ความสูญเสียในทางดูด
NET POSITIVE SUCTION HEAD (NPSH)

Net Positive Suction Head ($NPSH_R$)

$NPSH_R$ is dependent upon the pump design and is determined by the pump manufacturer. $NPSH_R$ is an important value which greatly contributes to the successful operation of a centrifugal pump. It is the amount of positive head in metre of liquid absolute required at the pump suction to prevent vaporization or cavitation of the fluid. $NPSH_R$ values usually vary with pump capacity and are based on clear water with a specific gravity of 1.0.

Net Positive Suction Head Available ($NPSH_A$)

$NPSH_R$ is dependent upon the system in which the pump operates. **NPSHA** is the amount of head or pressure that is available to prevent vaporization or cavitation of the fluid in the system. It is the amount of head available above the vapor pressure of the liquid at a specified temperature and is measured in metre of liquid absolute.

$$NPSH_A = \frac{(P_1 - P_V) \times 10.20 + Z_1 - H_{fs}}{Sp.Gr.}$$

Where P_1 = Absolute pressure on liquid surface in bar.
Absolute pressure is equal to gage reading plus atmospheric pressure.

P_v = Vapor pressure of liquid in bar at pump temperature.

Z_1 = Height of liquid surface above pump suction, measured in metre. If surface is blow pump, use minus sign.

H_{fs} = Friction loss in metre of liquid in suction pipe including entrance loss from tank to pipe, and losses in all valves, elbows and other fittings.

Sp. Gr. = Specific gravity of liquid being handled.

$NPSH_A$ vs. $NPSH_R$ Comparison

To prevent vaporization of cavitation of the liquid in the suction side of the pump and to ensure rated pump performance, $NPSH_A$ must be greater of equal to the $NPSH_H$. We recommend a safety margin of 0.5 metre.

That is : $NPSH_A > NPSH_R + 0.5$ metre.

ความสามารถปั๊มน้ำที่สามารถดูดน้ำขึ้นได้
Maximum Suction Lift

Calculation of Maximum Suction Lift

The theoretical limit of the suction lift H will be equivalent to the barometric pressure. At sea level this is 10.3 metres equivalent to 760 mm mercury (Hg).In practice, this value is reduced by the following factors.

H_f : Friction loss in suction pipe and foot valve.

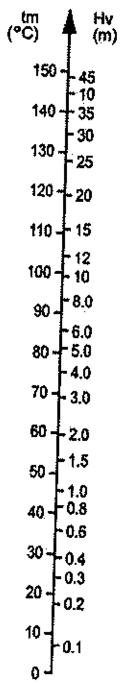
H_d : Vapour pressure of the pumped liquid. Vapour formation (cavitation) should be avoided on the suction side.

NPSH : Stands for **N**et **P**ostitve **S**uction **H**ead. Pressure drop from the suction port to the place in the impeller where the lowest pressure occurs (decides whether cavitation occurs in the pump).

H_s : Safety. When deciding this value, estimate the possible variations in Hf, Hd and NPSH, for instance increased friction losses due to deposits in the suction pipe, changes in water tem perature and variations in pump ca pacity Q.

H can be calculated from the following formula:

$H = H_b - NPSH - H_f - H_d - H_s$



Vapour pressure

The lowest barometric pressure Hb (atmospheric pressure) which occurs should be included in the calculation. For each pump , an NPSH curve is shown, from which the NPSH value at a given capacity can be determined.

