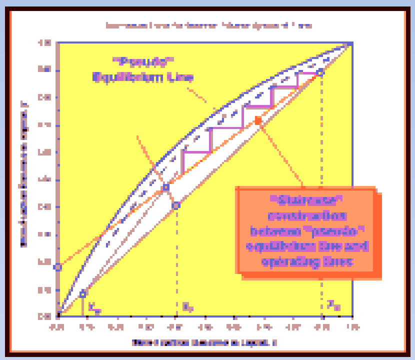
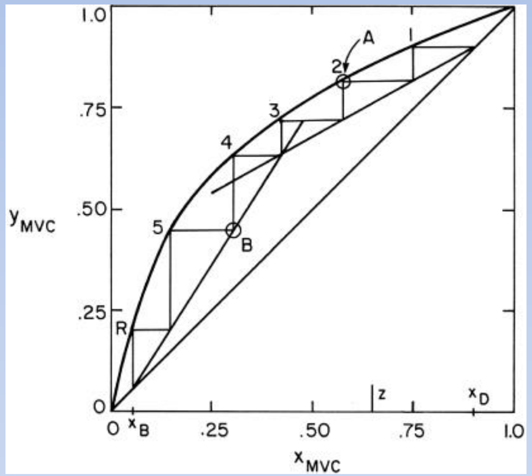
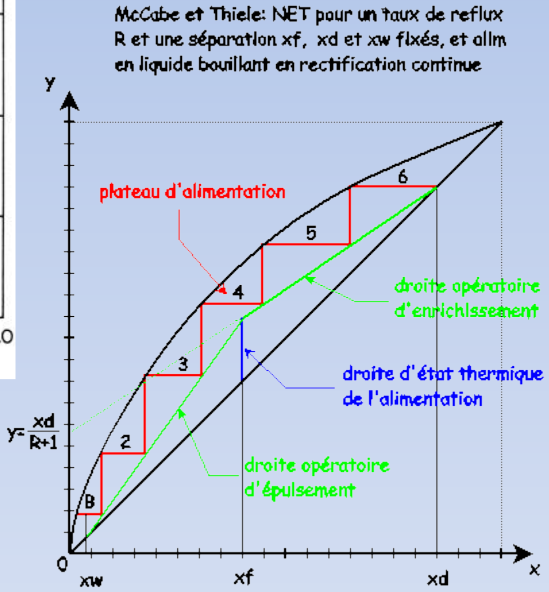
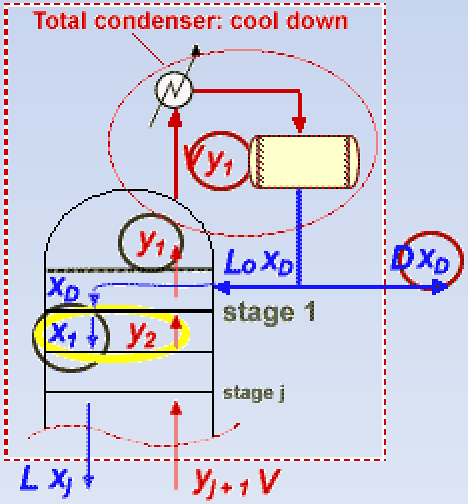
Fondamenti delle operazioni unitarie dell'industria chimica

