4 Suction Characteristic of Centrifugal Pumps

1. General

The basis of the suction capacity of pumps is the lasting pressure of the liquid level within the suction container, thus in an open container this is the **atmospheric air pressure.** Its median value at sea level is **pb = 101320 N/m²** (= 1.0132 bar) and is equal to the pressure of a water column of 10.33 m height at 4° C. Subsequently the normal air pressure should enable the pump to move water from a dept of app. 10 m. The geodesic suction head actually obtainable $H_{S\,geo}$ is, however, substantially smaller. The reasons for this are:

a) Liquids evaporate when the **vapour pressure p_D N/m²,** which is dependent on the temperature, is met. At the highest point of the suctioned liquid column the pressure can therefore only drop to this value. (Refer to EDUR work sheet “State parameters of water”).

b) **Head losses** occur in the suction line, specifically due to the velocity of fluid – $v_S^2/2\,g$ [m], as well as due to fluid friction, directional changes and changes in diameter **H_{VS} [m].**

c) An additional head loss is caused due to friction and velocity changes when the liquid enters into the vane channels. In order to prevent the generation of steam, the total energy head (static head plus the velocity head $v_S^2/2g$ listed under b) must be greater than the vapour head of the transmitted liquid in the entry diameter of the pump by a certain amount. This difference in energy is designated with the English expression **NPSH [m]**, the abbreviation of “Net positive suction head”, and is identical with the previously German expression “Haltedruckhöhe H_H”.

When installing the pump above the suction water level the height difference $H_{S\,geo}$ with horizontal shaft and open suction container may therefore not be greater than

$$H_{S\,geo} = \frac{p_b}{g \cdot \rho} - \frac{p_D}{g \cdot \rho} - H_{VS} - NPSH \qquad (12)$$

with the drop acceleration g in m/s² and the density ρ in kg/m³.
If the suction container is closed, then the absolute head in container $(p_l + p_b)/g{\cdot}\rho$ takes the place of $p_b/g{\cdot}\rho$, whereby p_l designates the excess pressure in the container. With the pressure value in bar, the density ρ in kg/dm³ and g = 9.81 m/s² the equation (12) receives the generally valid shape:

$$H_{S\,geo} = \frac{10{,}2 \cdot (p_l + p_b - p_D)}{\rho} - H_{VS} - NPSH \;\; m \qquad (13)$$

In case of **negative pressure** in the suction container p_l gets a negative sign.

2. The Required NPSH (NPSHR)

The smallest value of NPSH, at which the pump under the actual working conditions (rotational speed, transmission flow, pump head pressure, transmitted liquid) can be operated continuously, can be read off from the characteristic curves outlined in the EDUR work documents. The NPSH thus defined is also designated with NPSHR (NPSH required). It is not a constant value but significantly increases with an increased transmission flow (Fig. 6).
When comparing rotary pumps with differing specific rotational speed, one will notice that the NPSH value increases with increasing specific rotational speed.
Therefore the suction efficiency diminishes. Pumps with high speeds are therefore in cold water applications only able to overcome small suction heads or can only be operated with a tank head pressure. An improvement is possible by choosing a smaller operational speed, although at a loss in economy.

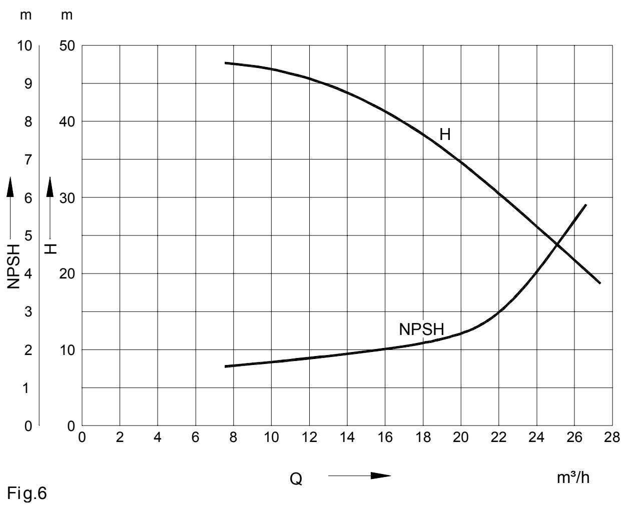

Fig.6

3. The Available NPSH (NPSHA).

For an existing or planned system the NPSHA available at the entry diameter of the pump can be determined when equation (13) is resolved according to NPSH:

$$\text{NPSHA} = \frac{10{,}2 \cdot (p_l + p_b - p_D)}{\rho} - H_{VS} - H_{S\,geo} \quad \text{m} \quad (14)$$

