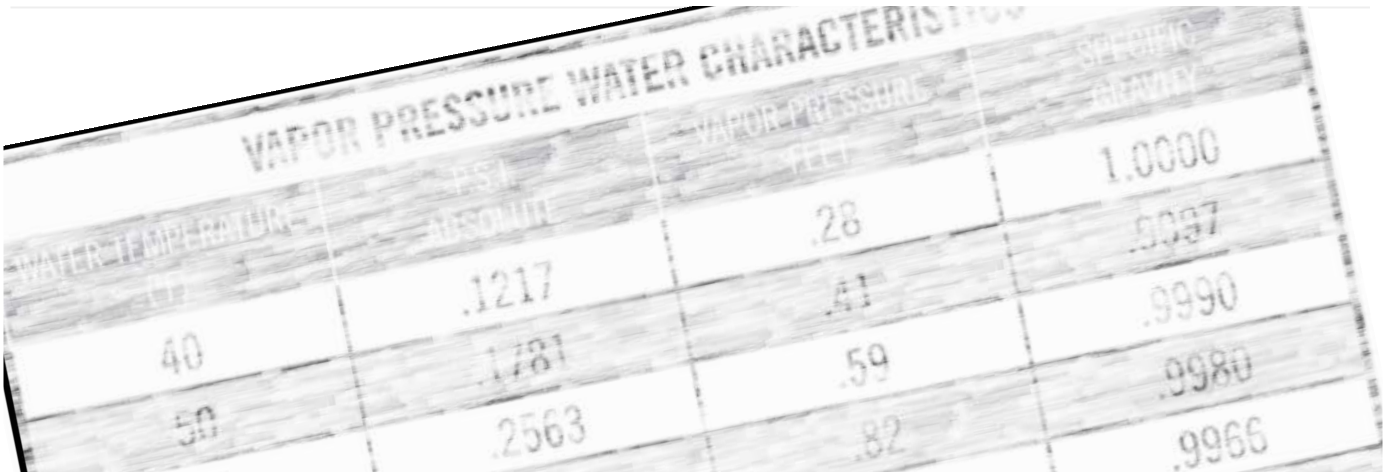
GORMAN-RUPP PUMPS DNet

Education Safety

Net Positive Suction Head



The topic of this bulletin is arguably one of the least understood issues of pump application and operation. Net Positive Suction Head (NPSH) is not difficult to calculate and is very important to successful pump and system design and operation. NPSH should be calculated during the design of all pumping systems or revisions to existing systems.

This bulletin will discuss definitions, what is NPSH, how to calculate NPSH, what affects occur to pumps and systems when there is insufficient NPSH, and what can be done when NPSH is a limiting factor.

Definitions

Net Positive Suction Head (NPSH) – The measurement of liquid pressure at the pump end of the suction system, including the design of the pump.

Net Positive Suction Head Available (NPSHa) – The difference between standard atmospheric pressure and the combination of atmospheric pressure at elevation, total dynamic suction lift, vapor pressure, and safety factor. The result must be equal to or greater than NPSHr.

Net Positive Suction Head Required (NPSHr) – This is the amount of atmospheric pressure required to move liquid through the suction side of the pump. NPSHr is directly related to pump design.

Ambient Atmospheric Pressure – The weight of atmosphere at a given time and location.

Standard Atmospheric Pressure – The weight of atmosphere at sea level under normal atmospheric conditions (14.7 PSI, 33.9 Feet of Water, 10.3 Meters, and 29.9 Inches of Mercury)

Total Dynamic Suction Lift (TDSL) – This is the combination of the static lift or head and friction loss during operation within the suction pipe. On a suction lift, the total dynamic suction lift is calculated by adding the static suction lift plus the friction loss at flow rate. On a system with the water higher than the pump, the total dynamic suction lift is calculated by subtracting the friction loss from the positive inlet pressure or static head. In either case, the value of any total dynamic suction lift or total dynamic suction head of a system is the suction gauge reading, while the pump is operating.

Vapor Pressure (VP) – The pressure at which a liquid will vaporize. This pressure is relative to the liquid's temperature.

Specific Gravity (SG) – The weight of any liquid relative to that of water.

