The function of valves is to control the fluid path or the pressure or the flow rate. Depending on design, these can be divided into the following categories:

1- Directional control valves.
   – Input/signaling elements
   – Processing elements
   – Control elements
   – Power elements.

2- Flow control valves.

3- Pressure control valves.
Directional control valves

Directional control valves are devices which influence the path taken by an air stream. Normally this involves one or all of the following: opening the passage of air and directing it to particular air lines, canceling air signals as required by blocking their passage and/or relieving the air to atmosphere via an exhaust port.

Configuration and construction

The directional control valve is characterized by:
- **Construction type** (Poppet or slide).
- **Over Lapping** (with or without overlapping).
- **Number of controlled connections or ways (Ports)**: (1 way, 2 way, 2 ports, 3 ports, …)
- **Number of switching positions**: (2 positions, 3 positions, …)
- **Method of actuation**: Direct control (Manual, mechanical and solenoid) or Indirect Control (piloted control).
- **Method of return actuation**: (Spring return, air return, …)
- **Special features of actuation**: (Manually overrides, …)
- **Size**: (Port size, spool size, …)
- **Switching time**.
- **Service life**.
Directional Control Valve
Construction type

• Poppet valves

• Slide valves

Poppet valves
With poppet valves the connections are opened and closed by means of balls, discs, plates or cones. The valve seats are usually sealed simply using flexible seals.

Characteristics:
• Seat valves have few parts which are subject to wear and hence they have a long service life.
• Absolutely tight.
• They can switch quickly over short strokes.
• Insensitive to dirt and are robust.
• Need high actuating force (relatively high as it is necessary to overcome the force of the built-in reset spring and the air pressure).
• Can be actuated from one side only.
Slide Valves

In slide valves, the individual connections are linked together or closed by means of spools or plate slide valves.

Characteristics:

• Easy to produce.
• Compact size.
• Low actuating force required.
• Can be actuated from both sides.
• Long switching strokes.
• Limited tightness.
• Sensitive to dirt.
The term overlapping describes the behavior of the valve during the switch over phase.

- With overlapping, if during the switching phase ports A, P, and R are connected.
- Without overlapping, the connection of P to A after closing R.
3/2 Directional Control Valve, Manual operated by push button, normally closed, return by spring, slide valve.
Graphical Symbols For Directional Control Valves

- Number of switching positions = Number of squares.
- Number of ports = Number of port marks (main ports only. No control ports are counted)
- Graphical symbols with additional lines = continuously adjustable valve.
Home positions

- **Normal Position:** The normal position on valves with existing reset, e.g. spring, refers to the switching position assumed by the moving parts of the valve, if the valve is not connected.

- **Initial Position:** The initial position is the switching position assumed by the moving parts of a valve after the valve has been installed in a system and the system pressure has been switched on and possibly also the electrical voltage, and with which the designated switching program starts.

Valve Description

1. Number of ports.
2. Number of switching position.
3. Valve type.
4. Type of actuation.
5. Type of return.
6. Type of mid position sealing.
7. Construction type (If you can)
Valve switching positions are represented as squares.

The number of squares shows how many switching positions the valve has.

Lines indicate flow paths, arrows show the direction of flow.

Shut off positions are identified in the boxes by lines drawn at right angles.

The connections (inlet and outlet ports) are shown by lines on the outside of the box.

