PDHonline Course M346 (2 PDH)

NPSH – Concept and Calculations

Instructor: Jurandir Primo, PE

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PDH Online | PDH Center

5272 Meadow Estates Drive
Fairfax, VA 22030-6658
Phone: 703-988-0088
www.PDHonline.com

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NPSH – Concept and Calculations

1. NET POSITIVE SUCTION HEAD:

The **NPSH** called as the **Net Positive Suction Head** is a necessary calculation whenever an installation of a pump is designed in order to prevent cavitation for safe and reliable operation of the system.

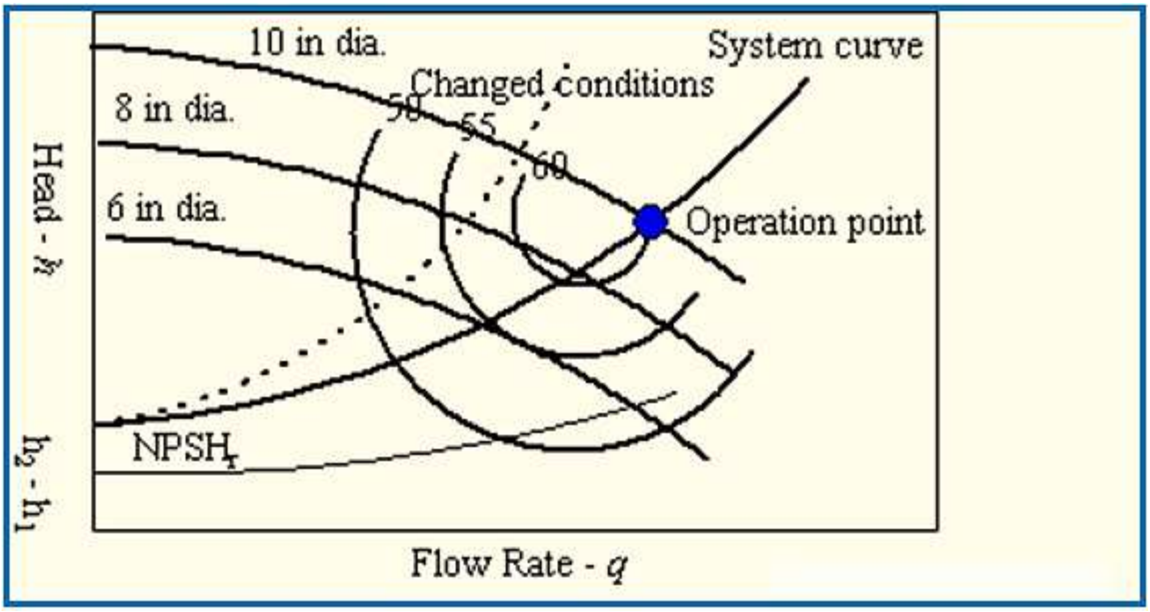
The suction gauge is defined as the absolute feet taken on the suction nozzle corrected to pump centerline, minus the Vapor Pressure in feet absolute corresponding to the temperature of the liquid, plus Velocity Head at this point. There are two conditions to calculate an NPSH pumping system, as described below:

a. Available NPSH - $NPSH_a$:

$NPSH_a$: Called as **Available Net Positive Suction Head** is the normal operation head determined during design and construction or determined experimentally from a physical system.

b. Required NPSH - $NPSH_r$:

$NPSH_r$: Called as **Required Net Positive Suction Head** is the maximum head required by the pump in order to prevent cavitation for safe and reliable operation of the pump. Generally is determined experimentally by the pump manufacturer and is part of the documentation of the pump with a graphic named pump curve as the example below.



Note: The available $NPSH_a$ of the system should always exceed the required $NPSH_r$ of the pump to avoid vaporization and cavitation of the impellers and pump inner walls. The $NPSH_a$ is also calculated to avoid that head loss in the suction pipe and in the pump casing, local velocity accelerations and pressure decreases, start boiling the fluid on the impeller surface.

Obs.: Note that the required **$NPSH_r$** increases with the square capacity. Pumps with double-suction impellers have lower $NPSH_r$ than pumps with single-suction impellers. A pump with a double-suction impeller is considered hydraulically balanced but is susceptible to an uneven flow on both sides with improper pipe-work. The terms commonly used to calculate the NPSH in pumping systems are:

2. STATIC HEAD:

Static head: Is measured from the liquid level to the centerline of the pump. If the liquid level is above the pump centerline you will have a **positive number**. If the level is below the centerline you will have a **negative number**.

3. PRESSURE HEAD:

Atmospheric pressure: Is **14.7 psi at sea level** to be converted to feet, using a formula to the static head where ever you have an open tank. If the fluid is **under vacuum** we can convert to the absolute pressure reading to head instead of atmospheric pressure. Vacuum is often read in **inches of mercury** so you will need a formula to convert it to head. Here is the formula:

$$\text{Feet of liquid} = \frac{1.133 \times \text{inches of mercury}}{\text{Specific gravity}}$$

4: TOTAL DYNAMIC HEAD:

Total Dynamic Head: Is the **vertical distance** between the source of supply and the point of discharge when pumping at required capacity increases the velocity head, friction, inlet and exit losses, divided in two conditions: **Total Dynamic Discharge Head** is the Total Dynamic Head minus **Total Dynamic Suction Head.**

a. Total Dynamic Discharge Head: Is determined on tests where Suction Head exists. It is the reading of the gauge attached to the discharge nozzle of pump, minus the reading of a gage connected to the suction nozzle of pump, plus or minus vertical distance between centers of gauges (depending upon whether suction gage is below or above discharge gage), plus excess, if any, of the Velocity Head of discharge over Velocity Head of suction as measured at points where instruments are attached.

b. Total Dynamic Suction Head: Is also determined on tests where Suction Head exists and also divided in three conditions:

1. SUCTION LIFT:

a. Suction Lift: Exists when the suction is measured at the pump nozzle and then corrected to the centerline of the pump, below atmospheric pressure.

b. Static Suction Lift: Is the vertical distance from the free level or source of the supply system, to the center line of a pump.

c. Dynamic Suction Lift: Is also determined on tests, is the reading of the mercury column connected to suction nozzle of pump, plus vertical distance between point of attachment of mercury column to centerline of pump, plus head of water resting on mercury column, if any.

