A Look at Centrifugal Pump Suction Hydraulic – Part 2

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Introduction

Pump suction side hydraulic calculation is always one of the most important checking done for all pumps. This calculation may determine pump suction line size, suction piping layout, suction vessel elevation and pump type. Addition to allowable suction velocity and pressure drop which have to be in the range defined by project design criteria, Net Positive Suction Head (NPSH) is another parameter that check the adequacy of selected pump in specified service. There are two types of NPSH. First is NPSH Available which is a function of the hydraulic parameters of system in which the pump operates. $NPSH_A$ is the excess pressure of the liquid over its vapor pressure as it arrives at the pump suction nozzle in height of liquid absolute. The second is NPSH Required which is the positive head required at the pump suction to overcome pressure drops in the pump and maintain the majority of the liquid above its vapor pressure. $NPSH_R$ is the specification of pump and it depends on pump mechanical design, so it can be only given by pump vendor. The $NPSH_R$ is determined by pumping cold water through the pump with constant impeller size and RPM while reducing the suction head until the pump showed a reduction in discharge head of three percent (3%), due to the low suction head and any formation of bubbles within the pump. This point is called "the point of incipient cavitation".

In designing a pumping system, it is essential to provide adequate $NPSH_A$ for proper pump operation. Insufficient $NPSH_A$ may seriously restrict pump selection, or even force an expensive system redesign. On the other hand, providing excessive $NPSH_A$ may unnecessarily increase system cost.

Cavitation is one of the main causes of pump damage which can happen as a result of vaporization, gas/air entrainment, internal recirculation, and turbulence or combination of them. This note focuses on pump cavitation due to gas entrainment, internal recirculation and turbulence.

Gas/Air Entrainment

A centrifugal pump can handle up to 0.5%vol air or gas without any major problem but at 6% the results can be disastrous. The gas bubbles collapse as they pass from the eye of the pump to the higher pressure side of the impeller. Entrained gas seldom causes damage to the impeller or casing but it does lower the capacity of the pump. It should be noted that increasing suction head has no effect on this type of cavitation. Figure 1 shows the typical effect of incondensable gas on pump head and capacity. Gas gets into the pump system in several ways such as:

- Vortexing
- Previously flashed process liquid conveying flashed gas into the suction piping.
- Injection of gas, which is not absorbed into liquid which can be eliminated by using static mixer.
- Valves, seals, flanges in vacuum systems or in suction lift application allowing air to leak into the stream.
- Gas producing chemical reaction.

Pulling gas through vortexing fluid is one of the pump damaging events that may occur due to bad design of pump suction nozzle. This can occur when the liquid height above suction nozzle lowers below specific level. There are two ways for preventing gas entrainment due to vortexing:

- Installing vortex breaker and setting pump trip about half of suction nozzle (min 150mm) above top of vortex breaker
- Setting pump trip at a level high enough to prevent vortex formation and gas entrainment. Perry's chemical engineering handbook equation 6-137 and 6-138 should be referred.

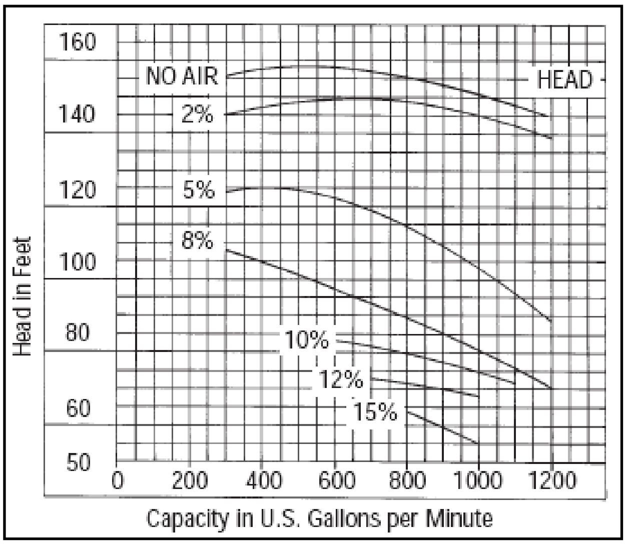

Figure 1 – The effect of air on head water pump

For tray draw off nozzle which vortex breaker cannot be employed and liquid level is not so high, one of the arrangements depicted in Figures 2a and 2b is suggested.

