Automation and Control Lab

Experiments 5: Introduction to Pneumatics

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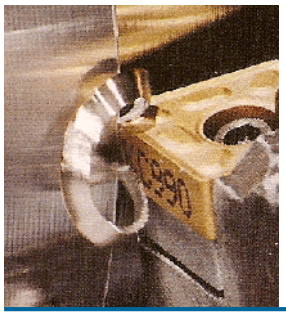
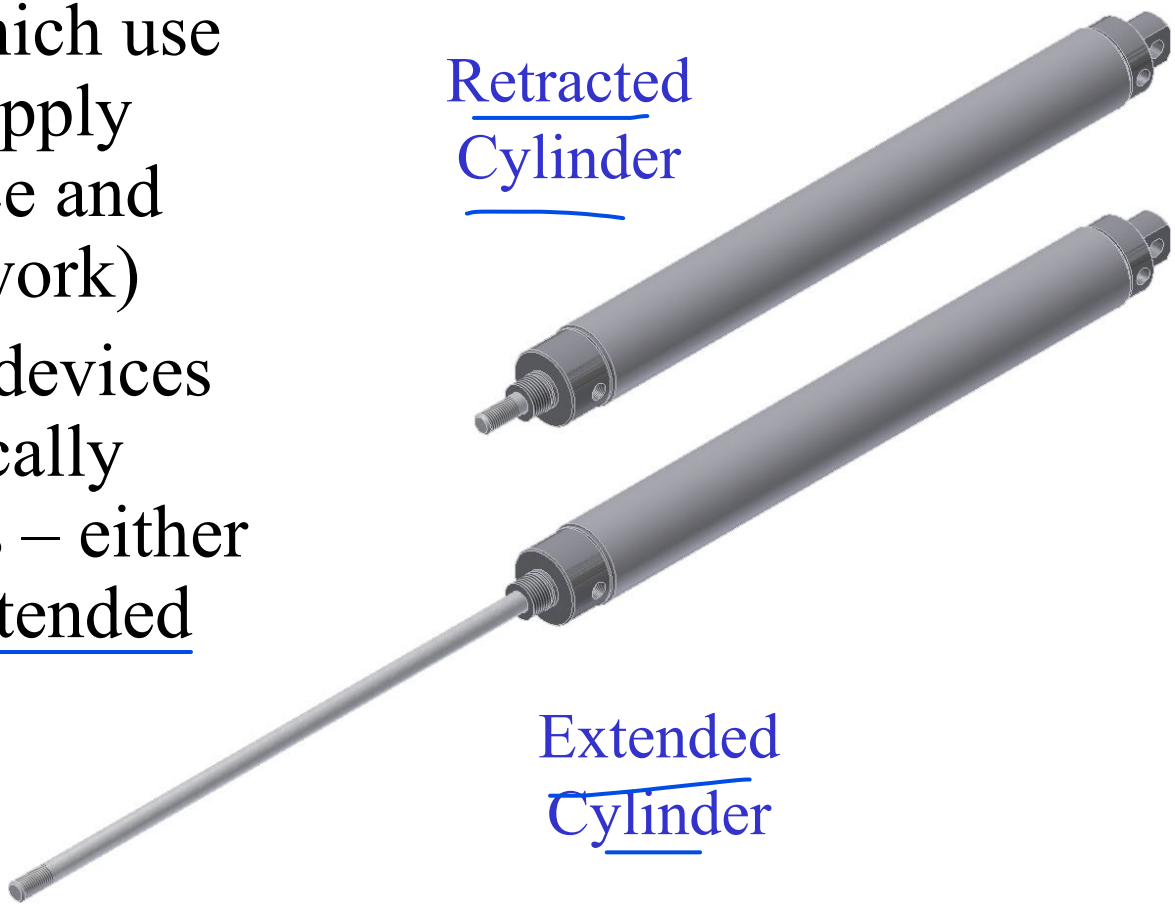
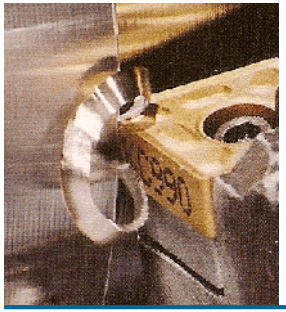


What are pneumatics

- Mechanisms which use air pressure to apply mechanical force and displacement (work)
- The pneumatic devices we use are basically binary actuators – either retracted or extended





What are pneumatics good for?

- Mechanisms requiring (2) discrete states
  - Gear shifters
  - Gripper articulation
  - Lifters
  - Brakes
- …and a significant force or displacement

Pneumatics refers to the use of compressed air or gas to generate mechanical motion or perform work. Pneumatic systems typically consist of components like compressors, valves, cylinders, and actuators that work together to convert the energy stored in compressed air into mechanical energy. These systems are widely used in various industrial and commercial applications due to their simplicity, reliability, and safety.

Applications of Pneumatics:
Industrial Automation:

Pneumatic Cylinders: Used for linear motion in machines, such as in assembly lines for pushing, pulling, lifting, or holding components.
Pneumatic Actuators: Control the movement of machine parts, such as in robotic arms or conveyor belts.
Transportation:

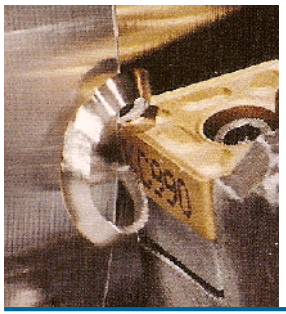
Air Brakes: Used in large vehicles like trucks and buses, where compressed air is used to activate the braking system.
Suspension Systems: Some vehicles use pneumatic suspension systems to provide a smoother ride by adjusting the suspension height using compressed air.
Construction:

Pneumatic Tools: Such as drills, jackhammers, and nail guns, which are powered by compressed air for tasks like drilling, breaking concrete, or driving nails.
Concrete Vibrators: Used to remove air bubbles and ensure a uniform mixture when pouring concrete.
Healthcare:

Dental Drills: Powered by compressed air for high-speed drilling during dental procedures.
Respiratory Devices: Like ventilators and CPAP machines, which use compressed air to assist patients with breathing.
Packaging and Material Handling:

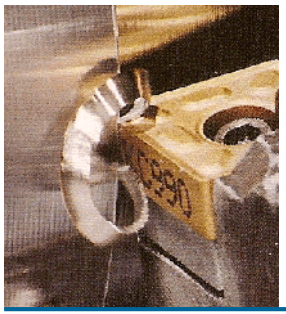
Pneumatic Conveyors: Used to move materials, such as powders or granules, through a system using compressed air.
Packing Machines: Utilize pneumatic components to fill, seal, and label packages.
Entertainment:

Pneumatic Special Effects: Used in theme parks or movies to create realistic motion effects, such as in animatronics or motion platforms.
Pneumatic Props: Used in theaters and films to simulate real-world actions, like doors slamming or objects moving.
Pneumatics is preferred in many applications due to its speed, ease of use, and ability to generate high force with relatively simple systems.



