Pneumatic Transmission of Energy

The reason for using pneumatics, or any other type of energy transmission on a machine, is to perform work. The accomplishment of work requires the application of kinetic energy to a resisting object resulting in the object moving through a distance. In a pneumatic system, energy is stored in a potential state under the form of compressed air. Working energy (kinetic energy and pressure) results in a pneumatic system when the compressed air is allowed to expand. For example, a tank is charged to 100 PSIA with compressed air. When the valve at the tank outlet is opened, the air inside the tank expands until the pressure inside the tank equals the atmospheric pressure. Air expansion takes the form of airflow.

To perform any applicable amount of work then, a device is needed which can supply an air tank with a sufficient amount of air at a desired pressure. This device is positive displacement compressor.

What a Positive Displacement Compressor Consists of

A positive displacement compressor basically consists of a movable member inside a housing. The compressor has a piston for a movable member. The piston is connected to a crankshaft, which is in turn connected to a prime mover (electric motor, internal combustion engine). At inlet and outlet ports, valves allow air to enter and exit the chamber.

How a Positive Displacement Compressor Works

As the crankshaft pulls the piston down, an increasing volume is formed within the housing. This action causes the trapped air in the piston bore to expand, reducing its pressure. When pressure differential becomes high enough, the inlet valve opens, allowing atmospheric air to flow in. With the piston at the bottom of its stroke, inlet valve closes. The piston starts its upward movement to reduce the air volume which consequently increases its pressure and temperature. When pressure differential between the compressor chamber and discharge line is high enough, the discharge valve opens, allowing air to pass into an air receiver tank for storage.

Control of Pneumatic Energy

Working energy transmitted pneumatically must be directed and under complete control at all times. If not under control, useful work will not be done and machinery or machine operators might be harmed. One of the advantages of transmitting energy pneumatically is that energy can be controlled relatively easily by using valves.

Control of Pressure

Pressure in a pneumatic system must be controlled at two points - after the compressor and after the air receiver tank. Control of pressure is required after the compressor as a safety for the system. Control of pressure after an air receiver tank is necessary so that an actuator receives a steady pressure source without wasting energy.

Control of Pressure after A Compressor

In a pneumatic system, energy delivered by a compressor is not generally used immediately, but is stored as potential energy in air receiver tank in the form of compressed air.

In most instances, a compressor is designed into a system so that it operates intermittently. A compressor usually delivers compressed air to a receiver tank until high pressure is reached, then it is shut down. When air pressure in the tank decreases, the compressor cuts in and recharges the tank. Intermittent compressor operation in this manner is a power saving benefit for the system.

A common way of sensing tank pressure and controlling actuation and de-actuation of relatively small (2-15 HP) compressors, is with a pressure switch.

Pressure Switch

System pressure is sensed with a spring-loaded piston within the switch housing. When pressure in the system is at its low level, the spring pushes the piston down. In this position a contact is made causing an electrical signal to turn on the compressor.

As pressure in the receiver tank rises, it forces the piston upward. With system pressure at its high level, the piston breaks the electrical contact shutting down the compressor.

Safety Relief Valve

Maximum pressure developed by a compressor is designed to be regulated by a control system which senses discharge or tank pressure. In case of an emergency, such as the failure of a control system to function properly, a positive displacement compressor system is generally equipped with a safety relief valve.

A safety relief valve is a normally closed valve. The poppet of the safety relief valve is seated on the valve inlet. A spring holds the poppet firmly on its seat. Air cannot pass through the valve until the force of the spring biasing the poppet is overcome.

Air pressure at compressor outlet is sensed directly on the bottom of the poppet. When air pressure is at an undesirably high level, the spring will be compressed, the poppet will move off its seat, and air will exhaust through the valve.

A safety relief valve on a compressor is not intended to operate frequently. A safety relief valve is designed only to be a safety device. Many times safety relief valves are equipped with whistles or horns to alert personnel that something has failed or a problem exists.

Pressure Regulator

In a pneumatic system, energy that will be used by the system and transmitted through the system is stored as potential energy in an air receiver tank in the form of compressed air. A pressure regulator is positioned after a receiver tank and is used to portion out this stored energy to each leg of the circuit.

