

Robot drives

Robot drives

- To drive the mechanical links to a desired position
- Four basic methods
 - Hydraulic
 - Pneumatic
 - Electrical (AC & DC motors)
 - Electrical (Stepper motor)

Selection of robot drives

- Based on
 - Power consumption
 - Accuracy
 - Speed of operation
 - Stability
 - Reliability
 - Cost
 - Type of control system

Robot actuators/drives

- Hydraulic or Pneumatic cylinders with Solenoid controlled valve
- Electrical motors with electrical amplifiers and controllers.

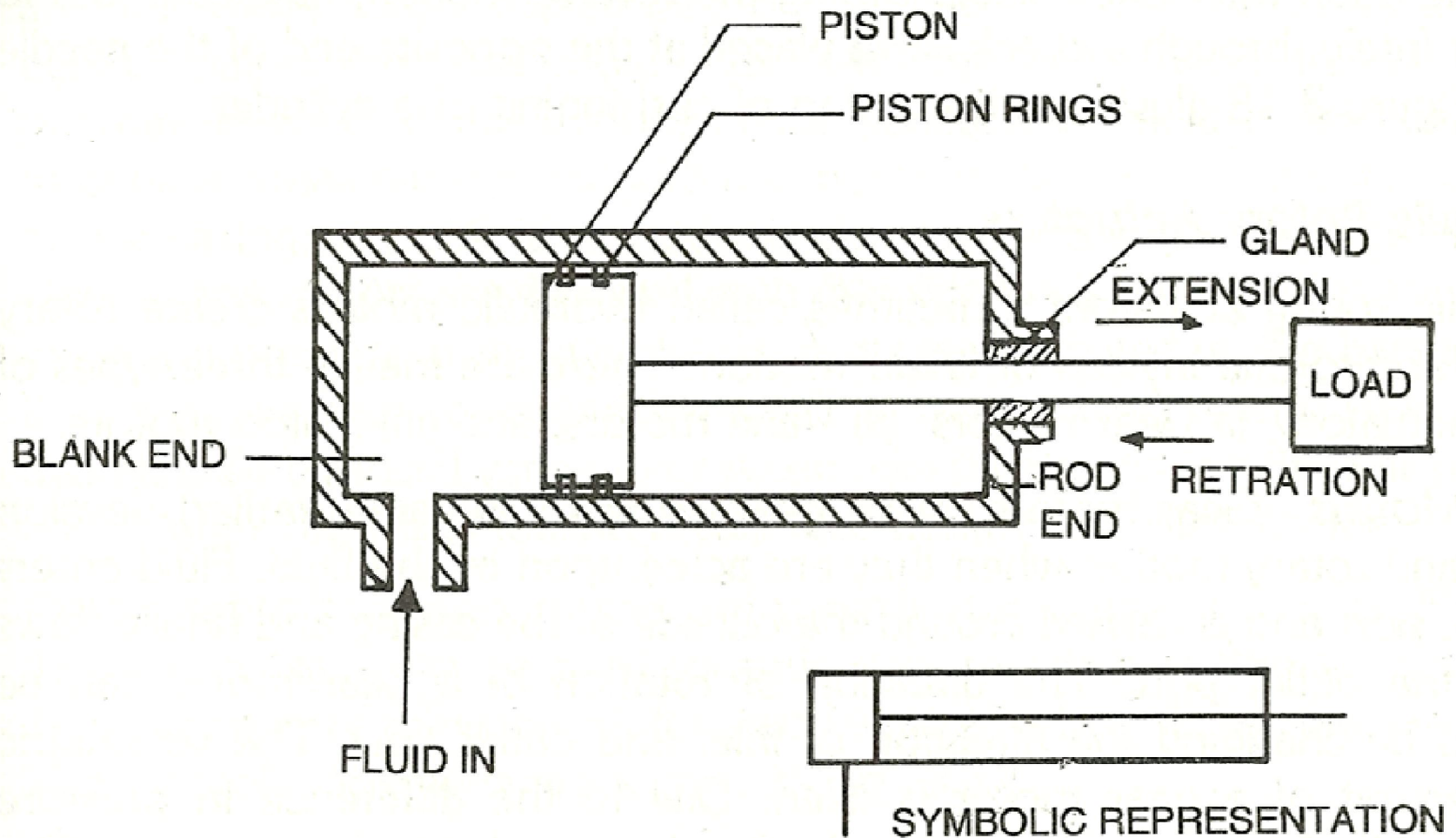
Hydraulic actuators/drives

- Converts energy extracted out of a fluid to mechanical work.
- Two types
 - Linear actuator or hydraulic cylinder
 - Rotary actuator or hydraulic motor

Linear hydraulic actuator

- Hydraulic cylinder which may be
 - single acting or
 - double acting
- Two ends of the cylinders are
 - Blind or Blank end
 - Rod end
- Single acting cylinder
 - Piston rod is extended from blank end to rod end by the application of fluid.
 - Retraction takes place either by compression spring or gravity.
 - Piston rings prevents oil leakage from the cylinder sides.
 - Gland seals the oil and supports the piston rod.

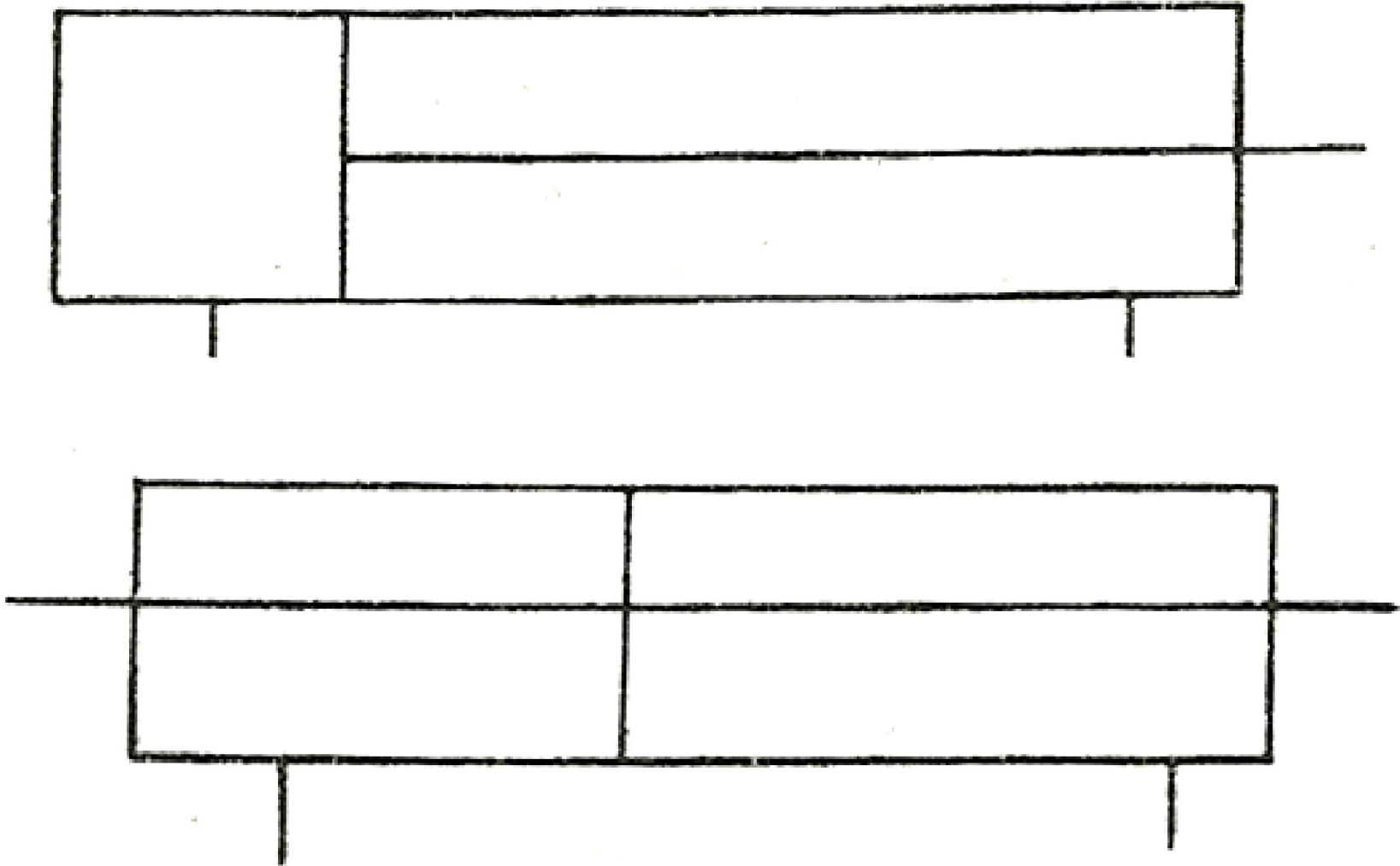
Single acting cylinder



Double acting cylinder

- Types
 - Single rod
 - Double rod
- Extension – Fluid pumped from blind end
- Retraction - Fluid pumped from rod end
- Extending force is greater than retracting force.
- Extending force and speed is equal to retracting force and speed in a double rod cylinder.

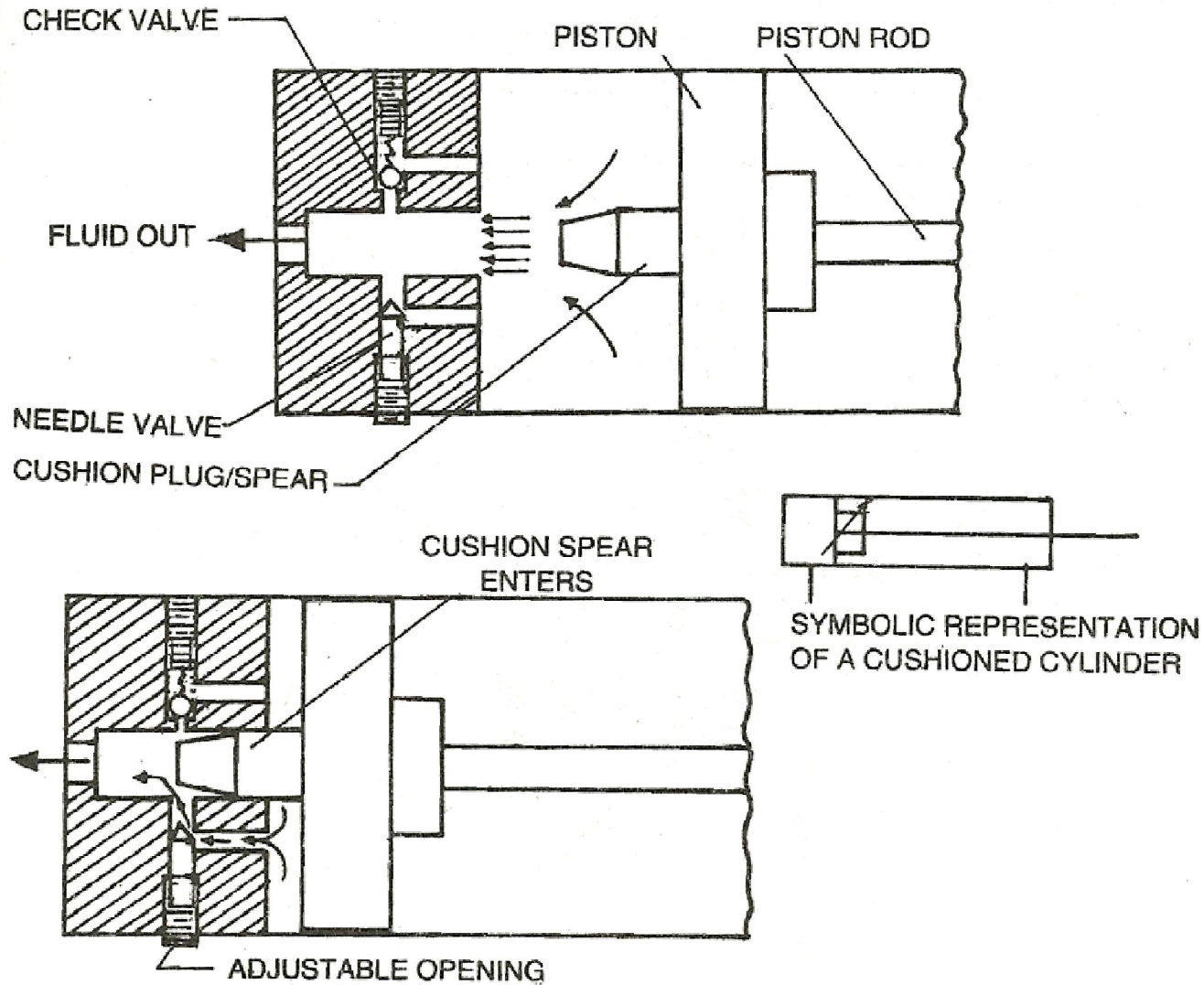
Double acting cylinder



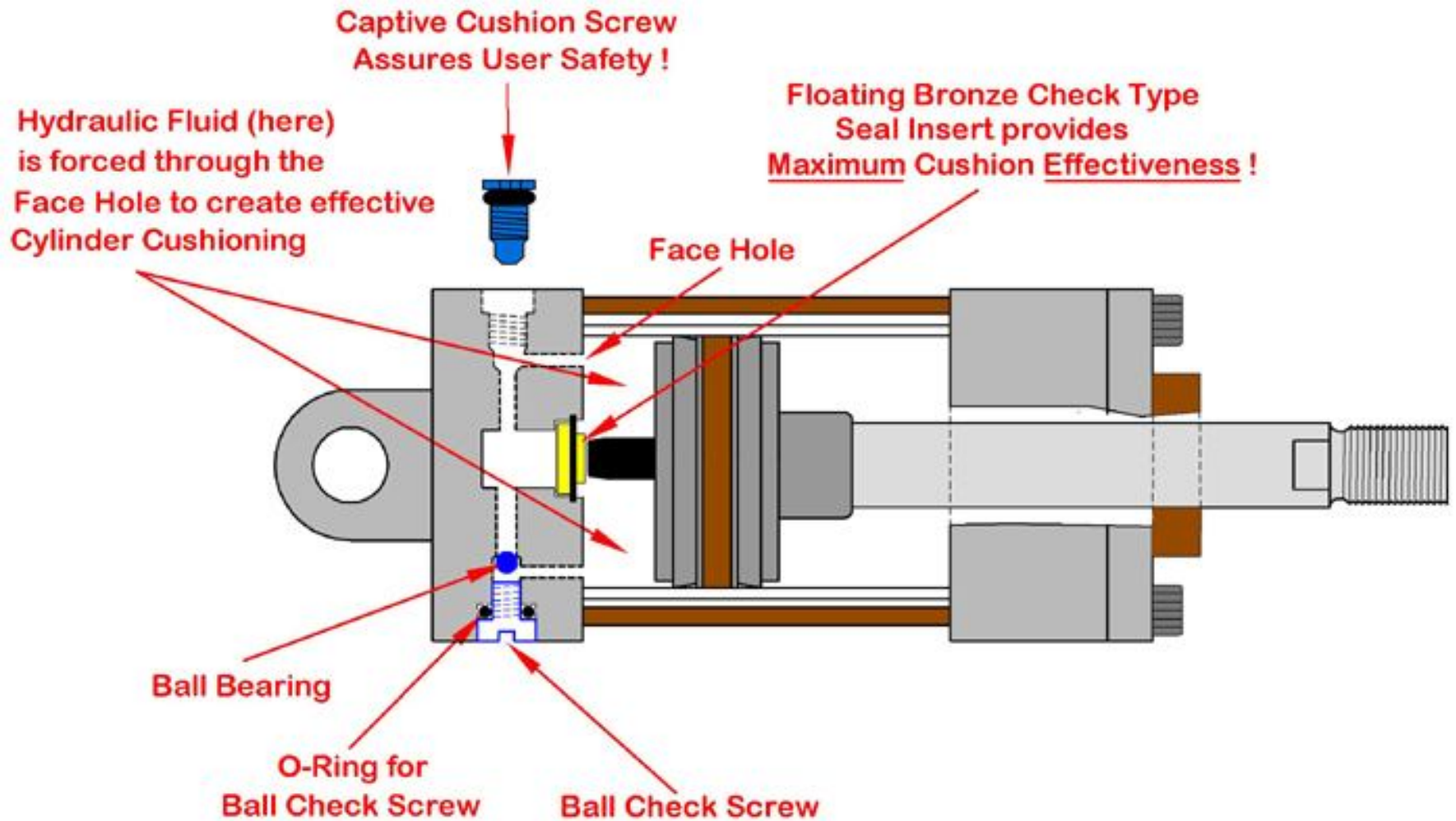
Cushioned cylinder

- To absorb shock when piston moves to the ends of the cylinder
- When the piston moves towards the end, a tapered spear enters the main opening restricting the exit flow from the piston.
- Finally the spear closes off the main opening and the fluid flow through a small opening which can be adjusted by a needle valve.

Cushioned cylinder



Cushioned cylinder



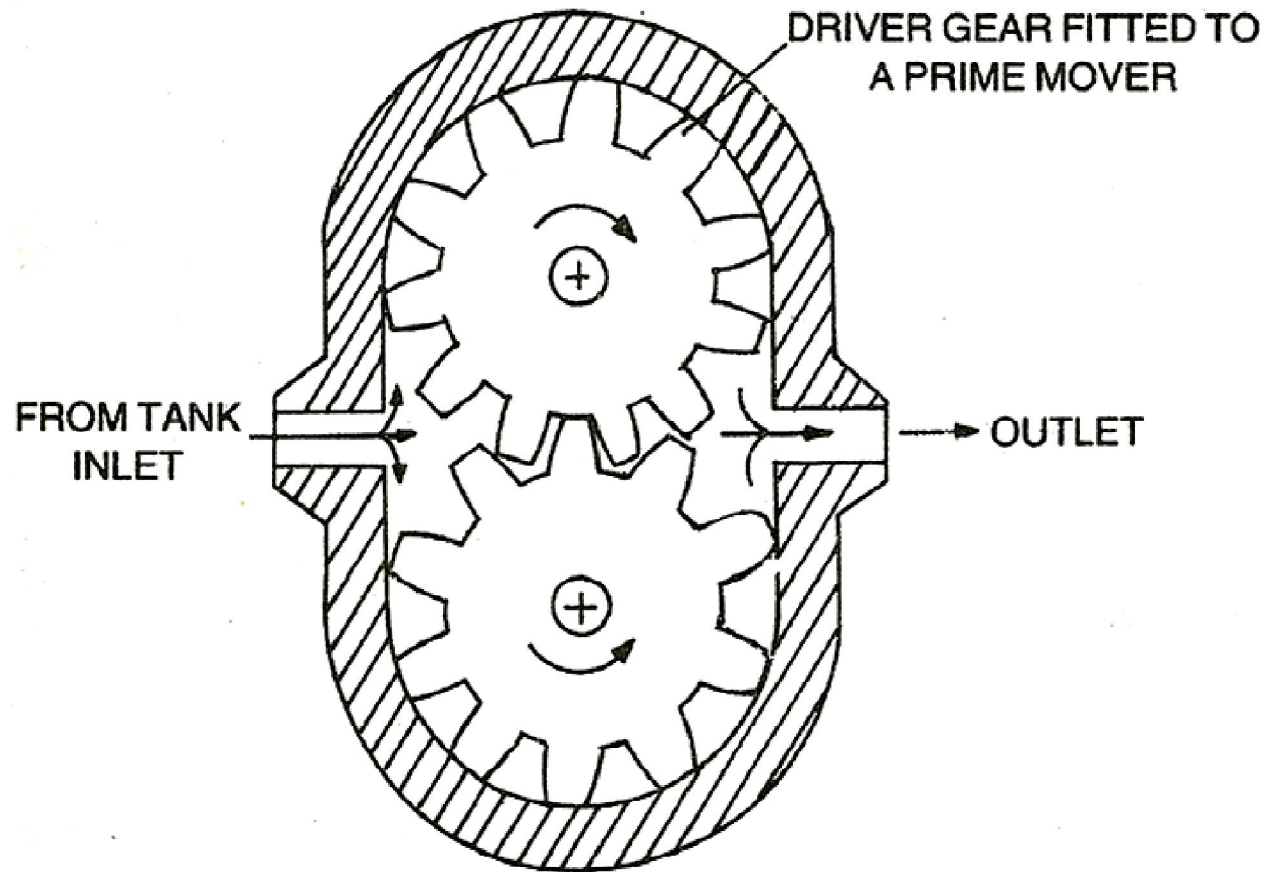
Hydraulic rotary actuators

- Creates torque instead of linear motion
- Three types
 - Gear motors
 - Vane motors
 - Piston motors
 - Rack and pinion actuator