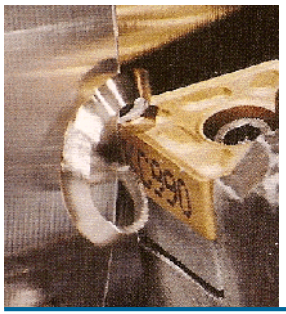
Strengths

- High durability and reliability
- Simple design and Easy to control
- High effectiveness : can apply a lot of force from a small, light package, and force is limited by air pressure and cylinder diameter
- High adaptability to harsh environment
- Safety aspects



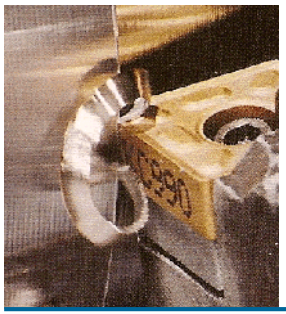
Drawbacks

- Relatively low accuracy
- Not well suited for non-binary actuation
- Low loading
- Noise
- Processing required before use.
- Uneven moving speed – As air can easily be compressed, the moving speeds of the pistons are relatively uneven.



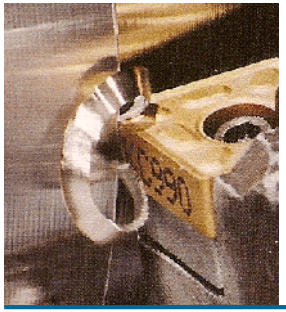
Pneumatic Actuators

- An actuator is an output device for the conversion of supply energy into useful work.
- The output signal is controlled by the control system, and the actuator responds to the control signals via the control element.
- The pneumatic actuator can be described under two groups, linear and rotary :
- Linear motion: Single-acting cylinders and Double-acting cylinders.
- •Rotary motion : Air motor, Rotary cylinders and Rotary actuators.



Single Acting cylinders

- With single-acting cylinders compressed air is applied on only one side of the piston face. The other side is open to atmosphere.
- The cylinder can produce work in only one direction.
- The return movement of the piston is effected by a built-in spring or by the application of an external force.
- The spring force of the built-in spring is designed to return the piston to its start position with a reasonably high speed under no load conditions.



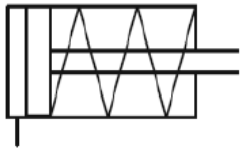
Single Acting cylinders

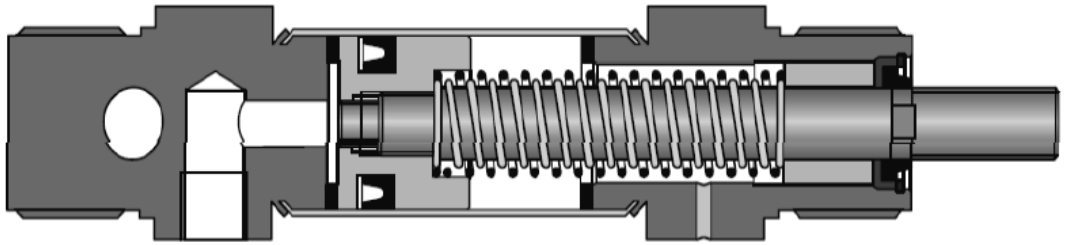
A single-acting pneumatic cylinder operates in one direction only.

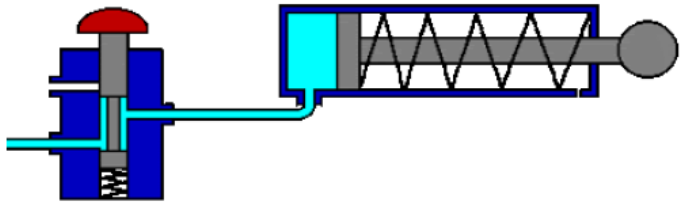
Compressed air is supplied to one side of the piston, forcing it to extend and perform work. The return stroke is achieved by an external force, typically a spring, but can also be gravity, a weight, or another mechanical means.

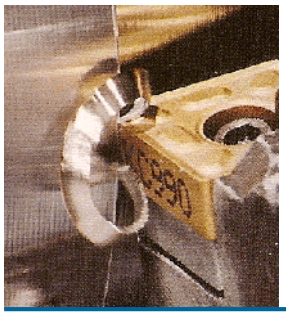
Components of a Single-Acting Cylinder
Cylinder body: The housing that contains the piston.
Piston: A movable component that seals the cylinder and transmits force.
Piston rod: Extends from one end of the piston and transmits force to the load.
Spring: Returns the piston to its original position (in most cases).
Air port: The inlet for compressed air.
Working Principle
Compressed air is supplied: Air is introduced through the air port to one side of the piston.
Piston extends: The pressure from the compressed air forces the piston to move, extending the piston rod.
Work is performed: The extended piston rod performs the desired action (e.g., lifting, pushing, clamping).
Air supply is cut off: The air supply is stopped or vented.
Return stroke: The spring (or other external force) pulls the piston and rod back to their original position.
Types of Single-Acting Cylinders
Push type: Compressed air pushes the piston out.
Pull type: Compressed air pulls the piston in.
Applications
Single-acting cylinders are suitable for applications where work is performed in one direction only, such as:

Clamping
Positioning
Marking
Light assembly
Simple lifting mechanisms
Note: While single-acting cylinders are simpler and often less expensive than double-acting cylinders, they are limited in their applications due to their unidirectional operation.





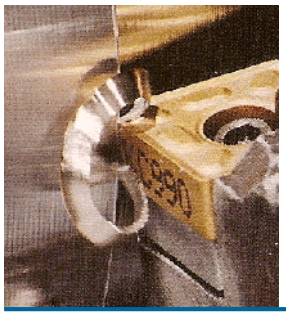




Single Acting cylinders

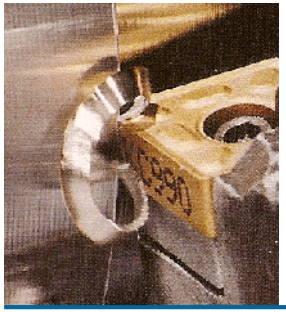
- For single-acting cylinders with built-in spring, the stroke is limited by the natural length of the spring.
- Single-acting cylinders are therefore only available in stroke lengths of up to approximately 80 mm.
- The construction and simplicity of operation of the single-acting cylinder makes it particularly suitable for compact, short stroke length cylinders for the following types of applications:

  a. Transferring
  b. Branching
  c. Clamping
  d. Ejecting

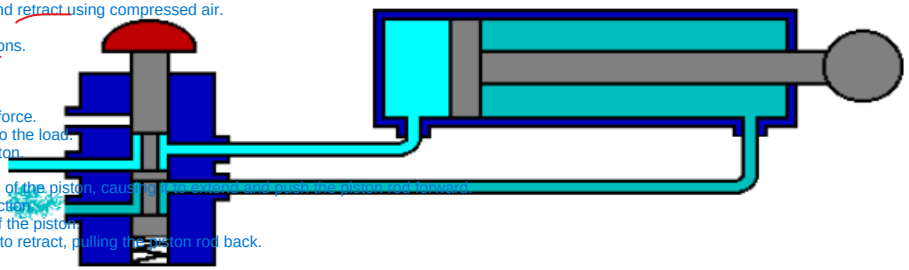


Double Acting cylinders

- The construction principle of a double-acting cylinder is similar to that of the single-acting cylinder. However, there is no return spring, and the two ports are used alternatively as supply and exhaust ports.
- The double-acting cylinder has the advantage that the cylinder is able to carry out work in both directions of motion. Thus, installation possibilities are universal.
- The force transferred by the piston rod is somewhat greater for the forward stroke than for the return stroke as the effective piston surface is reduced on the piston rod side by the cross-sectional area of the piston rod.



