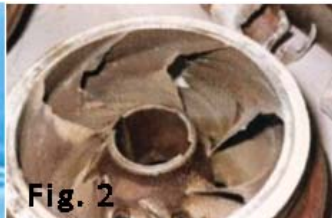
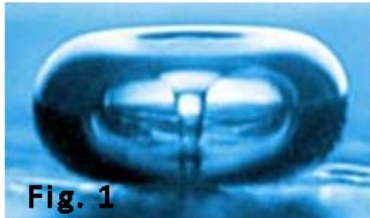


In the third installment of our series entitled “The Deadly Sins of Centrifugal Pump Ownership” we discuss pump cavitation. Pump cavitation is a much talked about and often misunderstood subject. What follows is a description of cavitation and the application of appropriate Net Positive Suction Head (NPSH) margins to centrifugal pumps.

Dale B. Andrews



Vapor bubbles form in a pump inlet whenever the local absolute pressure of the liquid falls below its vapor pressure. These bubbles collapse rapidly and violently when the local absolute pressure increases due to kinetic forces imparted by the impeller. Cavitation is the rapid

formation and collapse of these vapor bubbles. Collapsing cavitation bubbles cause noise, vibration, and erosion of material from the impeller. Pump service life is shortened significantly when cavitation occurs. The severity of the effects of cavitation varies as a function of a machine's suction energy which is discussed further herein. Fig. 1 shows a photograph of a cavitation bubble implosion. Fig 2 shows an impeller that has been severely damaged by cavitation. Fig 3 is a diagrammatic view of the cavitation bubble implosion sequence.



Fig 3: Cavitation bubble implosion onto a solid surface, arrows indicate fluid pressure.

For any given flow rate, every pump has an absolute suction head at which cavitation will occur. This suction head is referred to as the Net Positive Suction Head Required (NPSHR). Head is always expressed in feet or meters to make it independent of any specific fluid. The absolute suction head available at the pump inlet is termed the Net Positive Suction Head Available (NPSHA). To avoid cavitation, the NPSHA must be greater than NPSHR by an adequate margin.

NPSHA is determined by subtracting the absolute vapor pressure of the fluid pumped from the total suction head available. Total suction head is the static head (suction gage pressure) corrected to the impeller centerline (or impeller inlet if vertical), plus the velocity head (found in most pipe friction tables), plus atmospheric pressure. All values should be expressed in feet or meters of liquid.

NPSHR is determined by hydraulic testing and is available from the pump manufacturer. Pump manufacturers perform a series of 'breakdown' tests to determine the NPSHR (Fig 4.) The pump is operated at a constant flow rate while the NPSHA is steadily decreased. A sudden drop in the total output head is evidence of cavitation. Industry standards establish that a 3% drop in total head is point where the NPSHR reading is to be taken.

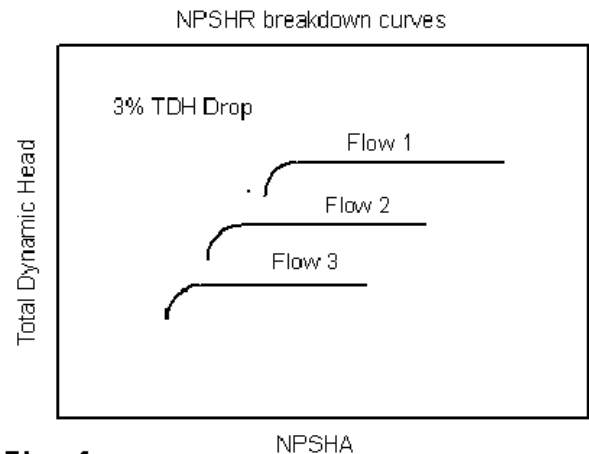


Fig. 4

It is important to note that ***an actual test curve showing NPSHR test results reflects a pump that is cavitating.*** To operate cavitation free, pumps need a margin of additional NPSH above the test values.

The amount of margin depends on the suction energy of the pump. Suction energy reflects energy available for cavitation damage, and it is a function of the suction specific speed (S) of the pump.

$$S = \frac{rpm \times \sqrt{Q}}{NPSHR^{3/4}}$$

Table 1 reflects the margin that should be maintained between the NPSHA and the NPSHR as recommended by the Hydraulic Institute.

