PUMP TYPES

Kinetic Pumps

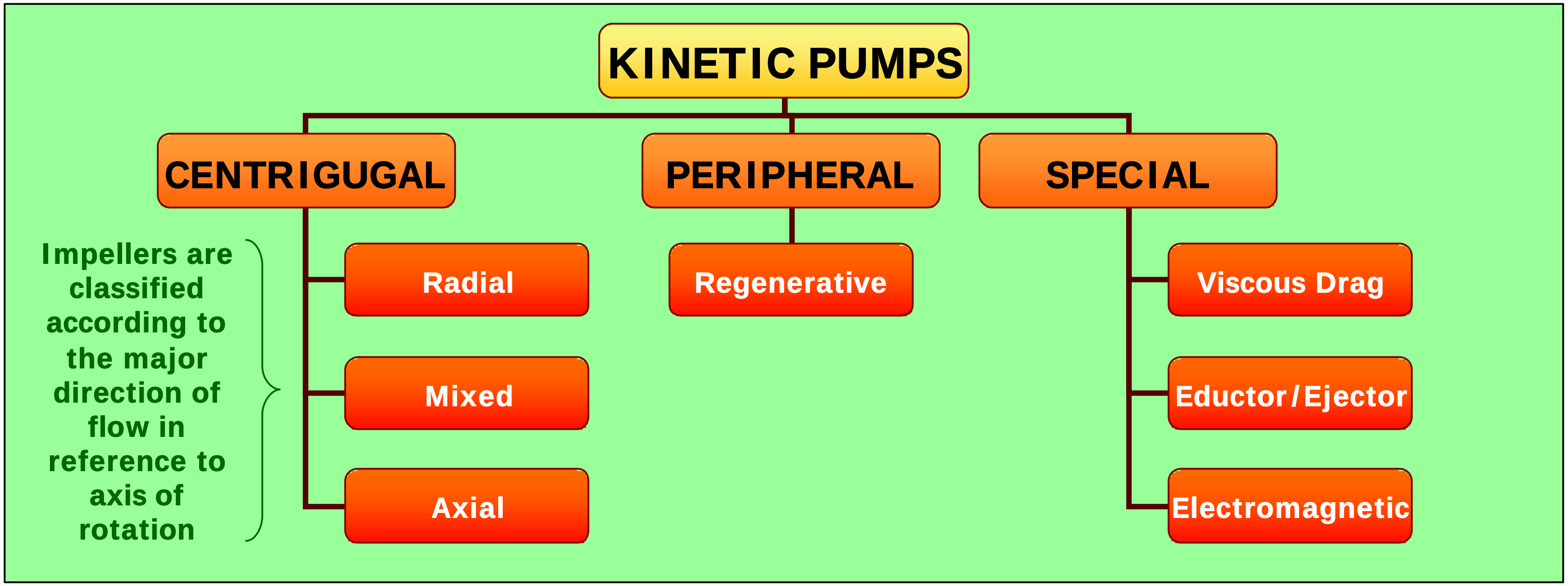
Positive Displacement Pumps

Classification of Pumps

- The hierarchy of pump classification is as follows
  - The way the energy is added to the fluid
    - **Kinetic / Dynamic Pumps** adds energy **continuously**
    - **Positive Displacement Pumps** adds energy **periodically**
  - The way this principle (addition of energy) is implemented
    - **Kinetic Pumps**
      - **Centrifugal**
      - Special Effect
    - **Positive Displacement**
      - **Reciprocating**
      - **Rotary**
  - Delineation of specific geometries
    - Kinetic Pumps
      - **Centrifugal**
        - Axial
        - Mixed Flow
        - Radial
    - Positive Displacement
      - **Reciprocating**
        - Piston
        - Diaphragm
      - **Rotary**
        - Single rotor
        - Multiple Rotor

Kinetic (Dynamic) Pumps

- Kinetic pumps add energy continuously to increase the fluid velocity (kinetic energy) within the pump element such that subsequent velocity reduction in pump volute produces a pressure increase (potential energy).

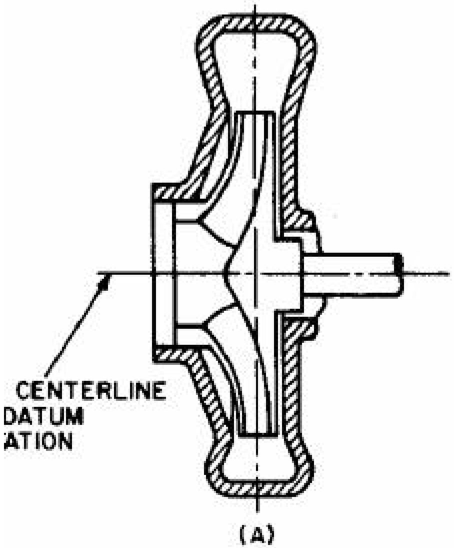


Centrifugal Pump
Operating Principle

- A centrifugal pump is one of the simplest pieces of equipment in any process plant.
- Its purpose is to convert energy of a prime mover (an electric motor or turbine) first into velocity or kinetic energy and then into pressure energy of a fluid that is being pumped.
- The energy changes occur by virtue of two main parts of the pump, the impeller and the volute (or diffuser).
  - The impeller is the rotating part that converts driver energy into the kinetic energy.
  - The volute or diffuser is the stationary part that converts the kinetic energy into pressure energy.

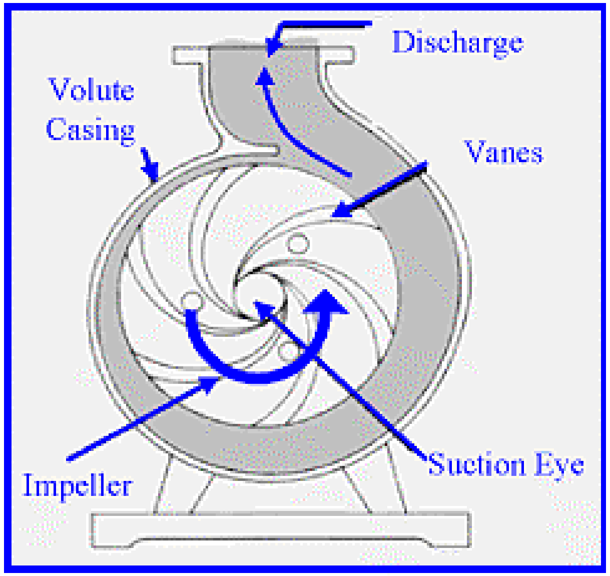
Centrifugal Pump
Operating Principle

- The **centrifugal** pumps utilize one **pumping principal**: The impeller increases the kinetic energy of the fluid by accelerating it from the impeller center out to the tip.
  - The impeller tip speed largely determines the pressure generated by a pump
  - Tip Speed = pi * Tip Dia (OD) * (RPM / 60)
- At the periphery of the impeller exit the fluid is directed into the pump casing (volute).
- The volute has a constantly increasing cross sectional area along its length.
- As the fluid proceeds along the volute channel its velocity is reduced as a result the pressure of the fluid increases.



Centrifugal Pump
Operating Principle

- The key idea is that the energy created by the centrifugal force is *kinetic energy*.
- The amount of energy given to the liquid is proportional to the *velocity* at the edge or vane tip of the impeller.
  - The faster the impeller revolves or the bigger the impeller is, **(higher the tip speed)** then the higher will be the velocity of the liquid at the vane tip and the greater the energy imparted to the liquid.
- This kinetic energy of a liquid coming out of an impeller is harnessed by creating a *resistance* to the flow.
  - The first resistance is created by the pump volute (casing) that catches the liquid and slows it down.
  - In the discharge nozzle, the liquid further decelerates and its velocity is converted to pressure according to Bernoulli's principle.



