AUTOMATION TECHNOLOGIES FOR MANUFACTURING SYSTEMS

Manufacturing Systems

A manufacturing system can be defined as a collection of integrated equipment and human resources that performs one or more processing and/or assembly operations on a starting work material, part, or set of parts

- The integrated equipment consists of production machines, material handling and positioning devices, and computer systems
- The manufacturing systems accomplish the value-added work on the part or product

Automation Fundamentals

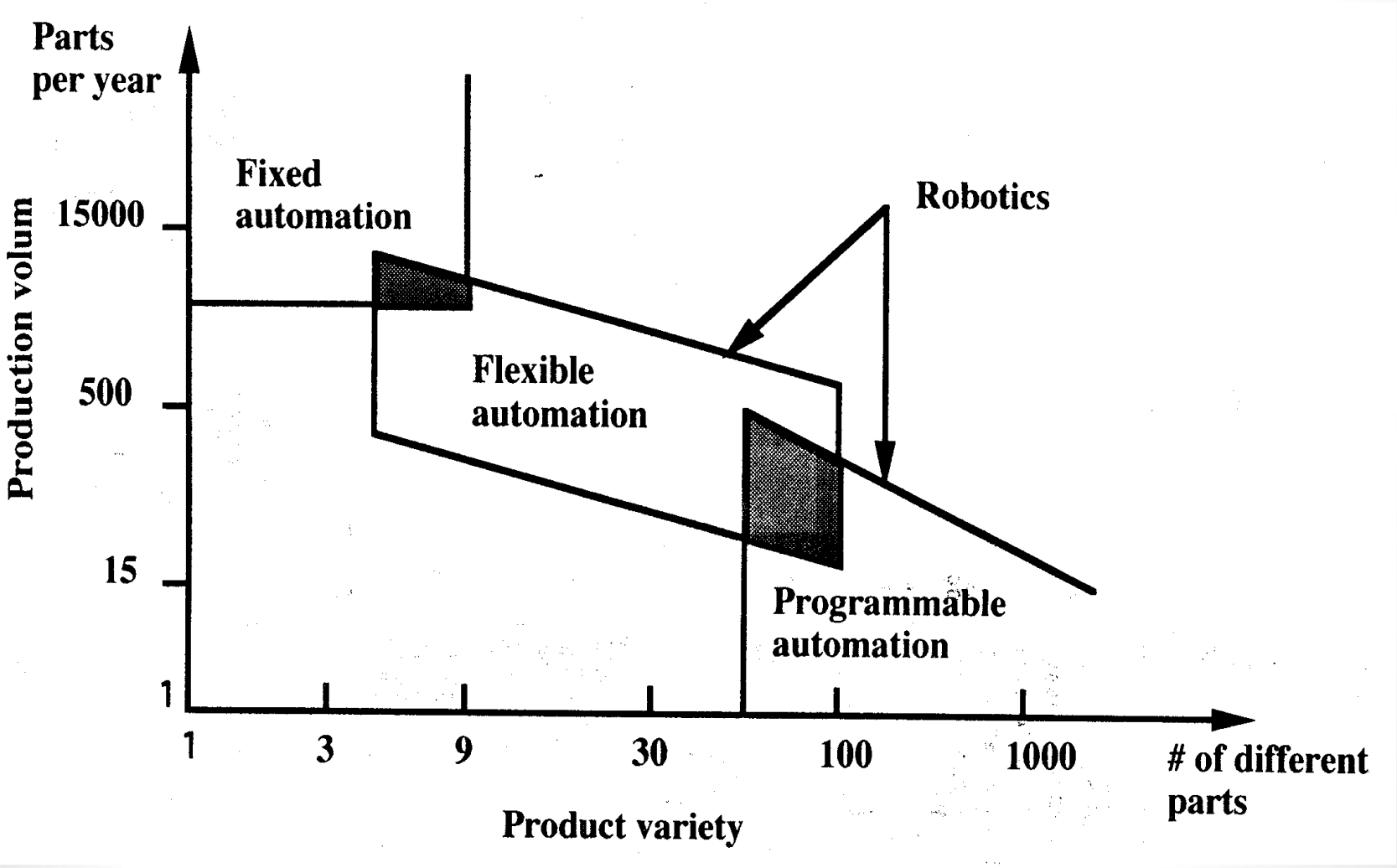
Automation can be defined as the technology by which a process or procedure is performed without human assistance

- Humans may be present, but the process itself operates under is own self-direction
- Three components of an automated system:
  1. Power
  2. A program of instructions
  3. A control system to carry out the instructions

Three Basic Types of Automation

- Fixed automation - the processing or assembly steps and their sequence are fixed by the equipment configuration
- Programmable automation - equipment is designed with the capability to change the program of instructions to allow production of different parts or products
- Flexible automation - an extension of programmable automation in which there is virtually no lost production time for setup changes or reprogramming

Three Basic Types of Automation

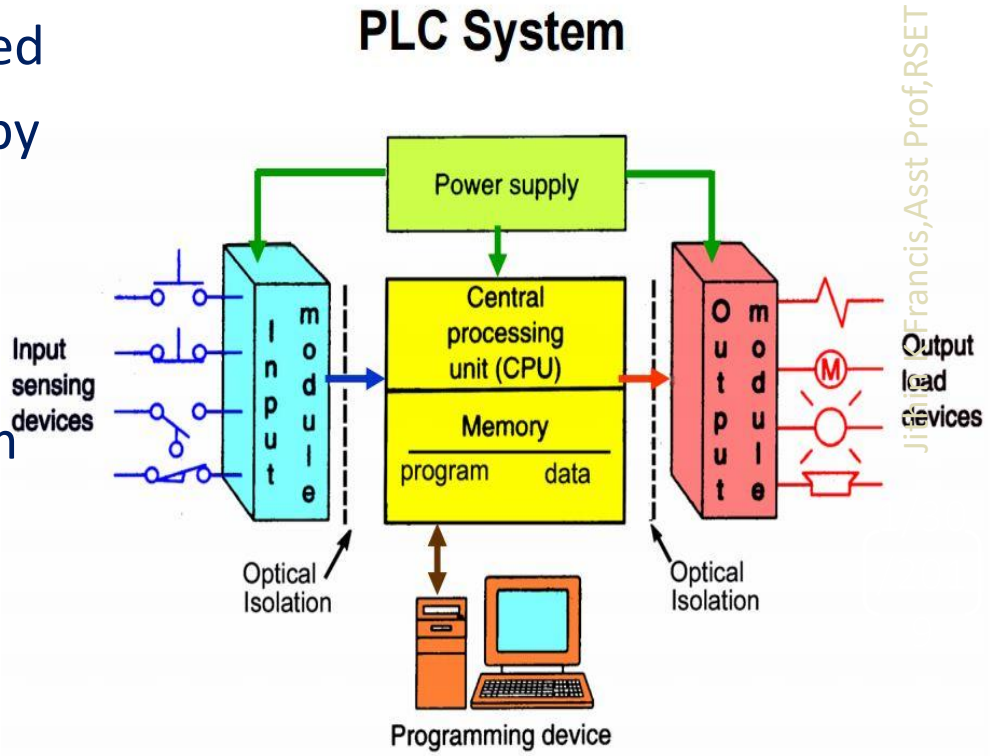


Features of Fixed Automation

- High initial investment for specialized equipment
- High production rates
- The program of instructions cannot be easily changed because it is fixed by the equipment configuration
  - Thus, little or no flexibility to accommodate product variety

Features of Programmable Automation

- High investment in general purpose equipment that can be reprogrammed
- Ability to cope with product variety by reprogramming the equipment
- Suited to batch production of different product and part styles
  - Lost production time to reprogram and change the physical setup
- Lower production rates than fixed automation



Features of Flexible Automation

- High investment cost for custom-engineered equipment
- Capable of producing a mixture of different parts or products without lost production time for changeovers and reprogramming
  - Thus, continuous production of different part or product styles
- Medium production rates

Hardware Components for Automation

- Sensors
- Actuators
- Interface devices
- Process controllers - usually computer-based devices such as a programmable logic controller

Sensors

A sensor is a device that converts a physical stimulus or variable of interest (e.g., force, temperature) into a more convenient physical form (e.g., electrical voltage) for purpose of measuring the variable

- Two types
  - An analog sensor measures a continuous analog variable and converts it into a continuous signal
  - A discrete sensor produces a signal that can have only a limited number of values

Actuators

An actuator is a device that converts a control signal into a physical action, usually a change in a process input parameter

- The action is typically mechanical, such as a change in position of a worktable or speed of a motor
- The control signal is usually low level, and an amplifier may be required to increase the power of the signal to drive the actuator
  - Amplifiers are electrical, hydraulic, or pneumatic

Interface Devices

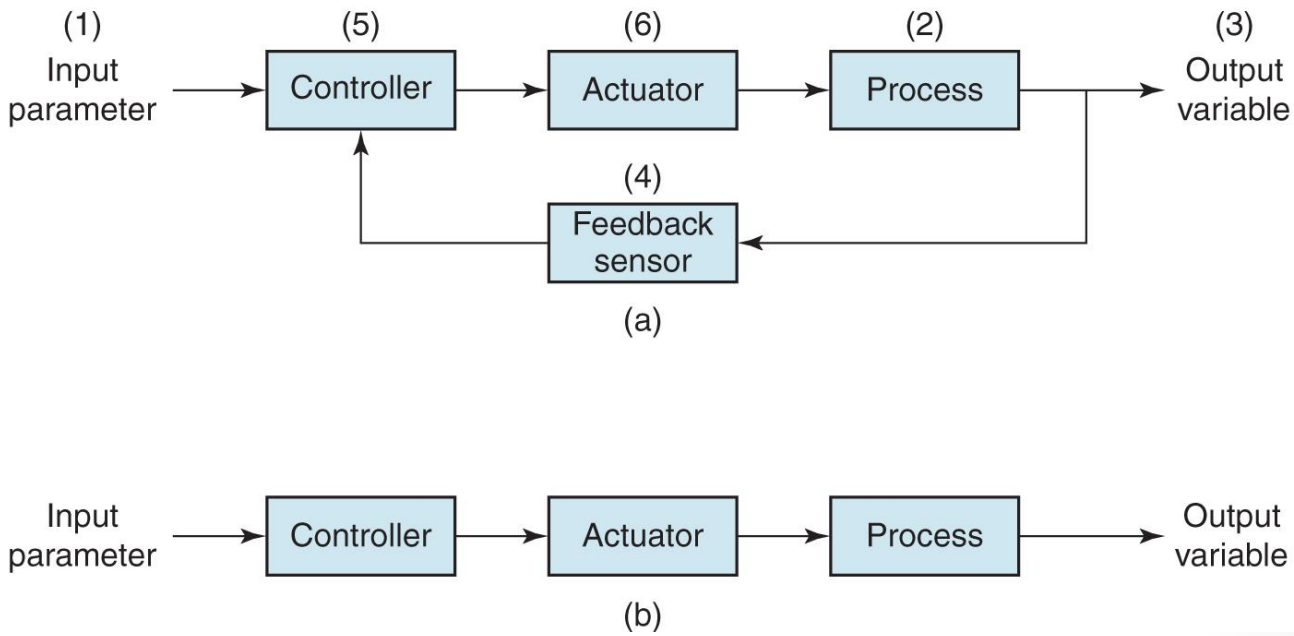
- Interface devices allow the process to be connected to the controller and vice versa
  - Sensor signals form the process are fed into the controller
  - Command signals from the controller are sent to the process

Process Controllers

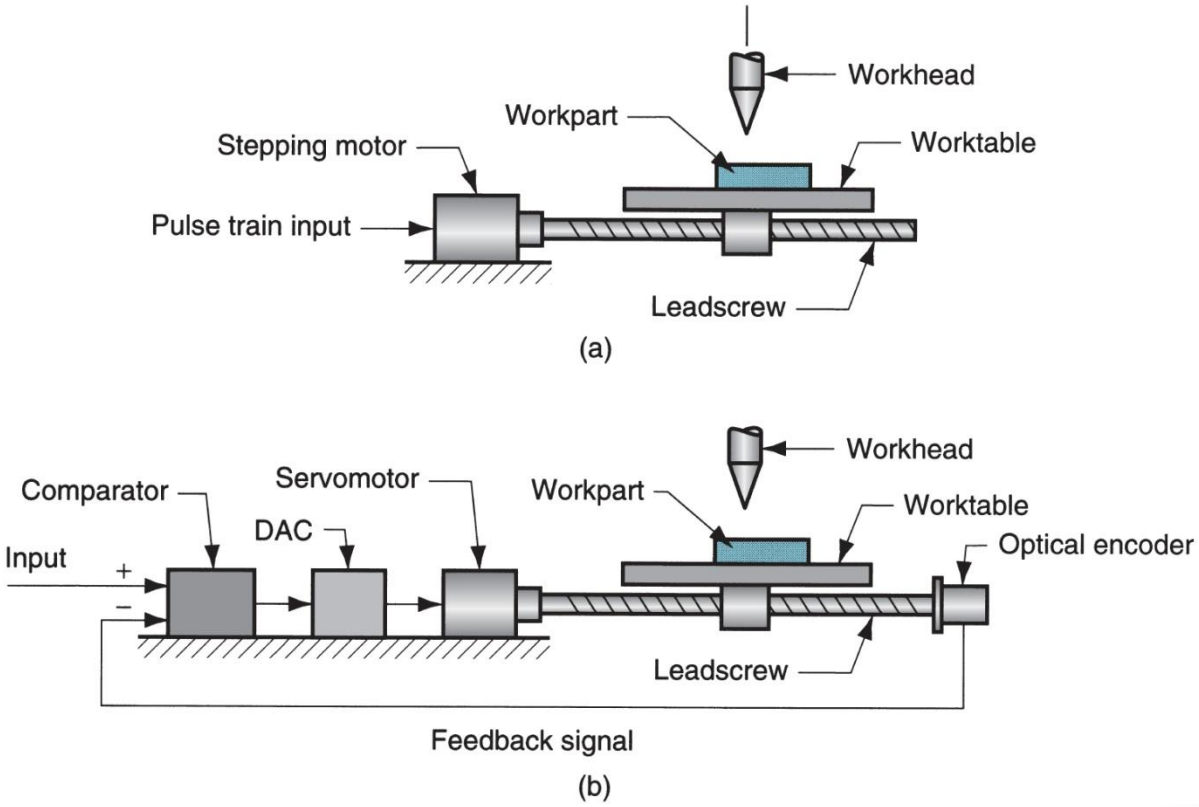
- Most process control systems use some type of digital computer as the controller
- Requirements for real-time computer control:
  - Respond to incoming signals from process
  - Transmit commands to the process
  - Execute certain actions at specific points in time
  - Communicate with other computers that may be connected to the process
  - Accept inputs from operating personnel

Two Types of Control System

- (a) Closed loop and (b) open loop



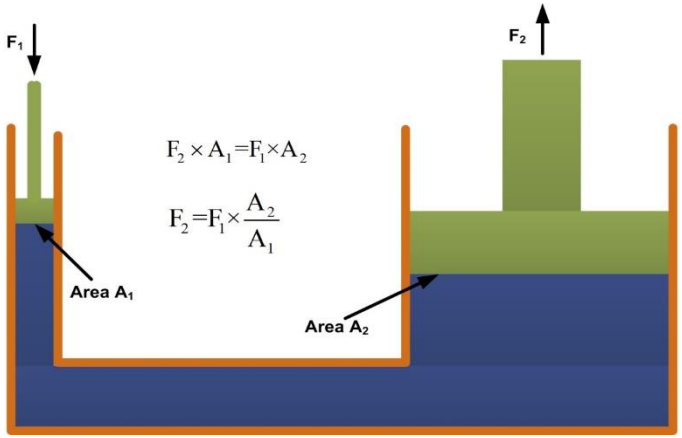
Two Basic Types of Control in Computer Numerical Control



HYDRAULIC SYSTEMS

- The hydraulic system works on the principle of Pascal's law which says that the pressure in an enclosed fluid is uniform in all the directions.

