1. Explain the construction and working of a gear pump.
[Dec 2007, May 2009, Dec 2009, Dec 2010, May 2011, Dec 2011]

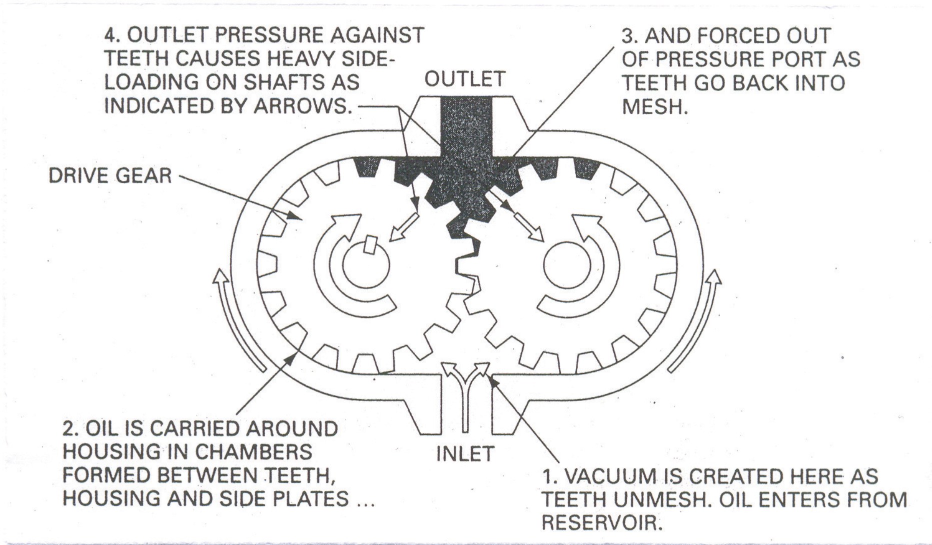
It is one of the positive displacement pumps (PDP) which ejects a fixed quantity of fluid power revolution of the pump shaft. As a result, pump output flow, neglecting changes in the small internal leakage, is constant and not dependent on system pressure.

Due to the geometrical necessity, the gears pump is a fixed displacement only. Gear pumps can be classified as

- External gear pumps
- Internal gear pumps
- Lobe pumps
- Screw pumps
- Gerotor pumps

External Gear pump

This pump develops flow by carrying fluid between the teeth of two meshing gears. One of the gears is connected to a drive shaft which item connected with a prime mover. The second gear is driven as it meshes with the driver gear.

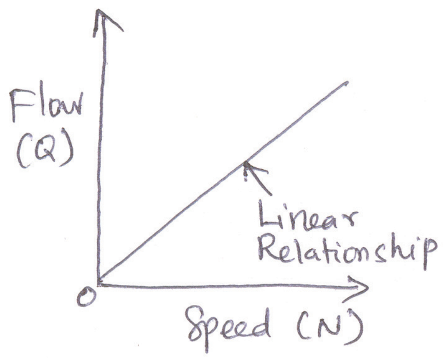


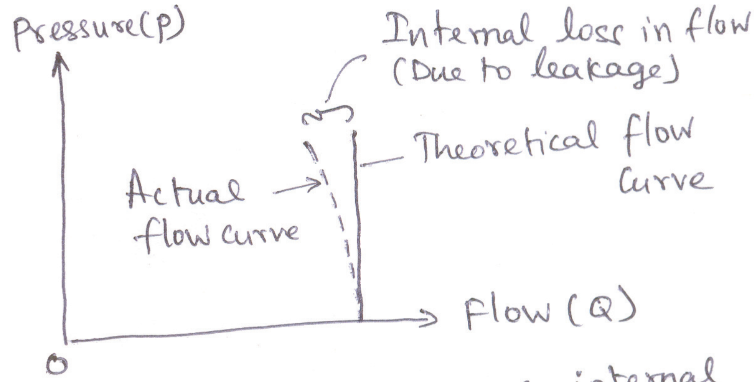

When the pump started, in suction side where teeth come out of mesh, volume expands and pressure reduces below atmosphere ie partial vacuum. So the fluid from reservoir is forced into the pump inlet. In the discharge side, teeth go into mesh and the volume decreases between the mating teeth. Pump is provided with a positive internal seal against leakage, the oil is positively ejected into the outlet port.

The volumetric displacement of a gear pump can be found by calculating the volume of hollow cylinder of outside diameter $D_o$ and inside diameter $D_i$.