If the liquid level is above the pump then the geodesic tank head pressure $H_{z\,geo}$ is inserted instead of $H_{s\,geo}$ and equation (14) evolves into:

$$\text{NPSHA} = \frac{10{,}2 \cdot (p_l + p_b - p_D)}{\rho} - H_{VS} + H_{Z\,geo} \quad \text{m} \quad (15)$$

When projecting a pump plant, choosing a pump with an NPSHR at least 0.5 m smaller than the available NPSHA is recommended.

The NPSHA is determined on a pump that is operating by measuring the pressure p_1 at the suction flange of the pump from the equation

$$\text{NPSHA} = \frac{10{,}2 \cdot (p_l + p_b - p_D)}{\rho} + \frac{v_1^2}{2 \cdot g} \quad \text{m} \quad (16)$$

with the previously named units for the pressures and the density. In case of a negative pressure p_1 is inserted with a negative sign. v_1 is the median flow velocity in the entry diameter A_1 of the pump, $v_1 = Q/A_1$ with Q in m³/s and A_1 in m.

4. The Influence of Air Pressure

The atmospheric air pressure has a significant effect on the suction efficiency. Aside from the fluctuations due to weather of ± 5% at the locally common median value, the air pressure decreases with an increase in altitude.

Altitude above sea level	0	500	1000	2000	3000	m
Median air pressure p_b	1,013	0,955	0,899	0,794	0,70	bar

5. Hot Water Pumps

Steam head plays a significant role when transmitting hot water. If a liquid is boiling, $p_l + p_b = p_D$ and $H_{s\,geo}$ in equation (12) becomes negative. A tank head pressure $H_{z\,geo}$ is therefore necessary. Furthermore, equation (14) is simplified to

$$\text{NPSHA} = H_{Z\,geo} - H_{VS} \quad \text{m} \quad (17)$$

Even when temperatures are still below the boiling point, the suction efficiency is diminished so that even at that point a tank head pressure might be necessary. Fig. 7 illustrates the relationship.

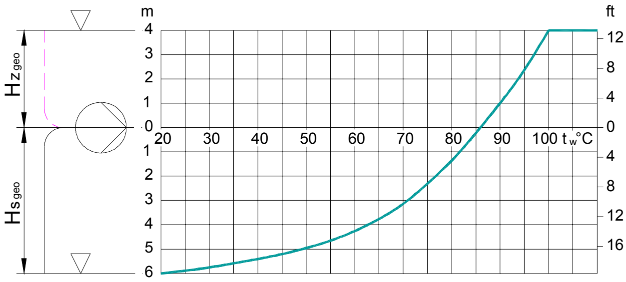

Fig.7

It is assumed that a pump at a water temperature of 20°C is able to overcome a geodesic suction head of $H_{S\,geo} = 6$ m. In case of an increasing water temperature and therefore increasing vapour pressure, $H_{S\,geo}$ will decrease and at a water temperature of $t_W \approx 87°C$ changes to a tank head pressure that, when the boiling point is reached, has the constant median value of $H_{Z\,geo} = 4$ m.