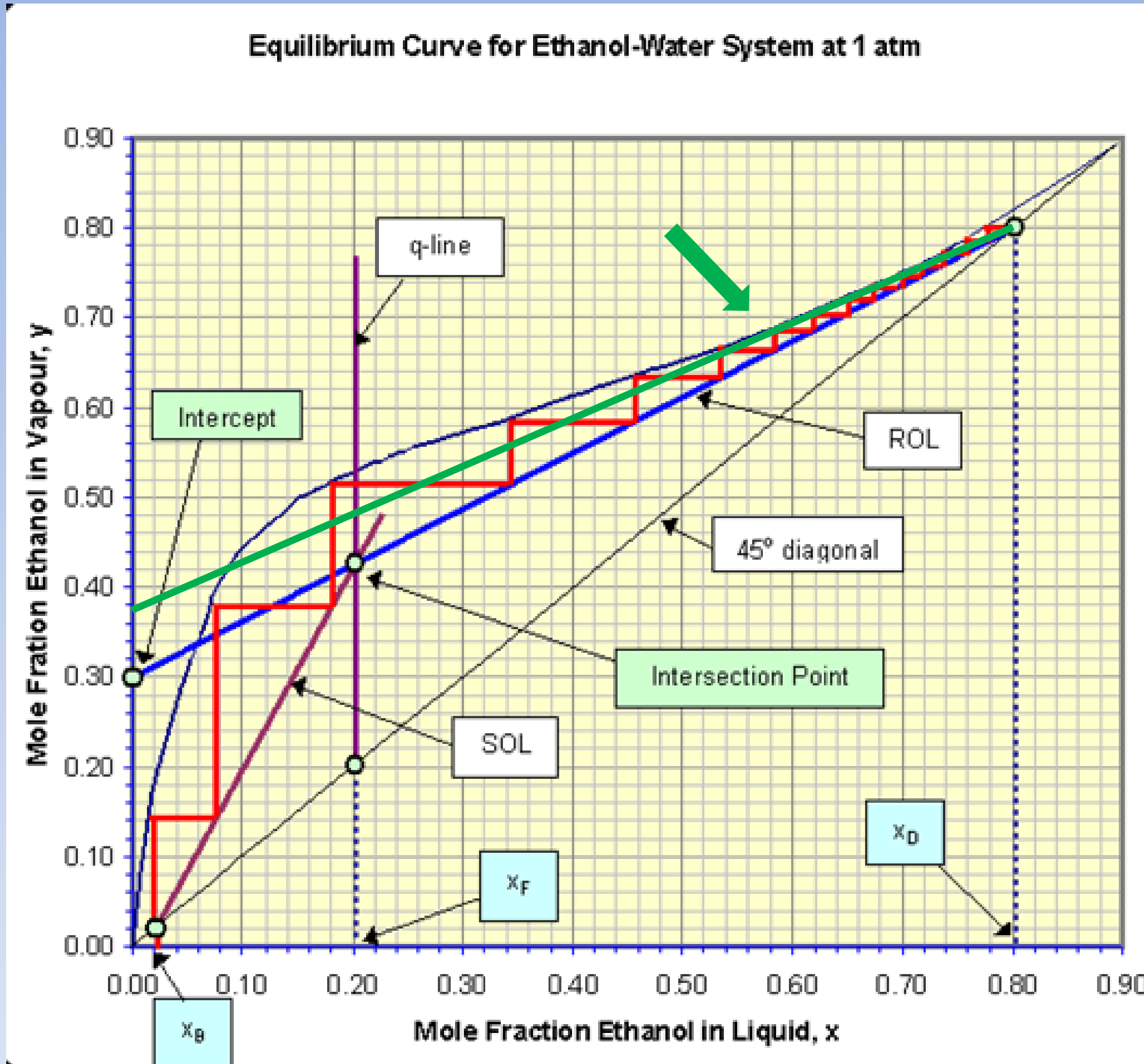
Distillazione - parte terza

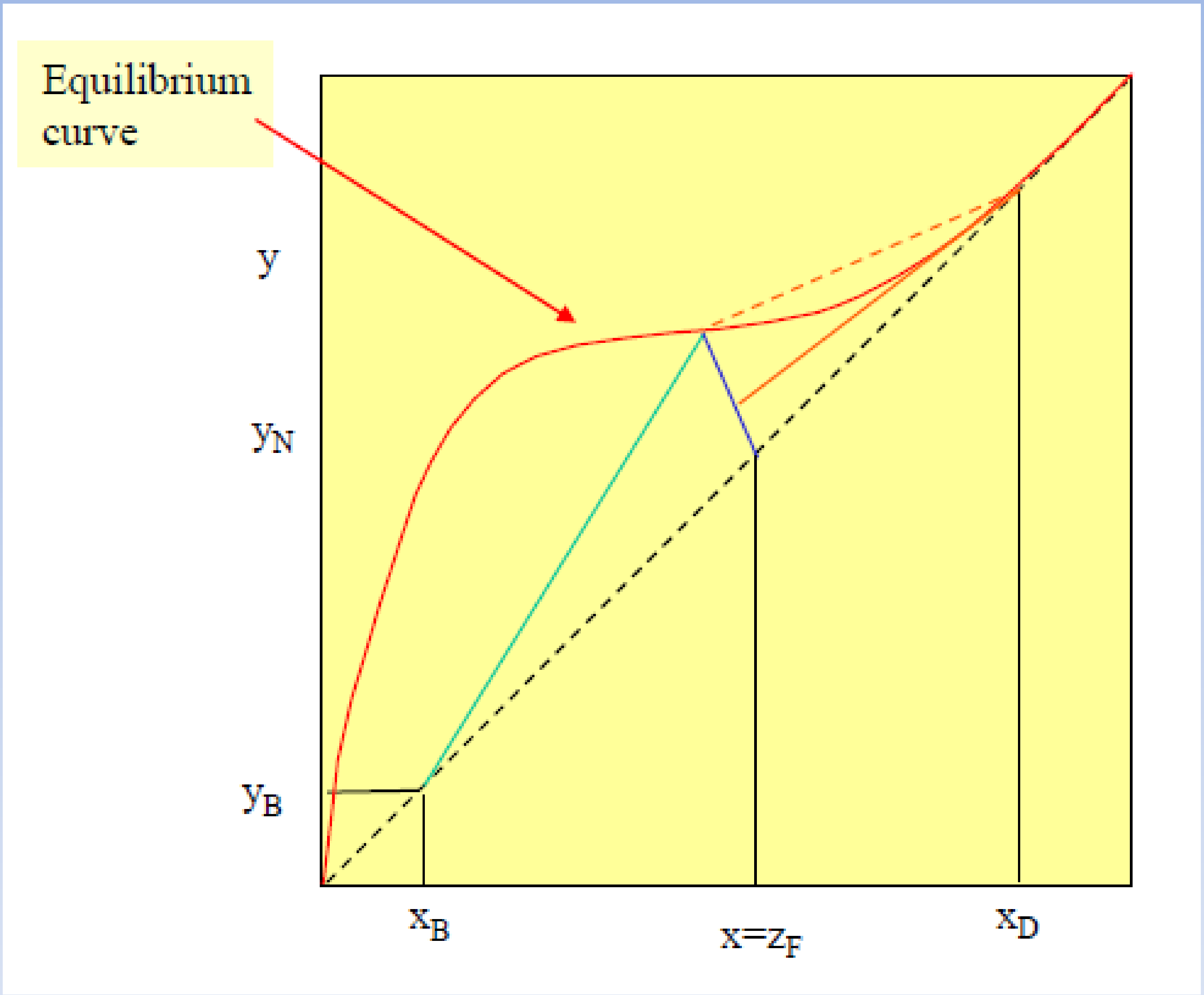






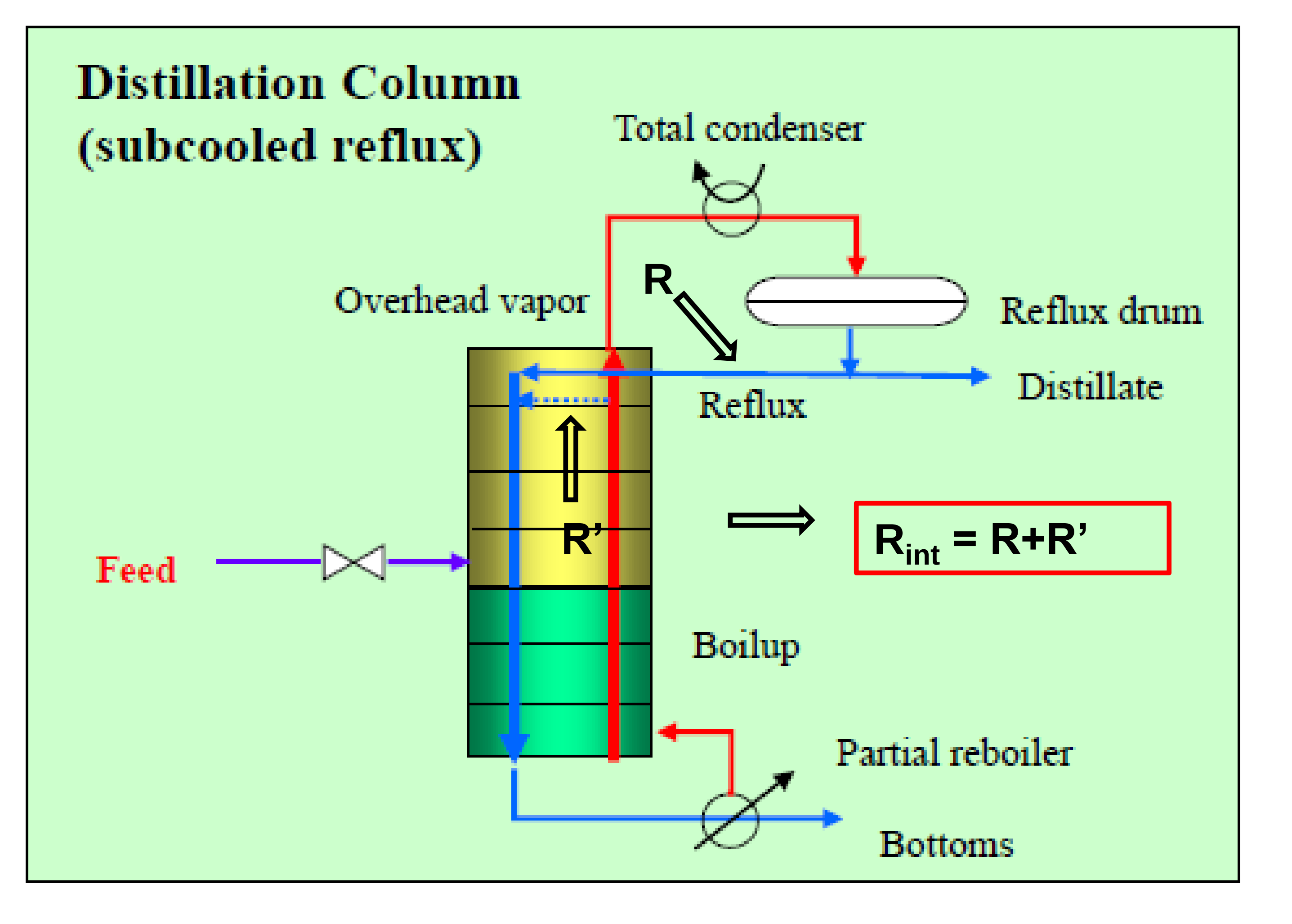



Equilibrium Curve for Ethanol-Water System at 1 atm
Mole Fration Ethanol in Vapour, y
Mole Fraction Ethanol in Liquid, x
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
q-line
Intercept
ROL
45° diagonal
Intersection Point
SOL
x_F
x_D
x_B



