NPSH

Net Positive Suction Head

1. Calculation of NPSH available

Net Positive Suction Head available

NPSHa is defined as the pressure energy that is available to the fluid at the Pump inlet over and above the vapor pressure value of the liquid being pumped at that temperature.

The liquid starts with some pressure (generally atmospheric) at the suction reservoir. This pressure energy is then converted into elevation potential energy (for suction lift condition) and suction pipe losses as the liquid reaches the pump inlet. Hence,

$$NPSH_A = h_{atm} + h_g - H_s - h_f - h_{vap}$$

Where, h_{atm} *= Atmospheric pressure head (m)*

h_g *= gauge pressure reading at suction vessel (m), for general case when liquid is pressurized at Reservoir*

H_s *= Pump Centerline elevation from suction level (m)*

h_f *= Friction losses in suction pipe (m)*

h_{vap} *= vapor pressure head at pumping temperature (m)*

Note: NPSHr is the min NPSH required by the pump for safe operation, and is a pump characteristic. While, NPSHa is the actual NPSH available and is a system characteristic. For design, $NPSH_R > NPSH_A$

CALCULATION OF AVAILABLE NPSH

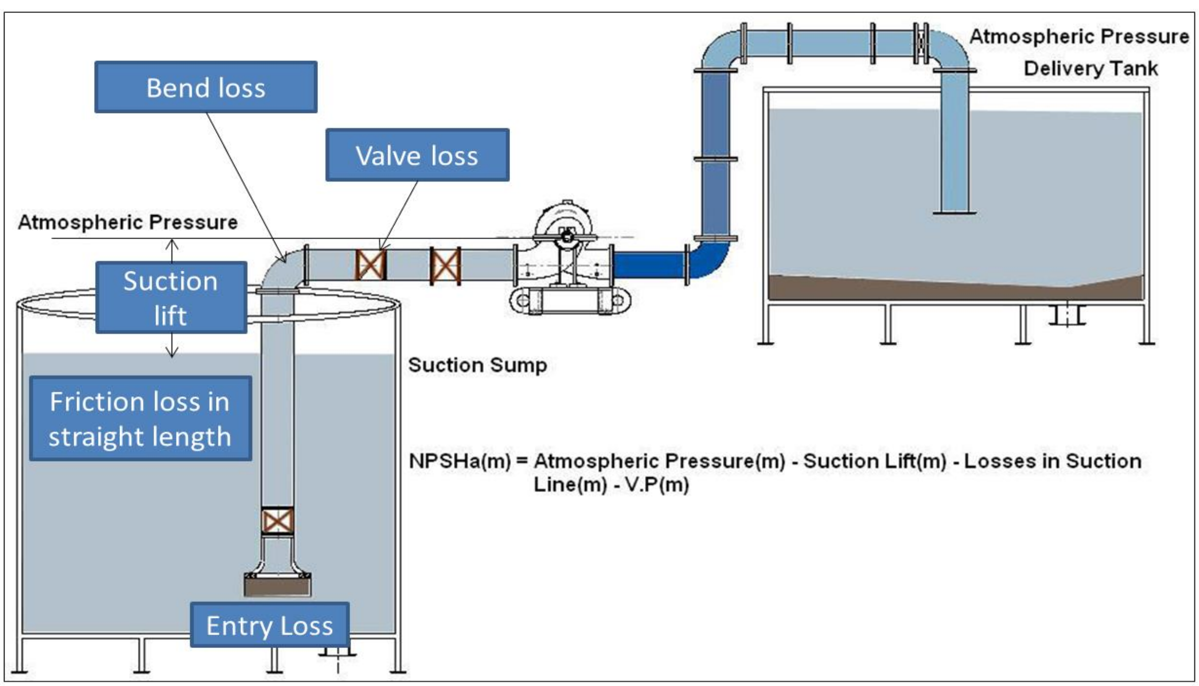
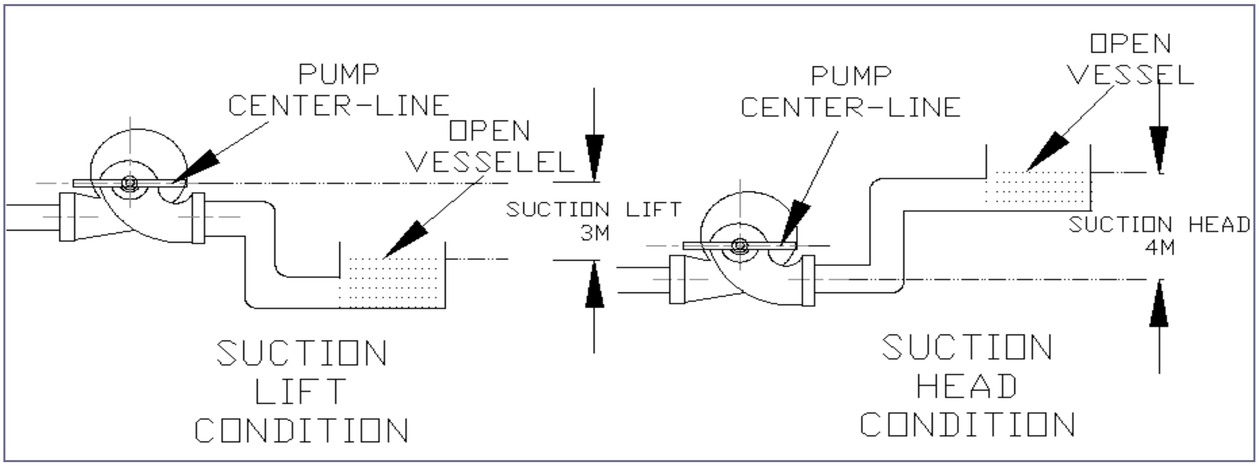


