# BUILDING BLOCKS OF PNEUMATIC CIRCUITS

Directional control valves consist of a body with ports that are connected to internal flow passages by one or more movable parts which control the direction of air flow. These valves may also function to block or allow air to flow. Other applications control the speed or sequence of an operation or even selecting either of two pressure sources to conserve energy.

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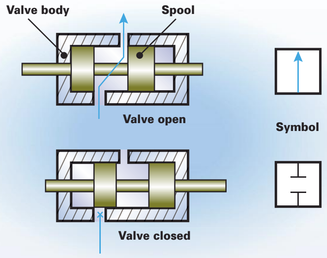
One method of classifying a directional control valve is by the flow paths existing in its various operating conditions. Important factors to be considered are the number of positions that the valve can be placed in, the number of individual ports, the number of flow paths the valve is designed for, and the internal connection of the ports with the movable spool or poppet.

## 2-Way, 2-Position Valves

A 2-way directional valve consists of two ports connected to each other through a passage that is either open or blocked. With the spool shifted to the extreme left the inlet port is open to the outlet port—the flow path through the valve is *open*. With the spool shifted to the extreme right, the spool blocks the path between the inlet and outlet ports—the flow path is *closed*. A 2-way directional valve provides an *on-off* function. This function is used in many systems to serve as an interlock and to isolate and connect various system parts.




## 3-Way, 2-Position Valves

A 3-way directional valve has three ports connected through passages within a valve body; they are shown at right as ports *B, C,* and *A*. Port *A* is connected to an actuator, port *B* to a source of pressure, and port *C* is open to exhaust. Exhaust air normally flows to the surrounding atmosphere and often through an exhaust muffler to reduce noise.

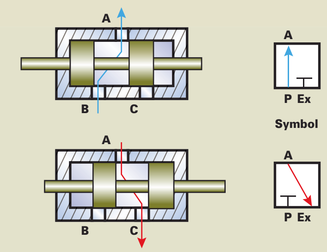
As shown in the drawing, the function of a 3-way, 2-position valve is to pressurize and exhaust one actuator port. When the spool of the valve is in one extreme position, its pressure port, *B*, is connected with the actuator's port, *A*. When in the other extreme position, the spool connects the actuator's port, *A*, with the valve's exhaust port, *C*. The valve can also be used to perform other circuit functions, such as switching between two supply pressures connected at ports *B* and *C* to supply a device connected to port *A*.

Three-way valves may be used individually to control a single-acting cylinder or in pairs to control a double-acting cylinder. For single-acting applications, lower-right, a 3-way valve directs pressurized air into the cap end of a spring-return cylinder When the spool is shifted to its other extreme position, flow and pressure from the cylinder are directed to the valve's exhaust port. The cylinder must be returned by some method, such as gravity, a spring, or weight of a load. (If the cylinder is spring extended, the 3-way valve connects to the rod-end port.)

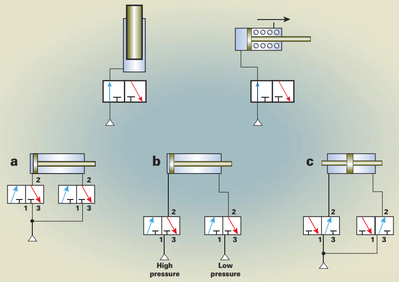
The figure at bottom right shows how a pair of 3-way valves can be used to operate a double acting-cylinder instead of using a 4-way valve. Using paired 3-way valves instead of one 4-way valve may be for one or more of the following circuit requirements (labeled *a, b,* and *c):*

High cylinder speeds are necessary—this requires air at high inlet pressures and an unobstructed low-pressure exhaust. Close coupling of 3-way valves to the cylinder ports cuts down on exhaust backpressure and pressure drop in lines, thereby allowing higher cylinder velocities.

Energy conservation—a pair of 3-way valves can use less compressed air than a single 4-way valve does. Each of the two 3-way valves can route a different source pressure to opposite ends of the cylinder. For example, a double-acting, single-rod cylinder usually needs high force on extension, but not retraction. Using the pair of 3-way valves as shown supplies a high pressure to cylinder's cap end for high-force extension and lower pressure (more economical) to the rod end for retraction.



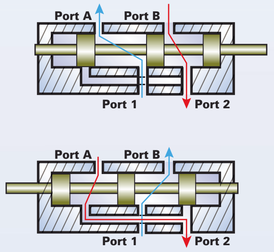

If intermediate positions are required with a double-rod cylinder, two normally open valves can be used. With equal pressure supplied to both valves, the cylinder is pneumatically locked due to equal pressure working on opposing sides of the piston. If only the valve supplying the right-end port of the cylinder is shifted, the piston rod will move to the right. When the right valve is allowed to shift back to its normal position, pressure will be reapplied, and the cylinder will stop and hold position.




