PUMP CLINIC 2

Introduction to Cavitation and Net Positive Suction Head

Cavitation in Centrifugal Pumps

When the pressure of flowing liquids drops to, or below the liquid's vapour pressure, the liquid boils and vapour cavities (bubbles) form locally inside the liquid. If the pressure within the flow path subsequently increases above the vapour pressure, the vapour cavities implode, releasing energy. The formation and sudden collapse of these bubbles is called **Cavitation.**

The generation of head in a centrifugal pump does not commence until the liquid enters the vane area and is accelerated towards pump discharge. As the liquid flows between the pump inlet flange and vanes, several points of head loss occur due to:

a) Friction in the suction nozzle.

b) Acceleration losses as the liquid velocity increases from the suction nozzle to the impeller eye.

c) Shock losses as the liquid contacts the leading edges of the impeller vanes.

The sum of these losses is known as the entry loss. If the suction head minus the entry loss reduce the liquid pressure to or below the vapour pressure, then a condition for cavitation exists. *Figure 1 Page 2* illustrates the above.

Net Positive Suction Head (NPSH)

The net positive suction head is a statement of the minimum suction conditions required to prevent cavitation. The required NPSH (referred to as NPSHR) is the minimum value of NPSH required at the pump inlet for satisfactory pump operation and must be determined by test and is stated by manufacturers (appears on the pump performance curve as an NPSHR curve). The NPSHR is equivalent to the entry loss as shown in *Figure 1.*

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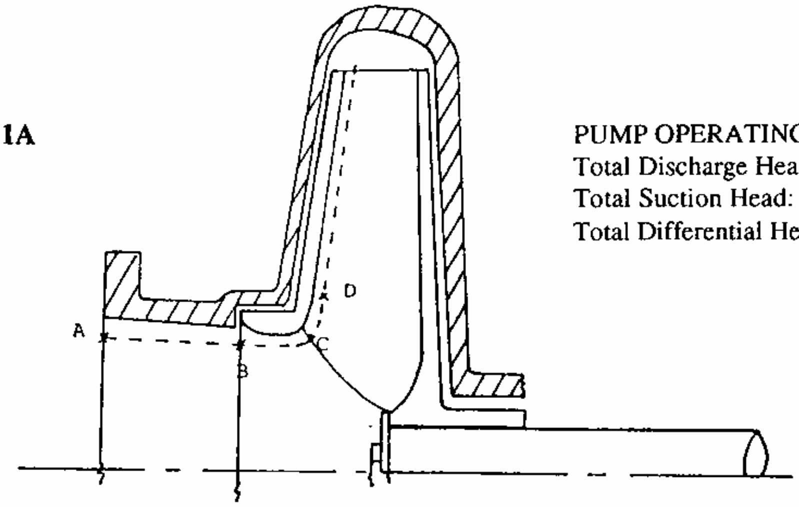
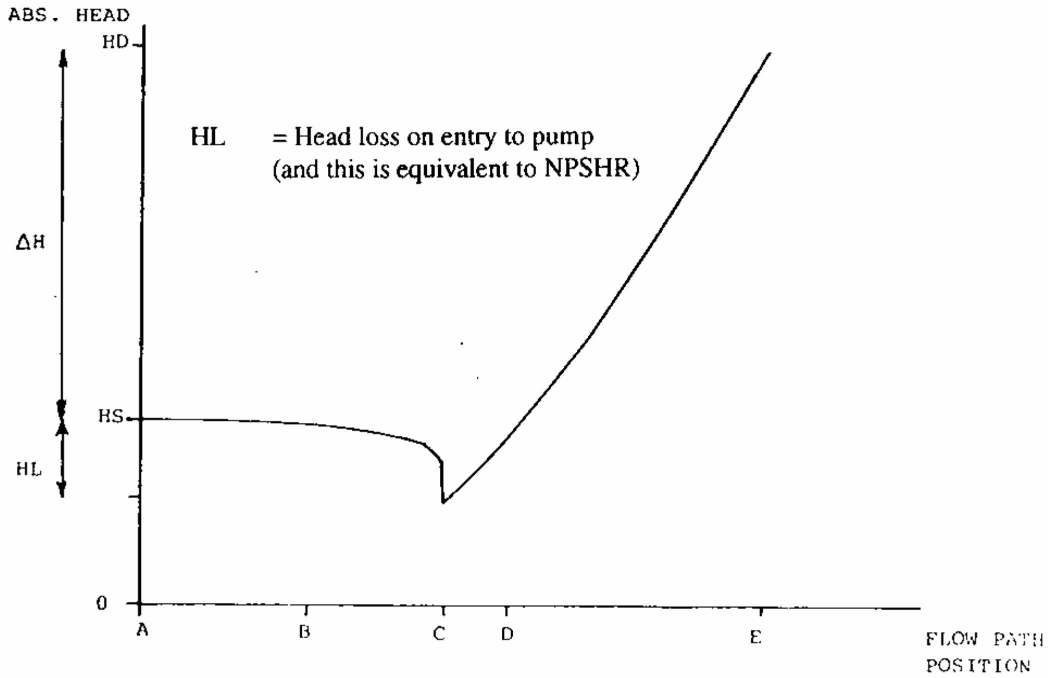
Figure 1 - FLOW PATH THROUGH A CENTRIFUGAL PUMP

