

approach wind. Approach wind of sufficient magnitude (the magnitude depending on the baffle arrangement which is designed to reduce drift) will cause cross-flow augmenting the natural draft. An adequate design requires the consideration of both flow conditions.

Expression for Cooling Tower Performance

The performance of a cooling tower is described in terms of its effectiveness as an energy exchanger. The effectiveness is defined as the ratio of the energy actually exchanged to the energy available for exchange.

Effectiveness expressions:

Case 1. The slope of the operating line on the $t-h$ diagram exceeds the slope of the saturation line in the region of water temperatures considered.

$$e = \frac{h_1 - h_2}{h_1^s - h_2}$$

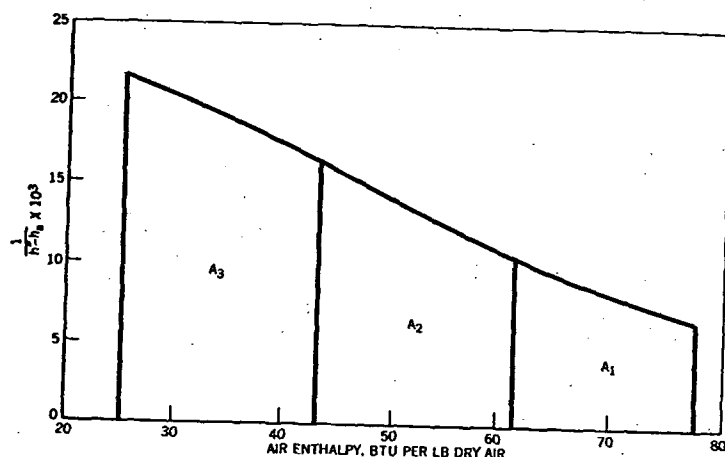


FIG. 7. GRAPHICAL INTEGRATION TO DETERMINE NUMBER OF TRANSFER UNITS REQUIRED FOR DESIRED OPERATING CONDITIONS OF EXAMPLE 1

Case 2. The slope of the saturation line exceeds that of the operating line.

$$e = \frac{h_1 - h_2}{\frac{Lc}{G} (t_1 - t_{wb})} = \frac{t_1 - t_2}{t_1 - t_{wb}}$$

This equation represents the *approach to wet-bulb*.

Usual tower operating conditions conform to Case 1. Because of the curvature of the saturation line, operating conditions may present themselves to which neither Case 1 nor 2 applies. Since a simple expression for the intermediate case is not available, the expression of Case 1 may be utilized for the small number of operating conditions falling into the intermediate classification.

When the logarithmic mean enthalpy difference is a sufficiently accurate

overall potential the effectiveness as defined may be expressed analytically as follows:

$$e = \frac{h_1 - h_2}{h_1^s - h_2} \text{ or } \frac{t_1 - t_2}{t_1 - t_{wb}} = \frac{1 - e^{NTU_{min}} (1 - r)}{r - e^{NTU_{min}} (1 - r)} \quad (8)$$

where NTU_{min} is $\frac{KaV}{G}$ for Case 1

or where NTU_{min} is $\frac{KaV}{Lc} (m)$ for Case 2

and r is the ratio, $\frac{Lc}{mG}$ or $\frac{mG}{Lc}$, taken so that it is always less than unity.

The average slope of the saturation line is, to a good approximation, the slope of the chord of the saturation line between the entrance and exit water temperatures. Solution of Equation 8 offers a method for determining the performance of a given tower when the number of transfer units, gas, and water rates are known and the slope of the saturation line does not vary greatly in the temperature range involved. If these same data are available, a trial and error solution of Equation 7 will also yield the tower performance.

Make-Up Water

Since the atmospheric water cooling equipment performs its functions chiefly by evaporating a portion of the water in order to cool the remainder, there is a continual drain on the quantity of water in the system, and this loss must be replaced. Approximately 1 gal of water is lost for every 1000 gal of water cooled per degree of cooling range; so if 1000 gpm of water are cooled through a 10 F range, 10 gpm of water will be required to replace evaporated water. Replacement supply is usually regulated by a float control valve. Because the evaporation of the water leaves behind the salts which the water contained, high concentration of salts may make chemical treatment of the make-up water necessary to

TABLE 5. COMPARISON OF VARIOUS TYPES OF ATMOSPHERIC WATER COOLING EQUIPMENT

Figures indicate order of desirability

	COOLING POND	SPRAY POND	SPRAY TOWER	DECK TOWER	MECHANICAL DRAFT	INDOOR TOWER
Cost.....	x	2	1	3	4	5
Area.....	5	4	3	2	1	x
Height.....	1	2	3	4-5	4-5	x
Weight per square foot.....	x	x	1	3	4	2
Independence of wind velocity.....	6	3	4	5	1-2	1-2
Drift nuisance.....	1	6	5	4	2-3	2-3
Make-up water required.....	1	6	5	4	2-3	2-3
Pumping head.....	1	2	3	4-5	4-5	6
Maintenance.....	2	1	3	4	5	6
Suitability for congested districts.....	x	5	4	3	1	2
Water quantity required for definite result.....	6	5	4	1-2	1-2	3

*Not comparable.