## Available Net Positive Suction Head (Simply NPSH)

The system head is given as:

$$h_s = Z_s + \frac{P_s}{\rho g} - h_{fs} = \frac{P_1}{\rho g} + Z_1 + \frac{V_1^2}{2}$$

From this equation:

$$h_s = Z_s + \frac{P_s}{\rho g} - h_{fs}$$

$$\frac{P_1}{\rho g} = h_s - \left(Z_1 + \frac{V_1^2}{2}\right)$$

It can be seen that if $Z_s$ is low or Q is high (high $h_{fs}$), then, $h_s$ will decreases.

- If $P_1$ becomes $\leq P_{vp}$ then the liquid will boil [bubbles will be formed at the inlet of the pump. This results in cavitation].
- If $P_1$ is slightly higher than $P_{vp}$, then cavitation will occur inside the pump as the pressure is further decreased inside the pump as a result of the liquid being accelerated inside the pump.

In view of the facts above, we define:

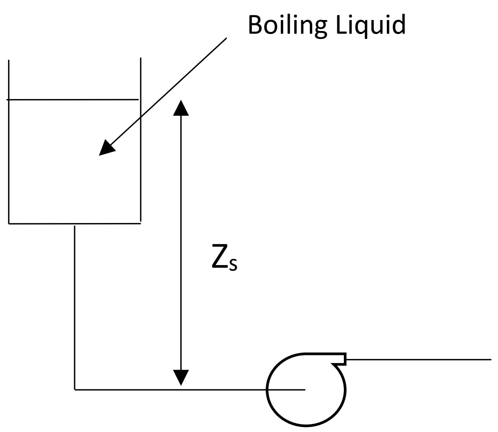
$$NPSH = h_s - \frac{P_{vp}}{\rho g} \quad ; \quad \frac{P_{vp}}{\rho g} \textit{ is the head corresponding to the vapor pressure}$$

Substituting for $h_s$ we have:

$$\boxed{NPSH = Z_s + \frac{P_s - P_{vp}}{\rho g} - h_{fs}}$$

Notes:

- NPSH should always be positive
- The available NPSH decreases with increasing flow rate (higher $h_{fs}$)
- At boiling or bubble points no suction lift is possible. In such cases: NPSH is –ve since Z is –ve i.e the liquid level is below the pump)
- In order to avoid cavitation, the available NPSH should be greater than the NPSH requirement for the pump, this is specified by the manufacturer.
- For boiling liquids ***Ps = Pvp***
  $NPSH_{Available} = (Z_s - h_{fs})$ Therefore $Z_s - h_{fs}$ should be > $NPSH_{Required}$




Therefore, care must be taken when specifying design value for Zs.

**Characteristic Curves for Centrifugal Pumps:**

These curves describe the performance of a pump for a particular rotational speed and liquid viscosity. Manufacturers usually provide these curves for water at ambient conditions.

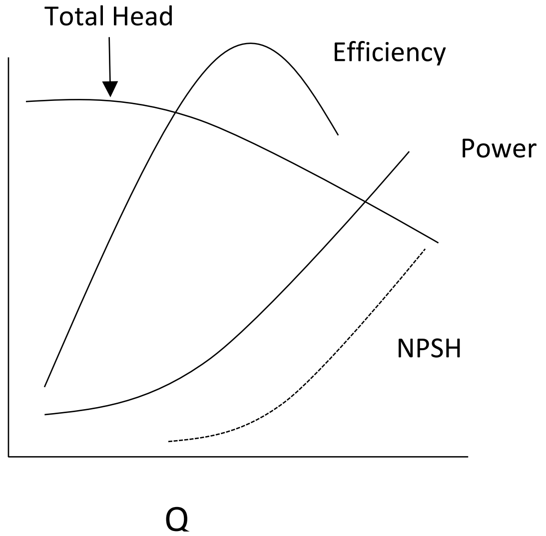
Types:

$\Delta h$ *vs* Q

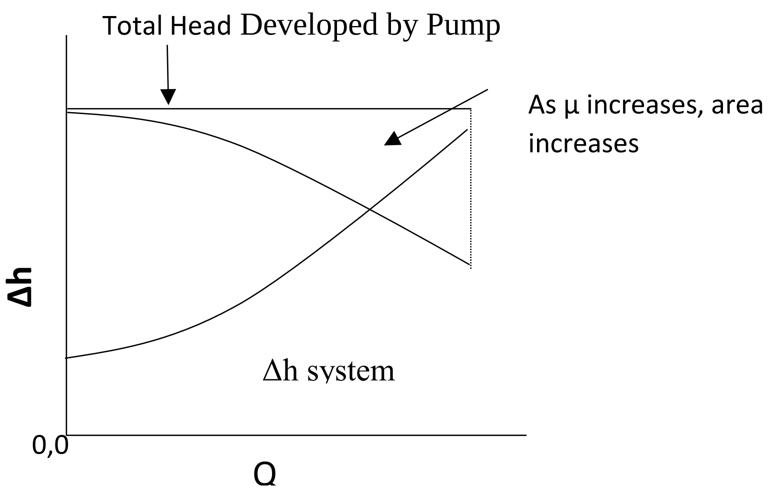
Power *vs* Q

NPSH *vs* Q

$\eta$ *vs* Q




Δh vs Q




$\Delta h$ vs Q is independent of $\rho$, therefore $\Delta P$ increases with $\rho$, i.e

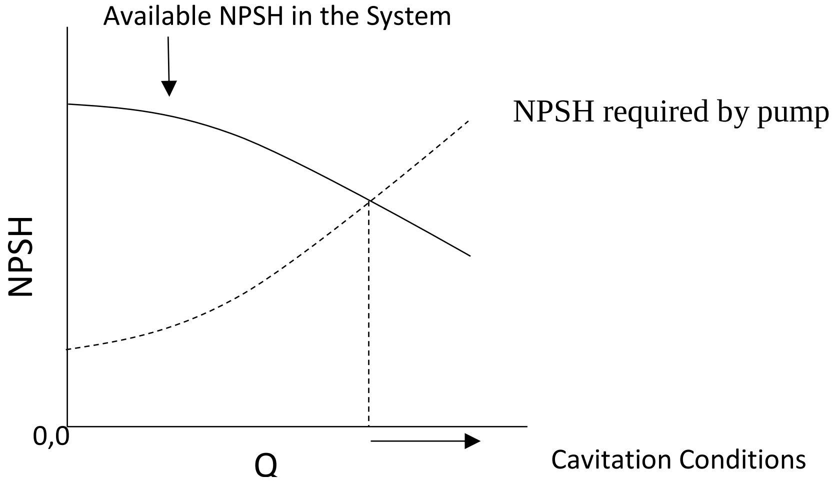
$$\boxed{\Delta P = \rho \Delta h g}$$

In a particular system, a centrifugal pump operates at only one point on $\Delta h$ vs Q curve. That is the point where the pump $\Delta h$ vs Q curve intersects with the system $\Delta h$ vs Q curve.

Note: for laminar flow, the system $\Delta h$ vs Q curve is a straight line. ($h_{fs} + h_{ds}$) is linearly proportional to Q.

Estimation of $\Delta h$ should be accurate. Very little or no safety should be included. This will result in achieving less flow rate than required.

NPSH vs Q




Pump Efficiency:

$$\eta = \frac{\text{Useful Work}}{\text{Total Work}}$$

$$= \frac{\Delta\left(\frac{P}{\rho g} + gZ + \frac{V^2}{2}\right)}{\widehat{W}}$$

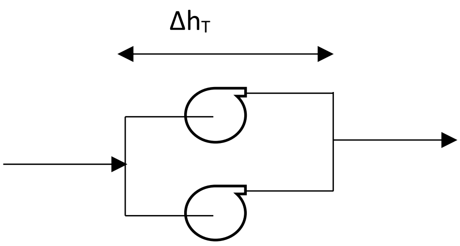
Alternatively

$$\eta = \frac{Hydraulic\ Power}{Supplied\ Power}$$

$$= \frac{\dot{m}\Delta\left(\frac{P}{\rho g} + gZ + \frac{V^2}{2}\right)}{Supplied\ power} = \frac{Work\ Power}{Brake\ Power}$$

# Pump Connection

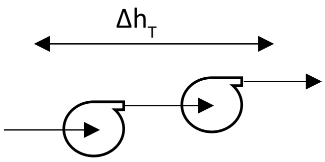
Parallel




$Q_T = Q_1 + Q_2$

$\Delta h_T = \Delta h_1 = \Delta h_2$

Series




$Q_T = Q_1 = Q_2$

$\Delta h_T = \Delta h_1 + \Delta h_2$