Applications of Hydraulics & Pneumatics

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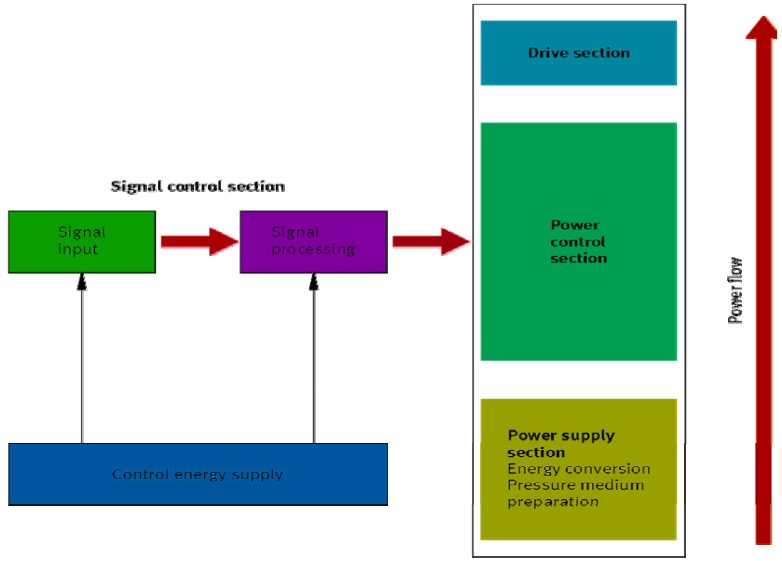
By: Alireza Safikhani

Hydraulics Systems



Power supply section

- The most important components in this section are:
  - drive
  - pump
  - pressure relief valve
  - coupling
  - reservoir
  - filter
  - cooler
  - heater
- In addition, every hydraulic system contains service, monitoring and safety devices and lines for the connection of hydraulic components.

Drive

- Hydraulic systems (with the exception of hand pumps) are driven by motors (electric motors, combustion engines). Electrical motors generally provide the mechanical power for the pump in stationary hydraulics, whilst in mobile hydraulics combustion engines are normally used.
- In larger machines and systems, the central hydraulics are of importance. All consuming devices in a system with one or several hydraulic power supply units and with the help of one or more reservoirs are supplied via a common pressure line. The hydraulic reservoir stores hydraulic power which is released as required.

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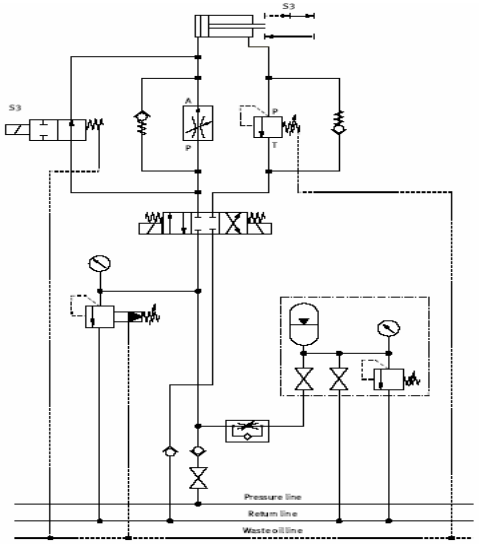
Sample of Central power supply



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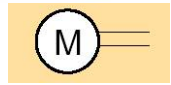
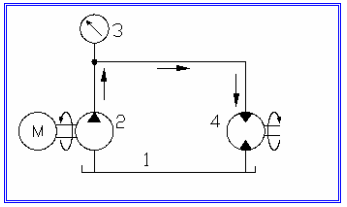
Drive: Electric Motors & Power

$$P = \frac{p \times (V_p \times n_p)}{600000 \times \eta_{t.p}}$$

Where

P	=	power in kiloWatts
p	=	pressure in bar
V_p	=	pump displacement (cm^3/rev)
n_p	=	pump shaft speed in rpm
$\eta_{t.p}$	=	pump overall efficiency (0.8 – 0.9)





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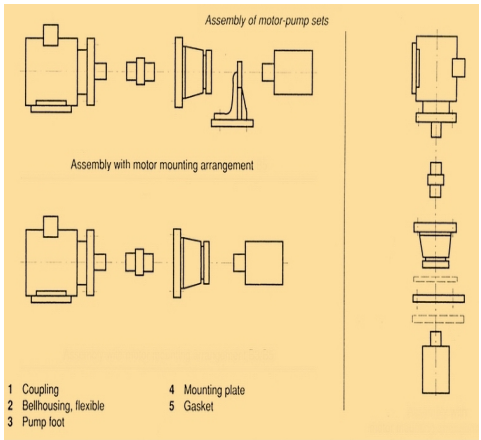
Assembly of Motor Pump Sets



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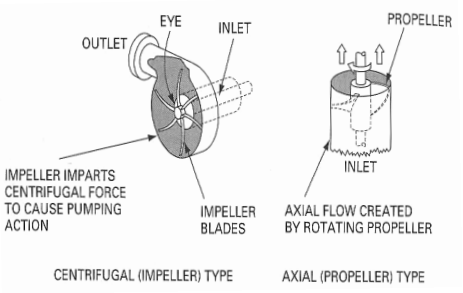
Pump

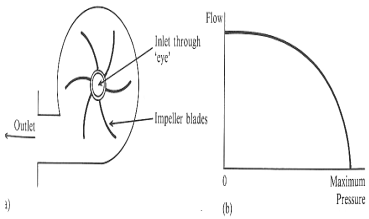
- converts the mechanical energy in a drive unit into hydraulic energy (pressure energy).
- Pump displaces the oil and it doesn't create pressure in the system.
- It is the resistance against the oil motion that cause pressure. The resistance arises from two sources:
  - 1- Resistance due to extra loaded actuators doing the work
  - 2- Resistance due to friction in lines.

