Module 4 – Lecture 1

Hydraulic Systems

SE501 – Fundamentals of Mechatronics
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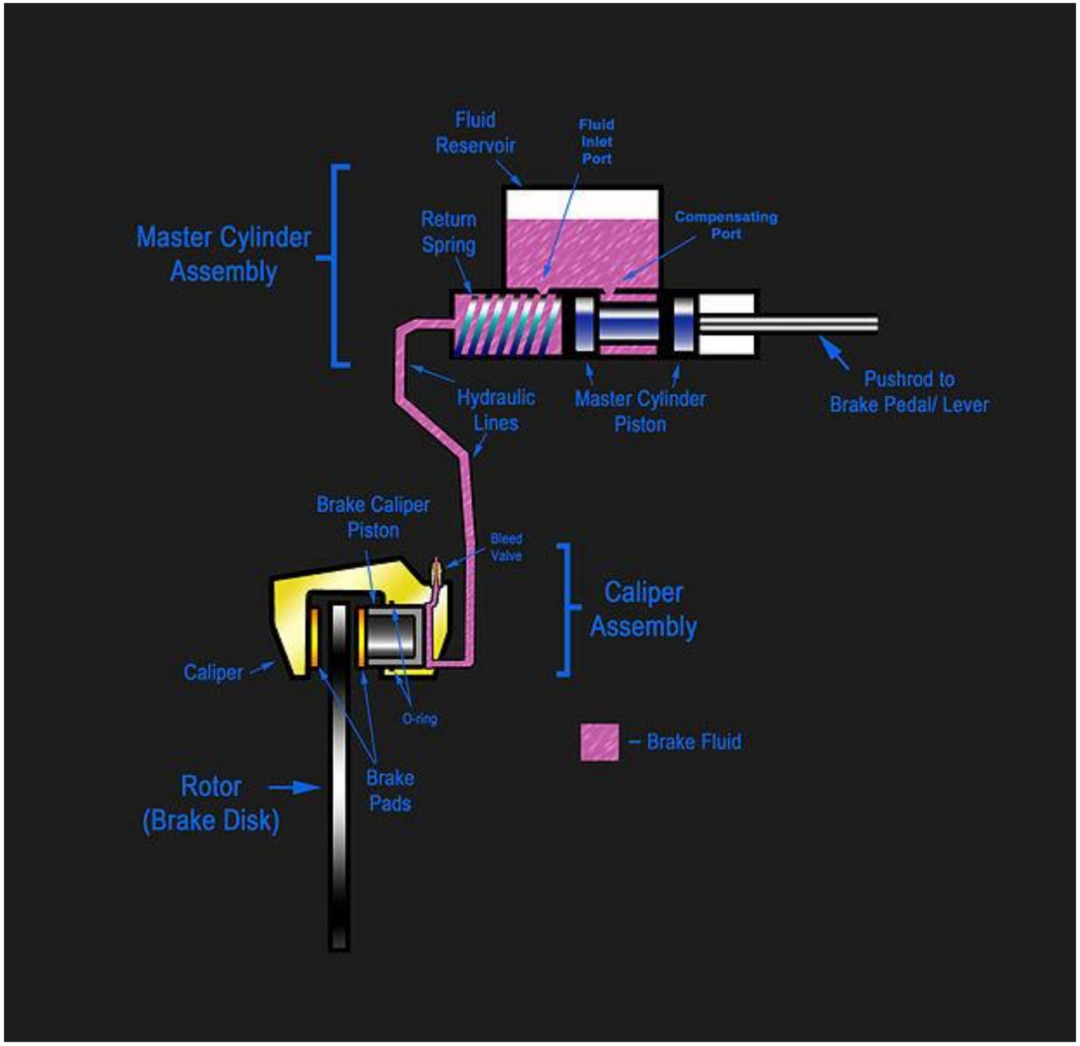
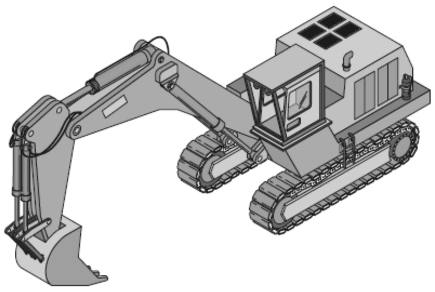
Assistant Professor
Indian Institute of Technology, Patna

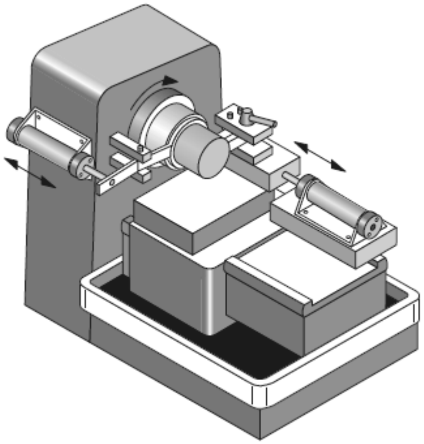
Example of Hydraulic Brake



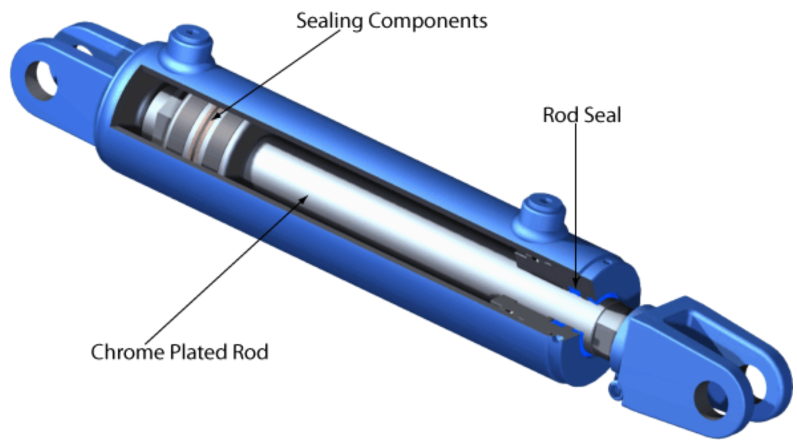
Hydraulics

- Generation of forces and motion using hydraulic fluids
- Hydraulic fluid used as medium for power transmission
- Application areas
  - Marine
  - Mining
  - Aircraft