In addition, an anticipated drop in pump head due to entrained gas may be offset by over-sizing the impeller.

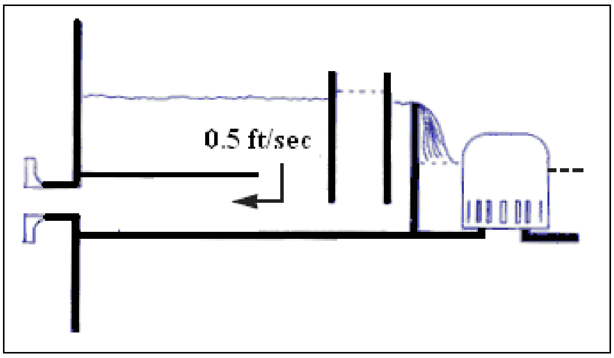

Figure 2a – Plate extension vortex breaker

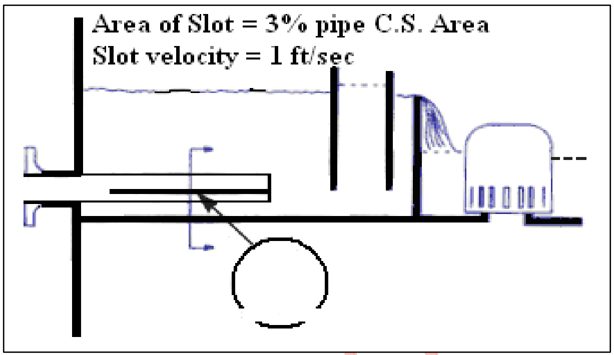

Figure 2b – Slotted pipe vortex breaker

Internal Recirculation

Pump internal recirculation is another cause of cavitation. As the name implies, the fluid re-circulates increasing its velocity until it vaporizes in form of bubbles and then collapses in the surrounding higher pressure. This condition is visible on the leading edge of the impeller, close to the outside diameter, working its way back to the middle of the vane. It can also be found at the suction eye of the pump. Suction specific speed has come into use as an indication of the suction characteristics of centrifugal pumps. Figure 3 shows the location on internal recirculation in pump suction side.

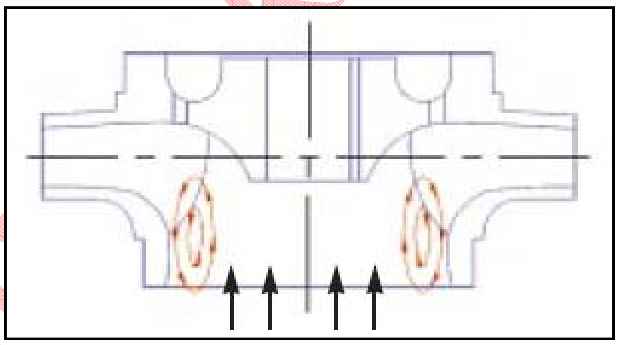

Figure 3 – Suction eye recirculation

Suction Specific Speed

Suction specific speed is defined as:

$$SSS = \frac{N\,Q^{0.5}}{NPSH_R^{0.75}} \qquad (1)$$

For a given pump, suction specific speed is an indication of the relative size of the eye of the impeller. A pump with a higher suction specific speed would typically have a larger eye and lower $NPSH_R$.

Pumps with suction specific speed in the range of 9000 to 11000 for optimum and trouble-free operation are preferred. Pump with SSS of 11000 and higher will require lower $NPSH_R$ but the problem is higher suction specific speed means the narrower safe operating range from BEP because flow separation and recirculation problems occur at the off-peak low-flow conditions. In other words, a higher suction specific speed design is better only if pump does not operate significantly below its BEP. That is why only some particular pumps like BFW and condensate pumps are designed with suction specific speed higher than 11000. Too high suction specific speed number will cause excessive internal recirculation problems at low flow leading to cavitation. Pump with suction specific speed of 7000 and lower is also categorized as poorly mechanical design. In this condition, pump will have comparatively small impeller eye, high entrance/internal loss and consequently high $NPSH_R$.

