Suction pipeline design

The root cause of many pump problems and failures can be traced to poor upstream, suction-side, pipeline design. Common problems to avoid are:

- Insufficient fluid pressure leading to cavitation within the pump.
- Narrow pipes and constrictions producing noise, turbulence and friction losses.
- Air or vapour entrainment causing noise, friction and loss of performance.
- Suspended solids resulting in increased erosion.
- Poor installation of pipework and other components.

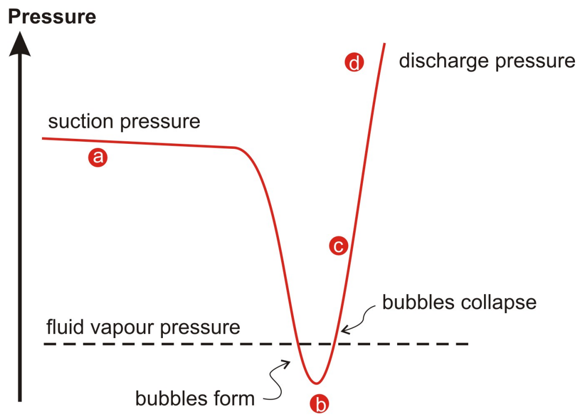
Cavitation

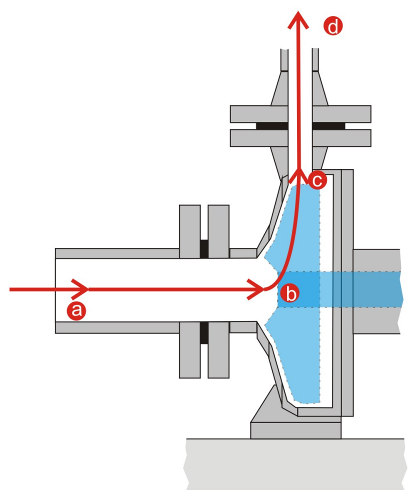
A liquid's boiling point corresponds to the temperature at which its vapour pressure is the same as the pressure of its environment. If water, for example, is subjected to a sufficient drop in pressure at room temperature, it will boil.

Across any pumping system there is a complex pressure profile. This arises from many properties of the system: the throughput rate, head pressure, friction losses both inside the pump and across the system as a whole. In a centrifugal pump, for example, there is a large drop in pressure at the impeller and an increase again within its vanes (see diagram). In a positive displacement pump, the fluid's pressure drops when it is drawn, essentially from rest, into the cylinder. The fluid's pressure increases again when it is expelled.

If the pressure of the fluid at any point in the pump is lower than its vapour pressure, it will literally boil, forming vapour bubbles within the pump. The formation of bubbles leads to a loss in throughput and increased vibration and noise but the big danger is when the bubbles pass on into a section of the pump at higher pressure. The vapour condenses and the bubbles implode, releasing, locally, huge amounts of energy. This can be very damaging, causing severe erosion of the pump's components.

To avoid cavitation, you need to match your pump to the fluid, system and application. This is a complex area and you are advised to discuss your application with the pump supplier.





Pressure gradient through a centrifugal pump experiencing cavitation: fluid enters the pump (a); pressure drops below vapour pressure at impeller (b), pressure rises as fluid passes out to discharge (d) and bubbles condense and collapse (c).

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Understanding NPSH

To avoid cavitation, the pressure of the fluid must be maintained above its vapour pressure at all points as it passes through the pump. Manufacturers specify a property referred to as the **Net Positive Suction Head Required** or NPSH-R – this is their minimum recommended fluid inlet pressure, expressed in metres. The documentation supplied with your pump may contain charts showing how NPSH-R varies with flow.

In fact, NPSH-R is defined as the suction-side pressure at which cavitation reduces the discharge pressure by 3%. So, in designing the suction-side pipework for your system, you must ensure that it exceeds the manufacturer's NPSH-R rating for the operating conditions. Your calculated value is termed the **NPSH-Available** (NPSH-A).

Remember, a manufacturer's NPSH-R rating is the *minimum* recommended inlet head pressure: a pump is already experiencing cavitation at this pressure. Consequently, it is important to build in a safety margin of 0.5 to 1m to take account of this and other factors such as:

- The pump's operating environment – is the temperature constant?
- Changes in the weather (changes in temperature and atmospheric pressure).
- Any increases in friction losses that may occur occasionally or gradually during the lifetime of the system.

Cavitation damage to an impeller

Calculating NPSH-A

$$\text{NPSH-A} = \frac{(P_e - P_v)}{\rho}.10.2 + H_z - H_f + \frac{V^2}{2g}.$$

where:

P_e = Absolute pressure in pumped vessel (bar)
P_v = Vapour pressure of fluid (bar)
ρ = Density of fluid (kg/dm³)
H_z = Minimum fluid level above pump (m) (negative term if below pump)
H_f = Friction losses in suction side pipework (m)
V = Fluid velocity in pump flange (m/s)
g = Acceleration due to gravity (9.81m/s²)

Ensure:

$$\text{NPSH-A} \geq \text{NPSH-R} + 0.5\text{m}$$

Turbulence and Friction

Pumps, and especially centrifugal pumps, work most efficiently when the fluid is delivered in a surge-free, smooth, laminar flow. Any form of turbulence reduces efficiency and increases wear and tear on the pump's bearings, seals and other components.

There should be at least 5 pipe diameters' worth of straight piping connecting to the pump. Never connect an elbow, reducer, valve, or strainer within this final run of pipework. If you connect an elbow directly to the pump flange, the fluid is effectively centrifuged towards the outer curve of the elbow and not directed into the centre (the eye) of the impeller. This creates stress on the pump's bearings and seals which often leads to wear and premature failure.