2. SUCTION HEAD:

a. Suction Head: Exists when the pressure measured at the suction nozzle and then corrected to the centerline of the pump is above the atmospheric pressure (sometimes also called Head of Suction).

b. Static Suction Head: Is the vertical distance from the free level of the source of supply to centerline of pump.

c. Dynamic Suction Head: Is the vertical distance from the source of supply, when pumping at required capacity, to centerline of pump, minus Velocity Head, entrance, friction, but not minus the internal pump losses.

Note: The Dynamic Suction Head, determined by tests, is the reading of a gage connected to suction nozzle of pump, minus vertical distance from center of gage to centerline of pump. The Suction Head, after deducting the various losses, may be a negative quantity, in which case a condition equivalent to Suction Lift will prevail.

3. VELOCITY HEAD:

The Velocity Head: Sometimes also called as "Head due to Velocity" of water with a given Velocity, is the equivalent head through which it would have to fall to acquire the same Velocity: or the head merely necessary to accelerate the water. Knowing the velocity, we can readily figure the Velocity Head from the simple formula:

$$\mathbf{h} = \frac{v2}{2.g} =$$

Where "g" is acceleration due to gravity 9.80665 m/s^2 (~32.1740 ft/s^2) or knowing the head (h). And thus obtain the **velocity head**:

$$\mathbf{v^2 = 2.g.\ h}$$

Obs.: The Velocity Head is a factor figuring the **Total Dynamic Head**, but the value is usually negligible; however, it should be considered when the Total Head is low and when the Suction Lift is high. Where the suction and discharge pipes are the same size, it is only necessary to include in the Total Head the Velocity Head generated in the suction piping.

If the discharge piping is of different size than the suction piping, which is often the ease, then it will be necessary to use the Velocity in the discharge pipe for computing the Velocity Head rather than the Velocity in the suction pipe.

In testing a pump, a vacuum gauge or a "**mercury column"** is generally used for obtaining **Dynamic Suction Lift**. The mercury column or vacuum gage will show the Velocity Head combined with Entrance Head, Friction Head, and Static Suction Lift.

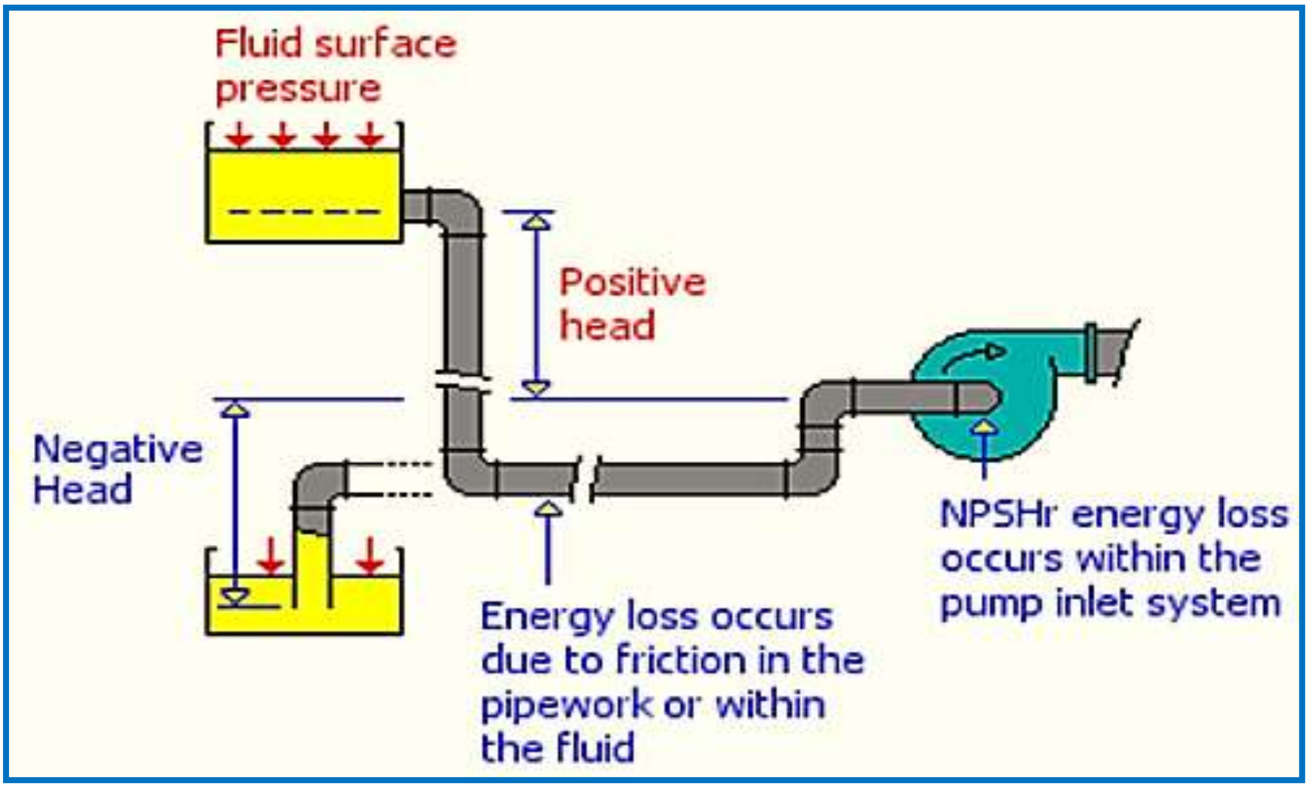
On the discharge side, a pressure gage is usually used, but a pressure gage will not indicate the Velocity Head and therefore be obtained either by calculating the Velocity or taking readings with a **Pitometer**.