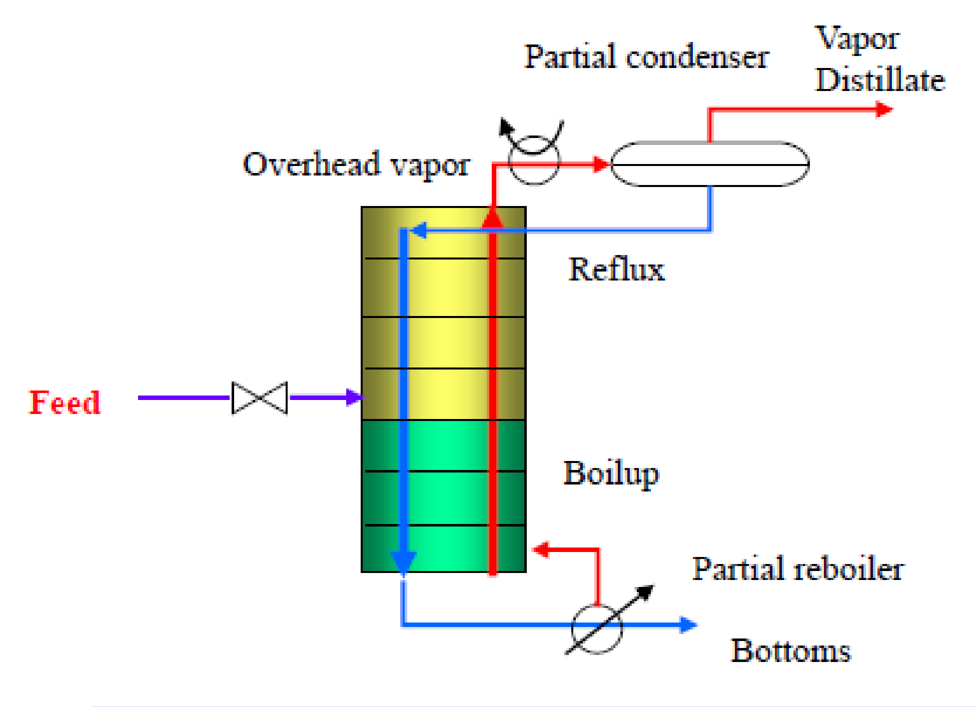
Equilibrium curve
y
yN
yB
xB
x=zF
xD

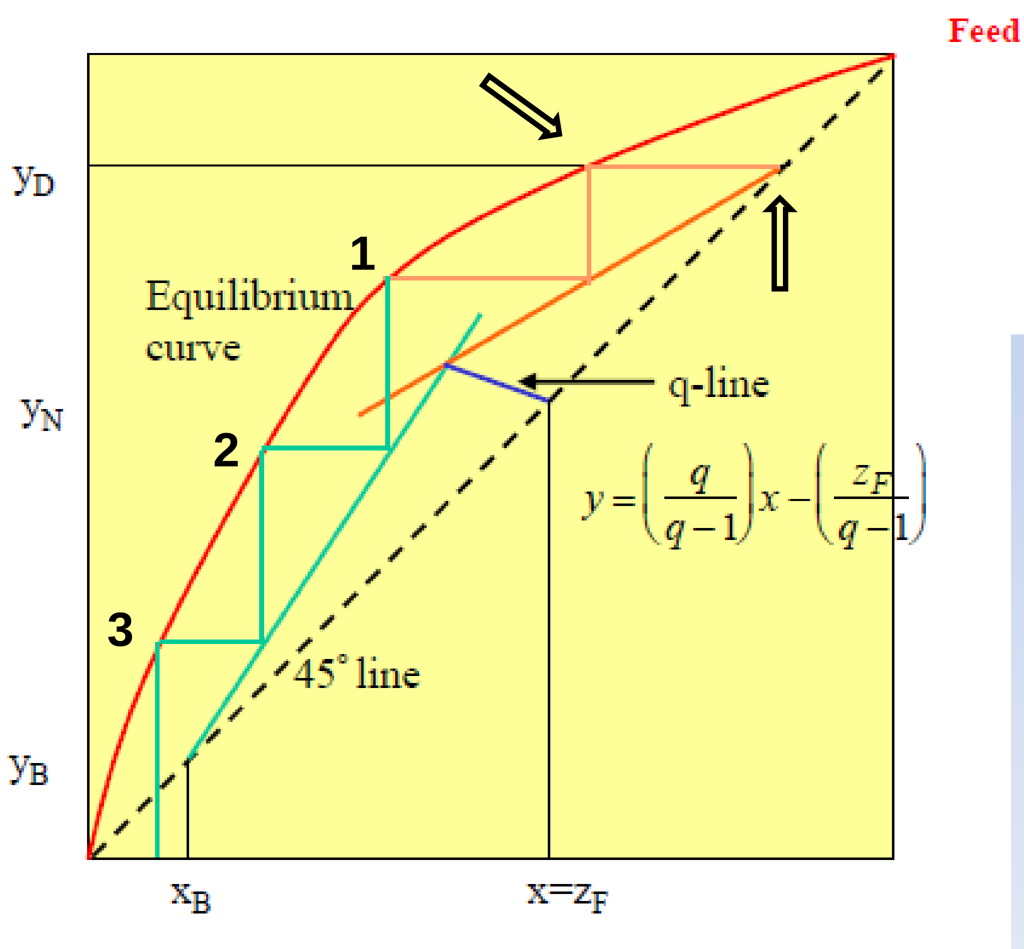
Riflusso sottoraffreddato

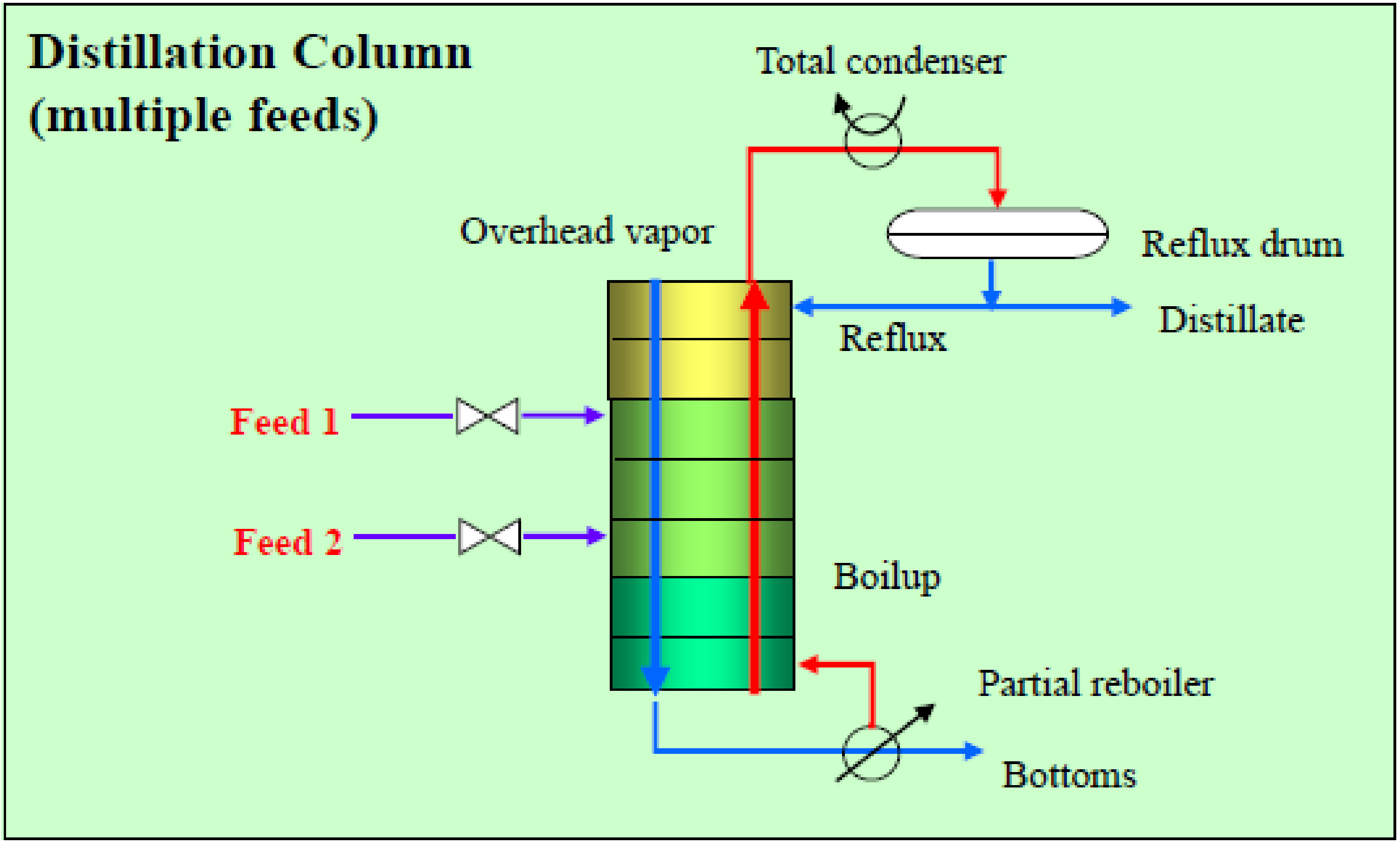


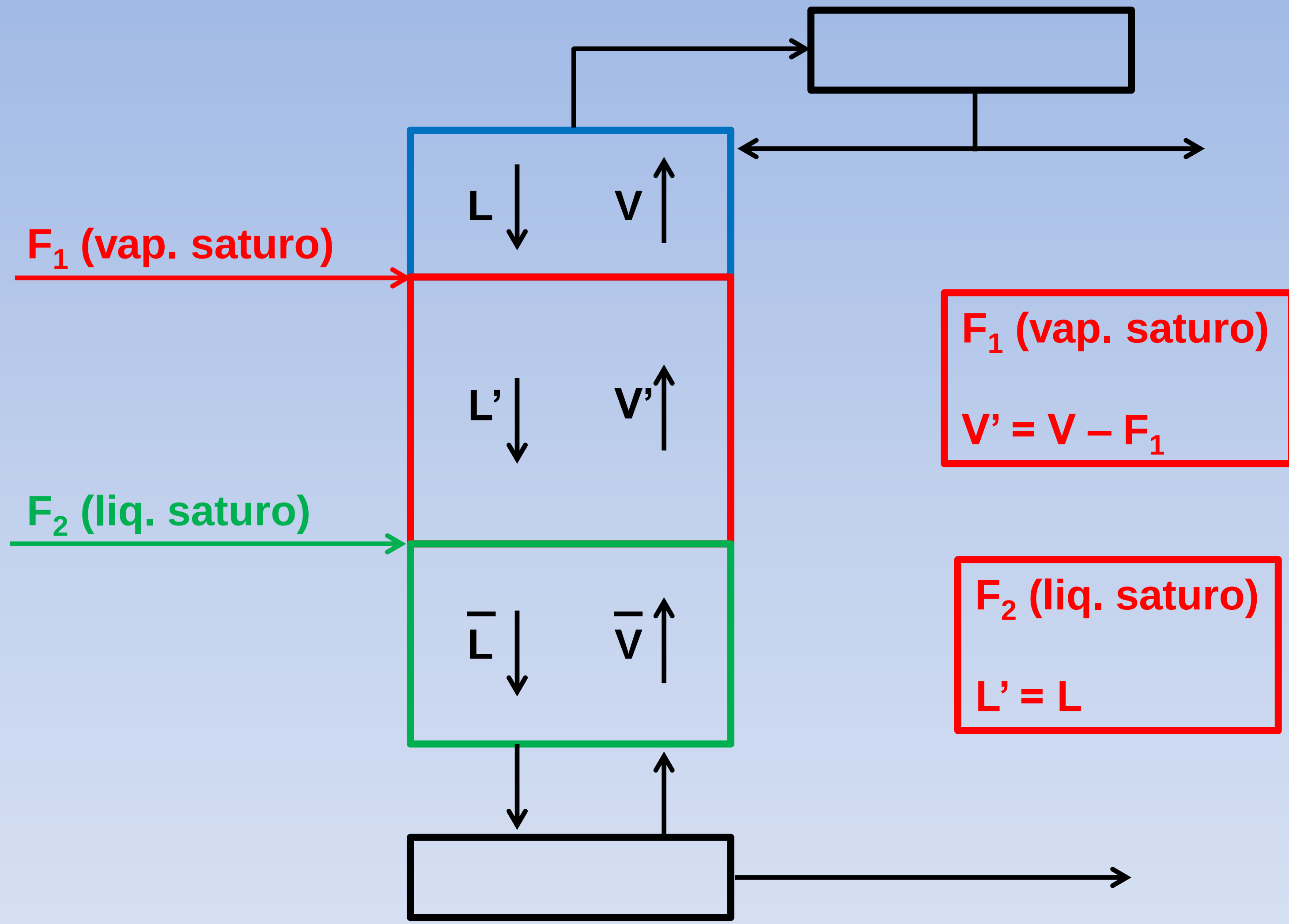
$$RC_P^L \Delta T_{sub} = R' \Delta H^{VAP}; \qquad R_{int} = R + R' = R\left(1 + \frac{C_P^L \Delta T_{sub}}{\Delta H^{VAP}}\right)$$