- **Number of ports**
  - **Number of positions**
  - **2/2 – Way directional control valve, normally open**
  - **3/2 – Way directional control valve, normally closed**
  - **3/2 – Way directional control valve, normally open**
  - **4/2 – Way directional control valve**
    - Flow from 1 → 2 and from 4 → 3
  - **5/2 – Way directional control valve**
    - Flow from 1 → 2 and von 4 → 5
  - **5/3 – Way directional control valve**
    - Mid position closed
## Port Designations

<table>
<thead>
<tr>
<th>Port Type</th>
<th>Letters</th>
<th>Digits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working ports</td>
<td>A, B...</td>
<td>2, 4...</td>
</tr>
<tr>
<td>Supply port</td>
<td>P</td>
<td>1</td>
</tr>
<tr>
<td>Exhaust/tank piping</td>
<td>R, S, T</td>
<td>3, 5</td>
</tr>
<tr>
<td>Hydraulic leakage ports</td>
<td>L</td>
<td>-</td>
</tr>
<tr>
<td>Pilot ports</td>
<td>X, Y, Z</td>
<td>10, 12, 14</td>
</tr>
</tbody>
</table>

## Working lines

<table>
<thead>
<tr>
<th>ISO 5599-3</th>
<th>Lettering System</th>
<th>Port or Connection</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>P</td>
<td>Pressure port</td>
</tr>
<tr>
<td>2, 4</td>
<td>A, B</td>
<td>Working lines</td>
</tr>
<tr>
<td>3, 5</td>
<td>R, S</td>
<td>Exhaust ports</td>
</tr>
</tbody>
</table>

## Pilot lines

<table>
<thead>
<tr>
<th>Number</th>
<th>Letter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Z</td>
<td>Applied signal inhibits flow from port 1 to port 2</td>
</tr>
<tr>
<td>12</td>
<td>Y, Z</td>
<td>Applied signal connects port 1 to port 2</td>
</tr>
<tr>
<td>14</td>
<td>Z</td>
<td>Applied signal connects port 1 to port 4</td>
</tr>
<tr>
<td>81, 91</td>
<td>Pz</td>
<td>Auxiliary pilot air</td>
</tr>
</tbody>
</table>
Manual Operated

General

Pushbutton

Lever Operated

Detend lever operated

Foot pedal
Mechanical Operated

Plunger

Roller operated

Idle return, roller

Spring return

Spring centred
Piloted Operated

Direct pneumatic actuation

Indirect pneumatic actuation (piloted)

Electrical Operated

Single solenoid operation

Double solenoid operation

Double solenoid and pilot operation with manual override
2/2 Directional Control Valve (On-Off Valve)
2/2 Directional Control Valve (On-Off Valve)

The 2/2-way valve has two ports and two positions (open, closed). It is rarely used except as an on-off valve, since its only function is to enable signal flow through and cannot release the air to atmosphere once in the closed position in contrast to the 3/2-way valve. The 2/2-way valve is normally of the ball seat construction. This valve can be operated either manually, mechanically or pneumatically.

3/2 Directional Control Valve
3/2 Directional control Valve
3/2 Directional Control Valve

The valve shown here is constructed on the disc seat principle. The sealing is simple but effective. The response time is short and a small movement results in a large cross-sectional area being available for air flow. Like the ball seat valves, they are insensitive to dirt and thus have a long service life. The 3/2-way valves are used for controls employing single-acting cylinders or for generating signals supplied to control elements.
3/2 Directional control Valve

3/2 Directional control Valve
3/2 Directional control Valve

3/2 directional control valve, normally closed, roller actuated, spring return, poppet valve, overlap free
The construction of the valve is simple. Actuation is effected by displacing the grip sleeve lengthwise. *This valve is used as a shut-off valve, primarily for the pressurising and exhausting of control systems or system components.*
In the actuated state, connection 1 and 2 are connected and the valve is switched to flow. The valve is actuated either manually or mechanically. The actuation force required is dependent on the supply pressure, spring force and the friction in the valve. The actuation force limits the feasible size of the valve. The construction of the ball seat valve is very simple and compact.
4/2 Directional Control Valve