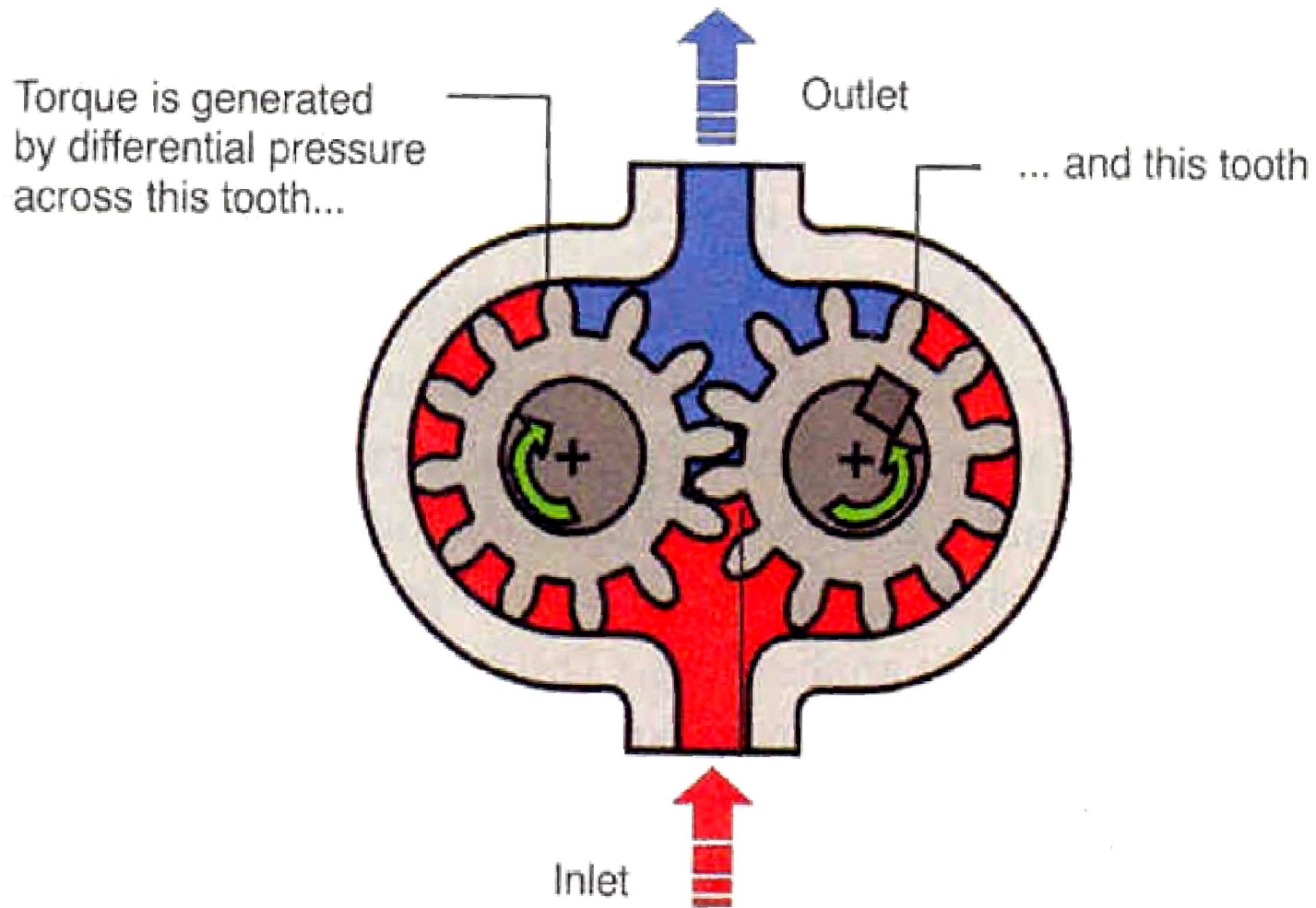
Gear motors

- 2 rotating gears are used
- The area of the gear teeth is where the pressure acts to create force.
- Both gears turn simultaneously
- One gear is connected to the output shaft and the other is an idler.
- High pressure oil is ported into one side of the gears, where it flows around the periphery of the gears, between the gear tips and to the outlet port.

Gear motors



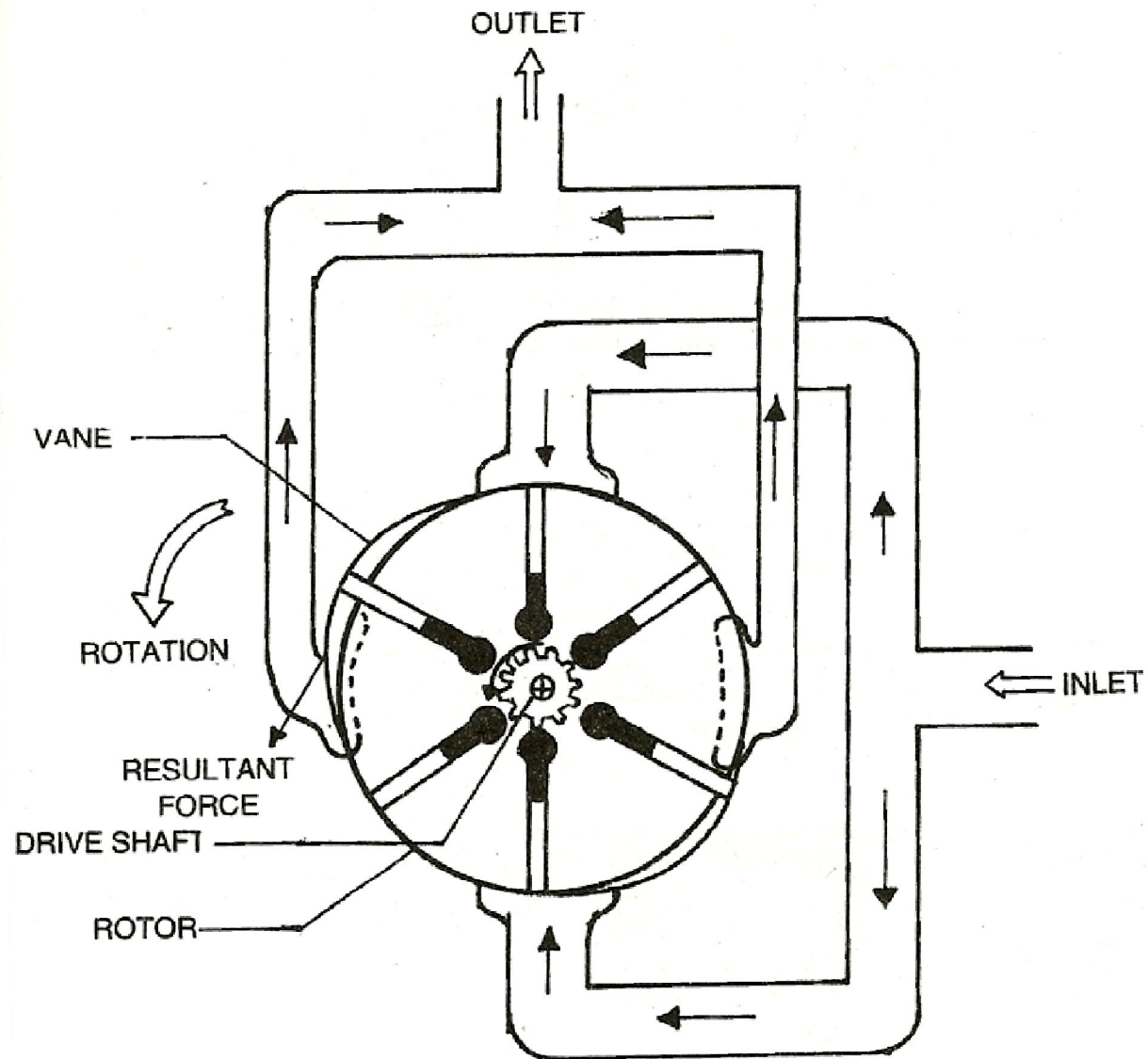
Gear motors



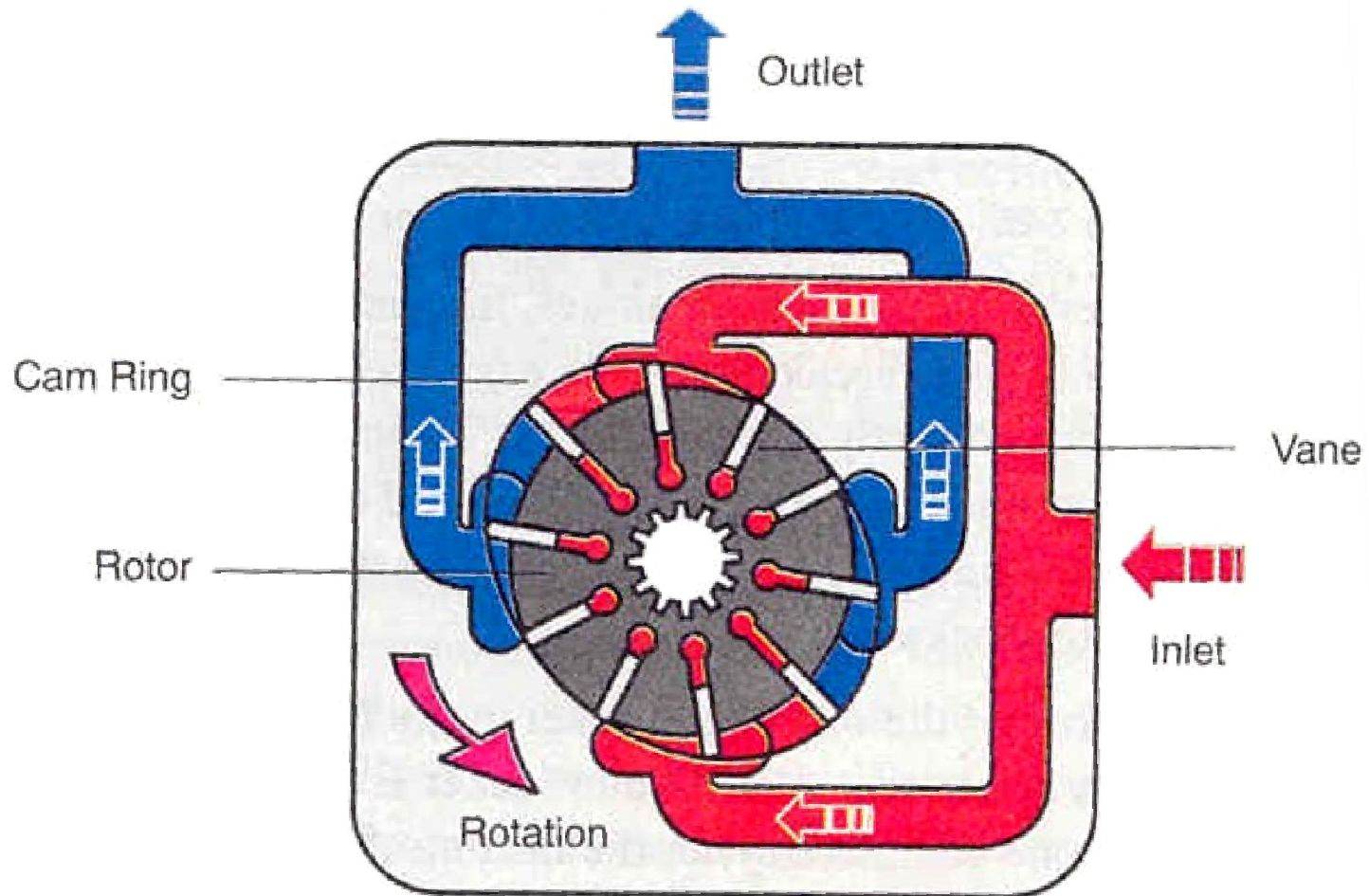
Vane motors

- Torque is developed due to the pressure acting on the vane.
- Spring loaded vanes are connected to a rotor
- The rotor turns inside a cam ring (elliptical hole)
- The vanes slide in and out of the slots in the rotor to make contact with the cam wall.
- The fluid enters through the inlet port and flow through two interconnected cavities and leave out through outlet port.
- Two inlet and two outlet ports are placed 180° apart.

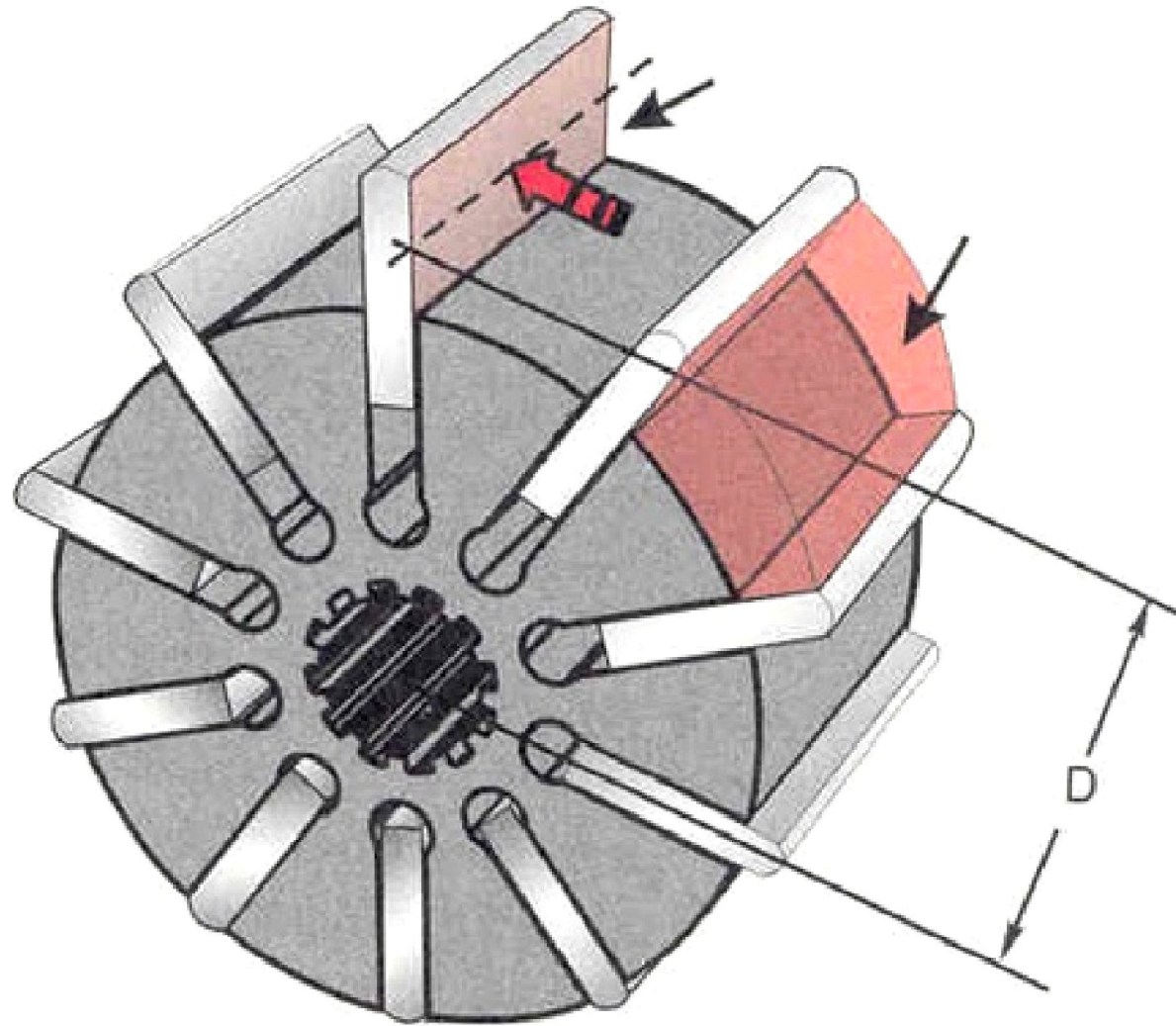
Vane motors



Vane motors



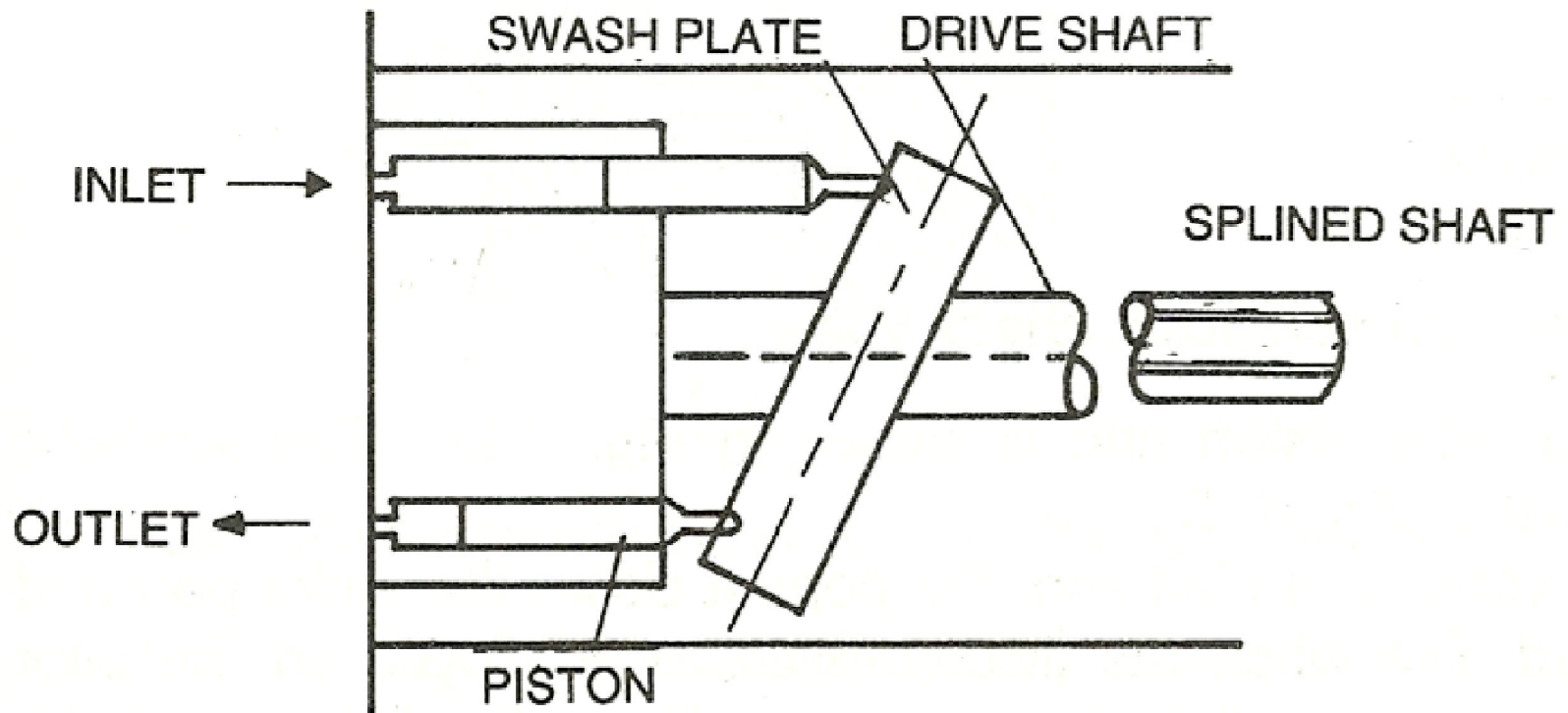
Vanes



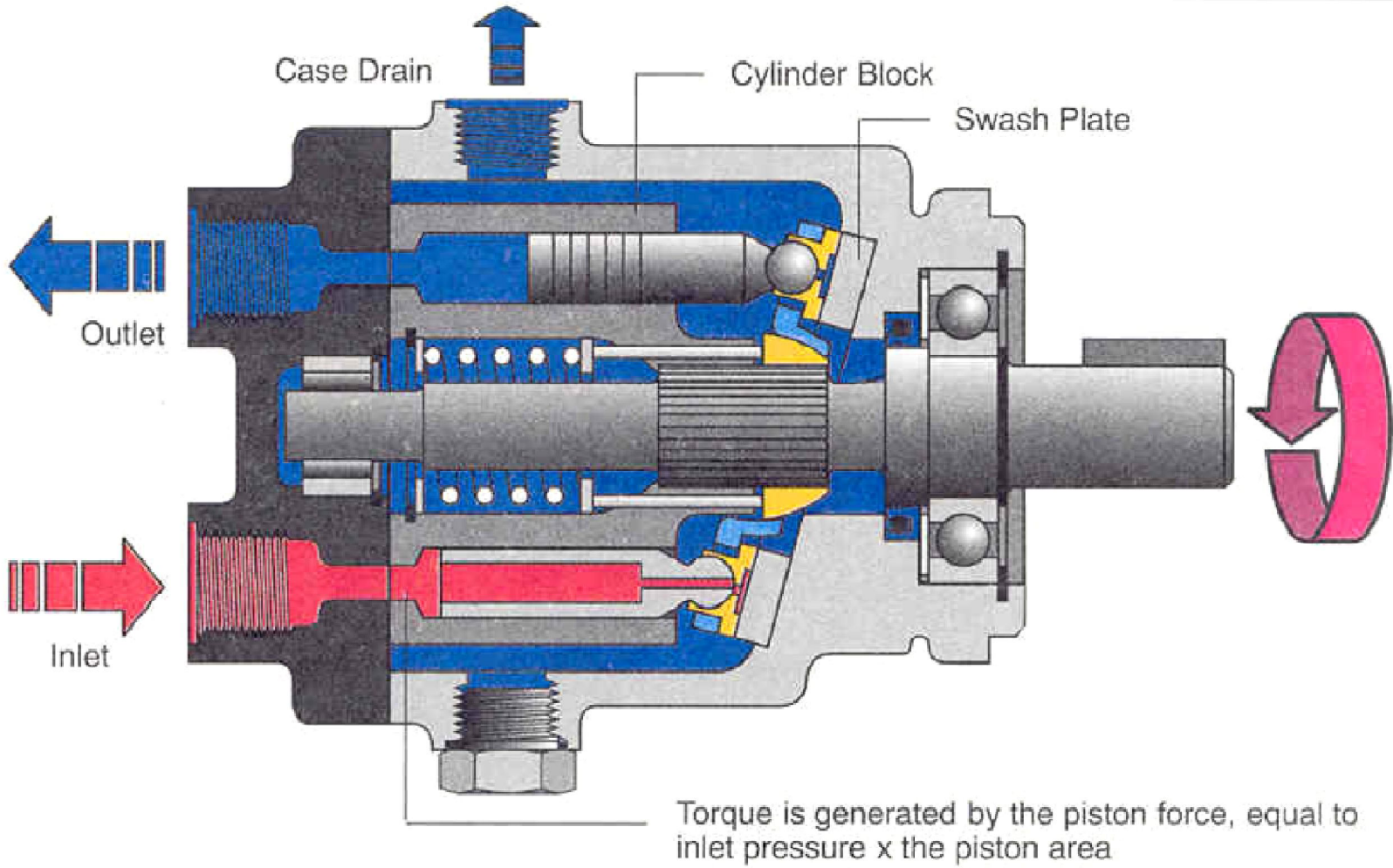
Piston motor

- Variable displacement motor
- Uses Swash plate which can be tilted towards right or left past the central position.
- Maximum tilting angle produce maximum displacement.
- Pistons with cylinders are arranged on the swash plate.

