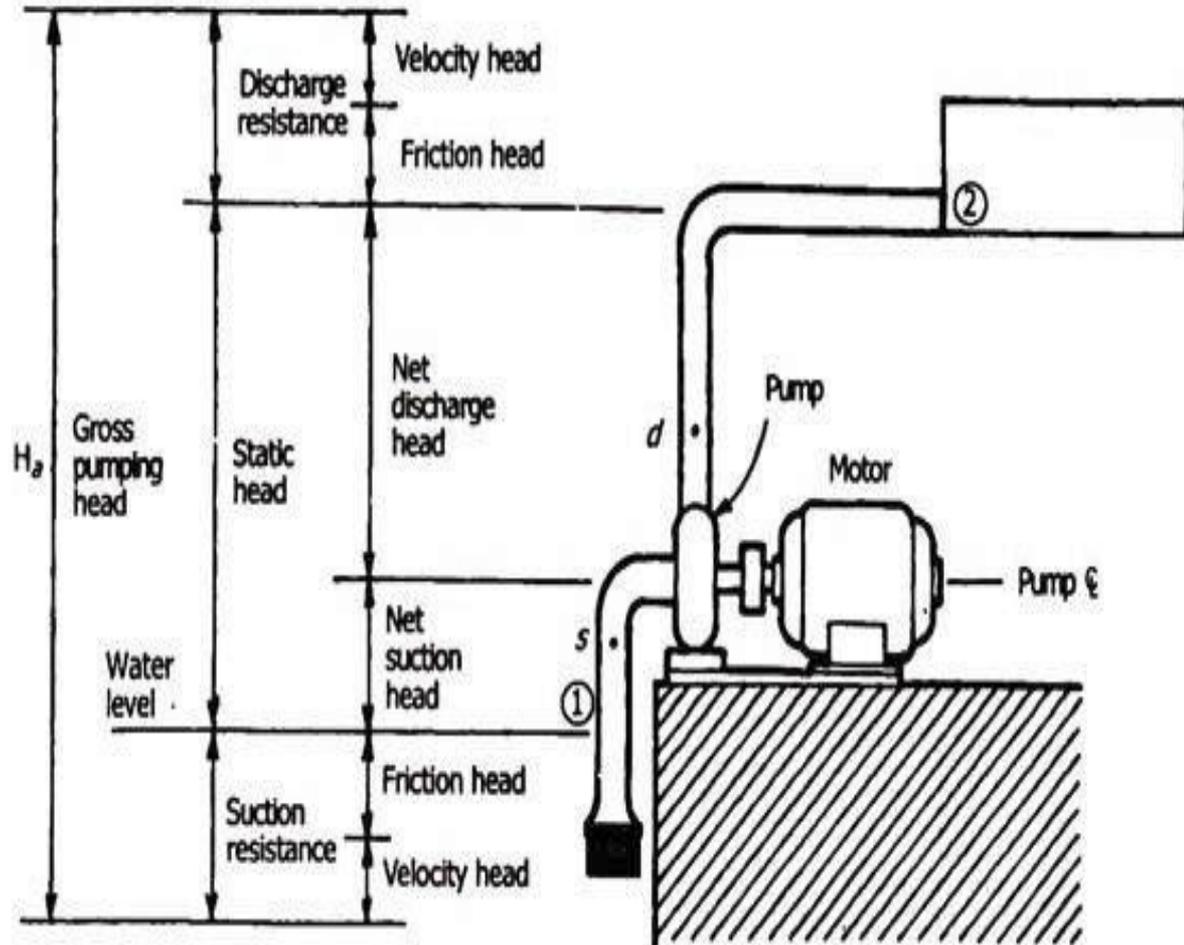# Understanding Net Positive Suction Head (NPSH) in Centrifugal Pumps

Centrifugal pumps are commonly used in various industries such as oil and gas, water treatment, and manufacturing. A critical aspect of their performance is ensuring the pump operates without cavitation- a phenomenon where vapor bubbles form and collapse within the pump, leading to damage. The concept of Net Positive Suction Head (NPSH) plays a significant role in preventing cavitation and ensuring efficient pump operation.

Pumping head in centrifugal pump installation.

What is NPSH?

- Net Positive Suction Head (NPSH) refers to the pressure available at the pump inlet to keep the fluid in a liquid state and avoid cavitation. Simply put, it's a measure of how much pressure is available to the pump above the vapor pressure of the liquid being pumped. If the NPSH is too low, the liquid can turn into vapor within the pump, leading to cavitation.

- **Key Definitions:**

  Cavitation: Formation and collapse of vapor bubbles within the pump, which can cause noise, vibration, efficiency loss, and potential damage to pump components like impellers.

