Gas Absorption

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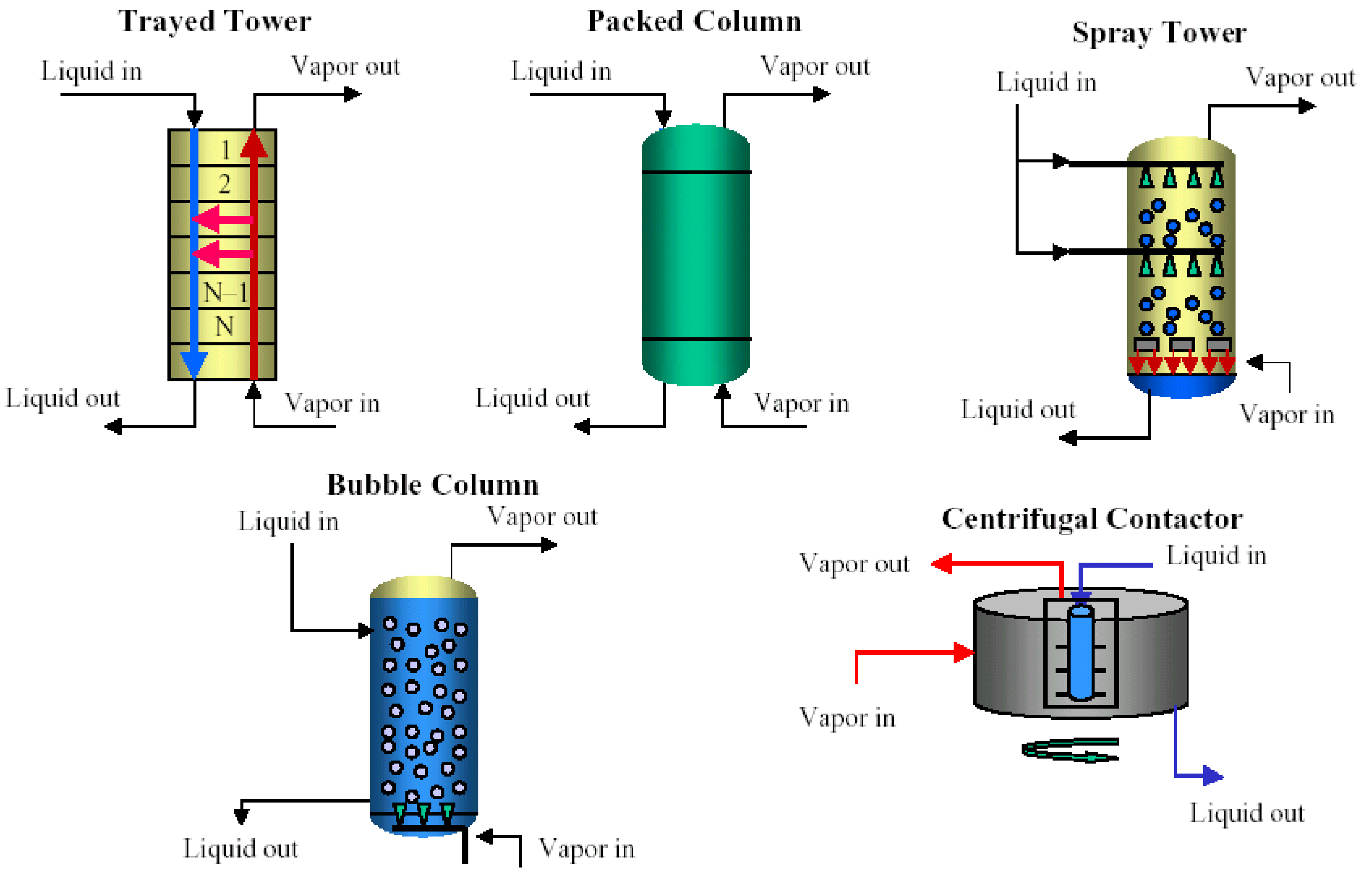
Processos de Separação

