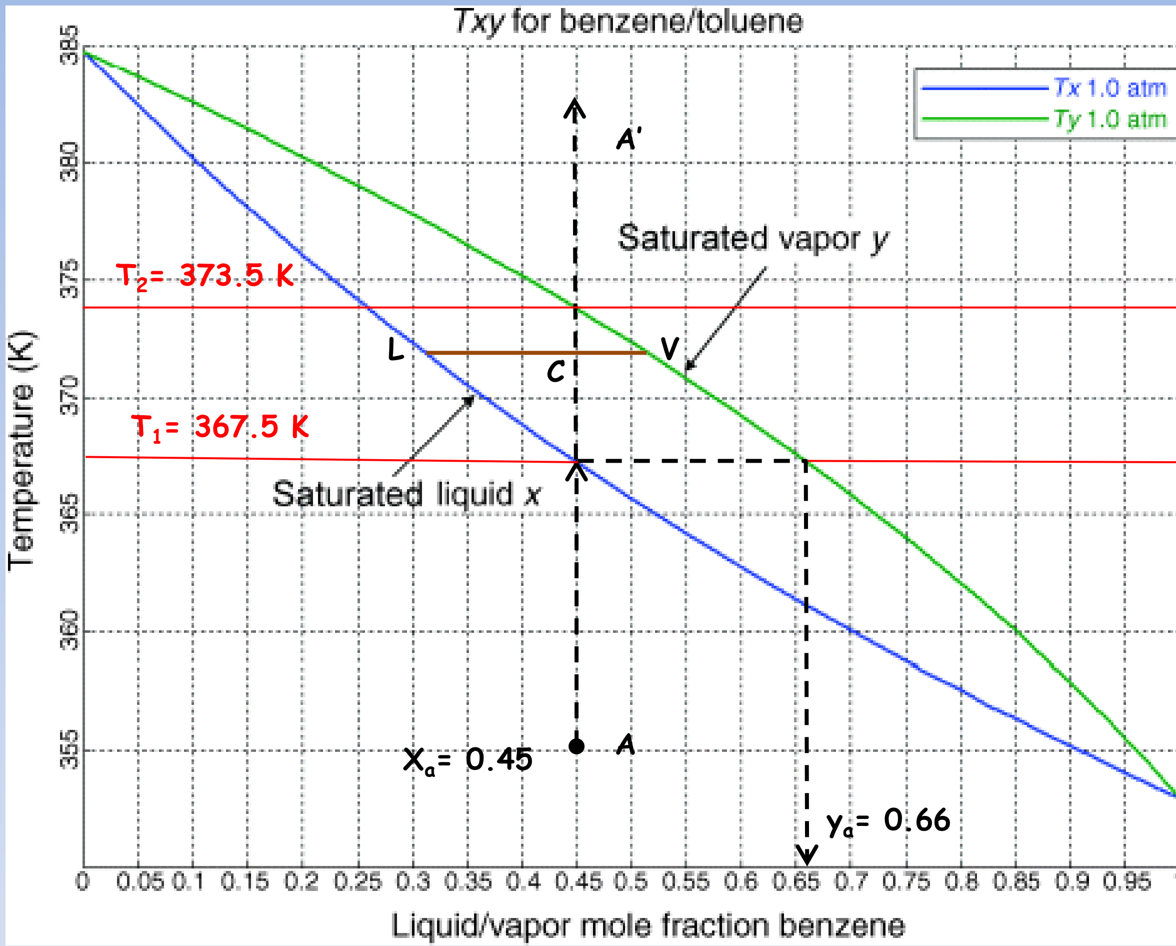
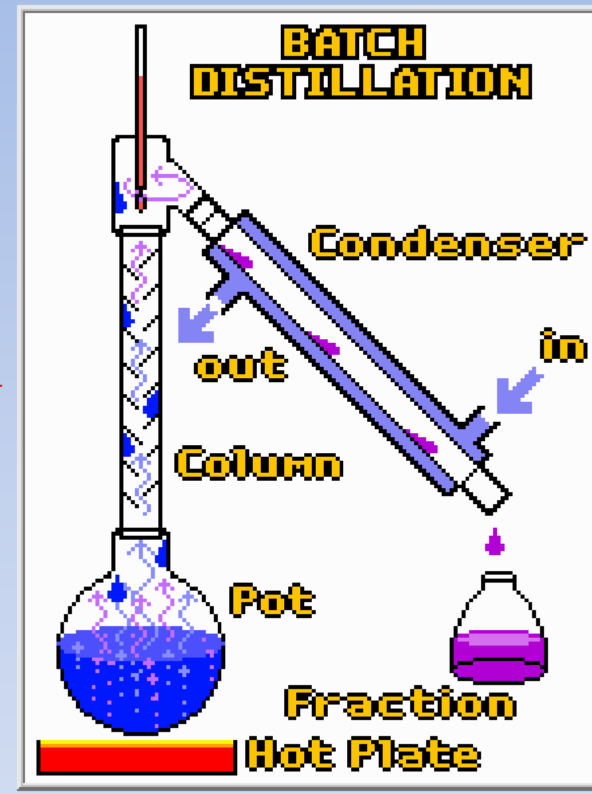
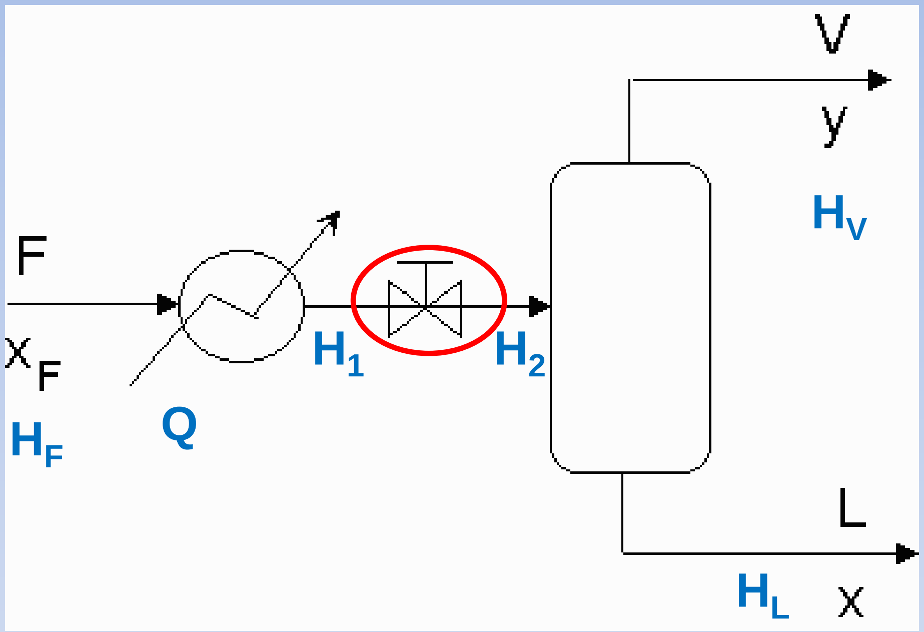
Fondamenti delle operazioni unitarie dell'industria chimica

