How to compute Net Positive Suction Head for centrifugal pumps

The importance of suction conditions is frequently overlooked and gives rise to operating problems with these pumps.

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One of the most important considerations in selecting and applying a centrifugal pump is the conditions existing on the pump's suction system. These conditions are best expressed as *Net Positive Suction Head* (NPSH). This term is officially defined in accordance with the standards of the Hydraulic Institute as "The total suction head in feet of liquid absolute, determined at the suction nozzle and corrected to datum, less the vapor pressure of the liquid in feet absolute." In somewhat simpler terms, NPSH is the absolute pressure in feet of liquid at pumping temperature available at the pump suction flange above vapor pressure.

Since centrifugal pumps are incapable of handling large quantities of vapor, the pump's external suction system must provide sufficient absolute pressure to prevent vaporization or flashing in the impeller. This pressure is normally referred to the centerline of the pump suction nozzle.

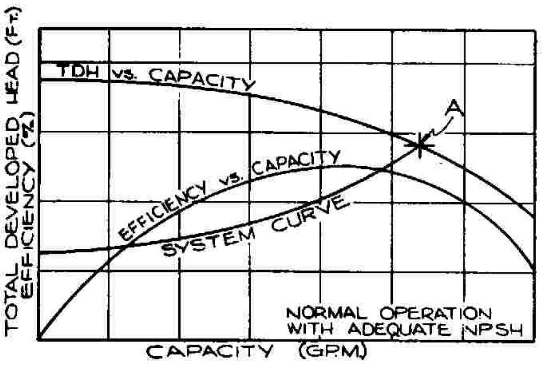

FIGURE 1. Performance curves for normal operation with adequate NPSH

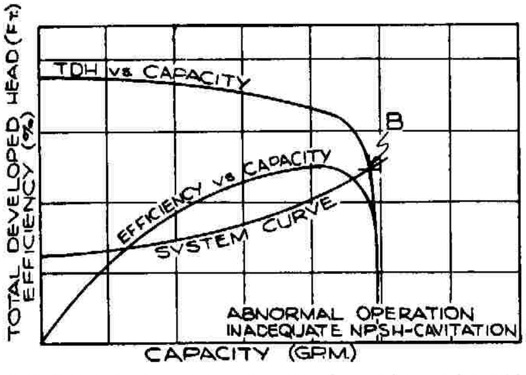

FIGURE 2. Performance curves for abnormal operation with inadequate NPSH.

When this pressure is not sufficient to prevent vaporization, the phenomenon known as "cavitation" occurs causing damage to the impeller, reduction in pump developed head and capacity, noise and vibration. Thus, a constant speed pump operating in a given pipe system at point A in Figure 1 with adequate NPSH would shift its operating condition to point B in Figure 2 with inadequate NPSH with a subsequent loss of capacity delivered to the system. Further reduction in NPSH would cause a further reduction in capacity and more cavitational damage.

Pump manufacturers determine by test the NPSH required at various capacities for a particular pump and plot it as a function of capacity. This is referred to as NPSIIR (net positive suction head required). Conversely, the NPSH available in the system is referred to as NPSHA (net positive suction head available). For cavitation free operation the NPSHA must equal or exceed the NPSHR at the desired capacity. Figure 3 shows that the pump referred to previously requires **X** feet NPSH in order to operate cavitation free at a capacity corresponding to a point A. Thus the system into which the pump is installed must have **X** or more feet NPSHA.

Determination of NPSH available

The determination of the NPSH available in a system is illustrated graphically by Figure 4. The left hand side shows a simple suction system where liquid is fed from a tank at a higher elevation than the pump, through a pipeline to the pump suction. The chart at the right of Figure 4 shows the absolute pressure on the vertical scale plotted against the horizontal distance between the tank and the pump suction.

The line **ABC** represents the hydraulic gradient in the piping system. The gradient **AB** represents entrance loss, pipe friction and elbow loss in the vertical run of piping. Gradient **BC** represents pipe friction loss through

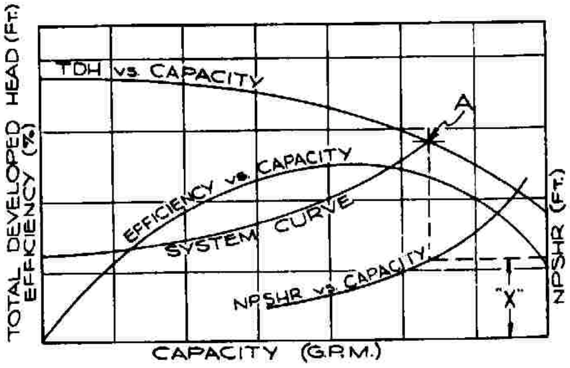

FIGURE 3. Performance curves showing required NPSH for cavitation-free operation.

the horizontal run of piping. Together they represent the loss in the total available suction head from the tank to the pump suction.

