단위조작
Unit operation

10.4 – 10.6
흡수탑에서의 물질전달

전달 법칙

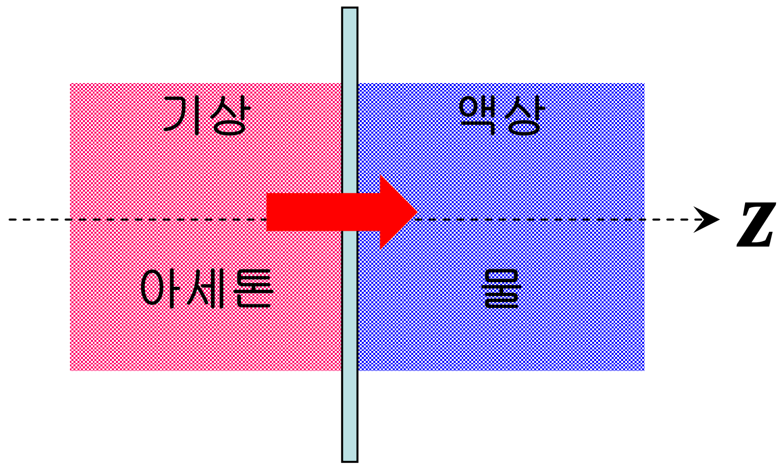
$$전달속도 = \frac{구동력}{저항}$$

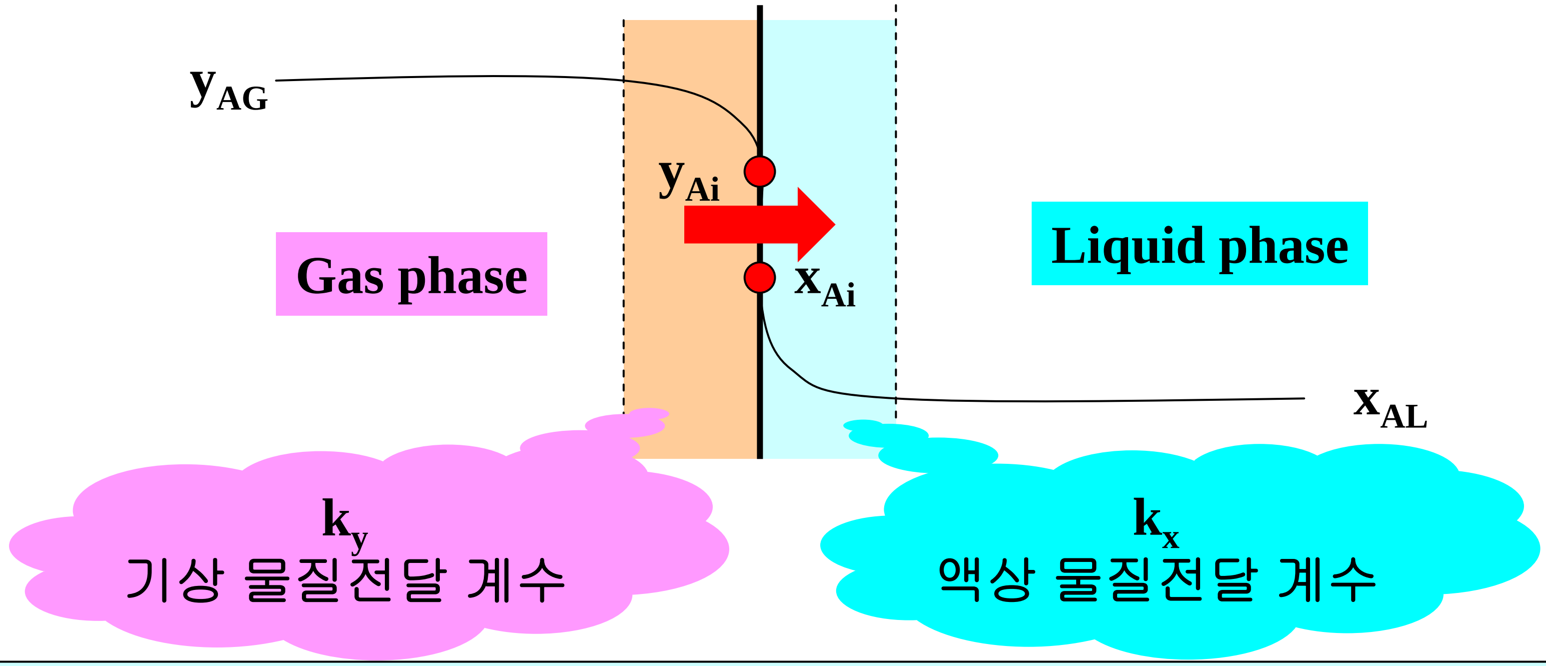
$$heat\ \ flux = \frac{구동력}{저항} = \frac{온도차}{열전달계수의\ 역수}$$

