

by the secondary louvers which extend upward from each primary louver's outer edge to the next primary louver above. The individual slats which comprise the secondary louvers may be arranged either vertically in an overlapping staggered manner with air passage between, or set horizontally with their flat surfaces sloping inward and spaced so their edges over-reach but permit free air passage. Secondary louvers reduce drift loss on this type of tower materially.

Efficiency of a deck tower is improved, within limits, by increased height, increased length, or increased width. The first two increase the area of water exposed to the wind, and the latter increases the time of contact of the air with the water. Performance is best when the wind blows crosswise to the tower and decreases with obliqueness of the angle until the effect of a lengthwise wind is virtually nil.

Wind Velocities on Natural Draft Equipment

Since natural air movement is the prime requirement for a deck type tower, spray cooling tower, or spray pond, the apparatus must be designed to produce the desired cooling at times when the wind velocity is below average, when the wet-bulb temperature is at the maximum chosen for design, and when the plant is operating at full load. The apparatus must also, for best results, be located with its longest axis at right angles to the direction of the prevailing hot weather breeze. Table 3, Chapter 15, gives the average summer wind velocities in representative United States cities. Natural draft cooling equipment should be designed to operate properly with *not more than one-half* of the average wind velocity, and in no case for a wind velocity of more than 5 mph. Natural draft equipment must not be obstructed by trees, buildings, or other wind deflectors.

Mechanical Draft Towers

Mechanical draft towers usually consist of box-like shells, constructed of wood, metal, or masonry, in which water is distributed uniformly at the top and falls to a collecting basin at the bottom. The inside of the tower may be filled with wood lattice work over which the water drips, or the water surface may be presented to the air by filling the entire inside of the structure with spray from nozzles.

Air is drawn through the tower by induced draft fans or propelled through it by forced draft fans. Since the air flows at a constantly sustained and comparatively high velocity (by contrast with natural draft equipment which varies in performance with every change of the wind's direction or velocity) the air and water are brought into contact under controlled conditions resulting in more efficient transfer of heat from a given quantity of water into a given volume of air. The least possible operating cost is achieved by that tower design which delivers the desired performance for the lowest total power input, both to fans for air movement and to pumps for raising and distributing the water.

The effectiveness of a mechanical draft tower is improved by increasing height, area, or air quantity. Increasing the height increases the length of time the air is in contact with the water without affecting seriously the fan power required, but it increases the pumping power needed. Increasing the area while maintaining constant fan power increases the air quantity somewhat and because of lowered velocities it increases the time this air is in contact with the water. The surface area of water in contact with the air is increased in both cases. Increasing the air quantity decreases the time the air is in contact with the water, but, since a greater quantity is passing through, the average differential between the water

temperature and the wet-bulb temperature of the air is increased, and this speeds up the heat transfer rate. Increased air quantities are obtained only at the expense of increased fan power, which increases approximately as the cube of the air quantity. Air velocities through mechanical draft towers vary from 250 to 450 fpm over the gross area of the structure.

Inside type cooling towers, where required, draw air from the outside and discharge the exhaust air to the outside at a point considerably distant from outdoor air intake. These indoor cooling towers may be either of the wood filled or the spray filled type but in many cases an air washer similar to a conventional type of air washer is used.

Cooling Tower Design

The method of design of equipment for energy transfer from water to an air-water vapor mixture is similar to that used for absorption equipment. Details of this procedure are available^{4, 5, 6} and its application to the problem of the cooling tower operating at atmospheric pressure is illustrated by the following development. The nomenclature used is as follows:

- a = over-all average wetted area (surface of water drops plus wetted tower surface) square feet per cubic foot of tower volume.
- c = specific heat of liquid water, Btu per (pound) (Fahrenheit degree).
- e = effectiveness.
- e = natural base.
- G = weight rate of flow of air, pounds of dry air per hour.
- h = enthalpy, Btu per pound of dry air.
- h_a = enthalpy of air-vapor mixture, Btu per pound of dry air.
- h^s = enthalpy of saturated air-vapor mixture at water temperature, Btu per pound of dry air.
- K = over-all energy unit conductance, Btu per (hour) (square foot over-all average wetted area) (Btu enthalpy difference per pound of dry air).
- Ka = over-all rate coefficient, Btu per (hour) (cubic foot of tower volume) (Btu enthalpy difference per pound of dry air).
- L = water rate, pounds per hour.
- lm = logarithmic mean.
- S = average cross-sectional area of cooling tower for air flow, square feet.
- t = water-main body temperature, Fahrenheit degrees.
- t_{wb} = wet-bulb temperature, Fahrenheit degrees.
- V = tower volume, cubic feet.

Note: Subscripts 1 and 2 when used in equations refer to water entrance and exit sections respectively, for the counter-flow tower.

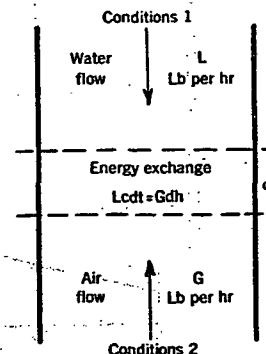


FIG. 4. SECTION OF TYPICAL COUNTER-FLOW TOWER

A section of a typical counter-flow tower is shown in Fig. 4. If the reduction in water rate due to evaporation within the volume is neglected, the energy balance for this differential section of the exchanger volume may be written as:

$$L c dt = G dh \quad (2)$$

The potential for net energy transfer due to heat and mass transfer from the water to the mixture in contact with it may be expressed with reasonable accuracy as the difference between the enthalpy of saturated air at the water temperature, h^s , and the enthalpy of the main stream air-vapor mixture⁷, h_a . The rate of energy transfer is given by the expression:

$$Ka (h^s - h_a) dV \quad (3)$$

which equation defines the over-all rate coefficient, Ka ; the latter being the product of the over-all energy unit conductance, K , and the ratio of the transfer surface to the exchanger volume, a .

Equations 2 and 3 are conveniently illustrated by means of the temperature-enthalpy diagram of Fig. 5. Equation 2 indicates that the