The distance **DE** represents the vapor pressure of the liquid, thus the NPSHA is represented by the distance **CD.**

From the chart the basic equation for net positive suction head available is:

$$NPSHA = +/-H_S - h_L - H_A - H_v$$

Where,

H_S = Static suction head (+) or lift (-)

$H_{L=}$ Suction line losses (friction, entrance and fittings) in feet

H_A = Absolute pressure at the liquids free surface in feet of liquid pumped.

H_V = Vapor pressure of liquid at pumping temperature converted to feet of liquid handled.

Note that the above definition of NPSHA does not include velocity head at the pump suction flange. Since this term is by definition included in NPSHR as shown on pump selection curves, it can be ignored in computing NPSHA. Some example problems are shown in Figures 5 through 10.

Note in the last example the total suction lift is the static lift (15 ft.) plus the dynamic lift 2 ft. (pipe friction) or 17 ft. Many pumps intended for cold water service contain suction lift lines instead of an NPSHR on the pump selection curve. For cold water conditions a convenient relationship between suction lift and NPSHA can be established as follows:

NPSHA = $\pm H_s - h_L + H_A - H_v$
For cold water conditions $H_A = 34$ **ft. and** $H_v = 2$ **ft. thus:**
NPSHA = $\pm H_s - h_L + 32$ **ft.**
When H_s **is minus** $(-H_s)$ **the sum** $-H_s - H_L$ **is dynamic suction lift S then:**
NPSHA = $-S + 32$ **ft. where dynamic suction lift S is a positive number**

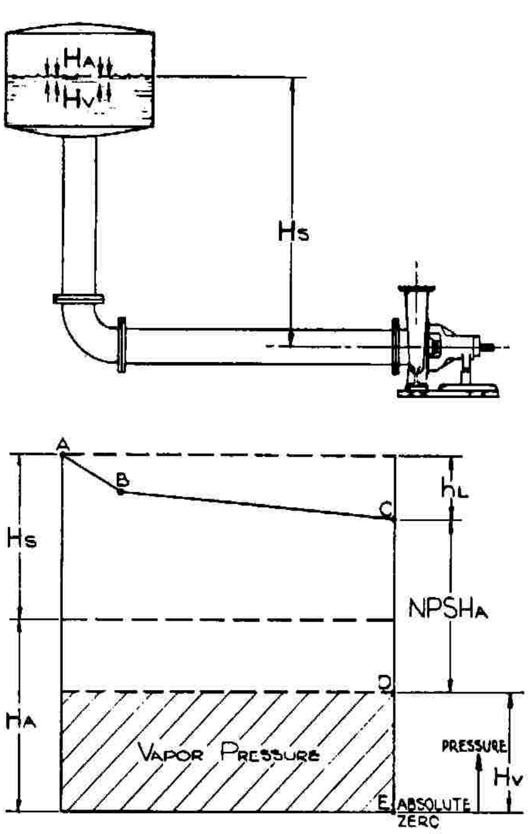

FIGURE 4. System for determination of NPSH.

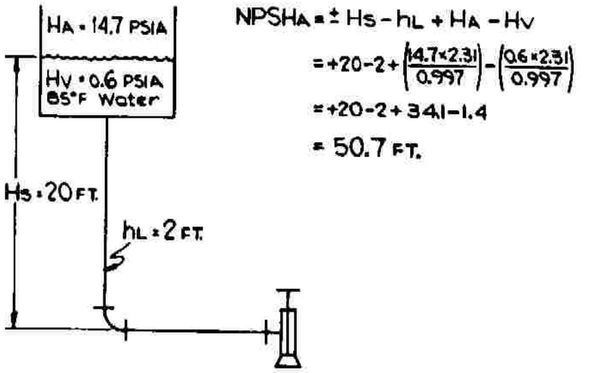

FIGURE 5. Open tank at sea level.

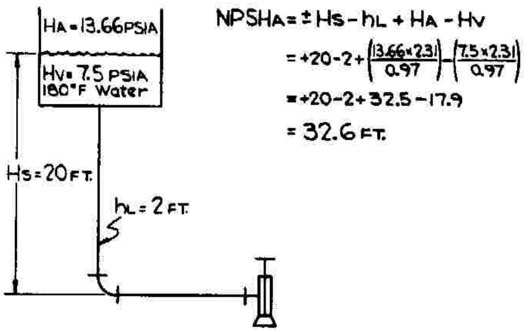

FIGURE 6. Open tank at 2,000 feet above sea level.