$$mass\ \ flux = \frac{구동력}{저항} = \frac{농도차}{물질전달계수의\ 역수}$$

$$mass\ \ flux = \frac{\Delta C_A}{1/k_1 + 1/k_2 + 1/k_3}$$

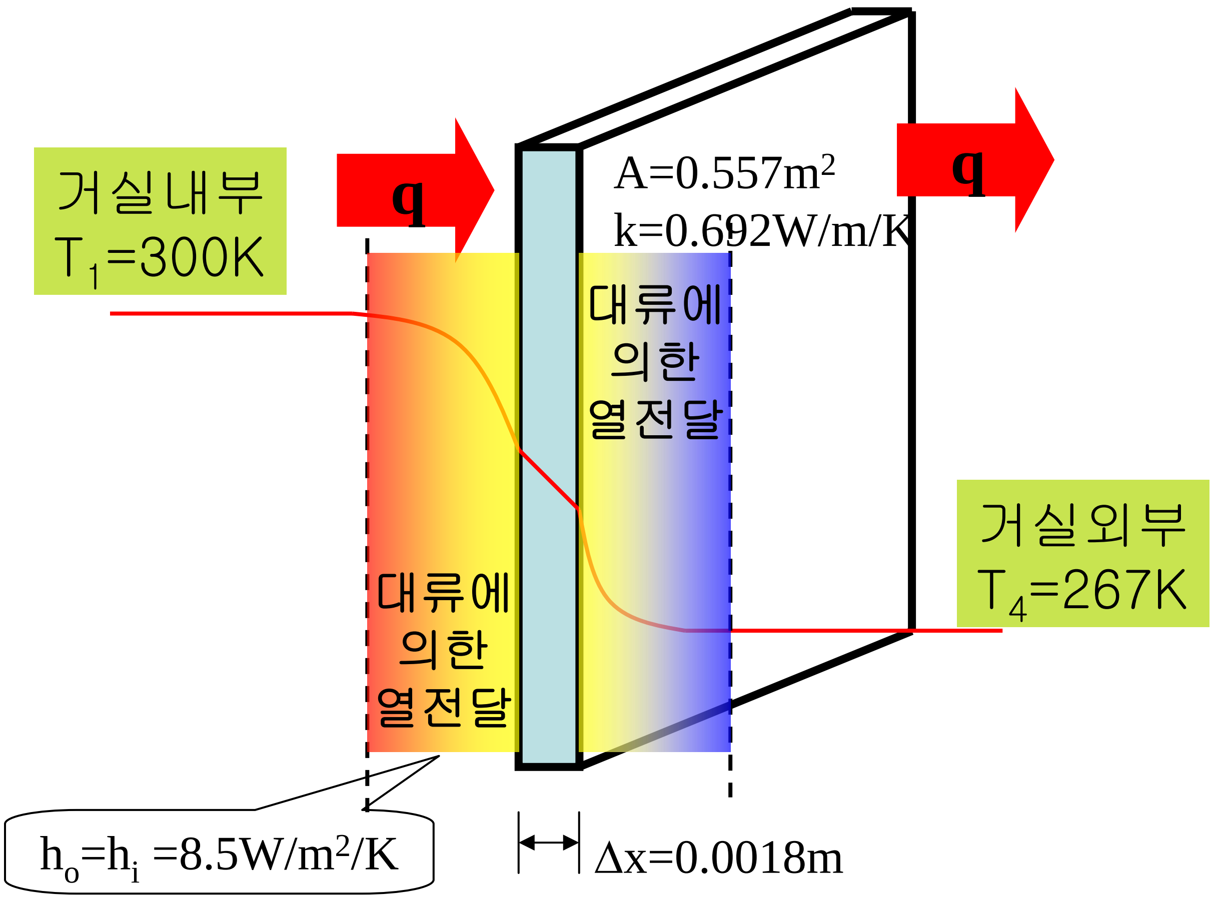
10.4 두 상간의 물질전달





4.3D 총괄열전달 계수 (conduction+convection)

- 문제 4.3-6 유리창 내부에서 외부로의 열손실



$$q = q_1 = q_2 = q_3$$

$$q_1 = h_i A (T_1 - T_2)$$

$$q_2 = kA \frac{(T_2 - T_3)}{\Delta x}$$

$$q_3 = h_o A (T_3 - T_4)$$

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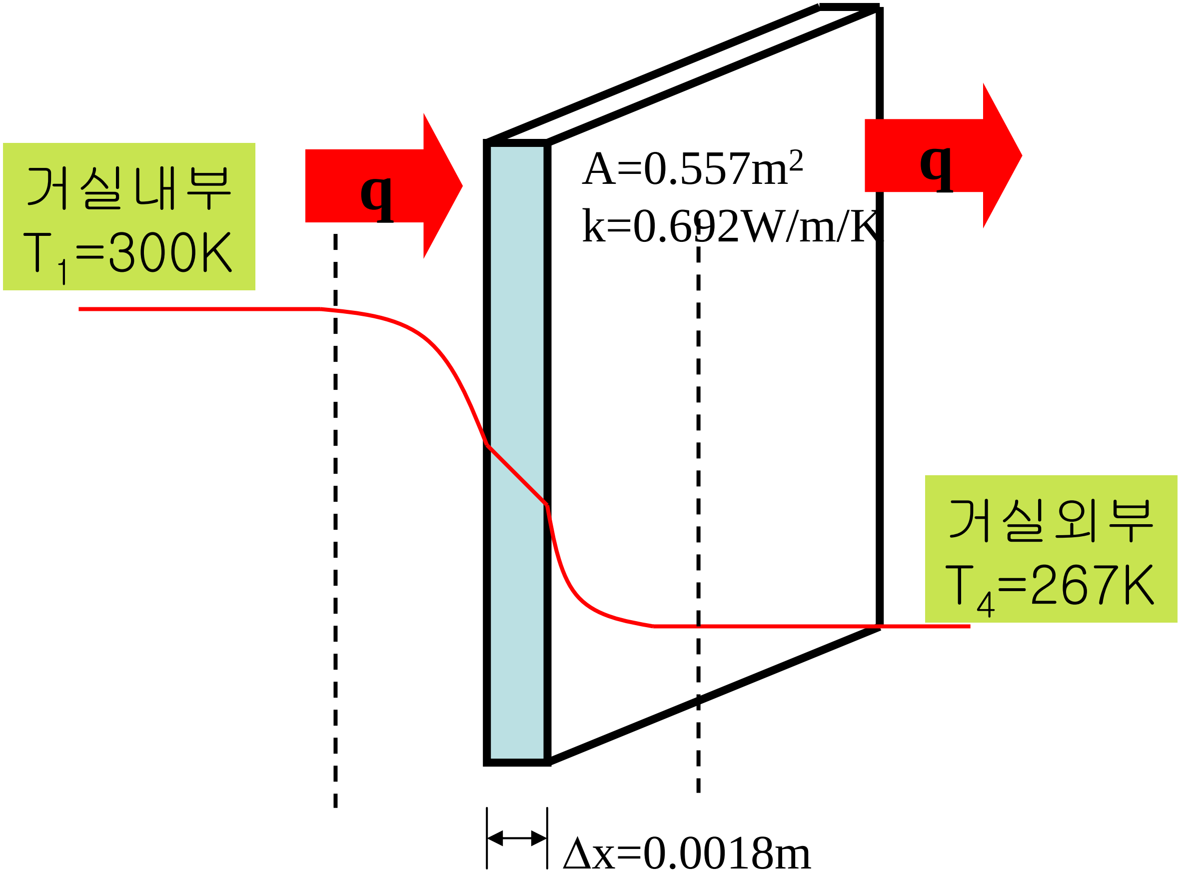
- 문제 4.3-6 유리창 내부에서 외부로의 열손실



$$q_1 = h_i A(T_1 - T_2)$$

$$q_2 = kA\frac{(T_2 - T_3)}{\Delta x}$$

$$q_3 = h_o A(T_3 - T_4)$$

$$(T_1 - T_2) = \frac{q}{h_i A}$$

$$(T_2 - T_3) = \frac{q}{kA/\Delta x}$$

$$(T_3 - T_4) = \frac{q}{h_o A}$$

$$(T_1 - T_4) = \frac{q}{h_i A} + \frac{q}{kA/\Delta x} + \frac{q}{h_o A}$$

$$q = \frac{1}{\dfrac{1}{h_i A} + \dfrac{\Delta x}{kA} + \dfrac{1}{h_o A}}(T_1 - T_4)$$

