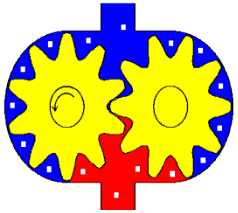
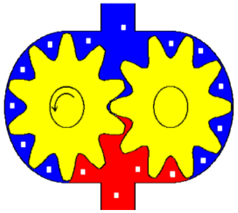


THE SOURCE OF HYDRAULIC POWER

PUMPS

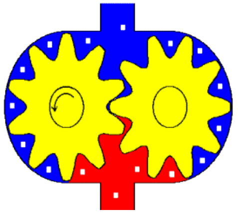
PUMP



- INTRODUCTION

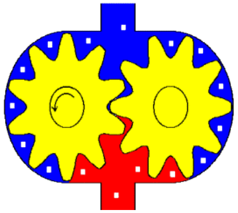
- A pump is device which converts mechanical energy into hydraulic energy.

TYPES OF PUMPS



- Dynamic (Non-positive Displacement)pumps
- Positive Displacement Pumps

Non-positive Displacement or Dynamic Pumps



- These are low pressure, high volume flow pumps.
- They are used only for fluid transport and are not used in fluid power industry because they cannot withstand high pressures.
- They have relatively small volumetric efficiency compared to positive pumps and low –pressure discharge output.
- Max pressure limited to 15 to 20 bars
- Examples of these pumps are:

  Centrifugal pumps (Impeller Type)

  Axial Pumps (Propeller Type)

Centrifugal and Axial pumps

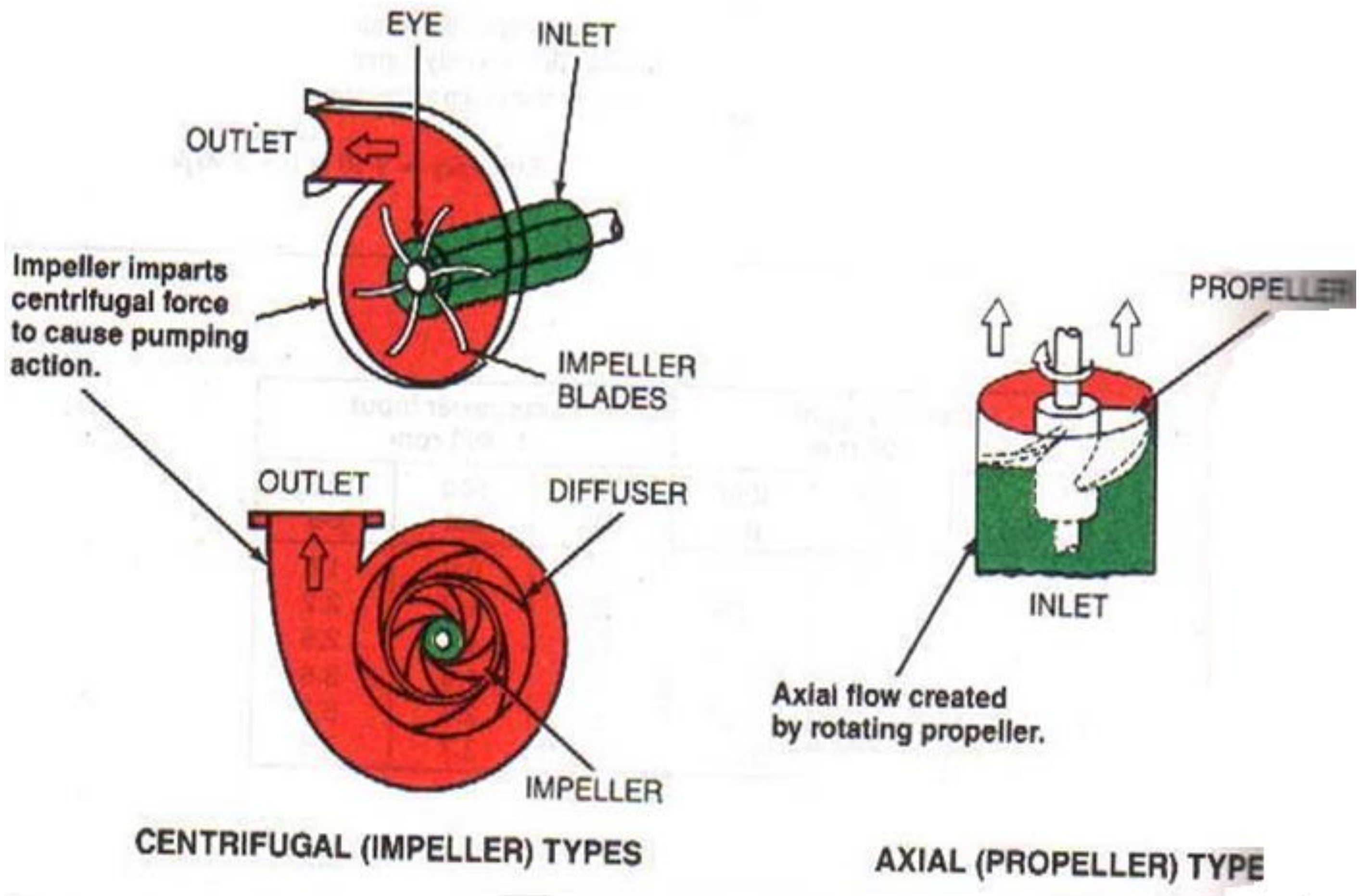
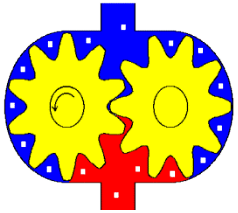


Fig. 1. Non -positive(Dynamic)displacement pumps

Positive Displacement Pumps



- This type is used universally for fluid power systems
- As the name implies, these pumps eject a fixed volume of flow into the hydraulic system per revolution of pump shaft
- They have large volumetric efficiency and high pressure discharge output.

These pumps have the following advantages:

- High pressure capacity, up to 700 bars
- Small, compact size
- Better performance characteristics, i.e., high efficiency over a wide range of speed and pressure.