Piston motor



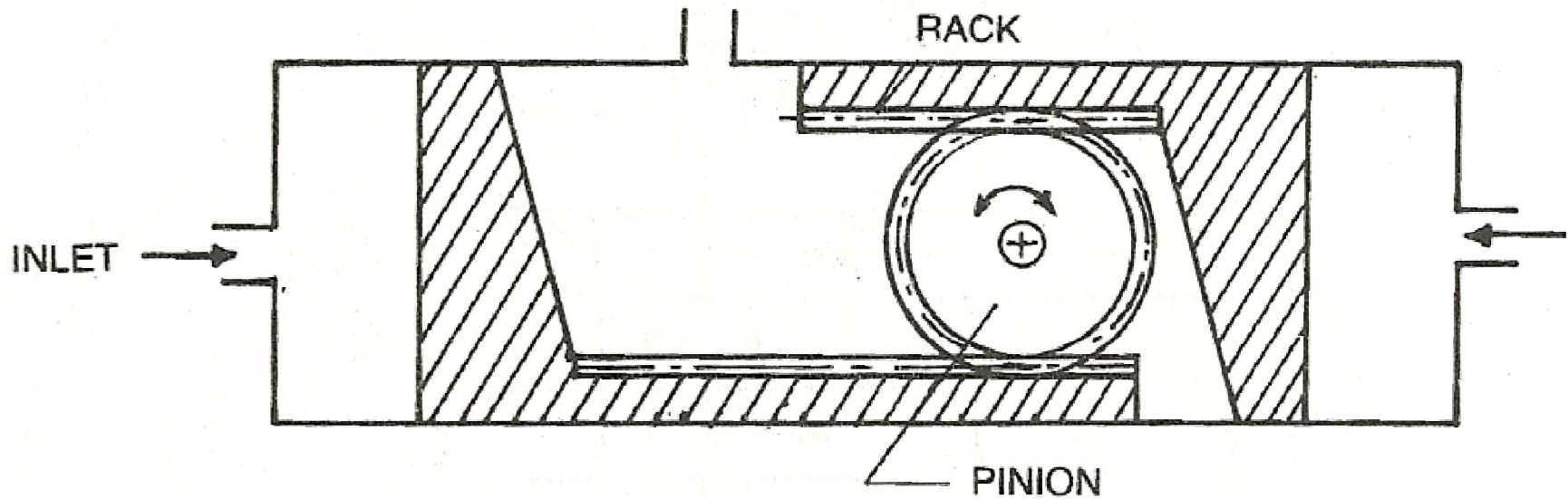
Piston motor



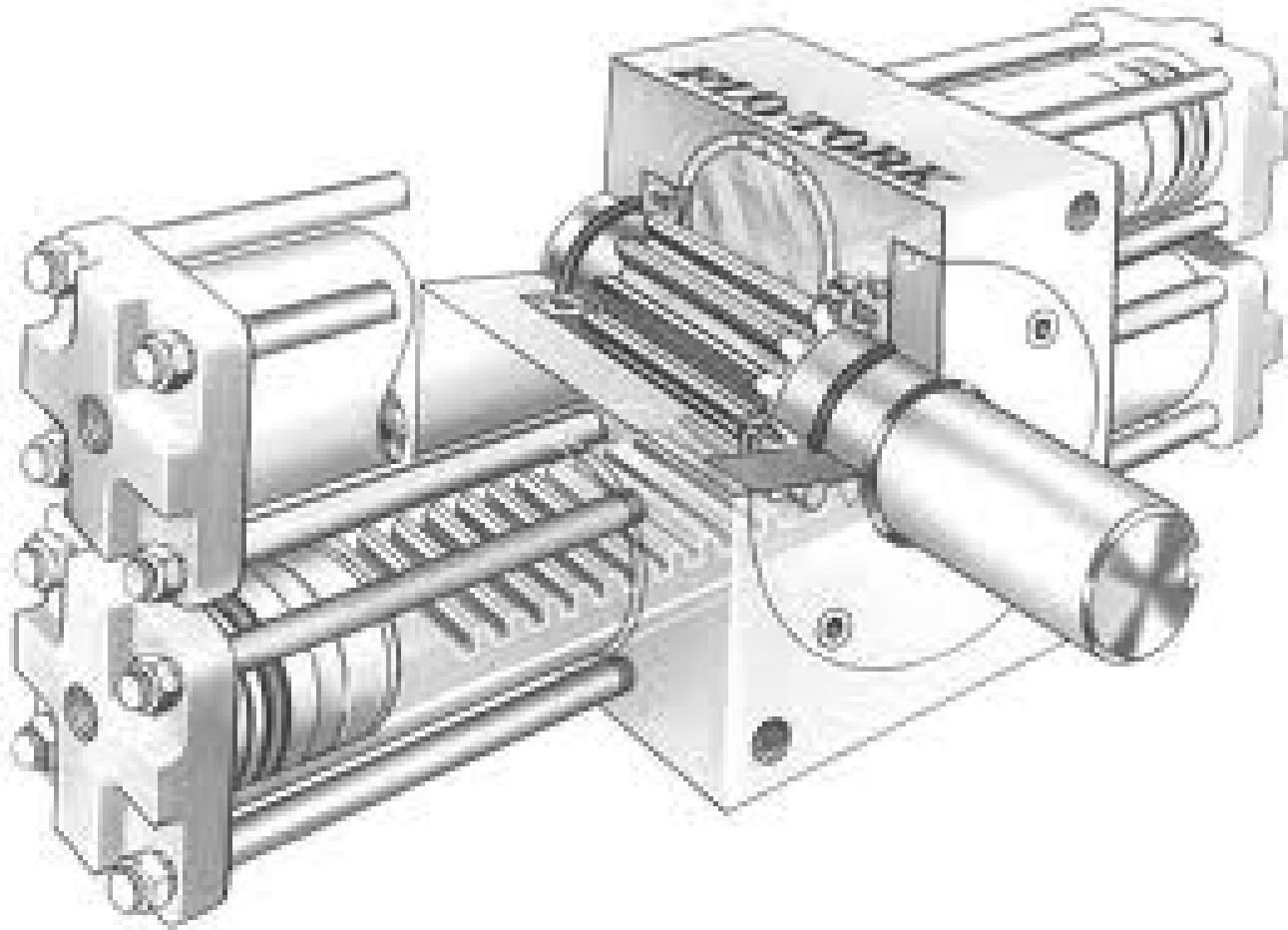
Rack and pinion actuator

- It is a type of actuator that comprises a pair of gears which convert rotational motion into linear motion or vice versa.
- A circular gear called "the pinion" engages teeth on a linear "gear" bar called "the rack"; rotational motion applied to the pinion causes the rack to move or vice versa.

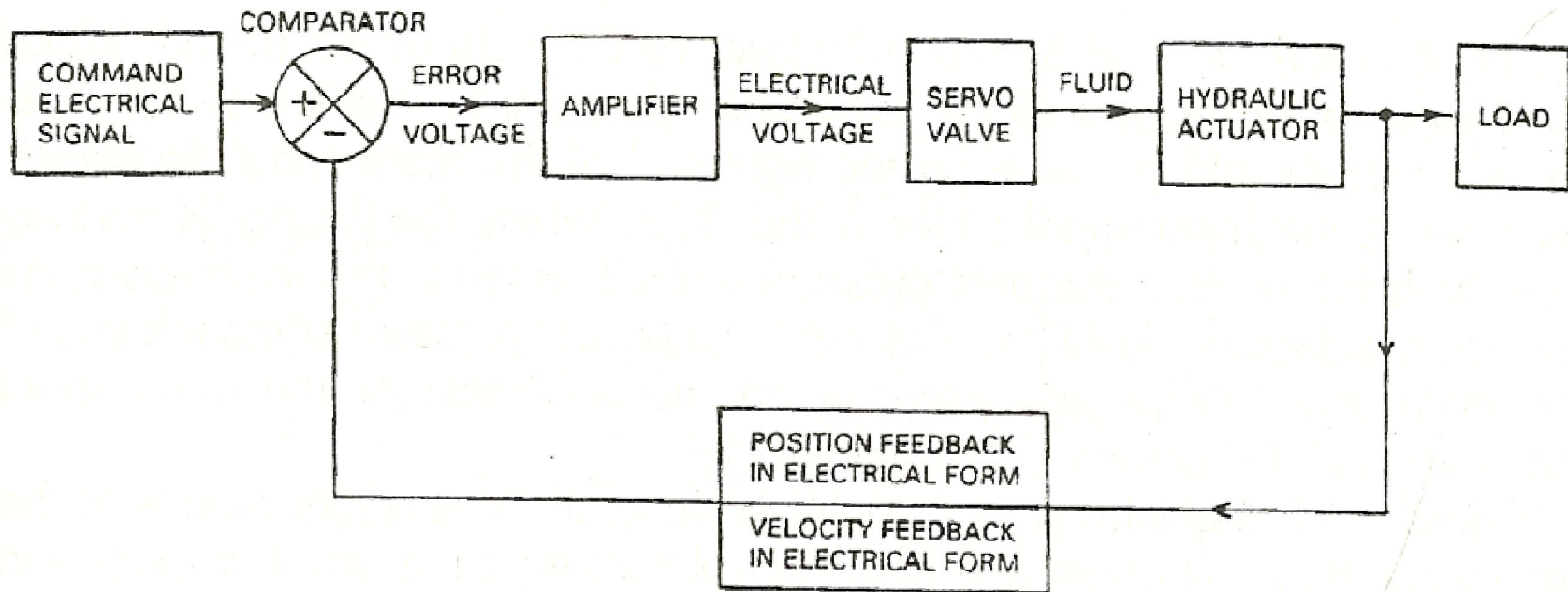
Rack and pinion actuator



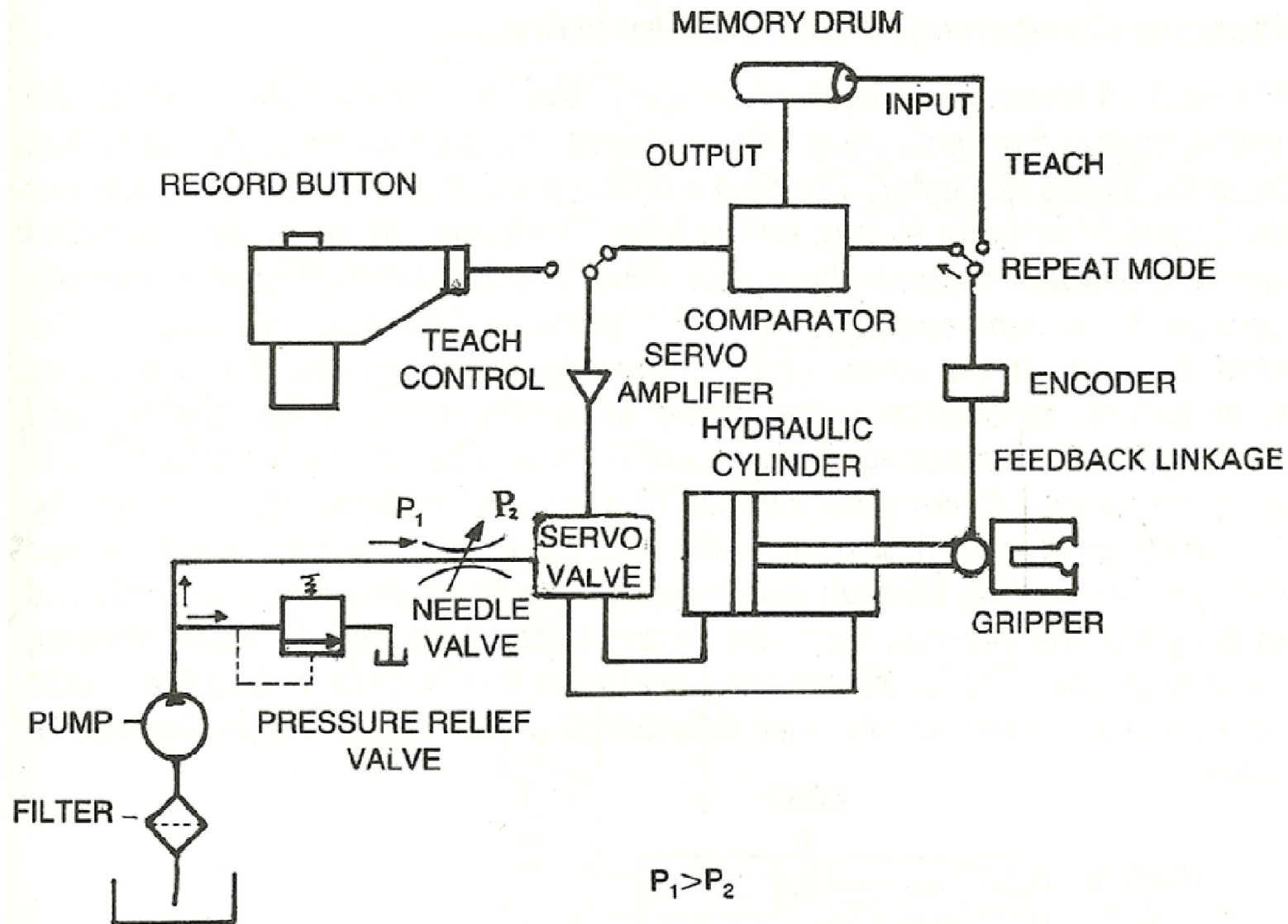
Rack and pinion actuator



Closed loop servo system



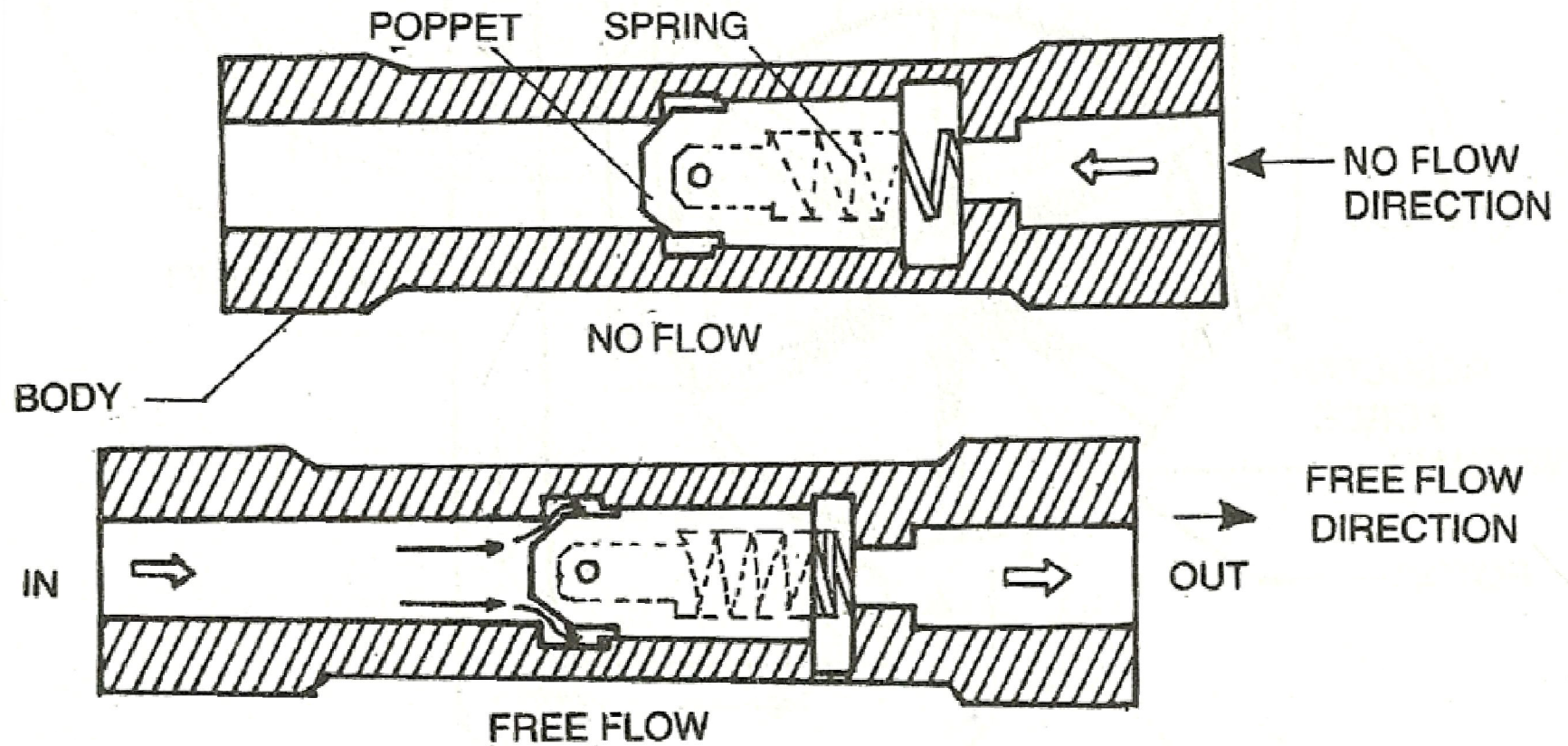
Hydraulic servo system



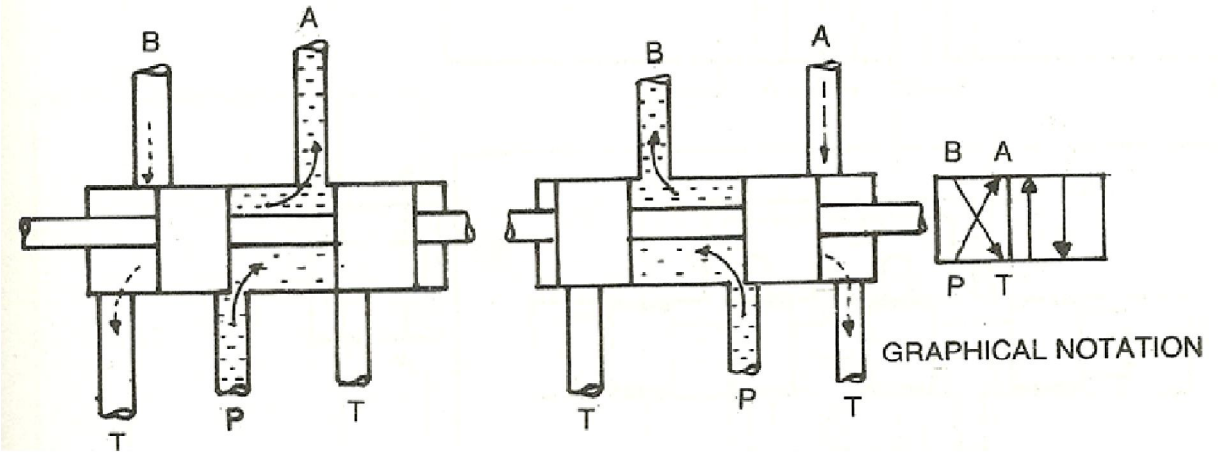
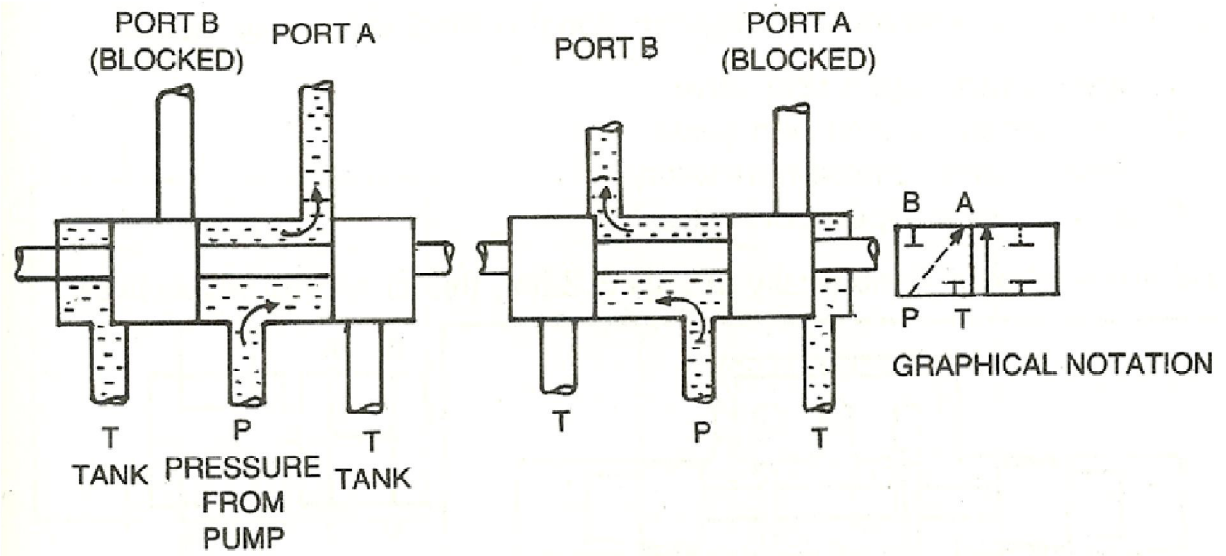
Elements in Hydraulic system