HYDRAULIC SYSTEMS



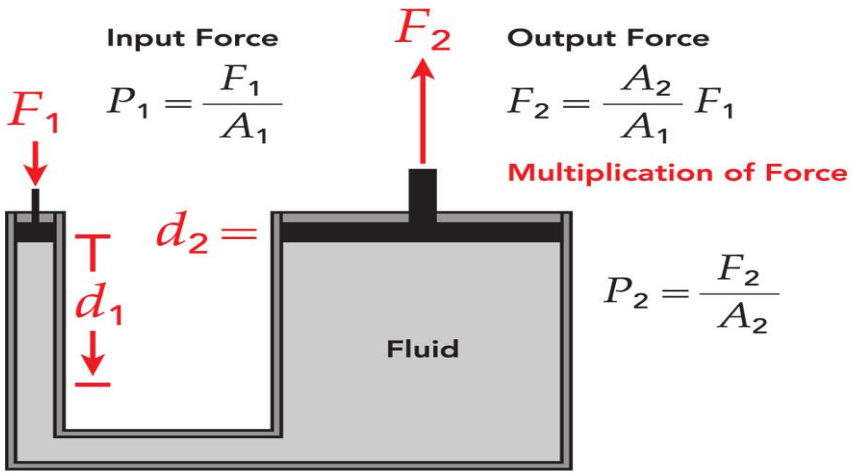
Pascal's Law

Pressure exerted by a confined fluid acts undiminished equally in all directions.

Pressure: The force per unit area exerted by a fluid against a surface

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

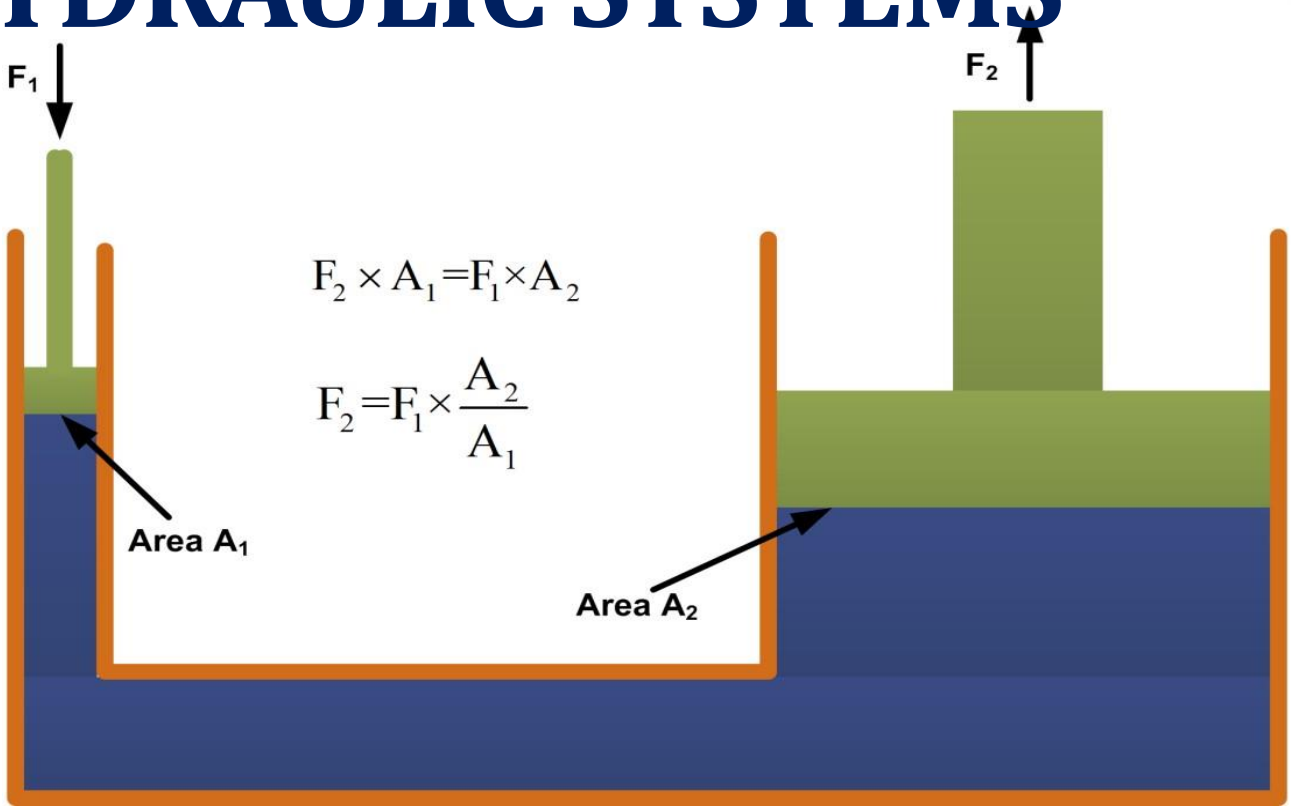
Symbol	Definition	Example Unit
p	Pressure	lb/in.^{2}
F	Force	lb
A	Area	in.^{2}



$$F_1 d_1 = F_2 d_2$$

$$d_1 = \frac{F_2}{F_1} d_2 = \frac{A_2}{A_1} d_2$$

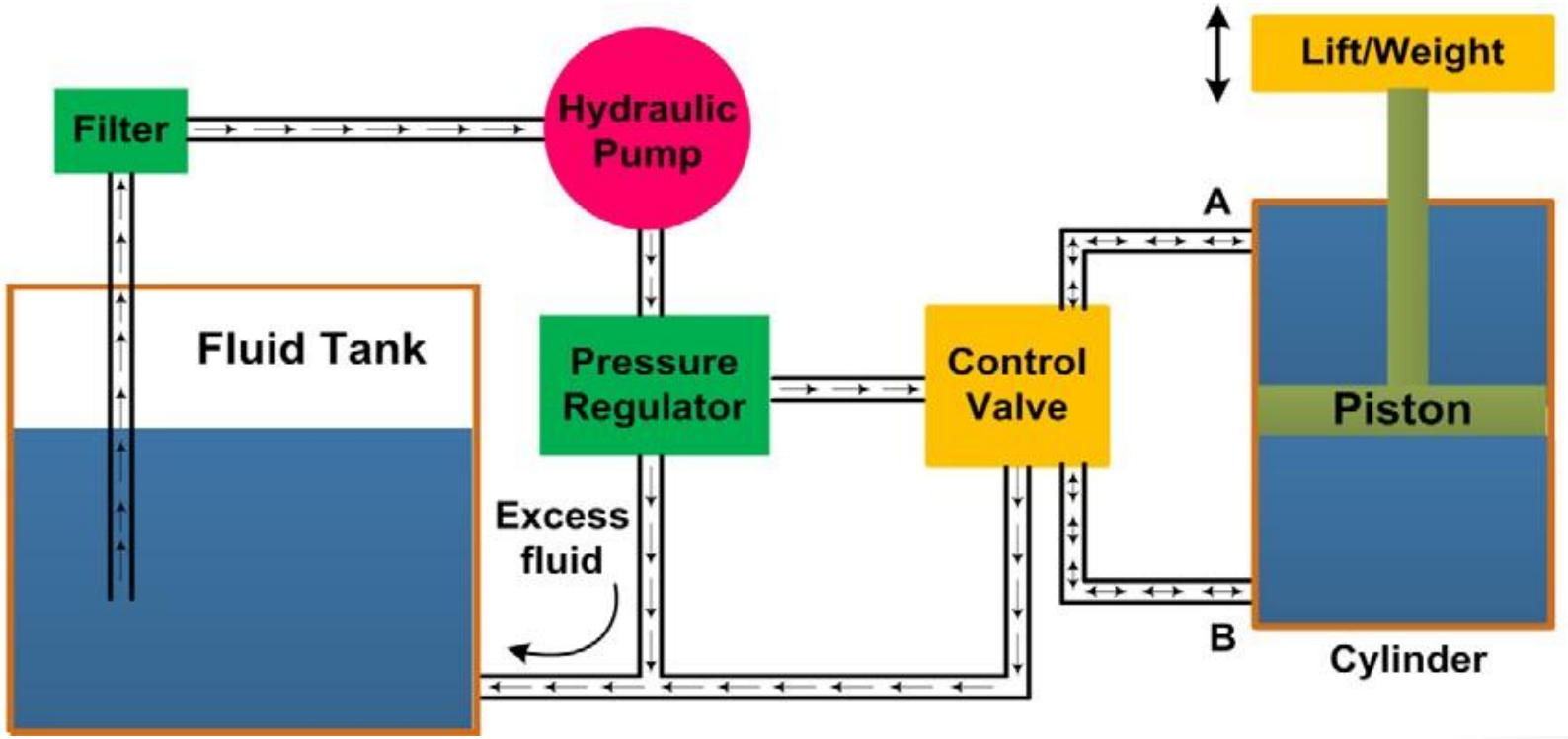
HYDRAULIC SYSTEMS



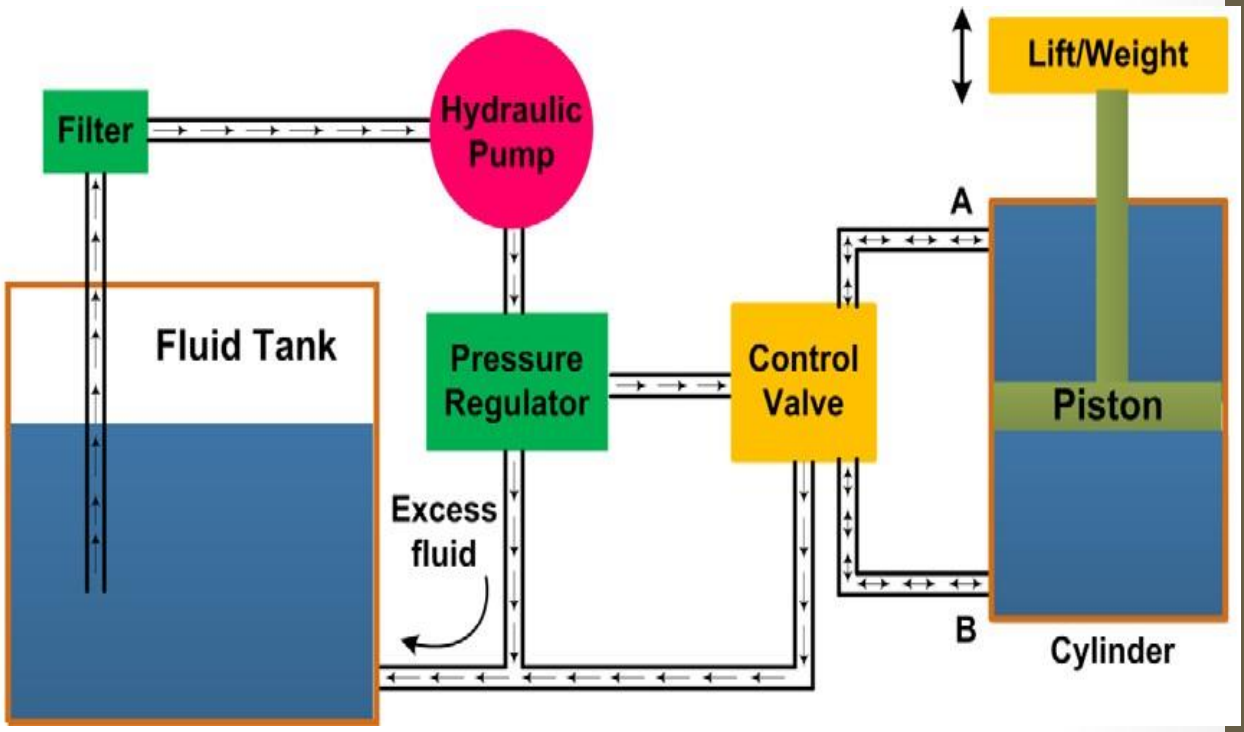
The force given by fluid is given by the multiplication of pressure and area of cross section. As the pressure is same in all the direction, the smaller piston feels a smaller force and a large piston feels a large force. Therefore, a large force can be generated with smaller force input by using hydraulic systems

- The hydraulic systems consists a number of parts for its proper functioning. These include storage tank, filter, hydraulic pump, pressure regulator, control valve, hydraulic cylinder, piston and leak proof fluid flow pipelines

Schematic of hydraulic system



- hydraulic system is shown in figure. It consists of:
- a movable piston connected to the output shaft in an enclosed cylinder (Actuator)
- storage tank
- filter
- electric pump
- pressure regulator
- control valve
- leak proof closed loop piping.



- **Applications of hydraulic systems**
- The hydraulic systems are mainly used for precise control of larger forces. The main applications of hydraulic system can be classified in five categories:
- **Industrial:** Plastic processing machineries, steel making and primary metal extraction applications, automated production lines, machine tool industries, paper industries, loaders, crushes, textile machineries, R & D equipment and robotic systems etc.