Theoretical discharge $Q_T = \frac{\pi}{4}\left[D_o^2 - D_i^2\right] \times b \times N$ $m^3/min$

where $D_o$ - Outside diameter of gear teeth in m
$D_i$ - inside 〃
$b$ - Width of gear teeth in m
$N$ - Pump speed in rpm

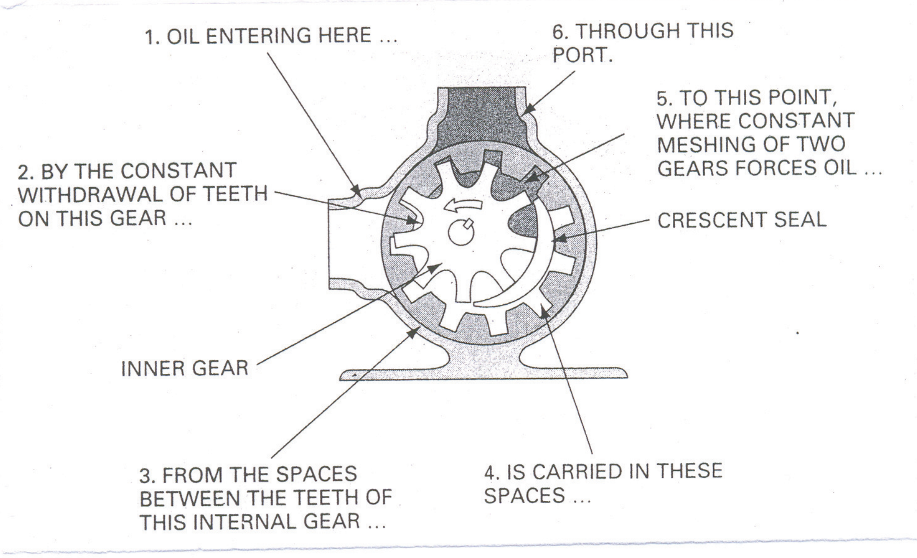



If Pressure increases, internal flow loss increases.

## Internal gear pump:

The following figure illustrates the construction and operation of the internal gear pump. This design consists of an internal gear,

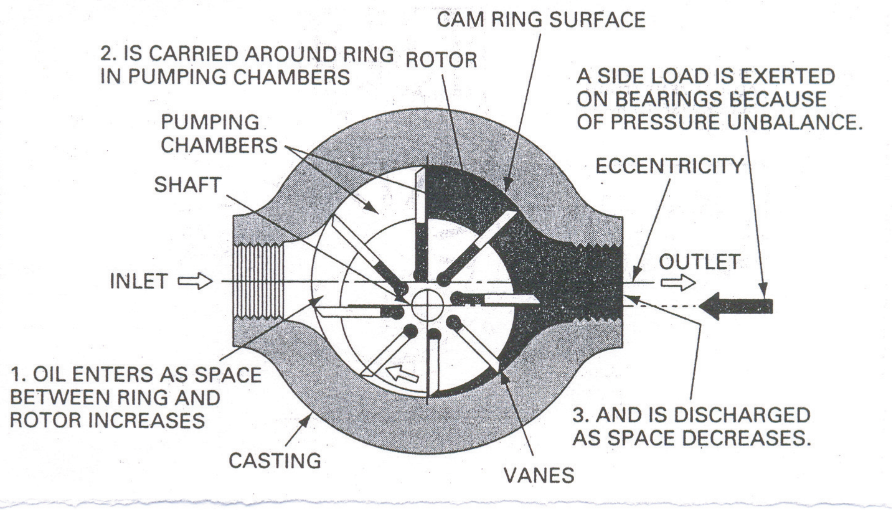


a regular spur gear, a crescent-shaped seal, and an external housing. The crescent seal placed acts to ensure a seal between suction and discharge.

As power is applied to either gear, the motion of the gears draws fluid from the reservoir and forces it around both sides of the crescent seal. When the teeth mesh on the side opposite to the crescent seal, the fluid is forced to enter the discharge port of the pump.

2. Draw the neat sketch of unbalanced type (Variable displacement) Vane pump, explain its construction and operation and also show how the same can operate as a reversible pump. Also give its standard graphical symbol. (Dec. 2007, May 2009).

The figure below illustrates the operation of a vane pump. The rotor, which contains radial slots, is splined to the drive shaft and rotates inside a cam ring. Each slot contains a vane designed to mate with the surface of the cam ring as the rotor turns.




The eccentricity between the centre of the rotor and cam ring is responsible for making the flow rate. As the eccentricity can be varied, this vane pump may be called as variable displacement pump. If the eccentricity is zero there will be no flow, the flow is maximum when the eccentricity is maximum.