Gas Absorption

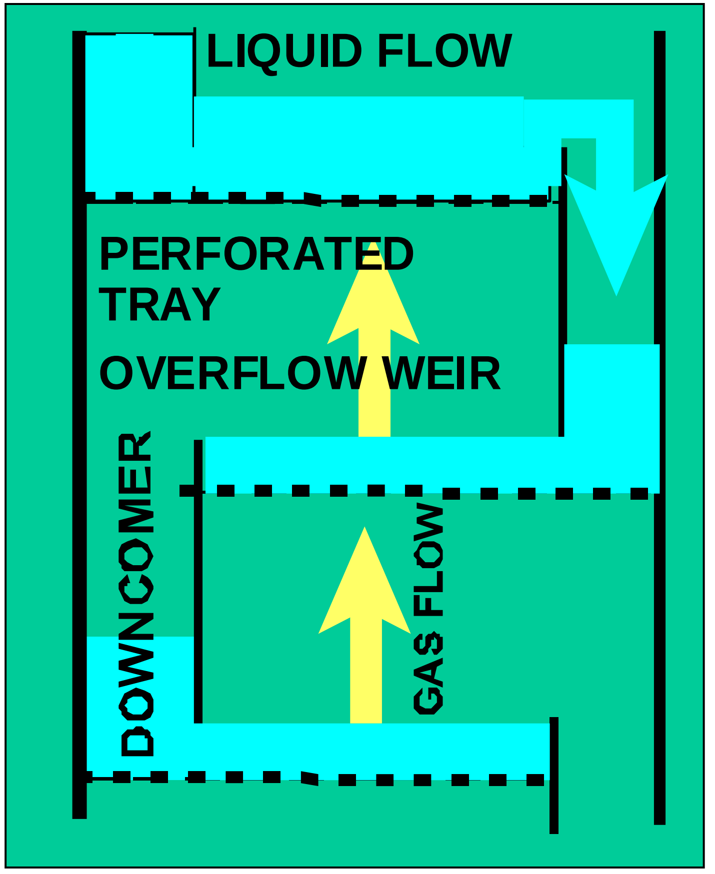
Absorption and Stripping Equipment



Gas Absorption – Tray Columns

CONTACT OCCURS IN THE LIQUID IN THE TRAY

- ✓ LIQUID CIRCULATES IN PARALLEL
- ✓ GAS CIRCULATES PERPENDICULARLY



TRAYS

SIEVE

- Construção simples
- Baratos
- Fáceis de limpar

VALVE

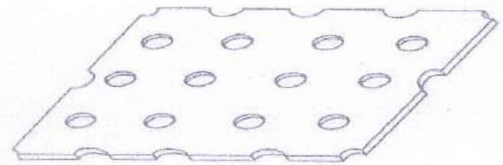
- Construção mais complicada
- Mais caros (+ 20%)
- Problemas de "fouling"
- Versáteis (larga gama de caudais)

BUBBLE

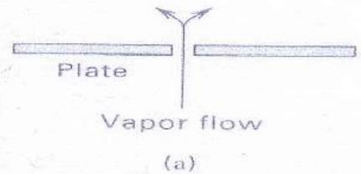
- Construção complexa
- Dispendiosos
- Problemas de "fouling"
- Menos flexíveis

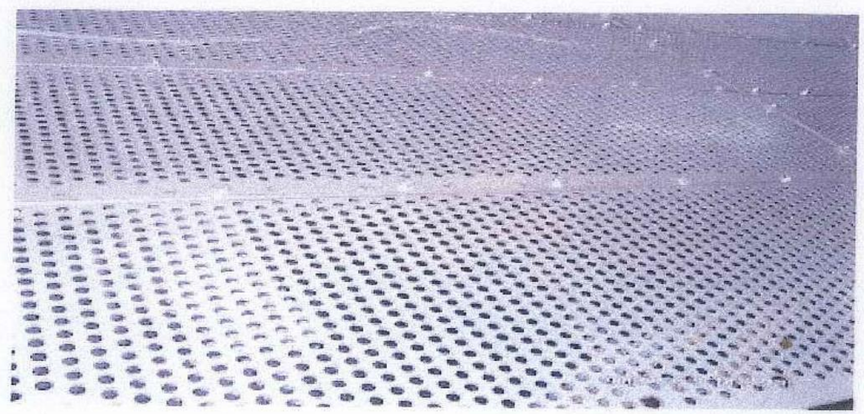
SIEVE TRAYS

Pratos perfurados
"sieve trays"



Ø: 3 – 10 mm

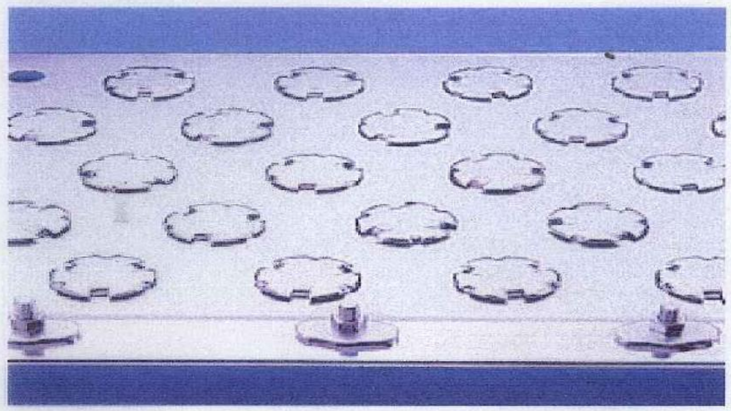


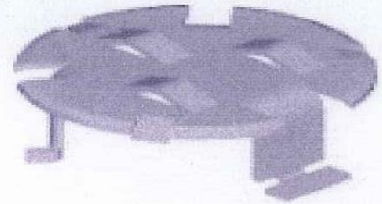


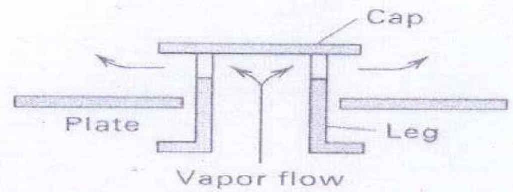
VALVE TRAYS

Pratos com válvulas
"valve trays"

