BITS Pilani
Pilani Campus

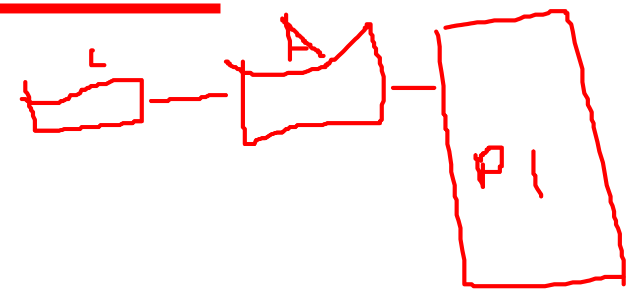
Mechatronics (Merged - DEZG516/DMZG511/ESZG511)

Lecture

Pneumatic and Hydraulics

Fluid Power System

- Hydraulically Actuated
- Pneumatically Actuated



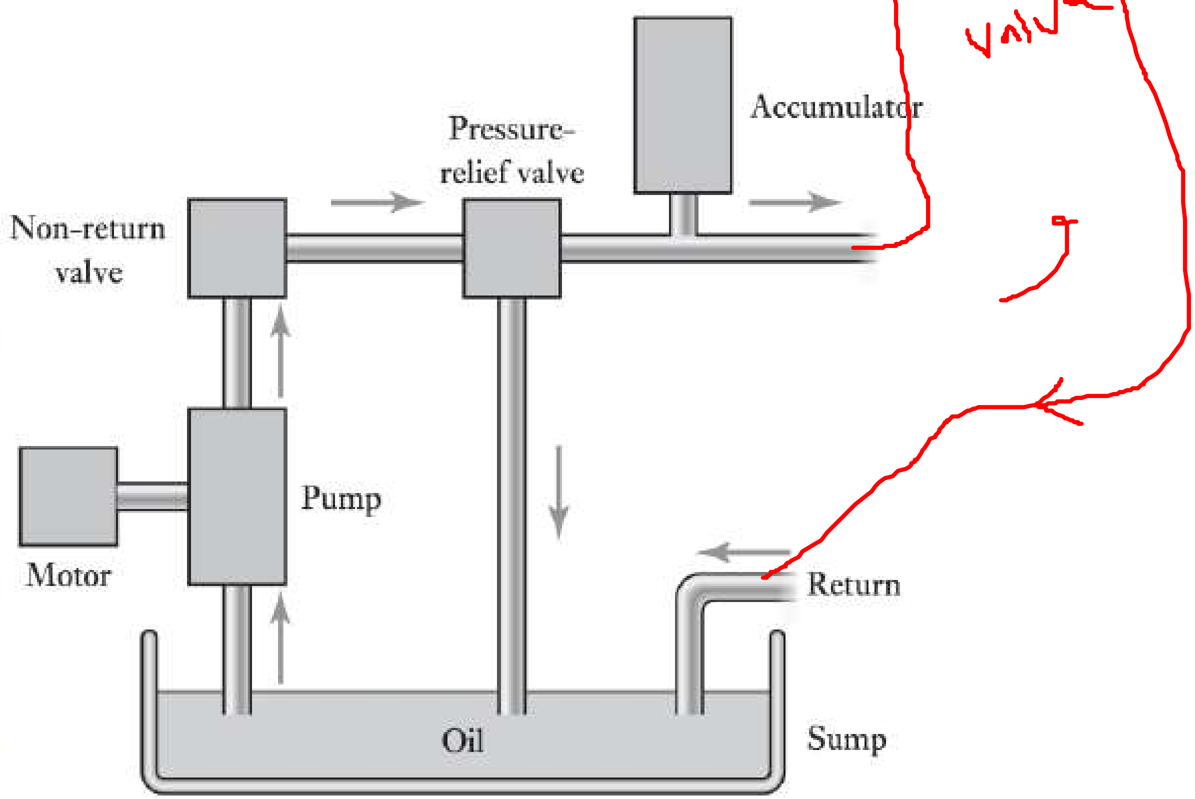
- Actuation systems are the elements of control systems which are responsible for transforming the output of a microprocessor or control system into a controlling action on a machine or device.

Typical Hydraulic circuit

R

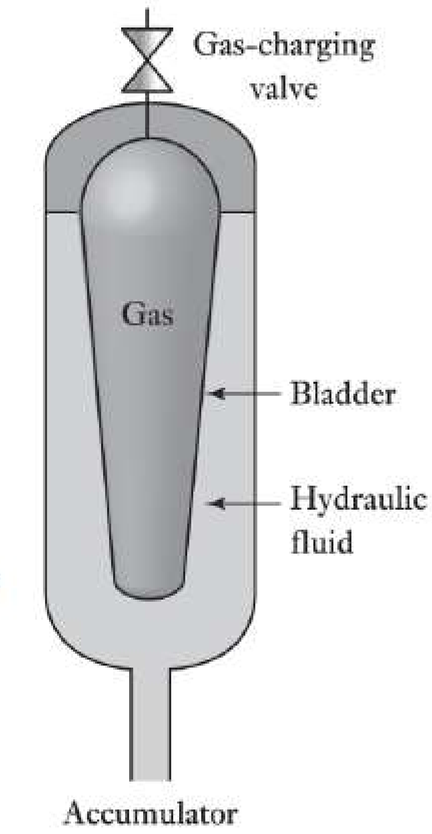
With a hydraulic system, pressurized oil (fluid) is provided by a pump driven by an electrical motor.

- The pump pumps oil from a sump through a non return valve and an accumulator to the system, from which it return to the sump.
- **The pressure relief valve is to release the pressure if it rises above a safe level,**
- **The accumulator is to smooth out any short term fluctuations in the output oil pressure**

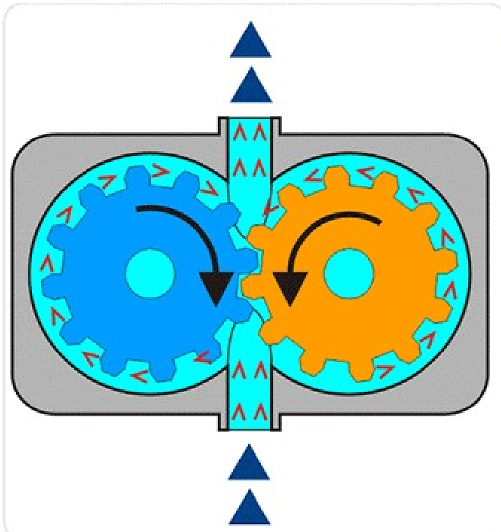


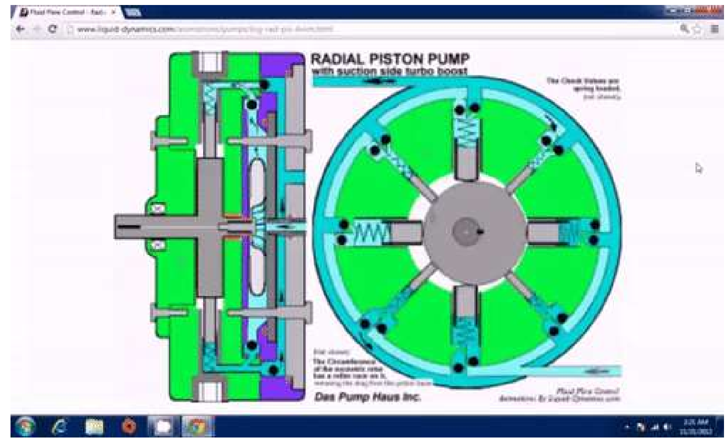
Typical Hydraulic circuit

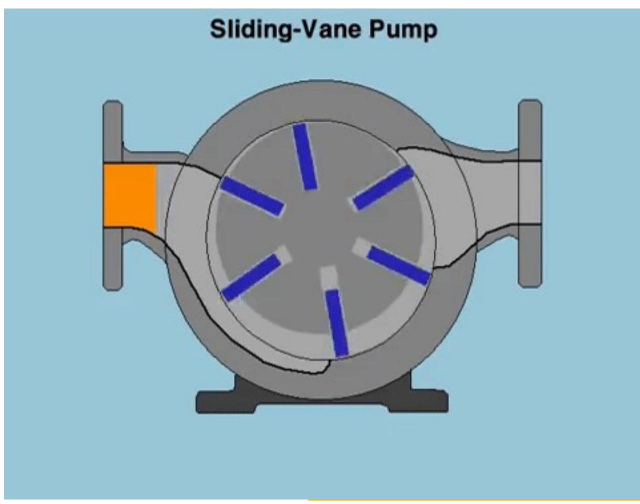
- The Accumulator Work
- Accumulator is a container in which the oil is held under pressure against an external force, which involves gas within a bladder in the chamber containing the hydraulic fluid
- If the oil pressure rises then the bladder contracts increase the volume the oil can occupy and so reduces the pressure.
- If the oil pressure falls the bladder expands to reduce the volume occupied by the oil and so increases its pressure.

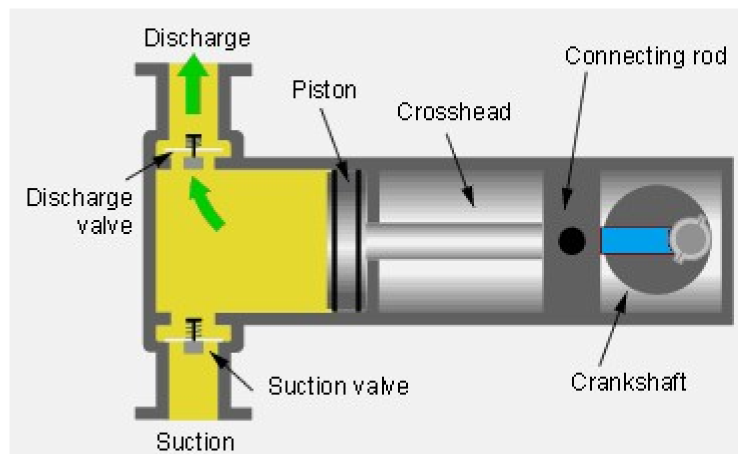


Hydraulic Pumps









Hydraulic Pumps

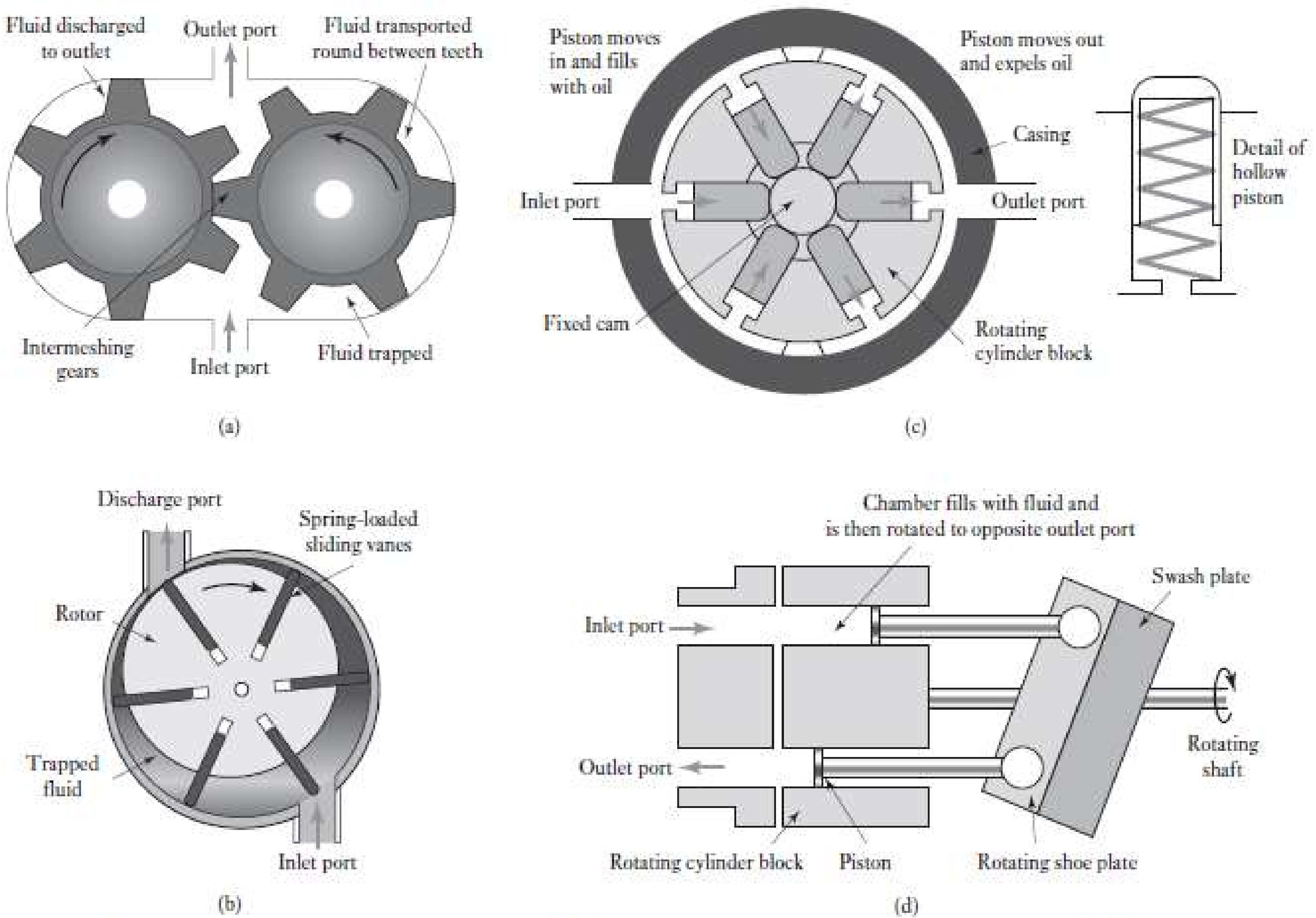


Figure 7.2 (a) Gear pump, (b) vane pump, (c) radial piston pump, (d) axial piston pump with swash plate.

