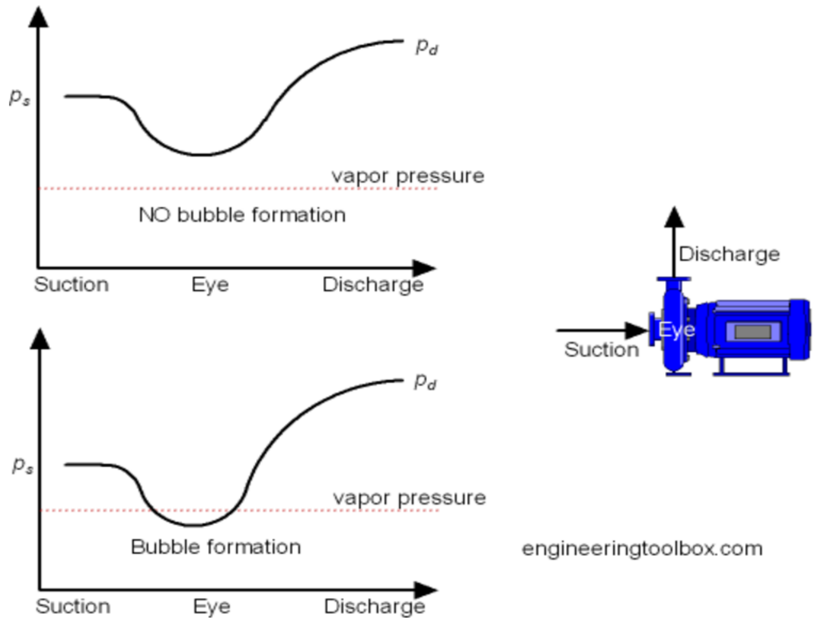
# Net Positive Suction Head (NPSH)

**Reference**: http://www.engineeringtoolbox.com/npsh-net-positive-suction-head-d_634.html

Low pressure at the suction side of a pump may cause the fluid to start boiling with

- reduced efficiency
- cavitation
- damage

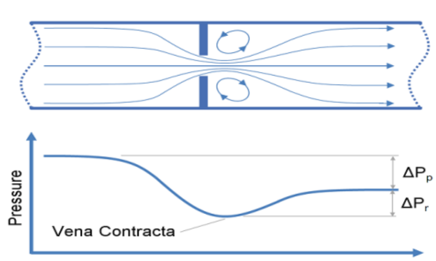
of the pump as a result. Boiling starts when the pressure in the liquid is reduced to the vapor pressure of the fluid at the actual temperature.




**Vena Contracta**

Cavitation occurs in liquid systems and is the result of rapid formation and collapse of vapour bubbles in the liquid. The consequences of this energy release are typically loud noise and pitting damage to contact surfaces.  Cavitation occurs at a region where the pressure is lower than the fluid vapour pressure, such as the pump suction, or where a large pressure reduction takes place.

In the case of a simple concentric restriction orifice the fluid is accelerated as it passes through the orifice, reaching the maximum velocity a short distance downstream of the orifice itself (the Vena Contracta). The intermediate pressure in the Vena Contracta is lower than the final system pressure and thus the highest chance of experiencing cavitation as demonstrated in the figures below.



To characterize the potential for boiling and cavitation the difference between

- the total head on the suction side of the pump - close to the impeller, and
- the liquid vapor pressure at the actual temperature

can be used.

### Suction Head

Based on the Energy Equation - the **suction head** in the fluid close to the impeller*) can be expressed as the sum of the **static** and **velocity head**:

$h_s = p_s / \gamma_{liquid} + v_s^2 / 2 g$ *(1)*

*where*

$h_s$ = *suction head close to the impeller (m, in)*

$p_s$ = *static pressure in the fluid close to the impeller (Pa (N/m$^2$), psi (lb/in$^2$))*

$\gamma_{liquid}$ = *specific weight of the liquid (N/m$^3$, lb/ft$^3$)*

$v_s$ = *velocity of fluid (m/s, in/s)*

$g$ = *acceleration of gravity (9.81 m/s$^2$, 386.1 in/s$^2$)*

*) We can not measure the suction head "close to the impeller". In practice we can measure the head at the pump suction flange. Be aware that - depending of the design of the pump - the contribution to the NPSH value from the suction flange to the impeller can be substantial.