A pressure regulator is a normally open valve.

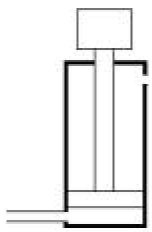
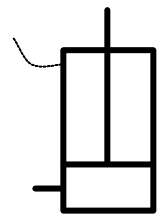
With a regulator positioned after a receiver tank, air from the receiver can expand (flow) through the valve to a point downstream. As pressure after the regulator rises, it is sensed in an internal pilot passage leading to the underside of the piston.

This piston has a large surface area exposed to downstream pressure and for this reason is quite sensitive to downstream pressure fluctuations. When downstream pressure nears the preset level, the piston moves upward pulling the poppet toward its seat. The poppet, once it seats, does not allow pressure to continue building downstream. In this way, a constant source of compressed air is made available to an actuator downstream.

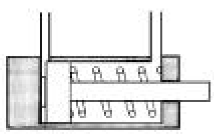
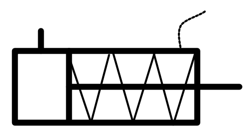
Common Types of Cylinders

There are many different cylinder types. The most common are listed below:

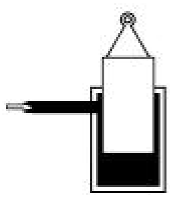
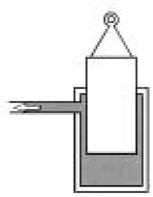
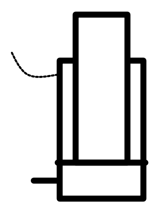
Single acting cylinder - a cylinder in which air pressure is applied to the movable element (piston) in only one direction.

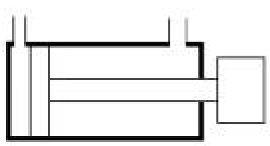
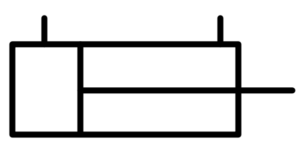
Spring return cylinder - a cylinder in which a spring returns the piston assembly.

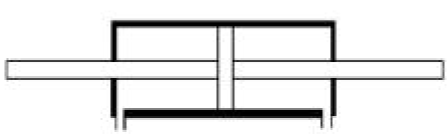
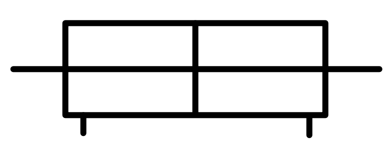
Ram cylinder - a cylinder in which the movable element is the piston rod.

Double acting cylinder - a cylinder in which air pressure may be alternately applied to the piston to drive it in either direction.

Double acting – double rod cylinder - Double acting cylinder with a piston rod extending form each end. The piston rods are connected to the same piston. Double rod cylinders provide equal force and speed in both directions.

Sizing a Cylinder

To determine the size cylinder that is needed for a particular system, certain parameters must be known. First of all, a total evaluation of the load must be made. This total load is not only the basic load that must be moved, but also includes any friction and the force needed to accelerate the load. Also included must be the force needed to exhaust the air from the other end of the cylinder through the attached lines, control valves, etc. Any other force that must be overcome must also be considered as part of the total load. Once the load and required force characteristics are determined, a working pressure should be assumed. This working pressure that is selected MUST be the pressure seen at the cylinder's piston when motion is taking place. It is obvious that cylinder's working pressure is less than the actual system pressure due to the flow losses in lines and valves.

With the total load (including friction) and working pressure determined, the cylinder size may be calculated using Pascal's Law. Force is equal to pressure being applied to a particular area. The formula describing this action is:

Force = Pressure * Area

Force is proportional to pressure and area. When a cylinder is used to clamp or press, its output force can be computed as follows: F = P * A