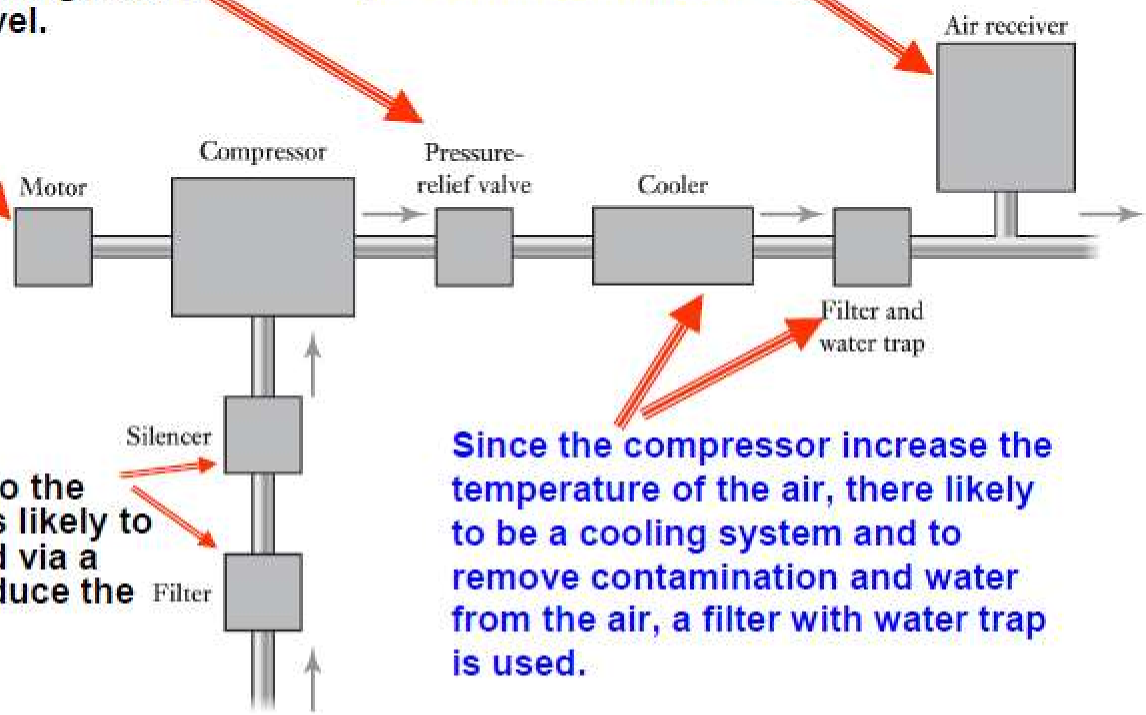
https://www.youtube.com/watch?v=Qy1iV6EzNHg

Pneumatic circuit

•A pressure relief valve provides protection against the pressure in the system rising above a safe level.

An air receiver increases the volume of air in the system and smoothes out any short-term pressure fluctuations.

In pneumatic power system an electric motor drives an air compressor.



•The air inlet to the compressor is likely to be filtered and via a silencer to reduce the noise level.

Since the compressor increase the temperature of the air, there likely to be a cooling system and to remove contamination and water from the air, a filter with water trap is used.

Air compressors

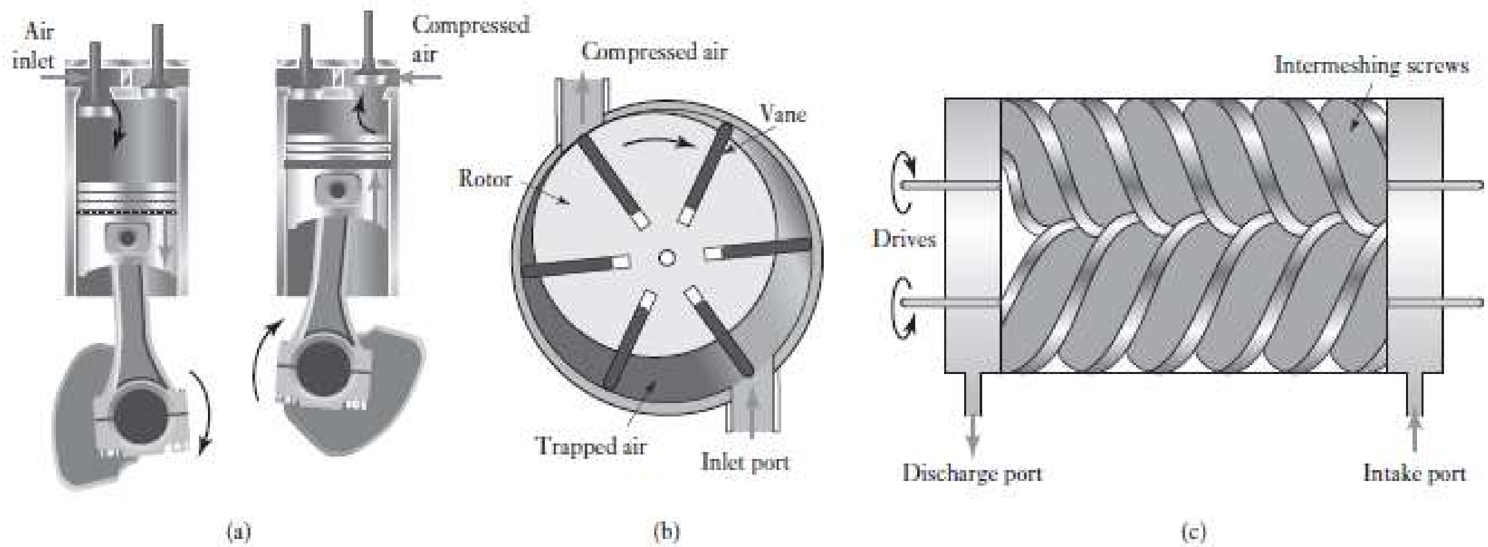


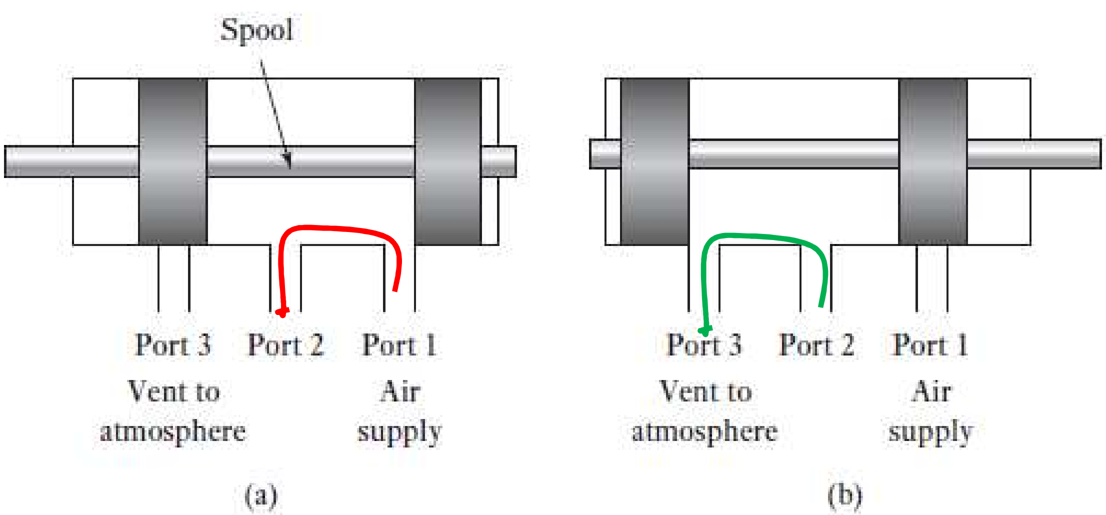
Figure 7.4 (a) Single-acting, single stage, vertical, reciprocating compressor, (b) rotary vane compressor, (c) screw compressor.

0.02 m^3/min free air delivery to about 600 m^3/min

Multistage compressors are used to increase pressures beyond 12 bar and to 140 bar of pressure

Valves

- Finite position valve
- Infinite position valve
- **Directional control valves**



Spool valve.

Directional control valves

Directional Control Valves-1

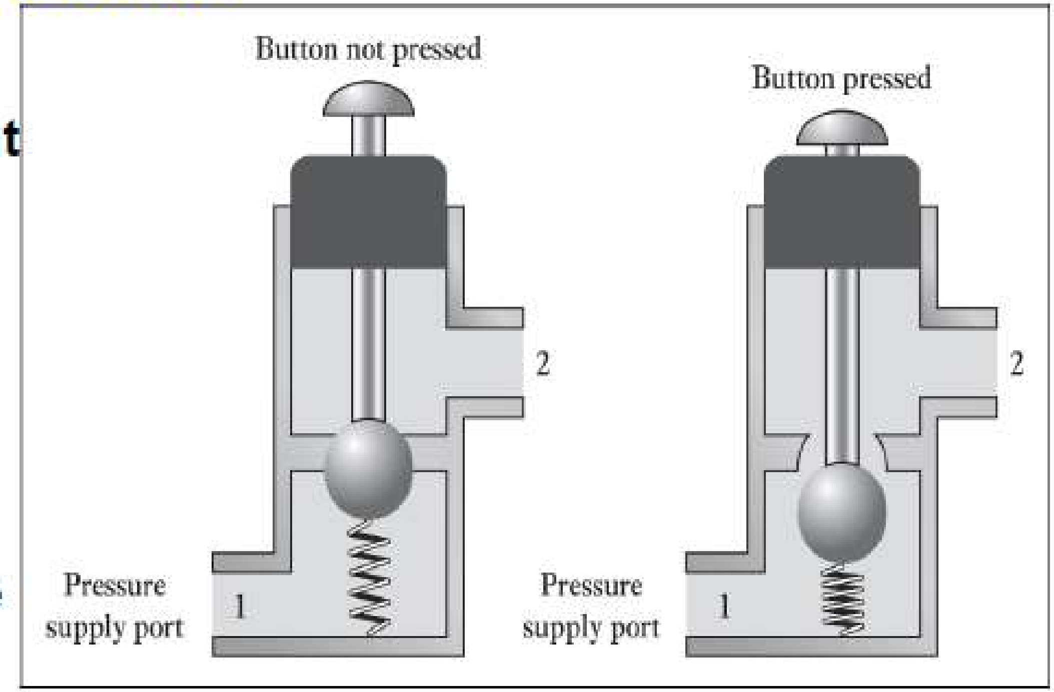
- Pneumatic and hydraulic systems use directional control valves to direct the flow of fluid through a system; its ON/OFF devices either completely open or closed
- They might be activated to switch the fluid flow direction by means of mechanical, electrical or fluid pressure signal

https://www.youtube.com/watch?v=CQPwvWXbV3w

Poppet Valves

- This valve is normally in closed condition. In this valve, balls, discs or cones are used in conjunction with valve seats to control the flow.

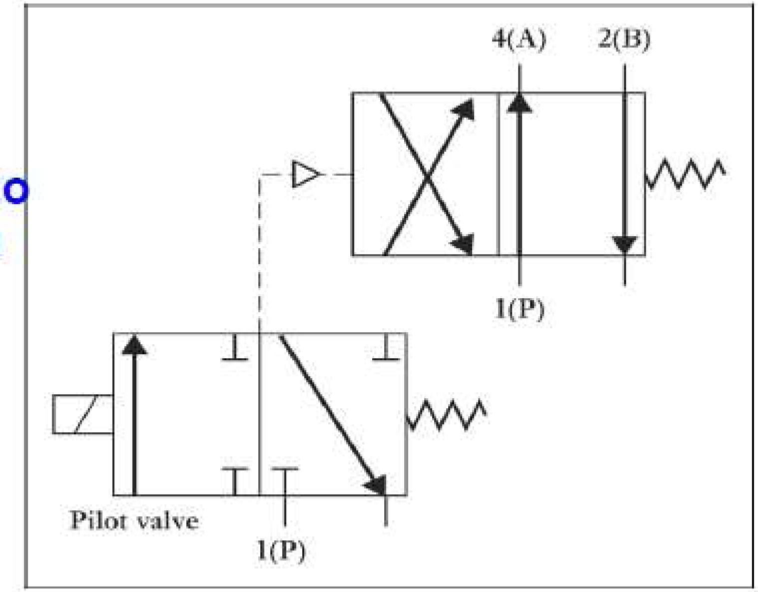
•When the push-button is depressed, the ball is pushed out of its seat and flow occurs as a result of port 1 being connected to port 2. When the button is released, the spring forces the ball back up against its seat and so closes off the flow.