Sometimes, it's just not possible to make provision for a sufficient settling distance in the pipework before the pump. In these cases, use an inline flow conditioner or straightener.

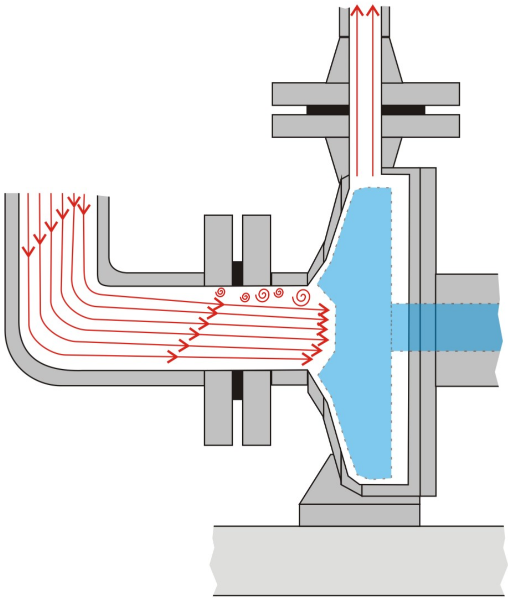
It's standard practice to employ suction-side piping one or two sizes bigger than the pump inlet - you should certainly never use any piping that is smaller than the pump's inlet nozzle.

Small pipes result in larger friction losses, which means it costs more to run your pumping system. On the other hand, larger diameter pipes are more expensive – so you need to weigh up the increased cost with the likely energy saving resulting from reduced friction losses.

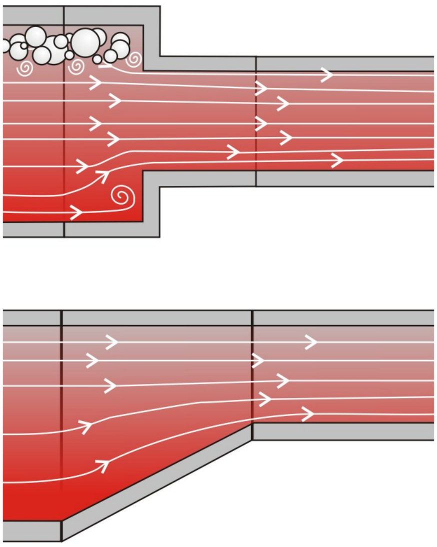
It also makes sense to keep the run of pipework to a minimum by positioning the pump as close as possible to the fluid source.

Larger pipework means that you'll need a reducer before the pump inlet. A reducer is a constriction and requires careful design to avoid both turbulence and the creation of pockets where air or vapour might collect. The best solution is to use an eccentric reducer orientated to eliminate the possibility of air pockets.

As a general rule of thumb, suction pipe velocities should be kept below 2 m/s. At higher velocities, the greater friction causes noise, higher energy costs and increasing erosion, particularly if the fluid contains suspended solids. If your system contains any narrow pipes or other constrictions, bear in mind that the pipe velocity will be a lot higher at these points.



Uneven flow resulting from an elbow too close to the pump



Eccentric reducers eliminate air/vapour pockets and minimize friction

Calculating Pipe Velocity

Pipe velocity (m/s) = $1.274\ q/d^2$

where q = volume flow (m^3/s)
and d= pipe inside diameter (m)

Air or Vapour Entrainment

It's best to keep air or vapour out of the pipework. Entrained gases cause a loss in pump performance, increase noise, vibration and component wear and tear. It's therefore important to position the feed pipe correctly in the tank or vessel. It should be fully submerged. If it's too close to the surface of the fluid, the suction creates a vortex, drawing air (or other vapours) into the liquid and through the pumping system. The feed pipe should also be clear of any other pipes, agitators or stirrer-paddles – anything that might drive air into the fluid. In shallow tanks or ponds, it may be advisable to use a baffle arrangement to protect the feed pipe from air entrainment.

Suspended Solids

You should also make sure that the feed pipe isn't too close to the bottom of the tank or pond. If it is, the suction may draw up solids or sludge instead of air or vapour! The fluid may contain suspended solids in any case.

Some displacement pumps can cope with a mixed phase supply without any damage or major loss in performance. Centrifugal pumps are not so robust and must be protected from solids. In this situation you'll need to install a filter or strainer. Filters can create a large pressure drop and be responsible for cavitation and friction-loss. The filter screen should have at least three times the free area of the pipe cross-section. Use a differential pressure gauge across the screen to look out for any increased pressure drop before clogging problems arise. This will also help in the accurate assessment of NPSH-A.

Installation

Obviously, pumps should be securely located - but so should the pipework. Don't use one to support the other. All other components must be just as securely located and create no stresses or strains on any other parts of the system. Ensure that the pipe connecting to the pump's inlet flange is aligned precisely with it. If you need to install non-return valves or flow control valves fit them on the discharge side of the pump, and never in suction-side pipework.

Summary

Problems in suction side pipework often have damaging consequences for the system pump and can be avoided by following these guidelines:

- Ensure that conditions do not favour cavitation, particularly if you are using a centrifugal pump. This requires careful selection of the pump, its positioning and the head pressure.
- Position the feed pipe to minimize entrainment of air/vapour and solids.
- Minimize friction and turbulence by choosing appropriate pipes and components:
  - Use pipes with a diameter twice that of the pump's suction side flange.
  - Ensure that the pipework is aligned with the pump's flange and straight for at least 5 pipe diameters.
  - Use an eccentric reducer orientated to eliminate air pockets.
- Keep the pipe velocity below 2m/s.

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