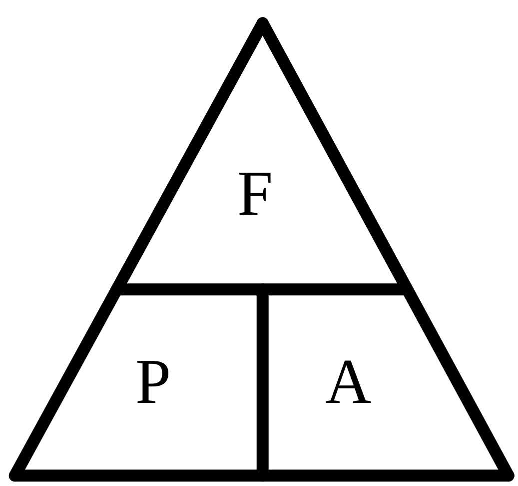
P = pressure	(PSI (Bar) (Pascal's))
F = force	(pounds (Newtons))
A = area	(square inches (square meters))

These pressure, force and area relationships are sometimes illustrated as shown below to aid in remembering the equations.

$$F = P * A$$

$$P = \frac{F}{A}$$

$$A = \frac{F}{P}$$

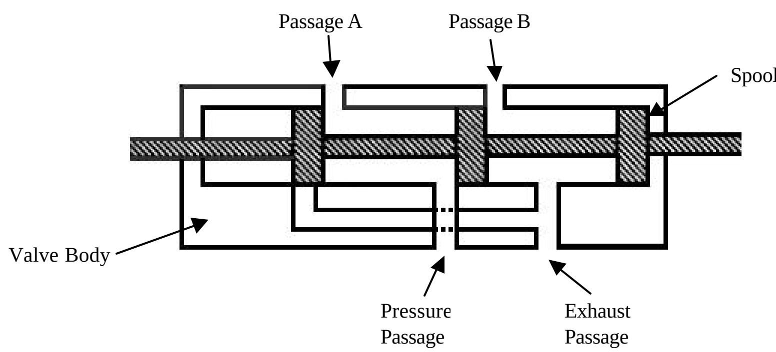


Directional Control Valves

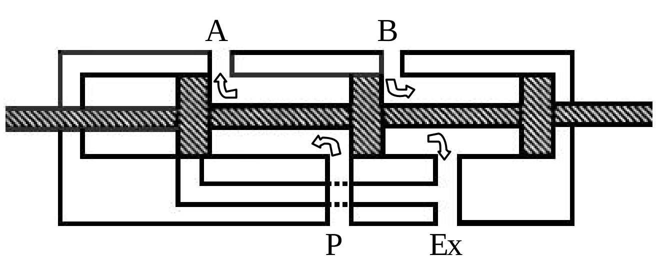
To change the direction of airflow to and from the cylinder, we use a directional control valve. The moving part in a directional control valve will connect and disconnect internal flow passages within the valve body. This action results in a control of airflow direction.

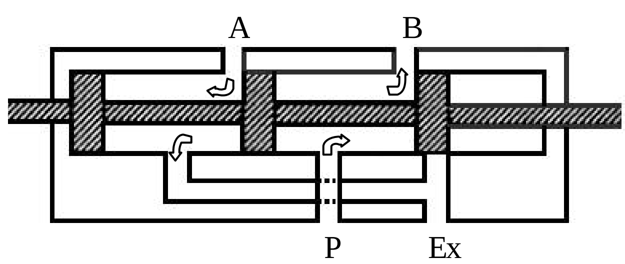
Valve flow diagrams are reprinted courtesy of Parker Hannifin Corporation.

The typical directional control valve consists of a valve body with four internal flow passages within the valve body and a sliding spool.



Shifting the spool alternately connects a cylinder port to supply pressure or the exhaust port. With the spool in the position where the supply pressure is connected to port A and port B is connected to the exhaust port, the cylinder will extend. Then, with the spool in the other extreme position, supply pressure is connected to port B and port A is connected to the exhaust port, now the cylinder retracts. With a directional control valve in a circuit, the cylinder's piston rod can be extended or retracted and work performed.



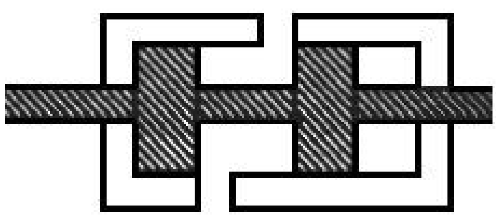


Functional Types of Directional Control Valves

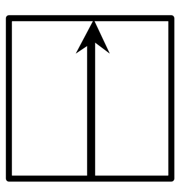
One method of classifying a directional control valve is by the flow paths that are set up in its various operating conditions. Important factors to be considered are the number of individual ports, the number of flow paths the valve is designed for and internal connection of ports with the movable part.