- Hydraulic tanks
- Filters
- Check valves
- Direction control valves
- Pressure control valves
- Flow control valves

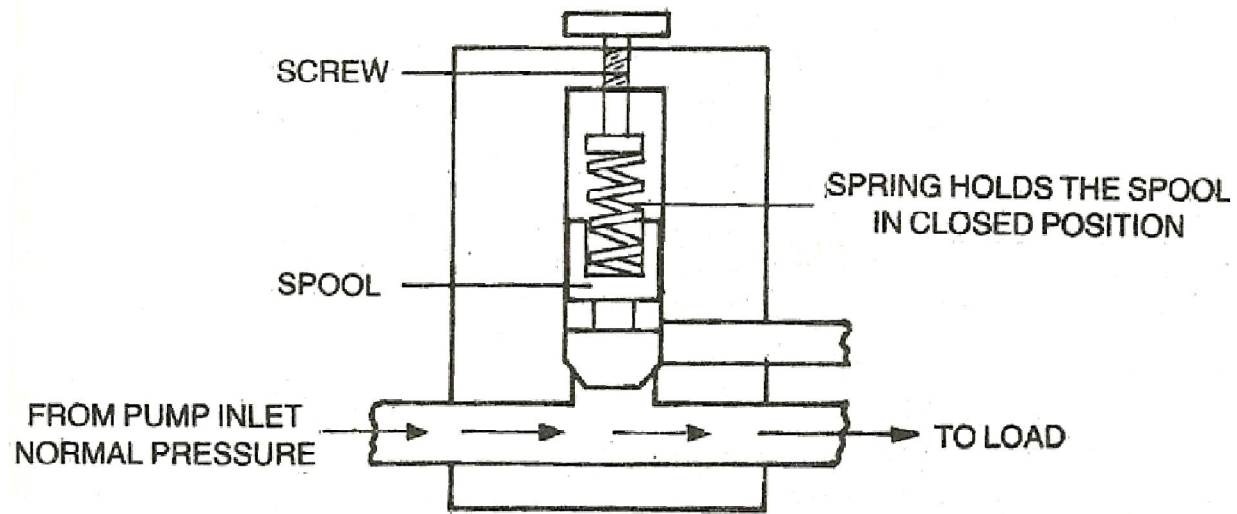
Check valves



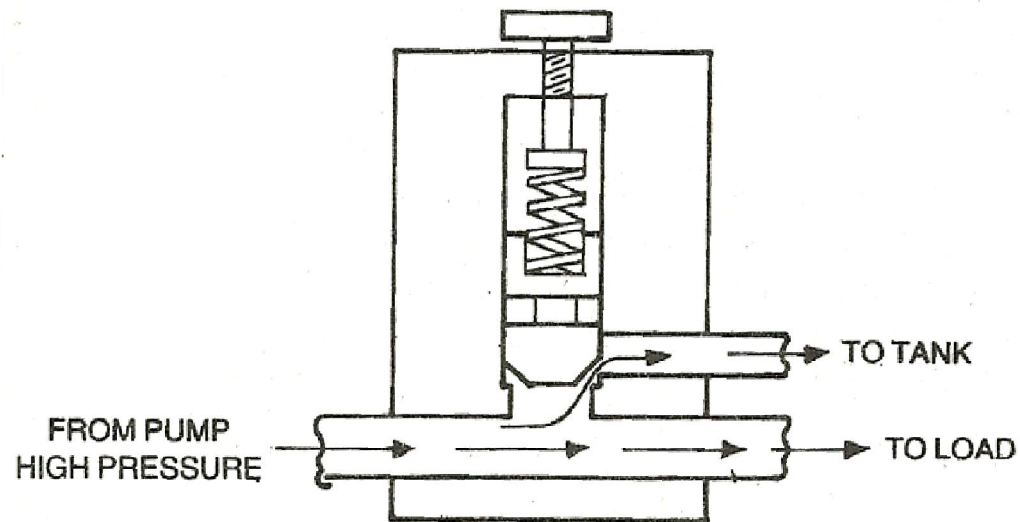
Direction control valves



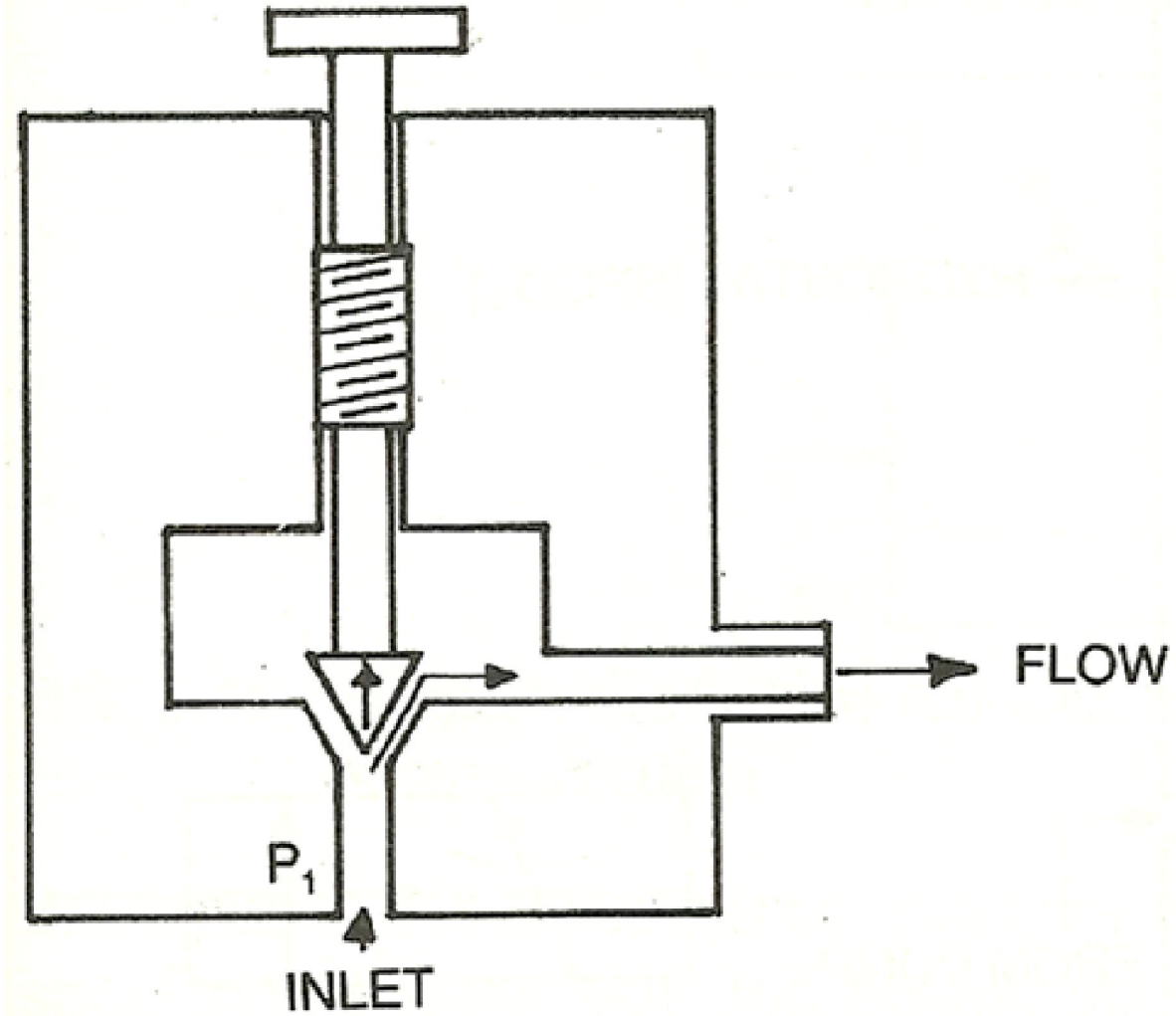
Pressure control valves



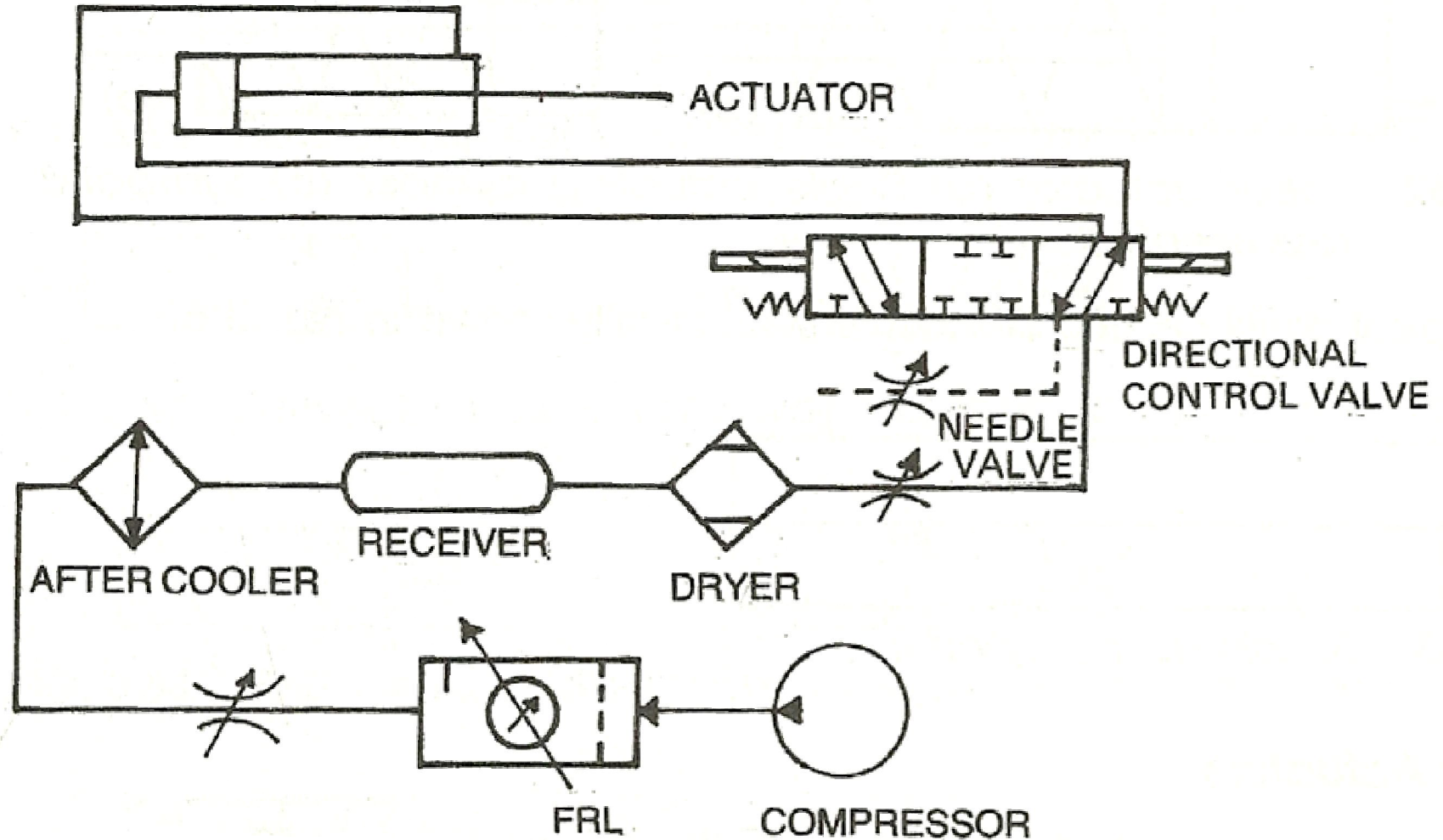
(a)



Flow control valves



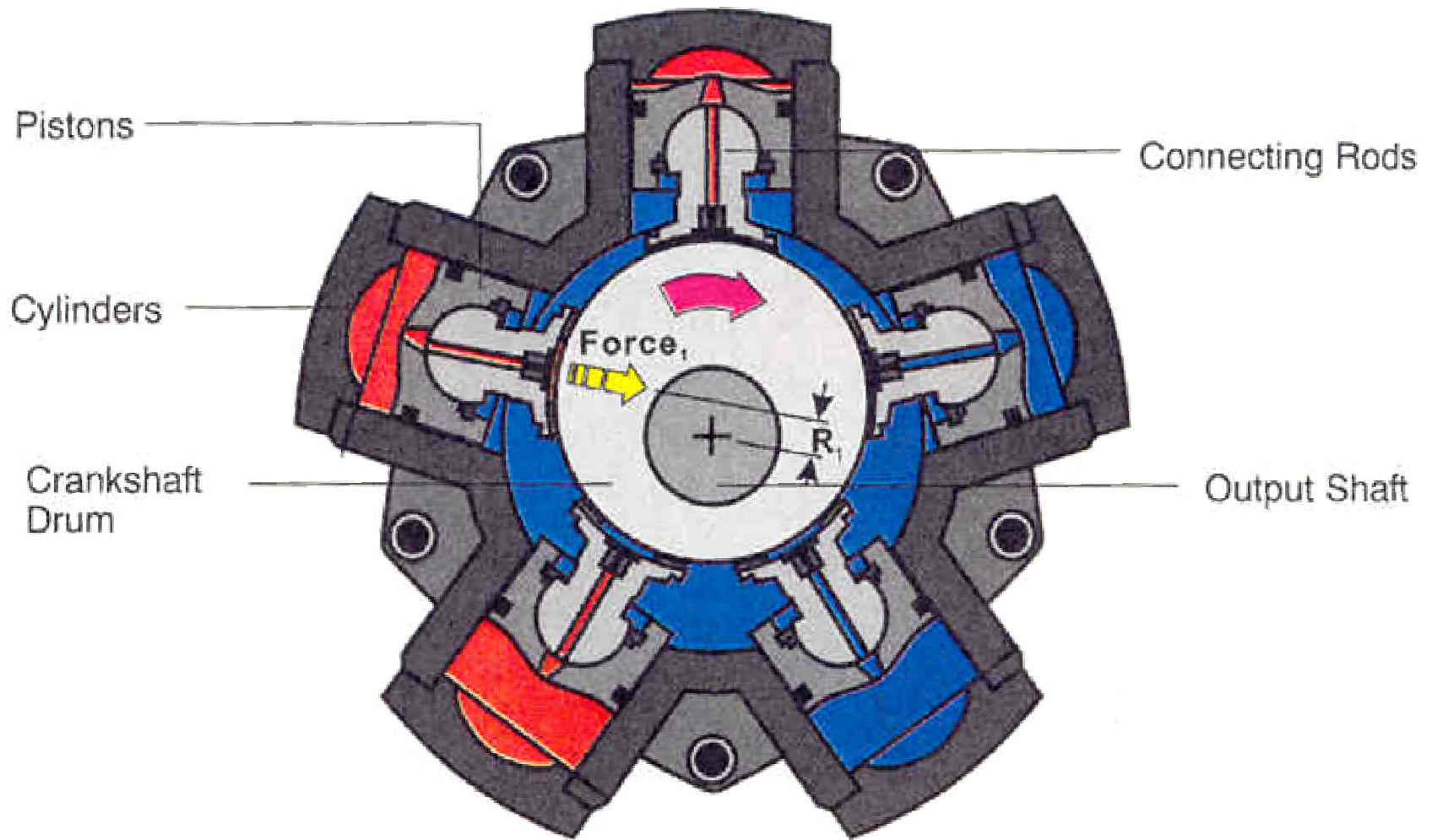
Pneumatic system



Pneumatic actuator/drives

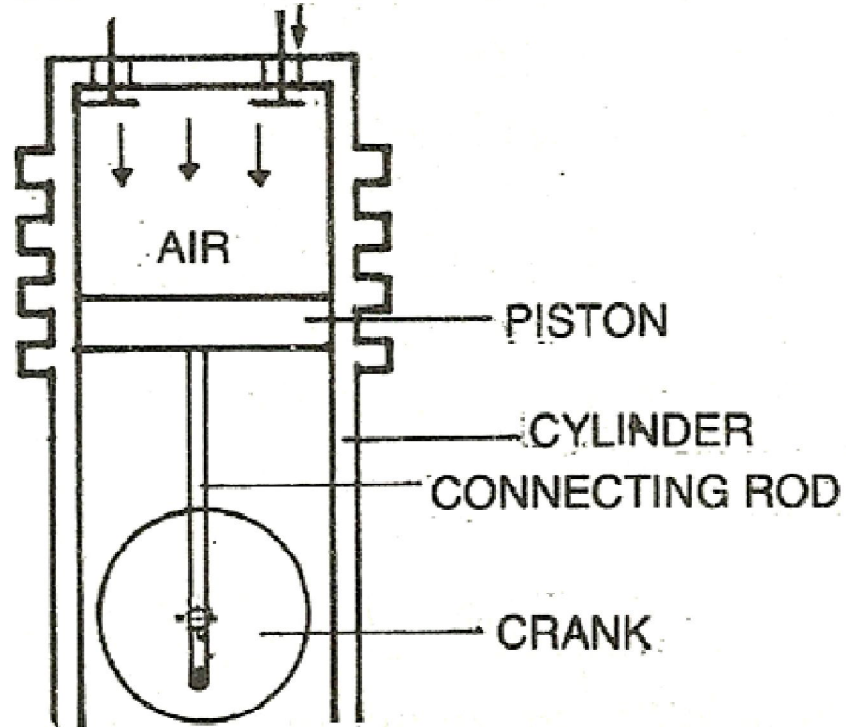
- Two types
 - Linear actuator
 - Cylinders – Single & Double acting
 - Rotary actuator
 - Low speed piston motor
 - Variable speed vane motor