Nonpositive-Displacement Pumps

- **discharge liquid in a continuous flow**



- **If the outlet of a nonpositive-displacement pump is completely closed, the discharge pressure will rise to the maximum for a pump operating at a maximum speed.**

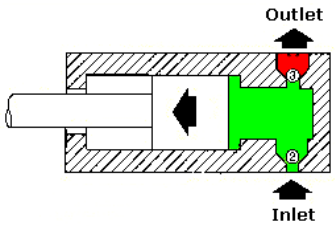


Nonpositive-Displacement Pumps: Hints

- Used in low-pressure, high volume flow rate applications.
- Maximum pressure capacity :250-300 psi.
- Rarely used in fluid power because this their flow output drops if pressure resistance increases

Positive-Displacement Pumps

- a definite volume of liquid is delivered for each cycle of pump operation, regardless of resistance, as long as the capacity of the power unit driving a pump is not exceeded.
- If an outlet is completely closed, either the unit driving a pump will stall or something will break. Therefore, a positive-displacement-type pump requires a pressure regulator or pressure-relief valve in the system



Positive-Displacement Pumps: Hints

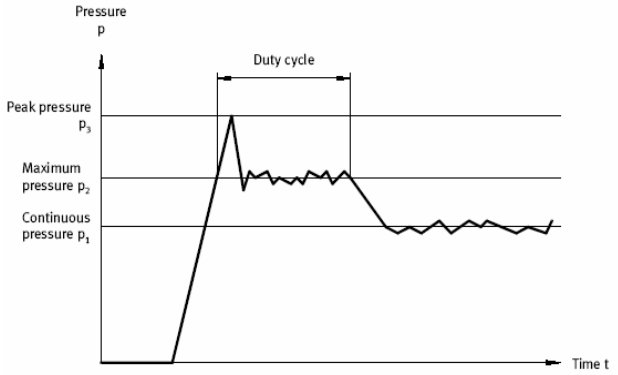
- High pressure capability (up to 12,000 psi)
- Small, compact size
- High volumetric efficiency
- Small changes in efficiency throughout the design pressure range
- Great flexibility of performance

Characteristic values: Displacement volume

- also known as the volumetric displacement or working volume) is a measure of the size of the pump.
- It indicates the volume of liquid supplied by the pump per rotation (or per stroke).
- The volume of liquid supplied per minute is designated as volumetric flow rate Q (delivery).
- This is calculated from the displacement volume V and the number of rotations n:
- $Q = n \cdot V$

Characteristic values: Operating pressure

- The operating pressure is of significance for the area of application of pumps.



Characteristic values: Speed

- The drive speed is an important criterion for pump selection since the delivery Q of a pump is dependent on the number of rotations n.
- Many pumps are only effective at a specific r.p.m. range and may not be loaded from a standstill. The most usual number of rotations for a pump is n = 1500 r.p.m.

Characteristic values: Efficiency

- Mechanical power is converted by pumps into hydraulic power resulting in power losses expressed as efficiency.
- When calculating the total efficiency η_{tot} of pumps, it is necessary to take into consideration the volumetric η_{vol} and the hydro-mechanical η_{hm} efficiency.

$$\eta_{tot} = \eta_{vol} . \eta_{hm}$$

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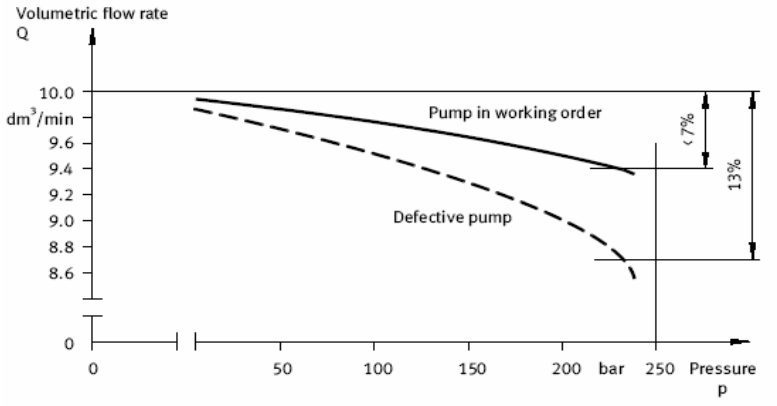
Pump characteristic Curve

- p = 0, the pump supplies the complete delivery Q.
- p > 0, Q is reduced owing to the leakage oil.



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Other Design features

- Other design features of a pump may also be of significance:
  - type of mounting
  - operating temperatures
  - noise rating
  - hydraulic fluid recommendations
  - pump type.