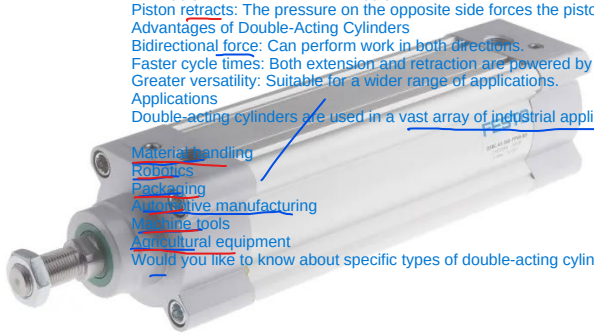
Double Acting cylinders



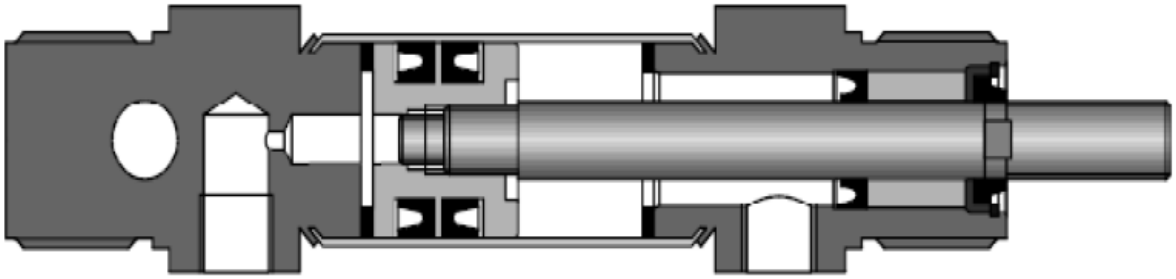
Double-Acting Cylinder Pneumatics Principle
Unlike single-acting cylinders, double-acting cylinders can extend and retract using compressed air.

This versatility makes them far more common in industrial applications.

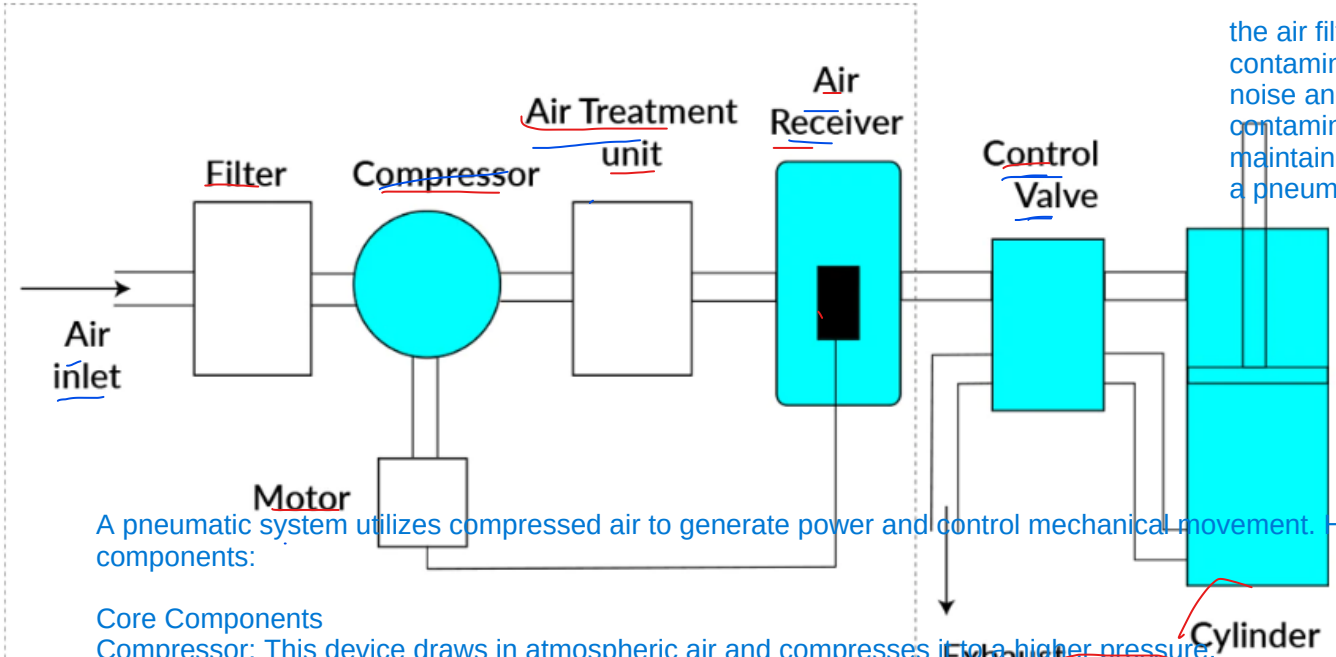
Components of a Double-Acting Cylinder
Cylinder body: The housing that contains the piston.
Piston: A movable component that seals the cylinder and transmits force.
Piston rod: Extends from one end of the piston and transmits force to the load.
Air ports: Two inlets for compressed air, one on each side of the piston.
Working Principle
Compressed air is supplied to one port: Air is introduced to one side of the piston, causing the piston and push the piston rod forward.
Work is performed: The extended piston rod performs the desired action.
Air supply is reversed: The air supply is switched to the other side of the piston.
Piston retracts: The pressure on the opposite side forces the piston to retract, pulling the piston rod back.
Advantages of Double-Acting Cylinders
Bidirectional force: Can perform work in both directions.
Faster cycle times: Both extension and retraction are powered by compressed air.
Greater versatility: Suitable for a wider range of applications.
Applications
Double-acting cylinders are used in a vast array of industrial applications, including:



Material handling
Robotics
Packaging
Automotive manufacturing
Machine tools
Agricultural equipment
Would you like to know about specific types of double-acting cylinders, such as rodless cylinders or tandem cylinders? Or perhaps you're interested in comparing single-acting and double-acting cylinders for a particular application?