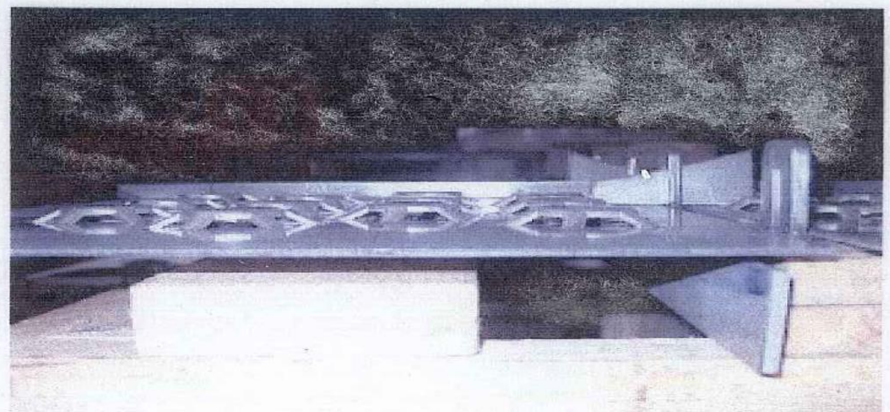
Ø: 35 - 50 mm





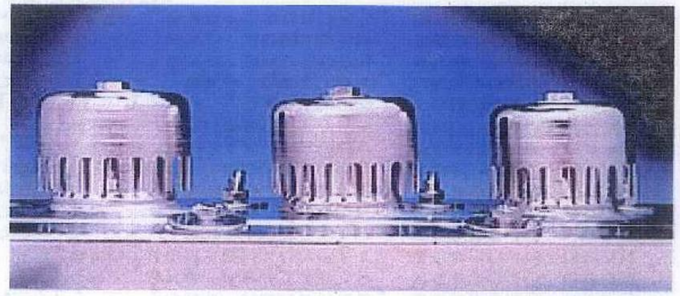


(b)

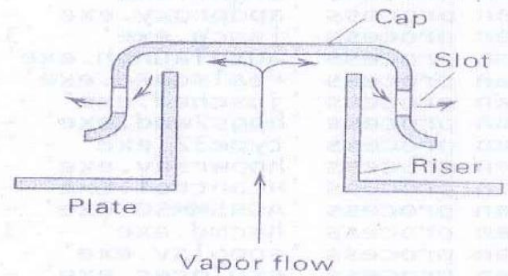


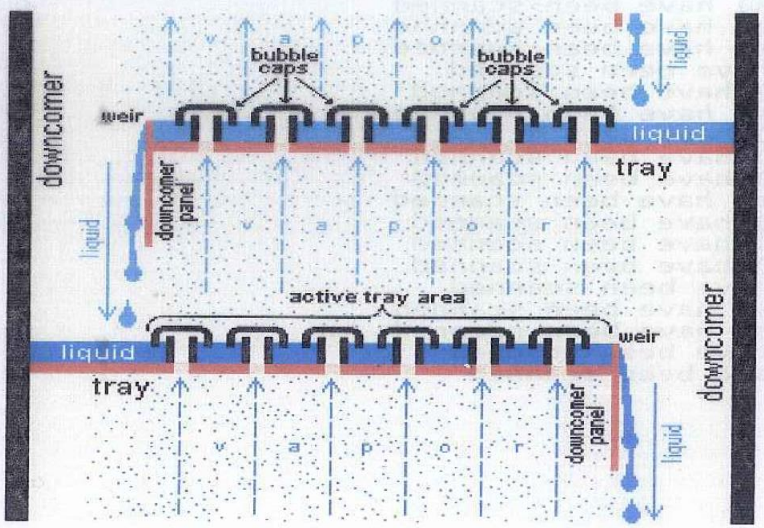
BUBBLE TRAYS

Campânulas de borbulhamento "bubble trays"