Pumping Theory

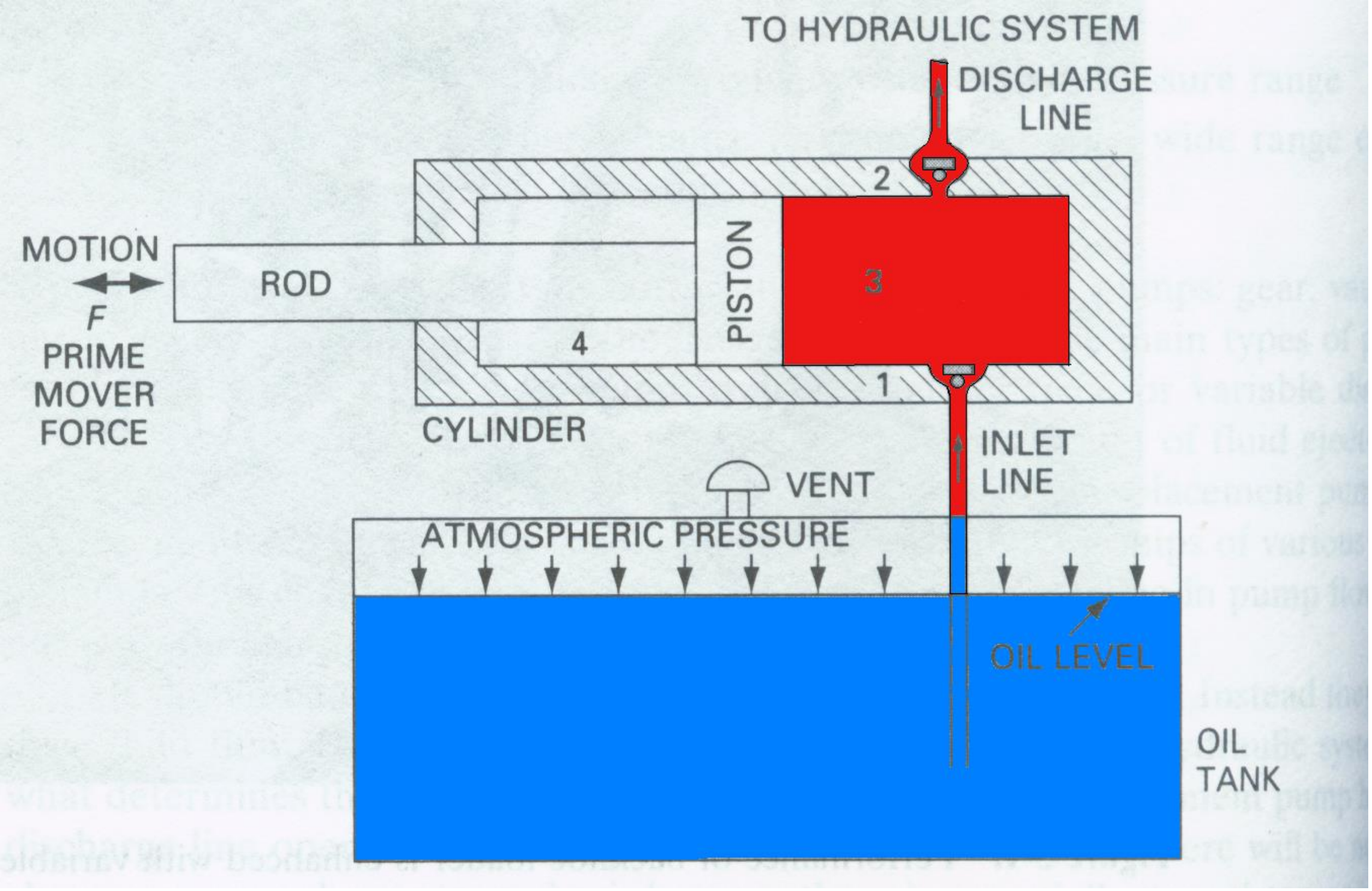
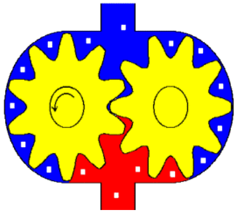


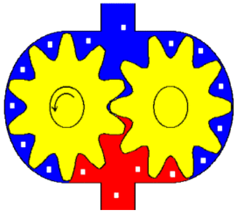
Fig. 2. Pumping action of a simple piston pump

Positive Displacement Pumps



1. Gear pumps
   a. External gear pumps
   b. Internal gear pumps
   c. Lobe pumps
   d. Screw pumps

Positive Displacement Pumps

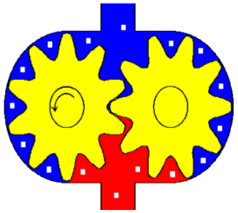


2. Vane pumps

a. Unbalanced vane pumps (fixed or variable displacement)

b. Balanced vane pumps (fixed displacement only)

Positive Displacement Pumps



3. Piston pumps

a. Axial design

b. Radial design

EXTERNAL GEAR PUMP

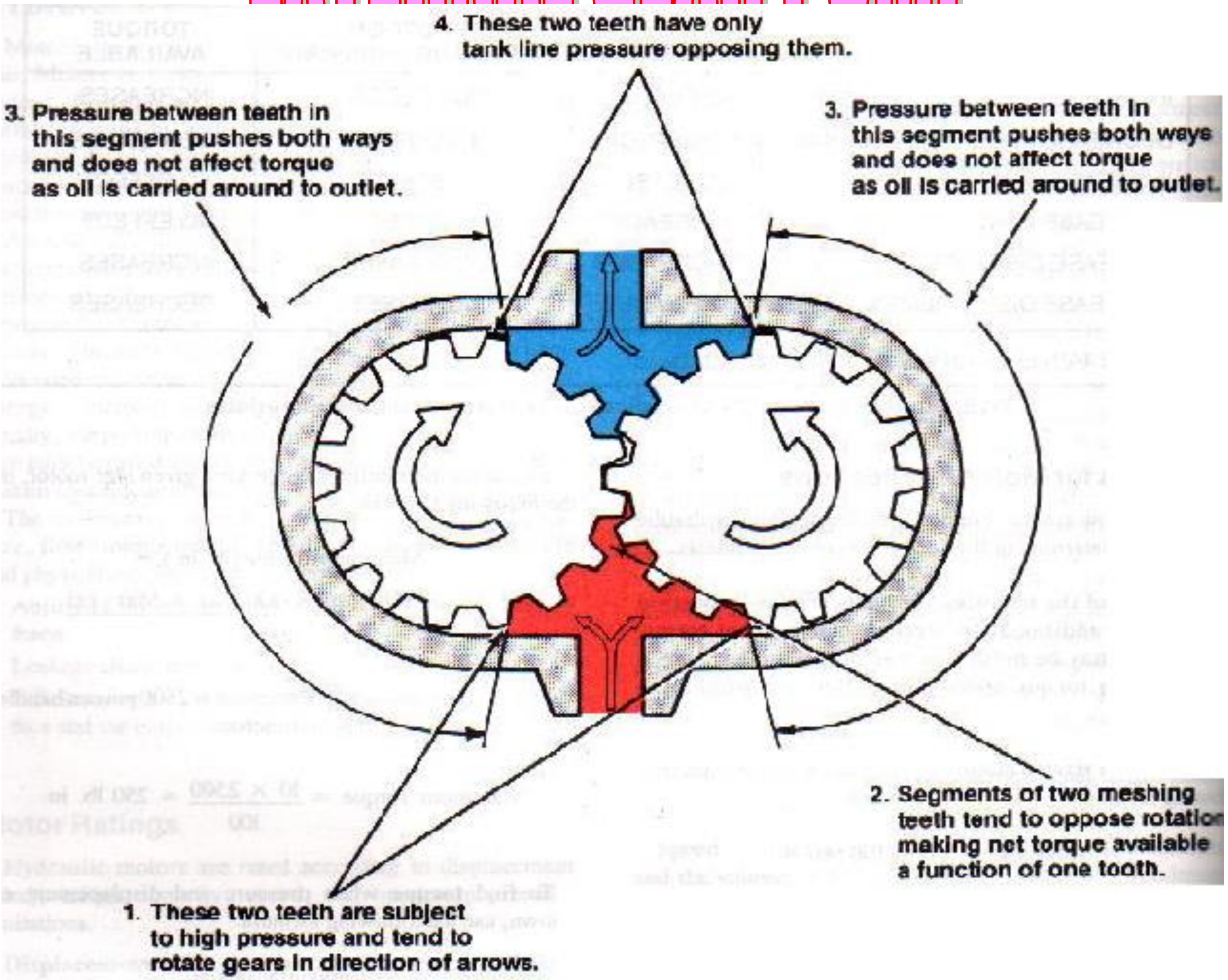
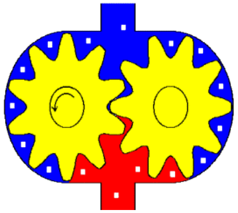
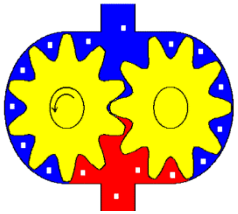


