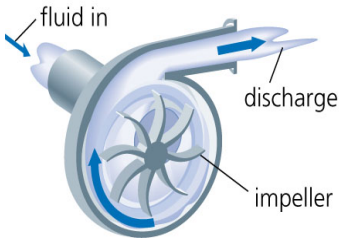
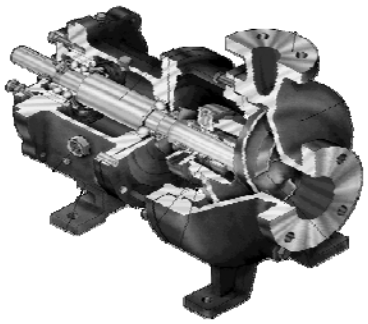



# Fluid Mechanics (0905241)

## Pumps



Prof. Zayed Al-Hamamre

Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22888


## Content

- Pumps and pumping of liquids
- Pump efficiency;
- Pump and system head:
  - Total head,
  - Suction head,
  - Discharge head,
  - NPSH head;
- Pump capacity, pump horsepower;
- Parameters involved in pump selection;
- Types of pumps,
- Pumps characteristic curves;
- Affinity laws of centrifugal pumps.



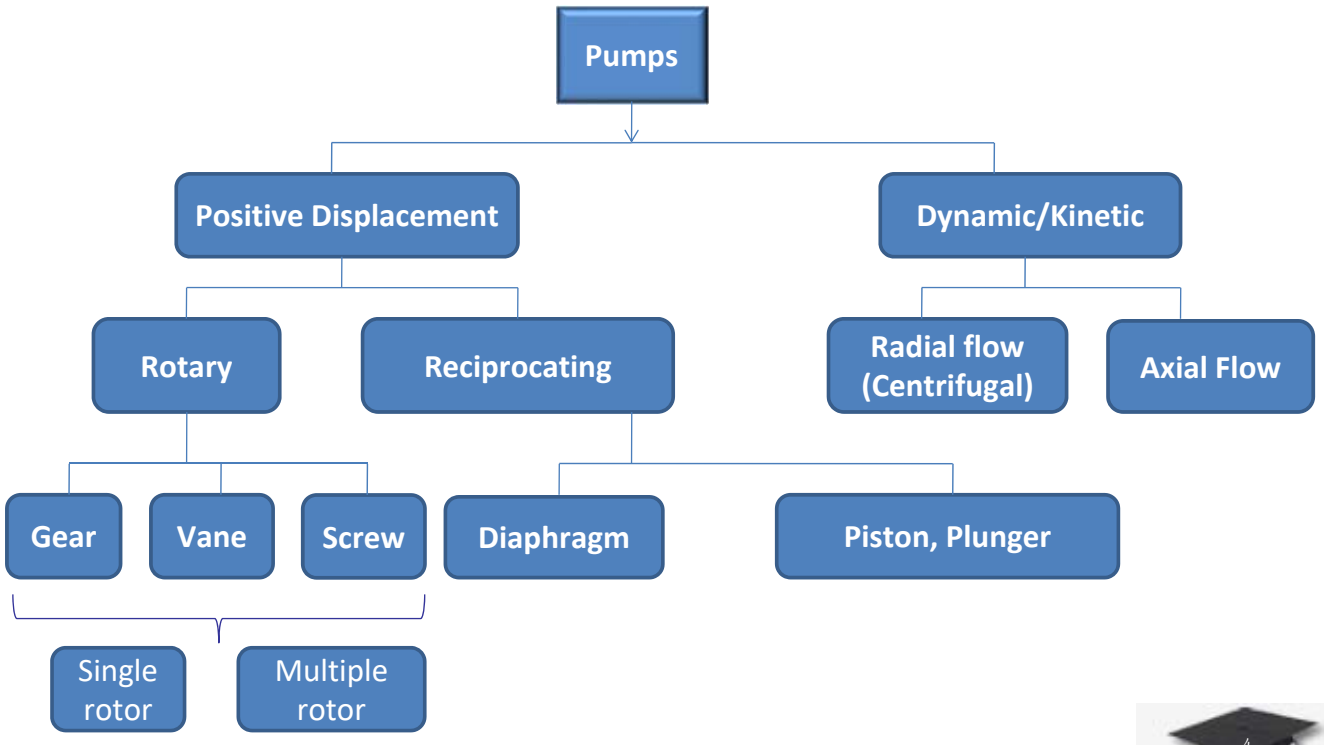
- A **pump** is a device used to move fluids, such as liquids, gases or slurries.
- It increases the mechanical energy of the fluid.
- The additional energy can be used to increase -

- Velocity (flow rate)
- Pressure
- Elevation



Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22888

# Pump Classification






Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22888

# Pump Classification

- This classification is based on the way by which the water leaves the rotating part of the pump.

  - In radial-flow pump the water leaves the impeller in radial direction,

  - while in the axial-flow pump the water leaves the propeller in the axial direction.

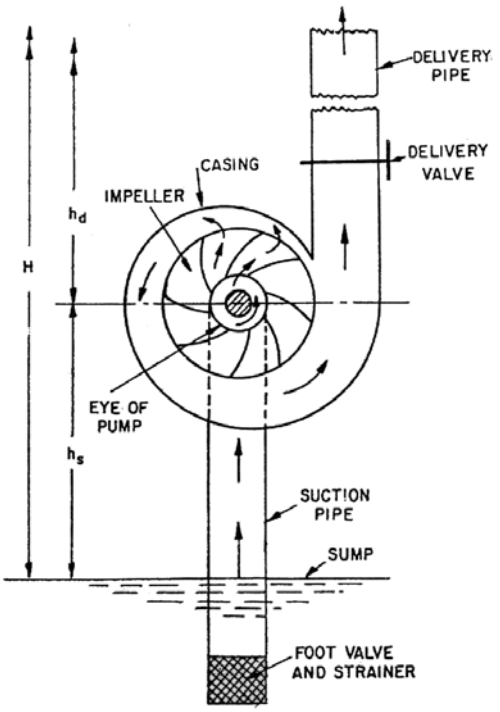
  - In the mixed-flow pump the water leaves the impeller in an inclined direction having both radial and axial components

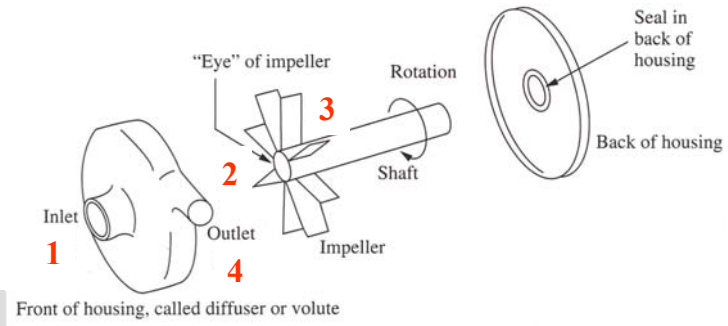


Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22888

# Centrifugal Pump

- Based on the concept of increasing the kinetic energy via the centrifugal action of the impeller and converting this kinetic energy to work
- Used predominantly for high-flow applications, less expensive, and less complex thereby minimizing maintenance
- Must be pre-charged with liquid or else it won't pump at start-up. Positive displacement pumps don't have this limitation.



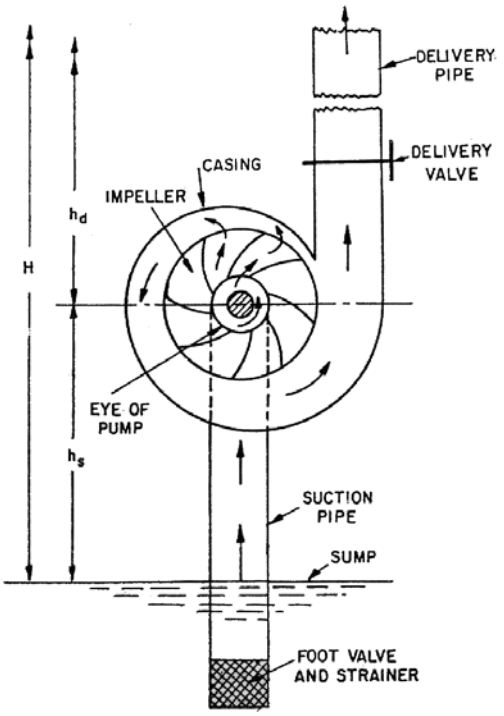



| Amman 11942, Jordan
Tel. +962 6 535 5000 | 22888

# Main Parts of Centrifugal Pumps

## 1. Impeller:

- Which is the rotating part of the centrifugal pump.
- It consists of a series of backwards curved vanes (blades).
- The impeller is driven by a shaft which is connected to the shaft of an electric motor.






Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22888

# Main Parts of Centrifugal Pumps

## 2. Casing

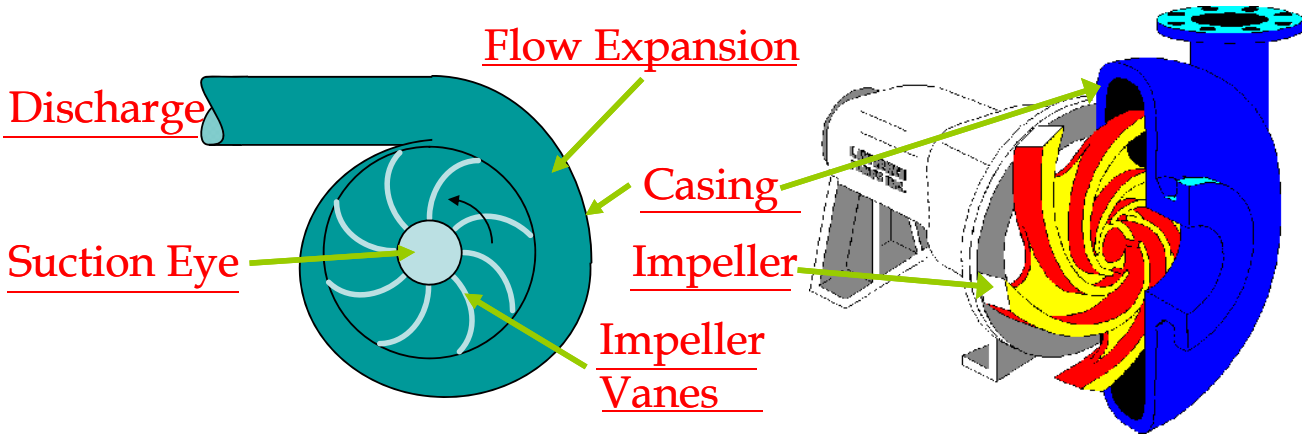
- Which is an air-tight passage surrounding the impeller
- designed to direct the liquid to the impeller and lead it away
- *Volute casing*. It is of spiral type in which the area of the flow increases gradually.

3. **Suction Pipe.**
4. **Delivery Pipe.**
5. **The Shaft**: which is the bar by which the power is transmitted from the motor drive to the impeller.
6. **The driving motor**: which is responsible for rotating the shaft. It can be mounted directly on the pump, above it, or adjacent to it.



Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22888

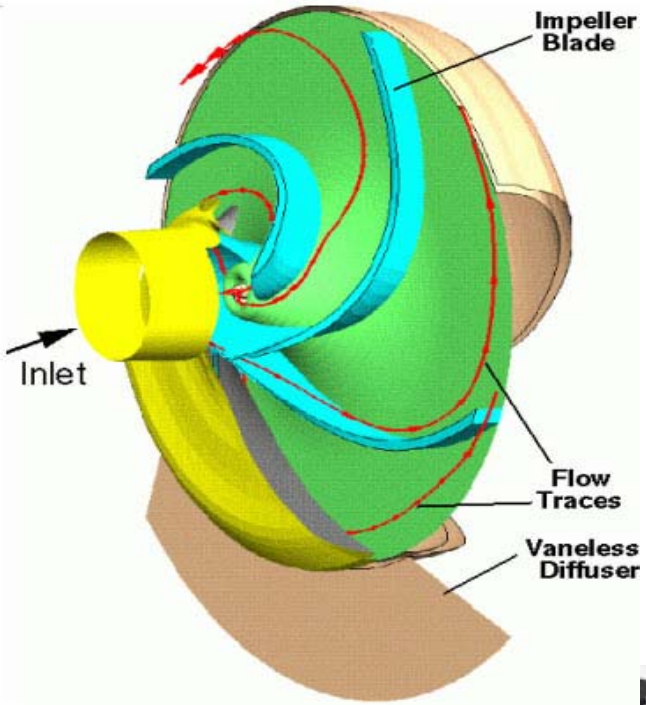
# Centrifugal Pump






Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22888

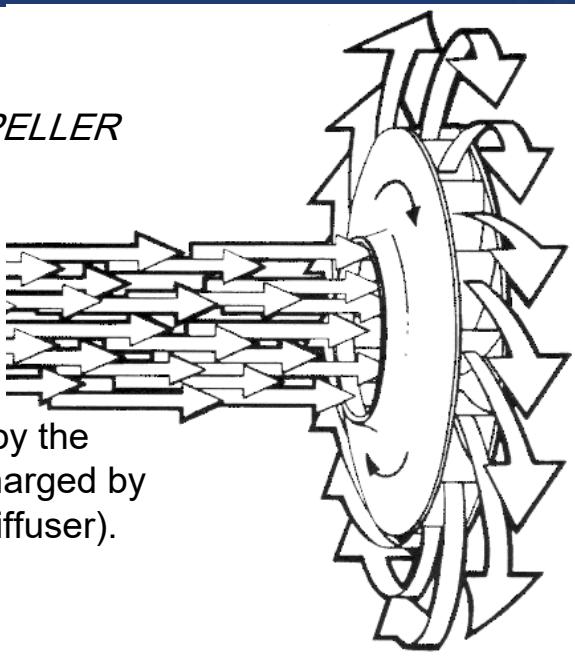
# Centrifugal Pump



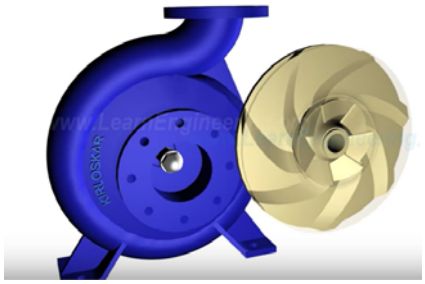

Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22888

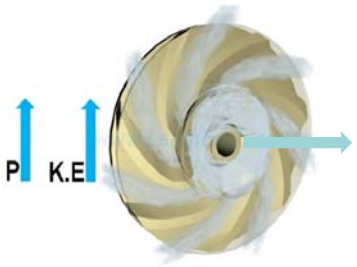
# Centrifugal Pump

- This machine consists of an *IMPELLER* rotating within a case (diffuser)
- Liquid directed into the center of the rotating impeller is picked up by the impeller's vanes and accelerated to a higher velocity by the rotation of the impeller and discharged by centrifugal force into the case (diffuser).

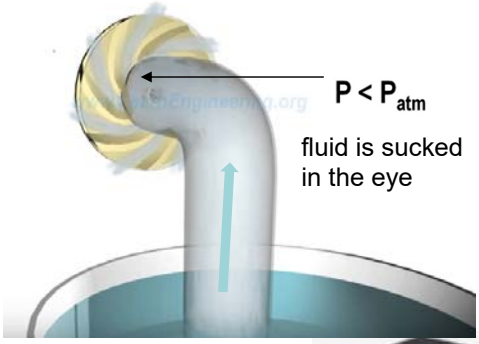






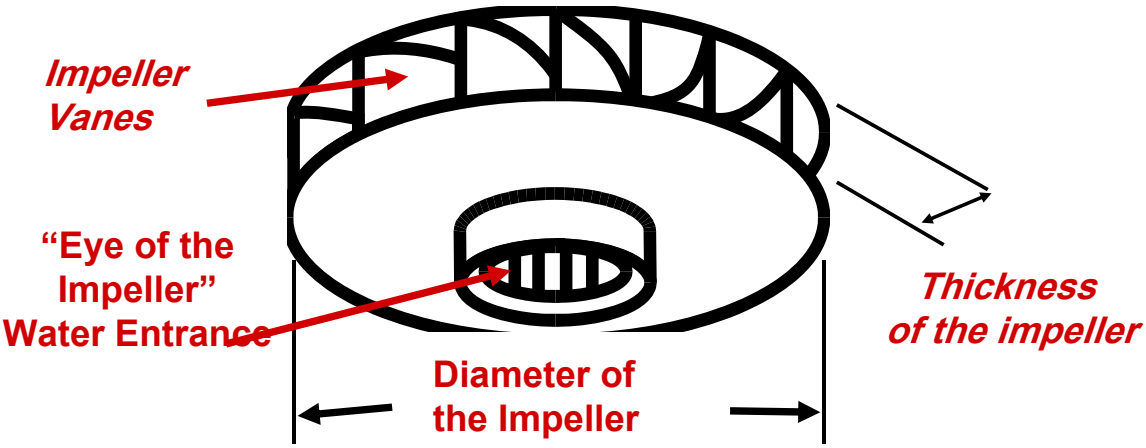



- As the impeller rotates, fluid is sucked in the eye
- The vanes add energy to the fluid



