

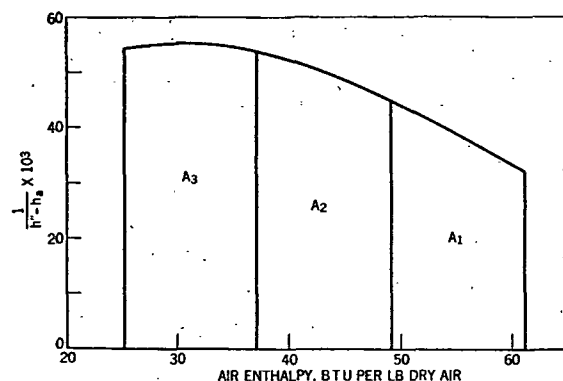


FIG. 7. GRAPHICAL INTEGRATION TO DETERMINE NUMBER OF TRANSFER UNITS REQUIRED FOR DESIRED OPERATING CONDITIONS OF EXAMPLE 1

under the curve from the initial enthalpy of the air, 25.1 Btu per pound, to the final enthalpy of the air, 61.1 Btu per pound is 1.72, the Number of Transfer Units required. The effect of the rapid decrease in potential due to the cooling of the water is indicated by comparison of area A_1 , A_2 , and A_3 of Fig. 7. Each represents the Number of Transfer Units required to achieve a water temperature reduction of about 10 F.

$$A_1 = 0.471 \text{ NTU (110 to 100 F)}$$

$$A_2 = 0.595 \text{ NTU (100 to 90 F)}$$

$$A_3 = 0.657 \text{ NTU (90 to 80 F)}$$

The use of the logarithmic mean driving potential is illustrated by applying Equation 7 to Example 1:

$$NTU = \frac{(Ka) V}{G} = \frac{h_1 - h_2}{\Delta h_{lm}}$$

$$\Delta h_{lm} = \frac{(h_1^a - h_1) - (h_2^a - h_2)}{\ln_e \frac{h_1^a - h_1}{h_2^a - h_2}} = \frac{30.7 - 18.4}{\ln_e \frac{30.7}{18.4}} = 24$$

$$NTU = \frac{61.1 - 25.1}{24} = 1.5$$

The Number of Transfer Units required as determined by use of the logarithmic mean driving potential equals 1.5 which compares favorably with the correct magnitude, 1.72.

A variation of the design method according to Equation 6 is further possible¹¹ through the introduction of Equation 2 to yield

$$\int_{h_2}^{h_1} \frac{cdt}{h^* - h_a} = \frac{KaV}{L} \quad (8)$$

The advantage of this form is in the fact that the left side of the equation may be dealt with as a thermodynamic function only, while the right side depends upon the tower construction and operation. A series of performance curves may be determined from a graphic evaluation of the integral, which will serve either as a convenient means of analyzing experimental data to determine the conductance Ka , or as a rapid method

of performance prediction, once the tower characteristic, $\frac{KaV}{L}$, is known.

These performance curves may be expressed in terms of the following variables; approach to wet-bulb, cooling range, L/G , and wet-bulb temperature of the entering air; and as such they will serve to accurately cover the tower performance in consistent terms.

The application of the foregoing design method to atmospheric towers is difficult because rate coefficients and flow conditions are not yet well defined for such equipment. If these are known, application of Equation 7 to sections of the tower small enough to justify use of the logarithmic mean potential will yield the tower volume required for each section. The sections must be taken perpendicular to the path of water flow. A correction to adjust the logarithmic mean potential, evaluated as for counter-flow, to the reduced effectiveness of cross-flow, has been derived for heat transfer and may be applied to this case¹².

For small size counterflow spray towers intended for a low cooling range only considerable data^{13,14} are available on the performance of the spray system in terms of the logarithmic mean enthalpy potential. These data show the importance of proper nozzle arrangement and spray distribution within the tower. The greatest cooling effect is shown to be obtained in a region close to the nozzles; and the beneficial effects of packing added in the lower section of the tower follow as increasing the cooling range.

Atmospheric towers operate with natural draft, produced in a vertical direction by the stack action of the tower structure, at zero velocity of the 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.

$$e = \frac{h_1 - h_2}{h_1^a - h_2} \quad (9)$$

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

$$e = \frac{h_1 - h_2}{\frac{Lc}{G}(t_1 - t_{wb})} = \frac{t_1 - t_2}{t_1 - t_{wb}} \quad (10)$$

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.