Pumps - operation

Operational Problems

- Cavitation
- Priming

Net Positive Suction Head (NPSH)

- If the suction pressure at pump inlet is less than or equal to or just slightly greater than the vapor pressure of the liquid, the liquid may flash into vapors inside the pump. This is called Cavitation
- It greatly reduces the capacity of pump and also causes severe Erosion.
- To Avoid Cavitation, the Pressure at the pump inlet must exceed the vapor pressure of liquid by a certain amount which is called Net Positive Suction Head (NPSH)
- There are two types of NPSH
  - Net Positive Suction Head Available (NPSHa)
  - Net Positive Suction Head Required (NPSHr)

Net Positive Suction Head (NPSH)

- $NPSH_R$
  - absolute pressure in excess of vapor pressure REQUIRED at pump inlet to prevent cavitation
  - given by pump manufacturer
- $NPSH_A$
  - pressure in excess of vapor pressure AVAILABLE at pump inlet
  - determined by pump installation (elevation above reservoir, frictional losses, water temperature)
- If $NPSH_A$ is less than $NPSH_R$ cavitation will occur
- ***$NPSH_A$ must always be greater than $NPSH_R$***

$$NPSHr = \frac{\text{Absolute P at Pump suction - Vapor P at pump temp}}{\text{Specific Gravity x 0.433}}$$

NPSHa calculation

The formula for calculating the NPSHa is stated below:

$$NPSHa = Ha + Hs - Hvap - H_f$$

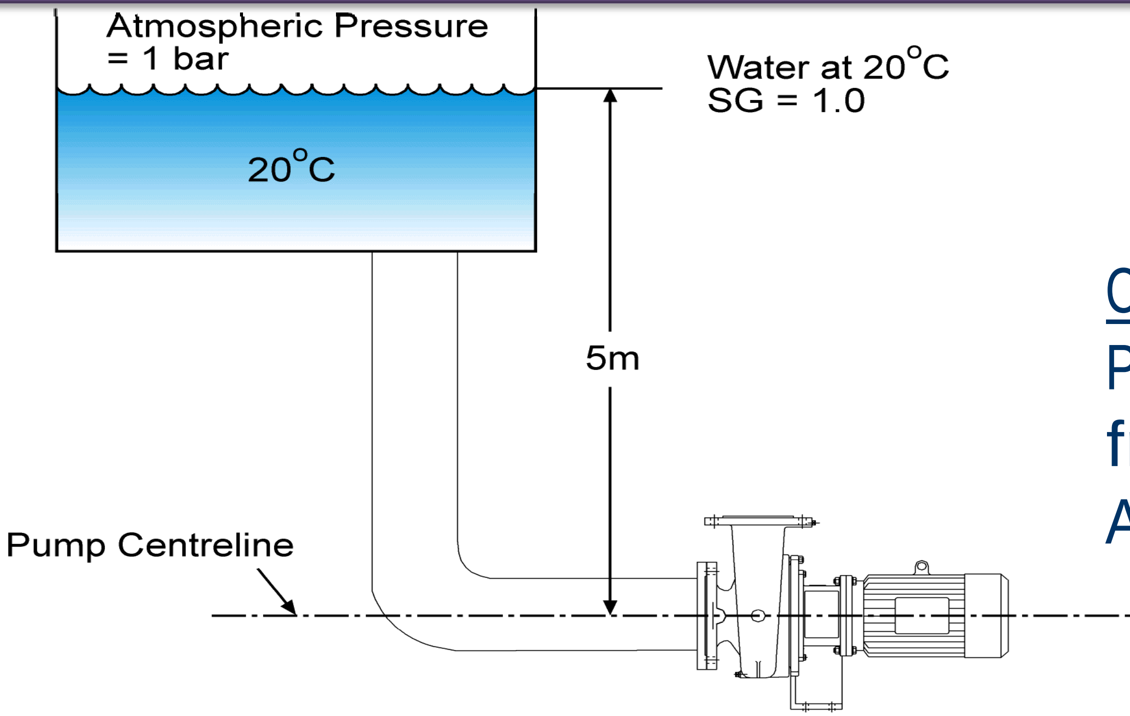
Ha Pressure Head i.e Barometric Pressure of the suction vessel converted to Head

Hs Static suction Head i.e.the vertical distance between the eye of the first stage impeller centerline and the suction liquid level.

