the incorporation of non return elements.

➤ **Flow control valves**

Flow control valves restricts or throttles the air in a particular direction to reduce the flow rate of the air and hence control the signal flow.

- ❖ If flow control valve is wide open then the flow should be almost the same as if restrictor not fitted
- ❖ Can be fitted with a non return valve then flow is uni directional. Flow control valve as close as possible to working element

➤ **Pressure control valves**

Pressure control valves :

- ❖ Pressure regulating valves- controls the pressure in a control circuit and keeps the pressure constant irrespective of any pressure fluctuations in the system.
- ❖ Pressure limiting valves are utilised on the up-stream side of the compressor to ensure the receiver pressure is limited, for safety, and that the supply pressure to the system is set to the correct pressure.
- ❖ Pressure sequence valve senses the pressure of any external line and compares the pressure of the line against a pre-set adjustable value, creating a signal when the pre-set limit is reached.

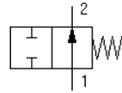
➤ **Combinational valves**

Combinational valves: The combined functions of various elements can produce a new function. The new component can be constructed by the combination of individual elements or manufactured in a combined configuration to reduce size and complexity.

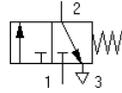
Valves described by:

- No. of ports or openings (ways)
 - ⇒ 2 way, 3 way, 4 way etc.
- No. of positions
 - ⇒ 2 positions, 3 positions, etc.
- Method of actuation of the valve
 - ⇒ Manual, air pilot, solenoid, etc.
- Methods of return actuation
 - ⇒ Spring return, air return, etc..
- Special features of operation
 - ⇒ Manual overrides, etc..

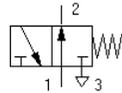
Number of ports
Number of positions
2 / 2 way directional control valve



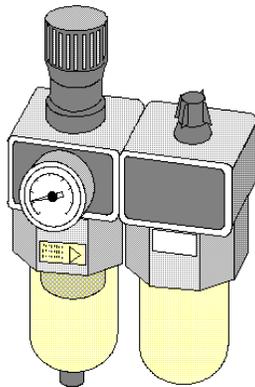
3 / 2 way directional control valve
Normally closed



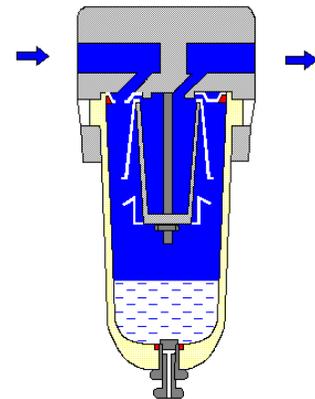
3 / 2 way directional control valve
Normally open



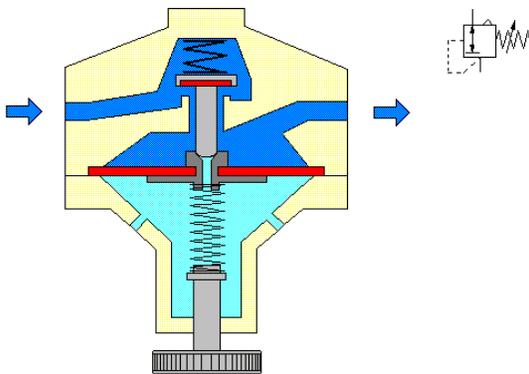
Symbols for directional control valves (1)



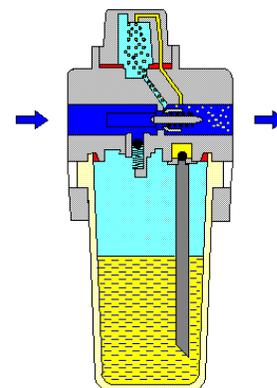
Compressed air service unit



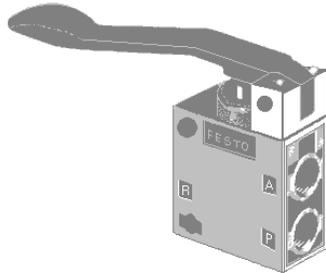
Compressed air filter



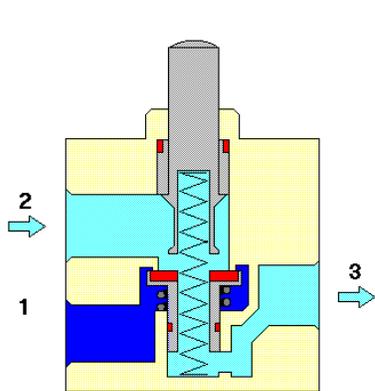
Air supply: Pressure regulator with vent hole