  Vapor Pressure: The pressure at which a liquid starts to boil and turn into vapor at a given temperature.

Importance of NPSH:

- NPSH is critical in pump design and operation because it ensures that the pressure at the pump inlet is sufficient to prevent cavitation. Proper management of NPSH prevents the deterioration of pump performance and extends the pump's operational life.
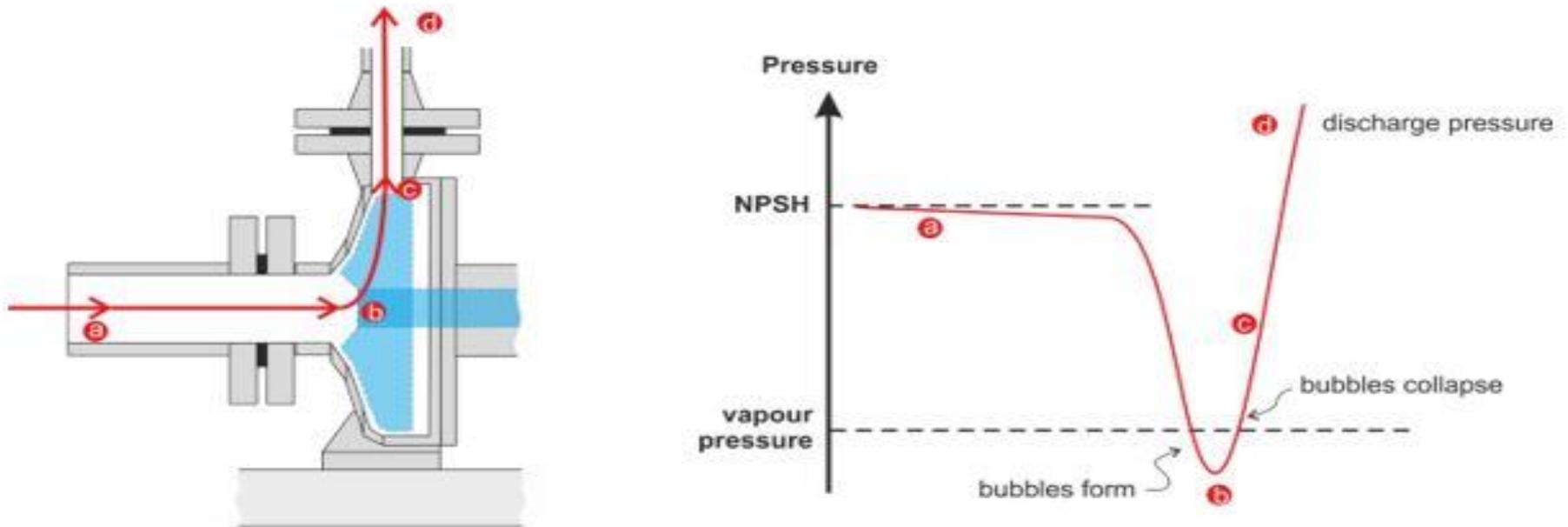

Figure 1. Pressure gradient through a centrifugal pump experiencing cavitation: fluid enters the pump (a); pressure drops below vapour pressure at impeller (b), pressure rises as fluid passes out to discharge (d) and bubbles condense and collapse (c).

Types of NPSH: NPSHa vs. NPSHr

- **NPSHa (Net Positive Suction Head Available)**: This is the absolute pressure at the suction port of the pump, minus the vapor pressure of the liquid being pumped. NPSHa is determined by the system and is the responsibility of the pump operator.

$$\text{NPSHa} = \frac{P_{\text{atm}}}{\rho g} + \frac{h_s}{g} - \frac{P_{\text{vapor}}}{\rho g} - \frac{h_f}{g}$$

Where:

- P_{atm} = Atmospheric pressure (or pressure at the liquid surface in a closed system)

- h_s = Static head (elevation difference between the liquid surface and the pump centerline)

- P_{vapor} = Vapor pressure of the liquid at pumping temperature

- h_f = Friction head loss due to pipework, valves, and fittings

- g = Acceleration due to gravity

- ρ = Density of the liquid

Types of NPSH: NPSHa vs. NPSHr

- **NPSHr (Net Positive Suction Head Required)**: This is the minimum pressure required at the suction side of the pump to prevent cavitation. It is determined by the pump manufacturer and is based on the pump's design characteristics.

$$\text{NPSHr} = \frac{P_{\text{suction}}}{\rho g} - \frac{P_{\text{vapor}}}{\rho g}$$

Where:

- P_{suction} = Pressure at the suction inlet of the pump

- P_{vapor} = Vapor pressure of the liquid at the pump's inlet temperature

How is NPSH-R measured?

