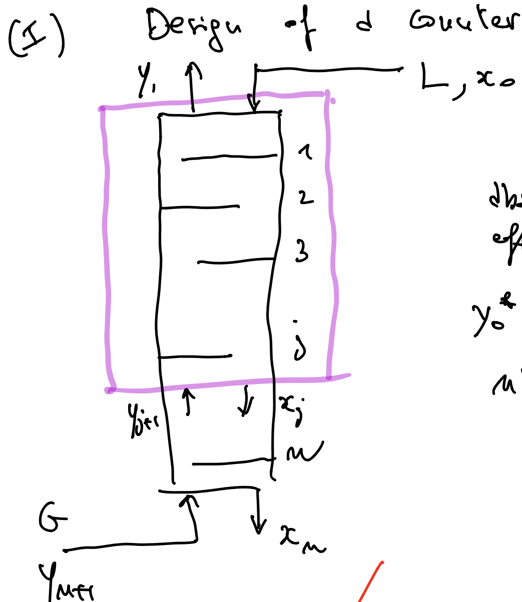
(I) Design of a Countercurrent absorber



$$\alpha = \frac{y_{m+1} - y_1}{y_{m+1} - y_0^*} = \frac{A^{m+1} - A}{A^{m+1} - 1} = \alpha$$

absorption efficiency

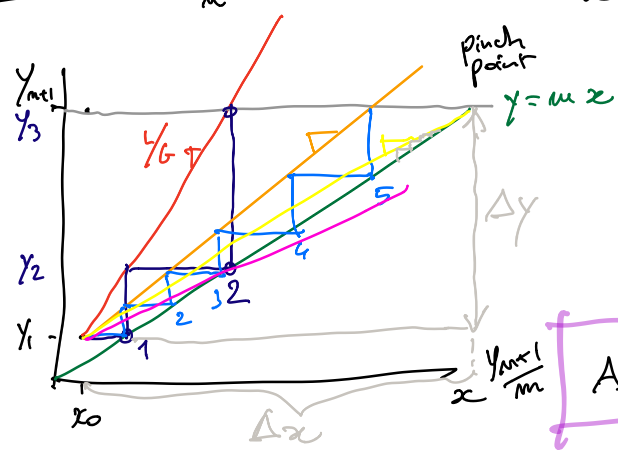
$y_0^* = m x_0$

$$A = \frac{L/G}{m}$$ operating parameter

m-size — operating condition: A

absorption efficiency α

Kremser equation



Data

G, y_{m+1}, x_0, $m(T,P)$

Specification

$y_1^{max} \geq y_1$

$$\boxed{A^{m+1}(1-\alpha_{min}) - A + \alpha_{min} = 0}$$

① $m, A \rightarrow \alpha \rightarrow y_1 = y_{m+1} - \alpha(y_{m+1} - y_0^*)$

② $\alpha_{min}(y_1^{max}), A \rightarrow m$

③ $\alpha_{min}, m \rightarrow A$ numerical solution

$$A^m(1-\alpha_{min}) = 1 - \frac{\alpha_{min}}{A}$$

$$\boxed{m = \frac{1}{\ln A} \ln\left(\frac{1 - \frac{\alpha_{min}}{A}}{1-\alpha_{min}}\right)}$$

$$\boxed{A_{min} = \alpha_{min}}$$

L/G (or A) ↓ m ↑

$$\left(\frac{L}{G}\right)_{min} = \frac{\Delta y}{\Delta x} = \frac{y_{m+1} - y_1}{y_{m+1}/m - x_0} = \frac{m(y_{m+1} - y_1)}{y_{m+1} - y_0^*}$$

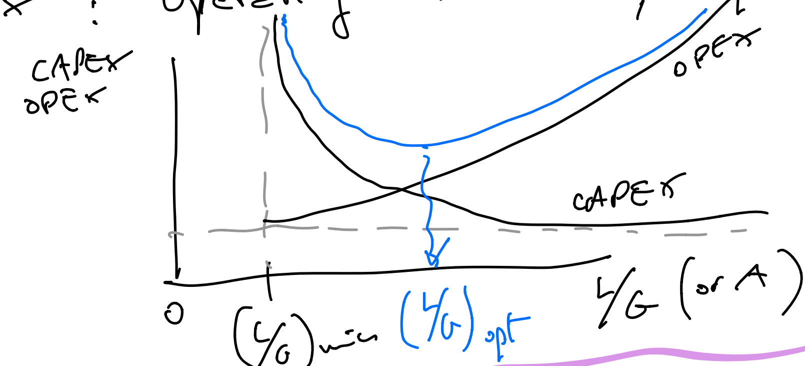
minimum L/G ratio, that depends on the problem (y_{N+1}, x_0, y_1^{max}) and on thermodynamics (m)

↳ $N \to \infty \Rightarrow A > A_{min}$?!

