

Cavitation is the evaporation (formation of vapour bubbles) in a liquid when it flows into a region where the static pressure is reduced to the vapour pressure, and the subsequent condensation (collapse or implosion of the bubbles) when they move into a region where the static pressure is above the vapour pressure.

NPSH – What to Watch for

Dipl. Ing. Peter Hergt
Dr. Gerhard Mollenkopf

Fall in pressure

The transfer of mechanical energy to the pumped fluid, in other words the development of head in the pump, necessarily creates regions within the impeller in which the pressure falls below the static pressure prevailing at the impeller inlet. Depending on the level of the static pressure, the phenomena described above can therefore occur. This can have various negative consequences for pump operation as will be described below.

To avoid these consequences, a certain margin between the static pressure at the impeller inlet and the vapour pressure of the fluid is required. Since the pressure directly at the impeller inlet is difficult to ascertain, the total pressure, i.e. the energy content of the fluid, determined at a specified location upstream of the pump (2 x DN) is chosen as a more easily measured reference value instead. The difference between this total pressure and the vapour pressure is called NPSH (Net Positive Suction Head).

$$NPSH = (P_{1, tot/in, obs} - P_v) / \rho \cdot g =$$

$$\left[\left(P_1 + P_{amb} + \rho \cdot C_1^2 / 2 \right) - P_v \right] / \rho \cdot g$$

The NPSH value of a pump or pumping system is therefore a neutral number which only takes on a meaning when there is agreement about which property of the pump it is to characterize.

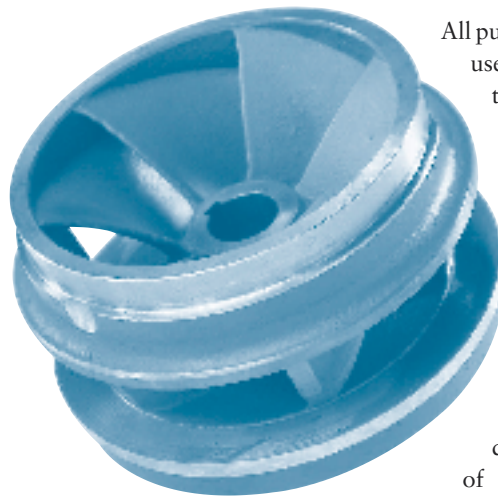


Photo: New Etanorm impeller

All pump manufacturers generally use the criterion of a 3% reduction in the developed head due to cavitation (NPSH₃) as the value reported in sales documentation.

Different pumps can therefore be compared on a common basis. Whether the criterion is used for pump selection and how it is applied depend on the intended use of the pump. The following recommendations provide a starting point for choosing a criterion:

Several criteria applied in practice are:

- Incipient cavitation NPSH_i
- Head drop by a specific percentage 0%
NPSH₀ (= start of the head drop)
- 1 % NPSH₁
- 2 % NPSH₂
- 3 % NPSH₃
- X % NPSH_x
- Breakdown of pumping, fully cavitating NPSH_{full}
- Efficiency drop by a certain value NPSH_{Δη}
- Erosion of a certain quantity of material per unit of time NPSH_{Am}
- Exceeding a certain noise level NPSH_{phon}
- Operation at a certain vibration level NPSH_{vibr}

Photo: Etanorm impeller destroyed by cavitation



Fig. 1 shows the relationship of the criteria in terms of the drop in developed head due to cavitation as a function of flow rate for a volute casing pump.

The operating point with optimum flow entering the impeller (zero incidence angle), at or at least near the pump's best efficiency point, is characterized by a minimum in the criterion for incipient cavitation ($NPSH_1$).

Cavitation bubbles form on the impeller blade surfaces even at relatively high NPSH values, and they must lengthen significantly until the developed head starts to fall measurably as the NPSH is further reduced. It is also worthy of note that just a small reduction of the NPSH available below the $NPSH_3$ value may sometimes make pumping impossible. This fact was formerly occasionally used for self-regulation of a pump in a system (such as a condensate pump).