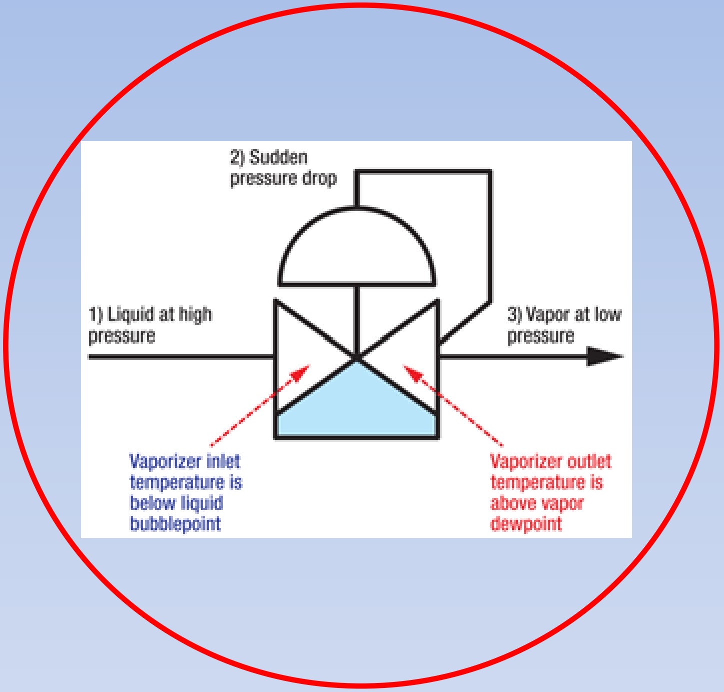
Distillazione - parte prima


Txy for benzene/toluene
Tx 1.0 atm
Ty 1.0 atm
A'
Saturated vapor y
T2= 373.5 K
L
V
C
T1= 367.5 K
Saturated liquid x
Xa= 0.45
A
ya= 0.66
Temperature (K)
Liquid/vapor mole fraction benzene