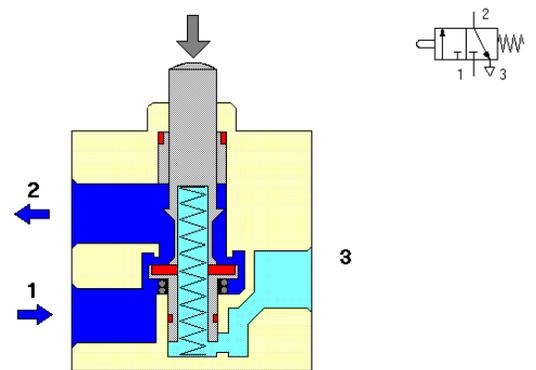
Air lubricator



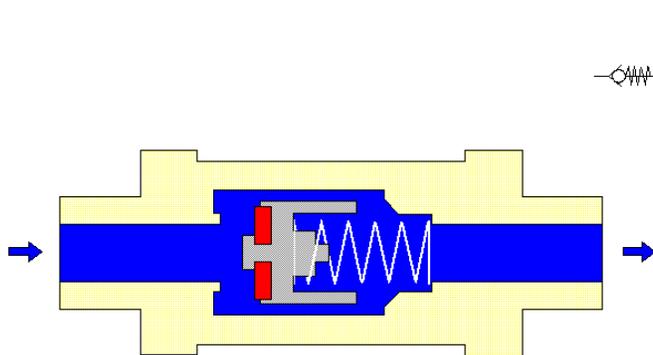
3/2 way valve



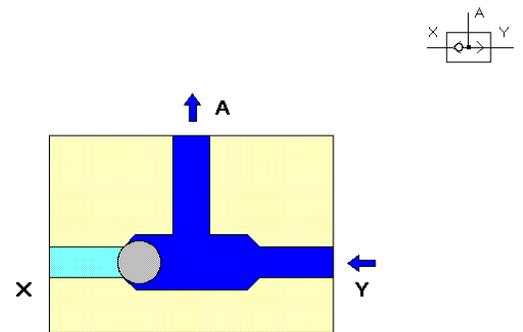
3/2 way valve, disc seat normally closed



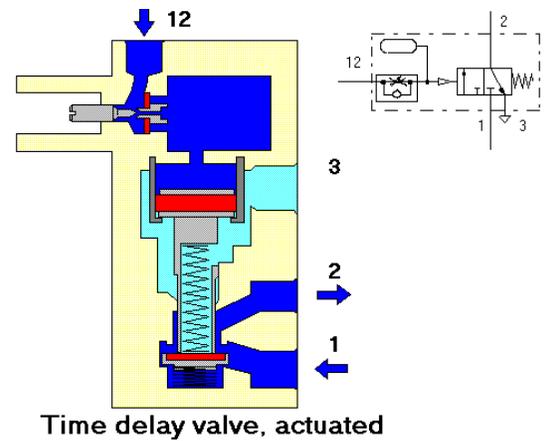
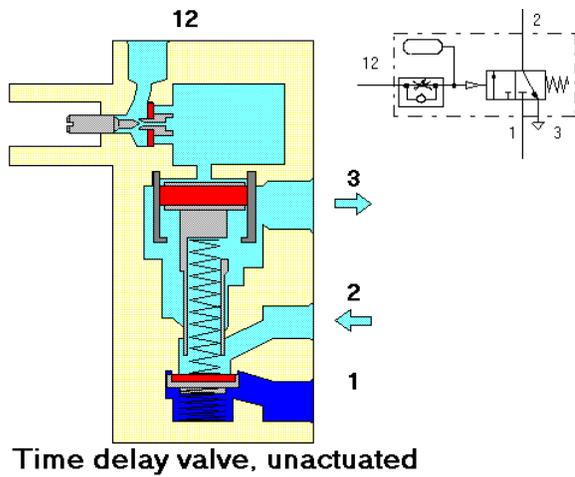
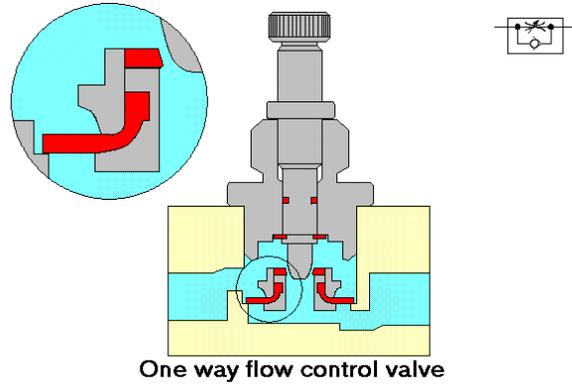
3/2 way valve, disc seat normally closed