- **Applications of hydraulic systems**
- **Mobile hydraulics:** Tractors, irrigation system, earthmoving equipment, material handling equipment, commercial vehicles, tunnel boring equipment, rail equipment, building and construction machineries and drilling rigs etc.
- **Automobiles:** It is used in the systems like breaks, shock absorbers, steering system, wind shield, lift and cleaning etc.
- **Marine applications:** It mostly covers ocean going vessels, fishing boats and navel equipment.

- **Advantages**
- The hydraulic system uses incompressible fluid which results in higher efficiency.
- It delivers consistent power output which is difficult in pneumatic or mechanical drive systems.
- Hydraulic systems employ high density incompressible fluid. Possibility of leakage is less in hydraulic system as compared to that in pneumatic system. The maintenance cost is less.
- These systems perform well in hot environment conditions.

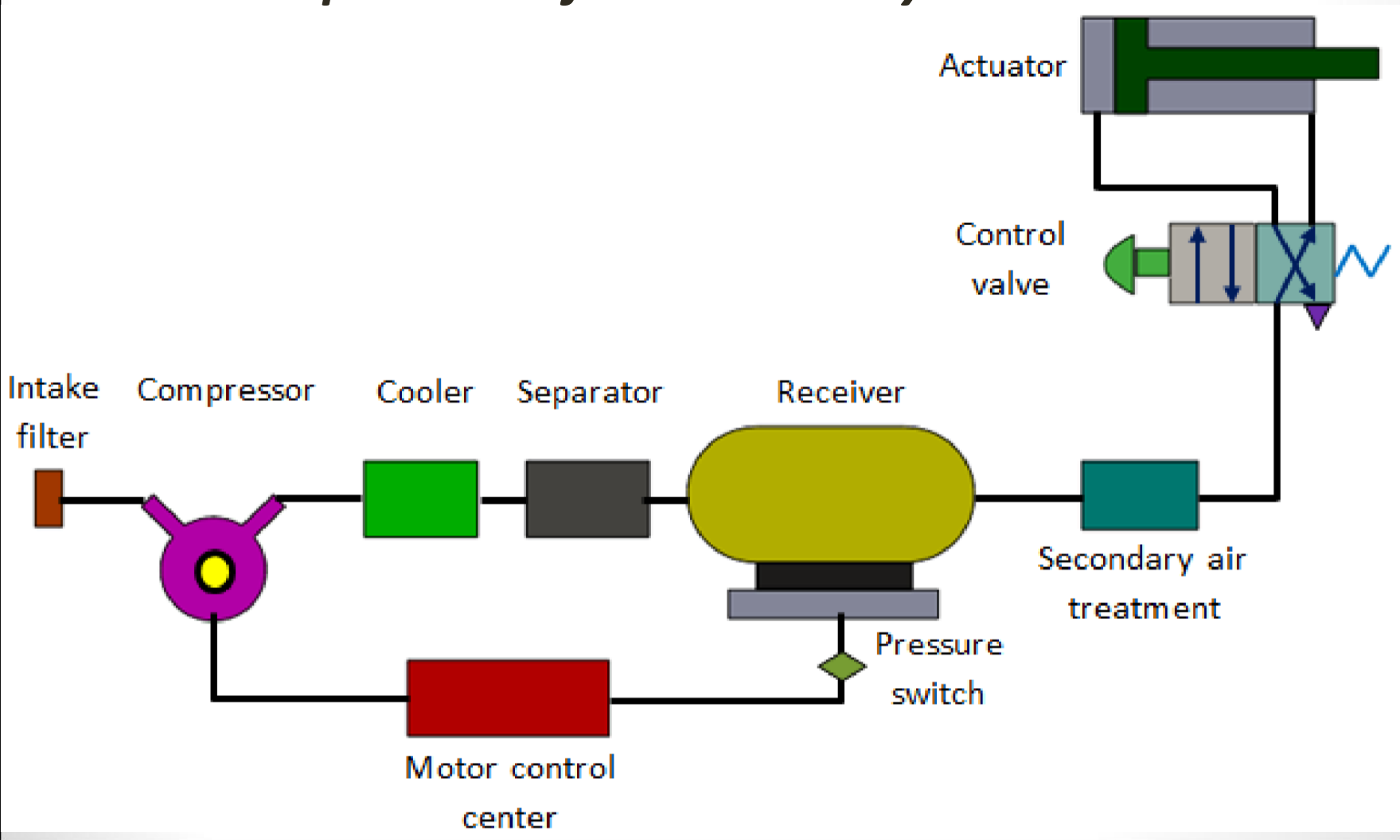
- **Disadvantages**
- The material of storage tank, piping, cylinder and piston can be corroded with the hydraulic fluid. Therefore one must be careful while selecting materials and hydraulic fluid.
- The structural weight and size of the system is more which makes it unsuitable for the smaller instruments.
- 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.

PNEUMATIC SYSTEM

- Pneumatic technology deals with the study of behaviour and applications of compressed air in our daily life in general and manufacturing automation in particular. Pneumatic systems use air as the medium which is abundantly available and can be exhausted into the atmosphere after completion of the assigned task.

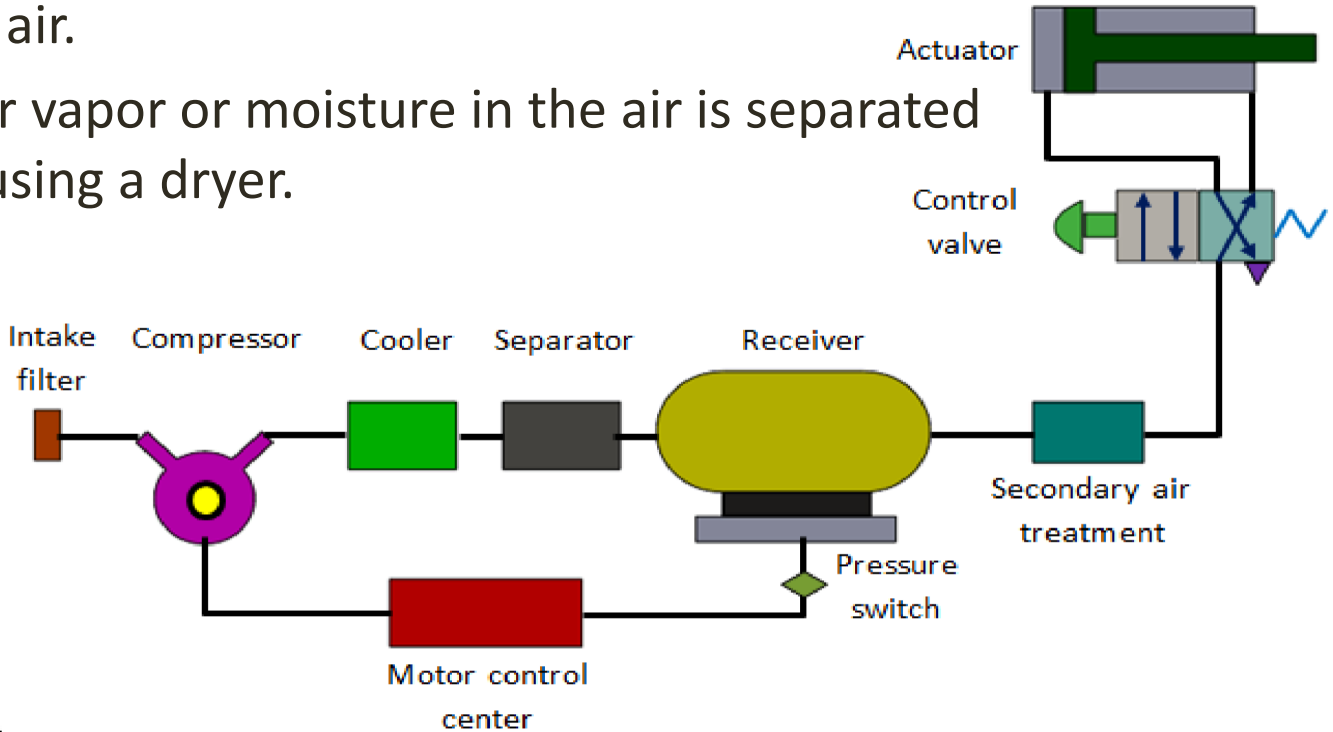
PNEUMATIC SYSTEM

- ***Basic Components of Pneumatic System:***



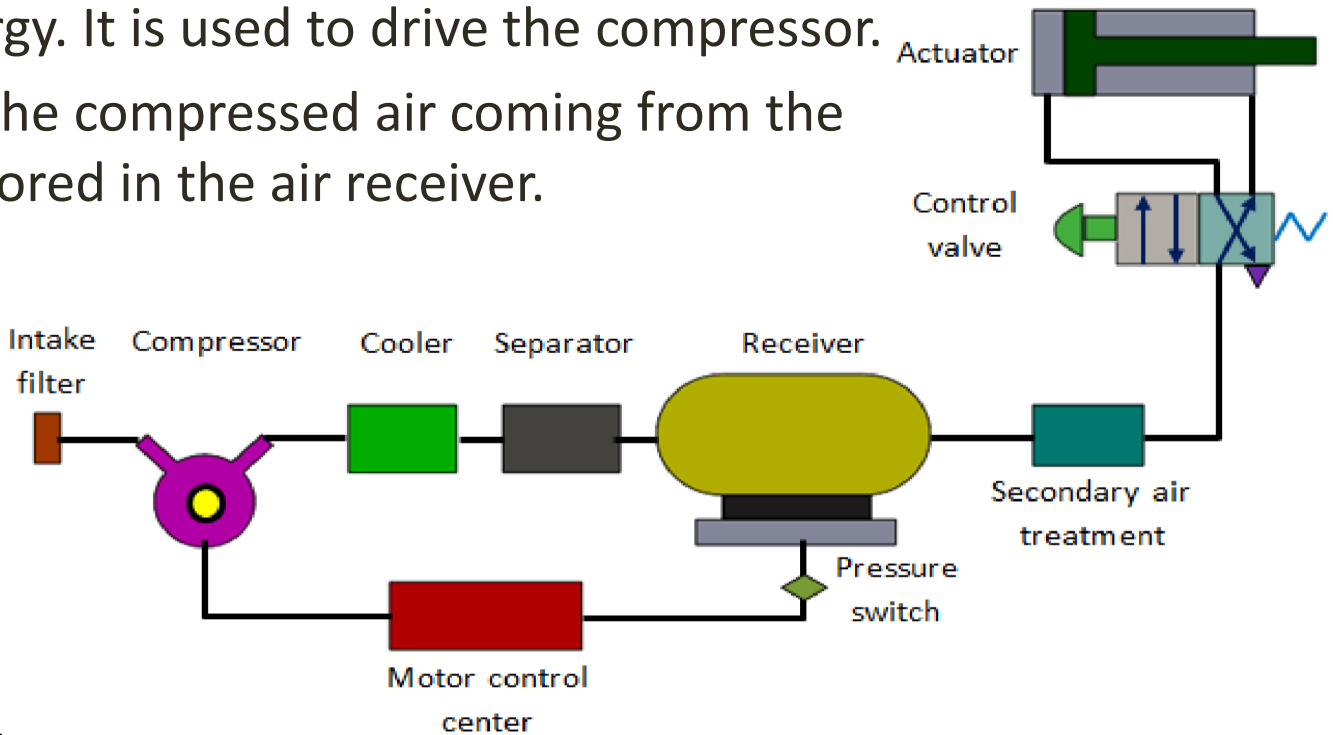
PNEUMATIC SYSTEM

- ***Basic Components of Pneumatic System:***
- **Air filters:** These are used to filter out the contaminants from the air.
- **Compressor:** Compressed air is generated by using air compressors.
- **Air cooler:** During compression operation, air temperature increases. coolers are used to reduce the temperature of the compressed air.
- **Dryer:** The water vapor or moisture in the air is separated from the air by using a dryer.

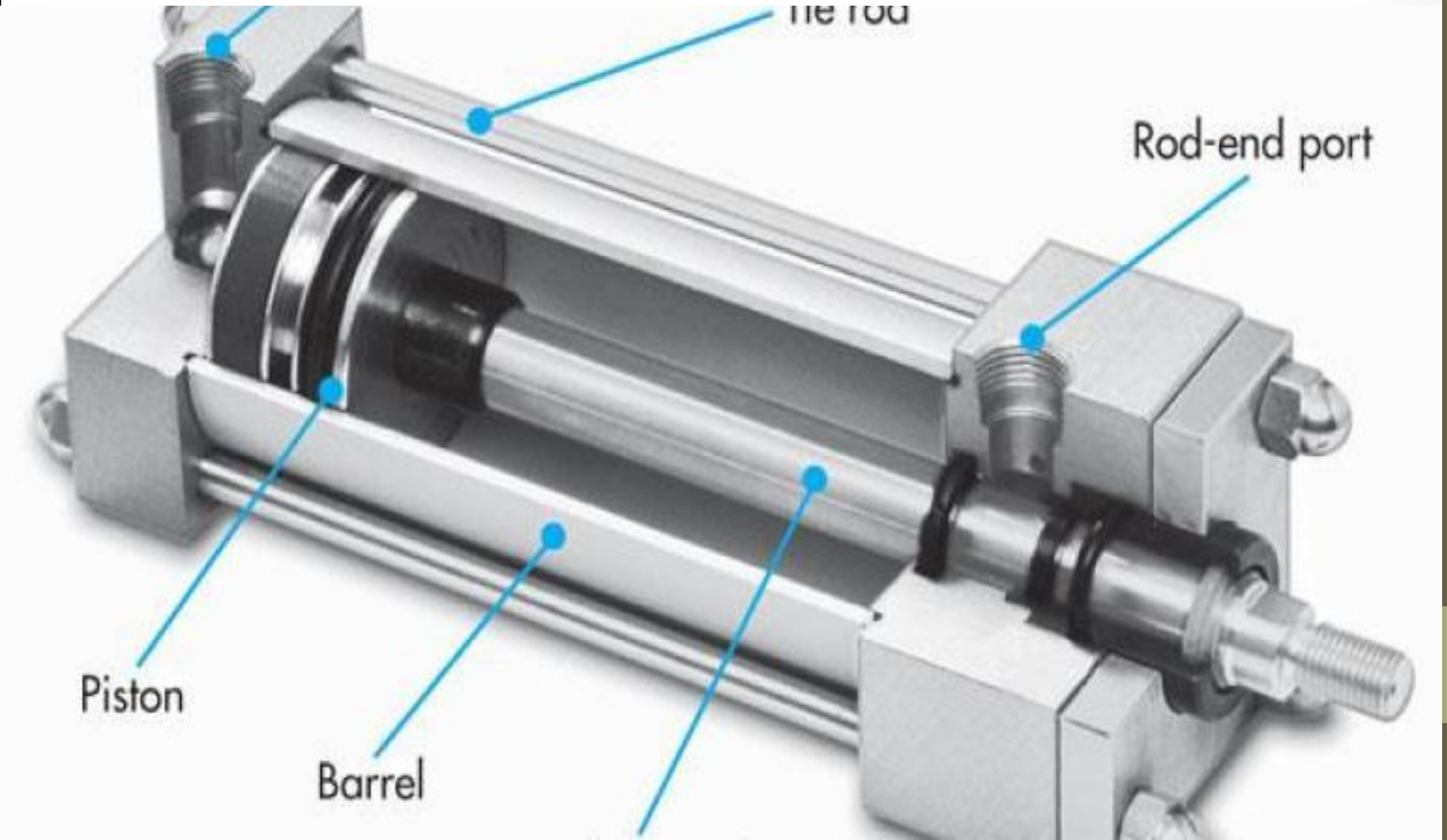


PNEUMATIC SYSTEM

- ***Basic Components of Pneumatic System:***
- **Control Valves:** Control valves are used to regulate, control and monitor for control of direction flow, pressure etc.
- **Air Actuator:** Air cylinders and motors are used to obtain the required movements of mechanical elements of pneumatic system.
- **Electric Motor:** Transforms electrical energy into mechanical energy. It is used to drive the compressor.
- **Receiver tank*:*** The compressed air coming from the compressor is stored in the air receiver.