BATCH
DISTILLATION
Condenser
out
in
Column
Pot
Fraction
Hot Plate

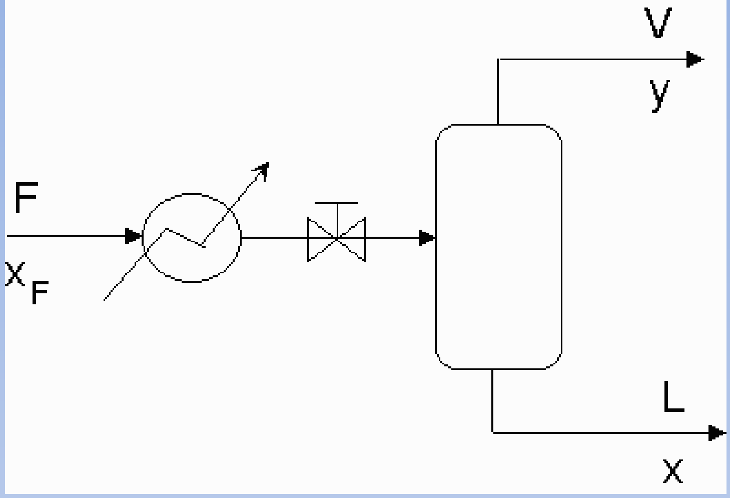
Vaporizzazione flash





$H_1 = H_2$

H	J/mol
Q	W
F	mol/s



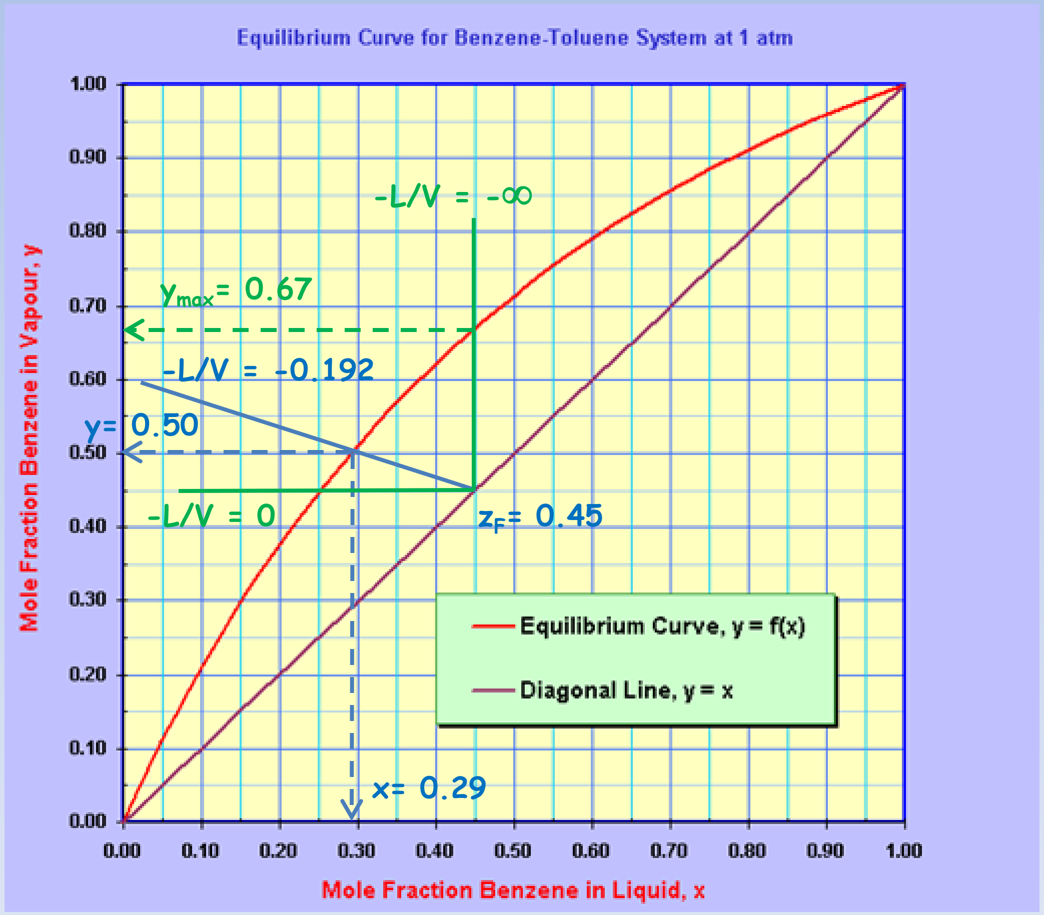
$$F = L + V;$$

$$Fz_F = Lx + Vy;$$

$$(L + V)z_F = Lx + Vy;$$

$$L(z_F - x) = V(y - z_F);$$

$$-\frac{L}{V} = \frac{y - z_F}{x - z_F}$$



$$-\frac{L}{V} = \frac{y - z_F}{x - z_F}$$

Assegnato un rapporto L/V, bilancio di materia ed equilibrio chiudono il problema: si determinano x, y (e viceversa).

$$FH_F + Q = LH_L + VH_V$$

Q = ?

$$\frac{F}{V}H_F + \frac{Q}{V} = \frac{L}{V}H_L + H_V$$

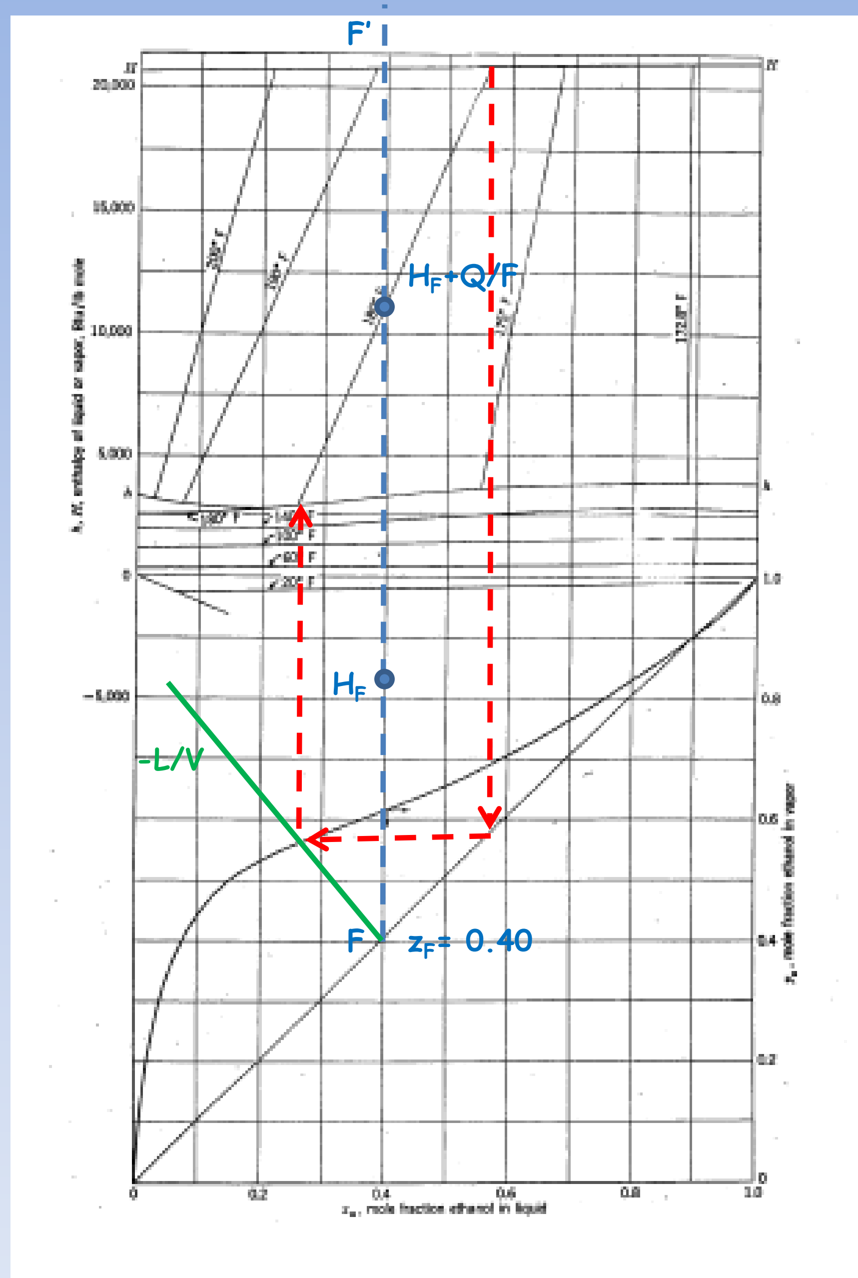
$$\frac{(L+V)}{V}H_F + \frac{(L+V)}{V}\frac{Q}{F} = \frac{L}{V}H_L + H_V$$