cost optimization ⟶

CAPEX : Capital Expenditures, depend on $\boxed{N}$

OPEX : Operating ", depend on $\boxed{A}$



Data (y_{N+1}, G, x_0, m) + Specs ($y_1^{max} \to \alpha_{min}$) ⟶

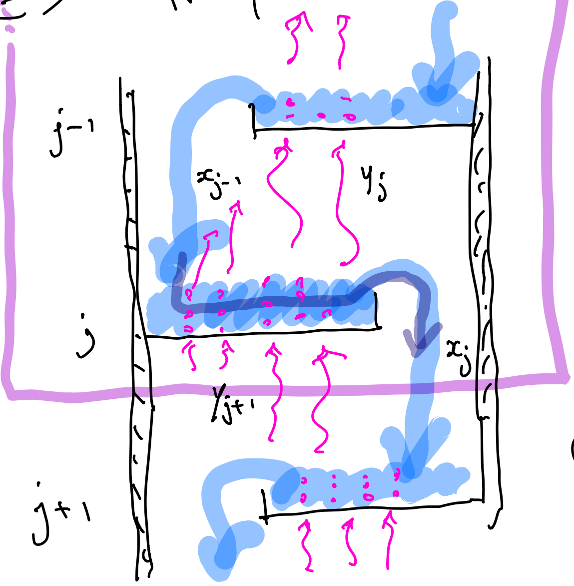
⟶ A_{min} ($= \alpha_{min}$) ⟶ $A > A_{min}$ ⟶ L/G ($=Am$) ⟶

② ⟶ N^* ($N^* \in \mathbb{R}$) ⟶ $N^* < N < N^*+1$ ⟶

① ⟶ $\alpha > \alpha_{min}$ ⟶ $y_1 < y_1^{max}$ $\xrightarrow[\text{overall mat. bal.}]{}$ x_N

$$G y_{N+1} + L x_0 = G y_1 + L x_N$$

(II) Tray columns



Eq. stage $\quad y_j = m x_j$

Stage not-at-equilibrium

① mat. balance $\quad \boxed{G y_{j+1} + L x_0 = G y_1 + L x_j}$

② eq. condition $\quad \boxed{y_j^* = m x_j}$

③ stage efficiency (Murphree) $\quad E_j^{MG} = \dfrac{y_{j+1} - y_j}{y_{j+1} - y_j^*}$

$E_j^{MG} = E < 1$ constant

$$\boxed{y_j = y_{j+1}(1-E) + E\, y_j^*}$$

$$\Rightarrow \boxed{y_{j+1} = A' y_j + B'(y_1 - A y_0^*)}$$

$$A' = \frac{A}{E + A - EA} \qquad B' = \frac{E}{E + A - EA}$$

when $E = 1$: $A' = A$, $B' = 1$

$E = 1 \longrightarrow$ eq. stages

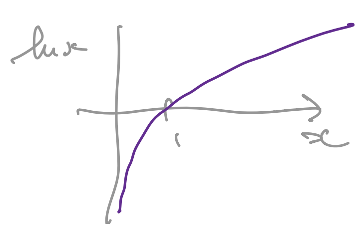
$j = 0$: $\quad \boxed{y_0 = y_{j+1}(1-E) + E\, y_0^*}$

$$\boxed{y_j = \left[y_1(1-E) + E\, y_0^* - \frac{B'}{1-A'}(y_1 - A y_0^*) \right] (A')^j + \frac{B'}{1-A'}(y_1 - A y_0^*)}$$

$j = n+1 \longrightarrow y_{n+1} \longrightarrow \alpha = \dfrac{y_{n+1} - y_1}{y_{n+1} - y_0^*}$ as always

$$\boxed{\alpha = \frac{(A')^{n'} - 1}{(A')^{n'} - 1/A}}$$

generalized Kremser eq.

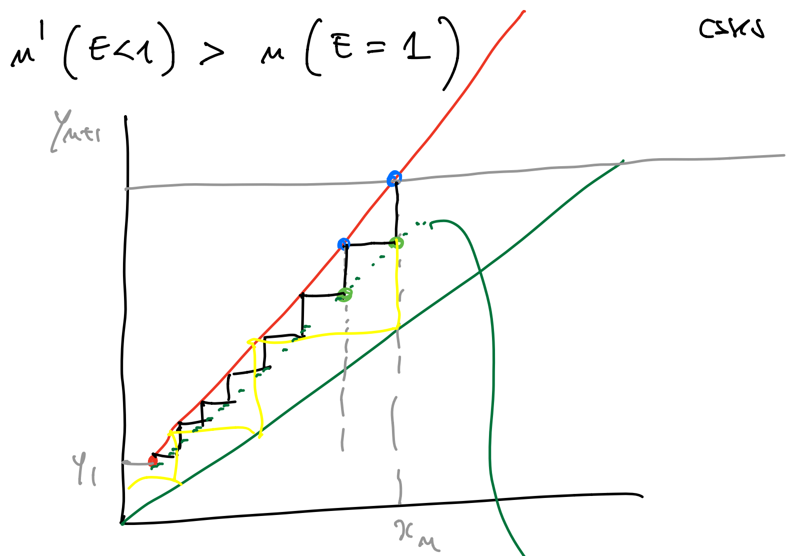


$$n' = \frac{1}{\ln A'} \ln\left(\frac{1-\frac{\alpha_{min}}{A}}{1-\alpha_{min}}\right)$$

