NPSH (Net Positive Suction Head)

NPSH is undoubtedly one of the most misunderstood factors in pump selection. The pump NPSH consideration is actually not a difficult concept once you understand two essential concepts:

1. We tend to think that water boils at 212°F, which is true at atmospheric pressure at sea level. In reality, water boils at different temperatures, depending upon its pressure. The table below, however, shows the relationship. *The pressure at which water boils at a given temperature is called its* ***vapor pressure.*** A graph of vapor pressure vs. temperature appears on page

" Hg Vacuum	PSIG	Approx. Boiling Temp, °F
20"	-9.8	157
15"	-7.3	179
10"	-4.9	192
5"	-2.45	204
0	0	212
	12	244
	30	274

Under certain operating conditions, as the pump attempts to pull water into the eye of the impeller, it can create a negative pressure (vacuum). If the pressure created drops to the water's **vapor pressur**e, the water will begin to boil. Obviously, *this is more likely to happen if the pump is pumping hot water than if it is pumping cool water*.

2. The second principle is that a pump is designed to handle pure liquid, not boiling liquid, which is a mixture of liquid and vapor (steam in the case of water).

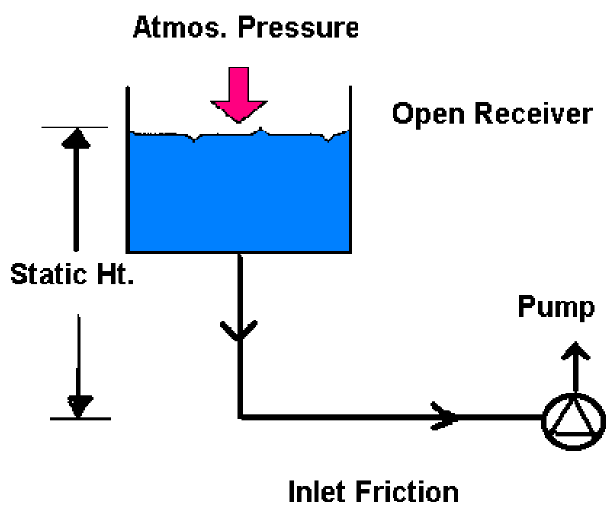
What happens when water begins to vaporize as it is drawn into the pump?

- Vapor bubbles begin to form, just as they do when you boil water on your stove.
- As the fluid moves into the vanes of the impeller, it picks up energy from centripetal acceleration ("centrifugal force"). This causes an increase in the pressure of the boiling liquid. This causes the bubble to implode (collapse violently). The process of bubbles forming then collapsing violently is called cavitation. When a pump experiences cavitation:

- Performance falls off.

- The pump sounds as if it is pumping marbles or gravel (Some people have actually opened up their pumps to find out how the heck the gravel got in!).
- The impeller and perhaps the casing begin to suffer damage. This happens when the bubbles implode so violently that the water chips away at the metal surfaces. In extreme cases, holes are worn in the impeller, eventually resulting in a "swiss cheese" appearance to the impeller surfaces.

Cavitation normally takes place in open systems. The diagram below shows the forces that determine the pressure on the water at the lowest pressure point of the system, the entrance to the impeller.



- **Atmospheric pressure**: The pressure from the atmosphere is a positive force of 14.7 PSIA. The factor to convert PSI to feet of water is 2.31, so the atmospheric pressure is 14.7 X 2.31 = 33.96 feet.
- **Static height**: This is the height of the water level above the pump inlet. The greater this height, the more positive force is exerted on the water. (Note that if the pump must *lift* water from a reservoir, that the *static height becomes a negative value*).
- **Inlet friction:** Strainers, piping, valves and other accessories all cause a pressure drop, contributing to a *lower pressure.*

- **NPSHr (NPSH Required) of the pump**: The NPSHr is a pressure drop within the pump inlet. The NPSHr for any given pump depends only on the quantity of flow. The NPSHr is shown on the pump curve, either as a separate curve or as a value printed across the top of the curve (Taco uses the latter method).

