Centrifugal Pumps

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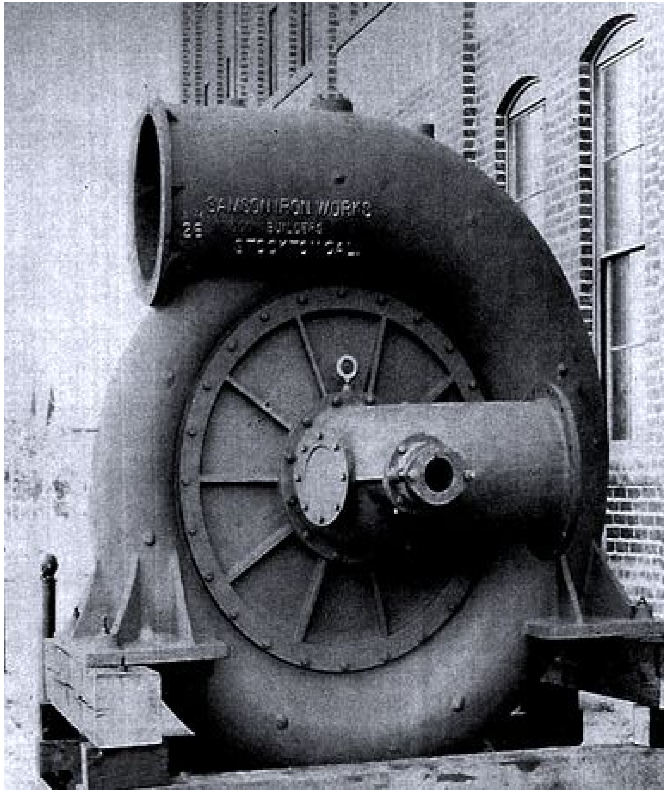
Introduction:

Centrifugal Pump: A mechanical device used to transport fluids by the conversion of rotational kinetic energy to the hydrodynamic energy of the fluid flow.

- Centrifugal pumps are the most popular pump used and are the chief pump type in the class of kinetic pumps.
- Used in various sectors such as: agriculture, power generation plants, municipal, industries, domestic purposes, etc.
- Common uses include: air, water, sewage, petroleum, petrochemical pumping.
- Consist of two major parts:
    1. impeller (a wheel with vanes)
    2. Circular pump

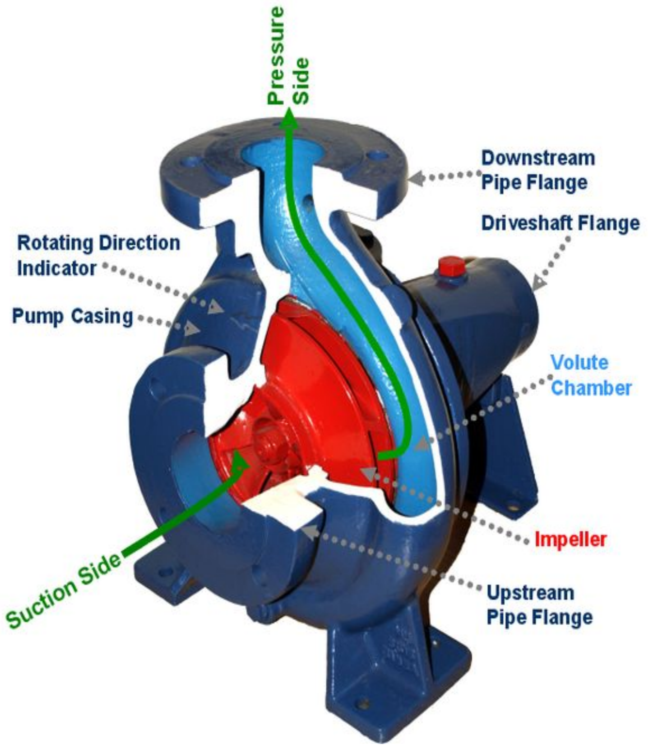
History

- First centrifugal pump was a mud lifting machine in late 1400"s by Italian Renaissance engineer Francesco di Giorgio Martini.
- Denis Papin developed the first true centrifugal pump in 1687, which was one with straight vanes that was used for drainage.
- John Appold, who was a British inventor, developed the first curved vane centrifugal pump in 1851.
- True centrifugal pumps developed in late 1600's in Europe and made its way to U.S. in early 1800's.
- Widespread use in last 75 years.
- improved performance and better materials of construction have helped improve efficiencies (93%+ for large pumps and 50%+ for small fractional horsepower units).