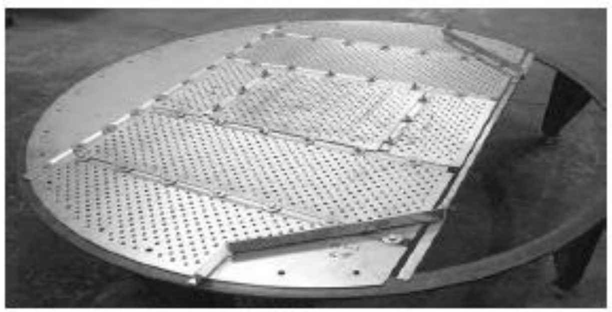
Ø: 50 – 76 mm



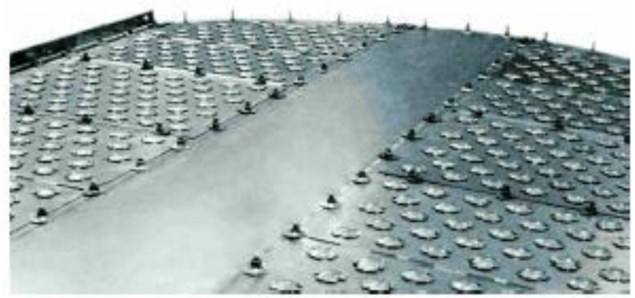


Bubble Cap Tray:
http://www.wermac.org/

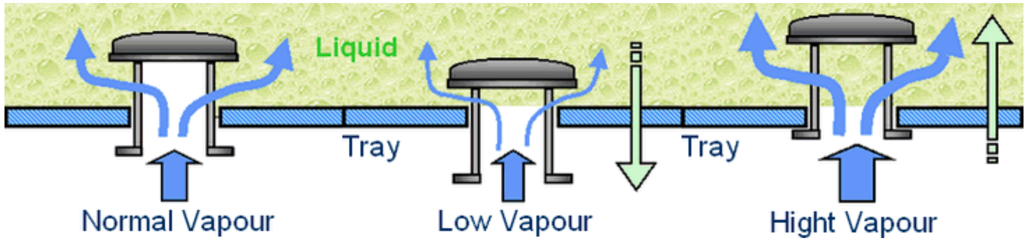
Perforated Tray:
https://www.sulzer.com/

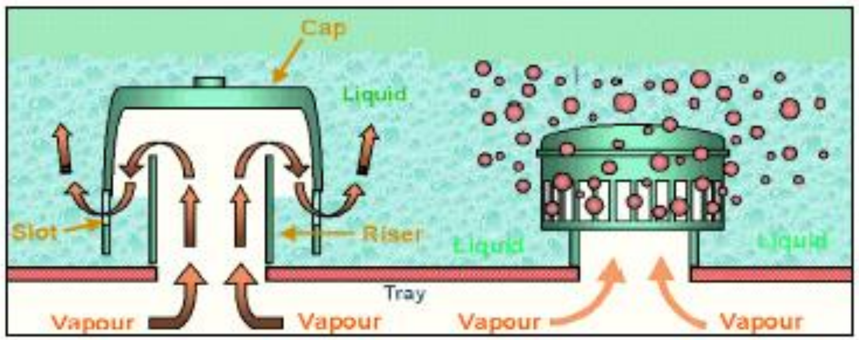


Sieve Tray:
http://www.wermac.org/



Valve Tray:
http://www.wermac.org/





http://www.wermac.org

Tray Stack.
Sulzer Chemtech Ltd., Switzerland.

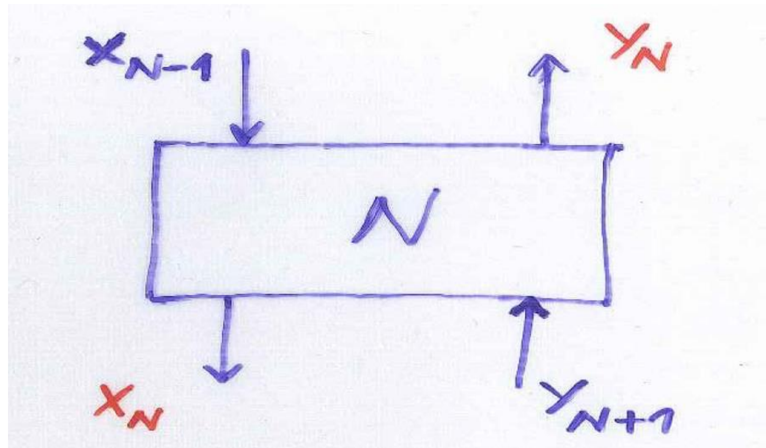
www.wermac.org
www.sulzer.com

GAS ABSORPTION

Theoretical Plate

The solute compositions in the gas and liquid leaving the tray are in equilibrium.

Y_N in equilibrium with X_N



How calculate N ?

GAS ABSORPTION- N ?