Safety Factor – This value is used in the NPSH calculation to take in to account for fluctuations in atmospheric pressure.

What Is NPSH?

NPSH is the amount of atmospheric pressure at the pump end of the suction system, including the pump. This value can be calculated and is the subject of this bulletin. Once understood, an NPSH calculation is simple and could be time well spent calculating it.

We live at the bottom of a sea of atmosphere. It is the pressure that this sea exerts on us that forces liquid into a pump. The force of this pressure is equal to 14.7 PSI, 33.9 feet of water, 10.3 meters of water, and 29.9 inches of mercury. (At sea level.) Imagine a tube 35 feet long sealed at one end. Take this tube and fill it with water while sealing it after filling. Turn the tube upside down into a bucket and open the end of the tube in the bucket. When the end of the tube in the bucket is removed, the water will drop from the top of the tube until the height of the water equals that of the atmospheric pressure exerted on the water in the bucket. This is the same principle that causes a pressure reading and reflects change in atmospheric pressure in a barometer.

Now that we understand what external force helps push water up the suction pipe during priming and dynamic operation, let's look at how we can calculate this force during dynamic operation to ensure that there is sufficient to adequately supply liquid to the pump. As we mentioned previously, standard atmospheric pressure at sea level, under normal atmospheric conditions equals 33.9 feet of water. Keep in mind that this value must be converted relative to the specific gravity of the liquid being pumped. From this pressure, five deductions must be made relative to the location, pump and system design, temperature, and product pumped. The deductions of elevation correction, vapor pressure of the liquid pumped, total dynamic suction lift, and safety factor determine the value of what is referred to as Net Positive Suction Head Available. From this, the fifth deduction, Net Positive Suction Head Required, is subtracted. This completes the calculation known as Net Positive Suction Head. This value must be greater than or equal to zero for the pump and system to function successfully. If this value is less than zero, the result will be suction cavitation within the pump. This does not mean that the pump will not prime, only that the pump will be subjected to cavitation once the pump achieves dynamic operation. When the reduction due to elevation results in a negative number, only then will the pump fail to prime. This means that the pump would have to be placed at an elevation high enough for atmospheric pressure not to support the static suction lift. In this case, the water would not be forced high enough in the suction pipe to reach the pump due to the fact that there wouldn't be enough atmospheric pressure.

Conversely to a calculated negative number a positive number will function as expected. Keep in mind that a value of 5 doesn't work any better than a value of 2 or a value of 10 doesn't work any better than 1. It just simply states that there is enough atmospheric pressure available to push liquid into the pump and keep liquid in a liquid state during operation.

Net Positive Suction Head is often calculated during the design phases of a pump and system. Upon completion of the design, NPSH is usually forgotten. Don't forget that NPSH changes when speed changes due to an increased flow requirement or suction piping changes are made. Therefore, the increase in speed will increase the velocity of the liquid in the suction pipe. This increase in velocity will increase the friction loss. In conjunction the total dynamic suction lift will increase as well. The additional flow rate will also increase the NPSHr deduction as well.

How to Calculate NPSH

As previously mentioned, we begin our calculation with Standard Atmospheric Pressure. This begins with 33.9 feet of water. Keep in mind that this value must be converted for liquids weighing different than water and water like liquids having a specific gravity of 1.0. Standard Atmospheric Pressure must be divided by the specific gravity of the pumped liquid to begin the calculation. Below is the conversion for correcting Standard Atmospheric Pressure of liquids lighter or heavier than that of water.

33.9 ÷ Specific Gravity = Feet of Water

For example: For gasoline having a specific gravity of .75

33.9 ÷ 0.75 = 45.2 feet

For industrial waste with a specific gravity of 1.2

33.9 ÷ 1.2 = 28.25 feet

Nonetheless, for this calculation, we will use water with a specific gravity of 1.0 beginning at 33.9 feet.

The five deductions from Standard Atmospheric Pressure are as follows.

Example:
1. Altitude or elevation at the job site.
2. Vapor Pressure of the liquid pumped.
3. Total Dynamic Suction Lift.
4. Safety Factor (2 feet for water and water like liquids, 3 feet for fuel and fuel like liquids).
5. Net Positive Suction Head Required by the pump.