A Pump Fact…

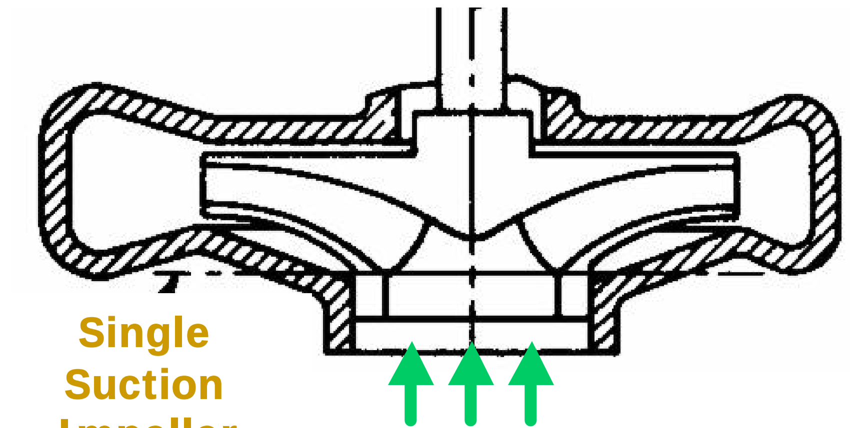
One fact that must always be remembered:

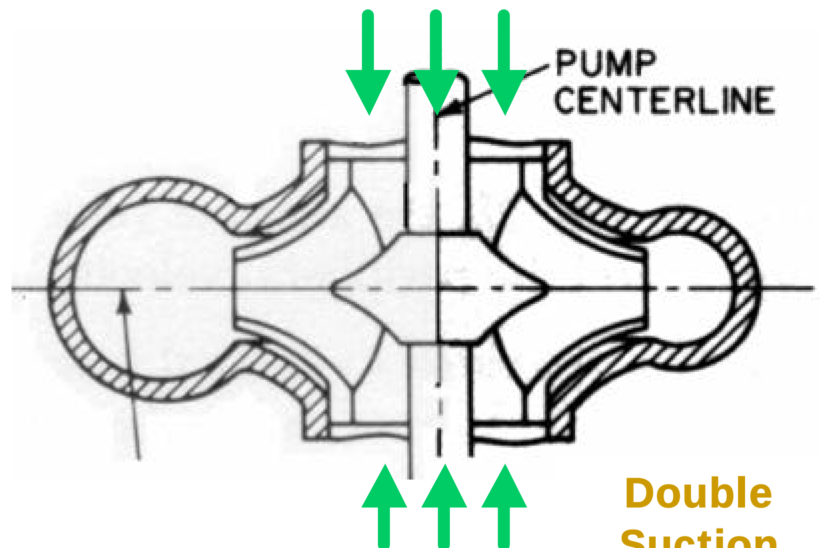
A pump does not create pressure, it only provides flow.

Pressure is a just an indication of the amount of resistance to flow.

Single & Double Suction Impellers

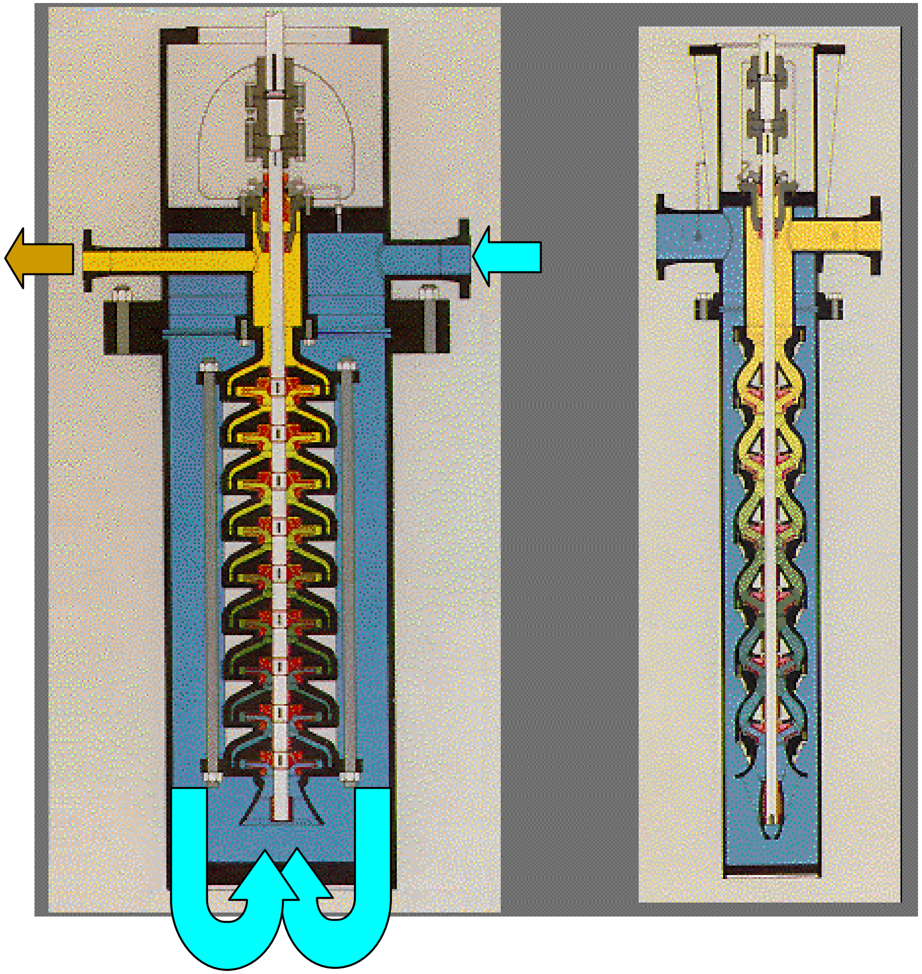
- Double suction pumps are used to increase the capacity of the pump for a given space.
  - Most widely used through out the industry.
  - Low initial cost
  - High efficiency and low NPSH for flow rates above 700-1000 GPM.
    - Lower inlet velocity due to increased (doubled) inlet flow area.
- Double suction pumps can be quite large, pump high capacities and can handle entrained gas or air.





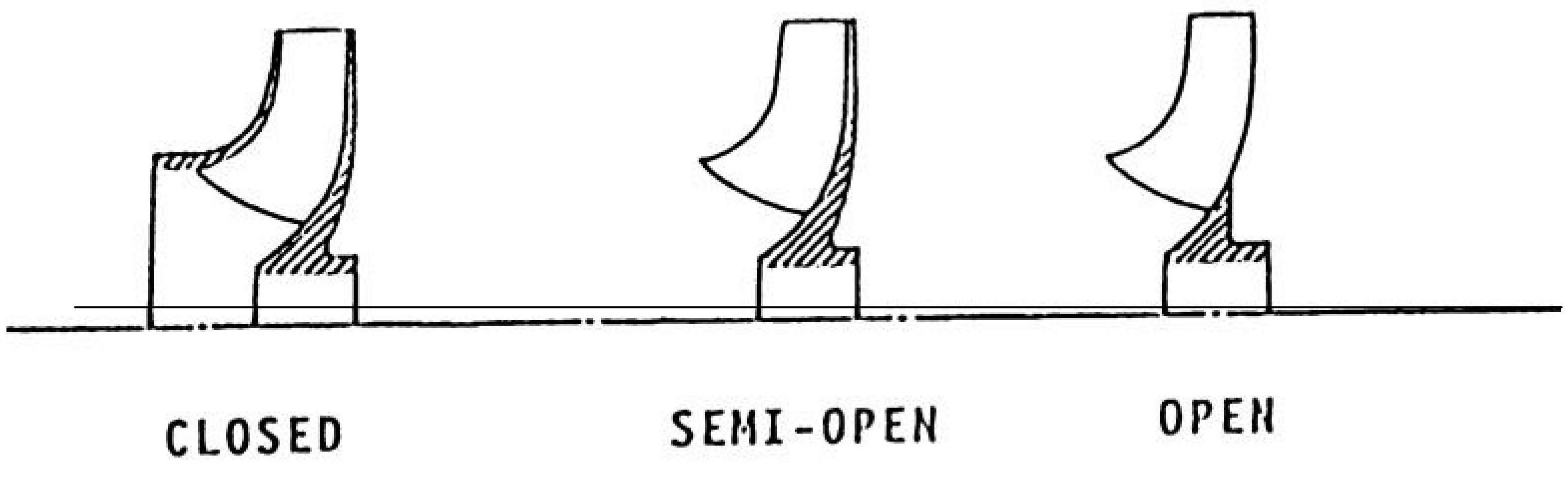
Centrifugal Pump
Single or Multi Stage

- Centrifugal pumps maybe single stage having a single impeller.
- They may be multiple stage having several impellers through which the fluid flows in series.
- Each impeller in the series increases the pressure of fluid at the pump discharge.