$$\frac{L}{V}\left(H_L - H_F - \frac{Q}{F}\right) = H_F - H_V + \frac{Q}{F}$$

$$-\frac{L}{V} = \frac{H_F + Q/F - H_V}{H_F + Q/F - H_L}$$

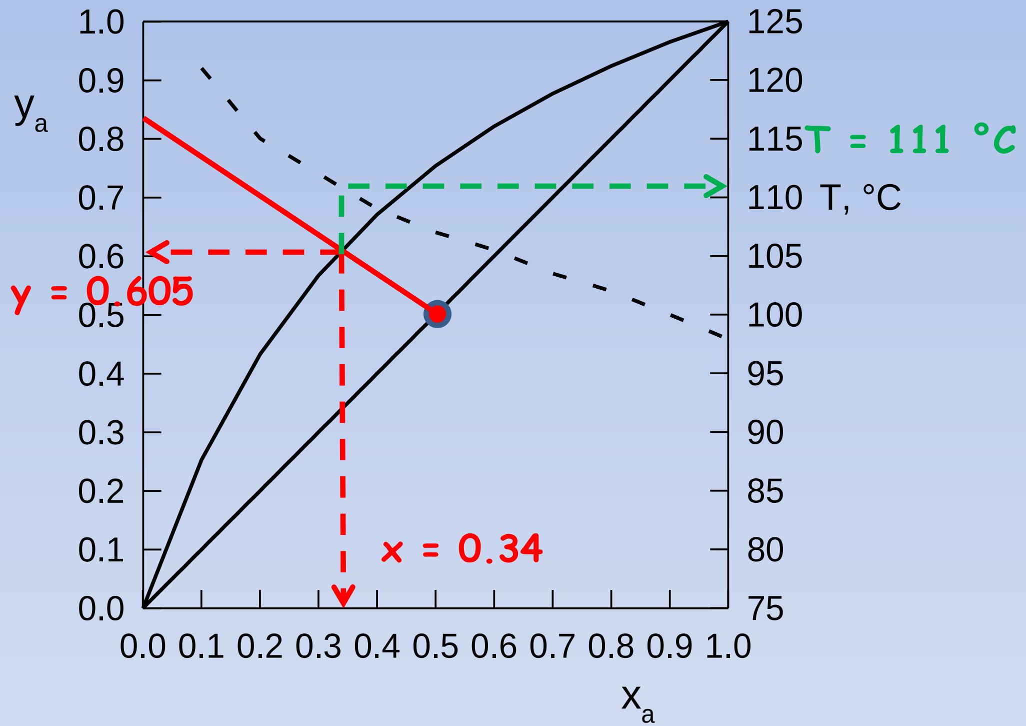
Assegnato un rapporto L/V, bilancio entalpico ed equilibrio chiudono il problema: si determinano x, y (e viceversa).

Il problema si può risolvere completamente per via grafica su un H-x con annesso y-x.


F'
H_F+Q/F
H_F
-L/V
F
z_F= 0.40
20,000
15,000
10,000
5,000
0
-5,000
0.2
0.4
0.6
0.8
1.0

Esercitazione numerica n. 3 – Distillazione

1) Una miscela liquida (50% in moli di n-eptano, 50% n-ottano) a 30 °C deve essere vaporizzata in continuo in un uno stadio flash ad 1 atm per ottenere il 60% di vapore. Determinare la composizione delle fasi ottenute e la temperatura dell'apparecchiatura.



$z_F = 0.5$

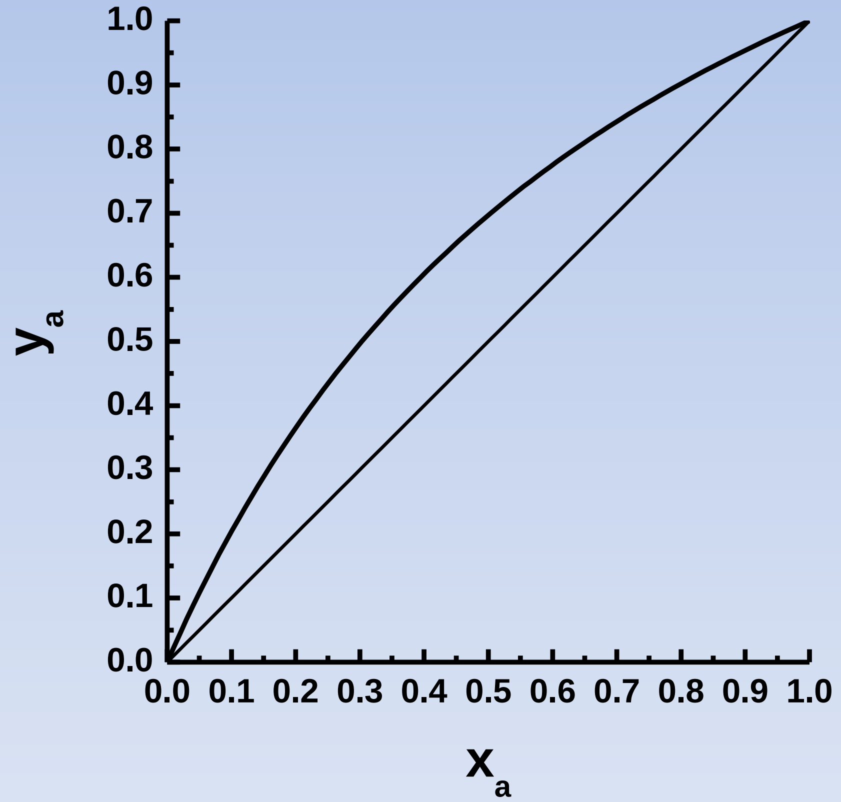
$V/F = 0.6$ $L/F = 0.4$

$-L/V = -0.4/0.6 = -0.67$

Esercizio aggiuntivo

A liquid containing 60 mol% toluene and 40 mol% benzene is continuously distilled in a single equilibrium stage at 1 atm. What percent of benzene in the feed leaves as vapor if 90% of the toluene entering in the feed leaves as liquid? Assume a relative volatility of 2.3 and obtain the solution graphically.