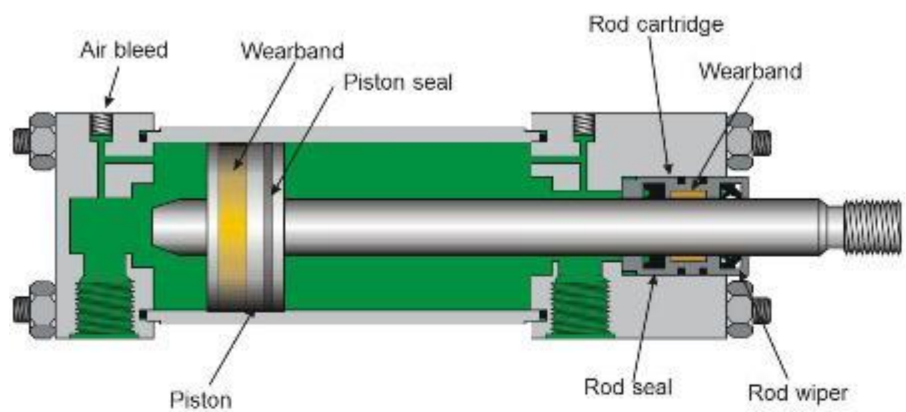




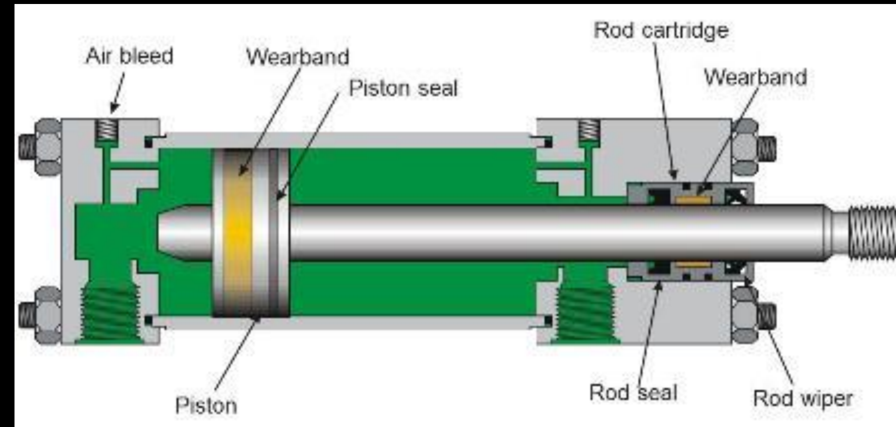
Hydraulic Cylinder and Piston

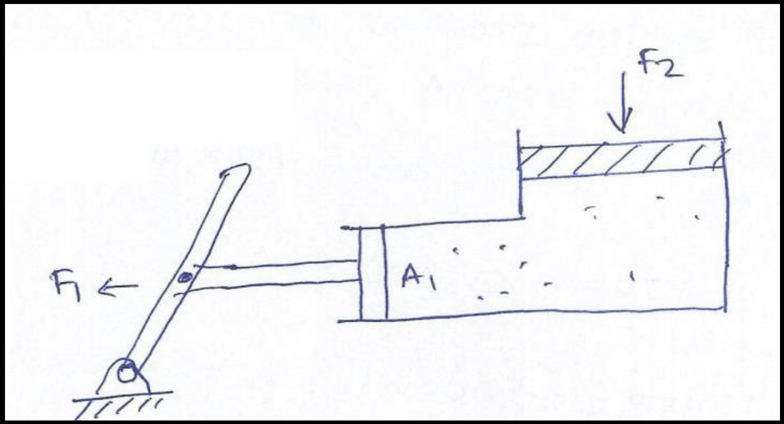


Cut-away View



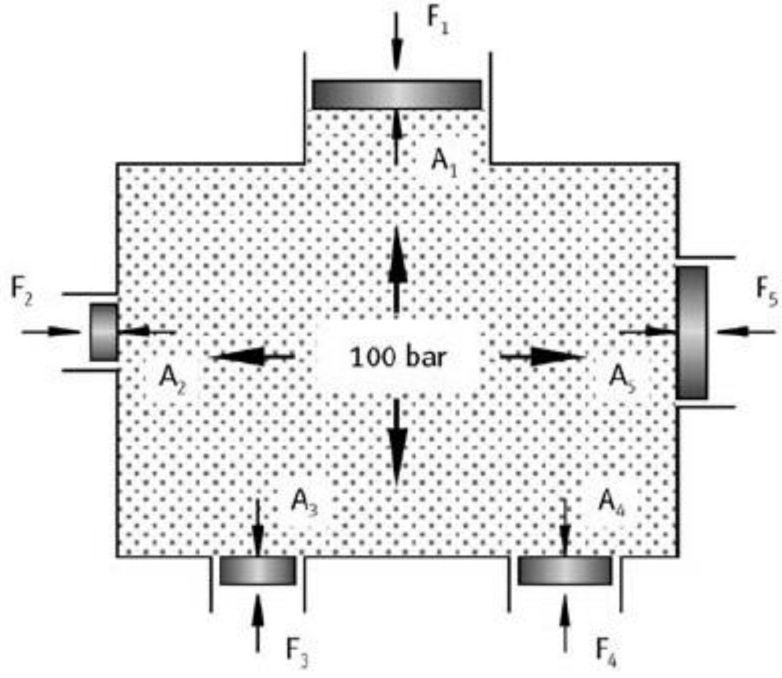
Section View


Rod cartridge
Air bleed
Wearband
Piston seal
Wearband
Piston
Rod seal
Rod wiper



F2
F1
A1

Hydraulic Force Transmission

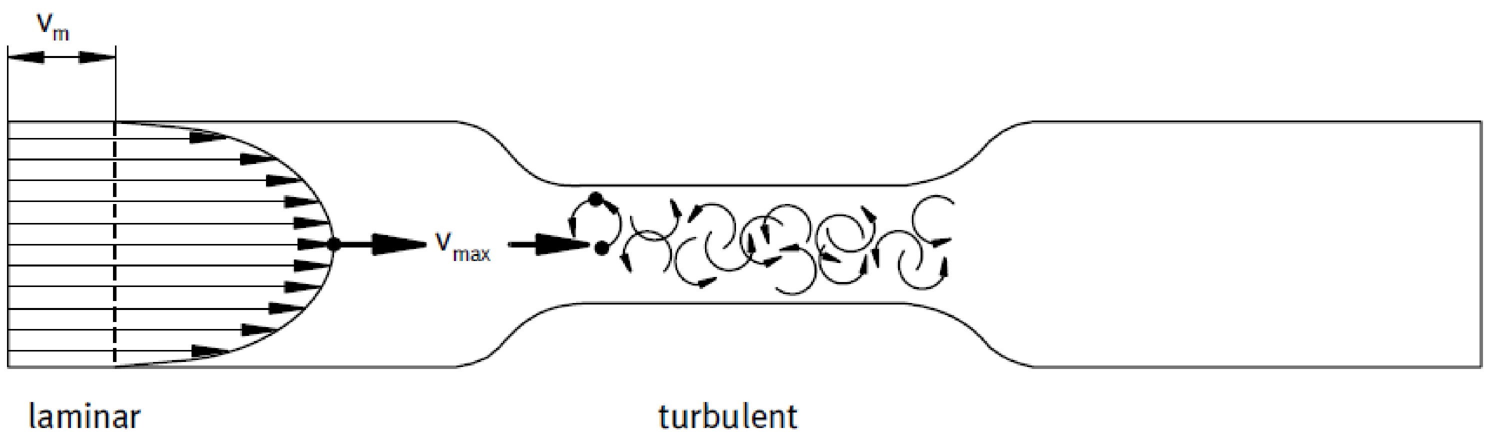


	Electricity	Hydraulics	Pneumatics
Leakage		Contamination	No disadvantages apart from energy loss
Environmental influences	Risk of explosion in certain areas, insensitive to temperature.	Sensitive in case of temperature fluctuation, risk of fire in case of leakage.	Explosion-proof, insensitive to temperature.
Energy storage	Difficult, only in small quantities using batteries.	Limited, with the help of gases.	Easy
Energy transmission	Unlimited with power loss.	Up to 100 m, flow rate v = 2 – 6 m/s, signal speed up to 1000 m/s.	Up to 1000 m, flow rate v = 20 – 40 m/s, signal speed 20 – 40 m/s.
Operating speed		v = 0.5 m/s	v = 1.5 m/s
Power supply costs	Low	High	Very high
	0.25 :	1 :	2.5
Linear motion	Difficult and expensive, small forces, speed regulation only possible at great cost	Simple using cylinders, good speed control, very large forces.	Simple using cylinders, limited forces, speed extremely, load-dependent.
Rotary motion	Simple and powerful.	Simple, high turning moment, low speed.	Simple, inefficient, high speed.
Positioning accuracy	Precision to ±1 µm and easier to achieve	Precision of up to ±1 µm can be achieved depending on expenditure.	Without load change precision of 1/10 mm possible.
Stability	Very good values can be achieved using mechanical links.	High, since oil is almost incompressible, in addition, the pressure level is considerably higher than for pneumatics.	Low, air is compressible.
Forces	Not overloadable. Poor efficiency due to downstream mechanical elements. Very high forces can be realized.	Protected against overload, with high system pressure of up to 600 bar, very large forces can be generated F < 3000 kN.	Protected against overload, forces limited by pneumatic pressure and cylinder diameter F < 30 kN at 6 bar.