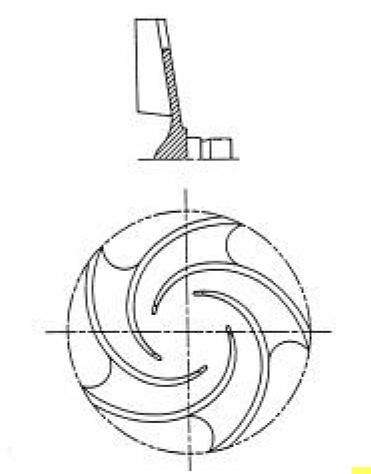


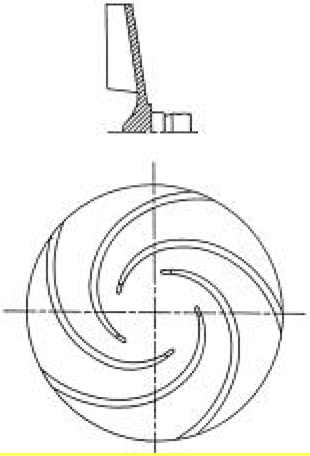
Centrifugal Pump
Open or Closed Blades

- The impeller of a centrifugal pump can be
  - open, close or semi-open
- In a closed design there's a shroud over the blades that covers the top of the impeller.
- In an open design there's no material between the top of the blades and housing.

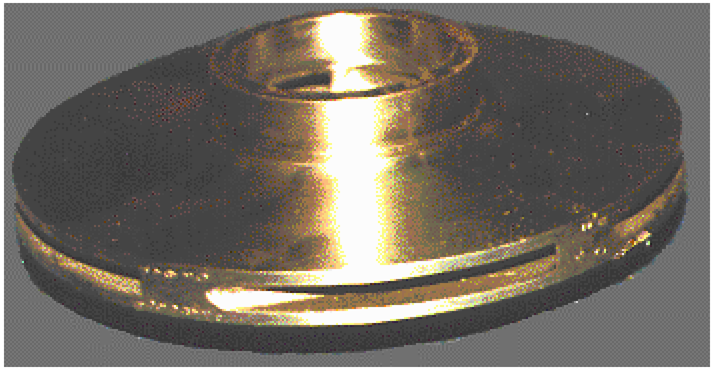


Centrifugal Pump
Open or Closed Blades





Full Back Open Shroud Impeller

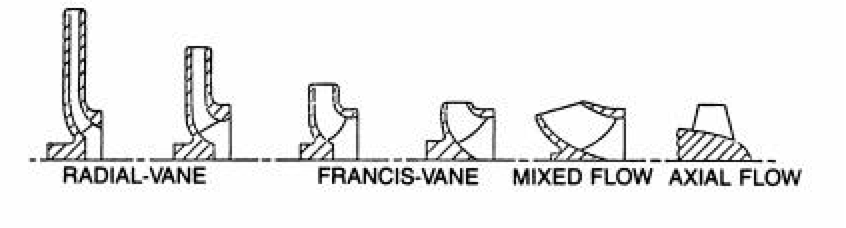


Closed impeller

- When compared with open designs, closed designs have
  - reduced leakage and therefore reduced losses
  - usually mean that thinner blades can be used as the shroud can add structural stiffness.
- However closed designs
  - usually cost more than open designs
  - if space is a constraint may result in shorter blade height

Pump Specific Speed

- The hydraulic performance of a centrifugal pump depends on the shape and proportions of the impeller.



- **Specific speed** is a **tool for use in comparing various centrifugal pump** types and selecting the most efficient and economical pump type for a given application.
- Specific speed is **defined as** the speed (in rpm) of a geometrically similar pump that will deliver 1 GPM against one foot of head.
- It is advantageous to calculate specific speed (N_s) of a pump at its best efficiency point (BEP) for comparison with published charts
  - Specific speed charts are prepared at pump best efficiency point

Pump Specific Speed (N_s)

Pump Specific Speed

$$N_S = \frac{RPM \times \sqrt{Q}}{Head^{0.75}}$$

- In US units Q is GPM & Head is in feet.
- Use one-half of Q for double suction pumps
- Specific speed arbitrarily assigned a unit of rpm!

- Impeller inlet design is a function of the impeller leading edge geometry and is independent from pump specific speed.
- Blade angle at impeller leading edge is a trade-off between efficiency and cavitation margin
  - For best efficiency, inlet flow angle should be large. For cavitation margin, inlet flow angle should be small.

Specific Speed

- **Specific speed identifies the type of pump** according to its design and flow pattern.
  - According to this criteria a pump can be classified as radial flow, mixed flow, or axial flow type.
    - **Radial** flow pump is one where the impeller discharges the liquid in the radial direction from the pump shaft centerline.
      - Radial flow impellers develop head principally through centrifugal force.
    - **Axial** flow pump discharges the liquid in the axial direction.
      - An axial flow or propeller pump with a specific speed of 10,000 or greater generates it's head exclusively through axial forces.
    - **Mixed** flow pump is one that is a cross between a radial and an axial flow pump design.
- Specific speed identifies the approximate acceptable ratio of the impeller eye diameter (D_1) to the impeller maximum diameter (D_2) in designing a good impeller.
  - N_S: 500 to 5000; $D_1/D_2 > 1.5$ - radial flow pump
    N_S: 5000 to 10000; $D_1/D_2 < 1.5$ - mixed flow pump
    N_S: 10000 to 15000; $D_1/D_2 = 1$ - axial flow pump

Specific Speed

Physical Meaning

- The major use of the specific speed is to help you specify pumps that are more efficient
  - The maximum, efficiency is obtained in the specific speed range of 2,000 to 3,000
  - Pumps for high head full capacity occupy the range 500 to 1,000 while low head high capacity pumps may have a specific speed of 15,000 or larger .
  - For a given head and capacity the good news is that the pump having the highest specific speed that will meet the requirements probably will be the smallest size and the least expensive. The bad news is that the pump will run at the highest speed where the abrasive wear and cavitation damage become a problem.
  - Efficiencies start dropping drastically below 1,000. Also smaller capacities exhibit lower efficiencies than higher capacities at all specific speeds.
  - In propeller and other high specific speed impellers (like axial flow) it is not practical to use a volute casing instead the impeller is enclosed in a pipe like casing.
  - The lower the specific speed number, the higher the power loss you get with wear ring clearance .

Specific Speed vs. Centrifugal Pump Type

For a given head and flow rate, the pump having the highest specific speed will be the **smallest and least expensive**

