A Look at Centrifugal Pump Suction Hydraulic – Part 1

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Introduction

Pump suction side hydraulic calculation is always one of the most important checking done for all pumps. This calculation may determine pump suction line size, suction piping layout, suction vessel elevation and pump type. Addition to allowable suction velocity and pressure drop which have to be in the range defined by project design criteria, Net Positive Suction Head (NPSH) is another parameter that check the adequacy of selected pump in specified service. There are two types of NPSH. First is NPSH Available which is a function of the hydraulic parameters of system in which the pump operates. $NPSH_A$ is the excess pressure of the liquid over its vapor pressure as it arrives at the pump suction nozzle in height of liquid absolute. The second is NPSH Required which is the positive head required at the pump suction to overcome pressure drops in the pump and maintain the majority of the liquid above its vapor pressure. $NPSH_R$ is the specification of pump and it depends on pump mechanical design, so it can be only given by pump vendor. The $NPSH_R$ is determined by pumping cold water through the pump with constant impeller size and RPM while reducing the suction head until the pump showed a reduction in discharge head of three percent (3%), due to the low suction head and any formation of bubbles within the pump. This point is called "the point of incipient cavitation".

In designing a pumping system, it is essential to provide adequate $NPSH_A$ for proper pump operation. Insufficient $NPSH_A$ may seriously restrict pump selection, or even force an expensive system redesign. On the other hand, providing excessive $NPSH_A$ may needlessly increase system cost.

Cavitation is one of the main causes of pump damage which can happen as a result of vaporization, gas/air entrainment, internal recirculation, and turbulence or combination of them. This note focuses on pump cavitation due to vaporization.

Vaporization

Vaporization of the liquid within the pump may occur because of small or no margin between $NPSH_A$ and $NPSH_R$. This may be because of poor design, mal-operation or bad maintenance. Cavitation due to operational and maintenance problems is out of scope of this paper, therefore providing sufficient NPSH margin as a major preventive method against vaporization cavitation in design stage will be discussed below.

NPSH margin

It is essential to provide adequate NPSH margin for proper pump operation. Insufficient NPSH margin may seriously restrict pump selection, or even force an expensive system redesign. On the other hand, providing excessive margin may needlessly increase system cost. According to the normal practice $NPSH_A$ should be minimum 3 ft higher than $NPSH_R$ of the pump to suppress incipient cavitation. The exact amount of margin is a function of Suction Energy, SE, and the critical nature of the application. The amount of energy in a pumped fluid, that flashes into vapor and then collapses back to a liquid in the higher pressure area of the impeller inlet, determines the extent of the noise and/or damage from cavitation. Suction Energy is defined as:

$$SE = D_e \times N \times SSS \times SG \quad (1)$$

ABBREVIATION	
BEP	a point on maximum impeller size curve with has the highest efficiency
ΔH	Pump differential head, ft
N	Pump speed, RPM
Q	Pump flow at BEP, gpm
$NPSH_R$	Pump NPSH required at BEP, ft
SE	Suction energy
SSS	Suction specific speed
D_e	Impeller suction eye diameter, inches
SG	Specific gravity of liquid

For estimating purposes you can normally assume that the impeller eye diameter is approximately 90% of the suction nozzle size for a single suction pump, and 75% of the suction nozzle size for a double suction split case pump. The required margin can be estimated based on Table 1. The higher suction energy means cavitation damage will be severe, so higher $NPSH_A$ to $NPSH_R$ is required.

As a common design practice, margin of 0.6m to 1.0m is maintained between $NPSH_A$ and $NPSH_R$ at pump operating point. If pump is equipped with auto-start facility or works in parallel with another one, almost half of above margin (0.3m to 0.5m) is specified at end of the pump curve. This is basically because when working pump or one the parallel pumps trips, second pump starts against no/low discharge pressure and move on its curve towards end of the curve. Higher margin ($NPSH_A$ = 1.5 x $NPSH_R$, with a minimum margin of 5m) is applied if pump suction fluid contain some dissolved gas.

Single Suction Pump	Double Suction Split Case Pumps	$NPSH_A$ / $NPSH_R$
SE <1.6 x 10^8	SE <1.2 x 10^8	1.1 - 1.3
1.6x10^8 ≤ SE < 2.4x10^8	1.2x10^8 ≤SE<1.8x10^8	1.2 - 1.7
SE ≥ 2.4 x 10^8	SE ≥ 1.8 x 10^8	1.7 - 2.5

Table 1 – NPSH margin criteria

$NPSH_R$ Estimation

$NPSH_R$ can be taken from pump characteristic curve which is usually given by vendor in ending stage of project so having $NPSH_R$ value in early stage will enable process engineer to finalize pump selection and suction piping configuration. When pumping liquid has high vapor pressure or it is in bubble point condition, having a good estimation of $NPSH_R$ is really essential to complete the pump hydraulic calculation and to determine the height of suction vessel from grade. Figure 1 can be used with very good degree of estimation for $NPSH_R$.