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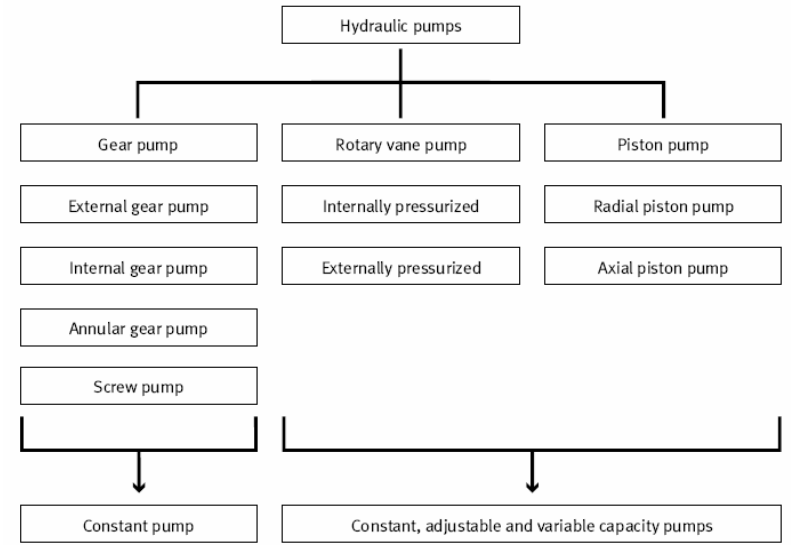
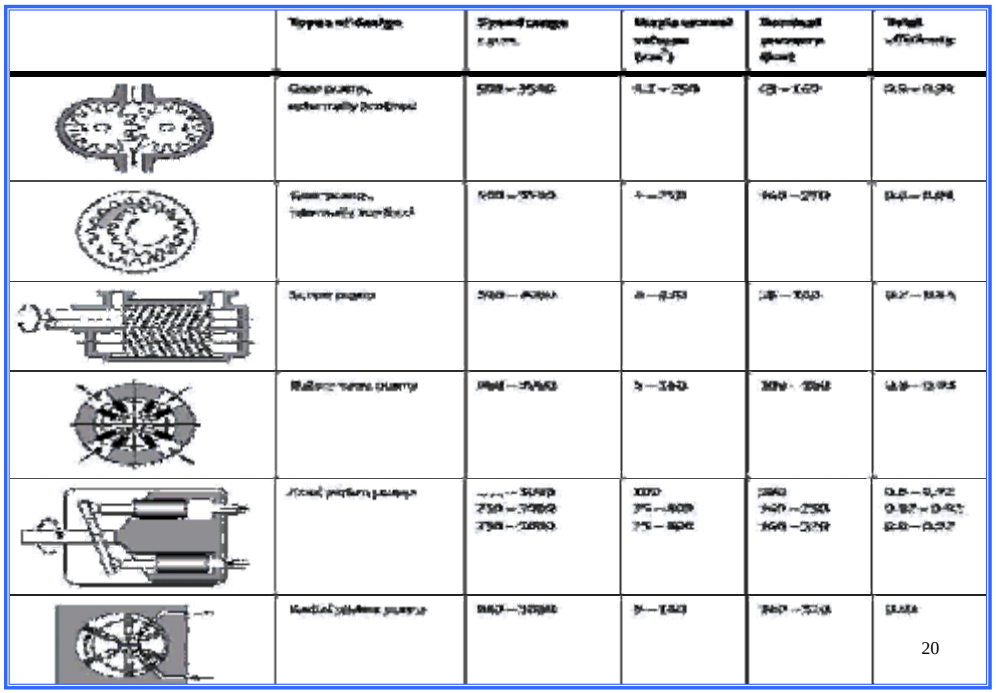
Type of Hydraulics Pump





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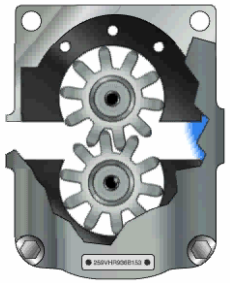
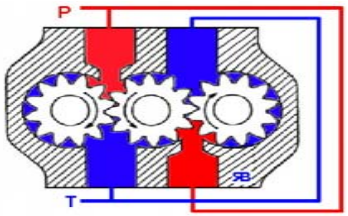
External Gear Pump: Animation



- One Stage



- Multi Stage

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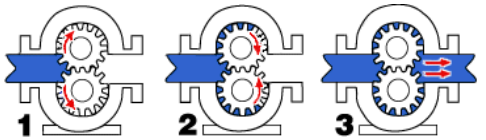
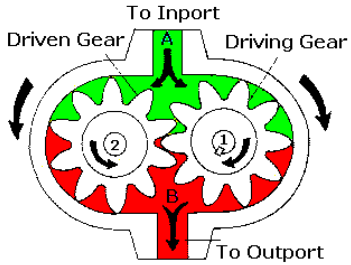
External Gear pumps

- 1. Liquid flows into the cavity and is trapped by the gear teeth as they rotate.
- 2. Liquid travels around the interior of the casing in the pockets between the teeth and the casing
- 3. Finally, gears forces liquid through the outlet port under pressure.





