Calculating NPSH for reciprocating plunger pumps must account for losses due to acceleration head for a reliable design that will meet the required duty

Ruhrpumpen

Ruhrpumpen is a global supplier of innovative centrifugal and reciprocating pump solutions for the oil and gas, petrochemical, chemical, process, industrial, water, power and mining markets.

Pumps are designed and manufactured to the most demanding quality standards and industry specifications, including API, ANSI, ISO and Hydraulic Institute Standards. When a standard pump is not suitable for a challenging application or duty, Ruhrpumpen engineers will design and manufacture a bespoke pumping solution, drawing on the company's breadth and depth of skills, expertise and technology. Quality is managed and controlled through the company's own integrated foundries, machine shops, service centres, and manufacturing plants located around the world.

Reciprocating Plunger Pumps

The Ruhrpumpen RDP series of high-quality triplex and quintuplex reciprocating plunger pumps are designed in the United Kingdom and used for high-pressure duties across the oil and gas, petrochemical, process, industrial and mining markets where low leakage, high reliability and reduced running noise are paramount.

The pumps fully meet API 674 3rd edition and ISO13710, and can handle pressures up to 1,000 bar (14,500 psi) at temperatures between -40C (-104°F) and 200C (392°F). Bespoke pumps can be engineered to meet customer specific requirements and duties.

Reciprocating plunger pumps accelerate the pumped fluid as the plunger moves through its stroke and this acceleration of the fluid has an impact on the calculation for NPSH which must be accounted for in the design and selection of reciprocating plunger pumps to avoid potentially catastrophic consequences

Net Positive Suction Head (NPSH) is a measure of the pressure of the fluid being presented to the pump in the suction line. $NPSH_A$ is the **A**vailable head, that is the absolute pressure at the suction port of the pump, and $NPSH_R$ is the pressure of fluid **R**equired by the pump to avoid cavitation (see Figure 1) and so perform to the required specification.

> $NPSH_A$ must always be greater $NPSH_R$ in a system for the pump to operate reliably otherwise the pump may suffer from erratic performance, reduced flow, high levels of noise and vibration, cavitation of the pumped fluid, undue wear and ultimately premature failure.

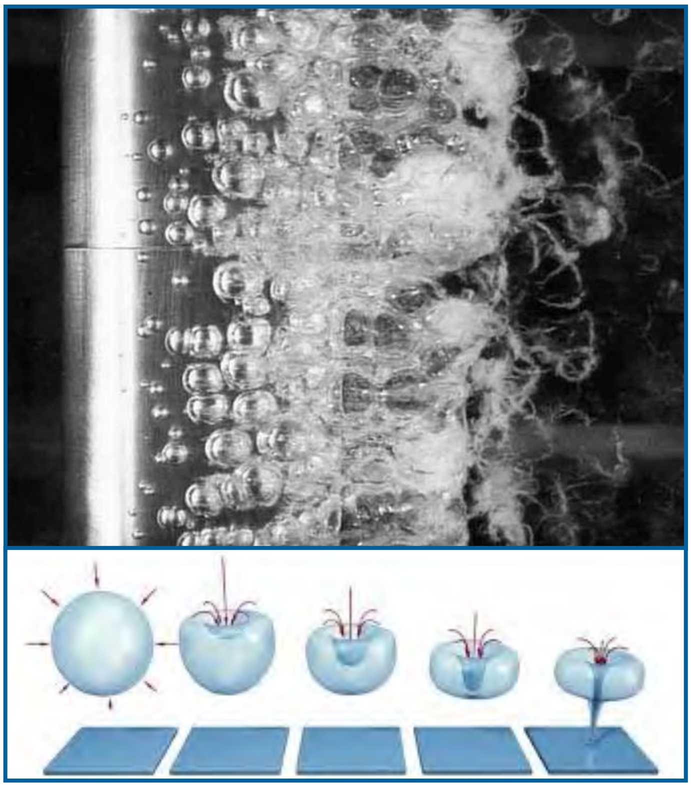

Figure 1– Cavitation is the result of a drop in pressure of a moving liquid. This reduced pressure causes bubbles to form, then as the pressure of the liquid increases again, the bubbles close to surface collapse generating an extremely high pressure jet of liquid for that is capable of eroding the surface material.