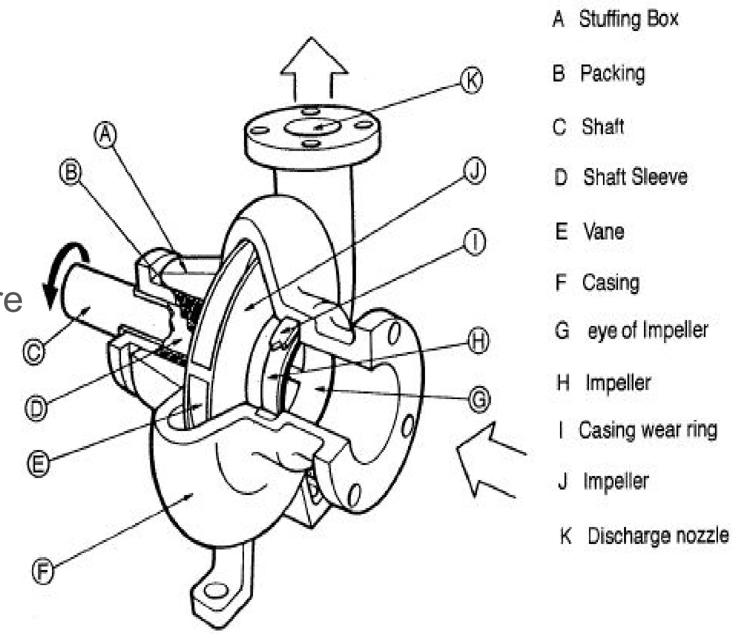
How it works

- Converts mechanical energy from a motor to energy of a moving fluid.
- Centrifugal pumps include a shaft driven impeller that rotates inside a casing.
- Energy conversion is due to the outward force that curved impeller blades impart on the fluid.
- When the impeller rotates, the fluid surrounding it also rotates. This imparts centrifugal force to the water particles, and water moves out.
- Pressure and kinetic energy of the fluid rises due to rotational mechanical energy transferred to the fluid.
- A negative pressure is induced at the eye because water is displaced at the suction side.



Types of Centrifugal Pumps

- Mechanically actuated
  - A motor uses a gear set or other mechanical mechanism to convert rotation into a reciprocating motion that moves the pump diaphragm
- Hydraulically Actuated
  - An intermediate fluid is pressurized, and this pressure flexes the diaphragm
- Solenoid
  - An electric motor energizes and de-energizes a solenoid that flexes a diaphragm
- Air Operated Double Diaphragm Pumps (AODD)
  - Air is delivered to two sides of a diaphragm, and the alternating cycles flex the diaphragm



Advantages

Advantages:

- Simple principle (don’t require valves or moving parts).
- Small in size compared to other pumps with same output.
- Can move at high speeds with minimal maintenance.
- Steady and consistent output
- Can handle large volumes of fluid
- Good for medium to low head
- Good for medium to low viscous fluids

Disadvantages

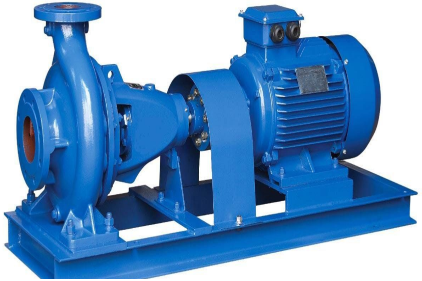
Disadvantages:

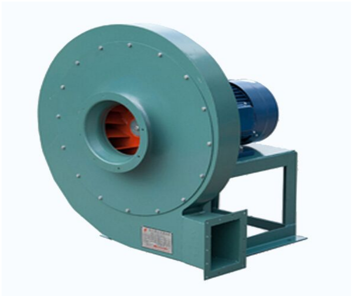
- Use rotation instead of suction to move water (very little suction power)
- Close fitting parts can cause maintenance issues as parts wear out
- Pump must be primed before use
- Can develop cavitation
- Not good for high head
- Not good with high viscous fluids