TABLE 1
NPSH MARGIN RATIO GUIDELINES (NPSHA/NPSHR)

SUCTION ENERGY LEVEL	
Suction Energy Level	Margin
Low	1.1-1.3
High	1.3-2.0
Very High	2.0-2.5

Margin is the ratio of NPSHA to NPSHR

Suction energy is a function of the momentum of the fluid approaching the impeller eye.

It is denoted by the equation: Suction Energy = $D_{eye} \times N \times S \times Sp.Gr.$

Where:

- D_{eye} = Impeller eye diameter (in)
- N = Pump rotative speed (rpm)
- S = Suction specific speed (see above)
- Sp.Gr. = Specific gravity of the pumped fluid.

Chart 1 shows suction energy levels for various inlet sizes at 1800 rpm

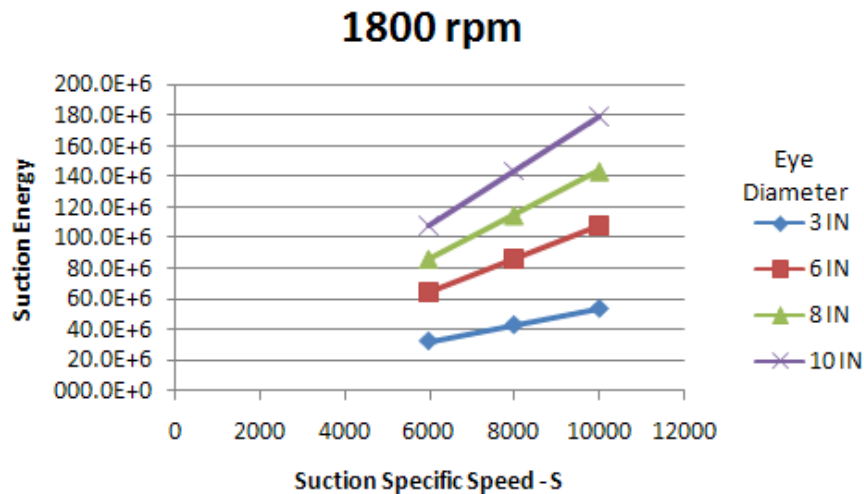


Chart 1

Threshold Values for End Suction Pumps

High suction energy 160 E6

Very high suction energy 240 E6

- Any value less than the high suction energy threshold is low suction energy
- Threshold values for split case/ radial inlet pumps are 0.75 x end suction values
- Threshold values for vertical turbine pumps are 1.3x end suction values
- For other pump rotative speed suction energy varies directly with the rpm ratio.
- The above does not apply to inducers, which require their own special considerations*.

It is generally good practice to add an additional 2-5 feet of NPSHA over the margin values to account for disparities between test data and actual site conditions.

It should also be noted that cavitation is not the same as gas entrainment. Often times, especially with vertical pumps, a pump that is pulling air into the suction will be described as cavitating. Although the symptoms are similar the cure is not the same. Gas entrainment warrants a separate discussion than cannot be accommodated here. For some information on the subject of gas entrainment see our [December 2007 newsletter](#) on the subject.

Finally, it should be noted that many cavitation problems are created by modification and not by design. Changes in process conditions such as increased flow or temperature, and physical changes to the suction side of the pump such as installation of upstream equipment, modification of pipe routes, or failure to maintain upstream equipment such as heat exchangers, may create cavitation problems. In order to keep capital costs low many system designs provide for adequate NPSH margins but not much of a cushion beyond that. Therefore, any proposed changes to a system, or its operation, should be scrutinized carefully to be sure that adequate suction conditions are maintained.

Fig 1.Courtesy of Solid State Fusion technologies

Fig 2 & 3. Lohrberg, H., Stoffel B., Intelligent Maintenance Management of Pumps; Pump Users International Forum, 2000

References on NPSH Margin – Hydraulic Institute – HI 9.6.1 and Pump Users Handbook, Bloch/Budris, Fairmont Press (2004).

*See - http://www.lawrencepumps.com/newsletter/news_v01_i2_july.html for a brief article on inducers