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Calculating $NPSH_A$ for centrifugal pumps

The calculation of $NPSH_A$ takes into account the static head from the supply tank and factors in various losses and adjustments. $NPSH_A$ is calculated for the system and it is the customer's responsibility to provide this to the pump manufacturer in the specifications for a pump. $NPSH_R$ is provided by the pump manufacturer for each pump and an acceptable margin between $NPSH_A$ and $NPSH_R$ is agreed, normally greater than 1m.

Most engineers specifying pumps are familiar with the calculation for $NPSH_A$ for centrifugal pumps which is expressed as:

$$NPSH_A = p_g + p_z - p_{vp} - p_f$$

where:

p_g is the static head from the supply tank

p_z is the head due to height difference

p_{vp} is the margin needed for vapour pressure

p_f is the head loss due to frictional losses

Accounting for acceleration head in reciprocating plunger pumps

Centrifugal pumps and reciprocating plunger pumps operate on entirely different principles. In its simplest form a centrifugal pump is a velocity generator in which the fluid moves through a pipeline at constant velocity, but a reciprocating plunger pump is a flow generator in that the fluid flow accelerates in sine wave as it moves through the pipeline. This acceleration and associated with the fluid being moved by a reciprocating pump introduces pulsation into the pumped fluid as the plungers displace a discrete volume of fluid for each stroke, which can be represented as a series of pressure waves.

The resistance of the flow acceleration in a particular system is known as impedance. The loss in $NPSH_A$ due to this impedance is also known as the acceleration head and must be accounted for when determining $NPSH_A$ for a system that will incorporate a reciprocating plunger pump, otherwise the $NPSH_A$ given by the customer to the pump manufacturer will be overstated with the result that the actual $NPSH_A$ in the system may be lower than the $NPSH_R$ of the selected pump with undesirable consequences.

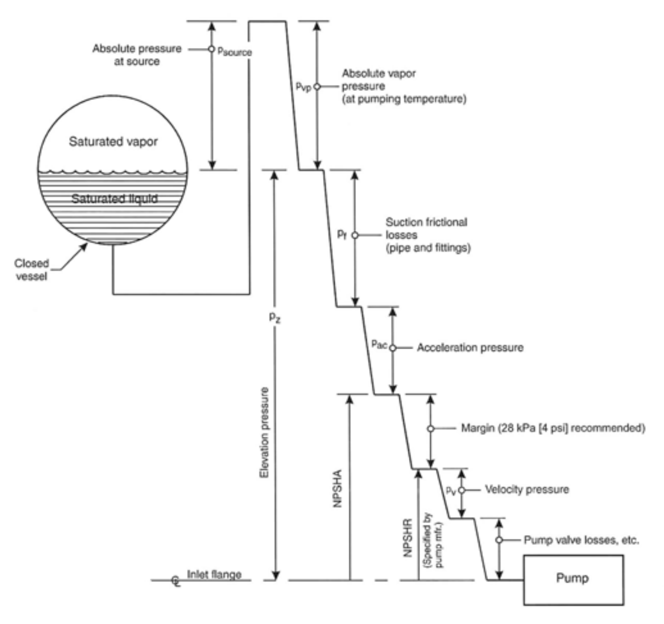

Figure 2—Illustration of how head losses are added and subtracted in a closed supply

The acceleration head for reciprocating pumps p_{ac} is subtracted from calculation of $NPSH_A$ used for centrifugal pumps as follows (and see Figure 2):

$$NPSH_A = p_g + p_z - p_{vp} - p_f - p_{ac}$$

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Effect of pipeline diameter on NPSHA for reciprocating plunger pumps

Fluid moving through a large bore pipe will result in low pressure waves and so have a low impedance whereas a small diameter bore will result in high pressure waves in the fluid and a high impedance. As such, the impedance of pumped fluid is proportional to the bore diameter of the pipeline (see Figure 3).