Condensatore parziale

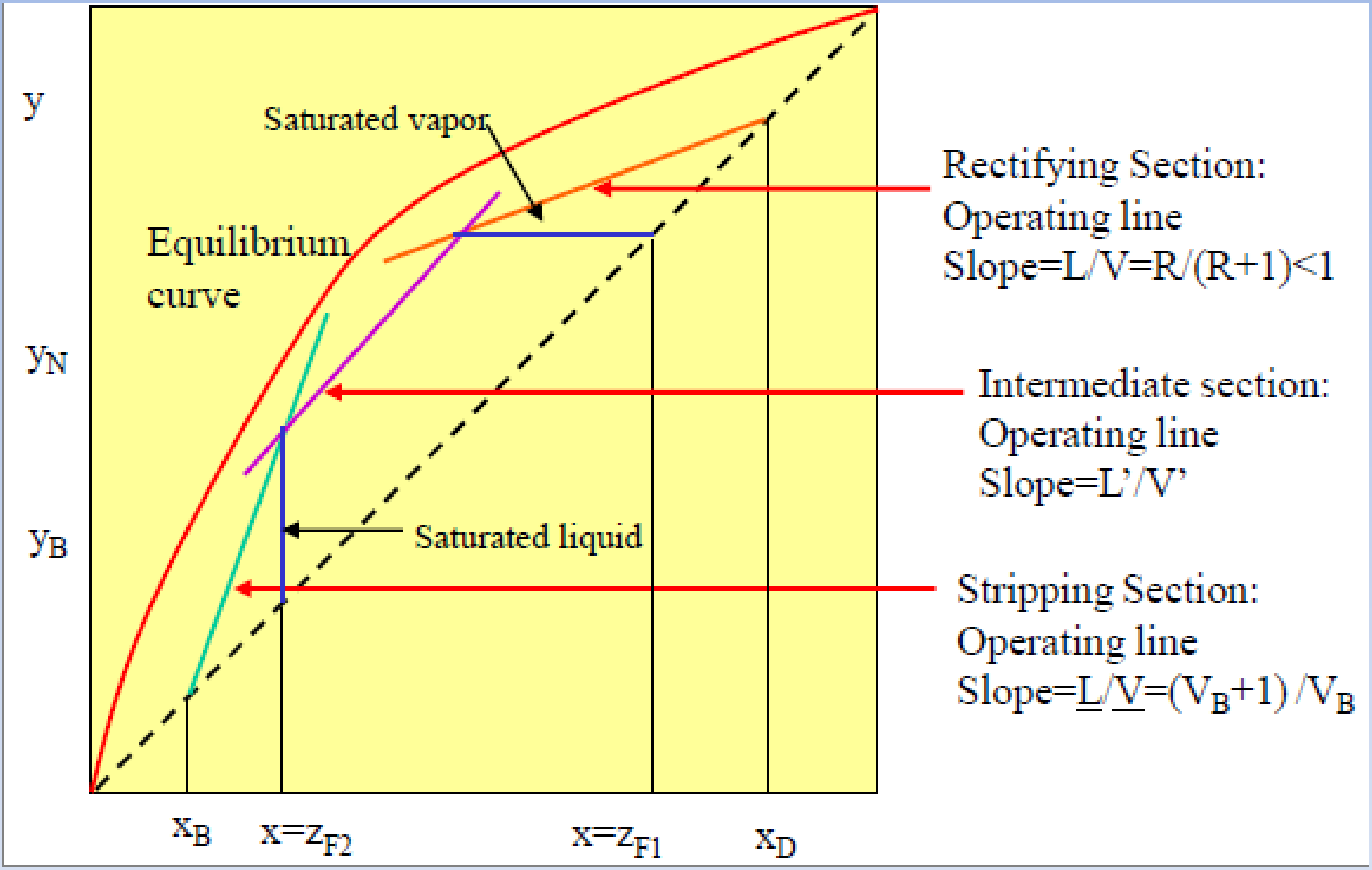




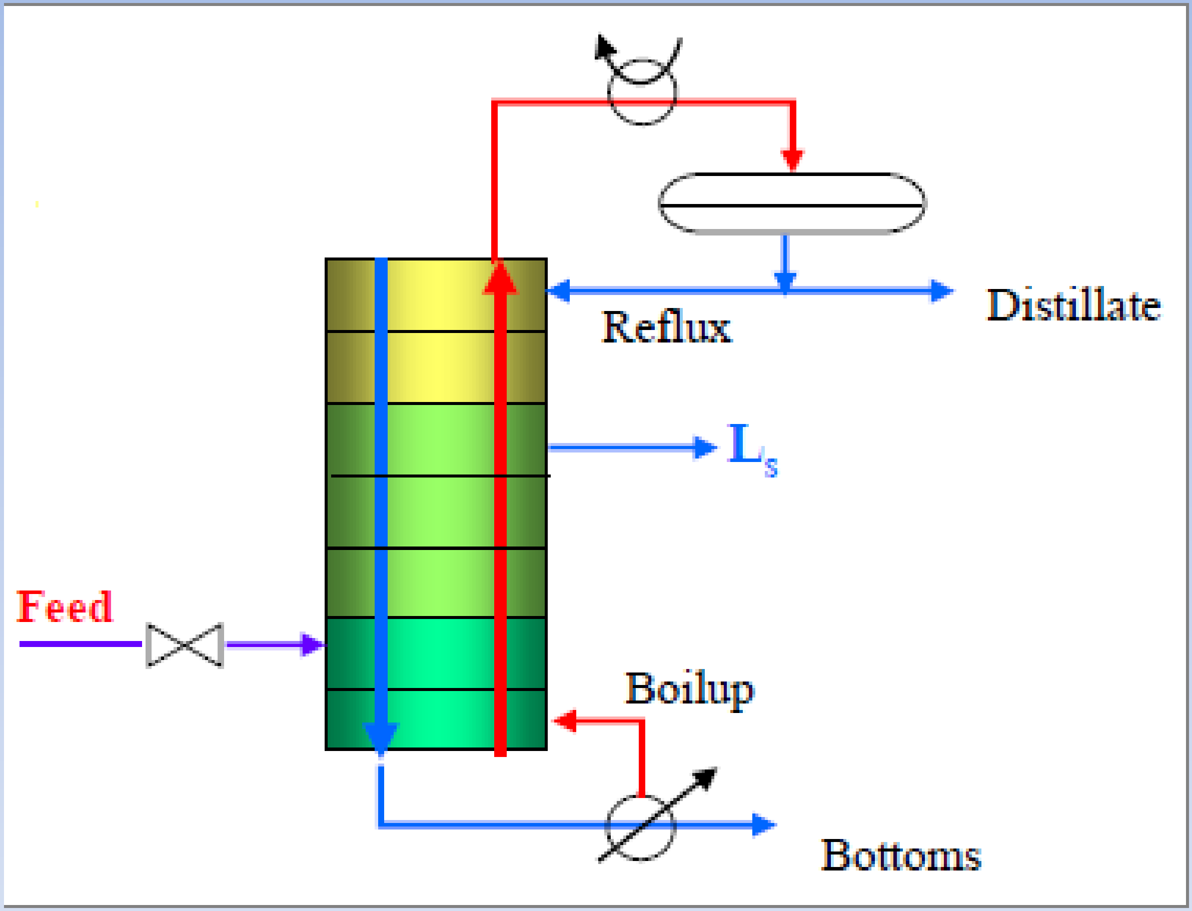

Distillation Column
(multiple feeds)
Total condenser
Overhead vapor
Reflux drum
Distillate
Reflux
Feed 1
Feed 2
Boilup
Partial reboiler
Bottoms

