

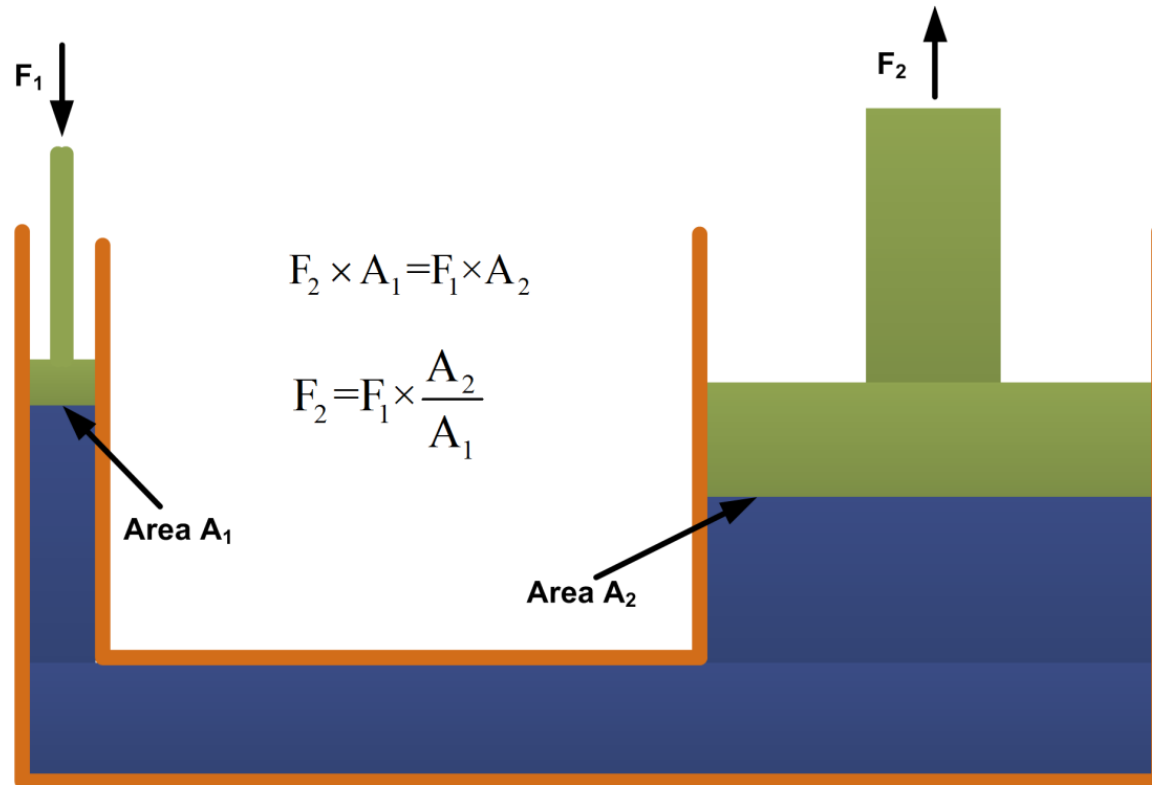
Hydraulic and pneumatic systems

ME 202M Mechatronics

Introduction

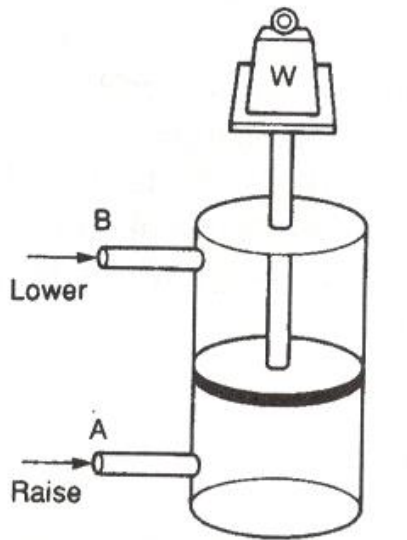
- Prime movers
- Electrical drives
- Enclosed fluids
 - Hydraulic
 - Pneumatic
- Softer actions
- Higher pressures and loads

Pascal's Law

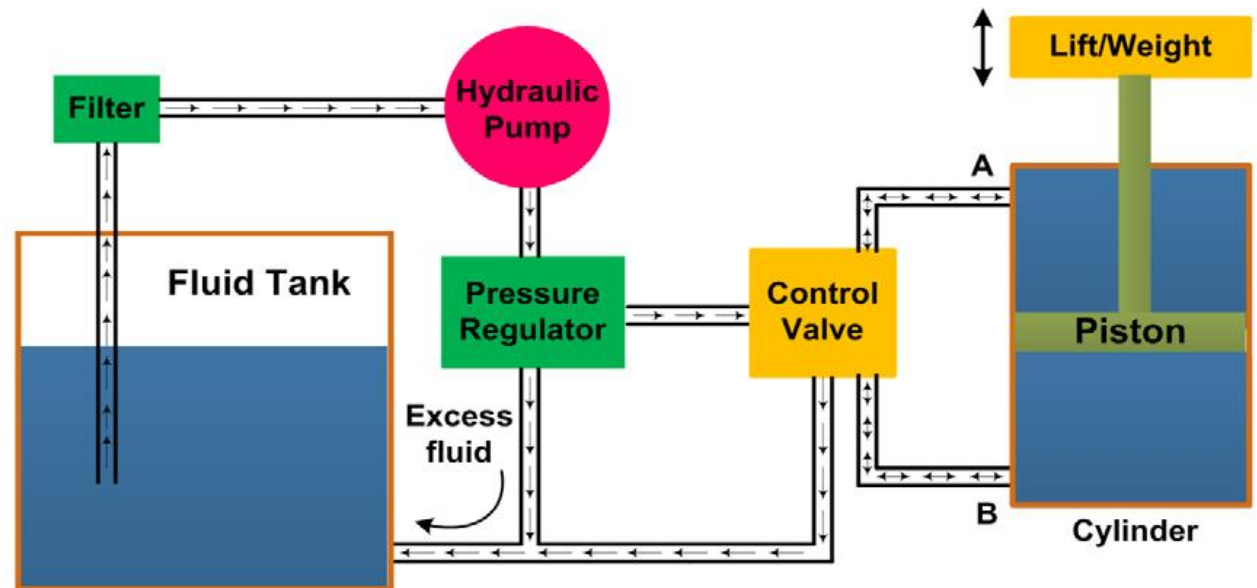


- The hydraulic system works on the principle of Pascal's law which says that the pressure in an enclosed fluid is uniform in all the directions.

A Hydraulic system



(a) Hydraulic cylinder



150 bar will lift 150
 kg/cm^2

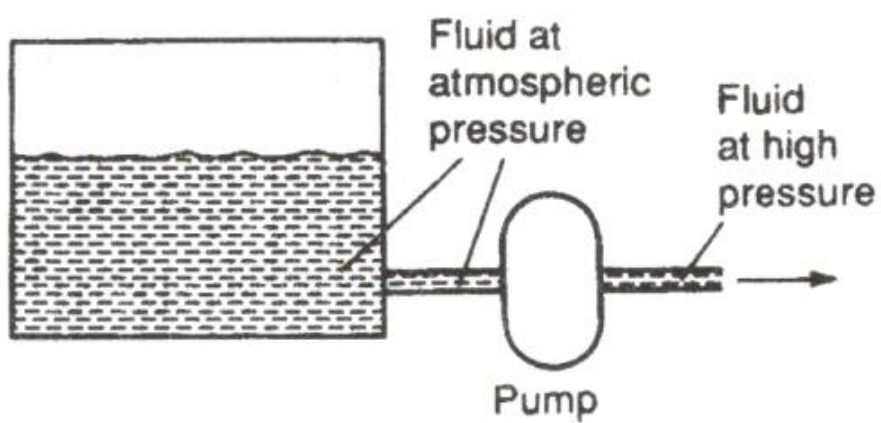
2000 kg would be lifted
by 4.2 cm dia piston

Applications

- **Industrial:** Plastic processing machineries, steel making and primary metal extraction, automated production lines, machine tool industries, paper industries, loaders, crushers, textile machineries
- **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.

Applications

- **Automobiles:** Breaks, shock absorbers, steering system, wind shield, lift and cleaning etc.
- **Marine applications:** Ocean going vessels, fishing boats and navel equipment
- **Aerospace equipment:** For radar control, landing gear, breaks, flight : airplanes, rockets and spaceships.



Hydraulic pump

(a) Operation of a pump

- The combined pumping and driving motor unit is known as hydraulic pump.
- In general, the speed of pump is constant and the pump delivers an equal volume of oil in each revolution.
- The amount and direction of fluid flow is controlled by some external mechanisms.

Hydraulic pump

- Servo controlled motor – complex system.
- flow rate capacity
- power consumption
- drive speed
- pressure delivered at the outlet
- efficiency of the pump.
 - volumetric efficiency
 - power efficiency

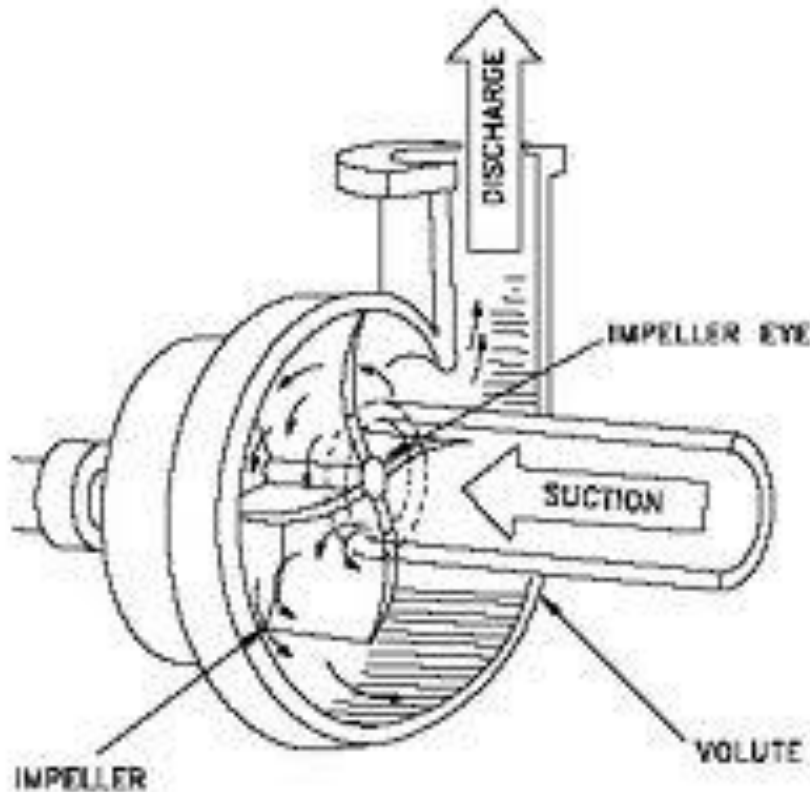
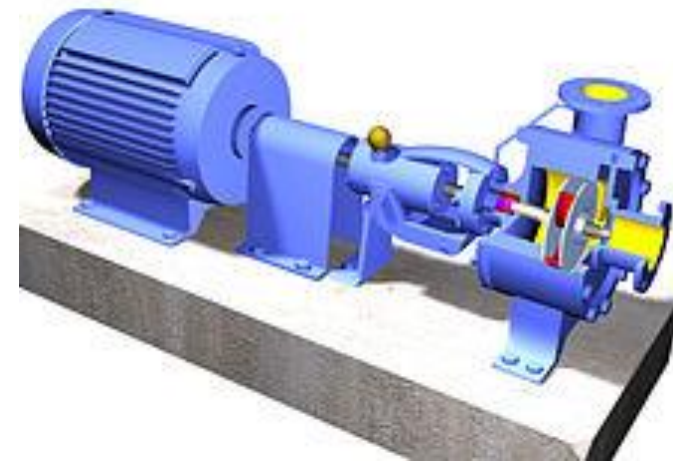
Types of pumps

The hydraulic pumps can be of two types:

- centrifugal pump
- reciprocating pump

Centrifugal pumps

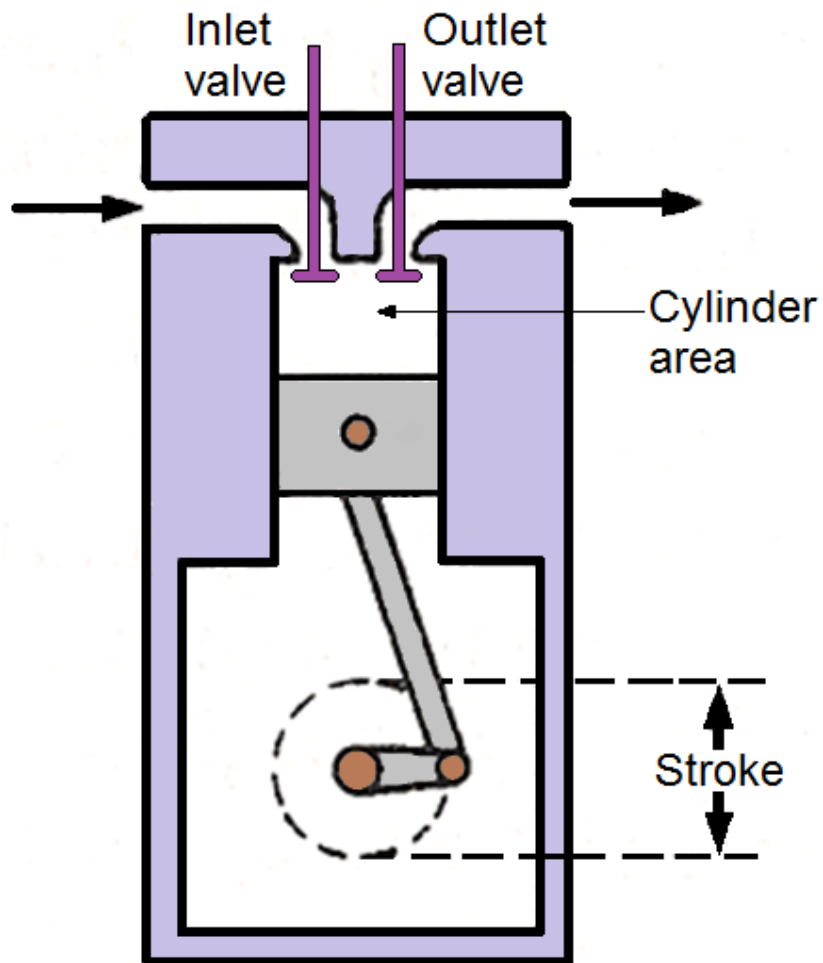
The hydraulic pump



- Rotational kinetic energy
- Volume delivery is not constant
- Leakage past the vanes
- Not suitable for high pressure applications
- 20-30 bars
- Water pumps

Reciprocating pump: positive
displacement

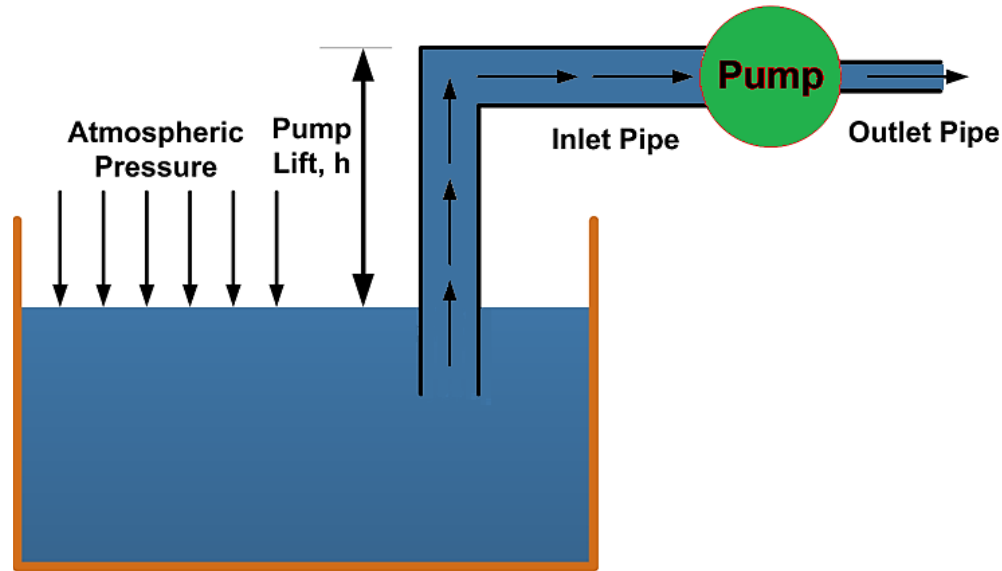
Positive displacement or hydrostatic pumps



- Small volume, large and constant pressures
- Exit pressure is maintained

Pump lift

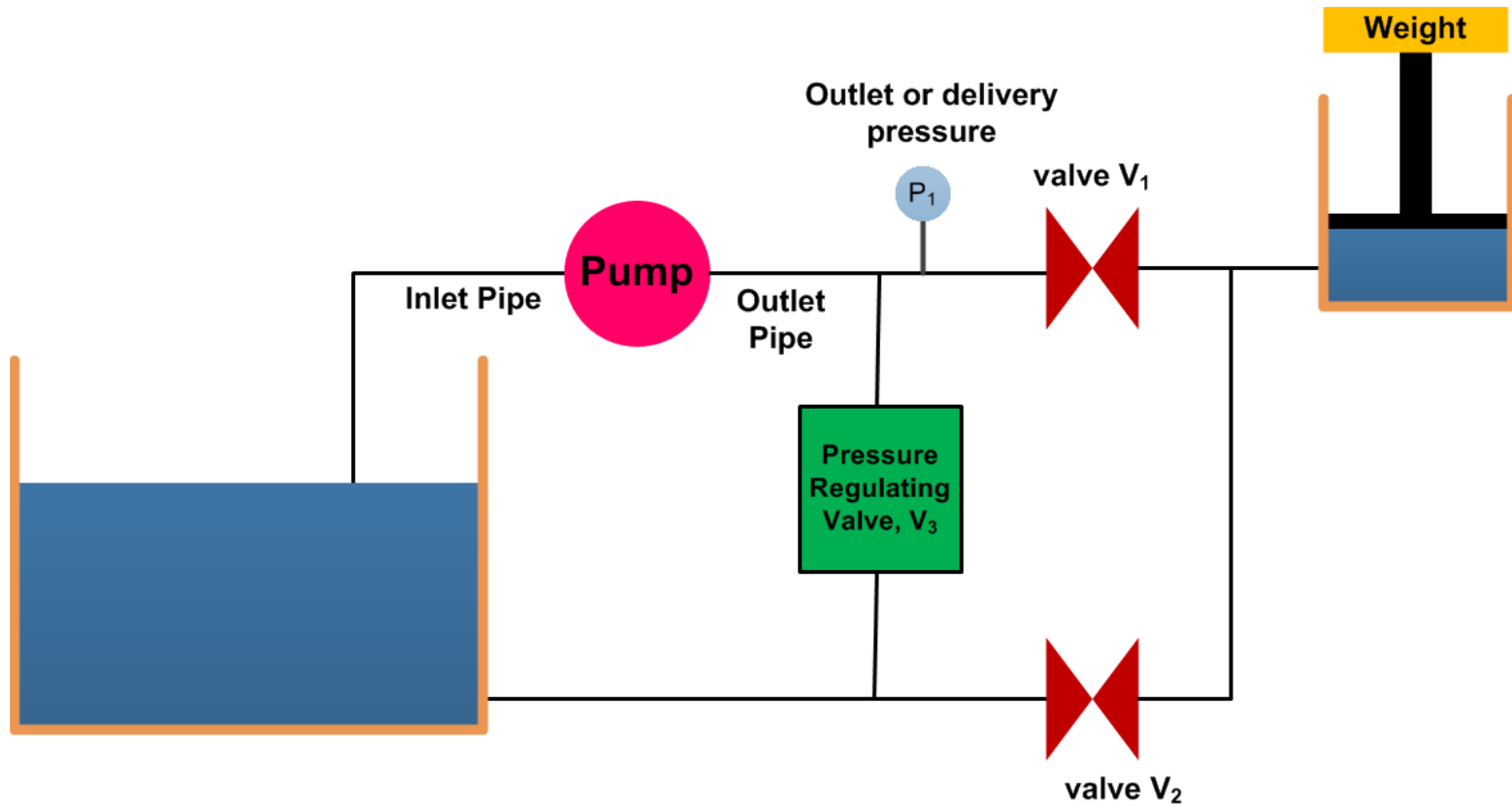
- Pressure Head, $P = \rho gh$
- A pump lift of 8 m is possible
- undesirable effects – cavitation
- Formation and destructive collapse of bubbles from partial vaporization of fluid



Cavitation

- The cavities can be small liquid-free zones ("bubbles" or "voids") formed due to partial vaporization of fluid (liquid).
- rapid changes of pressure
- at higher pressure, the voids implode and can generate an intense shockwave
- **lower flow velocity at the inlet and therefore the inlet pipes have larger diameter than the outlet pipes in a pump.**
- **The pump lift should be as small as possible to decrease the cavitation and to increase the efficiency of the pump.**

Pressure regulation

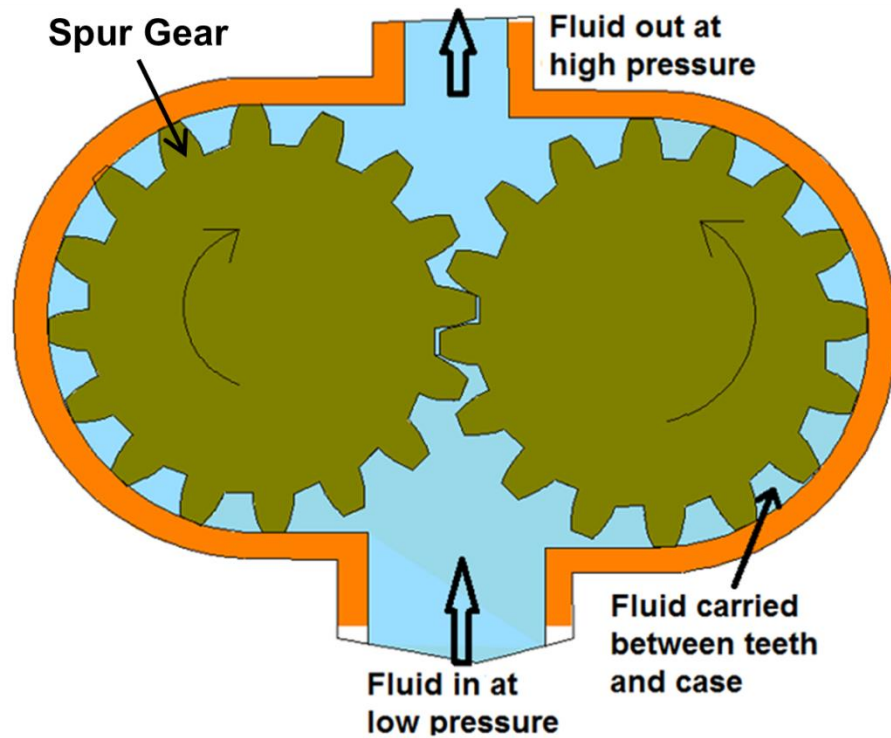


Types of pumps

- Non-positive displacement pumps
- Positive displacement pumps

POSITIVE DISPLACEMENT PUMPS

Gear pump



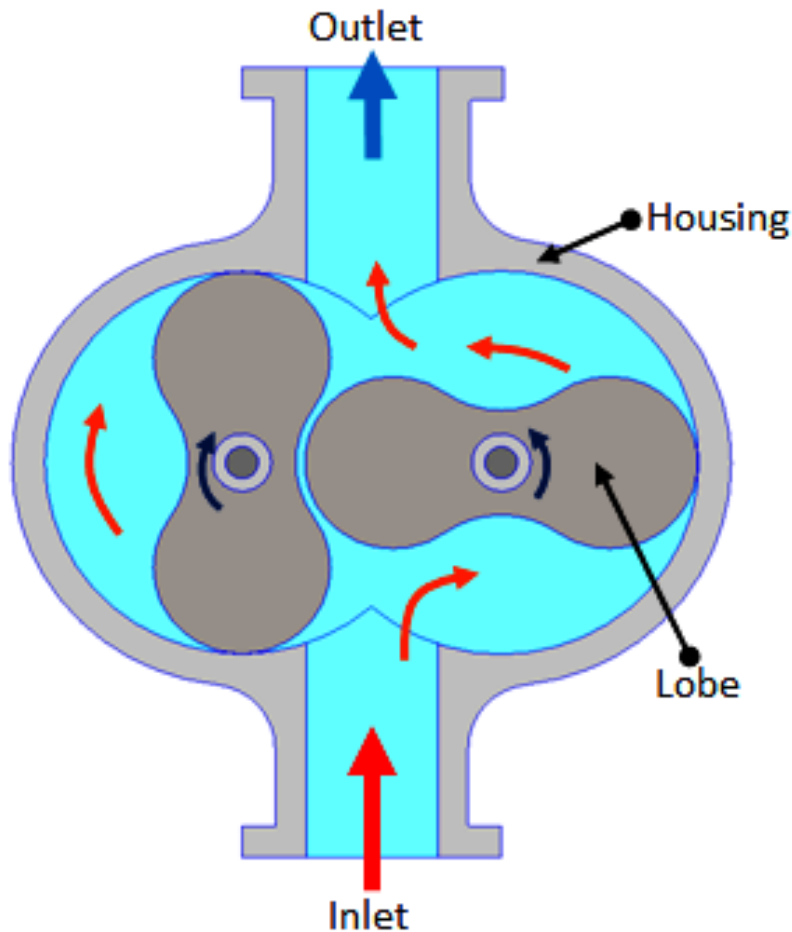
- Simplest and most robust positive displacement pump
- Non reciprocating
- Move at constant speed
- Experience uniform force
- Wear
- 150 bar
- 6750 lit/min
- 90%

Applications

Generally gear pumps are used to pump:

- Petrochemicals: Pure or filled bitumen, pitch, diesel oil, crude oil, lube oil etc.
- Chemicals: Sodium silicate, acids, plastics, mixed chemicals, isocyanates etc.
- Paint and ink
- Resins and adhesives
- Pulp and paper: acid, soap, lye, black liquor, kaolin, lime, latex, sludge etc.
- Food: Chocolate, cacao butter, fillers, sugar, vegetable fats and oils, molasses, animal food etc.

