liquid subcooling is read on the horizontal scale at the bottom of Fig. 41 as 12 F deg.

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CHAPTER 46

COOLING TOWERS AND SPRAY PONDS

Types of Cooling Equipment, Comparing Types of Equipment, Cooling Tower Theory, Tower Coefficients, Tower Characteristics, Design Conditions, Performance Curves, Selection and Evaluation, Installation and Operation

MOST industrial processes generate waste heat that must be removed and dissipated. Small quantities are readily rejected directly to the atmosphere, but large heat loads usually rely on a flow of cooling water. The water, if cheap or plentiful, may be wasted, or it may be cooled and recirculated through the system.

TYPES OF COOLING EQUIPMENT

A cooling tower is a steady-flow device that utilizes a combination of mass and energy transfer to cool water by exposing it as an extended surface to the atmosphere. The water surface is extended by spraying, which produces drops, or by filling, which presents a film surface or creates drops due to splashing. The air flow may be caused by natural wind currents, convection currents due to variations in density, or by mechanical means. The air flow may be cross-flow or counter-flow to the falling water. The types of cooling equipment are:

1. Spray ponds
2. Atmospheric towers
   a. Packed or spray-filled
   b. Air flow induced by wind or stack effect
3. Mechanical draft towers
   a. Packed or spray-filled
   b. Forced or induced draft
   c. Cross-flow or counter-flow

Spray Ponds

Heat is dissipated from the surface of a body of water by evaporation, radiation, and convection. A 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 the 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. 1. The design criteria in Table 1 provide a guide that can be used in laying out a pond.

The wind varies constantly in both direction and velocity. The wet-bulb temperature is usually also changing. 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 for 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*.

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 its temperature will rise slightly when it passes 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.

Example 1: Consider a spray pond consisting of 3 laterals on 25 ft centers. Each lateral contains 8 lengths of 12 ft pipe, with 6 spray nozzles per length, or a total of 144 nozzles. The spray system is 6 ft above the surface of the pond, operates at 6 psi, and circulates 6000 gpm. Determine performance with a 5 mph wind, both broadside and from the end, with 10 F cooling range and 73 F wet-bulb temperature.

Solution: The heat load is $6000 \times 10 \times 8.33 = 500{,}000$ Btu per min.

The spray system covers an area 96 ft long by 50 ft wide and the spray extends an average of 5 ft beyond on all sides, so the overall dimensions are 106 ft × 60 ft. The spray rises 6 ft (1 ft per psi), so the total spray height is 12 ft. The broadside air area is 106 ft × 12 ft = 1270 sq ft. The end area is 60 × 12 ft = 720 sq ft. Wind at 5 mph corresponds to 440 fpm. The specific volume at 93 F wet-bulb (assuming 92 F dry-bulb) is 14.2 cu ft per lb dry air.

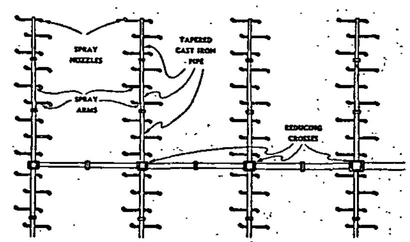

Fig. 1 .... Typical Nozzle Arrangement for a Spray Pond

The general responsibility for this chapter is assigned to TC 9.3, Cooling Towers, Evaporative Condensers.