The most effective way of protecting pump against cavitation due to internal recirculation is to keep the pump flow higher than a minimum flow which is specified by vendor. Following guideline can be used to specify this requirement in absence of pump vendor data:

- For water pumps, the minimum operating flow can be as low as 50% of the suction recirculation starting flow for continuous operation and as low as 25% for intermittent operation.
- For hydrocarbon pumps, the minimum operating flow can be as low as 60% of the suction recirculation flow for continuous operation and as low as 25% for intermittent operation.

Figures 4a and 4b show the capacity at which suction recirculation starts as a function of specific speed and suction specific speed.

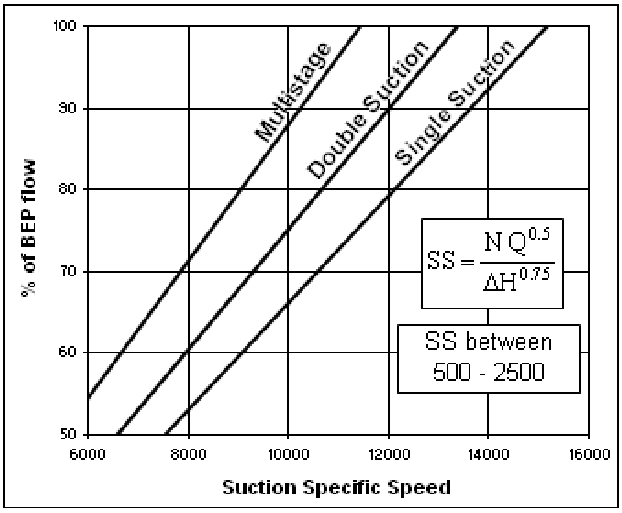

Figure 4a – Suction recirculation starting flow at low SS

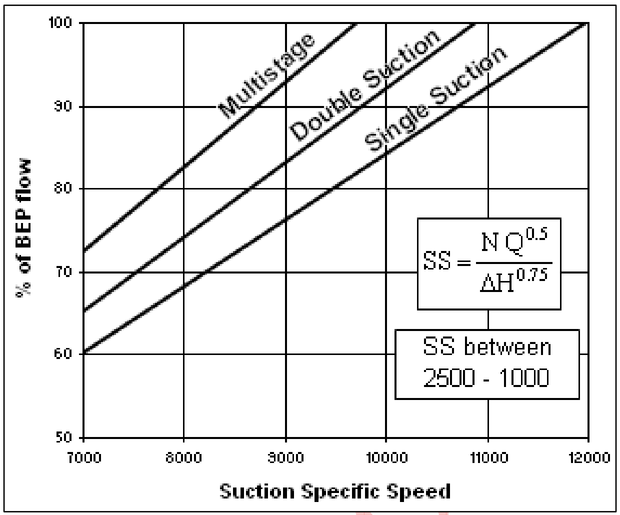

Figure 4b – Suction recirculation starting flow at high SS

For example, for single suction hydrocarbon pump with SS in the range specified in Figure 4a, if SSS is 14000 the suction recirculation starts at 93% of BEP flow. This means pump minimum operating flow should be about 56% (0.93 of 60%) of BEP flow.
It should be noted that cavitation because of internal recirculation is not eliminated by increasing the suction head.

Turbulence

It is generally preferred to have constant velocity of liquid in pump suction line especially in the immediate suction piping. Change in the velocity of liquid causes pressure change which is the main parameter in preventing or commencing cavitation. Any sudden flow directional change, pipe expansion or contraction, corrosion, and flow obstruction or throttling at suction changes the fluid velocity, causes more eddies and increases the probability of vacuum generation, internal recirculation and cavitation. Turbulence of the fluid can also result in release of entrained gases inside the pump suction piping.

Cavitation due to flow turbulence can be prevented through proper engineering of suction side of pump i.e. correct piping design, material selection and process considerations along with proper operation can guarantee trouble-free pumping.

Contact

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ABBREVIATION	
BEP	a point on maximum impeller size curve with has the highest efficiency
ΔH	Pump differential head, ft
N	Pump speed, RPM
Q	Pump flow at BEP, gpm
$NPSH_R$	Pump NPSH required at BEP, ft
SS	Suction Speed
SSS	Suction Specific Speed