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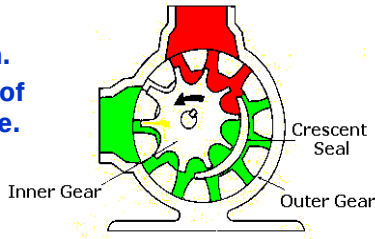
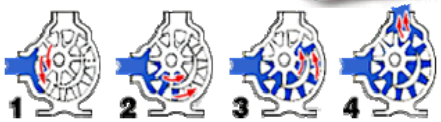
Internal gear Pump

1. **Liquid enters the suction port between the rotor and idler teeth.**
2. **Liquid travels between the teeth of the "gear-within-a-gear" principle. The crescent shape divides the liquid and acts as a seal between the suction and discharge ports.**
3. **forcing the liquid out of the discharge port.**
4. **Rotor and idler teeth mesh completely to form a seal equidistant from the discharge and suction ports. This seal forces the liquid out of the discharge port.**





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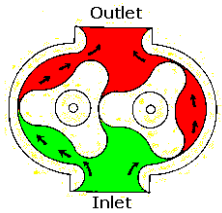
Lobe gear pumps

1. **Liquid flows into the cavity and is trapped by the lobes as they rotate.**
2. **Liquid travels around the interior of the casing in the pockets between the lobes and the casing**
3. **Finally, the lobes forces liquid through the outlet port under pressure.**



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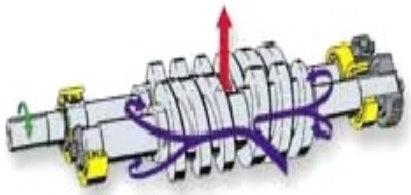
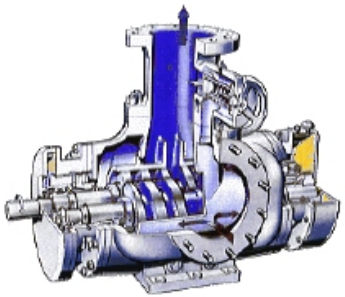
Screw Gear Pump

- The screw pump is an axial flow positive displacement unit.
- Screw pumps are self-priming, double ended positive displacement pumps with external timing gears and bearings.
- Their design provides complete axial balancing of the rotating elements and eliminates all metal-to-metal contact within the pump.





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Gerotor Gear Pump

- either the inner or the outer element is driven by a motor, and this element then drives the other.
- Since the outer element has one more tooth than the inner element, one tooth volume is swept each rotation. As the elements rotate, spaces between the teeth on the suction side increase, drawing fluid into the pump.

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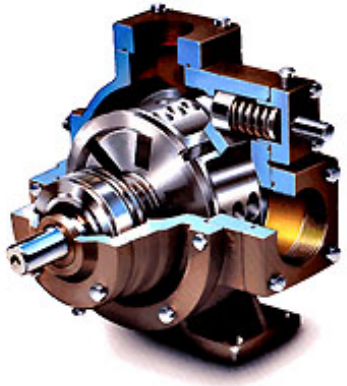
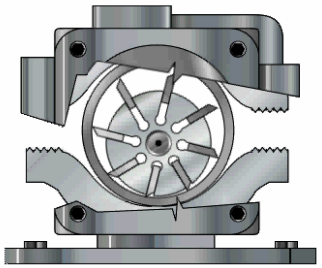
Vane Pumps :Animation





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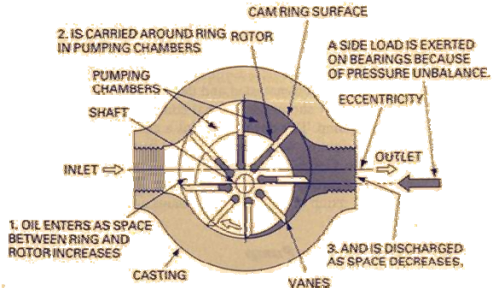
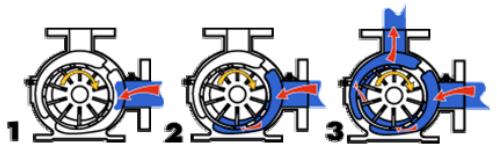
Vane Pump

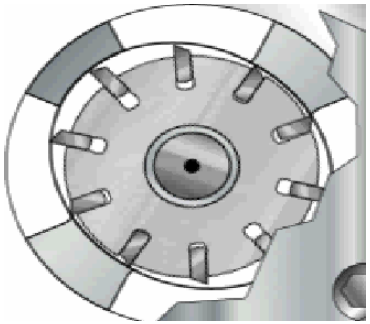
1. As the impeller rotates and fluid enters the pump, centrifugal force, hydraulic pressure, and/or pushrods push the vanes to the walls of the housing.
2. The housing and cam force fluid into the pumping chamber through holes in the cam. Fluid enters the pockets created by the vanes, rotor, cam, and sideplate.
3. The vanes sweep the fluid to the opposite side of the crescent where it is squeezed through discharge holes of the cam as the vane approaches the point of the crescent. Fluid then exits the discharge port



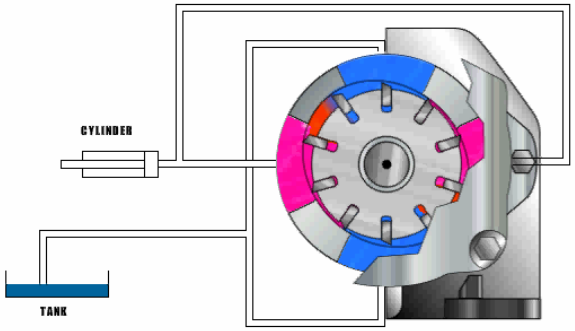


Balanced Vane Pumps

- **The two inlets and outlets are 180 degrees apart. Back pressures against the edges of a rotor cancel each other. Recent design improvements that allow high operating speeds and pressures have made this pump the most universal in the mobile-equipment field.**