Determining which type of pump to use

Centrifugal Pumps can be grouped into numerous types using criteria based on:

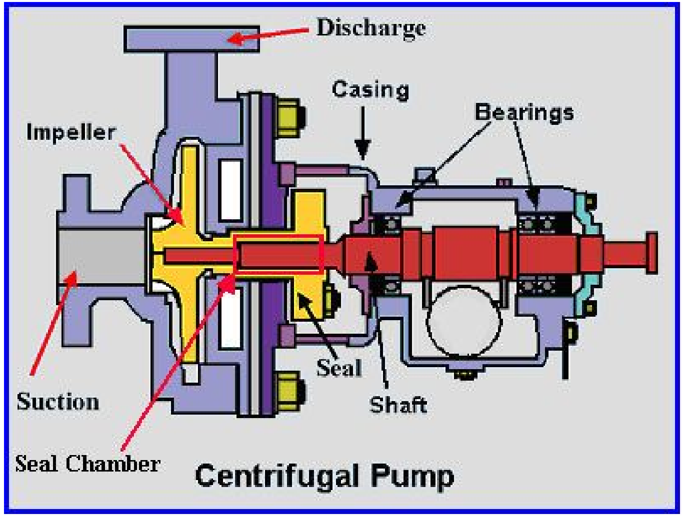
- Number of impellers in the pump.
- Compliance with industry standards
- Impeller suction
- Type of volute
- Nozzle location
- Shaft orientation
- Orientation of case-split
- Bearing support
- Shaft connection to driver



Applications of Centrifugal Pumps

- Energy & Oil Industries
  - Refineries and Power Plants
- Building Services
  - Pressure boosting, heating installations, fire protection sprinkler systems, drainage, air conditioning
- Industry and Water engineering
  - Boiler feed applications, water supply (municipal, industrial), wastewater management, irrigation, sprinkling, drainage and flood protection
- The Chemical and Process Industries
  - Paints, chemicals, hydrocarbons, pharmaceuticals, cellulose, petro-chemicals, sugar refining, food and beverage production



Centrifugal Pump Curve Example

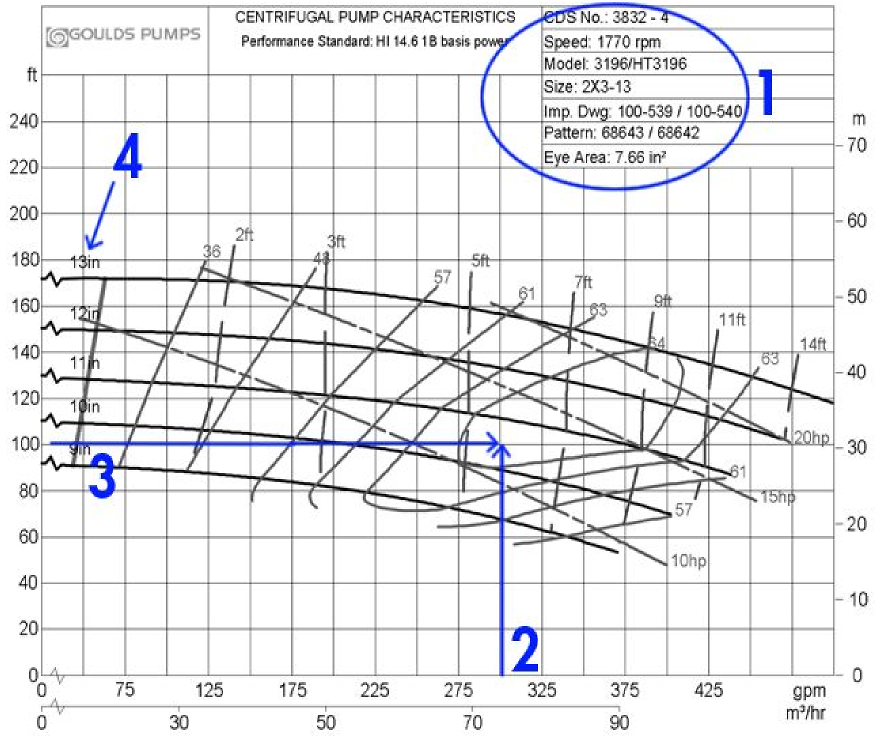
Section 1 (Title Box): Provides information such as model, size, and speed.