Total molar balance

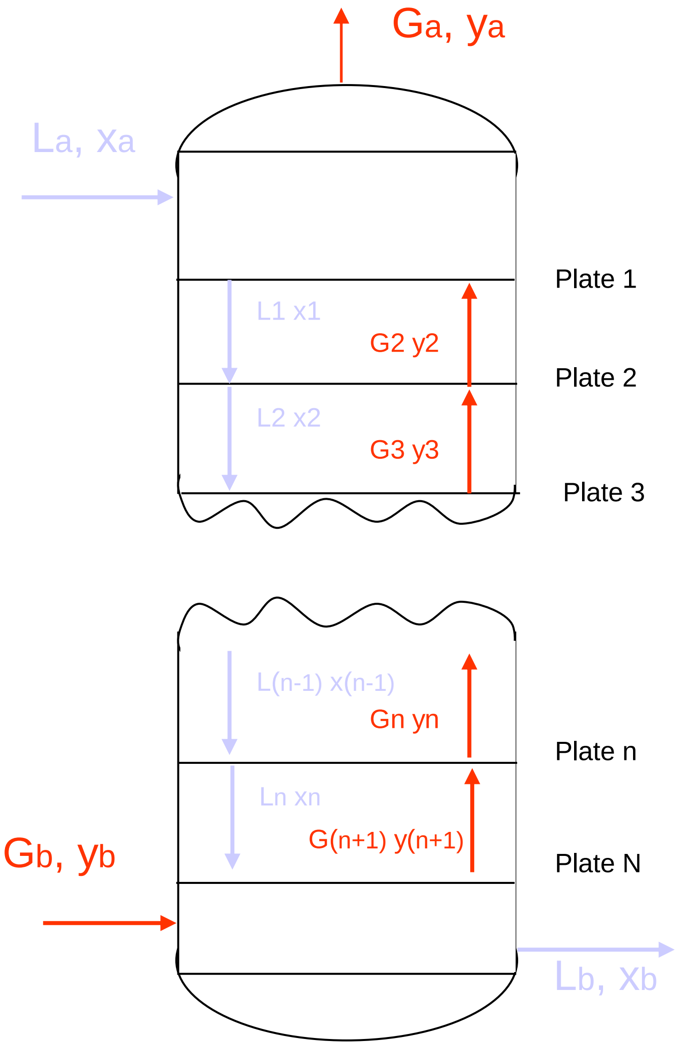
$$L_a + G_{n+1} = L_n + G_a$$

A molar balance

$$L_a x_a + G_{n+1} y_{n+1} = L_n x_n + G_a y_a$$

Operating line

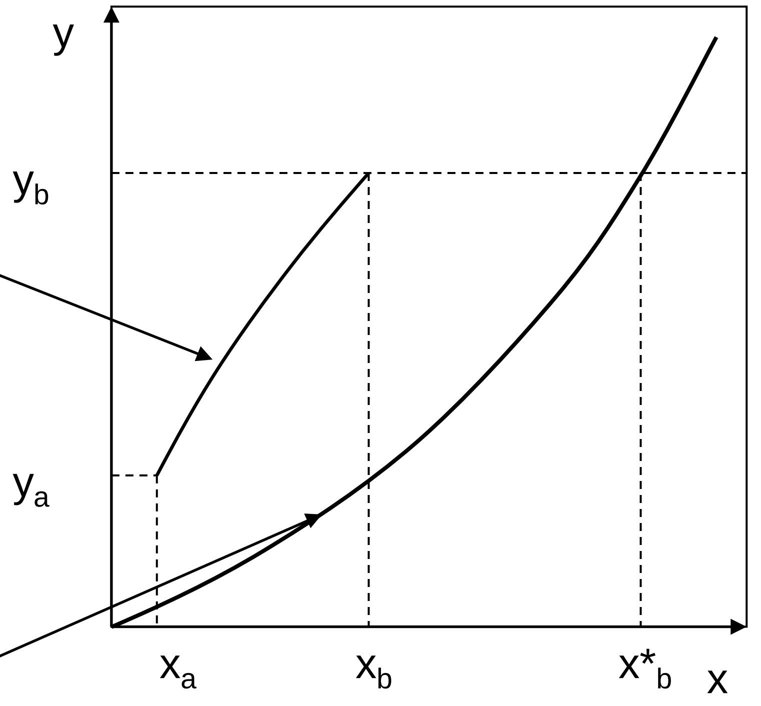
$$y_{n+1} = \frac{L_n}{G_{n+1}} x_n + \frac{G_a y_a - L_a x_a}{G_{n+1}}$$



GAS ABSORPTION- N ?