Festo

Laminar Vs Turbulent Flow

- Laminar flow fluid moves through pipe in ordered cylindrical layers
- In turbulent flow the fluid ceases to flow in ordered layers and form eddies



<u>Reynolds Number</u>

$$Re = \frac{v \cdot d}{\nu}$$

v: flow velocity (m/s)

d: Pipe diameter (m)

ν: Kinematic viscosity (m^2s^{-1})

Laminar flow : Re<2300

Turbulent flow : Re<2300

Components of Hydraulic System

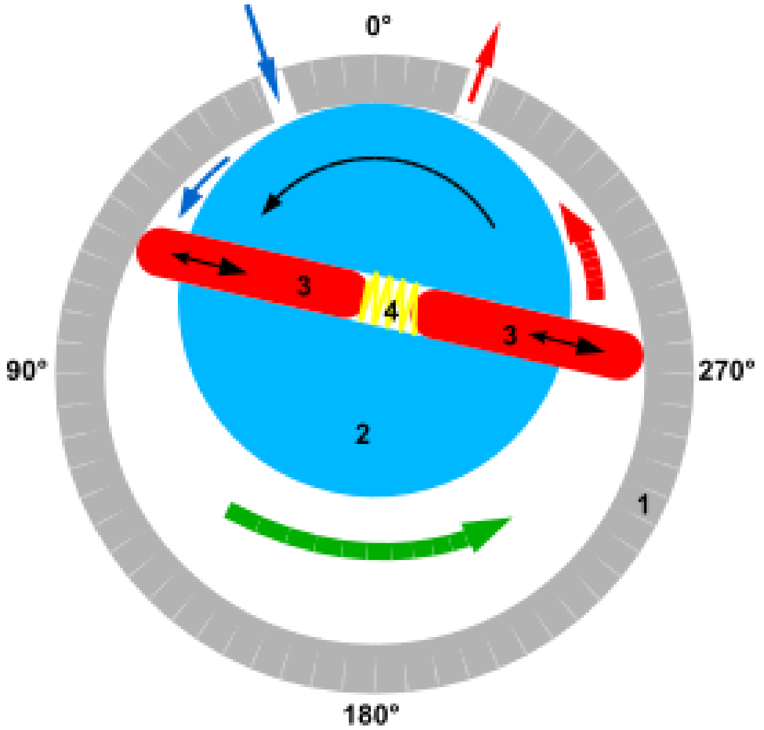
- Pumps
- Valves
- Accumulators
- Actuators
- Reservoir

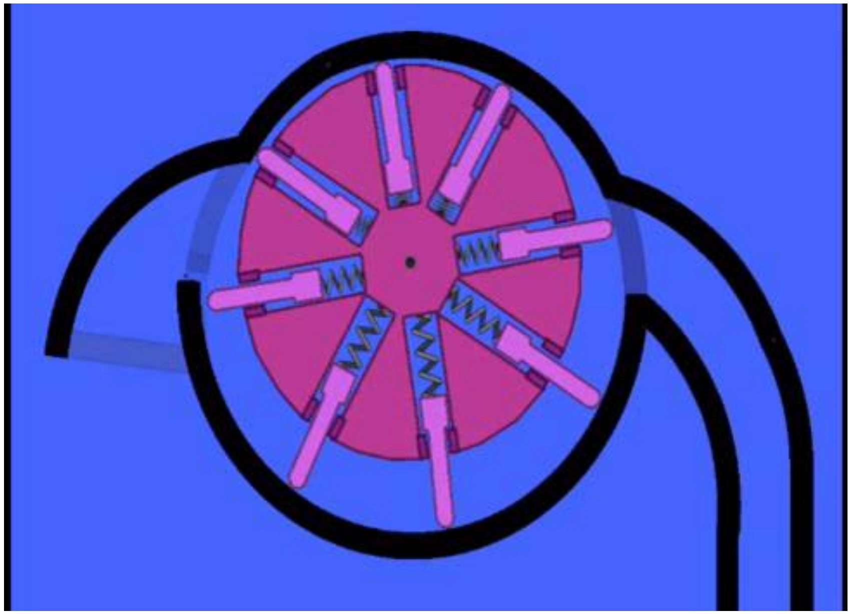
Pumps

- A hydraulic pump is a mechanical source of power
  - Converts mechanical power into hydraulic energy (hydrostatic energy i.e., flow, pressure)

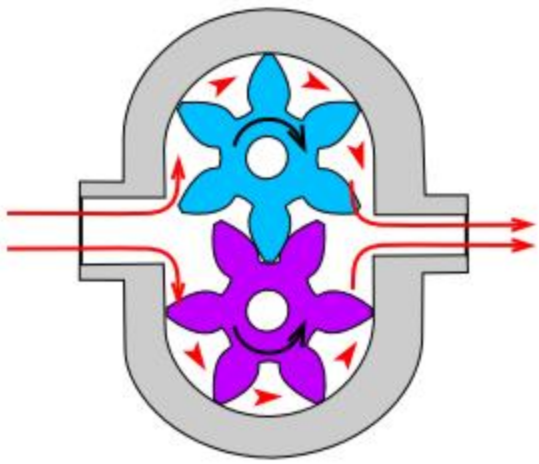
- Types of Pumps
  - Vane pump
  - Gear Pump
  - Axial Piston Pump