Section 2 (Flow): Flow is indicated across the bottom horizontal axis. Amount of flow required from the pump is identified.

Section 3 (Head): For a specified flow, total head the pump is required to overcome is identified.

Section 4 (Impeller Trim): Different performance points can be reached. Reducing impeller size allows the pump to reach specific performance requirement.

As pressure increases, the flow decreases which moves performance point to the left of the curve. As pressure decreases, the performance point goes to the right of the curve and flow increases.



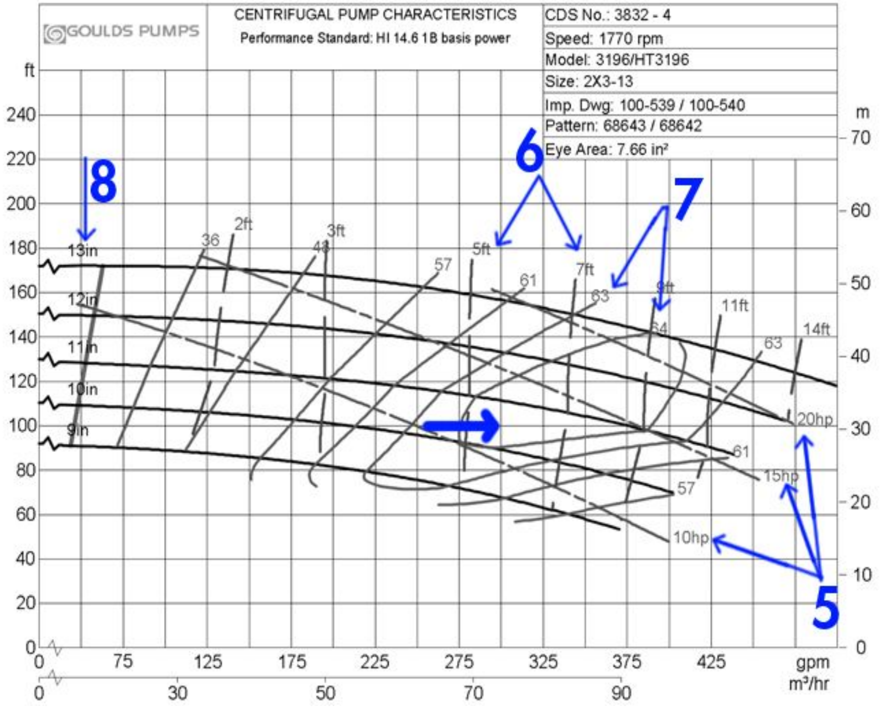
Centrifugal Pump Curve Example Continued

Section 5 (Horsepower): Determine amount of horsepower required

Section 6 (NPSHR): Net positive head required for proper pump operation.

Section 7 (Efficiency): Determine efficiency-the higher the efficiency, the less energy required to operate for a specific performance point.

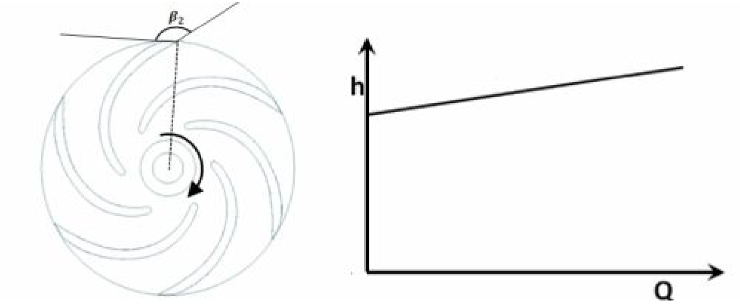
Section 8 (Minimum flow): Pump requires a minimum flow to be moving through the pump to dissipate heat created.



