P_s = static head of water level above the pump impeller (This is negative if water level is below the impeller.)
P_{vp} = vapor pressure of water, in feet, at operating temperature (see Tables 2.3 and 2.4)
P_f = friction of suction pipe, fittings, and valves, in feet of head

Equation 6.8 can be used for higher temperatures and elevations. Assume the following:

1. The maximum cooling tower water temperature is 95°F, so P_{vp} = 1.9 ft of vapor pressure. From Table 2.3.
2. The cooling tower sump is above the pump impeller, and P_s = 5 ft.
3. The installation altitude is 1000 ft; From Table 2.1, the atmospheric pressure, P_a = 32.8 ft.
4. The friction loss of the suction pipe, fittings, and valves P_f is 6 ft. Thus

$$\text{NPSHA} = 32.8 + 5 - 1.9 - 6 = 29.9 \text{ ft}$$

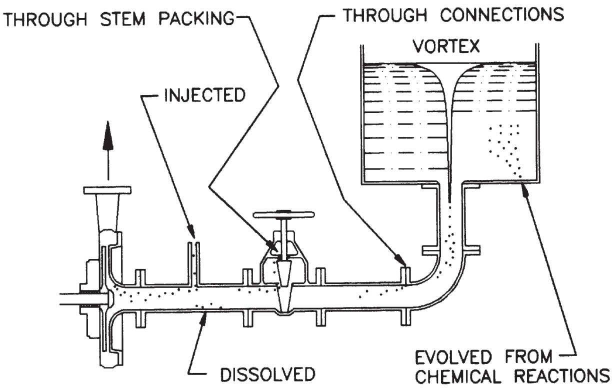
Any pump handling this water must have an NPSHR of less than 29.9 ft at any possible flow through the pump.

Warning. *Calculation of NPSHA for a cooling tower should be made at the maximum possible operating water temperature in the tower, not the design water temperature.*

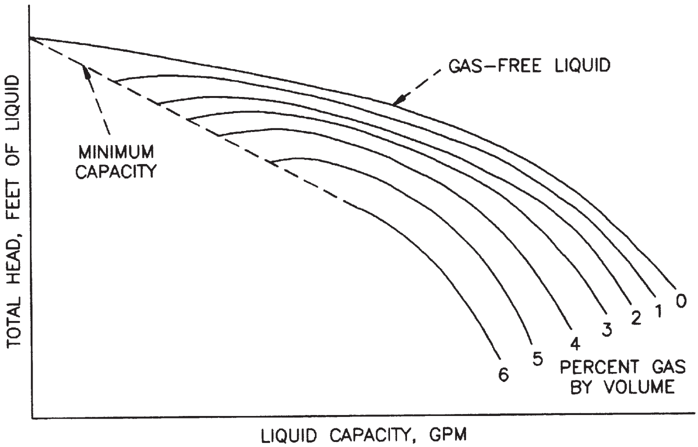
6.5.2 Air entrainment and vortexing

A companion to cavitation is *air entrainment* in the suction of centrifugal pumps. Air can enter the water system at several points, as shown in Fig. 6.16*a*. The effect of air entrainment on pump performance is described in Fig. 6.16*b*; it indicates the drastic reduction in both head and capacity when air is present. Every effort must be made to ensure that the water in a pump is free of air.

Air entrainment is often confused with cavitation when drawing water from a tank. It is thought that air entrainment cannot happen when a tank of water is 10 to 15 ft deep. Air entrainment can occur easily when water is taken from a free surface of water regardless of the depth of the water. Figure 6.17 describes the air entrainment that can occur if water is not removed properly from an open tank. As shown in Fig. 6.17*a,* a small whirlpool occurs on the surface, and this deepens into a vortex that will extend down to the water outlet from the tank, and finally, air will pass into the impeller of the pump, causing



a. Centrifugal pumps and entrained-air problems.[5]



b. Effects of various amounts of entrained gas on pump characteristics.

Figure 6.16 Entrainment of air in HVAC pumps. (*From John H. Doolin, Centrifugal pumps and entrained-air problems, Chemical Engineering, January 7, 1963, p. 103.*)

hammering similar to cavitation. Tank depth does not deter the development of the vortex.

Cavitation and air entrainment can cause similar noises in a pump. A simple method of eliminating cavitation as a source of noise is to run the pump at full speed and close the manual discharge valve on the pump until only a small flow is passing through the pump. Cavitation should cease, but air noise will persist at the low flow through the pump.