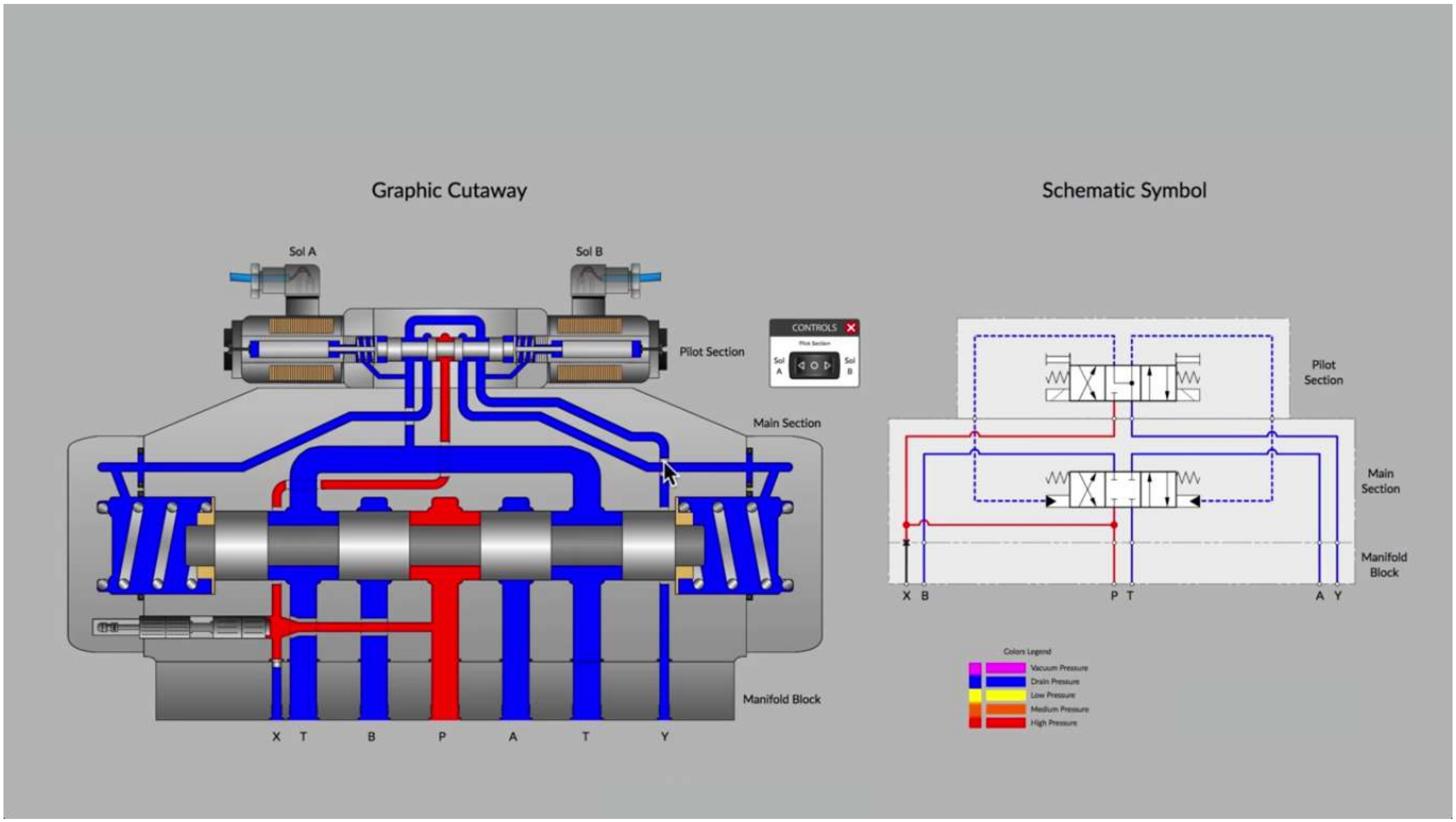
Pilot Operated valves

In pilot operated system one valve is used to control a second valve. In the Fig the pilot valve is small size and can be operated manually or by a solenoid.

It is used to overcome when the force required to move the ball shuttle in a valve can often be too large for manual or solenoid operation

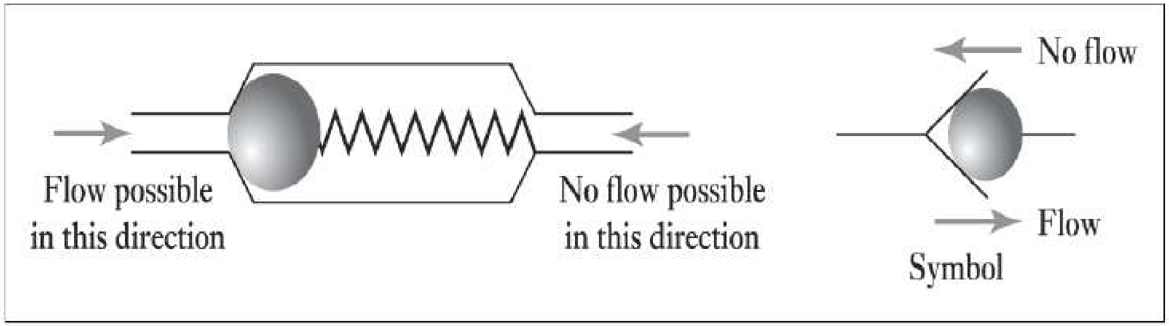


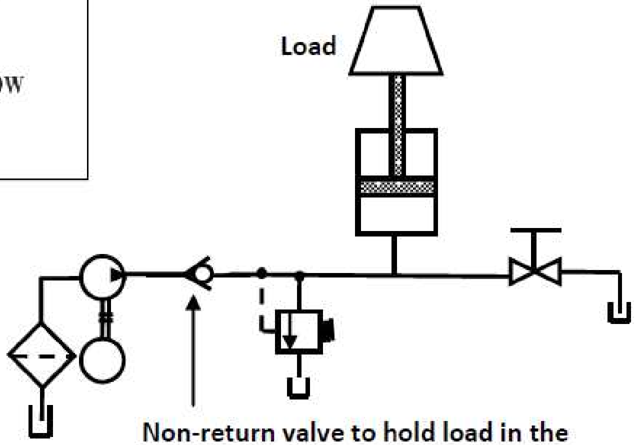
Pilot Operated valves



Directional Valves

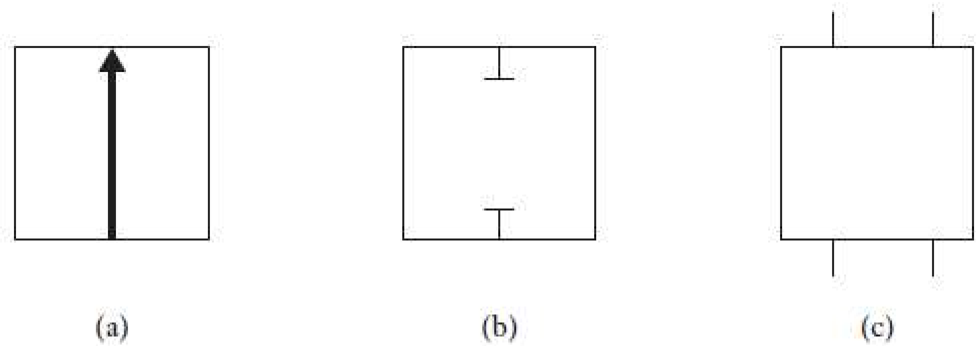
Free flow can only occur in one direction through the valve, flow in the other direction is blocked by spring.

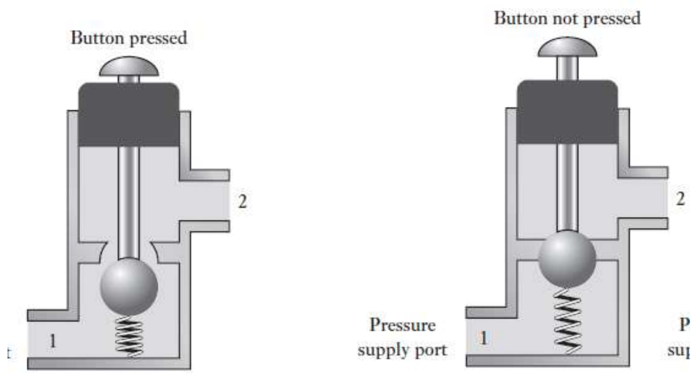


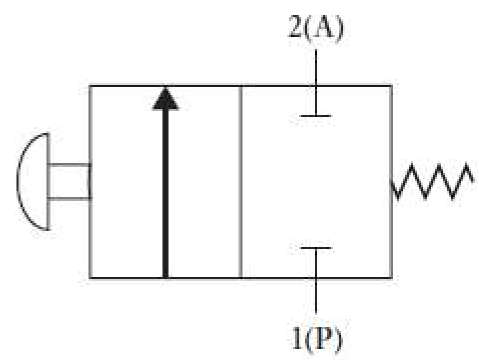


Valve symbols

Figure 7.7 (a) Flow path, (b) flow shut-off, (c) initial connections.



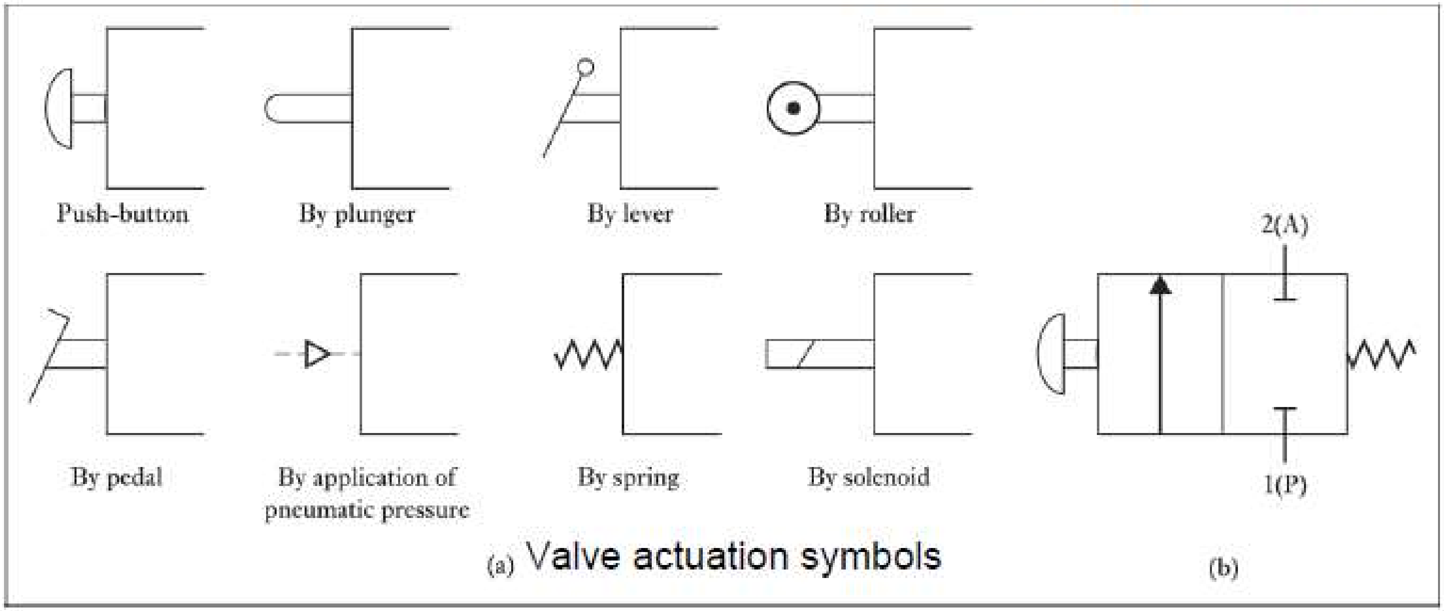




Valve symbols

Symbols of Valve actuation
It indicates the various ways the valves can be actuated (see Fig)

Ports are labeled
- 1 (or **P**) for pressure supply
- 3 (or **T**) for hydraulic return port
- 3 or 5 (or **R** or **S**) for pneumatic exhaust ports
- 2 or 5 (**B** or **A**) for output ports

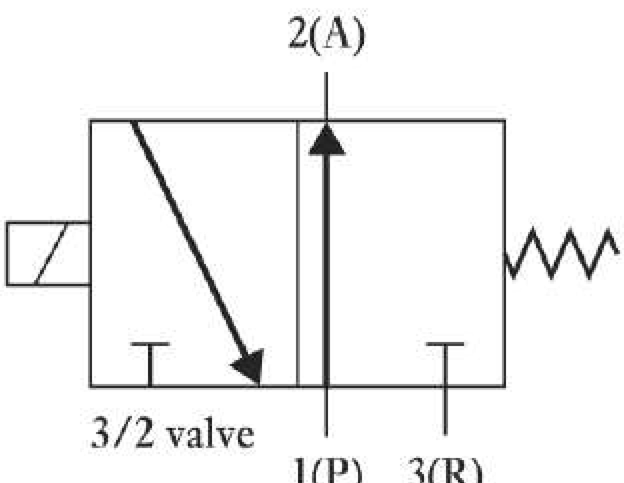


(a) Valve actuation symbols

Valve symbols

- Fig. shows the symbol for a 3/2 valve, the connection is shown for initial state i.e.
- 1(P) is connected to 2(A); 3(R) is closed.
- When the solenoid is activated, it gives the state indicated by the symbols used in the square to which it is attached, i.e we now have 1(P) closed and 2(A) connected to 3(R). When current through the solenoid ceases the spring pushes the valve back to its initial position.