- Manufacturers test pumps under conditions of constant flow and observe the discharge pressure (differential head) as NPSH (the suction pressure) is gradually reduced. Tests are usually performed with water at 20°C. NPSH-R is defined as the value at which the discharge pressure is reduced by 3% because of the onset of cavitation . NPSHr is sometimes shown as $NPSH_3$ or $NPSH_{3\%}$ to highlight this fact. For multistage pumps, only the first stage is taken into consideration for determining the 3% pressure drop.
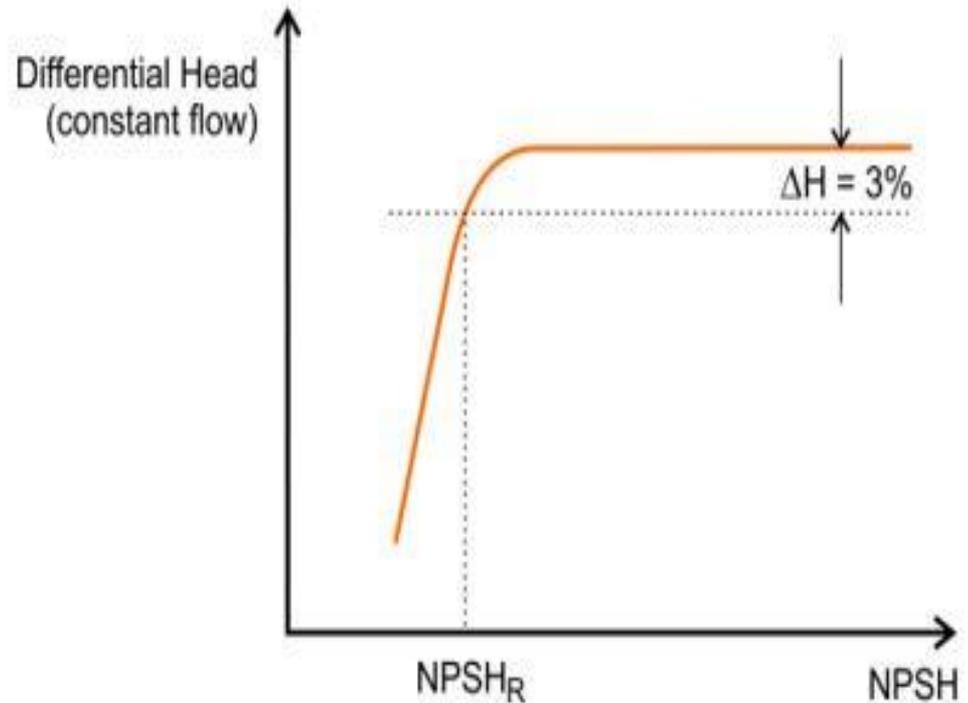
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Figure 2. Determining NPSH-R for a given flow.

NPSH Safety Margin:

- To ensure cavitation is avoided, the **NPSHa must always be greater than the NPSHr**. A common practice is to apply a safety margin, ensuring NPSHa is 10-20% higher than NPSHr. This helps account for any uncertainties or variations in system conditions.

Selected NPSH Margins from ANSI/HI 9.6.1-2012 Guideline for NPSH Margin

Industry	Application	NPSH Margin (use whichever is the greater value)
Petroleum / hydrocarbon process	Typical, except vertical canned pumps	1.1 ratio or 1.0 m (3.3 ft)
Chemical process	Typical	1.1 to 1.2 ratio or 0.6 m (2.0 ft) to 1.0 m (3.3 ft)
Electric power generation	Circulating / cooling water	1.0 m (3.3 ft)
	Boiler feed < 250 kW/stage	1.3 ratio
Water	Typical, stainless steel or aluminum-bronze impeller, < 75 kW/stage	1.1 ratio or 1.5 m (4.9 ft) minimum
Building services	Typical for pumps in open systems (not pressurized)	1.0 ratio up to a 1.1 ratio or 0.6 m (2.0 ft)
General	Often a standard catalog pump	1.1 ratio or 1.0 m (3.3 ft)