Non - return valve



Shuttle valve

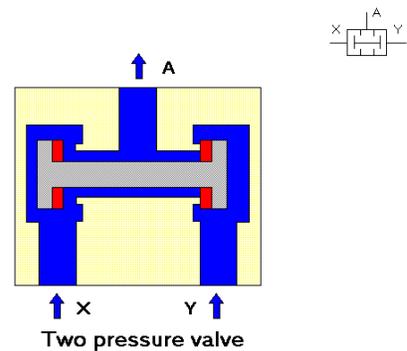
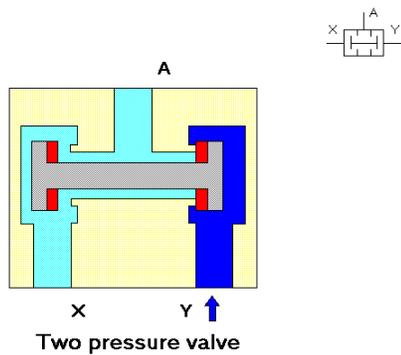


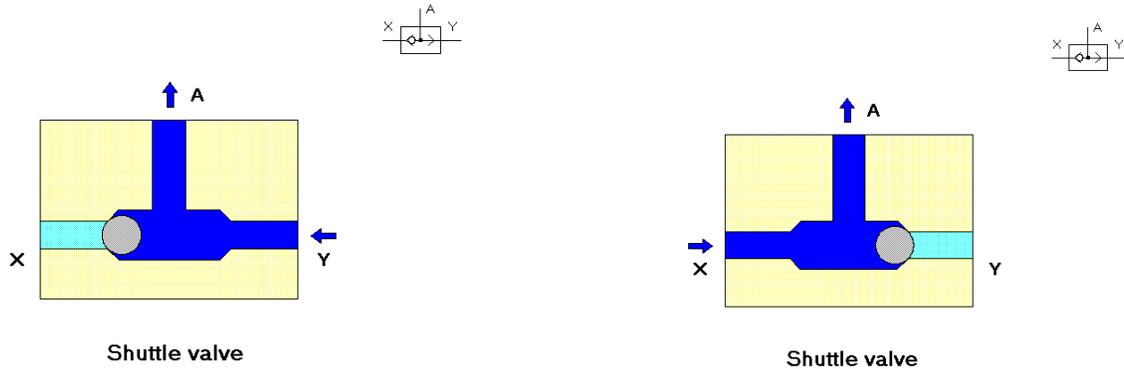
ious elements which condition the signal for the task

e.g.

- ◆ Two pressure valve (AND function)
- ◆ Shuttle valve (OR function)

They have logic based role and are fitted at the junction of three lines. They have 3 connections ; 2 in and 1 out.