Efficiencies will start dropping drastically below 1,000

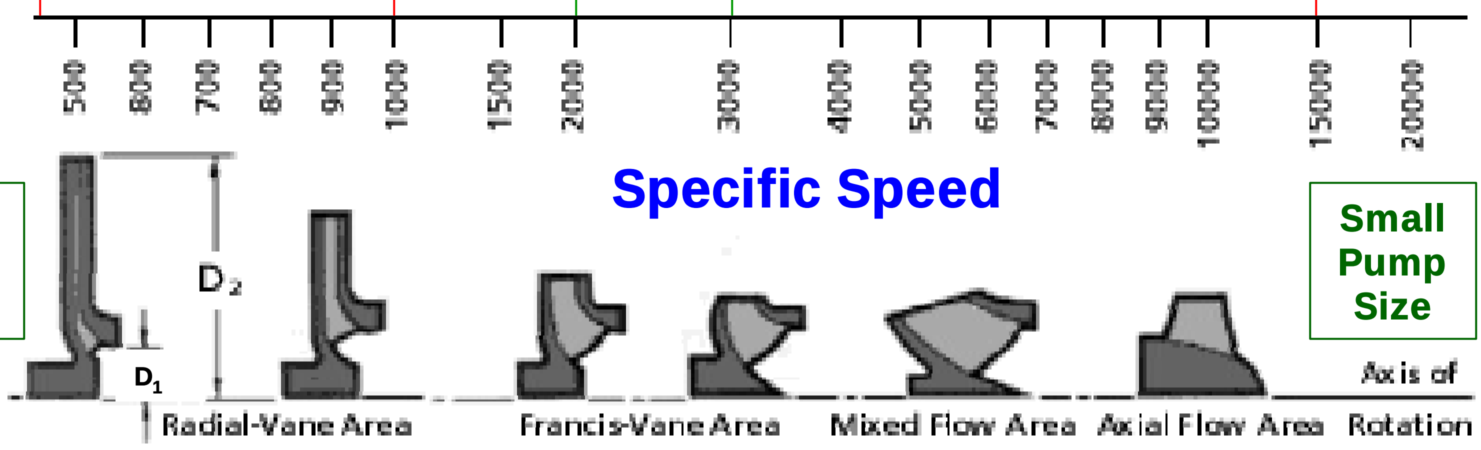
High Head
Low Capacity

Maximum
Efficiency

Low Head
High Capacity

Large
Pump
Size

Small
Pump
Size



$\frac{D_2}{D_1} > 4$ $\qquad$ $\frac{D_2}{D_1} = 1.5$ to 2 $\qquad$ $\frac{D_2}{D_1} < 1.5$ $\qquad$ $\frac{D_2}{D_1} = 1$

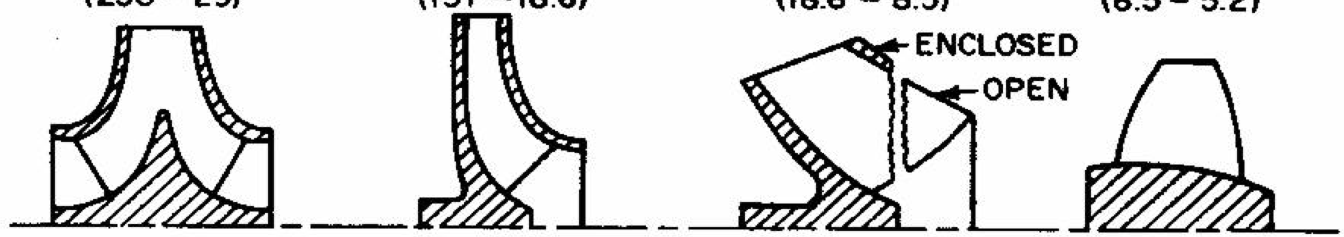
Specific Speed vs. Centrifugal Pump Type

SPECIFIC SPEED LIMIT VS. TOTAL HEAD WITH ZERO SUCTION HEAD

85°F (29.4°C), 1.0 S.G. WATER, SEA LEVEL EQUIVALENT TO 32.6 FT (9.94 m) NPSH

8,000 (4,900), SUCTION SPECIFIC SPEED

SPECIFIC SPEED RANGE	1,000 – 5,000	1,000 – 5,000	5,000 – 9,000	9,000 – 13,000
Suction Specific Speed	(600 – 3,000)	(600 – 3,000)	(3,000 – 5,500)	(5,500 – 8,000)
CORRESPONDING MAX. TOTAL HEAD RANGE IN FT OR (m) THAT CAN BE PUMPED WITH 32.6 FT (9.94 m) NPSH	821 – 96 (250 – 29)	516 – 61 (157 – 18.6)	61 – 28 (18.6 – 8.5)	28 – 17 (8.5 – 5.2)



CENTRIFUGAL IMPELLER DOUBLE-SUCTION ENCLOSED DESIGN	CENTRIFUGAL IMPELLER SINGLE-SUCTION ENCLOSED DESIGN	MIXED-FLOW IMPELLER SINGLE-SUCTION ENCLOSED & OPEN DESIGN	PROPELLER SINGLE-SUCTION OPEN DESIGN

Suction Specific Speed

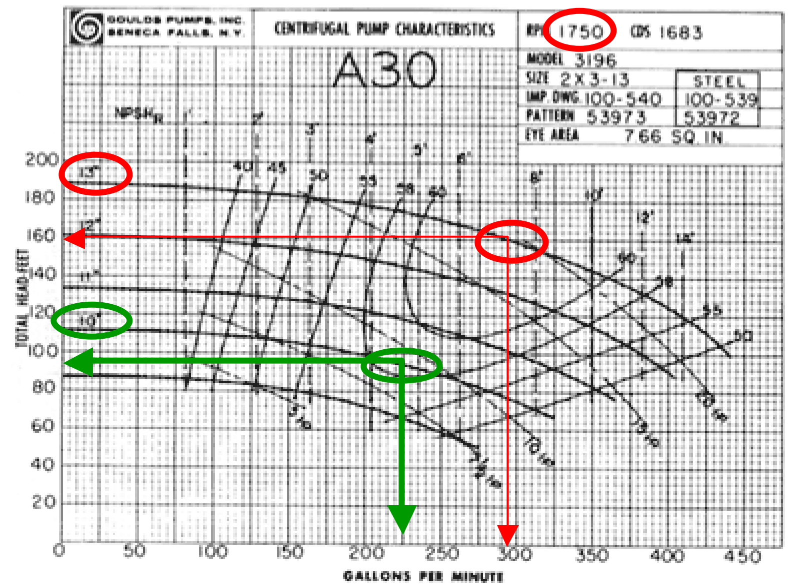
$$N_{SS} = \frac{RPM \times \sqrt{Q}}{NPSH^{0.75}}$$

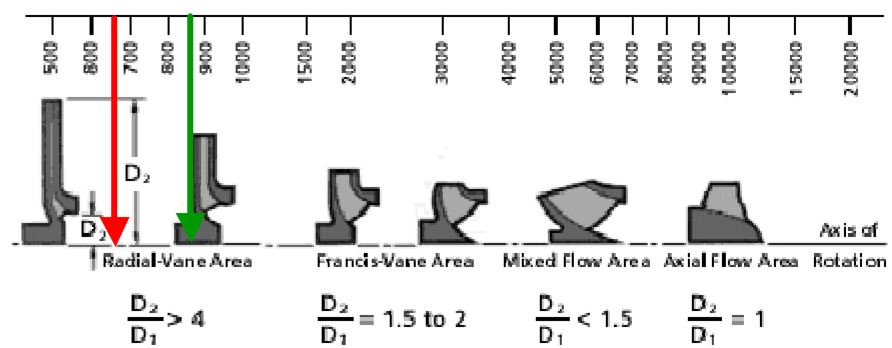
Example - Specific Speed

- Determine the type of pump from the given performance curve using specific speed.
  - 13” Impeller generates 290 gpm and 160 ft at its best efficiency point running at 1750 rpm.