Fig. 1: Determination of Net Positive Suction Head available

Now, let us consider two different cases of **(a) Suction lift condition (b) Suction head condition** to calculate NPSHa:



CASE 1 (LIFT) Fig. 2: Two cases of suction CASE 2 (HEAD)

Provided,

Pipe losses = 1.5 m

Specific gravity of liquid = 0.8

Vapor pressure = 0.45 kgf/cm^2 (at the pumping temperature of the liquid)

Now, we have to find out the value of $NPSH_a$ for the two cases below:

a) The suction lift = 3.0 m
b) The suction head = 4.0 m

Note: The suction vessel is open

Description

Vapor pressure is **0.45 kgf/cm^2**

We know,

$$Pressure\ (kg/cm^2) = \frac{head\ (m) \times specific\ gravity}{10}$$

Using this we can calculate the atmospheric pressure head (h_{atm}), vapor pressure head (h_{vap}) etc.

h_{vap} = 5.6 m ***h_f = 1.5 m***

h_{atm} *(in terms of water)* ***= 10.325 m*** *water column*.

h_{atm} *(Equivalent column of the liquid being used) =* $\frac{10.325}{specific\ gravity} = \mathbf{12.9\ m}$

The vessel is open so it is at atmospheric pressure.

So, ***h_g = 0 m***

h_g is gauge pressure converted to head compared to atmospheric head (m).

Case -1

We know, for the **suction lift condition**

$$NPSH_A = h_{atm} + h_g - H_s - h_f - h_{vap}$$

$$= \quad (12.9\ +\ 0 - 3 - 1.5 - 5.6)\ m$$

Putting the values in the equation, we get the value of ***$NPSH_A$ = 2.8 m***

Case -2

We know, for the **suction head condition**

$$NPSH_A = h_{atm} + h_g - H_s - h_f - h_{vap}$$

$$= (12.9\ +\ 0\ +\ 4 - 1.5 - 5.6)\ m$$

Putting the values in the equation, we get ***$NPSH_A$ = 9.8 m***

2. Determination of minimum NPSHa & Pump Selection

An end suction pump has been designed for the following duty:

Q = 1800 m^3/hr

H = 38 m

Impeller eye diameter (D_e) = 278 mm

NPSHr at design duty = 7.5 m

Speed = 1480 rpm

Specific gravity = 1

We have to calculate the **Suction Energy** and determine the **$NPSH_A$** to ensure **cavitation free safe operation**.

Description

Suction Energy: Generally, the pump is kept at some level above the sump (suction reservoir). The liquid uses its own energy to reach the pump inlet (**Pressure Energy ⟶ Elevation Potential Energy**). Suction energy, as the name suggests, is a measure of the liquid's energy used for suction from reservoir to pump inlet. Higher the Suction Energy, higher is the energy used from liquid to bring it from the suction reservoir to pump inlet. Thus, a higher value of suction energy indicates a lower liquid pressure at inlet and a higher chance of cavitation and corresponding damage extent.

$$\boldsymbol{Suction\ energy\ (S.E)\ =\ D_e \times N \times N_{ss} \times sp.gravity}$$

Where, ***D_e*** = *Impeller eye dia. (inches)*

N = *speed of the pump (rpm).*

N_{ss} = *suction specific speed in US units.*

Suction Specific Speed: It is the measure of Pump's suction capability. Defined as,

$$N_{ss} = \frac{N \times \sqrt{(\frac{Q}{eye})}}{NPSH_R{}^{0.75}}$$

Here, ***(Q/eye)*** *is the flow rate entering from each individual eye of the pump inlet.*

N_{SS} *is the Suction Specific Speed.*

$NPSH_R$ *is the NPSH required by the pump for cavitation free operation.*

$N_{ss} = \frac{1480 \times \sqrt{1800}}{75} = 11928$ *US units*

$S.E. = 10.94 \times 1480 \times 11928 \times 1 = 193 \times 10^6$

As discussed, the extent of cavitation damage depends on the value of suction energy. For design purpose, we assign different slabs for the magnitude of suction energy according to the type of pump, as shown below.