Piston motor

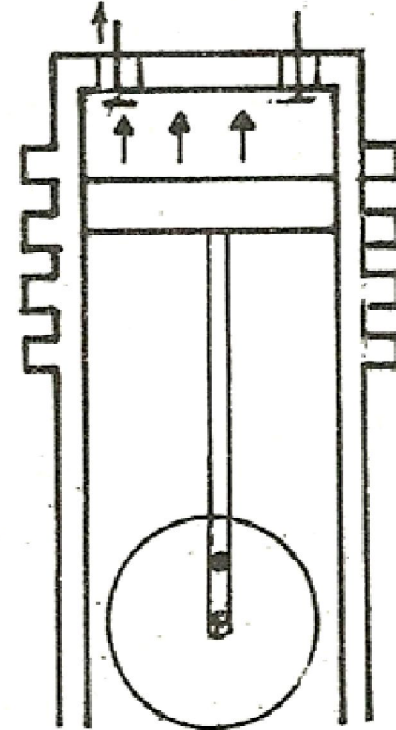


Reciprocating compressor

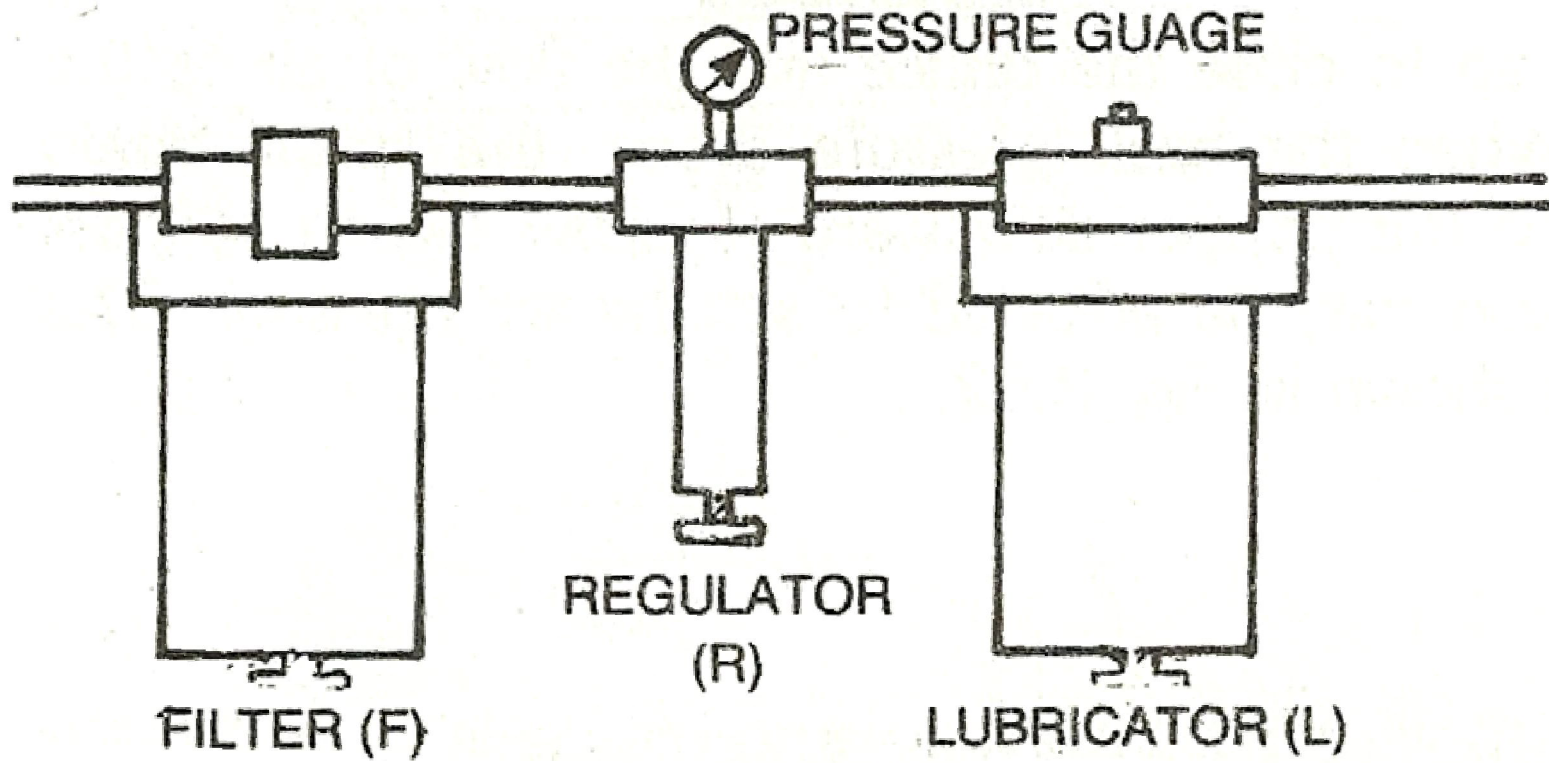
INTAKE VALVE (AIR IN)



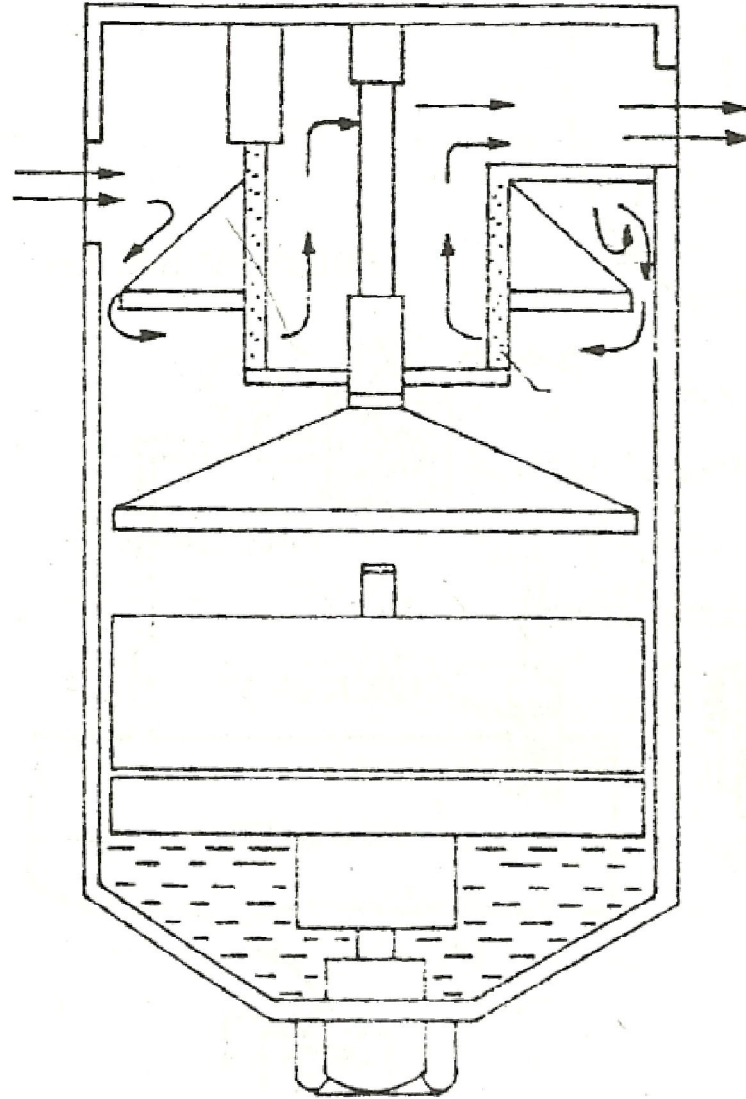
OUTLET VALVE (EXHAUST)



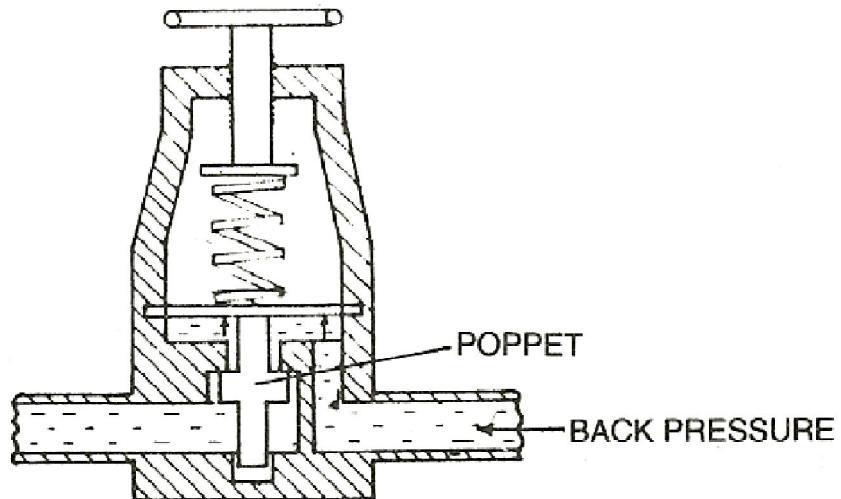
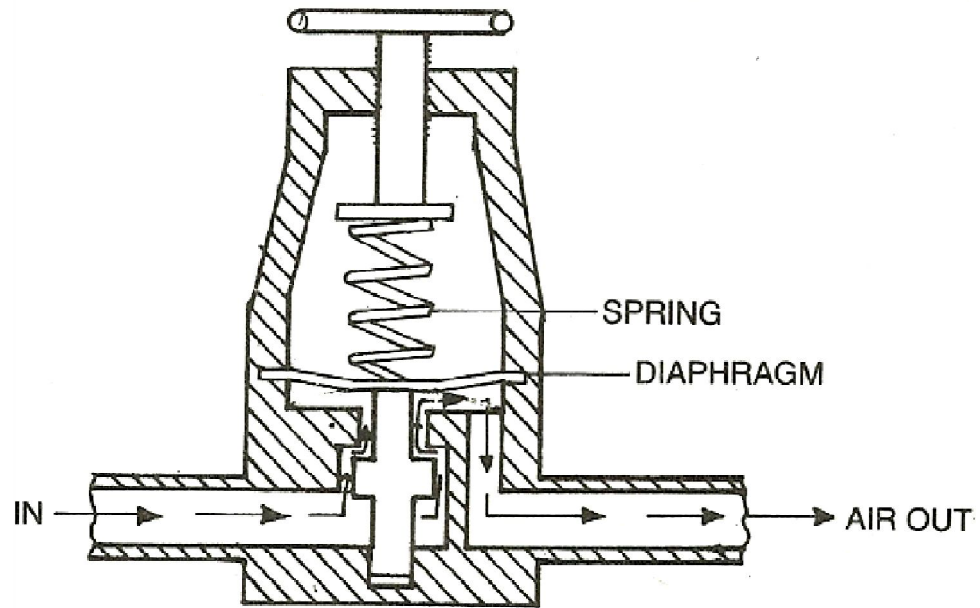
FRL



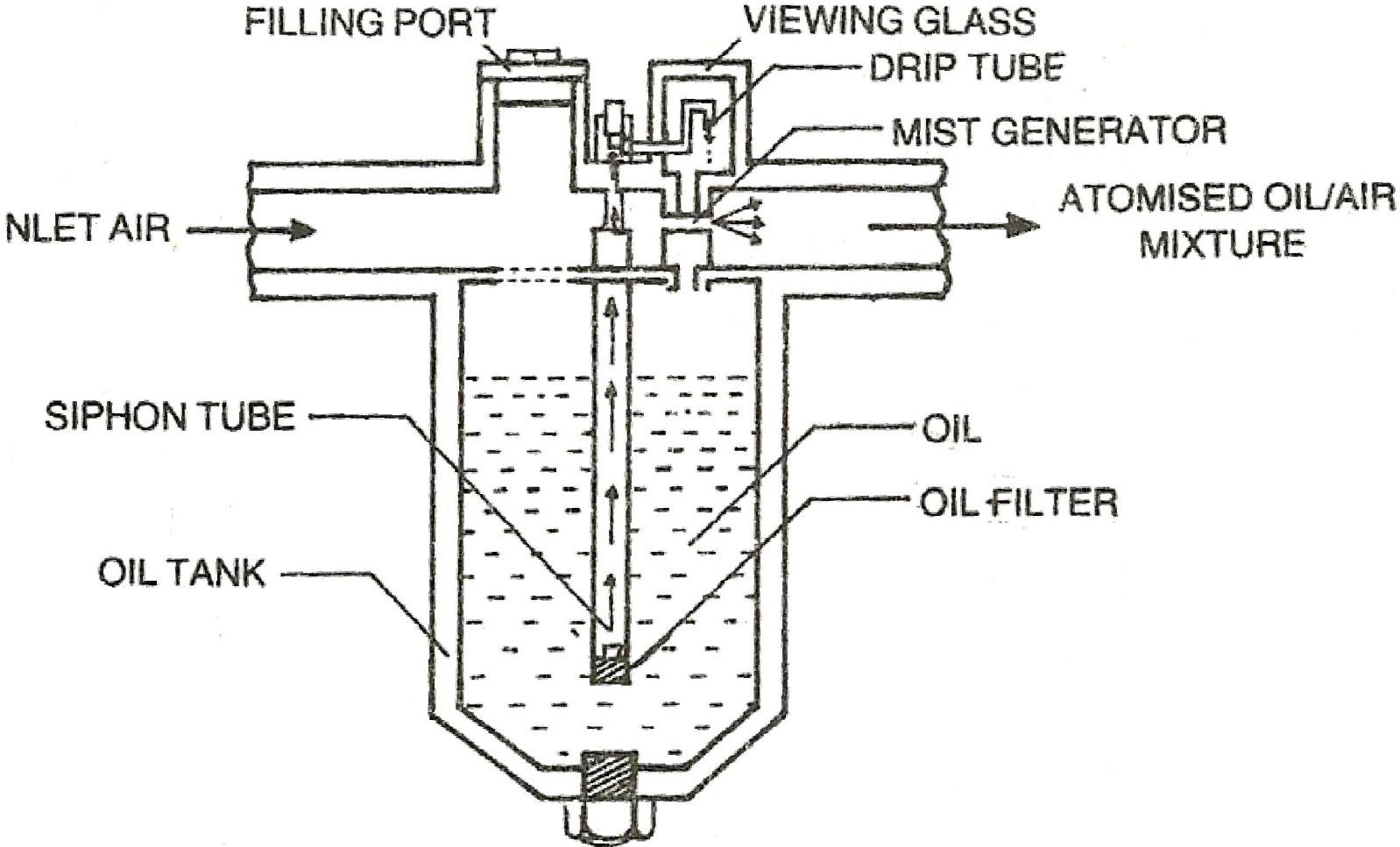
Filter



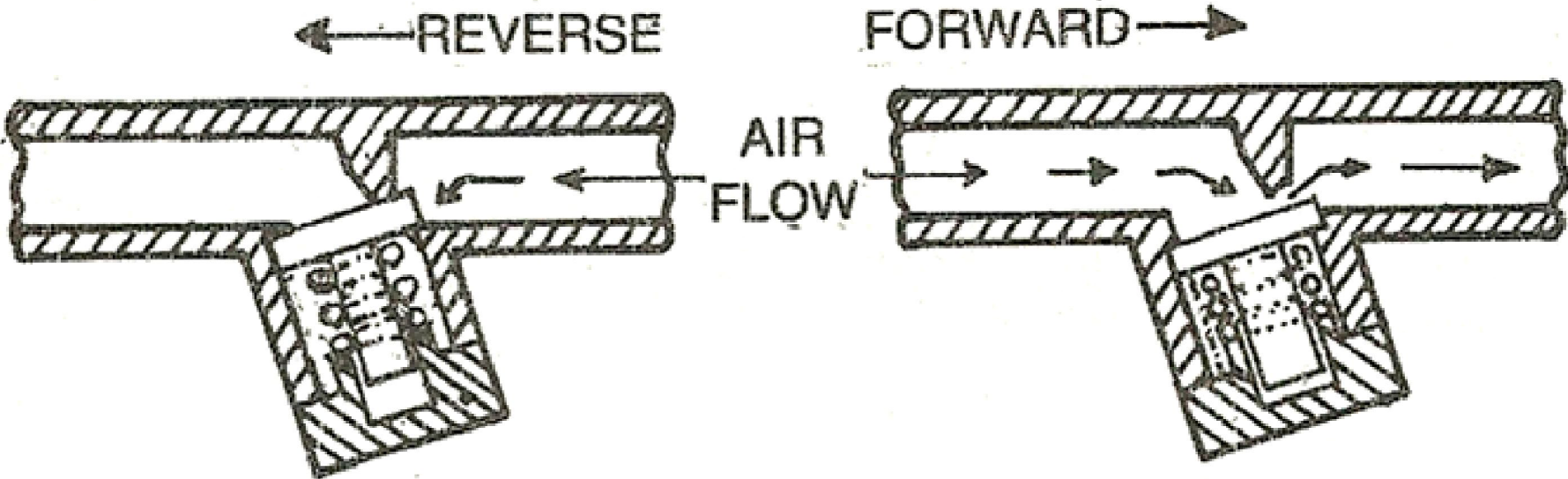
Regulator



Lubricator



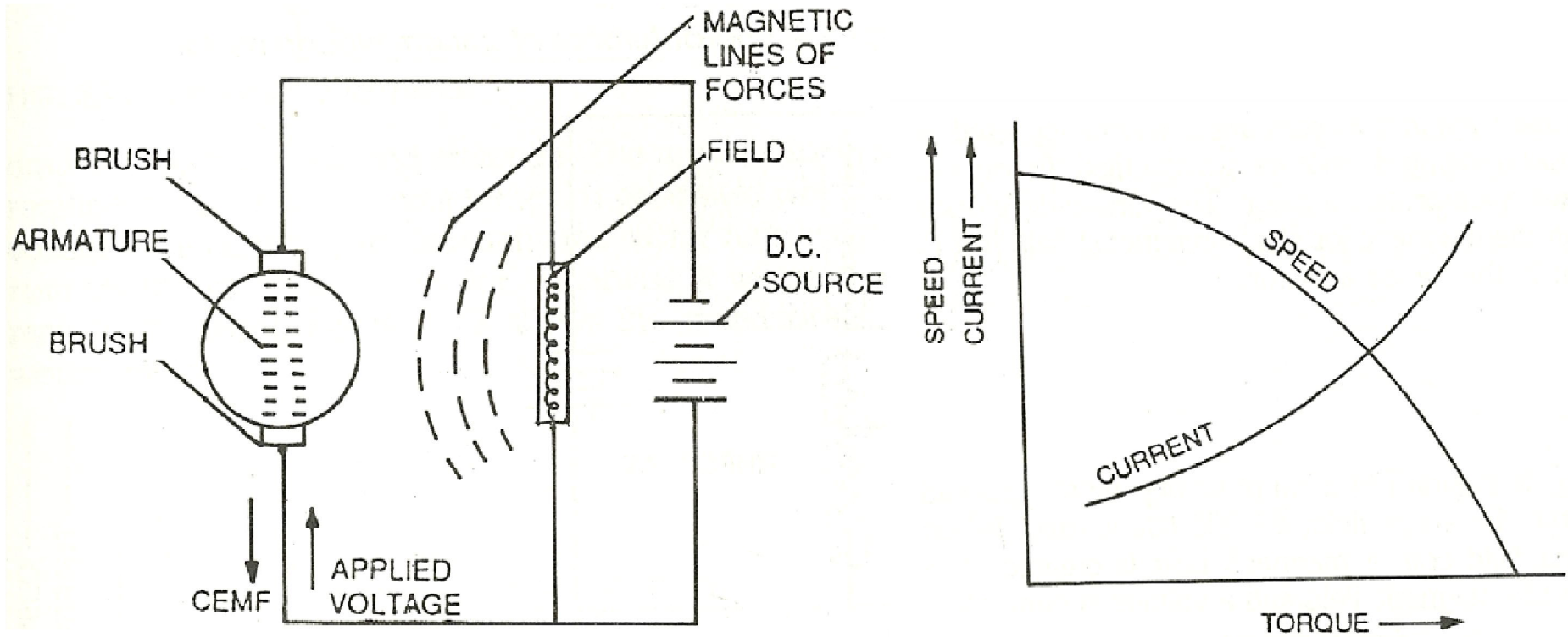
Check Valve



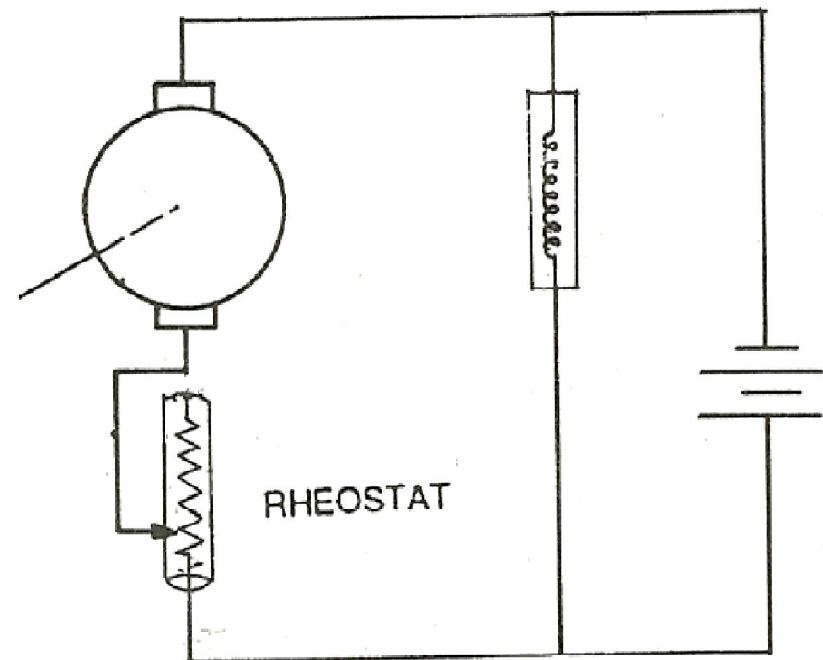
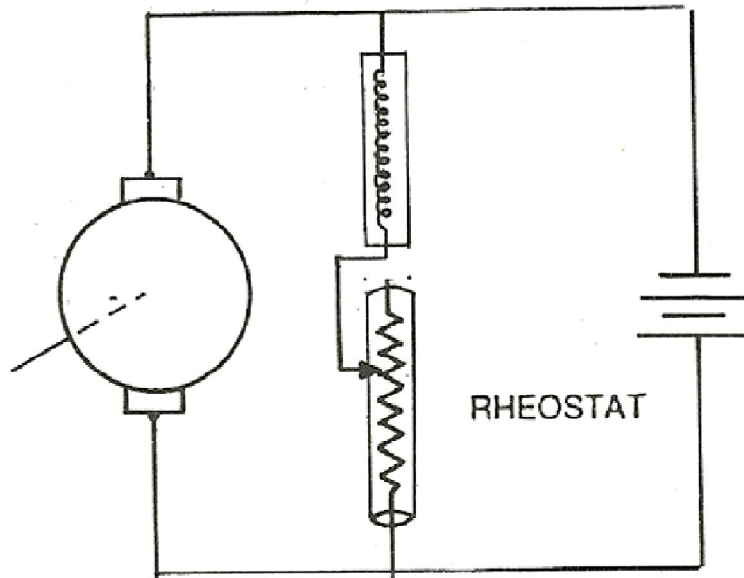
Electrical Drives

- DC motors are preferred because of
 - High torque
 - High precision
 - Good repeatability
- Two types
 - Motors with wound field coils
 - Shunt wound motors
 - Series wound motors
 - Compound motors
 - Permanent magnet motors
- DC motors have a stator and a rotor.
- Torque developed depends on magnetic field flux in the stator field and the current in the motor armature.

