PRIMING A PUMP

A major deficiency of centrifugal pumps is that the pump chamber must be filled completely with water upon startup in order for it to function correctly. If there exists a suction head (positive pressure on the suction side of the pump), the unit will always remain full, whether on or off, but with a suction lift, water tends to run back out of the pump and down the suction line when the pump stops. If the casing is filled with air or vapor, the impeller cannot create enough vacuum upon starting to draw water back into the unit, and the gas will just circulate around in the pump. The heat produced by the pump's mechanical action has no flowing water to dissipate it, and both pump and motor will overheat in a short time. It is best to always provide a positive suction head for a centrifugal pump, but if that is not possible, the pump must be separately primed (filled with water) each time it is started.

Rather than manually filling the pump with every startup, several different types of self-priming devices have been developed.

Foot Valve

A specialized check valve at the end of the suction line. It rides open when the pump is operating but shuts as the pump stops, trapping water in the unit and piping. Recorded efficiency of foot valves depends on installation; if the valve doesn't seat properly, water will leak out.

Vacuum Pumps and Ejectors

Separate units attached to the main pump casing, they create the vacuum needed to fill the pump before startup. These are commonly seen installed with low lift pumps at water treatment plants; disadvantage is extra capital cost and maintenance.

Priming Chamber

A permanently fitted reservoir of liquid above the pump. They are usually filled by a small recirculated flow of the pump discharge water, and empty their contents as the pump starts. Restriction is with size; this is a bulky unit, which must be able to completely fill the pump casing and associated piping.

Some self-priming pumps are built with a wide suction inlet which rides higher than the pump. Upon stopping, the discharge valve closes, and the water in this suction area slides back into the pump, rather than down the suction line. A vent exhausts any extra air.

CAVITATION

Water naturally contains a small gaseous phase, present as tiny bubbles or vapor molecules, which are in constant motion and always trying to escape the fluid. The percentage of this gaseous phase which remains in the water without evaporating, depends on the water's tendency to evaporate. At normal temperatures in an open vessel, atmospheric pressure upon the water minimizes this tendency; the vapor areas are fairly stable, and the water remains in the liquid phase. At elevated temperatures, or under conditions of lowered air pressure, the water's tendency toward vaporization increases. At higher elevations water boils at lower temperatures.

As water enters a pipe and pushes the air out, this evaporative tendency of the liquid, becomes, by comparison, more significant. If the water is under water pressure, instead of air pressure, the vaporizing tendency is minimal, but only because normal inpipe water pressures are usually a good deal more than atmospheric pressure (at 50 psi, water will not boil until a temperature of 300 degrees F is reached).

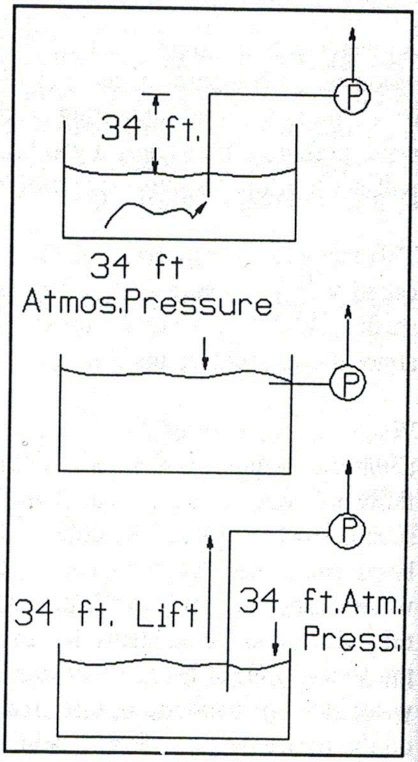
This tendency to vaporize, or, the pressure that the water exerts on its surroundings, is called Vapor Pressure. At 70 degrees F, water has a vapor pressure of .256 psia - very small. At 212 degrees F, water has a vapor pressure of 14.7 psia, the same as the atmospheric pressure upon it, and it boils.

When the pressure of the atmosphere falls below the vapor pressure of the water,the amount of vapor phase rapidly increases, bubbles are formed, and the water begins to flash into vapor. In a pipe, if the vapor cavity becomes so large as to fill the cross section of the pipe, a true column separation occurs. As we have seen, a water main break can cause this to happen. The increased flow creates vacuum, and some of the water flashes to vapor to fill the vacuum. If a valve is closed too rapidly, upstream of the valve pressure suddenly increases, causing hammer, but downstream of the valve, the Velocity Head keeps the water moving, vacuum forms in the space behind, and the water starts to vaporize in that area. Rapidly opening a valve can have the same effect on the upstream end. Power failure to a pump also will cause negative pressure waves to be set up which will travel downstream and produce vapor formation.