For a constant operating point ($Q = \text{const.}$), Fig. 2 shows the effects of cavitation on various properties of a pump. When the NPSH available in the system falls below the value of $NPSH_1$, the noise level L_{PA} of the impeller starts to increase. With a further reduction, depending on the quality of the material, erosion caused by the implosion of the vapour bubbles on the impeller vanes can occur (V_{A1} = erosion rate for less resistant materials such as

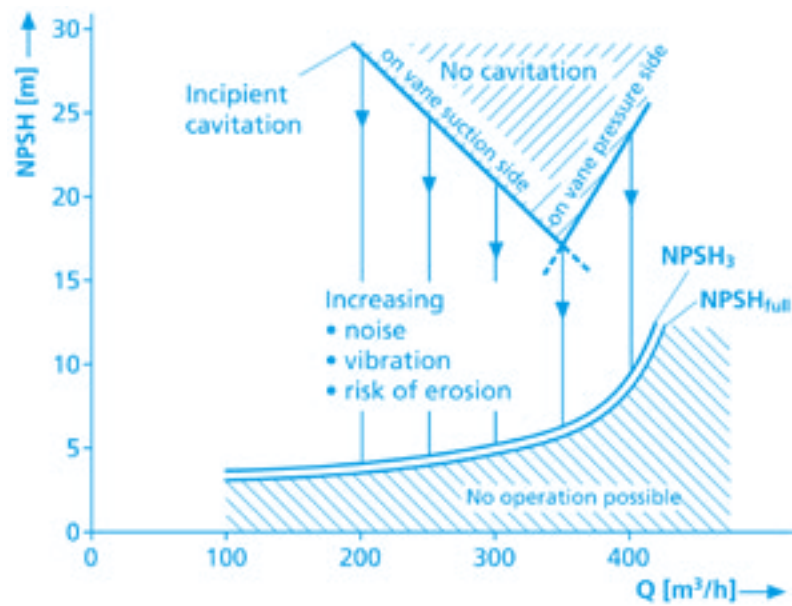


Fig. 1

grey cast iron, V_{A2} = erosion rate for higher grade material such as GSNBZ). It must be kept in mind that the starting point for material erosion is independent of the onset of the reduction of developed head. When the cavitation zone length L_{BL} exceeds a certain value, i.e., when the impeller channels become largely filled with vapour, the noise and material erosion are dramatically reduced. The developed head simultaneously breaks down completely.

In the following the effects of the NPSH values of the pump and / or

system on the initial investment and operating costs are shown.

Fig. 3 shows the impeller diameter as a parameter representing the pump size and the required NPSH as functions of the pump speed of rotation for $Q = 300 \text{ m}^3/\text{h}$ and $H = 36 \text{ m}$.

The following table supplements these data for the speeds 960 / 1450 / 2900 RPM with the power input requirements and list prices as a percentage of the complete pump unit for 2900 RPM.

Assuming that the NPSH available

Fig. 2

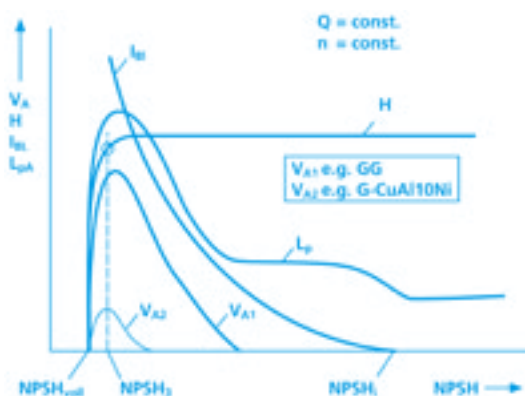
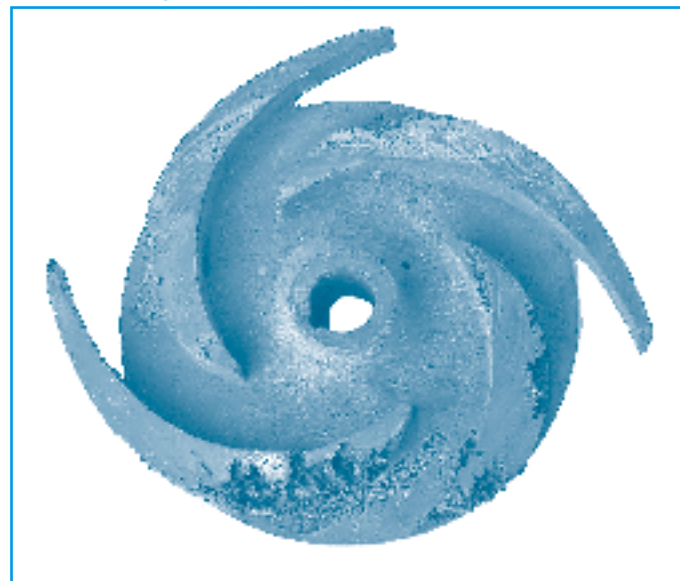