The lobe pump



- pulp and paper, chemical, food, beverage, pharmaceutical and biotechnology etc.
- solids (e.g., cherries and olives), slurries, pastes,
- minimum product degradation
- offer continuous and intermittent reversible flows

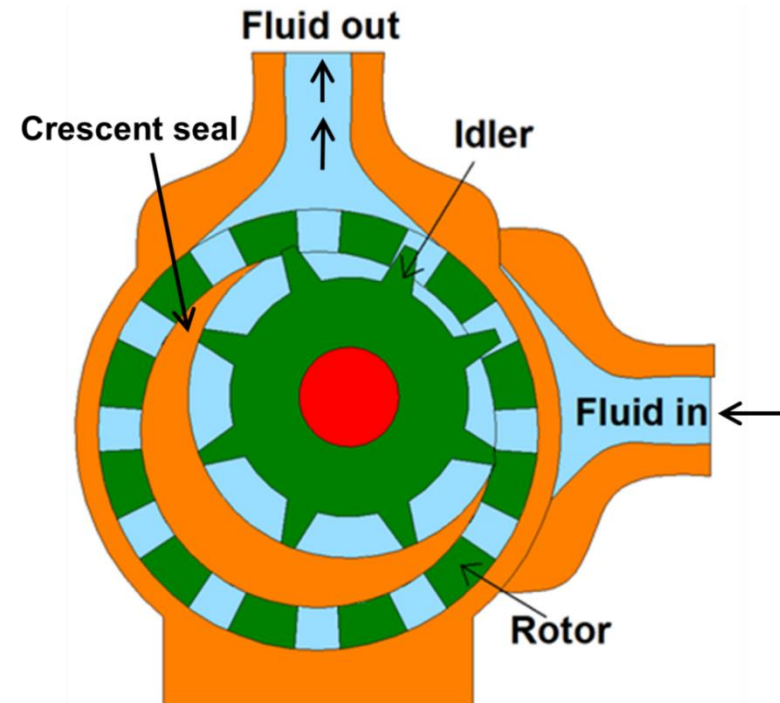
Performance

- Performance of any pump
 - Leakage -> efficiency
 - Ability to with stand the pressure differential
 - Capacity



Internal gear pumps

- low or medium viscosity fluids such as solvents and fuel oil
- non-pulsing, self-priming and can run dry for short periods
- bi-rotational
- simple to operate and easy to maintain
- not suitable for high speed and high pressure applications

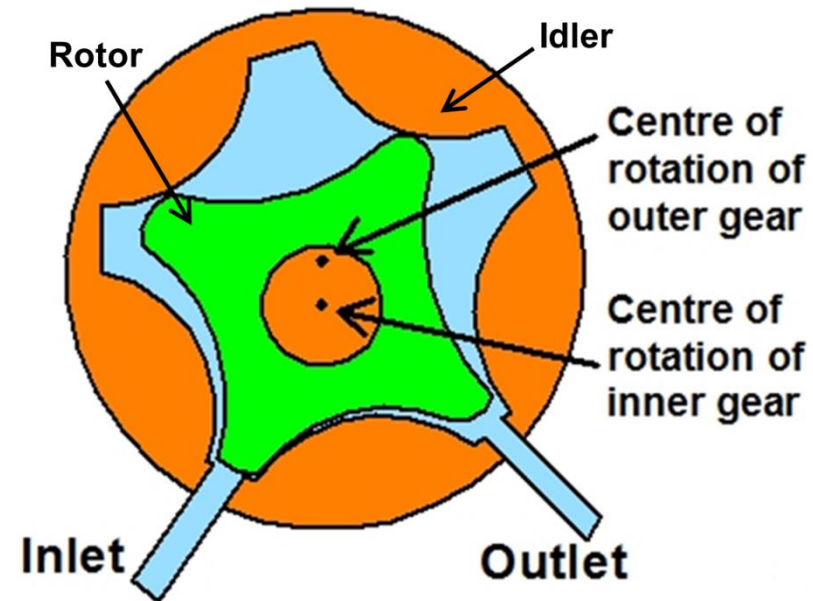
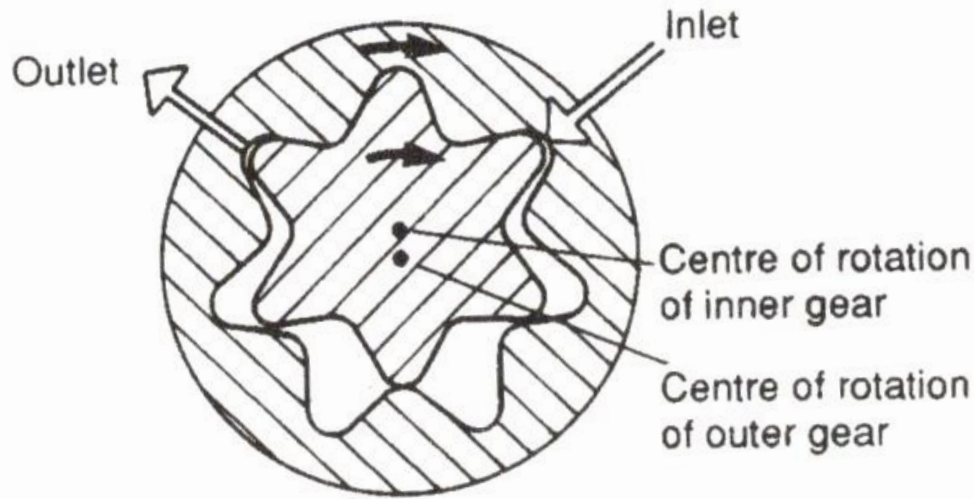


Applications

Some common internal gear pump applications are:

- All varieties of fuel oil and lube oil
- Resins and Polymers
- Alcohols and solvents
- Asphalt, Bitumen, and Tar
- Polyurethane foam (Isocyanate and polyol)
- Food products such as corn syrup, chocolate, and peanut butter
- Paint, inks, and pigments
- Soaps and surfactants
- Glycol

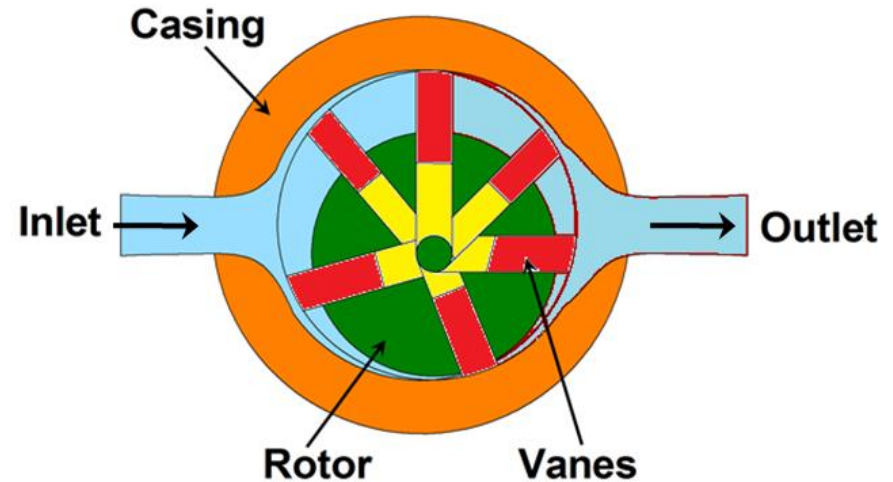
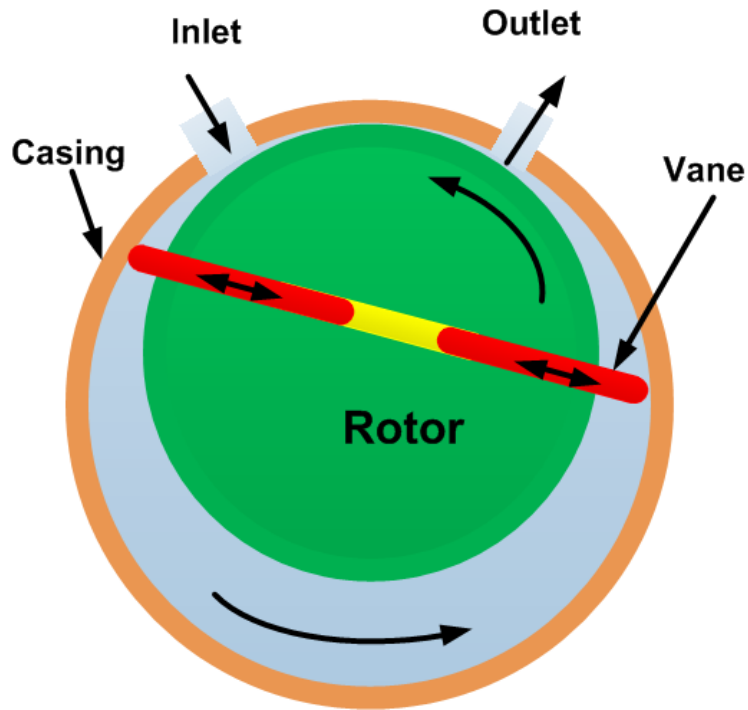
Gerotor pump (Generated rotor)



Applications

Common applications of Gerotor pump are:

- Light fuel oils
- Lube oil
- Cooking oils
- Hydraulic fluid

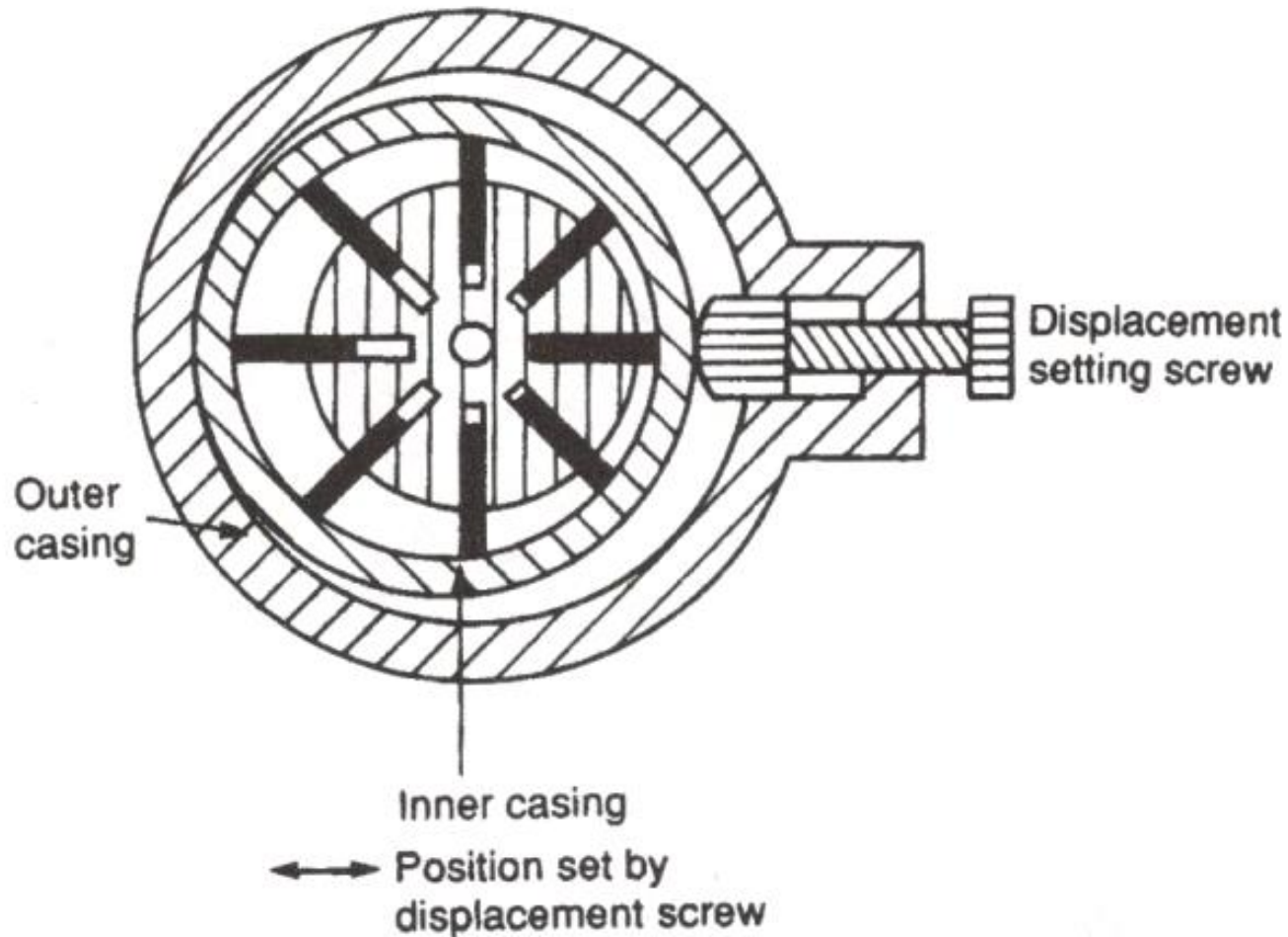


Vane pumps

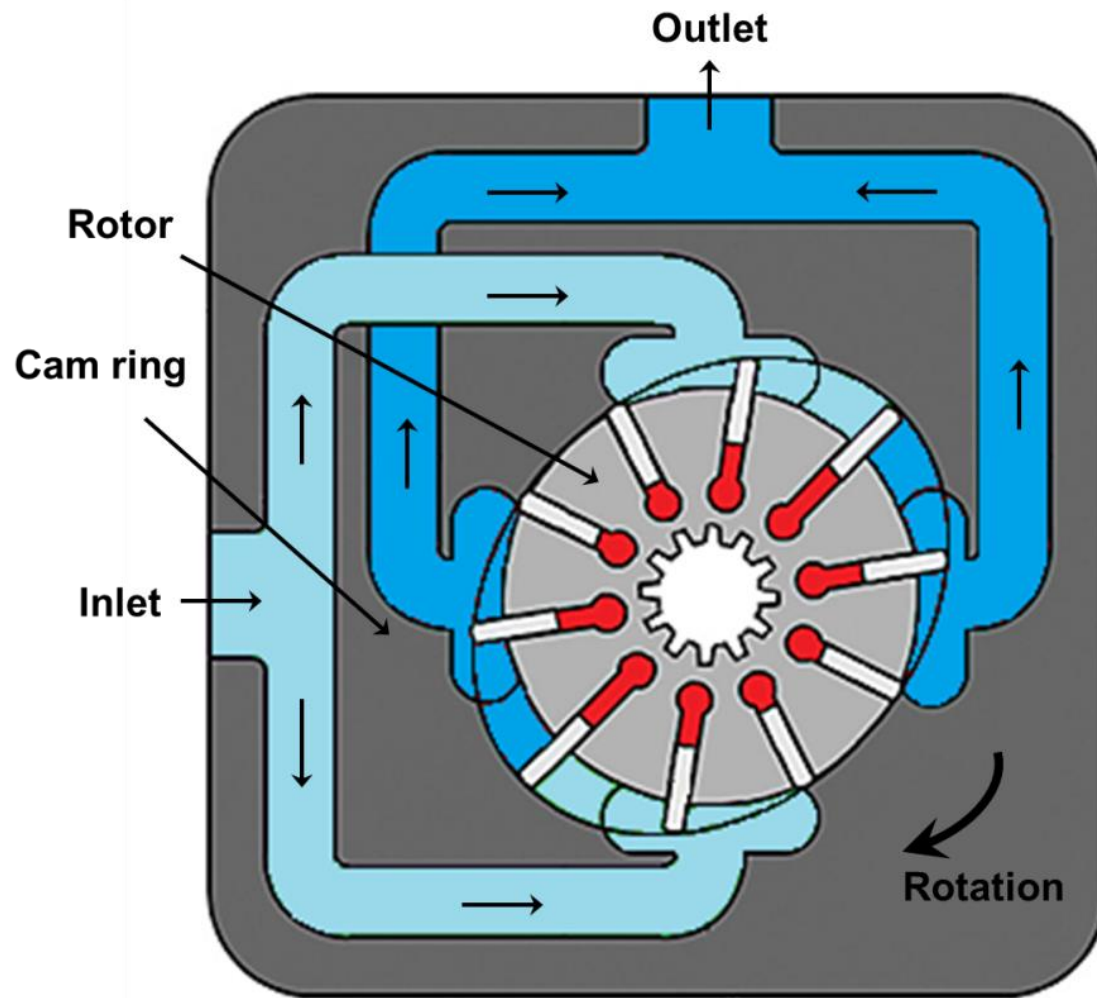
- Gear pumps: small leakage due to gap between gear teeth and pump housing
- Contacts are hardened and ground
- Automatic wear compensation
- High efficiency
- Pump displacement \propto eccentricity
- Unbalanced pressure at the outlet

Reduced leakage
95% efficiency

Adjustable vane pump: variable displacement



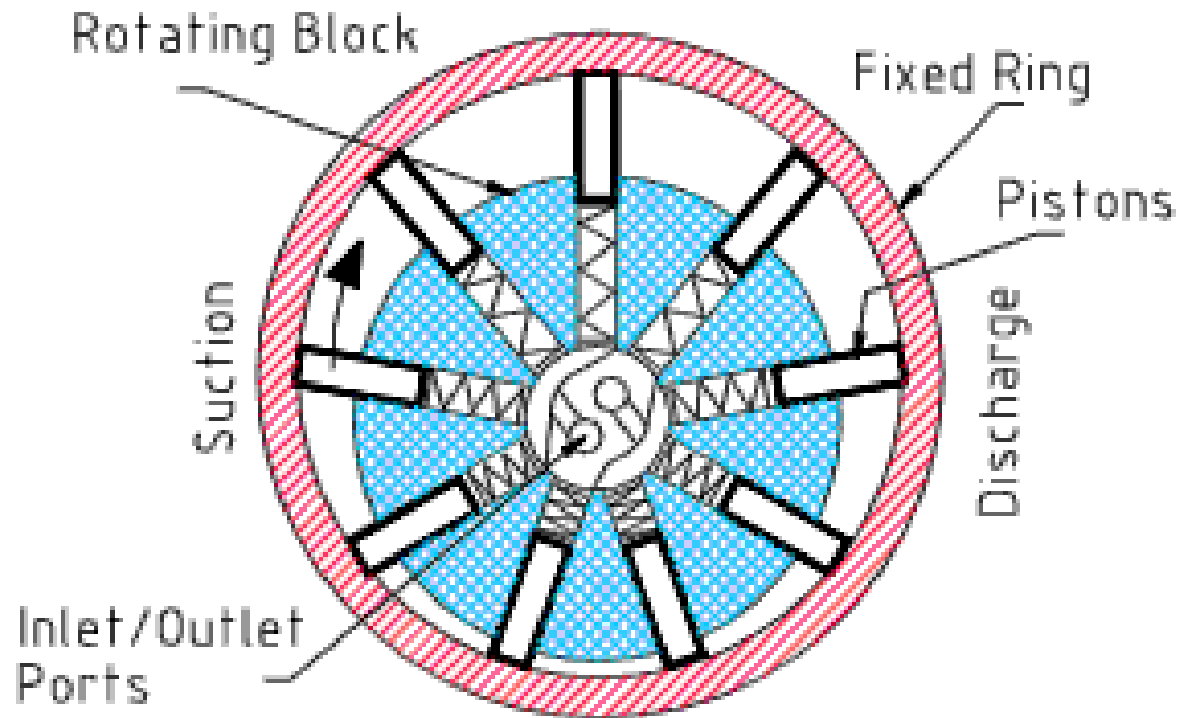
Balanced vane pump



Applications

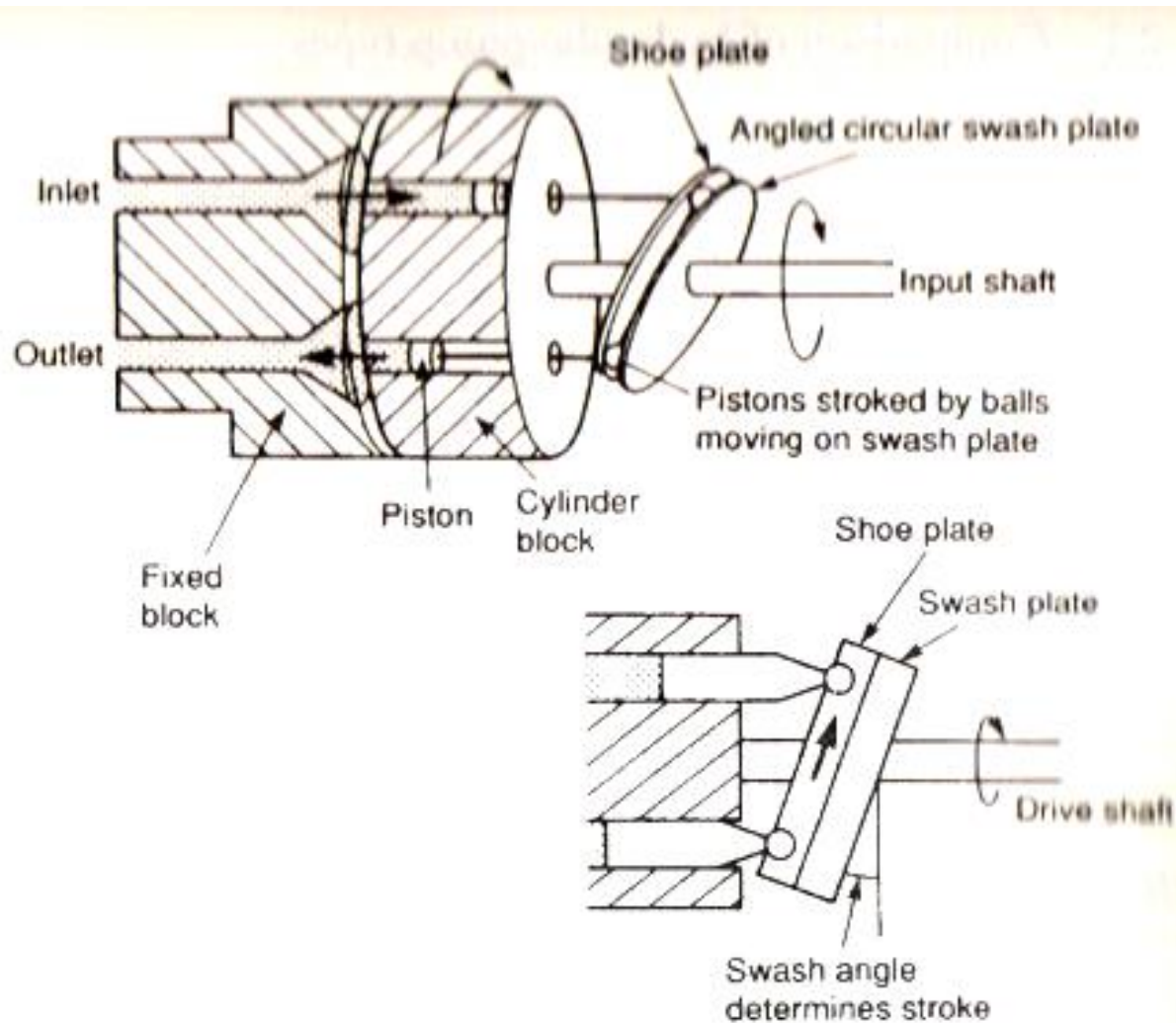
- Aerosol and Propellants
- Aviation Service - Fuel Transfer
- Auto Industry - Fuels, Lubes, Refrigeration Coolants
- Bulk Transfer of LPG and NH₃
- LPG Cylinder Filling
- Alcohols
- Refrigeration - Freons, Ammonia
- Solvents
- Aqueous solutions