•The spring movement gives the state indicated by the symbols used in the square to which it is attached.



A 3/2 valve

Bolton, Mechatronics, 4th edition Pearson limited 2008

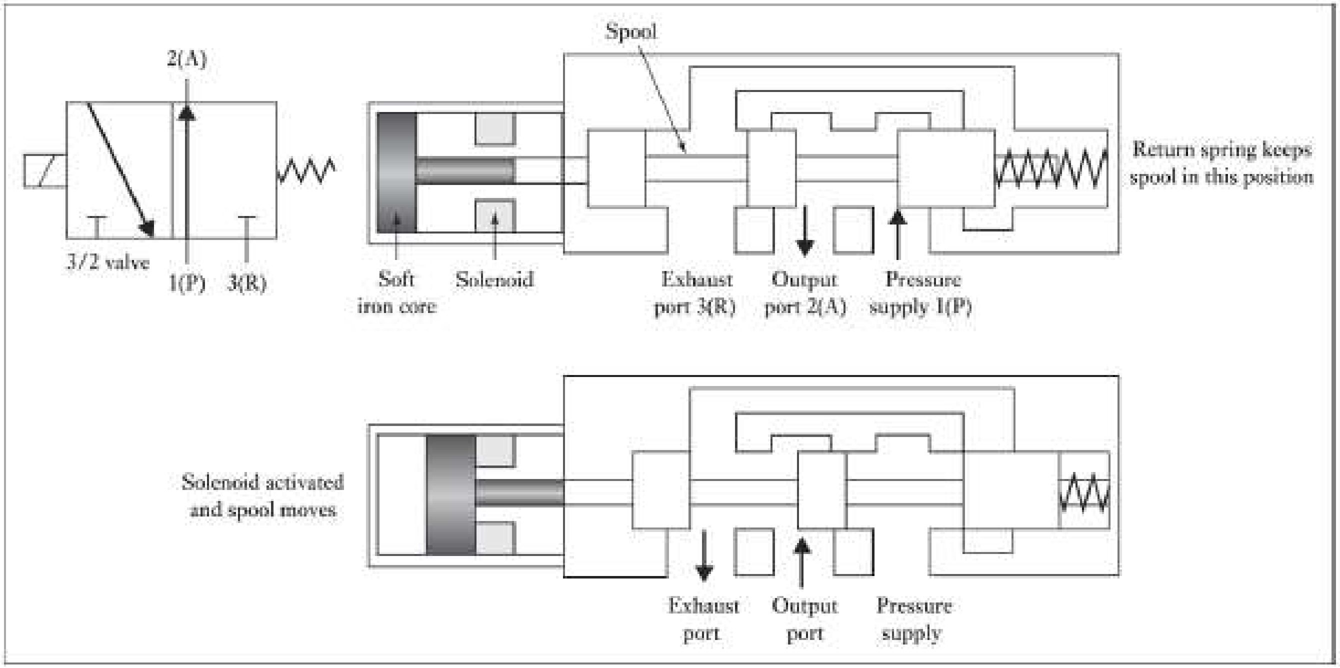
3 / 2 means

3 – Ports

2- Positions

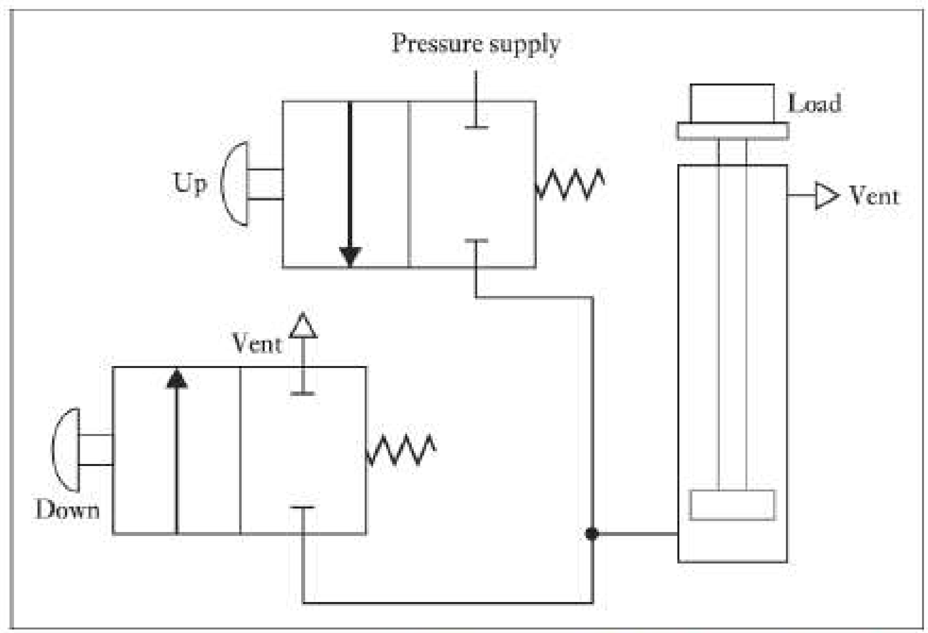
Valve symbols

Solenoid operated spool valve
The valve is actuated by a current passing through the solenoid
and return to its original position by spring



Valve symbols

- a simple example of an application of valves in a Pneumatic lift system



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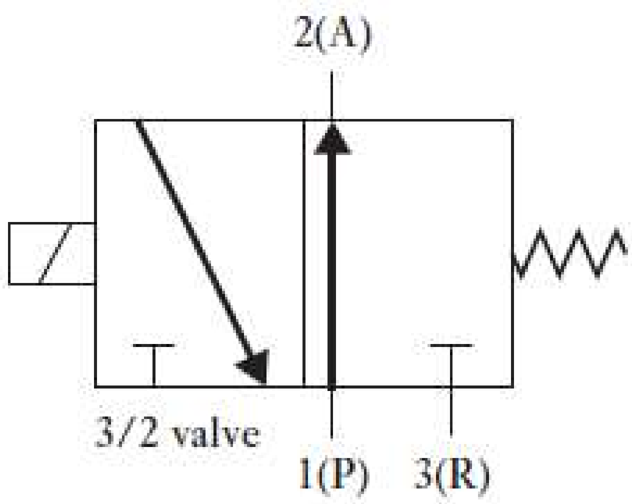
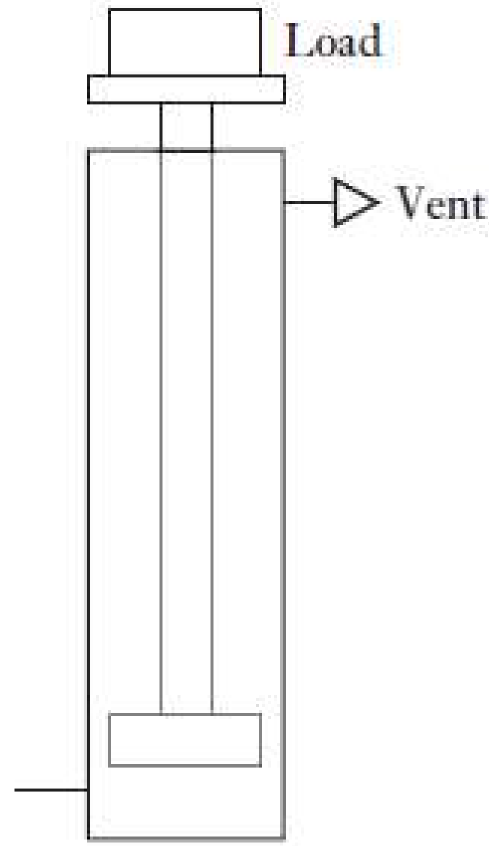
Valve symbols





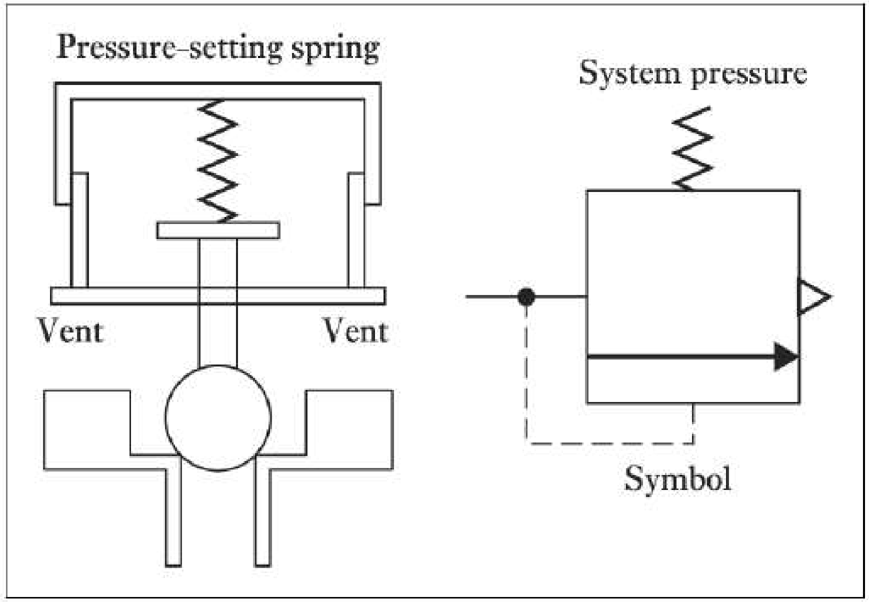
Can you re-design the load lifting with 3/2 Valve?

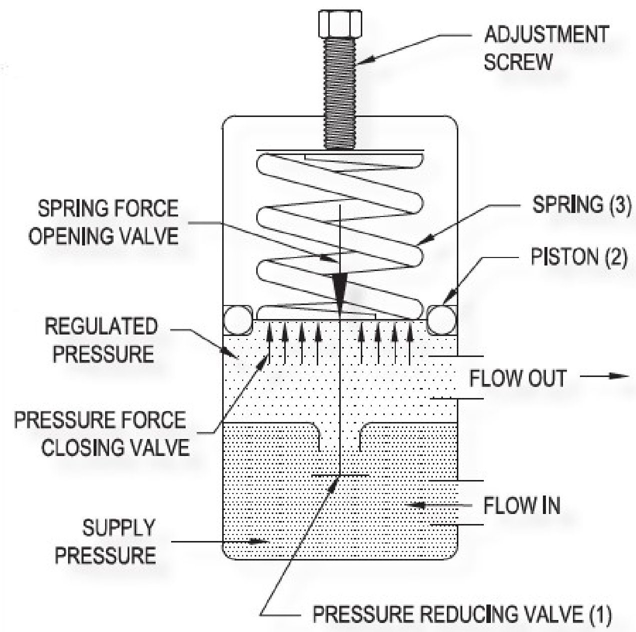
Pressure control valves

Three main types

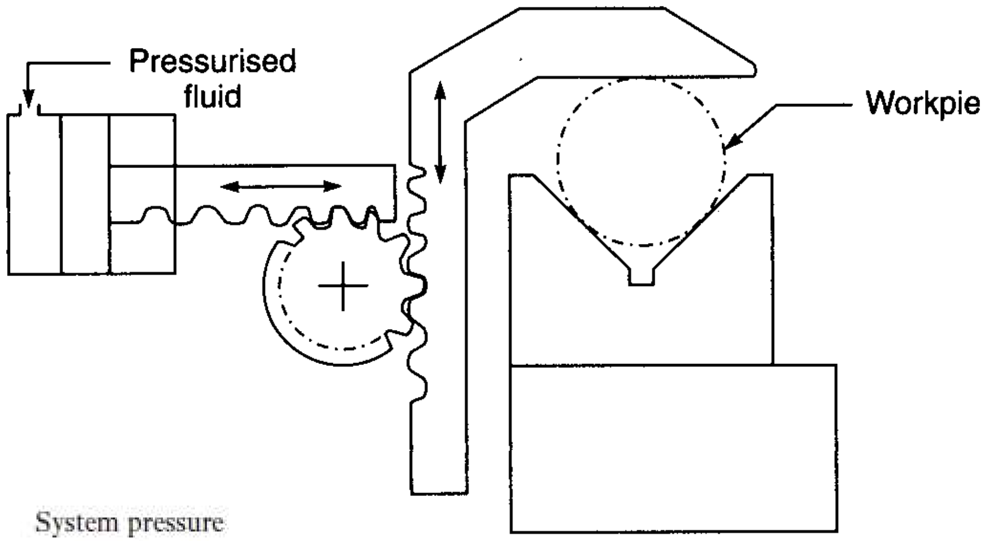
1- Pressure limiting valve: used to limit the pressure in a circuit to below some value

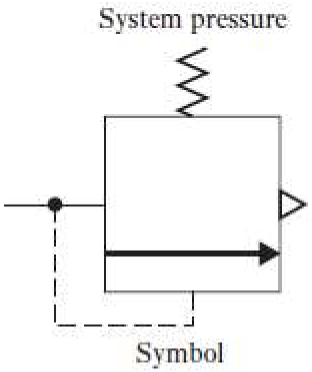
2- Pressure regulation valve: used to control the operating pressure in a circuit and maintain it at constant value.