As a general guideline, the following pump speeds are preferred in the case of electrical motor derive:

- If 5 ≤ pump capacity < 50 m3/hr then RPM = 2900
- If 50 ≤ pump capacity < 300 m3/hr then RPM=1450
- If 300 ≤ pump capacity < 750 m3/hr then RPM = 975

If initial hydraulic calculation shows low NPSH margin you can either increase $NPSH_A$ or decrease $NPSH_R$.

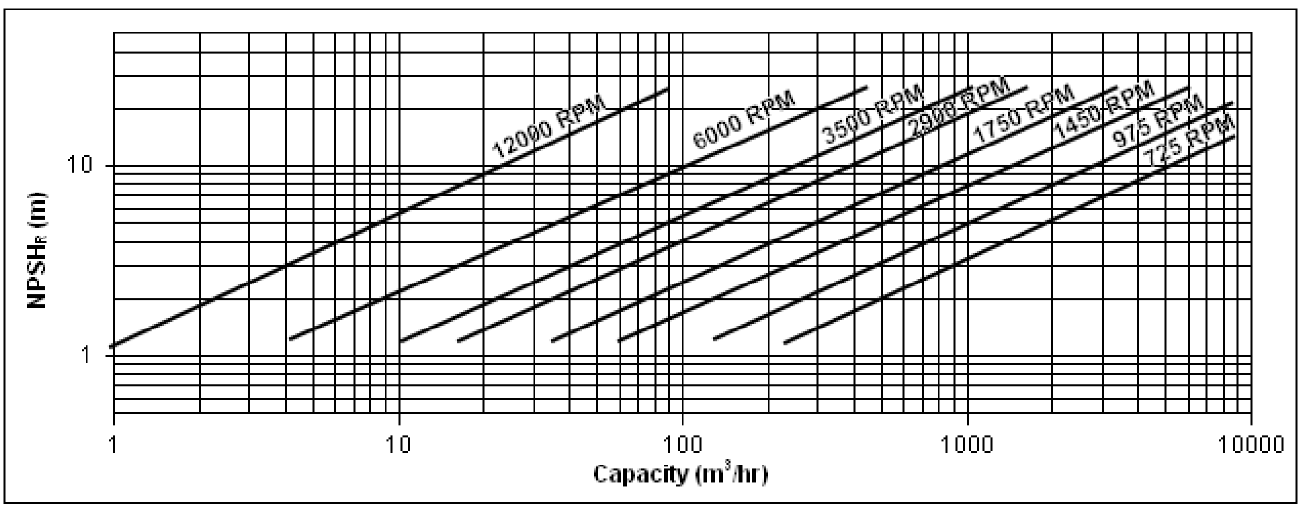

Figure 1 – NPSH required estimation graph

$NPSH_A$ Increase

The following solution may be considered to increase the available NPSH:

- Raise the liquid level in the suction vessel
- Increase the suction vessel elevation from ground

- Pressurize the suction vessel
- Place the pump in a pit
- Use vertical can pump. This kind of pump can be used with shaft having a length from drive end to impeller of approximately 1m minimum to 20m or more.
- Reduce the number of fitting in pump suction side.
- Increase the size of suction line
- Place the pump closer to suction vessel to minimize the suction pipe length. There should be at least 10 diameters of pipe between the suction of the pump and the first elbow.
- Elimination of suction strainer can be considered as an option as approved by client
- Lower the pumping fluid temperature
- Install a booster pump
- Reduce the liquid temperature by injecting small amount of cooler fluid at the suction if practical.
- Insulate the piping if temperature rise is substantial.
- Change the location of pump circulation line from suction line to suction vessel if it heats up the suction fluid.