Piston pumps



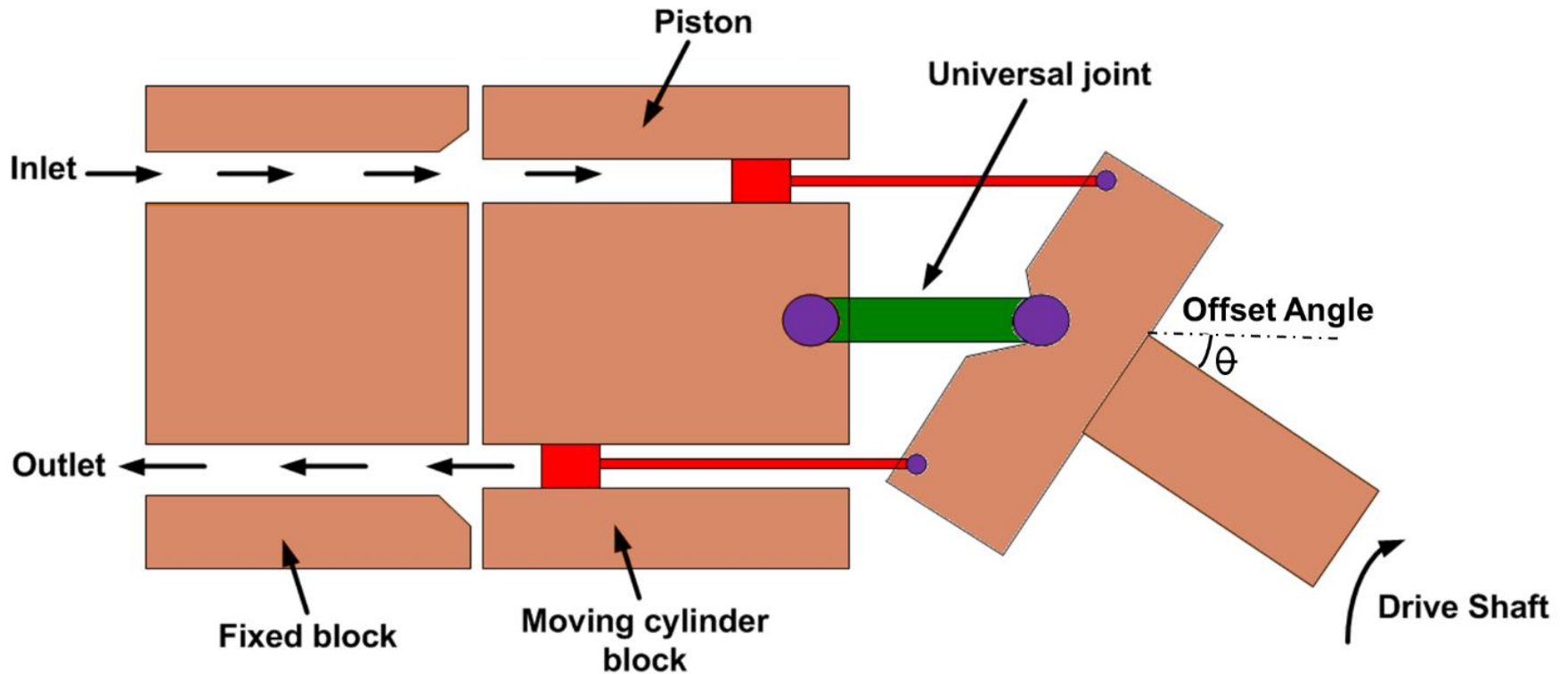
Radial Piston Pump

Axial pump with swash plate

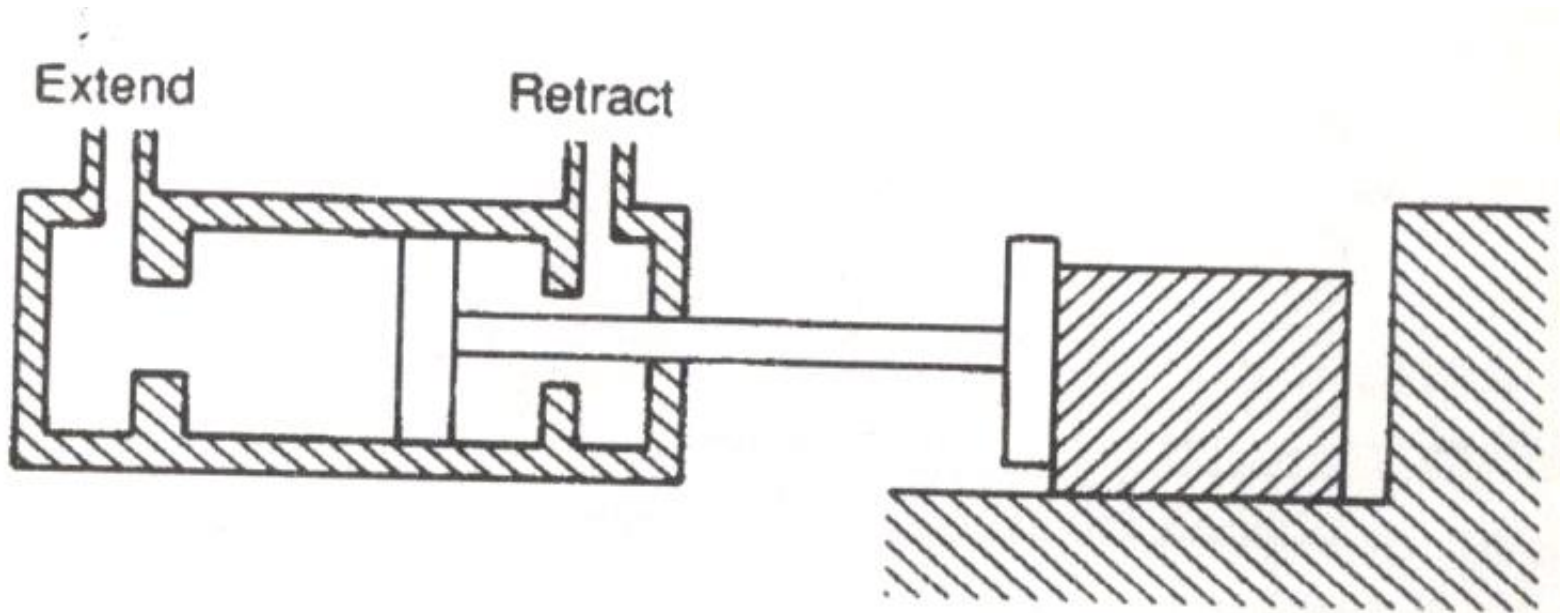


- Variable displacement

Bent axis piston pump

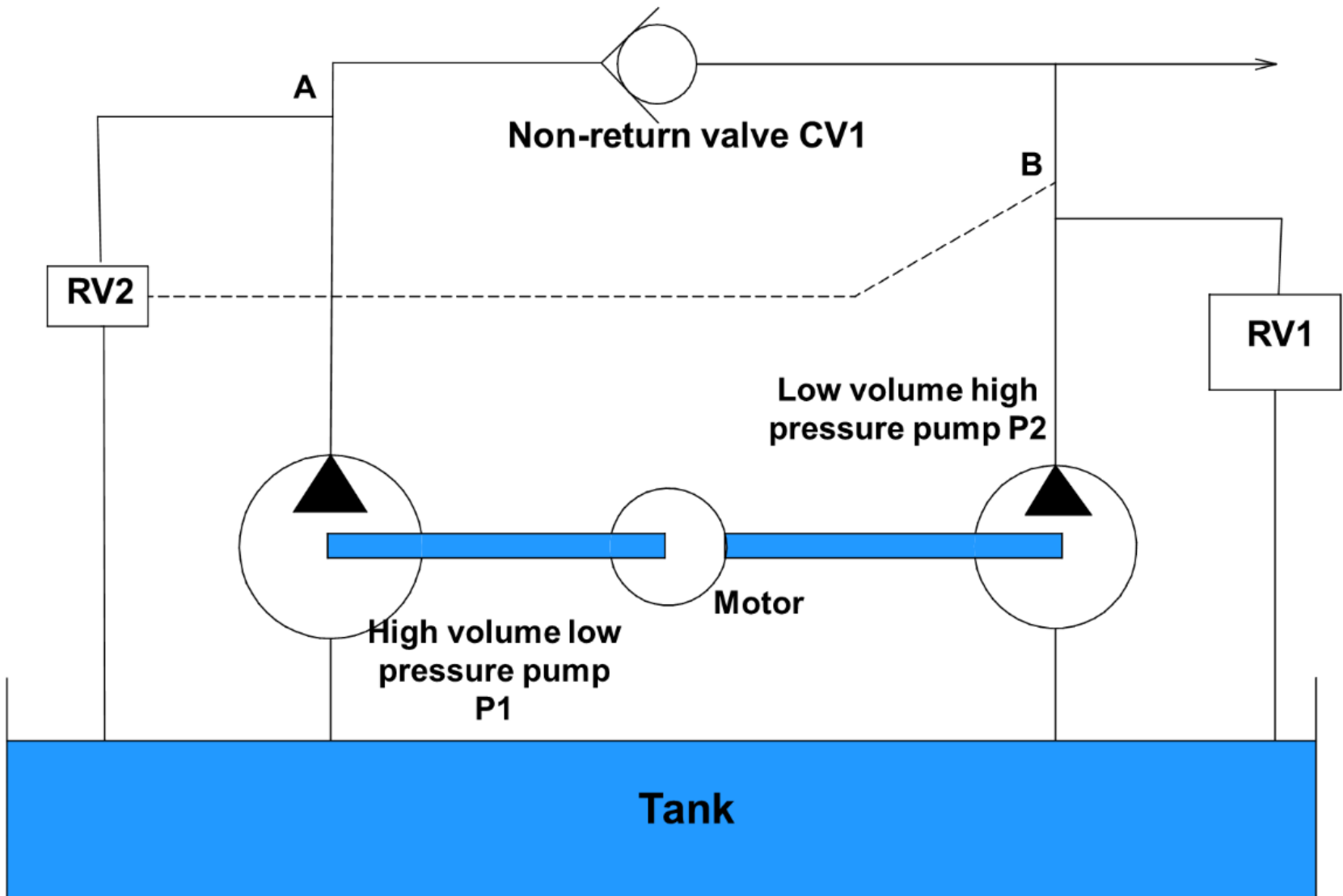


Combination pumps



- Hydraulic clamping/gripping operation
- Low pressure high volume : cylinder retracts or extends
- High pressure low volume : clamping

Combination pumps



Control valves

1. Directional control valves
2. Flow control valves
3. Pressure control valves

Directional control valve

Directional control valves can be classified in the following manner:

1. Type of construction:

- Poppet valves
- Spool valves

2. Number of ports:

- Two- way valves
- Three – way valves
- Four- way valves.

Types of direction control valves

3. Number of switching position:

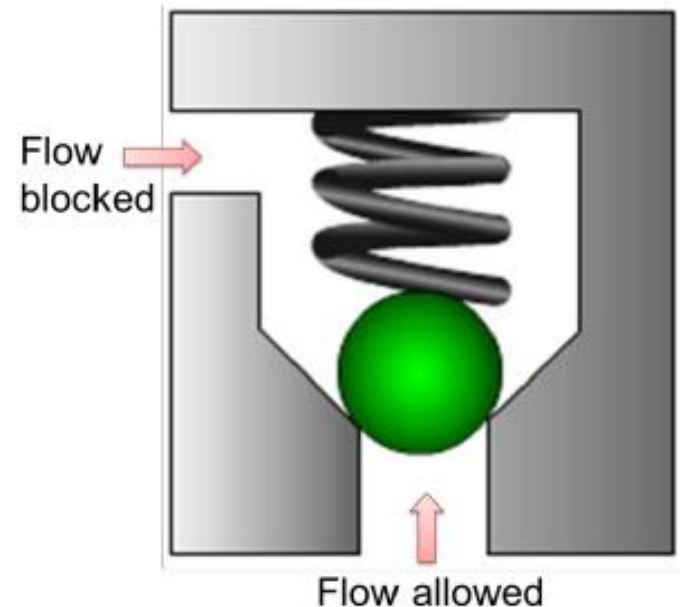
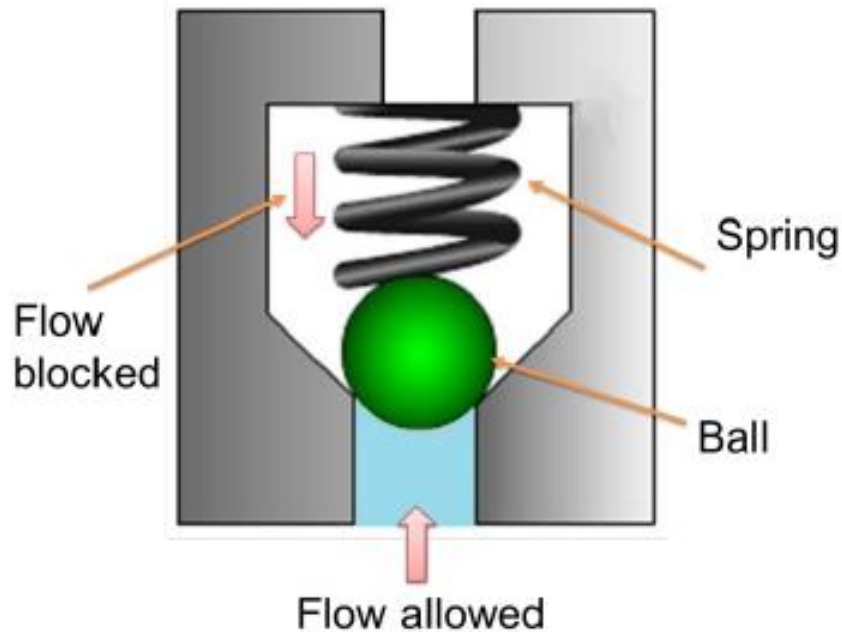
- Two – position
- Three - position

4. Actuating mechanism:

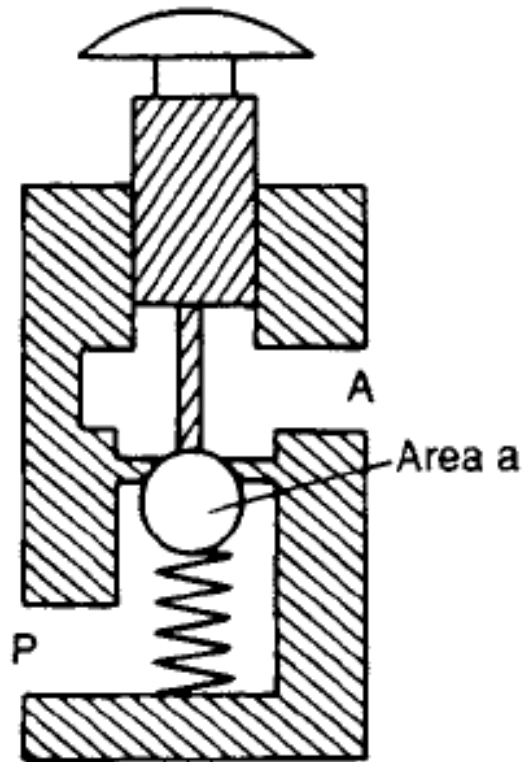
- Manual actuation
- Mechanical actuation
- Solenoid actuation
- Hydraulic actuation
- Pneumatic actuation
- Indirect actuation

Type of construction: check valve

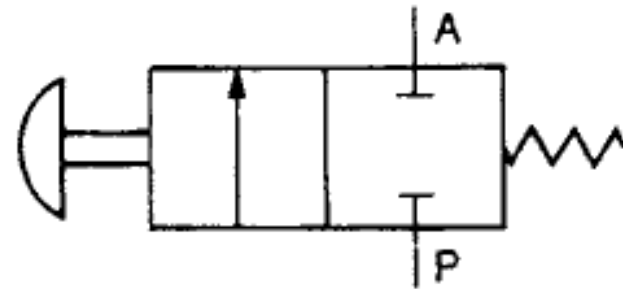
- Inline check valve Right angled check valve



Poppet valve

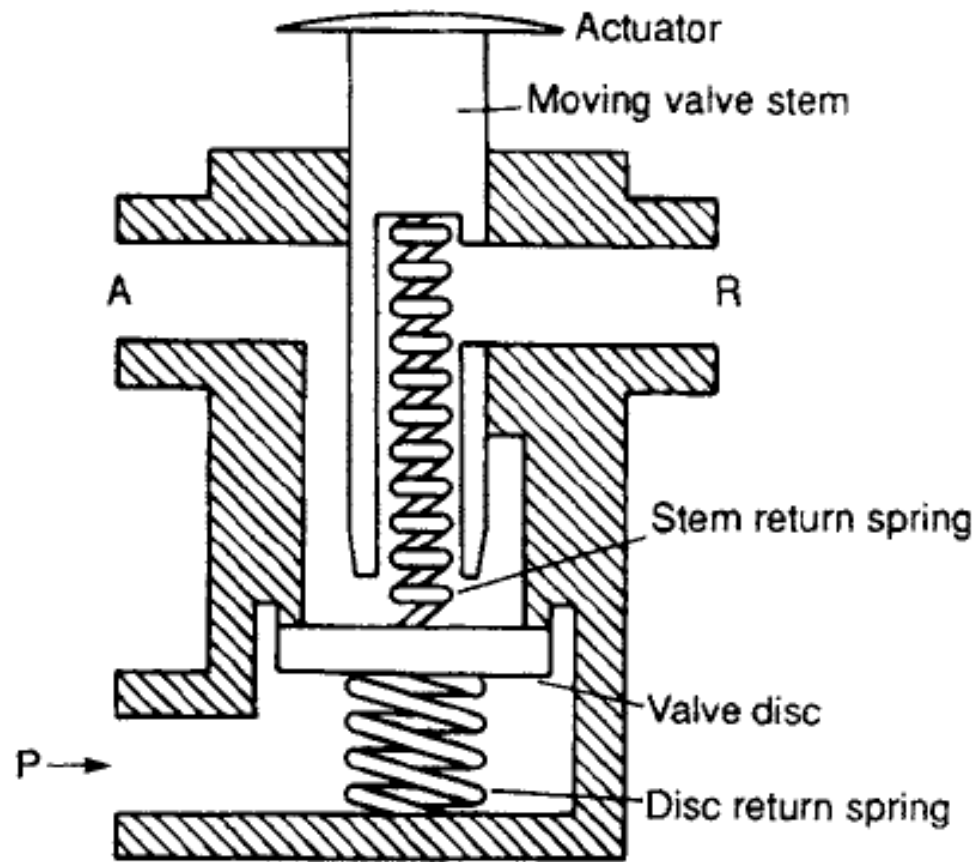


(a) Construction



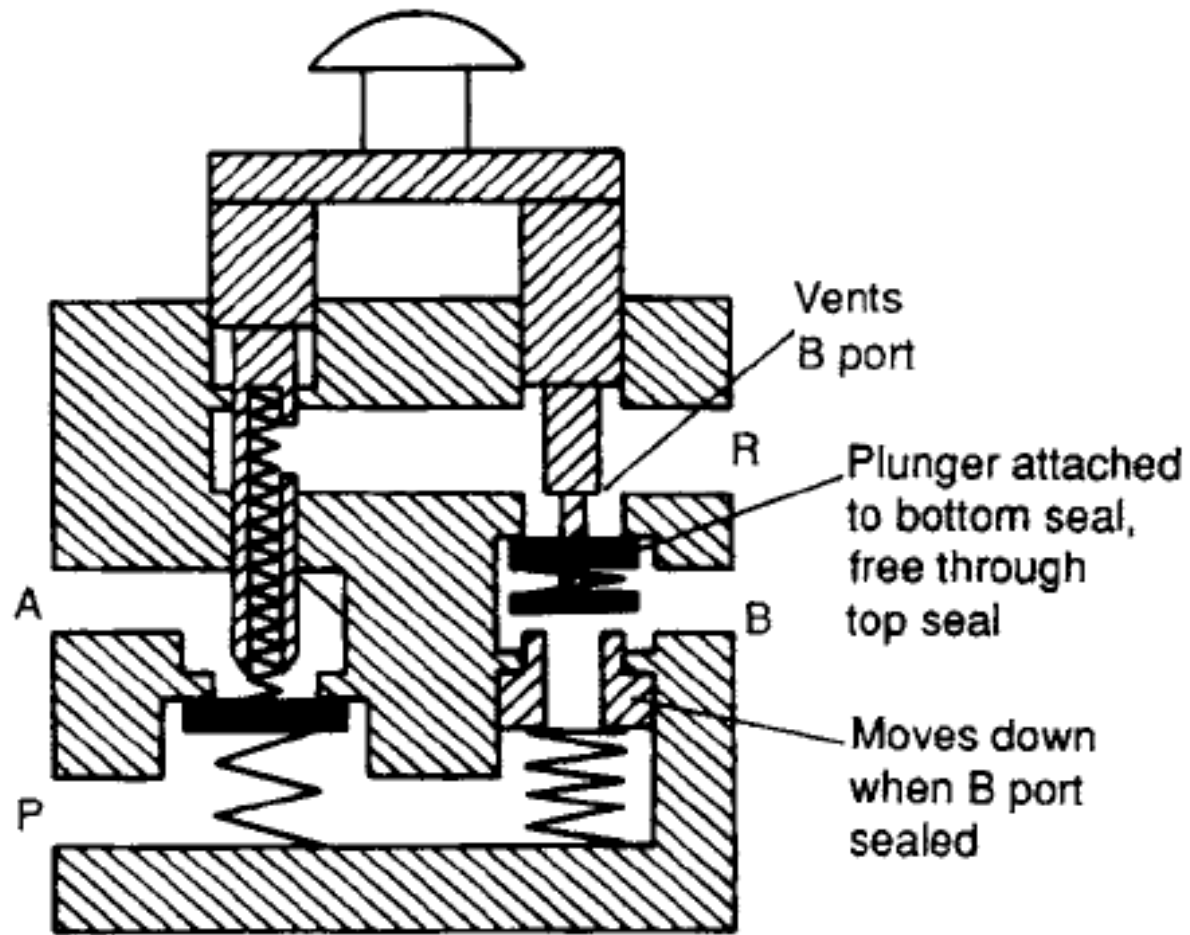
(b) Symbol

3/2 Poppet valve



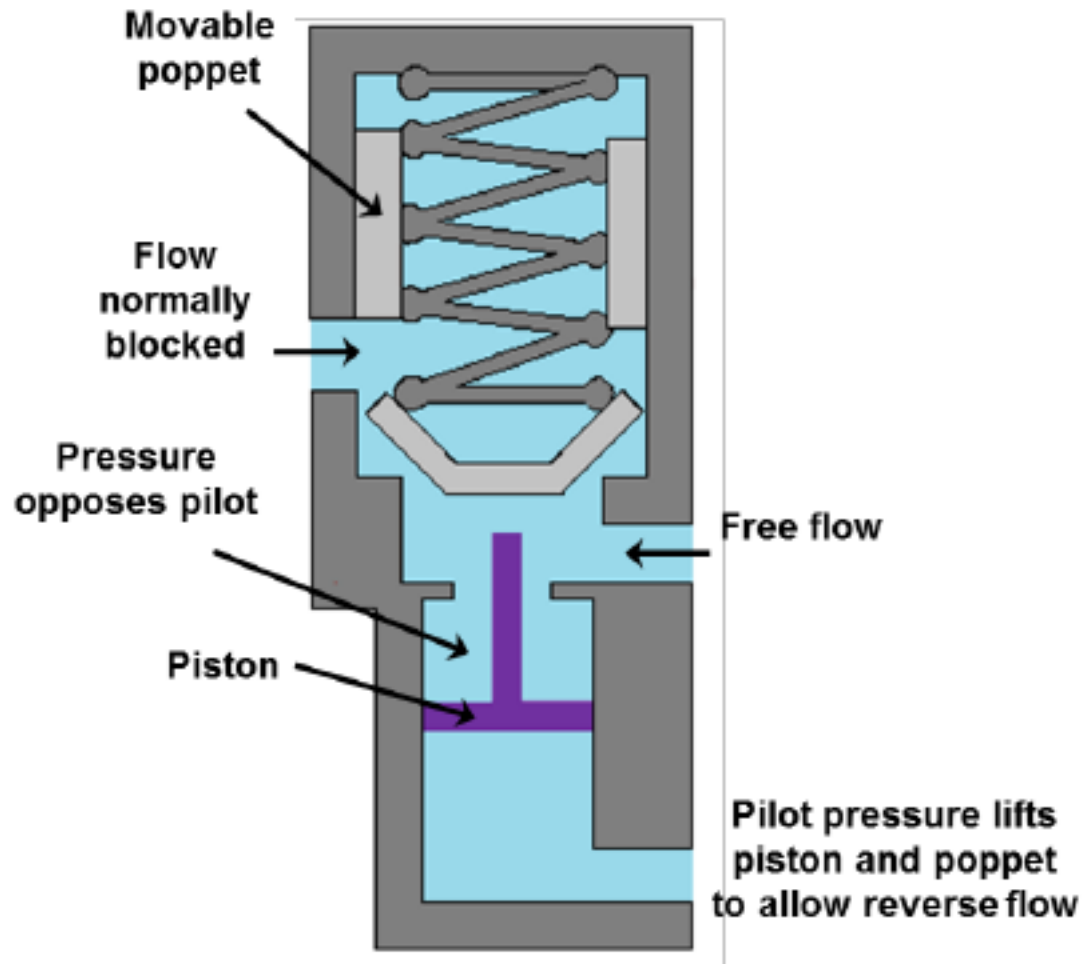
(a) Construction

4/2 Poppet valve

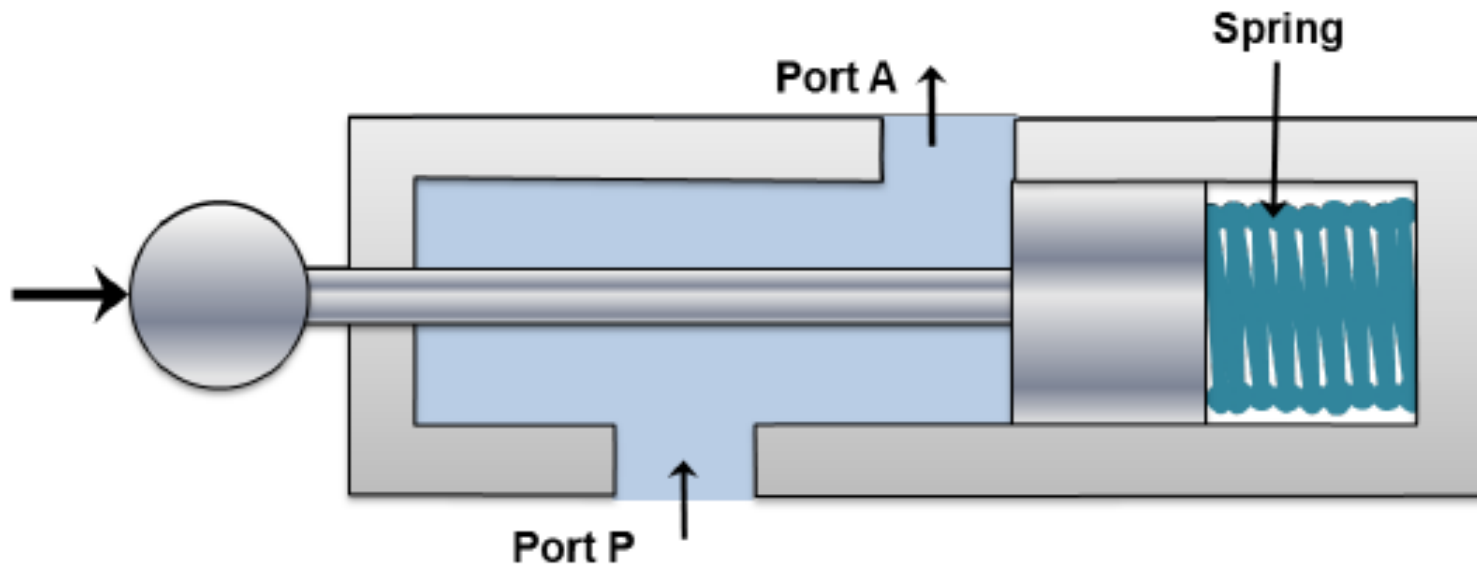
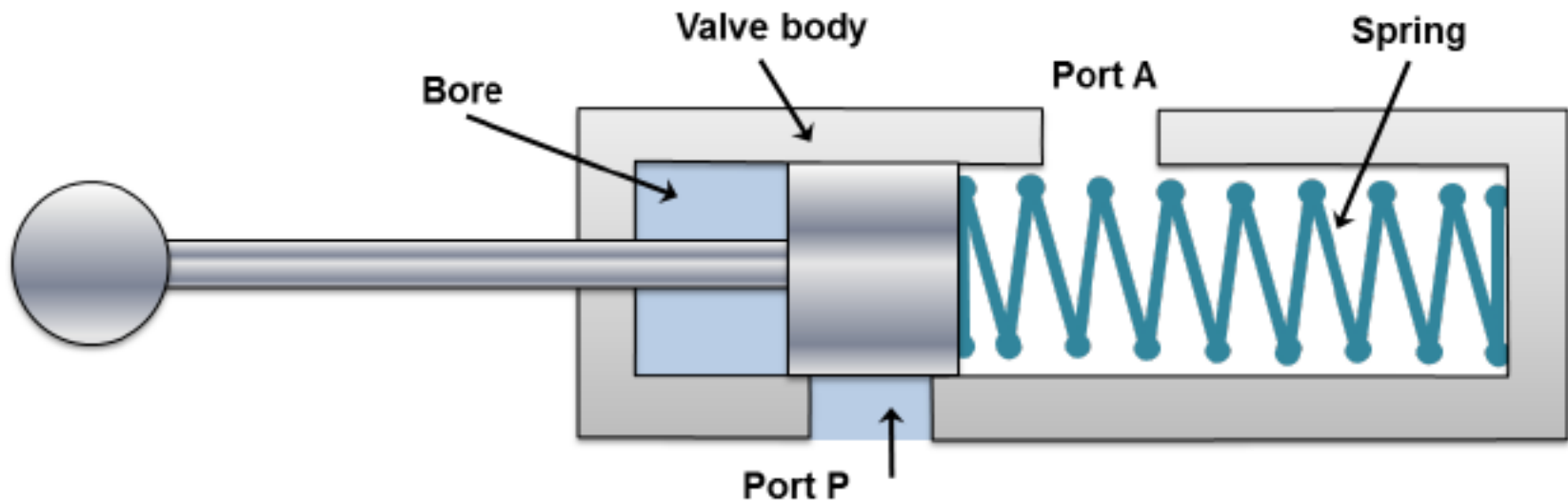