# Centrifugal Pump

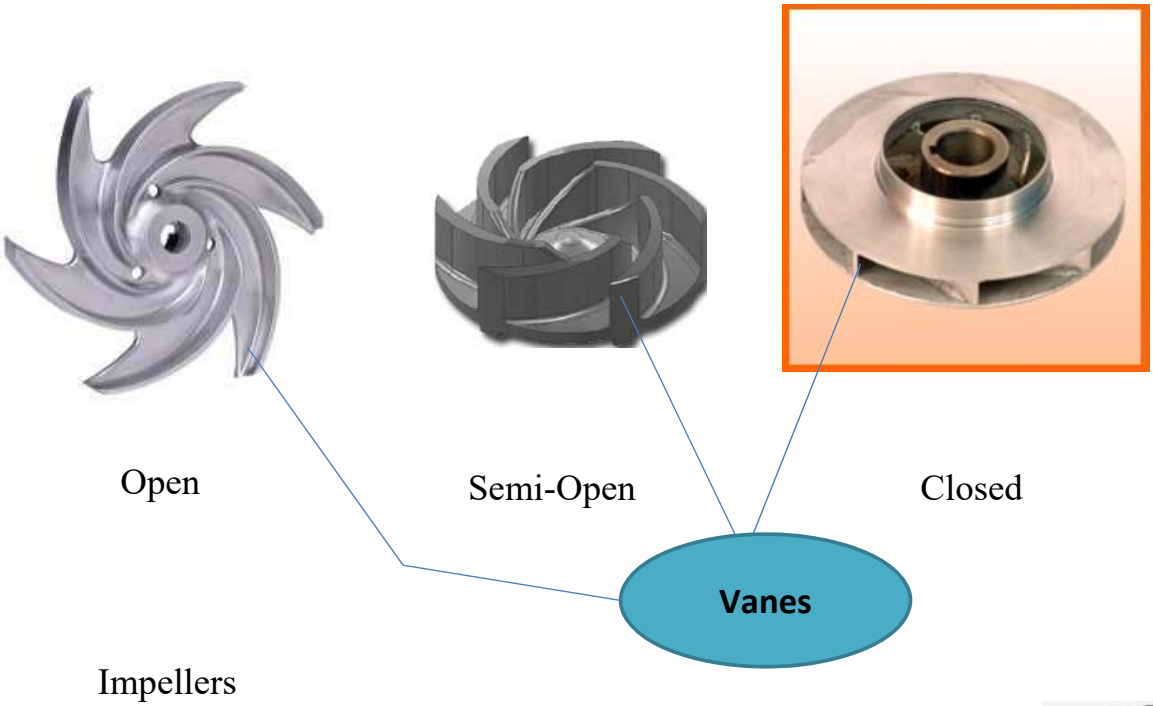
Centrifugal Impellers




- Thicker the Impeller- More Water
- Larger the DIAMETER - More Pressure
- Increase the Speed - More Water and Pressure



Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22888

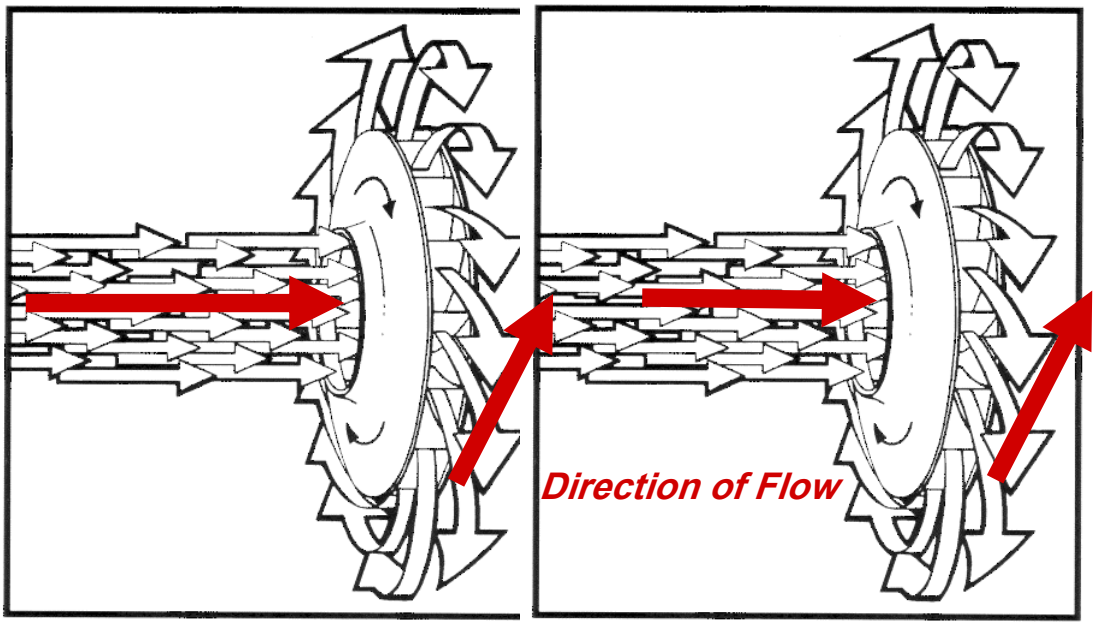





Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22888

# Centrifugal Pump

Two Impellers in Series

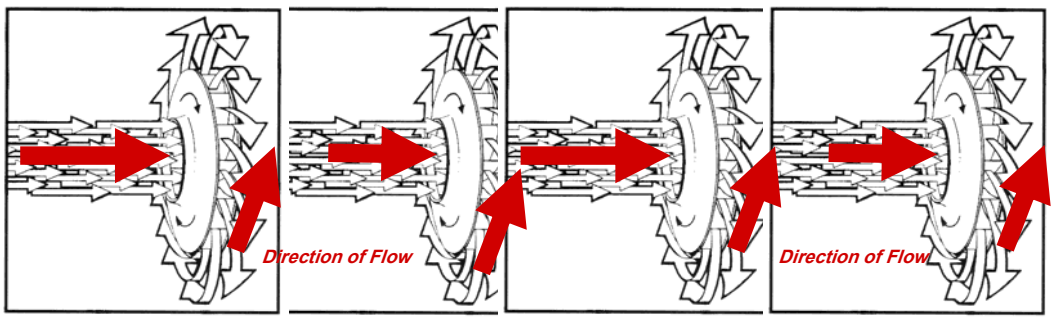



- Twice the pressure
- Same amount of water



# Centrifugal Pump

Multiple Impellers in Series




- Placing impellers in series increases the amount of head produced
- The head produced = # of impellers x head of one impeller




# Advantages of centrifugal pump

- As there is no drive seal so there is no leakage in pump.
- It can pump hazardous liquids.
- There are very less frictional losses.
- There in almost no noise.
- Pump has almost have 100 efficiency.
- Centrifugal pump have minimum wear with respect to others.
- There is a gap between pump chamber and motor, so there is no heat transfer between them.
- Because of the gap between pump chamber and motor, water cannot enter into motor.
- Centrifugal pump use magnetic coupling which breakup on high load eliminating the risk of damaging the motor.

# Disadvantages of centrifugal pump

- Because of the magnetic resistance there is some energy losses.
- Unexpected heavy load may cause the coupling to slip.
- Ferrousparticles in liquid are problematic when you are using magnetic drive.This is because particle collect at impeller and cause the stoppage of pump after sometime.



Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22888

# Positive Displacement Pump

- A positive displacement pump in which rotary motion carries the liquid from the pumps inlet to its outlet.
- A Positive Displacement Pump has an expanding cavity on the suction side of the pump and a decreasing cavity on the discharge side.
- Liquid is allowed to flow into the pump as the cavity on the suction side expands and the liquid is forced out of the discharge as the cavity collapses.
- This principle applies to all types of Positive Displacement Pumps whether the pump is a rotary lobe, gear within a gear, piston, diaphragm, screw etc.



Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22888

# Positive Displacement Pump

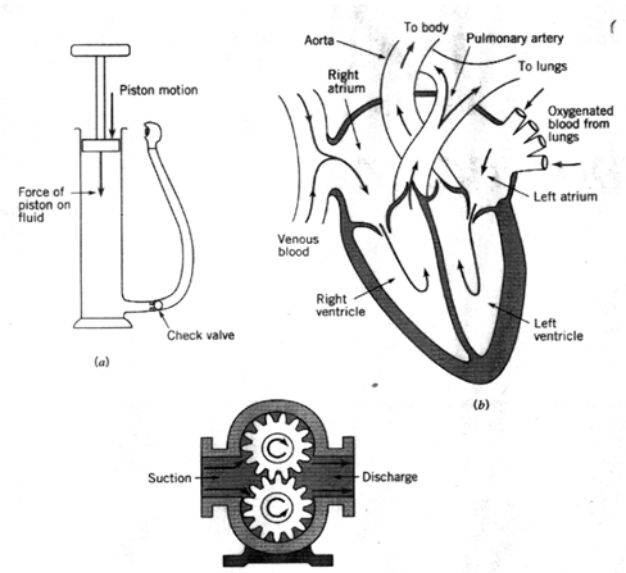
- A Positive Displacement Pump, unlike a Centrifugal Pump, will produce the same flow at a given RPM no matter what the discharge pressure is.
- A Positive Displacement Pump cannot be operated against a closed valve on the discharge side of the pump, i.e. it does not have a shut-off head like a Centrifugal Pump does.
- If a Positive Displacement Pump is allowed to operate against a closed discharge valve it will continue to produce flow which will increase the pressure in the discharge line until either the line bursts or the pump is severely damaged or both.



Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22888

# Positive Displacement Pump

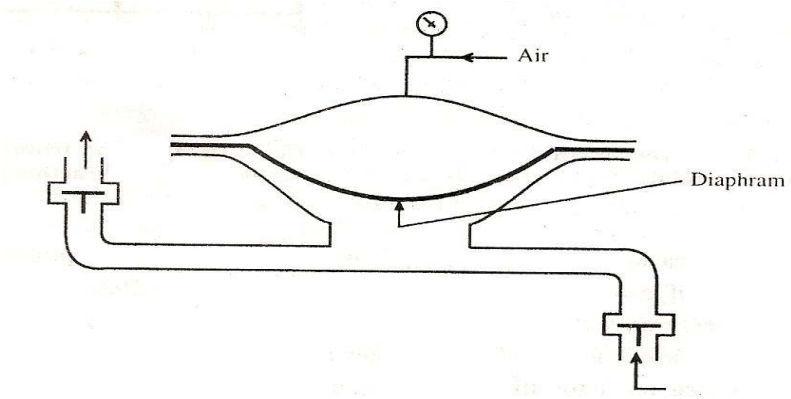
- Positive-displacement (PD) pumps work by allowing a fluid to flow into enclosed cavity from a low-pressure source, trapping the fluid, and then forcing it out into a high-pressure receiver by decreasing the volume of the cavity.
- Examples are the fuel and oil pumps on most automobiles, the pumps on most hydraulic systems, the lungs, the heart.
- Figure shows the cross-sectional view of a simple PD pump






Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22888

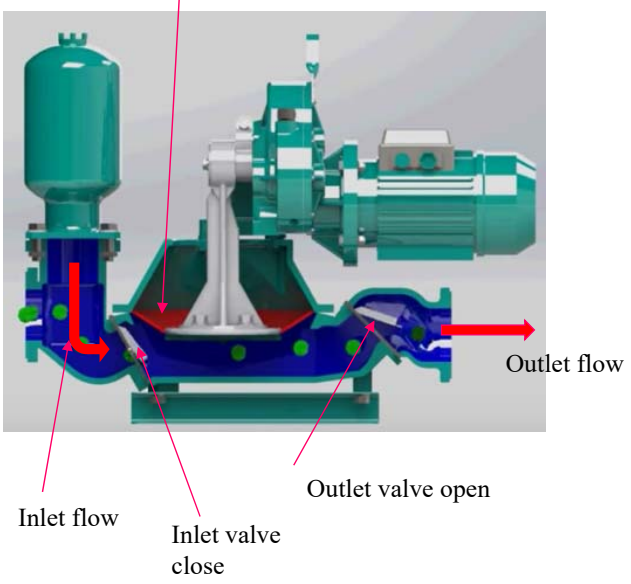
## Diaphragm Pumps

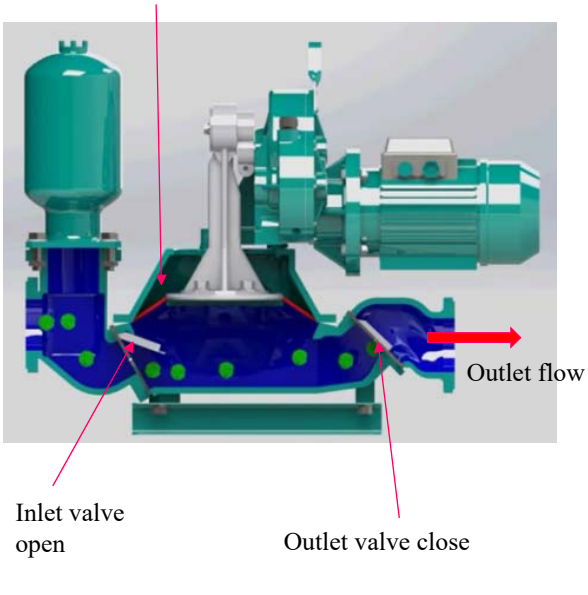



- For handling of corrosive & toxic liquids.
- Piston or plunger working in non corrosive fluid which actuates the diaphragm.
- Diaphragm made up of metal or rubber or plastic.
- Pneumatically actuated pump uses plant air.



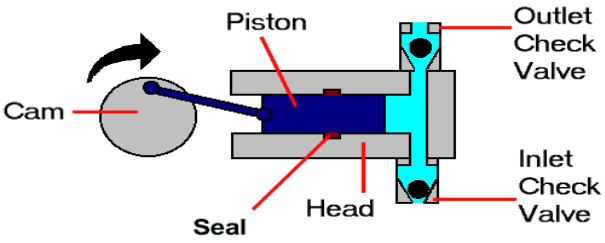


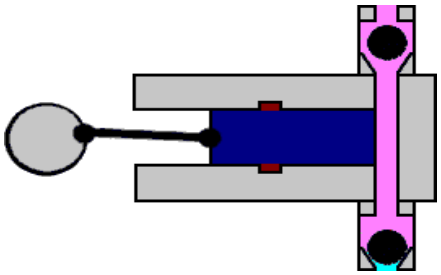


# Reciprocating Pumps

## Piston Pumps



Swept volume =

No. of strokes per second × area of piston × length of stroke

Volumetric efficiency =

Ratio of actual discharge to swept volume. Usually 90%.

Air vessel :

- At pump discharge.

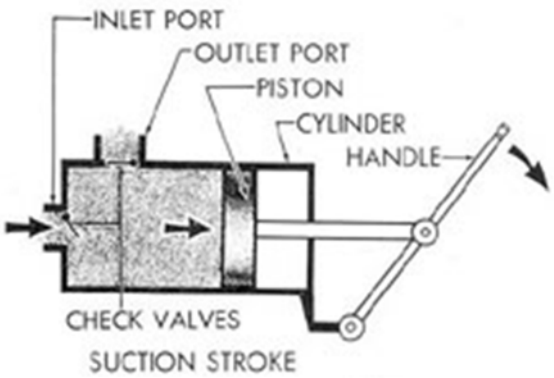
-To even out the flow in discharge line.

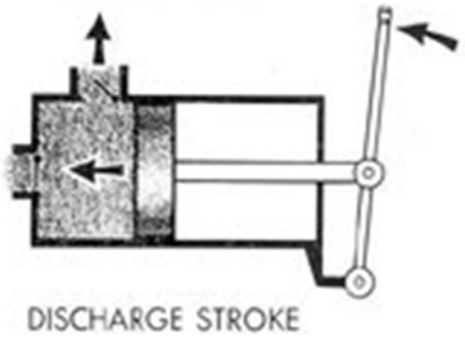
- Compressed air dilivers liquid to discharge when discharge decreases at the end of the stroke.

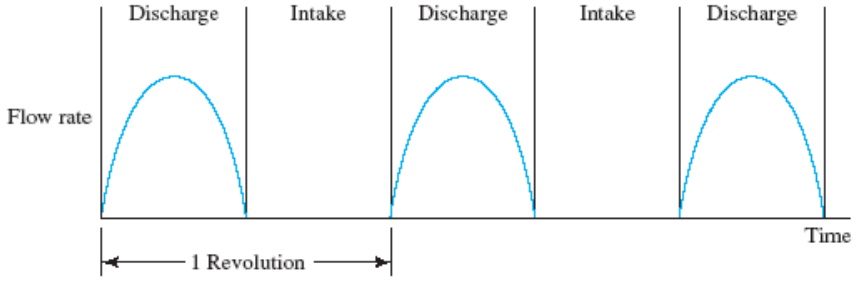
-Reduces Friction.



Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22888



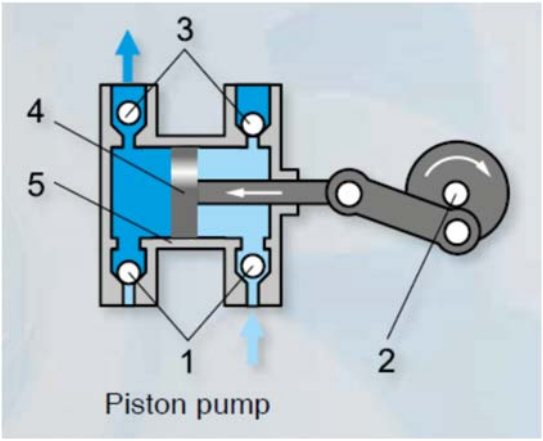




(a) Single-acting pump—simplex

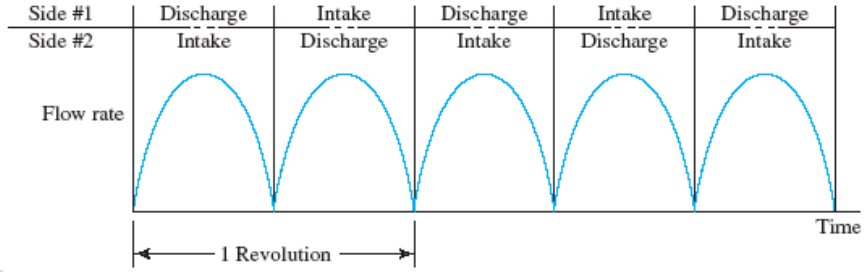


Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22888




***Structure of oscillating positive displacement pumps***

***1*** *suction valve,*
***2*** *crank mechanism,*
***3*** *pressure valve,*
***4*** *piston,*
***5*** *cylinder,*



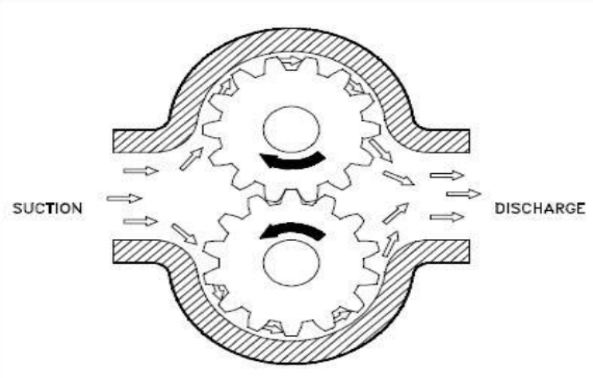

(b) Double-acting pump—duplex

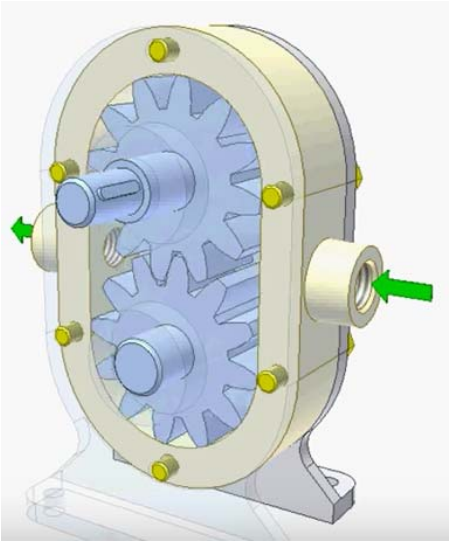


# Rotary Pumps

## Gear Pumps

- External Gear Pump



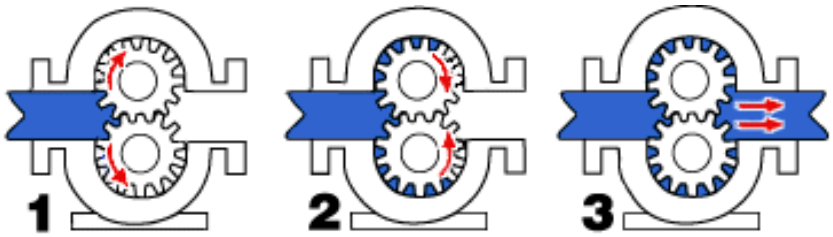





Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22888

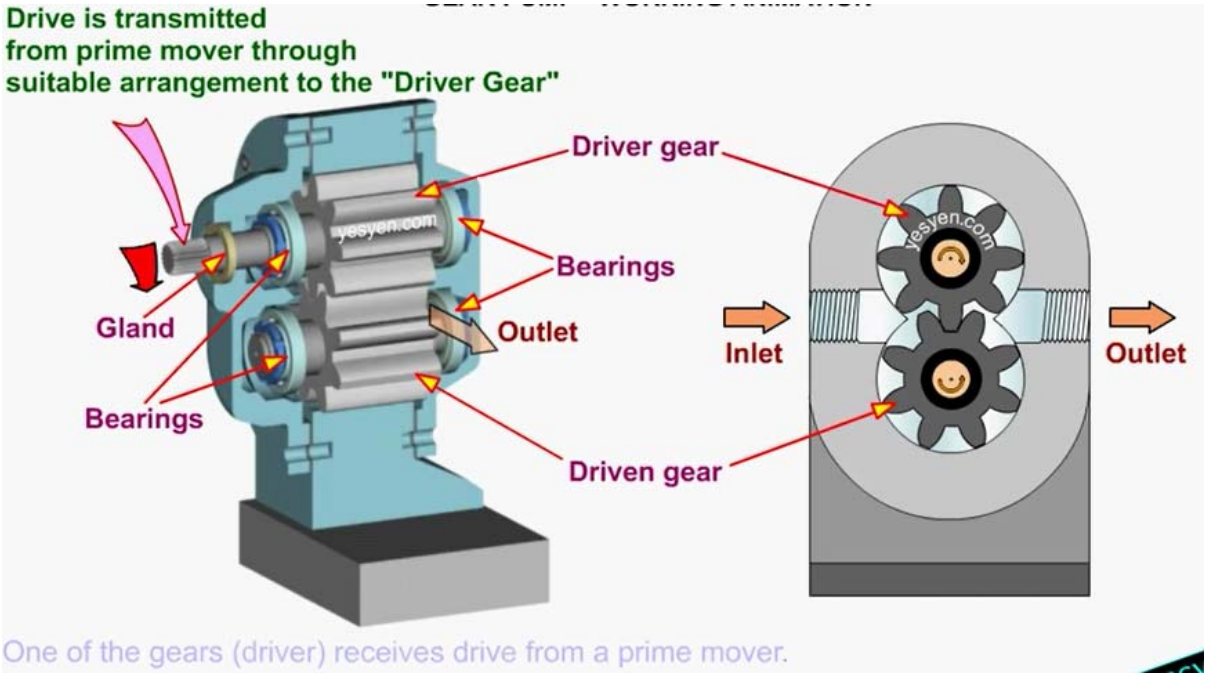
# Working of External Gear Pump

- The external gear pump is a positive displacement pump composed of a casing with two meshing gears with external teeth.
- One gear is driven by the shaft coupled to a driver. This gear drives the other gear.
- The rotation of the gears is such that the liquid comes into the inlet port and flows into and around the outer periphery of the two rotating gears.
- As the liquid comes around the periphery it is discharged to the outlet port.
- The flow of the pump is regulated by the size of the cavity (volume) between the teeth and the speed of the gears.

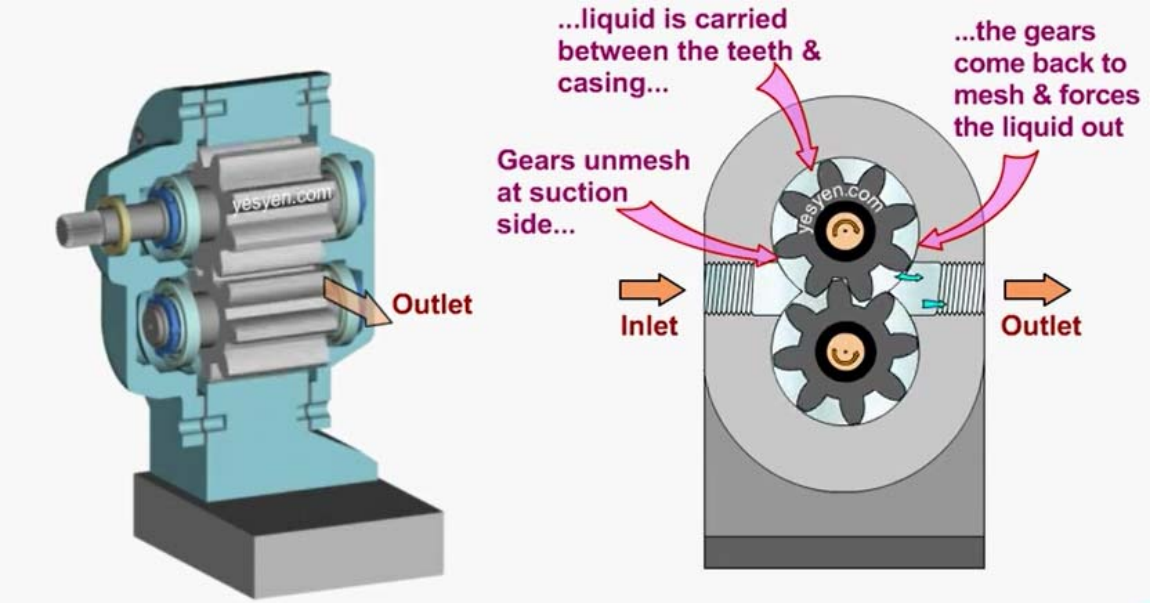





# Working of External Gear Pump



# Working of External Gear Pump






# Continued

- Flow from the outlet is further regulated by the amount of liquid that slips back to the inlet port.
- The amount of slip depends on the side clearance of the gears to the casing, the peripheral clearance of the gear and bore in the casing, gear-to-gear clearance, developed pressure, and viscosity of the liquid.
- The lower the viscosity, the greater the slippage.
- As the viscosity increases, the pump speed is lowered to allow the liquid to fill the space between the rotating teeth.

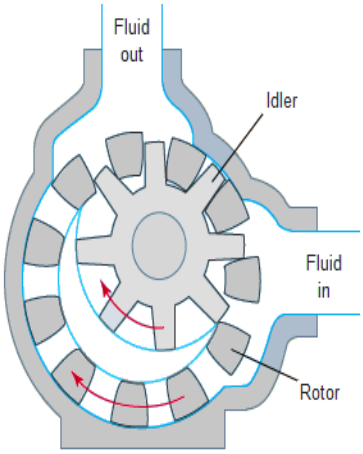
# Applications:

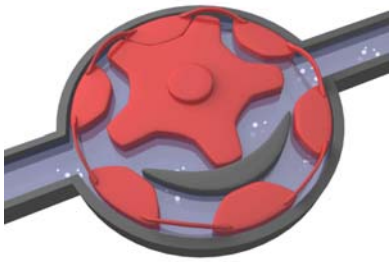
- The most common uses for these pumps are to supply fuel oil for burners, gasoline transfer, kerosene, fuel oil, and diesel oil.
- They are used for hydraulic devices such as elevators and damper controls.
- They also pump coolants, paints, bleaches, solvents, syrups, glues, greases, petroleum, and lube oils and are used in general industrial applications.
- External gear pumps can handle small suspended solids in abrasive applications but will gradually wear and lose performance.