Assume a relative volatility of 2.3

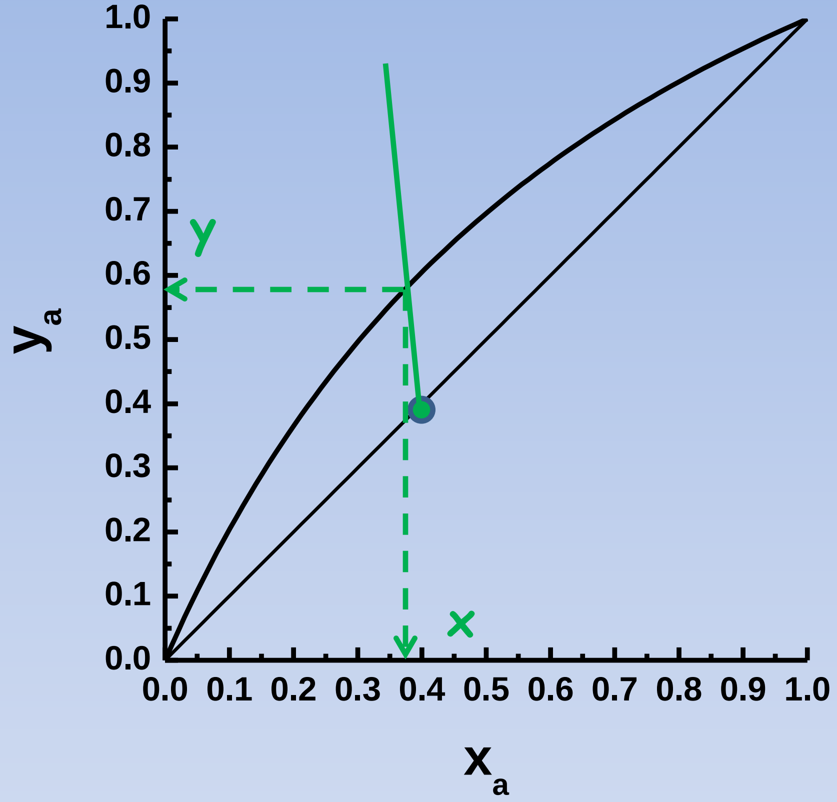


$$\alpha = \frac{\frac{y}{x}}{\frac{1-y}{1-x}} = \frac{y}{x}\frac{1-x}{1-y}$$

$$y = \frac{\alpha x}{(\alpha - 1)x + 1}$$

A liquid containing 60 mol% toluene and 40 mol% benzene z_F = 0.4

90% of the toluene entering in the feed leaves as liquid



Base: F = 100

0.9*0.6*100 = L(1-x)

54 = L(1-x)

6 = V(1-y)

-L/V = (54/6)(1-y)/(1-x)

-L/V = 9(1-y)/(1-x)

Procedura grafica

Si assume –L/V

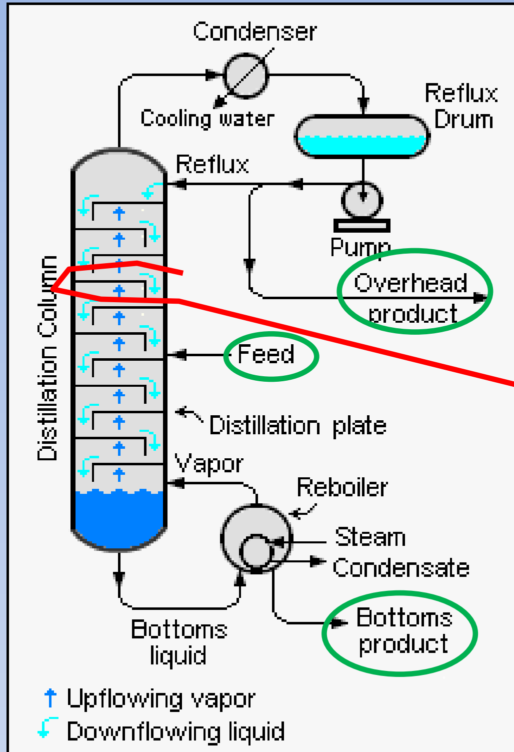
Si legge (x,y) dell’intersezione fra retta di lavoro e curva di equilibrio

