RULES TO FOLLOW TO AVOID PUMP PROBLEMS

(Why Can't Small Pumps Get Any Respect?)

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Most pump problems are due to suction issues. In all the years I have been in the pump business I have only found one instance of a pump problem that was related to the discharge, other than of course pumps that have had a discharge valve shut while the pump was running. Shutting a discharge valve off on a pump causes the fluid remaining in the pump to get very hot and damages the housing, bushings, seals, etc. Hence, the focus of this article will be about proper pump installations in regards to pump suction conditions. I will first cover six basic rules and then some additional thoughts or approaches to insure low maintenance and low cost operation of your pumps.

Before discussing the first rule about providing sufficient NPSH for the pump, we need to discuss the term the concept of Feet of Head. Pumps don't suck, rather the pump pushes or throws the fluid out of the pump leaving a partial vacuum. Atmospheric pressure (usually) then pushes the fluid into the pump. For centrifugals, this force is measured in Feet of Head. Atmospheric pressure at sea level is 14.7 psia. At sea level, this can also be stated in terms of 29.94 inches of mercury (barometers) or 33.9 feet of water. Hence, at sea level we can say that a tank has 14.7 psia of pressure on it from atmospheric pressure or we can say that it has 33.9 Feet of Head. The convention with centrifugals is measure pressure in Feet of Head. A quick formula to convert between Feet of Head and psi:

$$\text{Pressure (lbs. per sq. in.)} = \frac{\text{Head in Feet X Specific Gravity of fluid}}{2.31}$$

Where does the 2.31 come from? Divide 33.9 feet of head by 14.7 psia. Water has a specific gravity of 1.0. So the formula always works. If the specific gravity is known for the fluid that is being pumped, pressure gauge readings can be converted to Head in Feet, which is useful for determining where the centrifugal pump is operating on its pump curve. A final note before discussing NPSH. Pressure for centrifugal pumps (inlet and outlet) is measured in Feet of Head and pressure for positive displacement pumps is typically measured in psi. One of the exceptions is for air operated diaphragm (AOD) pumps, which is a positive displacement pump where discharge pressure is measured in Feet of Head.

Rule #1. PROVIDE SUFFICIENT NPSH

Simply put a pump will **not** operate properly without sufficient inlet pressure, the pump will cavitate. Cavitation is caused by the rapid formation of vapor pockets (bubbles) in a flowing liquid in regions of very low pressure and collapsing in higher pressure regions, often a frequent cause of structural damage to the propellers or other parts of the pump. $NPSH_R$ or Net Positive Suction Head Required is the technical term used to determine what pressure energy (in psia or feet of head) is needed to fill the pump inlet and not have the pump cavitate. $NPSH_R$ is based on pump design. It is a characteristic which varies primarily with pump speed and the viscosity of the fluid.

$NPSH_A$ or Net Positive Suction Head Available is based on the design of the system around the pump inlet. The average pressure (in psia or feet of head) is measured at the inlet port during operation, minus the vapor pressure of the liquid at operating temperature. It indicates the amount of useful pressure energy available to fill the pump. What we are asking is does the system provide enough pressure to fill the pump completely and not cavitate (given the pump design, speed, fluid viscosity, etc.)? The following is brief overview of $NPSH_A$ and how it is calculated.

$$NPSH_A = H_a + H_s - H_{vp} - H_f$$

Where

H_a = Atmosphere Head is the head or pressure (pressure is measured in feet of head) on the surface of the liquid in the tank that we are pumping out. In an open system like this, it will be atmospheric pressure, 14.7 psi or 34 feet of water.

H_s = the vertical distance, measured in feet, between the free surface of the liquid to the centerline of the pump impeller. If the liquid is below the pump, this becomes a negative value.

H_{vp} = the vapor pressure of the liquid at the pumping temperature, expressed in feet of head.

H_f = the friction losses in the suction piping, expressed in feet of head.

To put this formula in simpler terms think of $NPSH_A$ as being the result of atmospheric head (pressure) pushing the fluid into the pump. The pump gains additional inlet head or pressure if the liquid level is above the pump inlet or minus head if the liquid level is below the pump. The fluid weight creates the pressure. The pump loses inlet head or pressure from friction loss of the fluid moving through the suction pipe (small pipes or long pipes have a lot of friction). And finally the inlet head or pressure is reduced by vapor pressure. This is an issue if the fluid is evaporates easily or is very hot. So $NPSH_A$ is atmosphere head plus or minus

One final note about $NPSH_R$ for a pump. Many pump manufacturers provide $NPSH_R$ curves for their pumps. This curve is determined in labs using methodology as set forth by Hydraulic Institute. The various points on this curve are determined by restricting the inlet pressure with a valve. The restricted inlet pressure creates loss of flow or cavitation. The $NPSH_R$ curve is drawn based upon the pump losing three percent of its rated flow. At various flow points a vacuum reading is taken on the inlet of the pump. These points are plotted below the pump curve showing the minimum inlet pressure the pump needs, but by definition this lost flow really is vapor bubbles and the pump is being damaged. When installing a pump, insure that the inlet conditions are **well above the** $NPSH_R$ **requirements of the pump.**

Rule #2. REDUCE THE FRICTION LOSSES

When a pump is taking its suction from a tank, it should be located as close to the tank as possible. This reduces friction losses on the NPSH Available. However, the pump must be far enough away that proper piping can supplied to the pump. Proper piping means that a straight shot of pipe is supplied to the pump that is at least ten (10) diameters of the pipe. We can this the 10D Rule. For example a minimum of 20" of straight pipe must be immediately in front of the pump if the inlet pipe is 2" in diameter. Pipe friction is reduced by using a larger diameter pipe. This limits the linear velocity, hence the friction losses. Many industries use 5 to 7 feet/sec., but this is not always possible.

