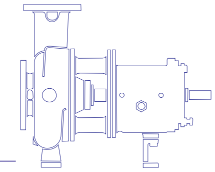

# Tech Talk

## Cavitation in Centrifugal Pumps

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Thinking you have sufficient system suction pressure to a pump, just because you exceed the net positive suction head required by the pump curve, is no guarantee of acceptable pump performance. You may need a margin to suppress the cavitation that exists in a pump substantially above the published NPSHR value. Cavitation does exist above the NPSHR. Then again, the pump might run fine with almost no margin above the NPSHR of the pump. This article clarifies this situation, and is based on the new Hydraulic Institute Standard on NPSH Margin (ANSI/HI 9.6.1-1998). It provides a method for identifying the likelihood of a pump experiencing cavitation problems, by providing a simple method of calculating the "Suction Energy" of the pump, and recommending NPSH Margins for levels of suction energy.

The noise, the vibration and possibly the reliability of a centrifugal pump and mechanical seal may be significantly affected if an appropriate Net Positive Suction Head (NPSH) margin is not provided above the published Net Positive Suction Head Required (NPSHR) of the pump. The NPSHR Margin is defined as the NPSH Available at the pump inlet, minus the NPSH required by the pump. The NPSH Margin Ratio is the NPSHA divided by the NPSHR.

By Hydraulic Institute definition, the NPSHR of a pump is the NPSHA that will cause the total head to be reduced by 3%, due to flow blockage from cavitation vapor in the impeller inlet. NPSHR is by no means the point at which cavitation starts; that level is referred to as incipient cavitation. The NPSHA at incipient cavitation can be from 2 to 20 times the 3% NPSHR value, depending on pump design and suction energy level. It can take from 1.05 to 2.5 times the NPSHR value just to achieve the 100 percent head point (NPSH "Required"-0%).

### Suction Energy

Due to the very high NPSH Margins required to completely suppress cavitation, we know that cavitation must exist in a high percentage of pump applications. However, we also know that acceptable life is achieved in most installations, despite this cavitation. So how can we predict when cavitation is likely to cause problems? The amount of energy in a pumped fluid which flashes into vapor and then collapses back to a liquid, in the high pressure areas of the impeller, determines the extent of the noise and/or damage from cavitation. Suction Energy is another term for the liquid momentum in the suction eye of a pump, which means that it is a function of the mass and velocity of the liquid in the inlet.

The following formulas, which are based on the "Suction Energy" graph presented in the Hydraulic Institute standard, can be used to approximate the Suction Energy in a pump:

**Suction Energy (SE) = (De x n x S x s.g.)**
- De = Impeller Eye Diameter (inches)
- n = Pump Speed (RPM)
- S = Suction Specific Speed RPM x (GPM).5/(NPSHR).75
- s.g. = Specific Gravity of Liquid

**De = Suction Nozzle Diameter x 0.9** (is a good approximation for End Suction Pumps)
**De = Suction Nozzle Diameter x 0.75** (is a good approximation for Side/Double Suction Pumps)

### Suction Energy Levels

The Hydraulic Institute has divided Suction Energy into three Regions:

- LOW SUCTION ENERGY – NPSH Margin is not critical, except for the effect on the head generated by the pump at very low margins.
- HIGH SUCTION ENERGY – Pumps with low NPSH Margins, especially when operated in the suction recirculation flow range, may experience noise, vibration and/or minor cavitation erosion damage with impeller materials that have low cavitation resistance.
- VERY HIGH SUCTION ENERGY – Pumps with low NPSH Margins, especially when operated in the suction recirculation flow range, may experience erosion damage, even with cavitation resistant materials such as stainless steel.

The following suction energy milestones, from the Hydraulic Institute graph, and field experience gained by ITT Industries, approximate the values of High and Very High Suction Energy.

**Start of High Suction Energy (De x n x S x s.g.)**
- End Suction Pumps: (SE) = 160 x $10^6$
- Horizontal Split Case Pumps/Radial Inlet: (SE) = 120 x $10^6$

**Start of Very High Suction Energy (De x n x S x s.g.)**
- End Suction Pumps: (SE) = 240 x $10^6$
- Horizontal Split Case Pumps/Radial Inlet: (SE) = 180 x $10^6$

### NPSH Margin Recommendations:

Table 1 summarizes the Hydraulic Institute minimum NPSH margin Ratio guidelines (NPSHA/NPSHR), which are applicable within the Allowable Operating Region of the pump.

