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PUMP CLINIC 19

ABOUT NET POSITIVE SUCTION HEAD (NPSH)

In past Pump Clinic Articles we have talked about cavitation which most people who have any involvement with pumps will come across at some stage. In this article however we want to talk only about NPSH and what it means as it is a term that is misunderstood by many people.

We do not want bubbles in our process fluid for a lot of reasons:

- Bubbles take up space, causing the pumping capacity to diminish. The head also reduces because energy has to be expended to increase the velocity of the liquid used to fill up the cavities, as the bubbles collapse. As the velocity goes up, the head or pressure goes down.
- Excessive vibration can occur when part of the impeller is handling a liquid and another part is handling a vapour. This vibration can lead to pump failure.
- Air is a poor heat transfer medium, meaning that the fluid we are pumping will get hotter and in almost no cases is there any advantage in heating up the process fluid.
- A bubble is a hole or cavity in the liquid. It is these cavities that are going to cause a cavitation problem that will damage both the impeller and volute.

Bubbles or cavities form in a liquid when the fluid temperature gets too high, or the fluid pressure gets too low. This is called vapourisation, or sometimes boiling although the word boiling tends to imply that the liquid is hot which need not be the case. We all know that if you throw dry ice into cold water it will bubble and vapourise, but it is not hot.

For the purpose of this article we will use *vapourise* and further state that a fluid will vapourise any time the pressure falls below its vapourisation point.

Since temperature is a variable with different fluids, there are charts that will give you the vapour pressure for any fluid at its various temperatures.

Take a look at the following chart. For the purpose of this article we will use a chart in imperial units. You will note that the vapour pressure for 60˚F chlorine is 80 psi (540kPa), and the vapour pressure for 68˚F fresh water is about 0.3 psi (2kPa). These numbers are required to calculate our NPSH available.

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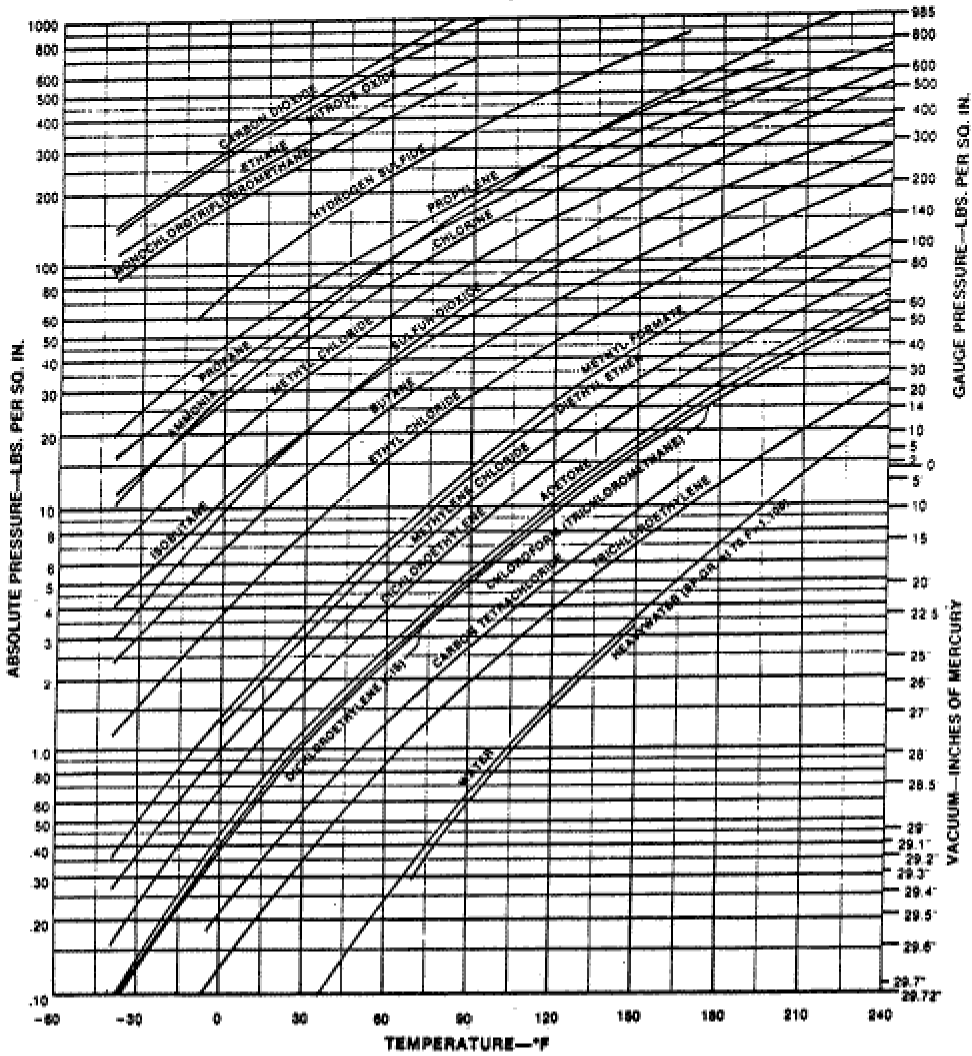
VAPOR PRESSURE—VARIOUS LIQUIDS CHART 1—60° to 240°F.



