MAKE NPSH ADD UP TO REDUCE CAVITATION

To help readers understand what NPSH is and how to calculate it, **flow** spoke to *Shaun Hampson*, Managing Director, Flowserve's Manchester Quick Response Centre.

Cavitation can cause significant damage to centrifugal pumps and their components, resulting in costly repairs and unplanned downtime. However, understanding NPSH and using its calculation as part of the pump specification process can significantly reduce the effects of cavitation.

flow: What is the meaning of NPSH and how important is it to a centrifugal pump application?

Shaun Hampson: A commonly used acronym within the pump industry, NPSH stands for Net Positive Suction Head. It is a consideration in centrifugal pump selection because it represents the adequacy of liquid feed relative to the need of a pump.

Starving the suction of a pump with poorly available NPSH can rapidly cause cavitation damage. NPSH is relatively simple to calculate, but some factors, such as where liquids approach their boiling point (vapour pressure), or applications where there are long torturous suction pipe-lines, can make it more challenging to accurately assess.

There are several areas which need to be considered when calculating NPSH. The first is cavitation, a very aggressive form of damage. The second is pressure head which is measured in metres, as opposed to conventional pressure measurements in bar, psi, Pascals, etc. The properties of the liquid being pumped also affect the NPSH calculation – where a special focus is needed when pumping LPG and liquids near to their boiling point, for example.

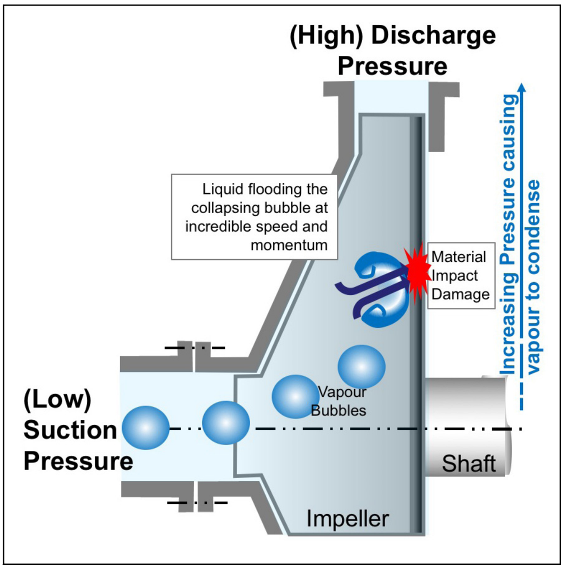
CAVITATION

In broad terms, cavitation starts with the partial evaporation of the liquid because it is being sucked hard, in a non-linear, and turbulent environment. As its vapour pressure is compromised, it starts to evaporate into entrained pockets of vapour.

These tiny pockets of vapour enter the pump impeller in their thousands, but are condensed as the surrounding fluid is internally pressurised toward the discharge.

Bubbles collapsing in the vicinity of the impeller ignite damage, as surrounding liquid rapidly fills each of these little voids. The impeller material acts as the backstop to liquid entering these cavities at supersonic speeds and the result is impact erosion known as cavitation damage, which can quickly destroy even hard material pumps. Consequently, it is vital to protect against cavitation by ensuring that there is adequate NPSH available from within the pumping system.

A specifier needs to distinguish between the NPSH required for the pump and the NPSH available from the application. NPSH required by the pump is commonly known as NPSH(r) and this information is provided by the pump manufacturer. NPSH available is termed NPSH(a) and needs to be calculated from the system characteristics.



Cavitation in action

To minimise cavitation there should be more NPSH(a) than NPSH(r) plus a reasonable safety margin in which to account for entrained liquid impurities which may distort its vapour pressure.

PRESSURE HEAD

Pressure head is used in the calculation of NPSH because conventional pressure is influenced by liquid density. As centrifugal pumps handle liquids of all types and with varying densities traditionally measured pressures vary.

So, rather than a manufacturer creating thousands of pump selection curves for an infinite variety of density options, it is standard practise to employ 'head', a column of liquid expressed in metres and which doesn't change. Head is the height of liquid which will be generated above the pump centre when an impeller of a given diameter is spinning at a given speed. While this remains constant, a conventional pressure measurement taken at the pump discharge will vary with different liquid densities.

f: How is NPSH calculated in a typical application?

SH: The key to understanding NPSH lies in the first term, 'Net'. This represents the total positive suction head once all plusses and minuses have been netted off.

There are four suction pressure variables needed to calculate NPSH(a). Two are always negative, they simply need to be added together and are easy to remember:

1. Static height of liquid. This is either above or below the pump (with suction lift pumps for example) and can be either a positive or negative figure.
2. Vapour pressure of the liquid. This must be removed and is therefore always negative.
3. Pipework and valve losses. This is measured upstream of the pump, back to the liquid source, and is always negative.
4. Atmospheric pressure head. This is the pressure acting on the liquid surface. While this pressure is in its absolute form, it is always positive, regardless of any possible suction vessel vacuum applications.