교재 254-257 쪽

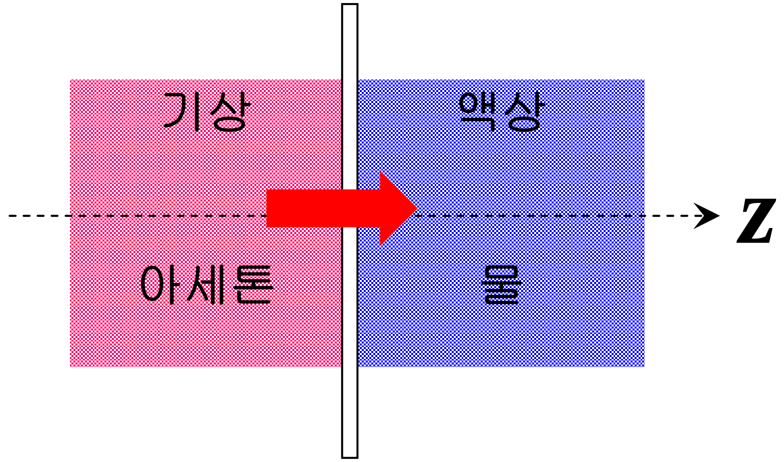
평판에 대한
열전도와 열대류에 의한 총괄계수, U

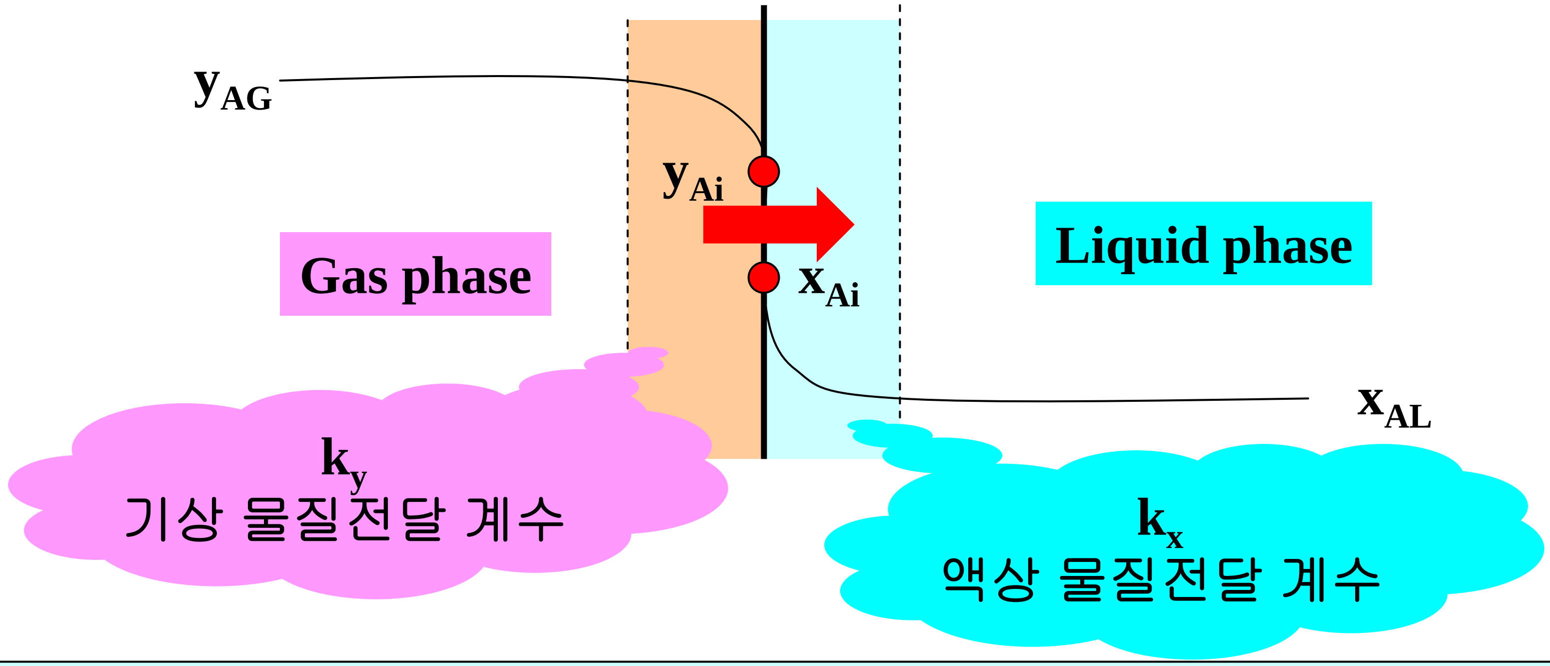
$$q = \frac{1}{\dfrac{1}{h_i A} + \dfrac{\Delta x}{kA} + \dfrac{1}{h_o A}}(T_1 - T_4)$$

$$q = UA\Delta T$$

$$where,\ U = \frac{1}{\sum_i R_i} = \frac{1}{\dfrac{1}{h_i} + \dfrac{\Delta x}{k} + \dfrac{1}{h_o}}$$