4/2 Directional Control Valve
4/2 Directional Control Valve

Actuation of the valve: When the two plungers are actuated simultaneously, 1 to 2 and 4 to 3 are closed by the first movement. By pressing the valve plungers further against the discs, opposing the reset spring force, the passages between 1 to 4 and from 2 to 3 are opened. The valve has a non-overlapping exhaust connection and is returned to its start position by the spring. The valves are used for controls employing double-acting cylinders. There are other actuating methods and types of construction available for the 4/2-way valve including push button, single air pilot, double air pilot, roller lever actuated, spool and sliding plate. In the main, the 4/2-way valve is utilised in similar roles as the 5/2-way valve.
4/3 Directional Control Valve
4/3 Directional Control Valve
4/3 Directional Control Valve

In this circuit diagram the lines of the 4/3-way valve are closed in the middle position. This enables the piston rod of a cylinder to be stopped in any position over its stroke range, although intermediate positions of the piston rod cannot be located with accuracy. Owing to the compressibility of air, another position will be assumed if the load on the piston rod changes.

Indirect Control (Piloted Operated)

Piloted valves are not actuated directly but they are controlled by a pressure signal. The main valve is actuated by the pressure of the medium to be controlled. The purposes of piloted valves are:

• Reduce the actuating force (also with large diameter).
• Minimum pressure necessary.
• Allow the use of smaller solenoid size.

(Note: the piloted valve has a longer switching time than with directly actuated valves).
3/2 directional control valve, normally open, mechanically actuated, piloted, spring return, poppet valve, not overlap free.
- Memory Function.
- Impulse Operated.
5/3 Directional Control Valve

In general the 4/2-way valve is replaced by the 5/2-way valve. The 5/2-way valve has advantages in passage construction and allows the exhaust of both extension and retraction air for cylinders to be separately controlled. The 5/2-way valve circuit carries out the same primary control functions as the 4/2-way valve circuit.
Solenoid Valves

A very common way to actuate a spool valve is by using a solenoid, illustrated in the following figure. As shown, when the electric coil (solenoid) is energized, it creates a magnetic force that pulls the armature into the coil. This causes the armature to push the spool of the valve. Solenoid switching behavior depends on excitation type.
4/2 directional control valve, solenoid actuated, spring return

Solenoid actuated

One winding
Twin windings, same direction
Twin windings, opposite direction
Solenoid Valve Electrical Characteristics

- Operating time for attraction and release.
- Supply: DC or AC.
- Power consumption: hold on power and inrush power.
- Protection methods: against accidental contact, water proof, pressure proof.
- Duty cycle (%).

DC Solenoid Characteristics

- Slower switching on and off (Self Inductance).
- Cut-out spikes.
- Smooth attraction.
- Safe against overload even with blocked armature.
- Bulkier than AC solenoid.
- Longer life.
- Resistance is equal to the ohmic resistance of the coil.
- Need freewheeling protection circuit.
AC Solenoid Characteristics

- Switching Fast and hard (due to reduced resistance at the moment of switching on, the reactance net yet having developed).
- High current drain when the armature is blocked.
- Smaller than DC solenoid.
- Eddy current and hysteresis losses.
- Total resistance consists of the ohmic resistance and reactance.
- Cannot be operate by direct current.
- Shorter life time.
- Noisy.

Dc solenoid

Ac solenoid
Air Return

The return of valve can be operated by a spring as well as by pneumatic pressure. When the return by pressure is integrated into the valve as a pneumatic feature it is known as air return.
Manual Override

Pneumatically or electrically operated valves are often equipped with a manual override. Thus operation is also possible in cases where the control energy is not available.
Valves With Differential Piston Actuation

For valves pressurized from both sides, the control can be by pistons of equal or different sizes.