In the above mentioned cases, the pressure changes are momentary; as pressure equalizes in the system, and returns to the area, the low pressure condition is eliminated. The column rejoins, and the vapor bubbles collapse, or implode - quite forcibly - against the surface of the surrounding metal, chipping and disintegrating that metal, bit by bit. This phenomenon is referred to as Cavitation.

The effects of cavitation are most damaging in areas where it is occurring repeatedly. In pumping operations employing a suction lift, there is no positive depth of water to provide an initial pressure to the water entering the pump, and it is here that cavitation is most significant.

As a pump impeller rapidly increases water velocity, pushing fluid out of the pump, a tendency toward vacuum is created in the water coming in; in effect, a space is left between molecules of incoming water, and pressure is low (Velocity Head increases, Pressure Head decreases). If the pump is lifting water from below, it is only atmospheric pressure on the intake reservoir which pushes the water in to fill the suction pipe and take up these spaces. Since atmospheric pressure at sea level and standard temperature is equivalent to 34 ft. of water pressure, we could picture that a pump feeding a tank whose suction water surface elevation is at the same level as the pump centerline, really has a positive suction head of 34 ft. of water, as absolute pressure. Theoretically, we could lower the suction pipe to 34 ft. below the pump, and still get liquid into the pump. This amount of absolute pressure needed to get the water into the pump is called Net Positive Suction Head (NPSH). It is the total amount of energy, in Absolute feet of water, at the pump centerline.



If this Net Positive Suction Head (theoretically 34 ft. or 14.7 psia) should drop below the vapor pressure of the water entering the pump, the external pressure will become less than the water's tendency to vaporize, and the water will start to flash into vapor at the pump entrance, eye, and impeller vanes. Bubbles will form, which will be forcibly collapsed as the water pressure suddenly increases near the pump exit. Cavitation will occur, with resulting chipping and destruction of internal pump parts. Operated this way for a length of time, the vibration caused will also damage bearings, shaft, and seals. The destructive effect is magnified further because of the fact that water molecules turning to vapor expand many times in the phase change. This enhances the repressurization and implosion.

But how does this theoretical 34 ft. of water pressure (14.7 psia) become less than the theoretical vapor pressure of water (.59 ft., .256 psia)? It does happen, because these are both only theoretical, and static quantities.

Consider first that there are friction losses within the mechanism of the pump itself. As the water enters the impeller eye, it makes a right angle turn. Then turbulence is increased by the vanes, adding to head loss. The eye, and the vanes, have a degree of roughness, etc. - all sources of head loss. Recognizing these internal pump losses, manufacturer's data will supply a specific amount of minimum positive absolute pressure which must be present in the water at pump entrance in order to overcome these head losses, and keep the pump running efficiently, and without cavitation. This is the Net Positive Suction Head Required (NPSHR). It is a characteristic of each pump, and is obtained by calculations and testing of the prototype pump of each model at a range of flows. It is determined by shape, size, and speed of pump; it increases with increased flow, and is often inserted as a NPSHR curve on the pump performance curve.

That is how much Absolute pressure is needed in order to use this pump. Now it must be determined how much pressure the system will provide. This amount is the Net Positive Suction Head Available (NPSHA), a characteristic of the system. It is defined as the energy actually available, in feet of Absolute Pressure, at the inlet of the pump. NPSHA is calculated for each installation with a simple formula:

NPSHA = (Atmospheric Pressure + Velocity Head) - (Lift + Losses + Vapor Pressure)

positive pressure forces negative pressure forces

All of the elements of the formula are recorded in Absolute feet of water.

Atmospheric Pressure

All of the components of this formula can vary; atmospheric pressure may be 14.7 psia at sea level, but it is substantially lower in Denver, Colorado, a mile above sea level (see chart). Therefore, in a high altitude area, there is less positive pressure to start with.

WATER CHARACTERISTICS TABLE

Altitude Below or Above Sea Level	Atmospheric Pressure Pressure PSIA	Equivalent Head of 75° Water Feet (Abs)	Water Boiling Point °F
- 1000	15.2	25.2	231.8
- 500	15.0	34.7	212.9
0	14.7	34.0	212.9
+ 500	14.4	33.4	
1000	14.2	32.8	210.2
1500	13.9	32.2	209.3
2000	13.7	31.6	208.4
2500	13.4	31.0	
3000	13.2	30.5	
3500	12.9	29.9	
4000	12.7	29.4	204.7
5000	12.2	28.3	
6000	11.8	27.3	201.0
7000	11.3	26.2	
8000	10.9	25.2	197.4
9000	10.5	24.3	
10,000	10.1	23.4	193.7
15,000	8.3	19.2	184