(a) Construction

Pilot operated check valve

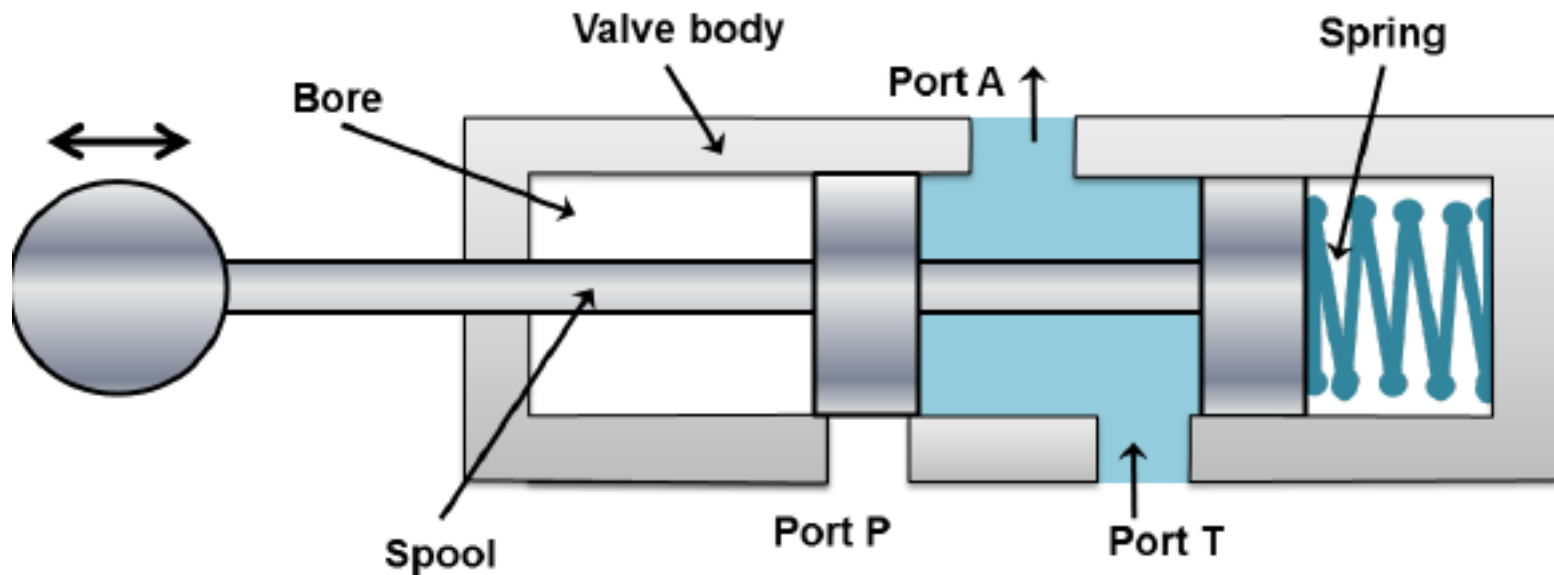


Spool valve

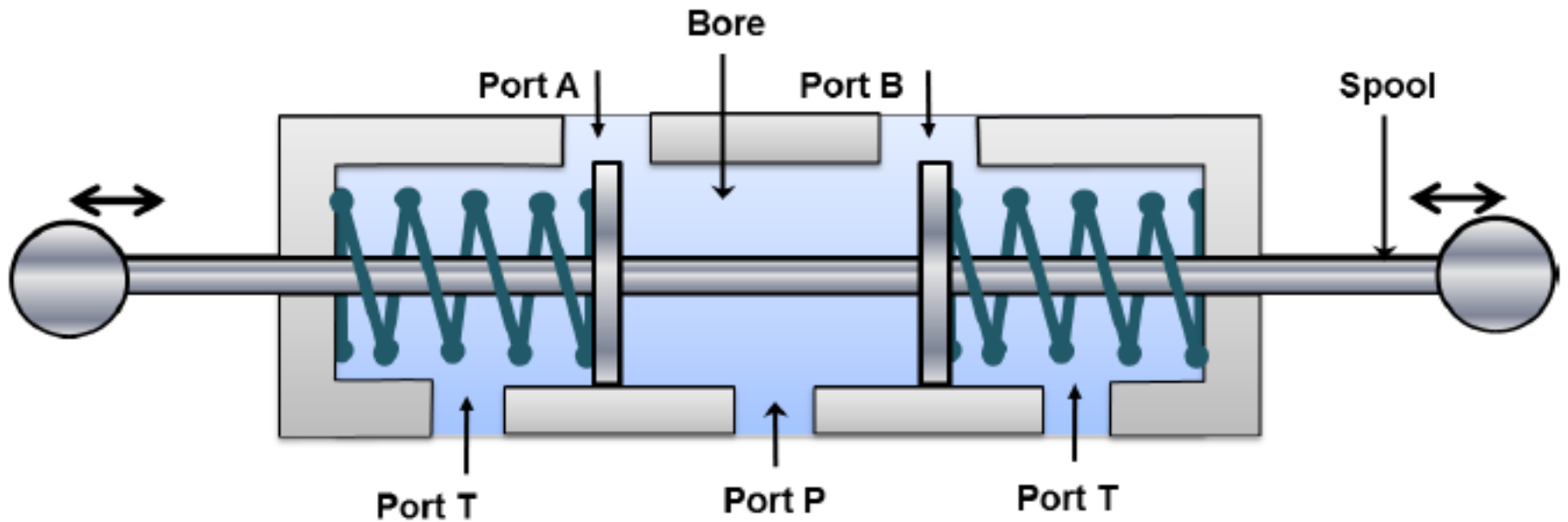


Types of valves: number of ports

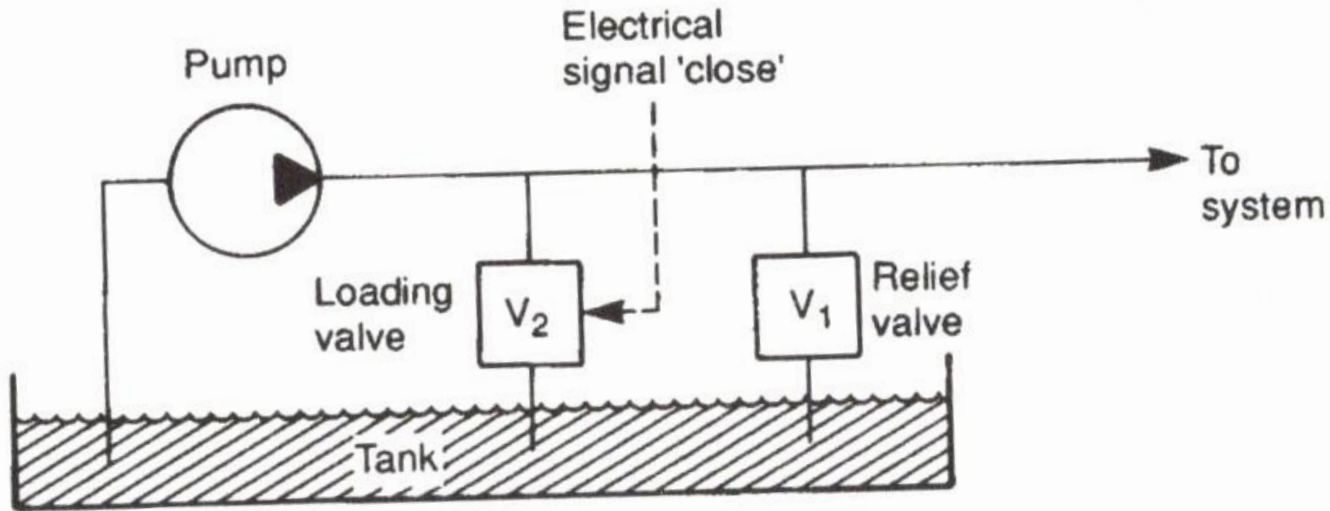
- Two way valves
- Three way valves



Four way valve

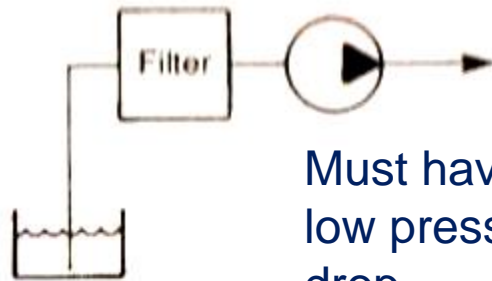


Pump loading/unloading valve



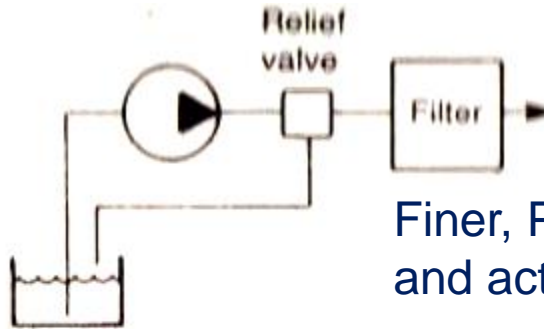
- Return to the tank via relief valve: wasteful of energy -> rise in temperature

Filters



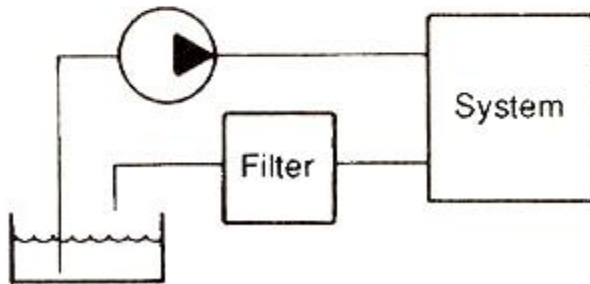
(a) Inlet line filter

Must have
low pressure
drop,
coarser



(b) Pressure line filter

Finer, Protects control valves
and actuators

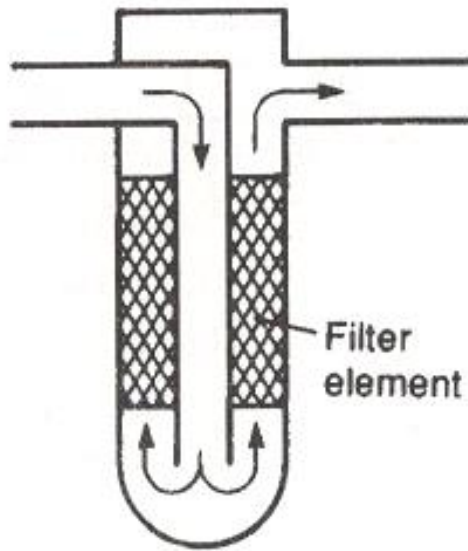


(c) Return line filter

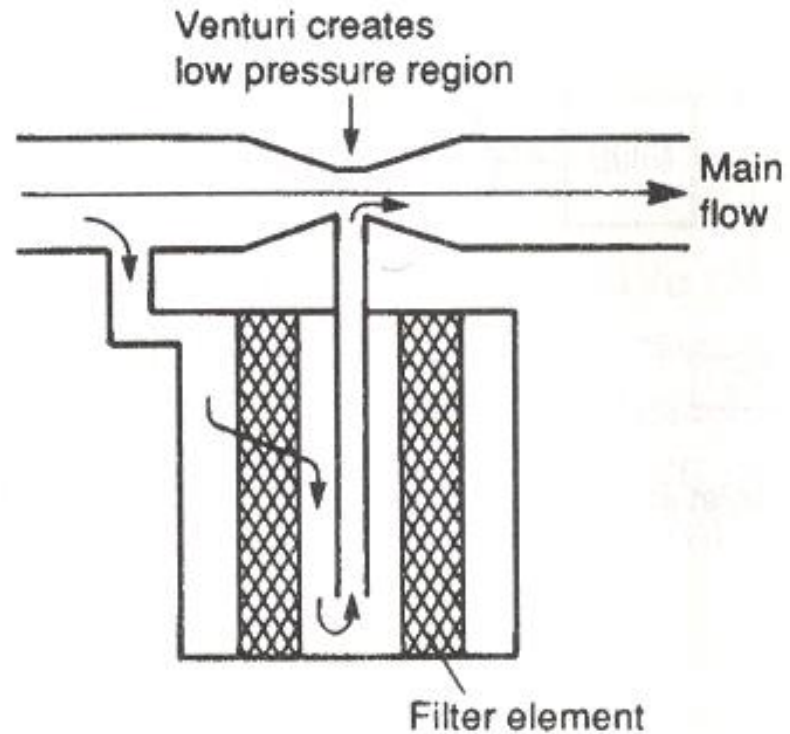
Can have high pressure drop,
very fine

- Dirt -> sticking -> failure of seals -> premature wear
- Strainers

Filters



(a) Full flow filter



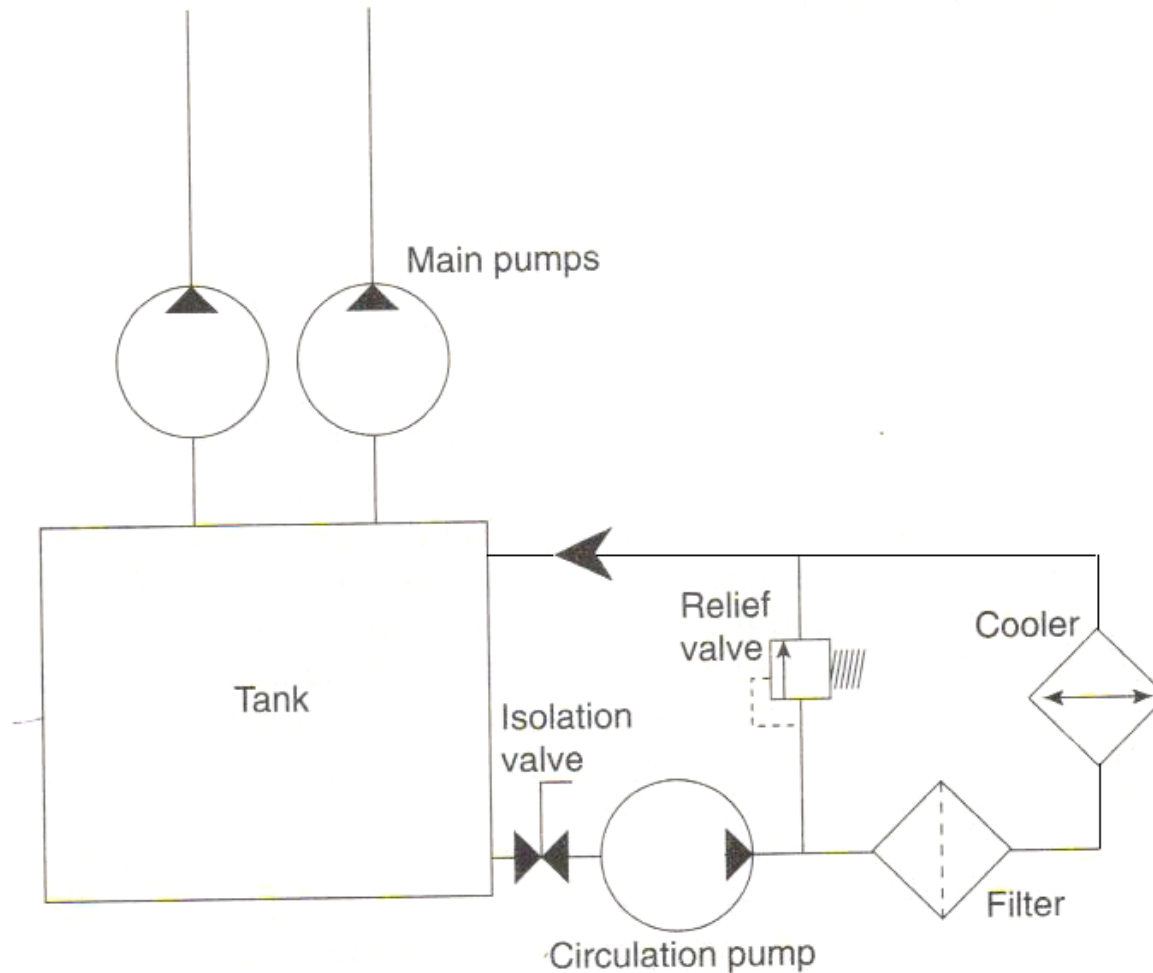
(b) Proportional flow filter

- Efficient
- High pressure drop
- Blocking -> separate relief valve
- Indicating filters – differential pressure meters

Filter materials

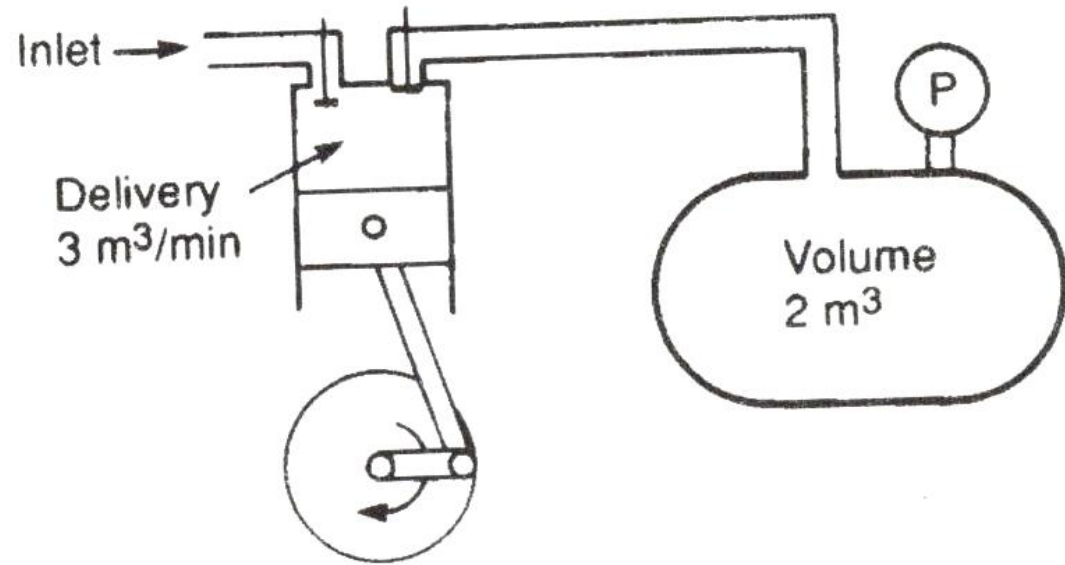
- **Mechanical: coarse, wire meshed**
- **Absorbent: paper, cotton, cellulose**

Separate circulation pump for filtering and cleaning



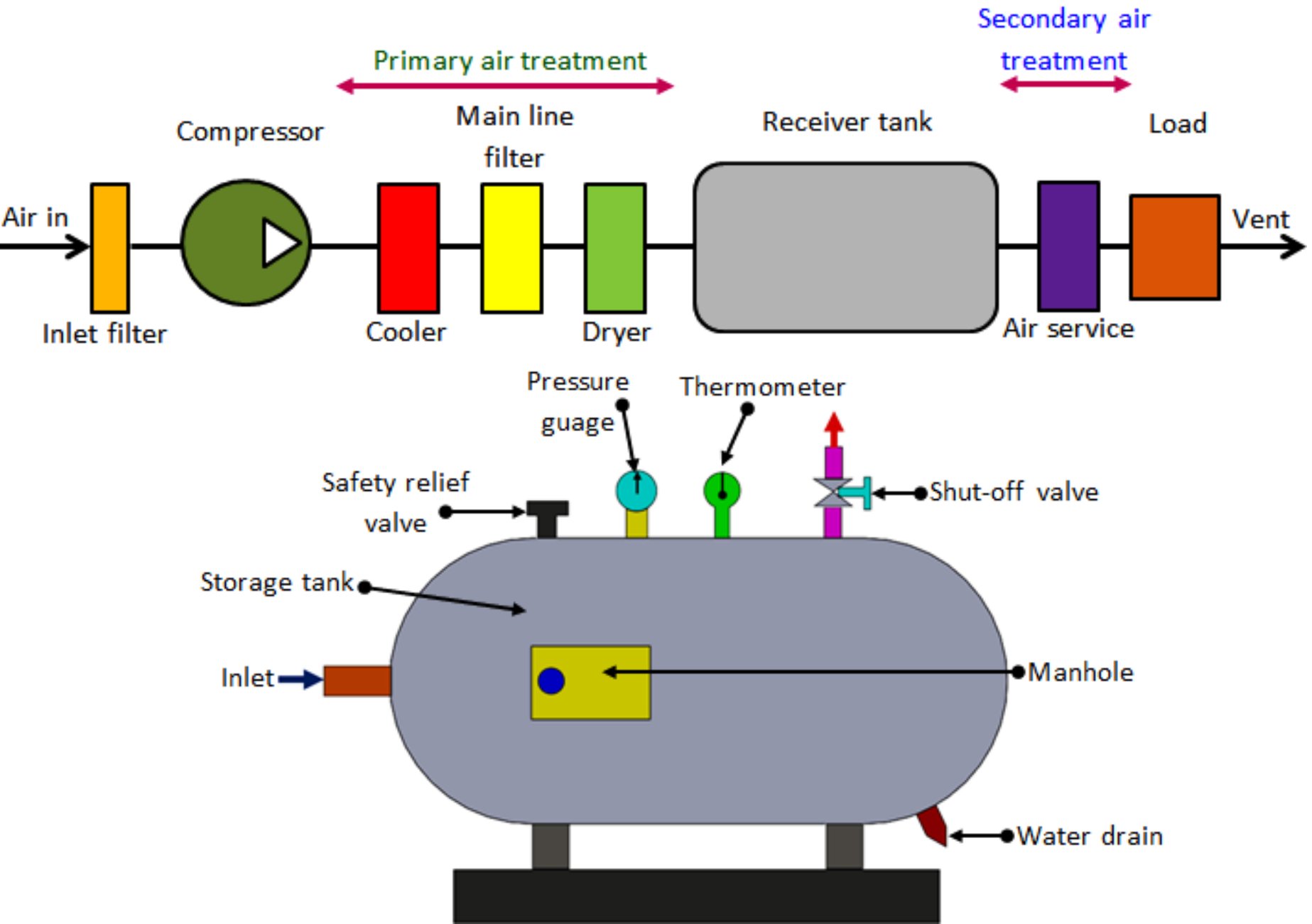
Pneumatic system

- Open, fluid is free
- Rise in pressure :
longer duration ->
storage
- Rise in temperature
- Fins, coolers
- Cooling -> liquid
droplets -> jamming
of valves