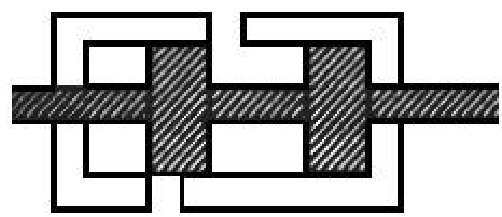
Two-Way Directional Valve

A two-way directional valve consists of two ports connected to each other with passages, which are connected and disconnected. In one extreme spool position, port A is open to port B; the flow path through the valve is open. In the other extreme, the large diameter of the spool closes the path between A and B; the flow path is blocked. A two-way directional valve gives an on-off function.

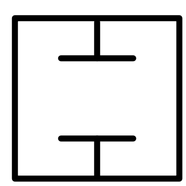


Flow Path Open





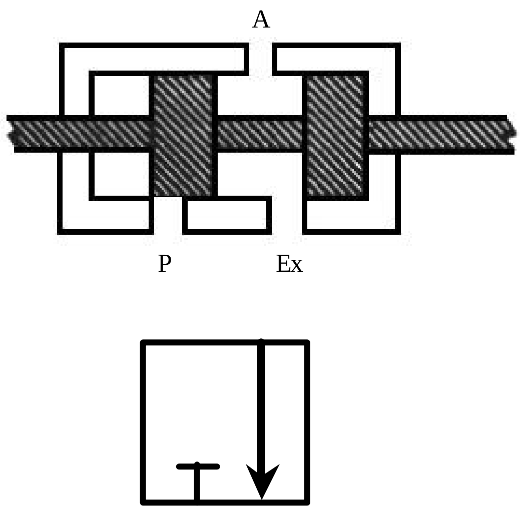
Flow Path Closed

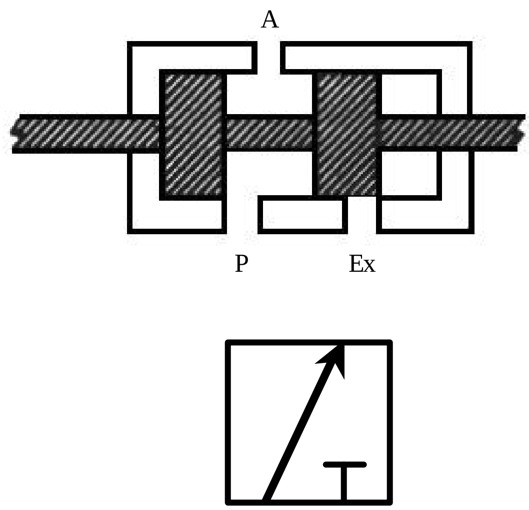


Three-Way Directional Valve

A three-way directional valve consists of three ports connected through passages within a valve body that are shown here as port A, port P and port Ex. If port A is connected to an actuator, port P to a source of pressure and port Ex is open to exhaust, the valve will control the flow of air to (and exhaust from) Port A.

The function of this valve is to pressurize and exhaust one actuator port. When the spool of a three-way valve is in one extreme position, the pressure passage is connected with the actuator passage. When in the other extreme position, the spool connects the actuator passage with the exhaust passage.