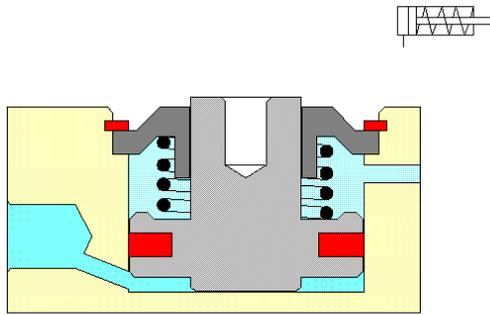




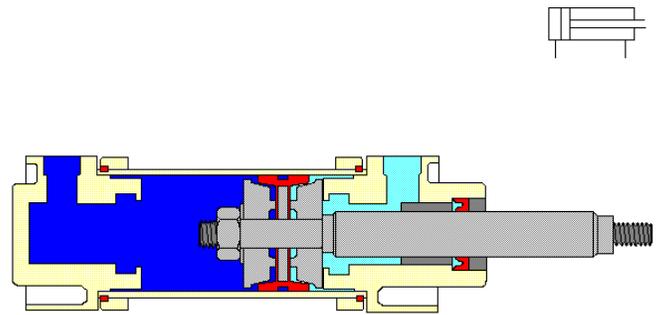
Modular processing unit consisting of DCV functions and logic elements to perform a combined processing task have been designed to reduce cost, size and complexity of system.

Actuator group includes various types of linear and rotary actuators of varying size and construction. The actuators are complemented by the final control element, which transfers the required quantity of air to drive the actuator. Normally this valve is fitted close to actuator to minimise losses and is connected directly to the air supply.

◆ Linear actuators

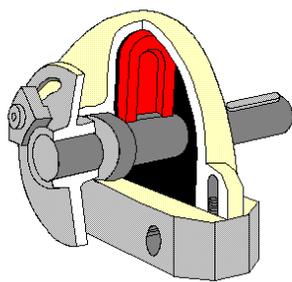


Single acting cylinder, un-operating

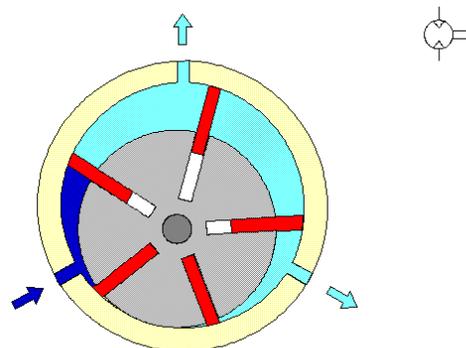


Double acting cylinder

Rotary Actuators



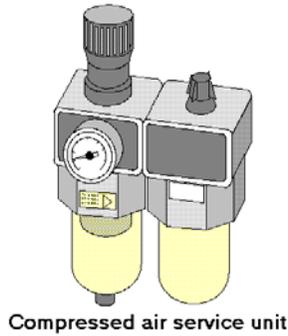
Semi - rotary actuator



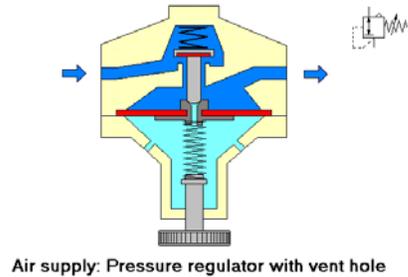
Air motor

Description and details of some components commonly used in fluid power systems.

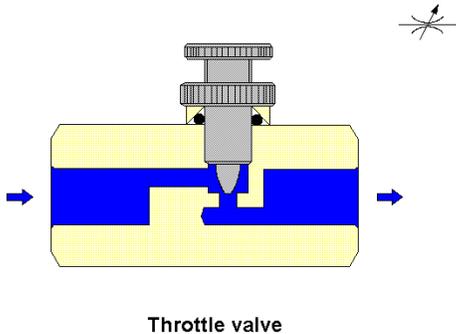
The filter is normally combined with the pressure regulator and lubricator to form a compressed air service unit. The selection of the correct filter plays an important role in determining the quality and performance of the control system which is to be supplied with compressed air.



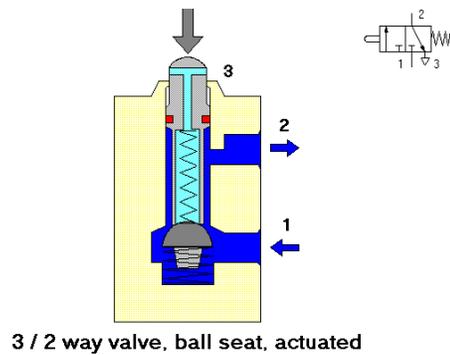
If the pressure on the secondary side increases considerably, the center-piece of the diaphragm then opens and the compressed air can flow to atmosphere through the vent holes in the housing.