These are the only deductions necessary.

The information noted below is the minimum required information to calculate NPSH.

Flow Rate – 1800 Gallons Per Minute (GPM)
Liquid – Water
Temperature – 100º Fahrenheit
Elevation At The Job Site – 2000 Feet
Total Dynamic Suction Lift (Gauge Reading) – 15 Feet

Let's assume that the pump has been selected based on the criteria above. There may be additional information supplied such as priming lift, total dynamic head, solids handling requirement, drive arrangement, etc.

The calculation sheet in Figure 1 reflects the calculation in the steps following. The last page of this bulletin is a calculation sheet for calculating NPSH.

Figure 1

NET POSITIVE SUCTION HEAD CALCULATION

Step 1	Standard Atmospheric Pressure Adjusted For Specific Gravity Of Liquid Being Pumped 33.9 ÷ Specific Gravity (1.0) = Feet	33.9 feet
Step 2	Altitude or Elevation Correction (2000 Feet)	2.3 feet
Step 3	Vapor Pressure of liquid (100°F)	2.19 feet
Step 4	Total Dynamic Suction Lift (Static lift + Suction line friction loss 15 Feet)	15 feet
Step 5	Safety Factor (2 Feet)	2 feet
Step 6	Total Deductions	21.49 feet
Step 7	Net Positive Suction Head Available (Subtract Step 6 From Step 1)	**12.41 feet**
Step 8	Net Positive Suction Head Required (See Attached Performance Curve)	8 feet
Step 9	Net Positive Suction Head (Subtract Step 8 From Step 7)	**4.41 feet**

Note: If the Net Positive Suction Head is a positive number, the suction system will function properly. If the Net Positive Suction Head is a negative number, the suction system will not function properly. This negative result of this calculation will result in damage to the pump.

Step 1
Insert the Standard Atmospheric Pressure. Don't forget to correct for liquids of different weight than water and water like liquids. Insert the value of 33.9.

Figure 2

ATMOSPHERIC PRESSURE CONDITIONS, ELEVATIONS ABOVE SEA LEVEL

ALTITUDE ABOVE SEA LEVEL (FEET)	ATMOSPHERIC PRESSURE (P.S.I)	BAROMETER (IN. HG.)	EQUIV. HEAD OR WATER (FEET)	REDUCTION TO MAX. DYNAMIC SUCTION LIFT (FEET)
0	14.7	29.9	33.9	0
1000	14.2	28.8	32.7	1.2
2000	13.6	27.7	31.6	2.3
3000	13.1	26.7	30.2	3.7
4000	12.6	25.7	29.1	4.8
5000	12.1	24.7	27.9	6.0
6000	11.7	23.8	27.0	6.9
7000	11.2	22.9	25.9	8.0
8000	10.8	22.1	24.9	9.0

Step 2

The altitude at the job site is noted as 2000 feet. To convert this elevation see Figure 2, Atmospheric Pressure Conditions, Elevation Above Sea Level (Feet). In this chart, the left hand column notes Altitude Above Sea Level. Locate 2000 Feet. The value used for the deduction is that in the column noted "Reduction To Practical Dynamic Suction Lift". In line with 2000 feet is 2.3 feet. Insert the value noted of 2.3.

Figure 3

VAPOR PRESSURE WATER CHARACTERISTICS

WATER TEMPERATURE (°F)	P.S.I. ABSOLUTE	VAPOR PRESSURE FEET	SPECIFIC GRAVITY
40	.1217	.28	1.0000
50	.1781	.41	.9997
60	.2563	.59	.9990
70	.3631	.82	.9980
80	.5069	1.17	.9966
90	.6982	1.61	.9950
100	.9492	2.19	.9931
110	1.275	2.94	.9910
120	1.692	3.91	.9888
130	2.223	5.15	.9857
140	2.889	6.68	.9833
150	3.718	8.56	.9803
160	4.741	10.95	.9773
170	5.992	13.84	.9738
180	7.510	17.35	.9702
190	9.339	21.55	.9660
200	11.53	26.65	.9632
210	14.12	32.60	.9592
220	17.19	39.70	.9552

Step 3

The temperature of the water is 100º Fahrenheit. To convert this temperature to a deductible value, see Figure 3, Vapor Pressure, Water Characteristics. In this chart, the left hand column notes "Temperature, Degrees Fahrenheit". Locate 100º Fahrenheit. The value used for this deduction is that in the column noted "Vapor Pressure, Feet". In line with 100º Fahrenheit is 2.19. Insert the value noted of 2.19.