(a) Components

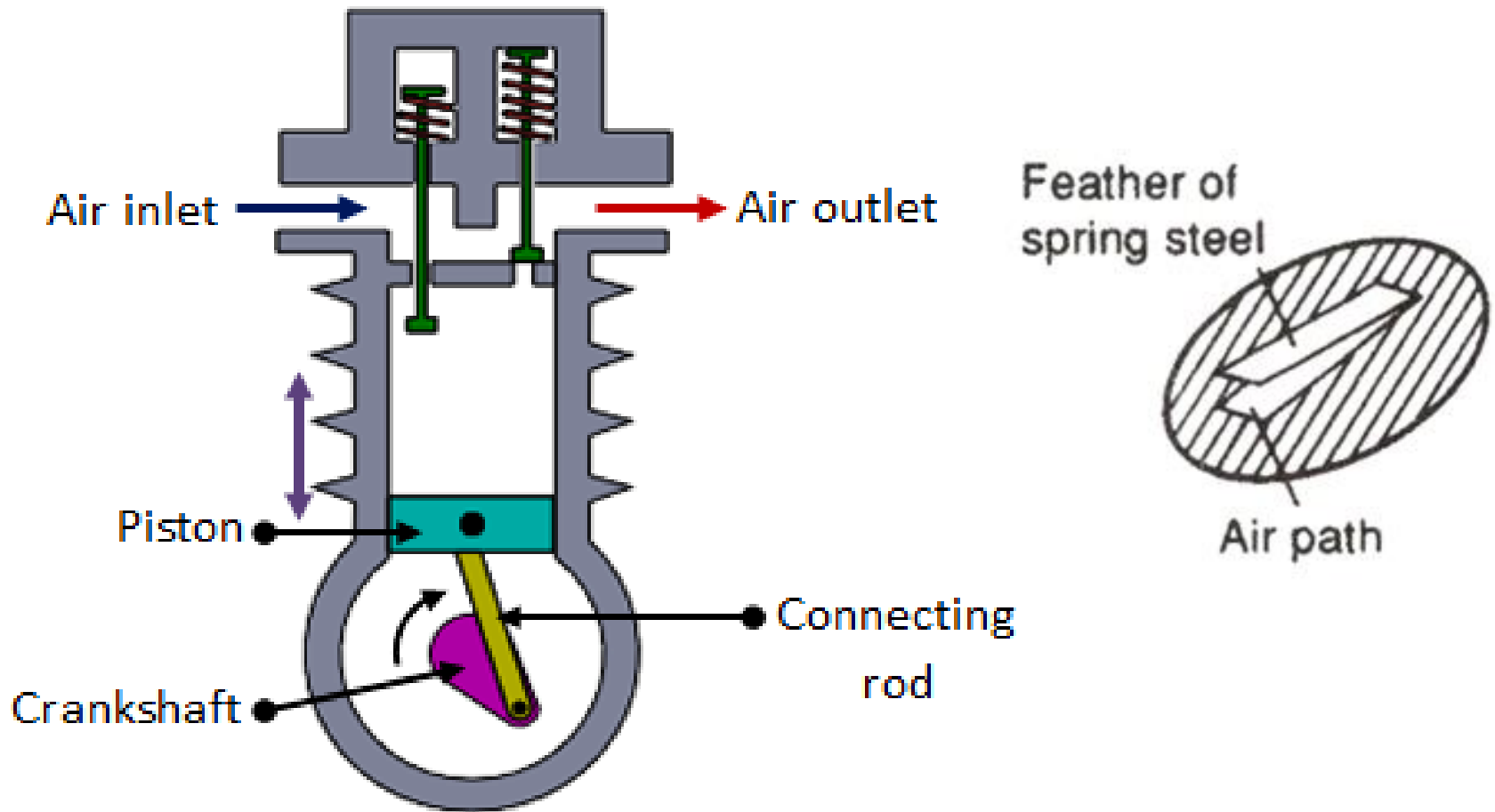
Pneumatic system



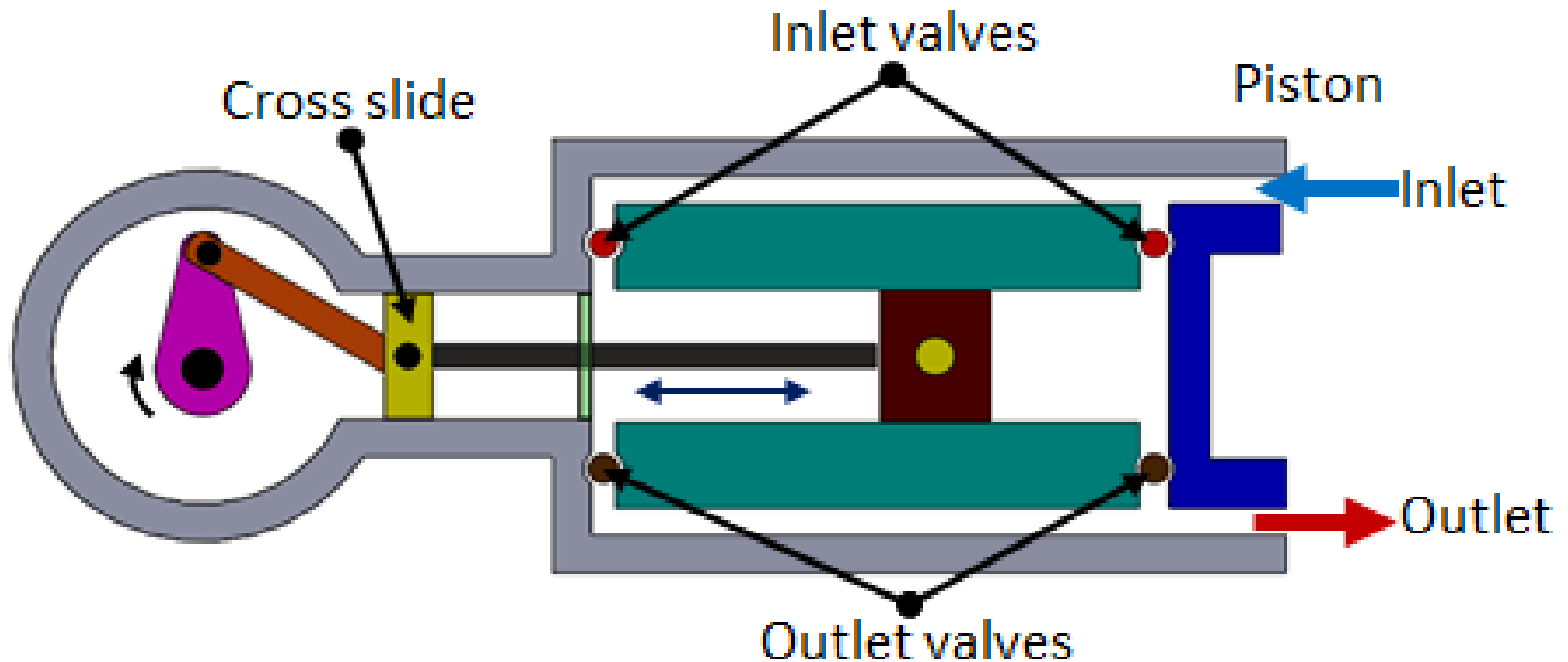
Compressors

- Positive displacement devices
- Dynamic devices : centrifugal or axial blowers
- Pressure at compressor outlet : working pressure
- Pressure at the device operating point: operating pressure

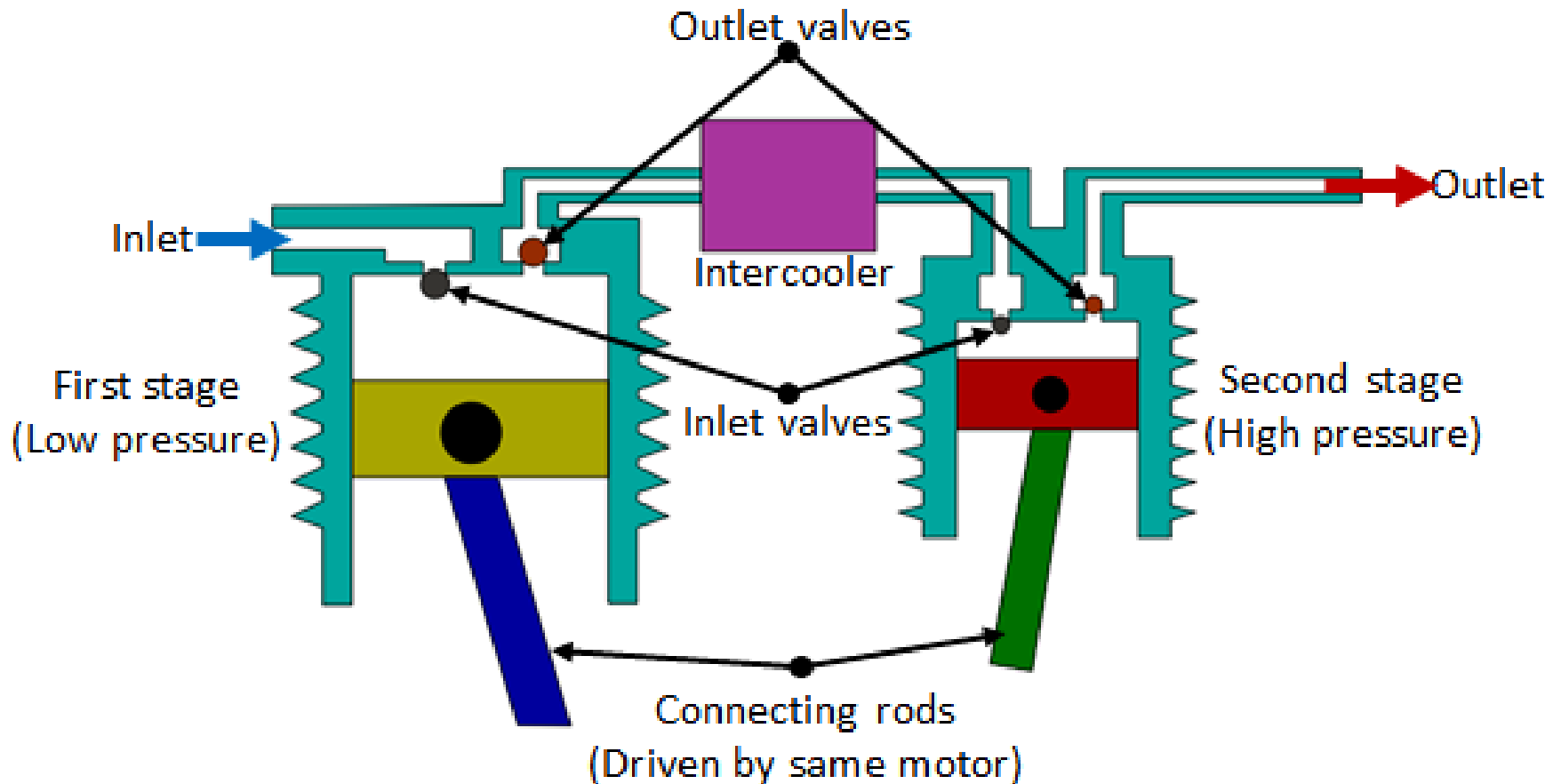
Single cylinder compressor



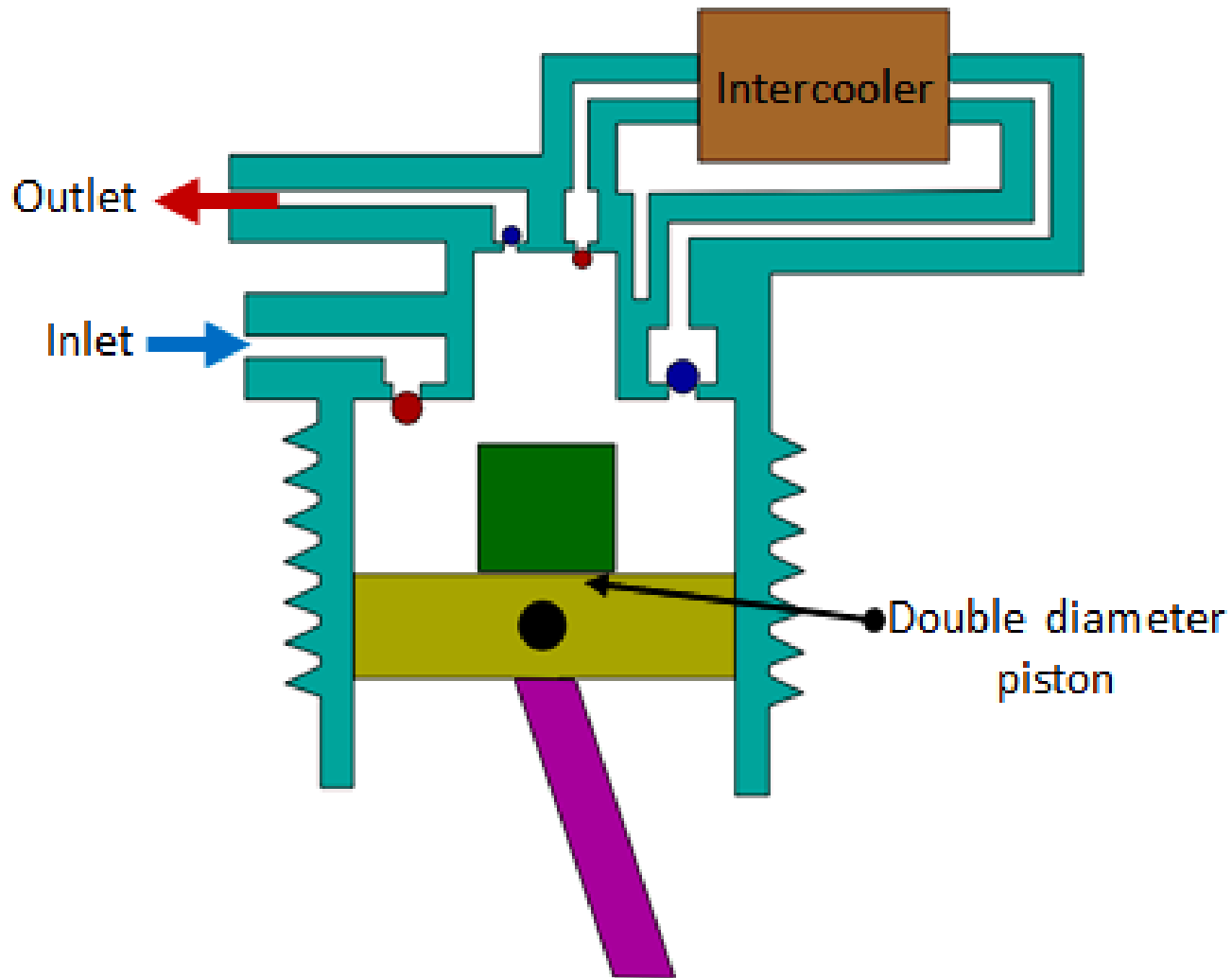
Double acting compressor



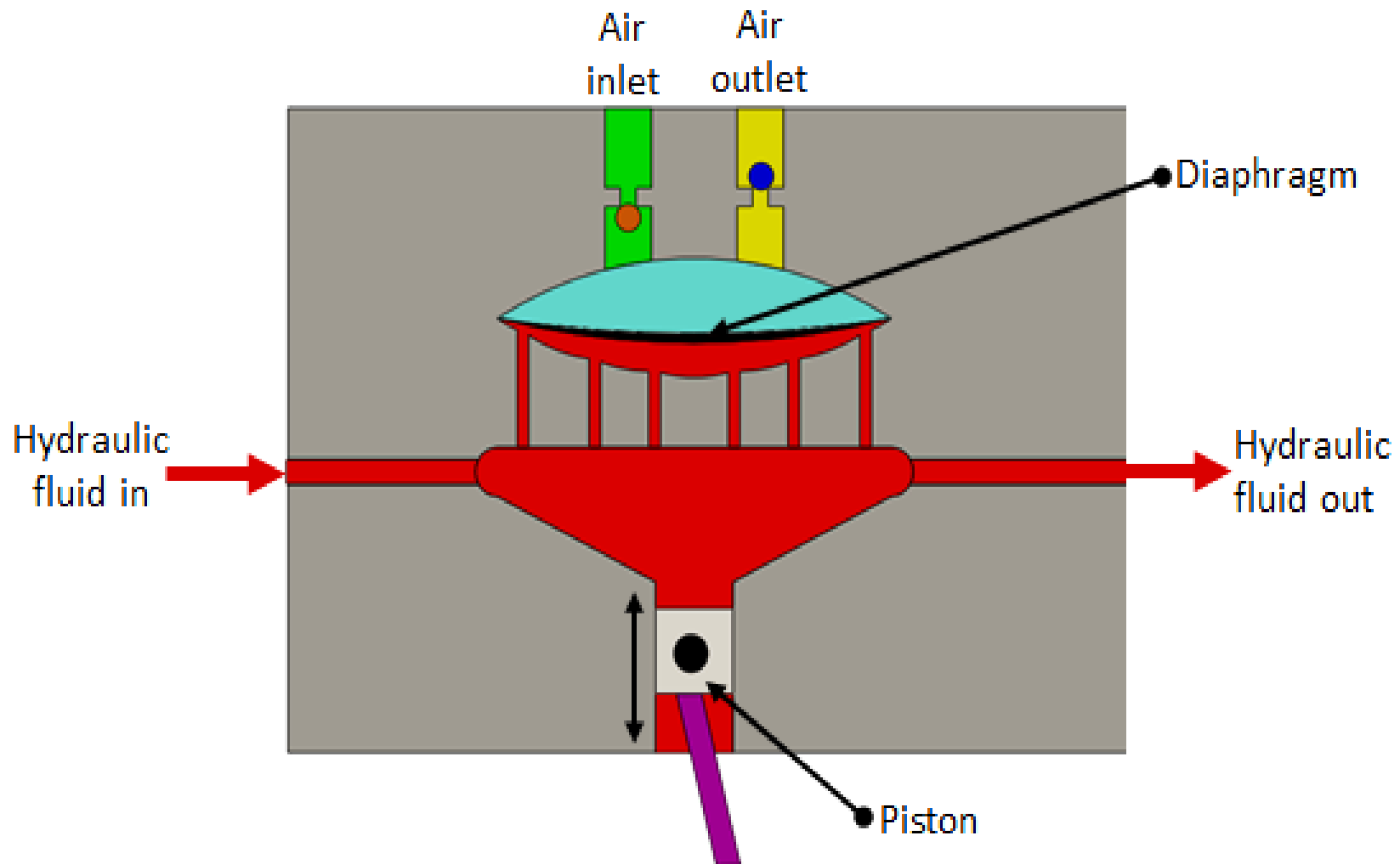
Multi-stage compressors



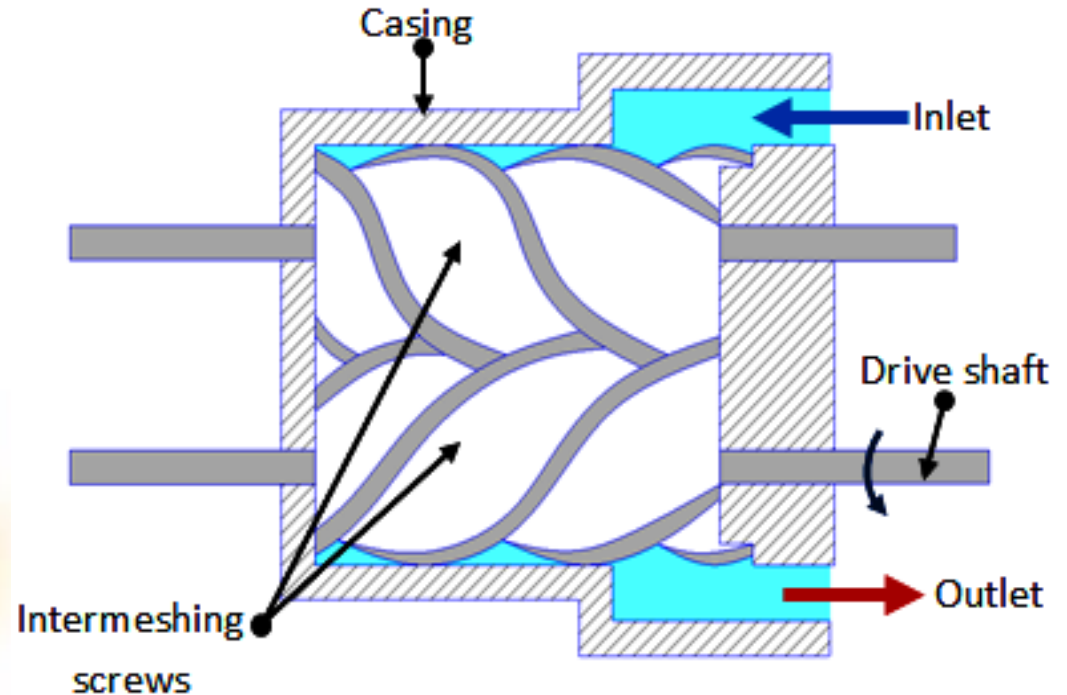
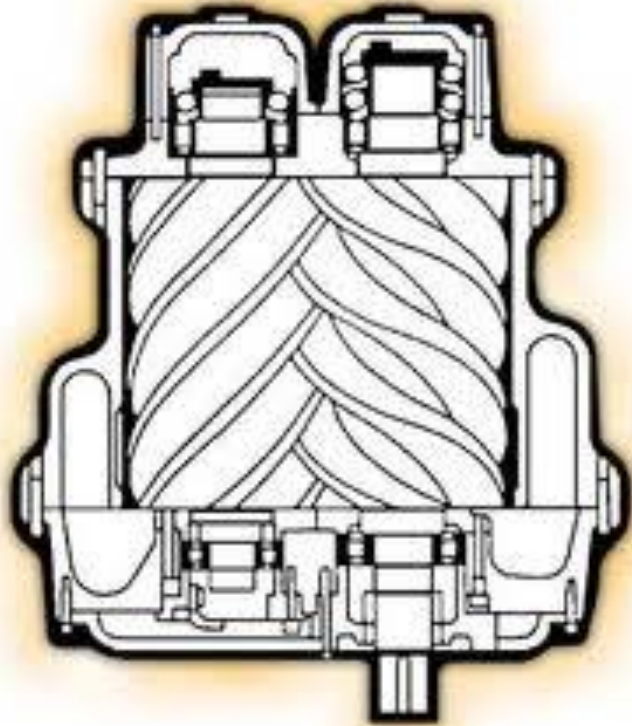
Combined two-stage compressor



Flexible diaphragm

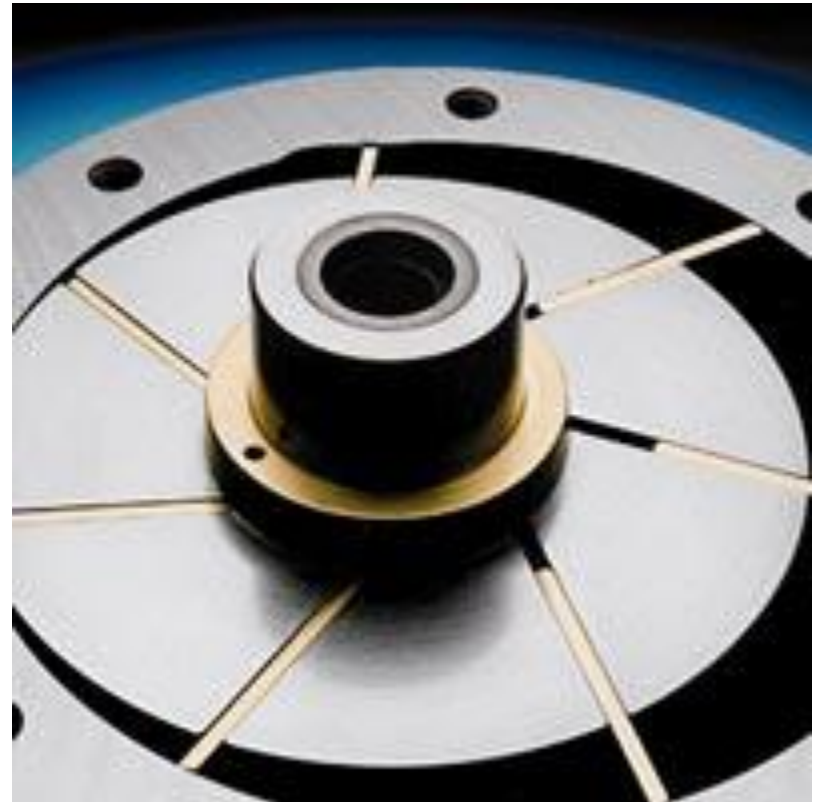
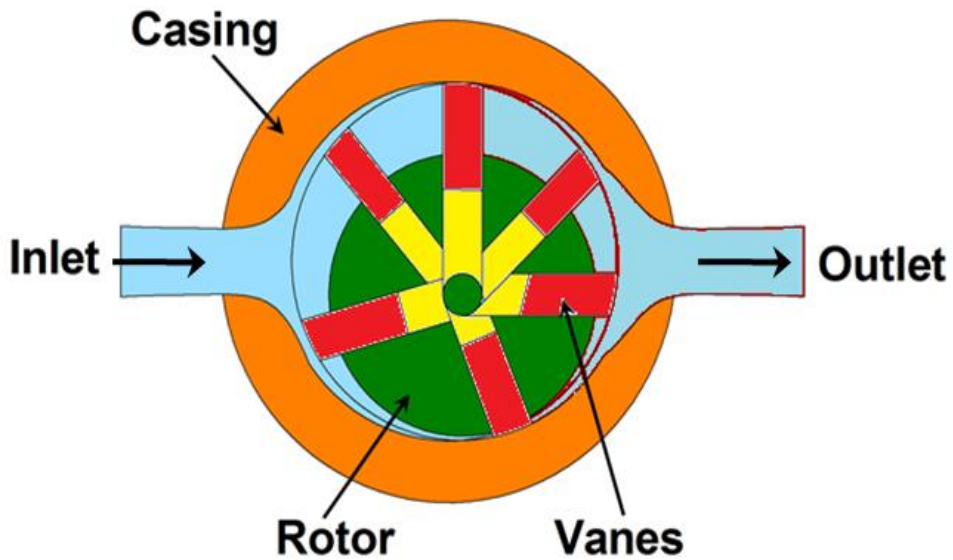


Screw compressor (Medium level applications up to 10 bar)

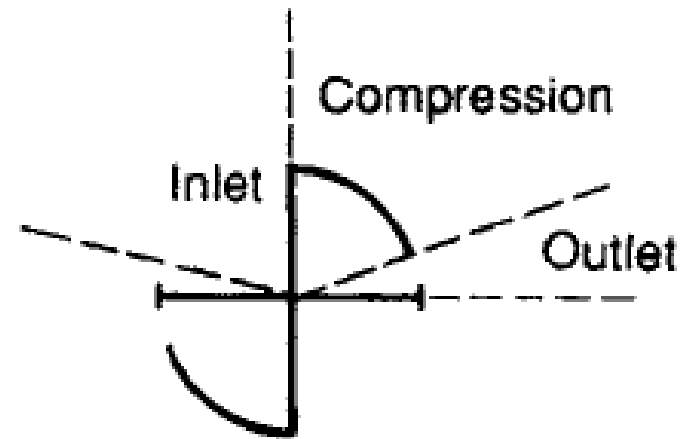
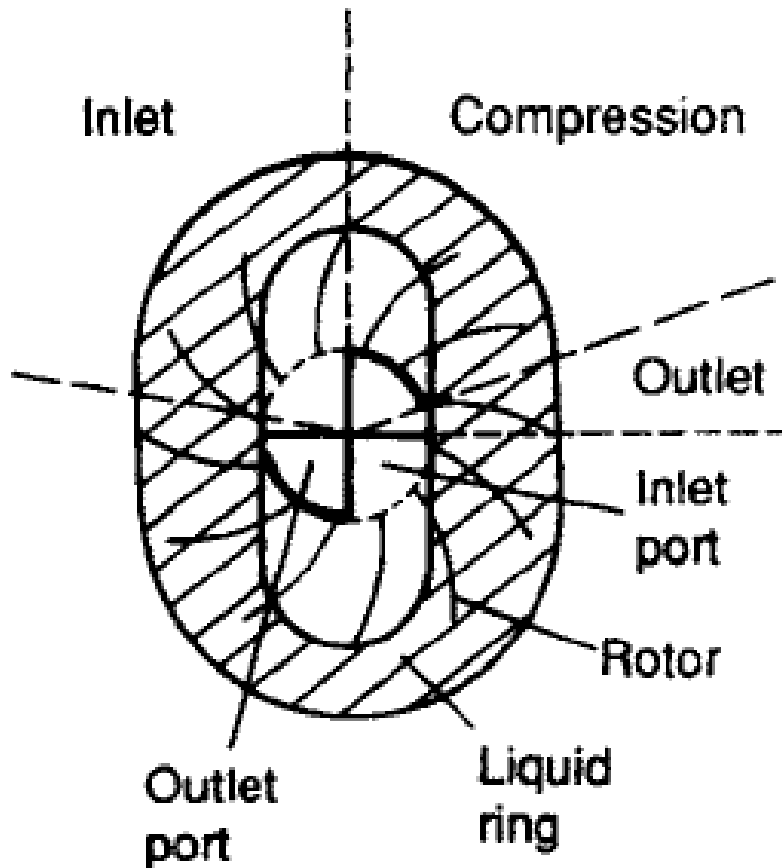