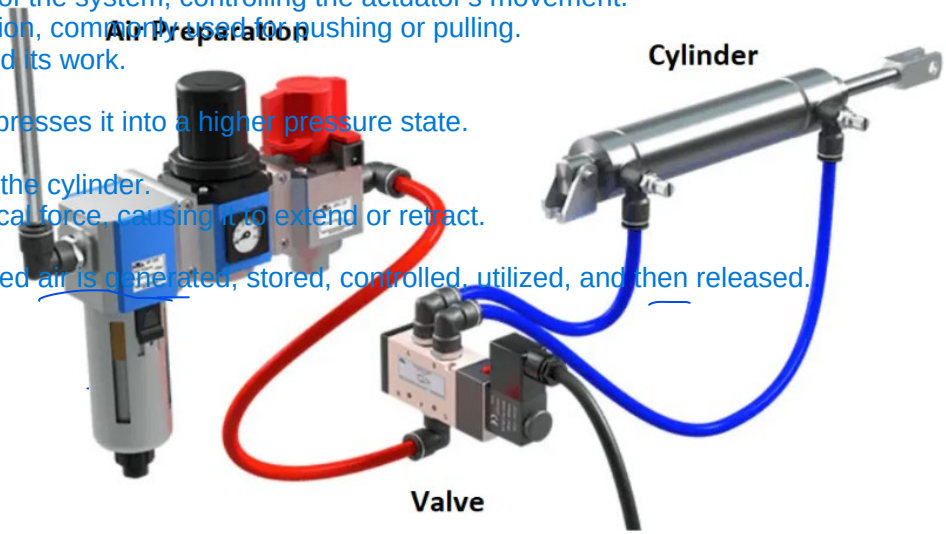
The pneumatic system

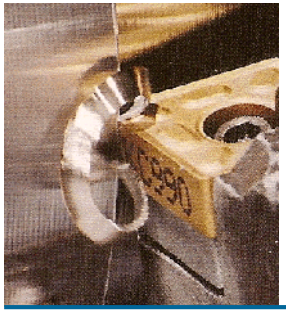


the air filter protects the system from incoming contaminants, while the exhaust helps to control noise and, in some cases, outgoing contaminants. Both components are essential for maintaining the efficiency, reliability, and safety of a pneumatic system.

A pneumatic system utilizes compressed air to generate power and control mechanical movement. Here's a brief description of its key components:

Core Components
Compressor: This device draws in atmospheric air and compresses it to a higher pressure.
Motor: The compressor is typically driven by an electric motor, although other power sources can be used.
Air Receiver: A storage tank for compressed air, ensuring a steady supply and reducing pressure fluctuations.
Control Valve: Directs the flow of compressed air to various parts of the system, controlling the actuator's movement.
Cylinder: An actuator that converts compressed air into linear motion, commonly used for pushing or pulling.
Exhaust: The outlet for spent compressed air after it has performed its work.
System Function
Compression: The compressor draws in atmospheric air and compresses it into a higher pressure state.
Storage: Compressed air is stored in the air receiver for later use.
Control: The control valve regulates the flow of compressed air to the cylinder.
Actuation: The cylinder converts the compressed air into mechanical force, causing it to extend or retract.
Exhaust: The spent air is released through the exhaust.
In essence, a pneumatic system is a closed loop where compressed air is generated, stored, controlled, utilized, and then released.





Directional Control Valves

- Directional control valves are devices which influence the path taken by an air stream.
- The directional control valve is represented by two numbers. The first number represents the number of ports, and the second number represents the number of positions.

Directional control valves are the brains of hydraulic and pneumatic systems, directing the flow of fluid (oil or air) to control the movement of actuators (cylinders or motors).

They essentially determine the path the fluid will take through the system.

Key functions of DCVs:

Start, stop, and change the direction of fluid flow: They control when and where the fluid goes.
Determine the fluid flow path: They select which components in the system will receive fluid.
DCVs are characterized by:

Number of ports: How many connections the valve has. (depending on the number of actuators)
Number of positions: How many different flow configurations the valve can create.
Center position: The valve's state when no input is applied.
Operator: How the valve is activated (manual, solenoid, pilot, etc.).
Common types of DCVs include:

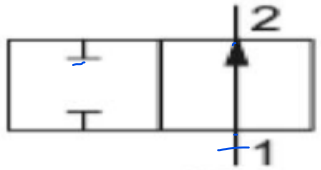
Spool valves: Most common type, using a sliding spool to control flow.
Poppet valves: Use a moving poppet to control flow, often used for high-pressure applications.
By carefully selecting and combining DCVs, engineers can create complex and precise control systems for a wide range of machinery and equipment.

Directional Control Valves

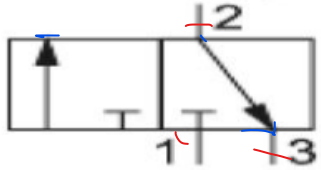
Number of ports

Number of positions

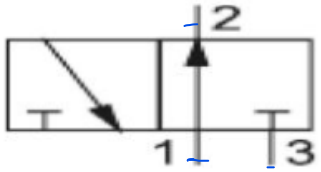
2/2 — Way directional control valve, normally open



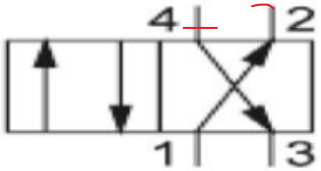
3/2 — Way directional control valve, normally closed



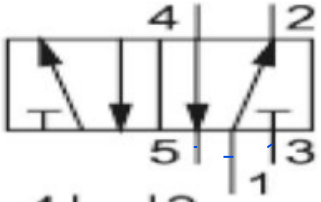
3/2 — Way directional control valve, normally open



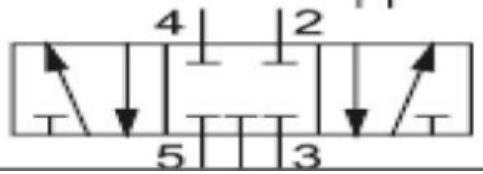
4/2 — Way directional control valve
Flow from 1 → 2 and from 4 → 3

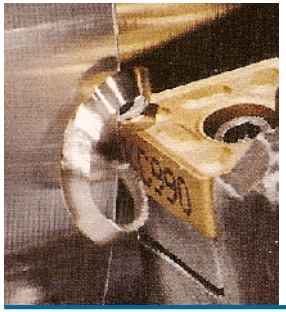


5/2 — Way directional control valve
Flow from 1 → 2 and von 4 → 5



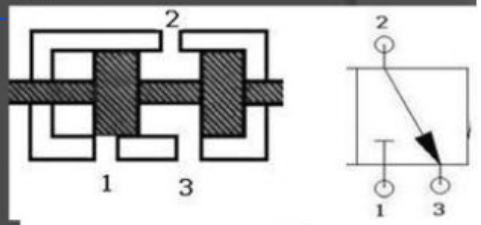
5/3 — Way directional control valve
Mid position closed