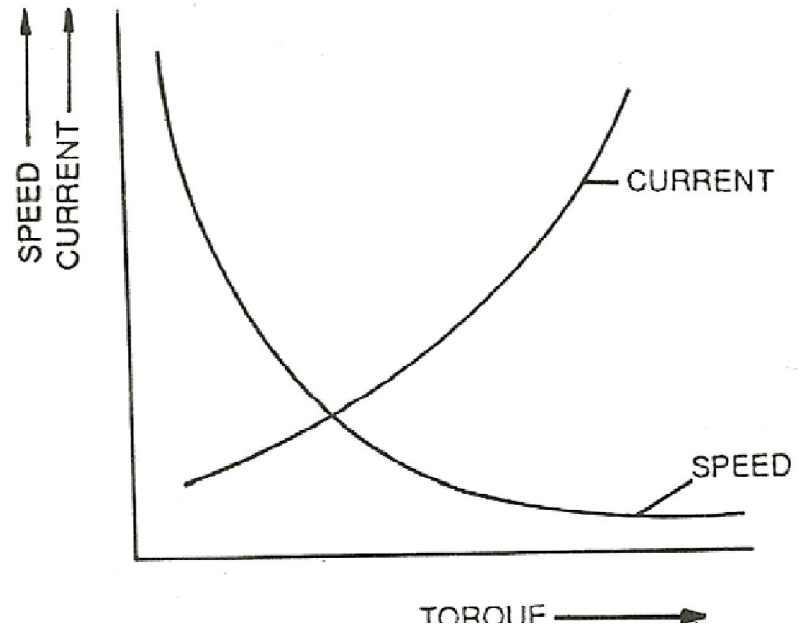
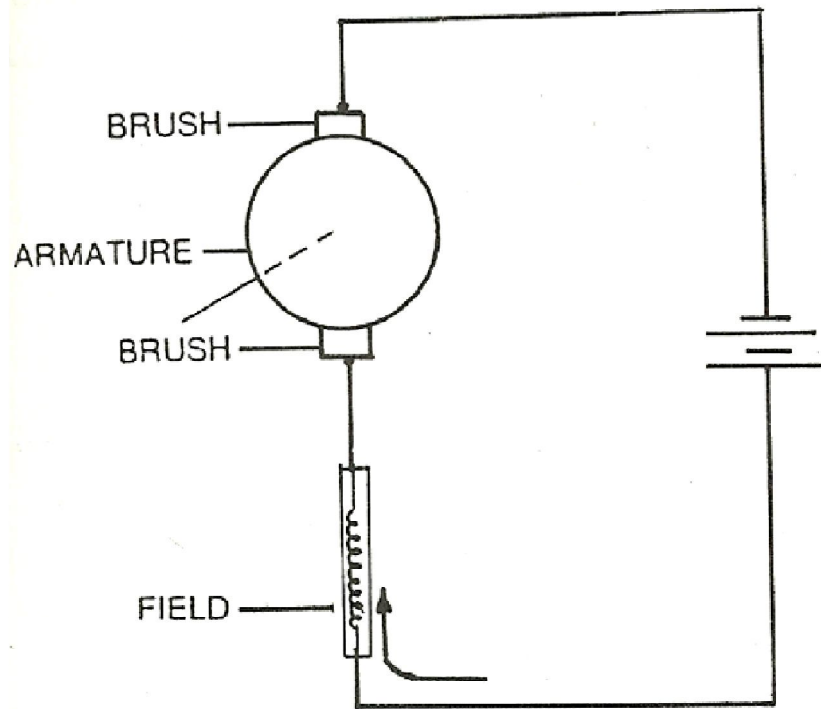
DC Shunt motor



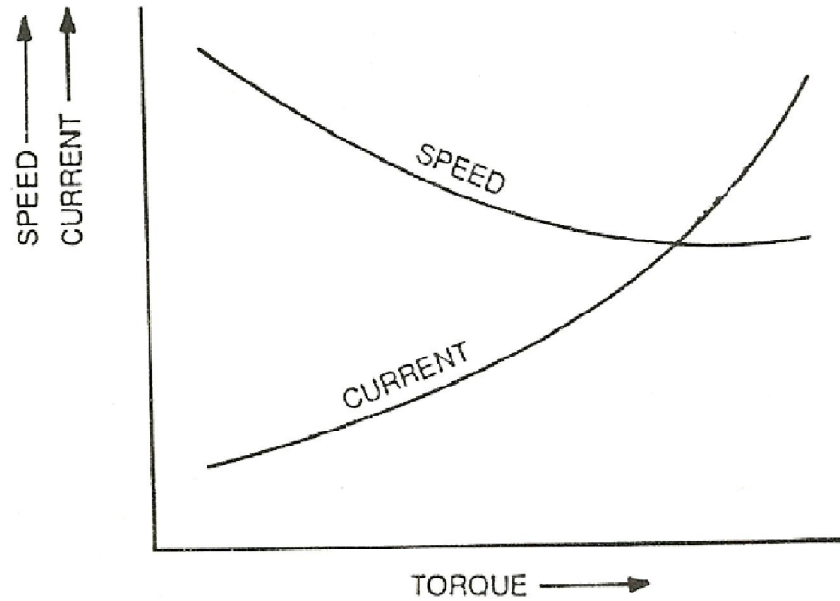
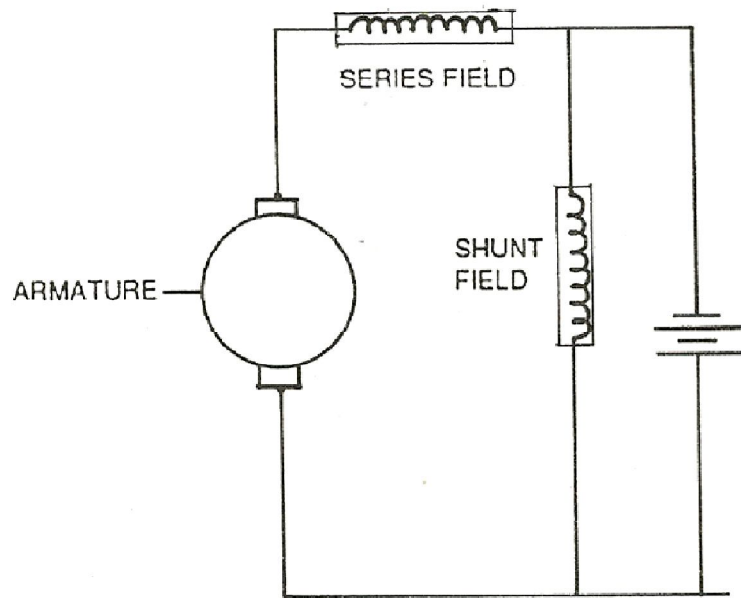
Speed control of DC Shunt motor



DC Series motor



Compound motor



Servo motor

- Servo Motors are motors equipped with a servo mechanism for precise control of angular position.
- The servomotor is paired with some type of encoder to provide position/speed feedback.
- So the motor shaft can be positioned to specific angular positions by sending the servo a coded signal.
- As long as the coded signal exists on the input line, the servo will maintain the angular position of the shaft.
- As the coded signal changes, the angular position of the shaft changes.

Servo motor

- Servo motors usually have a rotation limit from 90° to 180° . Some servos also have rotation limit of 360° or more.
- But servos do not rotate continually. Their rotation is restricted in between the fixed angles.

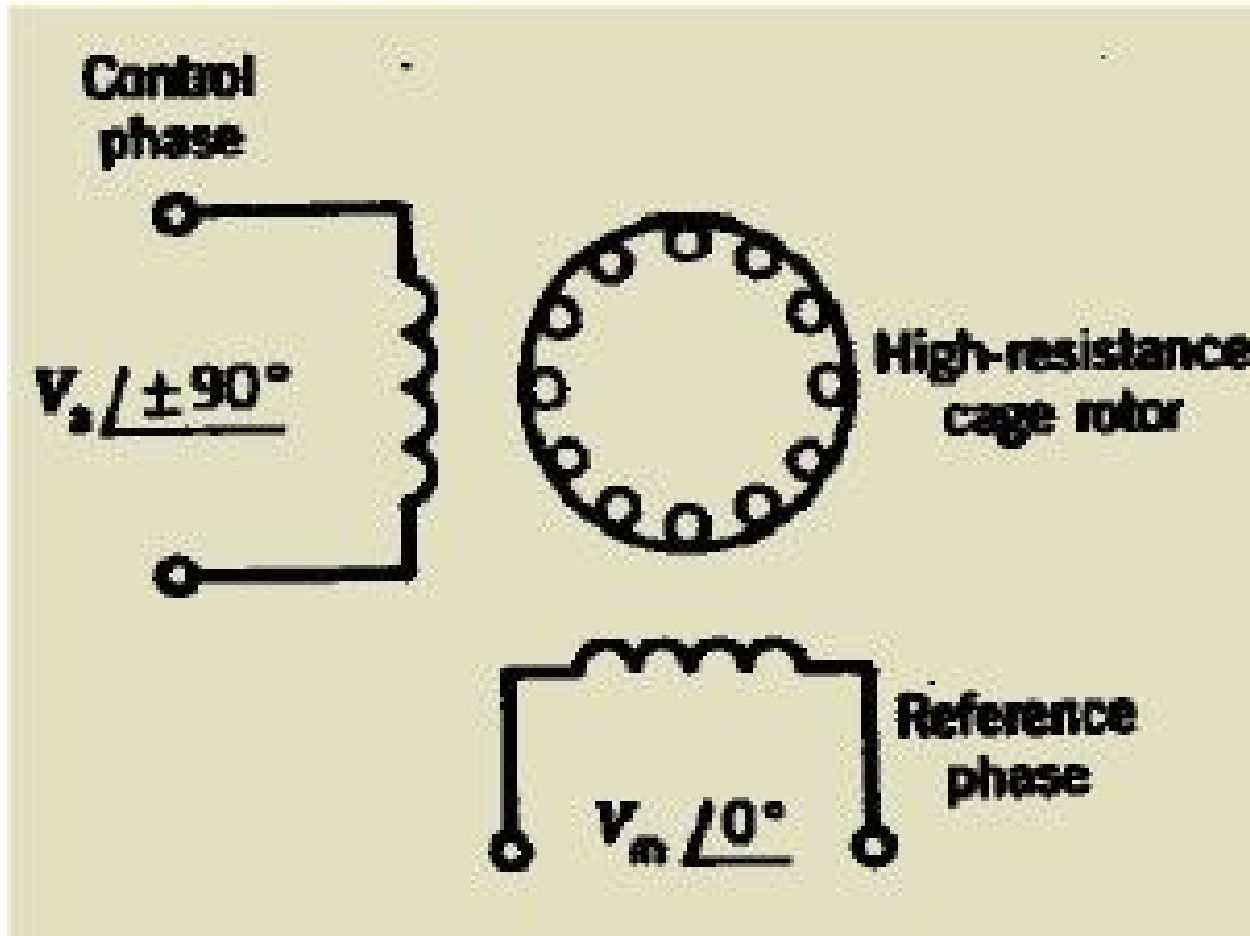
Types of servo motors

- Three basic types of servo motors are used
- AC servo motors, based on induction motor designs;
- DC servo motors, based on dc motor designs;
- AC brushless servo motors, based on synchronous motor designs.

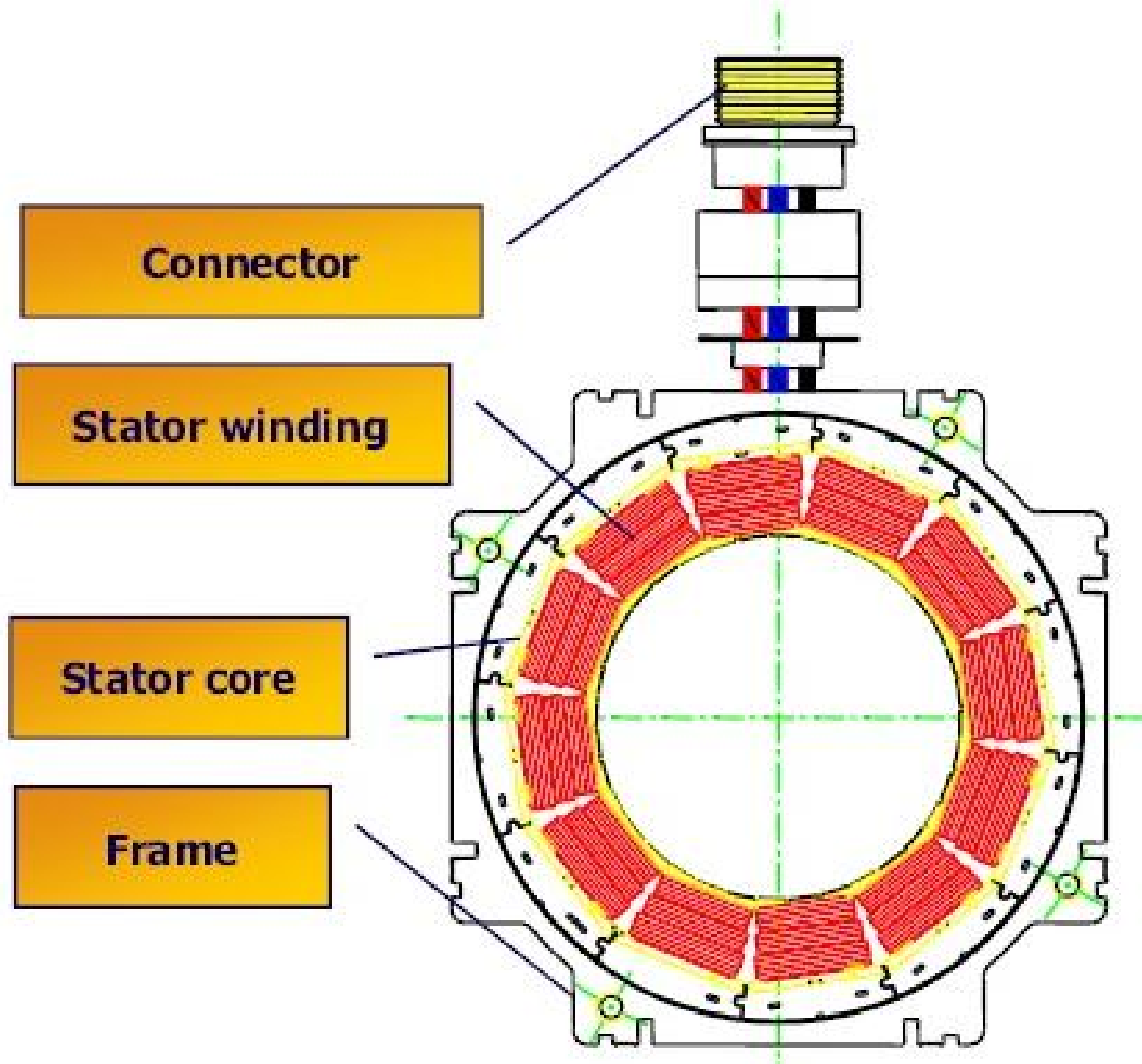
AC servo motors

- AC servomotors are of 2-phase squirrel-cage induction type.
- The stator has two distributed windings displaced 90° electrical degree apart.
- One winding is the reference phase and is connected to a constant voltage source.
- The other winding is the control phase and is supplied with a variable voltage of the same frequency as the reference phase but is phase-displaced by 90° electrical degree.