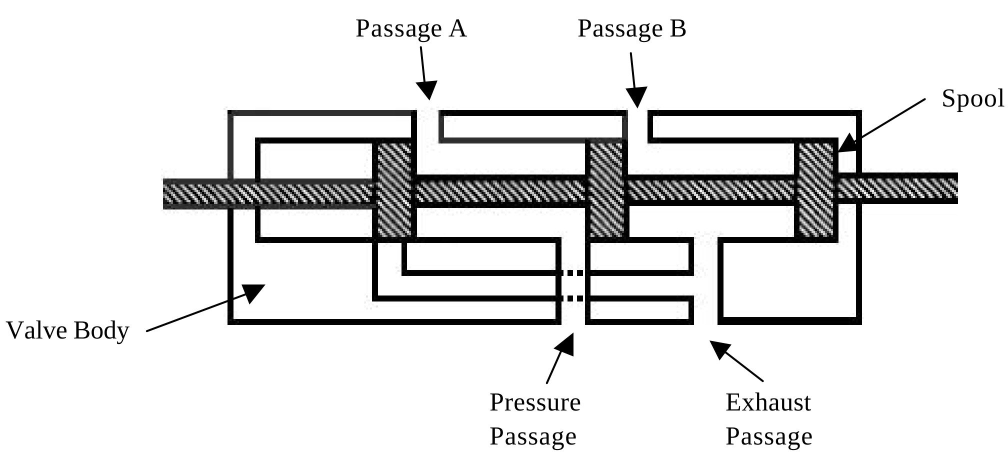


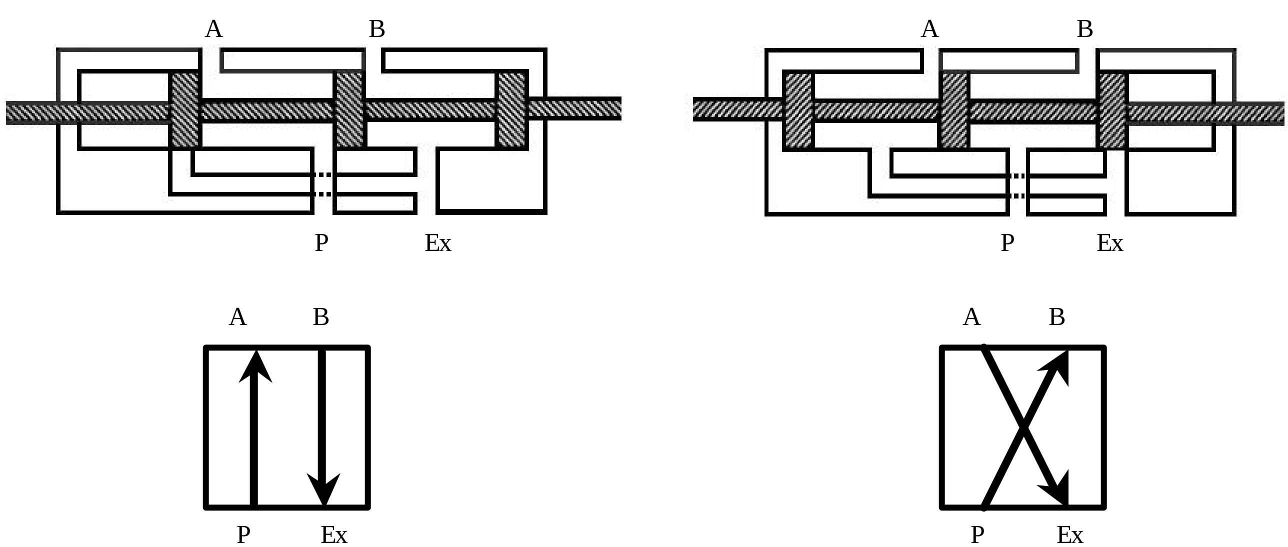


Four-Way Directional Valve

Perhaps the most common directional valve in simple pneumatic systems consists of pressure port, two actuator ports and one or more exhaust ports. These valves are known as four-way valves since they have four distinct flow paths or "ways" within the valve body.

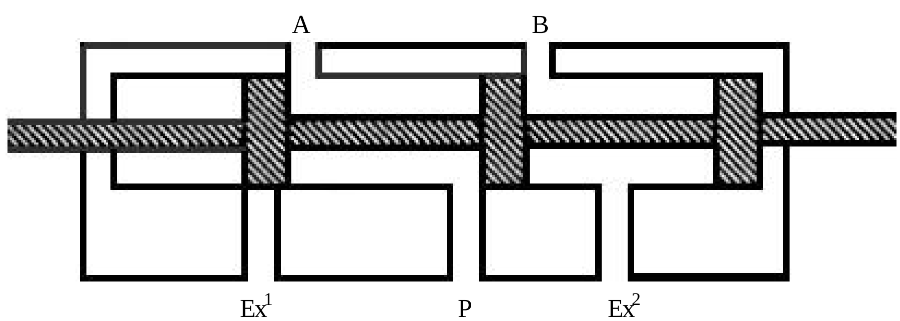
A common application of four-ported four-way directional valve is to cause reversible motion of a cylinder or motor. To perform this function, spool connects the pressure port with one actuator port. At the same time, the spool connects the other actuator port with the exhaust port. This is a four-ported four-way valve.