### Liquids Vapor Head

The **liquids vapor head** at the actual temperature can be expressed as:

$h_v = p_v / \gamma_{vapor}$ *(2)*

*where*

$h_v$ = *vapor head (m, in)*

$p_v$ = *vapor pressure (m, in)*

$\gamma_{vapor}$ = *specific weight of the vapor (N/m$^3$, lb/ft$^3$)*

**Note!** The vapor pressure in a fluid depends on the temperature. Water, our most common fluid, starts boiling at *20 °C* if the absolute pressure is *2.3 kN/m$^2$*. For an absolute pressure of *47.5 kN/m$^2$* the water starts boiling at *80 °C*. At an absolute pressure of *101.3 kN/m$^2$* (normal atmosphere) the boiling starts at *100 °C*.

## Net Positive Suction Head - NPSH

The Net Positive Suction Head - NPSH - can be defined as

- the difference between the Suction Head, and
- the Liquids Vapor Head

and can be expressed as

$NPSH = h_s - h_v$ *(3)*

*or, by combining (1) and (2)*

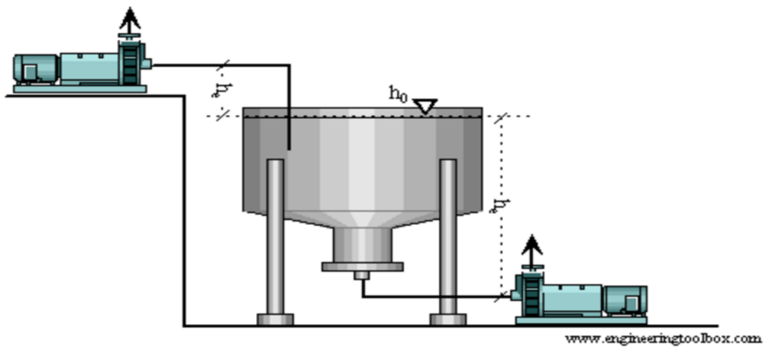
$NPSH = p_s / \gamma + v_s^2 / 2 g - p_v / \gamma$ *(3b)*

*where*

*NPSH = Net Positive Suction Head (m, in)*

### Available NPSH - $NPSH_a$ or NPSHA

The Net Positive Suction Head available from the application to the suction side of a pump is often named $NPSH_a$. The $NPSH_a$ can be estimated during the design and the construction of the system, or determined experimentally by testing the actual physical system.




The available $NPSH_a$ can be estimated with the Energy Equation.

For a common application - where the pump lifts a fluid from an open tank at one level to an other, the energy or head at the surface of the tank is the same as the energy or head before the pump impeller and can be expressed as:

$$h_0 = h_s + h_l \qquad (4)$$

*where*

$h_0$ = *head at surface (m, in)*

$h_s$ = *head before the impeller (m, in)*

$h_l$ = *head loss from the surface to impeller - major and minor loss in the suction pipe (m, in)*

In an open tank the head at the surface can be expressed as:

$$h_0 = p_0 / \gamma = p_{atm} / \gamma \qquad (4b)$$

For a closed pressurized tank the absolute static pressure inside the tank must be used.

The head before the impeller can be expressed as:

$$h_s = p_s / \gamma + v_s^2 / 2 g + h_e \qquad (4c)$$

*where*

$h_e$ = *elevation from surface to pump - positive if pump is above the tank, negative if the pump is below the tank (m, in)*

Transforming (4) with (4b) and (4c):

$$p_{atm} / \gamma = p_s / \gamma + v_s^2 / 2 g + h_e + h_l \qquad (4d)$$

The head available before the impeller can be expressed as:

$$p_s / \gamma + v_s^2 / 2 g = p_{atm} / \gamma - h_e - h_l \qquad (4e)$$

or as the available $NPSH_a$:

$$NPSH_a = p_{atm} / \gamma - h_e - h_l - p_v / \gamma \qquad (4f)$$

*where*

$NPSH_a$ = *Available Net Positive Suction Head (m, in)*

**Available $NPSH_a$ - the Pump is above the Tank**

If the pump is positioned above the tank, the elevation - $h_e$ - is positive and the $NPSH_a$ decreases when the elevation of the pump increases (lifting the pump).

At some level the $NPSH_a$ will be reduced to zero and the fluid will start to evaporate.

**Available $NPSH_a$ - the Pump is below the Tank**

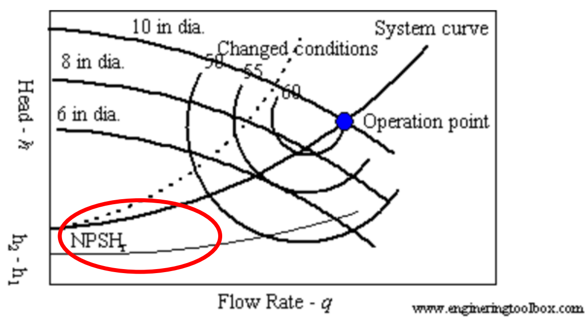
If the pump is positioned below the tank, the elevation - $h_e$ - is negative and the $NPSH_a$ increases when the elevation of the pump decreases (lowering the pump).