## 4-Way, 2-Position Valves

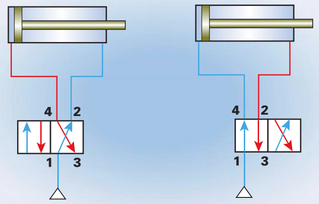
A 4-way directional valve can have four or five ports and two or three positions. A 2-position valve has two distinct flow paths in each position and a 3-position valve has a normal (neutral) center condition of either all ports blocked center, exhaust center, or pressure center.

The function of a 2-position, 4-way directional valve is to cause the reverse motion of a cylinder, rotary actuator, or bidirectional motor. To perform this function, the spool directs flow from the pressure port, port 1, to one actuator port (*A* or *B*) when it is in one discrete position. At the same time, the spool is positioned so that the other actuator port (*A* or *B*) is exhausted to atmosphere at port 2.




Because all 2-position, 4-way valves consist of a body and an internal moving part, the moving part of all valves has two positions—either of two extremes. These two positions are depicted at right by two separate squares. Each square uses arrows to show how the spool connects the passages within the body at that position.

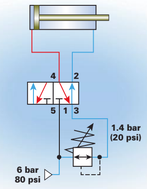
When the valve is shown symbolically, the two squares are connected together. But when placed in a circuit, one, and only one square is connected in the circuit. With this arrangement, the condition within the valve is shown while a cylinder is moving in one direction. To picture the cylinder moving in the opposite direction, the other square of the symbol must be mentally slid into position.




## 5-port, 4-Way, 2-Position Valves

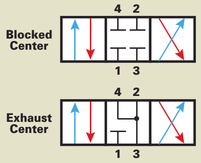
The 5-port version of the 2-position, 4-way valve has five individual ports, which provide various valve configurations such as: single pressure with individual exhaust and dual pressure with a common exhaust.

The 4-way, 5-port valve can be used to supply dual pressure to a cylinder. The flow from port 5 to port 4 is at 6 bar (80 psi), supplying high extension force. Flow from port 3 to port 2, controlled by the regulator, is at 1.4 bar (20 psi), enough to retract the piston rod at low pressure. Using the lower pressure to release the clamp conserves energy, lowers operating cost, and extends life of the equipment.




## 4-Port, 4-Way, 3-Position Valves

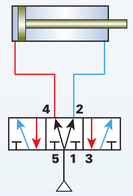
The 4-port, 4-way directional valve is also available in a 3-position version. The most common center conditions for this valve are the all-ports-blocked center and exhaust center. The two extreme positions of the 4-port, 4-way valve are the power positions of the valve that control movement of the cylinder. The valve's center position is designed to satisfy some system requirement, such as locking the cylinder's piston rod or allowing it to float, respectively.




## 5-Port, 4-Way, 3-Position Valves

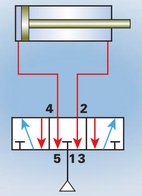
The 5-port, 4-way valve is also offered in a three-position version. Besides having the two center conditions of all ports blocked and exhaust, there is a third condition, known as the pressure center. As with all the 3-position valves, the center position is commonly referred to as the normal, or neutral position.

The pressure-center type valve can control positioning of a cylinder. When used in connection with a double rod, double-acting cylinder, the center position will deliver equal pressure to both cylinder ports, pneumatically locking the cylinder's piston position. If used with a single rod, double-acting cylinder, as shown, the center position will cause the cylinder to drift to a fully extended position because of the differential area of the cylinder's piston. In the circuit, whenever the valve is shifted to one of the extreme positions, air exhausts from one end of the cylinder while the opposite end remains pressurized.

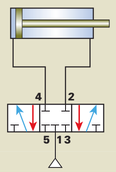



## Cylinder Ports Open to Exhaust—Pressure Port Blocked

With the exhaust center condition, the cylinder is free to float. In other words, with the valve in its neutral state, both ports of the cylinder are opened to exhaust, so the cylinder rod can be moved (subject to internal friction and external loading). When the valve is shifted, the piston rod extends or retracts.




## All Ports Blocked




The blocked center condition blocks all working ports and is often called *closed center*. Depending on the circuit design and cylinder loading conditions, this center condition may provide a holding action on the actuator the valve controls. With suitable controls and the compressibility of air taken into account, this type of valve can be used to stop a cylinder along its stroke as it travels in either direction.