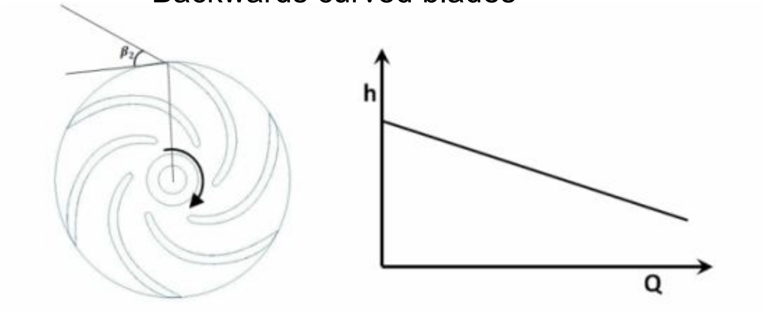
Designing a Centrifugal Pump

As it has already been stated centrifugal pumps are used mostly for high discharge and low to medium head at the outflow. because of this most pumps are designed to maximize the power to discharge ratio. The most common way to do this is through changing the angle of the impeller blades. The angle of the blades will also have an effect on discharge to head ratio as shown in the graphs.

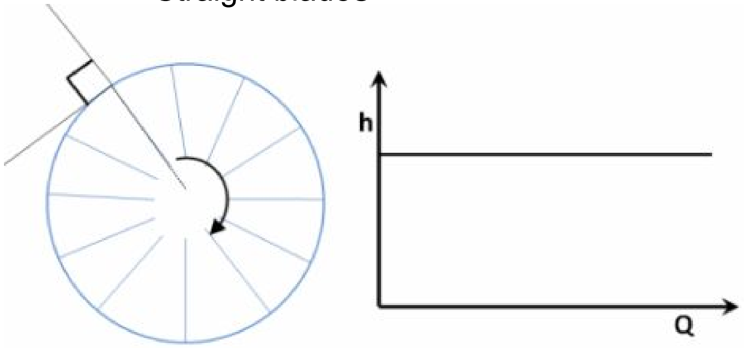
Forward curved blades



Backwards curved blades

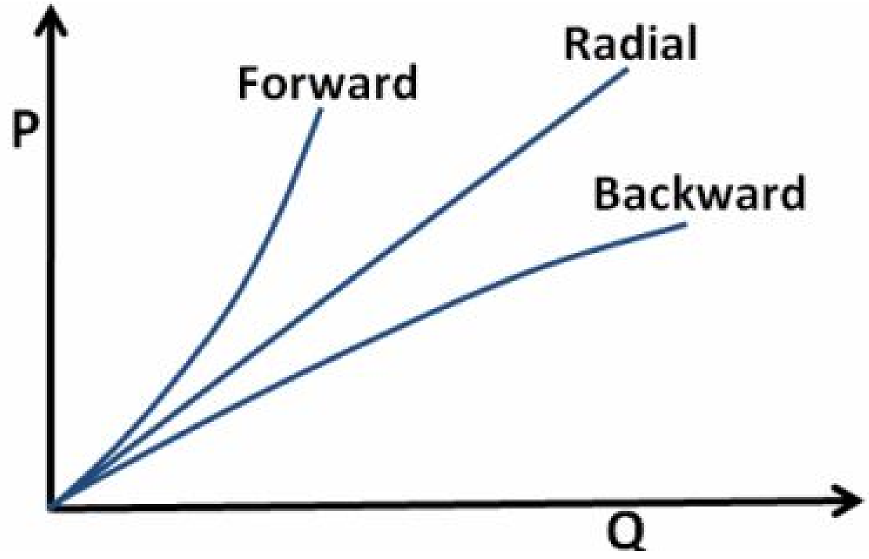


Straight blades



Blade Angle

The most efficient blade angles will always be backward curved, this is because the more rotational force the blades impart on the fluid the more energy the pump must put out the get the same discharge. As a textbook explains if the vanes of the wheel are straight and radial; but if they are curved, as is more commonly the case, the outward force is partly produced through the medium of centrifugal force, and partly applied by the vanes to the water as a radial component of the oblique pressure, which, in consequence of their obliquity to the radius, they apply to the water as it moves outwards along them” (Saylor Academy 2).