- Simple, fewer moving parts
- Rotating at constant speed
- Steady delivery of air

Rotary compressors (3 bar apprx)



Liquid ring compressor



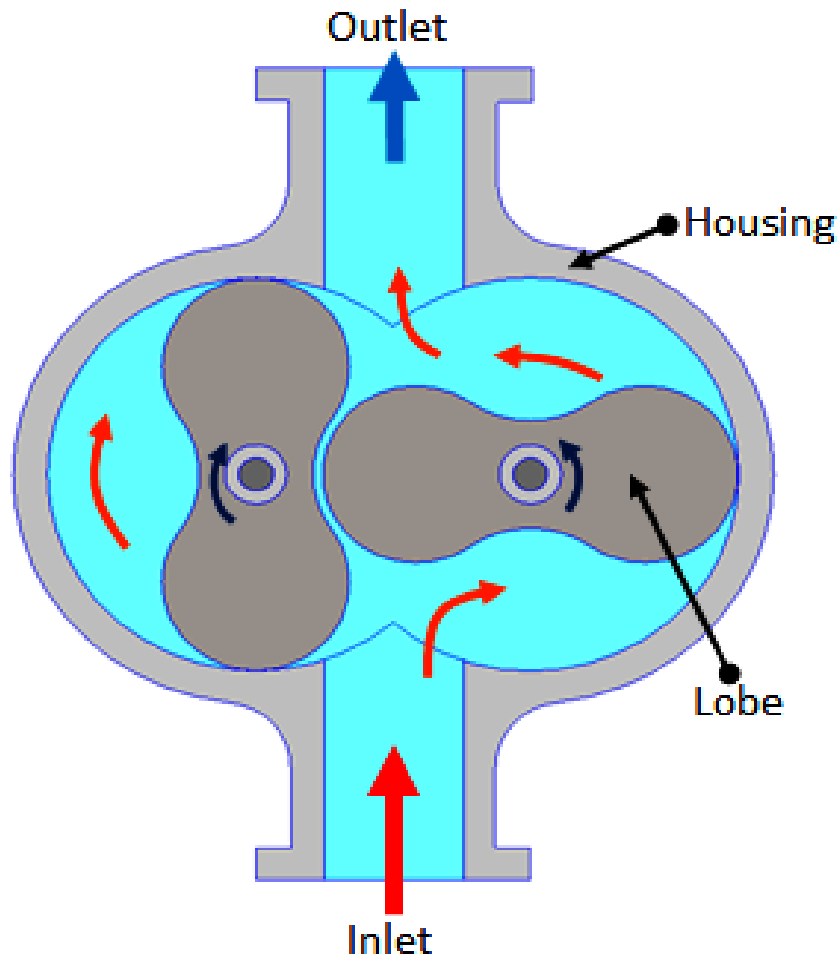
Port positions mirrored at 180°

Rotation speed : 3000 rpm

Pressure low : about 5 bar

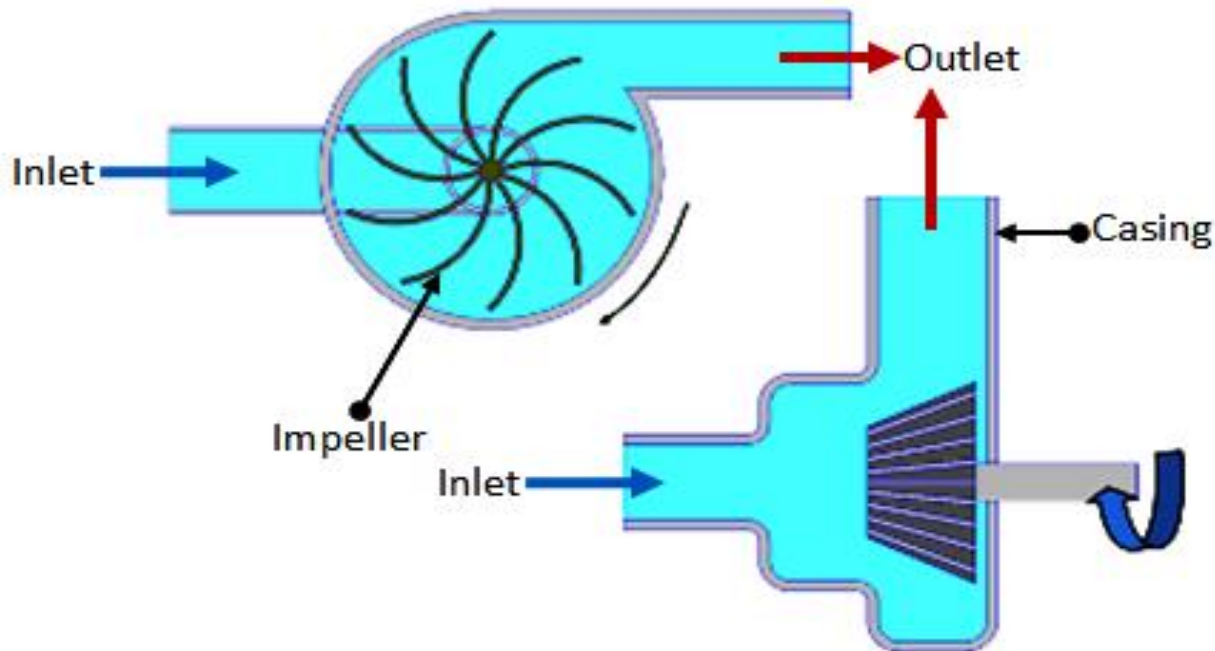
- [One more demo](#)

Lobe compressor



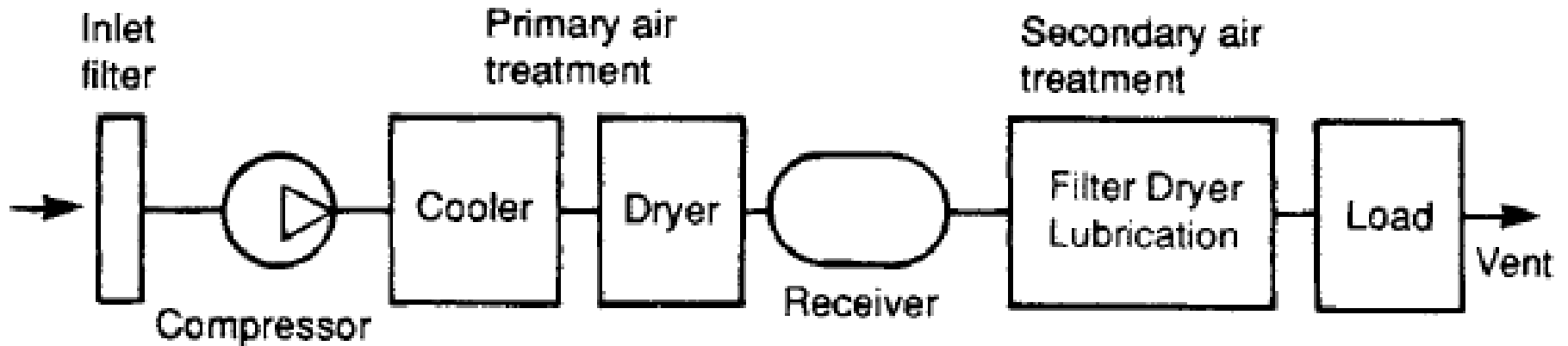
- high delivery volume but low pressure (typically 1-2 bar)

Non-positive displacement compressors



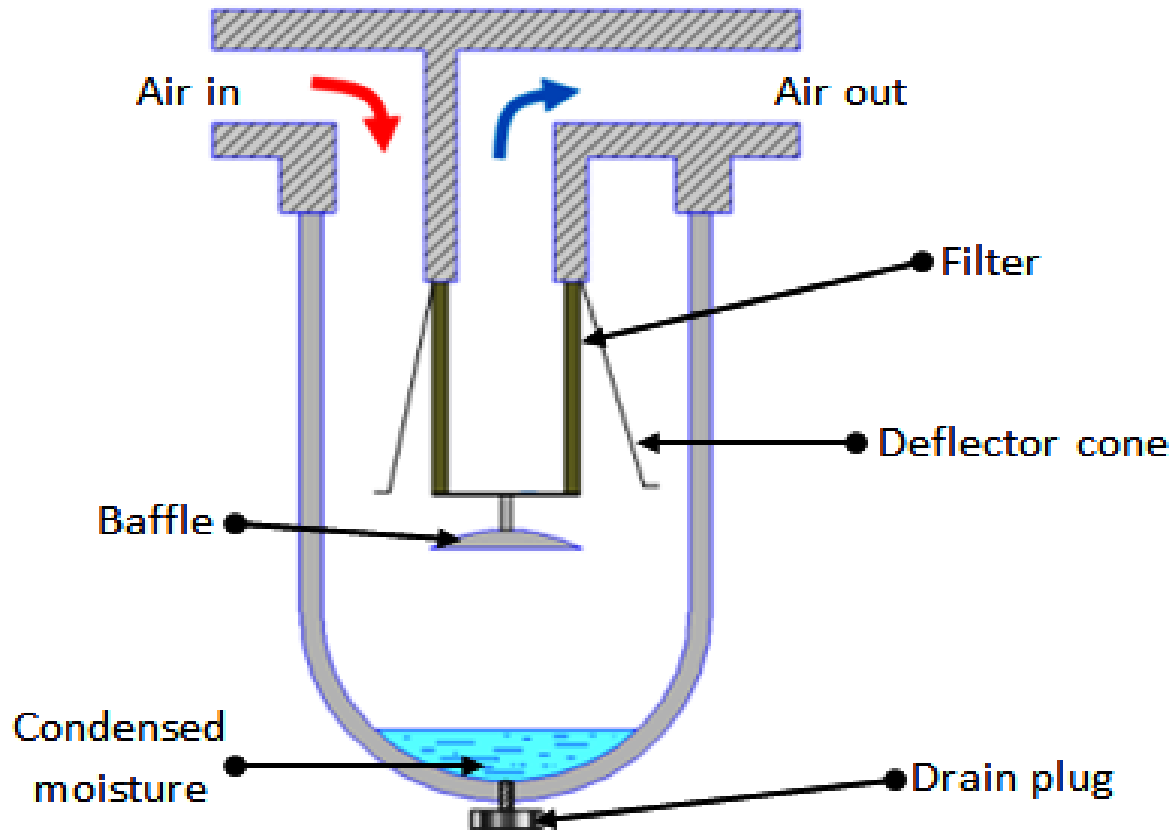
- Large volume of air : pneumatic conveying of powder
- Ventilation, combustion and process air

Stages of air treatment



- Filters : dirt and smoke
 - Dry filters
 - Wet filters
- Micro filters
- Macro filters (strainers)
- Dust particles 100 μm
- Smoke : 1 μm

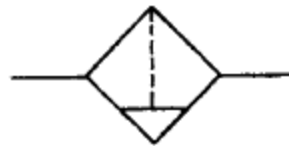
Air dryer + filter



- Sudden change in direction of flow over the deflector cone

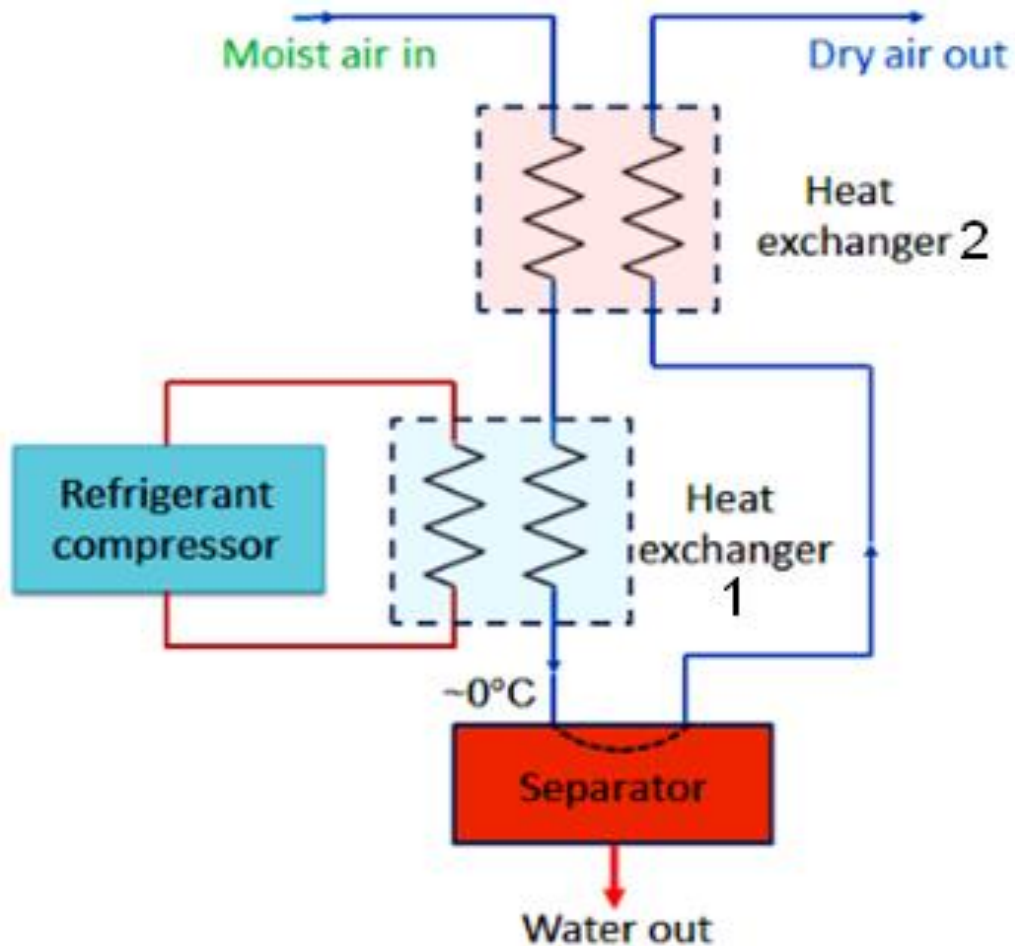


(b) Swirl introduced by deflector cone



(c) Symbol

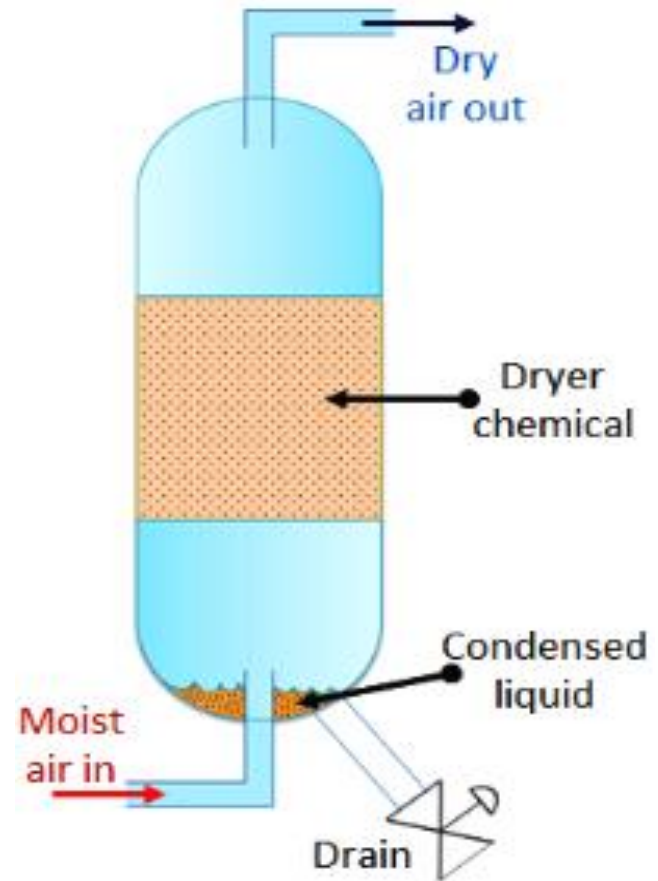
Refrigerated dryers



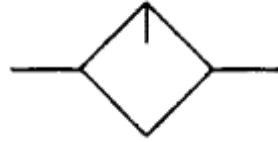
- Works just above 0°C
- Pre-chilling heat exchanger

Chemical dryers

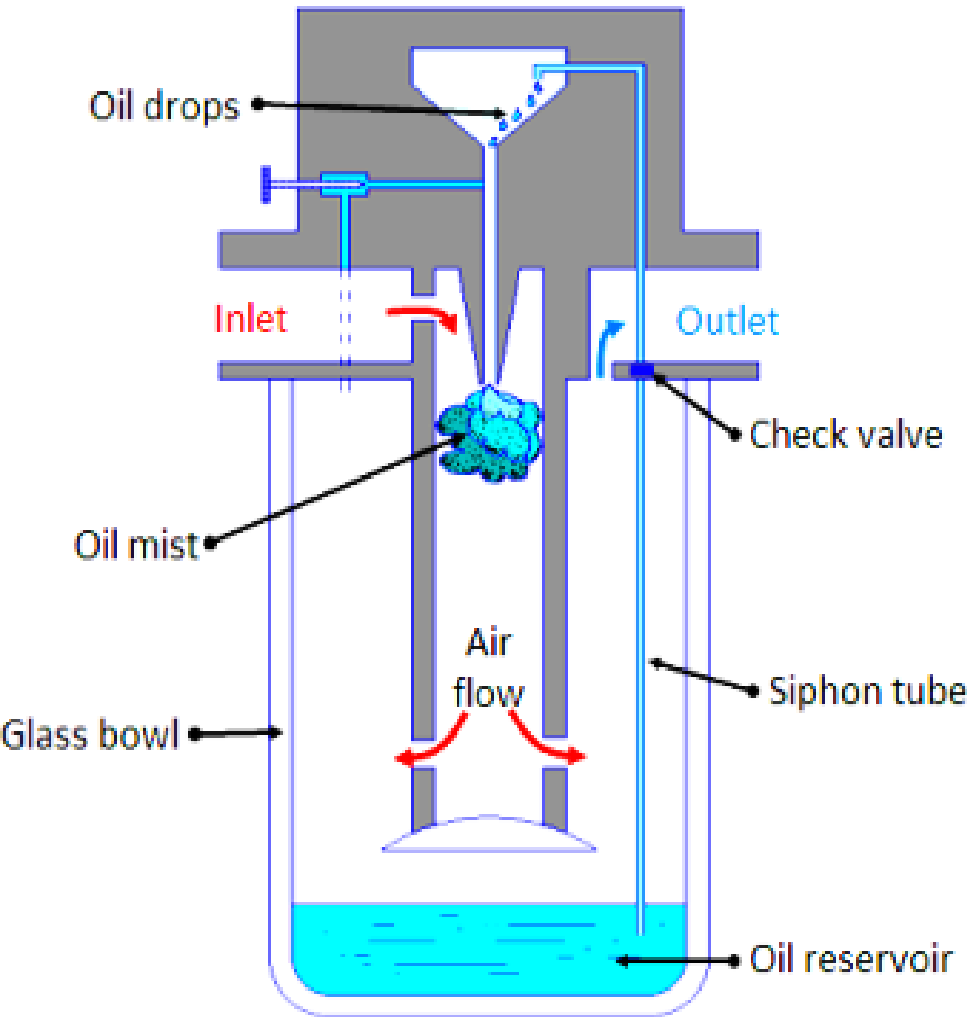
- Absolute dry air
- Desiccant dryer
- Hygroscopic substances
- silica gel, activated charcoal, calcium sulfate, calcium chloride



- Absorption dryer

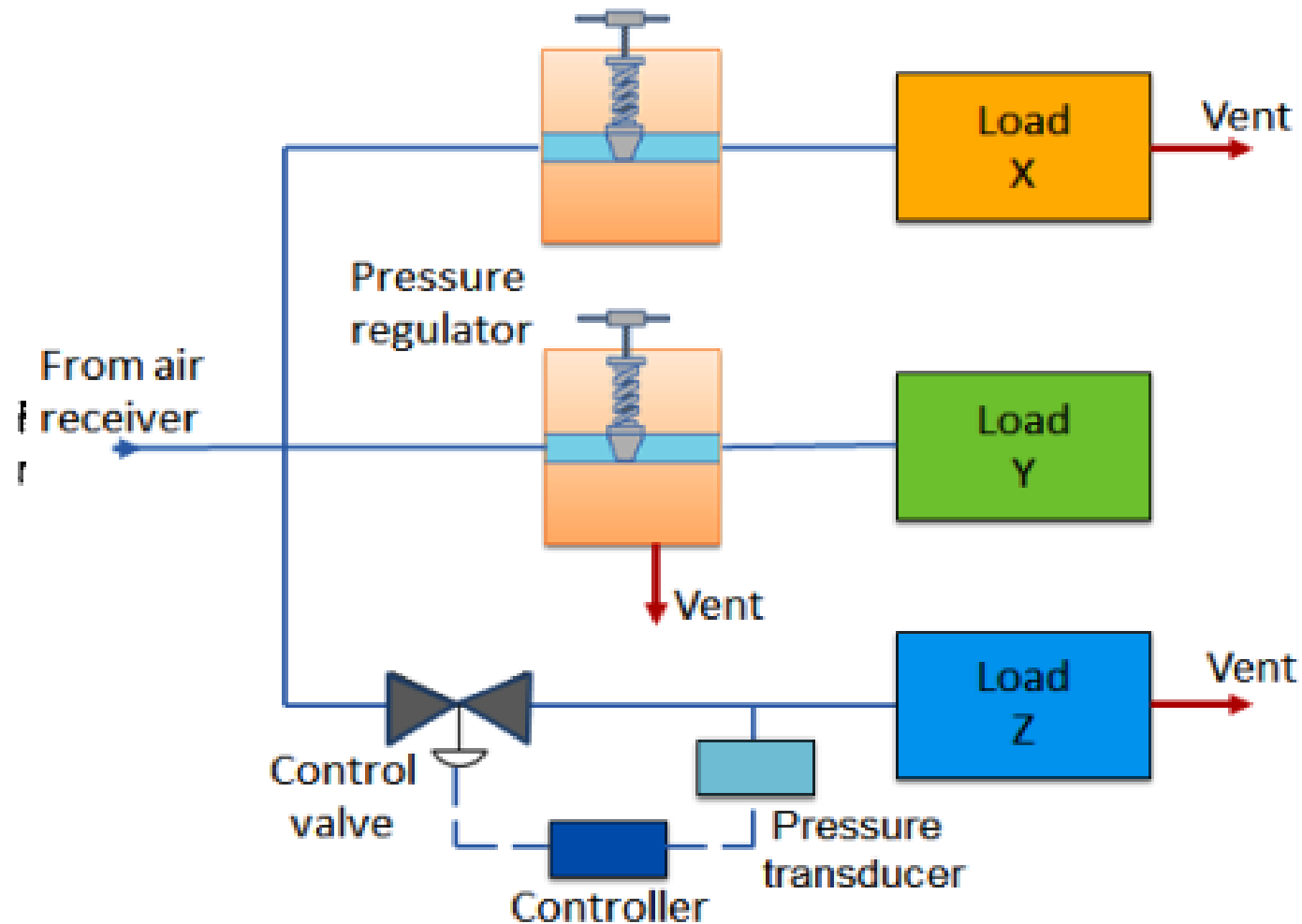


Lubricators

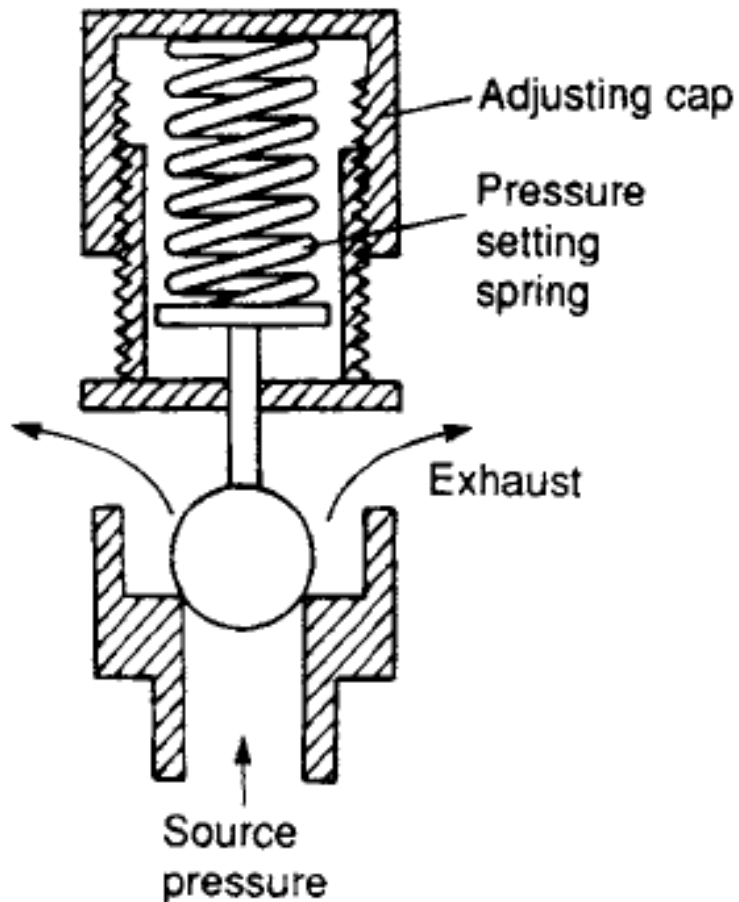


- To add 'fine mist of oil' in to clean and dry air
- Venturi ring
- Swirling to remove larger droplets