H_b : Barometric pressure (atmospheric pressure)

H_b : $\frac{pb}{p \times g}$ (m)

P_b : Barometric pressure (Pa)

P : Density of liquid (kg/m^3)

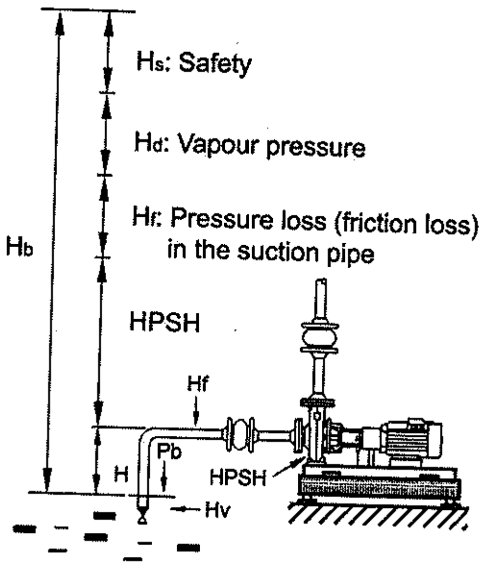
g : 9.81 m/s^2

H_b : $\frac{\Delta p}{p \times g}$ (m)

Δp: Loss of pressure in suction pipe and foot valve (Pa)

If **H** is negative (most relevant for hot liquisa), the pump must operate at a static inlet pressure of H (m) to avoid cavitation.

Cavitation or vapour formation in the pump, as a result of the local pressure of the liquid falling below its vapour pressure, will cause noise and may damage the pump.



การคำนวณความสูญเสียในเส้นท่อ

Table of Head Losses

Head Losses in Ordinary Water Pipes

Small figures indicate the velocity of water in m/sec
Large figures indicate head loss in metres
per 100 metres of straight pipes.