Vane Pump

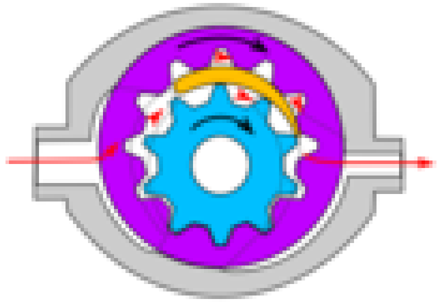




Gear Pump

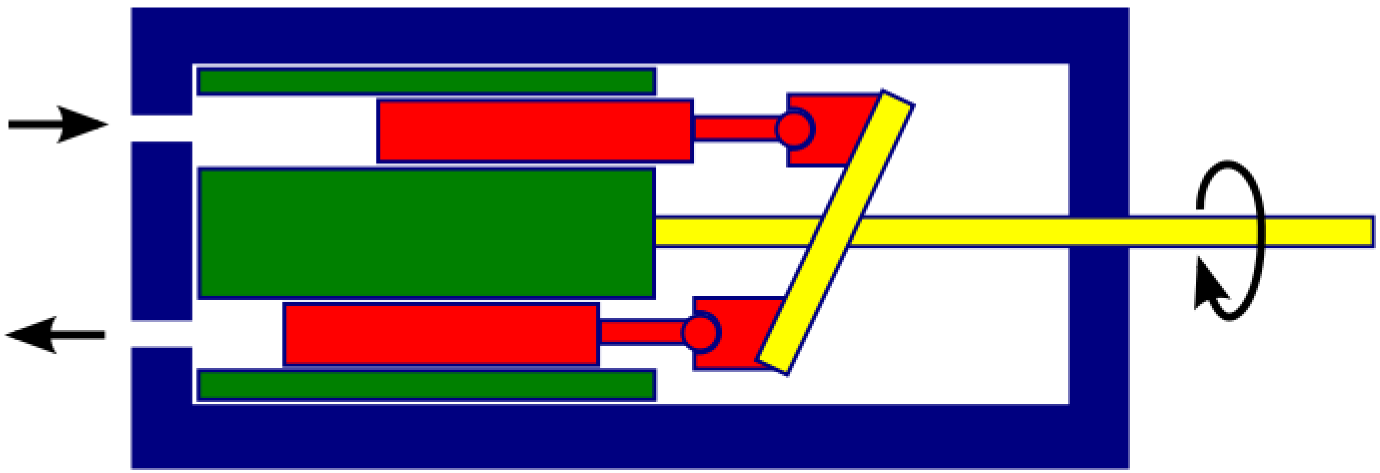


External Gear Pump



Internal Gear Pump

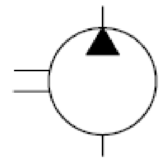
Axial Piston Pump



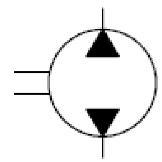
Symbolic Representation of Pump

Hydraulic pumps with fixed displacement

– with one flow direction

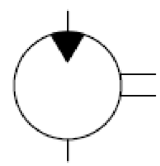


– with two flow directions

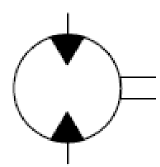


Hydraulic motors with fixed displacement

– with single direction of rotation



– with two directions of rotation



Valves

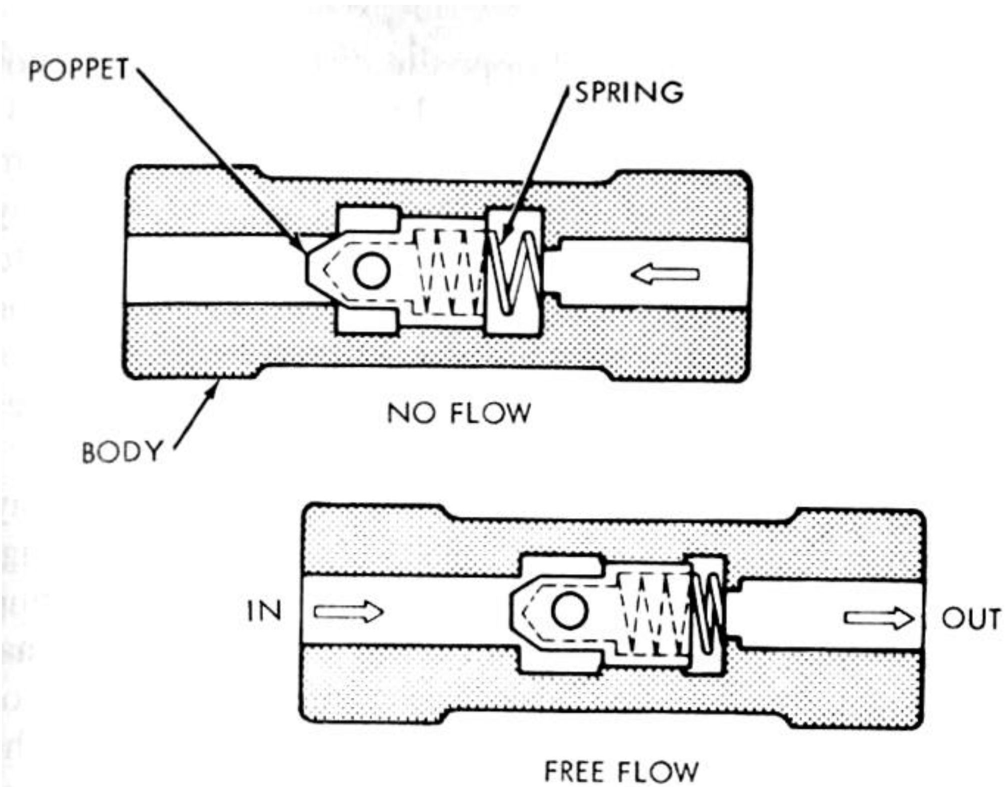
- To change flow direction (Direction Control)
- To change flow rate (Flow Control)
- Change fluid pressure (Pressure Control)

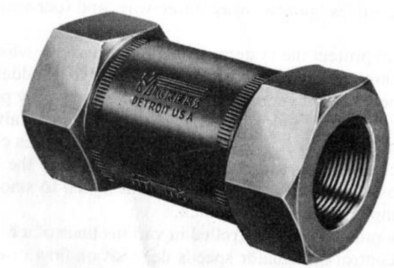
Simplest example of valve is your basin tap

What does that do among above three?