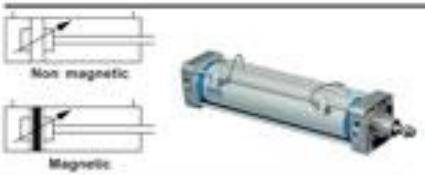
WORKING ELEMENTS - (CYLINDERS OR ACTUATORS)



WORKING ELEMENTS - (CYLINDERS OR ACTUATORS)

JANATICS
Pneumatic

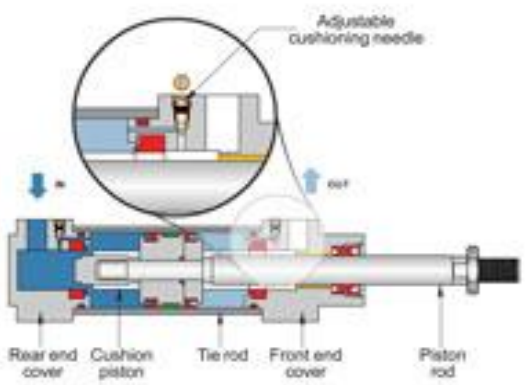
Working Elements

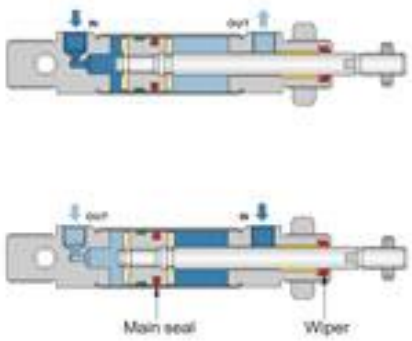


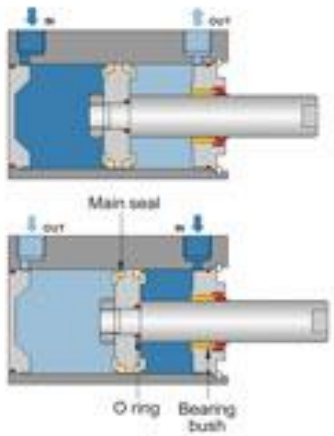
STANDARD CYLINDERS
- Sizes : Ø32, 40, 50, 63, 80, 100, 125, 160, 200mm
- Adjustable cushioning at both ends
- Tie rod & end cover bolt assembly facilitates dismantling & assembling for maintenance

MINIATURE CYLINDERS
- Sizes : Ø12, 16, 20, 25mm
- Low friction, Higher speeds achievable
- Long life seal design
- Fixed elastomer cushioning at both ends
- Space saving

COMPACT CYLINDERS
- Sizes : Ø12, 16, 20, 25, 32, 40, 50, 63, 80, 100mm
- Large clamping force in relation to their size
- Low friction, long life seal design
- Compact, light weight, and space saving design
- Elastomer end cushion







Introduction to Hydraulics

All machines require some type of power source and a way of transmitting this power to the point of operation.

The three methods of transmitting power are:

- Mechanical
- Electrical
- Fluid

- In this course we are going to deal with the third type of power transmission which is the Fluid Power

Introduction to Hydraulics

- **Fluid power** is the method of using pressurized fluid to transmit energy.

- **Liquid** or **Gas** is referred to as a **fluid.** Accordingly, there are two branches of fluid power; **Pneumatics**, and **Hydraulics**.

- **Hydraulic systems** use **liquid** to transfer force from one point to another.
- **Pneumatic systems** use **air** to transfer force from one point to another. Air is

Introduction to Hydraulics

- Hydraulic systems are commonly used where mechanisms require large forces and precise control.

- Examples include vehicle power steering and brakes, hydraulic jacks and heavy earth moving machines.

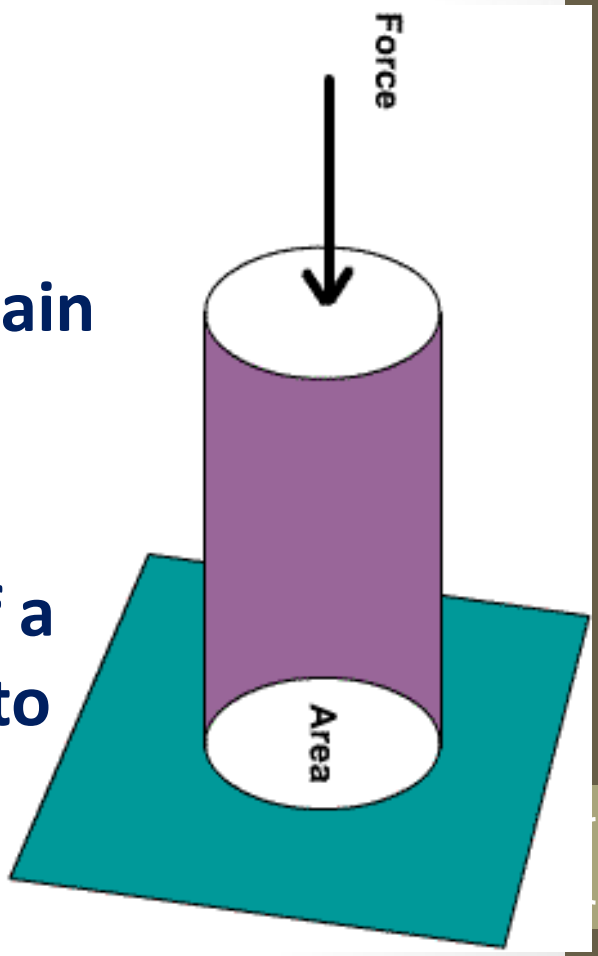
Uses of hydraulics

- Hydraulics plays an important role in many industries; there are a lot of hydraulic applications in manufacturing, transportation, and construction sectors.

- Hydraulics systems are used where large, precise forces are required.

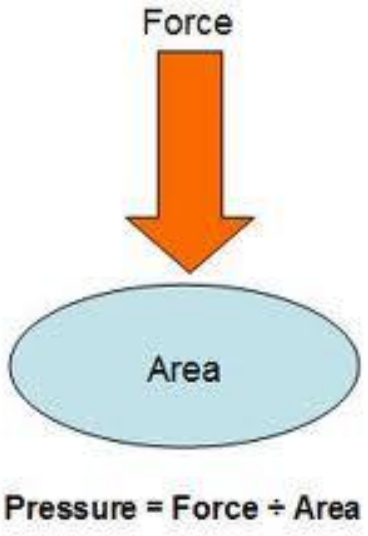
Fundamental laws of Hydraulics

- All hydraulic systems operate following a defined relationship between area, force and pressure.
- Laws have been established to explain the behavior of hydraulic systems.
- Hydraulic systems use the ability of a fluid to distribute an applied force to a desired location.



Fundamental laws of Hydraulics Pressure

- When a force (F) is applied on an area (A) of an enclosed liquid, a pressure (P) is produced as shown in Fig.
- Pressure is the distribution of a given force over a certain area.
- Pressure can be quoted in bar, pounds per square inch (PSI) or Pascal (Pa) .



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

Pressure

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

Where
Force is in newtons (N) and
Area is in square meters (m^2).

1 Pascal (Pa) =1 N/m^2.
1 bar= 100,000 Pa= 10^5 Pa.
10 bar= 1 MPa (mega Pascals)

Pressure

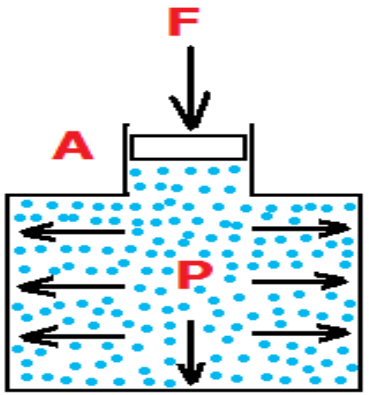
- If the pressure is calculated using a force in Newton, and area in square millimeters, the pressure in bar can be calculated.

Example 1-1.

A cylinder is supplied with 100 bar pressure; its effective piston surface is equal to 700 mm2. Find the maximum force which can be attained.

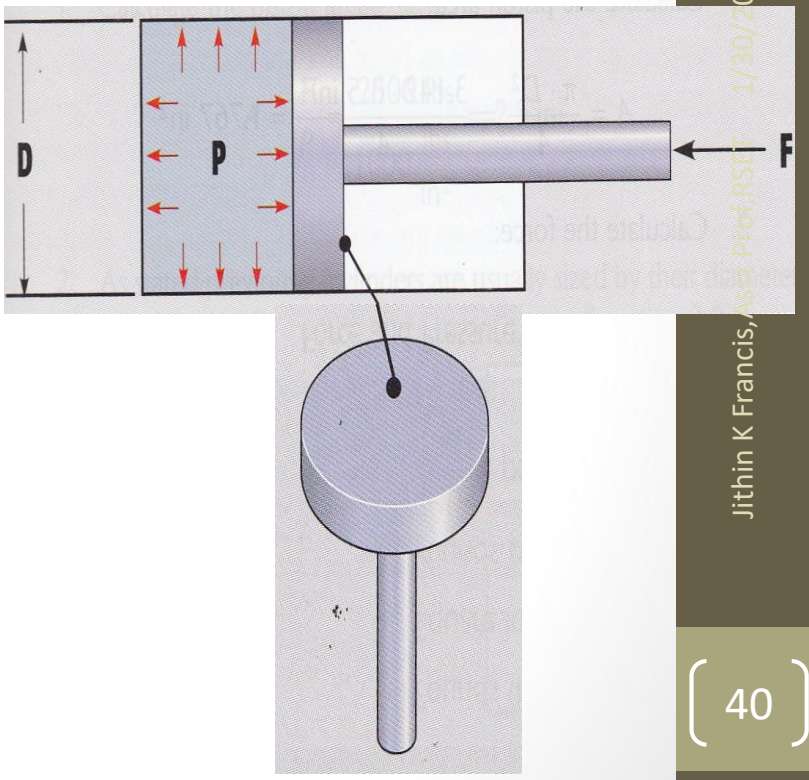
- P= 100 bar = 100X100000 N/m2.
- A= 700/1000000=0.0007 m2.
- F= P.A= 100X100000X0.0007= 7,000 N

Pascal's Law



- **Pascal's law** states that: "***The pressure in a confined fluid is transmitted equally to the whole surface of its container***"

- **When force F is exerted on area A on an enclosed liquid, pressure P is produced. The same pressure applies at every point of the closed system as shown in Fig.**



(a) Pascal's law.

Pascal's Law

- Fig. shows that, if a downward force is applied to piston A, it will be transmitted through the system to piston B.
- According to Pascal's law, the pressure at piston A (P1) equals the pressure at piston B (P2)

