since a reduction of the water rate may reduce the wetted area within the exchanger[10]. The results included in Fig. 6 probably represent magnitudes of Ka which were obtained for complete wetting. Within the cooling tower operating range the over-all rate coefficient for energy transfer is nearly the same numerically as the over-all rate coefficient for mass transfer. The conditions of test corresponding to the data presented in Fig. 6 are not well enough known in most cases to warrant recomputation of Ka. Therefore the magnitudes of the over-all rate coefficient for mass

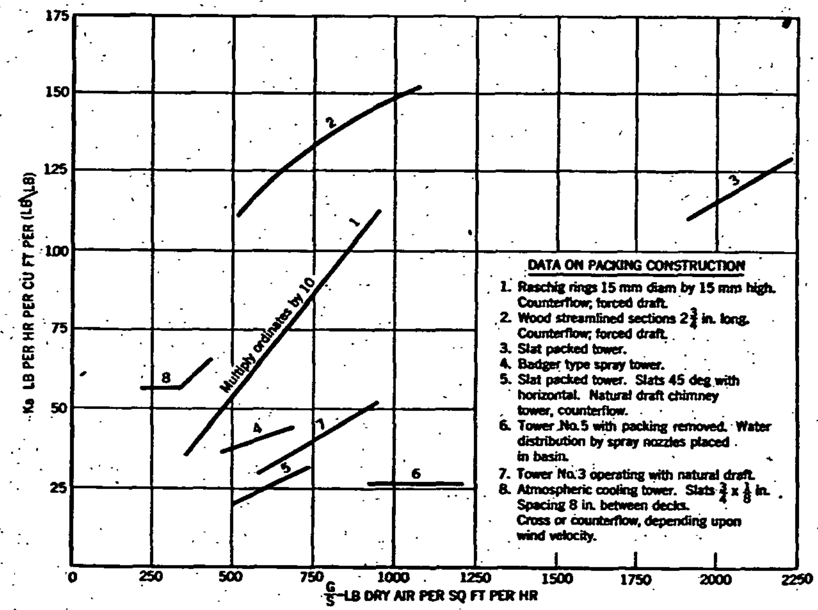

FIG. 6. UNIT CONDUCTANCES FOR VARIOUS TYPES OF PACKING CONSTRUCTION

transfer presented in Fig. 6 may be used directly in Equations 5 and 6, the units of Ka in these equations being Btu per (hour) (cubic foot per pound of dry air).

A typical design procedure is outlined in an illustrative example:

Example 1. The rate of air flow, arbitrarily assumed in the data given, is related to the tower volume by economic considerations. A balance between air rate and tower volume rests on consideration of the costs of producing air flow and of the tower construction[11]. A counter-flow forced draft cooling tower is to cool 36,000 lb of water per hour from an initial temperature of 110 F to a final temperature of 80 F. Air having an initial condition of 65 F dry-bulb and 58 F wet-bulb temperature will be forced through the tower counter to the direction of water flow at the rate of 30,000 lb of dry air per hour.

The cross-section of the tower is to be 8 ft x 8 ft and the packing is to be of the type producing a rate coefficient as indicated in curve No. 2 of Fig. 6. For this type of packing the average cross-sectional area for air flow will be 36 sq ft.

[10]Loc. Cit. Note 5.
[11]Loc. Cit. Note 4, p. 142.

Solution:

Initial air enthalpy = 25.1 Btu per pound of dry air.

Final air enthalpy:

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

$$(h_1 - 25.1) = \frac{36{,}000 \times 1}{30{,}000}(110 - 80)$$

$$h_1 = 61.1 \text{ Btu per pound dry air.}$$

A numerical integration (Table 4) is employed to determine the Number of Transfer Units (NTU) required. Temperature increments of 2 F are used between successive determinations of the quantity $\frac{1}{h'' - h_a}$. The energy balance indicates that the enthalpy

TABLE 4. NUMERICAL INTEGRATION FOR THE NUMBER OF TRANSFER UNITS

Water Temperature Interval Deg F	Mean Water Temperature Deg F	Mean Air Enthalpy, h_a Btu per Lb. Dry Air	Saturated Air Enthalpy, h'' Btu per Lb Dry Air	Enthalpy Potential $h'' - h_a$	$\frac{\Delta h}{h'' - h_a}$
80–82	81	26.3	44.6	18.3	0.131
82–84	83	28.7	46.9	18.2	0.132
84–86	85	31.1	49.2	18.1	0.133
86–88	87	33.5	51.7	18.2	0.132
88–90	89	35.9	54.4	18.5	0.130
90–92	91	38.3	57.1	18.8	0.128
92–94	93	40.7	60.0	19.3	0.124
94–96	95	43.1	63.0	19.9	0.121
96–98	97	45.5	66.2	20.7	0.116
98–100	99	47.9	69.6	21.7	0.111
100–102	101	50.3	73.2	22.9	0.105
102–104	103	52.7	77.0	24.3	0.099
104–106	105	55.1	80.9	25.8	0.093
106–108	107	57.5	85.1	27.6	0.087
108–110	109	59.9	89.5	29.6	0.081
					1.723

increments corresponding to these temperature increments are:

$$\Delta h = \frac{Lc}{G}\Delta t = \frac{36{,}000}{30{,}000} \times 2 = 2.4 \text{ Btu per pound of dry air.}$$

The result of the integration is that the Number of Transfer Units required (NTU) = 1.72.

Unit gas mass velocity, $\frac{G}{S} = \frac{30{,}000}{36} = 830$ lb per (hour) (square foot average cross-sectional air flow area).

From Curve 2, Fig. 6, Ka = 138 Btu.

The tower volume required is:

$$V = \frac{G}{Ka}(NTU) = \frac{30{,}000}{138} \times 1.72 = 217 \times 1.72 = 374 \text{ cu ft.}$$

Height of the packed section is:

$$\frac{374}{8 \times 8} = 5.9 \text{ ft.}$$

The graphical solution for the Number of Transfer Units required for the desired performance is plotted in Fig. 7. $\frac{1}{h'' - h_a}$ is plotted as a function of h, and the area