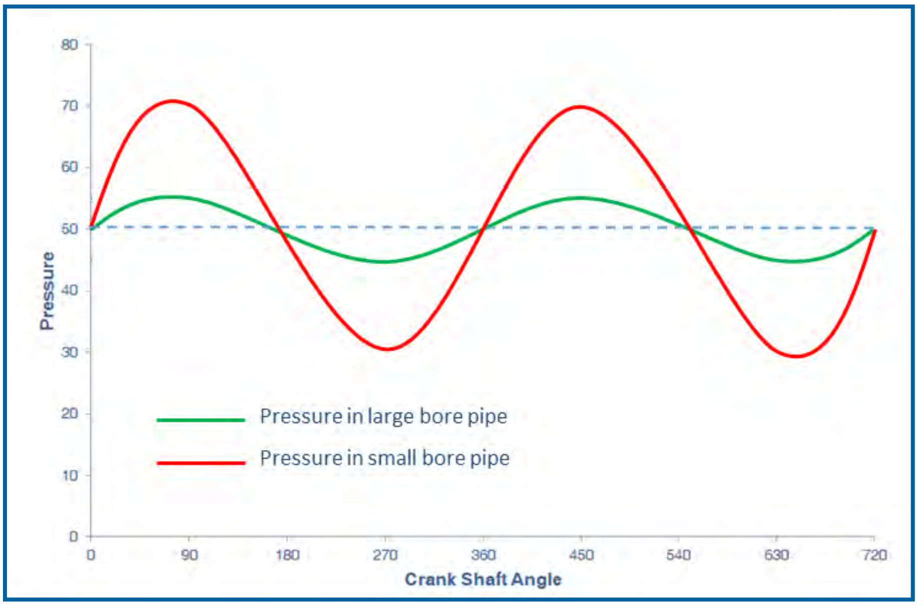

Figure 3 - Relative pressure waves between large bore and small bore pipe

The acceleration head p_{ac} used in the calculation of $NPSH_A$ is therefore related to the bore diameter of the suction pipe, and in addition the length of suction pipe and the reciprocating pump speed and displacement. The calculation of the acceleration head p_{ac} (in metres) is made as follows:

$$p_{ac} = \frac{C_1 LNQS}{D^2}$$

where:

C_1 is the constant for the type of pump and specified in the ANSI standard for Reciprocating Power Pumps (ANSI 6.1-6.5-2000) as 0.066 for triplex pumps and 0.040 for quintuplex pumps

L is the length of suction pipe, m

N is the pump speed, rpm

Q is the pump displacement, m^3/s

S is the specific gravity of liquid

D is the inner diameter of the suction pipe, m

The key point to note in the above calculation of the acceleration head is that the bore diameter of the suction pipe is **squared** and so increasing or decreasing the bore diameter of the suction pipe has a large impact on the acceleration head that must subtracted from the $NPSH_A$. A small bore diameter suction pipe will generate significantly more acceleration losses than a large bore diameter suction pipe and so a much greater reduction in the resulting $NPSH_A$, which if not accounted for correctly could easily be greater than the margin between $NPSH_A$ and $NPSH_R$ normally agreed resulting in catastrophic consequences for the pump.

Furthermore, as increasing the bore diameter decreases the impedance this also has the positive effect of reducing the pulsation in the pump and associated pipework which may eliminate or reduce the need for pulsation dampeners.

Summary

The customer ***is responsible for providing the $NPSH_A$*** for a given system to the pump manufacturer so that the pump manufacturer ensure that a pump with a lower $NPSH_R$ is selected. In the case of reciprocating pumps, Ruhrpumpen should check that the $NPSH_A$ provided by the end-user ***fully accounts for the acceleration head losses*** when using reciprocating plunger pumps, particularly if the end-user is not familiar with reciprocating pumps or the duty could be performed by both a centrifugal and reciprocating pump, in which cases the customer may have mistakenly used the $NPSH_A$ calculation for centrifugal pumps.

Using the correct $NPSH_A$, which fully accounts for the acceleration head loss, will ensure that a suitable reciprocating plunger pump for the duties is selected that will deliver the required performance with low noise and vibration levels and long-term reliability.

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