During one-half revolution of rotor rotation, the volume increases between the rotor and cam ring. Due to the volume expansion pressure

This is a Suction process, which causes fluid to flow through the inlet port and fill the void. As the rotor rotates through the second half, the Surface of the cam ring pushes the vanes back into their slots, and the trapped volume is reduced. This ejects the trapped fluid through the discharge port.

From geometry,

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

where
e - eccentricity, m
$D_c$ - Dia of Cam ring, m
$D_R$ - Dia of rotor, m

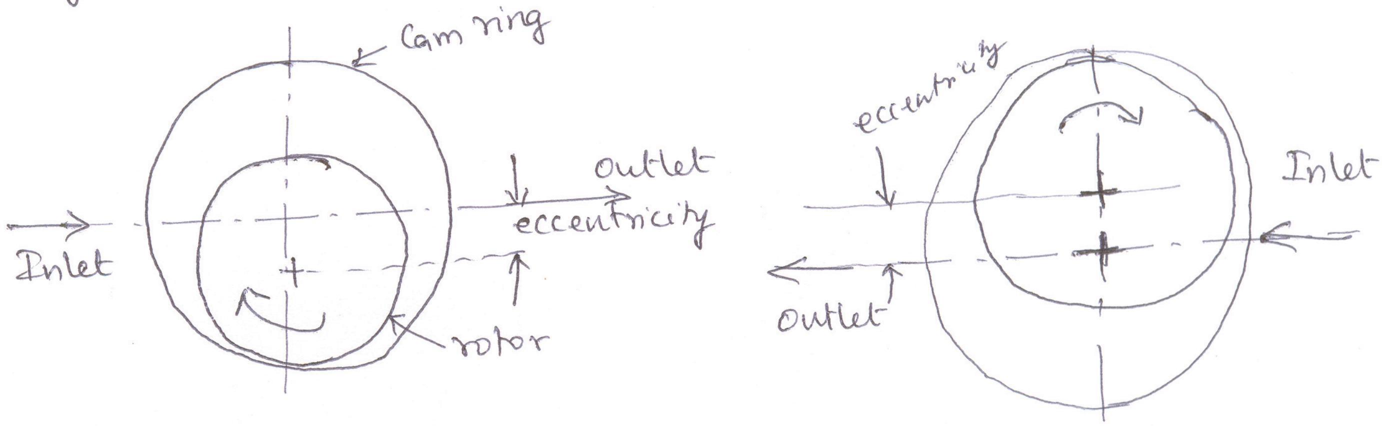
$$V_{D max} = \frac{\pi}{4}(D_c^2 - D_R^2)L$$

$V_D$ - Volumetric Displacement, $m^3$
L - width of rotor, m

$$= \frac{\pi}{4}(D_c + D_R)(D_c - D_R) \cdot L$$

$$\Rightarrow \quad = \frac{\pi}{4}(D_c + D_R) \cdot 2 \cdot e_{max} \cdot L$$

The direction of flow through the pump can be reversed by movement of the cam ring on either side of the center.

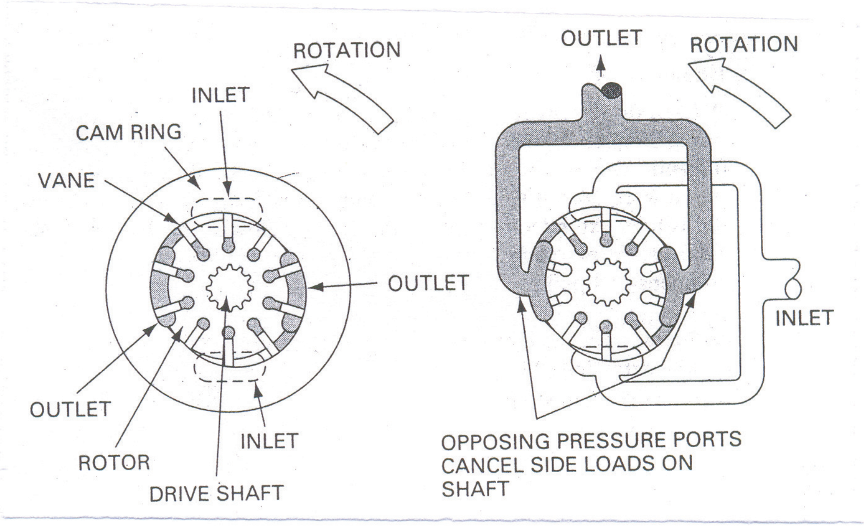



3. With a neat sketch explain the construction and operation of a balanced vane pump (May 2011)

A balanced vane pump is one that has two inlet and two outlet ports placed diametrically opposite to each other. Thus the pressure ports are opposite to each other, and a complete hydraulic balance is achieved.