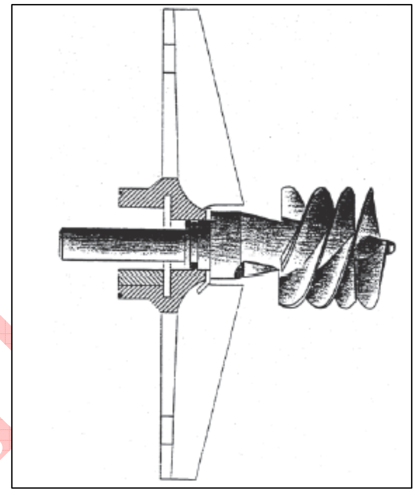

Figure 2 – Inducer

$NPSH_R$ Decrease

Review the following remedies when increasing $NPSH_A$ is not feasible anymore.

- Use a double suction split case pump. This mitigation can reduce the $NPSH_R$ by 25%.
- Use several smaller pumps. Lower capacity pumps can operate with higher speed and consequently and lower $NPSH_R$. Required NPSH for pump working at 200m3/hr and 1450 RPM from figure 1 is 2.6m. This pump can be replaced by two 100 m3/hr pumps at the same speed with 1.7m of $NPSH_R$. Three 50% capacity pumps can be cheaper than two 100% large pump.
- Use a pump with lower RPM.
- Use a pump with larger impeller eye opening.
- Install an Inducer. An Inducer is an axial flow impeller with blades that wrap in a helix around a central hub. An Inducer serves as a small booster pump for the main impeller. Usually inducers have between 2 and 4 vanes, although there may be more. The inducer imparts sufficient head to the liquid so that the NPSH requirement of the adjacent main impeller is satisfied. It can cut $NPSH_R$ by almost 50% because it can be used successfully with suction specific speed numbers of approximately 24000.
- Because of type of method utilized by pump vendor, the $NPSH_R$ given by vendor for pump operation without cavitation and vibration is practically higher than the actual value. Hydraulic Institute introduces a graph for correcting $NPSH_R$. The following rules apply while using this Figure 3.

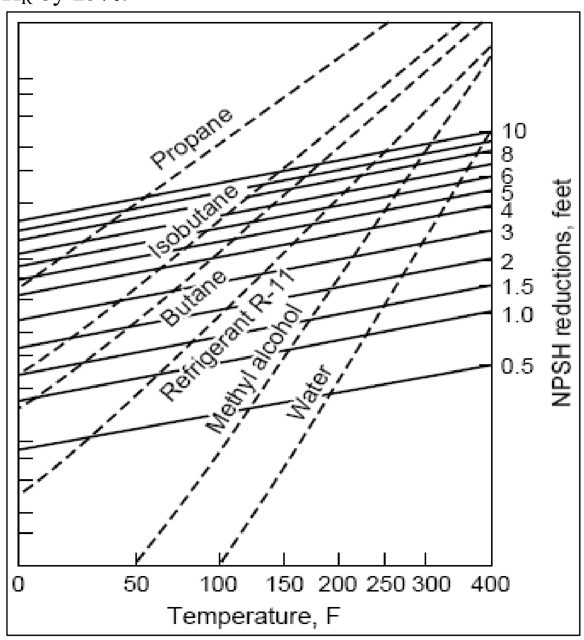

Figure 3 – NPSHR reduction graph

➢ If graph value > vendor NPSHR/2 then corrected NPSHR = vendor NPSHR/2

- If graph value < vendor NPSHR/2 then corrected NPSHR = vendor NPSHR - graph value

Utilizing Figure 3 for other liquids or extrapolation of data beyond the ranges indicated in the graph may not produce accurate results. Generally it is not advised to reduce $NPSH_R$ and better to consider it as a safety margin, rather than design for it.

Some Notes

- $NPSH_R$ number shown on the pump curves is for fresh water at 20°C and not for the fluid or combinations of fluids being pumped.
- If suction pressure varies with weather conditions, using typical atmospheric pressure of 1.013bara can lead to a cavitation problem.
- Low flow usually means a lower NPSH required, but low flow can also mean a temperature build up inside the pump.
- For the vessel located downstream of condenser, containing boiling liquid or liquid-vapor in equilibrium such as column overhead drum, reboiled column, flare KOD the operating and vapor pressure are same. Hence the NPSH is supposed to be provided by elevating the suction equipment.
- If suction vessel is gas blanketed, some of conservative practices recommend considering the liquid at its bubble point. This is to prevent releasing dissolved gas in pump suction eye as pressure decreases.
- The following table may be used for estimating horizontal centrifugal or rotary pump centerline elevation which is needed for $NPSH_A$ calculation. For vertical pump impeller depth below grade should be used.

Pump Rated Capacity (m^3/h)	Elevation (m)
Up to 45	0.76
45 to 227	0.91
227 to 2270	1.07
2270 to 4540	1.37

Contact

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