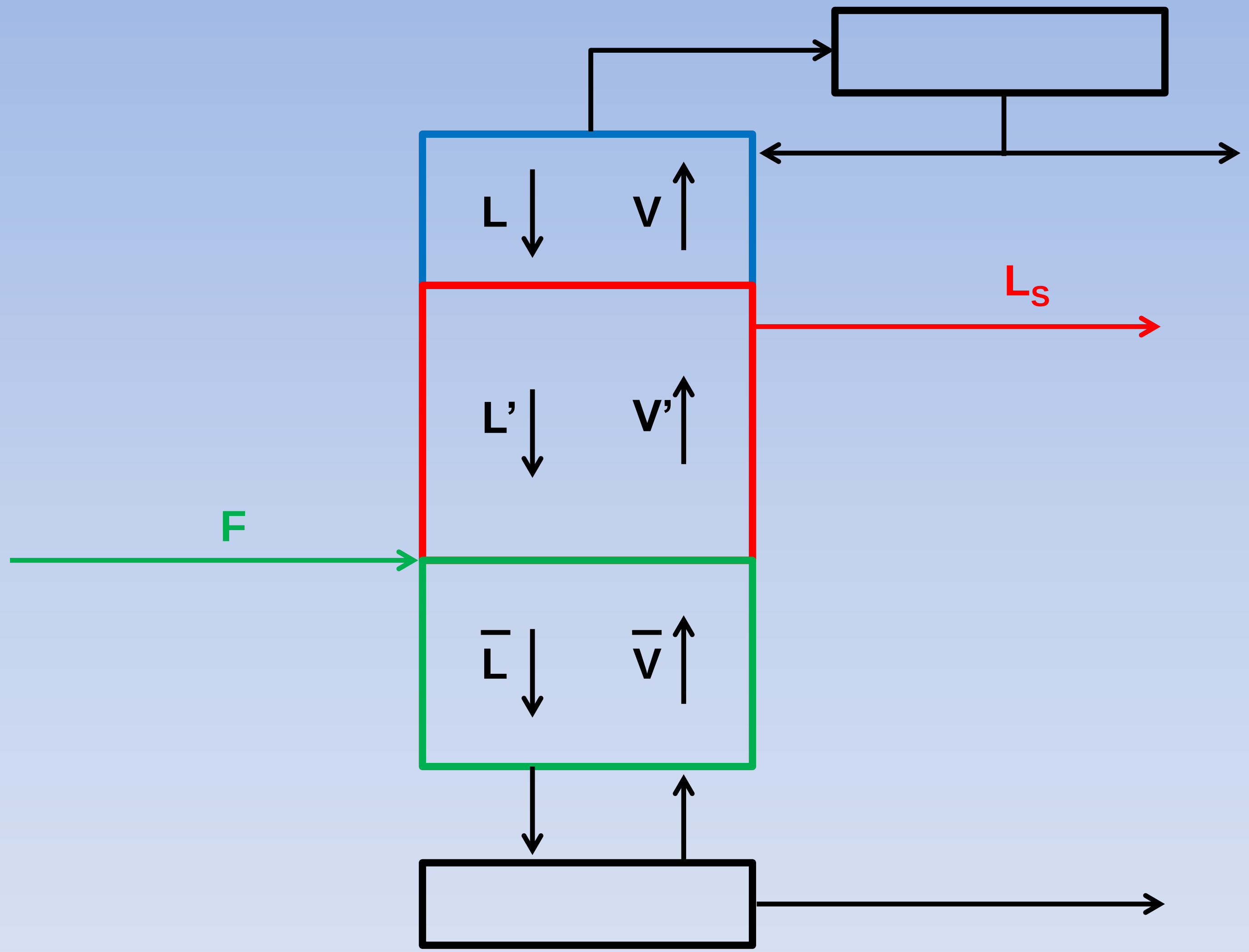


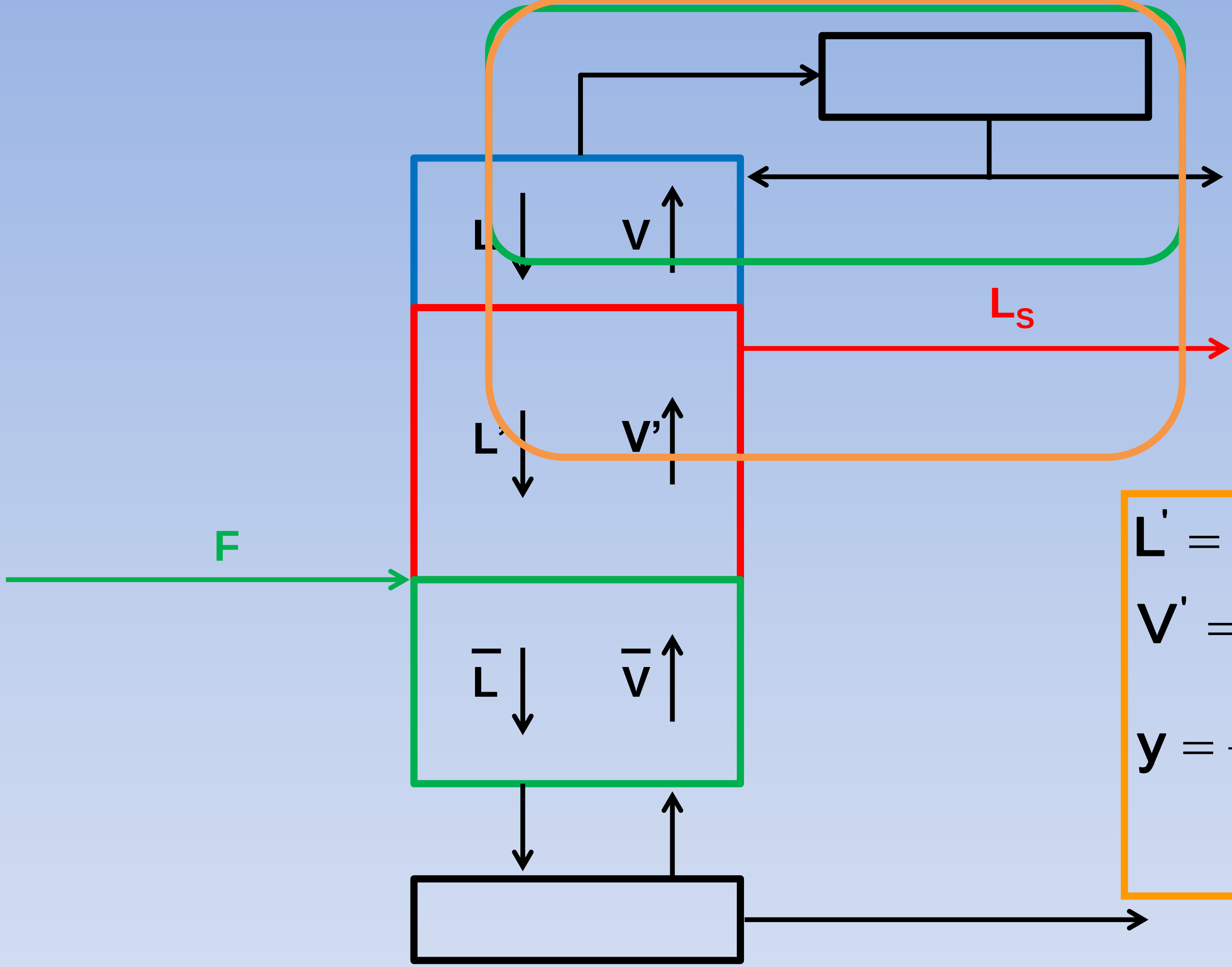
F1 (vap. saturo)
F2 (liq. saturo)
L
V
L'
V'
L̄
V̄
F1 (vap. saturo)
V' = V – F1
F2 (liq. saturo)
L' = L


y
Saturated vapor
Equilibrium curve
y_N
y_B
Saturated liquid
x_B
$x=z_{F2}$
$x=z_{F1}$
x_D
Rectifying Section:
Operating line
Slope=L/V=R/(R+1)<1
Intermediate section:
Operating line
Slope=L'/V'
Stripping Section:
Operating line
Slope=$\underline{L}/\underline{V}$=($V_B$+1) /$V_B$

Prelievo intermedio (side stream)