Fig. 3. External gear pump operation

Volumetric Displacement and Theoretical Flow Rate



- D_0= out side diameter of gear teeth in meter
- D_i= inside diameter of gear teeth in meter
- L= width of gear teeth in meter
- V_D=displacement volume of pump in cubic meter per revolution
- N= rpm of pump
- Q_T= theoretical pump flow – rate



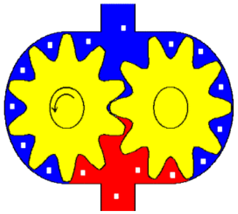
Volumetric displacement

- $V_D = \Pi/4(D_0^2 - D_i^2)L$

Theoretical flow rate

- $Q_T = V_D \text{ X } N$

Volumetric Efficiency



- There must be a small clearance (~25 microns) between the teeth tip and pump housing. As a result some of oil at the discharge port can leak directly back toward the suction port. This means actual flow rate Q_A is less than the theoretical flow rate Q_T

$$\eta_V = Q_A / Q_T$$

- Higher the discharge pressure , the lower the volumetric efficiency because internal leakage increases with pressure.

Numerical Problems

1. A gear pump has a 30mm outside diameter, a 20 mm inside diameter, and a 10 mm width. If the actual pump flow at 1800 rpm and rated pressure is 20 bar, what is the volumetric efficiency?
2. A gear pump has a 75mm outside diameter, a 50 mm inside diameter, and a 25 mm width. If the volumetric efficiency is 90% at rated pressure, what is the corresponding actual flow-rate? The pump speed is 1000 rpm.

VANE PUMP

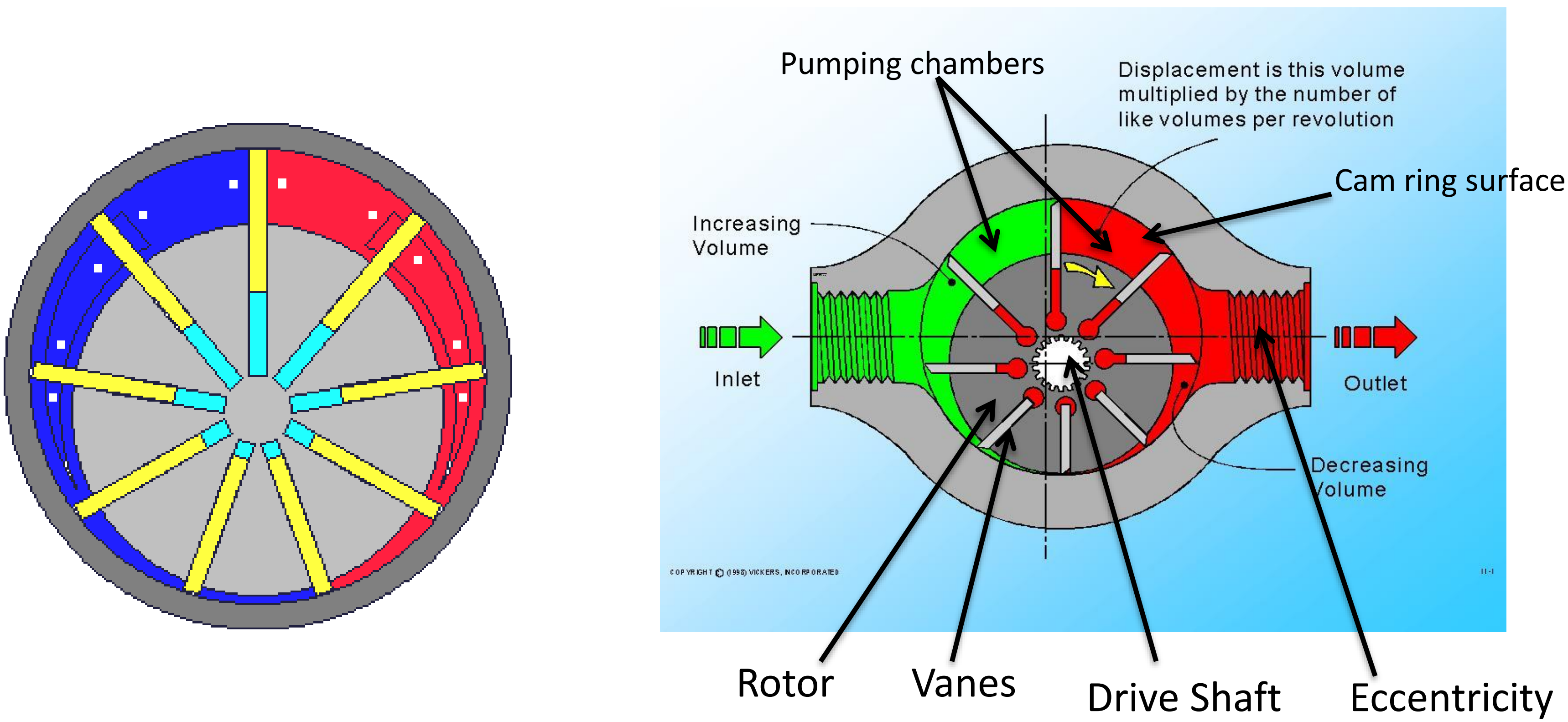
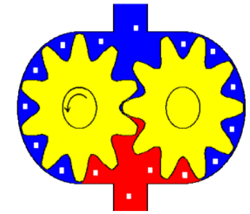