Quantity of Water			Head Losses in Ordinary Water Pipes											
			Nominal Pipe Diameter in inches and Internal diameter in mm											
m³/h	Litres/ min	Litres/ sec	1/2" 15.75	3/4" 21.25	1" 27.00	1 1/4" 35.75	1 1/2" 41.25	2" 52.50	2 1/2" 68.00	3" 80.25	3 1/2" 92.50	4" 105.0	5" 130.0	6" 155.5
0.6	10	0.16	0.855 9.910	0.475 20402	0.292 0.784									
0.9	15	0.25	1.282 20.11	0.705 4.862	0.438 1.570	0.249 0.416								
1.2	20	0.33	1.170 33.53	0.940 8.035	0.584 2.588	0.331 0.677	0.249 0.346							
1.5	25	0.42	2.138 49.93	1.174 11.91	0.730 3.834	0.415 1.004	0.312 0.150							
1.8	30	0.50	2.585 69.34	1.409 16.50	0.786 5.277	0.498 1.379	0.374 0.700	0.231 0.223						
2.1	35	0.58	2.993 91.54	1.844 21.17	1.022 6.949	0.581 1.811	0.436 0.914	0.269 0.291						
2.4	40	0.67		1.879 27.66	1.168 8.82	0.684 2.290	0.499 1.160	0.308 0.368						
3.0	50	0.83		2.349 41.40	1.460 13.14	0.830 3.403	0.623 1.719	0.385 0.544	0.229 0.159					
3.6	60	1.00		2.819 57.74	1.751 18.28	0.986 4.718	0.748 2.375	0.462 0.751	0.275 0.218					
4.2	70	1.12		3.288 76.49	2.043 24.18	1.162 6.231	0.873 3.132	0.539 0.988	0.321 1.287	0.231 0.131				
4.8	80	1.33			2.335 30.87	1.328 7.940	0.997 3.988	0.618 1.254	0.367 0.363	0.263 1.164				
5.4	90	1.50			2.627 38.30	1.494 9.828	1.122 4.927	0.693 1.551	0.413 0.449	0.296 0.203				
6.0	100	1.67			2.919 46.49	1.660 11.90	1.247 5.972	0.770 1.875	0.459 0.542	0.329 0.244	0.248 0.124			
7.5	125	2.08			3.649 70.41	2.075 17.93	1.558 8.967	0.962 2.802	0.574 0.809	0.412 0.365	0.310 0.185	0.241 0.101		
9.0	150	2.50				2.490 25.11	1.870 12.53	1.154 3.903	0.668 1.124	0494 0.506	0.372 0.256	0289 0.140		
10.5	175	2.92				2.904 33.32	2.182 16.66	1.347 5.179	0.803 1.488	0.576 0.670	0.434 0.338	0.337 0.184		
12	200	3.33				3.319 42.75	2.493 21.36	1.539 6.624	0.918 1.901	0.659 0.855	0.496 0.431	0.365 0.234	0.251 0.018	
15	250	4.17				4.149 64.86	3.117 32.32	1.924 10.30	1.147 2.860	0.823 1.282	0.620 0.646	0.461 0.350	0.314 0.126	
18	300	5.00					3.740 45.52	2.309 14.04	1.377 4.009	0.988 1.792	0.744 0.903	0.577 0.488	0.377 0.175	0.283 0.074
24	400	6.67					4.987 78.17	3.078 24.04	1.836 6.828	1.317 3.053	0.992 1.530	0.770 0.829	0.502 0.294	0.351 0.124
30	500	8.33						3.848 36.71	2.295 10.40	1.647 4.622	1.240 2.315	0.962 1.254	0.628 0.445	0.438 0.187
36	600	10.0						4.618 51.84	2.753 14.62	1.976 6.505	1.488 3.261	1.155 1.757	0.753 0.623	0.526 0.260
42	700	11.7							3.213 19.52	2.306 8.693	1.736 4.356	1.347 2.345	0.879 0.831	0.614 0.347
48	800	13.3							3.671 25.20	2.835 11.18	1.984 5.582	1.540 3.009	1.005 1.066	0.702 0.445
54	900	15.0							4.130 31.51	2.964 13.97	2.232 6.983	1.732 3.762	1.130 1.328	0.790 0.555
60	1000	16.7							4.589 38.43	3.294 17.06	2.480 8.521	1.925 4.595	1.265 1.616	0.877 0.674
75	1250	20.8								4.117 26.10	3.100 13.00	2.408 7.010	1.570 2.458	1.097 1.027
90	1500	25.0								4.941 36.97	3.720 18.42	2.887 9.892	1.883 3.468	1.318 1.444
105	1750	29.2									4.340 24.76	3.368 13.30	2.197 4.665	1.535 1.934
120	2000	33.3									4.960 31.94	3.850 17.16	2.511 5.995	1.754 2.496
150	2500	41.7										4.812 26.26	3.139 9.216	2.193 3.807
180	3000	50.0											3.767 13.05	2.832 5.417
240	4000	66.7											5.023 22.27	3.509 8.926
300	5000	83.3												4.386 14.42
90° bands, slide valves			1,0	1,0	1,1	1,2	1,3	1,4	1,5	1,6	1,6	1,7	2,0	2,5
T-pieces, non-return valves			4,0	4,0	4,0	5,0	5,0	5,0	6,0	6,0	6,0	7,0	8,0	9,0

The table is calculated in accordance with H. Lang's new formula a = 0.02 and for a water temperature of 10°C

The head loss in bends, slide valves, T-pieces and non-return valves is equivalent to the metres of straight pipes stated in the last two lines of the table. To find the head loss in foot valves, multiply the loss in T-pieces by two.