Pressure regulation

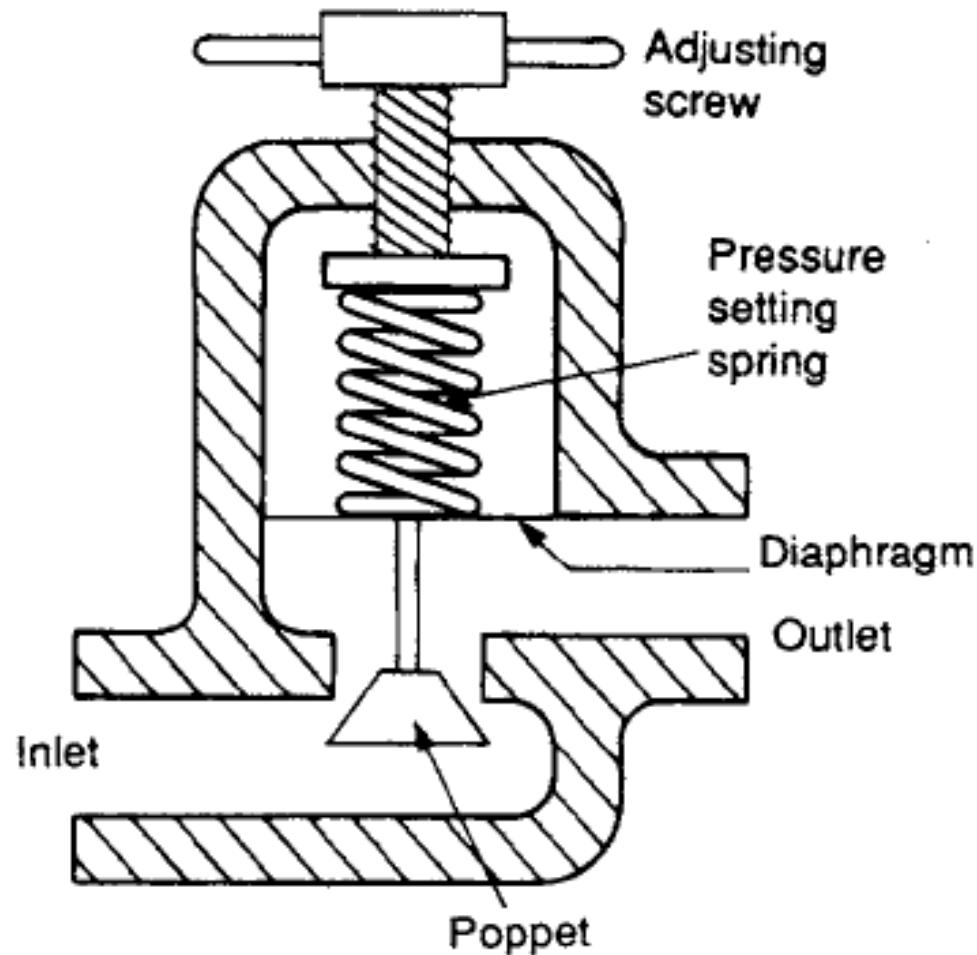


Relief valves

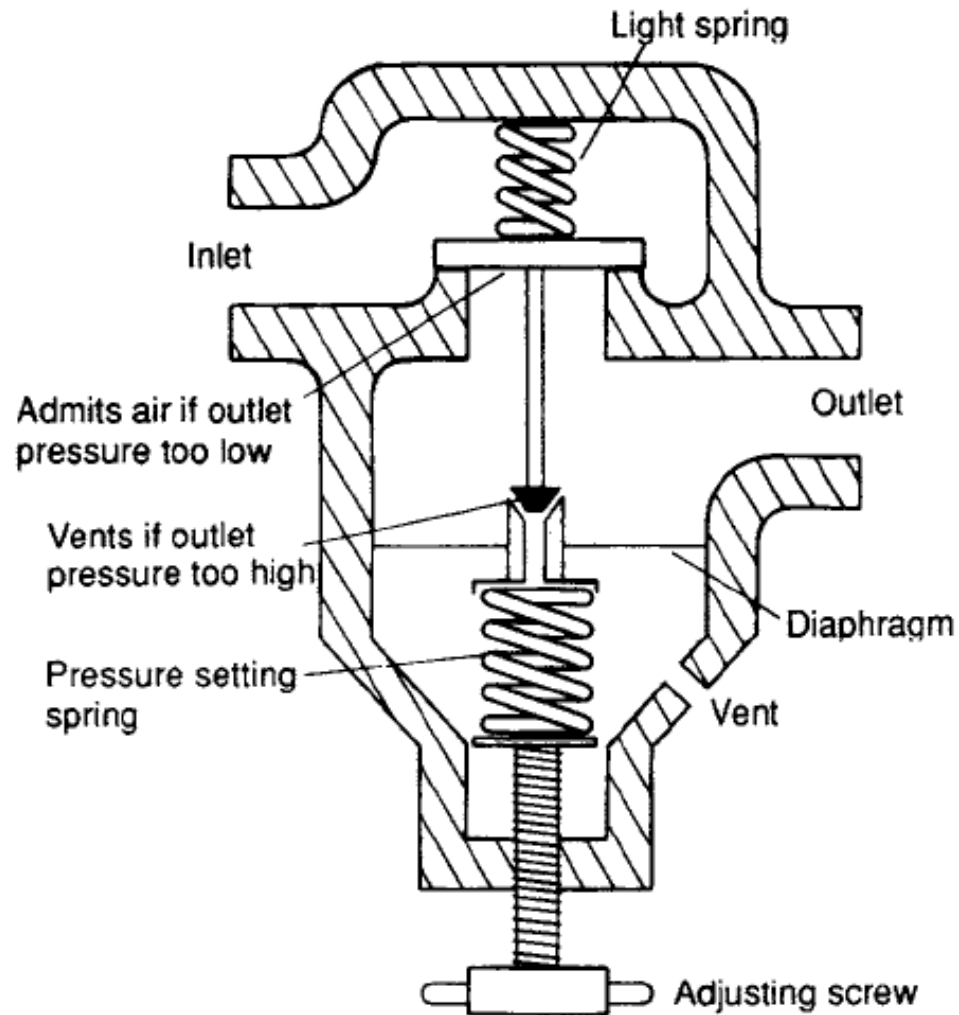


- Back-up device
- Fitted on air-receivers
- Specifications
 - Operating pressure range
 - Span of pressure between cracking and full flow
 - Full flow rate

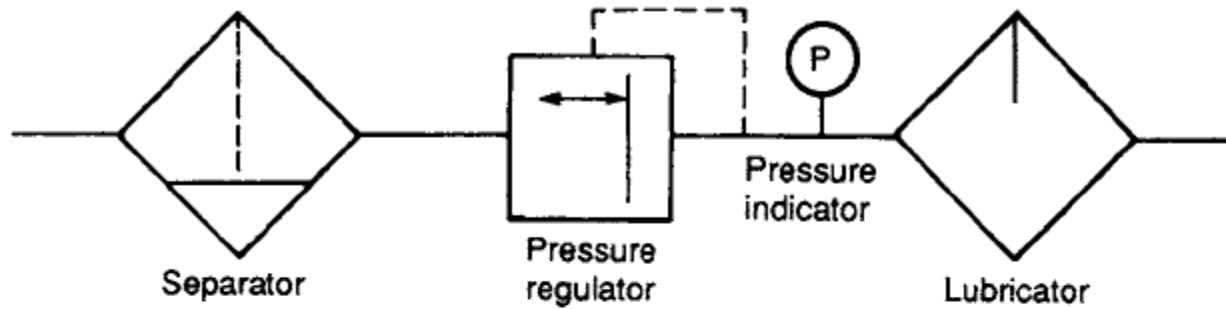
Non-relieving pressure regulators



Relieving pressure regulator



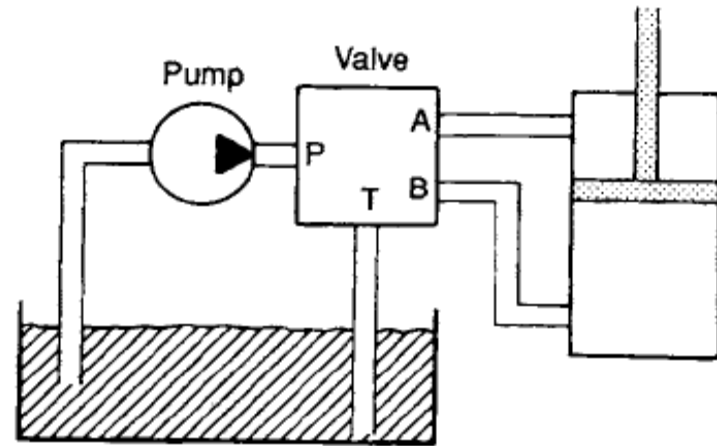
Service units



(a) Symbols for individual components

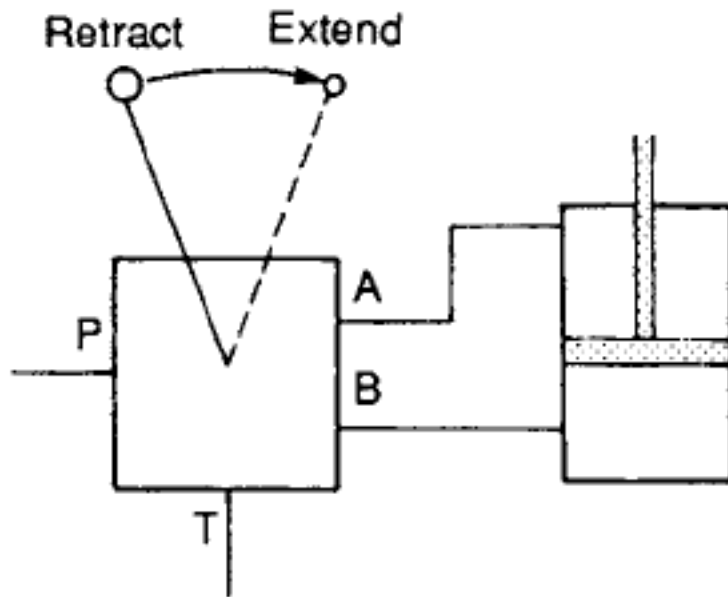
Control valves

- Need for both hydraulics and pneumatics systems
- Infinite position control valves
- Finite position valves : block or allow the fluid



(a) Hydraulic system

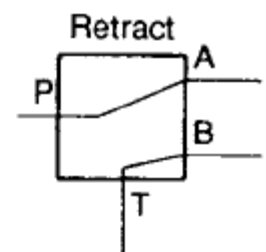
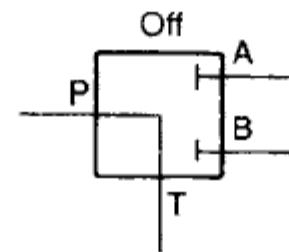
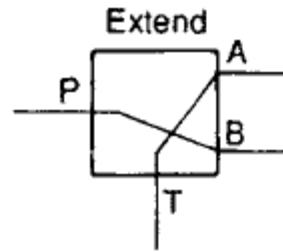
Valve control positions



(a) Two position valve

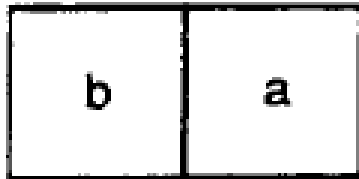
Valve control positions

- Finite position valves :
port / position valve
- 4/3 valve
- 4/2 valve
- 2/2 : simple
block/allow valve

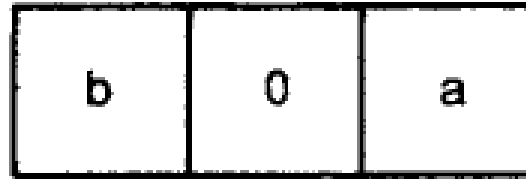


Graphic symbols

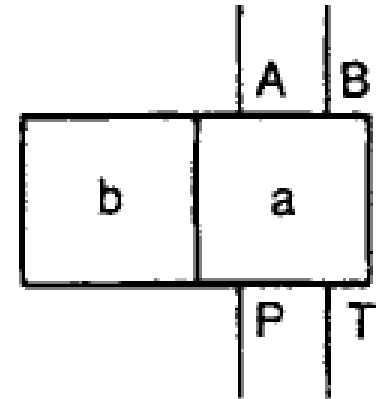
- DIN24300, BS2917, ISO1219



(a) Two position valve



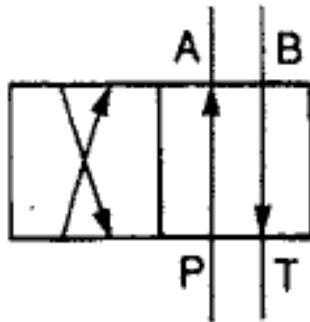
(b) Three position valve



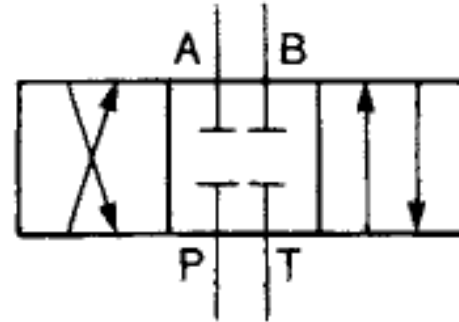
(c) 4/2 valve

Port	Designation
Working lines	A, B, C and so on
Pressure (power) supply	P
Exhaust/Return	R, S, T and so on (T normally used for hydraulic systems, R and S for pneumatic systems)

Valve symbols

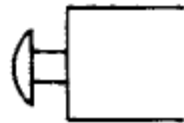


(a) 4/2 valve

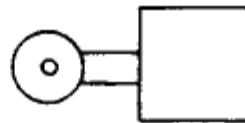


(b) 4/3 valve centre off
(load isolated)

Actuation symbols



Push button



Roller limit SW



Spring



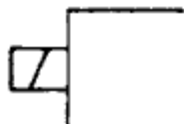
Pressure line (pilot)



Lever



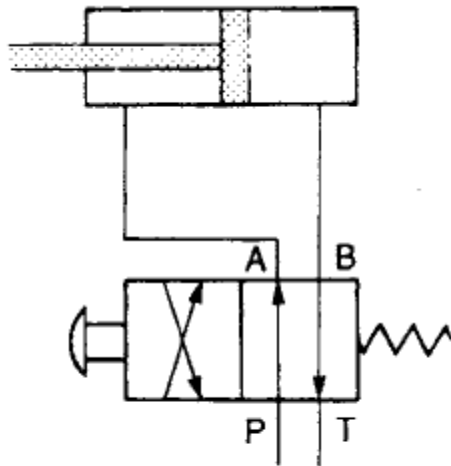
Detent (holds position)



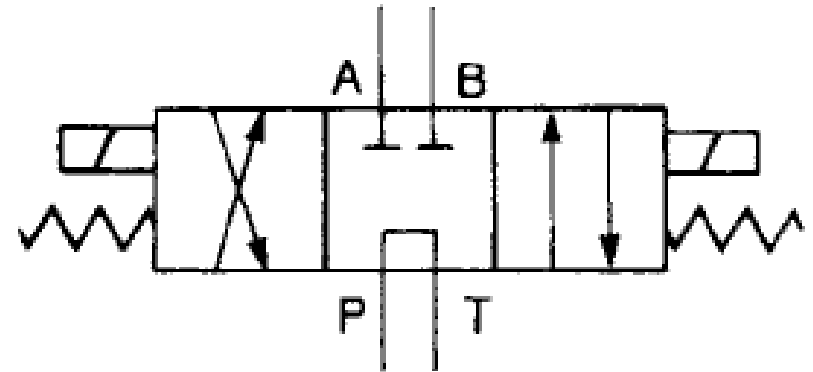
Solenoid

(a) Actuation symbols

Typical valve symbols

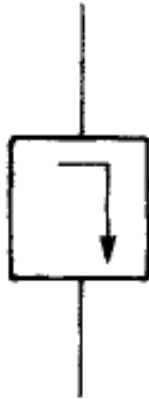


(b) Pushbutton extend, spring retract when pushbutton released

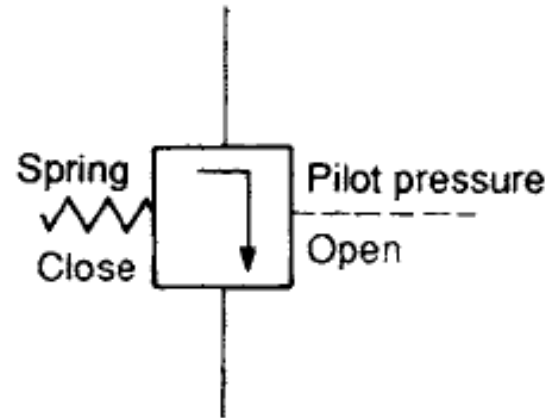


(c) 4/3 valve, solenoid operated, spring return to centre. Pressure line unloads to tank and load locked in centre position

Infinite position valves



(a) Infinite position valve

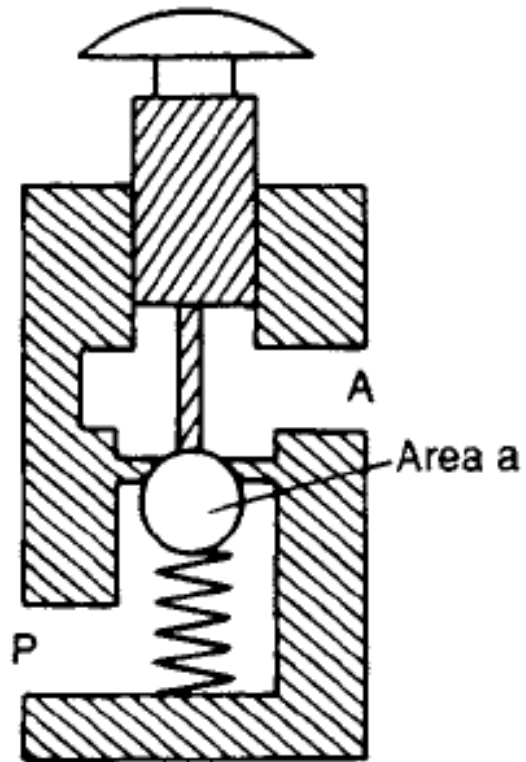


(b) With actuation symbols

Types of control valves

- Poppet valves
- Spool valves
- Rotary valves

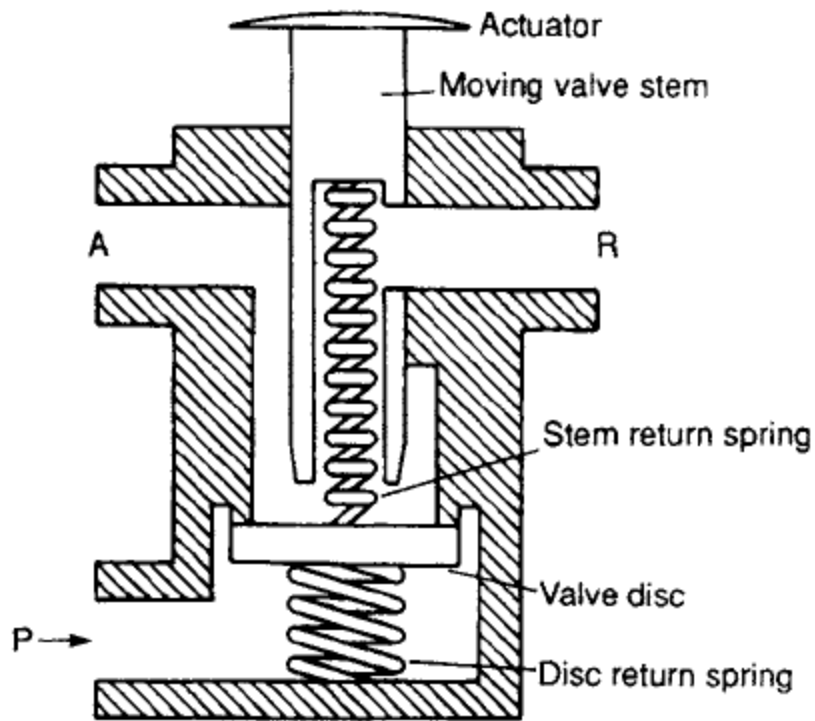
Poppet valve



(a) Construction

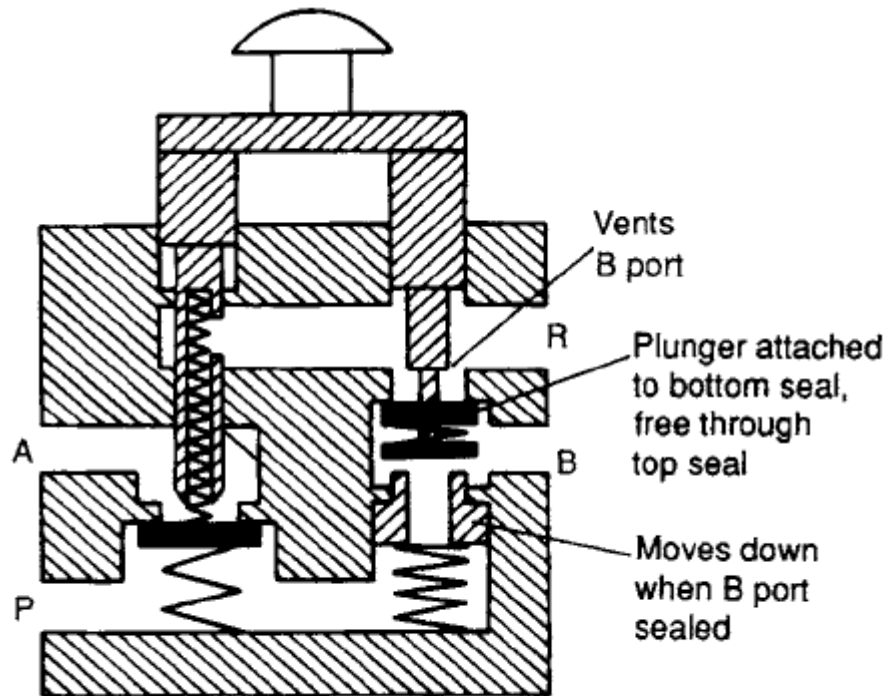
Simple 2/2 poppet valve

3/2 Poppet valve



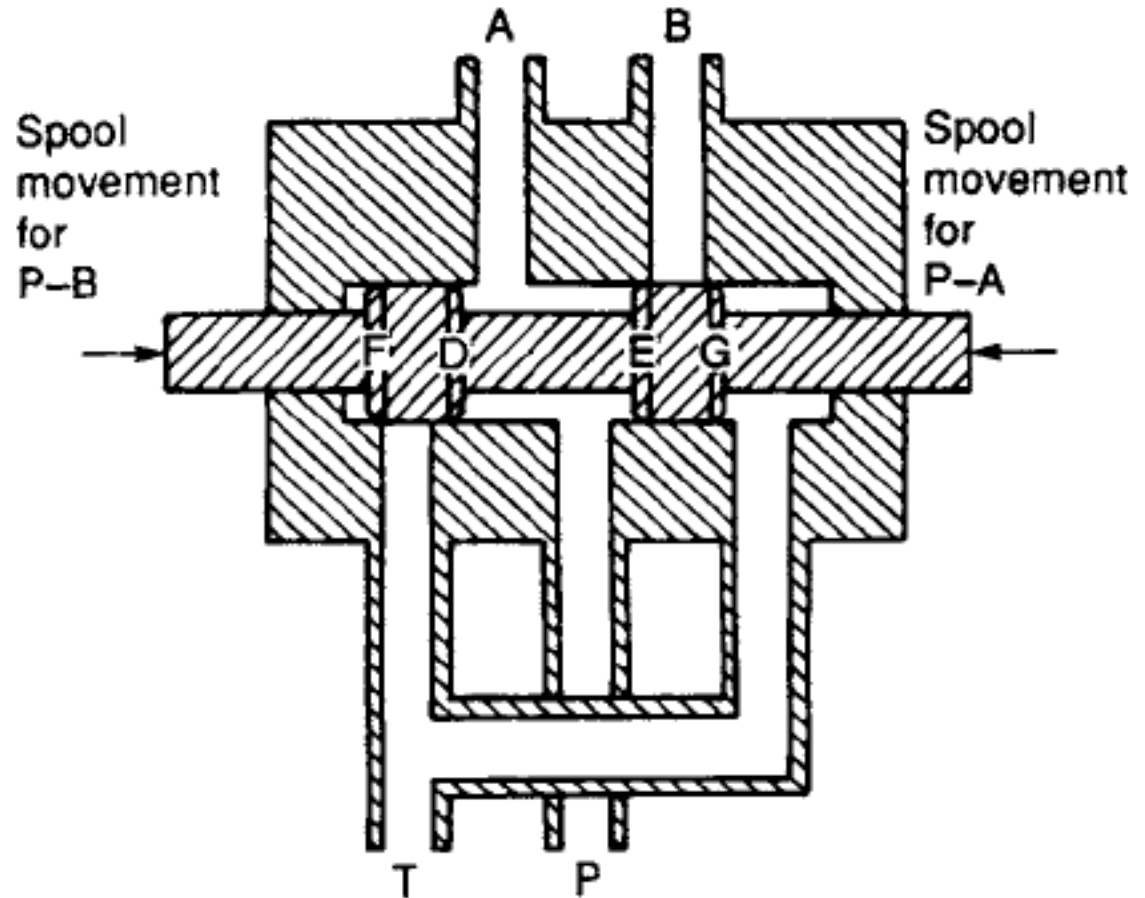
(a) Construction

4/2 Poppet valve



(a) Construction

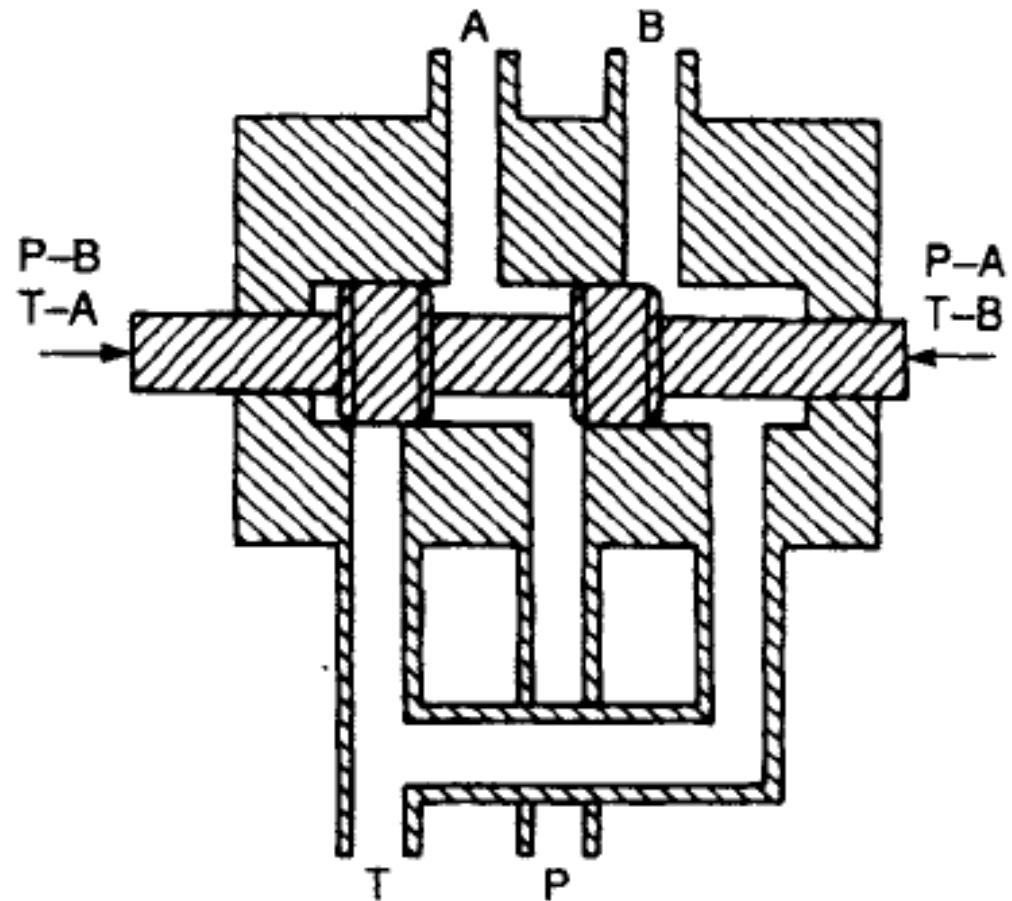
Two way spool valve



(b) Construction

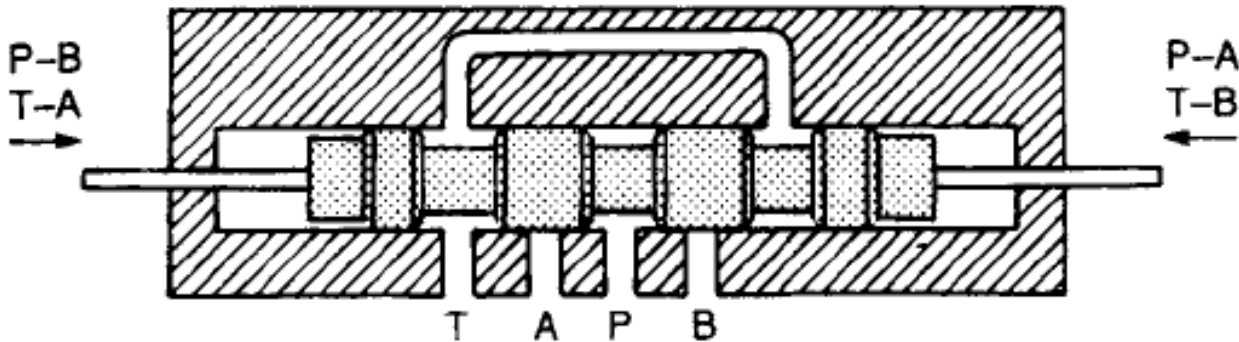
Different operations can be achieved with a common body and different spools