Fig. 4. Vane pump operation

Analysis of Volumetric Displacement



- D_c =diameter of cam ring (m)
- D_R =diameter of rotor (m)
- L = width of rotor (m)
- V_D = pump volumetric displacement (cubic meter)
- e = eccentricity (m)
- e_{max} = maximum possible eccentricity (m)
- V_{Dmax} =maximum possible volumetric displacement (m)

From geometry, we can find the maximum possible eccentricity:

$$e_{max} = \frac{D_C - D_R}{2}$$

This maximum value of eccentricity produces a maximum volumetric displacement

$$V_{Dmax} = \frac{\pi}{4}(D_C^2 - D_R^2)L$$

Noting that we have the difference between two squared terms yields

$$V_{Dmax} = \frac{\pi}{4}(D_C + D_R)(D_C - D_R)L$$

Substituting the expression for emax yields

$$V_{Dmax} = \frac{\pi}{4}(D_C + D_R)(2e_{max})L$$

The actual volumetric displacement occurs when emax=e

$$V_{Dmax} = \frac{\pi}{2}(D_C + D_R)eL$$

BALANCED VANE PUMP

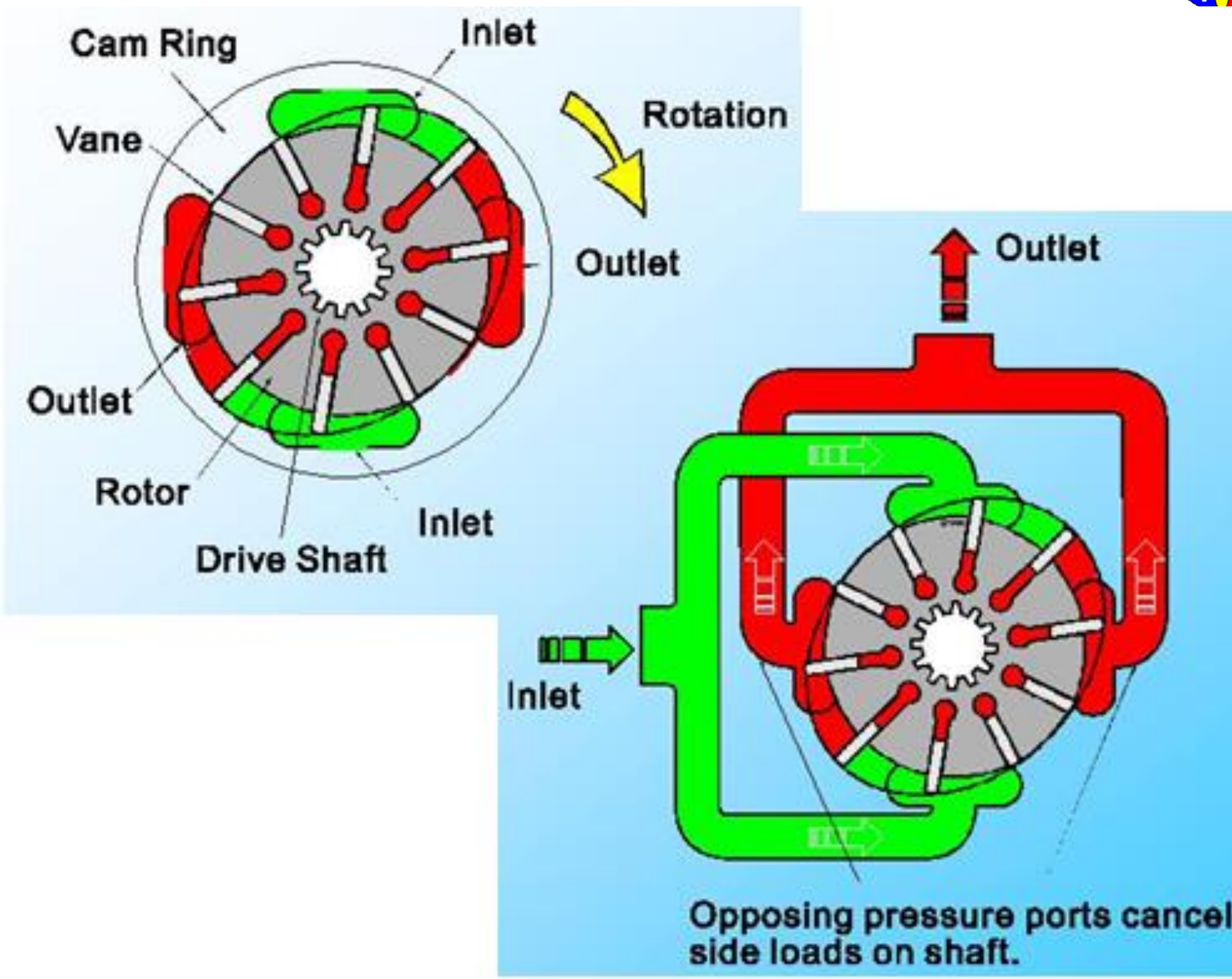
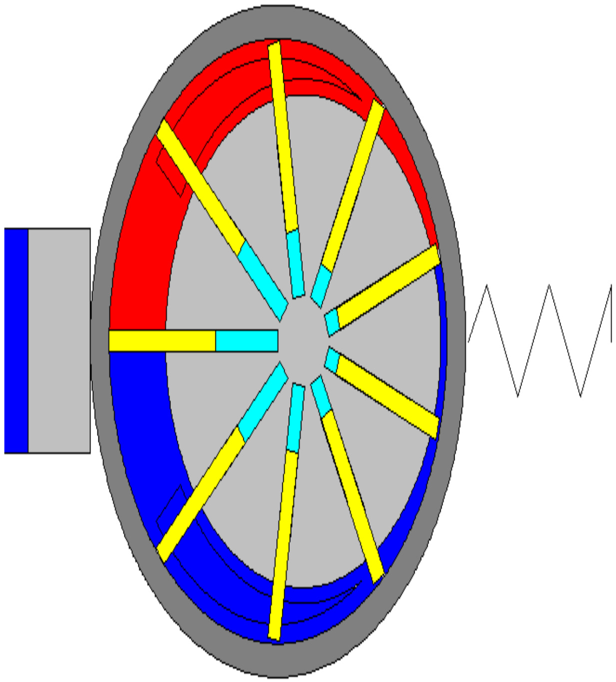
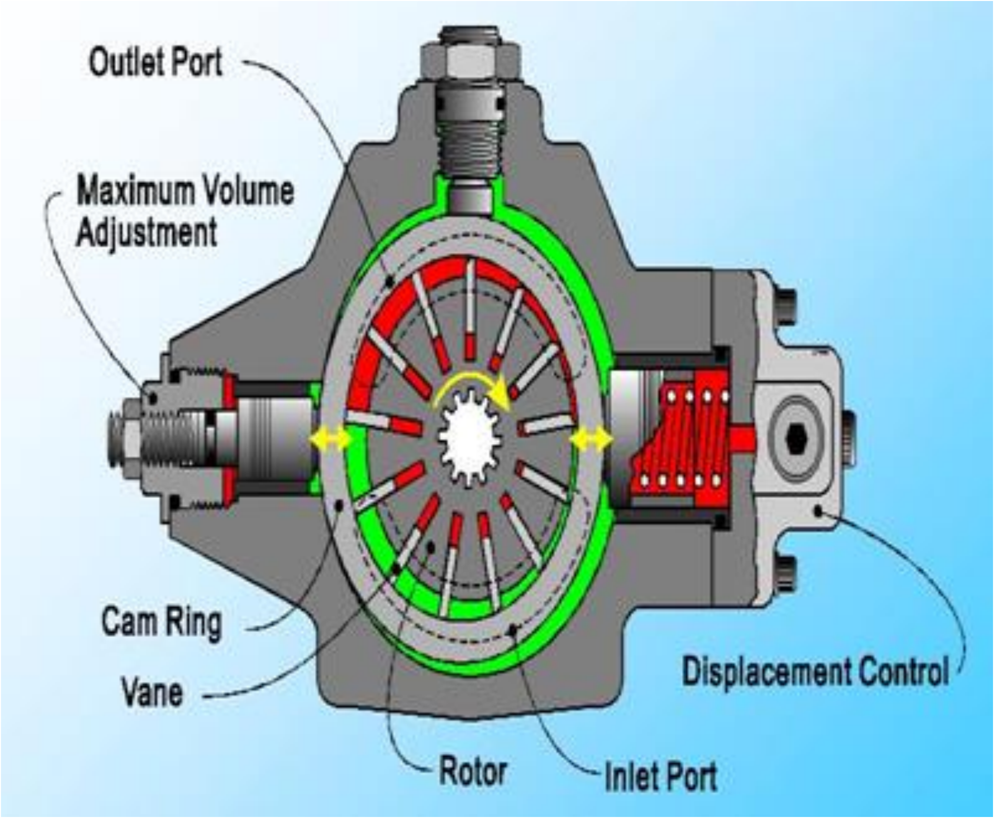