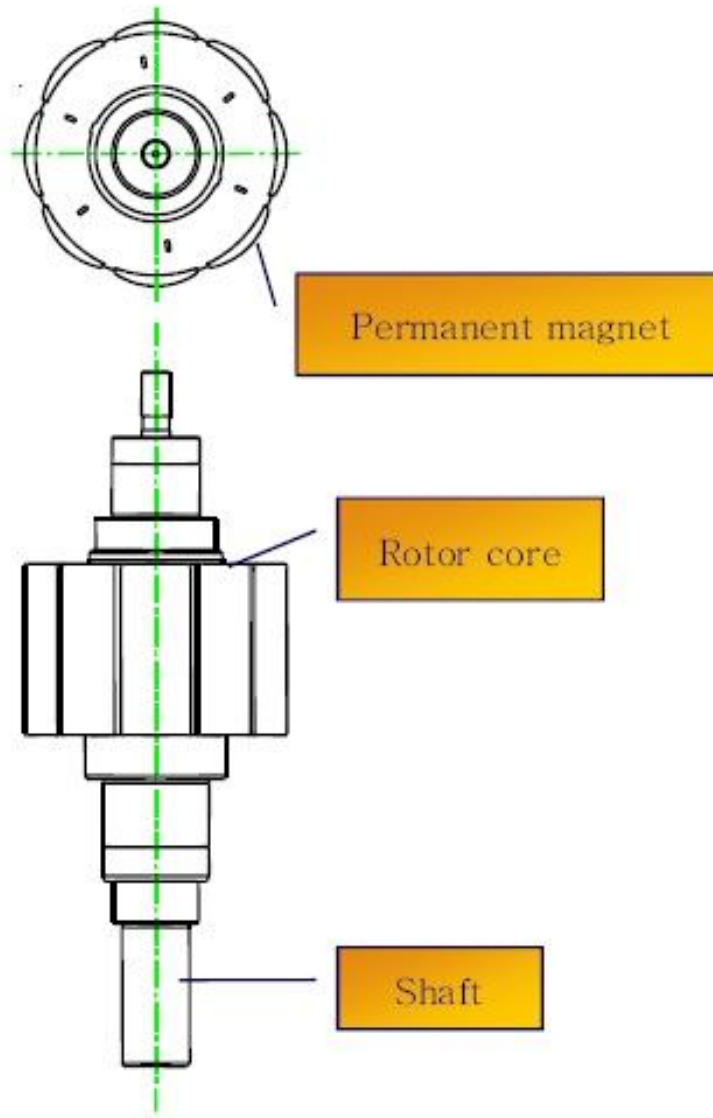
AC servo motors



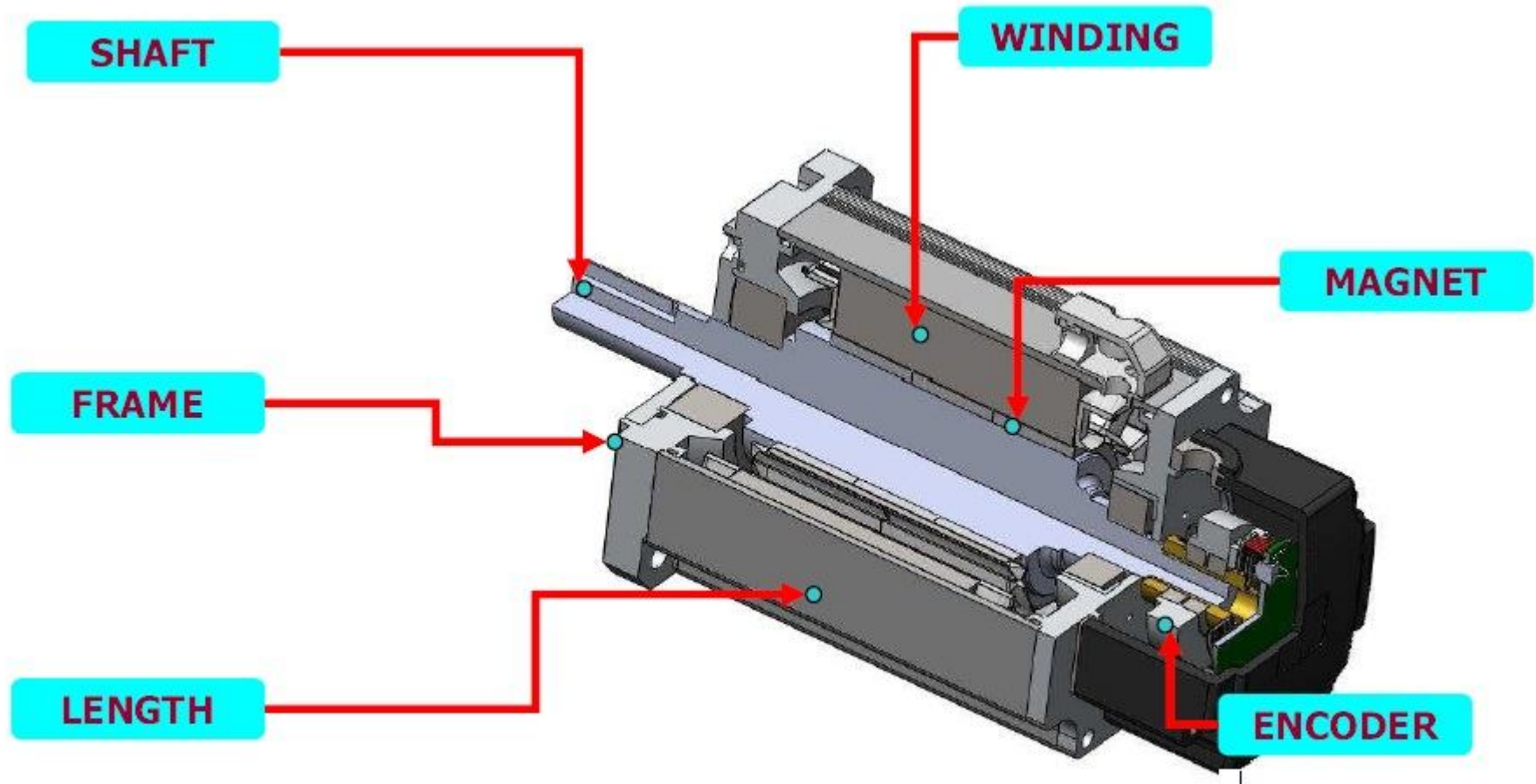
Stator



Rotor

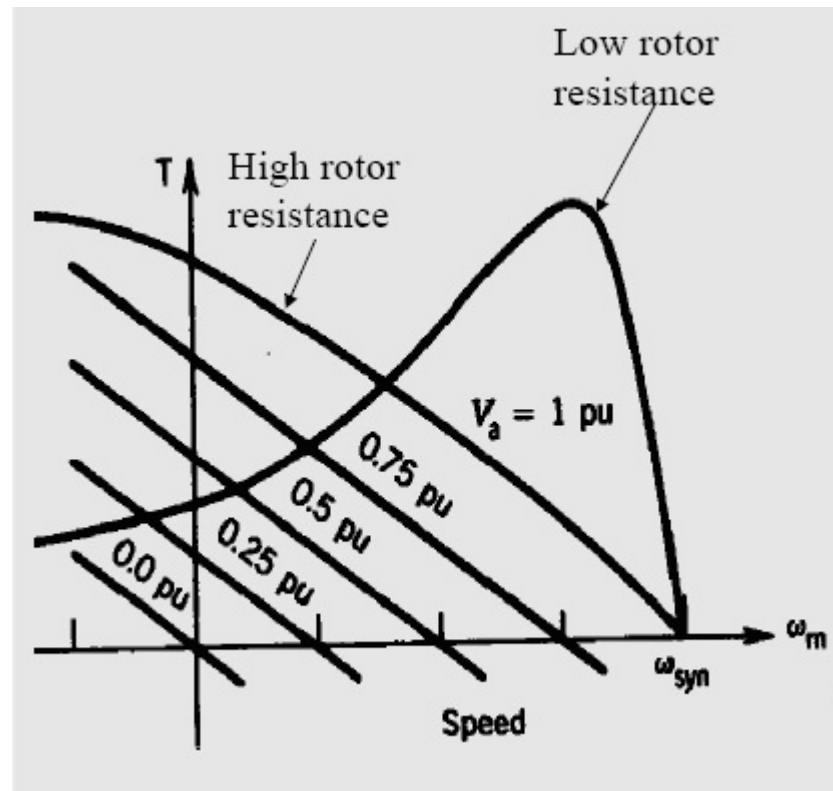


AC servo motors



Characteristics

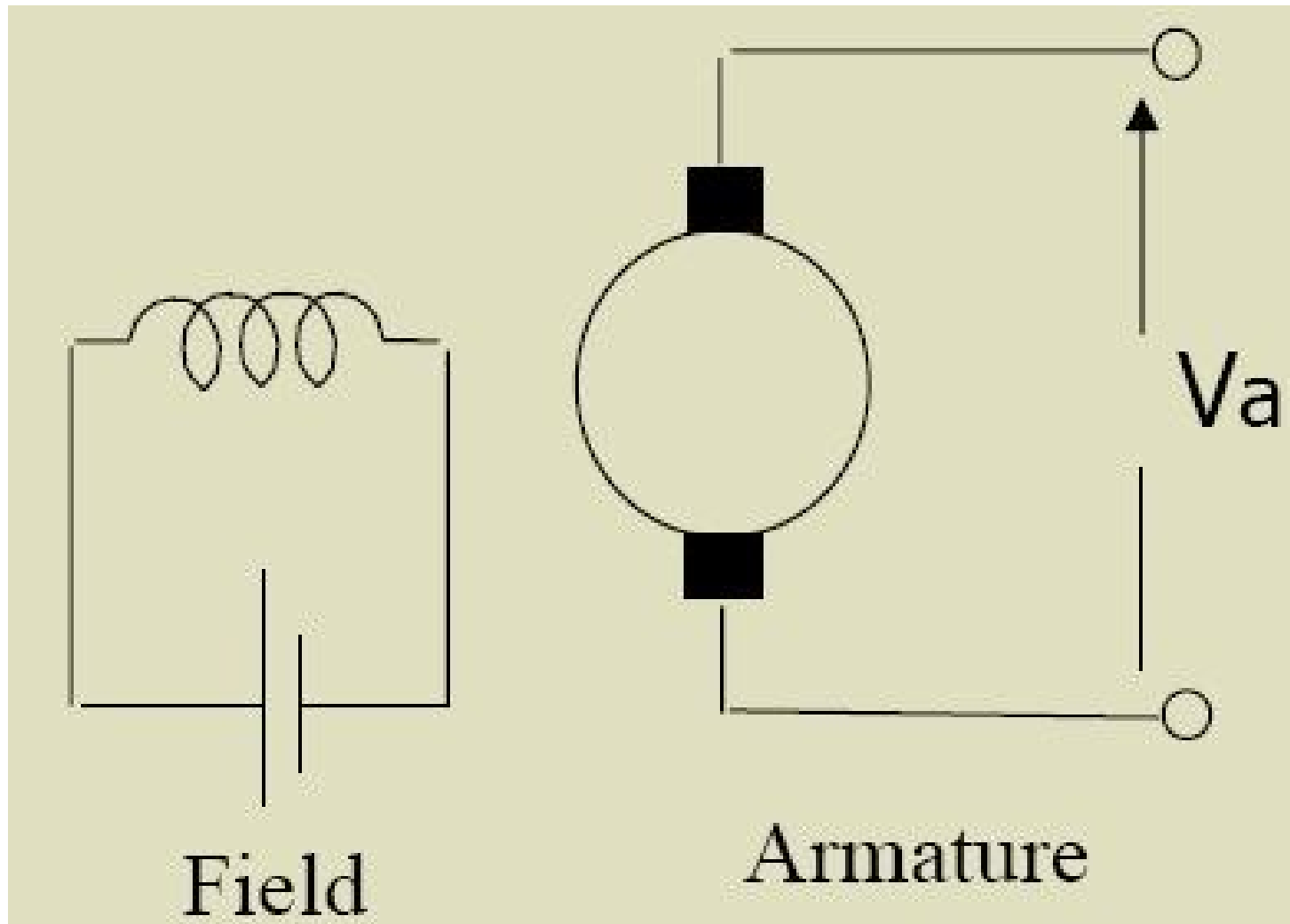
- If the rotor resistance is high the characteristic will be linear over a wide range of speed.



DC servo motor

- DC Servomotors are separately excited dc motor or permanent magnet dc motor.
- They are controlled by armature voltage. The armature is designed to have large resistance so that the torque-speed characteristics are linear.
- Therefore, a step change in the armature voltage results in a quick change in the position or speed of the motor.

DC servo motor



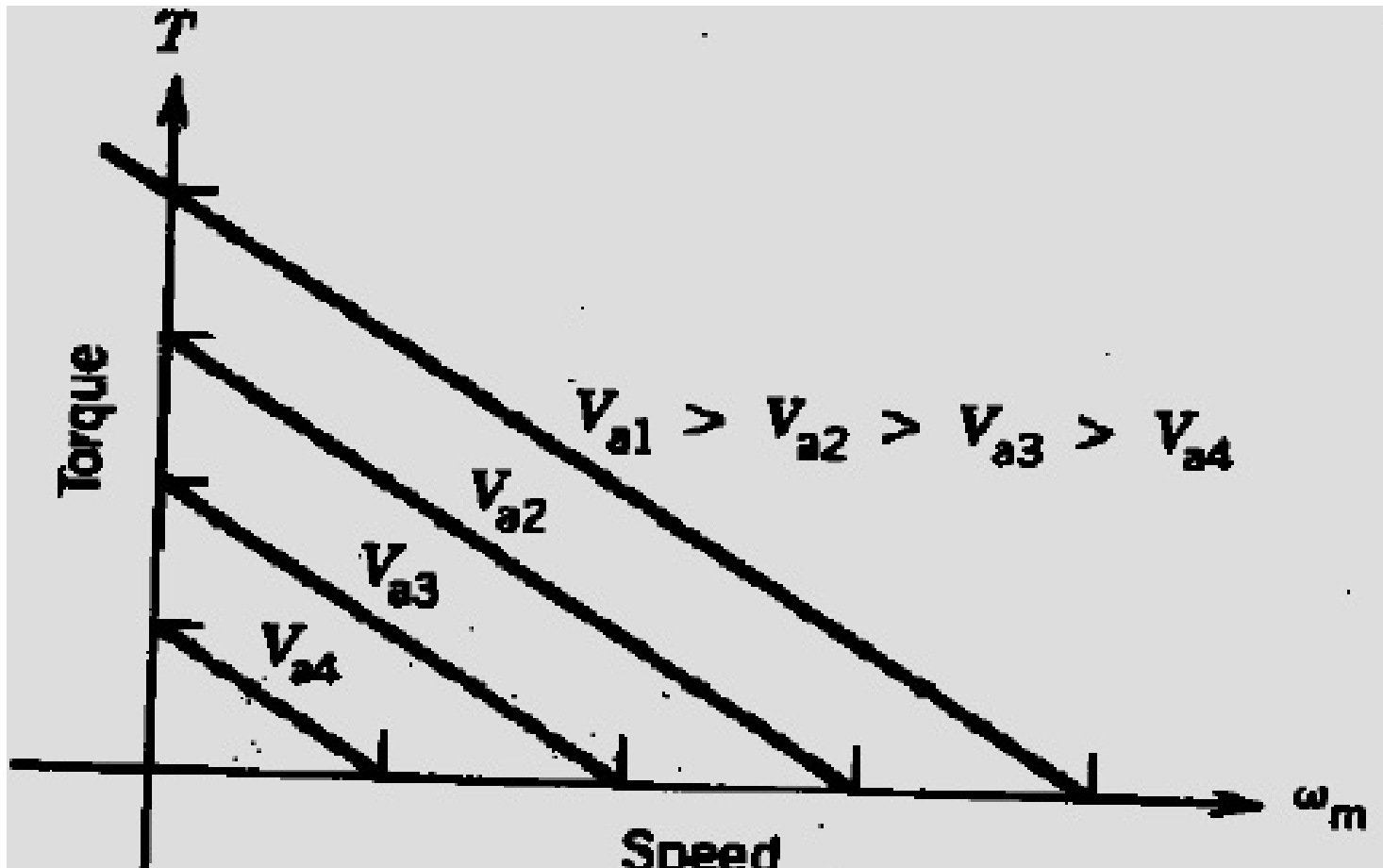
DC servo motor

- The rotor consists of a cylindrical shell of copper or aluminum wire coils which rotate in a magnetic field in the annular space between magnetic pole pieces and a stationary iron core.
- Field is provided by cast AlNiCo magnets whose magnetic axis is radial. Servo motors usually have two, four, or six poles.

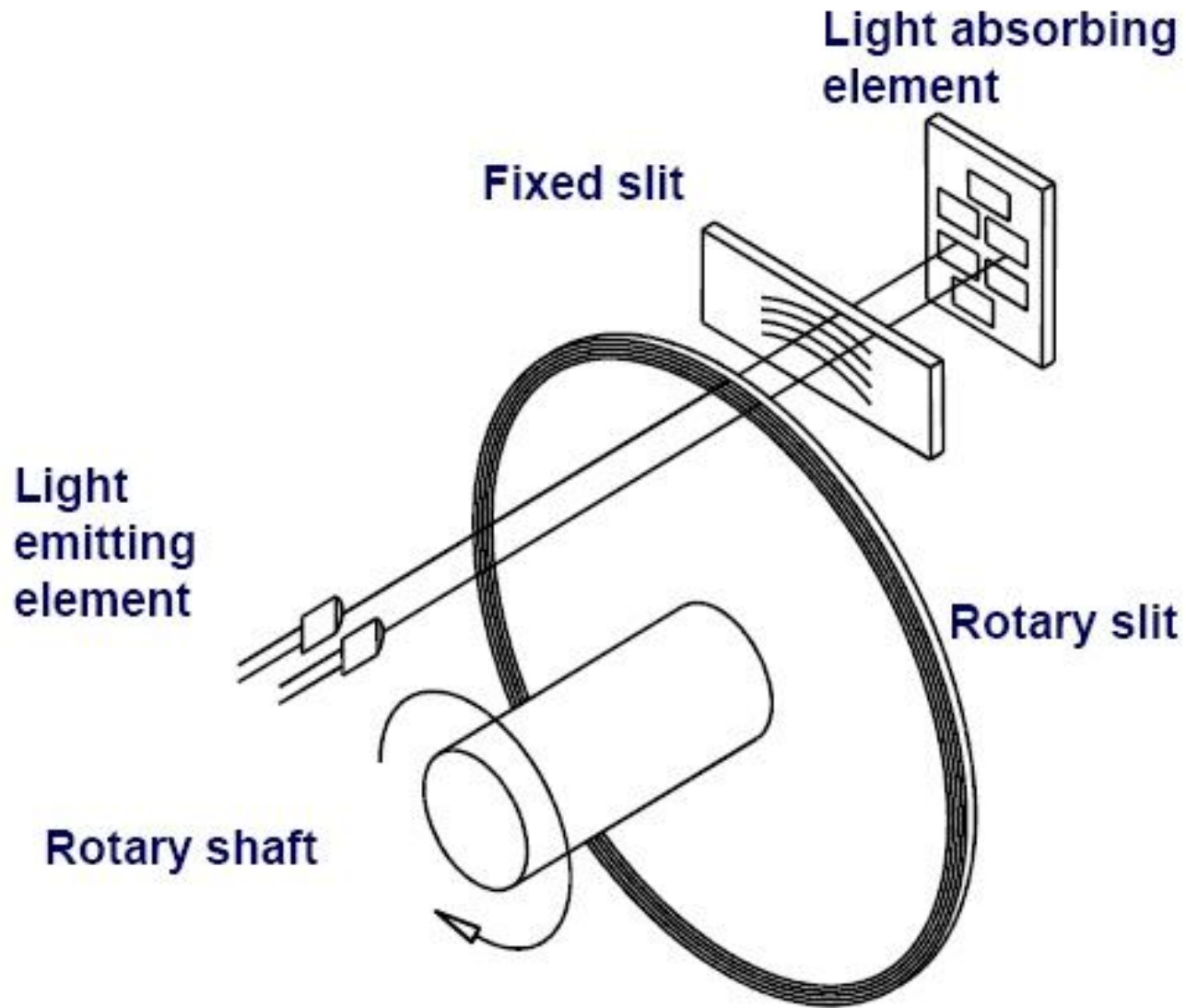
DC servo motor



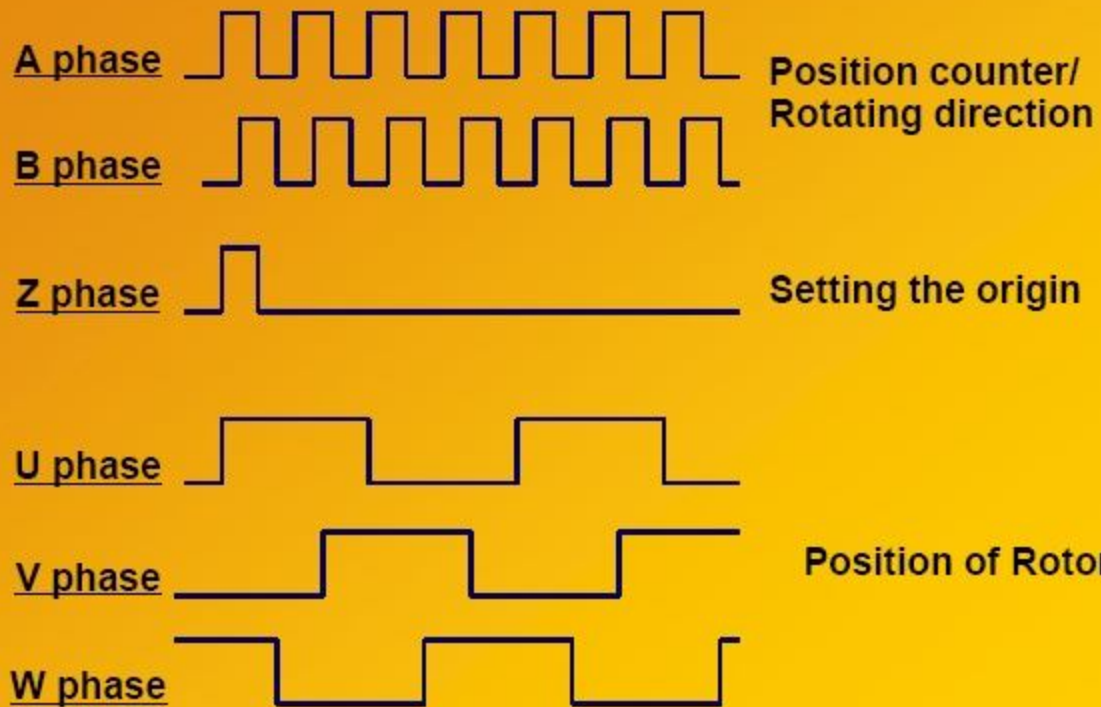
Characteristics



Optical encoder



Output signal of Incremental type



Stepper motor

- SM is an incremental motion motor. Its rotation is not continuous but in steps for each input current pulse received.
- Used for open loop position control which requires very low speed but high precision rotation.
- Average stepper motor's resolution is the amount of degrees rotated per pulse.
- Stepper motors are constant power devices. As motor speed increases, torque decreases.

Stepper motor

- Stepper motors consist of a permanent magnet rotating shaft, called the rotor, and electromagnets on the stationary portion that surrounds the motor, called the stator.
- Its rotor which does not contain any windings and commutator.
- Doubling the resolution of motors is done by a process known as "half-stepping."

Types

- Variable reluctance type
- Permanent magnet type
- Hybrid type

VR SM

- Variable reluctance type SM can be operated using 4 modes which are
 - 1 Phase ON (Full step operation)
 - 2 Phase ON
 - Half step operation
 - Microstepping

VR SM - construction

- It has three to five windings and a common terminal connection, creating several phases on the stator.
- The rotor is toothed and made of metal, but is not permanently magnetized.
- If the rotor has four teeth and the stator has three independent windings, it creates 30 degree steps.