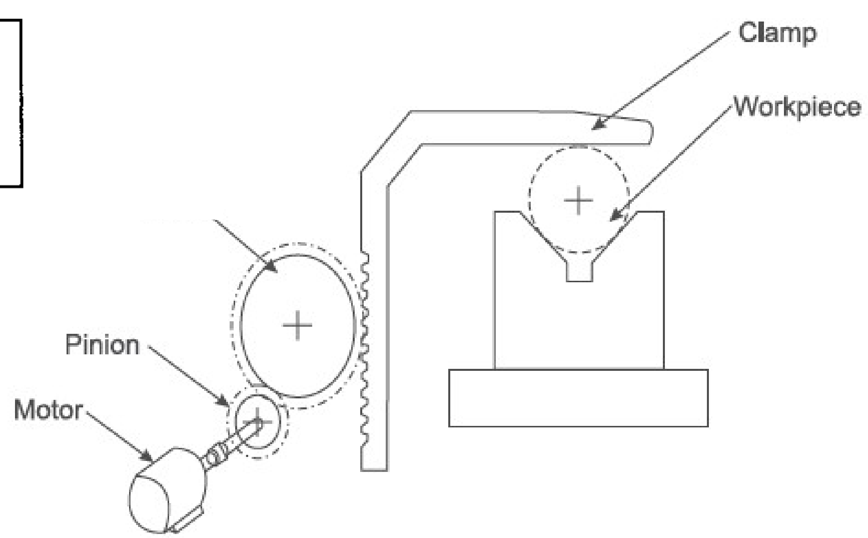




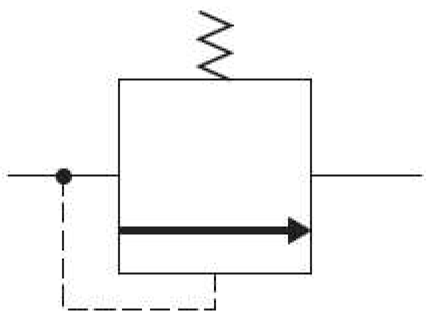
Pressure sequence valves



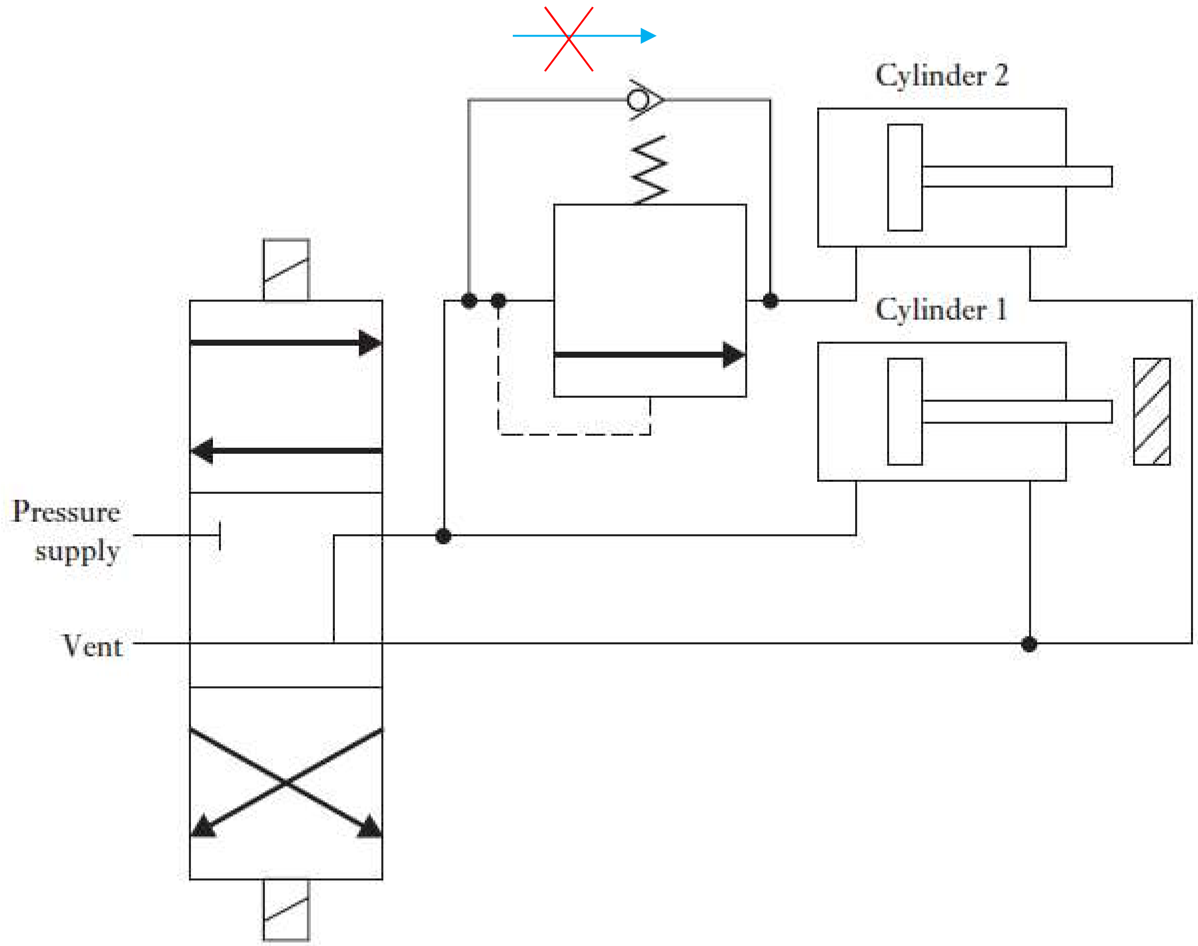




Sequencing controls



(a)



(b)

Cylinders (Single acting)

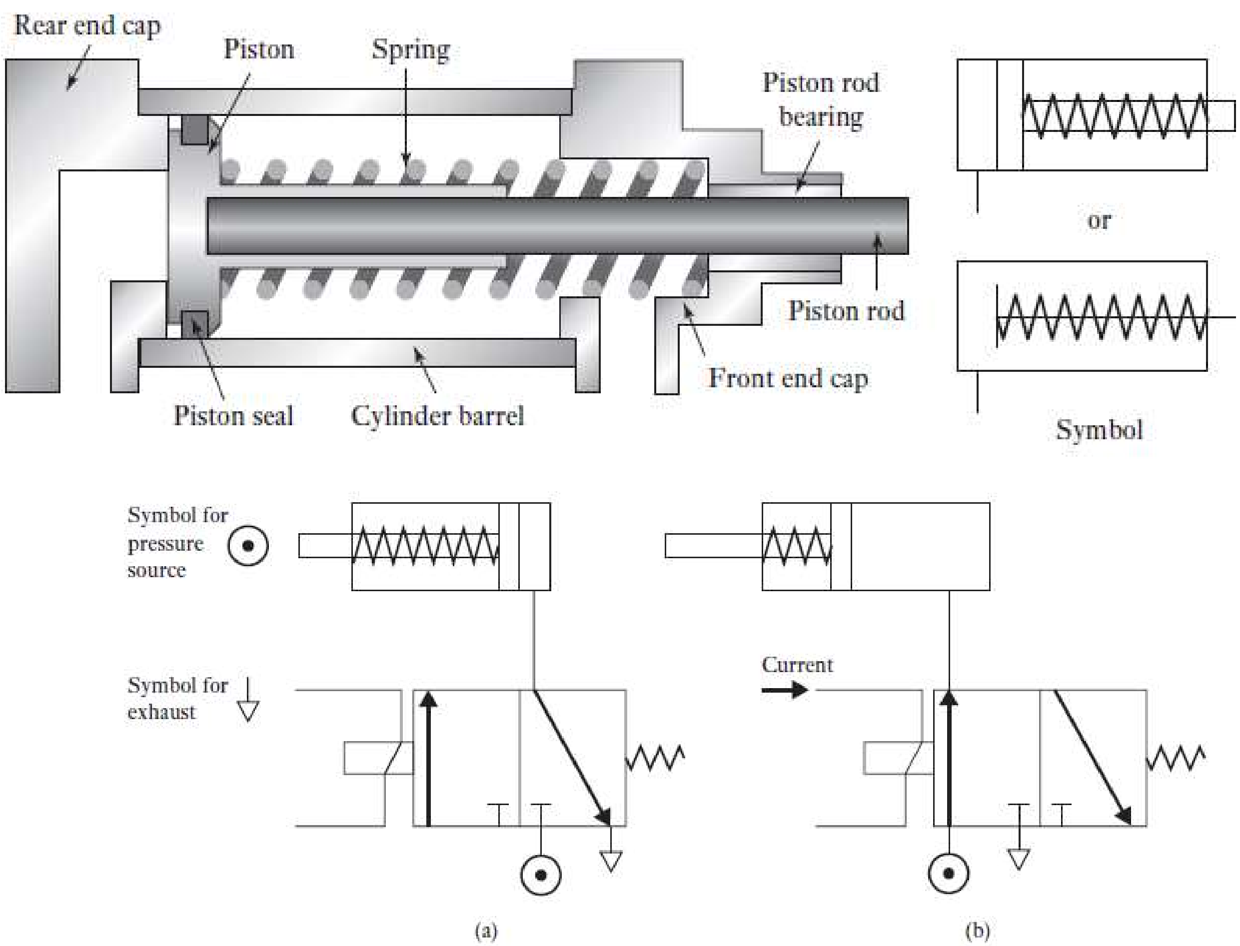
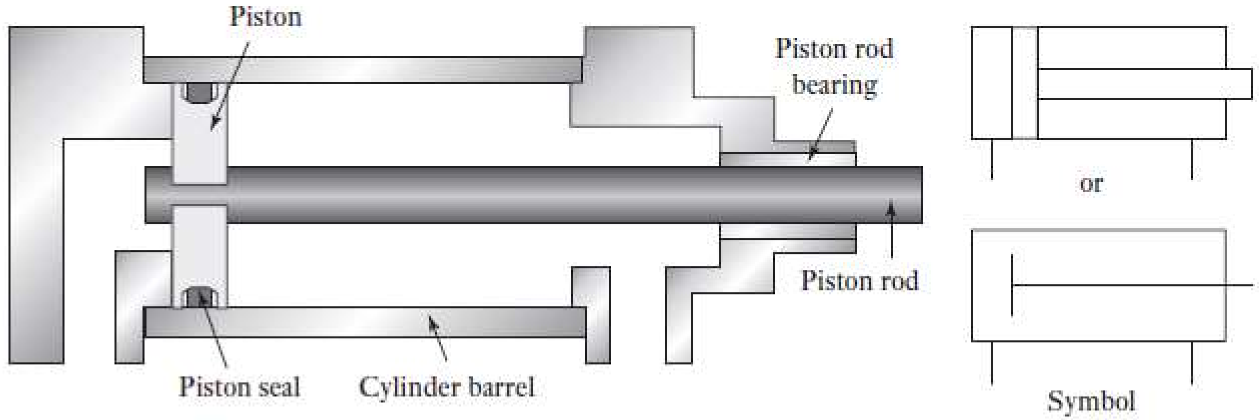
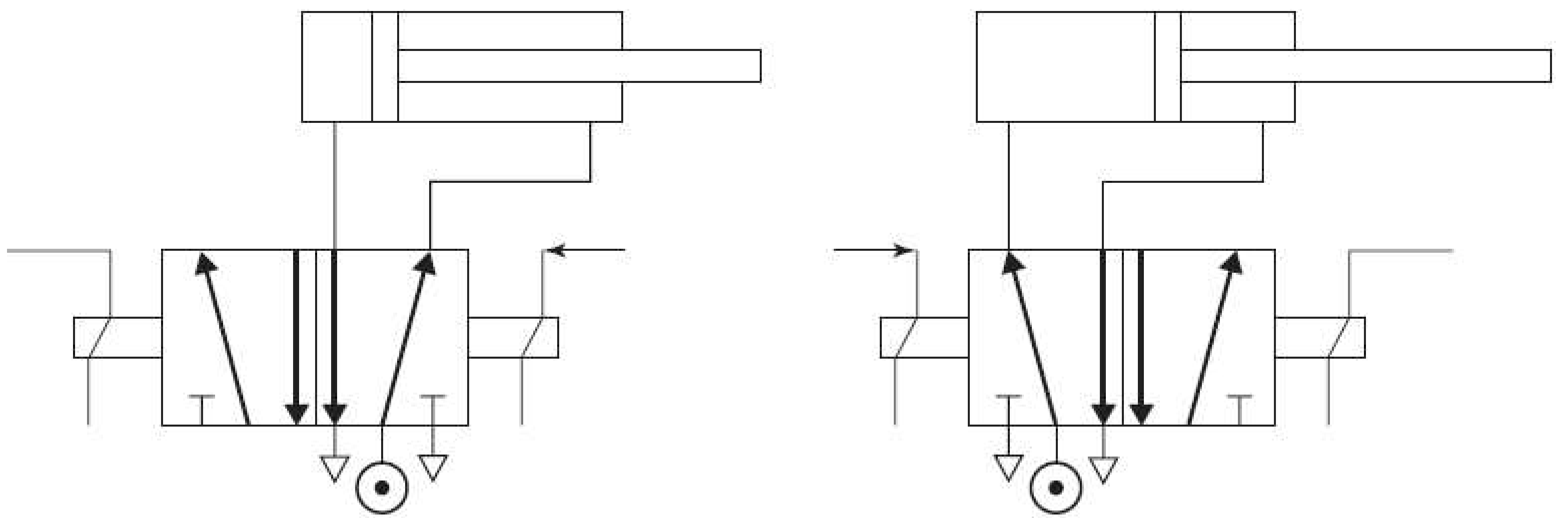