Fig. 5. Balanced Vane pump principal

Pressure compensated vane pump





PISTON PUMPS

Piston pumps

- Axial design
  - Bent-axis design
  - Swash plate design
- Radial design

Axial piston pump (bent axis design)

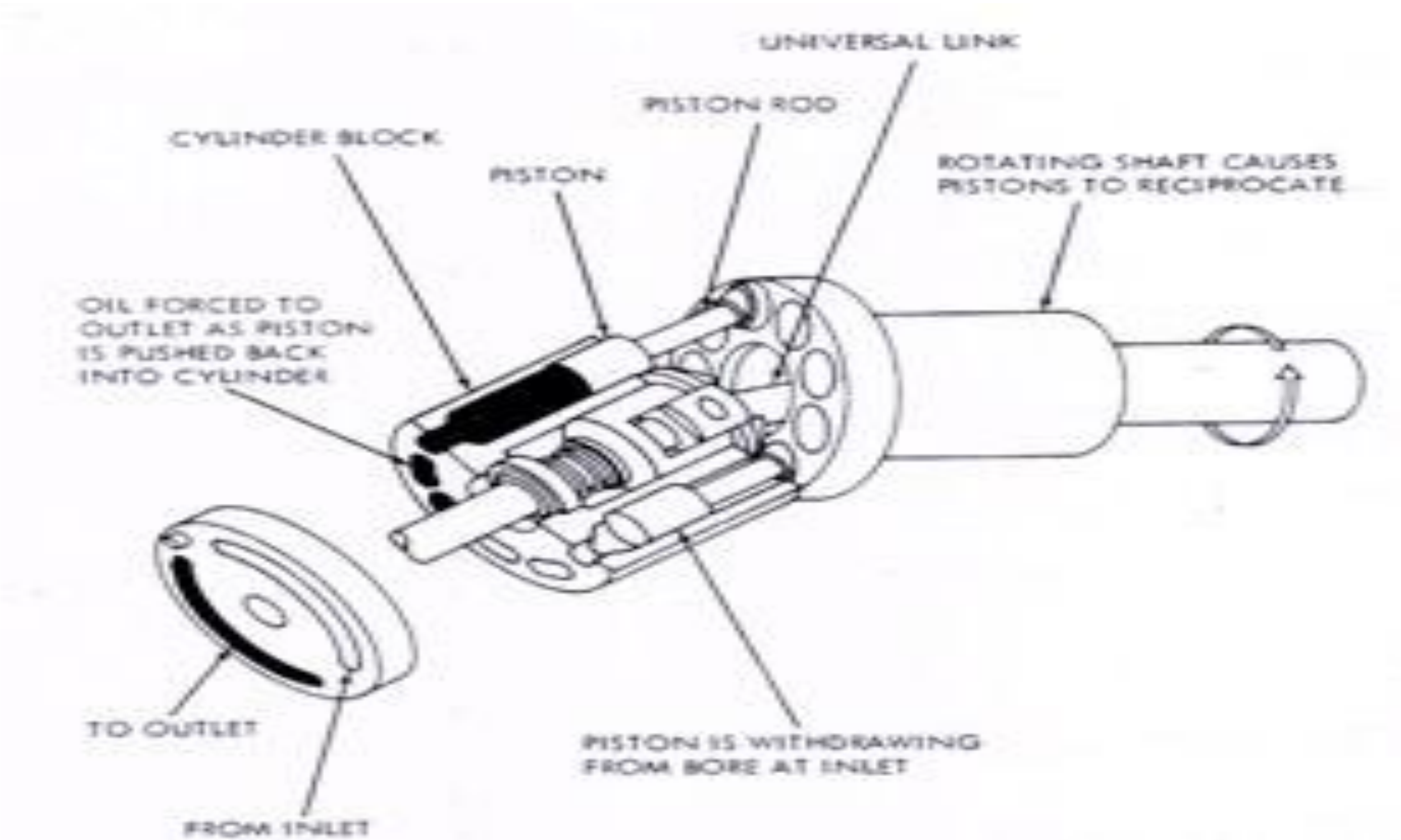


Fig. 8. Axial piston pump(bent axis type)