The Velocity varies considerably at different points in the cross section of a stream. It is important in using the Pitometer to take a number of readings at different points in the cross section.

Table 1. VELOCITY – VELOCITY HEAD:

Velocity in feet/ sec.	Velocity Head in ft.	**Velocity in feet/ sec.**	Velocity Head in ft.	**Velocity in feet/ sec.**	Velocity Head in Ft.	**Velocity in feet/ sec.**	Velocity Head in Ft.
1.0	0.02	**6.0**	0.56	**9.5**	1.4	**12.0**	2.24
2.0	0.06	**7.0**	0.76	**10.0**	1.55	**13.0**	2.62
3.0	0.14	**8.0**	1.0	**10.5**	1.7	**14.0**	3.05
4.0	0.25	**8.5**	1.12	**11.0**	1.87	**15.0**	3.50
5.0	0.39	**9.0**	1.25	**11.5**	2.05		

Static Suction Head (H): Is positive when liquid line is above pump centerline and negative when liquid line is below pump centerline, as can be seen at the sketch below.



Note: See the **tables** indicating the energy loss due friction for water flow through **ASME/ANSI B36.10 schedule 40 steel piping and fittings.** The friction loss can be also calculated by, **f (loss)** = **K x v^2/2g** (g = 32.17 ft/s^2).

Imperial and Metric relations:

- 1 foot of head = **0.433 psi** = 0.030kg/cm^2
- 1 psi = **2.31 feet** (water) **=** 0.0703 kg/cm^2

TABLE 02.a – WATER VAPOR PRESSURE CHART, psia:

Temperature		Water Vapor Pressure
F°	**C°**	**psia**
40	**4.4**	**0.1217**
50	**10**	**0.1781**
60	**15.6**	**0.2563**
70	**21.1**	**0.3631**
80	**26.7**	**0.5069**
90	**32.2**	**0.6982**
100	**37.8**	**0.9492**
110	**43.3**	**1.275**
120	**48.9**	**1.692**
130	**54.4**	**2.223**
140	**60**	**2.889**
150	**65.6**	**3.718**
160	**71.1**	**4.741**
170	**76.7**	**5.992**
180	**82.2**	**7.510**
190	**87.8**	**9.339**
200	**93.3**	**11.50**
212	**100**	**14.70**

TABLE 02.b = SUCTION HEAD – TEMPERATURE – WATER VAPOR PRESSURE:

Temperature		Abs. Water Vapor Pressure		Max. Elevation	
C°	***F°***	***psi/psia***	***bar***	***(m)***	**(ft)**
0	**32**	0.0886	0.0061	0.062	0.2044
5	**40**	0.1217	0.0084	0.085	0.2807
10	**50**	0.1781	0.0122	0.125	0.4108
15	**60**	0.2563	0.0176	0.180	0.5912
21	**70**	0.3631	0.0250	0.255	0.8376
25	**77**	0.4593	0.0316	0.322	1.0594
30	**86**	0.6152	0.0424	0.432	1.4190
35	**95**	0.8153	0.0562	0.573	1.8806
40	**104**	1.069	0.0737	0.751	2.4658
45	**113**	1.389	0.0957	0.976	3.2040
50	**122**	1.789	0.1233	1.258	4.1267
55	**131**	2.282	0.1573	1.604	5.2639
60	**140**	2.888	0.1991	2.030	6.6618
65	**149**	3.635	0.2506	2.555	8.3849
70	**158**	4.519	0.3115	3.177	10.424
75	**167**	5.601	0.3861	3.938	12.9199
80	**176**	6.866	0.4733	4.827	15.8379
85	**185**	8.398	0.5790	5.904	19.3718
90	**194**	10.167	0.7010	7.148	23.4524
95	**203**	12.257	0.8450	8.618	28.2735
100	**212**	14.695	1.0132	10.332	33.8973

Viscosity: Is the internal friction of a liquid tending to reduce flow. Viscosity is defined by instruments termed as Viscosimeters of which there are several types as **Saybolt Universal and Redwood**.

Obs.: In the United States the Saybolt Universal is in general use with few exceptions. Viscosity is expressed as the number of seconds required for a definite volume of fluid under an arbitrary head to flow through a standardized aperture at constant temperature.

5. SPECIFIC GRAVITY:

Specific Gravity (S.g): Is the ratio of the weight of **any volume** to the weight of an equal volume of some other substance taken as a **standard** at stated temperatures. As an example, for solids or liquids the **standard** is usually **water**, and for gases the standard is **air** or **hydrogen**.

