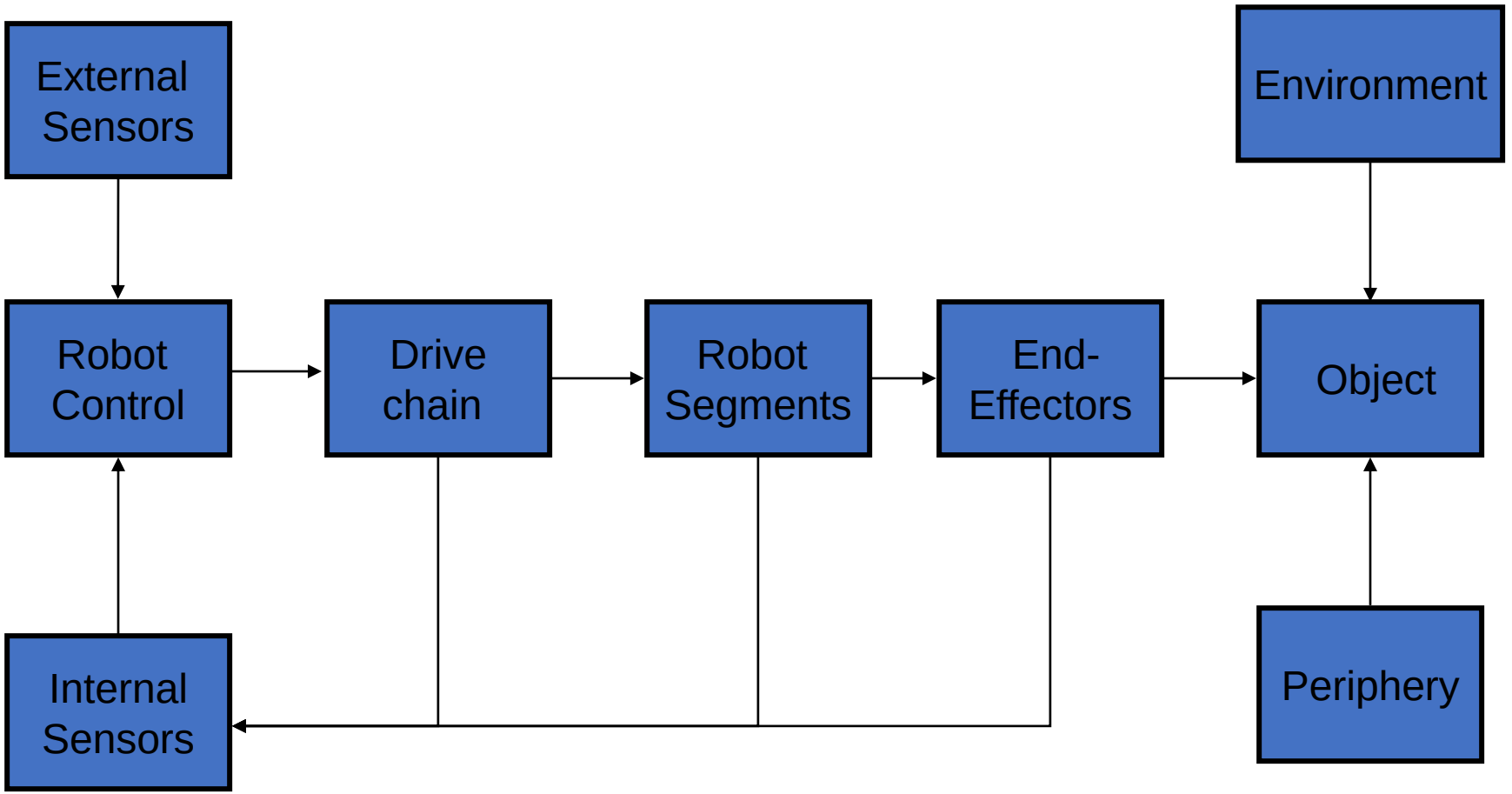
Hydraulic and Pneumatic Actuators

Robot Systems



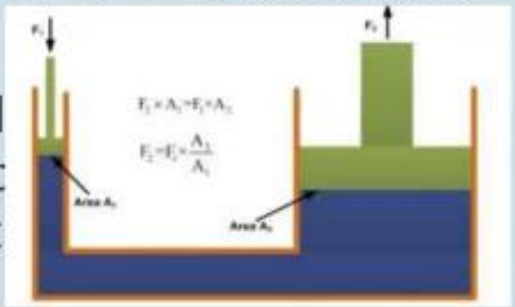
Drives

Drive principle	Scope	Benefits	Disadvantages
Pneumatic	Passive Elements, Auxiliary devices	• Cheap • Low weight	• Compressibility of the air
Hydraulics	Manipulators with very high load capacity and very large working space	• High Dynamics • High-power • Weight ratio	• Necessary Directions: Pump, hoses, Servo Valves "Dirty" Maintenance Low efficiency Warming
Electric	Standard for Industrial robot	• High Dynamics • Very generally favorable opportunity • High performance Relationship • High Speed Ratio	• Necessary gear transmission • Warming

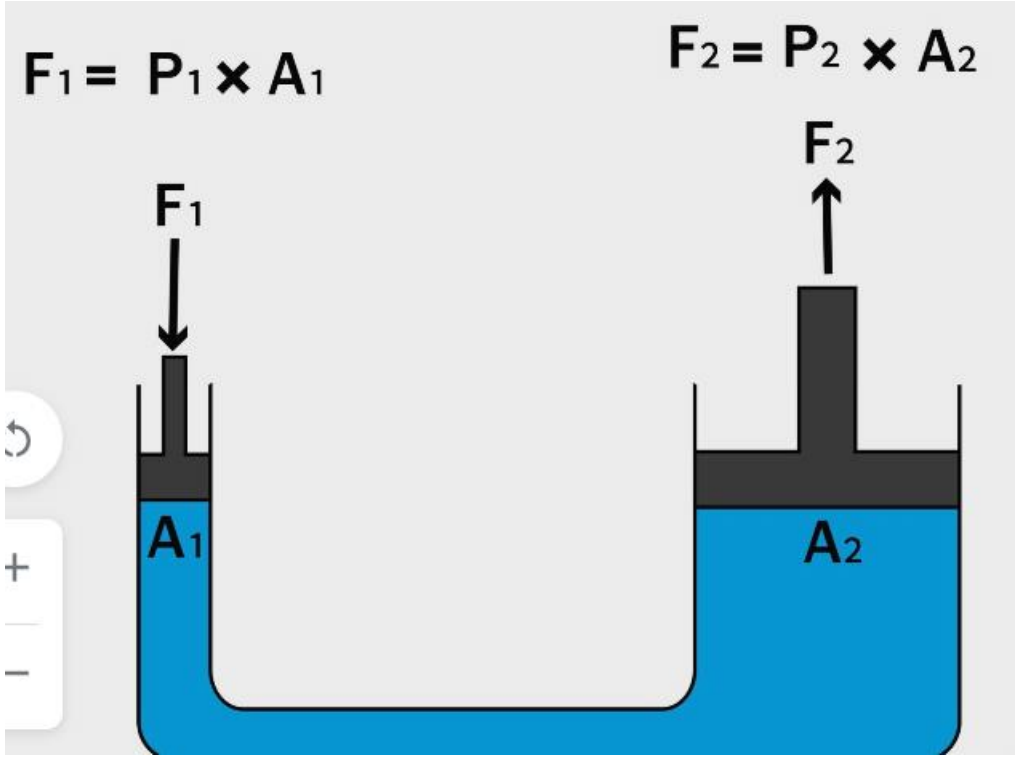
Types of Drive System

Basic Working Principle of Hydraulic/Pneumatic Drive System

- The controlled movement of parts or a controlled application of force are performed mainly by using electrical machines or diesel, petrol and steam engines as a prime mover. These prime movers can provide various movements to the objects by using some mechanical attachments like screw jack, lever, rack, and pinions etc.
- The enclosed fluids (liquids and gases) can also be used as prime movers to provide controlled motion and force to the objects or substances. The specially designed enclosed fluid systems can provide both linear as well as rotary motion. The high magnitude controlled force can also be applied by using these systems.
- This kind of enclosed fluid based systems using pressurized incompressible liquids as transmission media are called as hydraulic/pneumatic systems. They work on the principle of Pascal's law which says that the pressure in an enclosed fluid is uniform in all the directions. The Pascal's law is illustrated in the figure.
- The force given by fluid, is given by the multiplication of pressure and
  of cross-section. As pressure is same in all direction, the smaller pistc
  a smaller force, the larger piston feels a large force. So, a large force c
  generated with smaller force input by using hydraulic systems.



Pascal's Principle and Hydraulics



Pascal's law states that when there is an increase in pressure at any point in a confined fluid, there is an equal increase at every other point in the container.

The formulas that relate to this are shown below:
P1 = P2 (since the pressures are equal throughout).
Since pressure equals force per unit area, then it follows that
F1/A1 = F2/A2

Pascal's law is a principle in fluid mechanics given by Blaise Pascal that states that a pressure change at any point in a confined incompressible fluid is transmitted throughout the fluid such that the same change occurs everywhere.

Because the volume of fluid pushed down on the left side equals the volume of fluid that is lifted up on the right side, the following formula is also true **V1 = V2**

by substitution, **A1 D1 = A2 D2**

- **A** = cross sectional area
- **D** = the distance moved

A1/A2= D2/D1

This system can be thought of as a simple machine (lever), since force is multiplied. The mechanical advantage can be found by rearranging terms in the above equation to

Mechanical Advantage(IMA) = D1/D2 = A2/A1

Hydraulic Actuators

- A car makes use of a hydraulic system. If we look at the braking system of the car we see that only moderate force applied to the brake pedal is sufficient to produce force large enough to stop the car.
- The underlying principle of all hydraulic systems was first discovered by the French scientist Blaise Pascal in 1653. He stated that “if external pressure is applied to a confined fluid, then the pressure is transferred without loss to all surfaces in contact with the fluid”
- The word fluid can mean both a gas or a liquid
- Where large forces are required we can expect to find hydraulic devices (mechanical diggers on building sites, pit props in coal mines and jacks for lifting cars all use the principle of hydraulics.

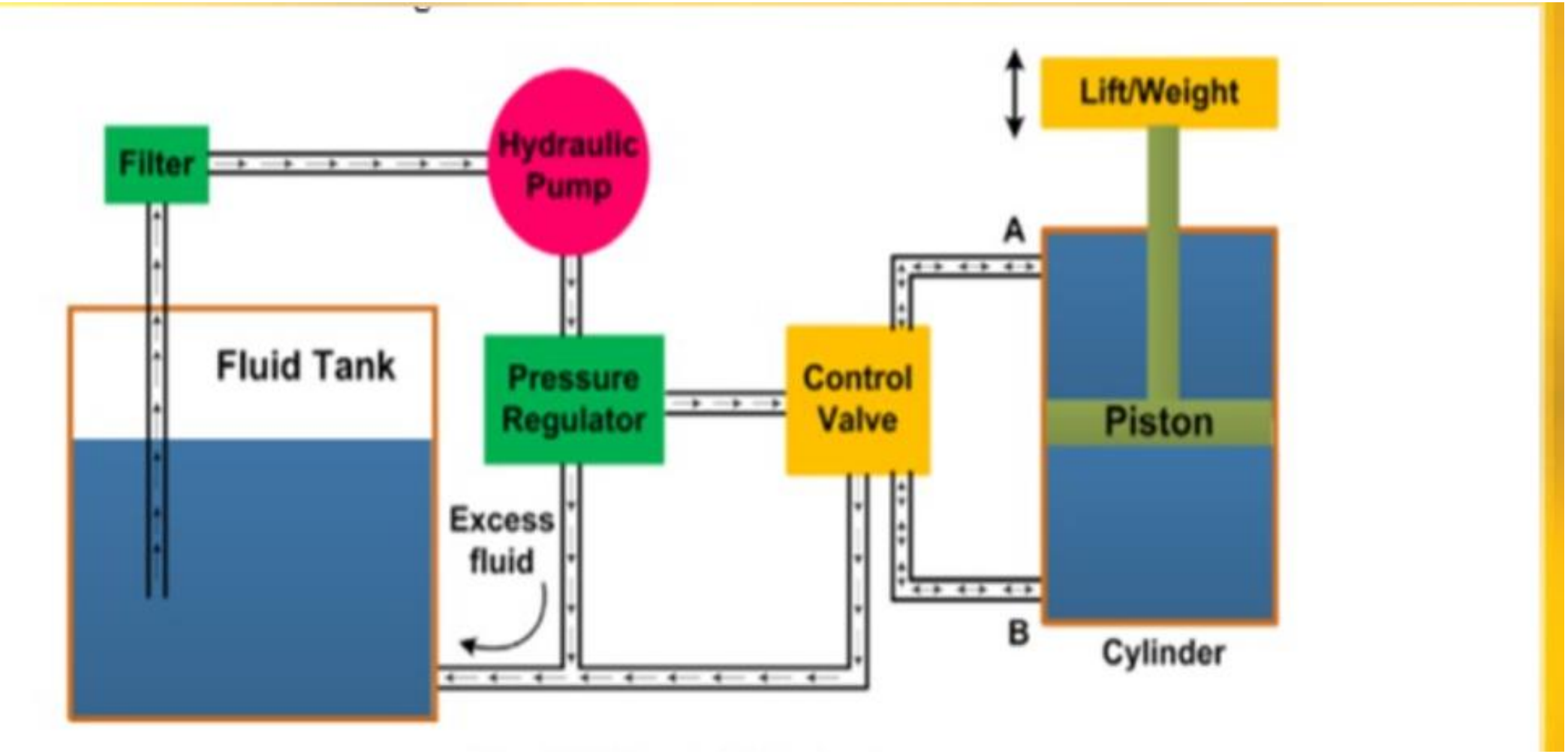
Hydraulic system

- A Hydraulic system is a power transmission system in which the transmission of power takes place through a fluid medium .
- Hydraulic system is most convenient & highly efficient .