When calculating NPSH all units need to be consistent. This means converting the atmospheric pressure head (p) and vapour pressure (Vp) from millibars to metres. This is done using the following formula:

$$p=\rho gh \text{ or } h=p/\rho g$$

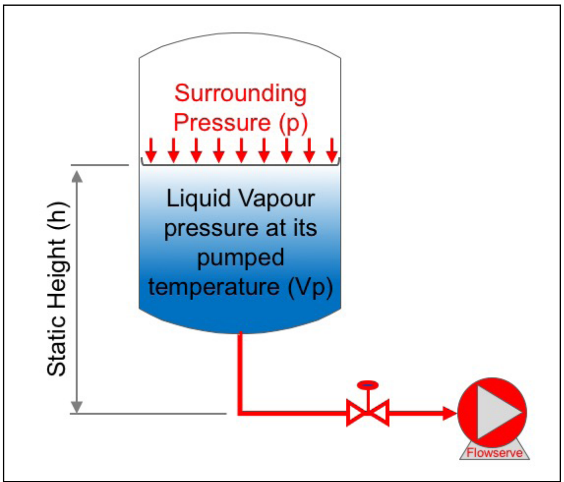
Where:
p= pressure (pa)
ρ= density (kg/m³)
g= gravity (9.81m/s²)
h= liquid column height above its dadtum (m)

NPSH CALCULATION

In an example where the system is pumping water at 50°C with flooded suction and a positive height of 5m, the calculation is as follows:

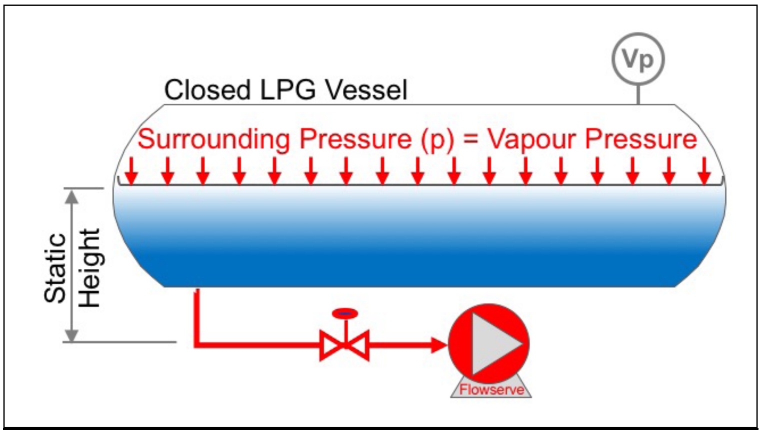
a. Static height: This is 5m
b. Vapour pressure (Vp): At 50°C, the vapour pressure of water is 0.12335 bar. This converts to 1.27m using the above formula.
c. Pipework losses: This is an involved topic in itself, but for this example 0.5m is assumed.
d. Surrounding pressure (p): In an open vessel this would be atmospheric pressure, but it could be much lower, especially in chemical applications, while a vessel is under vacuum. Assuming 1.014 bar, read from a barometer, the converted figure is 10.46m.

Using these values, **NPSH(a) = a-b-c+d = 5m −1.27m – 0.5m + 10.46m = 13.69m.**



It would be good practice to allow a safety margin and 0.5m would suit such an application. So, we are now looking for a pump with NPSH(r) of less than 13.19m at the duty point on the pump curve. Most conventional end-suction liquid centrifugal pumps are in the region of 1 to 5m and would be suitable for this application.

f: How do liquids close to their boiling point, or those under pressure such as LPG, affect the calculation?
SH: Pumping LPG follows the same characteristics as any liquid being transferred at its own boiling point. Like boiling water at 100°C, its vapour pressure will equal the surrounding pressure and these two components ultimately cancel each other out.
This leaves a calculation for NPSH with only two components, (a) static height, and (c) pipework losses.



LPG or any liquid at its boiling point

In an example with a minimum static height of 1.5m and pipework losses of 0.5m, NPSH(a) calculates as 1.0m

If a safety margin of 0.5m is also applied in this example, a pump with an extremely low level of 0.5m NPSH(r) at the duty point is required. Alternatively, by excavating the pump or raising the vessel, the static height can be adjusted to change the NPSH value. Or indeed the users can accept the results of the cavitation and the additional maintenance it will require. However, these alternatives are often expensive and impractical and low NPSH pumps do exist.

Low NPSH pumps are, arguably, better when constructed in a horizontal configuration. Unlike vertical pumps, any internal or entrained vaporisation can flow upwards naturally and escape through the discharge of a horizontal machine. Because the mechanical seal sits in the uppermost cavity of a conventional vertical pump it can become surrounded by vapour and its life can be compromised through insufficient lubrication.

It is also worth mentioning that the NPSH required for a conventional centrifugal pump can also be reduced by adding an inducer to the impeller. This volumetric feed screw type device induces flow into the eye of the impeller. Arguably, inducers are designed to operate in a very precise duty (flow vs differential head) envelope and become unstable when the user varies the process due to temperature, demand, speed, or simple valve opening and closing.

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