L
V
L_S
L'
V'
F
$\bar{L}$
$\bar{V}$



$$y = \frac{L}{V}x + \frac{D}{V}x_D$$

$$L' = L - L_S$$

$$V' = V$$

$$y = \frac{L'}{V'}x + \frac{L_S x_S + D x_D}{V'}$$

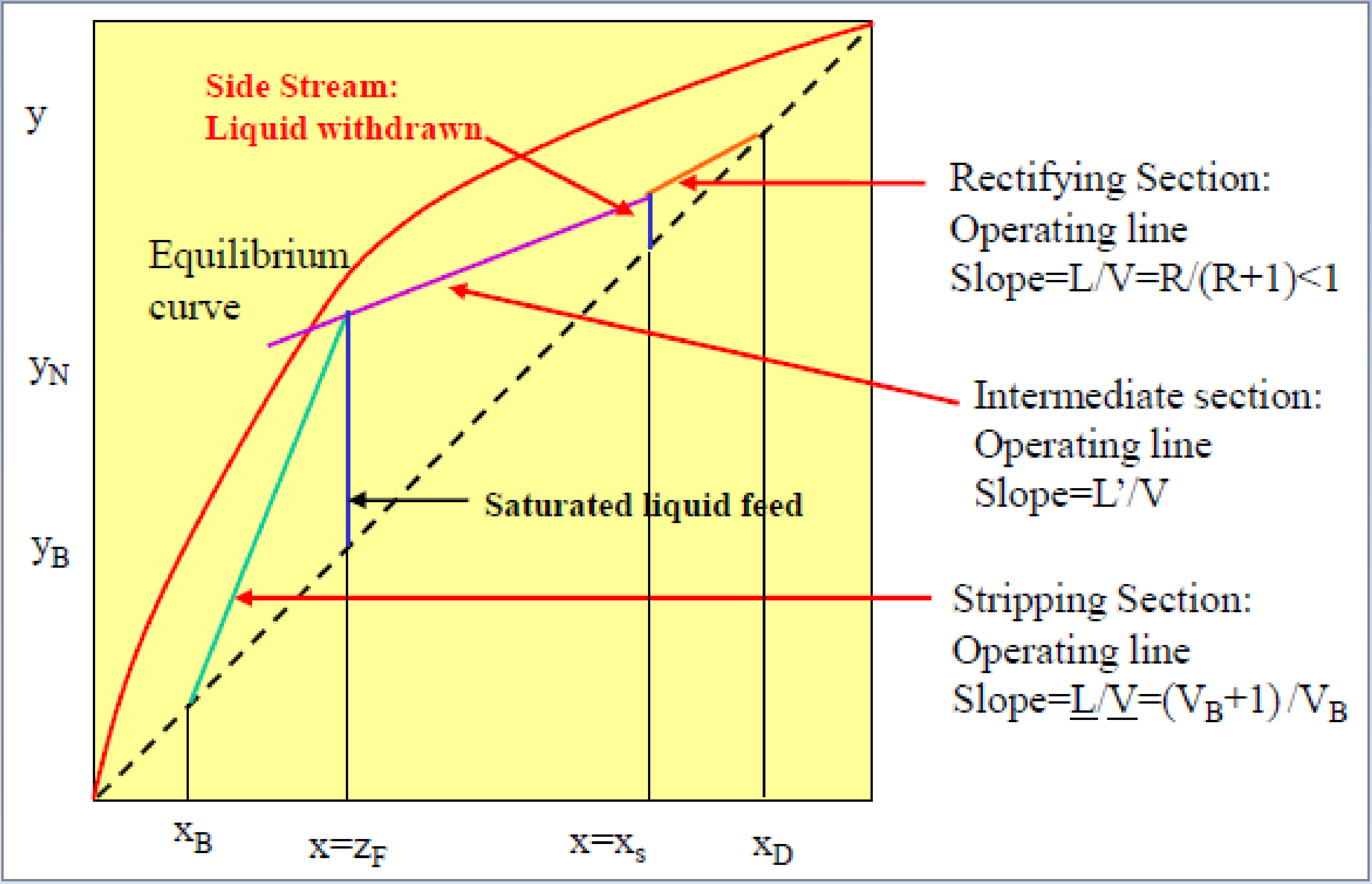
Intersezione tra le due rette

$$y = \frac{L}{V}x + \frac{Dx_D}{V}$$

$$y = \frac{L'}{V'}x + \frac{L_S x_S + Dx_D}{V'}$$

$$\left(L' = L - L_S; V' = V\right)$$

Le due rette
Passano per $x = x_S$



Side Stream:
Liquid withdrawn
y
Equilibrium
curve
y_N
y_B
Saturated liquid feed
x_B
$x=z_F$
$x=x_s$
x_D
Rectifying Section:
Operating line
Slope=L/V=R/(R+1)<1
Intermediate section:
Operating line
Slope=L'/V
Stripping Section:
Operating line
Slope=$\underline{L}$/$\underline{V}$=(V_B+1) /V_B

Vaporizzazione flash multicomponente

Miscela ideale $\Rightarrow$ $y_j = m_j x_j$

Bilanci di materia $\Rightarrow$ $L/V = (y_j - z_{j,F})/(z_{j,F} - y_j/m_j)$

Ricavando y_j $\Rightarrow$

$$y_j = \frac{z_{j,F}(L/V+1)}{1+(L/V)/m_j}$$

Schema di calcolo

1) Fissare un L/V
2) Calcolare gli y_j
3) Verificare se $\Sigma y_j = 1$

3) Un liquido di composizione molare 50% benzene (A), 25% toluene (B), 25% o-xilene (C) è vaporizzato in un flash ad 1 atm e 100 °C. Determinare l'ammontare del liquido e del vapore e la loro composizione. [Tensioni di vapore a 100 °C (mmHg): A=1370, B=550, C=200]