Figure 7.17 Control of a single-acting cylinder with (a) no current through solenoid, (b) a current through the solenoid.

Cylinders (Double acting)

Figure 7.18 Double-acting cylinder.





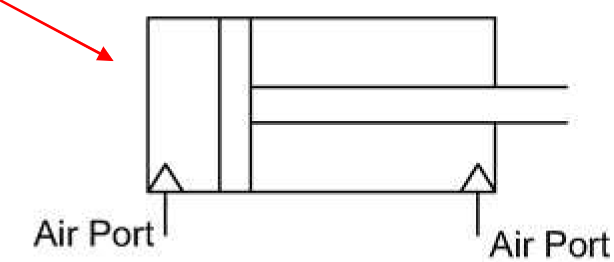
Cylinders (Double acting)

Formula

Force = Pressure * Area

Flow = Area x velocity

- Pressure of fluid determines the force exerted by the piston
- Flow rate determines the velocity of the piston
  - *Note push and pull forces are different.*



Double-Acting Cylinder (Force in Push and Pull Direction)

Problem

- A hydraulic cylinder to be used to move a work piece in a manufacturing operation through a distance of 250 mm in 15 s. if a force of 50 KN is required to move the work piece, what is the required working pressure and hydraulic liquid flow rate if a cylinder with a piston diameter of 150 mm is available.
- Solution:
- $A=\pi r^2 = \pi(0.15/2)^2 = 0.0117\ m^2$
- The working pressure = F/A = $50x10^3/0.017=2.8$ MPa
- The speed of a hydraulic cylinder = flow rate of the liquid through the cylinder
- $v=Q/A$
- Flow rate= $A.v=0.0117(0.250/15)=29.5x10^{-4}\ m^3/s$

Cylinder sequencing

A+, B+, A−, B−

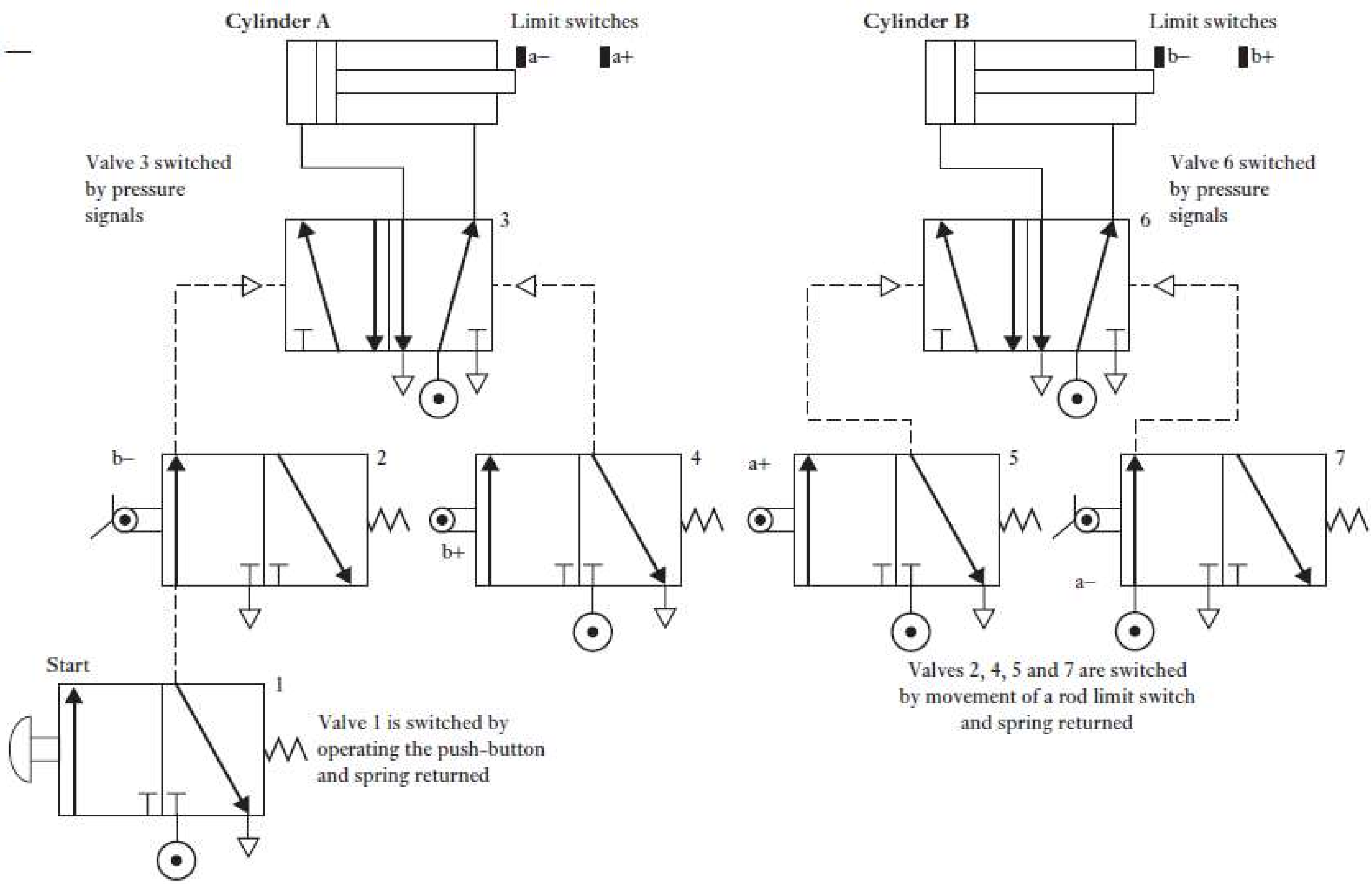
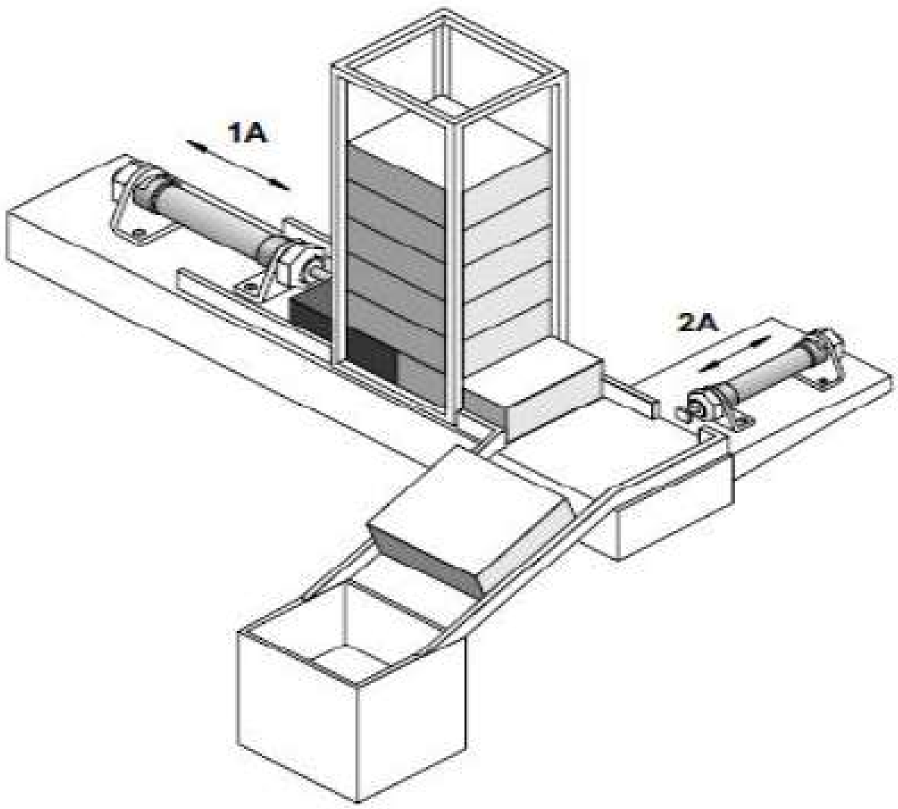


Figure 7.20 Two-actuator sequential operation.

Cylinder sequencing

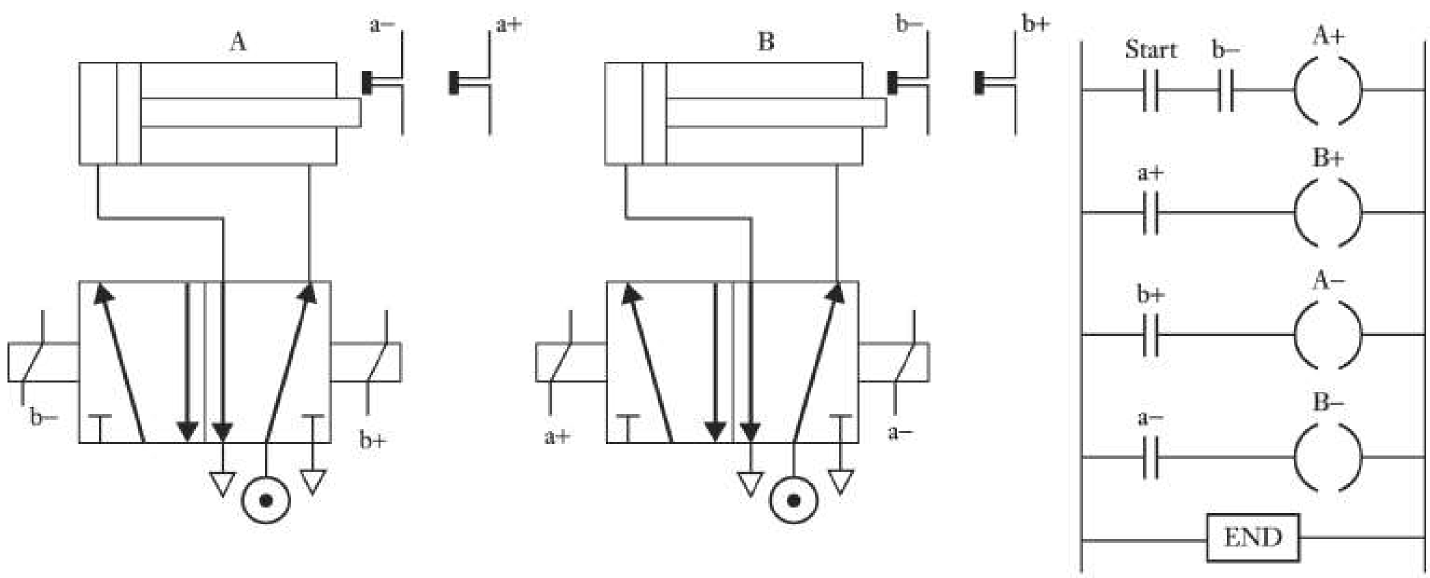


Cylinder sequencing

Sequencing

The required activation sequence is: A+, B+, A-, B-

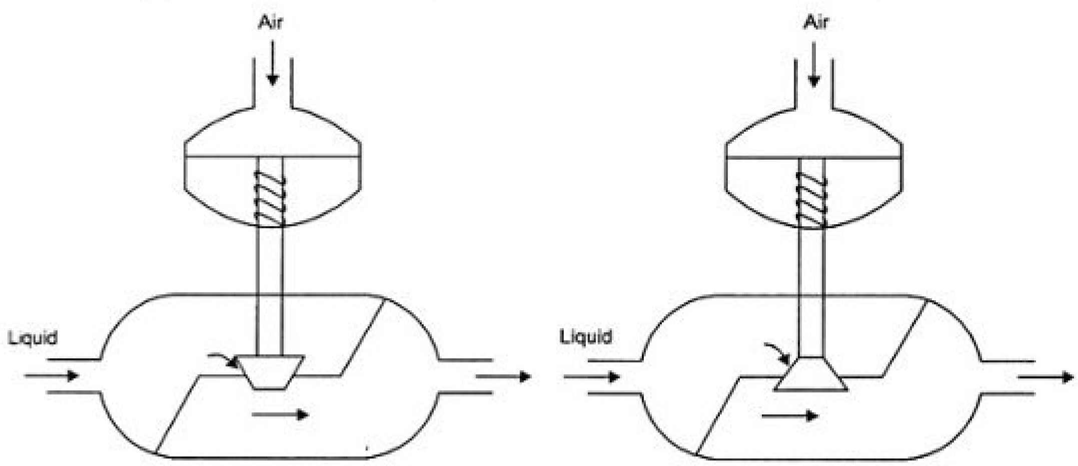
…a-, a+, b-, and b+ are limit switches for cylinder A and B as Shown. Assume a starting switch to start operation and that initially switch b- is active . Program a PLC to achieve the job