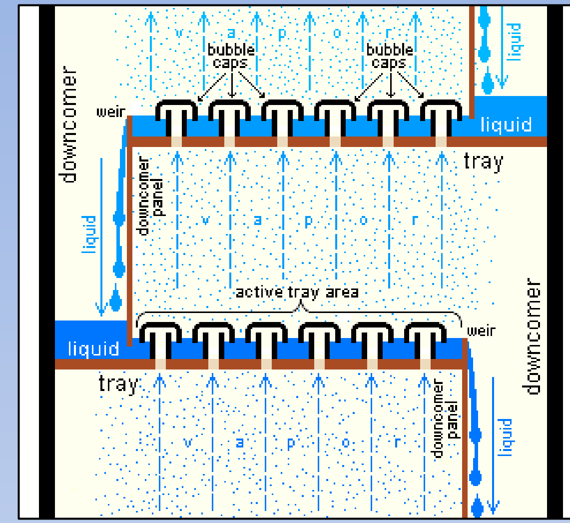
Si verifica se torna

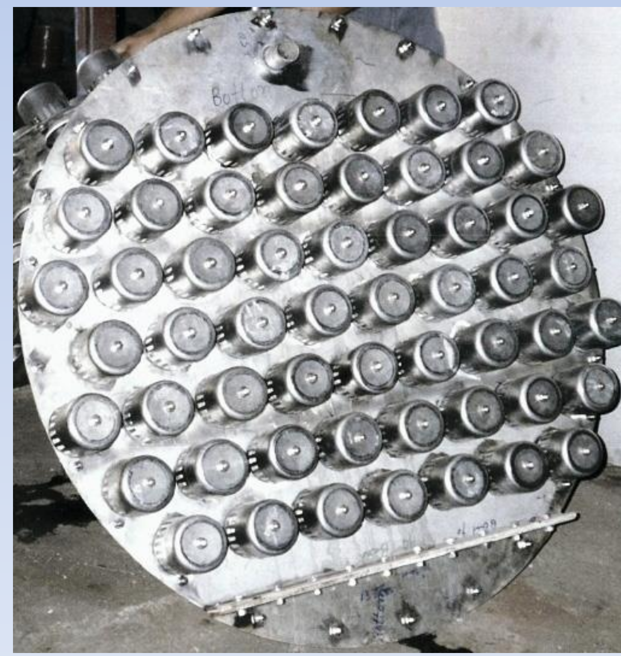
-L/V = 9(1-y)/(1-x)