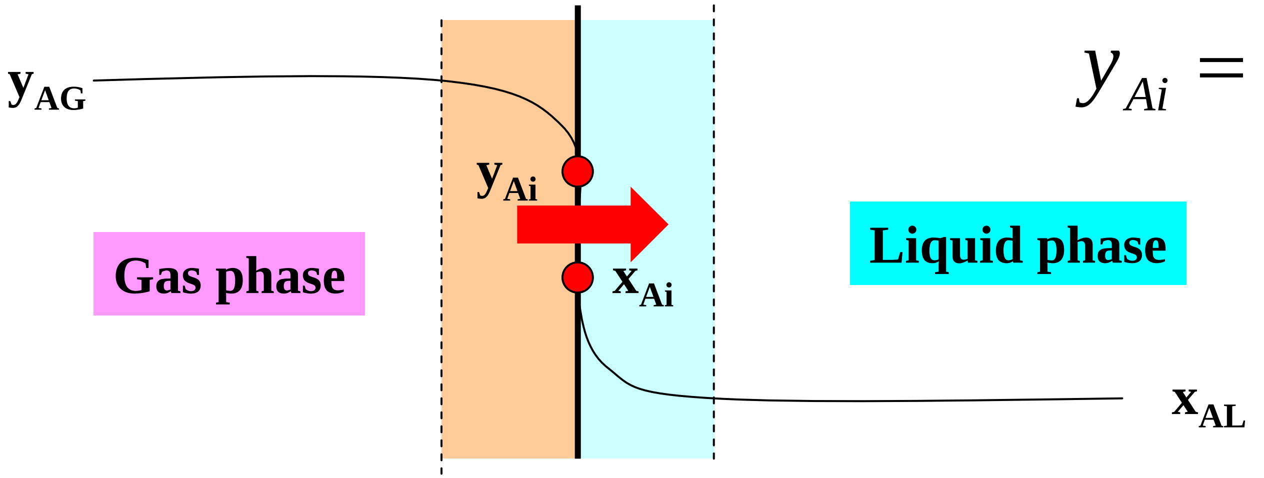
10.4 두 상간의 물질전달





교재 655 쪽

10.4 두 상간의 물질전달



$$y_{Ai} = m \cdot x_{Ai}$$

$$N_A = N_{AG} = N_{AL}$$

$$N_{AG} = k_y (y_{AG} - y_{Ai})$$

$$N_{AL} = k_x (x_{Ai} - x_{AL})$$

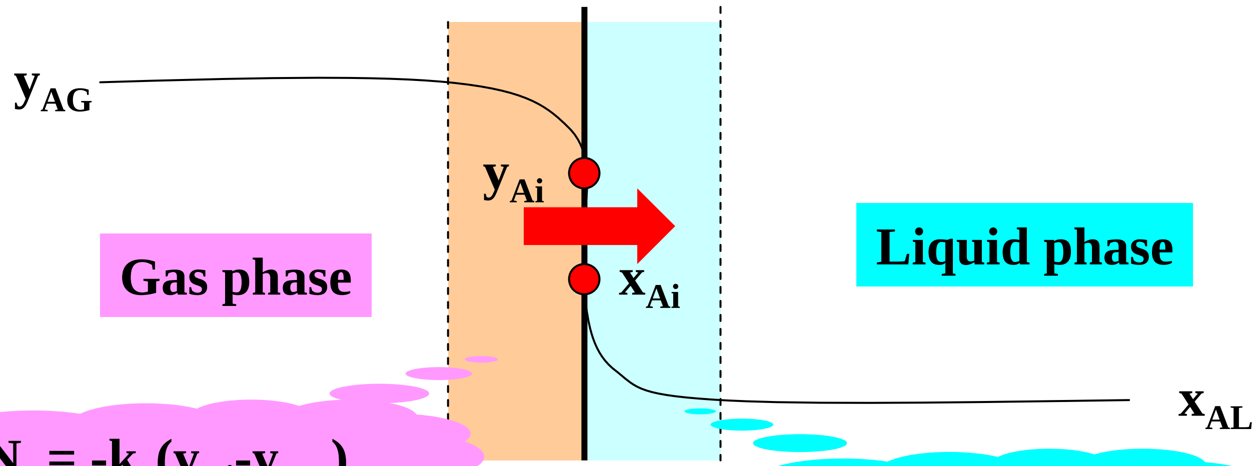
$$y_{AG} - y_{Ai} = \frac{N_A}{k_y}$$

$$x_{Ai} - x_{AL} = \frac{N_A}{k_x}$$

$$N_A = \frac{1}{1/k_y + 1/k_x} (y_{AG} - m \cdot x_{AL})$$

교재 655 쪽

10.4 두 상간의 물질전달



$$N_A = -k_y(y_{Ai} - y_{AG})$$

$$N_A = -k_x(x_{AL} - x_{Ai})$$

$$N_A = -D_A \frac{dC_A}{dx} + v_{bulk} C_A$$

확산항

대류항

$$N_A = -D_A \frac{dC_A}{dx} + \frac{C_A}{C_A + C_B}(N_A + N_B)$$

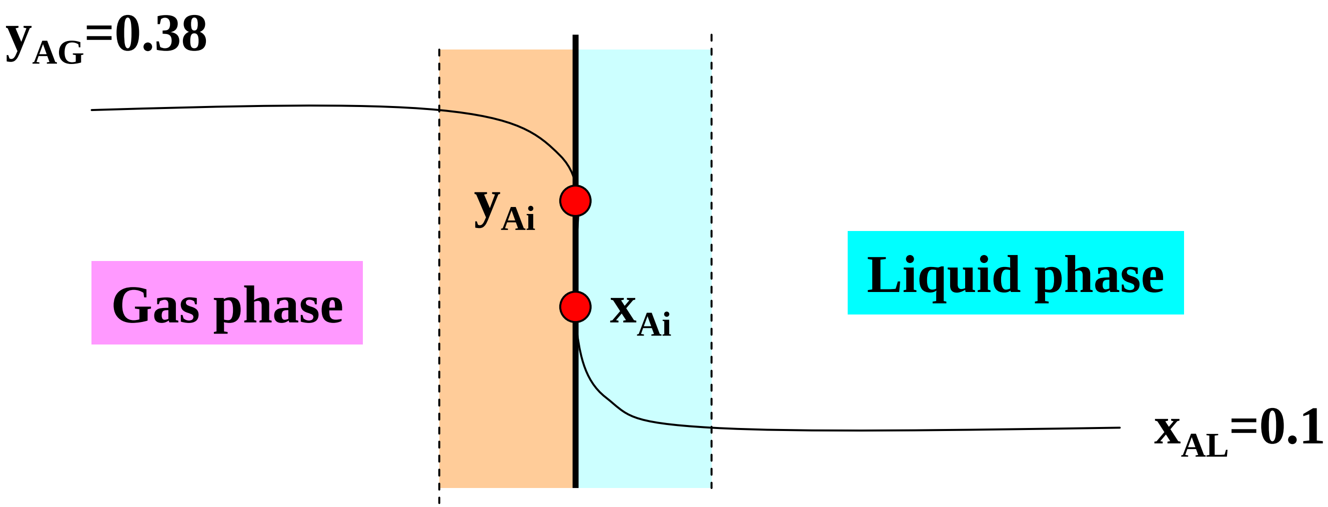
$$N_A = \frac{c_{total} D_{AB}}{(z_2 - z_1)} \ln\left(\frac{1 - y_{Ai}}{1 - y_{AG}}\right)$$

$$N_A = \frac{c_{total} D_{AB}}{(z_2 - z_1)} \ln\left(\frac{1 - y_{Ai}}{1 - y_{AG}}\right) \frac{y_{AG} - y_{Ai}}{(1 - y_{Ai}) - (1 - y_{AG})}$$