การคำนวณความสูญเสียในเส้นท่อ
Table of Head Losses

Head Losses in Ordinary Water Pipes

Quantity of Water			Head Losses in Ordinary Water Pipes							
m^3/h	Litres/min	Litres/sec	Nominal Pipe Diameter in inches and Internal diameter in mm							
			8"	10"	12"	14"	16"	18"	20"	24"
51	850	14.17	0.439 0.09							
54	900	15.00	0.465 0.1							
57	950	15.83	0.491 0.12							
60	1000	16.67	0.561 0.13							
66	1100	18.33	0.568 0.15							
72	1200	20.00	0.62 0.18							
78	1300	21.67	0.671 0.21							
84	1400	23.33	0.723 0.25							
90	1500	25.00	0.775 0.28							
96	1600	26.67	0.826 0.32							
102	1700	28.33	0.876 0.36							
108	1800	30.00	0.93 0.40	0.59 0.12						
114	1900	31.67	0.981 0.43	0.622 0.14						
120	2000	33.33	1.03 0.47	0.655 0.15						
132	2200	36.67	1.14 0.57	0.721 0.18						
144	2400	40.00	1.24 0.66	0.786 0.21						
156	2600	43.33	1.34 0.78	0.852 0.26	0.6 0.10					
168	2800	46.67	1.45 0.89	0.917 0.29	0.646 0.12					
180	3000	50.00	1.55 1.01	0.983 0.33	0.692 0.13	0.573 0.08				
210	3500	58.33	1.81 1.37	1.15 0.44	0.81 0.18	0.668 0.11				
240	4000	66.67	2.07 1.76	1.31 0.56	0.923 0.24	0.764 0.14				
270	4500	75.00	2.32 2.19	1.47 0.70	1.04 0.30	0.86 0.18	0.658 0.09			
300	5000	83.33	2.58 2.68	1.64 0.86	1.15 0.35	0.955 0.22	0.731 0.11			
360	6000	100.00	3.1 3.81	1.96 1.21	1.38 0.50	1.15 0.32	0.877 0.16			
420	7000	116.67	3.61 5.1	2.29 1.61	1.61 0.66	1.34 0.43	1.02 0.21	0.808 0.12		
480	8000	133.33	4.13 6.64	2.62 2.09	1.84 0.87	1.53 0.55	1.17 0.28	0.924 0.15		
540	9000	150.00	4.65 8.34	2.96 2.62	2.08 1.09	1.72 0.68	1.31 0.34	1.04 0.19		
600	10000	166.67	5.16 10.14	3.28 3.2	2.31 1.33	1.91 0.83	1.46 0.42	1.15 0.24		
720	12000	200.00	6.2 14.41	3.93 4.57	2.77 1.88	2.29 1.17	1.75 0.58	1.38 0.33	1.11 0.19	
840	14000	233.33	7.23 19.52	4.59 6.13	3.23 2.51	2.67 1.56	2.05 0.79	1.62 0.45	1.3 0.26	
960	16000	266.67	8.26 25.35	5.24 7.93	3.69 3.24	3.06 2.02	2.34 1.01	1.85 0.57	1.49 0.33	1.03 0.13
1080	18000	300.00		5.9 9.97	4.15 4.07	3.44 2.51	2.63 1.27	2.08 0.71	1.67 0.41	1.16 0.16
1200	20000	333.33		6.55 12.16	4.61 4.98	3.82 3.09	2.92 1.55	2.31 0.86	1.86 0.5	1.28 0.20
1500	25000	416.67		8.19 18.70	5.77 7.75	4.77 4.79	3.65 2.39	2.89 1.33	2.32 0.78	1.61 0.31
1800	30000	500.00			6.92 11.04	5.73 6.84	4.38 3.39	3.46 1.87	2.79 1.1	1.93 0.44
2100	35000	583.33			8.07 14.92	6.68 9.23	5.12 4.56	4.04 2.53	3.25 1.47	2.25 0.58
2400	40000	666.67			9.23 19.42	7.64 11.96	5.85 5.91	4.62 3.26	3.72 1.9	2.57 0.76
2700	45000	750.00			10.38 24.43	8.59 15.02	6.58 7.42	5.19 4.09	4.18 2.38	2.89 0.94
3000	50000	833.33				9.55 18.50	7.31 9.08	5.77 5.02	4.64 2.9	3.21 1.15
3300	55000	916.67					8.04 10.94	6.35 6.07	5.11 3.51	3.53 1.39
3600	60000	1000.00					8.77 12.98	6.93 7.24	5.58 4.20	3.86 1.65
3900	65000	1083.33					9.5 15.23	7.5 8.4	6.04 4.85	4.18 1.93
4200	70000	1166.67					10.2 17.38	8.08 9.76	6.51 5.64	4.5 2.21
4500	75000	1250.00					11 20.24	8.66 11.24	6.97 6.42	4.82 2.51