Photo: Destroyed Etaprime impeller



in the system is 3 m, then use of the pump with 2900 RPM would not be possible in this case and the speed $n = 1450$ RPM would have to be chosen instead. An increase in $NPSH_A$ by 2.5 m (for example by increasing the height of the liquid level on the suction side) would bring down the pump unit price by 30%, since then 2900 RPM would be possible.

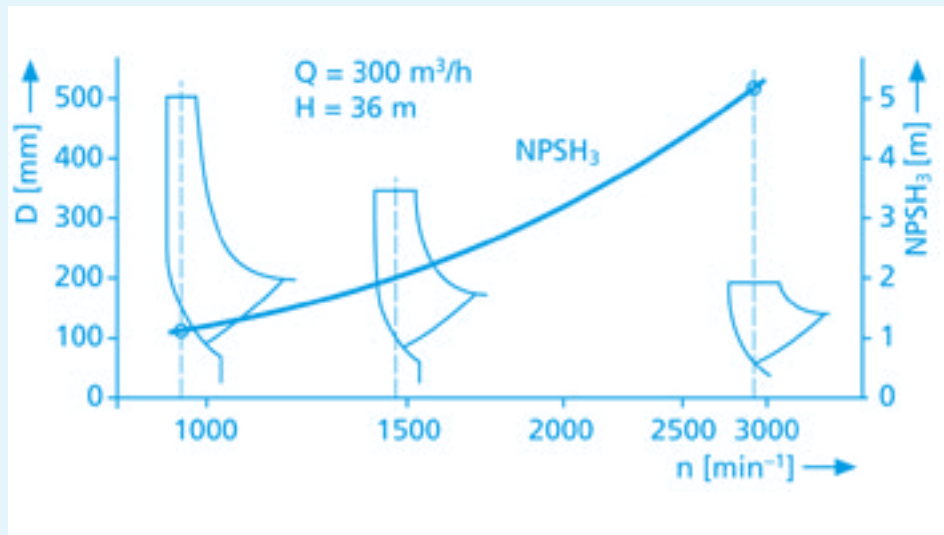


Fig. 3

		960 RPM	1450 RPM	2900 RPM
Rel. pump price	[%]	145	75	35
Rel. pump set price	[%]	240	130	100
Power	[kW]	37.2	35.7	35
Nominal diameter	[mm]	150	125	100

2000 DM/year of operating costs could be saved based on an operating time of 8000 h/year, if the $NPSH_{av}$ could be increased from 1.5 to 5.5 m.

Whether this results in total net savings depends on the individual case as outlined above.

Whether or not such an investment is justified must be checked on a case by case basis.

In terms of operating cost, it can usually be said that the required power input for a given Q and H will drop as the speed of rotation is increased.

The relationship between the $NPSH$ available in the system ($NPSH_{av}$)

$NPSH_A = 1.5$ m	$n = 960$ RPM	$P = 37.2$ kW
$= 2.5$ m	$= 1450$ RPM	$= 35.7$ kW
$= 5.5$ m	$= 2900$ RPM	$= 35$ kW

and the maximum possible speed of rotation is given in Fig. 3 and in the following table: In the present case, in addition to the lower costs for the initial investment, approximately

Photo: Detail of destroyed Etaprime impeller