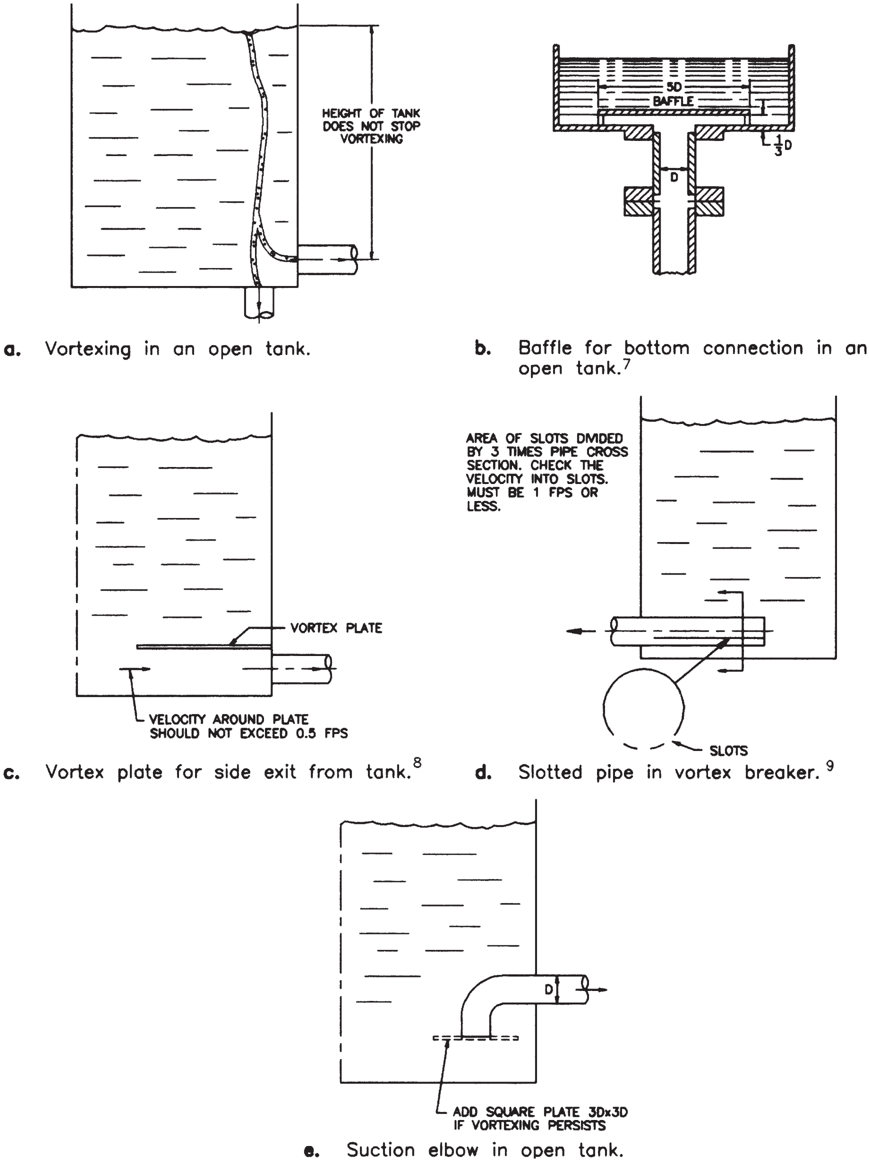


Figure 6.17 Vortexing in HVAC pumps. (*From James H. Ingram, Suction side problems: Gas entrainment, Pump and System Magazine, September 1994, p. 34.*)

Vortexing can occur easily when water is taken from a tank, particularly if the water outlet is on the side or bottom of the tank, as shown in Fig. 6.17*a*; a fully developed vortex is shown in this figure. Vortexing can be eliminated by placing an antivortexing plate above a bottom inlet, as shown in Fig. 6.17*b*; a side inlet can be corrected by placing an antivortexing plate above the inlet (Fig. 6.17*c*). On shallow cooling tower sumps, if vortexing persists, it may be necessary to install a slotted vortex breaking tube, as shown in Fig. 6.18*d*. As an alternative, an elbow can be installed on the suction connection of a side inlet and pointed downward, as shown in Fig. 6.17*e*. If vortexing still occurs, a square plate can be installed on the suction of the elbow. Vortex-breaking devices must be designed to avoid substantial additional friction losses. Normally, the friction loss of an entrance from a tank is equal to about $0.5 \times V^2/2g$, where V is the velocity of the water in the entering pipe. The vortex-breaking device should not increase this entrance loss if possible.

A simple method to determine if vortexing is occurring is to place mats or rafts on the water surface above the inlet from the tank. This prevents the vortex from forming and can be done without draining the tank.

Vortexing should not occur in HVAC tanks and sumps. The precautions are so simple that the design of these tanks and sumps should always accommodate them.

6.5.3 Submergence of pumps in wet pits or open tanks

Pumps installed in a tank, such as vertical turbine pumps, have a specific submergence requirement. The *submergence,* or distance above the inlet bell of such a pump, must be great enough to ensure that the friction loss of the water passing through the bell and entering the pump is made up by the static height of the water over the suction bell. This height is determined by whether the suction of the pump is or is not equipped with a suction strainer. Most manufacturers of axial-flow pumps have adequate data on submergence and clearance from the bottom of the tank for the water system designer; their recommendations should always be followed. Table 6.1 describes

TABLE 6.1 Typical Submergences for Vertical Turbine Pumps (for Operation at 1750 rev/min)

Bowl size, in	Submergence, in	Bowl size, in	Submergence, in
4	7	13	23
6	11	14	30
8	12	15	32
10	16	16	36
11	20	18	36
12	24	20	42