- The major components of hydraulic system is:
  - Prime Mover
  - Pump
  - Control Valve
  - Actuators (Hydraulic Motors , Pistons)
  - Piping System
  - Fluid

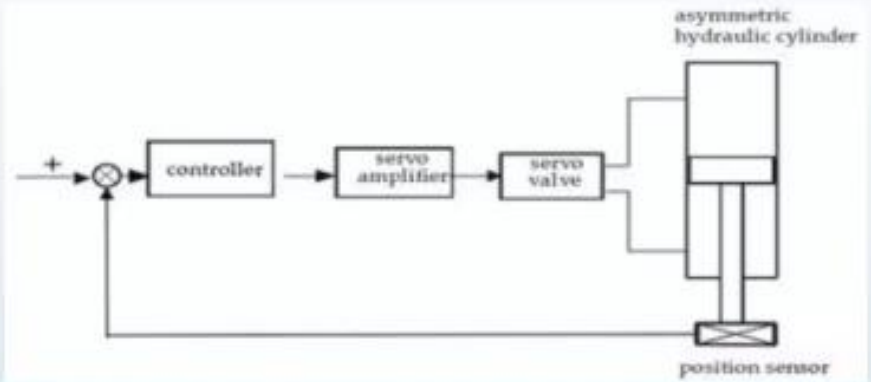
- Basic principle of a hydraulic system are:
  - Prime mover to power the system
  - Pump to move fluid
  - Reservoir to store fluid
  - Relief valve or pump compensator to control maximum system pressure
  - Filter to clean the fluid
  - Plumbing to transport fluid to components

Schematic of Hydraulic system



Hydraulic Drive System

Hydraulic systems apply pressure to fluid in order to generate power. A pump moves mechanical energy into the system by transporting fluid. Usually a hydraulic oil or synthetic lubricant, into a reservoir, where the fluid is stored and residual material including air and other moisture particles are removed.



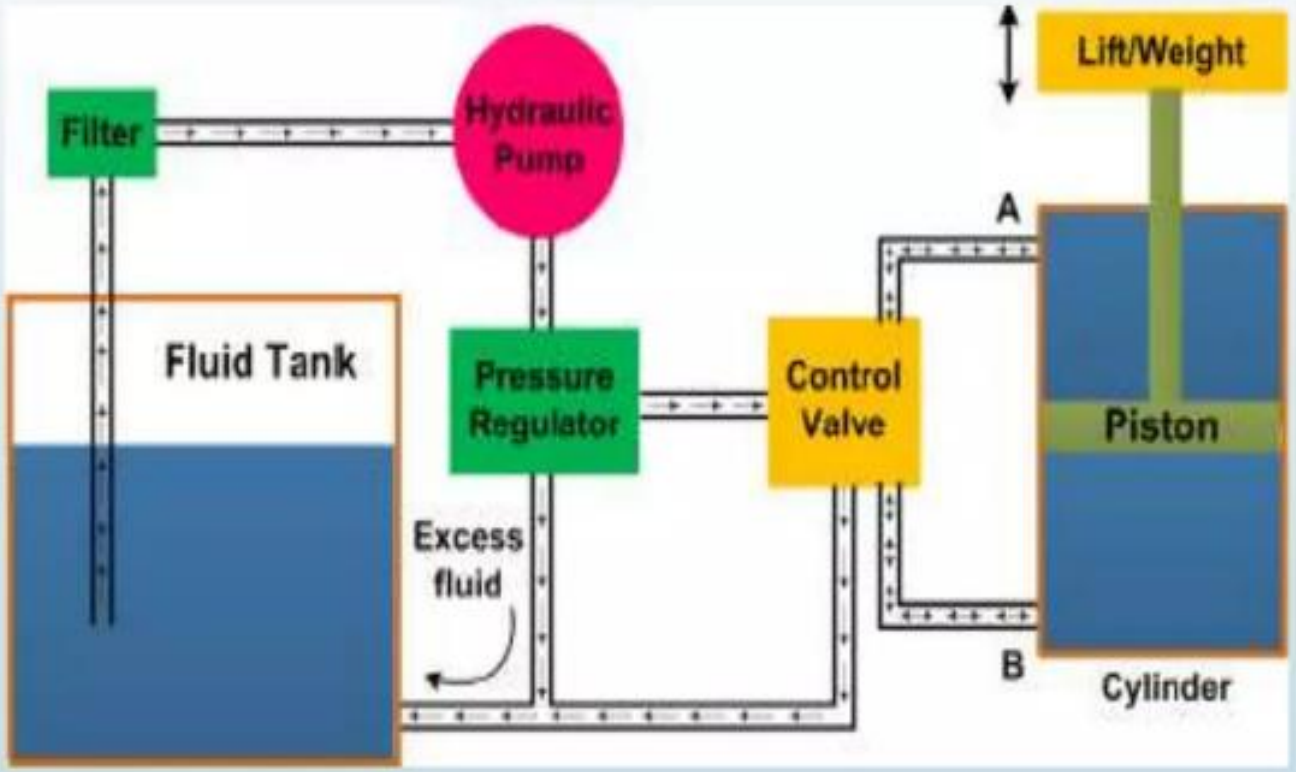
Then, pressure is exerted against one side of the reservoir, forcing the liquid through valves using electrical, manual, hydraulic, pneumatic, or mechanical methods. The fluid is forced against an actuator, such as a hydraulic motor, cylinder, or piston on the opposite side of the reservoir. Energy is transferred to the actuator and turned from hydraulic energy into mechanical energy, forcing the actuator to move.

Due to the pressure exerted through the fluid, the actuator is not able to move in the opposite direction unless the pressure is released by a system operator. If the actuator is a piston being used, for example, to raise a forklift's prongs, the prongs will remain elevated until the hydraulic pressure is released.

Hydraulic Drive System

Hydraulic systems consists a number of parts for its proper functioning. Schematic of a simple hydraulic system is shown. The system usually consists of:

- A movable piston connected to output shaft in an enclosed cylinder
- Storage tank
- Filter
- Electric pump
- Pressure regulator
- Control valve
- Leak-proof closed loop piping



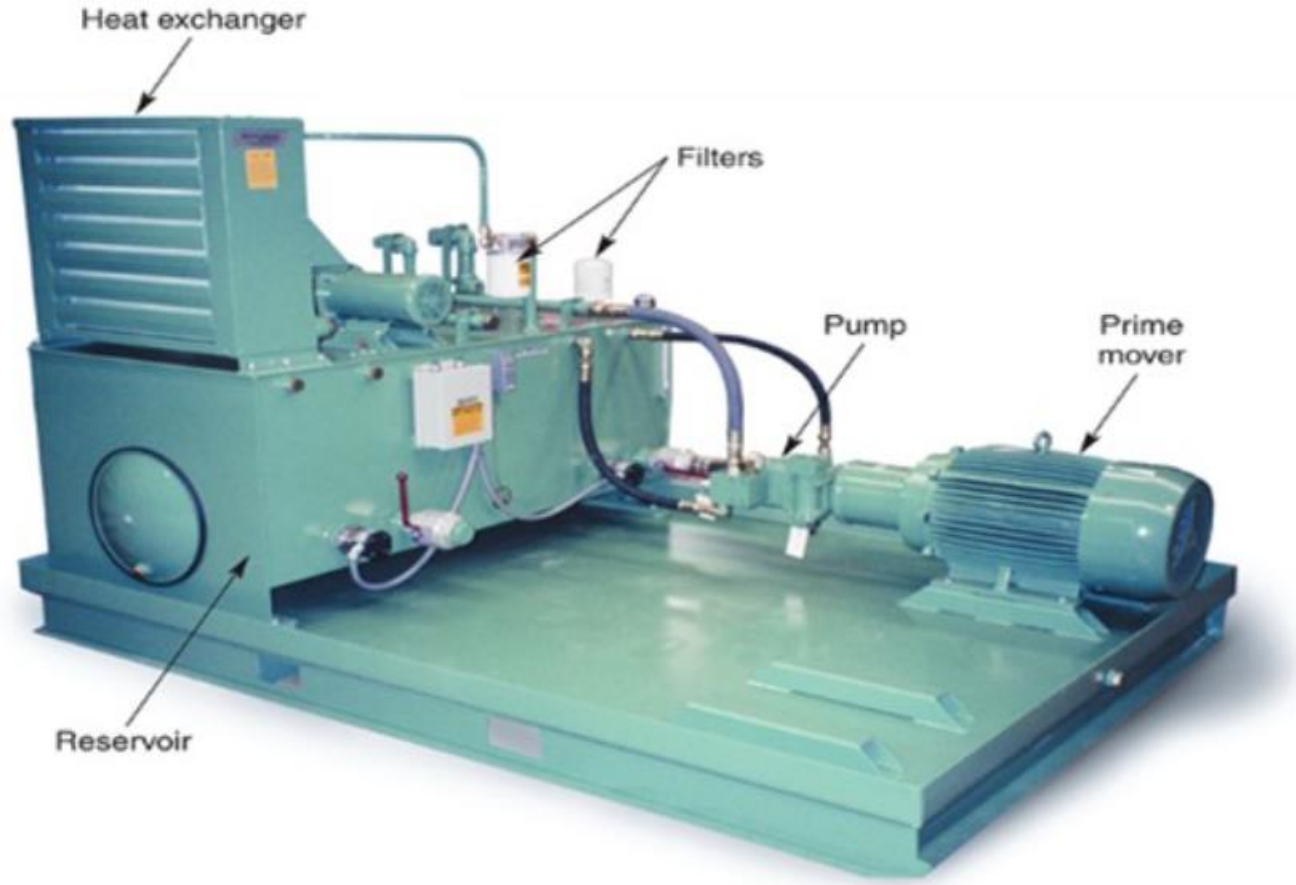
Hydraulic Drive System

- Output shaft transfers motion/force. All other parts help to control the system.
- Storage/fluid tank is a reservoir for the liquid used as a transmission media.
- Liquid used is generally high-density incompressible oil. It is filtered to remove dust or any other unwanted particles, then pumped by the hydraulic pump.
- Capacity of pump depends on system design. They generally deliver constant volume in each revolution of pump shaft. Therefore, the fluid pressure can increase indefinitely at the dead end of the piston until the system fails.
- Pressure regulator is used to avoid such circumstances which redirect the excess fluid back to the storage tank. The movement of piston is controlled by changing liquid flow from port A and port B.
- Cylinder movement is controlled by using control valve which directs fluid flow. Fluid pressure line is connected to port B to raise piston and it is connected to port A to lower down piston. The valve can also stop the fluid flow in any of the port

Hydraulic drives

- High energy concentration
- Small size
- Low weight
- No gear needed
- Leaks are detrimental
- Costs (+ power unit oil reservoir 100-150 liters)
- Friction
- Heat
- Difficult interpretation of the regulator
- Long ranges (over 3m)
- Large payload masses (over 150 kg)
- Typical oil pressure ≈ 60 bar
- Seal

Example : Basic Components of Hydraulic Power pack



- And Supporting Components Are:
  - Filters
  - Heat Exchanger
  - Accumulators
  - Measuring Gauges
  - Electrical Devices

Prime Mover

- It is a power producing device .
- Prime mover may be an elec-

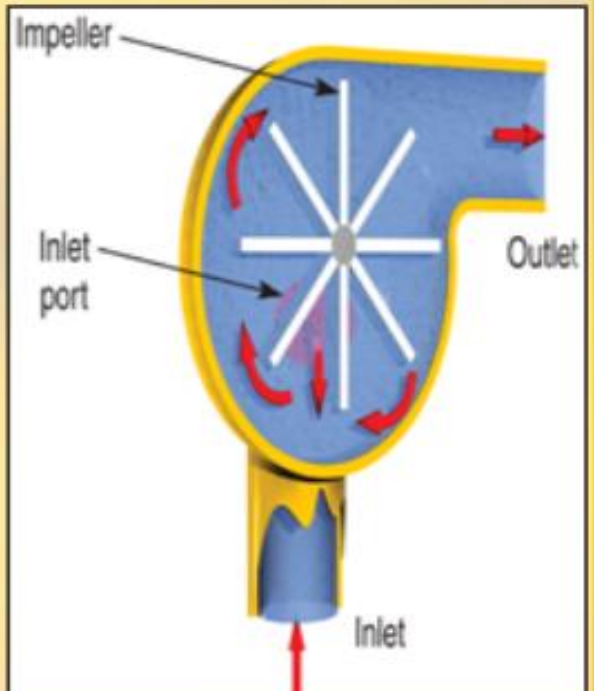
ctrical motor.