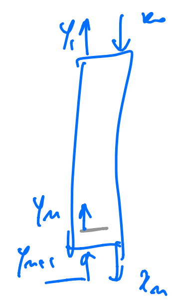
$$\boxed{A_{min} = \alpha_{min}}$$

$$\frac{n}{n'} = \frac{\ln A'}{\ln A} < 1 \rightarrow \underbrace{1 < A' < A \qquad A < A' < 1}_{\text{these are the only cases when } A' = \frac{A}{E+A-EA}}$$

$$n'(E<1) > n(E=1)$$



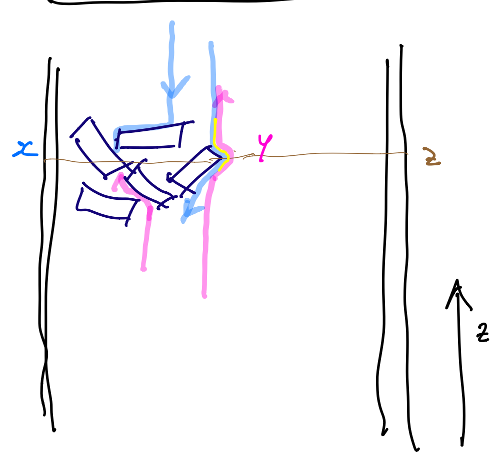
$$0.4 = E = \frac{y_{j+1} - y_j'}{y_{j+1} - y_j^*} < 1$$

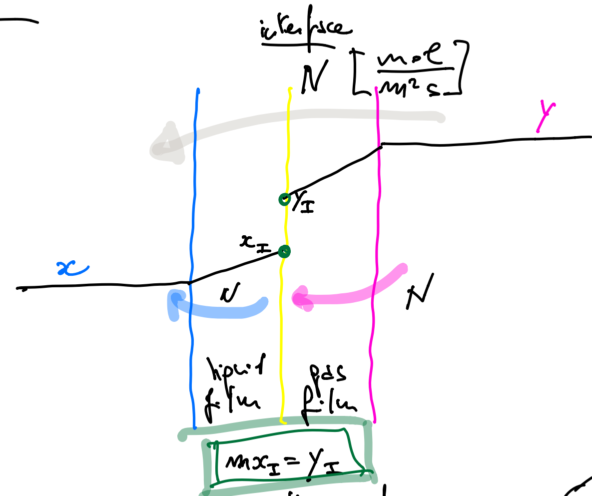


pseudo-equilibrium line

$\rightarrow$??

(IV) Packed columns





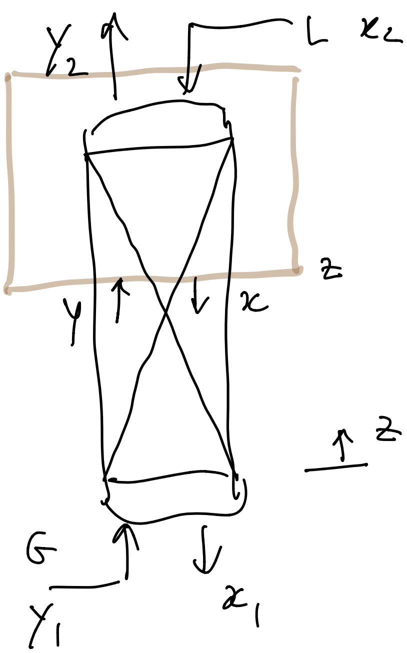
$$\boxed{N = k_G (y - y_I)} = \boxed{k_L (x_I - x)}$$

$$\frac{N}{k_G} = y - y_I \qquad m\frac{N}{k_L} = m(x_I - x) = y_I - mx = y_I - y^*$$

$$N\left(\frac{1}{k_G} + \frac{m}{k_L}\right) = y - y^* \qquad \frac{1}{K_G} = \frac{1}{k_G} + \frac{m}{k_L}$$

$$\boxed{N = K_G (y - y^*) = K_G (y - mx)}$$

2-film theory



① $\boxed{Gy + Lx_2 = GY_2 + Lx}$

② $\boxed{y^* = mx}$

③ mass transfer

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$$P y = H(T)\, x$$

Henry's law

$H(T)$ Henry's constant

$$y = \frac{H(T)}{P} x$$

$$y = mx \qquad m = \frac{H(T)}{P} \; : \text{ my nomenclature}$$