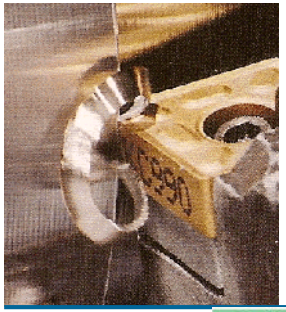




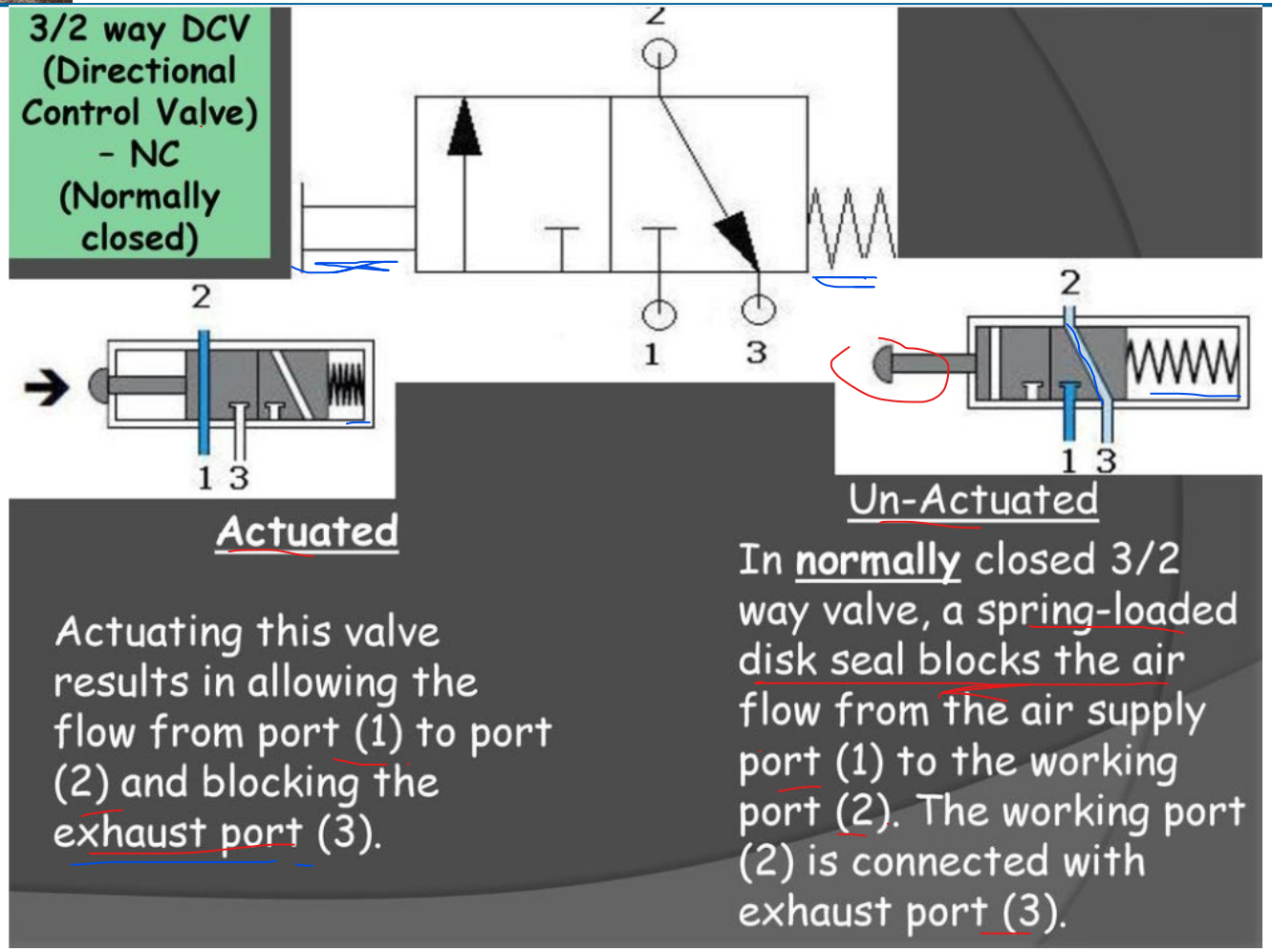
3/2 way DCV –NC (Normally Closed)

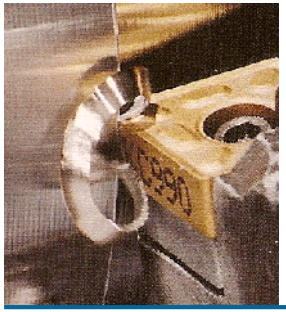
- A 3/2-way valve has 3 ports (1, 2 and 3) and 2 switching positions (before operating and after operating).
- It is represented by the normal position.
- Normally closed means that compressed air cannot flow through the valve





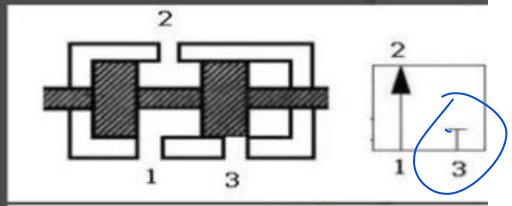
3/2 way DCV –NC (Normally Closed)

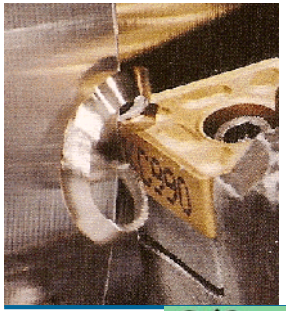




3/2 way DCV –NC (Normally Open)

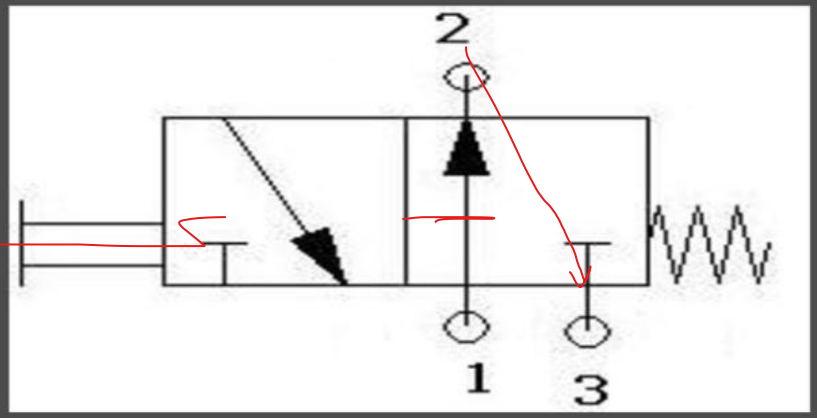
- Normally open means that compressed air flows through the valve.
- When the pushbutton is actuated the valve is closed, thus stopping the air to flow from port (1) to port (2).





3/2 way DCV –NC (Normally Open)

3/2 way DCV (Directional Control Valve) – NC (Normally closed)

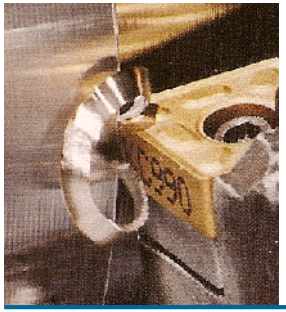


Actuated

Actuating this valve results in allowing the flow from port (2) to port (3) and blocking the supply air port (1).
Fig. (3.5.b) shows the ISO symbol of 3/2 way valve normally open (N/O) and spring reset.