TABLE 03 = PRESSURE AND EQUIVALENT FEET HEAD OF WATER

PSI or Lb/sq. in.	Feet Head	PSI or Lb/sq. in.	Feet Head	PSI or Lb/sq. in.	Feet Head	PSI or Lb/sq.in.	Feet Head
1.0	2.31	**20.0**	46.28	**120.0**	277.07	**225.0**	519.51
2.0	4.62	**25.0**	57.72	**125.0**	288.62	**250.0**	577.24
3.0	6.93	**30.0**	69.27	**130.0**	300.16	**275.0**	643.03
4.0	9.24	**40.0**	92.36	**140.0**	323.25	**300.0**	692.69
5.0	11.54	**50.0**	115.45	**150.0**	346.34	**325.0**	750.41
6.0	13.85	**60.0**	138.54	**160.0**	369.43	**350.0**	808.13
7.0	16.16	**70.0**	161.63	**170.0**	392.52	**375.0**	865.89
8.0	18.47	**80.0**	184.72	**180.0**	415.61	**400.0**	922.58
9.0	20.78	**90.0**	207.81	**190.0**	438.90	**500.0**	1154.48
10.0	23.09	**100.0**	230.90	**200.0**	461.78	**1000.0**	2310.00
15.0	34.63	**110.0**	253.98				

TABLE 04 = FEET HEAD OF WATER AND EQUIVALENT PRESSURE

Feet Head	PSI or Lb/sq. in.	Feet Head	PSI or Lb/sq. in.	Feet Head	PSI or Lb/sq. in.	Feet Head	PSI or Lb/sq. in.
1.0	0.45	**30.0**	12.99	**140.0**	60.63	**300.0**	129.93
2.0	0.87	**40.0**	17.32	**150.0**	64.96	**325.0**	140.75
4.0	1.73	**60.0**	25.99	**170.0**	73.63	**400.0**	173.24
5.0	2.17	**70.0**	30.32	**180.0**	77.96	**500.0**	216.55
7.0	3.03	**90.0**	38.98	**200.0**	86.62	**700.0**	303.16
8.0	3.46	**100.0**	43.31	**225.0**	97.45	**800.0**	346.47
10.0	4.33	**120.0**	51,97	**275.0**	119.10	**1000.0**	433.09
20.0	8.66	**130.0**	56.30				

TABLE 05 = ALTITUDE AND ATMOSPHERIC PRESSURE

ALTITUDE AT SEA LEVEL		ATMOSPHERIC PRESSURE	
Feet	**Meters**	**Psia**	**Kg/cm² abs.**
0.0	**0.0**	14.69	1.033
500.0	**153.0**	14.43	1.015
1000.0	**305.0**	14.16	0.956
1500.0	**458.0**	13.91	0.978
2000.0	**610.0**	13.66	0.960
2500.0	**763.0**	13.41	0.943
3000.0	**915.0**	13.17	0.926
3500.0	**1068.0**	12.93	0.909
4000.0	**1220.0**	12.69	0.892
4500.0	**1373.0**	12.46	0.876
5000.0	**1526.0**	12.23	0.860
6000.0	**1831.0**	11.78	0.828
7000.0	**2136.0**	11.34	0.797
8000.0	**2441.0**	10.91	0.767
9000.0	**2746.0**	10.50	0.738
10000.0	**3050.0**	10.10	0.710
15000.0	**4577.0**	8.29	0.583

TABLE 06 = PRACTICAL SUCTION LIFTS - ELEVATIONS ABOVE SEA LEVEL

ELEVATION	Barometer Reading **Psi**	Theoretical Suction Lift **Feet**	Practical Suction Lift **Feet**	Vacuum Gauge* **Inches**
At sea level	**14.7**	33.9	22	19.5
¼ mile – 1320 ft – above sea level	**14.0**	32.4	21	18.6
½ mile – 2640 ft – above sea level	**13.3**	30.8	20	17.7
¾ mile – 3960 ft – above sea level	**12.7**	29.2	18	15.9
1 mile – 5280 ft – above sea level	**12.0**	27.8	17	15.0
1 ¼ mile – 6600 ft – above sea level	**11.4**	26.4	16	14.2
11/4 mile – 7920 ft – above sea level	**10.9**	25.1	15	13,3
2 miles – 10560 ft – above sea level	**9.9**	22.8	14	12.4

NOTES:

1. Multiply barometer in inches by **0.491** to obtain **psi**. *Vacuum gauge readings inches correspond to suction lift in feet only when pump is stopped. Pipe friction increases the vacuum gauge readings when pump is running. For quiet operation, vacuum gauge should **never** register more than **20 inches** when pump is running.
2. When pumping volatile liquids as **gasoline and naphtha**, special consideration to the amount of **suction lift** and the **size of the suction pipe**. The suction lift, the pipe line friction should never exceed **12 feet**.
3. For liquids such as **lube oil, molasses**, etc., a **suction lift up to 24 feet**, sea level, is usually satisfactory.

