

Table 1.... Spray Pond Design Data
Conventional Up-Spray System

	Units	Standard	Min	Max
Water capacity per nozzle	gpm	35 to 50	25	60
Nozzles per 12 ft length of pipe		6	4	6
Height of nozzles above water level	ft	6	5	12
Nozzle pressure	psig	6	5	7
Size of nozzles and nozzle arms	in.	2	1 1/4	2
Distance between spray lateral piping	ft	25	13	38
Distance nozzles from pond side, unfenced	ft.	25 to 35	20	50
Distance nozzles from pond side, fenced	ft	15 to 20	15	25
Height of lower fence	ft	12	12	12
Depth pond basin	ft	4 to 5	2	—
Friction loss allowed per 100 ft pipe	ft	1 to 3	—	—
Design wind velocity	mph	5	3	—

The broadside air flow is $1270 \times 440 + 14.2 = 39,296$ lb. The end air flow is $720 \times 440 + 14.2 = 22,310$ lb.

The heat rise of the air is $500,000 + 39,296 = 12.72$ Btu/lb for broadside wind, or $500,000 + 22,310 = 22.41$ Btu/lb for end wind.

The entering enthalpy of the air is 35.83 Btu/lb, so the outgoing air is:

Broadside: $35.83 + 12.72 = 48.55$ Btu/lb, corresponding to 84 F wet-bulb.

End: $35.83 + 22.41 = 58.24$ Btu/lb, corresponding to 92 F wet-bulb.

By using Table 2 and interpolating, the cold-water temperature for end wind operation will be 2 F below the outgoing wet-bulb temperature, or 90 F. The cold-water temperature for a broadside wind will be 3 F above the outgoing wet-bulb, or 87 F.

Wind passing through a pond carries away entrained water as drift. This creates a nuisance in the area on the leeward side of the pond. This must be considered when selecting the location of the pond. The drift loss can be minimized by enclosing the spray pond within a lower fence 10 to 12 ft high. Fogging, which can occur during cold weather, presents another hazard to buildings or roadways. A pond should be located with due regard for seasonal variations in wind directions, to provide maximum cooling during the hot summer months and minimum hazard to roadways during the winter.

Lower water temperatures can be obtained from a spray pond than from a cooling lake, and a much smaller area is needed. This reduces the initial cost when a natural lake is not available. This saving in cost is offset by the cost of piping, supports, and spray nozzles. Pumping costs may also be higher, due to the back pressure imposed by the spray nozzles.

Atmospheric Towers

An atmospheric spray-filled tower is essentially a spray pond with louvered walls and an elevated spray system which usually sprays downward. While the spray pond uses large nozzles handling 25 to 50 gpm each, the spray tower will have 1 in. to 1 1/2 in. nozzles handling 2 to 5 gpm each. Water loadings vary from 0.6 to 3.0 gpm per sq ft of plan area, and the heights vary from 6 to 15 ft. The design conditions are generally based on a 3 mph wind, but the down-spray nozzles have an aspirating effect that can induce a downward air

Table 2.... Degree Adjustments to be Applied to Leaving Air Wet-Bulb Temperature to Find Cooled Water Temperatures of Spray Ponds*

Cooling Range F deg	Entering Wet-Bulb Temp. F	Adjustment in F Degrees		
		Length of Air Travel* (Feet)		
		100	50	25
10	80 WB	-3	+2	+4
	70 WB	-2	+3	+5
	60 WB	-1.5	+3.5	+5.5
15	80 WB	-5.0	+1	+5
	70 WB	-4	+2	+6
	60 WB	-3.5	+2.5	+5.5
20	80 WB	-7	0	+6
	70 WB	-6	+1	+7
	60 WB	-5.5	+1.5	+7.5

* Cooled-water temperature = wet-bulb temperature of leaving air plus or minus the values shown.

^b Wet-bulb temperature of air entering spray-filled volume. See text.

^c Length of air travel through spray-filled volume.

movement of up to 400 fpm. However, wind is needed, to carry the hot vapors away and prevent recirculation.

Atmospheric spray towers seldom exceed 50 ft in length. They frequently serve small refrigerating systems, or cool jacket water of internal combustion engines. The performance can be estimated by calculating the outgoing wet-bulb temperature, as with the spray pond. The cold-water temperature will be approximately equal to the outgoing wet-bulb temperature, and performance can be estimated on that basis. An inadequate spray system will increase the water temperature several degrees. Spray towers require less basin area, less piping, and no more mechanical equipment than spray ponds, but savings may be offset by the extra cost of the structure.