- Power developed by the

Prime mover will be transmitted & utilized .

Basic Pump

- Pump Which is driven by Prime mover .
- Convert Mechanical energy into Fluid energy .
- The output flow rate of a hydraulic pump is determined by:
  - Volume of the pumping chamber
  - Operating speed of the prime mover



Control Valves

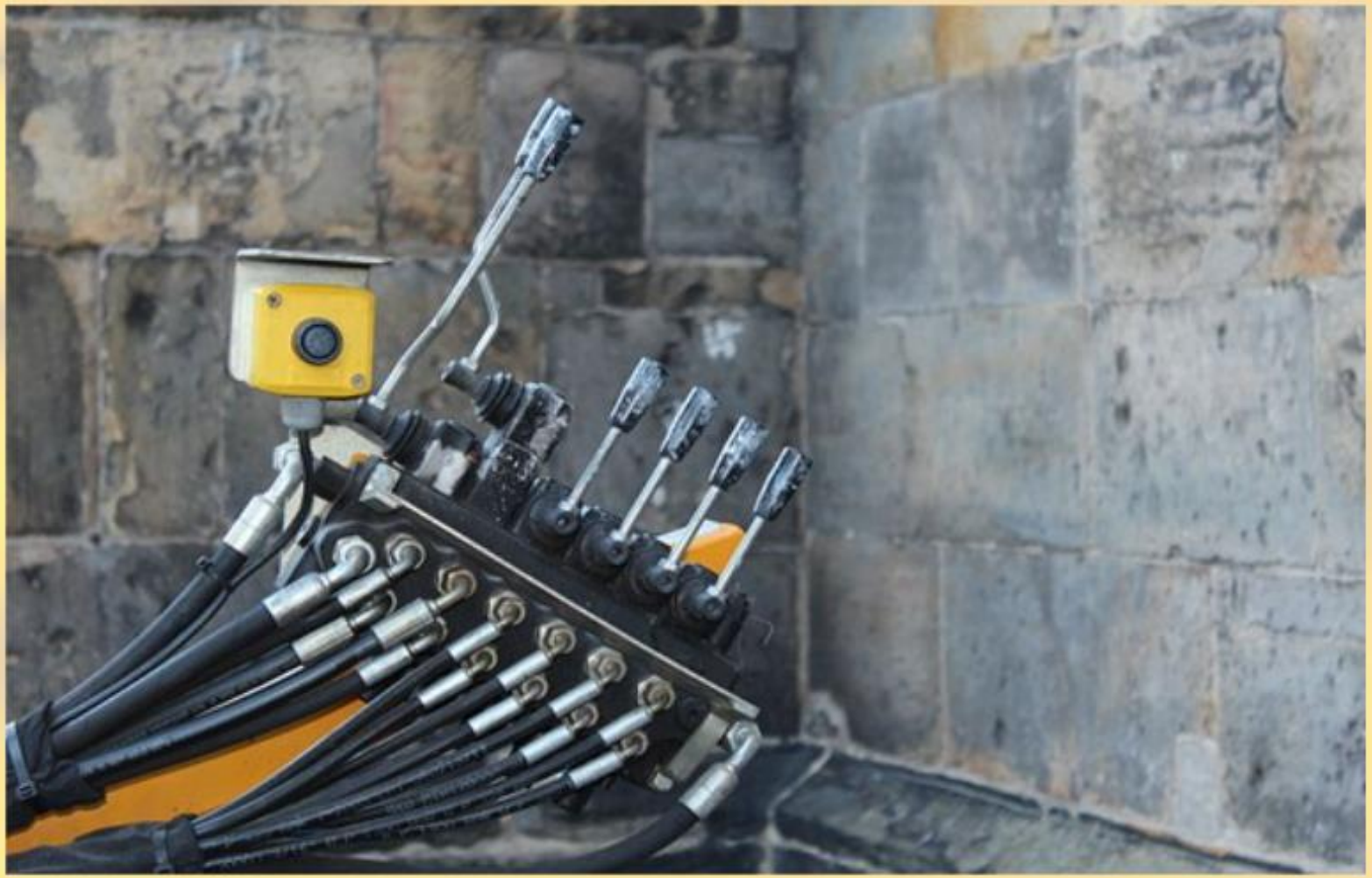
- Pressurised fluid supplied by the pump is requird to be diverted to various parts of the system .
- Classified into three types:

➢ Pressure Control Valve- Conrols the pressure .

➢ Flow Control Valve – Control rate of flow .

➢ Direction Control Valve –Control Direction of flow .

Control Valves



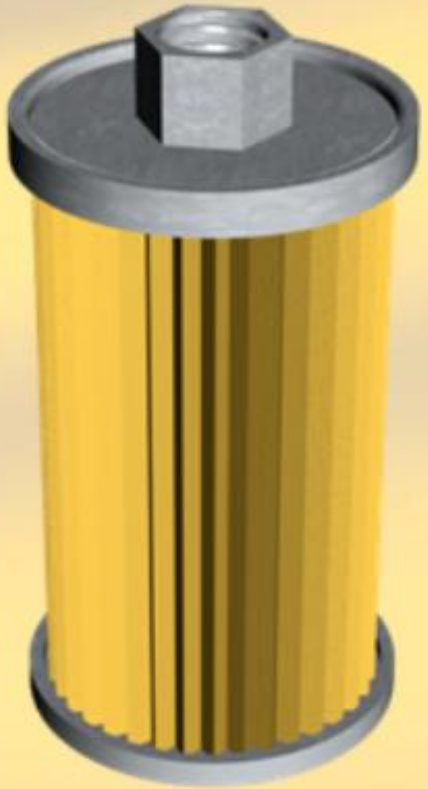
Actuators

- It converts pressurised fluid to mechanical energy .
- It may be Linear or Rotary Type
- In Linear actuator single acting or double acting cylinders are considerd .
- In Rotary type rotational motar considerd .

ACTUATORS

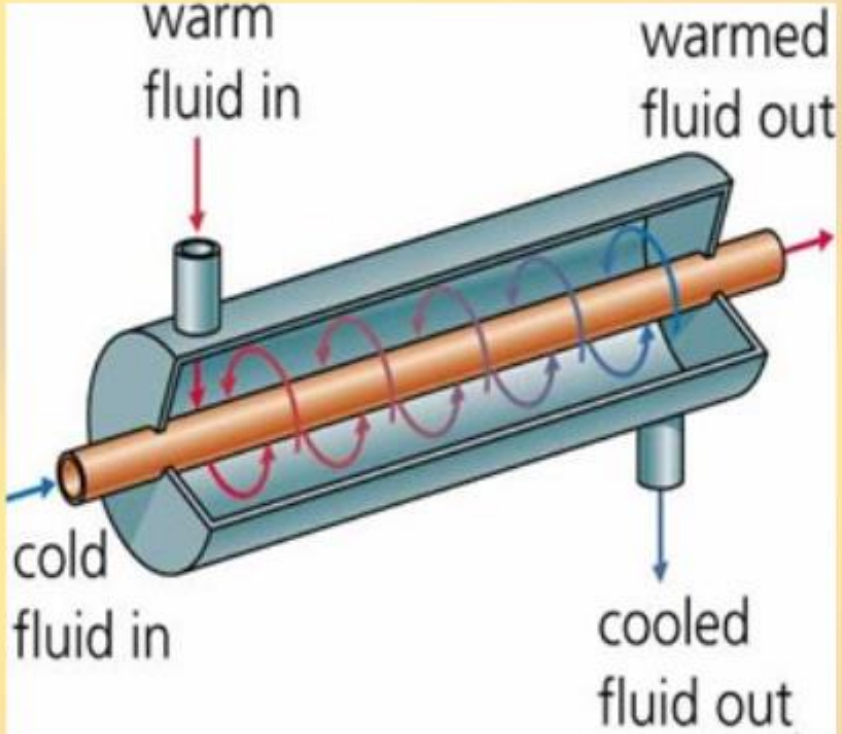
Filters

- Filters and strainers are included in a power unit to remove debris from the fluid



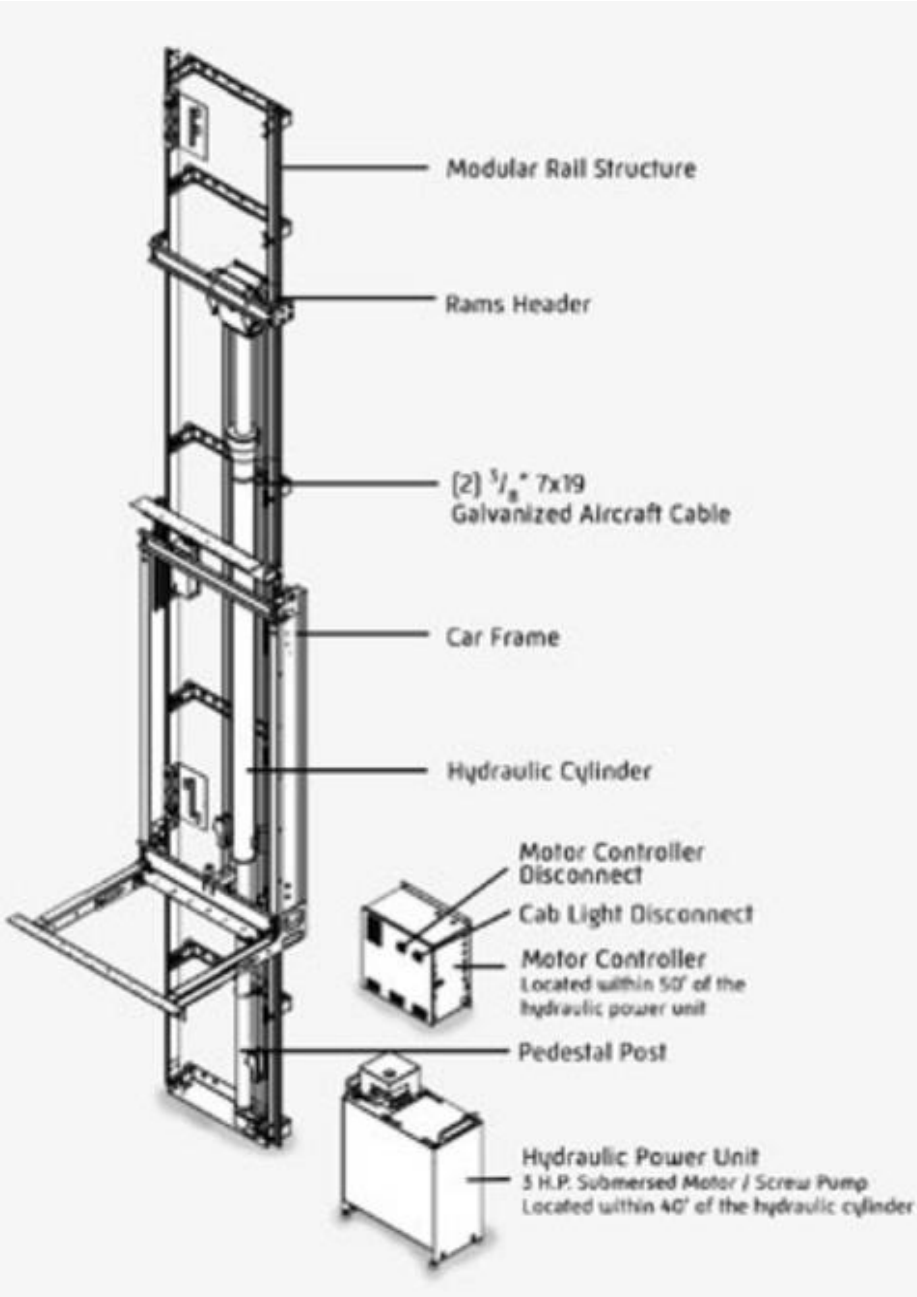
Heat Exchanger

- It is a device transferring from one medium to another .
- When hydraulic system operate in cold climates temperature is very low hence there may be requirement of heating .