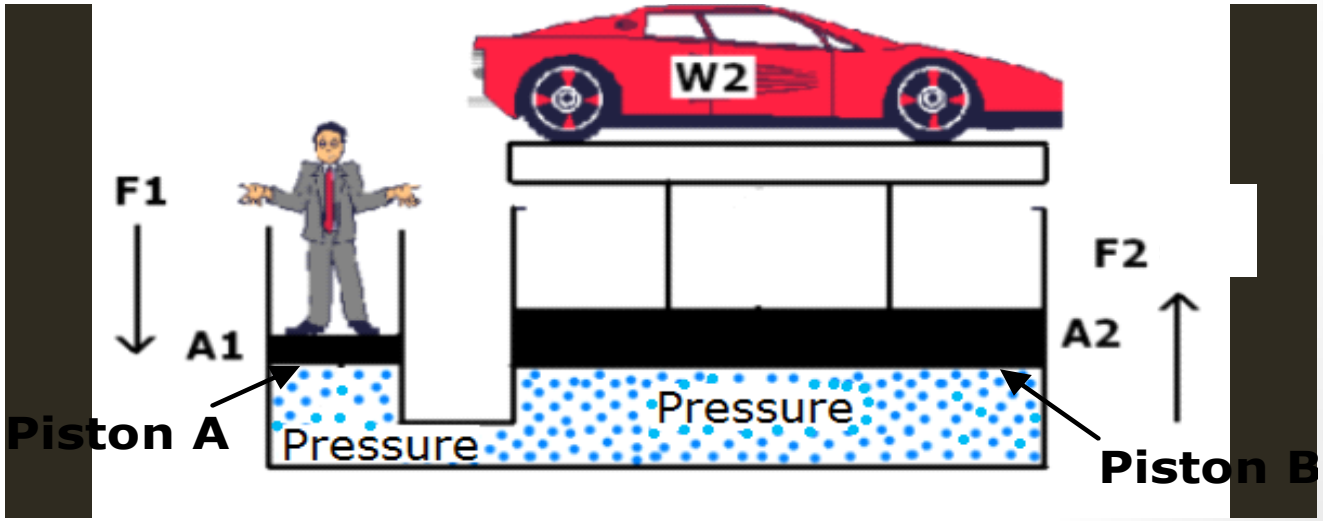
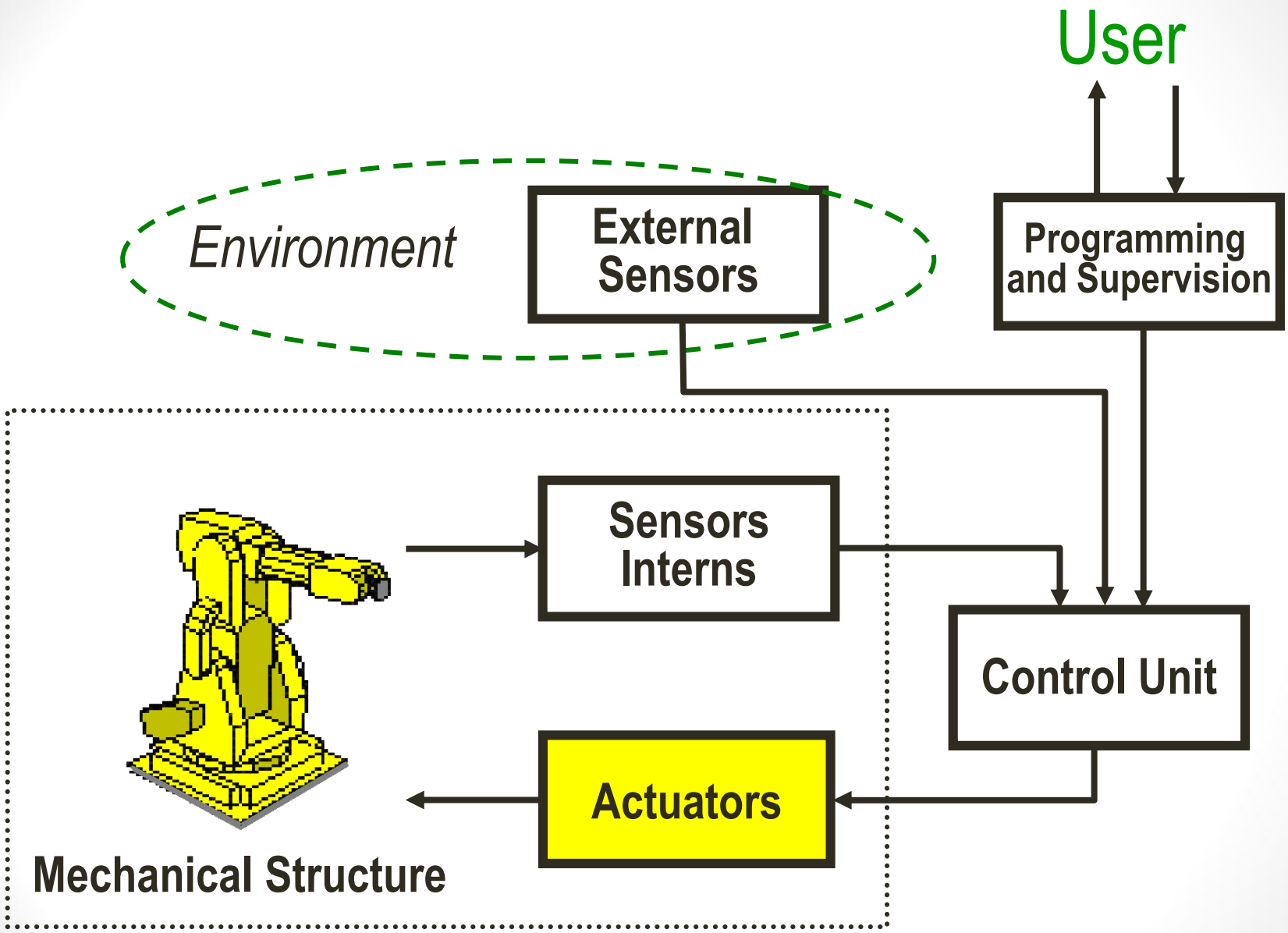


Fig. Power transmission

$$P_1 = P_2$$

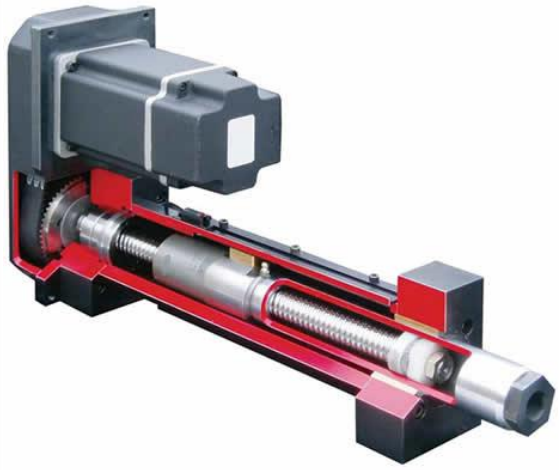
Actuators

WORKING ELEMENTS - (CYLINDERS OR ACTUATORS)

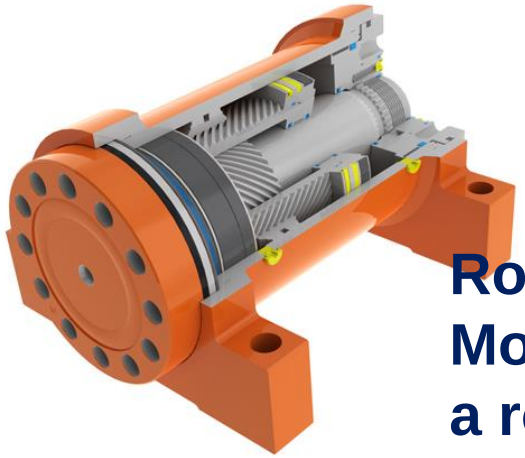

User
Environment
External Sensors
Programming and Supervision
Sensors Interns
Control Unit
Actuators
Mechanical Structure

Hydraulic Cylinders

Actuator – Converts fluid power back into mechanical power. It is most commonly a cylinder or



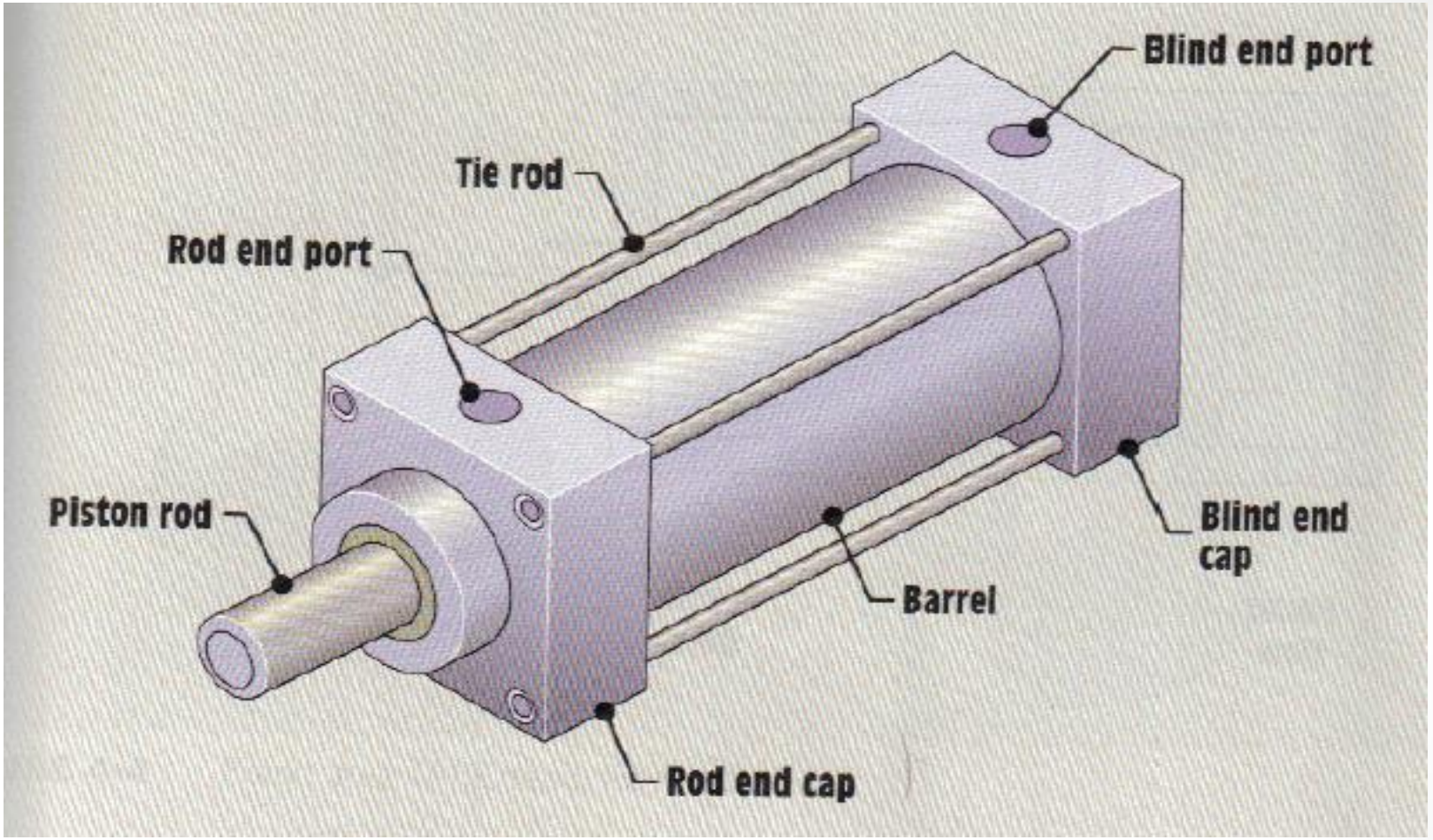
Linear Actuators – Cylinders that produce a straight line motion.



Rotary Actuators – Motors that produce a rotational motion.

Double Acting Cylinders – produce force in both directions by applying pressure to either side of the piston.

Parts of Hydraulic Cylinders



Motion is produced by applying pressure to either side of the piston, causing the piston to move back and forth.

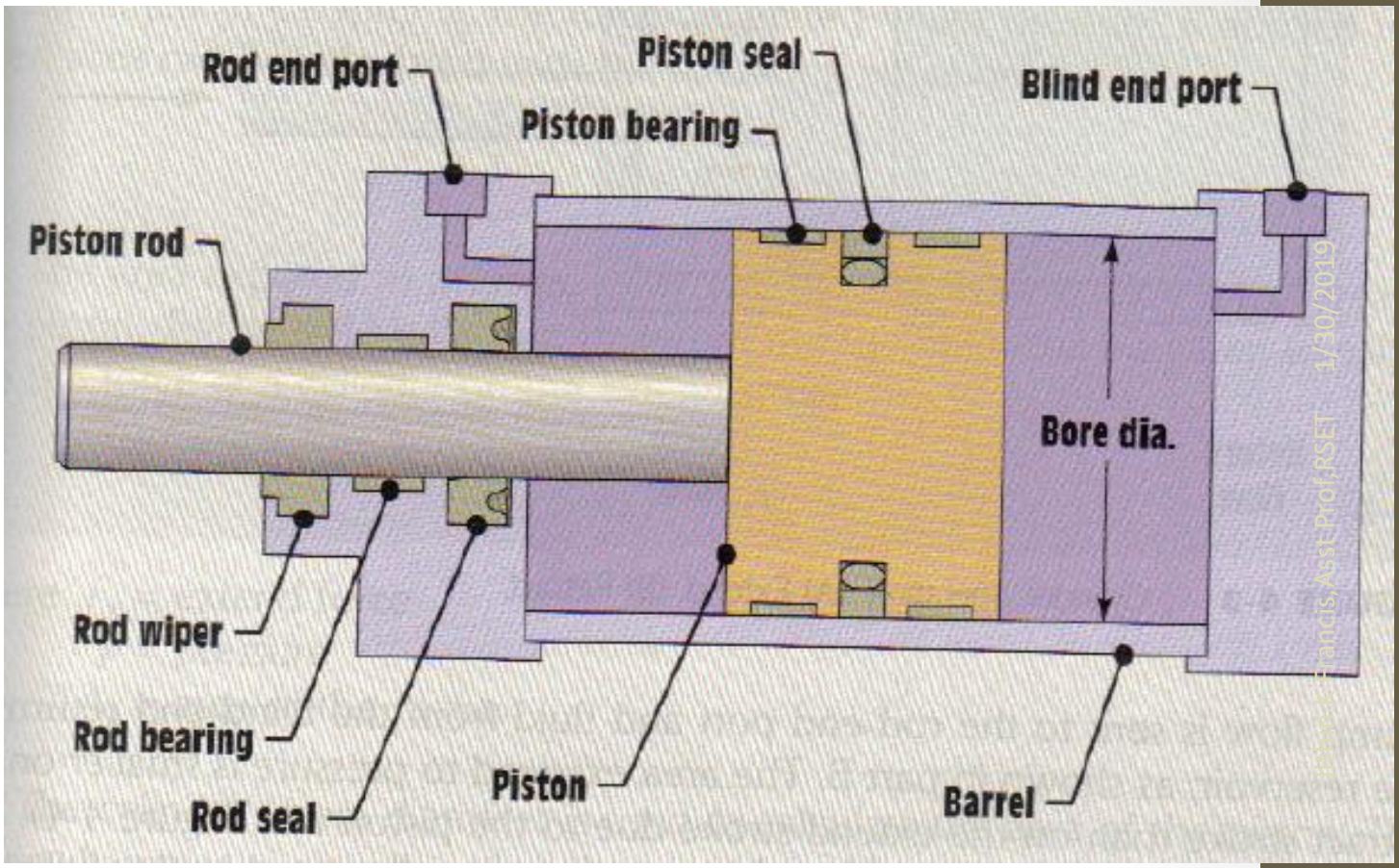
Load is attached to the piston rod.

Parts of Hydraulic Cylinders

Piston extends from the left side or the rod end.

Fluid is fed in from the blind end rod end ports.

Sized by the bore diameter which is the diameter of the barrel.