$$N_S = \frac{1750 \times \sqrt{290}}{160^{0.75}} = 662$$

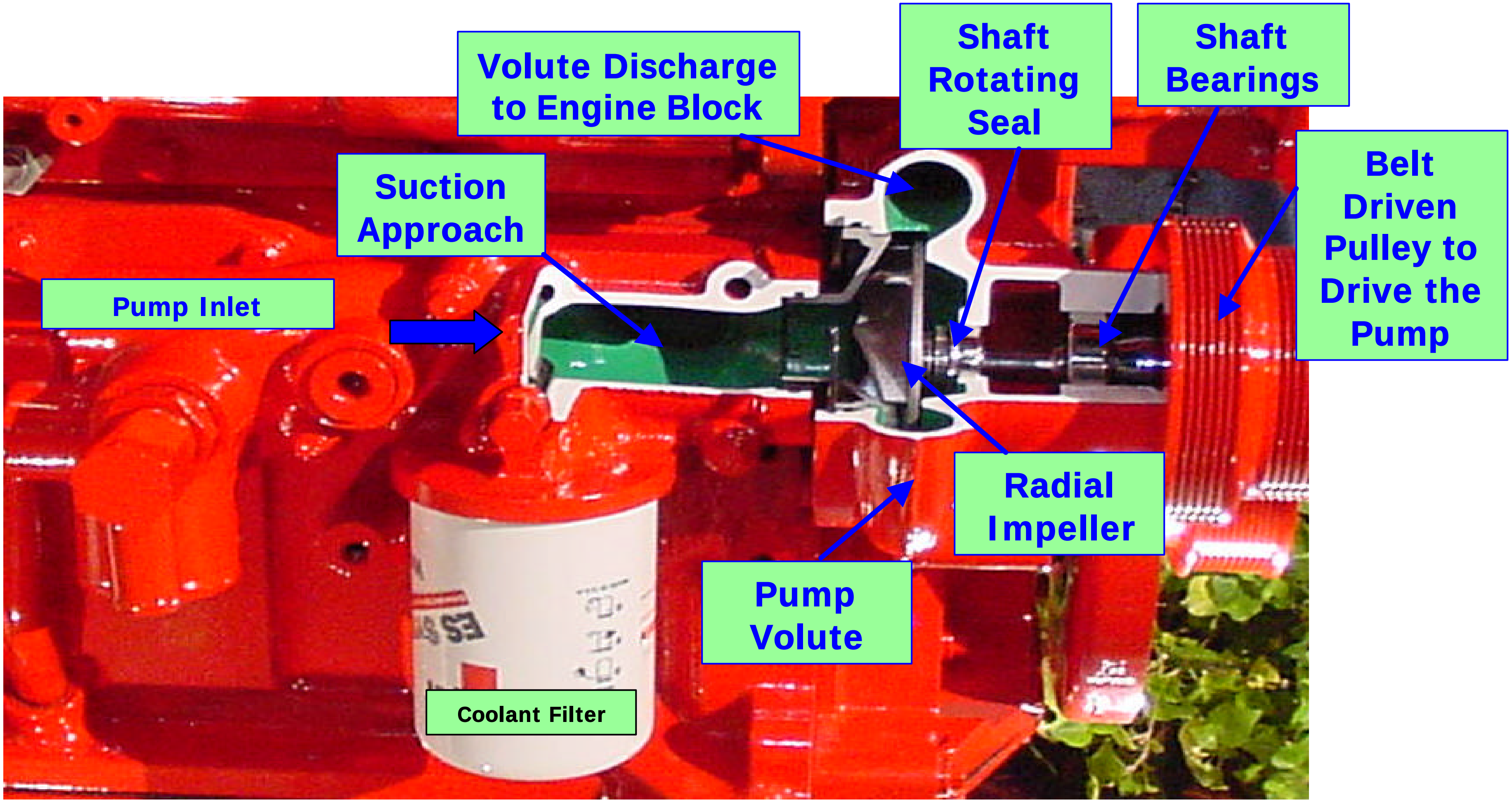
  - Radial impeller with tip diameter 4 times greater than the inlet diameter.
- Same conclusion will be reached if calculated using the 10” impeller. (N_s=862)
  - Obviously D_2/D_1 is smaller since D_2 is smaller





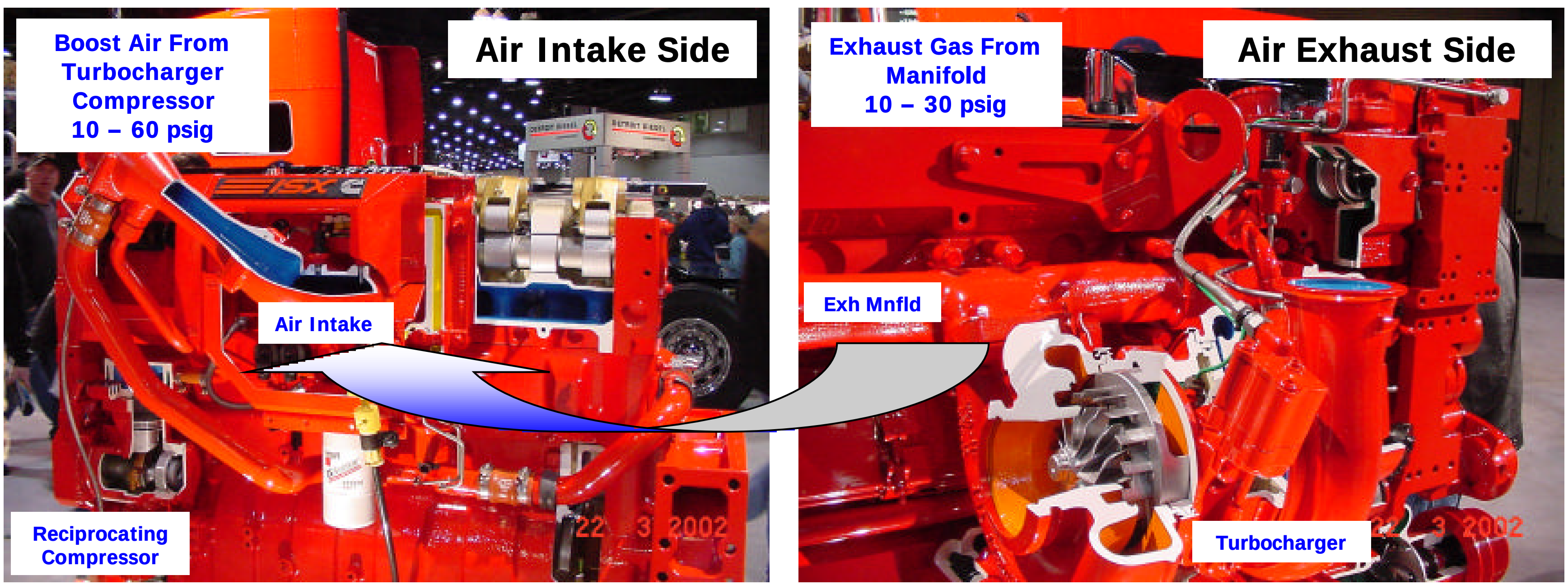
Radial Flow Centrifugal Pump

Water Pump of a Diesel Engine



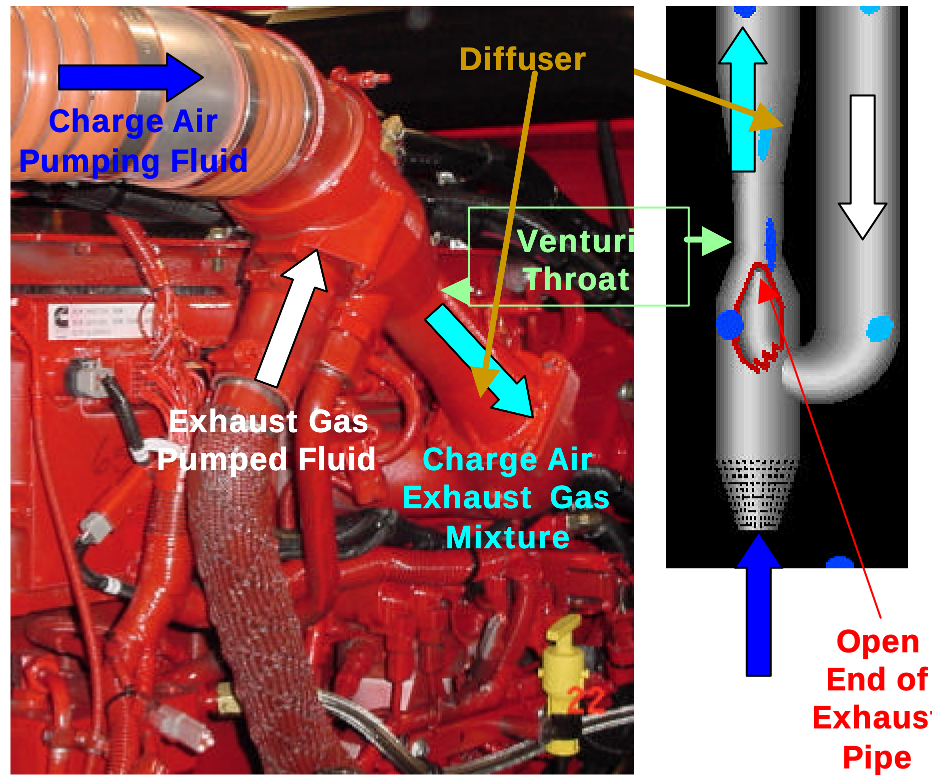
Ejector Pumps
Also Known as Eductor or Jet Pumps

- How do you pump a 10-30 psig exhaust gas into a 10-60 psig compressed intake air on 15L diesel engine?
  - One obvious answer is using a positive displacement pump, reciprocating compressor.
    - Very costly solution due to the number of parts involved
    - Additional space & packaging requirements – hard to find in an underhood



Ejector Pump
Operating Principles

- A source of pressurized fluid (**charge air** in the case of a diesel engine exhaust ejector pump) is connected to an exhaust pipe fed by the exhaust manifold.
- The pressurized fluid is forced through the **venturi throat** increasing its velocity and decreasing its pressure.
- **Exhaust pipe has an opening at the start** of the venturi throat where the pressure is its lowest level inside the ejector pump.
- Pressure differential created by the pumping fluid (charge air) creates a suction at the **open end of the exhaust pipe** located at the venturi throat.