$$N_A = k'_y \frac{y_{AG} - y_{Ai}}{(1 - y_A)_{lm}}$$

교재 430 쪽

예제 10.4-1 두 상간의 물질전달



$$k_y = 1.465\times10^{-3}\,\frac{kmol}{s\cdot m^2\cdot molfrac}$$

$$k_x = 1.967\times10^{-3}\,\frac{kmol}{s\cdot m^2\cdot molfrac}$$

$$y_A^* = 0.7x_A^*$$

$$x_{Ai} = 0.257$$

$$N_A = ?$$

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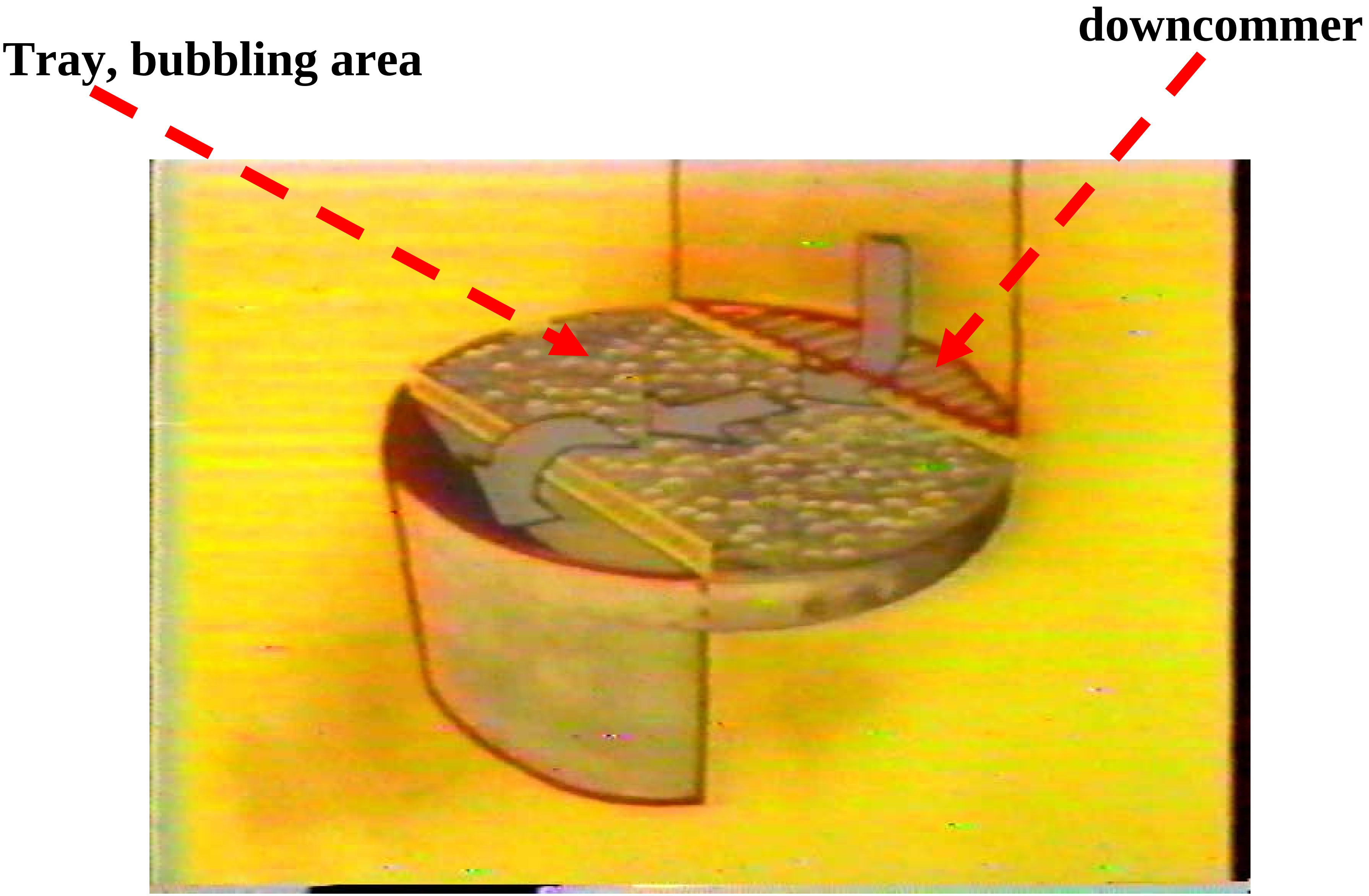
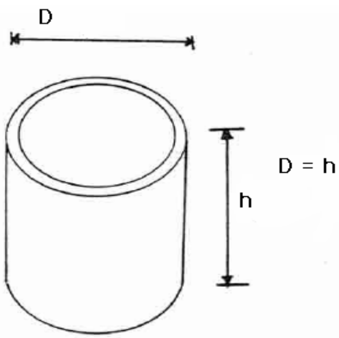
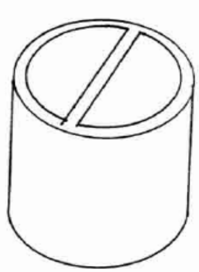
10.6 흡수탑/증류탑