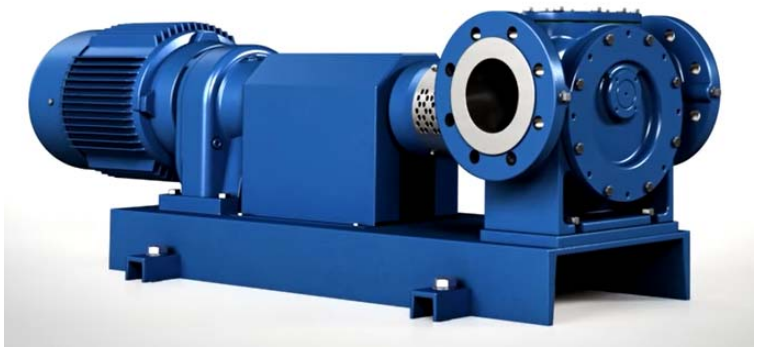


Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22888

# Internal Gear Pump



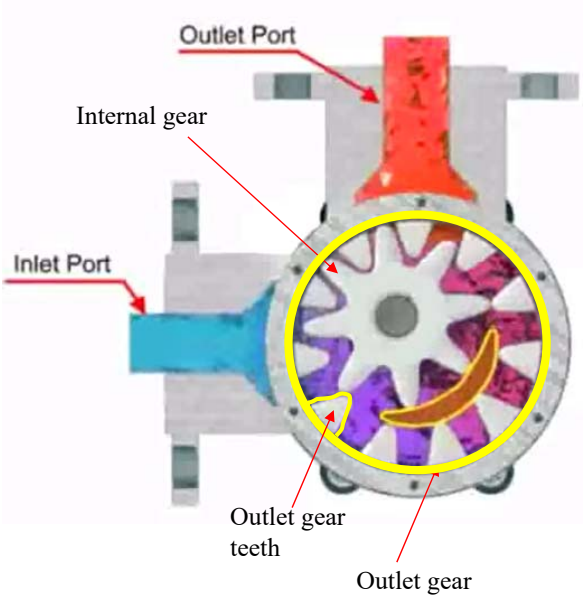




Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22888

# Working of Internal Gear Pump

- The internal gear pump is a rotary flow positive displacement pump design, which is well-suited for a wide range of applications due to its relatively low speed and inlet pressure requirements.
- These designs have only two moving parts and hence have proven reliable, simple to operate, and easy to maintain.
- They are often a more efficient alternative than a centrifugal pump, especially as viscosity increases.
- Internal gear pumps have one gear with internally cut gear teeth that mesh with the other gear that has externally cut gear teeth.






# Continued…

- Pumps of this type are made with a crescent-shaped partition.
- Designs are available to provide the same direction of flow regardless of the direction of shaft rotation.
- As the gears come out of mesh on the inlet side, liquid is drawn into the pump. The gears have a fairly long time to come out of mesh allowing for favorable filling.
- The mechanical contacts between the gears form a part of the moving fluid seal between the inlet and outlet ports. The liquid is forced out the discharge port by the meshing of the gears.

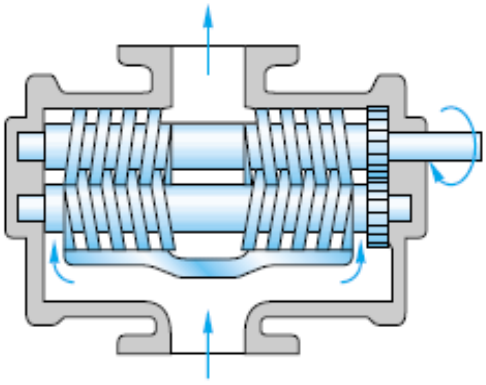
# Applications:

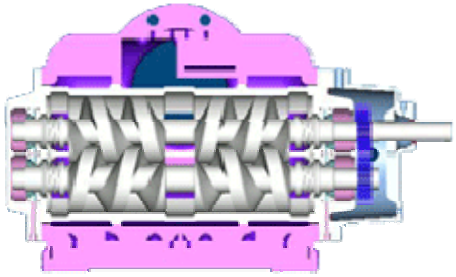
- Internal gear pumps are applied in petrochemical, marine, terminal unloading, chemical, and general industrial applications for transfer, lubrication, processing, and low-pressure hydraulics handling a wide range of fuel oils, lube oils, and viscous chemicals (both corrosive and noncorrosive).

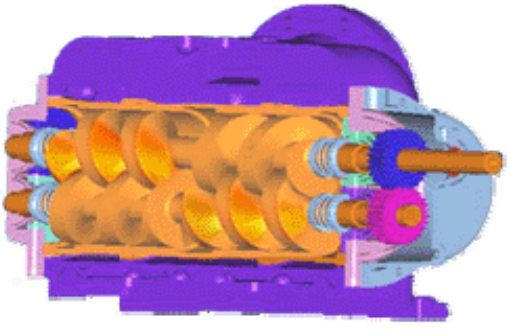


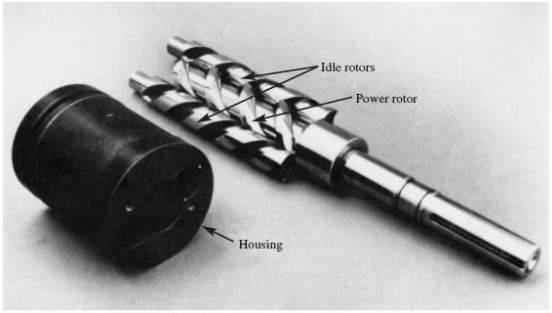
Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22888

# Screw Pump











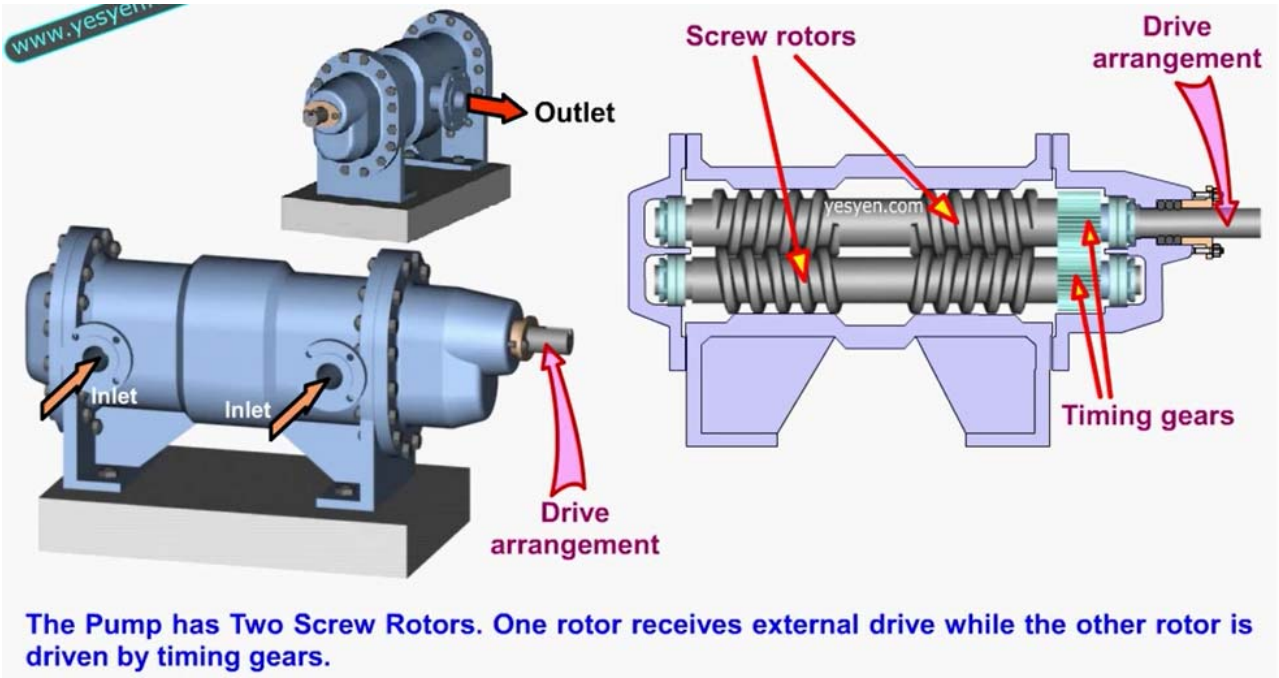

Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22888

# Screw Type PDRP

- There are many variations in the design of the screw type positive displacement, rotary pump. The primary differences consist of the number of intermeshing screws involved, the pitch of the screws, and the general direction of fluid flow.
- Two common designs are the two-screw, low-pitch, double-flow pump and the three-screw, high-pitch, double-flow pump.
- The two-screw, low-pitch, screw pump consists of two screws that mesh with close clearances, mounted on two parallel shafts.
  - One screw has a right-handed thread, and the other screw has a left-handed thread.
  - One shaft is the driving shaft and drives the other shaft through a set of herringbone timing gears.
  - The gears serve to maintain clearances between the screws as they turn and to promote quiet operation.
  - The screws rotate in closely fitting duplex cylinders that have overlapping bores.



Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22888




The Pump has Two Screw Rotors. One rotor receives external drive while the other rotor is driven by timing gears.



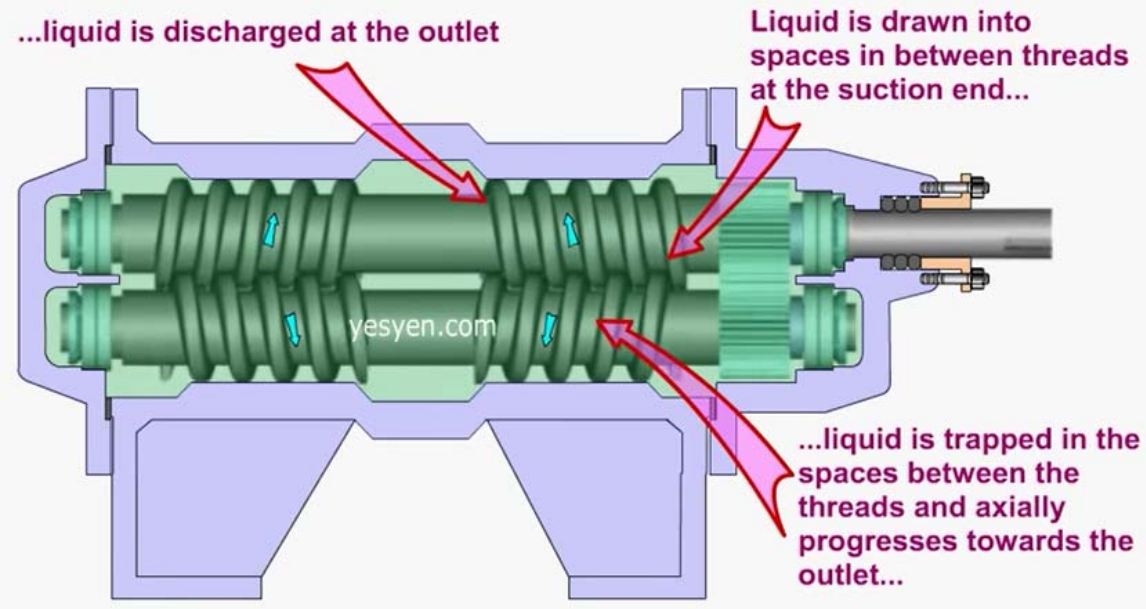
Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22888

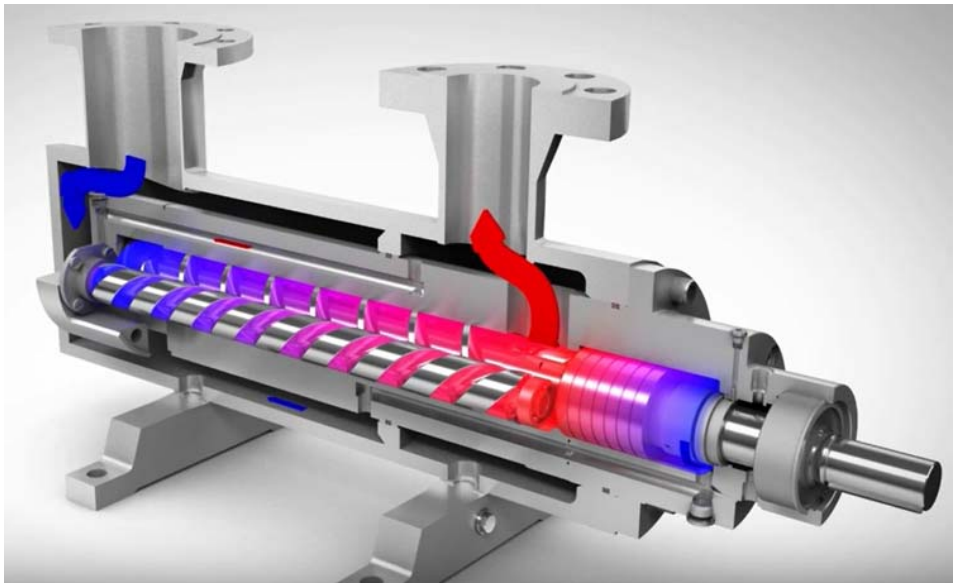
# Continued

- All clearances are small, but there is no actual contact between the two screws or between the screws and the cylinder walls.
- The complete assembly and the usual flow path are shown in Figure. Liquid is trapped at the outer end of each pair of screws. As the first space between the screw threads rotates away from the opposite screw, a one-turn, spiral-shaped quantity of liquid is enclosed when the end of the screw again meshes with the opposite screw.
- As the screw continues to rotate, the entrapped spiral turns of liquid slide along the cylinder toward the center discharge space while the next slug is being entrapped.
- The removal of liquid from the suction end by the screws produces a reduction in pressure, which draws liquid through the suction line.



# Screw Pump







# Applications:

- Loading / unloading of fuel oil and other products from: Railway wagon rakes, Truck tankers, Barges, Ships and Tankers.
- Lubrication, circulation and cooling.
- Process pumping of high viscous products, bitumen, molasses, soap and similar products.
- Long distance pipeline pumping of viscous products.

- *Major Industries:*
- Petroleum refineries, Terminals, Depots, Oil blending stations, Thermal power plants, Steel plants, Fertilizer industries, Petrochemical plants, Carbon black, Sugar, Paper and Pulp, Marine.

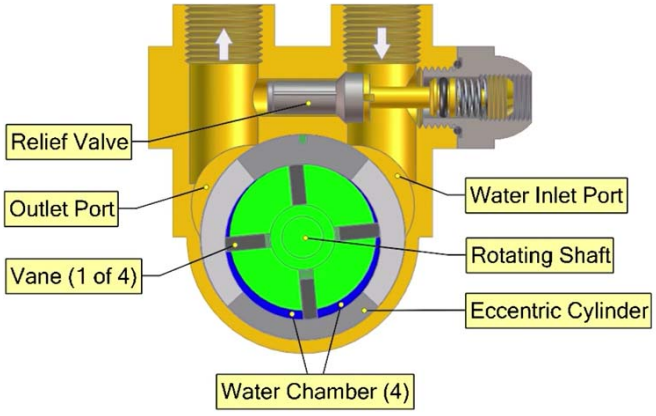
# Vane Pump

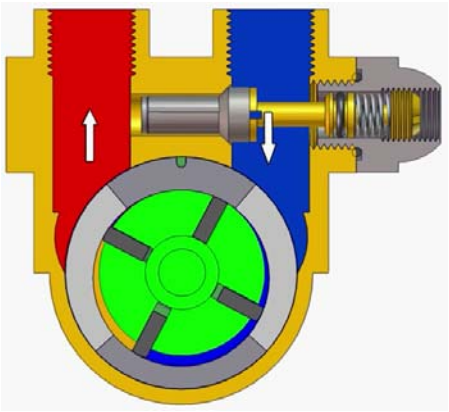
- The simplest vane pump is a circular rotor rotating inside of a larger circular cavity. The centres of these two circles are offset, causing eccentricity.
- Vanes are allowed to slide into and out of the rotor and seal on all edges, creating vane chambers that do the pumping work.
- On the intake side of the pump, the vane chambers are increasing in volume. These increasing volume vane chambers are filled with fluid forced in by the inlet pressure. Inlet pressure is actually the pressure from the system being pumped, often just the atmosphere.
- On the discharge side of the pump, the vane chambers are decreasing in volume, forcing fluid out of the pump. The action of the vane drives out the same volume of fluid with each rotation.



Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22888

# Vane Pump





Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22888

# Advantages and disadvantages

***Advantages***

- Handles thin liquids at relatively higher pressures
- Compensates for wear through vane extension
- Sometimes preferred for solvents, LPG
- Can run dry for short periods
- Can have one seal or stuffing box
- Develops good vacuum

***Disadvantages***

- Can have two stuffing boxes
- Complex housing and many parts
- Not suitable for high pressures
- Not suitable for high viscosity
- Not good with abrasives



Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22888

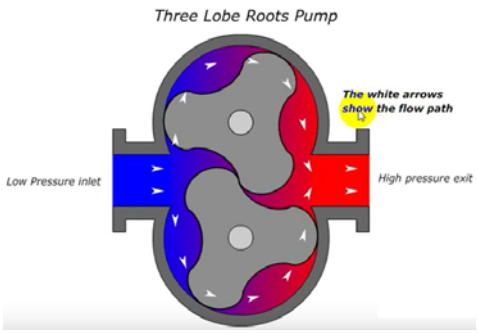
# Applications

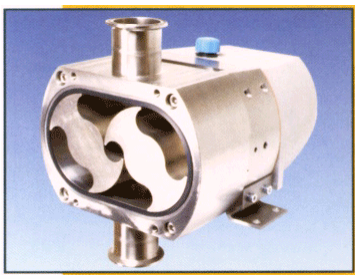
- Fuel Transfer
- Auto Industry - Fuels, Lubes, Refrigeration Coolants
- Bulk Transfer of LPG and $NH_3$
- LPG Cylinder Filling
- Alcohols
- Refrigeration - Freons, Ammonia
- Solvents