PUMP TYPE	LOW S.E.	HIGH S.E.	VERY HIGH S.E.
2 VANE SEWAGE PUMP	$< 100 \times 10^6$	100×10^6 TO 150×10^6	$> 150 \times 10^6$
DOUBLE SUCTION PUMPS	$< 120 \times 10^6$	120×10^6 TO 180×10^6	$> 180 \times 10^6$
END SUCTION PUMPS	$< 160 \times 10^6$	160×10^6 TO 240×10^6	$> 240 \times 10^6$
VERTICAL TURBINE PUMPS	$< 200 \times 10^6$	200×10^6 TO 300×10^6	$> 300 \times 10^6$
INDUCERS	$< 320 \times 10^6$	320×10^6 TO 480×10^6	$> 480 \times 10^6$

Fig. 3: Suction Energy Level designation according to Pump Type

For cavitation free operation, we must operate at a required $NPSH_R$ value that is greater than the available system $NPSH_A$. We define a minimum NPSH margin for safe operation as shown below.

$$Minimum\ NPSH\ margin = \frac{NPSH_R}{NPSH_A}$$

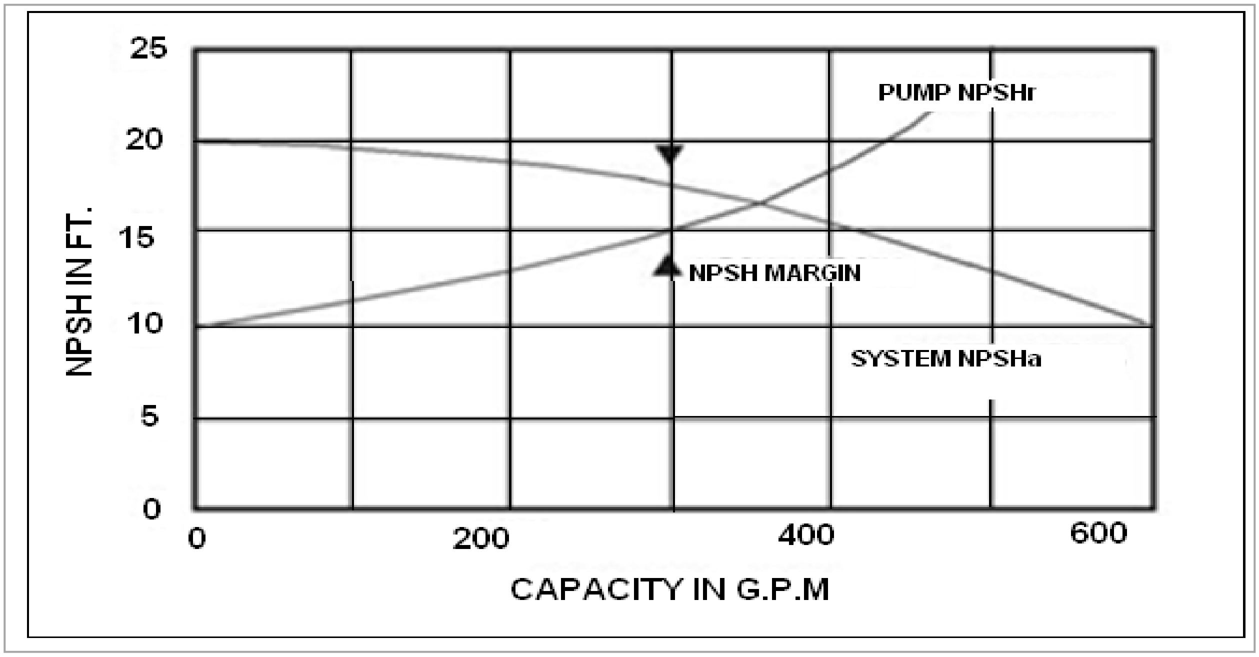


Fig. 4: $NPSH_R$ margin as function of operating point (region to the right of intersection is safe)

Now, higher the suction energy level, higher is the extent of cavitation. Hence, we must assign a minimum $NPSH_R$ margin depending on the level of S.E. (higher margin for higher SE). According to **HIS,** the recommendation for safe operation is:

HYDRAULIC INSTITUTE RECOMMENDS MINIMUM NPSH MARGIN FOR VARIOUS LEVELS OF SUCTION ENERGY	
SUCTION ENERGY LEVEL	**MINIMUM NPSH MARGIN (NPSHa/NPSHr)**
LOW	**1.1 TO 1.3**
HIGH	**1.3 TO 2**
VERY HIGH	**2 TO 2.5**

Fig. 5: HIS Recommendation for minimum NPSH margin

From the above data we can find out that for End Suction Pump, the duty point in consideration gives high S.E. value. Taking a conservative margin of 2 according to HIS recommendation:

The value of minimum $NPSH_A$ should be $7.5 \times 2 = \mathbf{15\ m}$

This minimum $NPSH_A$ is our criteria for proper pump selection.