Non-Return Valves (Isolating Valves)

Non-return valves are devices which preferentially stop the flow in one direction and permit flow in the opposite direction. Non-Return valves Include:

- One Way Valves (Check Valves).
- Shuttle Valve (Logic OR Valve).
- Dual Pressure Valve (Logic AND Valve).
- Quick Exhaust Valves.
- Shutoff Valves.
One Way Valve
(Check Valve)
Unlatchable Check Valve

This valve offers the possibility of canceling the check action in the blocking direction by means of a control signal applied to the additional pilot port. In this way, flow through the valve is possible in either one direction or the other.
Dual Pressure Valve (AND Valve)  
(Double Cutoff Valve)
Shuttle Valve (OR Valve)
Logic Not Valve
Quick Exhaust Valve

Quick Exhaust Valve
Shutoff Valve
Flow Control Valves

\[ Q = A \sqrt{\Delta P} \]

Flow control valves influence the volumetric flow of the compressed air in both directions. Flow Control valves Include:

- **Throttle Valves.**
  - Chock Throttle Valves.
  - Disc Throttle Valves.
- **One Way flow control valves (Check Chock Valves).**
  - Manually Adjustable.
  - Mechanically Adjustable.
Bi-Directional Chock Valves
One Way, Manually Adjustable Flow Control Valve
(Check Chock Valve)
One Way Mechanically Adjustable Flow Control Valve
Pressure Control Valves

Pressure control valves are elements which predominantly influence the pressure or are controlled by the magnitude of the pressure. They are divided into the three groups:

- Pressure regulating valve (Pressure Reduce Valve)
- Pressure limiting valve (Pressure Relief Valve)
- Pressure sequence valve (Pressure Switch).
Main components are: 1 Spring, 2 Diaphragm, 3 Valve seat for flow control, 4 Supply port, 5 Delivery port, 6 Exhaust valve seat (for regulator with exhaust)

Pressure Relief Valve

Section view and graphic symbol acc. to DIN ISO 1215 of a pressure relief valve
Pressure Relief Valve

The pressure limiting valves are used mainly as safety valves (pressure relief valves). They prevent the maximum permissible pressure in a system from being exceeded. If the maximum pressure has been reached at the valve inlet, the valve outlet is opened and the excess air pressure exhausts to atmosphere. The valve remains open until it is closed by the built-in spring after reaching the preset system pressure.

Pressure Sequence Valve
Pressure Sequence Valve

Section view and graphic symbol acc. to DIN ISO 1216 of a pressure switching valve with variable switching point
Combinational valves

Components of different control groups can be combined into the body of one unit with the features, characteristics and construction of a combination of valves.

• Time delay valves: for the delay of signals.
• 5/4-way valve: for the stopping of double-acting cylinders in any position.
• Vacuum generator with ejector: for pick and place applications
Time Delay valves

The time delay valve is a combined 3/2-way valve, one way flow control valve and 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. An accurate switch-over time is assured, if the air is clean and the pressure relatively constant.
Time Delay Valve
(Normally Open)
Signal shortening / signal switch-off

Signal lengthening
Pneumatic Proximity Sensors

With pneumatic proximity sensors the presence and absence of an object is detected by means of contactless sensing with air jet (*Flapper and Nozzle system*). When an object is present, a signal pressure change occurs, which can be further processed.

Pneumatic Proximity Sensors
Advantages

• Operational safety in dusty environments.
• Operational safety with high ambient temperature.
• Can be used in areas of explosion hazard.
• Insensitive to magnetic influences and sound waves.
• Reliable even in extreme ambient brightness and for sensing of light transparent objects where optical proximity sensors may not be suitable.
Pneumatic Proximity Sensors
Disadvantage

Since the price of a complete proximity sensors (Nozzle, pressure amplifier and pressure switch) is generally higher than that of a standard inductive, capacitive or even optical proximity sensors, pneumatic proximity sensors are used preferably for special applications where other proximity sensors are unsuitable.