1A



PUMP OPERATING WITH:
Total Discharge Head: HD
Total Suction Head: HS
Total Differential Head: ΔH

1B



HEAD VS FLOW PATH POSITION

2

The available NPSH (referred to as NPSHA) is a function of the suction side pumping system and is defined as the absolute pressure head on the liquid surface, plus the static liquid level above the pump centre line (negative for suction lift) minus the friction loss in the piping system leading to the pump minus the vapour pressure head at the pumping temperature. The discharge pumping system has no effect on NPSHA.

Figure 2 Page 4 shows four typical suction systems with the NPSHA formulae applicable to each. Please note that the units of the terms in the formulae are metres **absolute** of the liquid being pumped.

To avoid cavitation, NPSHA must always be greater than NPSHR at the design flow.

Problems Caused By Cavitation

The presence of cavitation due to inadequate NPSH can be diagnosed during pump operation by a steady crackling noise in and around the pump suction. This should not be confused with a random crackling noise with high intensity knocks which indicates another condition termed suction recirculation (not covered in these notes).

If the problem was one of noise alone, it is likely that most situations would call for no remedial action. However, continual cavitation causes mechanical and operational problems as follows:

1) Erosion of impeller, particularly at the leading edges of the impeller vanes. In some cases, the casing itself will show signs of erosion. The extent of damage experienced is significantly affected by product-related factors such as corrosion and abrasion. Apart from the damage to the parts, the erosion can cause loss of pump efficiency and out-of-balance problems with the impeller.

2) The vibrations caused by cavitation and unbalanced loads significantly accelerate the rate of bearing and mechanical seal failures.

3) The vapour cavities will impede the flow of liquid through the impeller. In some cases, the flow may be completely blocked. This will result in reduced capacity plus reduced and/or unstable developed head.

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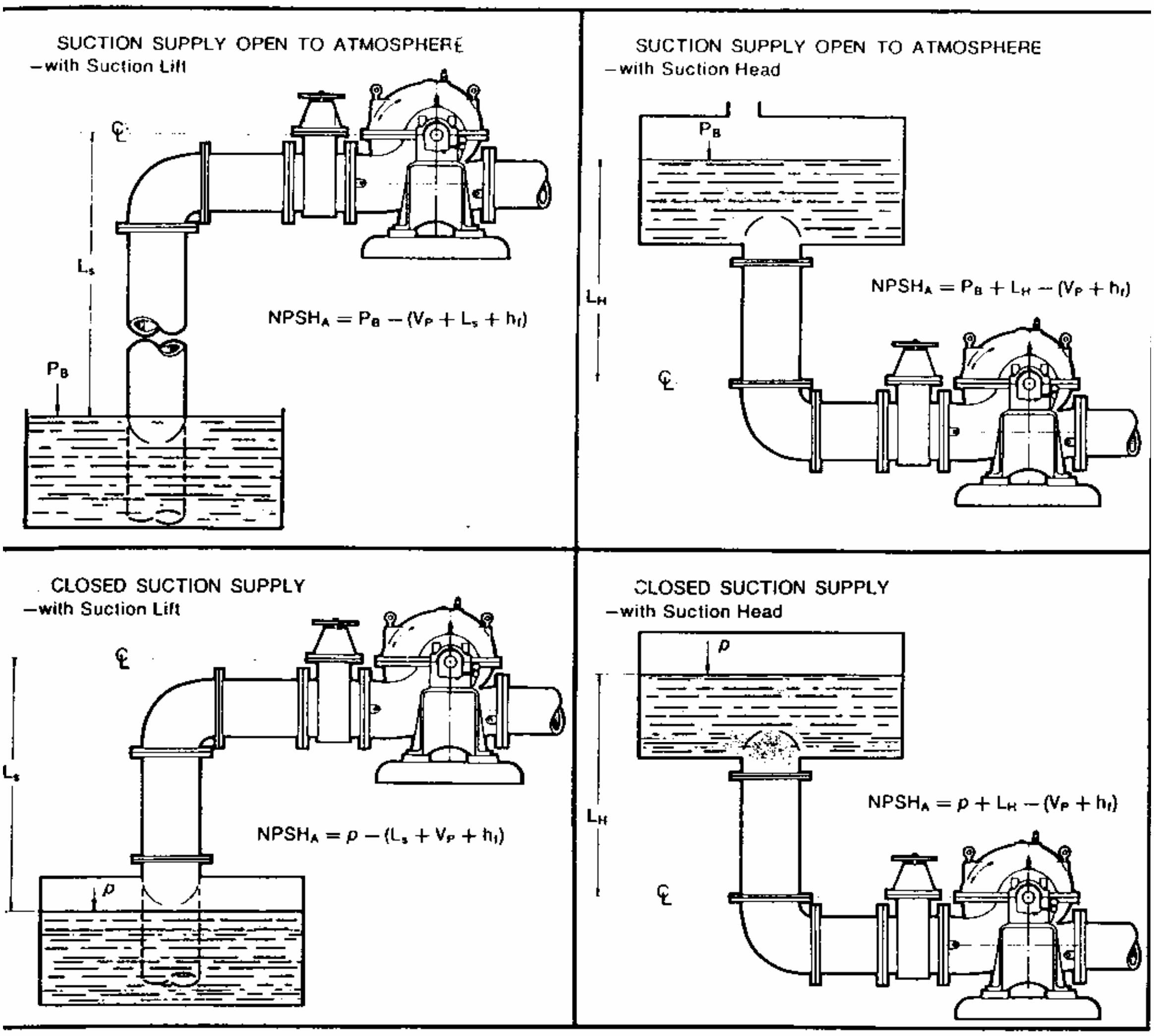