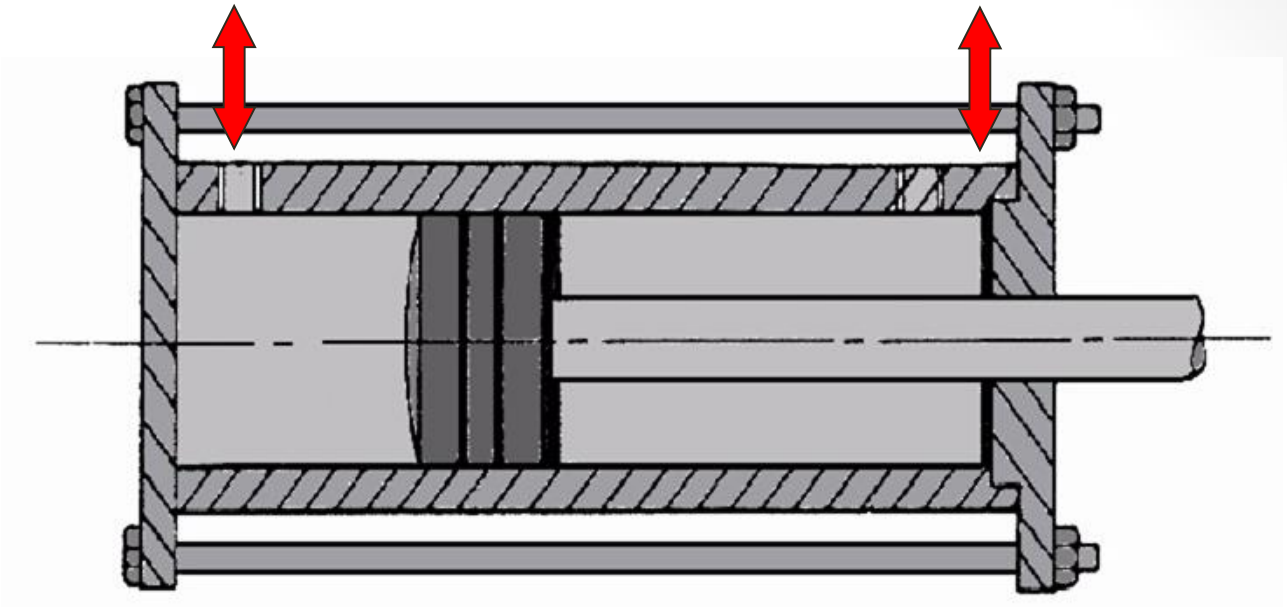
Rod wiper prevents contaminants from entering the cylinder.

WORKING ELEMENTS - (CYLINDERS OR ACTUATORS)

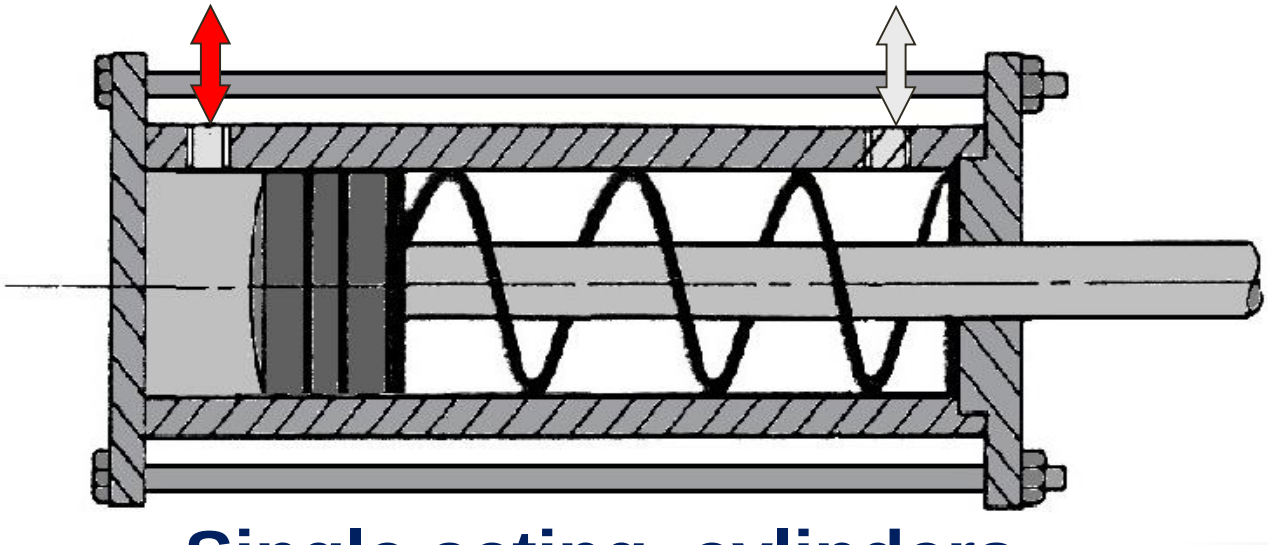
- Cylinder or Actuator is an output device, which converts Pneumatic energy to mechanical energy. The work done by a pneumatic actuator can be linear or rotary. Linear motion is obtained by piston cylinders, reciprocating motion with an angle up to 270^0 by vane or rack and pinion type actuators and continuous rotation by air motors.

Linear Cylinders

- Pneumatic cylinders of varying designs are the most common power components used in pneumatic automation. There are two basic types from which special constructions are derived.
- Single acting cylinders with one air inlet to produce a power stroke in one direction.
- Double acting cylinders with two air inlets to produce extending retracting power strokes.



Double acting cylinders

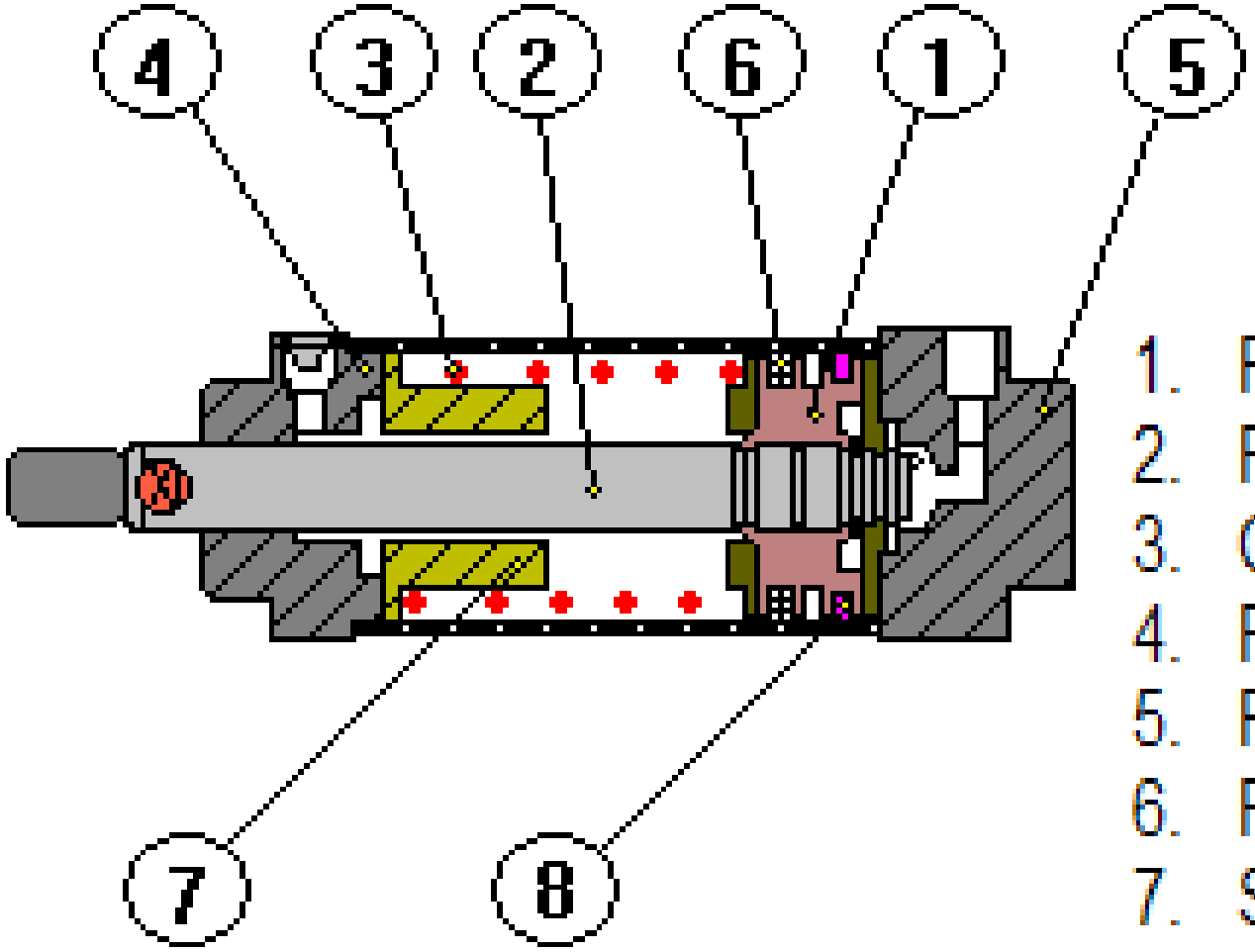


Single acting cylinders

Single Acting Cylinder

- A single acting cylinder develops thrust in one direction only The piston rod is returned by a return spring or by external force from the load or spring. It may be a push or pull type

Single Acting Cylinder



1. Piston
2. Piston rod
3. Compression spring
4. Front end cap
5. Rear end cap
6. Piston rings
7. Stop
8. Barrel

Single Acting Cylinder

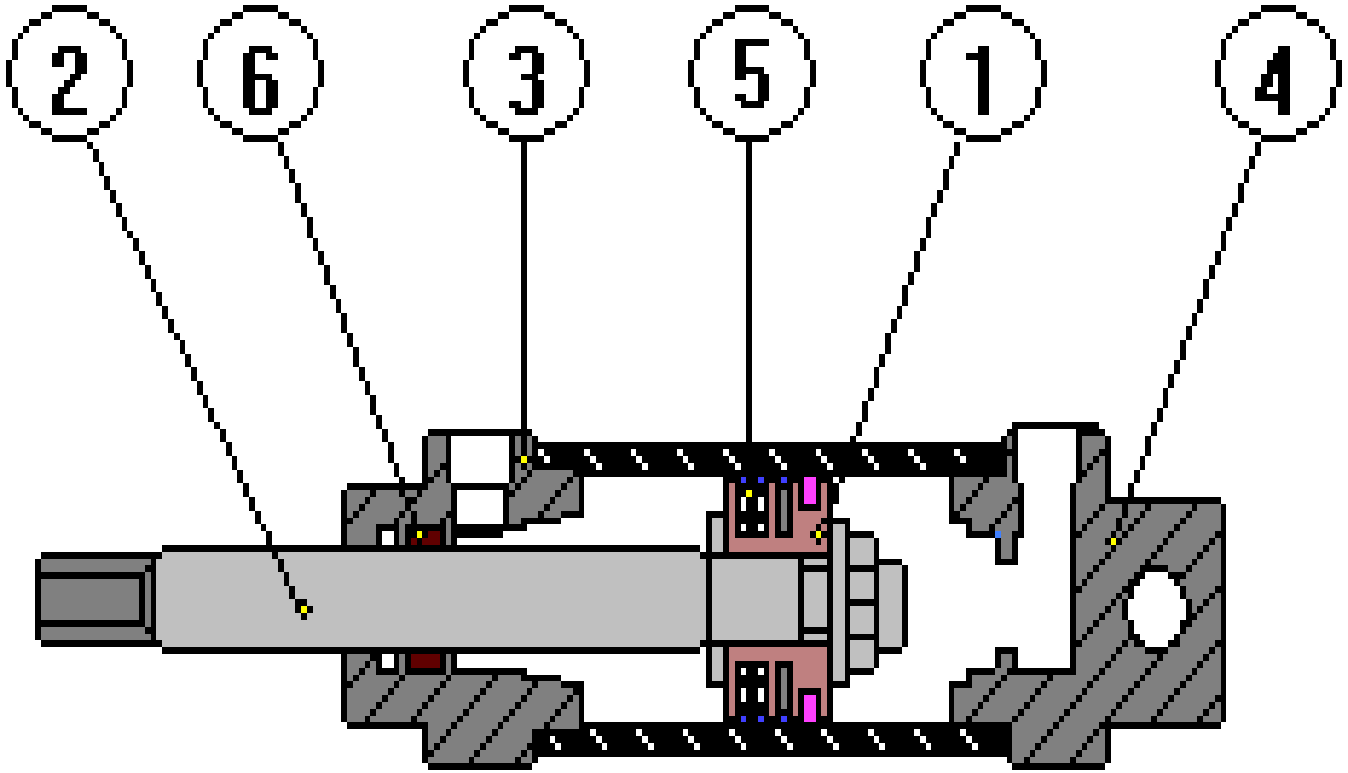
- Single acting cylinders are used for clamping, marking or ejecting. They have a somewhat lower air consumption compared with the equivalent size of double acting cylinders. How ever there is an reduction in thrust due to the opposing spring force, and so a larger bore required. Also accommodating the spring results in a longer overall length and limited stroke length.

Double Acting Cylinder

- With this actuator, thrust is developed in both extending and retracting directions as air pressure is applied alternately to opposite sides of a piston. The thrust available on the retracting stroke is reduced due to the smaller effective piston area, but is only a consideration if the cylinder is to pull the same load in both the directions.