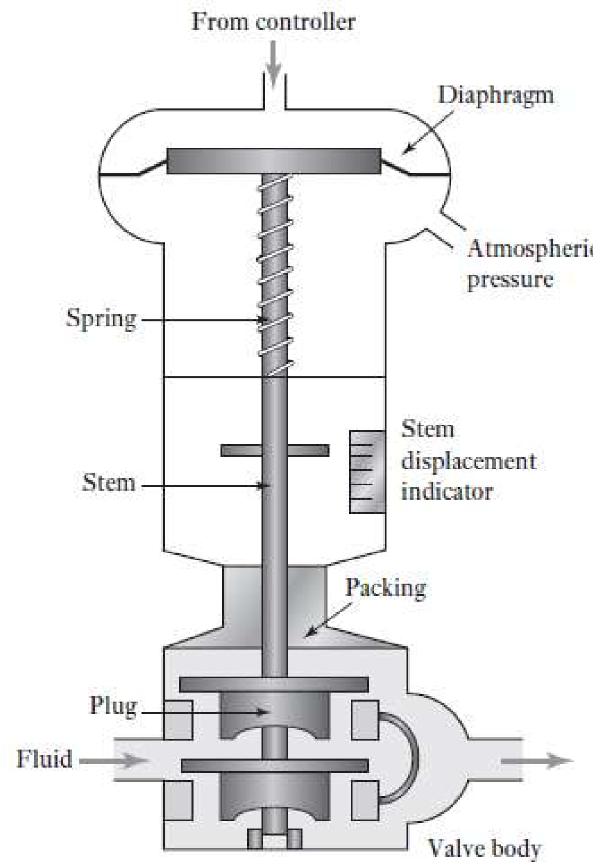


Process control Valves

FAIL OPEN
(Air to Close)

FAIL CLOSED
(Air to Open)





(b)

Valve types

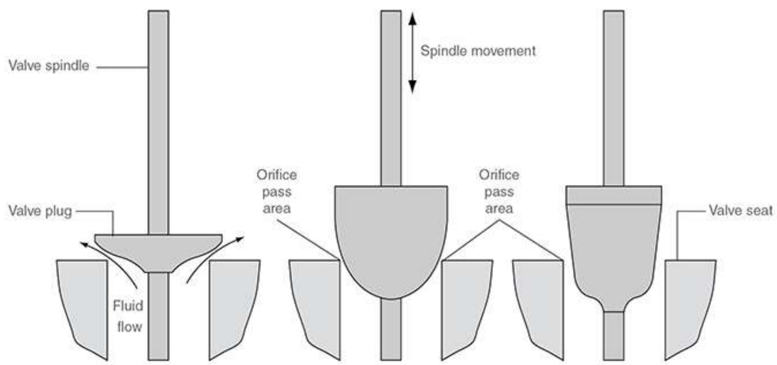
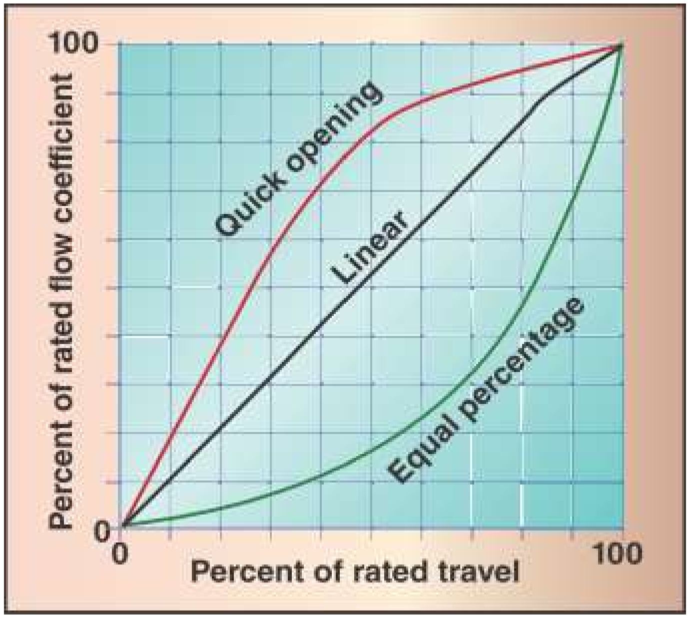
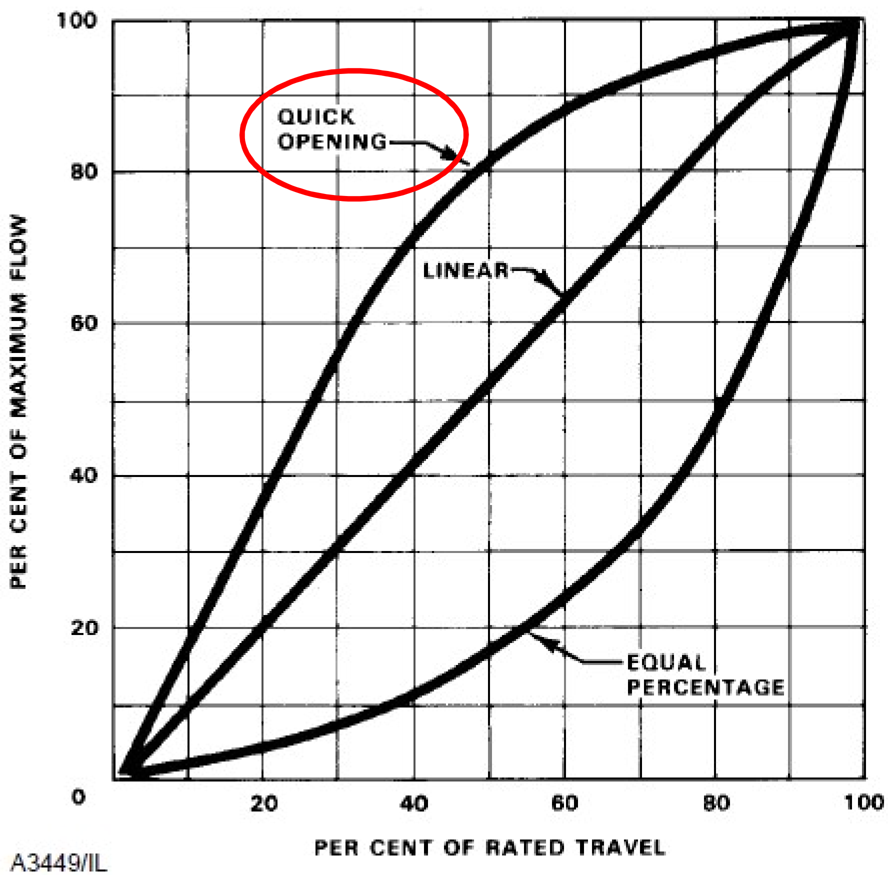


Fig. 6.5.1 The shape of the trim determines the valve characteristic



Quick opening

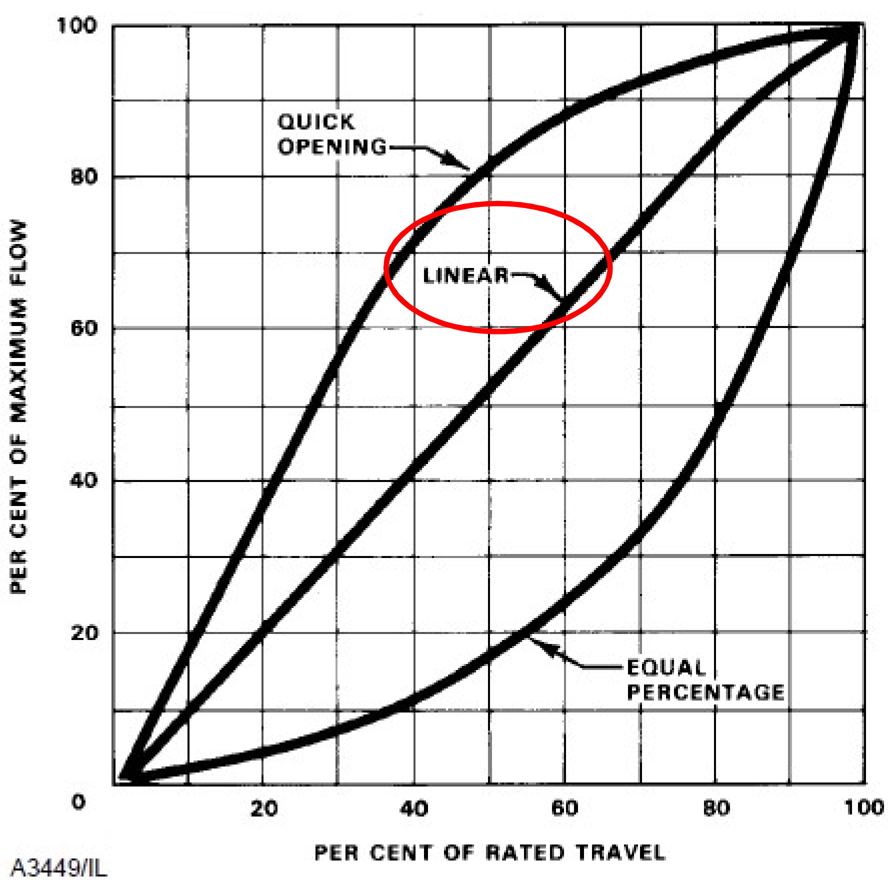


<u>Quick opening</u>

An inherent flow characteristic in which a maximum flow coefficient is achieved with minimal closure member travel

In a control valve, the quick opening valve plug is used primarily for on-off service;

Linear

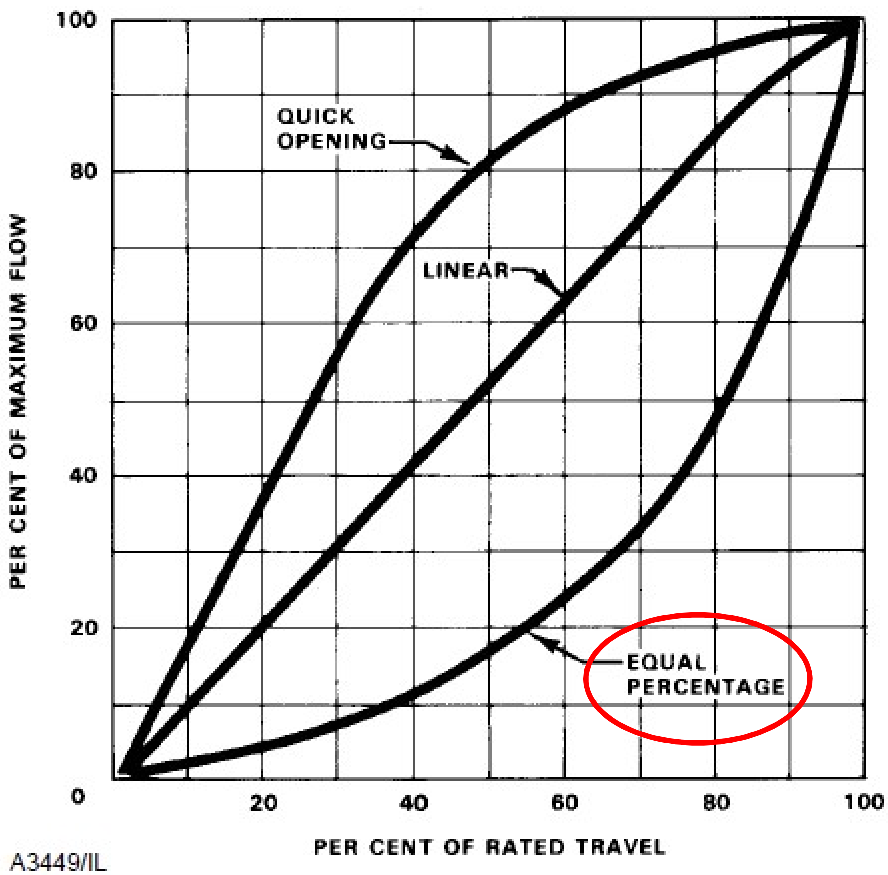


<u>Linear</u>

An inherent flow characteristic that can be represented by a straight line on a rectangular plot of flow coefficient (C_v) versus rated travel. Therefore equal increments of travel provide equal increments of flow co-efficient