P_B =	Barometric pressure, in metres absolute	L_S =	Maximum static suction lift in metres
V_P =	Vapour pressure of the liquid at maximum pumping temperature, in metres absolute	L_H =	Minimum static suction head in metres
p =	Pressure on surface of liquid in closed suction tank, in metres absolute	h_f =	Friction loss in metres in suction pipe at required capacity

Figure 2 CALCULATION OF SYSTEM NET POSITIVE SUCTION AVAILABLE FOR TYPICAL SUCTION CONDITIONS

What Can be Done?

The obvious answer is to ensure proper pump selection at the initial stage. Most users would agree that the majority of pump vendors are sufficiently competent in giving customers what was asked for in the specifications. Having said this, it is imperative that the issue of NPSHA vs NPSHR is properly understood and considered by both user and supplier.

The solutions to existing cavitation conditions can be determined by considering both NPSHA (the system) and NPSHR (the pump). On the system side, the NPSHA can be increased by one or more of the following:

a) Increase the static liquid level above the pump or reduce the suction lift. This can be done in the case of a flooded suction by raising the liquid level in the suction tank, raising the suction tank to a higher level or lowering the pump, e.g. one floor down.

   In the suction lift situation, the liquid level in the sump or suction tank can be raised or the pump can be lowered, e.g. mounting the pump off the sump side or building a dry sump beside the existing sump.

b) Reduce the friction losses by increasing pipe sizes and reducing the length of pipe runs and the number of fittings, e.g. tees, bends, valves. Selection of fittings with lower friction loss, e.g. long radius elbows and full flow ball valves should also be considered. In particular, resist the use of suction strainers that can clog.

c) Reduce the vapour pressure by reducing the temperature of the product. This can be done by reducing the operational temperature of the process (if feasible) or cooling the temperature in the suction line, e.g. cooling annulus on the suction pipework. It must be noted the reduction of vapour pressure by reducing the temperature is rarely possible.

The remedies detailed below can be applied to the pump:

a) Reduce the flow rate by throttling on the pump discharge. This will generally reduce NPSHR (always check the pump curve) and increase NPSHA (due to reduced friction losses). Care must be taken to ensure that the flow rate is not reduced below the minimum flow rate recommended by the manufacturer.

b) Reduce the pump speed as this reduces NPSHR. This will require the user to accept reduced pump performance

c) Reduce the pump speed and install a larger diameter impeller. This will have a two-fold effect as lower speed means lower NPSHR and in many cases the larger impeller diameter has lower NPSHR characteristics.

d) Install a different pump. This would normally mean installation of a larger pump as they generally have a better NPSHR value for the same flow rate. The selection of a larger pump is sometimes required with speed reduction.

e) Change the impeller material to one that is more resistant to erosion, e.g. from cast iron to stainless steel. This does not eliminate cavitation but will reduce the impact of cavitation.

What Types of Installations Are More Likely To Encounter Cavitation Problems?

The presence of any of the conditions detailed below significantly increases the possibility of low NPSHA values and cavitation. Please consider this in your pump selections and if in doubt, discuss the matter with the pump supplier.

1. **High temperature or boiling liquids:** This will increase the vapour pressure head.

2. **Volatile liquids:** These have a high vapour pressure head.

3. **Suction tank under vacuum:** This will reduce the absolute pressure head on the liquid surface.

4. **High suction lift applications**

5. **Circuitous suction pipework:** This will lead to increased friction loss.

6. **A high number of fittings in suction pipework:** This will increase friction losses.

Conclusion

Cavitation and NPSH seem to be some of the least understood topics associated with pump applications. To some engineers, these topics appear mysterious or, at best, are only partially understood.

Many highly technical research papers have been written on this subject. These notes are an attempt to give a simple introduction to cavitation and highlight areas where some critical thought should be applied.

It should also be stated that although these notes are based on application to centrifugal pumps, the majority of the principles apply equally to all other types of pumps.