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NET POSITIVE SUCTION HEAD and Cavitation in a Centrifugal Pump.

NPSH AND CAVITATION

Liquid vaporization within a pump intake is called "cavitation". Cavitation reduces a pumps performance and will damage the pump.

To understand the occurrence of cavitation, it is important to remember that a liquid will vaporize at a relatively low temperature if its pressure is reduced sufficiently. Water, for instance, will boil (vaporize) at 100^0F if it is exposed to a vacuum of 28 inches of mercury. The pressure at which a liquid will vaporize is called its "vapor pressure".

NPSH CONDITIONS

A reduction in pressure of a liquid close to its vapor pressure will cause it to vaporize. The pressure on the liquid entering a centrifugal pump is reduced as it moves through the suction eye up until the point at which it starts to be pressurized in the impeller. To prevent cavitation the pressure reduction in the suction eye must be compared to the vapor pressure entering the pump to determine whether the liquid will vaporize. The amount of excess pressure above the vaporization pressure is called net positive suction head (NPSH). We call the proximity of the liquid to its vapor pressure its "available NPSH" and the pressure reduction inside the pump, the "required NPSH". We compare the available NPSH to the required NPSH. When the available NPSH is equal to or greater than the required NPSH the pump will not cavitate.

AVAILABLE NPSH

A more precise definition of available NPSH is "the difference between the total suction head and the vapor pressure of the liquid, in feet of liquid, at the suction flange". We can calculate the total suction head of the pump and measure the liquid temperature to determine the vapor pressure. The difference between these two values is the available NPSH. The following equation is the mathematical expression for available NPSH:

$h_{sv} = h_{sa} - h_{vpa}$ Equation 1

where:

h_{sv} = available net positive suction head, in feet of liquid

h_{sa} = total suction head, in feet of liquid, absolute

h_{vpa} = vapor pressure of liquid at suction nozzle, in feet of liquid, absolute

REQUIRED NPSH

The required NPSH or $NPSH_R$ can be defined as "the reduction in total head as the liquid enters the pump".

The pump manufacturer determines the $NPSH_R$ for each pump it manufactures through testing, and plots the results on a standard performance curve for that pump.

NPSH PROBLEMS

If the available NPSH is not greater than that required by the pump, many serious problems can result; there will be a marked reduction in head pressure and capacity, or even a complete failure to operate. Excessive vibration can occur when parts of the impeller are handling vapor and other parts are handling liquid. Probably the most serious problem is pitting and erosion of the pump impeller, resulting in an extremely shortened pump life. The pitting and erosion are caused by the collapse of vapor bubbles as they pass into the impeller regions of higher pressure. The vapor is under going a phase transformation from a gas to a liquid. Excessive noise (low pitched rumbling) and vibration usually accompany cavitation. As the vapor bubbles collapse, the adjacent impeller walls are subjected to a tremendous shock from the inrush of liquid into the cavity left by the bubble collapse. This shock actually flakes off small bits of metal and the walls take on the appearance of having been badly eroded. This erosion shows up not at the point of lowest pressure where the bubble is formed, but further downstream where the bubble collapses.

The energy expended in accelerating the liquid to high velocity in filling the void left by the bubble is a system loss, and causes the drop in head pressure associated with cavitation. The loss in capacity is the result of pumping a mixture of vapor and liquid instead of liquid. Water, for example, at 70^0F increases in volume about 54 times when vaporized, and thus even a slight amount of cavitation will reduce the capacity significantly.

A pump operating with insufficient available NPSH will often pump spurts of liquid. This is caused by the following chain of events: As the pump is started, the liquid accelerates in the suction eye until it reaches the capacity at which it is to operate; as the liquid accelerates, friction losses increase and lower the absolute pressure until the liquid flashes into vapor; as soon as this happens, the pumping action is reduced, and the flow decreases. With the decreased flow, the losses are lower, the absolute pressure is higher, and the liquid does not vaporize. This causes the pump to start pumping liquid again. This increases the flow, reduces the pressure etc. until the whole cycle is repeated. The cycle of cavitation events result in an erratic flow rate with spurts of liquid from the discharge pipe.

CALCULATING AVAILABLE NPSH OF A PIPING SYSTEM

The available NPSH can be calculated by use of the following formula:

$h_{sv} = h_{psa} + h_{ss} - h_{fs} - h_{vpa}$ Equation 2

where:

h_{sv} = available net positive suction head in feet of liquid.

h_{psa} = suction surface pressure, in feet of liquid, absolute, on the surface of the liquid from which the pump draws its suction. This will be the atmospheric pressure, in the case of an open tank.

h_{ss} = static suction head, in feet of liquid. Static head is the height, in feet of the liquid surface in the suction tank above the pump impeller centerline. (Positive if the liquid level is above the pump, negative if the liquid level is below the pump)

h_{fs} = friction head loss, in feet of liquid, between the liquid surface in the suction tank and the suction flange of the pump.

h_{vpa} = vapor pressure of the liquid, at the pumping temperature, in feet of liquid, absolute.

Note that the first three terms in Equation 2 equal the total suction head, h_{sa}, and if we replace the first three terms with h_{sa}, we get Equation 1 which is a mathematical definition of available NPSH.

Each calculation of available NPSH for a piping system requires the five following steps:

Step 1: Determine the suction surface pressure, $h_{psa.}$ This is the pressure on the surface of the liquid in the suction tank. When the suction tank is open, the suction surface pressure equals atmospheric pressure. When the suction tank is closed the pressure on the surface of the liquid must be measured. In either case, the pressure must be converted to feet of liquid, absolute.

Step 2: Determine the static suction head, h_{ss}. This is the height, in feet of the liquid surface in the suction tank above or below the pump centerline. When the liquid level is below the pump centerline, the static suction head is a negative value,

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Step 3: Determine the suction friction head, h_{fs}. This is the sum of all the friction losses in the suction line from the inlet to the suction flange of the pump, at the specified flow rate. The friction loss factors can be read from the Pipe Friction Manual of the Hydraulic Institute.
Step 4: Determine the vapor pressure, h_{vpa} - of the liquid at the pumping temperature, in feet of liquid, absolute. The vapor pressure must be known and converted to feet of liquid.
Step 5: Calculate the available NPSH from Equation 2 using the values determined in steps 1 through 4.

What to do if cavitation is a Problem in your MART Power Washer:

1. Lower the operating temperature of the pumped liquid.
2. Raise the vapor pressure of the liquid by adding chemicals to raise the boiling point.
3. Increase the liquid level relative to the pump suction eye.

The most significant effect will be had by lowering the liquid temperature. The vapor pressure increases exponentially for each degree of temperature rise toward its vapor pressure. A several degree reduction in operating temperature can gain many feet of NPSH.

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