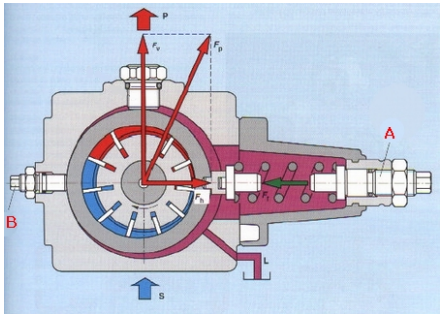


Balanced: Animation

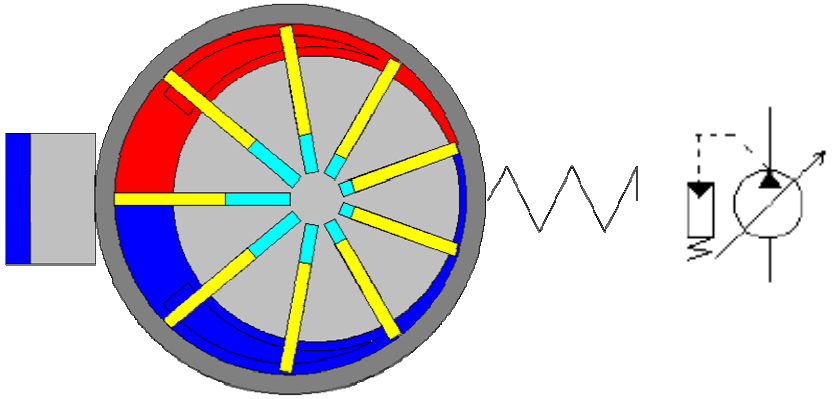


Variable delivery vane pump

- The principles are the same but adjusting items (A) and (B) on the diagram below can change the eccentricity of the ring relative to the rotor. This enables the quantity of oil being pumped to be set to a required value. The pump can be designed so that as the pressure increases beyond a set limit, it forces the ring to a concentric position and reduces the flow to zero thus protecting the pump.

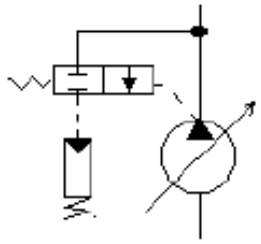


Variable delivery vane pump



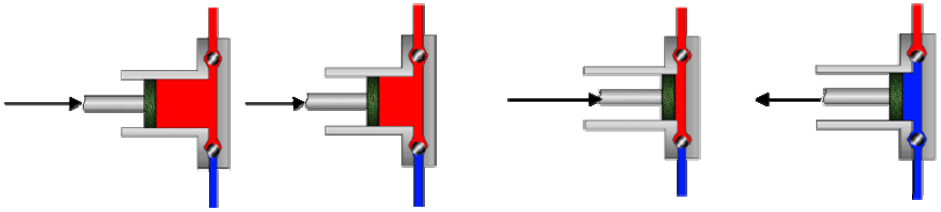
Variable delivery vane pump

- In many systems we do not want the flow to decrease with pressure until a dangerous pressure is reached. In this case a simple pilot operated valve is used which opens at a preset pressure and allows the ring to be centralized.

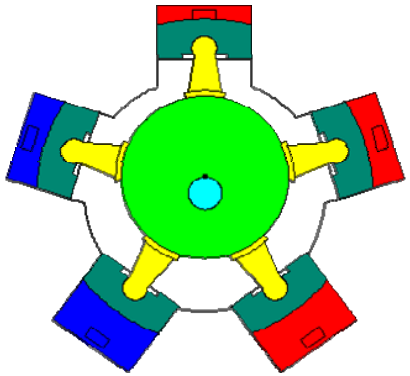


Piston Pump: General

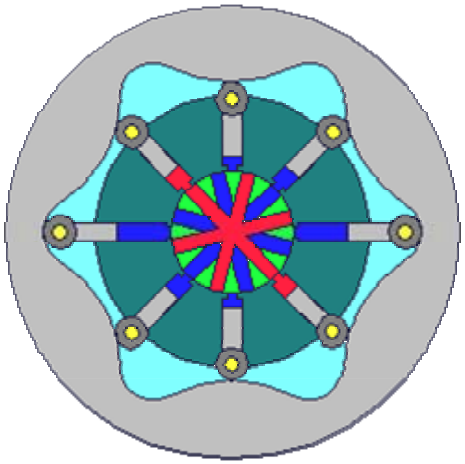
- **The piston pump generates a pumping action by causing positions to reciprocate in a piston bore**