Direction Control (DC) Valve

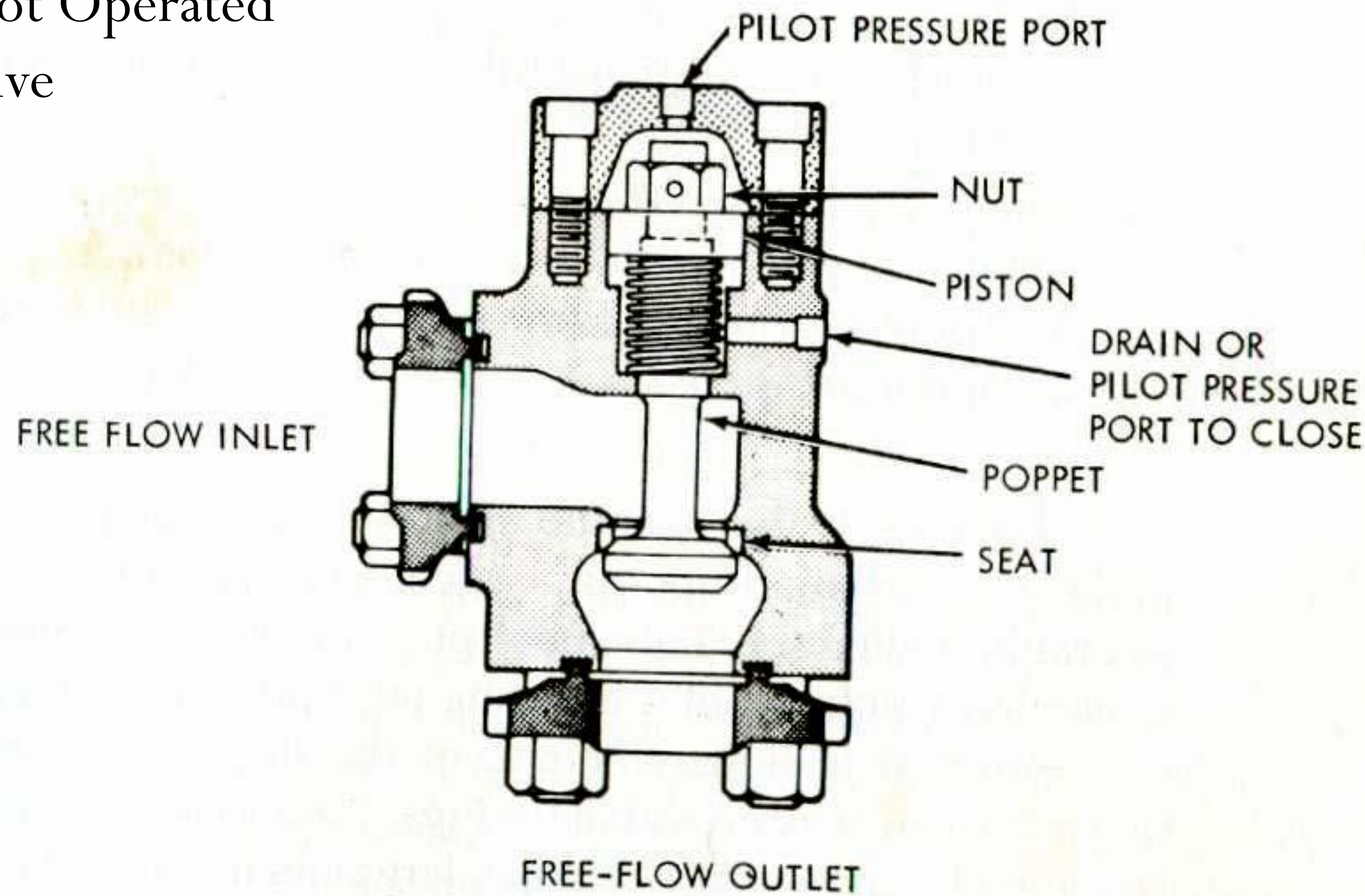
Check Valve





Direction Control (DC) Valve

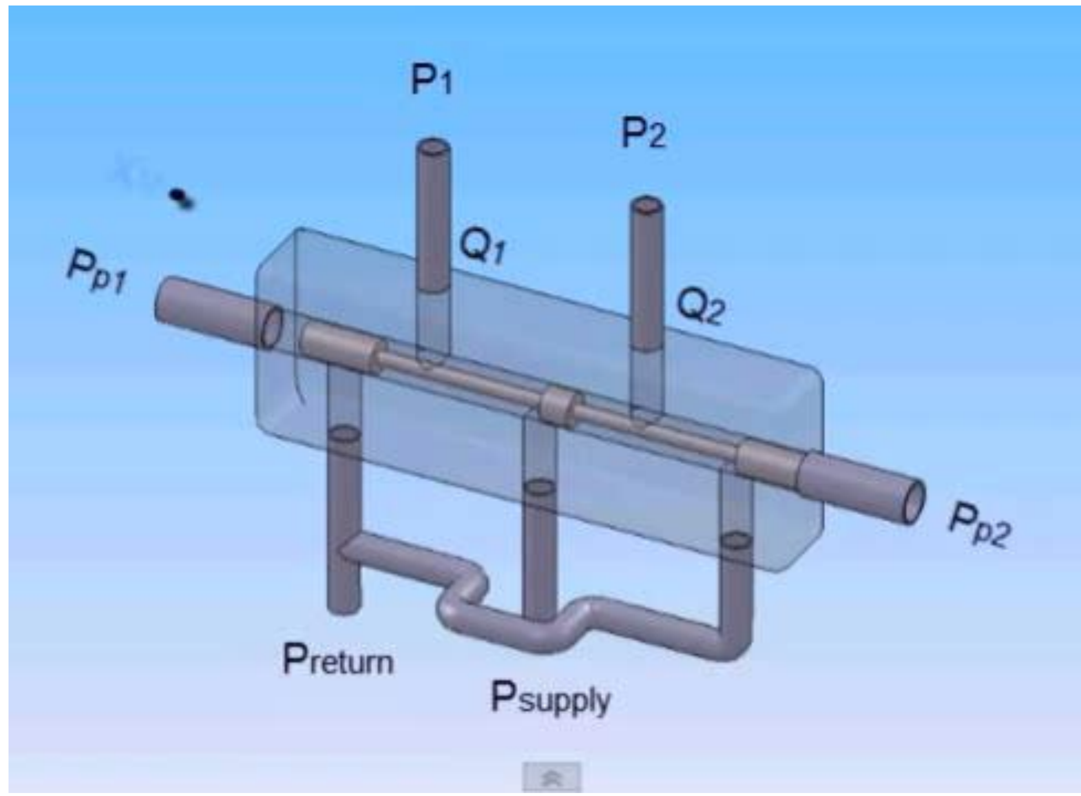
Pilot Operated Valve



Direction Control Valve

- Spool can be placed
  - Manually
  - Mechanically
  - Pilot pressure
  - Electrical solenoid

Spool Valve

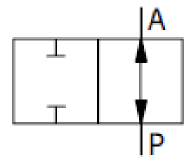


Symbolic Representation of Valves

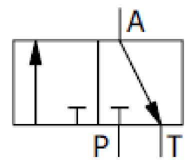
Number of ports

Number of switching positions

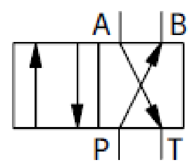
2/2 – way valve



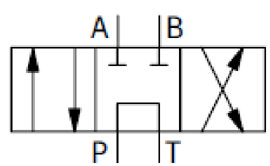
3/2 – way valve



4/2 – way valve



4/3 – way valve



Port designations

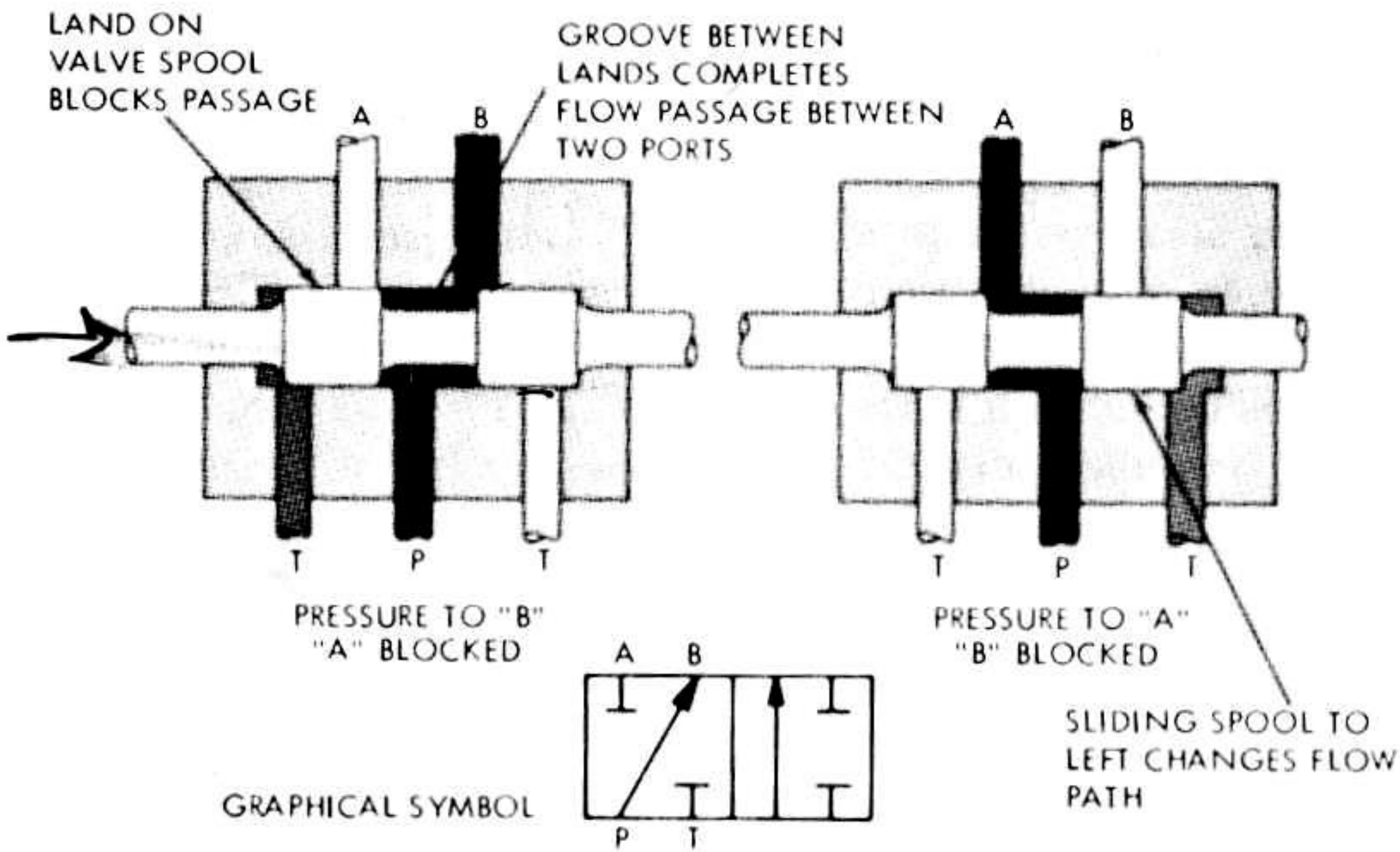
P	pressure port
T	return port
A, B	power ports
L	leakage oil

or:

A	pressure port
B	return port
C, D	power ports
L	leakage oil

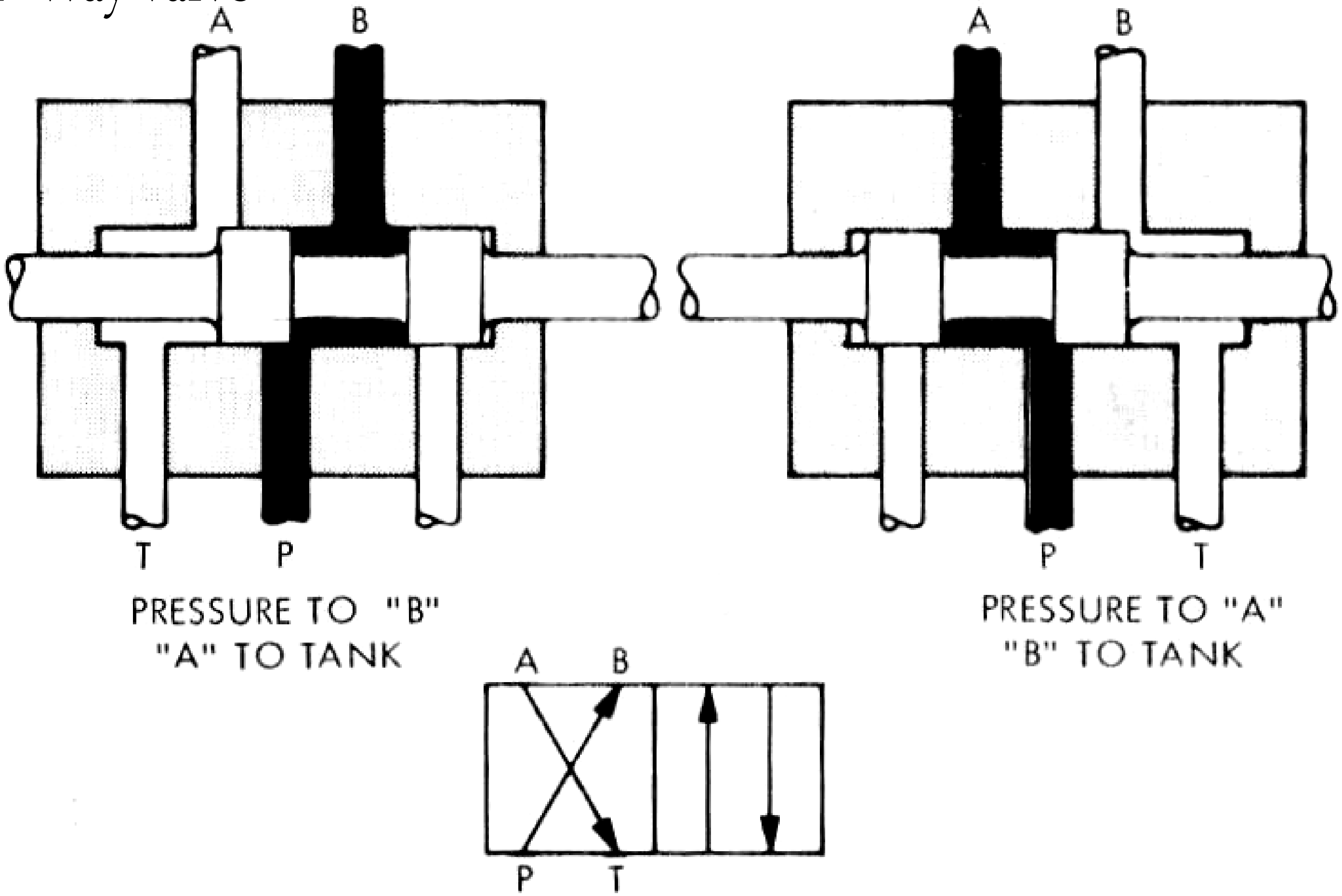
Direction Control Valve

Two-Way Valve

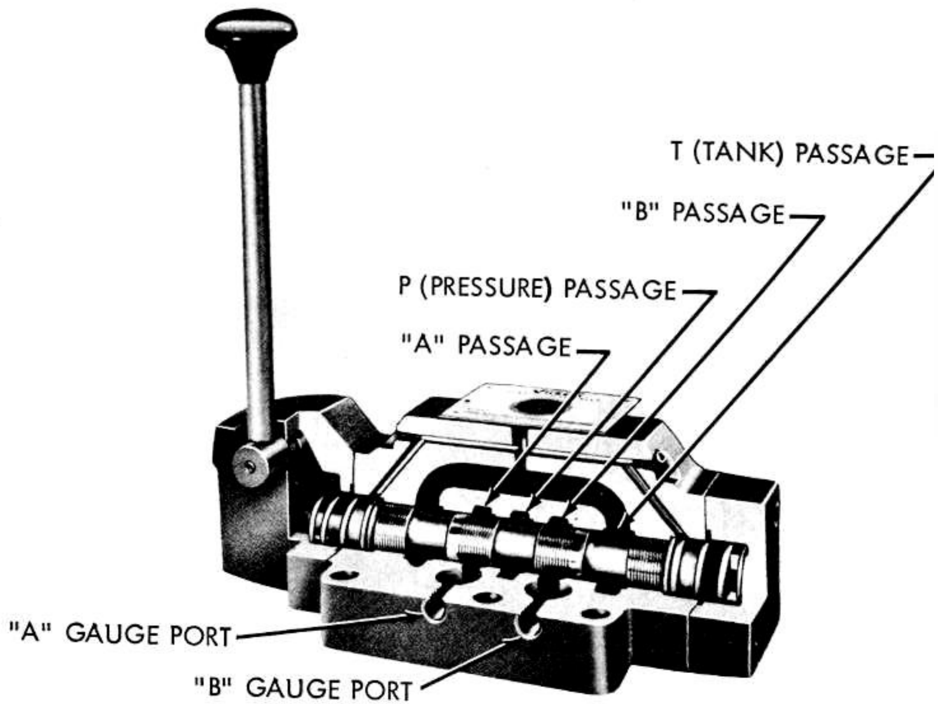


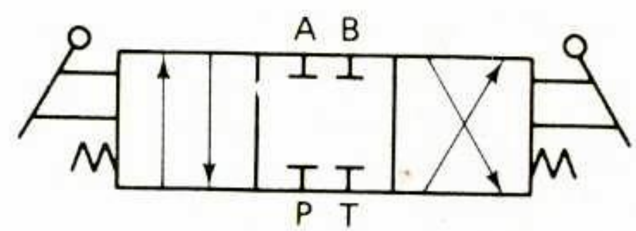
Direction Control Valve

Four-Way Valve

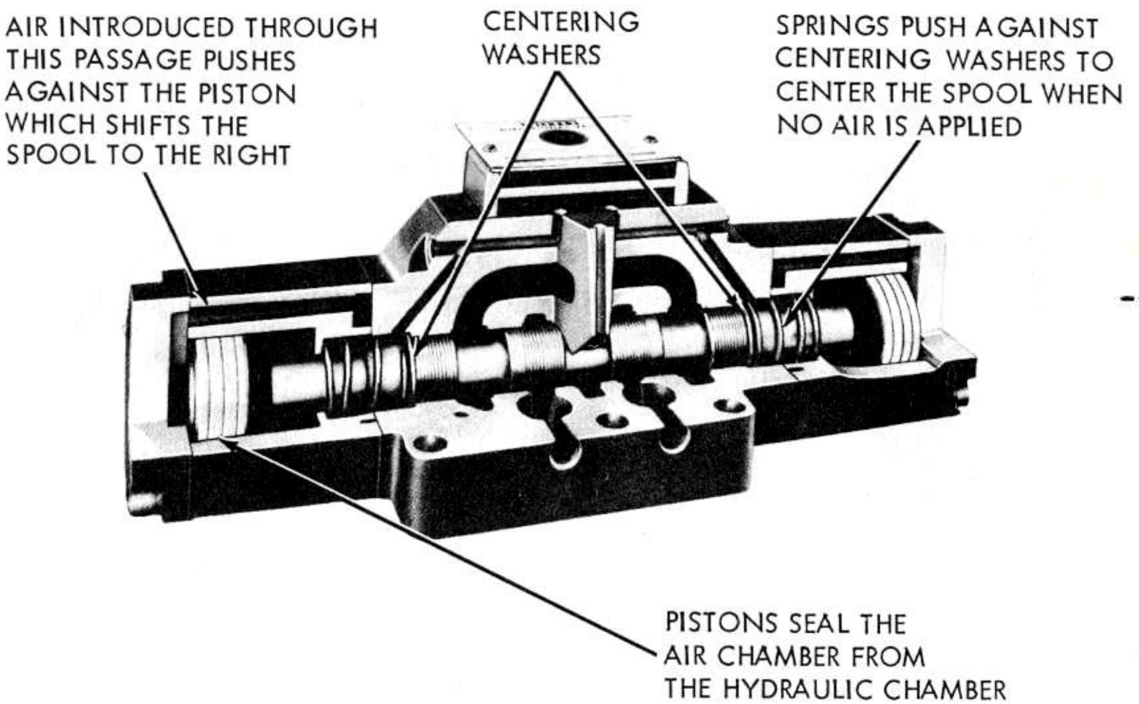


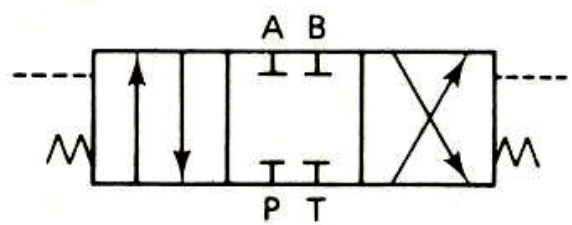
Manually Actuated 4/3 Valve



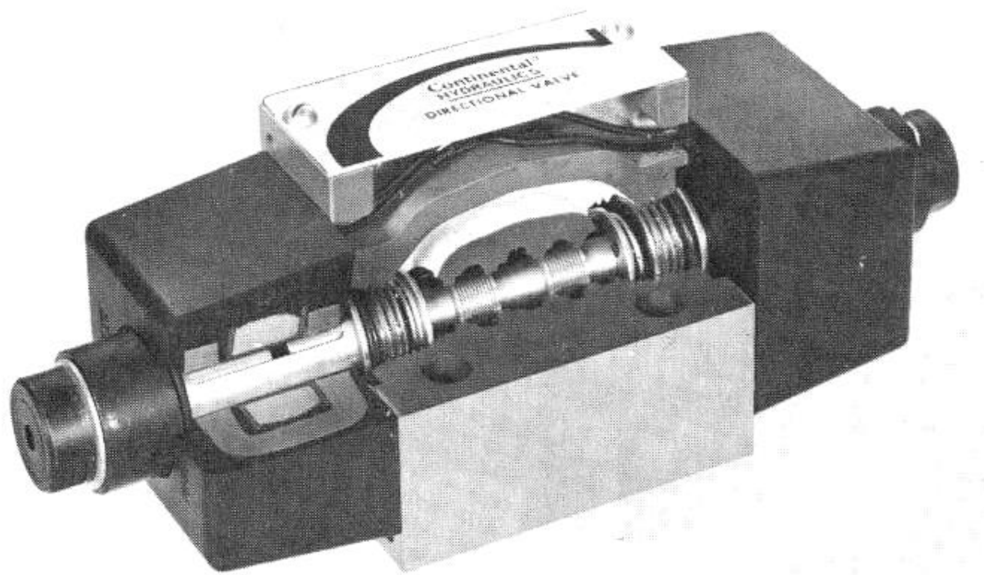


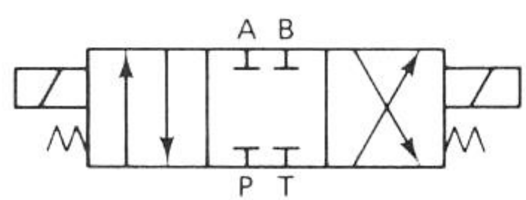
Air Pilot Actuated 4/3 Way Valve





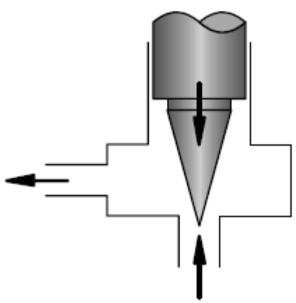
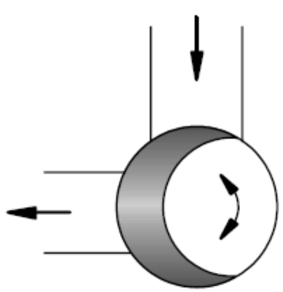
Solenoid Actuated DC Valve





Flow Control Valve

- Used to reduce the speed of cylinder or rpm of motor
- Functions
  - Flow control
  - Flow regulating

	Needle restrictor	Increase in velocity, high friction owing to long throttling path	Considerable owing to high friction	Excessive cross-sectional enlargement with a short adjustment travel, unfavourable ratio area to control surface	Economical, simple design