One disadvantage of this pump is that it cannot be designed as a variable displacement pump.

Instead of having a Circular Cam ring, it has an ellipitical housing, which forms two seperate chambers on opposite sides of the rotor. Due to the ports placement in opposite (diametrical) elimination of bearing side loads is assured and thus permits higher operating pressures.



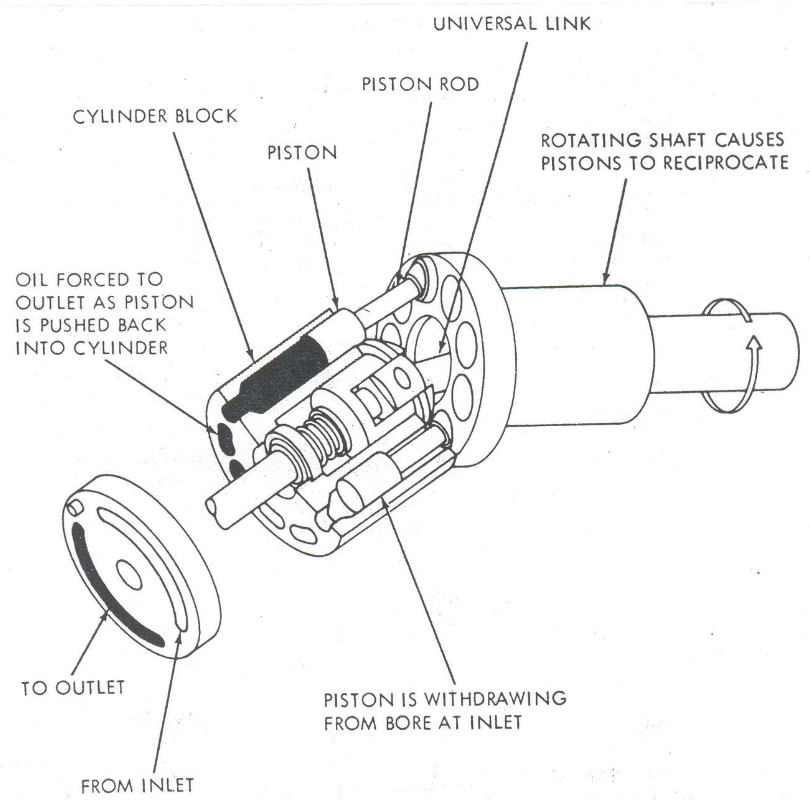

4. Explain the working of a variable displacement axial piston pump with a neat sketch. Also write an expression for the theoretical displacement per revolution of the crank. (May 2011, Dec 2011, Dec 2013) May 2013

A piston pump works on the principle that a reciprocating piston can draw the fluid in when it retracts into a cylinder bore and discharge it when it extends.

There are two basic type of piston pumps

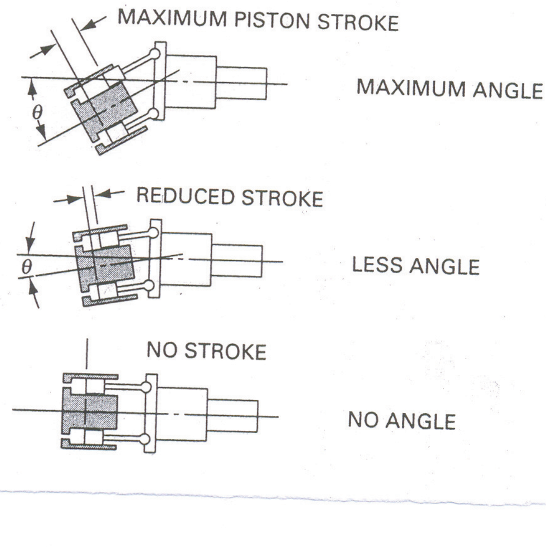
(i) Axial piston pumps
  (a) Bent axis type
  (b) Swash plate type

(ii) Radial piston pump




Above figure shows a bent-axis type piston pump that contains a cylinder block rotating with the drive shaft. However, the centerline of the cylinder block is set at an offset angle "θ" relative to the centerline of the drive shaft. The cylinder block contains a number of pistons arranged along a circle. The piston rods are connected to the drive shaft flange by ball-and-socket joints. The pistons are forced in and out of their bores as the distance between the drive shaft flange and the cylinder block changes.

The volumetric displacement varies with the offset angle 'θ' as shown in fig. Fixed displacement units are provided with 23° or 30° offset angle.