VR SM - operation

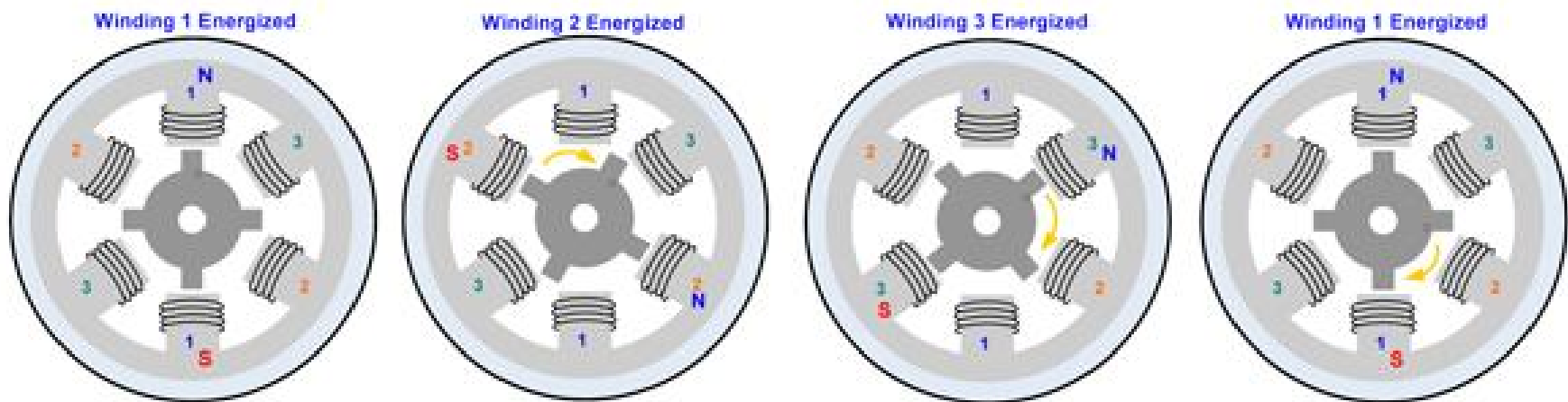
- The rotation is produced by energizing individual windings.
- When a winding is energized, current flows and magnetic poles are created, which attracts the metal teeth of the rotor.
- The rotor moves one step to align the offset teeth to the energized winding.
- At this position, the next adjacent windings can be energized to continue rotation to another step, or the current winding can remain energized to hold the motor at its current position.
- When the phases are turned on sequentially, the rotor rotates continuously.

Rotation control of variable reluctance stepping motor

- Winding sequence:
1, 2, 3, 1 → 3 steps → quarter turn
12 steps per rotation
- Energizing each of the windings in sequence moves the rotor a quarter turn, 12 steps are required for a full rotation.

Winding 1	0	+	0	0
Winding 2	0	0	+	0
Winding 3	+	0	0	+

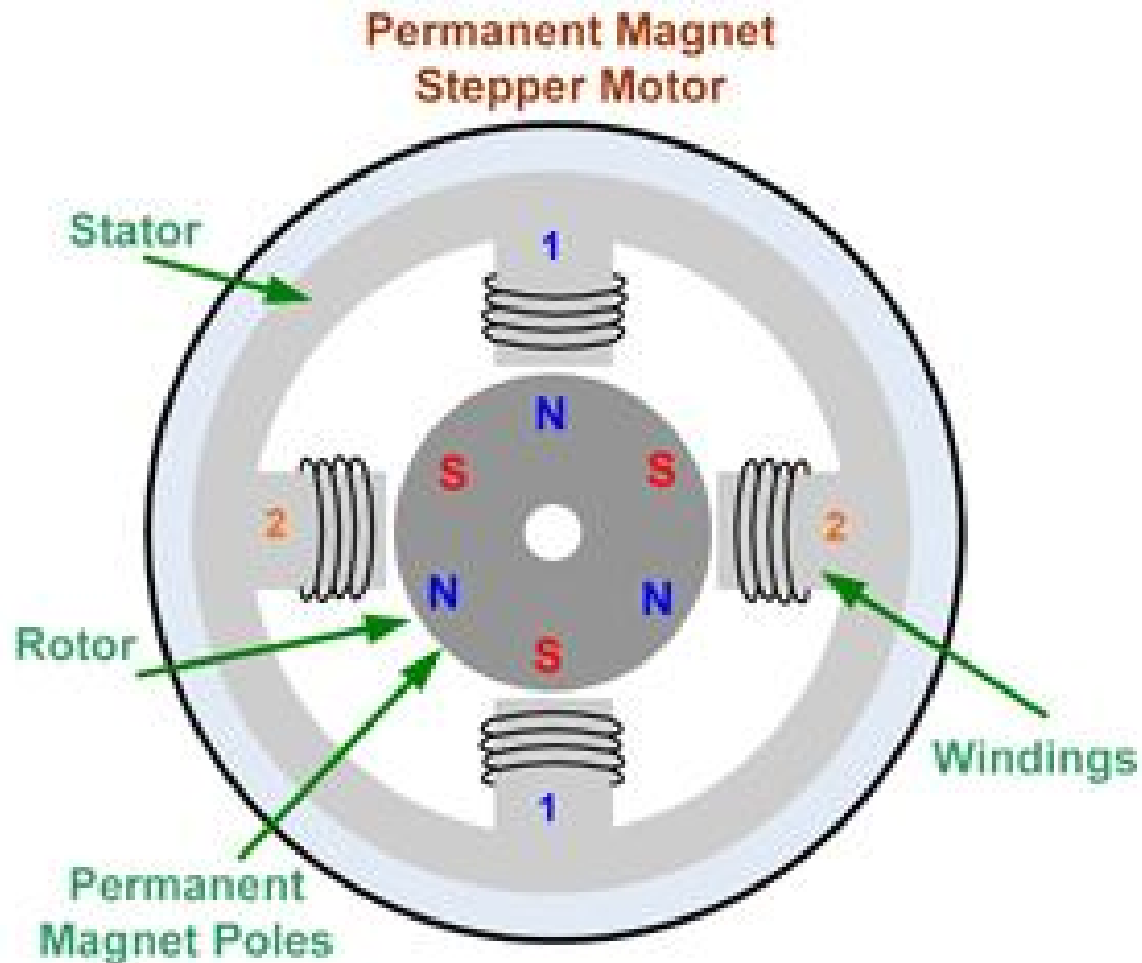
Rotation control of variable reluctance stepping motor



Permanent magnet stepping motor

- A permanent magnet stepping motor consists of a stator with windings and a rotor with per
- Rotation is produced by energizing individual windings in a positive or negative direction.
- When a winding is energized, a north and south pole are created, depending on the polarity of the current flowing.
- These generated poles attract the permanent poles of the rotor so that the rotor moves one step to align the offset permanent poles to the corresponding energized windings.
- At this position, the next adjacent windings can be energized to continue rotation to another step, or the current winding can remain energized to hold the motor at its current position.
- When the phases are turned on sequentially the rotor is continuously rotated.

Permanent magnet stepping motor

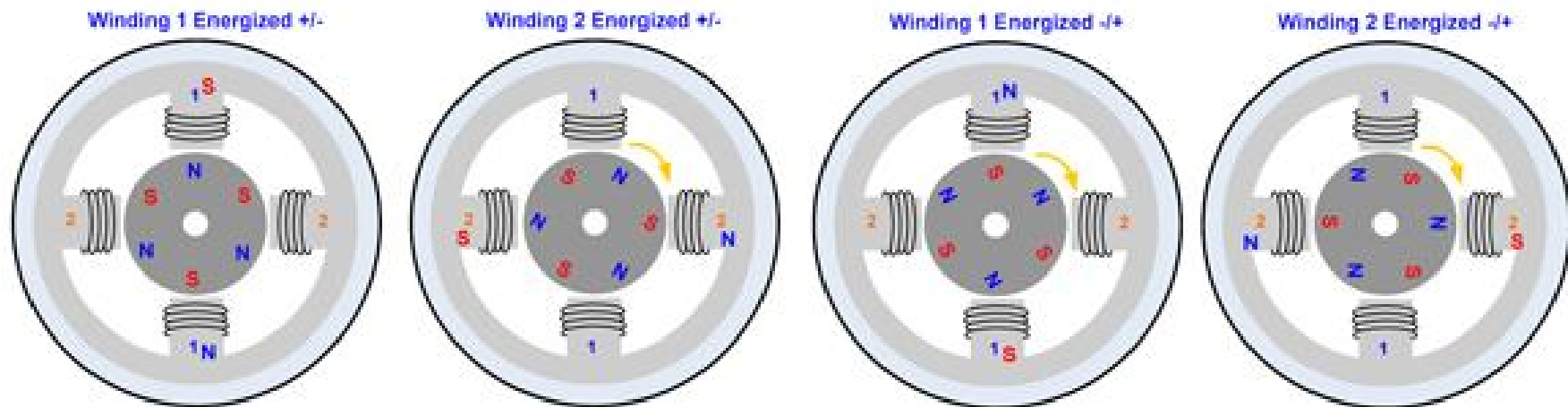


Permanent magnet stepping motor

- Winding in sequence:
1 +/-, 2 +/-, 1 -/+, 2 -/+ → 3 steps → quarter
turn
12 steps per rotation

Winding 1	+	0	-	0
Winding 2	0	+	0	-

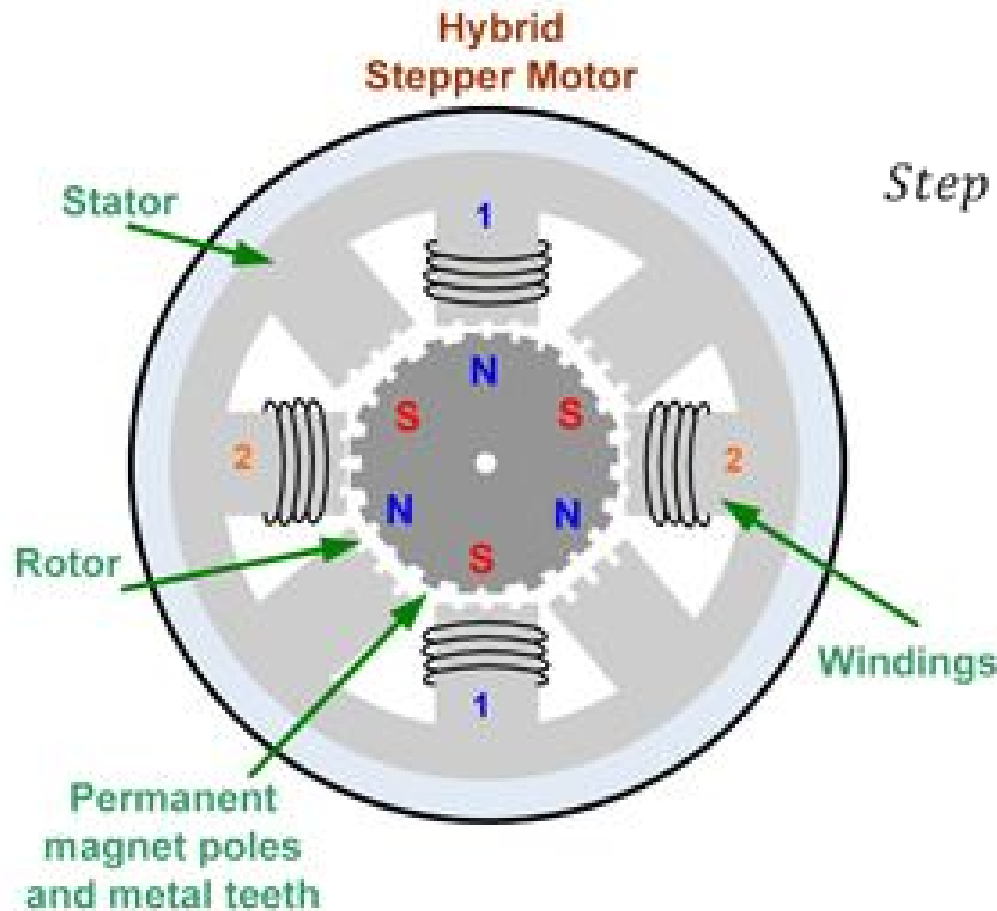
Permanent magnet stepping motor



Hybrid stepping motor

- It combines a permanent magnet and a rotor with metal teeth to provide features of the variable reluctance and permanent magnet motors.
- Hybrid motors are more expensive than motors with permanent magnets, but they use smaller steps, have greater torque, and have greater maximum speeds.
- A hybrid motor rotor has teeth placed on the directional axes. The rotor is divided into parts between constant magnet poles. The number of rotor pole pairs is equal to the number of teeth on one of the rotor's parts.
- The hybrid motor stator has teeth creating more poles than just the main poles containing windings.

Hybrid stepping motor



$$\text{Step Angle} = \frac{360}{\frac{\text{Poles}}{\text{phase} * \text{phases}}}$$
$$= \frac{360}{\text{total poles}}$$

Hybrid stepping motor

- Rotation is produced by energizing individual windings in a positive or negative direction.
- When a winding is energized, a north and south pole are created, depending on the polarity of the current flowing.
- These generated poles attract the permanent poles of the rotor and the finer metal rotor teeth.
- The rotor moves one step to align the offset magnetized rotor teeth to the corresponding energized windings.

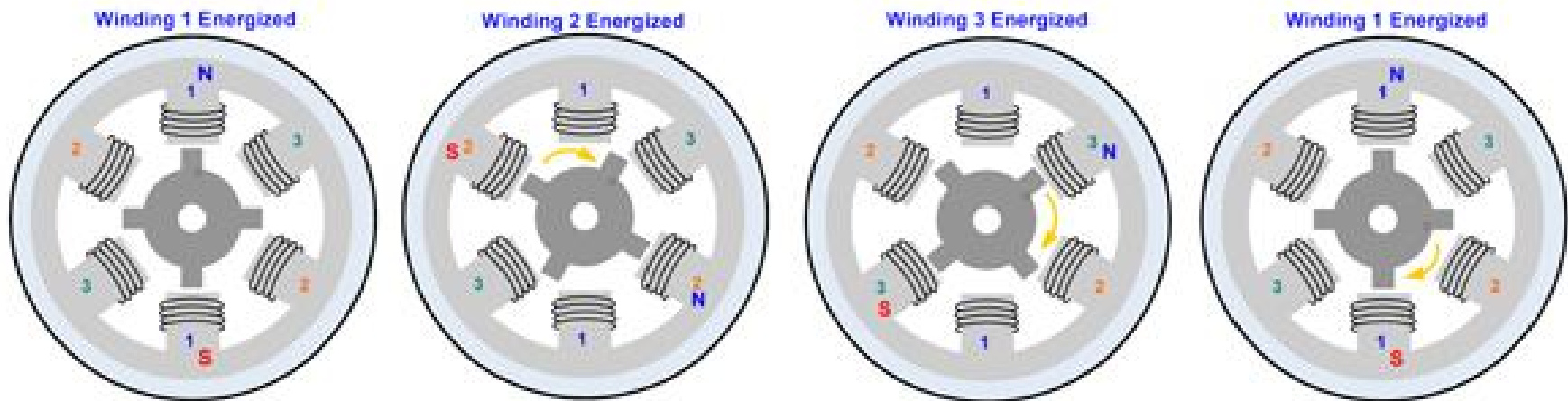
Stepping motor control

- Its rotor position occurs when aligned with the stator magnetic field.
- When the stator changes position, the rotor rotates to occupy a new position.
- There are several stepper motor drive modes:
 - Full-step mode.
 - Double-step mode.
 - Half-step mode.
 - Microstep Mode.

Full-step mode

- Only one winding is turned ON at a time.
- In this mode, the rotor's balanced position for each step is in line with the stator poles.
- With only half of the motor coils used at a given time, the full torque obtained is limited.

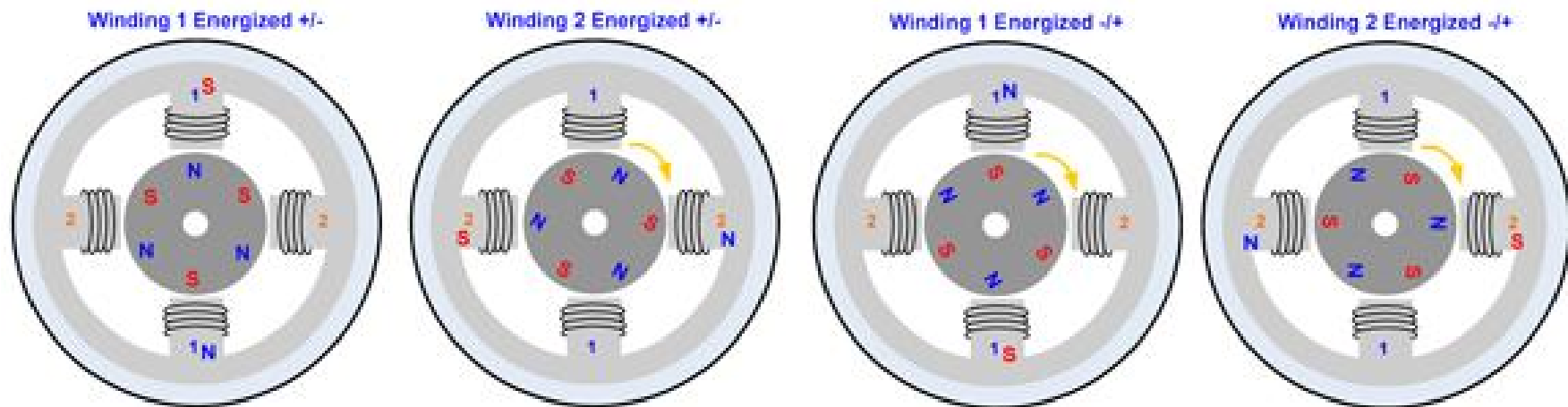
Full-step mode



Double-step mode

- Also called as two phase scheme.
- Two windings are energized in each step.
- This doubles the current through the motor and provides 40 percent more torque.
- With two windings energized, the rotor's balanced position for each step is halfway between the two energized stator poles.

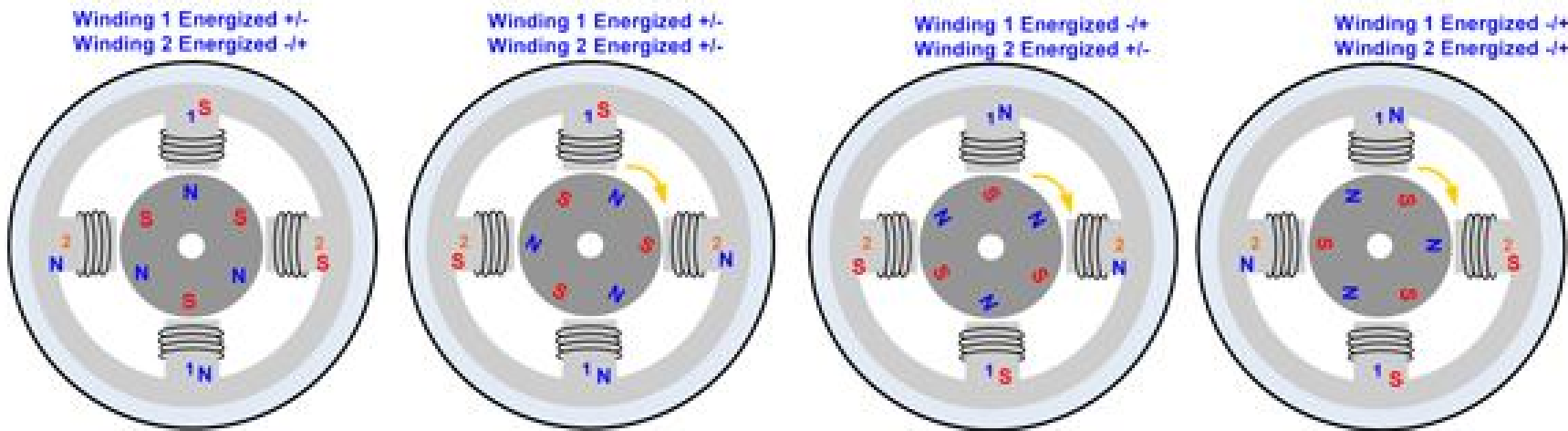
Double-step mode



Half-step mode

- The full-step and double-step drive modes can be combined to generate half-steps of rotation for half-step mode.
- First one winding is turned on, and then the first and second winding is energized, moving the rotor half a step towards.

Half-step mode



Microstep mode

- Microstepping mode is an extension of the half-step drive mode.
- Instead of switching the current in a winding from on to off, the current is scaled up and down in smaller steps.
- When two phases are turned on and the current of each phase is not equal, the rotor position is determined by the current phase ratio.
- This changing current ratio creates discrete steps in the torque exerted on the rotor and results in smaller fractional steps of rotation between each full-step.

Microstep mode