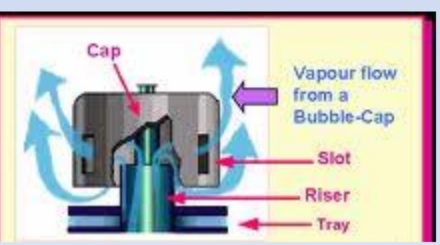
Si itera fino a convergenza

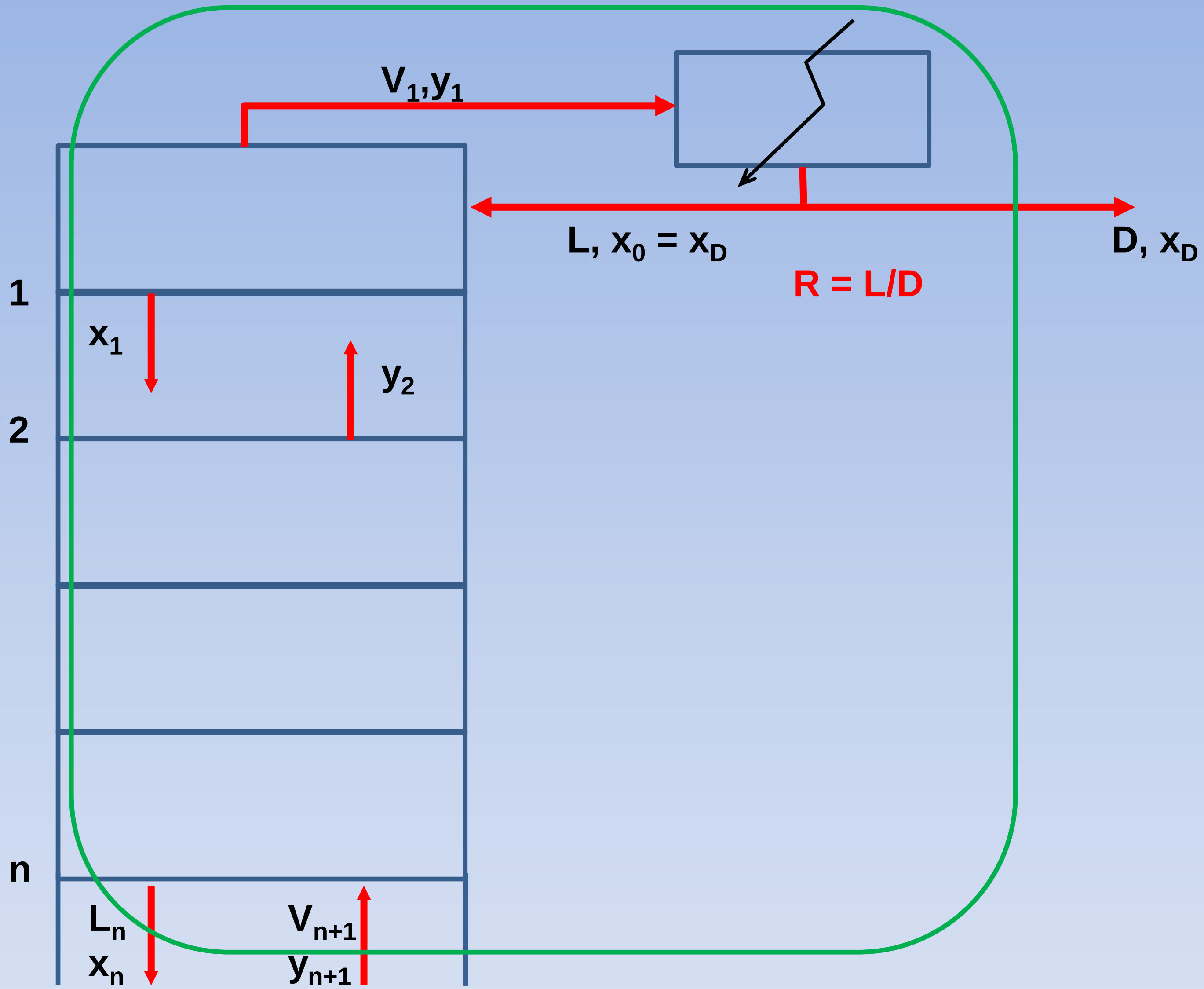
Distillazione frazionata











a) $V_{n+1} = L_n + D$

b) $V_{n+1} y_{n+1} = L_n x_n + D x_D$

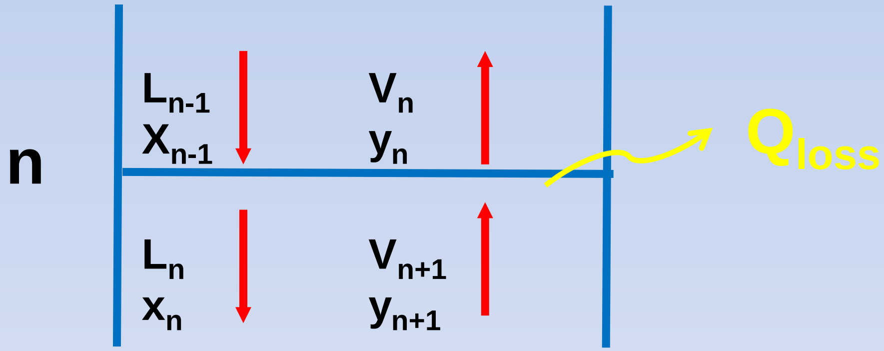
Assunzioni di McCabe & Thiele

1. Calori latenti di vaporizzazione circa costanti;

2. Variazioni di calori sensibili ($C_p \Delta T$) e di miscela trascurabili rispetto a quelle dei calori latenti;

3. Colonna praticamente adiabatica;

4. Perdite di carico trascurabili (colonna isobara).



$$L_{n-1} = L_n$$

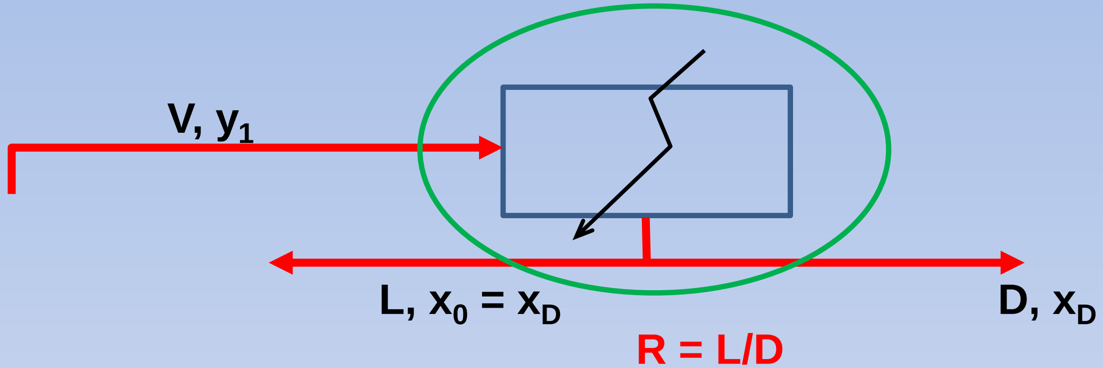
In base al bilancio di materia totale a),
se L è costante, allora lo è anche V