From trignometry

$$\tan\theta = \frac{S}{D}$$

$\theta$ = offset angle
S = piston stroke length, m
D = Piston circle diameter, m
A = Area of the piston, $m^2$
Y = Number of pistons.
N = Speed in rpm

Volumetric Displacement

$$V_D = Y.A.S.$$

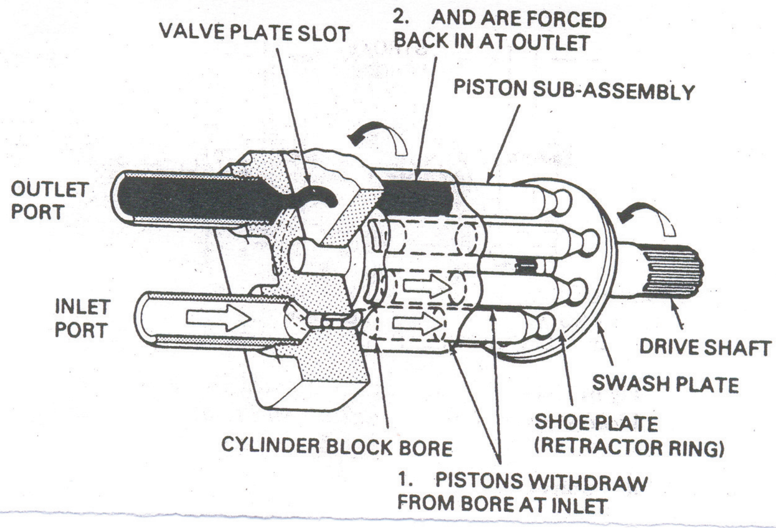
$$\Rightarrow = Y.A.D.\tan\theta$$

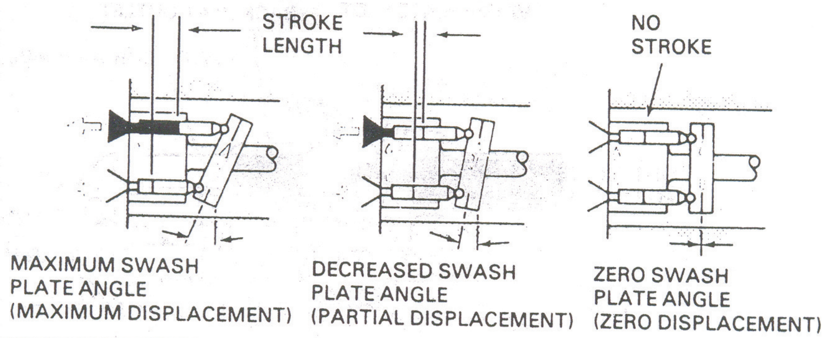
Theoritical Discharge

$$Q_T = Y.A.D.\tan\theta.N$$

5. Explain the construction and working of a swash plate type piston pump with neat sketch. (Dec. 2012)

In this type, the cylinder block and drive shaft are located on the same centerline. The pistons are connected to a shoe plate which bears against an angled swash plate.



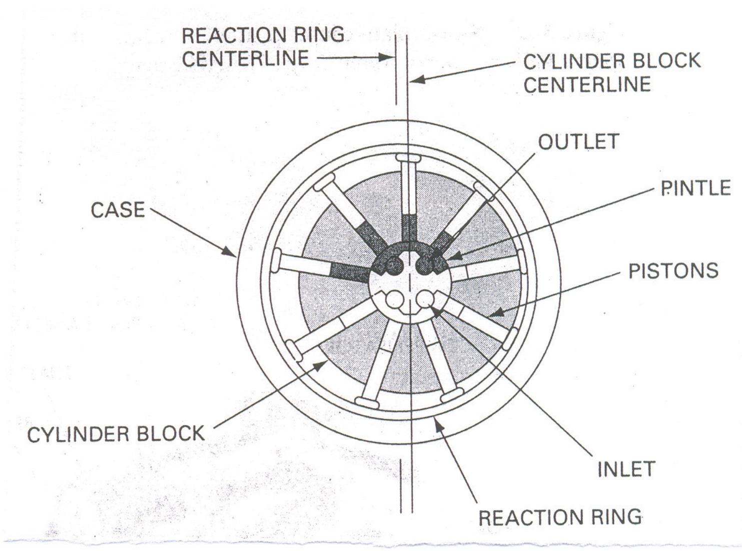



As the cylinder rotates, the pistons reciprocate because the piston shoes follow the angled surface of swash plate. The inlet and outlet ports are located in the valve plate so that the pistons pass the inlet as they are being pulled out and pass the outlet as they are being forced back in.