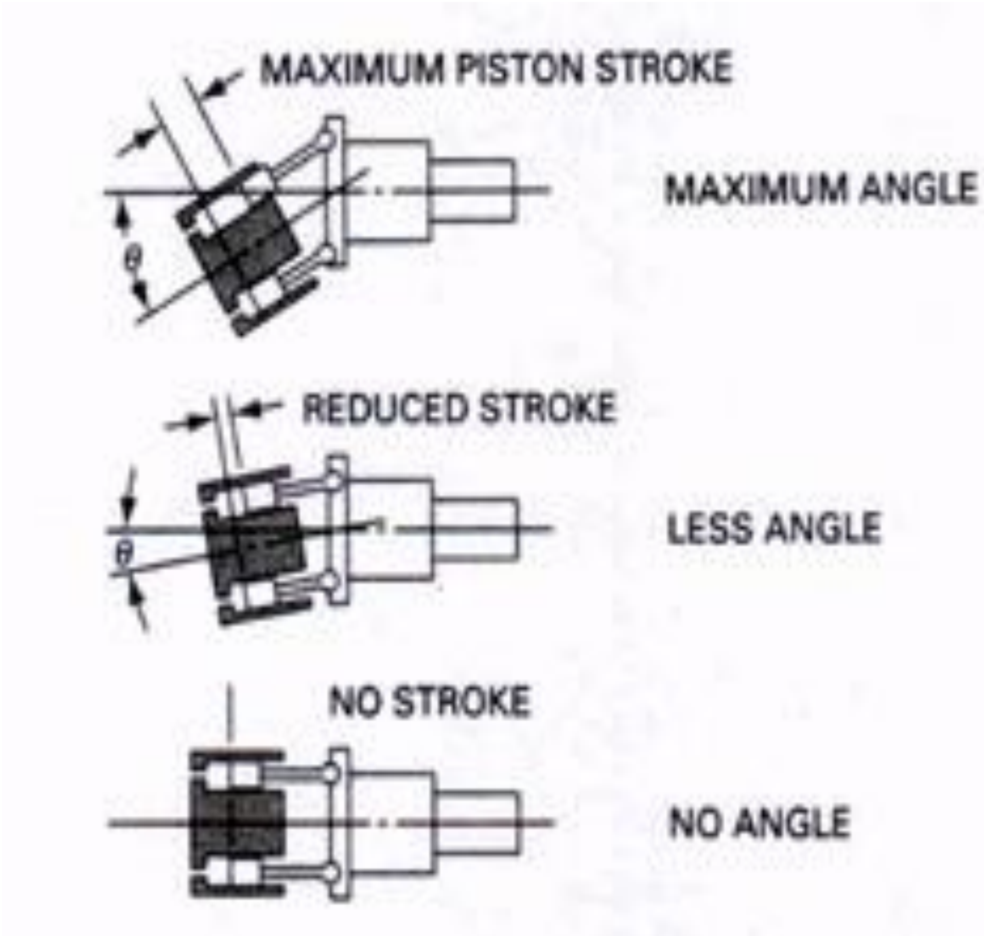
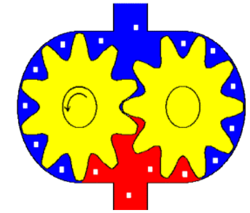


Fig. 9. Volumetric displacement changes with offset angle.



- The volumetric displacement of the pump varies with the offset angle θ as shown in figure.
- No flow is produced when the cylinder block centre line is parallel to the drive shaft centre line. This angle can vary from 0° to a maximum of 30°.

Problem:

What is the theoretical flow rate from a fixed-displacement axial piston pump with a nine- bore cylinder operating at 2000 RPM? Each bore has a diameter of 15 mm and stroke is 20 mm.

Solution: Theoretical flow rate is given by

$$Q_T = \text{Volume} \times \text{RPM} \times \text{Number of pistons}$$

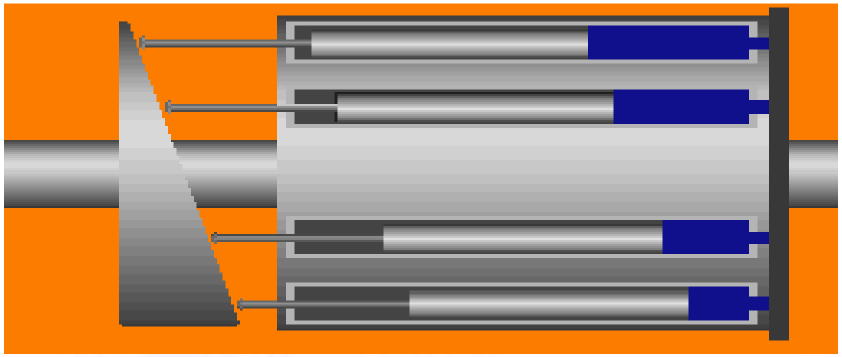
$$= \frac{\pi}{4} \times D^2 \times L \times N \times n$$

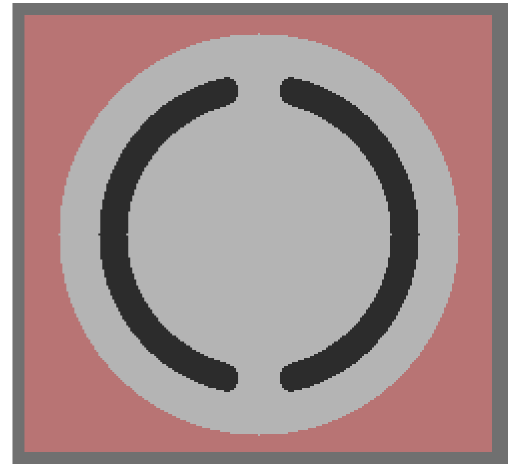
$$= \frac{\pi}{4} \times 0.015^2 \times 0.02 \times \frac{2000}{60} \times 9$$

