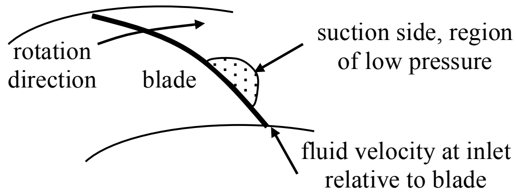
2. Net Positive Suction Head (NPSH)

Along the suction side of the impeller blade near the pump inlet are regions of low pressure.



If the local pressure is less than the vapor pressure of the liquid, then cavitation will occur:

$p \leq p_{\text{vapor}} \Rightarrow$ cavitation

Recall that cavitation is "boiling" (liquid turning to vapor) occurring when the pressure is less than the liquid's vapor pressure. Cavitation can not only significantly decrease the performance of a pump, but it can also cause pump damage, vibration, and noise. Vapor bubbles caused by cavitation move into regions of higher pressure, collapse violently, and produce localized regions of very high pressure that can chip away at surfaces. The result is that the pump material erodes away. One can often hear when cavitation occurs because of the noise generated by the collapsing vapor bubbles.

Let's define a quantity that will aid us in determine when cavitation in a pump might occur:

$$\text{net positive suction head, } NPSH \equiv \left(\frac{p}{\rho g} + \frac{V^2}{2g} \right)_s - \frac{p_v}{\rho g} \tag{13}$$

Notes:

1. The first term in NPSH is the head at the suction side of the pump near the impeller inlet. This is the region where we expect to have the lowest head. (Note that we define our reference plane for elevation along the centerline of the pump $\Rightarrow z = 0$.)

2. The second term in NPSH is the vapor pressure head. This is the head when the liquid turns to vapor. The vapor pressure is typically given in terms of an absolute pressure so the suction pressure should also be an absolute pressure. Note that vapor pressure increases as temperature increases.

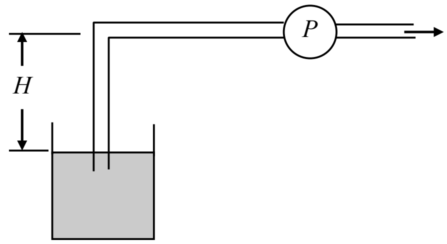
3. $(NPSH)_R$ ≡ Net Positive Suction Head Required to avoid cavitation. This quantity is a pump property and is determined experimentally.

4. $(NPSH)_A$ ≡ Net Positive Suction Head Available to the pump. This quantity is a system property and can be determined via analysis or experiments. $NPSH_A$ is related to the total head available to the pump at the pump inlet (minus the vapor head).

5. We must have $(NPSH)_A > (NPSH)_R$ to avoid cavitation. Regulations typically recommend at least a 10% margin for safety. For critical applications such as for power generation or flood control, a 100% margin is often used.

6. $NPSH_R$ increases with increasing flow rate since the pressure at the suction side of the pump blade near the pump inlet will decrease (consider Bernoulli's equation). Similarly, the pressure will decrease with increasing blade rotation rate resulting in an increased $NPSH_R$.

Example:
Determine the NPSHA for the following system



SOLUTION:

Choose point 1 to be on the surface of the tank and point 2 to be just upstream of the pump.

Apply the EBE from 1 to 2:

$$\left(\frac{p}{\rho g}+\alpha\frac{\bar{V}^2}{2g}+z\right)_2=\left(\frac{p}{\rho g}+\alpha\frac{\bar{V}^2}{2g}+z\right)_1-H_{L12}+H_{S12}$$

where

$p_2 = p_s$ $\qquad$ $p_1 = p_{atm}$

$\bar{V}_2 = \bar{V}_s$ (assume turbulent flow $\Rightarrow \alpha = 1$) $\qquad$ $\bar{V}_1 \approx 0$

$z_2 = z_1 + H$ $\qquad$ $H_{S12} = 0$

$H_{L12} = H_{L12}$

Substitute and simplify to get:

$$\left(\frac{p}{\rho g}+\frac{\bar{V}^2}{2g}\right)_S=\frac{p_{atm}}{\rho g}+\underbrace{\left(z_1-z_2\right)}_{=-H}-H_{L12}$$

From the definition of NPSH we have:

$$\boxed{NPSHA=\frac{p_{atm}}{\rho g}-H-H_{L12}-\frac{p_v}{\rho g}}$$

Notes:
1. Increasing H, H_{L12}, or p_v decreases NPSHA and increases the likelihood of cavitation since the difference between NPSHA and NPSHR is reduced.
2. Increasing p_{atm} increases NPSHA and decreases the likelihood of cavitation.
3. p_v varies with temperature
4. p_v is usually given in terms of absolute pressure