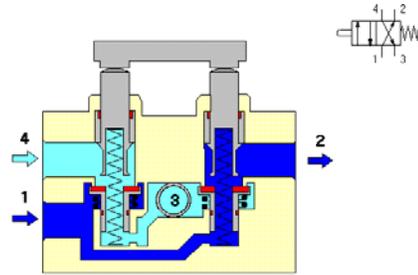
Throttle valves are normally adjustable and the setting can be locked in position. These valves are used to regulate the speed regulation of actuators and if possible, should be mounted directly on the cylinder. Compare the flow control with throttle valves and one-way flow control valve .



Actuation of the valve plunger causes the sealing element to be forced away from the seat. In doing this, the opposing force of the reset spring and that generated from the compressed air must be overcome. The air supply is then open to the output side of the valve and a signal is generated. The load on the stem is dependent on the size of the valve

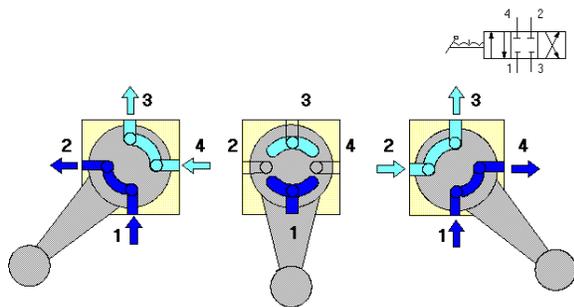


The 4/2-way valve has four ports and two positions. A disc seat 4/2-way valve is similar in characteristic to the combination of two 3/2-way valves, one valve normally closed and the other normally open. The plungers can be operated by an auxiliary mounted device such as a roller lever or push-button.



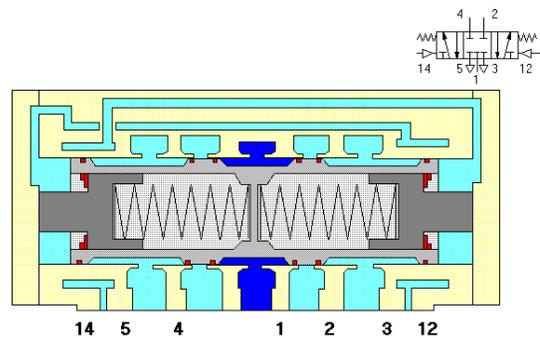
4 / 2 way valve, disc seat, unactuated

The 4/3-way valve has four ports and three positions. An example of the 4/3-way valve is the plate slide valve with hand or foot actuation. By turning two discs, channels are interconnected with one another.



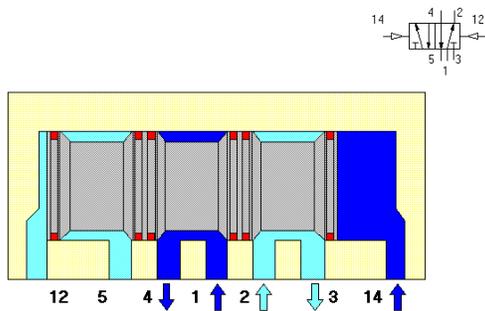
4 / 3 way valve, mid position closed

The 5/3-way valve has five ports and three positions. Signals applied at ports 14 or 12 operate the valve. It is shown closed in the mid-position. The valve is spring centered.



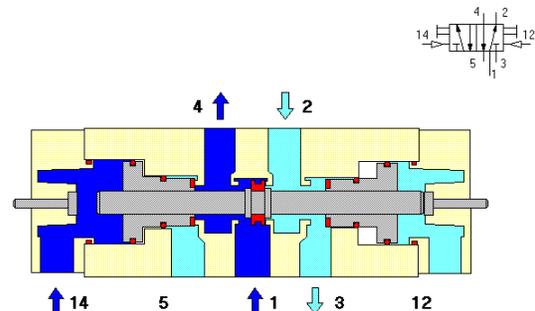
5 / 3 way valve

To avoid damage to seals, the ports can be distributed around the circumference of the housing. The actuation travel is considerably larger than with seat valves. The valve is shown here with pilot pressure at 14.