The atmospheric deck tower contains wooden latticework

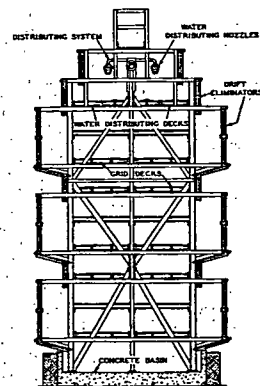


Fig. 2.... Atmospheric Deck Tower

Cooling Towers and Spray Ponds

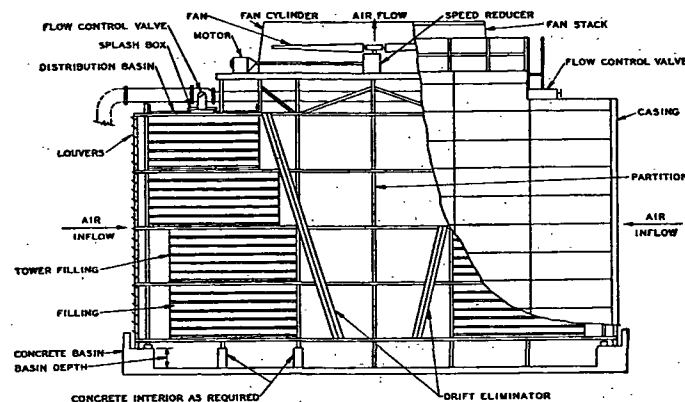


Fig. 3.... Cross-flow Mechanical Draft Tower

decks, regularly spaced from top to bottom. This filling interrupts the falling water, greatly increases the exposed water surface, and prolongs the time of contact with the air. Towers, such as shown in Fig. 2, are 20 to 50 ft high and 8 to 16 ft wide. The hot water is distributed at the top by a spray system or, more frequently, by open troughs. Except for the vagaries of the wind, the performance is quite predictable. This is done by the method described later for cross-flow, mechanical-draft towers.

The cooling range of spray ponds or spray towers, which is the temperature difference between the water entering and leaving the pond or tower, seldom exceeds 15 F deg. It is difficult to obtain less than a 10 F deg approach, which is a temperature difference of less than 10 F deg between the leaving water and the air wet-bulb, unless the cooling range is lower. These performance limitations do not apply to the atmospheric deck tower. The designer can control performance by variations in tower height, water loadings, and density of the filling.

The drift loss of a deck tower is considerable, and the nuisance is similar to that caused by the spray pond or spray towers. Both spray and deck towers are frequently located on building roofs, but the drift nuisance is seldom tolerated in congested areas. Water cooling systems that depend on the wind for air movement are not suitable for many services where the temperature requirements are more exacting.

Mechanical-Draft Towers

The mechanical-draft tower is equipped with fans to provide a positive and constant air flow. Since performance does not depend on the wind, it is possible to design mechanical-draft towers for exacting conditions. The fans may operate to provide forced or induced draft, depending on their location at the inlet or outlet of the tower. The tower may be cross-flow, as shown in Fig. 3, or counter-flow, as shown in Fig. 4. The addition of the fan makes it possible to design wider towers that are more compact than the long, narrow atmospheric towers. Early mechanical-draft towers were

frequently of the spray-filled, forced-draft type. These spray-filled towers are rarely used at present, except in congested areas where fire codes prohibit the use of wood filling.

The mechanical-draft tower is subject to recirculation of the exhaust vapors. These vapors will usually rise vertically on a still day and cause no trouble. Wind blowing across a tower creates a low-pressure area on the leeward side. The exhaust vapors may then move downward and flow back into the tower. This increases the entering wet-bulb temperature and affects the performance accordingly. Recirculation is worse with forced-draft towers because of their low exit velocities. As a result, most towers built since 1940 are of induced-draft type. The forced-draft towers, however, have

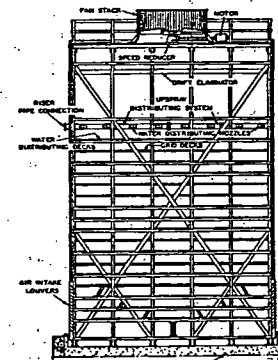


Fig. 4.... Counter-flow Induced-Draft Cooling Tower