Operating line

$$y_{n+1} = \frac{L_n}{G_{n+1}} x_n + \frac{G_a y_a - L_a x_a}{G_{n+1}}$$

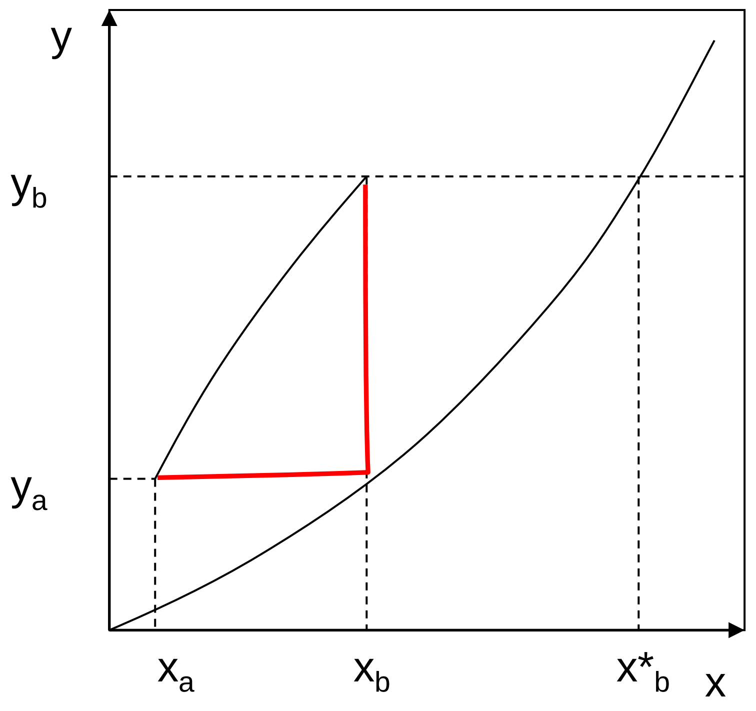


$$y_A^* = f(x_A)$$

Equilibrium line

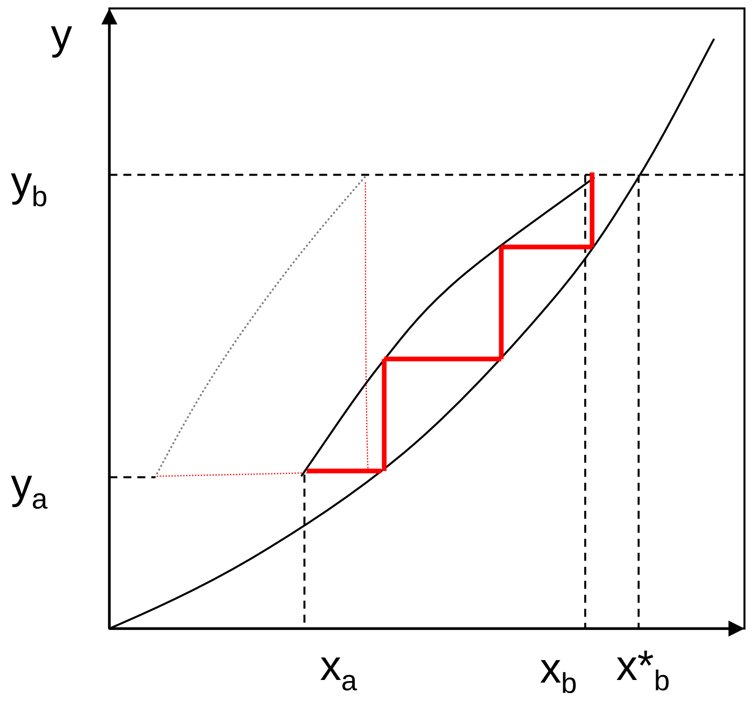
GAS ABSORPTION- N ?

McCabe-Thiele



GAS ABSORPTION- N ?

McCabe-Thiele



GAS ABSORPTION- N ?

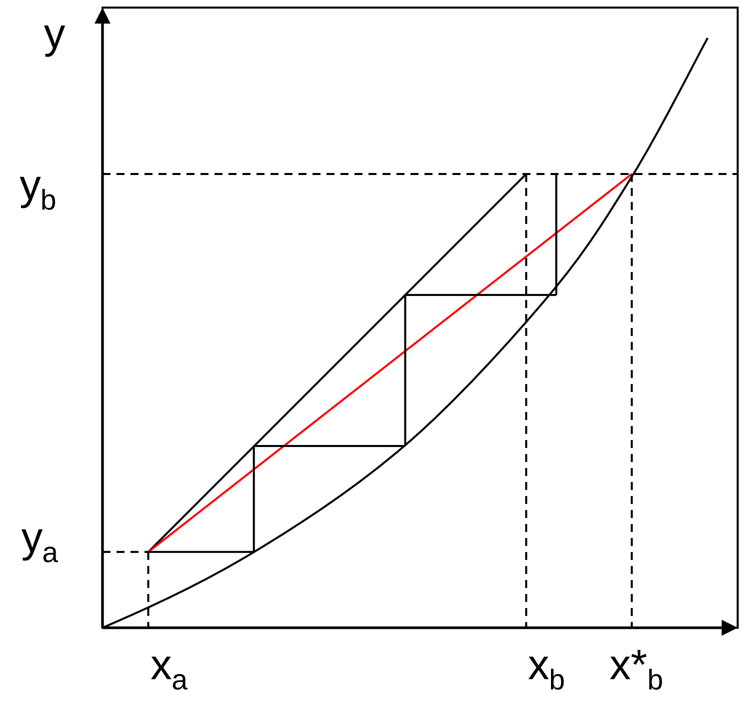
Constant flowrate

$G1 \sim G2 \sim G$

$L1 \sim L2 \sim L$

L, G constant -> L/G constant

$$y_b = \frac{L}{G} x_b^* + \frac{G y_a - L x_a}{G} \Rightarrow \left(\frac{L}{G}\right)_{\min} = \frac{y_b - y_a}{x_b^* - x_a}$$



GAS ABSORPTION- N ?