Hvap Vapor pressure Head i.e. vapor pressure of liquid at its max. pumping temperature converted to Head

H_f Friction Head i.e. friction and entrance pressure losses on the suction side converted to Head

Net Positive Suction Head Available (NPSHa)



<u>Case 1</u>
Positive Suction
from an open tank.
At Ambient Temperature

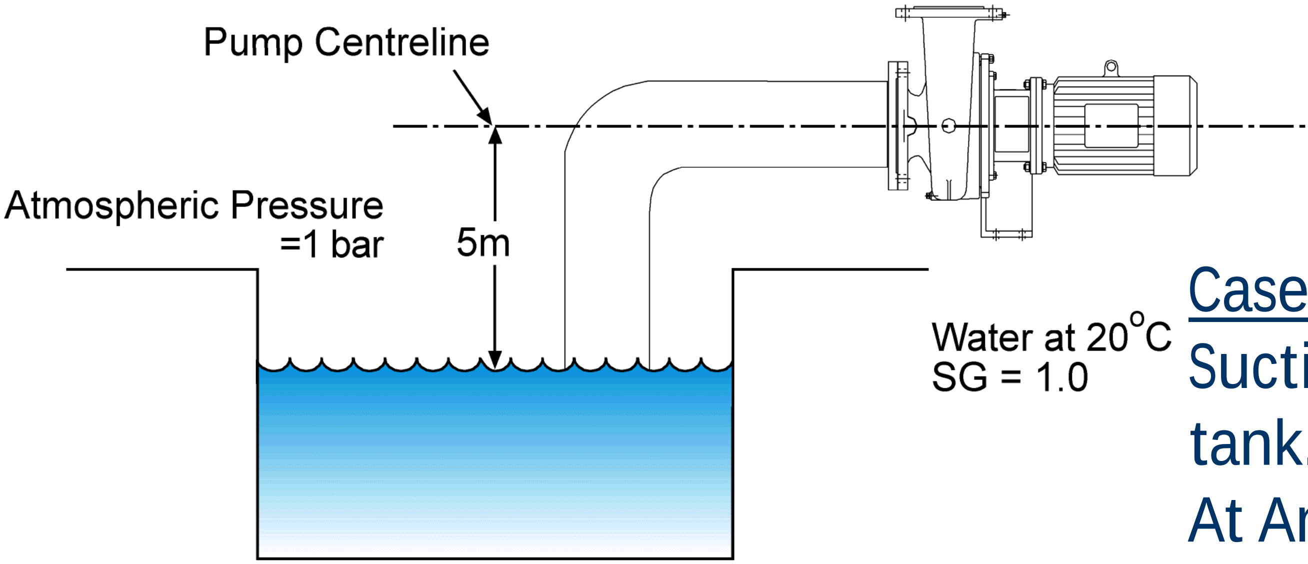
Atmospheric Pressure, Ha (1 bar) = $\frac{1 \times 10.2}{1.0}$ = 10.2 metres

Friction Loss in Suction Pipe, Hf = 1.5 metres

Static Suction Head, Hs = 5 metres

NPSH available at pump suction, NPSHa = Ha + Hs - Hf
= 10.2 + 5 - 1.5
= 13.7 metres

Net Positive Suction Head Available (NPSHa)



Case 2

Suction lift from an open tank.