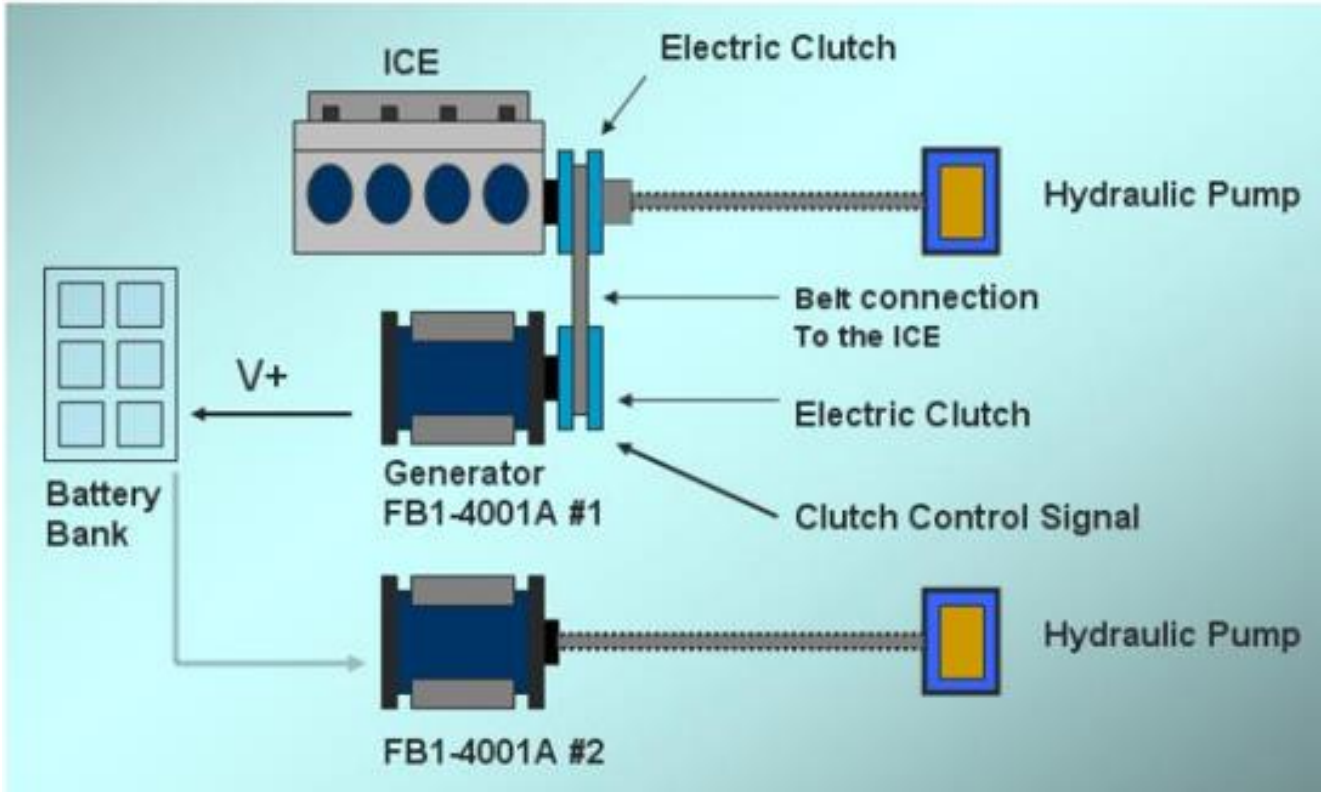


A hydraulic drive is a method of providing movement to a robot manipulator.It uses a special hydraulic fluid, usually oil-based, to transfer forces to various joints, telescoping sections, and end effectors.

The hydraulic drive consists of a power supply, one or more motors, a set of pistons and valves, and a feedback loop. The valves and pistons control the movement of the hydraulic fluid. Because the hydraulic fluid is practically incompressible, it is possible to generate large mechanical forces over small surface areas, or, conversely, to position large-area pistons with extreme accuracy.

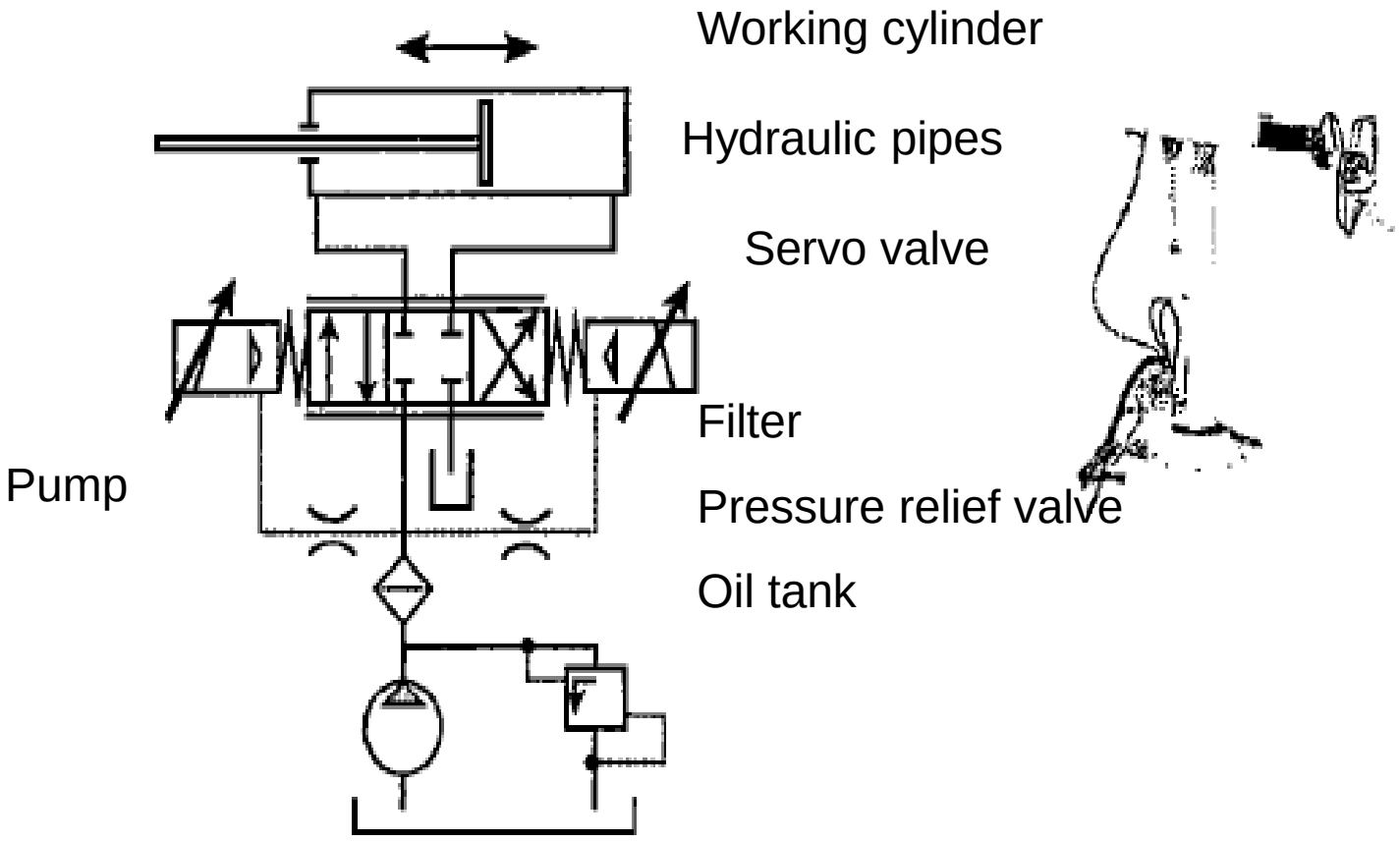


The feedback loop consists of one or more force sensors that provide error correction and ensure that the manipulator follows its intended path.



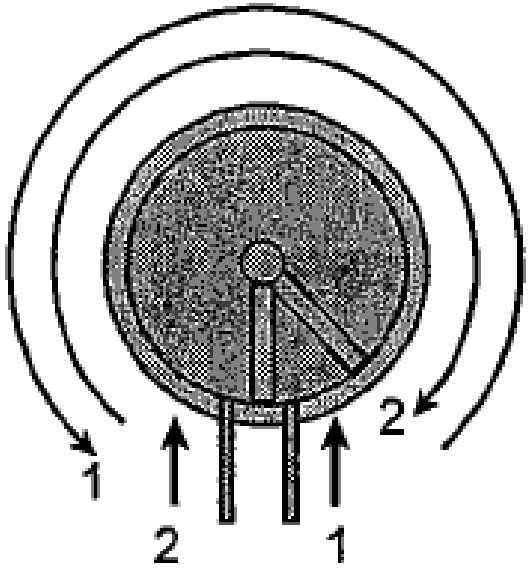
Hydraulically driven manipulators are used when motions must be rapid, precise, and repeated numerous times. Hydraulic systems are also noted for the ability to impart considerable force, so they are good for applications involving heavy lifting or the application of large amounts of pressure or torque.In addition, hydraulically driven robot manipulators resist unwanted movement in the presence of external forces.

Hydraulic Actuators - cylinder drive



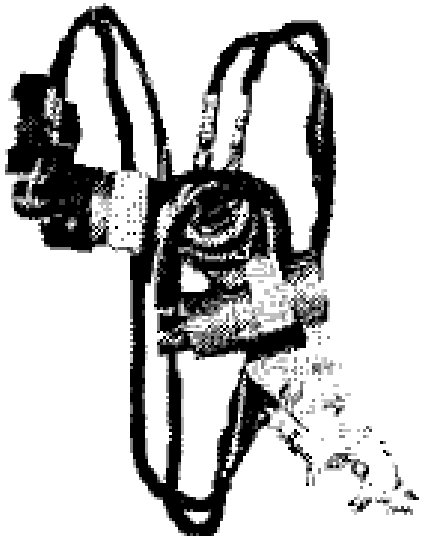
Hydraulic Actuators - rotary wing drive

1 Wing 270º - 300º



Oil pressure

2 Wing 100º - 135º



Advantages

- Higher Efficiency
- Absence of linkage
- Self lubricating & Self cooling
- Leakage is less
- Extremely smooth & jerk free motions
- Good heat transfer characteristics
- Less Noisy

Disadvantages

- Frictional losses
- Variation of viscosity due to change in temperature
- Structural weight & size of system is more
- Bursting of pipe can cause injury
- The small impurities in the hydraulic fluid can permanently damage the complete system

Hydraulic Drive System

Advantages

- Hydraulic system uses incompressible fluid which results in **higher efficiency**.
- Delivers **consistent power o/p** which is difficult in pneumatic/mechanical drive systems.
- Hydraulic systems employ high-density incompressible fluid. **Possibility of leakage is less** in a hydraulic system as compared to that in a pneumatic system. The **maintenance cost is less**.
- These systems **perform well in hot environmental conditions**.

Disadvantages

- The material of storage tank, piping, cylinder, and piston **can be corroded with the hydraulic fluid**. Therefore one must be careful while selecting materials and hydraulic fluid.
- The **structural weight and size of the system is more** which makes it unsuitable for the smaller instruments.
- The **small impurities in the hydraulic fluid can permanently damage the complete system**, therefore one should be careful and suitable filter must be installed.
- The **leakage of hydraulic fluid** is also a critical issue and suitable prevention method and seals must be adopted.

Hydraulic Drive System

Applications

Hydraulic drive system is mainly used for precise control of larger forces. The main applications of the hydraulic system can be classified into five categories:

1. Industrial: Plastic processing machinery, steel making and primary metal extraction applications, automated production lines, machine tool industries, paper industries, loaders, crushes, textile machinery, R & D equipment and robotic systems etc.

2. Mobile hydraulics: Tractors, irrigation system, earthmoving equipment, material handling equipment, commercial vehicles, tunnel boring equipment, rail equipment, building, and construction machinery and drilling rigs etc.

3. Automobiles: It is used in the systems like breaks, shock absorbers, steering system, wind shield, lift, and cleaning etc.

4. Marine applications: It mostly covers ocean-going vessels, fishing boats, and navel equipment.

5. Aerospace equipment: There are equipment and systems used for rudder control, landing gear, breaks, flight control and transmission etc. which are used in airplanes, rockets, and spaceships.

