spread over the deck surfaces, but since some deck designs furnish a resistance to air flow, too many decks may be a detriment.

To prevent the loss of water on the leeward side of the tower, wide splash boards are attached at regular intervals from top to bottom. In some towers these boards or louvers extend outward and upward, usually with lower edge (which is attached to the frame of the tower) somewhat below the level of the outer and upper edge of the next louver board below it. Some louvering designs add *secondary* louvering to these *primary* louvers. In such designs the primary louvers are generally broader and do not slope so sharply nor overlap one another, since their function is merely to return to the interior of the tower the water caught by the secondary louvering which extends upward from each primary louver's outer edge to the next primary louver above. The individual slats which comprise the secondary louvering 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 louvering reduces 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 1, Chapter 7, gives the average summer wind velocities and directions in representative 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.

Mechanical draft water cooling equipment may be set up inside buildings, where it usually draws its air supply from the general space in which it is installed, and discharges its exhaust air through a duct to the outside. Indoor cooling towers may be either of the wood-filled or the spray-filled type. In many cases where little height but considerable area is available, water is cooled in a spray-filled structure similar to an air washer, with the air passing horizontally through the apparatus and being discharged through a duct to the outside.

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) (degree Fahrenheit).
$\dot{e}$ = 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'' = 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, degrees Fahrenheit.
t_{wb} = wet-bulb temperature, degrees Fahrenheit.
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.

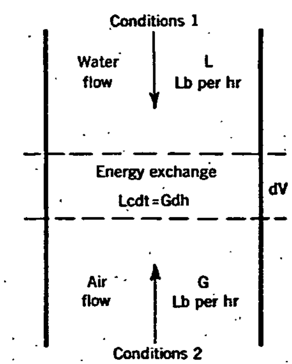

FIG. 4. SECTION OF TYPICAL COUNTER-FLOW TOWER

[4] Principles of Chemical Engineering, by W. H. Walker, W. K. Lewis, W. H. McAdams and E. R. Gilliland (McGraw-Hill Co., 1937, p. 480).

[5] Absorption and Extraction, by T. K. Sherwood (McGraw-Hill Co., 1937, p. 91).

[6] Performance Characteristics of a Mechanically Induced Draft, Counterflow, Packed Cooling Tower, by A. L. London, W. E. Mason and L. M. K. Boelter (*A.S.M.E. Transactions*, January, 1940, Vol. 62, p. 41).