At Ambient Temperature

Atmospheric Pressure, Ha (1bar) = $\frac{1 \times 10.2}{1.0}$ = 10.2 metres

Static suction head, Hs = -5m (i.e.suction/Ht)

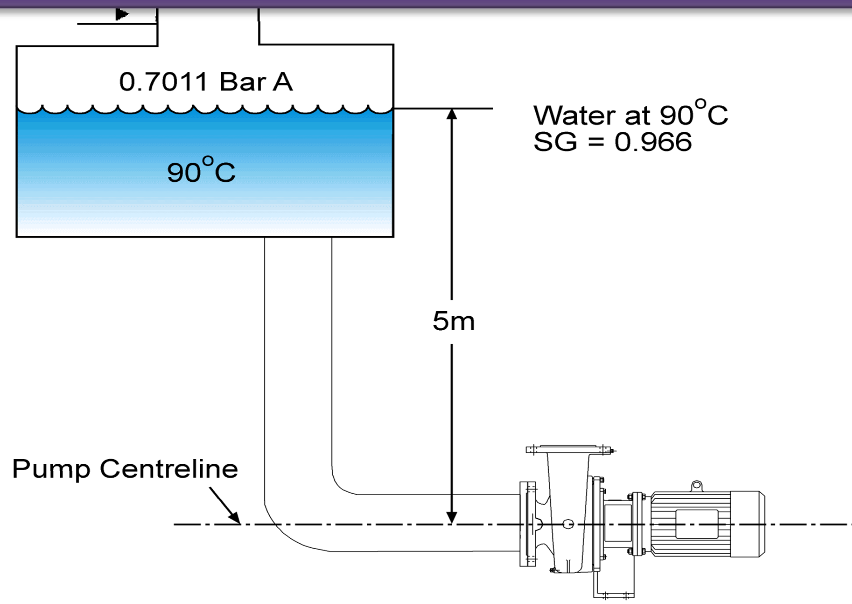
Friction loss in suction pipe, Hf = 1.5 metres

NPSH available at pump suction, NPSHa = Ha + Hs - Hf

= 10.2 - 5 - 1.5

= 3.7 metres

Net Positive Suction Head Available (NPSHa)



Case 3

Suction from a closed tank and temperatures greater than ambient.

System pressure, Ha (0.7011 bar) = $\frac{0.7011 \times 10.2}{0.966}$ = 7.4m

Friction loss in suction pipe, Hf = 1.5m

Static suction head, Hs = 5m

Vapour pressure of water at 90°C, (0.7011 bar)

$$= \frac{0.7011 \times 10.2}{0.966} = 7.4\text{m (Hvap)}$$

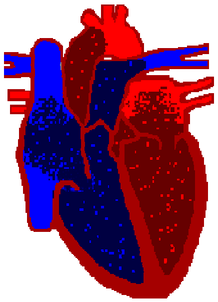
NPSH available at pump suction, NPSHa = Ha - Hs - Hf - Hvap
= 7.4 + 5 - 1.5 - 7.4
=3.5 metres

To Increase the NPSHa

- Raise the suction tank (or level in the tank).
- Lower the pump.
- Increase the pressure in the suction tank.
- Cool the liquid to reduce vapor pressure.
- Modify the suction piping. - Increase pipe diameter
- Reduce the piping length - change fittings - modify valve type - reduce number of fittings.

Cavitation

Cavitation can be termed as: "The Heart attack of the pump"



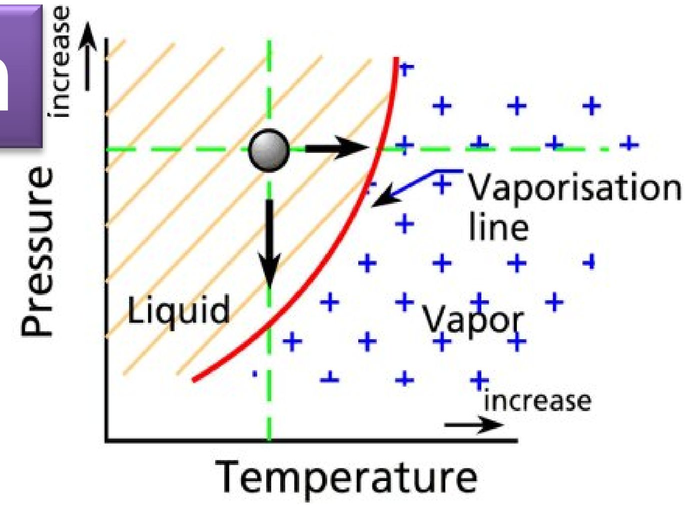
It has been described as

- A reduction in pump capacity
- A reduction in the head of the pump
- The formation of bubbles in a low pressure area of the pump
- A noise that can be heard when the pump is running
- Damaged that can be seen on the pump impeller and volute