1 Bar = 10.221 $m.H_2O$

The table is calculated in accordance with H. Land's new formula
a = 0.02 and for a water temperature of 10°C

สูตรการคำนวณพลังงาน
Some Useful Formulae

1. Brake Horsepower or Brake Kilowatt

To determine the horse power or kilowatt required, the following formulae can be used:

a) Brake horsepower $= \dfrac{\text{Total Head (ft)} \times \text{IGPM} \times \text{Sp.GR.}}{\text{efficiency \%} \times 33}$

b) Brake horsepower $= \dfrac{\text{Total Head (ft)} \times \text{USGPM} \times \text{Sp.GR.}}{\text{efficiency \%} \times 39.6}$

c) Brake horsepower $= \dfrac{\text{Total Head (m)} \times \text{m}^3\text{/hr} \times \text{Sp.GR.}}{\text{efficiency \%} \times 3.67}$

2. Affinity Law

When the pump speed is changed from n1 to n2, the following relations exist:

$$\frac{Q^2}{Q_1} = \frac{n_2}{n_1} \qquad \frac{H_2}{H_1} = \left(\frac{n_2}{n_1}\right)^2 \qquad \frac{P_2}{P_1} = \left(\frac{n_2}{n_1}\right)^3$$

When n = Speed, Q = Flow, H = Head, P = Power

3. Hazen Willams Formula

The Hazen and williams empirical formula is the most widely used for calculating friction losses for water flowing under turbulent conditions. And it reads:

$$hf = 0.002083\,L \left(\frac{100}{C}\right)^{1.85} \times \frac{usgpm^{1.85}}{d^{4.8655}}$$

Where h_1 = Friction losses in feet.

L = Length of pipe including equivalent lengths for loss through fittings in feet.

C = A friction factor for various types of pipe.

d = Internal diameter of circular pipe.

Type of pipe (example)	Av.value C for clean pipe	Commonly used C for Design purpose
Cement-Asbestos	150	140
Fibre	150	140
Copper,brass, lead or tin	140	130
Wood-stave	120	110
Welded & seamless steel	130	100
Concrete	120	100
Corrugated steel	60	60

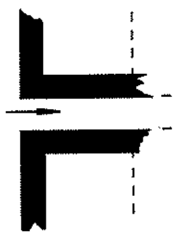
Flow Through Orifices And Nozzles

The approximate discharge through orifices and nozzles can be calculated by the following formulae:

$$Q = 19.636\, C d_1^2 \sqrt{h} \sqrt{\frac{1}{1-\left(\frac{d_1}{d_2}\right)^4}}$$ where $\frac{d_1}{d_2}$ is greater than 0.3

$$Q = 19.636\, C d_1^2 \sqrt{h}$$ where $\frac{d_1}{d_2}$ is less than 0.3

Where Q = Flow in US gpm
d_1 = Dia. of orifice or nozzle opening in inches
h = Differential head at orifice in feet of liquid
d_2 = Dia. of pipe in which orifice is placed in inches
C = Discharge coefficent (typical values for water)

RE-ENTRANCE TUBE	SHARP EDGED	SQUARE EDGED	RE-ENTRANCE TUBE	SQUARE EDGED	WELL ROUNDED
					
length 1/2 to 1 dia.		stream clear both sides	length 2.5 dia.	full flows	
C = .52	C = .61	C = .61	C = .73	C = .82	C = .98

***Approximate flow through venturi tube can be read as:**

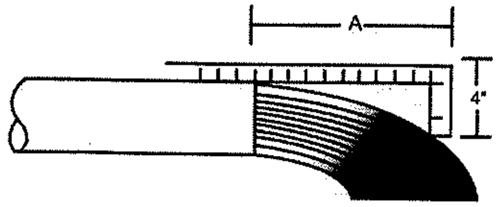
$$Q = 19.05\, d_1^2 \sqrt{H} \sqrt{\frac{1}{1-\left(\frac{d_1}{d_2}\right)^4}}$$ for any venturi tube

$$Q = 19.05\, d_1^2 \sqrt{H}$$ for venturi tube where $d_1 = 1/3\, d_2$

Where Q = Flow in US gpm
d_1 = Diameter of venturi throats in inches
d_2 = Diameter of main pipe in inches
H = Differential head between upstream end and throat (ft)