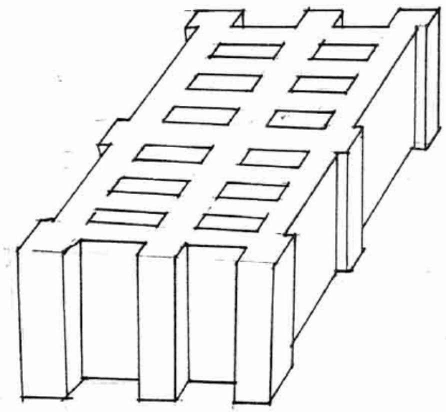
흡수탑에서의 충전물질



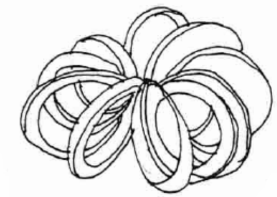
Resching Ring



Ressing Ring



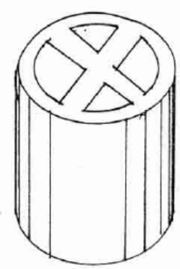
Grid Packing



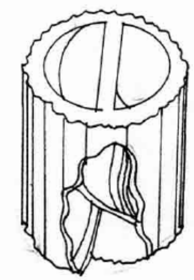
Tellerette

Berl saddle

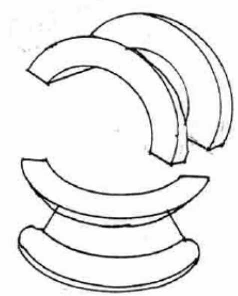
Pall Ring



Cross Partition Ring

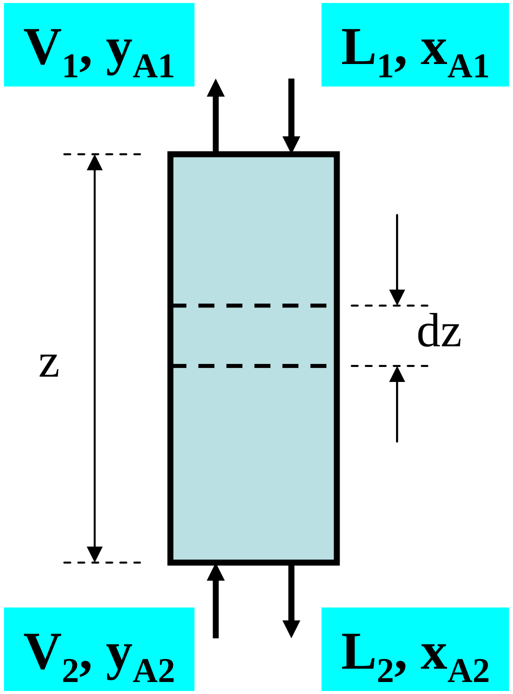


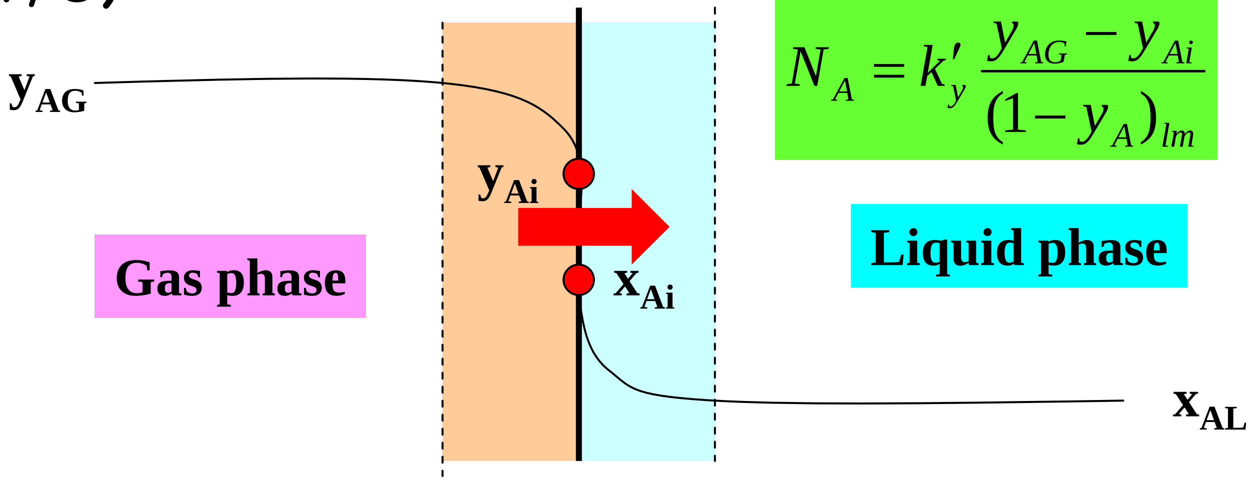
Cyclohelix Spiral Ring



Intalox Saddle

10.6 흡수탑 설계(1/5)





$$N_A = k'_y \frac{y_{AG} - y_{Ai}}{(1 - y_A)_{lm}}$$

$$Q_V = V_2 y_{A2} - V_1 y_{A1}$$

$$Q_L = L_1 x_{A1} - L_2 x_{A2}$$

$$Q_t = N_A A = A \cdot k'_y \frac{y_{AG} - y_{Ai}}{(1 - y_A)_{lm}}$$

흡수탑에서의 질량 보존

1. 기상의 물질이 잃은 유량 (Q_V)
2. 액상의 물질이 얻은 유량 (Q_L)
3. 두 상간 전달된 유량 (Q_t)

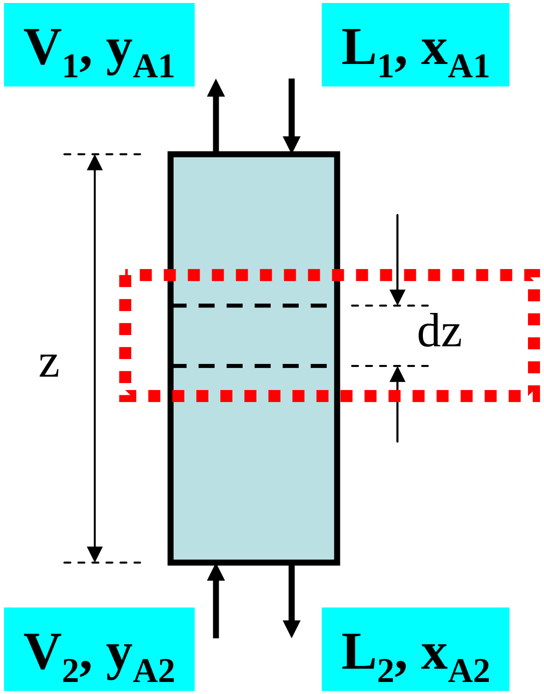
$$\mathbf{Q_V = Q_L = Q_t}$$

열교환기에서의 에너지 보존

1. 뜨거운 액체가 잃은 열량 (q_h)
2. 차거운 액체가 얻은 열량 (q_c)
3. 두 액체간 전달된 열량 (q_t)

$$\mathbf{q_h = q_c = q_t}$$

10.6 흡수탑 설계(2/5)



흡수탑에서의 질량 보존

1. 기상의 물질이 잃은 유량 (Q_V)
2. 액상의 물질이 얻은 유량 (Q_L)
3. 두 상간 전달된 유량 (Q_t)

$$Q_V = Q_L = Q_t$$

$$Q_V = V_2 y_{A2} - V_1 y_{A1}$$

$$Q_L = L_1 x_{A1} - L_2 x_{A2}$$

$$Q_t = N_A A = A \cdot k_y' \frac{y_{AG} - y_{Ai}}{(1-y_A)_{lm}}$$

$V(1-y_A)=V'$

$$dQ_V = d(Vy_A)$$

$$dQ_L = d(Lx_A)$$

$$dQ_V = d(Vy_A) = \frac{Vdy_A}{1-y_A}$$

$$dQ_L = \frac{Ldx_A}{1-x_A}$$

$$dQ_t = N_A dA = k_y' \frac{y_A - y_{Ai}}{(1-y_A)_{lm}} \cdot dA$$

$$dQ_t = k_y' \frac{y_A - y_{Ai}}{(1-y_A)_{lm}} \cdot aSdz$$

$dA=aSdz$

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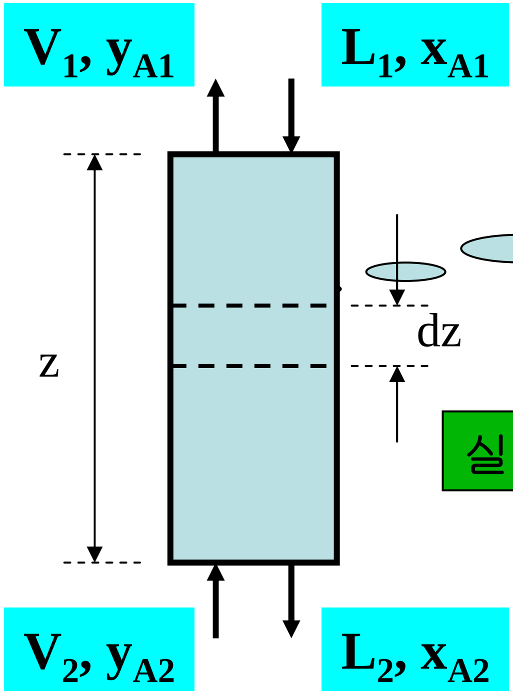
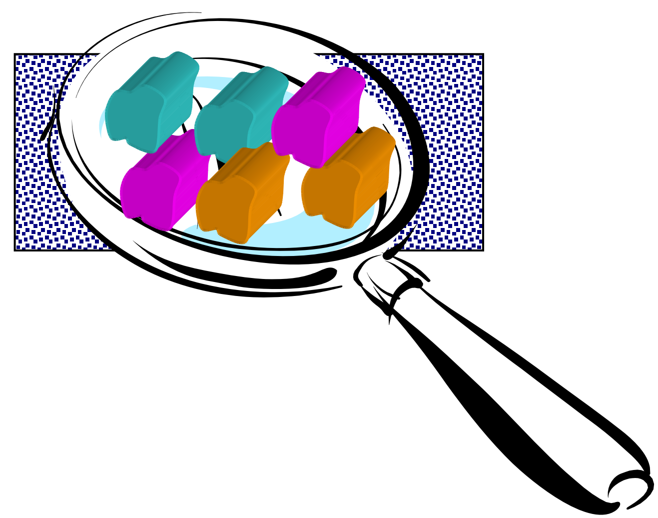
10.6 흡수탑 설계(3/5)