PNEUMATICS SYSTEMS

- Use air under pressure
- Is a low power system
- Transmitting medium is compressible
- Leaks are clean
- Components are lighter and less expensive as compared to electronic linear actuators
- Air is cheap

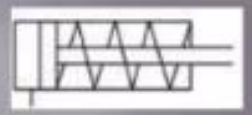
BENEFITS OF COMPRESSED AIR

- Fast
- Easily transportable
- Easily stored
- Overload safe
- Variable speed
- Variable pressure
- Clean and pollution free
- Simple construction
- Stroke setting
- Compact
- Wide operating temperature

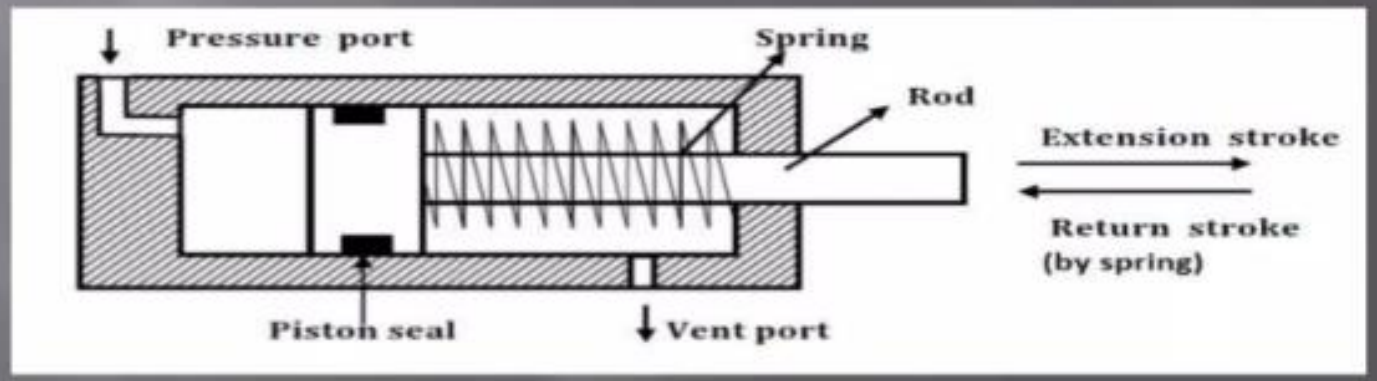
APPLICATIONS OF PNEUMATIC SYSTEMS

- Industrial robots and automation
- Operation of bus doors
- Operation of machine tools
- Operation of work holding devices
- Air tools
- Precision drills used by dentists
- Dentist chair
- Pneumatic brakes(air brakes) used by buses , trucks, trains.
- Nail gun

SINGLE ACTING PISTON

- SYMBOL : 

- Working : Single acting cylinder has one working port. Forward motion of the piston is obtained by supplying compressed air to working port. Return motion of piston is obtained by spring placed on the rod side of the cylinder. Single acting cylinders are used where force is required to be exerted only in one direction. Single acting cylinder is usually available in short stroke lengths [maximum length up to 80 mm] due to the natural length of the spring.

- 

ADVANTAGES, DISADVANTAGES AND USES

ADVANTAGES:

- Lower air consumption as compared to double acting cylinders.
- Three way valve needed instead of 4 way valve which makes it less expensive than double acting cylinders.
- Single acting cylinders require only about half the air volume consumed by a double acting cylinder for one operating cycle

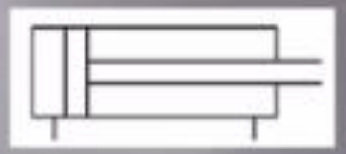
DISADVANTAGES:

- Reduction in piston thrust.
- Longer length body due to size of spring.
- Single Acting Cylinder exert force only in one direction.

USES:

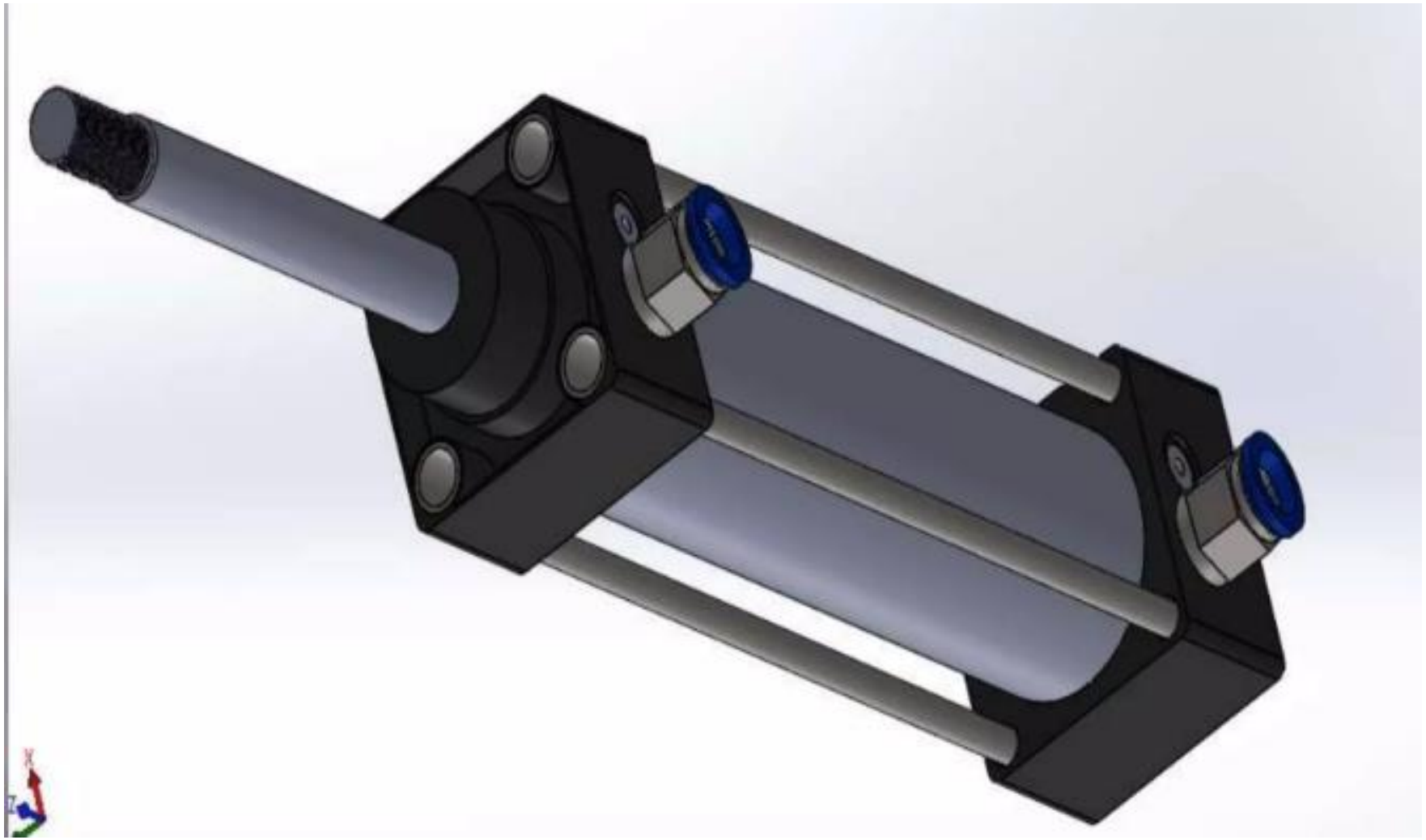
- Used in applications such as clamping, feeding, sorting, locking, ejecting, braking etc.

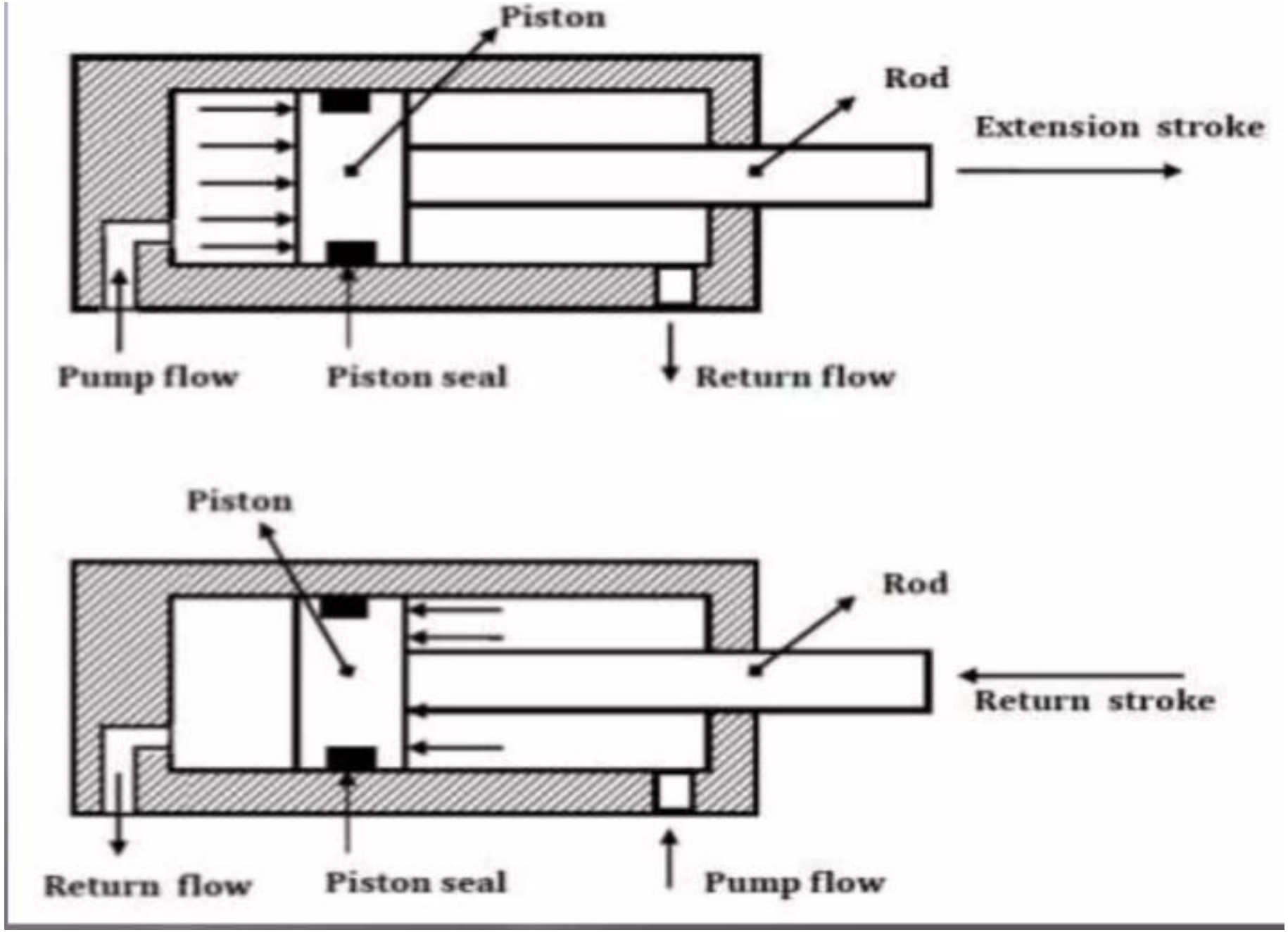
DOUBLE ACTING PISTON

- SYMBOL : 

Working:

- Double Acting Cylinders are equipped with two working ports- one on the piston side and the other on the rod side. To achieve forward motion of the cylinder, compressed air is admitted on the piston side and the rod side is connected to exhaust. During return motion supply air admitted at the rod side while the piston side volume is connected to the exhaust. Force is exerted by the piston both during forward and return motion of cylinder.




Piston
Rod
Extension stroke
Pump flow
Piston seal
Return flow
Piston
Rod
Return stroke
Return flow
Piston seal
Pump flow

Advantages of double acting cylinders over single acting cylinders

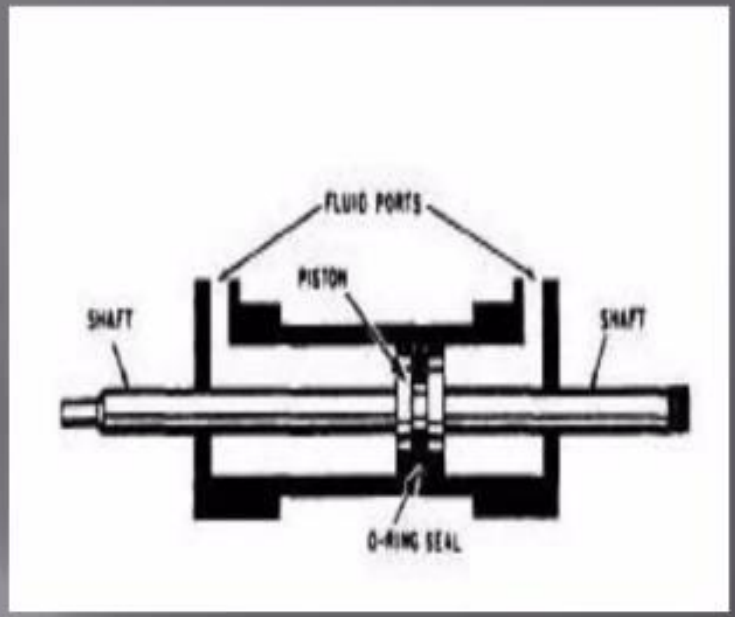
- In single acting cylinder, compressed air is fed only on one side. Hence this cylinder can produce work only in one direction. But the compressed air moves the piston in two directions in double acting cylinder, so they work in both directions
- In a single acting cylinder, the stroke length is limited by the compressed length of the spring. But in principle , the stroke length is unlimited in a double acting cylinder
- While the piston moves forward in a single acting cylinder, air has to overcome the pressure of the spring and hence some power is lost before the actual stroke of the piston starts. But this problem is not present in a double acting cylinder.
- Double rod cylinders can withstand higher side loads because they have an extra bearing one on each rod to withstand the loading.