Pneumatic Proximity Sensors
Types

• Back pressure sensor (Pilot Tube).
• Reflex Sensor (Reflection eye).
• Air barrier sensor (Air Gate).
Pneumatic Proximity Sensors

*For all sensors types the signal pressure generated depends on the supply pressure and the distance between the nozzle and the object.*

*Detectable distance range from 0 to 100 mm.*

---

Pneumatic Proximity Sensors

**Requirements**

- Reduce the system air pressure to a low pressure range by using pressure regulator.
- Clean and oil free air is essential.
- As the pneumatic signal is generated too weak for further evaluation, a pressure amplifier needs to be connected downstream.
- A pneumatic proximity sensor with binary electric output signal is created with the help of pneumatic to electrical converters (Electrical pressure switch).
Back Pressure Sensor (Pilot tube)

The obstructing of an air jet (Nozzle) by means of an object to be detected leads to a signal pressure build-up in the control port to the level of the supply pressure. When the nozzle is completely covered (full efficiency obtained), an output pressure will be at the same level with supply pressure. By choking the air supply and by appropriate channel shaping you can use a normal pressure level as supply pressure to the sensor. In this case, an amplification of the output is unnecessary, and at the same time, the air consumption is reduced. For this type, the sensing distance is between 0 to 0.5 mm.
Reflex Sensor (Screen Nozzle)

The reflex type sensor consists of an annular ring jet nozzle (Emitter) and central receiver nozzle arranged concentrically.

**Function:** The annular air flow causes a negative pressure in the centrally positioned receiver channel if the air flow is not unobstructed. When the object approaches, the pressure becomes positive and reaches the supply value when the nozzle is completely obstructed. The following curve represents the relationship between the output signal and the sensing distance.
Reflex Sensor (Screen Nozzle)

*For this type, the sensing distance is between (2 to 6 mm) up to 15 mm.*

For a supply pressure of (0.1 to 0.5) bar, the usable output signal pressure range is (0.5 to 2) mbar.
Example of a practical version

Graphic symbol

Control pressure vs. sensing distance
Air Barrier Sensor

By placing a ring jet nozzle (Emitter) directly opposite a receiver nozzle, it is possible to construct an air barrier which is interrupted by an object.

There are two types of air barrier sensor:

- Air barrier without pressure receiver.
- Air barrier with Pressure receiver.

For this type, the sensing distance is up to 100 mm.
Air barrier Sensor

*Without Pressure receiver:* Simple construction,
Consists of: Transmitter nozzle, normal receiver nozzle (with out pressure).

The disadvantage of this type the sensitivity to external influence (dust)

*With Pressure receiver:* In order to reduce the sensitivity to external influences, the receiver nozzle is pressurized.

Air barrier with out Pressure receiver
Air barrier with Pressure receiver

Supply pressure (1) Output pressure (signal pressure) (2)

a) Receiver nozzle
b) Emitter nozzle
Fork-shaped air barrier

Fork-shaped air barrier with pressurised receiver nozzle

Gap sensor

Gap sensor with pressurized receiver nozzle
Air Barrier Sensor

Air barrier are pressurized with low pressure (0.1 to 0.5) bar, in order to obtain a usable output signal pressure from (0.5 to 2) mbar. This signal must be amplified.
2. Dynamic Pressure Switch

In contrast to the pilot tube, in the dynamic pressure switch the backpressure channel is integrated into a 3-port 2-position directional control valve. In this way the sensing point can be designed as a simple nozzle if it is connected to the dynamic pressure switch via a pipe. The length of the connecting pipes can cause switching delays.

Properties

The advantage of the dynamic pressure switch is the possibility of using normal supply pressure and, in the case of a covered nozzle, of obtaining an output signal of equal value. A low pressure regulator and amplifier are therefore unnecessary.
7.8 Pneumatic Amplifiers

Pneumatic pressure is amplified by changing the areas. Depending on the amplification factor required, single- or two-stage types are used. The amplification factor $V$ is the ratio of the output pressure $p_A$ to the pilot pressure $p_X$.

$$V = \frac{p_A}{p_X}$$

1. Single Stage Pressure Amplifier

The pilot pressure $p_X$ acts on the pilot area $A_X$ generating an actuating force $F_X$, opposing the pressure $p$ and acting on the sealing disc area $A_D$ and the force of the spring. Depending on the ratio of the areas, an amplification factor as high as 10 can be obtained in practice.
2. Two-Stage Pressure Amplifier

These are usually designed so that low pressure air is supplied to the first stage, the second stage handling the full pressure.