Important Equations

Work to increase fluid velocity

$$W = \rho Q(U_2 V_{\theta 2} - U_1 V_{\theta 1})$$

Head increase

$$h = \frac{1}{g}(U_2 V_{\theta 2} - U_1 V_{\theta 1})$$

We know that

$$V_{\theta_1} = 0$$

Thus

$$W = \rho Q(U_2 V_{\theta 2})$$

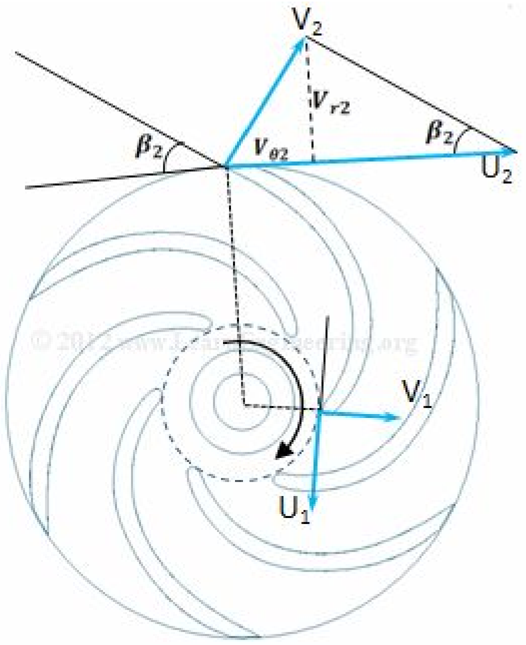
$$h = \frac{1}{g}(U_2 V_{\theta 2})$$

Flow through impeller

$$Q = 2\pi r_2 b_2 V_{r2}$$

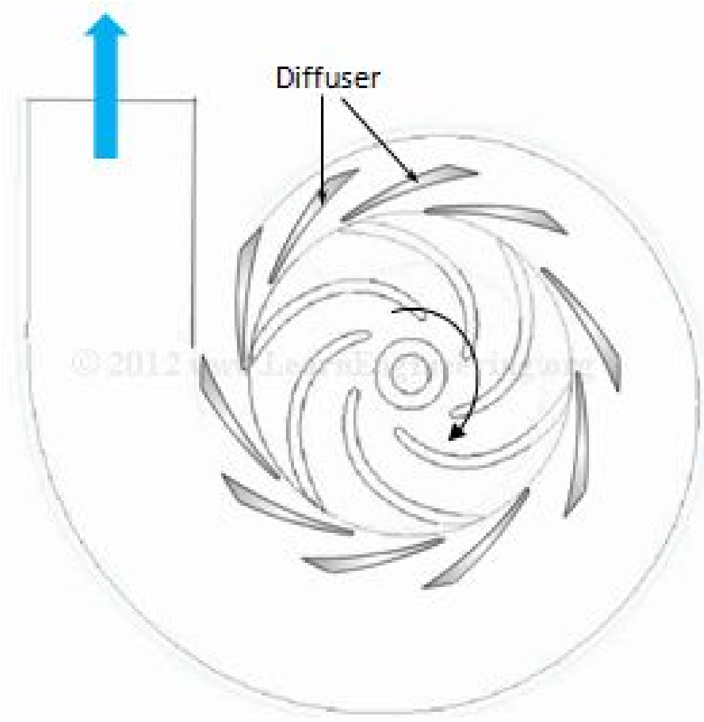
Blade angle

$$\cot \beta_2 = \frac{U_2 - V_{\theta 2}}{V_{r2}}$$

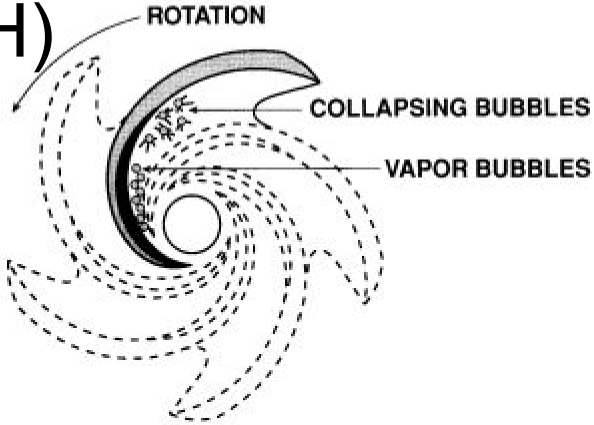


Diffuser Blades

In large centrifugal pumps attachments called diffuser blades. these help the pump convert dynamic into static energy. these exist to give a pump more capacity to to create head but at the expense of losing discharge.



