ABSORPTION OF CONCENTRATED MIXTURES IN PACKED TOWERS

Simplified design methods were given in the foregoing for absorption of dilute gases in packed towers when the mole fractions in the gas and liquid streams were less than about 10%. Straight operating lines and approximately straight equilibrium lines are obtained.

In concentrated gas mixtures, the operating line and usually the equilibrium line will be curved and mass tranfer coefficients may vary with total flows. Therefore, one should use

$$z = \int_0^z dz = \int_{y_2}^{y_1} \frac{V dy_{AG}}{\frac{k'_y aS}{(1-y_A)_{iM}}(1-y_{AG})(y_{AG}-y_{Ai})} = \int_{y_2}^{y_1} \frac{V dy_{AG}}{\frac{K'_y aS}{(1-y_A)_{*M}}(1-y_{AG})(y_{AG}-y_A^*)}$$

$$z = \int_0^z dz = \int_{x_2}^{x_1} \frac{L dx_{AL}}{\frac{k'_x aS}{(1-x_A)_{iM}}(1-x_{AL})(x_{Ai}-x_{AL})} = \int_{x_2}^{x_1} \frac{L dx_{AL}}{\frac{K'_x aS}{(1-x_A)_{*M}}(1-x_{AL})(x_A^*-x_{AL})}$$

PROCEDURE:

- Plot the equilibrium line using the thermodynamic data
- Plot operating line equation using the mass balance equation
- Compute mass transfer coefficients using $k'_x a = f(G_x^m);\ k'_y a = f\left(G_y^n\right)$. If its variation at the top and bottom of the tower is small, an average value can be used
- From point P_1, draw line P_1M_1 from P_1 (x_1, y_1) with slope,

$$-\frac{k_x}{k_y} = -\left[\frac{k'_x a}{(1-x)_{iM}}\right] \Big/ \left[\frac{k'_y a}{(1-y)_{iM}}\right]$$

to determine the M_1 (x_{1i}, y_{1i}) on the equilibrium line by trial and error method

- Similarly, draw line P_2M_2 from P_2 (x_2, y_2) with slope, $-k_x/k_y$, to determine the M_2 (x_{2i}, y_{2i}) on the equilibrium line
- The slopes of of lines P_1M_1 and P_2M_2 will be different. Take several points on the operating line and determine the corresponding interface concentrations using the above procedure to evaluate the following function

$$f(y, y_i) = V / \frac{k'_y a S}{(1 - y_A)_{iM}} (1 - y)(y - y_i)$$

- Integrate to obtain the adsorption tower height

$$z = \int_{y_2}^{y_1} f(y, y_i) dy$$

EXAMPLE 10.7-1. Design of an Absorption Tower with a Concentrated Gas Mixture

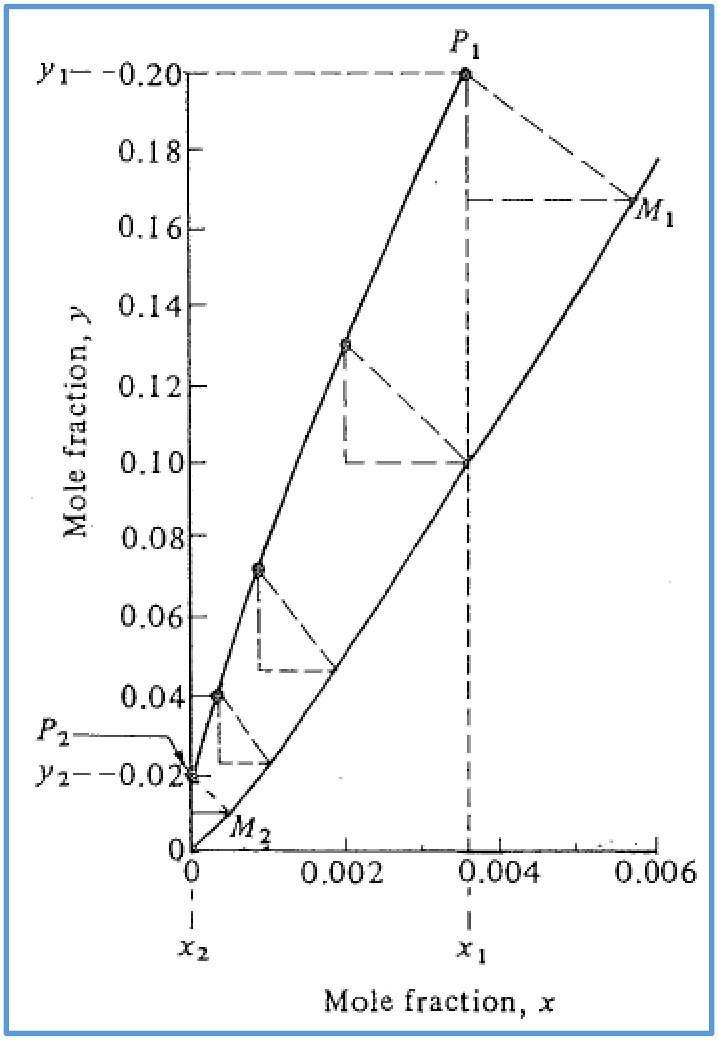
A tower packed with 25.4-mm ceramic rings is to be designed to absorb **SO_2** from air by using pure water at 293 K and 1.013 × 10^5 Pa abs pressure. The entering gas contains 20 mol % **SO_2** and that leaving 2 mol%. The inert air flow is 6.53 × 10^{-4} kg mol air/s and the inert Water flow is 4.20 × 10^{-2} kg mol water/s. The tower cross-sectional area is 0.0929 m^2. For dilute **SO_2**, the film mass-transfer coefficients at 293 K are for 25.4-mm rings:

$$k'_x a = 0.152 G_x^{0.82};$$

$$k'_y a = 0.0594 G_x^{0.82} G_y^{0.7};$$

$$(kg\ mol/s \cdot m^3 \cdot mol\ frac)$$

where *Gx* and *Gy* are kg total liquid or gas, respectively, per sec per m^2 tower cross section. Calculate the tower height.



SOLUTION:

P = 101.3 kPa;   T = 293K;

L = Water;   V = Air;   Solure (A)= SO_2

$\boldsymbol{V'} = 6.53 \times 10^{-4}$ kg mol inert air/s ; $\boldsymbol{L'} = 4.2 \times 10^{-2}$ kg mol inert water/s

$x_0 = 0.0;\ y_1 = 0.20; y_2 = 0.020;$

$$L' \frac{x_2}{(1-x_2)} + V' \frac{y_1}{(1-y_1)} = L' \frac{x_1}{(1-x_1)} + V' \frac{y_2}{(1-y_2)}$$

$$4.2 \times 10^{-2} \frac{0}{(1-0)} + 6.53 \times 10^{-4} \frac{0.20}{(1-0.20)} = 4.2 \times 10^{-2} \frac{x_1}{(1-x_1)} + 6.53 \times 10^{-4} \frac{0.02}{(1-0.02)}$$

$$x_1 = 0.00355$$

$$L' \frac{x}{(1-x)} + V' \frac{y_1}{(1-y_1)} = L' \frac{x_1}{(1-x_1)} + V' \frac{y}{(1-y)}$$

$$4.2 \times 10^{-2} \frac{x}{(1-x)} + 6.53 \times 10^{-4} \frac{0.20}{(1-0.20)} = 4.2 \times 10^{-2} \frac{0.00355}{(1-0.00355)} + 6.53 \times 10^{-4} \frac{y}{(1-y)}$$

Use above relationship to determine points on the operating line

y	x	V	L	G_y	G_x	$k'_y a$	$k'_x a$	x_i	y_i	$1-y$	$(1-y)_{iM}$	$y-y_i$	$\frac{V}{\frac{k'_y aS}{(1-y)_{iM}}(1-y)(y-y_i)}$
0.02	0	6.66×10^{-4}	0.04200	0.2130	8.138	0.03398	0.848	0.00046	0.0090	0.980	0.985	0.0110	19.25
0.04	0.000332	6.80×10^{-4}	0.04201	0.2226	8.147	0.03504	0.849	0.00103	0.0235	0.960	0.968	0.0165	12.77
0.07	0.000855	7.02×10^{-4}	0.04203	0.2378	8.162	0.03673	0.850	0.00185	0.0476	0.930	0.941	0.0224	9.29
0.13	0.00201	7.51×10^{-4}	0.04208	0.2712	8.196	0.04032	0.853	0.00355	0.1015	0.870	0.885	0.0285	7.16
0.20	0.00355	8.16×10^{-4}	0.04215	0.3164	8.241	0.04496	0.857	0.00565	0.1685	0.800	0.816	0.0315	6.33

$$z = \int_{y_2}^{y_1} f(y)dy = 1.59 \ (Graphical)$$

$$z = \int_{y_2=0.02}^{y_1=0.20} 2.71y^{-0.49}dy = 1.62$$