The linear valve plug is commonly specified for liquid level control

Equal percentage

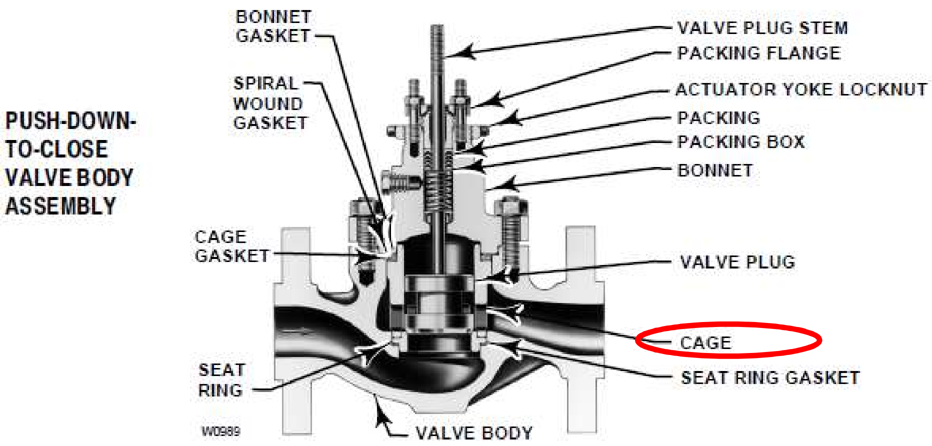


<u>Equal percentage</u>

An inherent flow characteristic that, for equal increments of rated travel, will ideally give equal percentage changes of the flow coefficient (Cv)

Valves with an equal percentage flow characteristic are generally used on pressure control applications

Types



Different cage designs for achieving different valve characteristics

QUICK OPENING

LINEAR

EQUAL PERCENTAGE

Linear control valve

$$\frac{Q}{Q_{max}} = \frac{S}{S_{max}}$$

or the percentage change in the flow rate equals the percentage change in the stem displacement.

To illustrate the above, consider the problem of an actuator which has a stem movement at full travel of 30 mm. It is mounted on a linear plug valve which has a minimum flow rate of 0 and a maximum flow rate of 40 m^3/s. What will be the flow rate when the stem movement is (a) 10 mm, (b) 20 mm? Since the percentage flow rate is the same as the percentage stem displacement, then: (a) a percentage stem displacement of 33% gives a percentage flow rate of 33%, i.e. 13 m^3/s; (b) a percentage stem displacement of 67% gives a percentage flow rate of 67%, i.e. 27 m^3/s.

Equal percentage valves

Table 6.5.1
Change in flowrate and valve lift for an equal percentage characteristic with constant differential pressure

Valve Lift (H)	Flowrate from ($\dot{V}$ m³/h)	Increase in flow previous increment (%)
0.0	0.20 *	-
0.1	0.30	48%
0.2	0.44	48%
0.3	0.65	48%
0.4	0.96	48%
0.5	1.41	48%
0.6	2.09	48%
0.7	3.09	48%
0.8	4.57	48%
0.9	6.76	48%
1.0	10.00	48%

* Flowrate according to theoretical characteristic due to rangeability. In practice the valve will be fully shut at zero lift.

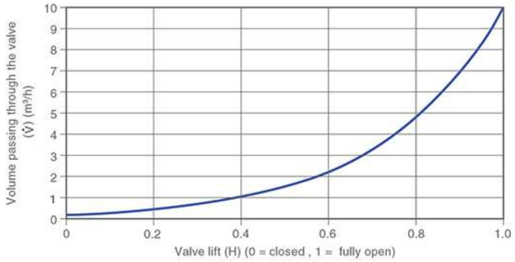
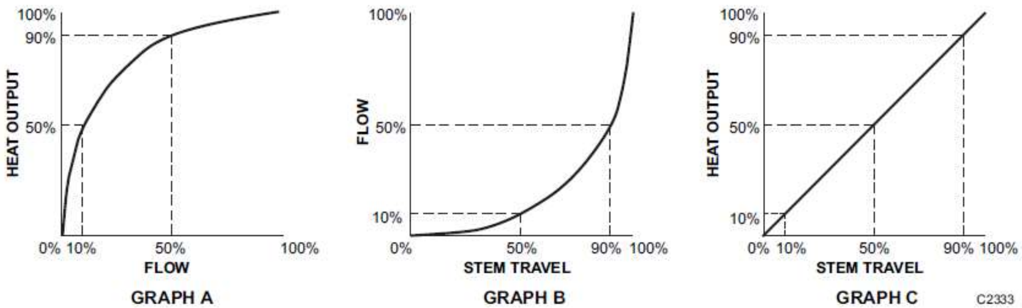


Fig. 6.5.4
Flowrate and valve lift for an equal percentage characteristic with constant differential pressure for Example 6.5.1



Equal percentage valves

$$\frac{Q}{Q_{\min}} = \left(\frac{Q_{\max}}{Q_{\min}}\right)^{(S - S_{\min})/(S_{\max} - S_{\min})}$$

The term rangeability R is used for the ratio $Q_{\max}/Q_{\min}$.

To illustrate the above, consider the problem of an actuator which has a stem movement at full travel of 30 mm. It is mounted with a control valve having an equal percentage plug and which has a minimum flow rate of 2 m^3/s and a maximum flow rate of 24 m^3/s. What will be the flow rate when the stem movement is (a) 10 mm, (b) 20 mm? Using the equation

$$\frac{Q}{Q_{\min}} = \left(\frac{Q_{\max}}{Q_{\min}}\right)^{(S - S_{\min})/(S_{\max} - S_{\min})}$$

we have for (a) $Q = 2 \times (24/2)^{10/30} = 4.6\ m^3/s$ and for (b) $Q = 2 \times (24/2)^{20/30} = 10.5\ m^3/s$.

Control Valve Sizing

$$Q = A_V \sqrt{\frac{\Delta P}{\rho}} \qquad Q = 2.37 \times 10^{-5} C_V \sqrt{\frac{\Delta P}{\rho}}$$

Flow coefficients	Valve size (mm)							
	480	640	800	960	1260	1600	1920	2560
C_V	8	14	22	30	50	75	110	200
$A_V \times 10^{-5}$	19	33	52	71	119	178	261	474

To illustrate the above, consider the problem of determining the valve size for a valve that is required to control the flow of water when the maximum flow required is 0.012 m^3/s and the permissible pressure drop across the valve at this flow rate is 300 kPa. Using the equation

$$Q = A_V \sqrt{\frac{\Delta P}{\rho}}$$

then, since the density of water is 1000 kg/m^3,

$$A_V = Q\sqrt{\frac{\rho}{\Delta P}} = 0.012\sqrt{\frac{1000}{300 \times 10^3}} = 69.3 \times 10^{-5}$$

Thus, using Table 7.1, the valve size is 960 mm.

Fluid control system

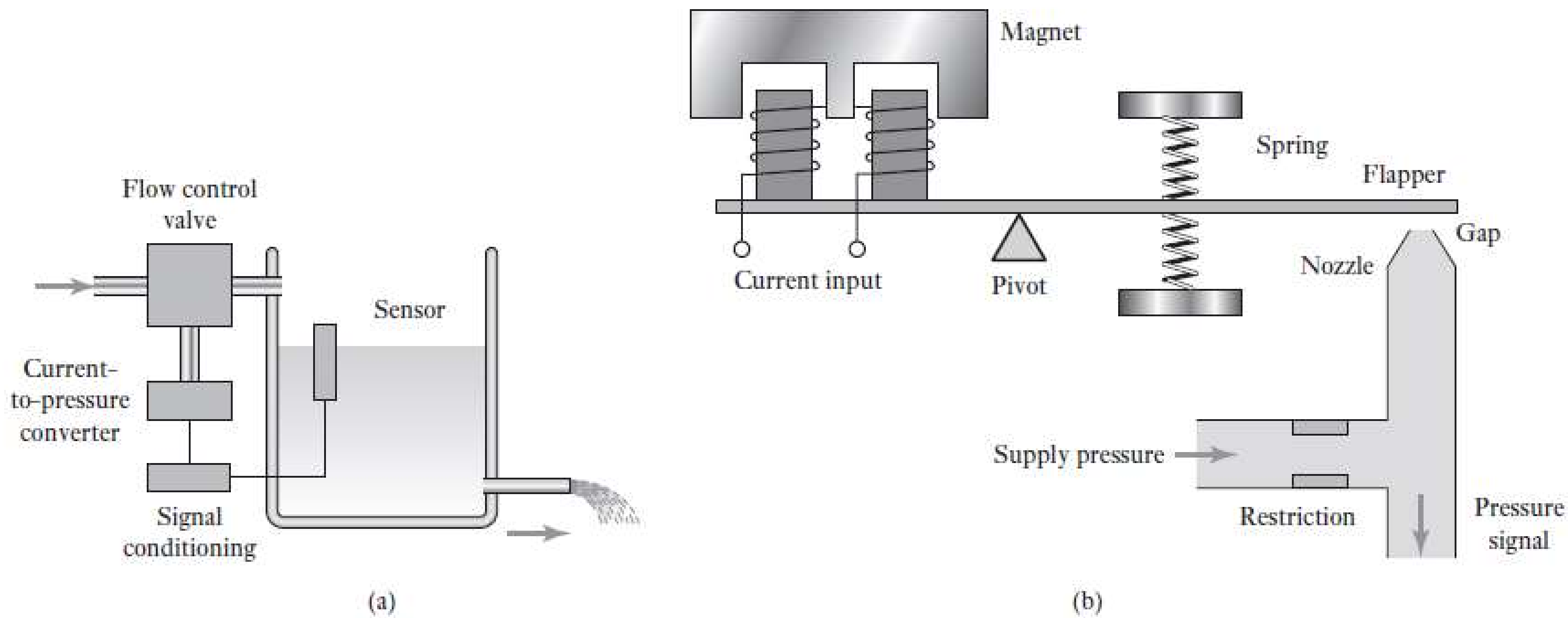
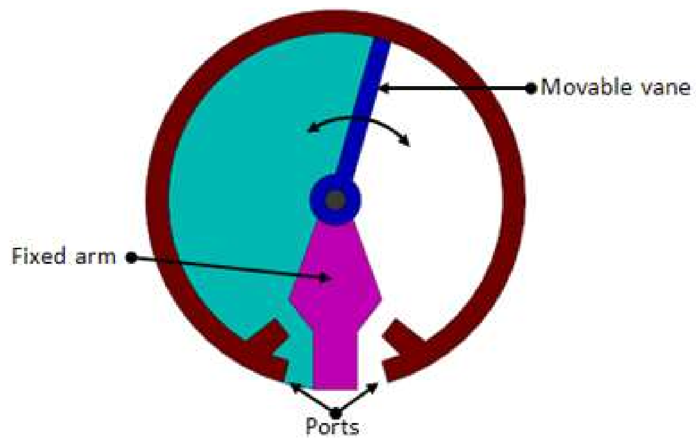
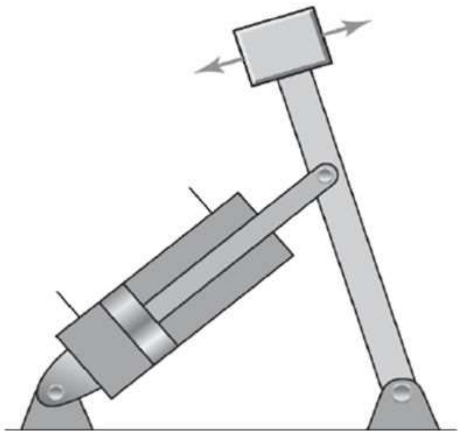
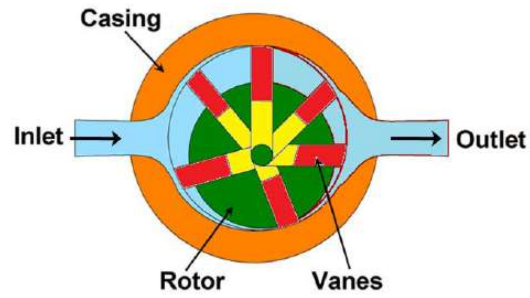


Figure 7.26 (a) Fluid control system, (b) current-to-pressure converter.

Rotary actuators







Thank you