This type of pump can also be designed to have variable displacement capability by mounting the swash plate in a movable yoke. The maximum swash plate angle is limitted to $17\frac{1}{2}^\circ$ by construction.

6. Explain the working of a radial piston pump with a neat sketch. Also write an expression for the theoretical displacement per revolution of crank. (Dec 2010)

The operation and construction of a radial piston pump is illustrated in the below figure. This design consists of a pintle to direct fluid in and out of the cylinders, a cylinder barrel with pistons, and a rotor containing a reaction ring. The pistons remain in constant contact with the reaction ring due to the centrifugal force and back pressure on the pistons. For pumping action, the reaction ring is moved eccentrically with respect to the pintle or shaft axis.



As cylinder barrel rotates, the pistons on one side travel outward. This draws in fluid as each cylinder passes the suction ports of the pintle. When a piston passes the point of maximum eccentricity, it is forced inward by the reaction ring. This forces the fluid to enter the discharge port of the pintle.

Theoretical discharge $Q_T = 0.5\, e\, Y \cdot \pi \cdot D^2 N$, $m^3/min$

Where, $e$ = eccentricity in m

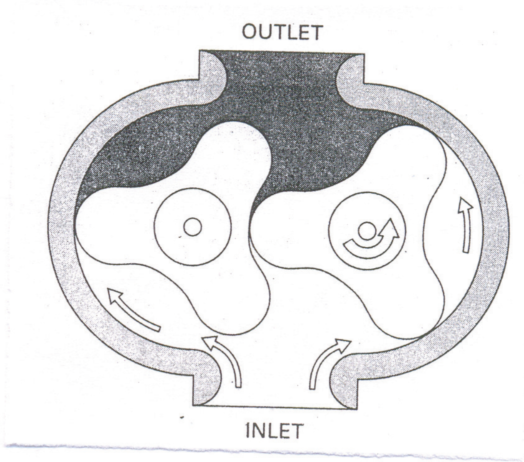
$Y$ = No. of pistons

$D$ = Diameter of piston in m

$N$ = Speed in rpm.

7. Write short Notes on lobe pump. (May 2013)

This pump works in a fashion similar to the external gear pump. But unlike the external gear pump, both lobes are driven externally so that they do not contact each other.




Thus, they are quiter than the other types of gear pumps. Due to smaller number of mating elements, the lobe pump output will have somewhat greater amount of pulsation, although its volumetric displacement is generally greater than that for other types of gear pumps.

8. Explain the following (i) pump characteristic curves (Dec 2008)
(ii) pump cavitation (Dec 2008, Dec 2010)
(iii) pump noise (Dec 2008)
(iv) pump selection (May 2008, Dec 2008, Dec 2010)

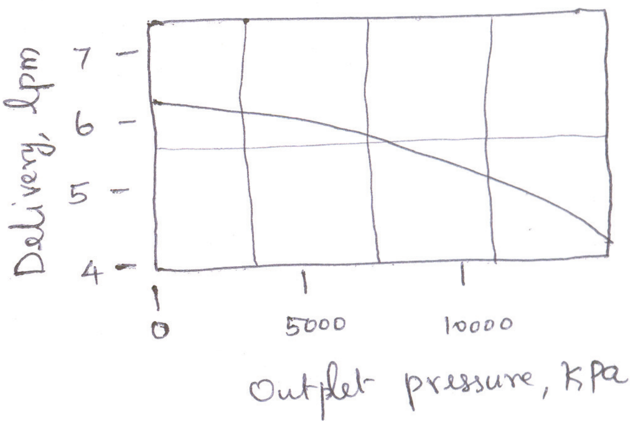
(i) pump characteristic curves:

The behavior of pump under varying conditions is shown by the curves known as characteristic curves of the pump.

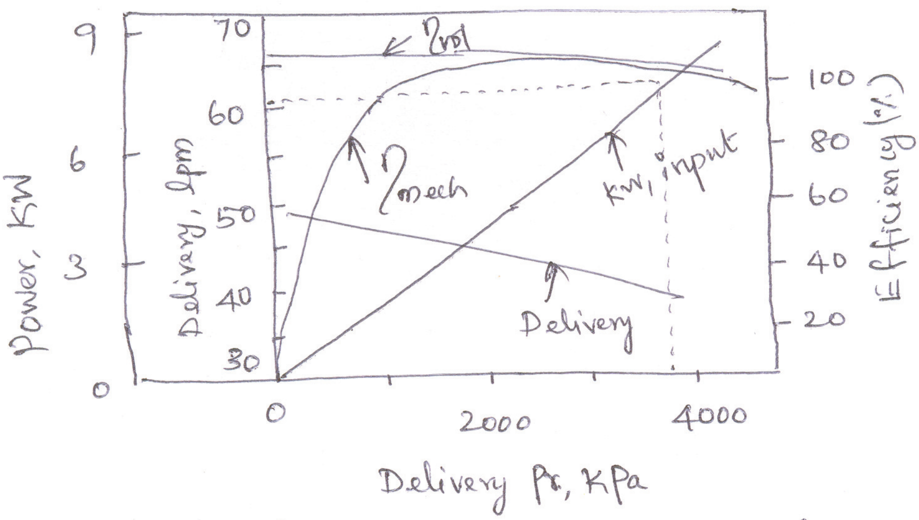
(a) Pump discharge pressure Vs Rate of discharge:

1800 rpm, SAE 10 @ 105°F

When the pump is running at constant speed, from the graph it is clear that less the pressure will give more rate of discharge.



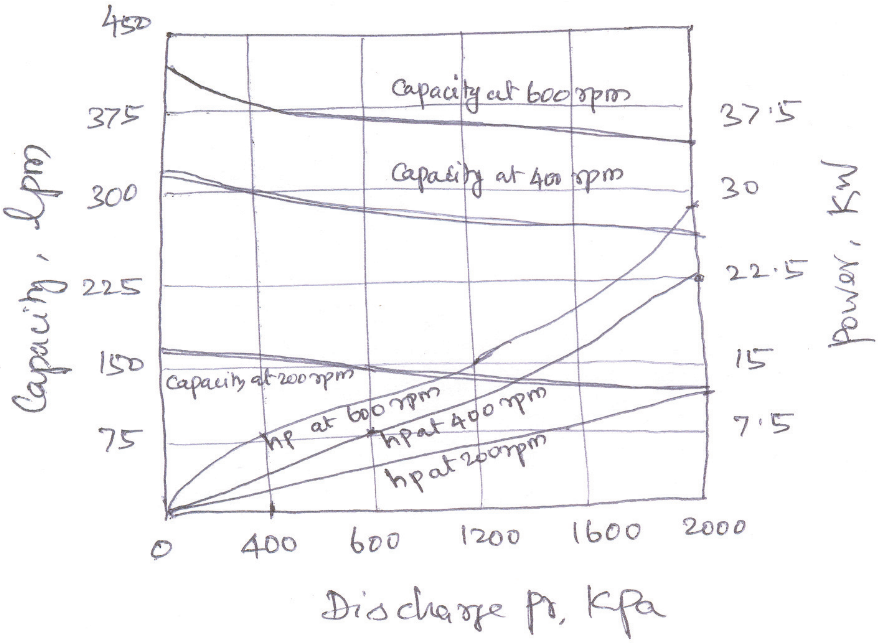

(b) Pump discharge pressure Vs power, efficiency, Rate of discharge




This graph shows, how much power must be supplied to the pump to obtain different rates of discharge against different discharge pressures.

This graph clears that more power is required to deliver higher discharge pressure. These curves also give information about the volumetric efficiency and mechanical efficiency at different discharge pressures.

(c) External gear pump characteristics [HQ curve/PQ curve.]




The curve showing the relationship between pump discharge pressure and pump capacity is head-capacity or HQ curve.

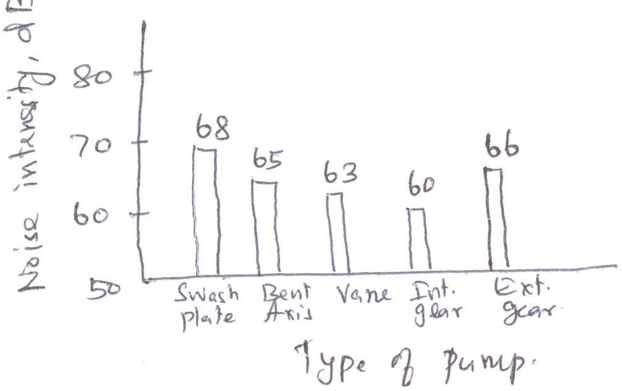
The curve showing the relation between the power input and pump capacity is termed as power-capacity or PQ curve.

(ii) Pump Cavitation [Refer Answer of

(iii) Pump Noise

The noise generated levels vary with

(a) pump
(b) pump component material
(c) pump mountings
(d) methods applied to eliminate vibration
(e) rigidity
(f) Manufacturing and fitting accuracies
(g) Size and flow capacity
(h) pressure, speed of rotation
(i) pressure pulsations
(j) other components connected.




Any pump which generates noise above 90 dB(A) is loud pump. Those around 60 dB(A) or less are considered quiet running.