$$dA = a \cdot S \cdot dz$$

- a : 충전부피당 충전입자들의 표면적 (m²/m³)
- S : 흡수탑 단면적(m²)
- dz : 높이
- dA : 실질적 기액상 물질전달 면적 (m²)

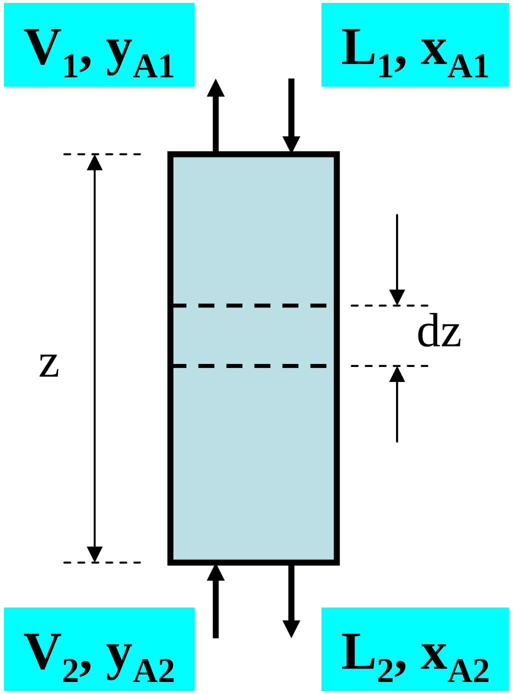


$$dQ_V = d(Vy_A) = \frac{Vdy_A}{1-y_A}$$

$$dQ_L = \frac{Ldx_A}{1-x_A}$$

$$dQ_t = k_y' \frac{y_A - y_{Ai}}{(1-y_A)_{lm}} \cdot aSdz$$

10.6 흡수탑 설계(4/5)



$$\frac{Vdy_A}{1-y_A} = k'_y \frac{y_A - y_{Ai}}{(1-y_A)_{lm}} \cdot aSdz$$

$$\int_0^z dz = \int_{y_0}^{y} \left(\frac{(1-y_A)_{lm}}{(1-y_A)\cdot(y_A - y_{Ai})} \cdot \frac{V}{k'_y \cdot a \cdot S} \right) dy_A$$

$$z = \int_{y_0}^{y} \left(\frac{(1-y_A)_{lm}}{(1-y_A)\cdot(y_A - y_{Ai})} \cdot \frac{V}{k'_y \cdot a \cdot S} \right) dy_A$$

$$dQ_V = d(Vy_A) = \frac{Vdy_A}{1-y_A}$$

$$z = \frac{V}{k'_y \cdot a \cdot S} \cdot \frac{(1-y_A)_{lm}}{(1-y_A)} \int_{y_0}^{y} \frac{dy_A}{(y_A - y_{Ai})}$$

$$dQ_t = k'_y \frac{y_A - y_{Ai}}{(1-y_A)_{lm}} \cdot aSdz$$

$$\frac{V}{S}(y_{A1} - y_{A2}) = k'_y \cdot a \cdot z \cdot (y_A - y_{Ai})_{lm}$$

Vapor mass flux **mass transfer flux**

교재 675-681 쪽

2004년 9월 5일 화공기사시험

- 문제 60: 도관의 내경이 49mm 이고 외경이 149mm 이며, 길이가 10m 일때, 이도관의 대수 평균표면적은?

가. 2.35 m^2
나. 2.54 m^2
다. 2.82 m^2
라. 2.92 m^2

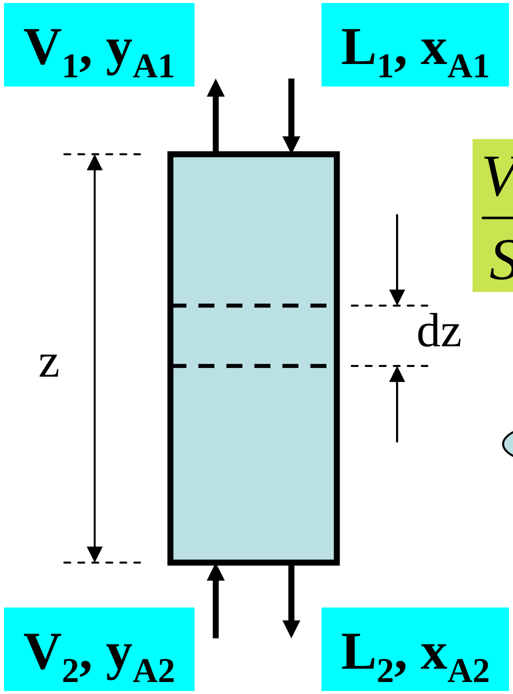
$$A_{\log mean} = \frac{A_2 - A_1}{\ln \frac{A_2}{A_1}}$$

$$A_2 = 2\pi r_2 L = \pi D_2 L = 3.14 \cdot 0.149 \cdot 10 = 4.68$$

$$A_1 = 2\pi r_1 L = \pi D_1 L = 3.14 \cdot 0.049 \cdot 10 = 1.54$$

$$A_{\log mean} = \frac{4.6786 - 1.5386}{\ln \frac{4.6786}{1.5386}} = 2.823$$

10.6 흡수탑 설계(5/5)



$$\frac{V}{S}(y_{A1}-y_{A2}) = k'_y \cdot a \cdot z \cdot (y_A - y_{Ai})_{lm} = k'_x \cdot a \cdot z \cdot (x_{Ai} - x_A)_{lm}$$