$z_A=0.5;\ z_B=0.25;\ z_C=0.25$ $m_A=1370/760=1.80;\ m_B=0.72;\ m_C=0.26$

$$y_A = \frac{0.5(L/V+1)}{1+(L/V)/1.80}$$

$$y_B = \frac{0.25(L/V+1)}{1+(L/V)/0.72}$$

$$y_C = \frac{0.25(L/V+1)}{1+(L/V)/0.26}$$

$L/V=2$

$y_A = 0.710$
$y_B = 0.198$
$y_C = 0.086$

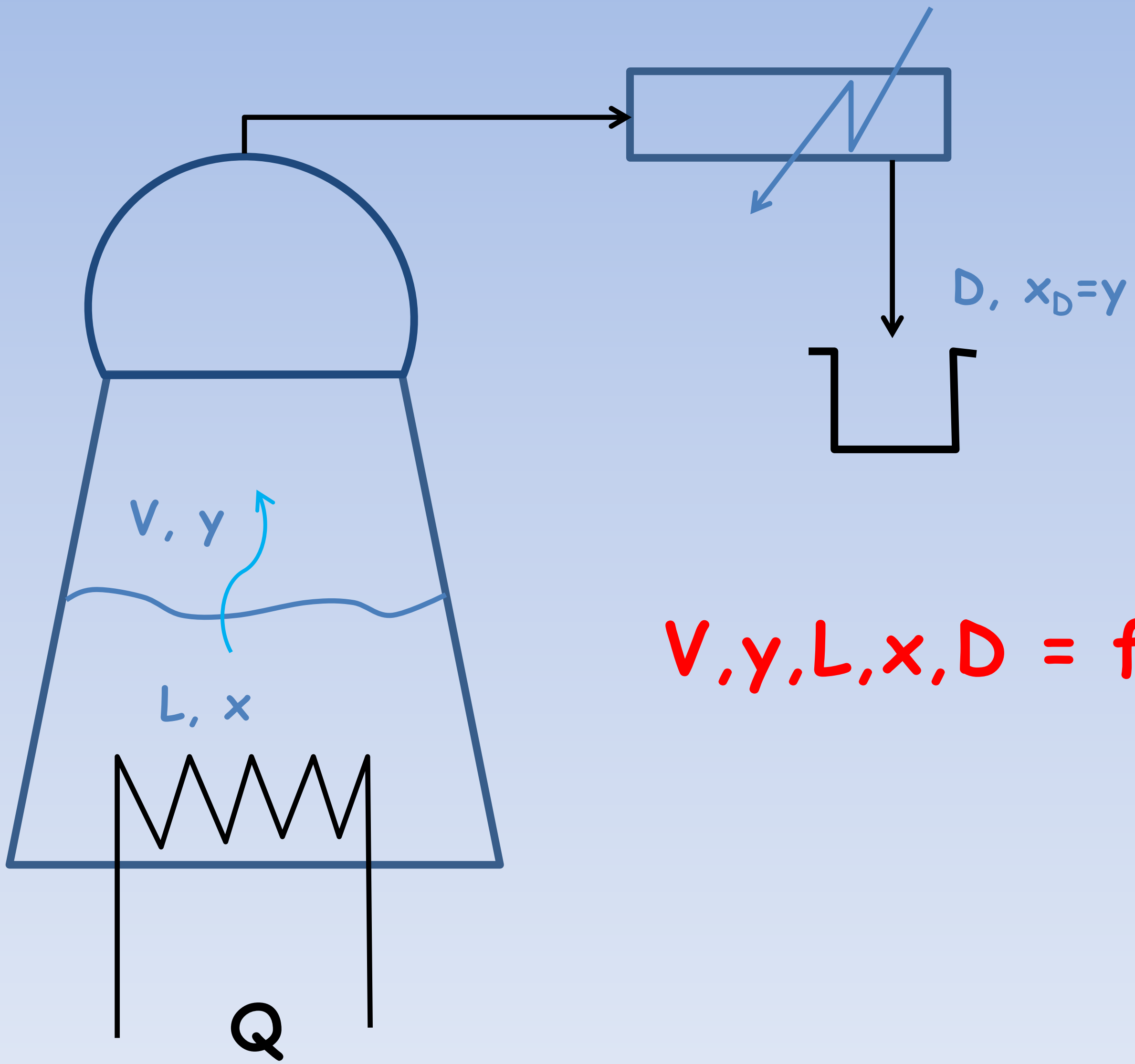
$\Sigma = 0.994$

$L/V=2.5$

$y_A = 0.732$
$y_B = 0.196$
$y_C = 0.082$

$\Sigma = 1.017$

Distillazione differenziale



$$V, y, L, x, D = f(t)$$

$dL = -dV$ Bilancio totale

$d(Lx) = -\,d(Vy)$ Bilancio sul componente

$d(Vy) = ydV + Vdy$ Vapore infinitesimo

$d(Lx) = Ldx + xdL = -\,ydV = ydL$

$$L\,dx + x\,dL = y\,dL$$

$$\int \frac{dL}{L} = \int \frac{dx}{y - x}$$

Equazione di Raileigh

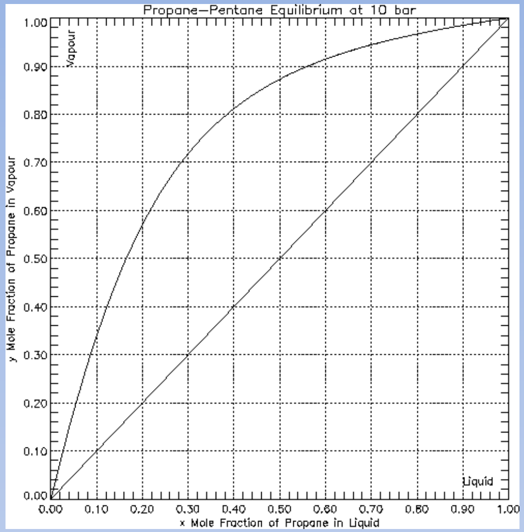
$$\ln\left(\frac{L_f}{L_i}\right) = \int_{x_i}^{x_f} \frac{dx}{y - x}$$

Occorre una relazione tra x e y

$$y = Kx; \qquad \ln\left(\frac{L_f}{L_i}\right) = \frac{1}{K-1}\ln\left(\frac{x_f}{x_i}\right)$$

$$\alpha = cost; \qquad \ln\left(\frac{L_f}{L_i}\right) = \frac{1}{\alpha-1}\left[\ln\left(\frac{x_f}{x_i}\right) - \alpha\ln\left(\frac{1-x_f}{1-x_i}\right)\right]$$

$$\ln\left(\frac{L_f}{L_i}\right) = \int_{x_i}^{x_f} \frac{dx}{y - x} \quad +$$



1) Per x corrente a partire da x_i si legge y;

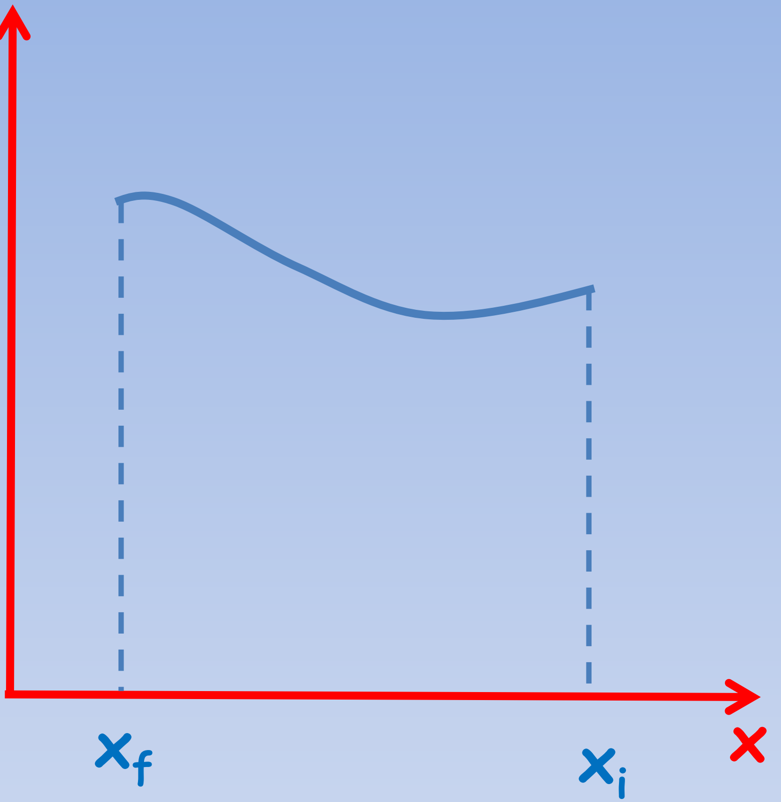
2) Si calcolano i valori di F =1/(y-x);

3) Si diagramma F =1/(y-x) in funzione di x;

4) Si valuta l'area sottesa dal diagramma;

5) L'area è pari a $\ln(L_f/L_i)$

$$\ln\left(\frac{L_f}{L_i}\right) = \int_{x_i}^{x_f} \frac{dx}{y - x}$$



Possibili calcoli

Noto il primo membro, calcolare x_f;

Noto x_f, calcolare il primo membro.

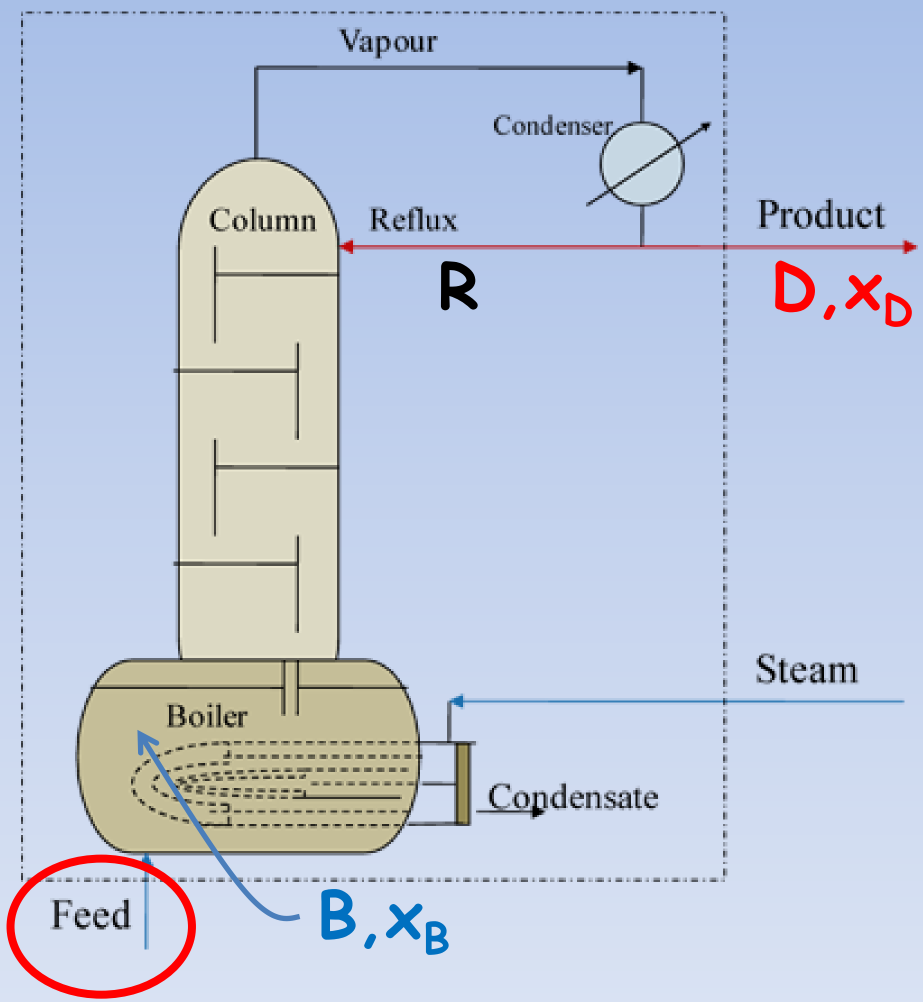
Oppure:
Richiesta una composizione media del distillato,
Calcolare quanta parte della carica iniziale va lavorata