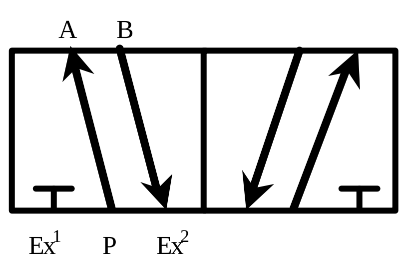


Five-Port / Four-Way Directional Valve

Four-way valves are also available with five external ports, one pressure port, two actuator ports, and two exhaust ports. Such valves provide the same basic control of flow paths as the four-ported version, but have individual exhaust ports. In the fluid power field this is referred to as a "five-ported, four-way valve." This type of valve brings all flow paths to individual external ports. The pressure port is connected to system pressure after a regulator. Actuator ports are connected to inlet and outlet ports of a cylinder or motor. Each exhaust port serves an actuator port.

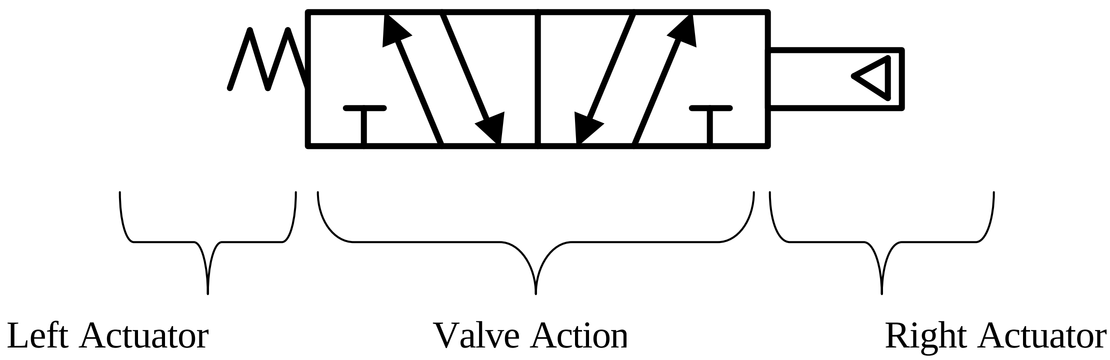


5-Ported, 4-Way Valve



Schematic Symbols for Directional Valves

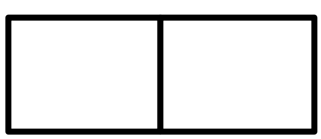
A directional valve is a valve that directs the flow of air in one with or another. It doesn't throttle or meter the airflow, and it doesn't change the pressure of the air. It just changes the direction of the airflow in some way. The ANSI symbol for directional valves are the most complicated of all the fluid power symbols, but some of the most important, so let us start with directional valves, see how the symbol system works. A typical directional valve symbol is made up of three parts:



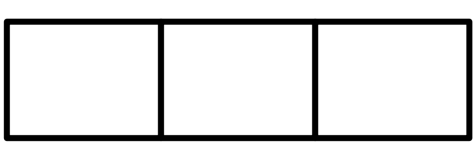
The actuators are the devices or methods that cause the valve to shift from one position to another. The valve action refers to the combinations of positions and flow paths which the valve offers.

Position Boxes

Every valve provides two or more usable positions, each position providing one or more flow paths. For example, the familiar single solenoid spring return valve provides two usable positions, one position occurring when the solenoid is in command of the valve, the other position occurring when the spring is in command of the valve. The ANSI symbol for a directional valve is built around a series of boxes or rectangles, one box for each usable position of the valve.