mass transfer flux: Vapor phase

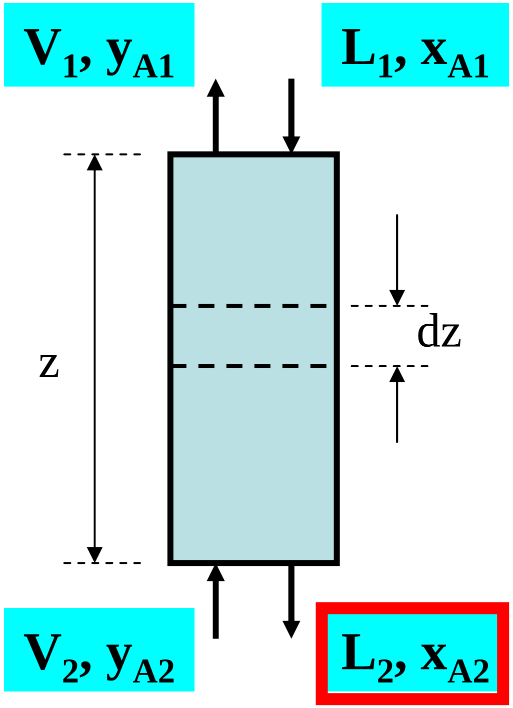
mass transfer flux: Liquid phase

$$(y_A - y_{Ai})_{lm} = \frac{(y_{A1}-y_{Ai1})-(y_{A2}-y_{Ai2})}{\ln\dfrac{(y_{A1}-y_{Ai1})}{(y_{A2}-y_{Ai2})}}$$

가정:

1. 희석기체 혼합물의 흡수이고 (몰분율이 10% 미만),
2. 조업선과 평형선이 직선으로 간주할 수 있으며,
3. $(1-y_A)_{lm}/(1-y) \approx 1$ 으로 간주할 때

예제: 10.6-2 아세톤 흡수탑

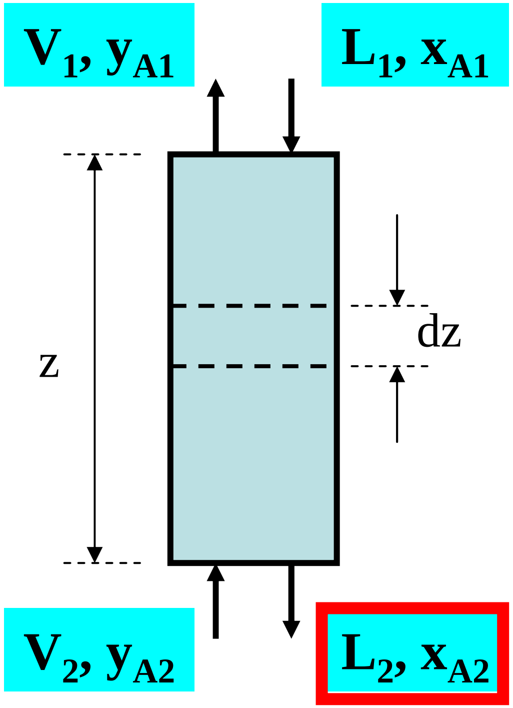


$S=0.186m^2$
$T=293K, P=1atm$
$V'=13.65kmol/h$ (air), $y_{A2}=0.06$, $y_{A1}=0.005$
$L_1=45.36kmol/h$ (water), $x_{A1}=0$
$k_y'a=0.0378kmol/s/m^3$
$k_x'a=0.0616kmol/s/m3$
$y=1.186x$

문제:
1) 평형단수는 몇 단인가?
2) 탑의 높이를 계산하시오.

계산순서
1) 미지수 (V_1, V_2, L_2, x_{A2}) 를 구한다.
2) 조업선과 평형선을 그린다.
3) 평형단수를 구한다.
4) 평형농도값을 구한다 (y_{Ai1}, y_{Ai2}) 를 구한다.
5) 식 (10.6-26) 을 이용하여 z 를 구한다.

예제: 10.6-2 아세톤 흡수탑



$S=0.186m^2$
$T=293K$, $P=1atm$
$V'=13.65$ kmol/h (air), $y_{A2}=0.06$, $y_{A1}=0.005$
$L_1=45.36$ kmol/h (water), $x_{A1}=0$
$k_y'a=0.0378 kmol/s/m^3$
$k_x'a=0.0616$ kmol/s/m3
$y=1.186x$

$$slope=-\frac{k_x' \, a/(1-x_1)}{k_y' \, a/(1-y_1)}$$

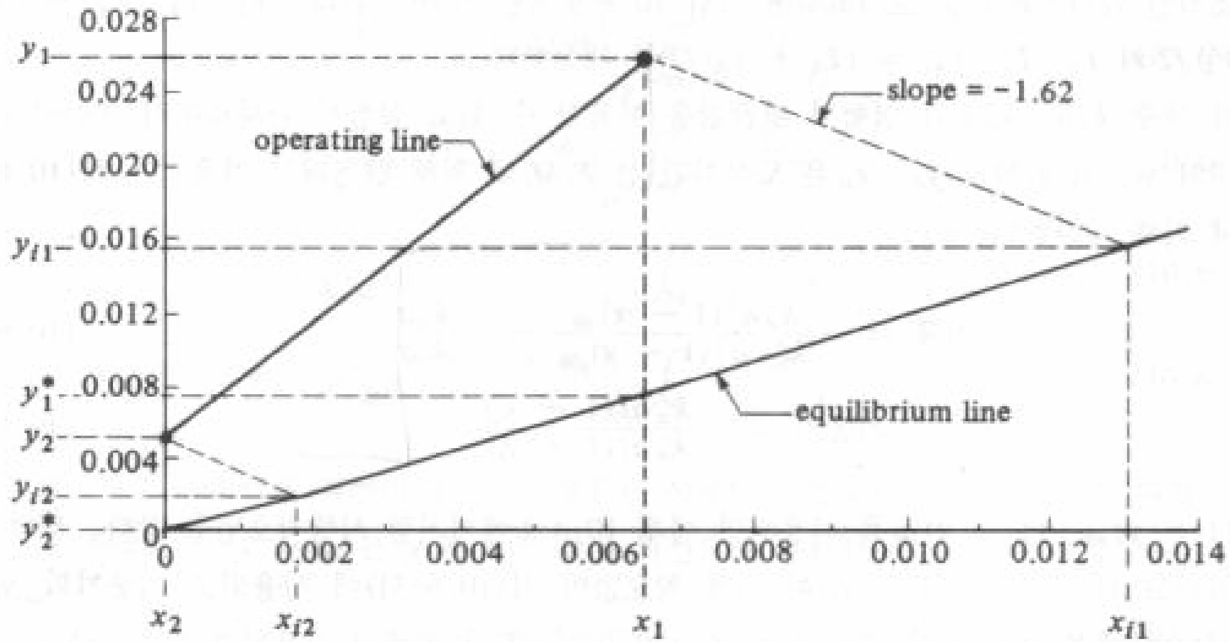


FIGURE 10.6-10. *Location of interface compositions for Example 10.6-2.*

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과제 2. 흡수탑 (10.2-4, 10.6)

- 10.2-1
- 10.2-3
- 10.3-1
- 10.6-6 (a)
- 10.6-8: 평형식; y=0.039x,
  예제 10.8-1 참조 (696쪽)