Hence Cavitation is an abnormal condition that can result in loss of production, equipment damage and worst of all, personnel injury

Mechanism of Cavitation

Mechanism of Cavitation

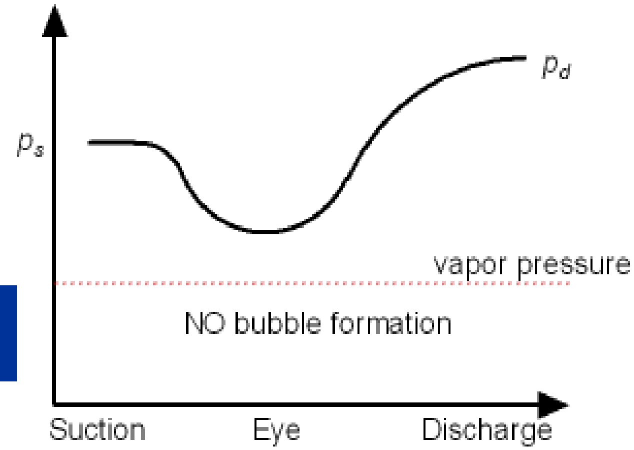


Formation of bubbles

Vaporization of Liquid

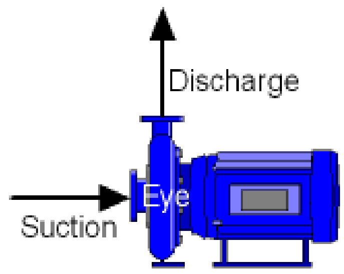
Increase in Temperature of Liquid

Decrease in Pressure



Growth of bubbles

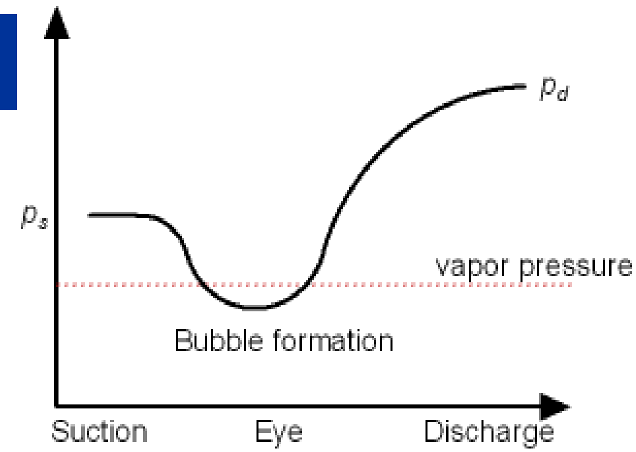
Operating Conditions



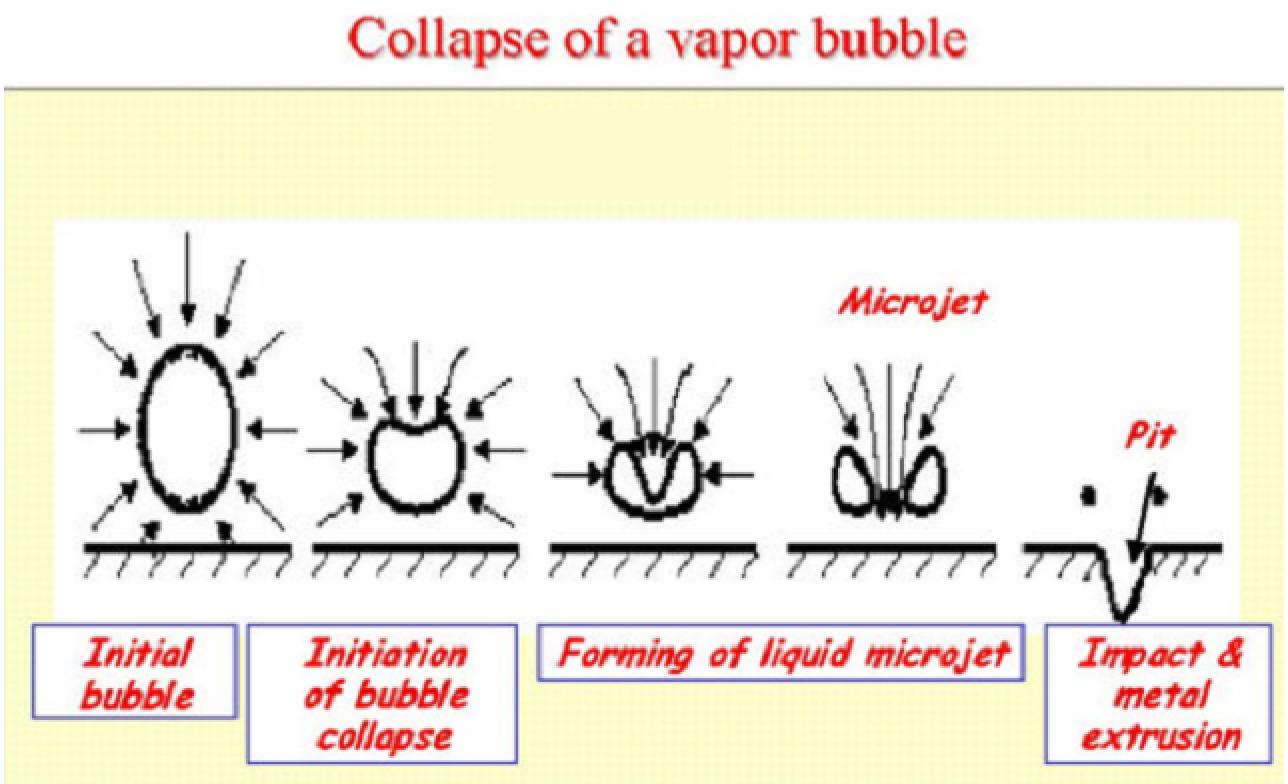
Collapses of bubbles

Liquid Micro Jet

Impeller Pitting



Mechanism of Cavitation



Mechanical Deformation due to Cavitation

- **Longer duration of cavitation condition can result in unbalancing of radial and axial thrusts on the impeller. This unbalancing often leads to following mechanical problems:**
  - **bending and deflection of shafts,**
  - **bearing damage,**
  - **thrust bearing damage from axial movement,**
  - **breaking of impeller nuts,**
  - **seal faces damage etc**

Cavitation Corrosion

- **The collapse of bubbles destroys existing protective layers making the metal surface permanently activated for the chemical attack.**
- **The rate of erosion may be increased if the liquid itself has corrosive tendencies**

Preventing Cavitation

- To prevent cavitation the NPSHa must be greater than the NPSHr
- The methods to increase NPSHa have already been described