Radial Piston Pumps

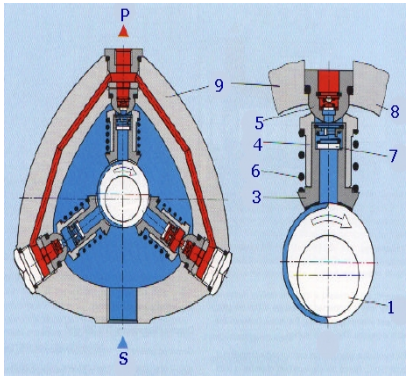


Radial Piston Pumps

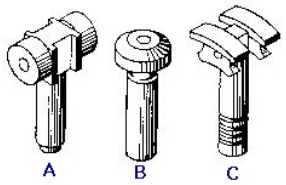


Radial Piston Pumps

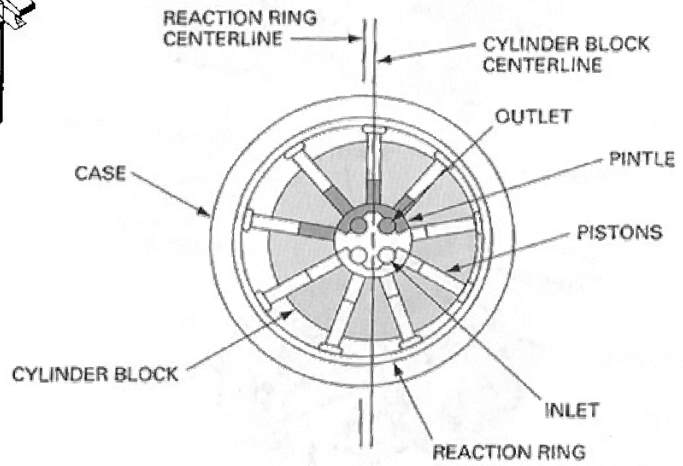
- The cam is part of the main shaft (1) and when it rotates the pistons are made to reciprocate inside cylinders (4) which lay on a radial line. When the piston moves inwards the space in the cylinder fills with oil through the suction valve (7) and the suction port (s). When the piston moves outwards, the oil is trapped inside and forced out to the pressure port (p).