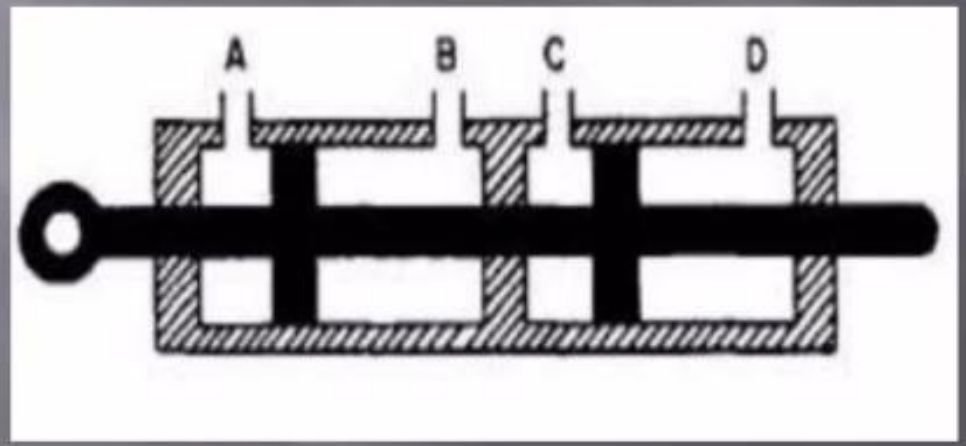
USES

- In industrial applications, single action cylinders are used ,but when speed or force are important double action cylinders are employed. Applications include opening and closing valves and doors, taking things off conveyor belts and putting things on conveyor belts. They are also used for lifting merchandise and moving merchandise around as well as for presses and punches.
- Double acting cylinders are used in automobile, motorcycle, airplane landing gear suspensions. Double acting cylinders are used in drilling, log splitters and earth moving equipment .Double acting cylinders are found in back hoes, elevators, trash compactors, garbage trucks, fork lifts, jacks and those machines in junk yards that compress old cars.
- Double rod cylinders are used when there is bending load and accurate alignment and maximum strength is required.

Tandem Cylinder

- This cylinder consists of two or more cylinder mounted in-line with pistons connected by a common piston rod.
- Rods seals are installed between cylinders to permit double acting operation of each cylinder.
- A tandem cylinder can provide amplified output force as compared to a conventional cylinder of the same bore diameter.
- In a tandem arrangement , it is possible through end to end linking of two to four cylinder of the same diameter and the same stroke length to obtain 2,3 or 4 times the thrust of a conventional cylinder.


FLUID PORTS
PISTON
SHAFT
SHAFT
O-RING SEAL


A
B
C
D

Multi-Position Cylinder

- A multi-position cylinder for 3 or 4 position consists of two separate cylinders of identical diameter, which are interconnected back to back by using a suitable mounting kit.
- The piston rod of one cylinder in the multi-position arrangement is fixed and the piston rod of the second cylinder is used for loading purpose.
- It is to be noted that if one end of the piston rod is fixed into position, the cylinder barrel will then execute the motion.

Impact Cylinder

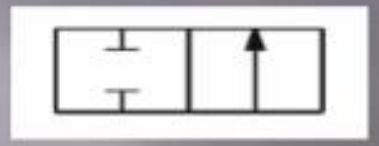
- The pressure is applied to both ports simultaneously.
- Then rapidly one port is exhausted using a quick-exhaust value.
- This accelerates the piston with high increasing velocity.
- This type of cylinders are used in many press.

DIRECTIONAL FLOW CONTROL VALVE

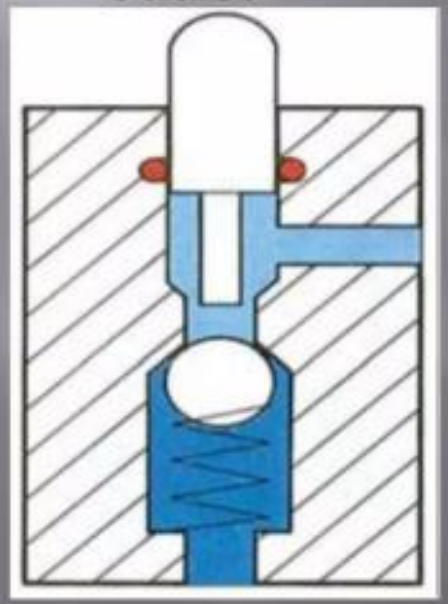
- Main purpose of direction control valve is to change the direction of air flowing through it. There are many variants of direction control valves and they are named according to the number of ports and number of position in which it can hold the pneumatic actuator. Types of the direction control valves are 2/2, 3/2, 4/2, 5/2. First number indicates *number of ports* and second number indicates *number of positions*

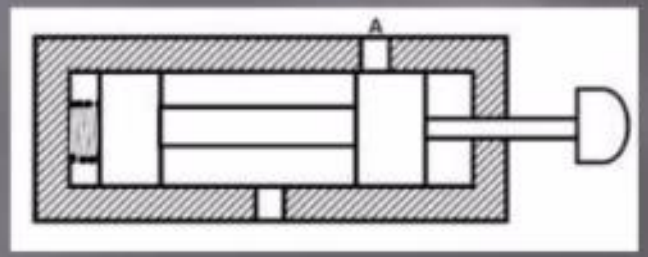
2/2 VALVE

- **SYMBOL:**

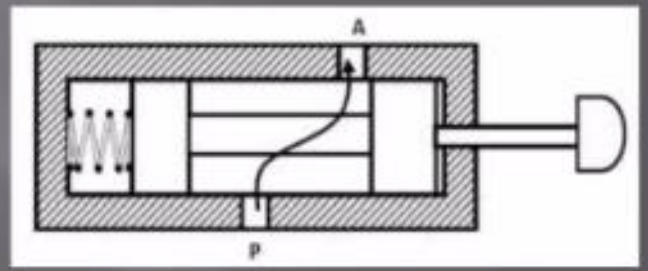


- **Working: When the shaft is pushed downwards it pushes the ball downwards thus connecting the inlet('P') and outlet('A'). As a result air flows from inlet to outlet. Similarly, in spool type of valve pushing shaft either connects or disconnects the inlet and outlet**





: initially blocked



: now unblocked

2/2 VALVE

Disadvantage:

- **It allows air to flow only in one direction.**

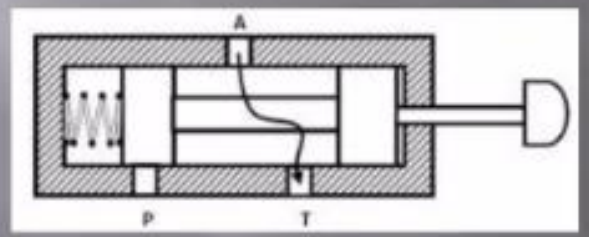
Applications:

- **To fill a vessel with a fluid or drain a fully filled vessel.**

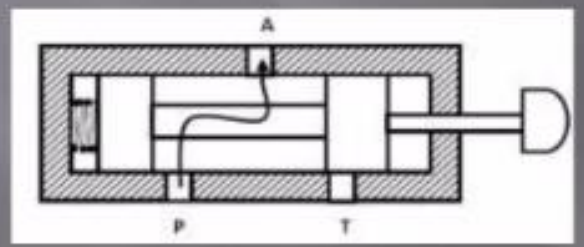
3/2 VALVE

- SYMBOL:

- Working: In its default state , pressure port is blocked because of spring. As a result, there is no flow of air in the system. But when the shaft is pressed first spool blocks the 'T' port and the pressure port is unblocked. Hence air flows through the system because of pressure difference.



: initial state(actuated)



: after piston is pressed

3/2 VALVE

Advantages:

- Air can be circulated in the system without letting it out in the atmosphere.
- Air can be reused if possible.

Disadvantages:

- It either blocks or allows the flow of air from the system.
- It has only one outlet port, hence only single pneumatic system can be controlled at a time.

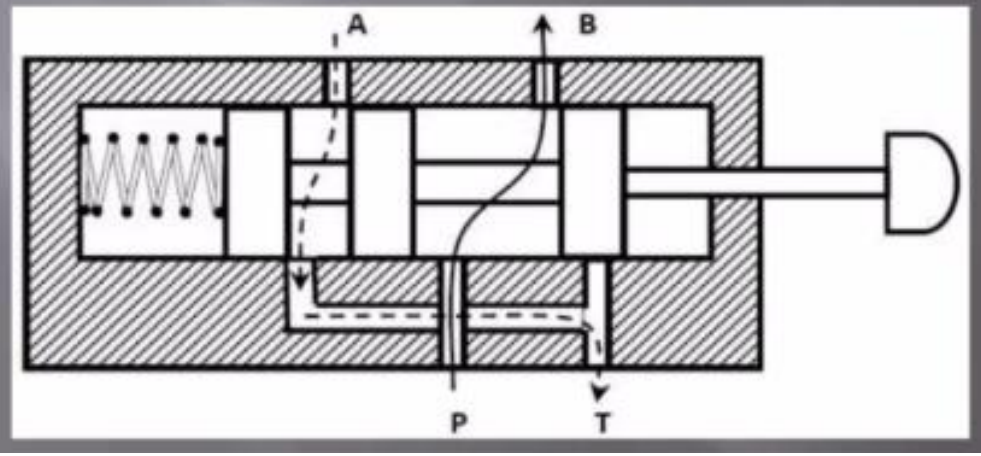
Application:

- It can be used to actuate a single acting cylinder. In which the cylinder remains retracted for the initial state and for final state it will give linear motion.
- It can also be used for controlling double acting cylinder with the help of some complicated pneumatic circuit.

4/2 VALVE

- SYMBOL:

- Working: Initially, outlet port 'B' is connected to the to the pressure port and port 'A' is connected to the tank. But when the valve is triggered, A which was previously connected to T, is isolated as the channel is blocked. On the contrary, A is now connected to P and channel B which had high pressure due to its previous connection with P loses the pressure as it gets connected to T.



: initially actuated

4/2 VALVE

Advantages:

- Simultaneously, two systems can be controlled due to two outlets.
- Air can made to flow in both the direction.

Disadvantages:

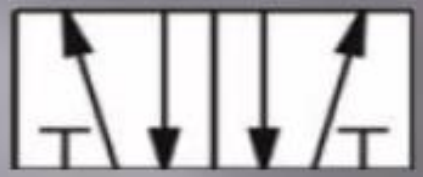
- It continuously sends air flow one direction or the other therefore decreases the efficiency of the system.