TABLE 07 = EQUIVALENT VALUES OF PRESSURE

Inches of Mercury	Feet of Water	psi	**Inches of Mercury**	Feet of Water	psi	**Inches of Mercury**	Feet of Water	psi
1.0	1.13	0.49	**11.0**	12.44	5.39	**21.0**	23.75	10.28
2.0	2.26	0.98	**12.0**	13.57	5.87	**22.0**	24.88	10.77
3.0	3.39	1.47	**13.0**	14.70	6.37	**23.0**	26.00	11.26
4.0	4.52	1.95	**14.0**	15.83	6.85	**24.0**	27,14	11.75
5.0	5.65	2.45	**15.0**	16.96	7.34	**25.0**	28.27	12.24
6.0	6.78	2.94	**16.0**	18.09	7.83	**26.0**	29.40	12.73
7.0	7.91	3.43	**17.0**	19.22	8.32	**27.0**	30.53	13.22
8.0	9.04	3.92	**18.0**	20.35	8.82	**28.0**	31.66	13.71
9.0	10.17	4.40	**19.0**	21.48	9.30	**29.0**	32.79	14.20
10.0	11.31	4.89	**20.0**	22.61	9.79	**29.92**	33.83	14.65

6. DISTANCE TO WATER LEVEL EQUIPMENT:

Example: Install a small pipe or tubing (about 1/8 inches or 1/4 in) in a well. The exact length must be carefully measured. The end of the air pipe should extend to the bottom of the pump suction. Install a reliable pressure gauge, so that the exact air pressure in pounds may be shown, when the hand pump is operated.

Solution: Attach the hand tire-pump and fill pipe until further pumping can not increase the reading on the gauge. Multiply the **reading** in pounds by **2.31**, and subtract the result from the **length** of air pipe. The difference will be the distance from the center of the pressure gauge face to the surface of the water. Any **horizonta**l distance of the pipeline from the well opening has no effect on the result.

Example: An air pipe is 100 feet long from center of gage face to bottom end of pipe. The highest pressure reading is 18 pounds, then, **18 x 2.31 = 41.58 feet of lift**.

- **41.58 – 100 = 58.42** - showing that the **water level is 58.42** feet below center of pressure gage.
- **Doubling the diameter of pipe** or cylinder **increases its capacity four times**. Friction of liquids in pipes increases with the square of the velocity.
- **Atmospheric pressure at sea level is 14.7 pounds per square inch**. This pressure with perfect vacuum will maintain a **line of mercury 29.9 inches or a column of water 33.9 feet high**.
- In practice, however, pumps should not have a total dynamic suction lift **greater than 26 feet**.

7. HOW TO CALCULATE THE NPSH OF A PUMP:

First determine if you are going to have a cavitation problem, you will need access to several additional parts of information:

- ✓ The pump curve is going to show you the **Net Positive Suction Head (NPSH) required** at a given capacity. Keep in mind that this **NPSH required** tables are for cold and fresh water.
- ✓ A chart or some type of publication will give you the **vapor pressure** of the fluid you are pumping.
- ✓ You need to know the **specific gravity** of your fluid. The number is temperature sensitive. You can get this number from a **Temperature – Pressure chart**.
- ✓ Find the charts showing the **head loss through the size of piping and charts to calculate the loss for fittings, valves and accessories**.
- ✓ Find the **atmospheric pressure** at the time you are making your calculation. The atmospheric pressure changes throughout the day, but the calculations have to start somewhere.
- ✓ The formulas for converting pressure to head and head back to pressure in the imperial system are as follows:

$$\textbf{Pressure} = \frac{\textbf{head x Sg}}{\textbf{2.31}}$$

$$\textbf{Head} = \frac{\textbf{pressure x 2.31}}{\textbf{Sg}}$$

Where:

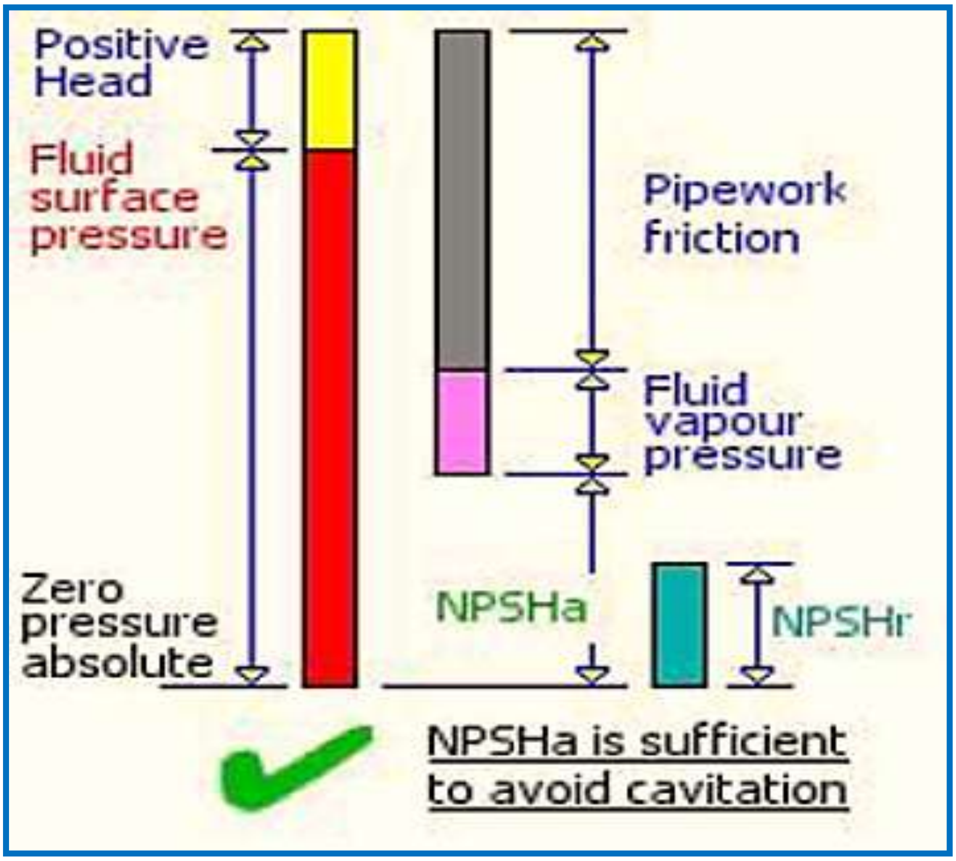
Sg = Specific Gravity;
Pressure = pounds per square inch, psi;
Head = feet

You also need to know the formulas that show you how to convert vacuum readings to feet of head. Here are a few of them:

- **Inches of mercury x 1.133 / specific gravity** = feet of liquid;
- **Pounds per square inch x 2.31 / specific gravity** = feet of liquid;
- **Millimeters of mercury / (22.4 x specific gravity)** = feet of liquid.