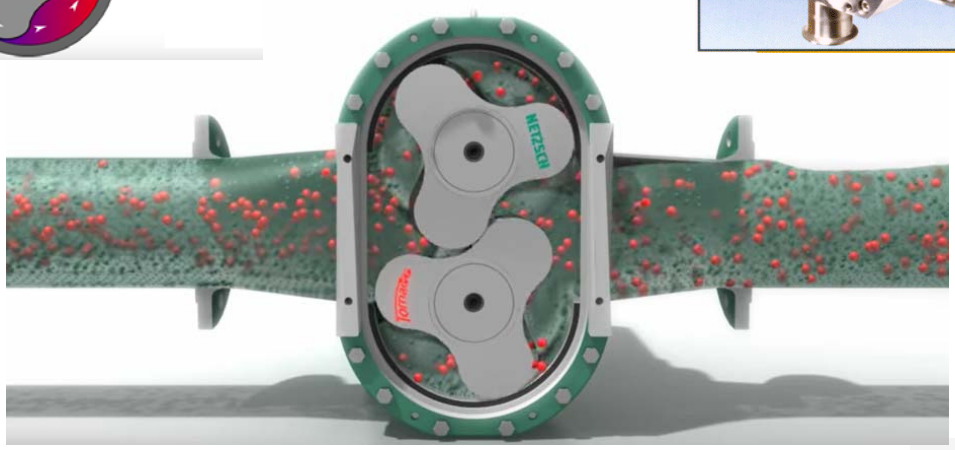


Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22888

# Three Lobe Pump



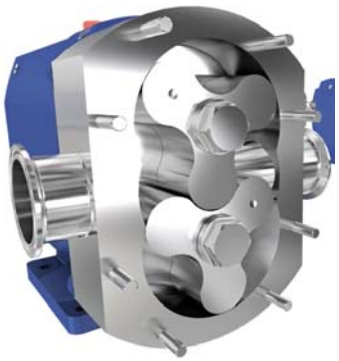





Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22888

# Working of lobe pump

- Lobe pumps are similar to external gear pumps in operation in that fluid flows around the interior of the casing. Unlike external gear pumps, however, the lobes do not make contact. Lobe contact is prevented by external timing gears located in the gearbox.
  1. As the lobes come out of mesh, they create expanding volume on the inlet side of the pump. 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—it does not pass between the lobes.
  3. Finally, the meshing of the lobes forces liquid through the outlet port under pressure.





Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22888

# Lobe pump

- Lobe pumps are frequently used in food applications because they handle solids without damaging the product. Particle size pumped can be much larger in lobe pumps than in other positive displacement types. Since the lobes do not make contact, and clearances are not as close as in other Positive displacement pumps, this design handles low viscosity liquids with diminished performance.
- Loading characteristics are not as good as other designs, and suction ability is low.
- High-viscosity liquids require reduced speeds to achieve satisfactory performance.
- Reductions of 25% of rated speed and lower are common with high-viscosity liquids.
- **Lobe pumps** are used in a variety of industries including pulp and paper, chemical, food, beverage, pharmaceutical, and biotechnology. They are popular in these diverse industries because they offer high efficiency, reliability, corrosion resistance.




# Centrifugal Vs Reciprocating Pump

| Characteristics | Centrifugal Pump | Reciprocating Pump |
|---|---|---|
| Construction | Simple because of less number of parts | Complex because of more number of parts |
| Weight/discharge ratio | Less | More |
| Suitability | Smaller heads but large discharge | Higher heads but low discharge |
| Floor area requirement | Less | More |
| Wear and tear | Less | More |
| Maintenance cost | Less | More |
| Liquid with solid suspension | Can handle | Cannot handle |
| Speed | Higher speed | Cannot run at high speed |
| Mode of delivery | Continuous | Pulsating |
| Air vessel requirement | No | Yes |
| Operation | Simple | Much care is needed |
| Priming | Required | Not required |
| Efficiency | Less | More |

| Parameter | Centrifugal Pumps | Reciprocating Pumps | Rotary Pumps |
|---|---|---|---|
| Optimum Flow and Pressure Applications | Medium/High Capacity, Low/Medium Pressure | Low Capacity, High Pressure | Low/Medium Capacity, Low/Medium Pressure |
| Maximum Flow Rate | 100,000+ GPM | 10,000+ GPM | 10,000+ GPM |
| Low Flow Rate Capability | No | Yes | Yes |
| Maximum Pressure | 6,000+ PSI | 100,000+ PSI | 4,000+ PSI |
| Requires Relief Valve | No | Yes | Yes |
| Smooth or Pulsating Flow | Smooth | Pulsating | Smooth |
| Variable or Constant Flow | Variable | Constant | Constant |
| Self-priming | No | Yes | Yes |
| Space Considerations | Requires Less Space | Requires More Space | Requires Less Space |
| Costs | Lower Initial<br>Lower Maintenance<br>Higher Power | Higher Initial<br>Higher Maintenance<br>Lower Power | Lower Initial<br>Lower Maintenance<br>Lower Power |
| Fluid Handling | Suitable for a wide range including clean, clear, non-abrasive fluids to fluids with abrasive, high-solid content.<br><br>Not suitable for high viscosity fluids<br><br>Lower tolerance for entrained gases | Suitable for clean, clear, non-abrasive fluids. Specially-fitted pumps suitable for abrasive-slurry service.<br><br>Suitable for high viscosity fluids<br><br>Higher tolerance for entrained gases | Requires clean, clear, non-abrasive fluid due to close tolerances<br><br>Optimum performance with high viscosity fluids<br><br>Higher tolerance for entrained gases |



Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22888

# Pump Selection

- Liquid properties
  pH, specific gravity, viscosity, temperature
  corrosive nature, aeration, solids in suspension,
  etc.
- Pump properties
  type of pump, flow rate, NPSH, capacity,
  materials of construction, economic life, etc.

- In selecting a particular pump for a given system:
  - The design conditions are specified and a pump is selected for the range of applications.
  - A system characteristic curve (H-Q) is then prepared.
  - The H-Q curve is then matched to the pump characteristics chart which is provided by the manufacturer.
  - The matching point (operating point) indicates the actual working conditions.



Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22888

# Parameters Involved In Pump selection:

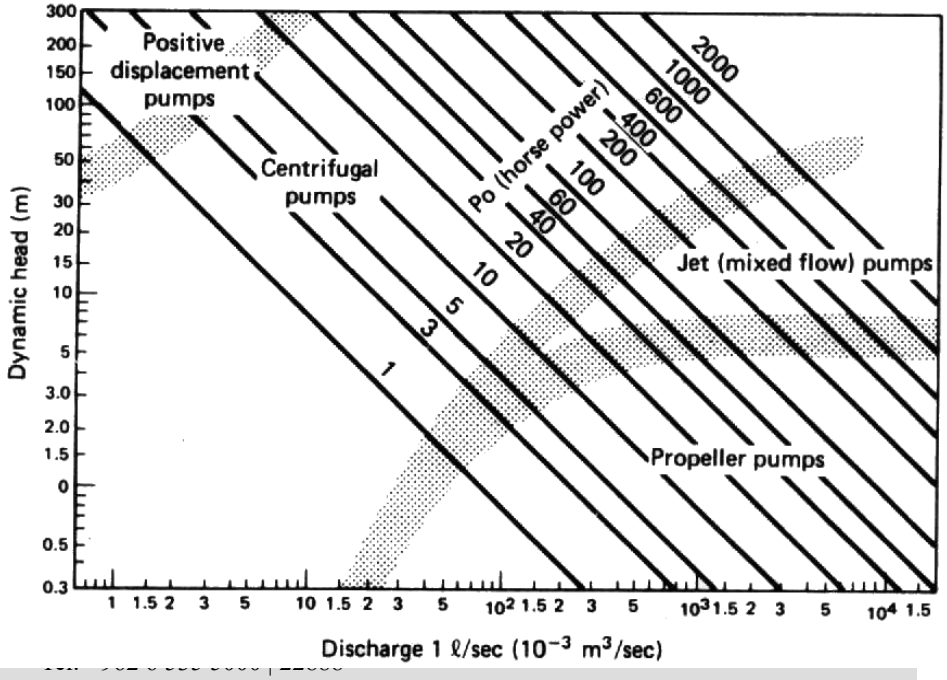
- When selecting a pump for a particular application, the following factors must be considered:
  1. The nature of the liquid to be pumped(viscosity, density, suspended solids, corrosive,..etc)
  2. The required capacity (volume flow rate)
  3. The conditions on the suction (inlet) side of the pump
  4. The conditions on the discharge (outlet) side of the pump
  5. The total head on the pump (the term from the energy equation)
  6. The type of system to which the pump is delivering the fluid
  7. The type of power source (electric motor, diesel engine, steam turbine, etc.)
  8. Space, weight, and position limitations
  9. Environmental conditions
  10. Cost of pump purchase and installation
  11. Cost of pump operation
  12. Governing codes and standards



Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22888

# Pump Selection

- It has been seen that the efficiency of a pump depends on the discharge, head, and power requirement of the pump.
- The approximate ranges of application of each type of pump are indicated in the following Figure.



Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22888