EDUR – Work sheet
„Parameters of Water“

Absolute Steam Pressure p_D and Density ρ depend on Water Temperature t

t °C	p_D bar	ρ kg/dm^3	t °C	p_D bar	ρ kg/dm^3	t °C	p_D bar	ρ kg/dm^3	t °C	p_D bar	ρ kg/dm^3
0	0.0061	0.9998	40	0.0738	0.9923	80	0.4736	0.9716	155	5.4330	0.9121
1	0.0066	0.9999	41	0.0778	0.9919	81	0.4933	0.9710	160	6.1810	0.9073
2	0.0071	0.9999	42	0.0820	0.9915	82	0.5133	0.9704	165	7.0080	0.9024
3	0.0076	0.9999	43	0.0864	0.9911	83	0.5344	0.9697	170	7.9200	0.8973
4	0.0081	1.0000	44	0.0910	0.9907	84	0.5557	0.9691	175	8.9240	0.8921
5	0.0087	1.0000	45	0.0958	0.9902	85	0.5782	0.9684	180	10.0270	0.8869
6	0.0093	1.0000	46	0.1009	0.9898	86	0.6011	0.9678	185	11.2330	0.8815
7	0.0100	0.9999	47	0.1061	0.9893	87	0.6251	0.9671	190	12.5510	0.8760
8	0.0107	0.9999	48	0.1116	0.9889	88	0.6495	0.9665	195	13.9870	0.8704
9	0.0115	0.9998	49	0.1174	0.9885	89	0.6751	0.9658	200	15.5490	0.8647
10	0.0123	0.9997	50	0.1234	0.9880	90	0.7011	0.9652	205	17.2510	0.8588
11	0.0131	0.9996	51	0.1297	0.9876	91	0.7284	0.9645	210	19.0770	0.8528
12	0.0140	0.9996	52	0.1361	0.9871	92	0.7561	0.9638	215	21.0690	0.8466
13	0.0150	0.9994	53	0.1430	0.9866	93	0.7852	0.9631	220	23.1980	0.8403
14	0.0160	0.9993	54	0.1500	0.9862	94	0.8146	0.9624	225	25.5130	0.8339
15	0.0170	0.9992	55	0.1575	0.9857	95	0.8455	0.9617	230	27.9760	0.8273
16	0.0182	0.9990	56	0.1651	0.9852	96	0.8769	0.9610	235	30.6450	0.8205
17	0.0193	0.9988	57	0.1732	0.9847	97	0.9100	0.9603	240	33.4780	0.8136
18	0.0206	0.9987	58	0.1815	0.9842	98	0.9430	0.9596	245	36.5360	0.8065
19	0.0220	0.9985	59	0.1902	0.9837	99	0.9780	0.9588	250	39.7760	0.7992
20	0.0234	0.9983	60	0.1992	0.9832	100	1.0133	0.9581	255	43.2610	0.7917
21	0.0248	0.9980	61	0.2087	0.9826	102	1.0881	0.9566	260	46.9430	0.7839
22	0.0264	0.9978	62	0.2184	0.9821	104	1.1672	0.9551	265	50.8940	0.7760
23	0.0281	0.9976	63	0.2286	0.9816	106	1.2509	0.9537	270	55.0580	0.7678
24	0.0298	0.9974	64	0.2391	0.9811	108	1.3395	0.9522	275	59.5080	0.7594
25	0.0317	0.9971	65	0.2502	0.9805	110	1.4327	0.9507	280	64.2020	0.7505
26	0.0336	0.9968	66	0.2615	0.9799	112	1.5321	0.9491	285	69.2000	0.7417
27	0.0356	0.9965	67	0.2734	0.9793	114	1.6367	0.9476	290	74.4610	0.7321
28	0.0378	0.9963	68	0.2856	0.9788	116	1.7470	0.9460	295	80.0500	0.7226
29	0.0400	0.9960	69	0.2984	0.9782	118	1.8634	0.9445	300	85.9270	0.7122
30	0.0424	0.9957	70	0.3116	0.9777	120	1.9854	0.9429	305	92.1440	0.7017
31	0.0449	0.9954	71	0.3254	0.9771	122	2.1151	0.9412	310	98.7000	0.6906
32	0.0475	0.9951	72	0.3396	0.9765	124	2.2491	0.9396	315	105.6100	0.6791
33	0.0503	0.9947	73	0.3544	0.9759	126	2.3940	0.9379	320	112.8900	0.6669
34	0.0532	0.9944	74	0.3696	0.9753	128	2.5442	0.9363	325	120.5600	0.6541
35	0.0562	0.9941	75	0.3856	0.9747	130	2.7013	0.9346	330	128.6300	0.6404
36	0.0594	0.9937	76	0.4019	0.9741	135	3.1310	0.9302	340	146.0500	0.6102
37	0.0628	0.9934	77	0.4191	0.9735	140	3.6140	0.9258	350	165.3500	0.5743
38	0.0662	0.9930	78	0.4365	0.9729	145	4.1550	0.9214	360	186.7500	0.5275
39	0.0699	0.9926	79	0.4549	0.9722	150	4.7600	0.9168	370	210.5400	0.4518