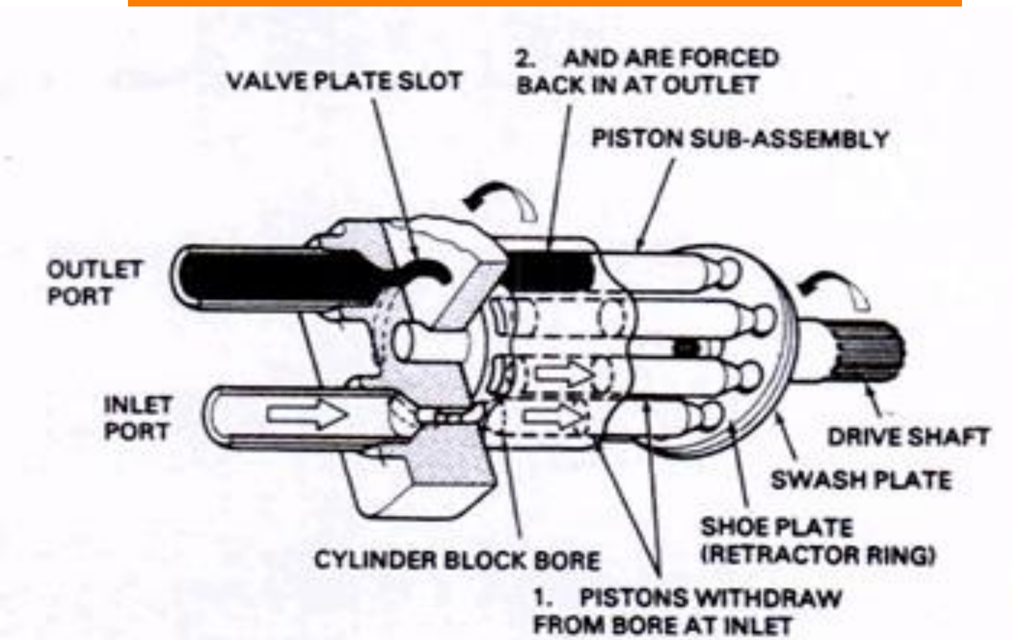
$$= 10.6 \times 10^{-3}\,\text{m}^3/\text{s}$$

$$= 1.06\ \text{LPS} = 63.6\ \text{LPM}$$

Axial piston pump (swash plate design)







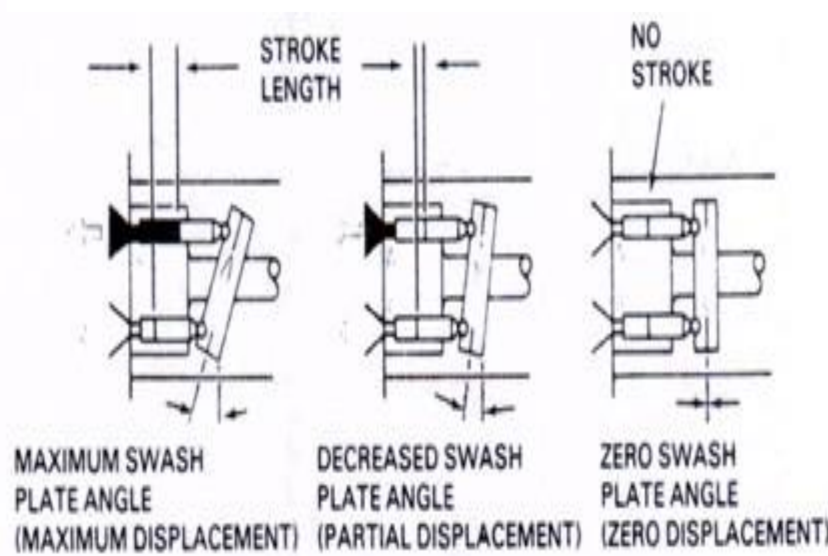
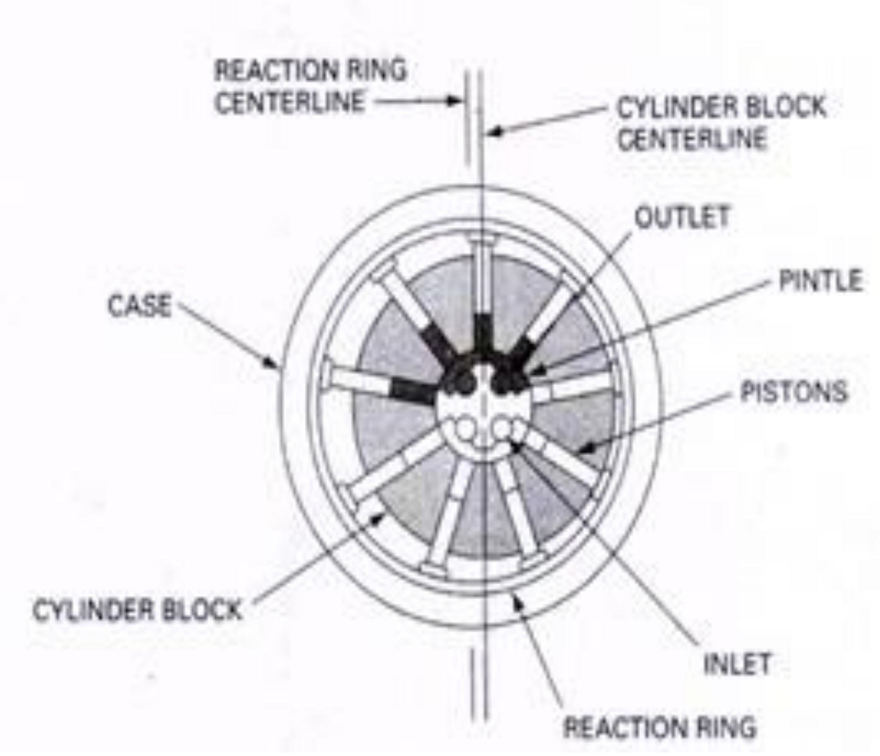


Fig. 10. variation in pump displacement.