- NPSH-R and NPSH-A are not constants – they are both functions of flow (Figure 3) and also temperature. If there are any changes in capacity, it is important to reassess the NPSH margin. NPSHa reduces at high flows, as frictional losses and the head requirement increase. Conversely, NPSHr increases with flow rate.
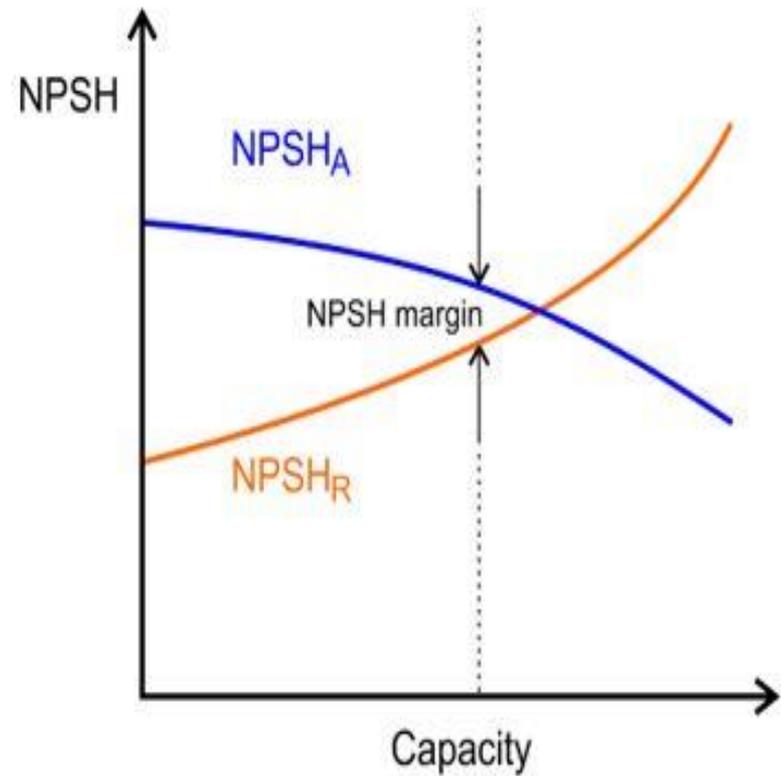

Figure 3. Variation of NPSH-R and NPSH-A with capacity (discharge flow)

Factors Affecting NPSH:

- **1. Pump Speed:**

Higher pump speeds generally increase the NPSHr because the fluid is moving faster, and it requires more pressure to avoid cavitation.

- **2. Fluid Properties:**

The temperature and vapor pressure of the liquid directly impact NPSH. Liquids with high vapor pressure (e.g., hot water or volatile chemicals) require higher NPSHa to avoid cavitation.

- **3. Suction Head (or Lift):**

The static height of the liquid relative to the pump's suction inlet affects the NPSHa. A higher suction head increases NPSHa, while a lower or negative suction head (as seen in suction lift applications) decreases it.

- **4. Friction Losses:**

Piping, valves, and fittings between the suction tank and the pump contribute to friction losses, which reduce NPSHa. Longer pipe runs, small diameters, or complex piping systems increase friction losses.

- **5. Atmospheric Pressure:**

The local atmospheric pressure contributes to NPSHa, so pumps installed at higher altitudes (where atmospheric pressure is lower) may have reduced NPSHa and be more prone to cavitation.

Practical Steps to Increase NPSHa:

If a pump is at risk of cavitation due to low NPSHa, the following actions can help increase it:

- **Reduce Suction Pipe Length**: Minimizing the distance between the fluid source and the pump reduces friction losses.

- **Increase Suction Pipe Diameter**: A larger diameter pipe reduces velocity and friction losses, thereby increasing NPSHa.

- **Lower the Pump Temperature**: Cooling the fluid reduces its vapor pressure, increasing the available NPSHa.

- **Raise the Fluid Source**: Increasing the static suction head provides more pressure to the pump.

- **Install a Booster Pump**: In systems where it's impossible to increase NPSHa sufficiently, a booster pump can provide the necessary pressure to the main pump.

Troubleshooting NPSH Problems:

Signs of Cavitation:

- **Unusual Noise**: A "gravel" or "marble" sound from the pump.

- **Vibration**: Cavitation bubbles collapsing can cause mechanical vibrations.

- **Decreased Performance**: Reduction in flow rate and head.

- **Physical Damage**: Cavitation can erode impellers and other pump components.

Steps to Prevent Cavitation:

- Ensure NPSHa exceeds NPSHr with an adequate safety margin.

- Regularly check for blockages in the suction line that could increase friction losses.

- Monitor fluid temperatures to prevent vapor pressure from rising above safe levels.

<u>Conclusion</u>

- Understanding and managing NPSH is critical for the successful operation of centrifugal pumps. Maintaining a sufficient NPSHa relative to the NPSHr ensures cavitation is avoided, which enhances pump efficiency and longevity. By paying attention to system design and fluid properties, operators can minimize the risk of cavitation and optimize the performance of their centrifugal pumps.

- By keeping these principles in mind and implementing good design and operational practices, engineers can avoid costly repairs, downtime, and pump failures related to cavitation.