Step 4

The Total Dynamic Suction lift is the combination of the static lift plus the friction loss of the suction piping. This value is also the suction gauge reading during operation at the designed flow rate. Insert the value of 15 feet.

Step 5

Insert the appropriate Safety Factor. As previously mentioned, this value is deducted to take into account the fluctuations in atmospheric pressure. Again, the Safety Factor value of 2 is for water and water like liquids and 3 for fuel and fuel like liquids. Insert the value of 2 feet.

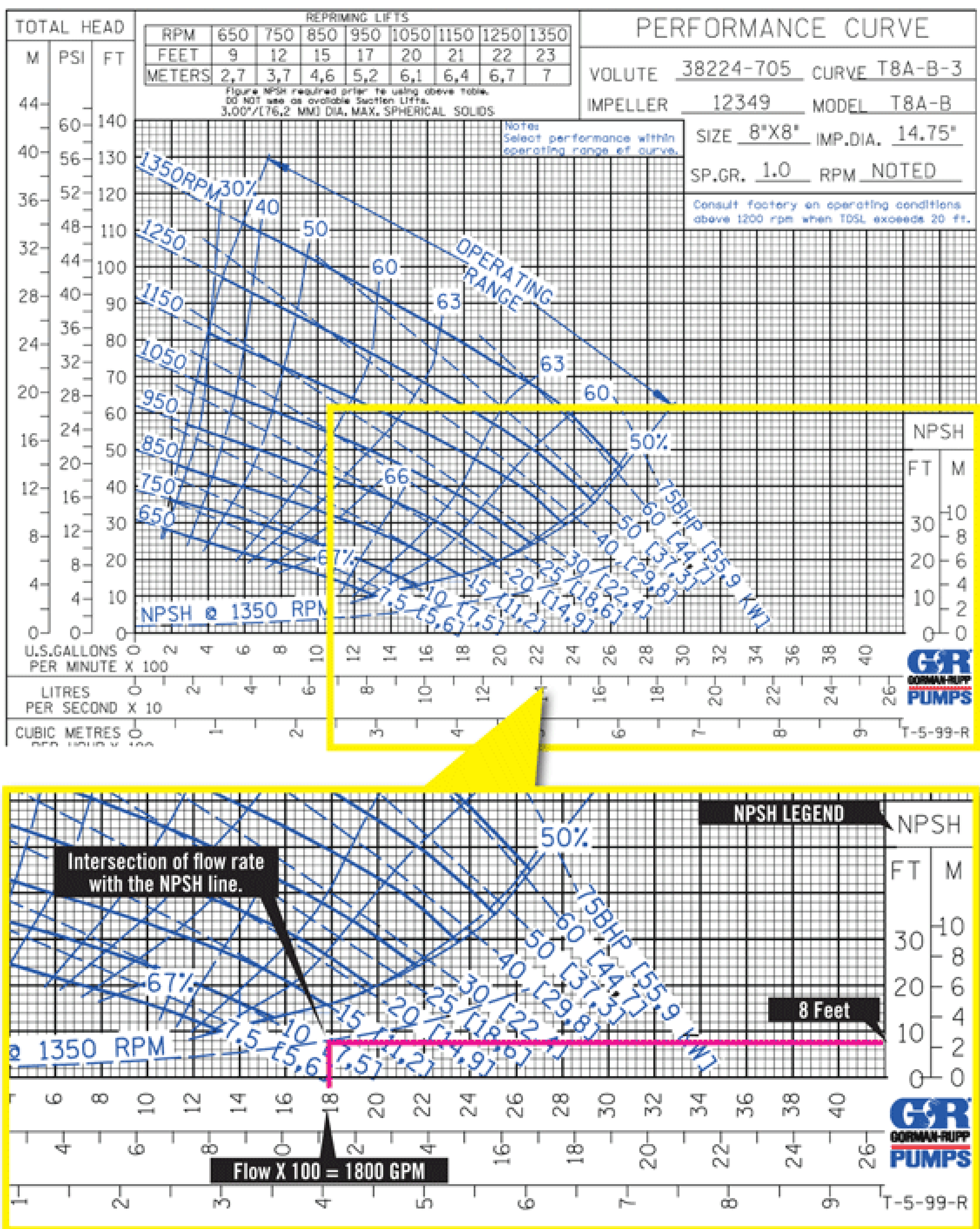
Step 6

This is the summation of values noted in Steps 2, 3, 4, and 5.

Step 7

Subtract the summation of Step 6 from the Standard Atmospheric Pressure in Step 1. This value is defined as the Net Positive Suction Head Available (NPSHa).

Figure 4



Step 8

Find the Net Positive Suction Head Required (NPSHr) from the pump performance curve in Figure 4. Note the curved line beginning in the lower left corner of the curve. It is noted as "NPSH @ 1350 RPM". To find the value of NPSHr, located the flow in gallons per minute across the bottom of the curve. At 1800 GPM, read vertically up until the 1800 GPM line intersects the NPSH line. Read straight across to the right from its intersection. The columns at the lower right corner of the curve note "NPSH, Feet, Meters". From the "FEET" column on the left, the value straight across from the intersection should be 8 feet.

Step 9
Subtract the NPSHr (Step 8) from the NPSHa (Step 7). This result is NPSH. You have completed the NPSH calculation. The calculation in the above example results in a positive number. This reveals that the system calculated will function properly on the suction side at the design condition point. If the NPSH calculation resulted in a negative number, there would not have been enough atmosphere pressure to keep liquid in a liquid state during operation at the design condition point. Thus, suction cavitation would occur.

How To Increase NPSH