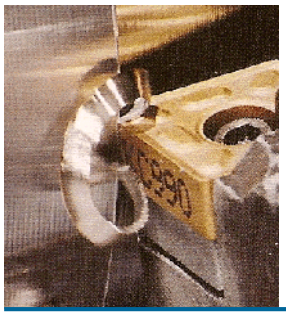
Un - actuated

- In the normally open 3/2 way valve, a spring loaded disk blocks exhaust port (3). The air supply port (1) is connected to the working port (2).



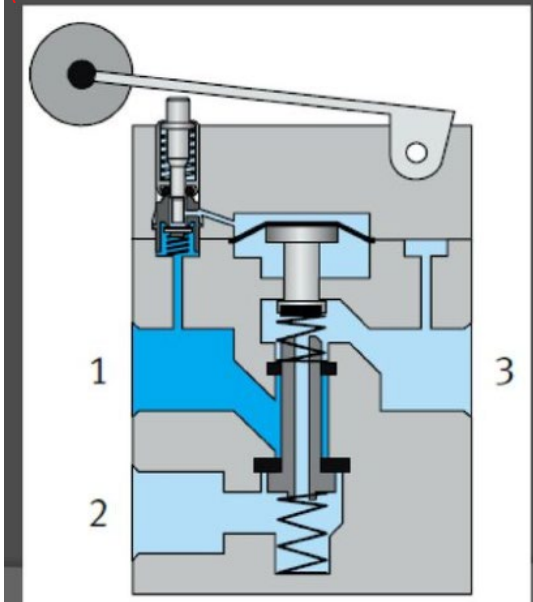
3/2 way Roller Lever Valve (N/C)

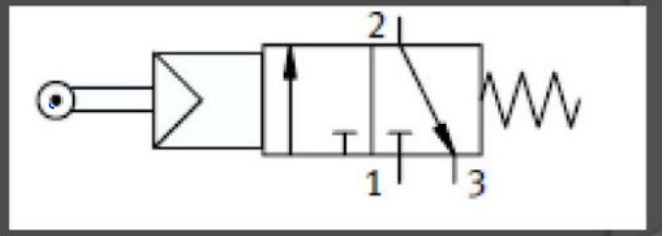
- The roller lever actuation way is considered to be one of the most important types of valve actuation that is used for automatic operation of the pneumatic cylinders.
- **It is generally known as pneumatic limit switch.**



3/2 way Roller Lever Valve (N/C)

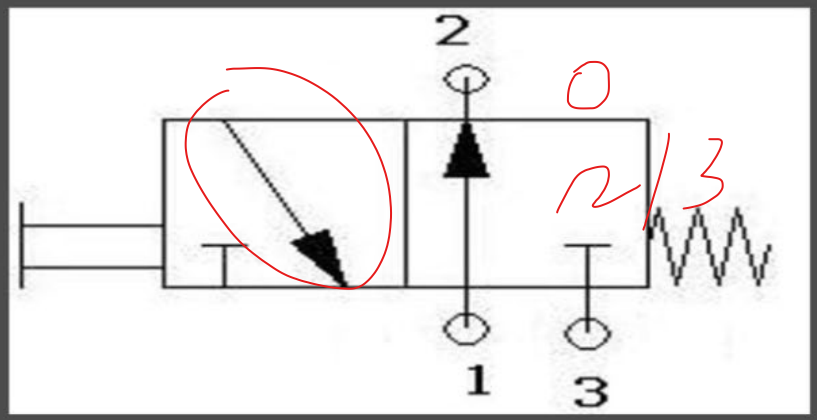
This valve is actuated by pressing the roller lever e.g. by means of cylinder trip cam. The valve is returned to the normal position via return spring after releasing the roller lever.





3/2 way DCV –NC (Normally Open)

3/2 way DCV (Directional Control Valve) – NC (Normally closed)

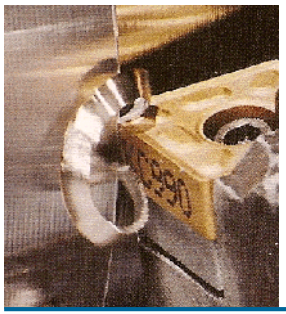


Actuated

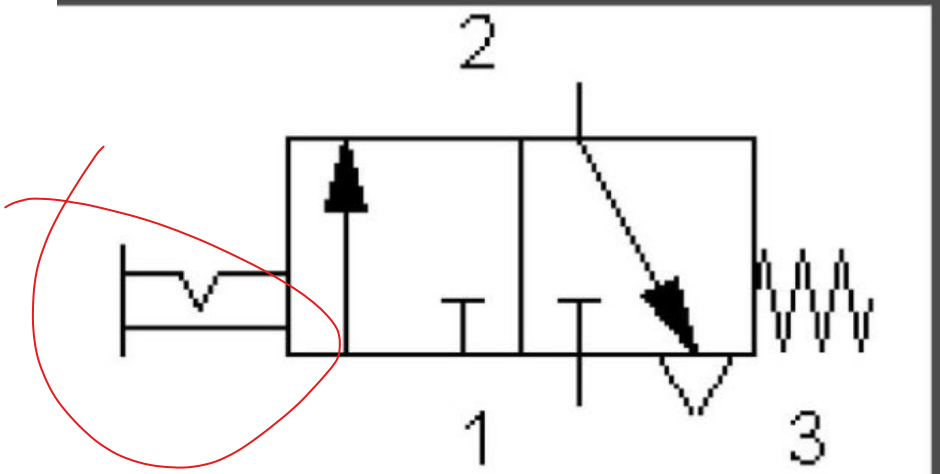
Actuating this valve results in allowing the flow from port (2) to port (3) and blocking the supply air port (1).
Fig. (3.5.b) shows the ISO symbol of 3/2 way valve normally open (N/O) and spring reset,

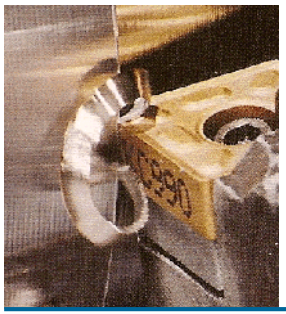
Un - actuated

- In the normally open 3/2 way valve, a spring loaded disk blocks exhaust port (3). The air supply port (1) is connected to the working port (2).