A fluid pressure can be lowered in several ways:

- Put the fluid in a container, and then pull a vacuum on the container. This happens in the hot well of condensers. This can be referred to as a loss of "pressure head"
- Lift the liquid out of a hole. This will diminish the position of the liquid level in respect to the pump centre line. This can be referred to as a loss of "static head"
- Accelerate the fluid. As its velocity increases its pressure will decrease. This is referred to as "velocity head"
- As the fluid moves through piping, fittings, restrictions and valving, some friction losses occur that will drop the fluid pressure. This is referred to as an increase in friction head, resulting in some loss of "positive suction head."

Heating of the incoming fluid is not usually a problem, but it can occur several ways:

- Internal recirculation in the pump because of worn wear rings or failure to make an impeller adjustment.
- Piping, exposed to the elements, can heat up the liquid on hot and sunny days.

We do not know how much pressure a centrifugal pump will develop, but we do know the head it can produce. The head is a function of the shaft speed and the impeller diameter. The faster the speed the higher the head.

The larger the diameter, the bigger the head. To determine the pressure we have to know the weight or "specific gravity" of the fluid we are pumping, and since any given centrifugal pump can move a lot of different fluids, with different specific gravities, it is simpler to discuss the pump's head and forget about the pressure.

Here are the formulas you can use to convert from one to the other:

$$\text{Head} = \frac{\text{Pressure} \times 0.1}{\text{Specific gravity}}$$

$$\text{Pressure} = \frac{\text{Head} \times \text{specific gravity}}{0.1}$$

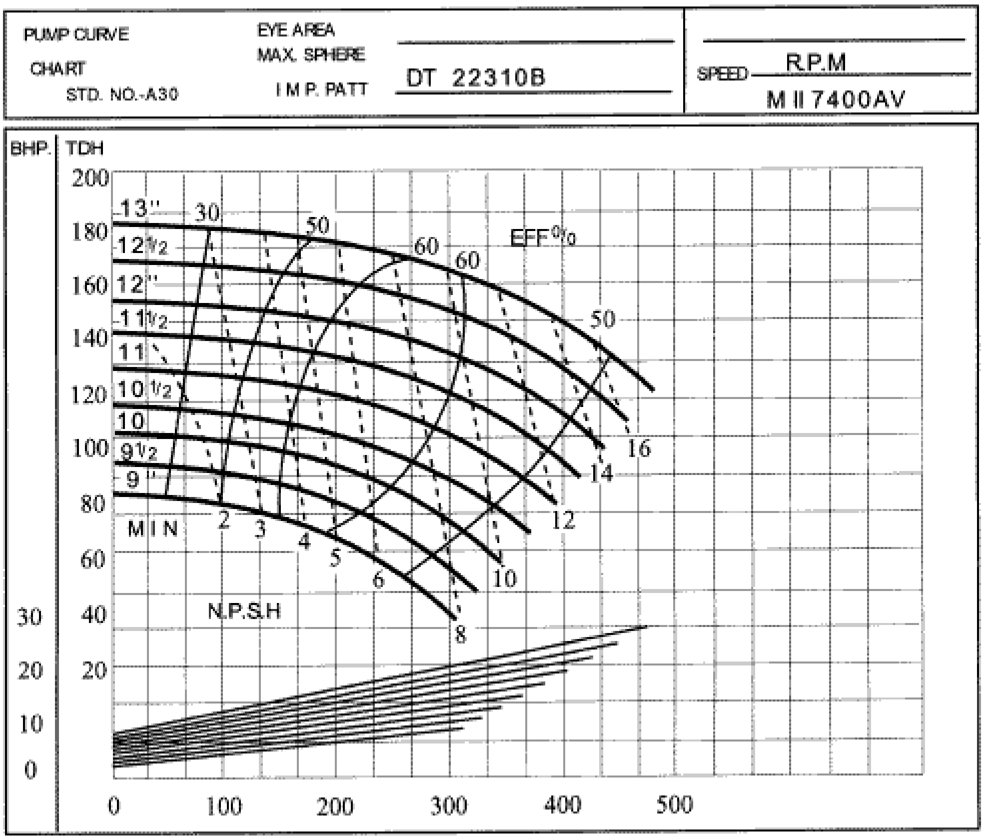
In the above formula:

- Head is measured in metres (m)
- Pressure is measured in kilopascals (kPa)

The pump manufacturer has decided how much head the pump needs to prevent cold water from vapourising at different capacities and these values are published on his pump curve. The values have been obtained by testing the pump at different capacities, throttling the suction side and waiting for the first signs of cavitation. The pressure was noted, converted to head, and transferred to the pump curve.

This observed number is called the "Net Positive Suction Head Required (NPSHR).

The attached pump curve shows the numbers. On the chart they are located at the bottom of the dotted lines and they run from 2 to 16. According to this graph a 13-inch impeller, running at its best efficiency point (60+%), would need a NPSH required of 9 feet. An 11-inch impeller running at its best efficiency point would need 7 feet of NPSH required. Remember this requirement is for cold water only.



Be sure to keep in mind that any discussion of NPSH or cavitation is only concerned about the suction side of the pump. There is almost always plenty of pressure on the discharge side of the pump to prevent the fluid from vapourising.

- If we go back to our formula and put the 0.3 psi/ 2kPa vapour pressure for 68˚ water into the numbers, it comes out to 0.7 feet or 0.2 metres of head is required to stop the water from vapourising and forming cavities. So why does the NPSH required increase as the capacity is increasing? It's because the velocity of the liquid is increasing, and anytime the velocity of a liquid goes up, the pressure or head comes down.

Now that we know what head is required, we can calculate the head we have available, and remember we are only interested in the suction side of the pump. Generally we will be looking at three kinds of head.

- The static head measured from the liquid level to the centre line of the pump. If the liquid level is above the pump centre line you will have a positive number. If the level is below the centre line you will have a negative number.

- The pressure head. Here we will be using only absolute numbers. In other words atmospheric pressure is 101kPa at sea level so you will add that number (converted to metres, using the above formula) to the static head if you have an open tank. If the fluid is under vacuum we will convert the absolute pressure reading to head and use that number, instead of atmospheric pressure. The friction loss in the piping will be a minus number. You get the number from charts showing pipes size vs flow, and flow through fittings and valves.

- The next thing we have to do is subtract the vapour pressure of our fluid (converted to feet of liquid) using the first formula I gave you. All of the above, added together is the NPSH available. If this number is equal to, or more than the NPSH required by the pump manufacturer, the liquid will not form bubbles or cavities on the suction side and the pump will not cavitate.

In summary, NPSH available is defined as:

NPSHA = Atmospheric pressure + static head + pressure head - the vapor pressure of your product - loss in the piping, valves and fittings.

NPSHA will always need to be greater than the NPSHR for the pump to operate without cavitation. Most people involved in pumping system design demand an additional safety factor of 1m.