	Circum-ferential restrictor	As above	As above, but lower than for the needle restrictor	Steadier cross-sectional enlargement, even ratio area to control surface, total adjustment travel only 90°.	Economical, simple design, more complicated than the needle restrictor

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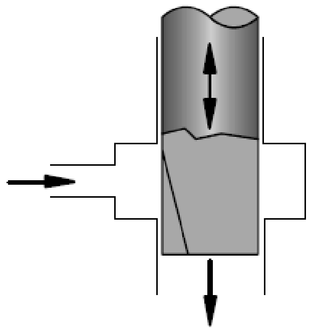
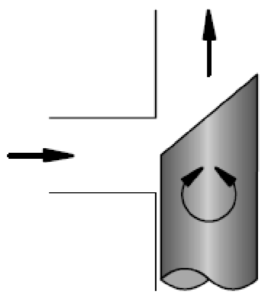
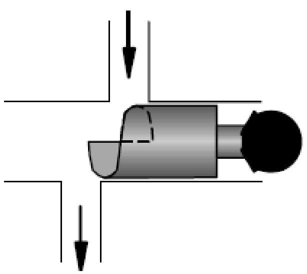
	Longitudinal restrictor	As above	As above	As above, however sensitive adjustment owing to long adjustment travel	As for circumferential restrictor
	Gap restrictor	Main part: increase in velocity, low friction, short throttling path	Low	Unfavourable, even cross-sectional enlargement, adjustment travel of 180°	Economical
	Gap restrictor with helix	Increase in velocity, maximum friction	Independent	Sensitive, even cross-sectional enlargement, adjustment travel of 360°	Expensive to produce helix

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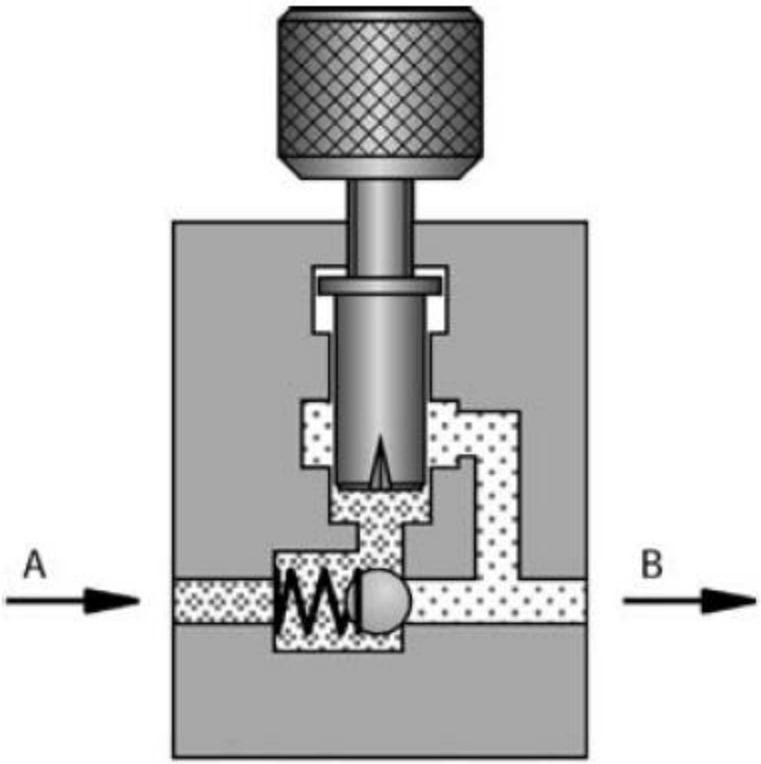
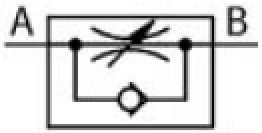
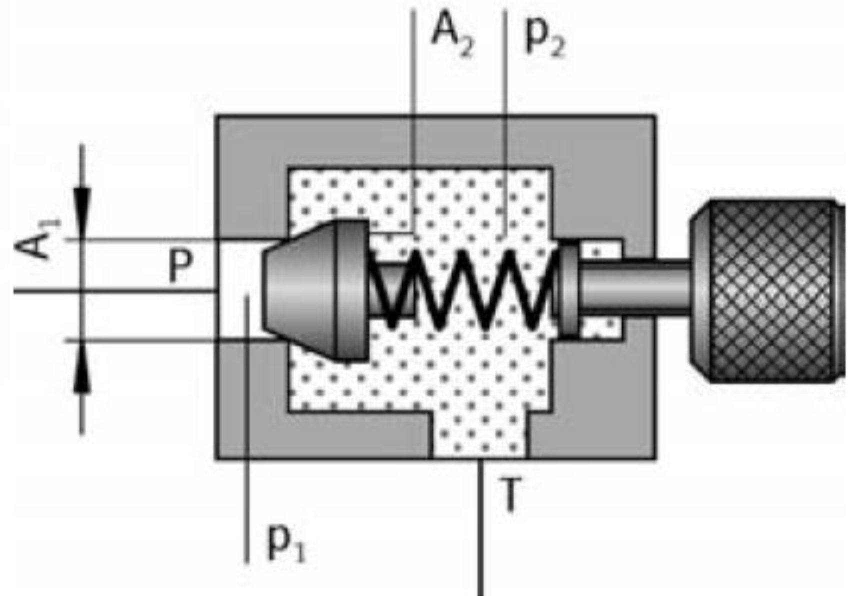
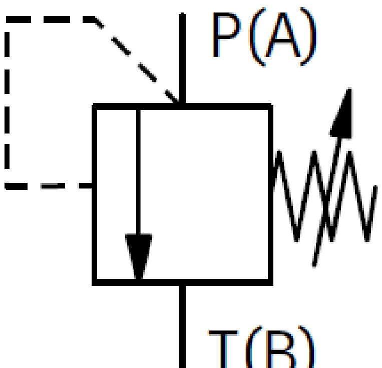
Flow Control Valve