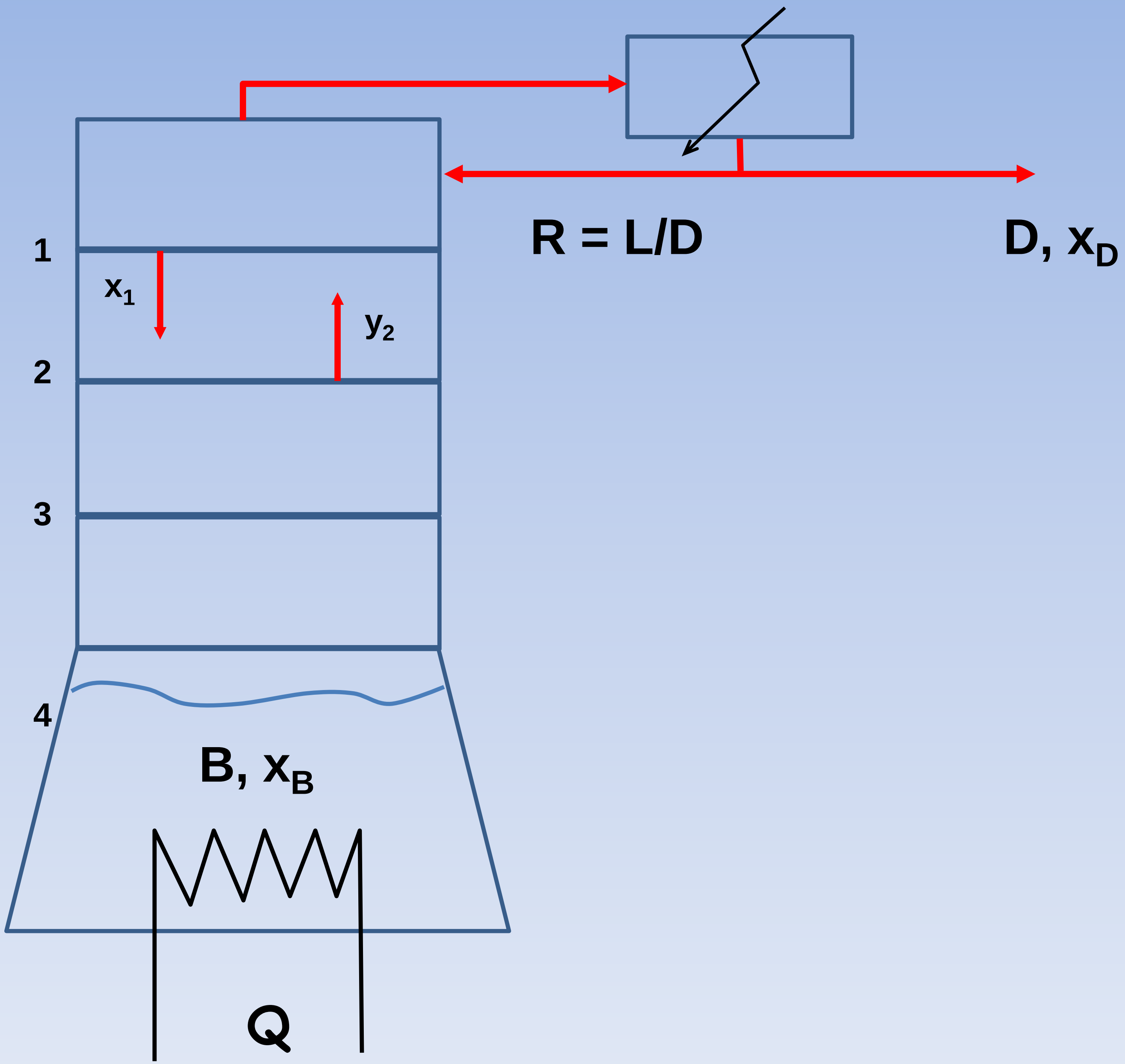
$$L_i x_i - L_f x_f = D\underline{x}_D$$

$$\underline{x}_D = (L_i x_i - L_f x_f)/(L_i - L_f)$$

mixing cup concentration

Distillazione batch





R = L/D
D, x_D
1
x_1
y_2
2
3
4
B, x_B
Q

moli di "a" rimosse

$$Bx_B = dB(x_D) + (B-dB)(x_B - dx_B)$$

moli di "a" nel fondo

moli di "a" rimaste

$$Bx_B = x_D dB + Bx_B - Bdx_B - x_B dB + dBdxB$$

$$B\,dx_B = (x_D - x_B)\,dB$$

$$\frac{dB}{B} = \frac{dx_B}{x_D - x_B}$$

$$\ln\left(\frac{B_f}{B_i}\right) = \int_{x_{Bi}}^{x_{Bf}} \frac{dx_B}{x_D - x_B}$$

Non integrabile direttamente!

(Tra x_D e x_B ci sono n stadi)

Operazioni a R costante
(Pendenze delle rette di lavoro costanti)

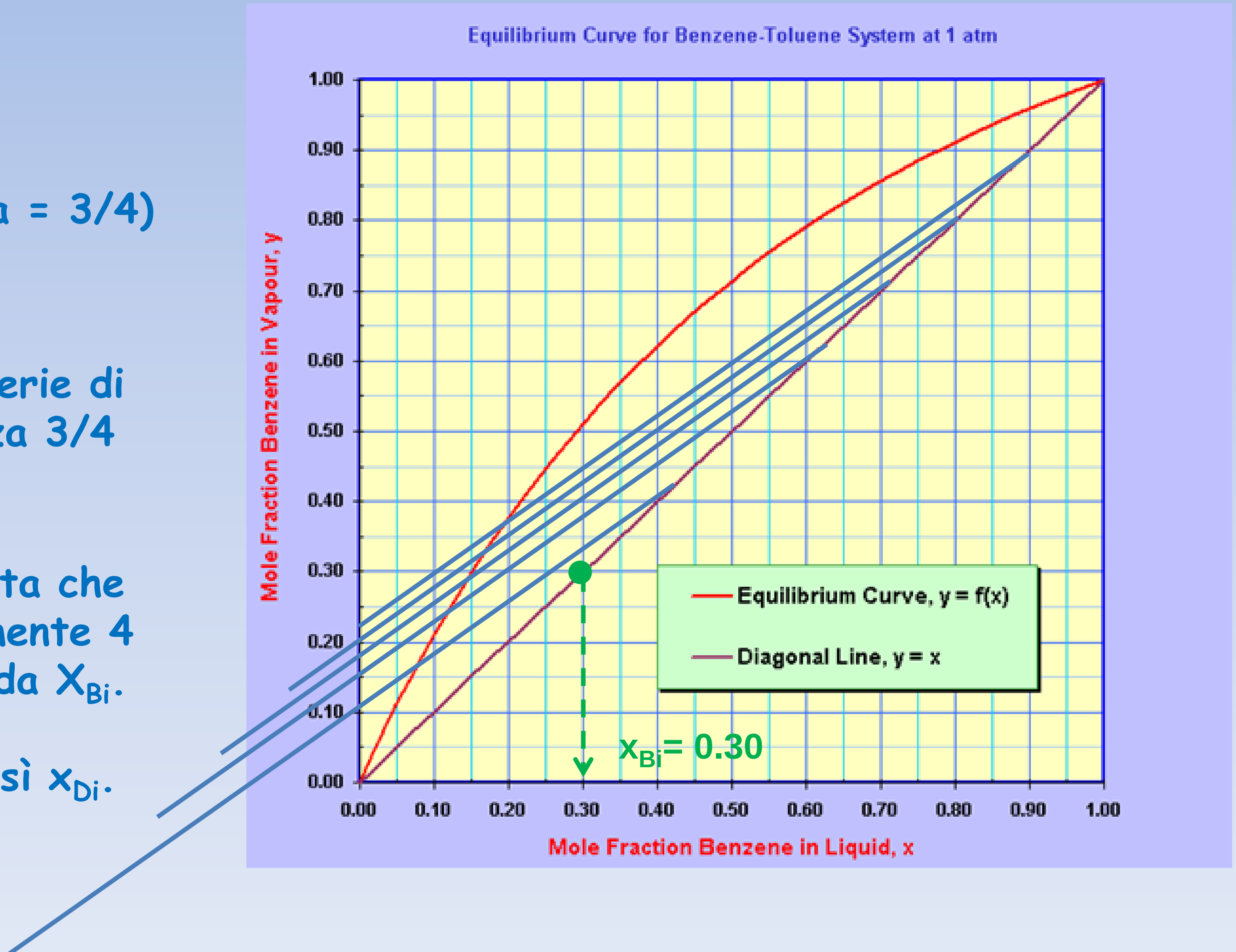
Esempio

R = 3 (Pendenza = 3/4)
x_{Bi}= 0.30

Tracciare una serie di rette a pendenza 3/4

Scegliere la retta che impiega esattamente 4 stadi partendo da X_{Bi}.

Si determina così x_{Di}.



Al passare del tempo le rette si abbassano e x_D diminuisce.

Contando 4 stadi si determinano valori decrescenti di x_B.

Si integra graficamente.