Net Positive Suction Head (NPSH)



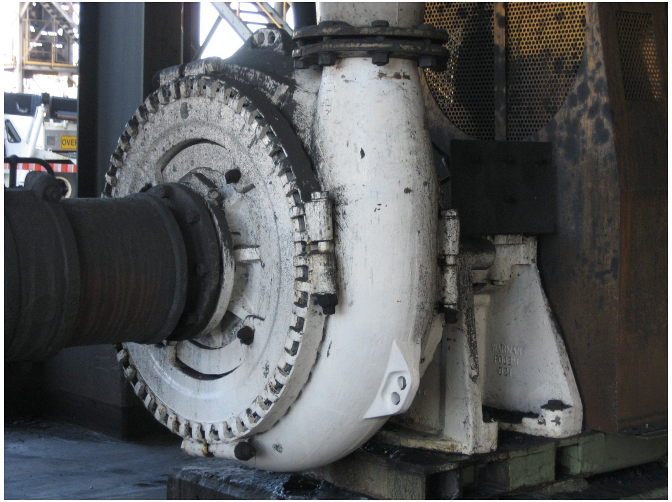
NPSH is a measure of how much pressure head loss can happen between the reservoir and the pump without causing cavitation. When liquids are pumped from a low body to a body higher above that of the first the pressure in the pipe will decrease along its length. if the liquid loses too much pressure it will phase change and turn into a gas. This phase change in itself isn't a problem but when energy is added back to the fluid at the pump it will give it enough to turn back into a liquid. The phase change can cause huge pressures and can damage the pump and the pipe.

Cavitation in a Pump

Play the video to listen to what cavitation in a working pump sounds like.

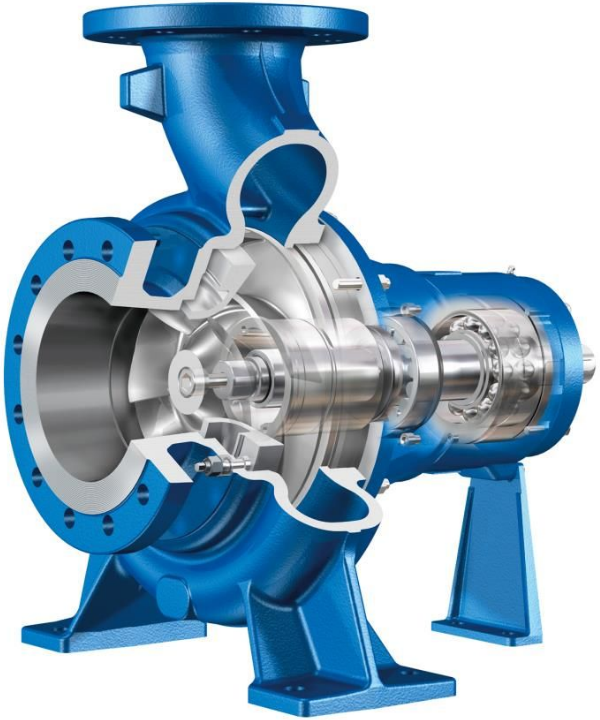
Centrifugal Pump Efficiency

- The overall efficiency of a pump is a product of three factors
  - Mechanical Efficiency (Losses in the bearing frame and mechanical seals)
  - Volumetric Efficiency (Losses due to leakage in wear rings and impellers)
  - Hydraulic Efficiency (Losses due to fluid friction within the pump casing)
- Centrifugal pumps can have very high efficiencies
  - Medium to Large pumps can be 75% - 90% efficient
  - Small pumps can be 50% to 70% efficient



Conclusion

- Centrifugal Pumps transfer rotational kinetic energy to increase the hydrodynamic energy and head of fluid flow
- Centrifugal Pumps have been used since the 1400's, and remain a popular choice in applications across multiple industries
- Centrifugal Pumps can handle high hydraulic heads, with variable flows
- When designing a Centrifugal Pump, Blade Angle, Rotations per Minute, and the number of impeller blades all impact the efficiency and discharge of a pump



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