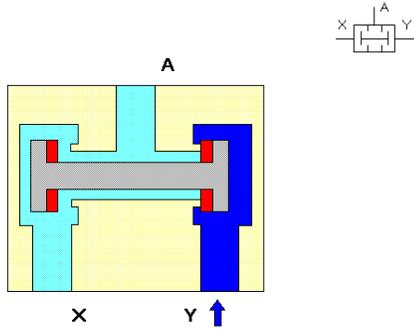
5 / 2 way valve, longitudinal slide principle

The last switched position is retained until a new switching position is initiated by a unique pilot signal from the opposite side. There are two manual override buttons to manually operate valve spool.



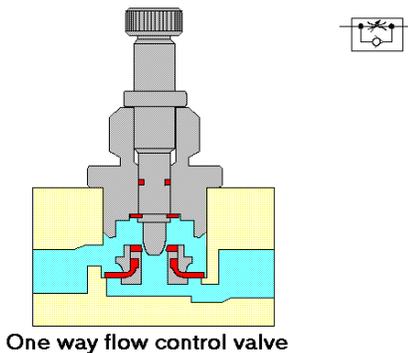
5/2-way valve, suspended disc seat

The two pressure valve has the inlets X and Y and one outlet A. The two pressure valve is used mainly for interlocking controls, safety controls, check functions or logic operations. The application of a signal at Y produces no pressure at A.



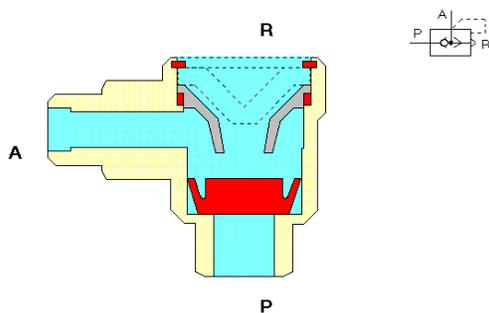
Two pressure valve

Flow of the compressed air. One-way flow control valves are normally adjustable and the setting can be locked in position. The influence of speed control is in one direction only.



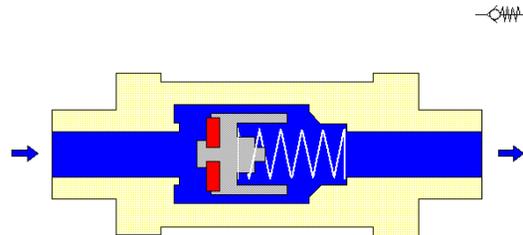
One way flow control valve

Quick exhaust valves are used to increase the piston speed of cylinders. Lengthy return times can be avoided, particularly with single acting cylinders. To reduce resistance to flow, the air is expelled to atmosphere close to the cylinder and through a large orifice.



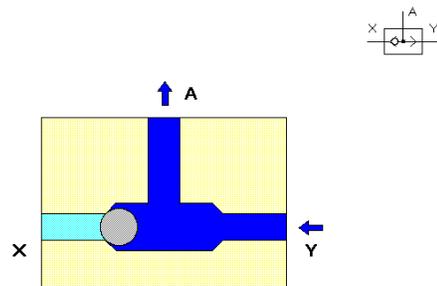
Quick exhaust valve

Non return valves can stop the flow completely in one direction. In the opposite direction the flow is free with a minimal pressure drop due to the resistance of the valve. The one-way blocking action can be effected by cones, balls, plates or diaphragms.



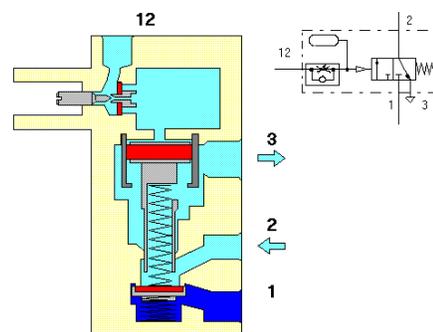
Non - return valve

This non-return valve outlet A. If compressed air is applied to the inlet Y, the valve seat seals off the opposing inlet X and the air flows to the outlet A. Note the similarity in construction to the two pressure valve.



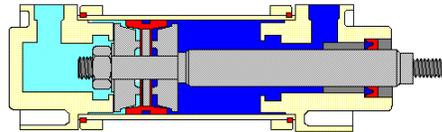
Shuttle valve

The time delay valve is a combinational valve consisting of a 3/2-way valve, throttle relief valve and an air reservoir. The 3/2-way valve can be a valve with normal position open or closed. The delay time is generally 0-30 seconds for both types of valves. By using additional reservoirs, the time can be extended.