Amplification factors up to $12\,000:1$ are possible.

The attainable amplification depends on the design, the supply pressure $p_1$ and the supply pressure $p_2$.

Application areas for pneumatic amplifiers are primarily the amplification of output signals of contactless sensors, amplification of pressure measurement data and of pilot tubes operating without covered nozzles.

Amplification by way of area difference

With two-stage amplifiers
- 1st stage is supplied with low pressure,
- 2nd stage with normal pressure.
7.9 Pneumatic-Electric Transducers

Pneumatic-electric transducers, also known as P/E transducers or pressure switches, are used for converting a pneumatic input signal into an electrical output signal.

1. Transducers with Fixed Switching Point
These have a fixed response pressure which depends upon the pressure range used. For transducers in the normal pressure range, it lies usually between 1 and 3 bar.

Function
A pneumatic drive system (piston, diaphragm) operates an electrical contact. Transducers are often equipped with a manual override to allow the triggering of a switching signal either for testing purposes or in case of an electrical supply failure.
2. Transducers with Adjustable Switching Point

These devices are freely adjustable within a fixed pressure range, and depending on the design and the materials of the equipment, can be used for various media.

Function

The switching force is generated by a pressure acting on an area in opposition to the force of an adjustable spring. If the pressure is greater than the spring force, it actuates one or more switch contacts.
### 5.13 Sizes of Pneumatic Valves

#### Port thread

<table>
<thead>
<tr>
<th>BSP Pipe thread</th>
<th>Major dia. (mm)</th>
<th>Metric</th>
<th>Nominal dia. $d_3$ (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>G. 1/8</td>
<td>9,7</td>
<td>M 5</td>
<td>2 – 2.7</td>
</tr>
<tr>
<td>G. 1/4</td>
<td>13,2</td>
<td>M 10 x 1</td>
<td>3 – 4</td>
</tr>
<tr>
<td>G. 3/8</td>
<td>18,7</td>
<td>M 14 x 1.5</td>
<td>6 – 7</td>
</tr>
<tr>
<td>G. 1/2</td>
<td>21</td>
<td>M 18 x 1.5</td>
<td>8 – 9</td>
</tr>
<tr>
<td>G. 3/4</td>
<td>25,5</td>
<td>M 22 x 1.5</td>
<td>12 – 13</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M 26 x 1.5</td>
<td>19 – 20</td>
</tr>
</tbody>
</table>

![Diagram](image1.png)

<table>
<thead>
<tr>
<th>Port thread</th>
<th>Flow (L/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M 5</td>
<td>60 – 180</td>
</tr>
<tr>
<td>G 1/8</td>
<td>150 – 400</td>
</tr>
<tr>
<td>G 1/4</td>
<td>600 – 1200</td>
</tr>
<tr>
<td>G 1/2</td>
<td>2000 – 4000</td>
</tr>
<tr>
<td>G 3/4</td>
<td>4500 – 8500</td>
</tr>
</tbody>
</table>
**Sizes of Pneumatic Valves**

Important criteria for the selection and application of valves are:

- Port size and nominal diameter
- Flow data

**Port Size and Nominal Diameter**

The port size is given by the thread size, normally as a BS pipe thread or a metric thread. The nominal diameter corresponds to the diameter of the minimum area through which the medium flows.

**Flow Data for Valves**

These permit a comparison of different devices as well as giving directions for practical use. These values are determined by measurement.

**Nominal Flow**

As the specifications nominal diameter/port thread are only reference values for the throughput of the valves, in practice the nominal flow or the kv value are also given.

---

**Set-up for measuring the nominal flow**