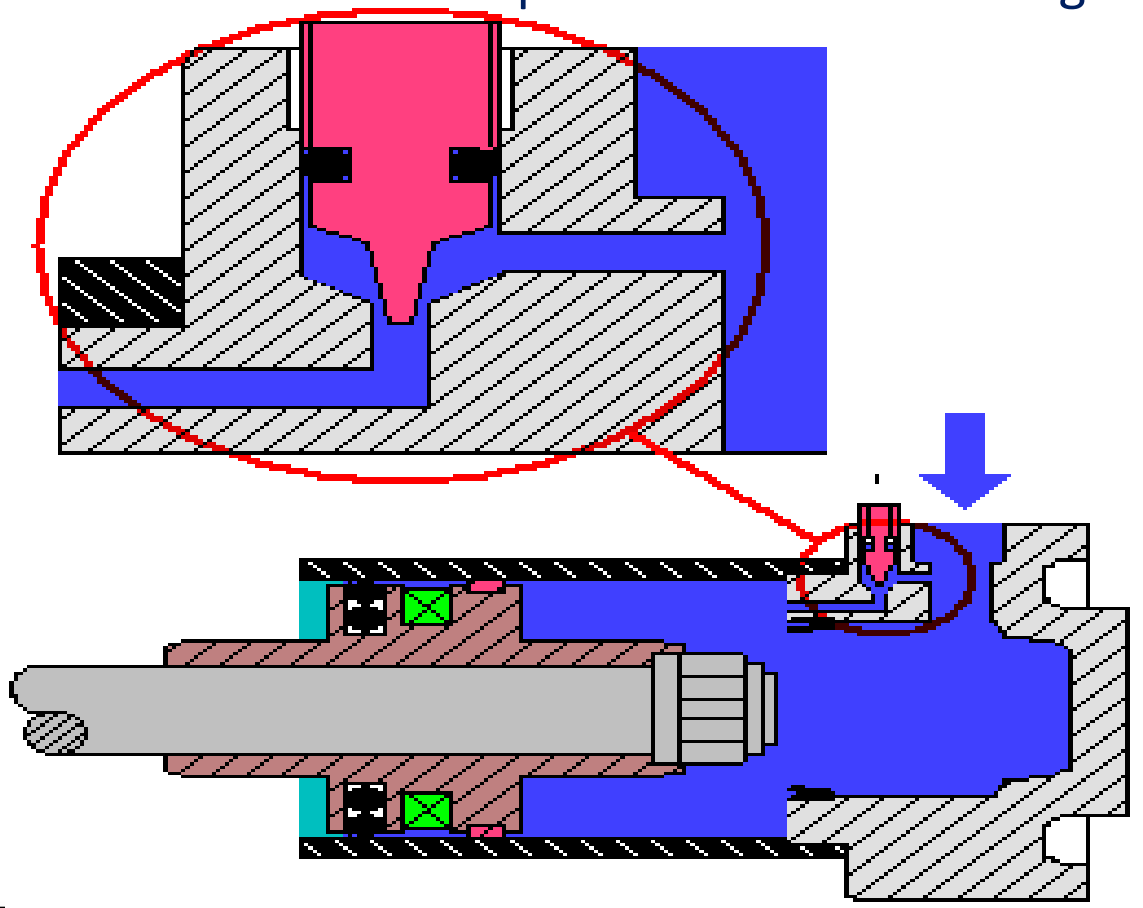
Double Acting Cylinder

1. Piston
2. Piston rod
3. Front end cap
4. Rear end cap
5. Piston rings
6. Rod seal / Scraper



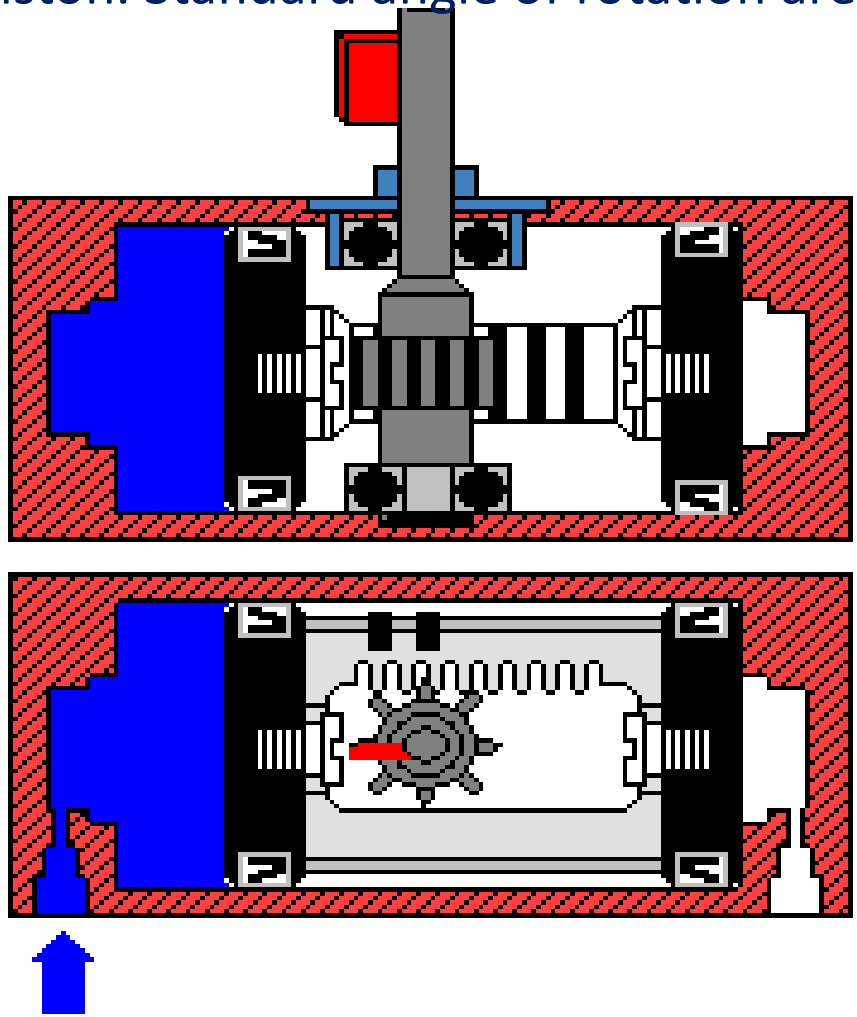
Cushioning

- Pneumatic cylinders are capable of very high speed and considerable shock forces can be developed on the end of the stroke. Smaller cylinder often have fixed cushioning i.e. rubber buffers, to absorb the shock and prevent internal damage to the cylinder



Rotary Actuators
Rack and Pinion type

- The output shaft has an integral pinion gear driven by a rack attached to a double piston. Standard angle of rotation are 90^0 or 180^0.



HYDRAULIC SYSTEMS: CONTROL VALVES

- In a hydraulic system, the hydraulic energy available from a pump is converted into motion and force by means of an actuator.
- The control of these mechanical outputs (motion and force) is one of the most important functions in a hydraulic system. The proper selection of control selection ensures the desired output and safe function of the system.
- In order to control the hydraulic outputs, different types of control valves are required. It is important to know various types of control valves and their functions. This not only helps

HYDRAULIC SYSTEMS: CONTROL VALVES

- In order to control the hydraulic outputs, different types of control valves are required. It is important to know various types of control valves and their functions. This not only helps to design a proper hydraulic system but also helps to discover the innovative ways to improve the existing systems.

HYDRAULIC SYSTEMS: CONTROL VALVES

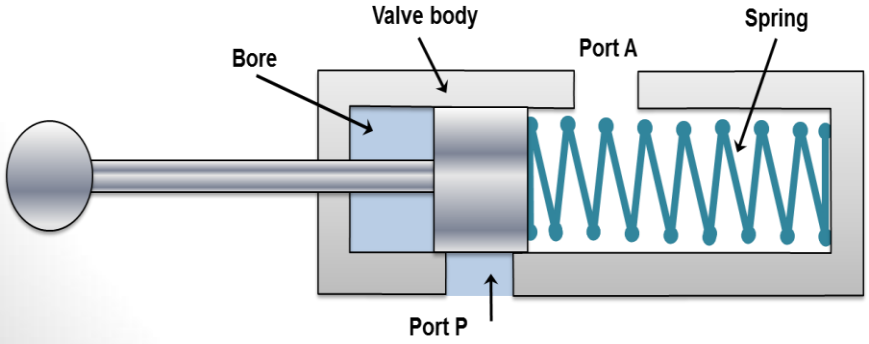
- There are basically three types of valves employed in hydraulic systems:
- Directional control valves
- Flow control valves
- Pressure control valves

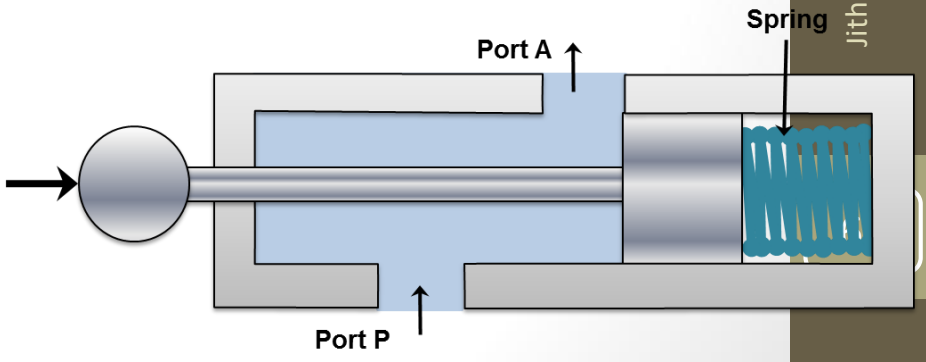
HYDRAULIC SYSTEMS: CONTROL VALVES

- Directional control valves can be classified in the following manner:
- Type of construction:
  - Poppet valves
  - Spool valves
- Number of ports:
  - Two- way valves
  - Three – way valves
  - Four- way valves.
- Number of switching position:
  - Two – position
  - Three - position
- Actuating mechanism:
  - Manual actuation
  - Mechanical actuation
  - Solenoid actuation
  - Hydraulic actuation
  - Pneumatic actuation
  - Indirect actuation

NUMBER OF PORTS

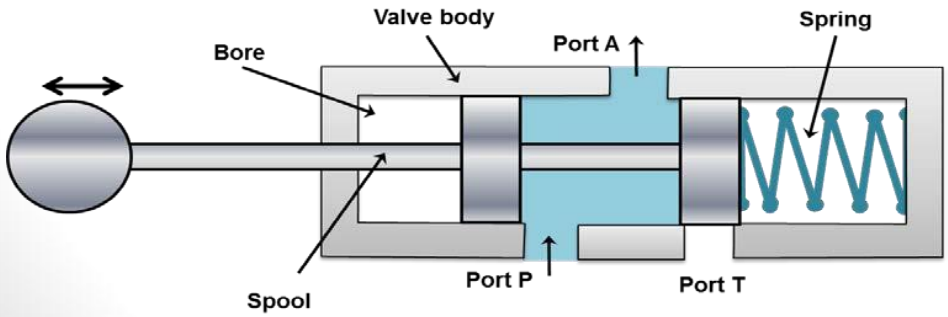
- **Two way valves**
- Two way valves have only two ports
- These valves are also known as on-off valves because they allow the fluid flow only in direction.
- Normally, the valve is closed.
- These are the simplest type of spool valves. When actuating force is not applied to the right, the port P is not connected with port A as shown in figure. Therefore, the actuation does not take place. Similarly, Figure shows the two way spool valve in the open condition. Here, the pressure port P is connected with the actuator port A.

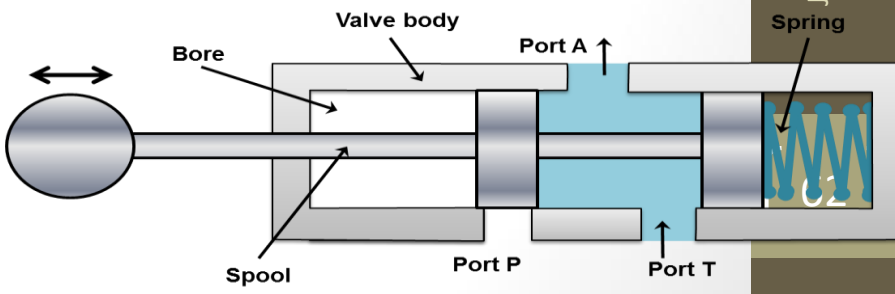




Three way valves

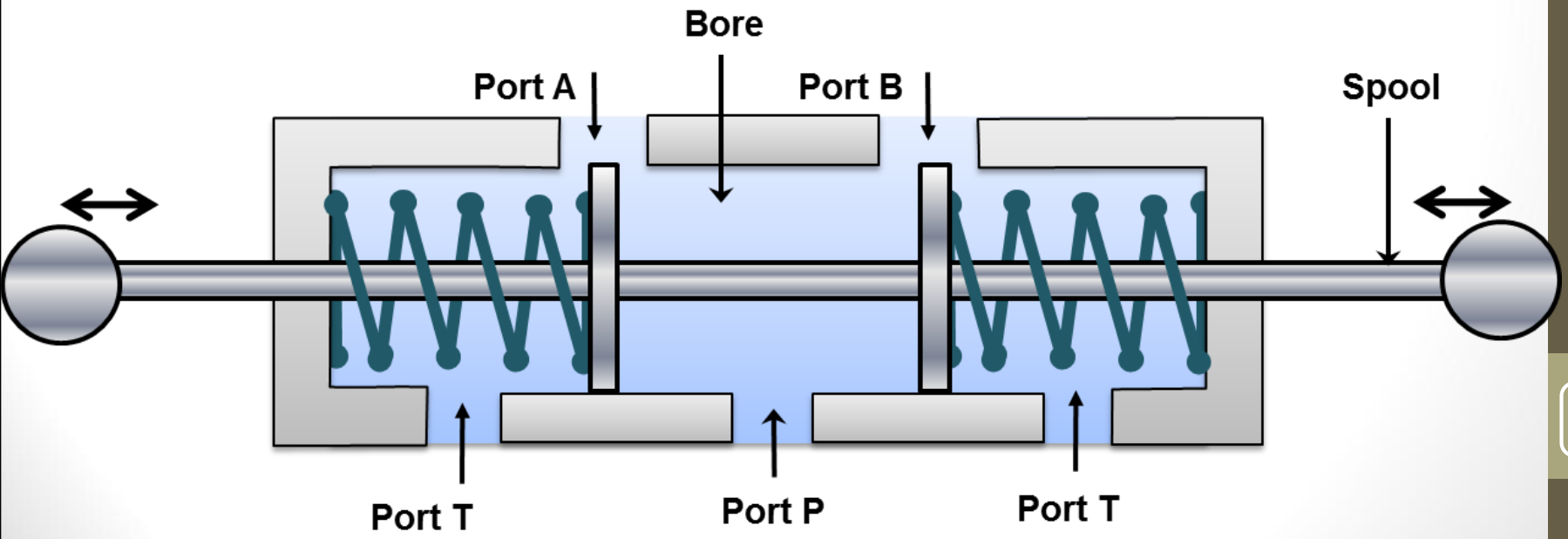
- When a valve has three pressure port it is known as three way valve.
- In this valve, the pressure port pressurizes one port and exhausts another one.
- only one actuator port is opened at a time.
- Generally, these valves are used to operate single acting cylinders.