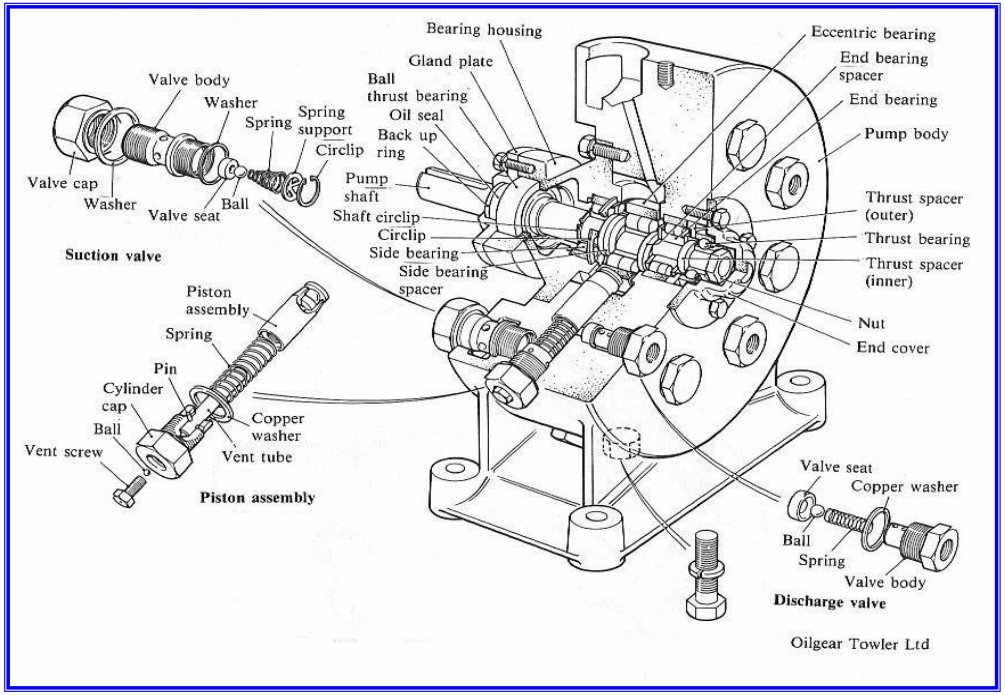


Parts of Radial Piston Pumps

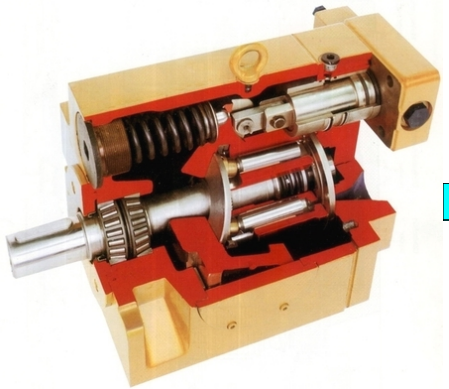


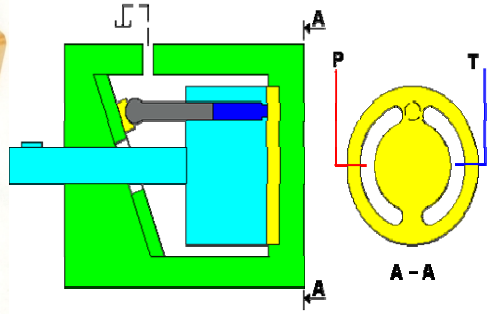
Type of Pistons





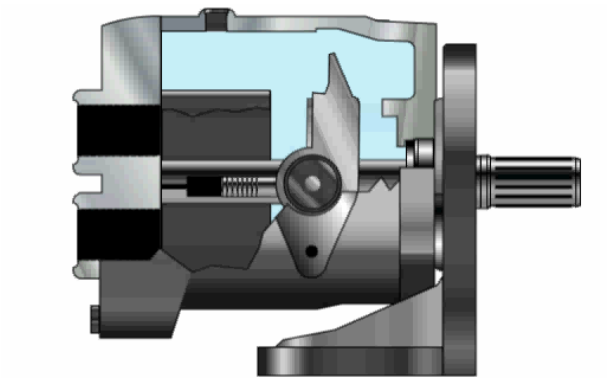
Axial Piston Pumps



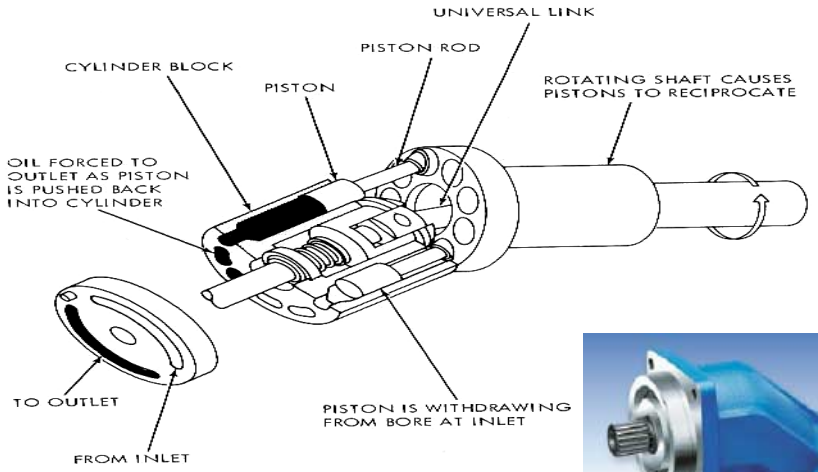


In- line Design

Animation



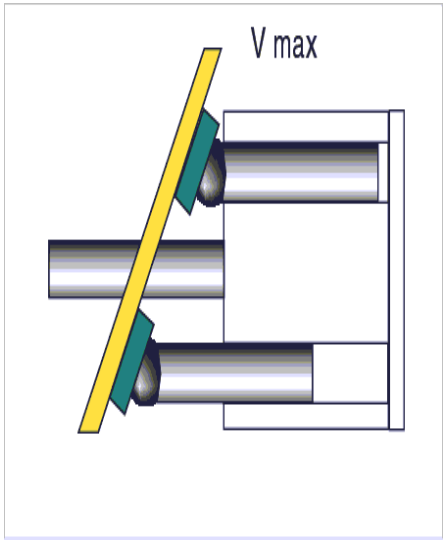
Operation



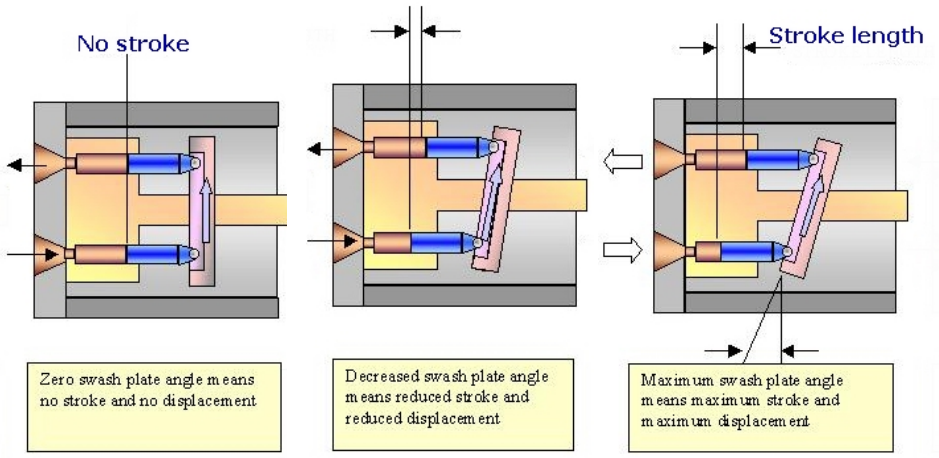
Angle or Bent Axis Design

Adjusting the Displacement

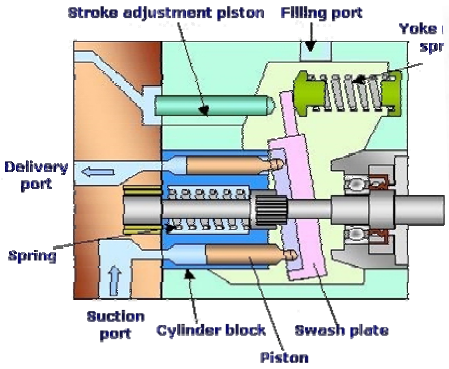
- **Variation in the piston stroke is possible by changing the swash plate angel. It is done by pushing yoke plate either manually through setting screw or through pilot line. Stoppers are provided for maximum and minimum stroke positions.**