If the value of NPSH results in a negative number during the design of a pump and system, usually simple changes to the design of the site results in positive NPSH calculations. But what if an existing system is changed in a manner that results in a negative NPSH calculation? If this occurs, refer to the calculation sheet made resulting in the negative number and begin asking questions at each step. For instance, in Step 1, the Standard Atmospheric Pressure at sea level is 33.9 feet. We all know that this number can not be changed and, in this case, increased. Can the safety factor be reduced? We suggest that the safety factor never be altered. This is part of the equation that takes the fluctuations in atmospheric pressure into account. Check every step. You'll find that Step 4, the Total Dynamic Suction Lift, may be the easiest to change. So what can be changed in the design of the suction side that would decrease the total dynamic suction lift? Let's look at two.

Static Suction Lift – Simply raising the water level in the sump will decrease the lift and therefore reduce the TDSL.

Pipe Diameter – Increasing the size of the suction pipe will slow the velocity of the water through the suction pipe, therefore reducing the friction loss. Reducing the friction loss will reduce the TDSL.

Don't forget that with every change there may be added consequences affecting the operation of the pump and system. For instance, increasing the size of the suction pipe will increase the priming time. A larger pipe means more air to evacuate during the priming cycle. A lower suction lift may consume valuable retention in the sump or cause septic conditions. Whatever the case, remain conscious of the possible adverse affects that may result in changes made in attempting to increase NPSH.

NET POSITIVE SUCTION HEAD CALCULATION

Step 1	Standard Atmospheric Pressure Adjusted For Specific Gravity Of Liquid Being Pumped 33.9 ÷ Specific Gravity = Feet	ft
Step 2	Altitude or Elevation	ft
Step 3	Vapor Pressure	ft
Step 4	Total Dynamic Suction Lift	ft
Step 5	Safety Factor	ft
Step 6	Total Deductions	ft
Step 7	Net Positive Suction Head Available (Subtract Step 6 From Step 1)	ft
Step 8	Net Positive Suction Head Required (See Attached Performance Curve)	ft
Step 9	Net Positive Suction Head (Subtract Step 8 From Step 7)	ft

Note: If the Net Positive Suction Head is a positive number, the suction system will function properly. If the Net Positive Suction Head is a negative number, the suction system will not function properly. This negative result of this calculation will result in damage to the pump.