Radial piston pump



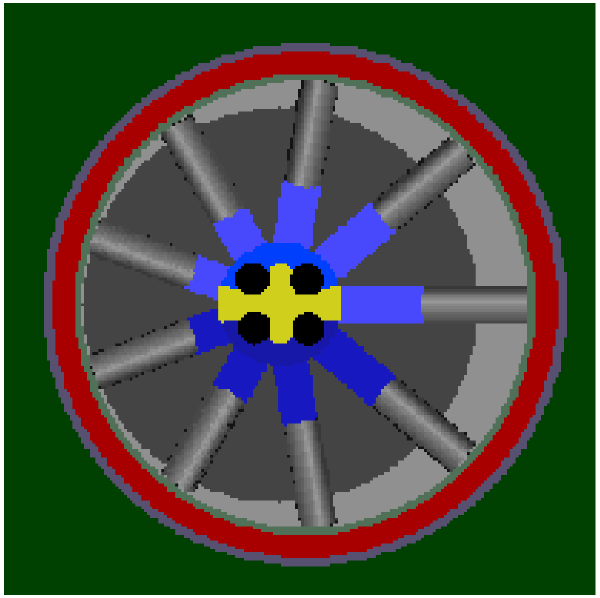
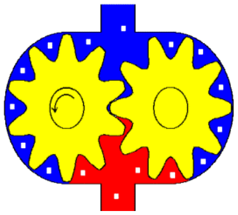
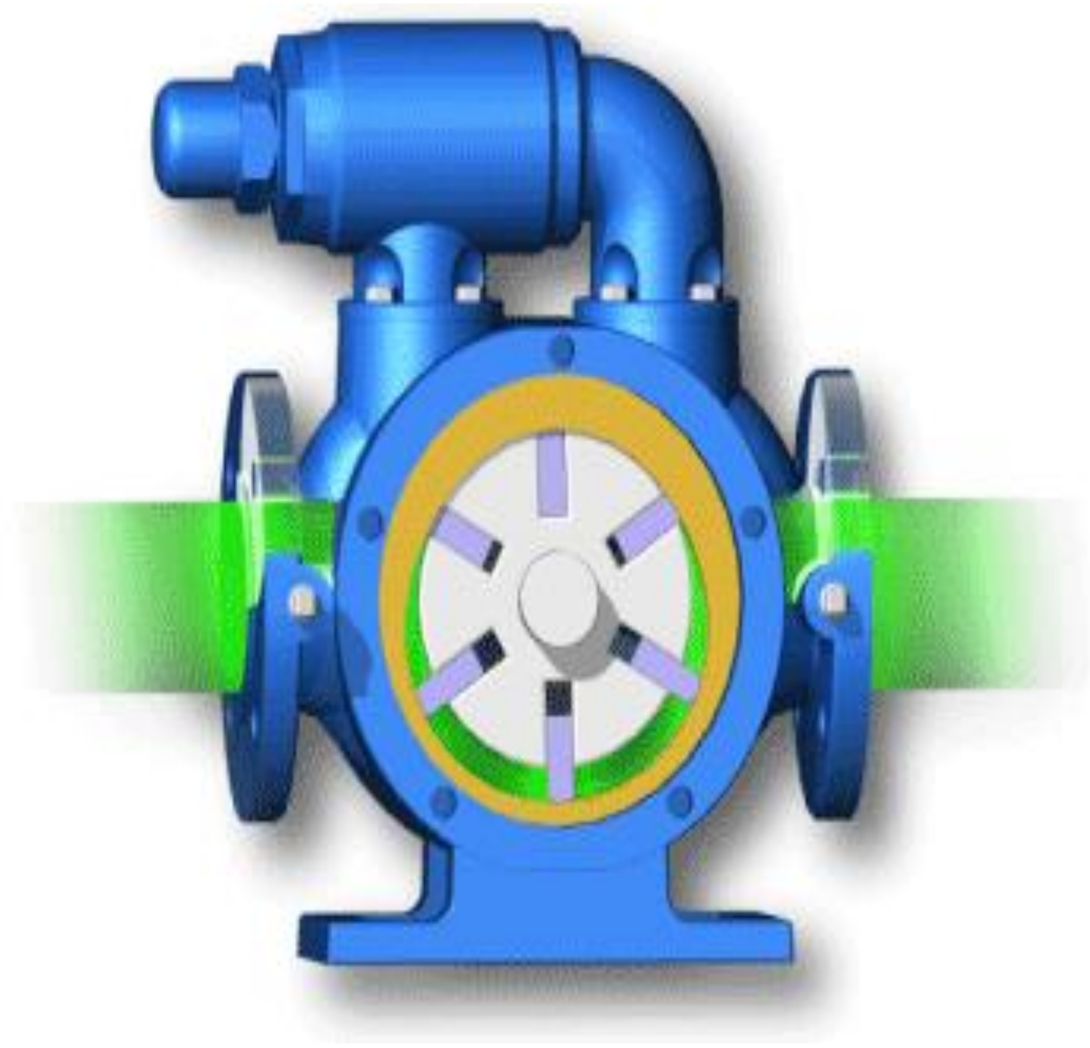
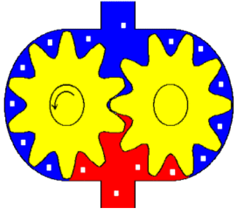


Fig. 11. Operation of radial piston pump.





PUMP EFFICIENCIES

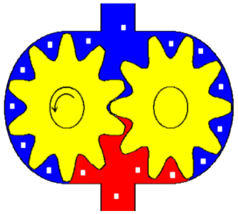


- Volumetric efficiency (η_V) :- *volumetric efficiency indicates the amount of leakage that takes place within the pump. This involves considerations such as manufacturing tolerances and flexing of the pump casing under design pressure operating condition.*

- *It is the ratio of actual flow rate produced by pump to the theoretical flow rate pump should produce.*

- $\eta_V = Q_A/Q_T$

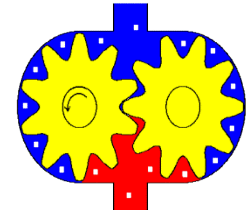
Mechanical efficiency(η_m)



- ***Mechanical efficiency*** indicates the amount of energy losses that occur for reasons other than leakages. This includes

- *Friction in bearings and between other mating parts.*
- *It also includes energy losses due to fluid turbulence.*

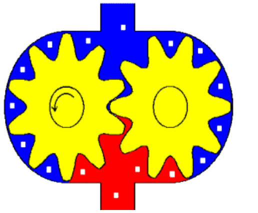
Mechanical efficiency



- It is the ratio of pump output power assuming no leakage to the actual power delivered to pump.
- $(\eta_m) = pQ_T/T_A N$

- p= pump discharge pressure (Pa)
- Q_T= pump theoretical flow rate (m^3/s)
- T_A = actual torque delivered to pump (m)
- N = pump speed (rpm)

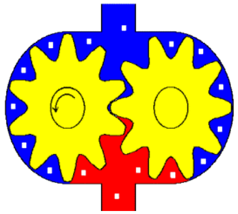
Mechanical efficiency in terms of torque



- ***It is the ratio of theoretical torque required to operate pump to the actual torque delivered to pump.***

$$(\eta_m) = \frac{T_T}{T_A}$$

THEORETICAL AND ACTUAL TORQUE



Theoretical torque(T_T)

$$\frac{V_D\ (m^3)\ X\ p\ (pa)}{2\Pi}$$

Actual torque (T_A)

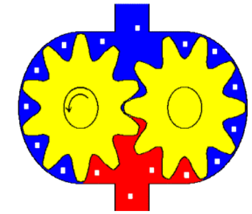
$$T_A = \frac{\text{actual power delivered to pump (W)}}{N(rad/s)}$$

Overall efficiency

The overall efficiency considers all losses hence it is defined as follows.

$$\text{Overall efficiency} = \frac{\textit{actual power delivered by pump}}{\textit{actual power delivered to pump}}$$

- The overall efficiency can also be represented mathematically as follows
- $\eta_o = \eta_v \times \eta_m$



$$\eta_o = \eta_v \times \eta_m = \frac{Q_A}{Q_T} \times \frac{pQ_T}{T_A N}$$

$$\eta_o = \frac{pQ_A}{T_A N}$$

The actual power delivered to a pump from a prime mover via a rotating shaft is called brake power and the actual power delivered by a pump to the fluid is called hydraulic power.