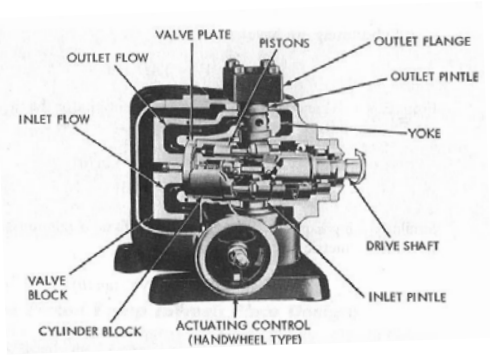


Adjusting the Displacement

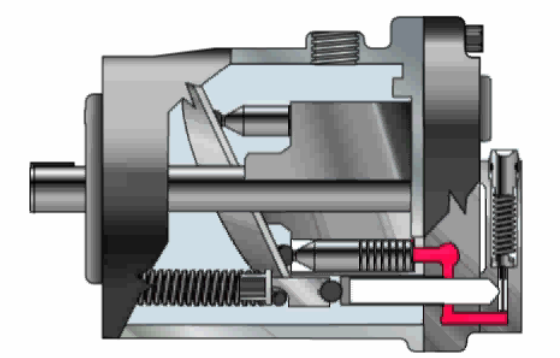


Adjustable Displacement



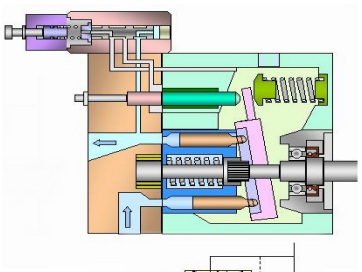


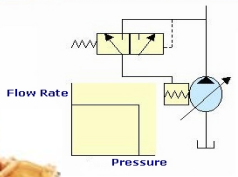
Variable delivery vane pump



Pump Pressure Compensator

- **When the pressure is high enough to overcome the valve spring, the spool is displaced and oil enters.**
- **The piston is forced by the oil pressure to decrease the pump displacement.**
- **Here compensator adjusts the pump out put to maintain preset pressure on load. This prevents excess power loss by avoiding relief valve operation at full pump output during holding or clamping.**
- **To move yoke it has to overcome the yoke return spring tension.**

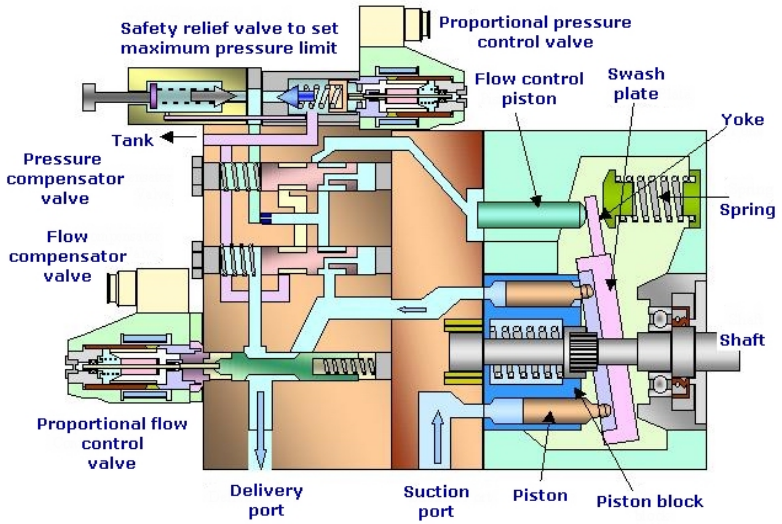




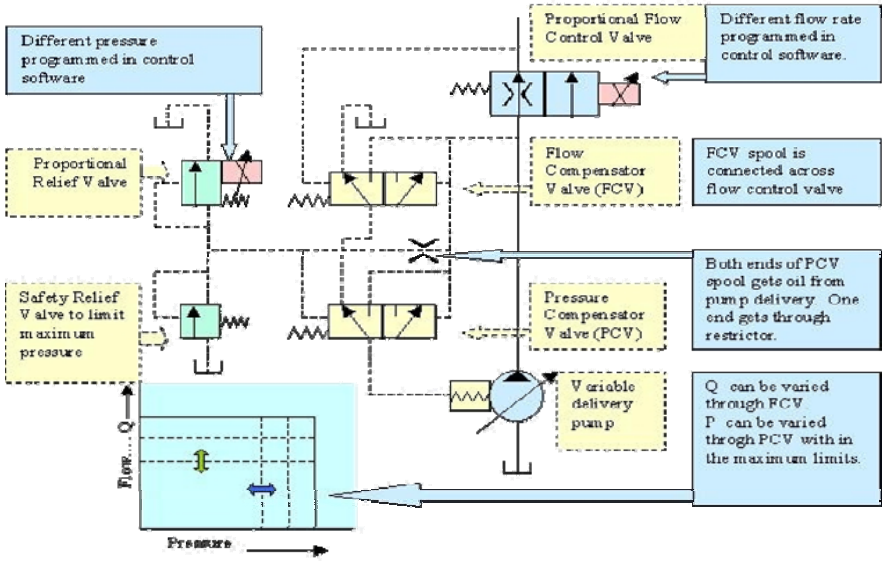
Load Sensing Control for Variable delivery pump

- Relief valve set at maximum permissible pressure for safety purpose,
- Proportional pressure relief valve - Programmed pressure settings done through software,
- pressure compensator valve- both end of spool gets oil from pump delivery,
- flow compensator valve - spool ends connected across Proportional flow control valve,
- Proportional flow control valve-Programmed flow settings done through software

Load Sensing Control



Internal Circuits



Plunger Pump