(iv) Pump selection

Pumps are selected by keeping into account a number of considerations, viz.,

(a) Flow-rate requirements ($m^3$/min)
(b) operating speed (rpm)
(c) pressure rating (kpa/bar)
(d) performance
(e) reliability
(f) Maintenance
(g) Cost
(h) Noise
(i) Application.

The selection of a pump typically entails the following sequence

1. Select the actuator (cylinder/motor), based on load
2. Determine flow rate requirement, based on load & speed.
3. Select the system pressure. Here power delivered by the pump is involved.
4. Determine the pump speed and select the prime mover.
5. Select the pump type, based on application
6. Select the reservoir and associated piping, valves, fitting etc.
7. Consider the factors like noise, maintenance, pump wear etc.
8. Calculate the over all cost.

Normally the sequence of operation is repeated several times with different sizes and types of associating components in order to optimize the selection.

9 List out the various types of hydraulic cylinders. Explain the construction parts and working of double acting cylinder with neat sketche (May 2011, Dec. 2011)

Hydraulic cylinders can be classified into many types based on various criteria. Some of them are given below:

1. Based on the cylinder action:
   (a) Single acting cylinder
   (b) Double acting cylinder

2. Based on the cylinder design:

(a) Plunger or ram cylinder
(b) Telescopic cylinder
(c) Tandem cylinder
(d) Cable cylinder

3. Based on cushioning feature:

(a) cushioned type cylinder
(b) Non-cushioned type cylinder

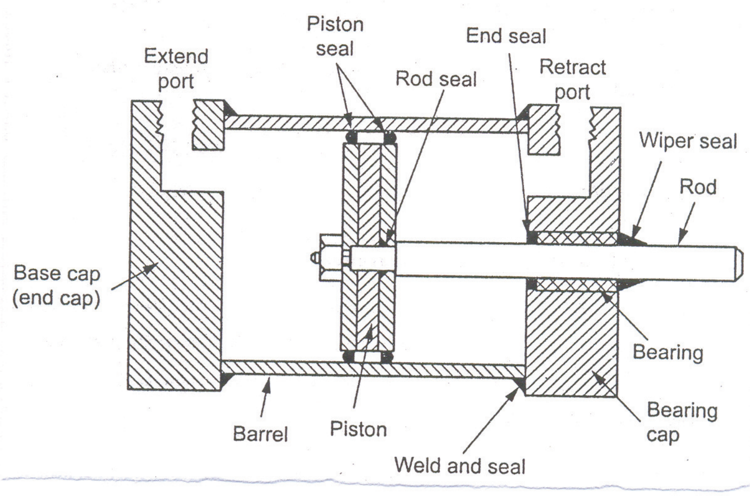
4. Based on piston or plunger used:

(a) piston type cylinder
(b) plunger type cylinder

## Double acting cylinder:

Here, liquid pressure can be applied to either side of the piston, thereby providing a hydraulic force in both directions. The five basic parts of the double acting cylinder are

1. Base cap with port connections
2. Bearing cap with port connections
3. cylinder barrel
4. piston and
5. piston rod.



The components are designed in such a way that the end caps and pistons are common to all cylinders of the same diameter and only barrels and piston rod need to be changed to construct different length cylinders. The end caps are welded to the barrel and the piston rods are threaded to the piston.

The barrel is made of seamless steel tubing, honed to a fine finish on the inside surface. The piston which is made of ductile iron contains U cup packings to seal the leakage between the piston and the barrel. The ports are located in the end caps which are secured to the barrel by the tie rods. The load of the piston rod at the neck is taken by a rod bearing, which is generally made of brass or bronze. A rod wiper is provided at the end of the neck to prevent foreign particles and dust from entering into the cylinder along with the piston rod.

When the fluid from the pump enters the cylinder through port 1, the piston moves forward and fluid returns to the reservoir from the cylinder through port 2. During the return stroke the fluid is allowed to enter the cylinder through port 2 and fluid from the other side of the piston goes back to the reservoir through port 1.

10. What is cylinder cushioning? Explain with diagram. (Dec. 2007, Dec. 2008, Dec. 2010, Dec. 2011, Dec. 2012, May 2013)

Double acting cylinders (expected to work at high speeds) contain cylinder cushions at the ends of the cylinder to slow the piston down near the ends of the stroke. This prevent excessive impact when the piston is stopped by the end caps, as illustrated in the figure below.

As shown, deceleration starts when the tapered plunger enters the opening in the cap. This restricts the exhaust flow from the cylinder to the port. During the last small portion of the stroke, the oil must exhaust through the adjustable opening. The cushion design also incorporates a check valve to allow free flow to the piston during direction reversal.