It is necessary to know the conditions below, using a pump graphic as shown below:

NPSHa > NPSHr = NPSH available (calculated) > NPSH required (pump curve).



a. Calculations using the following conditions:

NPSHa = +-H + Pa – Pv – Hf =

- **H =** Static Suction Head (positive when liquid line is above pump centerline, negative when liquid line is below pump centerline).
- **Pa =** Atmospheric pressure with installed pump according to altitude from sea level **(see table 05) –** converting to head - **suction pressure x 2.31/Sg**
- **Pv =** Vapor pressure according to temperature of water **(see table 02)** - converting to head - **vapor pressure x 2.31/Sg = Total feet**.
- **Hf =** See tables indicating friction loss for water flow through ASME/ANSI B36.10 schedule 40 steel piping. Fittings friction loss = **K x $v^2/2g$** (g = 32.17 ft/s^2).

Obs.: The ANSI/ASME codes or the Hydraulic Institute Standards is the source for pressure head **loss K coefficients**:

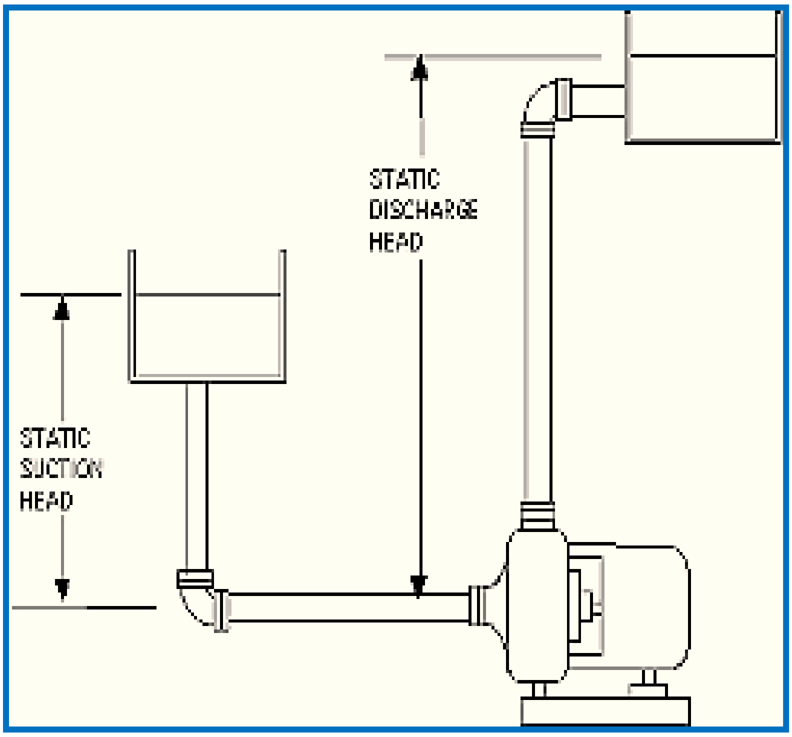
Application Example – Water Pumping:

- ✓ Fluid: Water;
- ✓ Pipe: Steel Pipe - Schedule 40;
- ✓ Temperature: *20.0 °C (68.0 °F)*;
- ✓ Density: *998.3 kg/m^3 (62.0 lb/ft^3)*;
- ✓ Kinematic Viscosity: *1.004. 10^{-6} m^2/s (0.01 stokes) (1.08. 10^{-5} ft^2/s);*
- ✓ Pipe Roughness Coefficient: *4.5. 10^{-5}*.

b. Examples for calculation:

1. Find the NPSHa from below data:

- **H** = Liquid level above pump centerline = +**5 feet**;
- **Pa** = Atmospheric pressure = **14.7 psi** - the tank is at sea level;
- **Suction and Discharge piping** = 2 inch diameter, plus two 90° regular screwed elbow = total length = 10 feet;
- **Pumping** =100 gpm @68°F – 10 ft/s as maximum velocity;
- **Pv** = Vapor pressure of 68°F water = **0.339 psia** (see table 02);
- **Sg** = Specific gravity = 1.0 (fresh cold water);
- **NPSHr** (net positive suction head required, as per the pump curve) = **9 feet**.



NPSHa = Static head + Atmospheric pressure (converted to head) + Vapor pressure of the fluid (converted to head) – Friction loss (in the piping, valves and fittings);

NPSHa = +-H + Pa – Pv – hf =

H - Static head = +5 feet.

Pa - Atmospheric pressure = pressure x 2.31/Sg. = **14.7 x 2.31/1 = +34 feet absolute**.