We can see from the diagram, that the following factors contribute to low pressure at the inlet:

- Low static height or a suction lift
- High inlet friction

The following factors that result in higher pressure at the inlet:

- Large static height
- Low inlet friction

Avoiding Cavitation

To avoid cavitation, we must select the pump to ensure that the water does not fall below its vapor pressure. From the force diagram above, and remembering that the *NPSHr of a pump is essentially another pressure loss,* we can say:

Atmospheric Pressure + Static Height – Inlet Friction – NPSHr must be greater than the Vapor Pressure of the water at the temperature being pumped.

Mathematically, with all values expressed in feet of head, this becomes:

33.96' + Static Height-Inlet Friction-NPSHr >Vp **_Equation 1_**

This equation is normally rewritten by rearranging terms:

33.96' + Static Height – Inlet Friction – Vp > NPSHr **_Equation 2_**

We need one more modification to the formula to make it practical. We would like to have about a 2' safety factor. Therefore, we can modify the formula as follows:

31.96' + Static Height – Inlet Friction – Vp > NPSHr **_Equation 3_**

The sum of the terms on the left of the equation is called the *NPSH avail*able or *NPSHa*. If this formula is satisfied, that is if NPSHa > NPSHr, then the selected pump should be a good selection as far as NPSH and cavitation are concerned.

Example 1:

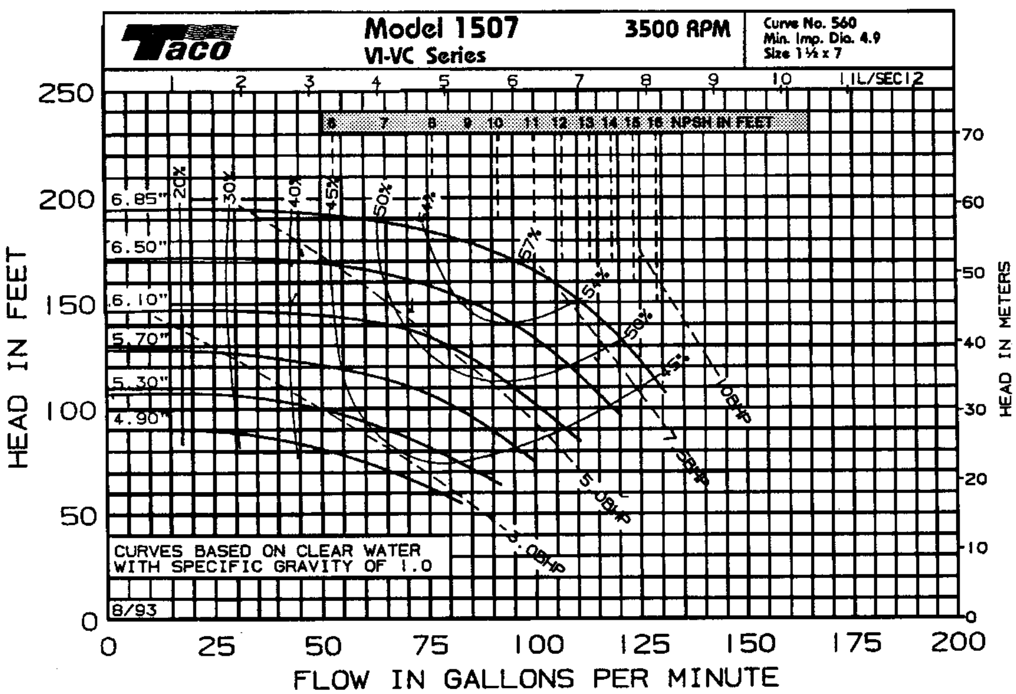
You wish to use a Taco #VI 1507 to pump 190 °-F water from a shallow tank having a water level of 2' above the pump inlet. You estimate that an inlet valve and

strainer will have a pressure drop of about 4'. The pump is to handle 100 GPM. Is this pump suitable?