Applications:

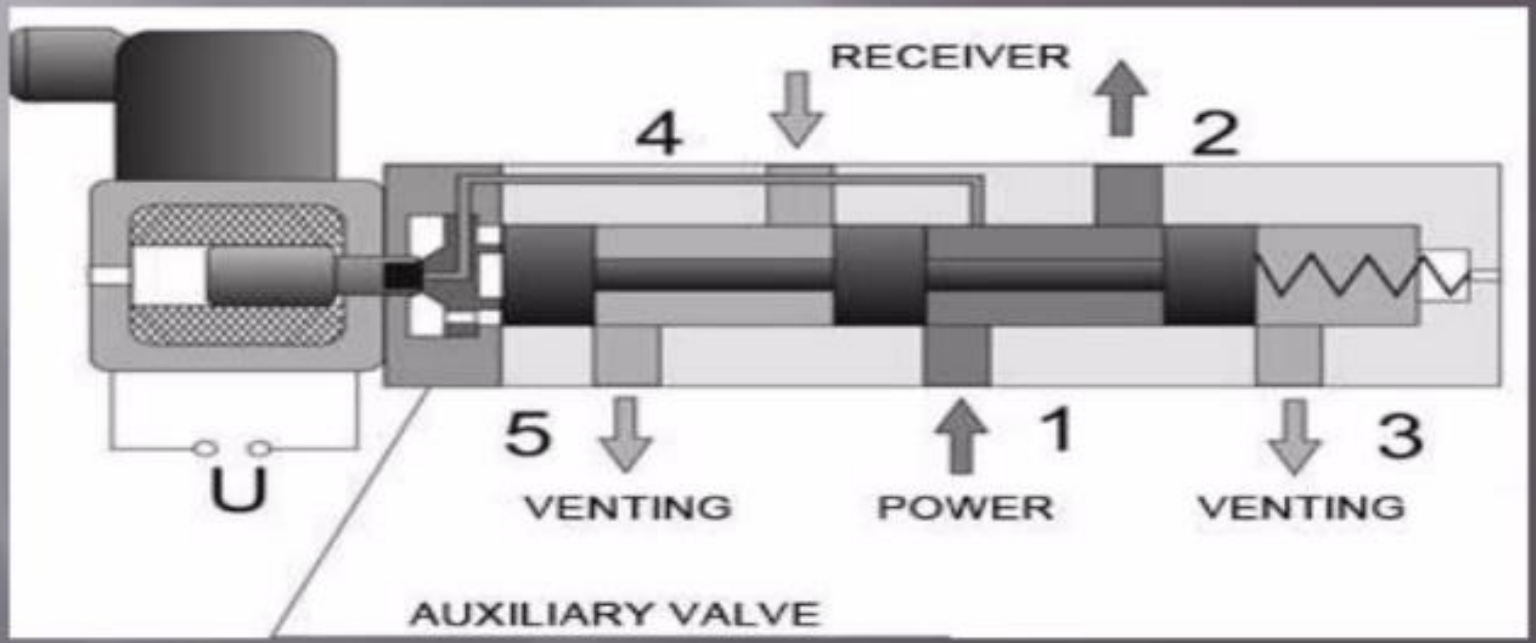
- It can be used to conveniently actuate single as well as double acting pneumatic cylinder.

5/2 VALVE

- **SYMBOL:**



- **Working: the diagram itself explains its working.**



5/2 VALVE

Advantages:

- They have short actuation movement.
- They are quick to operate because of small switching movement.
- If signals are applied at both ports, first signal will be dominant.

Disadvantages:

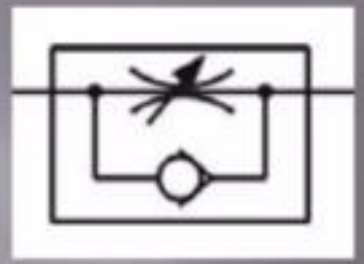
- Construction of the valve is complex.
- Expensive.

Applications:

- It is mainly used to actuate double acting pneumatic cylinder

FLOW CONTROL VALVE

- SYMBOL :



- Working:

- Function of a flow control valve is self –evident from its name. A flow control valve regulates the rate of air flow. The control action is limited to the air flow passing through the valve when it is open, maintaining a set volume per unit of time. Control valves are normally fitted with actuators and positioners.

- These types of valves are also known as automatic control valves. Automatic control valves do not require an external power source, meaning that the fluid pressure is enough to open and close them.

FLOW CONTROL VALVE

- Valves

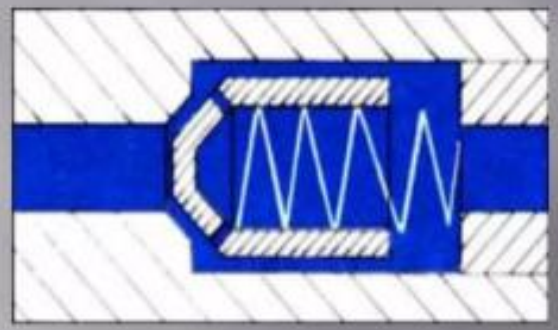
NON RETURN VALVE

- **SYMBOL:** 

- **Working: Non-return valves permit flow of air in one direction only, the other direction through the valve being at all times blocked to the air flow. Mostly the valves are designed so that the check is additionally loaded by the downstream air pressure, thus supporting the non-return action.**

NON RETURN VALVE

- VALVE:



CONNECTORS

- Linear type connector:

- T connector:

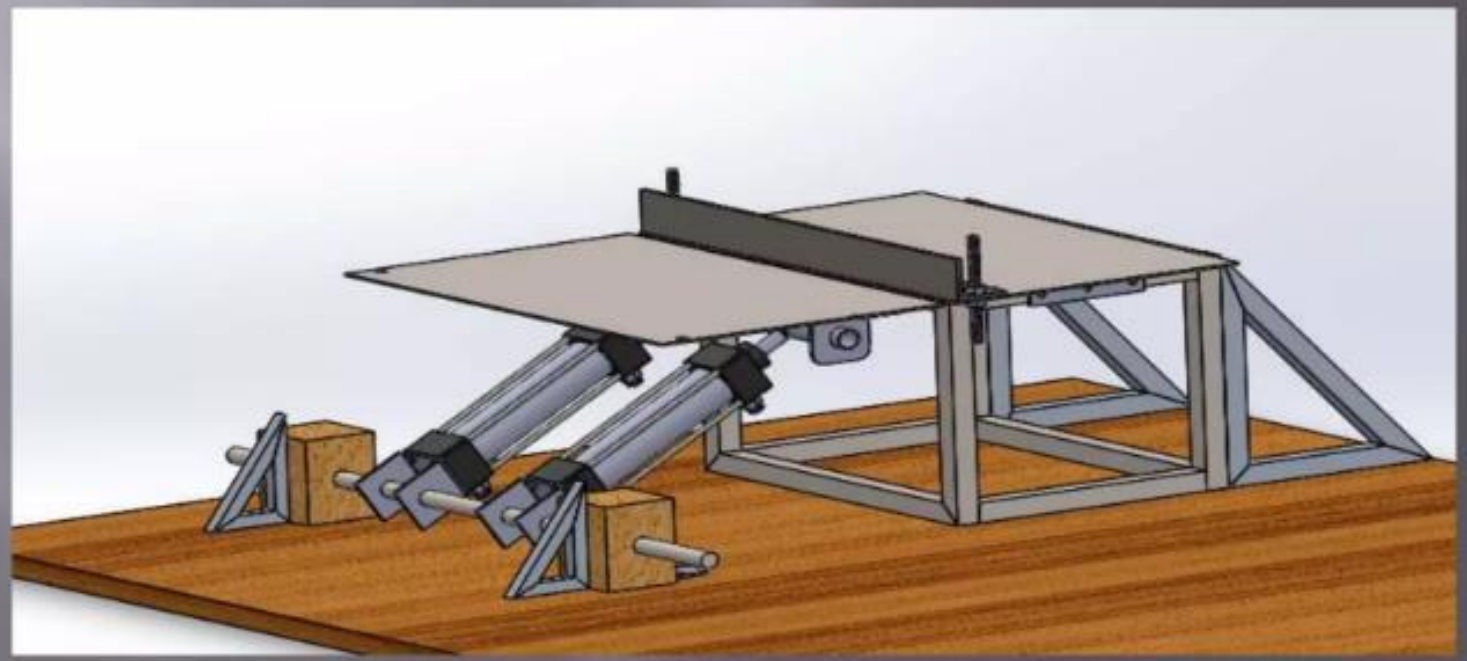
CONNECTORS

- Y connector:

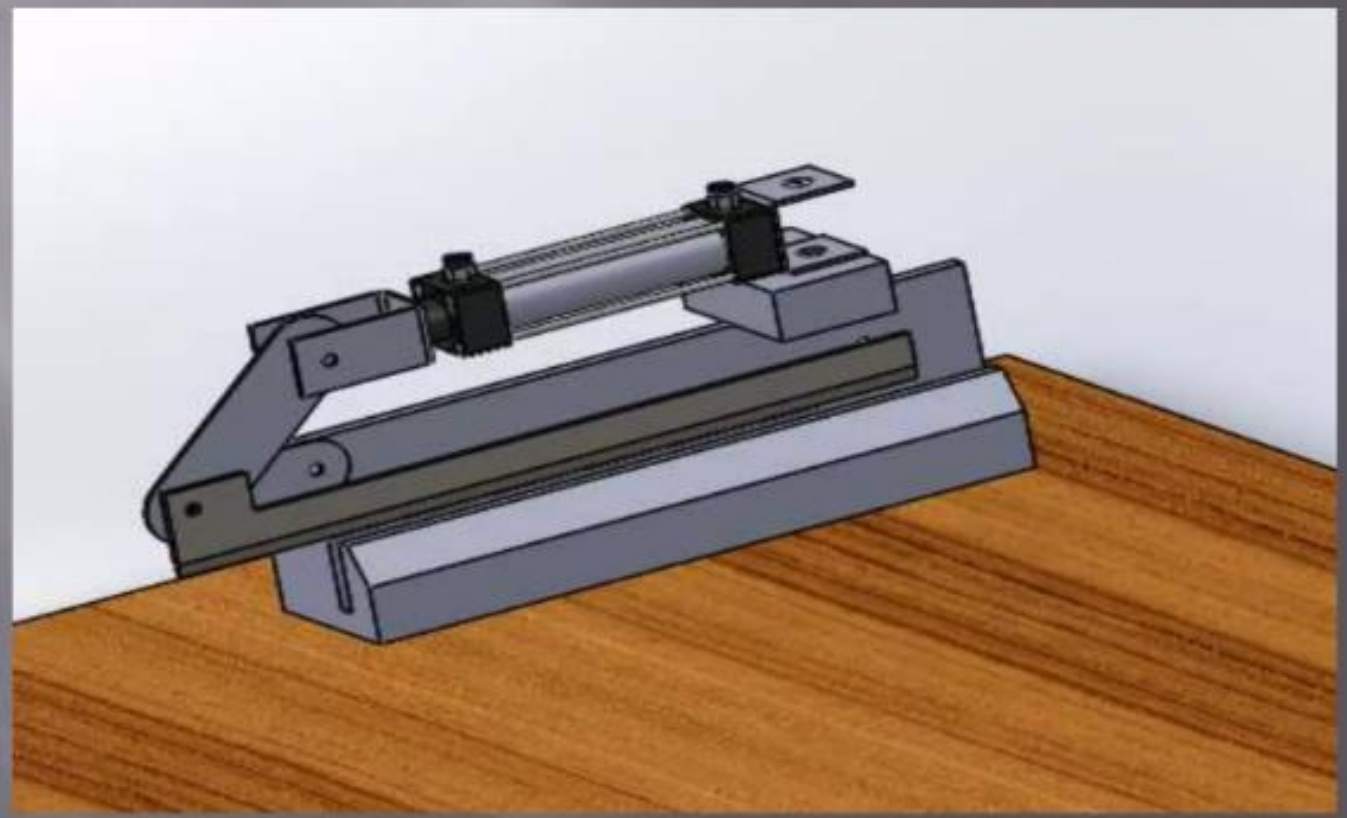
- Plus connector:

PNEUMATIC BENDING MACHINE

- PNEUMATIC BENDING MACHINE IS A MACHINE USED TO BEND SHEET METAL USING AIR PRESSURE.
- THIS MACHINE USES SQUARE PISTON , WHICH PROVIDE HUGE AMOUNT OF FORCE DEPENDING UPON THE SIZE OF THE PISTON.