Cummins Diesel Engine

- Exhaust gas is driven into the charge air.
- The mixture then goes through the **diffuser section** of the ejector pump and recovers most of the pressure loss created by the throat section.

Ejector Pumps
Pros & Cons

Benefits

- Pumping volatile fluids (which could ignite if exposed to the workings of a standard electric or internal combustion powered pump)
- High levels of debris (which could damage screws or blades in conventional pump designs).

Disadvantages

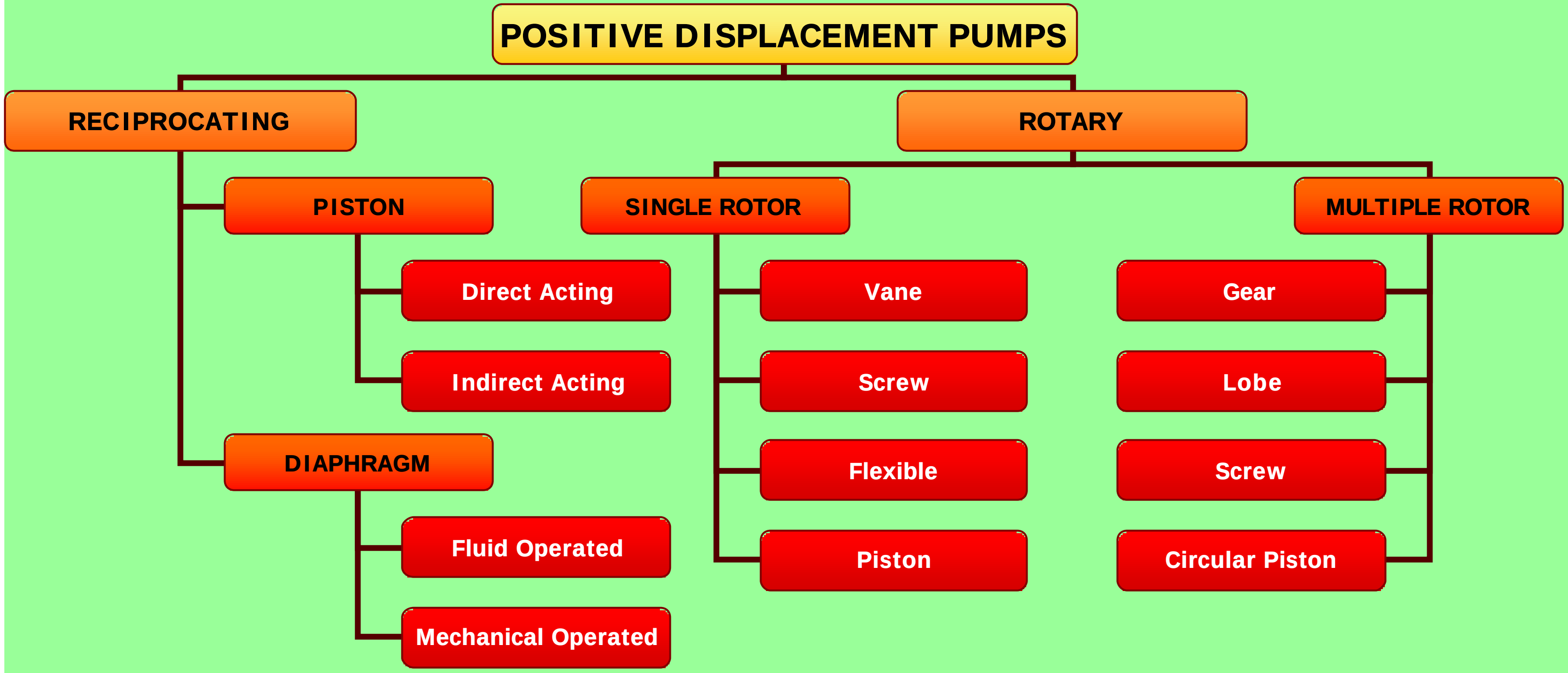
- Ejector pumps have very low efficiency
- Can only generate limited flow rates

Fans, Blowers & Compressors

- Gases and vapors are moved by fans, blowers, and compressors.
- Generally speaking, fans and blowers move large volumes of gas against small or moderate pressure drops, while compressors produce large pressure differences.
- There isn't a real distinction between a fan and a blower;
  - **Fan** is most commonly used for devices producing **small pressure differences** (inches of water) and
  - **Blower** for **larger pressure differences** (up to about 2 atm).
  - Both are rotary devices.

Positive Displacement Pumps

- **Positive displacement pumps** adds energy periodically
  by application of force to one or more movable boundaries
  of enclosed fluid containing volumes
  resulting in direct increase in pressure
  up to the value required to overcome the system resistance.



Positive Displacement (PD) Pumps

- By definition, PD pumps **displace a known quantity of liquid with each revolution** of the pumping elements (gears, rotors, screws, vanes).
- PD pumps displace liquid by creating a space between the pumping elements and trapping liquid in the space.
- The rotation of the pumping elements then reduces the size of the space and moves the liquid out of the pump.
- PD pumps can handle fluids of
  - all viscosities up to 1,320,000 cSt
  - capacities up to 1,150 m^3/hr (5,000 GPM)
  - pressures up to 700 Bar (10,000 PSI)
- Rotary pumps are self-priming and deliver a constant, smooth flow, regardless of pressure variations.

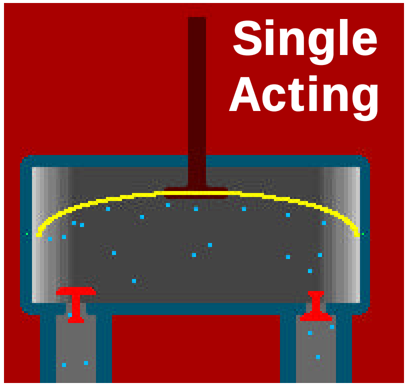
Reciprocating Pumps

- Reciprocating pumps use a piston, plunger, or diaphragm to raise liquid pressure.
- One-way valves surround the pumping chamber so that liquid only enter from the low pressure side and exit on the high pressure side.
- Reciprocating pumps always produce a pulsating flow.
- Since the flow rate is independent of pressure rise, they can be used to produce large pressure changes, even for small amounts of fluid.
  - This makes them best suited to low volume, high head applications (up to 50 000 psi).

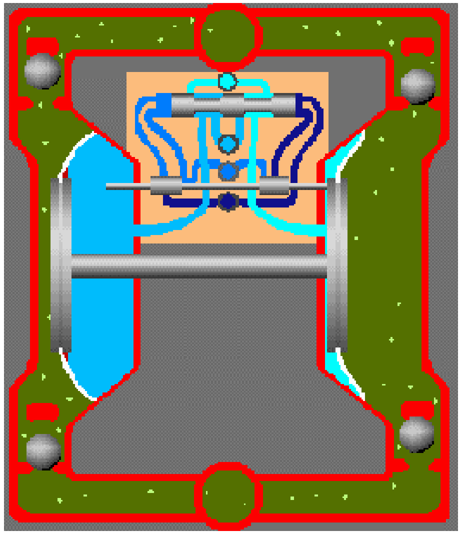
Reciprocating Diaphragm Pumps

Positive Displacement

- Diaphragm pumps are a sub-class of reciprocating pump.
- The pumping chamber is separated from the moving parts by a flexible diaphragm.
- Their **chief advantage** is that the fluid being pumped never comes in contact with the mechanism and so **eliminates leakage**; They are good for
  - Toxic & very expensive liquids.
- The **diaphragm material limits the head** that can be produced.