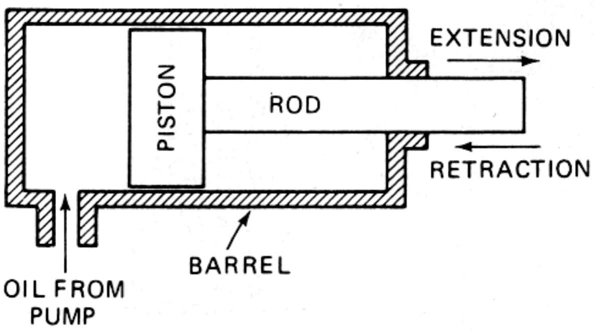


Pressure Relief Valve

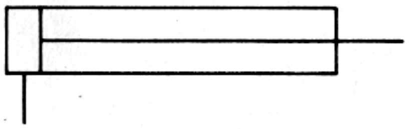




Linear Hydraulic Cylinders



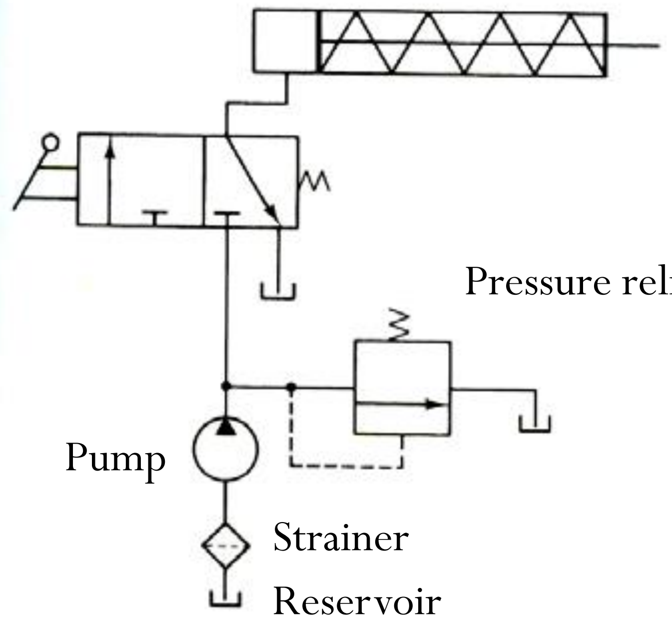
(a) SCHEMATIC REPRESENTATION



(b) SYMBOLIC REPRESENTATION

Hydraulic Circuit Design

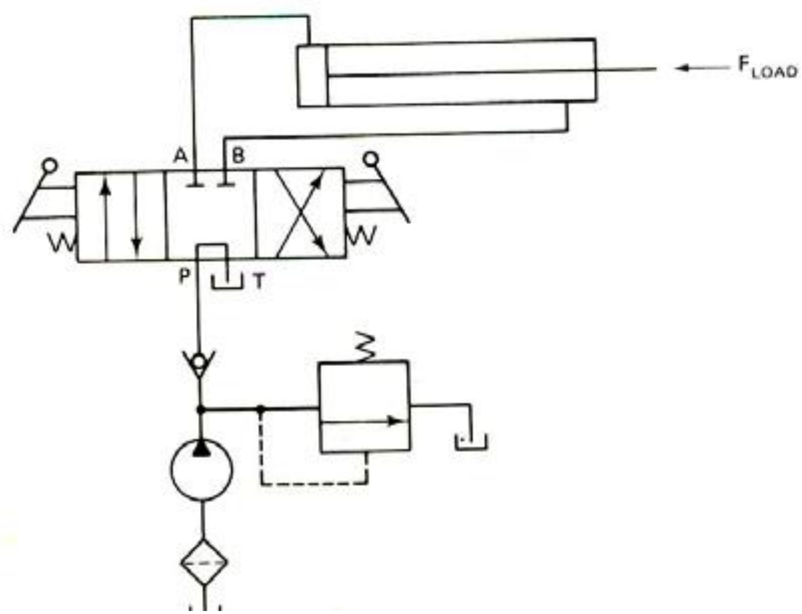
- Single acting cylinder



Hydraulic Circuit Design

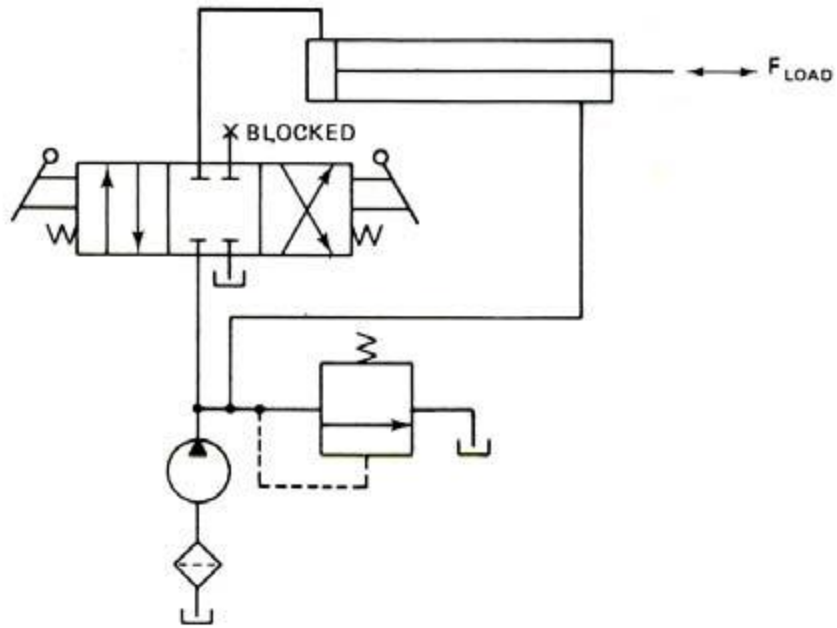
- Double acting cylinder

Three position four way manually controlled dc valve



Hydraulic Circuit Design

- Regenerative Circuit



Drilling Machine Example

- Spring centered position : Rapid Advance
- Left envelope: Slow feed
- Right envelope: Retracts piston