It's always possible to increase the $NPSH_a$ by lowering the pump (as long as the major and minor head loss due to a longer pipe don't increase it more). **Note!** It is important - and common - to lower a pump when pumping a fluid close to evaporation temperature.

### Required NPSH - $NPSH_r$ or NPSHR

The $NPSH_r$, called as the Net Suction Head as required by the pump in order to prevent cavitation for safe and reliable operation of the pump.

The required $NPSH_r$ for a particular pump is in general determined experimentally by the **pump manufacturer** and a part of the documentation of the pump.




The available $NPSH_a$ of the system should always exceed the required $NPSH_r$ of the pump to avoid vaporization and cavitation of the impellers eye. The available $NPSH_a$ should in general be significant higher than the required $NPSH_r$ to avoid that head loss in the suction pipe and in the pump casing, local velocity accelerations and pressure decreases, start boiling the fluid on the impellers surface.

Note that required $NPSH_r$ increases with the square of capacity.

Pumps with double-suction impellers has lower $NPSH_r$ than pumps with single-suction impellers. A pump with a double-suction impeller is considered hydraulically balanced but is susceptible to an uneven flow on both sides with improper pipe-work.

To prevent cavitation from occurring: $NPSH_a > NPSH_r$

### Example - Pumping Water from an Open Tank

When elevating a pump located above a tank (lifting the pump) - the fluid starts to evaporate at the suction side of the pump at what is the maximum elevation for the actual temperature of the pumping fluid.

At the maximum elevation $NPSH_a$ is zero. The maximum elevation can therefore be expressed by modifying (4f) to:

$$NPSH_a = p_{atm} / \gamma - h_e - h_l - p_v / \gamma$$

$$= 0$$

For an optimal theoretical condition we neglect major and minor head loss. The elevation head can then be expressed as:

$$h_e = p_{atm} / \gamma - p_v / \gamma \qquad (5)$$

The maximum elevation - or suction head - for an open tank depends on the atmospheric pressure - which in general can be regarded as constant, and the vapor pressure of the fluid - which in general vary with temperature, especially for water.

The absolute vapor pressure of water at temperature $20\ ^oC$ is $2.3\ kN/m^2$. The maximum theoretical elevation of a pump when pumping water at $20\ ^oC$ is therefore:

$$h_e = (101.33\ kN/m^2) / (9.80\ kN/m^3) - (2.3\ kN/m^2) / (9.80\ kN/m^3)$$

$$= \underline{10.1}\ m$$

Due to head loss in the suction pipe and the local conditions inside the pump - the theoretical maximum elevation normally is significantly decreased.

Maximum theoretical elevation of a pump above an open tank at different water temperatures are indicated below.

## Suction Head for Water as Affected by Temperature

Suction head for water - or max. elevation of a pump above a water surface - as affected by the temperature of the pumping water - is indicated below:

| Temperature | | Vapor Pressure | Suction Head | |
|---|---|---|---|---|
| *(°C)* | *(°F)* | *(kN/m²)* | *(m)* | (ft) |
| 0 | 32 | 0.6 | 10.3 | 33.8 |
| 5 | 41 | 0.9 | 10.2 | 33.5 |
| 10 | 50 | 1.2 | 10.2 | 33.5 |
| 15 | 59 | 1.7 | 10.2 | 33.5 |
| 20 | 68 | 2.3 | 10.1 | 33.1 |
| 25 | 77 | 3.2 | 10.0 | 32.8 |
| 30 | 86 | 4.3 | 9.9 | 32.5 |
| 35 | 95 | 5.6 | 9.8 | 32.2 |
| 40 | 104 | 7.7 | 9.5 | 31.2 |
| 45 | 113 | 9.6 | 9.4 | 30.8 |
| 50 | 122 | 12.5 | 9.1 | 29.9 |
| 55 | 131 | 15.7 | 8.7 | 28.5 |
| 60 | 140 | 20 | 8.3 | 27.2 |
| 65 | 149 | 25 | 7.8 | 25.6 |
| 70 | 158 | 32.1 | 7.1 | 23.3 |
| 75 | 167 | 38.6 | 6.4 | 21 |
| 80 | 176 | 47.5 | 5.5 | 18 |
| 85 | 185 | 57.8 | 4.4 | 14.4 |
| 90 | 194 | 70 | 3.2 | 10.5 |
| 95 | 203 | 84.5 | 1.7 | 5.6 |
| 100 | 212 | 101.33 | 0.0 | 0 |