3/2 way Selector Valve





Different Types of Actuators

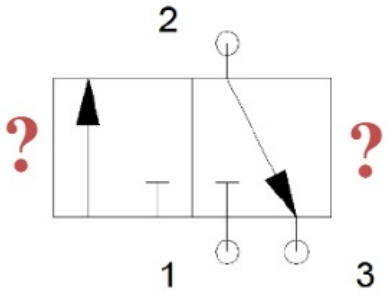
PLUNGER

PUSH BUTTON

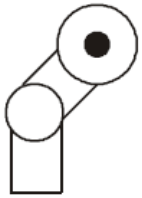
LEVER

ROLLER

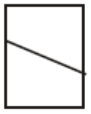
PILOT AIR



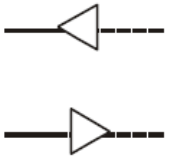
ROLLER TRIP



SOLENOID

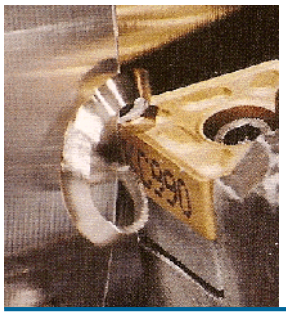


DIAPHRAGM

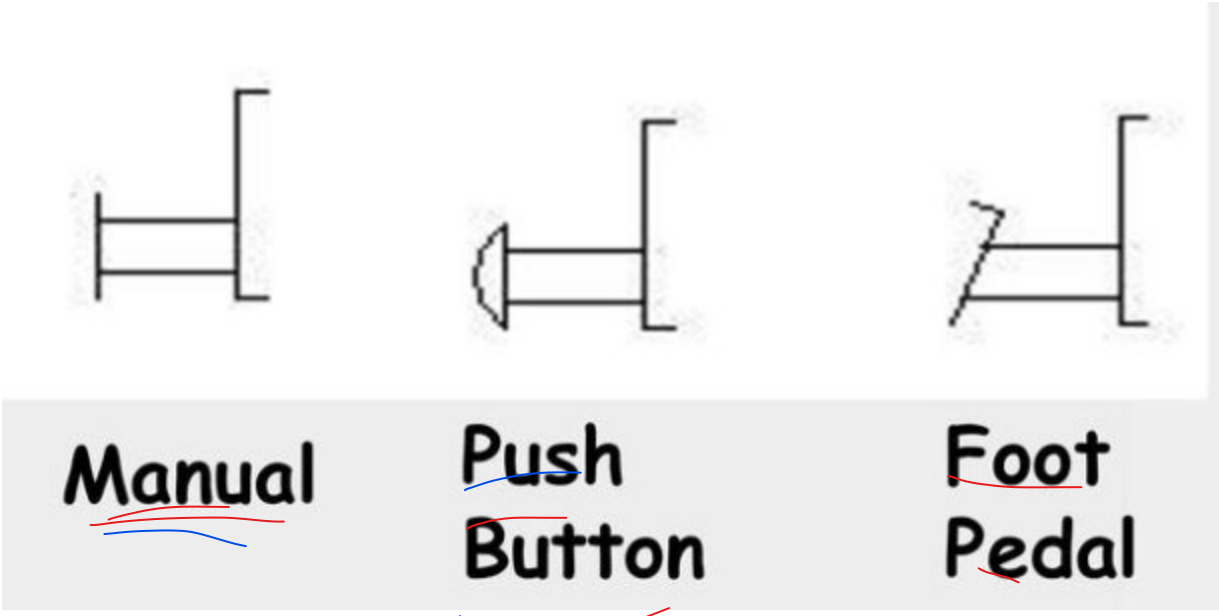


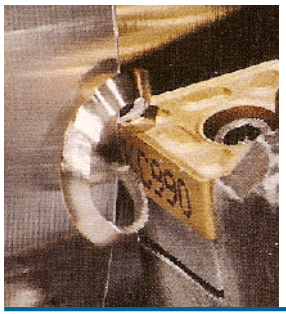
FOOT PEDAL

SPRING

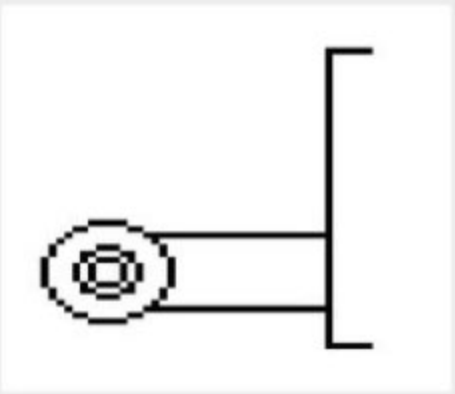


Manual Actuators

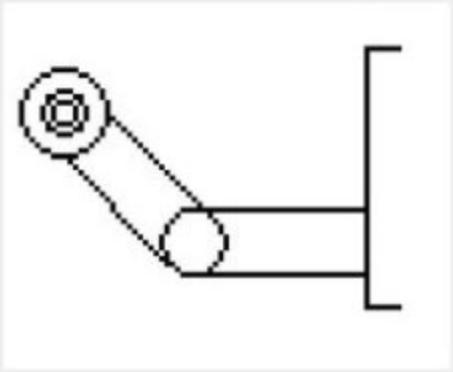




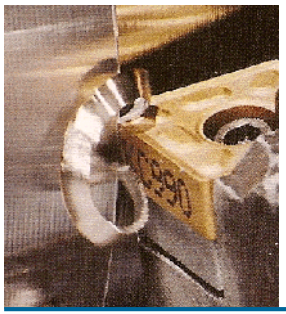
Mechanical Actuators



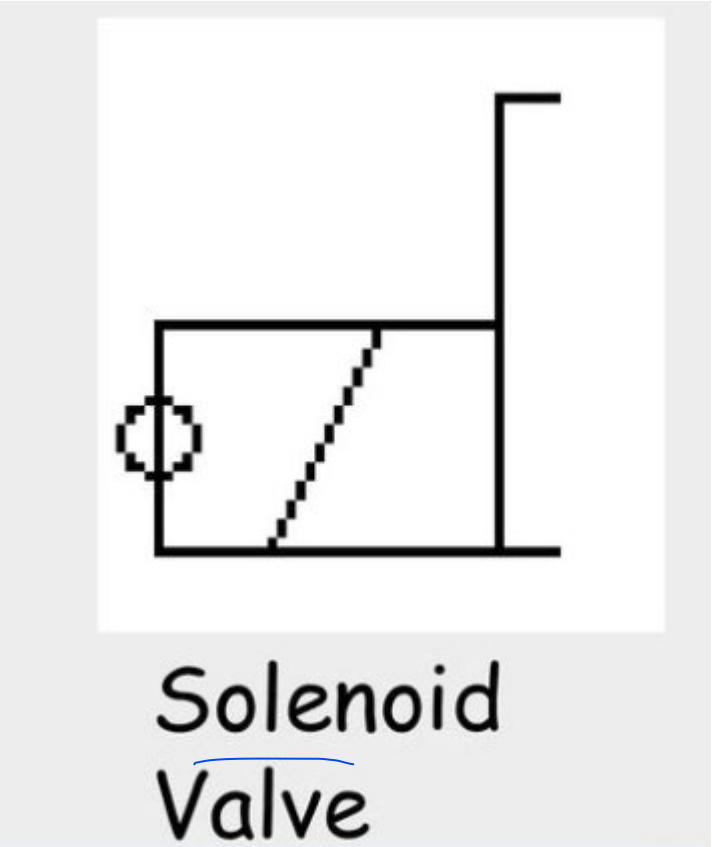
Roller

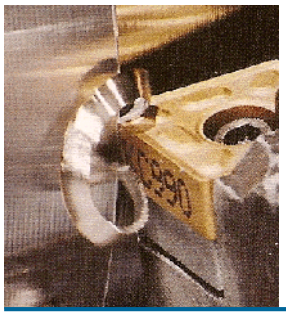


Idle
Return
Roller

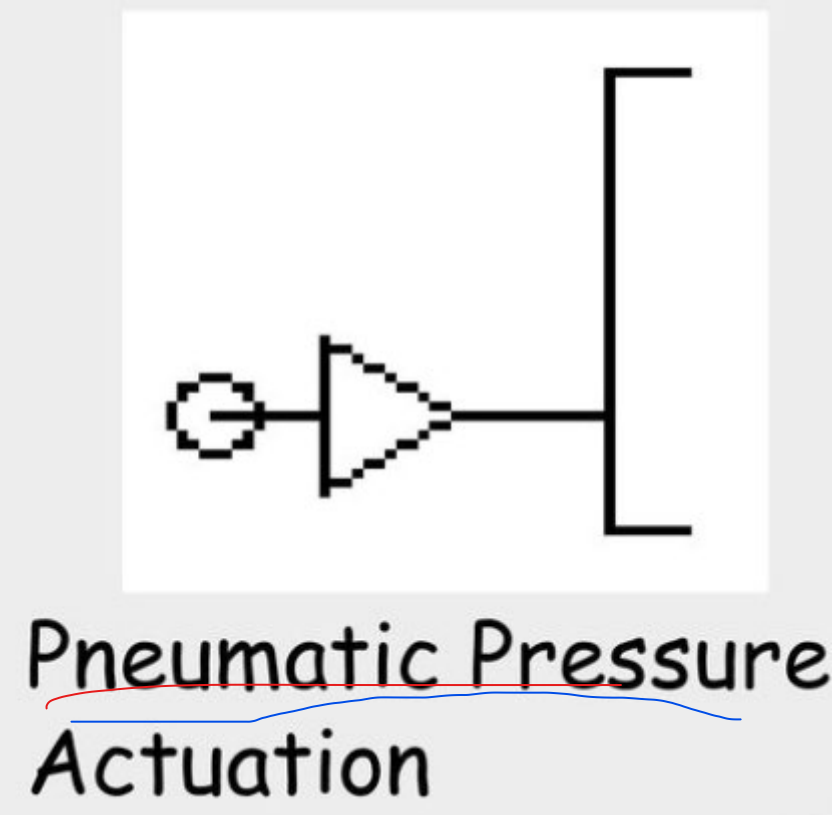


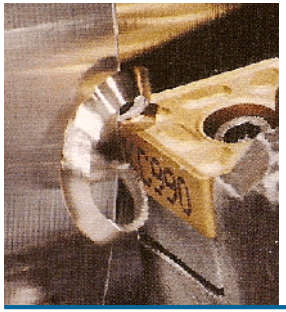
Electrical Actuators





Pneumatic Actuators

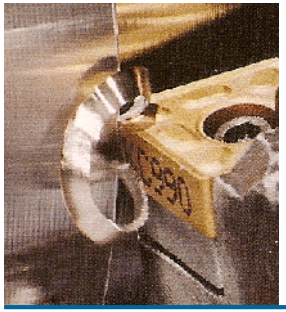




5/2 way Directional Control Valve

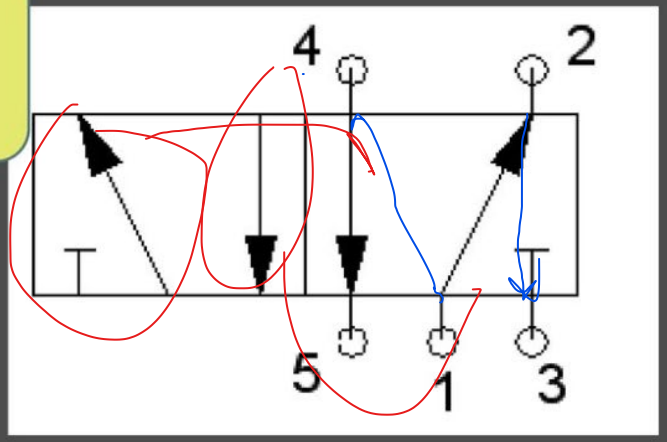
This valve contains 5 ports and 2 positions.

The 5/2 DCV could be actuated manually or by using pressure actuation (single pilot and double pilot), or by electrical actuation (solenoid).