Diaphragm Pump
Mechanical Operated



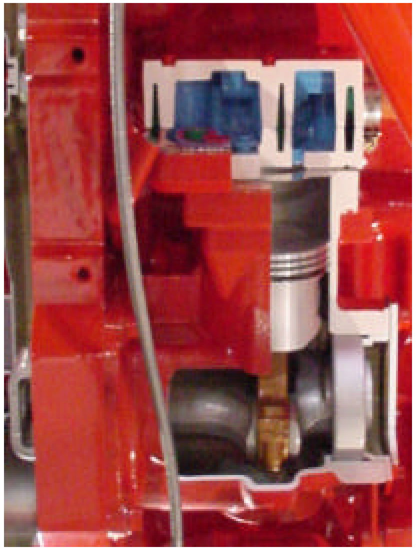
Double Diaphragm Pump
Fluid (Air) Operated

Reciprocating Pumps

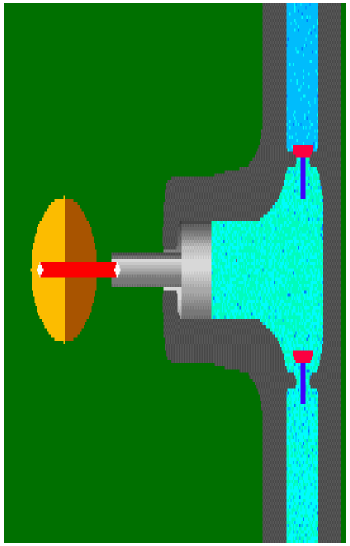
- If the fluid is moved only on the piston down stroke, the pump is called "**single-acting**";
- A "**double-acting**" pump moves liquid with both sides of the piston.

Reciprocating Piston Pumps - Compressors

- Reciprocating compressors uses pistons to "push" gas to a higher pressure.
- Reciprocating compressors can produce very large pressure differences, but because they produce a pulsating flow, may require a receiver vessel large enough to dampen the pulsation.
  - Air tank of your shop compressor



Air Compressor
Cummins Diesel Engine



Piston Pump
Direct Acting

- Diesel engine air compressors regulate their operation to keep a 90-125 psi air tank pressure available for brakes and other air actuated systems

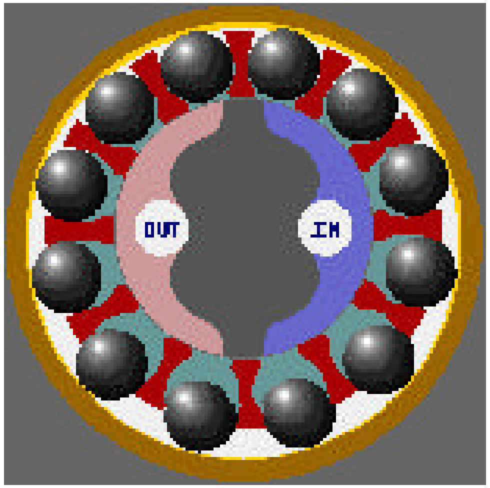
Advantages of Rotary Pumps

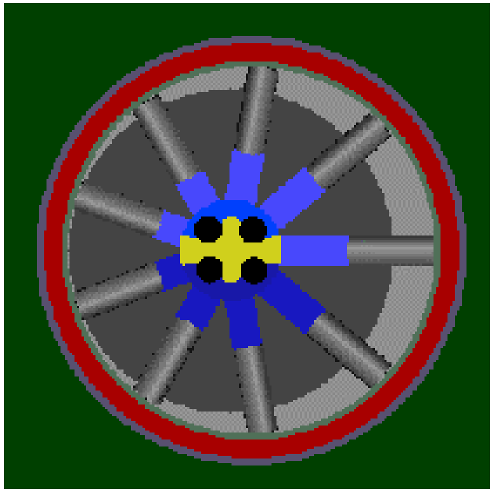
- Rotary pumps are used in a wide range of applications -- liquids, slurries, and pastes.
- And because **rotary pumps displace a known quantity of liquid with each revolution** of the pump shaft, they are a **popular choice for metering applications.**
  - Pumps in gas stations are rotary piston type PD's.
- They can accommodate high viscosity liquids, high pressures, and high capacities.
  - Rotary pumps are especially suited (become more efficient) for high viscosity fluids in that slip is limited.
- The **fluid pumped must be "lubricating"** and solids cannot be present.
- A key difference from centrifugal pumps is that discharge pressure variation has little effect on capacity.

Rotary Piston Pumps

- The pistons are usually forced out by springs in the case of rotary piston pump and by centrifugal forces in ball pistons.
- They are forced back in, expelling liquid, by the casing.
- An odd number of pistons is always used to smooth the hydraulic balance. These pumps revolve at speeds up to about 1200 RPM.

Ball Piston Pump
Direct Acting



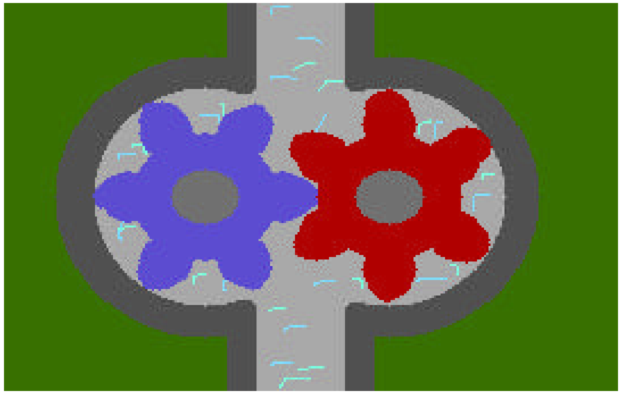


Rotary External Gear Pumps

Positive Displacement

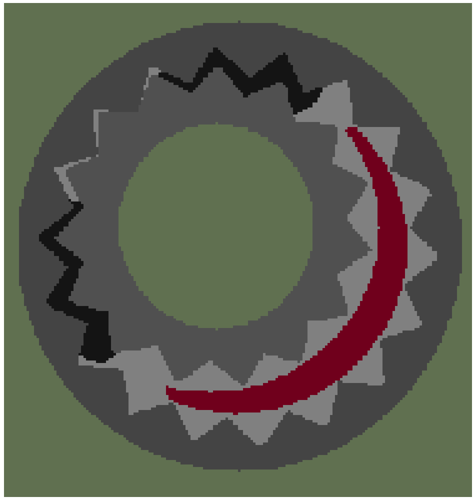
- **Rotary pumps** operate in a circular motion and displace a constant amount of liquid with each revolution of the pump shaft.
- As the gears come out of mesh, they create expanding volume on the inlet side of the pump. Liquid flows into the cavity and is trapped by the gear teeth as they rotate.
- Liquid travels around the interior of the casing in the pockets between the teeth and the casing -- Flow between the gears is minimal because of tight clearances.
- Finally, the meshing of the gears forces liquid through the outlet port under pressure.