PNEUMATIC SHEARING MACHINE

- PNEUMATIC SHEARING MACHINE IS THE MACHINE USED FOR CUTTING THE SHEET METAL USING BLADE ACTUATED BY SQUARE PISTON.
- 

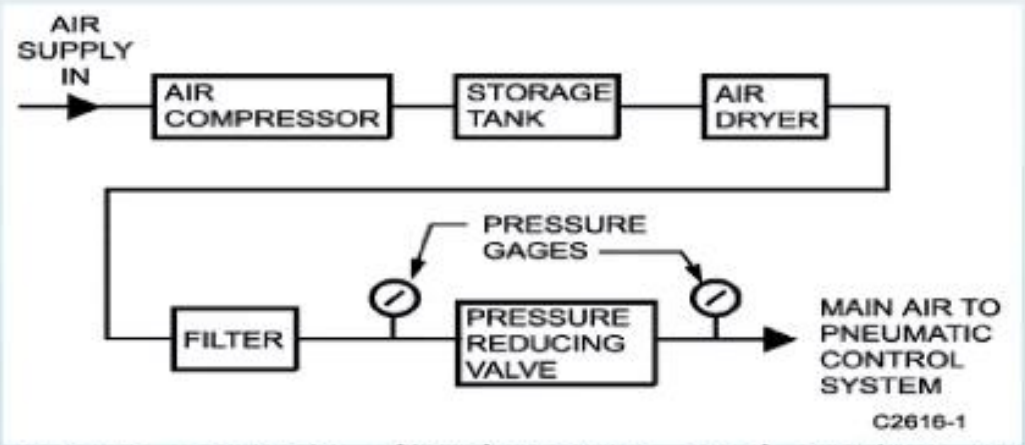
Components used

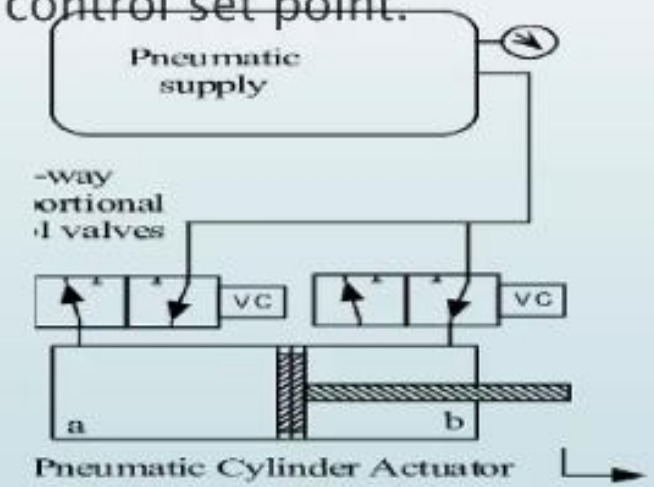
1) Reservoirs: 2 liters bottles are used to store compressed air.
2) AIR COMPRESSOR: Its takes in atmospheric air and compresses the air so as to increase the air pressure. It transfers the compressed air into an air receiver.
3) Pneumatic pipes: 6mm and 8mm pipes are used in the circuit , to transfer compressed air.
4) Piston: 32mm bore diameter and 10mm piston diameter, piston is used. This piston is double acting piston.
5) Valve: 5/2 valve directional valve is used, have five ports(air connections) and two states (operating position).
6) Quick exhaust valve: used to increase the speed of the piston, by applying large exhaust port.
7) Pressure regulator: maintains the pressure at constant value.(6 bar)

Pneumatic Drive System

A pneumatic control system uses compressed air as a method of control for HVAC systems. Compressed air is carried via copper and plastic tubes from a controller to a control device, usually a damper or valve actuator.

This control method relies on sensors and thermostats that bleed or retain the line pressure from the sensor to the control device and the actuator. Each senor responds to changes in temperature, humidity, and static pressure as examples, to provide feedback in a control loop to open or close the actuator to meet the control set point.



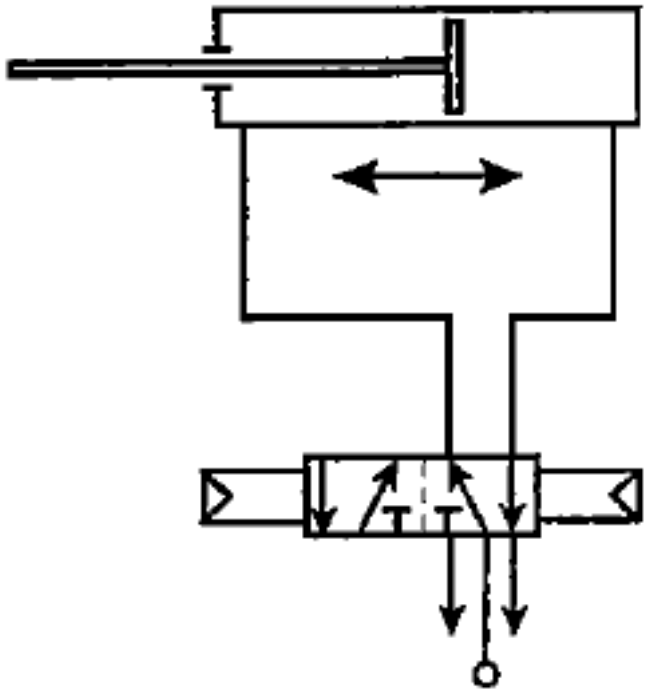


The actuators contain diaphragms and spring to function in sequence with the control signal. This system uses the compressed air as the communication method. Each thermostat in a building with a pneumatic control system has one or more air lines connected to it from the main source of compressed air and to some type of final device such as a valve.

Pneumatic drives

- Cheap
- Simple construction
- Low weight
- Clamp movement
- Point-to-point movement (stop)
- Control ► scheme difficult
- Low Positioning (Compressibility of the air)
- Expensive energy

Pneumatic working cylinder

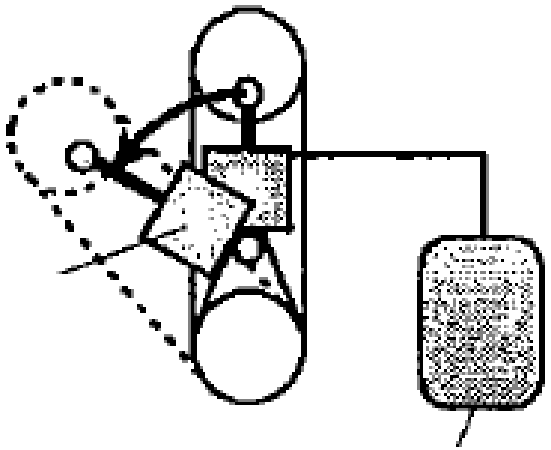


Pneumatic valve

Pneumatic Actuators - usage

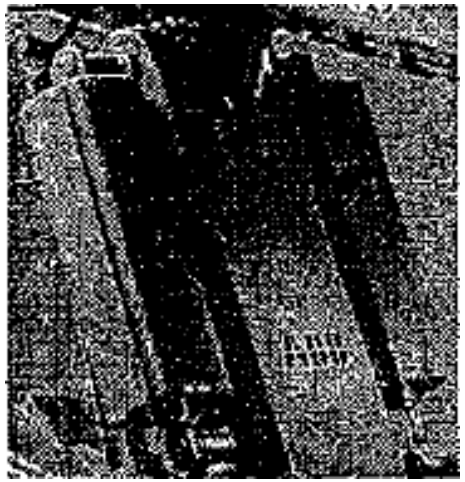
A pneumatic cylinder is used as a counterbalance to the individual robot axes.

Pneumatic Cylinder



Energy

Source: ABB



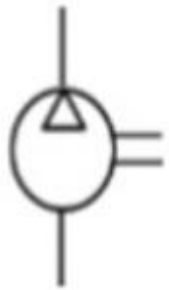
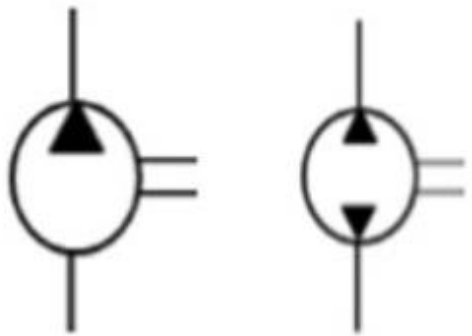
Example, an IR

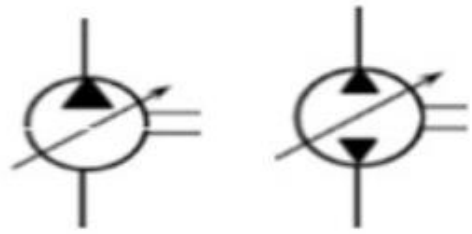
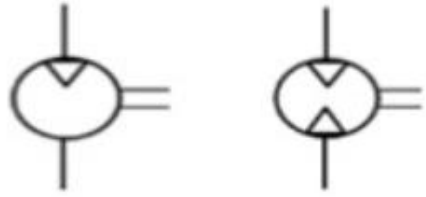
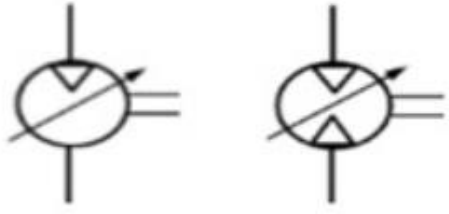
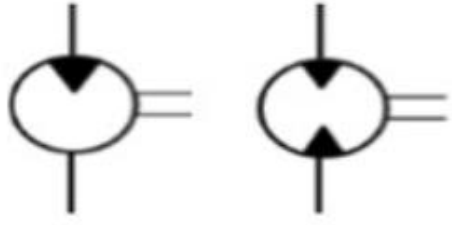
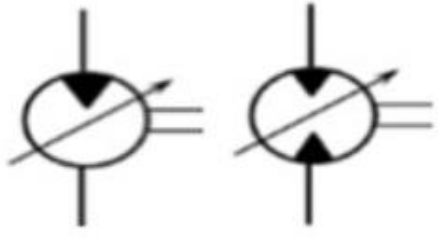
Comparative Study

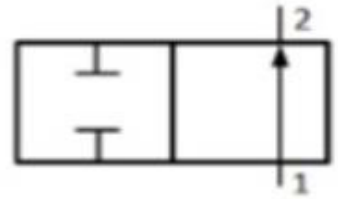
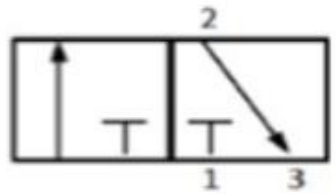
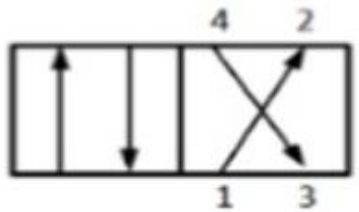
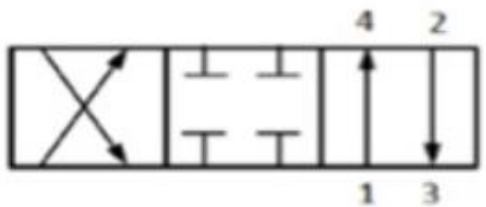
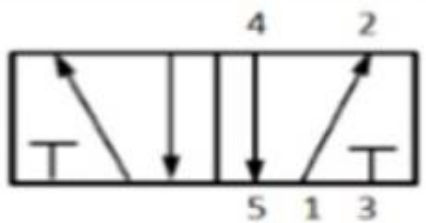
S. No.	Hydraulic System	Pneumatic System
1.	It employs a pressurized liquid as a fluid	It employs a compressed gas, usually air, as a fluid
2.	An oil hydraulic system operates at pressures up to 700 bar	A pneumatic system usually operates at 5–10 bar
3.	Generally designed as closed system	Usually designed as open system
4.	The system slows down when leakage occurs	Leakage does not affect the system much
5.	Valve operations are difficult	Valve operations are easy
6.	Heavier in weight	Lighter in weight
7.	Pumps are used to provide pressurized liquids	Compressors are used to provide compressed gases
8.	Automatic lubrication is provided	Special arrangements for lubrication are needed

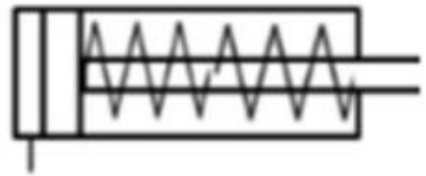
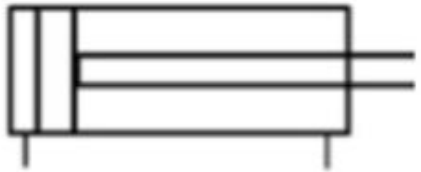
Hydraulic & Pneumatic

Hydraulic system	Pneumatic system
Working fluid is a liquid.	Working fluid is a gas.
Works at very high pressure.	Works at very low pressure.
Working fluid is a incompressible.	Working fluid is compressible.
System is more compact.	It is more bulky.
Self lubricating effect.	No Self lubricating effect.
Very high working forces could be developed.	Very high working forces could be developed.
Heavy tubes are required.	Light tubings would be sufficient

SYMBOL	DESIGNATION	EXPLANATION
Energy supply		
	Air compressor	One direction of rotation only with constant displacement volume
	Air receiver	Compressed air from the compressor is stored and diverted to the system when required
	Hyraulic pump	One direction and two direction of rotation with constant displacement volume

	Hydraulic pump	One direction and two direction of rotation with variable displacement
Rotary actuators		
	Pneumatic motor	One direction and two direction of rotation with constant displacement volume
		One direction and two direction of rotation with variable displacement
	Hydraulic motor	One direction and two direction of rotation with constant displacement volume
		One direction and two direction of rotation with variable displacement

	2/2 way valve	Two closed ports in the closed neutral position and flow during actuated position
	3/2 way valve	In the first position flow takes place to the cylinder In the second position flow takes out of the cylinder to the exhaust (Single acting cylinder)
	4/2 way valve	For double acting cylinder all the ports are open
	4/3 way valve	Two open positions and one closed neutral position
	5/2 way valve	Two open positions with two exhaust ports

Actuators		
	Single acting cylinder	Spring loaded cylinder with retraction taking place by spring force
	Double acting cylinder	Both extension and retraction by pneumatic/hydraulic force

Flow control valves		
	Flow control valve	To allow controlled flow
	Flow control valve with one way adjustment	To allow controlled flow in one direction and free flow in other