5/2 way Directional Control Valve

5/2 way Directional Control Valve

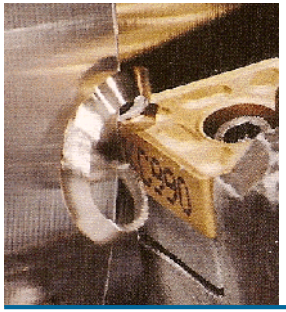


Actuated

After operating the valve by any method, the valve will be shifted to the other position and in this case, the flow will be from port (1) to port (4) while the exhaust will be from port (2) to port (3)

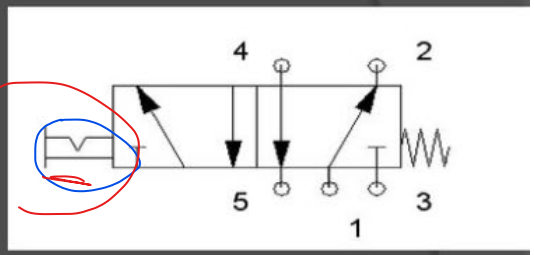
Before Actuation

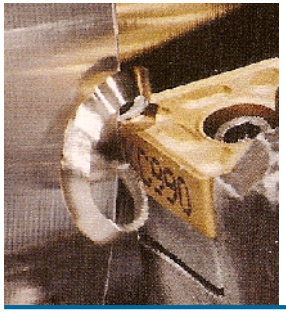
- When the 5/2-way valve is not actuated, the flow will be from port (1) to port (2) while the exhaust will be from port (4) to port (5)



5/2 way SelectorValve

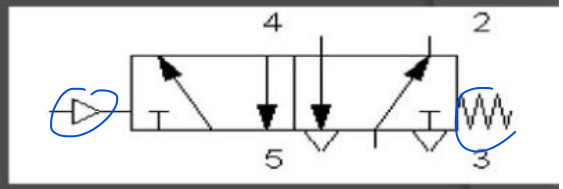
- This valve is used for manual operation, and you can control the valve by selector switch, and it is used in simple applications.

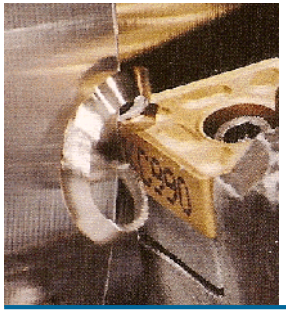




5/2 way Single PilotValve

- This valve is used for automatic operation, and you can control the valve by a pneumatic signal and a spring return.





5/2 way Double PilotValve

This valve is used for automatic operation, and you can control the valve by two pneumatic signals and this valve keeps the last position after removing the applied signal, and it is sometimes called memory valve.