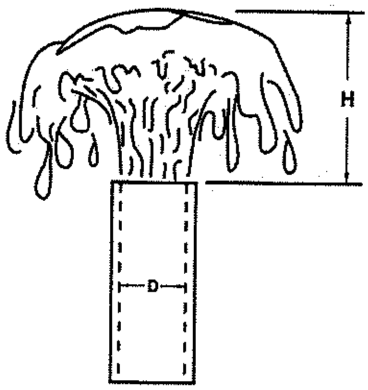
The above formulae are suitable for any liquid with viscosities similar to water.

Flow Estimation



DISCHARGE RATE IN GALLONS PER MINUTE (GPM) FOR LARGE CAPACITY SYSTEMS

Horizontal Distance (x) (in Inches)	Nominal Pipe size (in Inches)											
	1	1 1/4	1 1/2	2	2 1/2	3	4	5	6	8	10	12
	Discharge Rate in Gallons Per Minute (GPM)											
4	5.7	9.8	13.3	22.0	31	48	83					
5	7.1	12.2	16.6	27.5	39	61	104	163				
6	8.5	14.7	20.0	33.0	47	73	124	195	285			
7	10.0	17.1	23.2	38.5	55	85	146	228	334	380		
8	11.3	19.6	26.5	44.0	62	97	166	260	380	665	1060	
9	12.8	22.0	29.8	94.5	70	110	187	293	430	750	1190	1660
10	14.2	24.5	33.2	55.5	78	122	208	326	476	830	1330	1850
11	15.6	27.0	36.5	60.5	86	134	229	360	525	915	1460	2200
12	17.0	29.0	40.0	66.0	94	146	250	390	570	1000	1600	2220
13	18.5	31.5	43.0	71.5	102	158	270	425	620	1080	1730	2400
14	20.0	34.0	46.5	77.0	109	170	292	456	670	1160	1860	2590
15	21.3	36.3	50.0	82.5	117	183	312	490	710	1250	2000	2780
16	22.7	39.0	53.0	88.0	125	196	334	520	760	1330	2120	2960
17		41.5	56.5	93.0	133	207	355	550	810	1410	2260	3140
18			60.0	99.0	144	220	375	590	860	1500	2390	3330
19				100.0	148	232	395	820	910	1580	2520	3500
20					156	244	415	650	950	1660	2660	3700
21						256	435	685	1000	1750	2800	3890
22							460	720	1050	1830	2920	4060
23								750	1100	1910	3060	4250
24									1140	2000	3200	4440



Flow from Vertical Pipes

Flow from a vertical pipe can be estimated by measuring the vertical height, *H*, as shown in Figure 1.

$$Q = 5.68KD^2 H^{1/2}$$

where

Q = discharge, gpm

D = inside diameter of pipe, in

H = vertical height of water jet, in

K = a constant, varying from 0.87 to 0.97 for pipes 2 to 6 in diameter and H equal to 6 to 24 in

Flow from Vertical Pipes, gpm

Nominal I.D. PIPE, IN.	Verttical Height, *H*, of Water Jet, in: 3	3.5	4	4.5	5	5.5	6	7	8	10	12
2	38	41	44	47	50	53	56	61	65	74	82
3	81	89	96	103	109	114	120	132	141	160	177
4	137	151	163	174	185	195	205	222	240	269	299
6	318	349	378	405	430	455	480	520	560	635	700
8	567	623	384	730	776	821	868	945	1020	1150	1270
10	950	1055	1115	1200	1280	1350	1415	1530	1640	1840	2010