

lake increases from 0 to 10 Btu per (sq ft) (hr) (F deg temperature difference) of air and lake water surface, for duty up to 150 Btu per (sq ft) (hr) and wind velocities up to 6 mph with air temperatures varying from 20 to 80 F.

Spray Ponds

Heat is dissipated from the surface of a lake by evaporation, radiation, and convection. The spray pond divides the water into small drops, greatly extending the water surface, and brings it into intimate contact with the air.¹ The heat transfer is largely due to evaporative cooling as explained in the section Cooling Tower Theory. The driving force is the difference in enthalpy rather than temperature difference. The water temperature tends to approach the wet-bulb rather than the dry-bulb temperature of the air. This offers an inherent advantage in making it possible to cool the water to a temperature lower than the dry-bulb.

Cooling occurs in a spray pond as the water is propelled upward and then falls to the surface of the pond. The pond itself acts largely as a collecting basin. A typical nozzle arrangement is shown in Fig. 2. The design criteria in Table 1 provide a guide that can be used in laying out a pond.

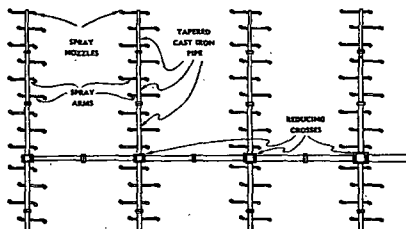


Fig. 2 Typical Nozzle Arrangement for a Spray Pond

The wind varies constantly in both direction and velocity. The wet-bulb temperature is usually changing also. These variations result in a continually changing temperature of the water as it strikes the surface of the pond. The pond acts as a reservoir so that the water temperature at the suction of the pump represents an average of past operating conditions. These characteristics make it difficult to test a spray pond or to develop ratings. As a result, spray ponds are not used when water temperatures must meet narrow limitations. They are usually designed for a 10 to 15 F deg cooling range and about a 10 deg approach of cold water temperature to the wet-bulb temperature.

The water leaving a spray nozzle will rise to a height of approximately 1 ft per psi of nozzle pressure. It will strike the surface of the pond in a circular pattern having a radius of about 10 ft. The cooling occurs within an active filled volume having a height equal to the elevation of the nozzles above the surface plus 1 ft per psi nozzle pressure, and a plan area extending 10 ft beyond the outer nozzles. The heat is transferred to the quantity of air passing through the air area which is the projected area of a vertical plane through the active filled volume and broadside to the direction of the air movement. The length of air travel is the horizontal distance the air moves through the filled volume.

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	1½	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	—

A reasonably accurate estimate of spray pond performance can be based on the outgoing wet-bulb temperature of the air passing through the filled volume. This temperature, obviously, cannot exceed the hot water temperature. It can approach the hot water temperature if it passes lengthwise through a long spray pond, but will have a small temperature rise when passing broadside through a narrow pond. The values in Table 2 can be used to obtain a reasonably accurate estimate of the cold water temperature with respect to the calculated outgoing wet-bulb temperature.

Wind passing through a pond carries away entrained water as drift. This creates a nuisance in the area on the leeward

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 ^b 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 the values shown.

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

* Length of air travel through spray-filled volume.

Evaporative Apparatus for Heat Rejection

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 feet 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 months.

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 Wind Towers

An atmospheric spray-filled tower (Fig. 3) is essentially a spray pond with lowered walls and an elevated spray system

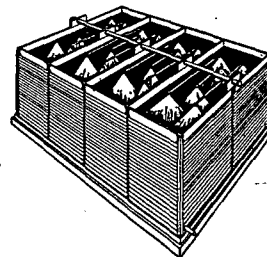


Fig. 3 Spray Filled Atmospheric Cooling Tower

which usually sprays downward. While the spray pond uses large nozzles handling 25 to 50 gpm each, the spray tower will have ¼ in. to ¾ 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 movement of up to 400 fpm. Despite this positive air movement, 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. These savings may be largely offset by the extra cost of the structure.

The atmospheric deck tower contains wooden latticework 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. 4, 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 seldom exceeds 15 F deg and it is difficult to obtain less than a 10 F deg approach unless the cooling range is shorter than that. These performance limitations do not apply to the atmospheric deck tower. The design 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. 5 or counter-flow as shown in Fig. 6. 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

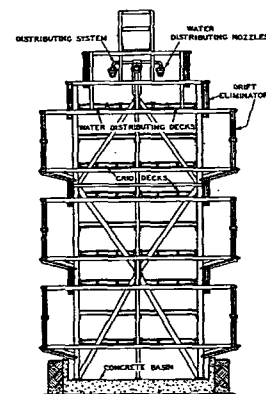


Fig. 4 Atmospheric Deck Tower