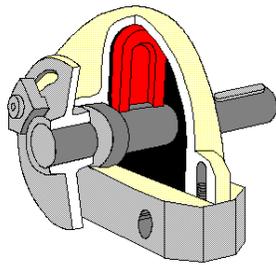
Time delay valve, unactuated

In front of the bearing bush is a scraper ring. This ring prevents dirt particles from entering the cylinder chamber. A sealing ring is fitted in the bearing cap to seal the piston rod. The bearing bush guides the piston rod and is made of sintered bronze or plastic-coated metal.



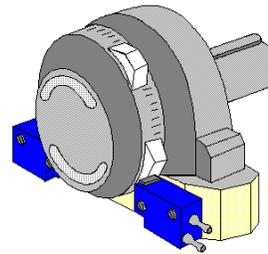
Double acting cylinder

The rotary actuator is compact with high torque ratings. The force is transmitted to the drive shaft by a rotary vane. The range of angular movement is adjustable with end stops. The angle can be adjusted between 0° and 180°



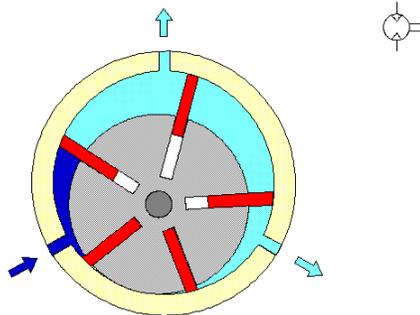
Semi - rotary actuator

The adjustable stop system is separate to the rotary vanes. This allows force to be absorbed by the stop blocks. At the end positions, impacts are cushioned by elastic cushioning rings.



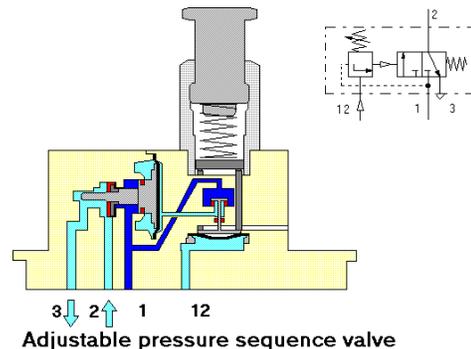
Semi - rotary actuator

Devices which transform pneumatic energy into mechanical rotary motion, with the possibility of continuous motion. They are categorized into the groups of piston motors, sliding vane motors, gear motors and turbines.

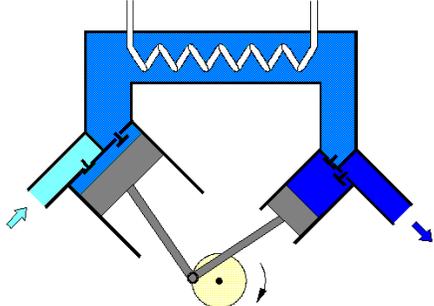
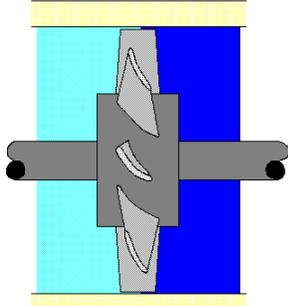


Air motor

Sequence valves are installed in pneumatic controls where a specific pressure is required for a switching operation. The output signal is transmitted only after the required operation pressure has been reached.



Adjustable pressure sequence valve

<p>The piston compressor is widely used. Multi-stage compressors are required for compressing to high pressure. The drawn in air is compressed by the first piston, cooled and then compressed further by the next stage.</p>  <p>Compressed air supply: Piston compressor</p>	<p>Flow compressors produce large volumes of air at small increases in stage pressure. The air is accelerated by the blades of the compressor but there is only a small increase in pressure. The kinetic energy is converted to pressure energy.</p>  <p>Compressed air supply: Axial flow compressor</p>
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REFERENCE:

1. Educational Materials + CDROM from FESTO Ltd.
2. Fluid Power with Applications by A. Esposito 5th Ed. Published by Prentice Hall