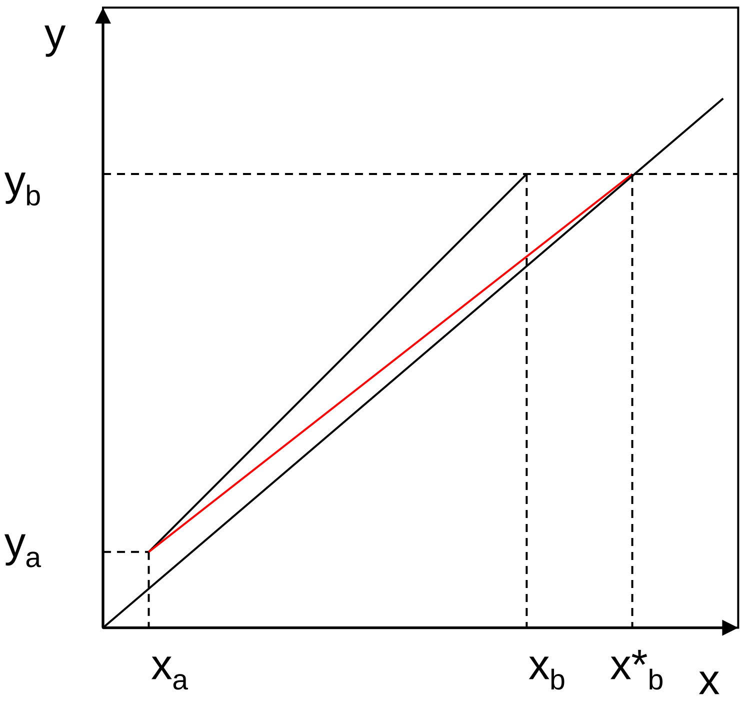
L, G constant -> L/G constant

Henry law

$y_e = m x_e$

$$y_b = \frac{L}{G} x_b^* + \frac{G y_a - L x_a}{G} \Rightarrow$$

$$\left(\frac{L}{G}\right)_{\min} = \frac{y_b - y_a}{x_b^* - x_a} = \frac{y_b - y_a}{y_b / m - x_a}$$



Operating line

$$y_e = mx_e \Rightarrow y_n = mx_n$$ Henry law

$$y_{n+1} = \frac{L_n}{G_{n+1}} x_n + \frac{G_a y_a - L_a x_a}{G_{n+1}}$$

$$A = L / mG = const$$

$$y_{n+1} = Ay_n + y_a - Amx_a = Ay_n - Ay_a^* + y_a$$

For each plate

$$y_2 = Ay_a - Ay_a^* + y_a = y_a(1 + A) - Ay_a^*$$

$$y_3 = Ay_2 - Ay_a^* + y_a = y_a(A + A^2) - A^2 y_a^* - Ay_a^* + y_a =$$

$$= y_a(1 + A + A^2) - y_a^*(A + A^2)$$

$$\vdots$$

$$y_{n+1} = y_a(1 + A + A^2 + \ldots + A^n) - y_a^*(A + A^2 + \ldots + A^n)$$

$$y_N = y_b = y_a(1 + A + A^2 + \ldots + A^N) - y_a^*(A + A^2 + \ldots + A^N)$$

$$y_{n+1} = y_b = y_a(1 + A + A^2 + \ldots + A^N) - y_a^*(A + A^2 + \ldots + A^N)$$

$$s_n = \frac{a_1(1 - r^n)}{1 - r}$$

$$y_b = y_a \frac{\left(1 - A^{N+1}\right)}{1 - A} - y_a^* A \frac{(1 - A^N)}{1 - A}$$

Kremser equation

Analytical Solution

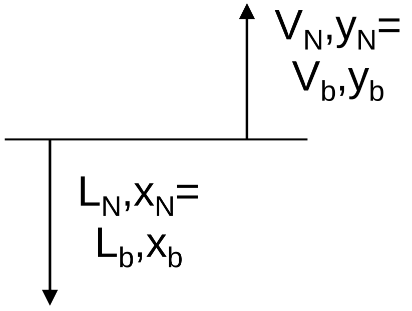
$$N = \frac{\ln\left[\left(\frac{y_1 - mx_2}{y_2 - mx_2}\right)(1 - 1/A) + 1/A\right]}{\ln A}$$

$$N = \frac{\ln\left[\left(\frac{x_2 - y_1/m}{x_1 - y_1/m}\right)(1 - A) + A\right]}{\ln(1/A)}$$

Kremser equation

$$y_b = Ay_N - Ay_a^* + y_a = Ay_b^* - Ay_a^* + y_a$$

$$y_a - y_b = -A(y_b^* - y_a^*)$$



From the operating line:

$$y_b = y_a \frac{\left(1 - A^{N+1}\right)}{1 - A} - y_a^* A \frac{(1 - A^N)}{1 - A}$$