Rule #3. NO ELBOWS ON THE SUCTION INLET

It is never acceptable to install an elbow on a suction flange! There is always an uneven flow in an elbow. When it is installed at the suction inlet of the pump, it introduces an uneven flow into the eye of the impeller. This can introduce turbulence and air entrainment, which may result in impeller damage and vibration. The only thing worse than an elbow on inlet of a pump is two elbows. As mentioned above, the established method of ensuring a laminar flow to the inlet of the pump is using the 10D rule, straight pipe into the pump. This also means no valves, reducers, tees, etc.

Rule #4. STOP AIR OR VAPOR FROM ENTERING THE SUCTION LINE

Always check the suction line for leaks. As the pump operates it creates a partial vacuum, which will suck air into the suction line. This will create an effect similar to cavitation and with the same results. Another source of air in the suction line is the return line in the tank if the pump is re-circulating the fluid through a system. If the return line or supply line is above the tank liquid level, the liquid will become very become aerated. This is a huge issue. Aerated tanks damage the pump just by creating cavitation like conditions for the pump. The fix is to submerge the return or supply line. Return lines in the tank can be to close to the outlet nozzle on the tank and can create the same issue. The solution is relocating the return line or baffling the tank.

The presence of an air pocket in the suction line is another example of a cause for pump troubles, which should never happen. Any high point in the suction line can become filled with air and interfere with proper operation of the pump. This is particularly true when the liquid being pumped contains an appreciable amount of air in the solution or of entrained air and the pump is handling a suction lift. Long suction lines are too frequently installed with improper pitch or with humps and high spots, where air can accumulate. If the liquid supply is below the pump the suction line should run up to the pump. Straight reducers are definitely a no-no. Use an eccentric reducer, mounted with the flat portion on top and sloping portion on the bottom. Install the other way around if source of supply is above pump.

Another common problem is pumping a tank to low or having a short tank that in general has low liquid levels above the outlet nozzle of the tank. If a pump is taking its suction from a tank with low liquid levels, the formation of vortices can draw air into the suction line and hence the pump. Vorticing can be eliminated, by installing a low liquid level sensor to turn off the pump. Alternatively, install a bell-mouth connection on the tank opening to lower the velocity on the tank outlet nozzle, hence lowering the liquid level requirements to keep the tank from vorticing. Or a vortex breaker can be installed on the discharge nozzle of the tank. They look very similar to the drain stopper in a modern bathroom sink, except the diameter of the top round disk on top is 1½ times the size of the ID of the tank discharge nozzle. Placing the tank outlet nozzle near the wall of the tank will also help break a vortex.

The following table shows the minimum submergence required over opening unless some of the suggested solutions mentioned above are employed:

Minimum Submergence of Outlet Nozzle	Velocity of Outlet Nozzle
1 foot	2 ft./sec.
2 feet	3.5 ft./sec.
3 foot	5 ft./sec.
4 foot	6 ft./sec.
5 foot	6.5 ft./sec.
6 foot	7.5 ft./sec.
7 foot	8 ft./sec.
8 foot	8.6 ft./sec.
9 foot	9.5 ft./sec.
10 foot	10 ft./sec.

The Hydraulic Institute states that typically one foot submergence for each foot per second of velocity at the suction pipe inlet is recommended, with a suggested maximum inlet velocity of six feet per second.

Rule #5. CORRECT PIPING ALIGNMENT

Piping flanges must be accurately aligned before the bolts are tightened and all piping, valves and associated fittings should be independently supported, so as to place no strain on the pump housing. Magnetically coupled pumps can have very short lives due to this issue. Plastic pumps will not take these forces and moments. Piping strains can affect seal life and bearings as well. Stress imposed on the pump casing by the piping reduces the probability of satisfactory performance and pump life.

ADDITIONAL THINGS TO WATCH

Sometimes when an electrician hooks up the motor is wired backward, meaning the pump may be spinning the wrong direction. The result is low flow and head. Before the pump is installed on the motor, quickly turn the motor on and off or "bump" it and check the direction of rotation and compare that to the direction marked on the pump casing. If the direction is wrong, reverse the electrical leads.

Special pumps are available from many manufacturers to handle slurries, yet most pumps are not designed to handle foreign material without damage to the pump. For this reason many applications have strainers or filters installed in front of the pump. The major problem with this that users fail to monitor the pressure drop that develops across the strainer or filter as it loads up with foreign matter. The result is high friction losses, which result in inadequate $NPSH_A$ and the pump cavitates. The solution is to install differential pressure drop instrumentation or a vacuum gauge or better yet switch, which can automatically alarm the operators. Sometimes the damage from insufficient NPSH is worse than if no strainer or filter was installed.

SUMMARY

When any of the above rules have been ignored, follow rules 1 through 5.

Lang Engineering has found that basic pipe design in small pumps is routinely ignored. This results in shorter life in seals or bearings. Just because the pump works does not mean that the pump is piped correctly! Even when the pump is working satisfactorily it doesn't mean that it is piped correctly, it merely makes it lucky.

The suction side of the pump is much more important than the piping on the discharge. If any mistakes are made on the discharge side, they can usually be compensated, by increasing the performance capability of the chosen pump. Problems on the suction side, however, can be the source of ongoing and expensive difficulties, which may never be traced back to rules 1 to 5.

The solution then on problem pumps may not be the pump, but the piping, the tank or any of the other issues discussed above. Good luck and happy pumping!

References:

1. ROSS C. MACKAY
2. IGOR J. KARASSIK