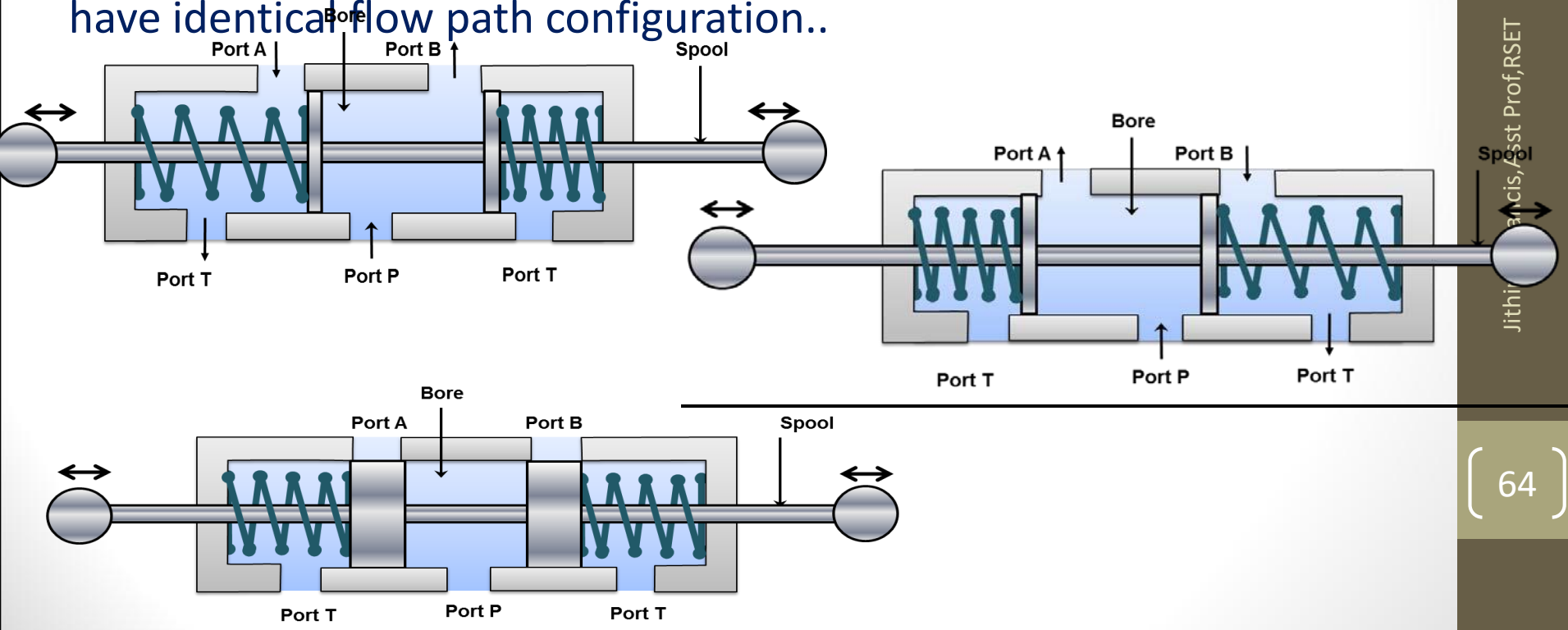
Four way valves

- It is generally used to operate the cylinders and fluid motors in both the directions. The four ways are: pump port P, tank port T, and two working ports A and B connected to the actuator. The primary function of a four way valve is to pressurize and exhaust two working ports A and B alternatively.



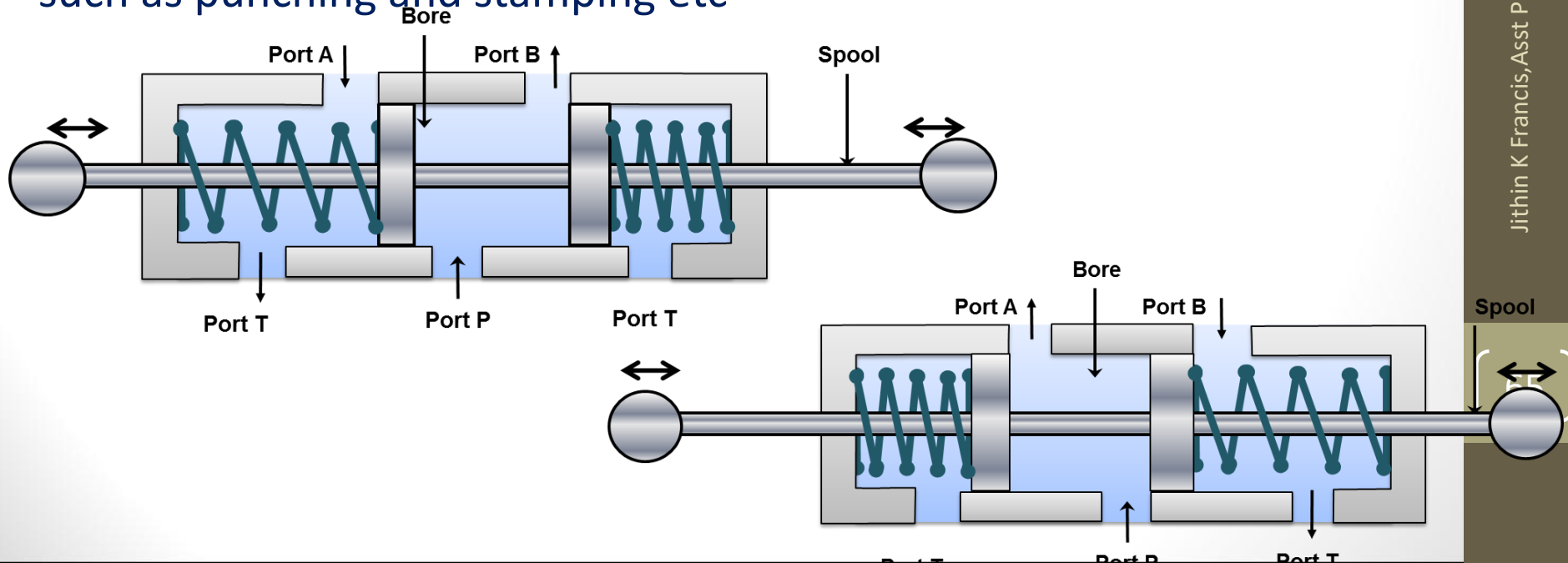
Classification of control valve according to number/ways of switching position

- **Three position four way (3/4) valves**
- Used in double-acting cylinders to perform advance, hold and return operation to the piston.
- These types of valves have three switching positions.
- They have a variety of possible flow path configurations but have identical flow path configuration..



Two position four way (2/4) valves

- The two position four way valves have only two switching positions and do not have any mid position.
- Also known as impulse valves.
- These valves can be used to operate double acting cylinders. These are also used to reciprocate or hold an actuator. The operation is faster because the distance between ports of these valves is smaller.
- Used on machines where fast reciprocation cycles are needed such as punching and stamping etc



DEVELOPMENT OF SIMPLE HYDRAULIC AND PNEUMATIC CIRCUITS USING STANDARD SYMBOLS

- The hydraulic and pneumatic elements such as cylinders and valves are connected through pipelines to form a hydraulic or a pneumatic circuit.
- It is difficult to represent the complex functioning of these elements using sketches.
- Therefore graphical symbols are used to indicate these elements

DEVELOPMENT OF SIMPLE HYDRAULIC AND PNEUMATIC CIRCUITS USING STANDARD SYMBOLS

- The symbols only specify the function of the element without indicating the design of the element.
- Symbols also indicate the actuation method, direction of flow of air and designation of the ports
- Symbols are described in various documents like DIN24300, BS2917, ISO1219 and the new ISO5599, CETOP RP3 and the original American JIC and ANSI symbols.

DEVELOPMENT OF SIMPLE HYDRAULIC AND PNEUMATIC CIRCUITS USING STANDARD SYMBOLS

- The symbol used to represent an individual element display the following characteristics:
- Function
- Actuation and return actuation methods
- Number of connections
- Number of switching positions
- General operating principle
- Simplified representation of the flow path

DEVELOPMENT OF SIMPLE HYDRAULIC AND PNEUMATIC CIRCUITS USING STANDARD SYMBOLS

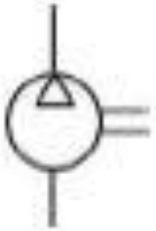
- The symbol does not represent the following characteristics:
- Size or dimensions of the component
- Particular manufacturer, methods of construction or costs
- Operation of the ports
- Any physical details of the elements
- Any unions or connections other than junctions

DEVELOPMENT OF SIMPLE HYDRAULIC AND PNEUMATIC CIRCUITS USING STANDARD SYMBOLS

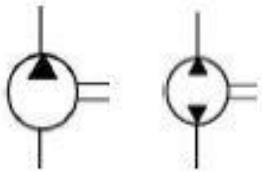
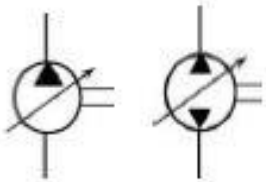
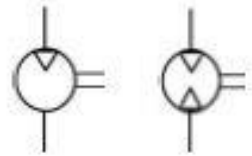
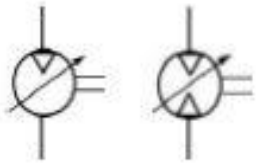
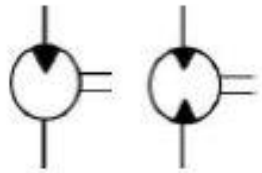
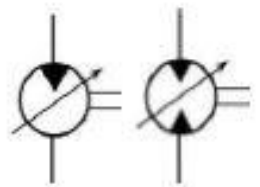
- **Table Symbols for ports**

Port	Letter system	Number system
Pressure port	P	1
Working port	A	4
Working port	B	2
Exhaust port	R	5
Exhaust port	S	3
Pilot port	Z	14
Pilot port	Y	12

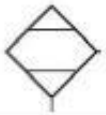
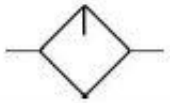
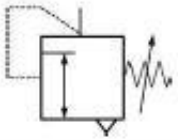
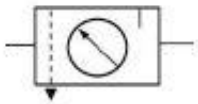
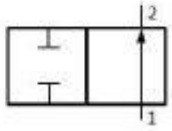
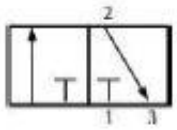
DEVELOPMENT OF SIMPLE HYDRAULIC AND PNEUMATIC CIRCUITS USING STANDARD SYMBOLS

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

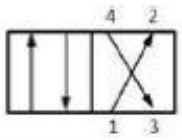
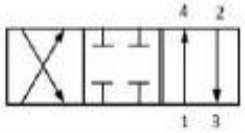
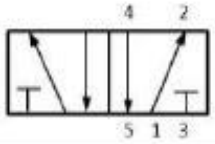
DEVELOPMENT OF SIMPLE HYDRAULIC AND PNEUMATIC CIRCUITS USING STANDARD SYMBOLS

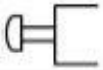
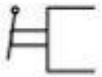
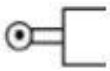
		One direction and two direction of rotation with constant displacement volume
	Hydraulic pump	One direction and two direction of rotation with variable displacement
Rotary actuators		
	Pneumatic motor	One direction and two direction of rotation with constant displacement volume
		One direction and two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

DEVELOPMENT OF SIMPLE HYDRAULIC AND PNEUMATIC CIRCUITS USING STANDARD SYMBOLS

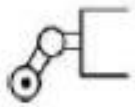
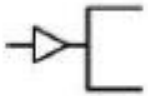
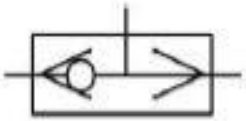
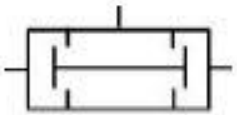
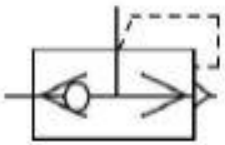
	Air filter	This device is a combination of filter and water separator
	Dryer	For drying the air
	Lubricator	For lubrication of connected devices, small amount of oil is added to
		the air flowing through this device
	Regulator	To regulate the air pressure
	FRL unit	Combined filter, regulator and lubricator system
Direction control valves (DCVs)		
	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)

DEVELOPMENT OF SIMPLE HYDRAULIC AND PNEUMATIC CIRCUITS USING STANDARD SYMBOLS

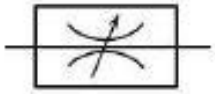
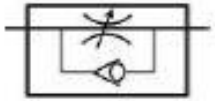
	4/2 way valve	For double acting cylinder all the ports are open
	4/3 way valve	Two open positions and one closed neutral position
	5/2 way valve	Two open positions with two exhaust ports

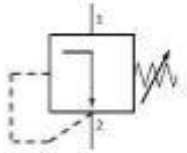
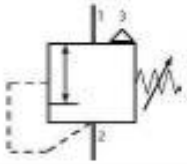
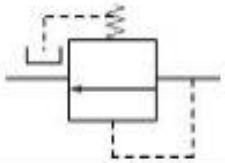
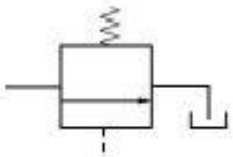
Direction control valve actuation methods		
	General manual actuation	Manual operation of DCV
	Push button actuation	
	Lever actuation	
	Detent lever actuation	
	Foot pedal actuation	Mechanical actuation of DCV
	Roller lever actuation	

DEVELOPMENT OF SIMPLE HYDRAULIC AND PNEUMATIC CIRCUITS USING STANDARD SYMBOLS

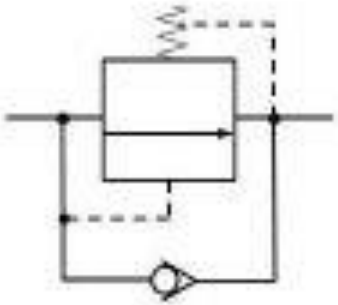
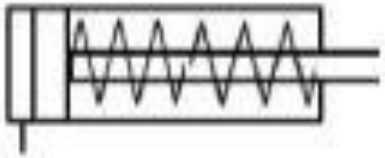
	Idle return roller actuation	
	Spring actuation	
	Direct pneumatic actuation	Pneumatic actuation of DCV
Non return valves		
	Check valve	Allows flow in one direction and blocks flow in other direction
	Spring loaded check valve	
	Shuttle/ OR valve	When any one of the input is given the output is produced
	AND valve	Only when both the inputs are given output is produced
	Quick exhaust valve	For quick exhaust of air to cause rapid extension/ retraction of cylinder

DEVELOPMENT OF SIMPLE HYDRAULIC AND PNEUMATIC CIRCUITS USING STANDARD SYMBOLS

	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

Pressure control valves		
	Pressure relieving valve	Non relieving type
		Relieving type with overload being vented out
	Pressure reducing valve	Maintains the reduced pressure at specified location in hydraulic system
	Unloading valve	Allows pump to build pressure to an adjustable pressure setting and then allow it to be discharged to tank

DEVELOPMENT OF SIMPLE HYDRAULIC AND PNEUMATIC CIRCUITS USING STANDARD SYMBOLS

	Counter balance valve	Controls the movement of vertical hydraulic cylinder and prevents its descend due to external load weight
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