Water Cooling with Air

1. A water-cooling tower of the wood-slat, forced draft, countercurrent-flow variety cools water from 45°C to 25°C when the ambient air is at 32°C with a wet-bulb temperature of 15°C. Previous experience with towers of this design leads the engineer to predict that $h_L a/k_Y a =$ 600 J/mol · °C and that $k_Y a$ (mol/h) = 0.2 G'. A liquid rate of 900 mol/h · m^2 of tower cross section will be used.

(a) Determine the minimum gas rate. At this rate, there will be a zero driving force somewhere in the column and an infinitely high tower will be necessary. Usually, at minimum gas rate the exit gas will be in equilibrium with the inlet water.

(b) Determine the necessary tower height if a gas flow rate twice the minimum found in part (a) is used.

2. A natural-draft cooling tower uses tower packing (attached Table, item 6) that is 4 m high. On one summer day the water to be cooled is sprayed onto the packing at 49°C whereas the air flowing up the tower enters at 29°C. Originally, the air is at 30 percent saturation and its flow rate is measured at 0.35 m/s. The water flows through the packing (60 m tower diameter) at a rate of 5000 L/s. The ratio of coefficients $h_L a/k_Y a$ is expected to be 0.63 W · s/mol · °C. Calculate the temperature of the cooled water, and the fraction of the water fed to the tower that is lost by evaporation.

Table 17.2 EXPERIMENTAL MASS-TRANSFER RATES FOR CONTACT OF A PURE LIQUID WITH A GAS (All data are given in English units)

Item	Equipment	Process and Notes	Range of Flow Rates	Equation	Reference
1	8-in. diam. tower, 1-in. Raschig rings	Liquid cooling with air and water, methanol, benzene, ethyl butyrate $k_g a$ corrected for end effects and independent of G_L for G_L = 1600–5000	$G_L = 1600$ $G_{V'} = 150–500$	$k_g a = 0.486 D^{0.15} G_{V'}^{0.72}$	20
2	10-in. diam. tower; 12.5 in. depth of 15-, 25-, and 35-mm Raschig rings	Humidification cooling, liquid cooling, and dehumidification with air-water	$G_L = 200–4160$	$k_Y a = 0.0155 G_{V'} G_L^{0.2}$	25
3	21.5-in. square tower, 1½-in. Berl saddles	Humidification cooling with air-water; corrected for end effects	$G_L = 120–6800$	$k_Y a = 0.0431 G_{V'}^{0.39}$	7
4	4-in. diam. tower, ½-in. spheres	Humidification cooling with air-water; corrected for end effects	$D_p G_{V'}/\mu = 304–927$ $G_L = 85–1895$	$H_G = \frac{13.4}{G_L^{0.5}}\left(\frac{D_p G_{V'}}{\mu}\right)^{0.1}$	22
5	6-ft square tower, 11-ft, 3-in. packed height; wood slats, ⅜ x 2 in., spaced parallel, 15 in. between tiers	Liquid cooling with air-water	$G_L = 350–3000$	$K_Y a = 0.0068 G_L^{0.4} G_{V'}^{0.5}$	11
6	41⅝- x 23⅞-in. tower, packed height 41⅜ in.; wood slats, ¼ x 2 x 23½ in., bottom edge serrated, on ⅝-in. horiz. centers, 3⅝- to 2⅝-in. vert. centers; 18 spray nozzles	Liquid cooling with air-water	$G_L = 880–1500$	$K_Y a = 0.00001 G_L G_{V'} - 0.00396 G_{V'} - 0.00458 G_L + 10.7$	19
7	Spray tower, 31.5 in. diam. by 52 in. high; 6 solid cone spray nozzles	Liquid cooling and dehumidification with air-water	$G_L = 300–800$	$N_{OG} = \frac{0.0526 G_L}{G_{V'}^{0.58}}$	18
8	Perforated plate (sieve tray); 83⅛-in. holes on ⅜-in. triangular centers	Humidification cooling with air-water	$G_{V'} = 670–1920$	Liquid depth, in — N_G: 0.5 — ca. 1.5 1 — 2 2 — 2.5	23

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Isosteres of Benzene on Activated Carbon

The following experimental data are reported by Josefowitz & Othmer (1948)† for the equilibrium adsorption of benzene on activated carbon.

(a) Plot the isosteres of benzene on a logarithmic paper using acetone as reference substance.
(b) Estimate the integral heat of adsorption of benzene upon activated carbon at 50°C as a function of adsorbate concentration *X*.

Adsorbate concentration, X = kg benzene adsorbed/kg carbon													
0.30		0.25		0.20		0.15		0.10		0.05		0.025	
t	$\bar{p}^*$	t	$\bar{p}^*$	t	$\bar{p}^*$	t	$\bar{p}^*$	t	$\bar{p}^*$	t	$\bar{p}^*$	t	$\bar{p}^*$
30	2.40	30	0.93	60	1.60	80	1.47	100	1.00	120	0.33	140	0.17
40	3.60	40	1.47	80	3.47	100	2.93	120	2.00	140	0.67	160	0.32
60	7.60	60	3.60	100	6.67	120	5.33	140	3.47	160	1.20	180	0.59
		80	7.47			140	10.0	160	5.60	180	2.00	200	1.00
								180	9.33	200	3.47		

t = temperature, °C
$\bar{p}^*$ = equilibrium partial pressure of benzene, kPa

† Josefowitz, S. & Othmer, D.F. (1948). Adsorption of Vapors. *Industrial & Engineering Chemistry* **40**(4), 739–743.