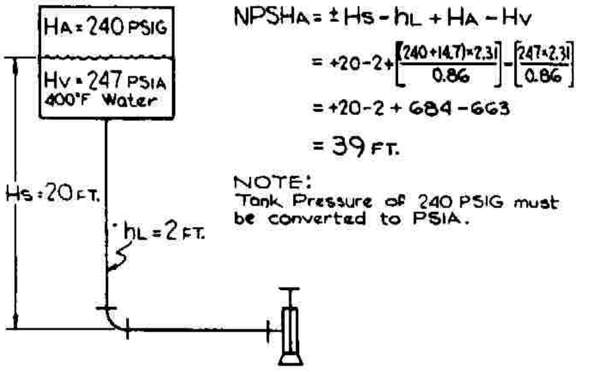

FIGURE 7. Closed pressure vessel.

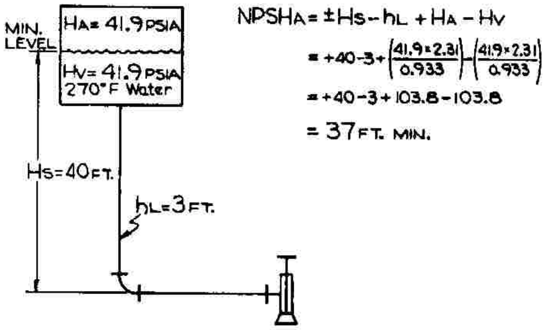

FIGURE 8. Feed water heater.

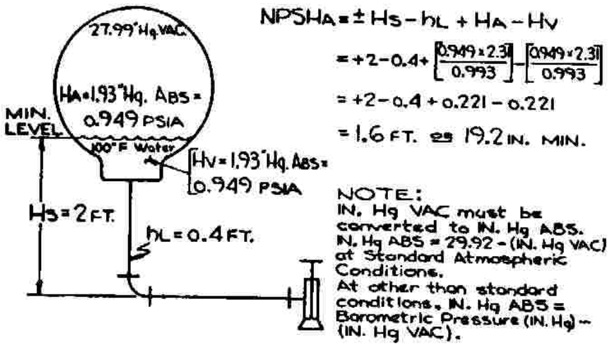

FIGURE 9. Condenser.

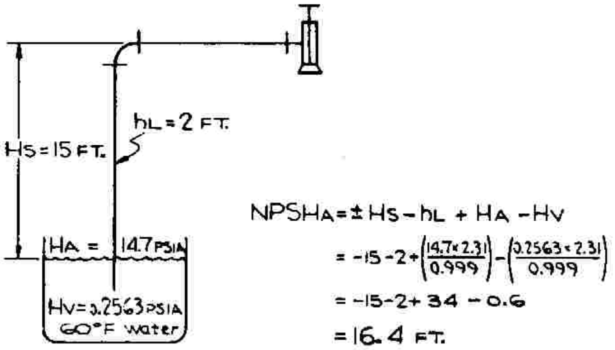

FIGURE 10. Pump under suction lift.

By using the above relationship it is possible to convert required NPSH to suction lift capability and vice versa, so long as standard conditions (cold water at sea level) prevail.

Other considerations

For cold water conditions at elevations other than sea level a correction for lower barometric pressure must be made. The atmospheric pressure reduces approximately 1.2 foot of water per 1000 ft. increase in elevation thus at an elevation of 1000 ft. the above relationship becomes NPSHA = S + 30.8 and at 2000 ft. NPSHA S + 29.6, etc.

As indicated previously, a centrifugal pump will always operate at the intersection of its head-capacity curve with the system curve (Figure 1). If insufficient NPSH is supplied to the pump suction this intersection will occur at a lower head and capacity as the pump curve "breaks-off" and noise and cavitation begins (Figure 2).

The NPSHR curve shown in Figure 3 is usually obtained by testing the pump on cold water by throttling the suction line to produce dynamic suction lifts at the pump suction corresponding to the desired value of NPSH.

By measuring the capacity at which the pump "breaks-off" the curve for NPSHR versus capacity is developed.

For condensate service involving low available NPSH, the test is conducted on a hotwell under vacuum corresponding to the saturation temperature of the liquid. The NPSHR is determined in a manner similar to the example shown in Figure 9

Normally pumps are not recommended for suction lifts of more than 20 ft. due to the difficulty in maintaining prime even though the NPSHR would indicate the pump could handle greater than 20 ft. lift. Condensate pumps, on the other hand, are offered for NPSH as low as 12 inches. In this case the source of suction must always be above the pump suction, so that if the pump should momentarily loose prime and "break-off", it can regain its prime by virtue of gravity flow.

In conclusion, many centrifugal pump operating difficulties arise from misunderstood or unfavorable suction conditions. It must be realized that suction conditions and NPSHA are every bit as important, if not more so, than the pump's capacity and total head. More attention to suction conditions and NPSHA will result in more trouble-free pump operation.