A 2-Position valve is shown by two boxes.

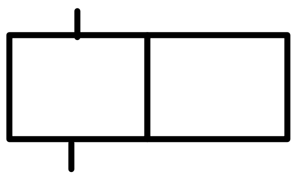


A 3-Position valve is shown by three boxes.

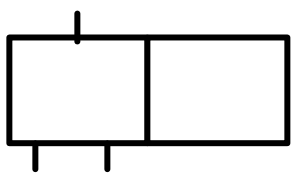
Most air moves are either 2-position or 3-position valves, but it would be possible to have an unusual valve with four or five or even six positions. In any case, there would be a box to represent each position of the valve.

Valve Ports

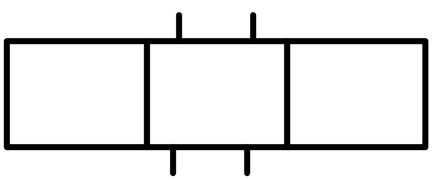
Every valve port, which appears on the outside of the valve, is supposed to be shown on the symbol. But the ports are shown on only one of the boxes, the box that represents the flow paths that exist at the start of the machine cycle. Some examples are:



A 2-position 2-port valve



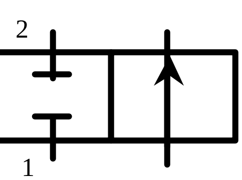
A 2-position 3-port valve



A 3-position 4-port valve

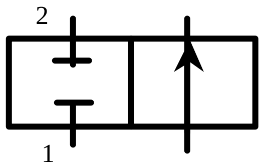
Flow Paths

Each box contains a group of lines that represent the flow paths the valve provides when it is in that position. If a port is blocked, we show that by the symbol  . If two ports are connected and air can flow, this is shown by a line drawn between the two ports.

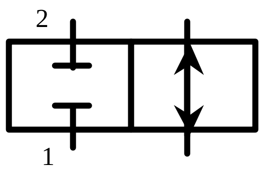


In the example above, the left box shows the conditions that exist at the start of the cycle. Port 1 is blocked, and port 2 is blocked. When the valve is shifted, the flow condition shown in the right hand box exists. Port 1 is open to port 2.

The direction in which air flows *during a normal operating cycle* is shown by putting arrowheads at the ends of the flow paths next to the ports where the air will come out.



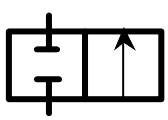
Example #1 - At the start of the cycle, the flow path from port 1 to port 2 is blocked. When the valve shifts, flow is from port 1 to port 2.



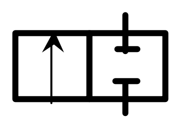
Example #2 - At the start of the cycle, the flow path from port 1 to port 2 is blocked. When the valve shifts, port 1 is opened to port 2, but during some part of the cycle air flows from port 1 to port 2, and during another part of the cycle air flows from port 2 to port 1.

Typical Symbols for Valve Actions

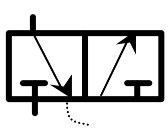
Two- Position Valves



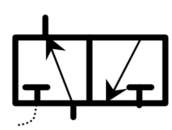
2-Way, Blocked at start of cycle



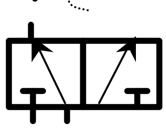
2-Way, Open at start of cycle



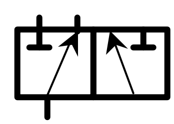
3-Way, Blocked at start of cycle



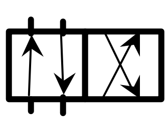
3-Way, Open at start of cycle



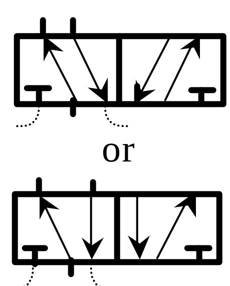
2-Inlet Selector



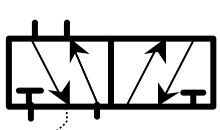
Distributor (Diverter)



4-Way, 4-port Single Inlet



4-Way, 5-Port Single Inlet Dual Exhausts



4-Way, 5-port Dual Pressure Common Exhaust