**Table 1**
NPSH Margin Ratio Guidelines (NPSHA/NPSHR)

| Suction Energy Level | NPSH Margin Ratio |
|---|---|
| Low | 1.1 to 1.3 |
| High | 1.3 to 2.0 |
| Very High | 2.0 to 2.5 |

High and Very High Suction Energy pumps that operate with the minimum NPSH Margin values recommended in Table 1 will normally have what is considered "acceptable" seal and bearing life, (but not necessarily optimal). They may still be susceptible to elevated noise levels and erosive damage to the impeller. This can require more frequent impeller replacement than would otherwise be experienced, had the cavitation been totally eliminated.

It will typically take a NPSHA of 4 to 5 times the 3% NPSHR of the pump to totally eliminate cavitation. This ratio can reach 20 for Very High Suction Energy pumps, and a low of 2 for some pumps with Low Suction Energy levels.

Additional NPSH Margin may be needed to cover uncertainties in the NPSHA (available) to the pump or operating flow point. If a pump runs further out on the curve than expected (which is very common), the NPSHA of the system will be lower than expected,

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and the NPSHR for the pump will be higher, thus giving a smaller (or possibly negative) actual NPSH Margin. All pumping systems must be designed to have a positive margin throughout the full range of operation.

Optimum pump performance also requires that proper suction/inlet piping practices are followed to ensure a steady uniform flow to the pump suction at the requred suction head. Poor suction piping can result in separation, swirl and turbulence at the pump inlet, which decreases the NPSHA to the pump and causes added cavitation.

NPSHA Margins of two to five feet are normally required (above those shown in Table 1) to account for these uncertainties in the actual NPSHR and NPSHA values. This added margin requirement could be even greater depending upon the severity of the conditions, especially if the pump is operating in suction recirculation. If the application is critical, a factory NPSH test should be requested.

### Summary

In summary, the following key points should be understood about cavitation in a centrifugal pump, NPSH Margin requirements, and how they are affected by the Suction Energy level of the pump:

- Cavitation exists at and substantially above the NPSHR of a pump.
- The Suction Energy level of a pump (as installed in a system) determines if the cavitation that frequently exists in a pump will cause noise, vibration and/or damage to the pump.
- High Suction Energy pumps are likely to be noisy with higher vibration and will possibly experience less than optimum pump life, if sufficient NPSH Margin is not provided.
- High Suction Energy pumps are more susceptible to problems from poor suction inlet piping, especially if they also operate in suction recirculation.
- Very High Suction Energy pumps will be noisy, will have high vibration and are likely to experience reduced pump life if sufficient NPSH Margin is not provided. Very High Suction Energy pumps are very susceptible to problems from poor suction inlet piping.

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*(continued from page 1)*

- Flowmeter-similar piping and wiring (power and communication lines) costs are avoided.
- Starter-The installation cost of the starter can be replaced by the cost to install PumpSmart.
- Recirculation line-costs associated with piping the line and installing valving is avoided.

### Operating Costs

Since PumpSmart utilizes a unique variable frequency controller with our Pump Control Software, it will automatically match pump operation to the system head requirements. Energy consuming control valves are no longer required. Our most recent installation of PumpSmart is on a 100 horsepower cooling tower pump (Model 3196 XLT). The system was designed with two duplicate pumps and control valves. The pump running with the valve in operation is consuming 98 horsepower, while the PumpSmart System is consuming only 63 horsepower and is running over 300 RPM slower. At $0.60$/kW-hr, this represents over 12,000 in energy savings per year. And because PumpSmart continuously calculates savings (see Figure 1), the running total, in dollars, will constantly be in view in the DCS control room or on the PumpSmart keypad.

### Maintenance Costs

Designing a pump that is heavier, with bigger bearings and a larger shaft does not automatically mean longer life. The primary components in pump failures are mechanical seals and anti-friction bearings. These are brought on not by general fatigue, but by excessive vibration, excessive loads and poor lubrication. These failures are caused primarily by the following upset conditions:

- Dry running-caused primarily by closed suction valves.
- Continuous operation below minimum flow.
- Cavitation due to insufficient NPSH available.
- Heat build-up and subsequent liquid vaporization due to a closed discharge valve.

PumpSmart detects all of these prior to the upset condition occurring and prevents the pump from operating during these transient conditions. The pump will react by stopping, slowing down, alarming or any combination of these actions, depending upon how you want PumpSmart to be programmed.
By utilizing the pump Reliability Factors seen earlier in this edition of Pumplines, we can quantitatively measure the anticipated increase in mean time between failure (MTBF) of PumpSmart as compared to a traditional pumping system. By running a pump at a slower speed, at or close to best efficiency and at a reduced impeller diameter, we will be able to calculate, with your help and input, the expected increase in MTBF for any given ANSI pump currently running in a process application.

PumpSmart is the next level of technology for our industry. This introduction to PumpSmart provides just a glimpse of the product's potential. Initially, this PumpSmart technology will be available on our ANSI models 3196 and 3298. Look for more information in the coming months.

*Figure 1*