$$y_b(1 - A) = y_a\left(1 - A^{N+1}\right) - y_a^*(A - A^{N+1})$$

$$A^{N+1}(y_a - y_a^*) = A(y_b - y_a^*) + y_a - y_b$$

$$y_a - y_b = -A(y_b^* - y_a^*)$$

$$A^{N+1}(y_a - y_a^*) = A(y_b - y_a^*) + y_a - y_b$$

$$A^{N+1}(y_a - y_a^*) = A(y_b - y_a^*) + A(y_b^* - y_a^*)$$

$$A^N = \frac{y_b - y_b^*}{y_a - y_a^*};$$

$$N = \frac{\ln\left[(y_b - y_b^*)/(y_a - y_a^*)\right]}{\ln A}$$

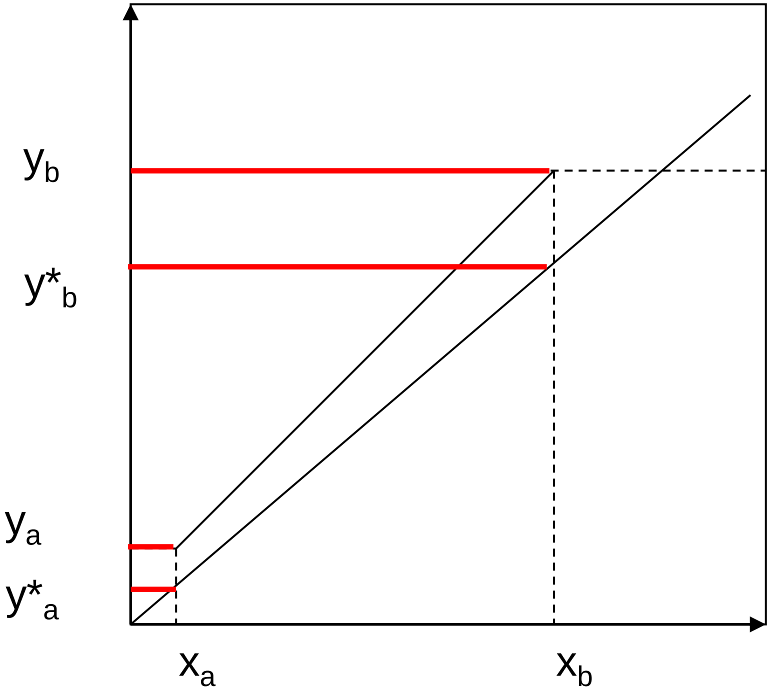
GAS ABSORPTION- N ?

$$y_e = mx_e \Rightarrow y_n = mx_n$$

Absorption factor

$$A = L / mG = const$$

$$N = \frac{\ln\left[(y_b - y_b^*)/(y_a - y_a^*)\right]}{\ln A}$$



Kremser equation (1930)

A stream of gas vented from a condenser in an aromatics plant has a flowrate of 200 kmol h^{-1}, a temperature of 25°C and a pressure of 5 bar. The composition (mole fractions) is

Hydrogen	0.900
Methane	0.07
Benzene	0.03

It is proposed to recover 98% of the benzene by absorption into an initially pure, non-volatile hydrocarbon oil using a plate column. Find:

[i] The minimum feed rate kmol h^{-1} of the oil for this separation

[ii] The minimum number of theoretical stages required at an oil rate 30.25 kmol h^{-1}

m is taken as the slope of the x-y equilibrium line.

Equilibrium data at 25°C and 5 bar.

Substance	$K_i = y_i/x_i$
Methane	43.0
Benzene	0.132

$G_b=200 kmol/h$

$y^*=0.132x$

$y_b=0.03 \qquad x_a=0$

$x_b^*=y_b/0.132=0.03/0.132=0.227$

$G_b\, y_b= G_s\, Y_b \qquad 200*0.03=G_s*(0.03/0.97)$

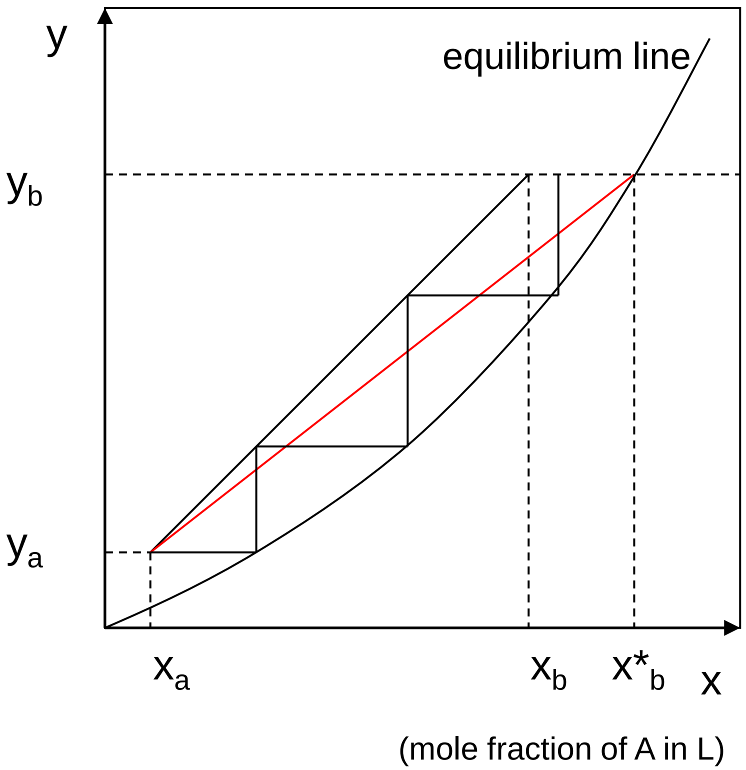
$G_s=194$ kmol/h (error 3%)

$G=200$ kmol/h

98% remoção $\quad y_a= (1-0.98)*0.03=0.0006$

$G\, y_b+ L_{min}\, x_a= G\, y_a +L_{min}\, x_b^*$

$L_{min}=25.9 kmol/h$



La=30.25 kmol/h

G yb+ L xa= G ya +L xb

xb=0.1944 yb*=0.132*xb=0.132*0.1944=0.0257

ya*=0.132*xa=0

A= L/mG=1.15

yb-yb*= 0.03-0.0257= 0.00434

ya-ya*=0.0006

$$N = \frac{\ln\left[(y_b - y_b^*)/(y_a - y_a^*)\right]}{\ln A}$$

N=14.2