Four way spool valve

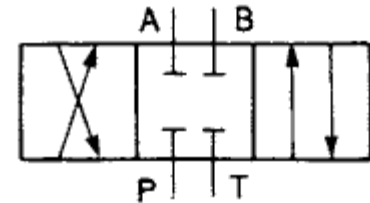


(b) Construction

4/3 spool valve

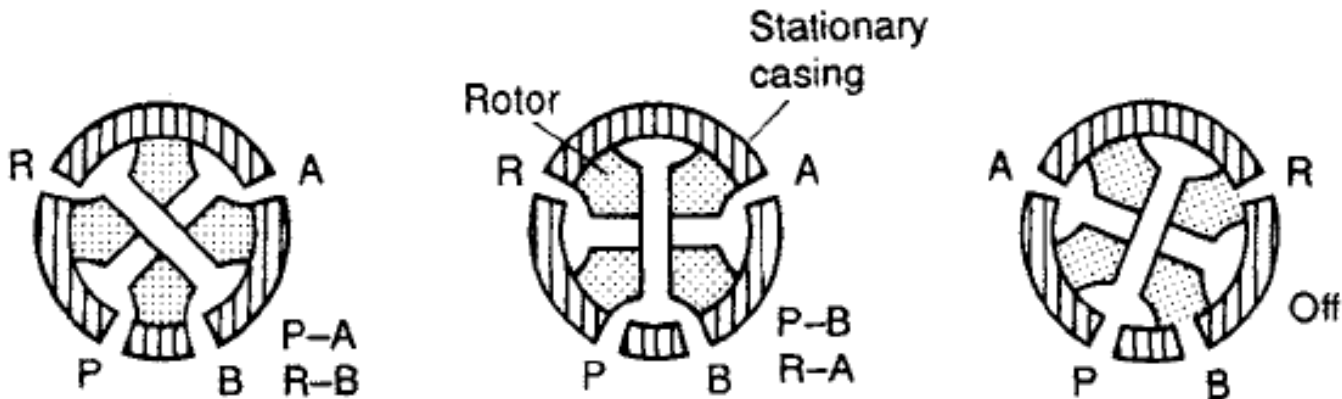


(a) Construction of centre off valve



- Spool valves are operated by shifting the spool. This can be achieved by button, lever or striker, or remotely with a solenoid.
- Self-centring can easily be provided if springs are mounted at the end of the spool shaft.

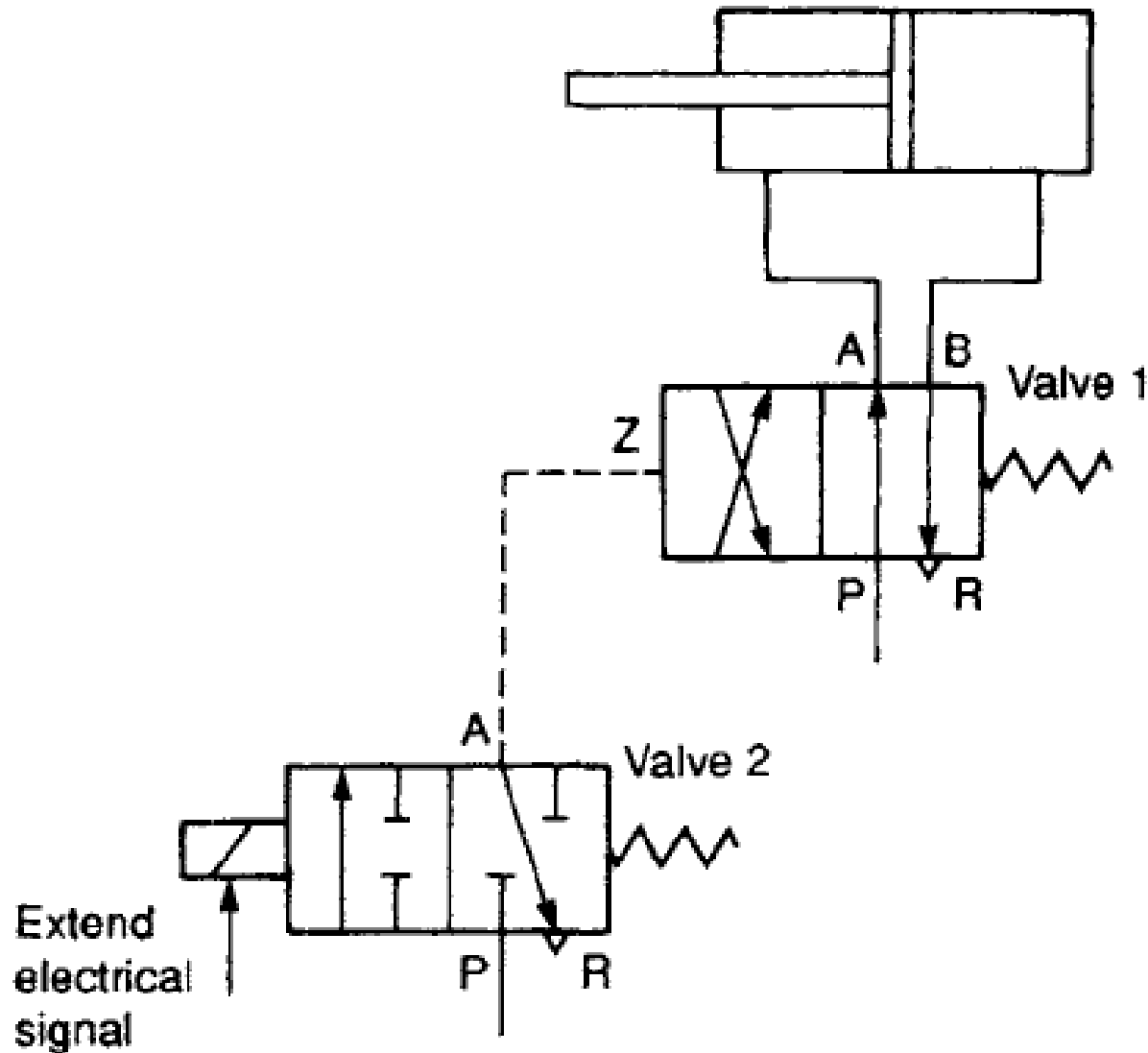
Rotary valves



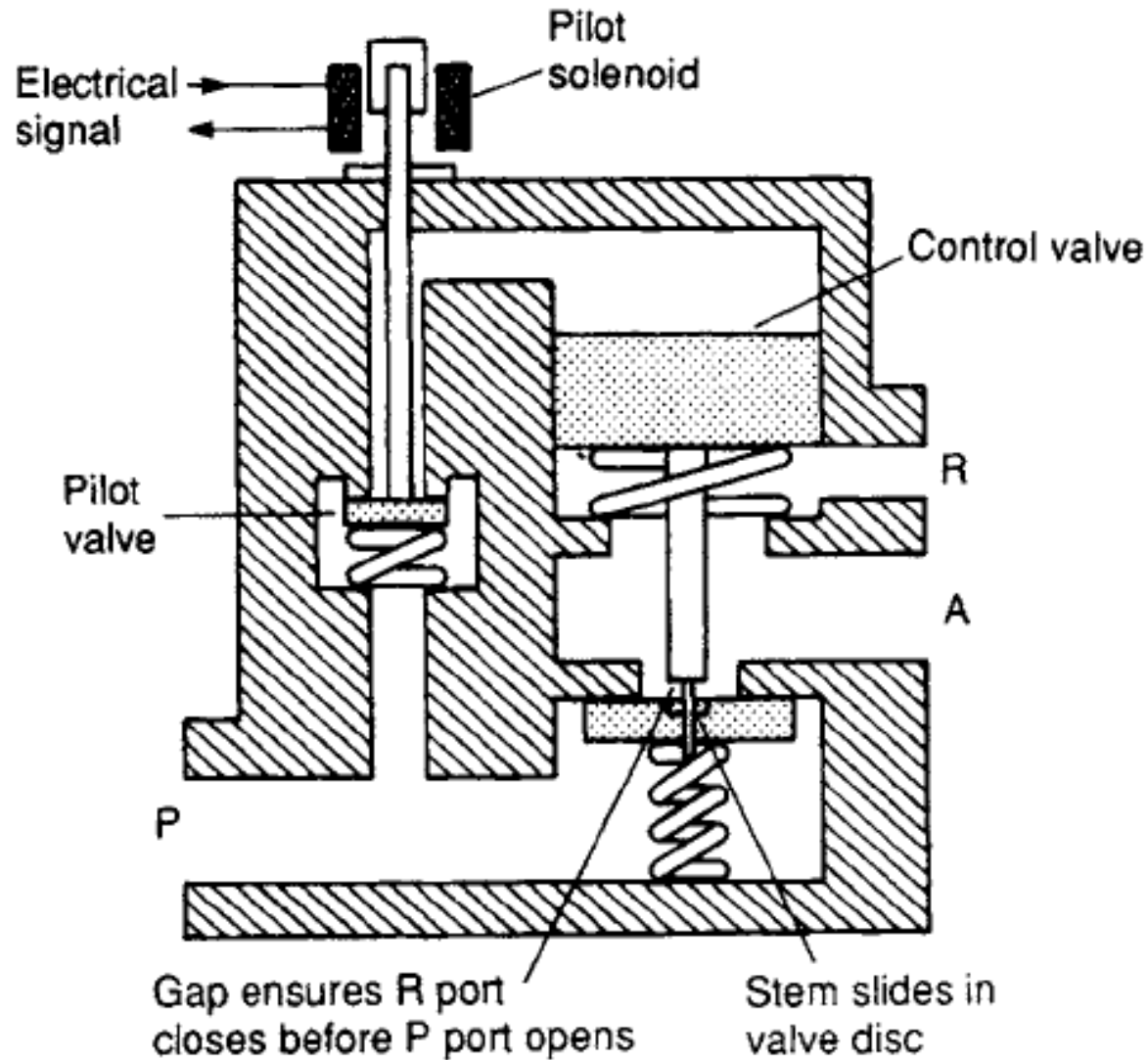
(a) 4/3 way valve

- Rotating spool
- Simple, compact, low operating forces
- Low pressure pneumatic applications

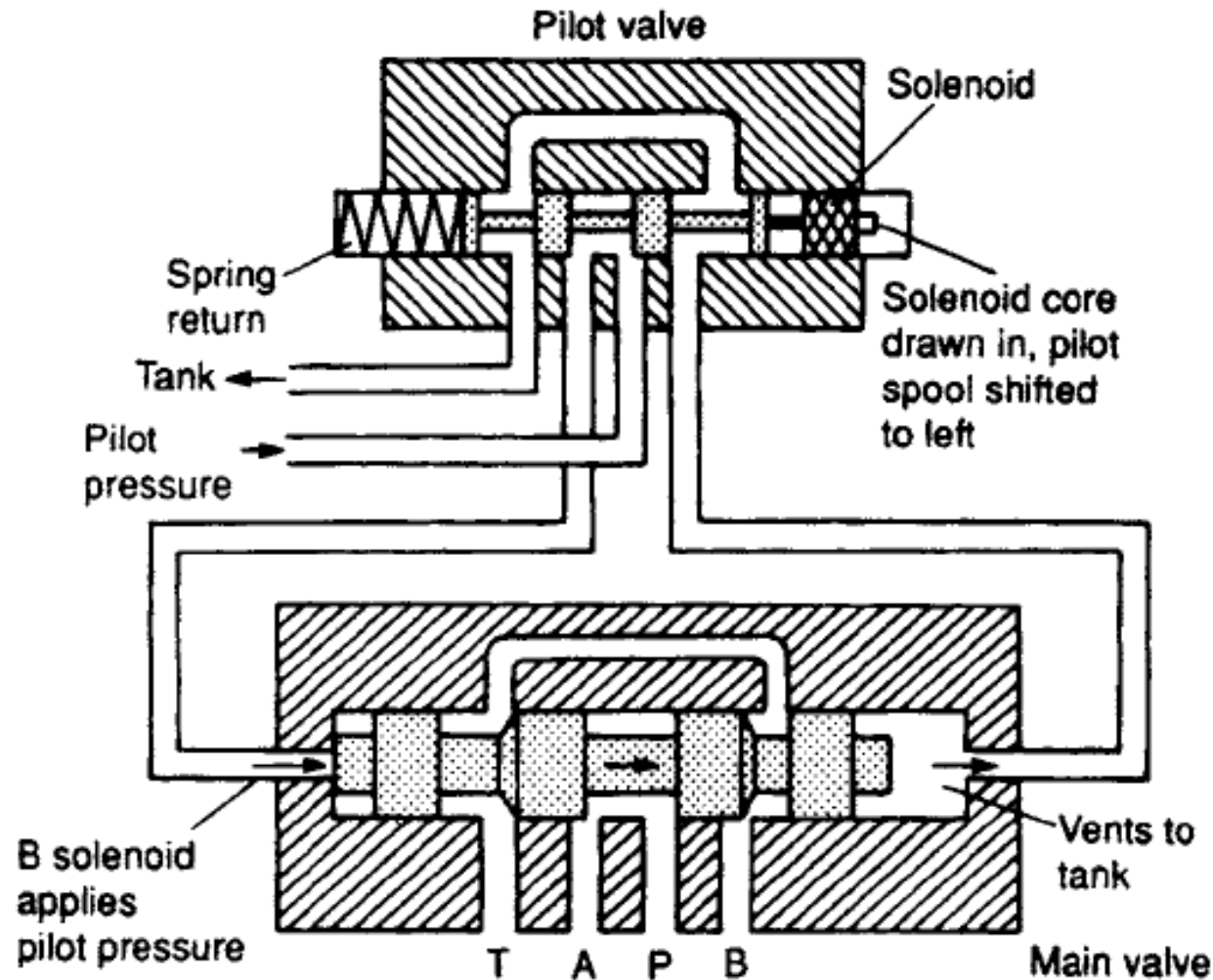
Hydraulic circuit reading comprehension: Actuation of piston-cylinder arrangement with pilot operated valve



Construction of 3/2 valve

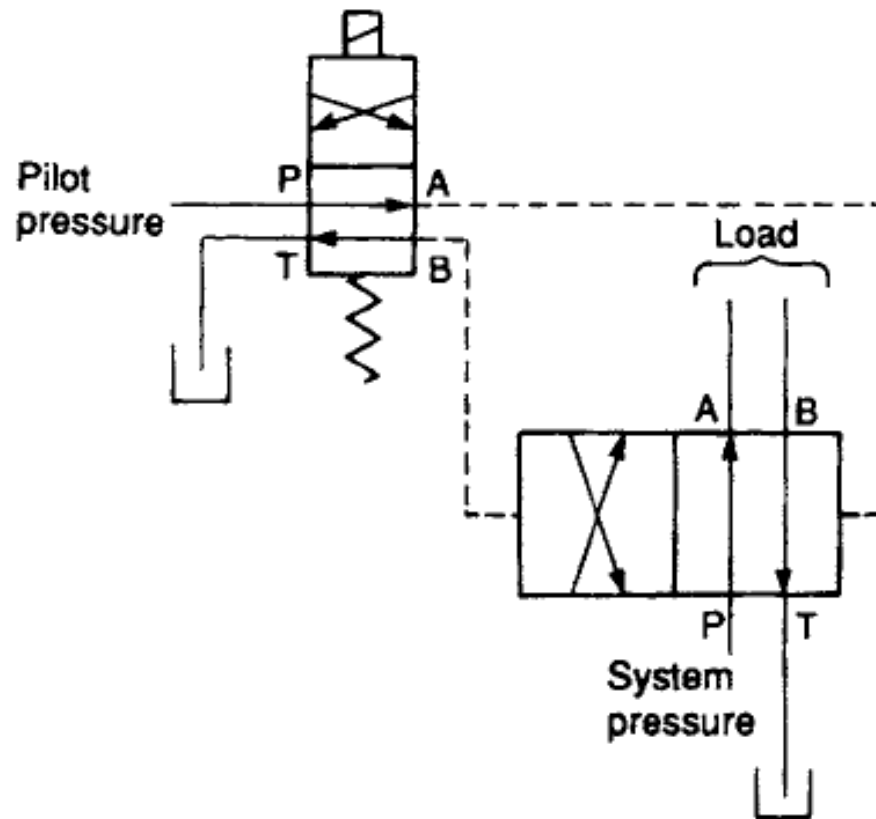


4/2 pilot operated spool valve



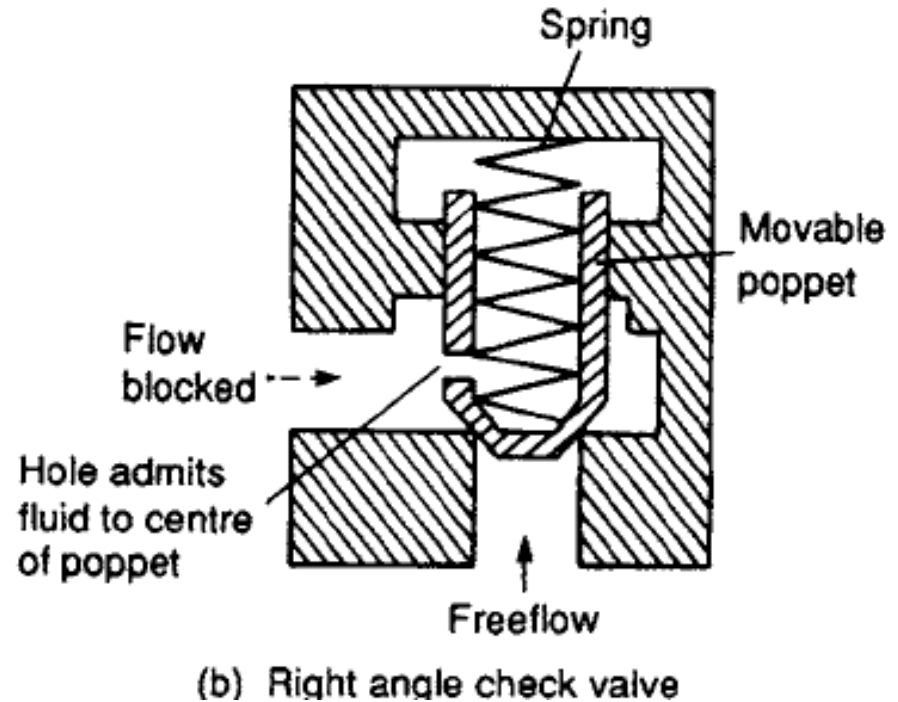
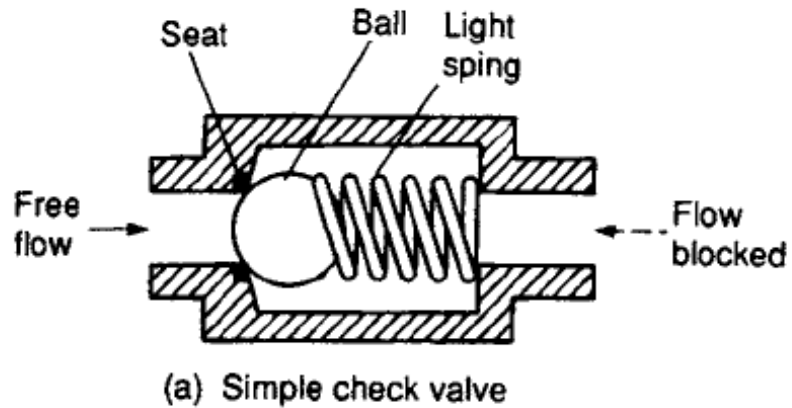
(a) Construction: power applied to solenoid has moved pilot spool to left. This applies pilot pressure to left hand end of main spool, shifting spool to right and connecting P & B ports

Study the construction and draw the graphical symbol

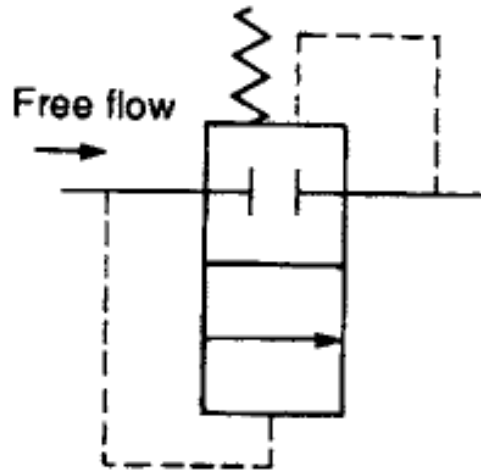


(b) Symbol

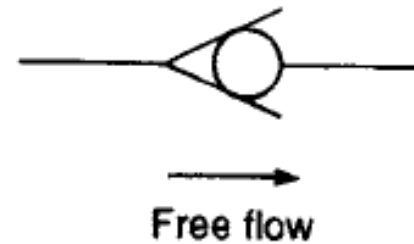
Check valves



Graphic symbol

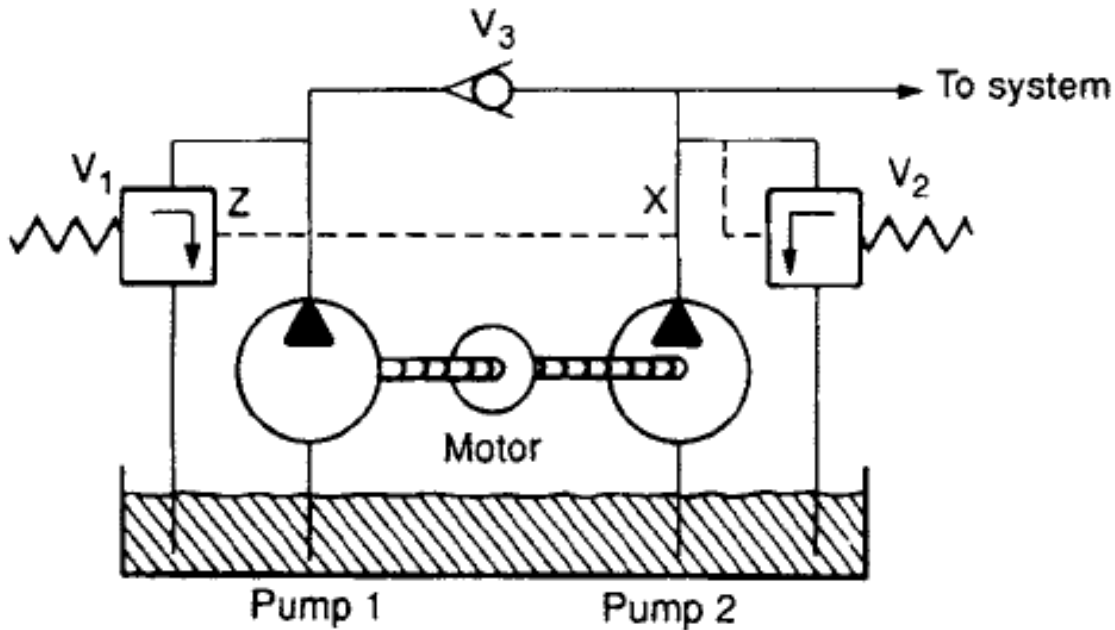


(a) Function symbol

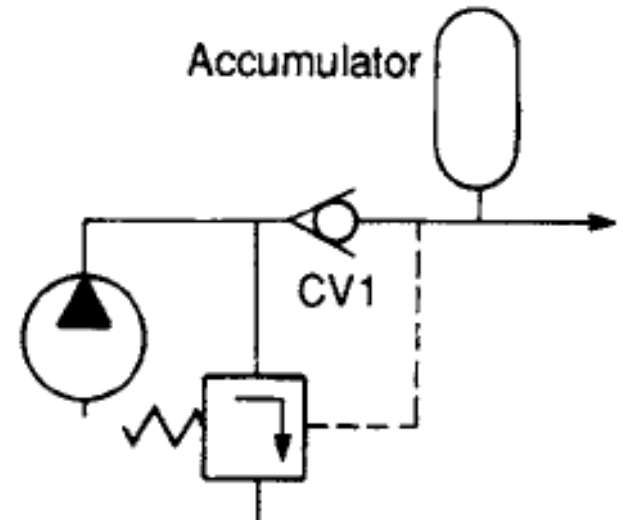


(b) Conventional symbol

Applications



(a) Combination pump



(b) An accumulator