Pump PRIMING

- A pump with air in its casing is **AIR BOUND** and can accomplish neither Suction Nor Discharge until the air is replaced with a liquid.
- **Priming is the solution of AIR BOUND pump.**
- Priming is the process in which Air/Gas is removed from the pump.

Pump PRIMING

- Air can be displaced by:
  - Priming the pump from an auxiliary priming tank connected to the suction line
  - Drawing the liquid into the suction line by an independent source of vacuum
- Also several types of Self-Priming centrifugal pumps are available
- Positive Displacement pumps can compress the gas/air inside the pump so they are Self-Priming pumps

Pros and Cons of Centrifugal Pump

- **Advantages**
  - Simple in construction and cheap
  - Little space requirements
  - Handle liquid with large amounts of solids
  - No need for internal lubrication
  - uniform pressure, without shock or pulsation.
  - Uniform flow at constant flow and Head
  - Maintenance costs are lower
  - Discharge valve closed will not damage pump for short periods

Pros and Cons of Centrifugal Pump

- **Disadvantages**
  - Cannot handle highly viscous fluids efficiently
  - Cannot be operated at very high heads
  - Multiple stages needed for high pressures
  - Maximum efficiency holds over a narrow range of conditions
  - must be primed
  - Backflow
  - Impeller damage if pumped liquid is abrasive