Pv - Vapor pressure of water at 68°F - pressure x 2.31/Sg = **0.339 x 2.31/1 = 0.78 feet.**

- **Hf** - Looking at the friction charts: **100 gpm - flowing through 2 inch pipe** shows a loss of **17.4 feet** for each **100 feet of pipe**, then:

- **Piping friction loss** = **17.4/10** = **1.74 feet.**

- **Fittings friction loss** = **K x v²/2g** = $\frac{0,57 \times 10^2}{2 \times 32.17}$ (x 2) = **1.77.**

- **Total friction loss for piping and fittings = Hf = 1.74 + 1.77 = 3.51 feet.**

a. NPSHa (available) = +-H + Pa – Pv – Hf =

b. NPSHa (available) = +5 + 34 - 0.78 – 3.51 =

c. Solution = 34.7 feet (NPSHa) > 9 feet (NPSHr).

The pump curve showed an NPSHr of only 9 feet of head at 100 gpm. According to above calculation we have NPSHa (available) = **34.7 feet**. So, we have plenty to spare.

2. Using the same data above, find the NPSHa in metric numbers:

- **H** = Liquid level above pump centerline = +**1.5 m**
- **Pa** = Atmospheric pressure = **1.033 kg/cm² =** at sea level
- Suction and discharge piping 2 in with two 90° regular screwed elbow = **3 m**
- Pumping flow – 100 gpm = 0.379 m³/min (22.7 m³/h) at 20º C (68º F)
- Maximum speed for a 2 in piping – 10 ft/s = 3.0 m/s
- **Pv** = Vapor pressure at 20º C = 0.024 kg/cm² (see table 02)
- **Sg** – Specific gravity = 0.998 (use 1.0) = 1000 kg/m³ (apparent water density)
- **NPSHr** (net positive suction head required, from the pump curve) = **2.75 m**

1) Converting **Pa** =1.033 kg/cm² in kg/m²:

1.033 kg/cm² x 10,000 = **10,330 kg/m²**.

Water density 1000 kg/m³ = $\frac{10{,}330 \text{ kg/m}^2}{1000 \text{ kg/m}^3}$ = **10.33 m** of water column (mwc)

2) Converting **Pv** = 0.024 kg/cm² in kg/m² = 0.024 kg/cm² x 10,000 = **240 kg/m²**:

Water density 1000 kg/m³ = $\frac{240 \text{ kg/m}^2}{1000 \text{ kg/m}^3}$ = **0.24 m** of water column (mwc)

3) Calculating **Hf** - Piping 2 in total length = ……………………………….3.0 m
Equivalent 2 in elbows length = 1.0 m (x 2) = …2.0 m
Total equivalent length = ………………………………..**5.0 m**

According to metric tables: for 22.7 m³/h using piping diameter 2 inches and length of 100.0 m, the **total friction loss** is considered = **~25%**, then:

5.0 m x 0.25 = **1.25 m**

Then:

a. NPSHa = **+-H + Pa – Pv – hf =**:

b. NPSHa = +3.0 + 10.33 – 0.24 – 1.25 = **11.84 m (NPSHa)** > **2.75 m (NPSHr)**.

c. Solution: The pump curve showed an **NPSHr of only 2.75 m** of head at **22.7 m³/h**. According to above calculation we have **NPSHa (available)** = **11.84 m**. So, we have plenty to spare.

Important Conversions:						
Convert from	**Convert to**					
	m^3/s	***m^3/min***	***m^3/h***	***liter/sec***	***liter/min***	***liter/h***
US gpm	0.000063	0.00379	0.227	0.0630	3.785	227.1
cfm	0.00047	0.028	1.699	0.472	28.32	1698.99

3) Net Positive Suction Head, according to the following data below:

- **Fluid**: Water – Static Suction Lift = **15 ft**; Static Discharge Head **= 7.5 ft.**
- **NPSHr** – according to performance pump curves = **5.0 ft**
- **Atmospheric pressure** - corrected = **6 ft**
- **Safety factor** for atmospheric pressure = **2.0 ft**