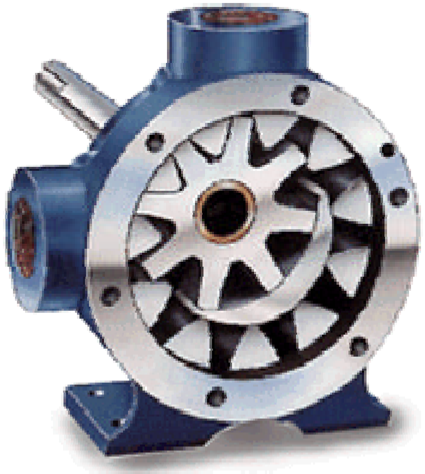
Gear Pump
Multiple Rotor



Internal Gear Rotary Pumps

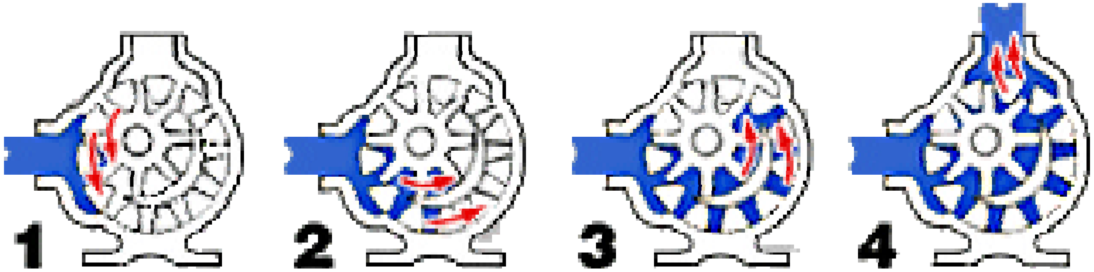
- Internal gear pumps carry fluid between the gear teeth from the inlet to outlet ports.
- The outer gear (rotor) drives the inner or idler gear on a stationary pin.
- The gears create voids as they come out of mesh and liquid flows into the cavities.
- As the gears come back into mesh, the volume is reduced and the liquid is forced out of the discharge port.
- The crescent prevents liquid from flowing backwards from the outlet to the inlet port.





Internal Gear Rotary Pumps

- Internal gear pumps are well-suited for a wide range of viscosity applications because of their relatively low speeds. This is especially true where suction conditions call for a pump with minimal inlet pressure requirements.
- For each revolution of an internal gear pump, the gears have a fairly long time to come out of mesh allowing the spaces between gear teeth to completely fill and not cavitate.
- Internal gear pumps successfully pump viscosities above 1,320,000 cSt and very low-viscosity liquids, such as liquid propane and ammonia.



Rotary Lobe Pumps

Positive Displacement

- 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.

Pump Operation:

- 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.
- Liquid travels around the interior of the casing in the pockets between the lobes and the casing -- it does not pass between the lobes.
- Finally, the meshing of the lobes forces liquid through the outlet port under pressure.

Single Rotor

Multiple Rotor

Rotary Lobe Pumps
Applications

- Advantages
  - Particle size can be larger than other PD pump types
    - Pass medium size solids.
  - No metal-to-metal contact.
    - Retains fluid integrity
  - Positive suction, non-pulsating discharge.
- Disadvantages
  - Requires a timing belt
    - Unlike gear pumps, both rotors are driven and timed individually
  - Reduced pumping action with thin liquids
- Applications
  - Food processing.
  - Beverages.
  - Dairy Produce.
  - Personal Hygiene Products.
  - Pharmaceutical.
  - Biotechnology.
  - Chemical.
- Fluids Pumped with Lobe Pumps
  - Cottage cheese, olives, cherries, cat food, baby food
  - Ketchup, mayonnaise, mustard
  - Beer, tooth paste

Rotary Pump Selection Guide

Pump Selection Guide						
	Abrasives	Thin Liquids	Viscous	Solids	Dry Prime	Diff. Pressure
Internal Gear	**G**	**G**	**E**	**P**	**A**	**G**
External Gear	**P**	**G**	**G**	**P**	**A**	**E**
Lobe	**G**	**A**	**E**	**E**	**A**	**G**
Vane	**P**	**E**	**A**	**P**	**G**	**A**
E = Excellent, G = Good, A = Average, P = Poor						

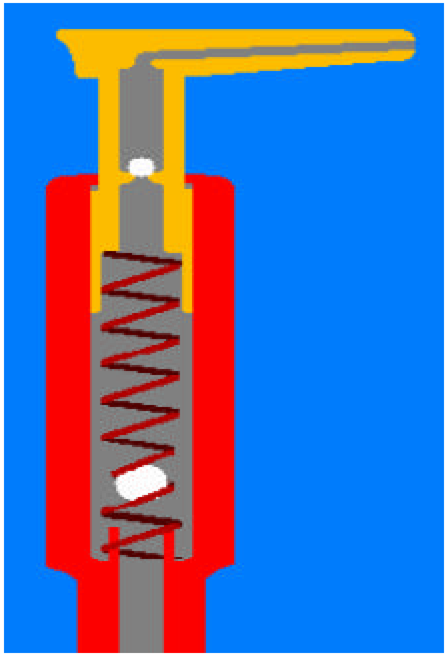
Comparisons Between Rotary and Centrifugal Pumps		
	Rotary	Centrifugal
Max. Viscosity (cSt / SSU)	1,320,000 / 6,000,000	550 / 2,500
Max. Capacity (M^3/Hr / GPM)	750 / 3,300	27,250 / 120,000
Pumping Efficiency	E	A
Energy Costs	E	A
Self-Priming	Yes	No
Flow Control	E	P
Life-Cycle Cost	G	G
Initial Cost	A	E
E = Excellent, G = Good, A = Average, P = Poor		

Materials Guide

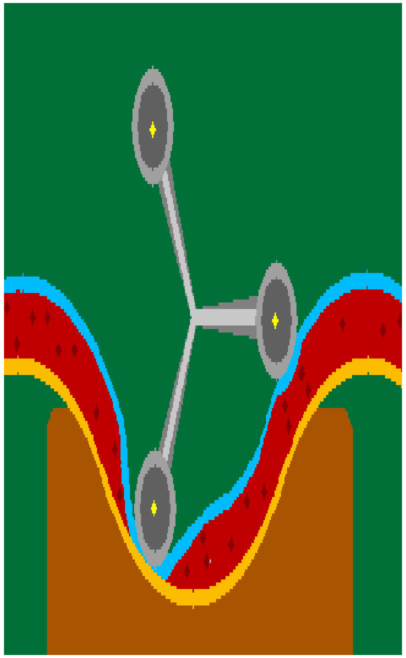
- **High-Viscosity Liquids.** Internal gear pumps are often a good choice.
- **Sanitary Liquids.** Sanitary lobe pumps work well for most food, beverage, pharmaceutical, and biotechnology applications.
- **Solids.** Pump selection depends on the particular application. For food-type applications containing solids, begin searching sanitary lobe pumps. For slurries and other industrial-type solids, start with internal gear pumps.
- **Corrosive Liquids.** Proper selection of the right materials of construction will have the greatest impact on pump performance. Composite external gear and stainless steel internal gear pumps are good starting points. Check out Pump School's page on handling abrasive and corrosive liquids. (www.pumpschool.com)
- **Abrasive Liquids.** A number of factors can combine to minimize the effects of abrasion. Begin with internal gear pumps manufactured with hardened steel parts.
- **Toxic, Hazardous, or Hard-To-Seal Liquids.** Preventing leaks is critical for handling these fluids. Magnetically-driven or mechanically sealed internal or external gear pumps offer a good starting point.
- **Extreme Temperature Conditions.** Internal gear pumps with jacketing features offer excellent temperature control. Learn more about handling high-temperature liquids in Pump School's "Tough Application" section.

Special Pumps

- **Wobble plate** piston pumps can develop incredible pressure -- 10,000 P.S.I. or more.
- It is commonly used for low-volume applications.
  - Hand-operated wobble pumps were used as emergency fuel pumps on some early aircraft.



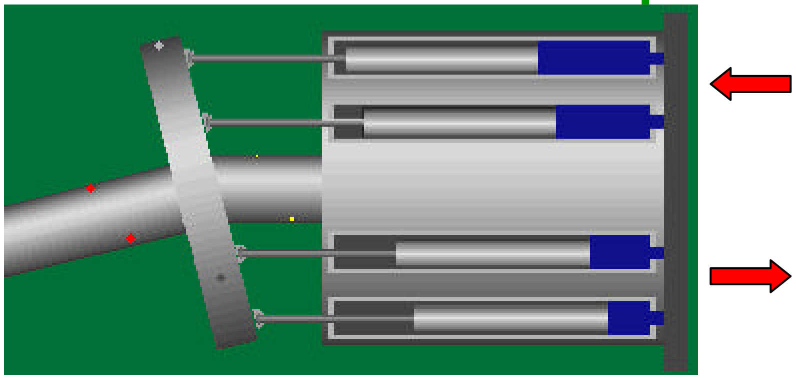
Hand Pump



Flexible Tube Pump

Single Rotor Peristolic Pump

Wobble Plate Piston Pump



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