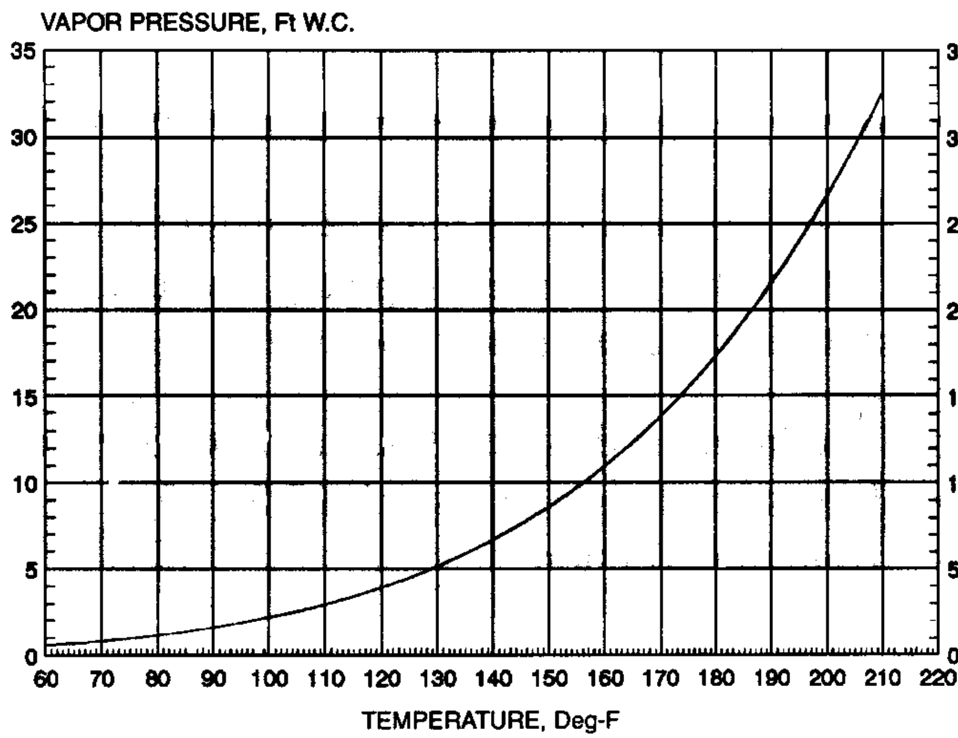
1. Per the discussion above, the pump selection must satisfy the following formula:

   31.96 + 2' (static height) – 4'(inlet friction) – 21.5'(vapor pressure) > NPSHr.

2. From the pump curve below you will note that the NPSHr at 100 GPM is 11 feet. From the vapor pressure curve, you will note that the vapor pressure is about 21.5'. Summing the terms on the left (31.96 + 2 – 4 –21.5) yields an NPSHa of 8.46'. This is *not* greater than the NPSHr of 11', so this is *not* a suitable selection.



VAPOR PRESSURE for WATER



Example 2:

Use the same parameters as in Example 1, except use a water temperature of 85 °-F. You will find that the NPSHa is over 28'! The NPSHr remains at 11', so the VI 1507 is definitely suitable for this application. *This demonstrates that it is critical to take into account the fluid temperature when considering NPSH.*

When a Selection Is Not Suitable

If the initial pump selection is not suitable, there are a number of possible solutions:

- Select a larger pump. Oversized pumps operate on the "left" areas of their curves, where NPSHr is lower.
- Select a lower speed pump. Lower speed pumps usually have lower NPSHr requirements.

- Reduce the inlet friction. Do away with unnecessary valves, accessories and fittings; oversize inlet piping.
- Lower the temperature, if practical.
- Raise the receiver to increase the static height.
- Use a low NPSH pump with a propeller inducer. This is a small propeller installed before the eye of the main impeller. Pumps made specifically for high temperature condensate often have such inducers.

Field Considerations

Sometimes a properly selected pump will cavitate when placed in service. There are usually two conditions that cause this:

1. The flow is not balanced, causing the pump to run out (to operate in the high flow areas of the curve). This is high NPSHr territory. The situation can be resolved by throttling the discharge valve to reduce the flow to the design level.
2. The inlet strainer or filter becomes plugged. This is common in swimming pool applications where the resulting extreme inlet pressure drop causes cavitation, even with 80° water. The solution is to keep the filters and strainers clean.

Clarifications

- The graph in **Figure 4** applies to water only. For other fluids, contact FHI.
- For most closed heating systems NPSH is not generally a problem. In a closed system, the expansion tank pressure replaces atmospheric pressure (31.96’) in **Equation 3**. The fill valve setting establishes this pressure to a level high enough to avoid cavitation.

Note that for closed (non-vented) process systems, such as deaerators and vacuum condensers, the atmospheric pressure is replaced by vapor pressure. This changes the condition to be met to:

Static Height – Inlet Friction – 2’ (safety) > NPSHr ***Equation 4***