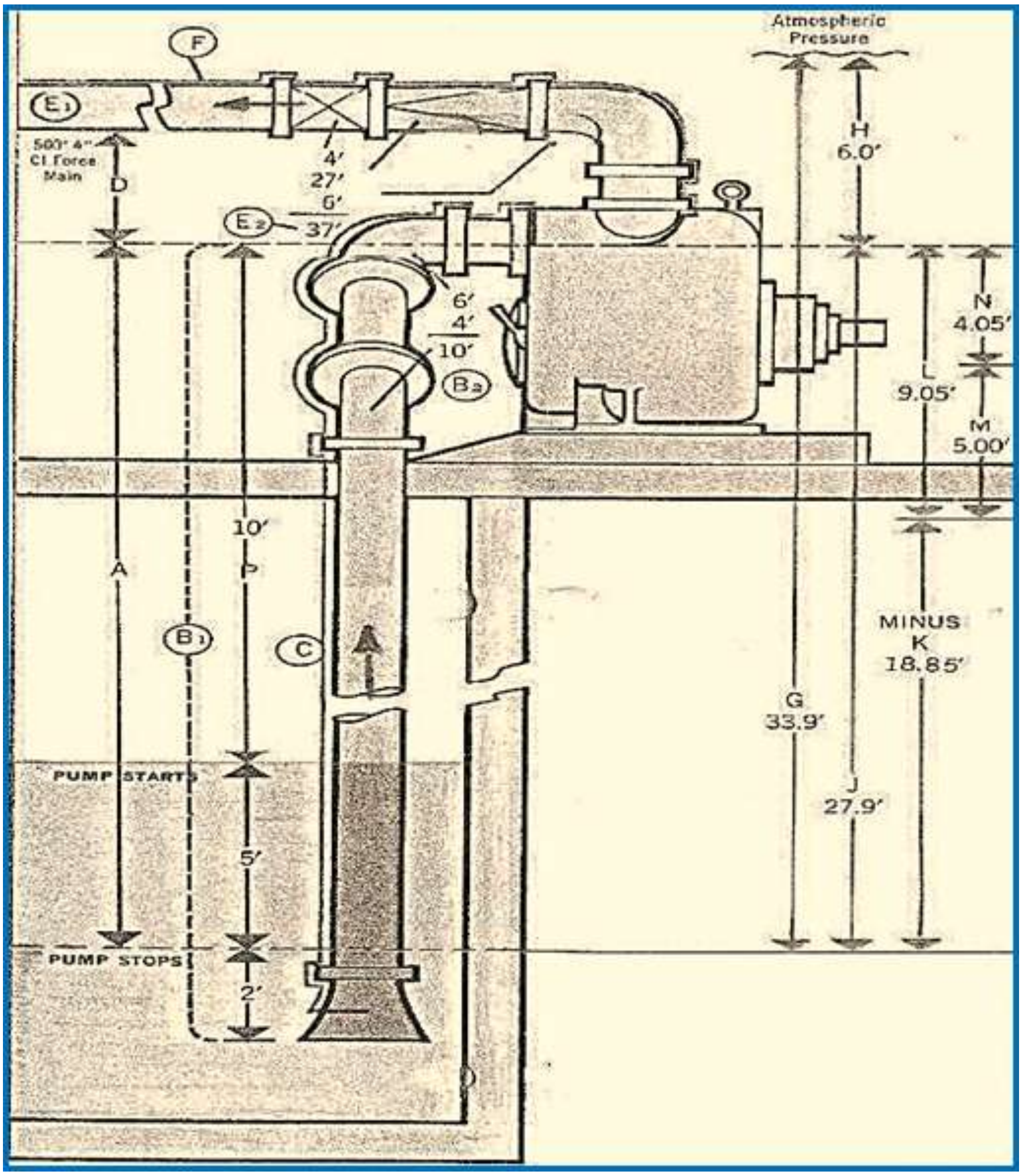
a) How to compute the Total Dynamic Head (see tables below):

A	**STATIC SUCTION LIFT**		**15 ft**
B	Friction, Suction (see tables):		
	a) Pipe diameter, 4"		
	Pipe total length =	17 ft	
	b) One elbow 90º, diameter, 4" = 6 ft		
	c) One elbow 45º, diameter, 4" = 4 ft		
	Fittings total length =	10 ft	
	Total equivalent length =	27 ft	
	d) Pipe friction loss (see tables) = 4.43 ft		
	e) Friction loss = 27' x 4.43/100 = ~1.20 ft		
	f) Correction factor = 0.71		
	Total friction loss, Suction Lift = 1.20 x 0.71 ....=		**0.85 ft**
C	Total Dynamic Suction Lift = (15 + 0.85) ....=		**15.85 ft**
D	**STATIC DISCHARGE HEAD**		**7,5 ft**
E	Friction, Discharge (consult tables):		
	a) Pipe diameter, 4"		
	Pipe total length =	500 ft	
	b) One elbow 90º, diameter, 4" = 6 ft		
	c) One check valve, diameter, 4" = 27 ft		
	d) One gate valve, diameter, 4" = 6 ft		
	Fittings total length =	37 ft	
	Total equivalent length =	537 ft	
	e) Pipe friction loss (table) = 4.43 ft		
	f) Friction loss = 537 x 4.43/100 = 23.8 ft		
	g) Correction factor = 0.71		
	Total friction loss, Discharge = 23.8 x 0.71 ....=		**16.9 ft**
F	Total Dynamic Discharge Head = (16.9 + 7.5) ....=		**24.40 ft**
	Total Dynamic Head – C + F = (15.85 + 24.4) ....=		**40.25 ft**

b) How to compute the NPSHa:

G	Atmospheric pressure at sea level =	**33.90'**		
H	Atmospheric pressure - corrected =	**- 6.00'**		
I	Atmospheric pressure available at job site………………. =		**+27.90'**	
J	Deductions from available atmospheric pressure: 1. Total dynamic suction lift………………………… = 2. Vapor pressure 74° (0.441 x 2.31 = 1.0')= 3. Safety factor (for atmospheric pressure) =	 **-15.85'** **-1.00'** **-2,00'**		
K	Net deductions from available atmospheric pressure…….		**-18.85'**	
L	**NPSHa (available) =** (27.9' – 18.85')…….…………………………….=			**+ 9.05'**
M	**NPSHr (required)**………………………………………………………….=			**- 5.00'**
N	**NPSH excess** or excess atmospheric pressure………………………….=			**4.05'**

c. Solution: NPSHa (9.05') > NPSHr (5.00') - See the sketch below:



REFERENCES:

Centrifugal Pumps- University of Sao Paulo, Engineering Lab
Gorman-Rupp - Pumps and Pumping Systems Catalog
Engineeringtoolbox.com – NPSH Tables
Fluid Mechanics – Munson, Young, Okiishi, 4th Edition, 2004
Hydraulics – Horace W. King, 4th Edition, 1945

Additional technical information, visit the following websites:

1. The Hydraulic Institute Standards at: www.pumps.org.
2. *Pumps* for process and chemical services - ASME B73.1 Standards.
3. Pumping equipment at www.pumpingequipmenttrade.com

Other Links:

http://www.tasonline.co.za/toolbox/pipe/veldyn.htm
http://docs.engineeringtoolbox.com/documents/797/hazen-williams-equation.xls
http://www.lightmypump.com
http://www.mcnallyinstitute.com/