$$V_{n+1}y_{n+1} = L_n x_n + D x_D$$

$$V y_{n+1} = L x_n + D x_D$$

$$y_{n+1} = (L/V)\, x_n + (D/V) x_D$$

$$y_{n+1} = (L/V)x_n + (D/V)x_D$$



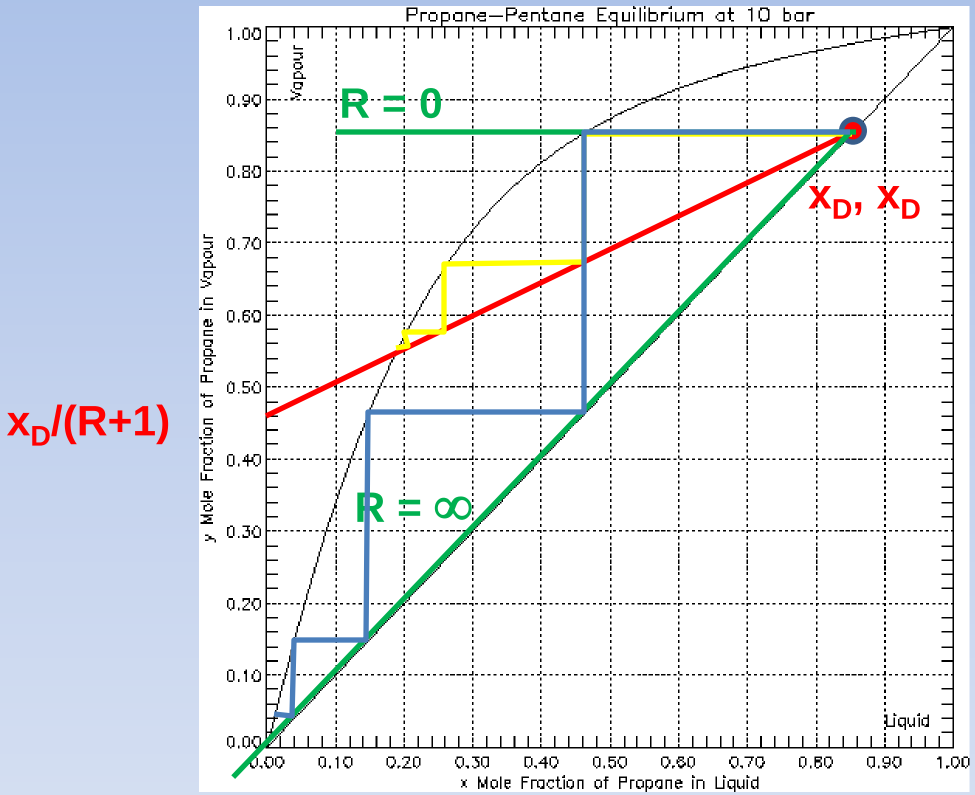
$$V = L + D$$

$$y_{n+1} = L/(L+D)x_n + D/(L+D)x_D$$

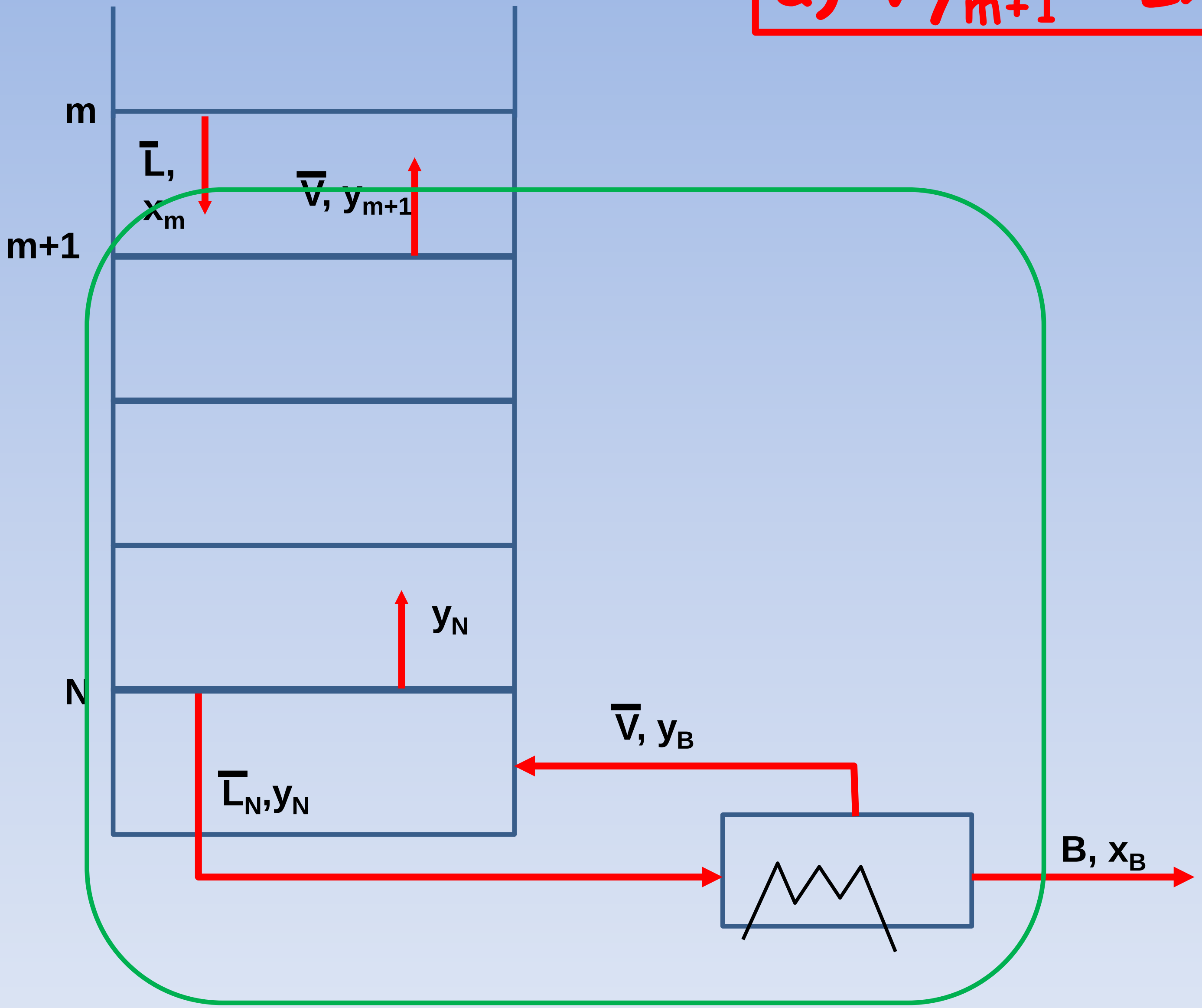
$$y_{n+1} = R/(R+1)x_n + x_D/(R+1)$$

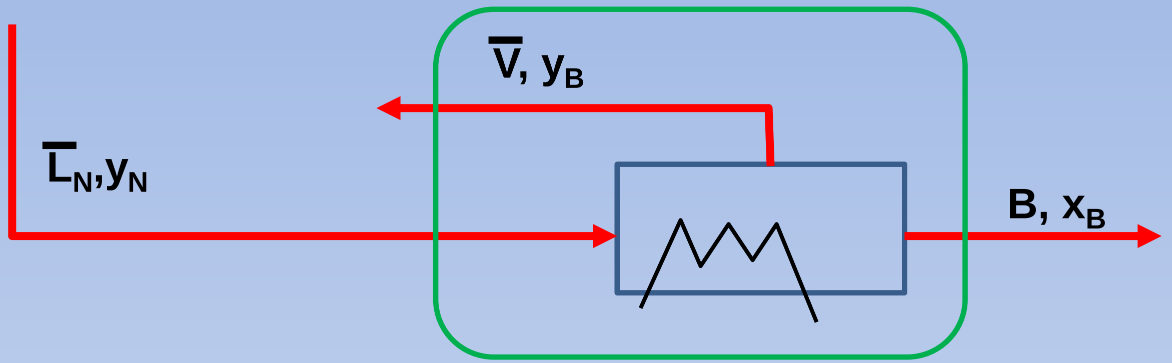
$$y_{n+1} = R/(R+1)x_n + x_D/(R+1)$$

$$R = L/D$$



$$a)\ \bar{V}y_{m+1} = \bar{L}x_m - Bx_B$$

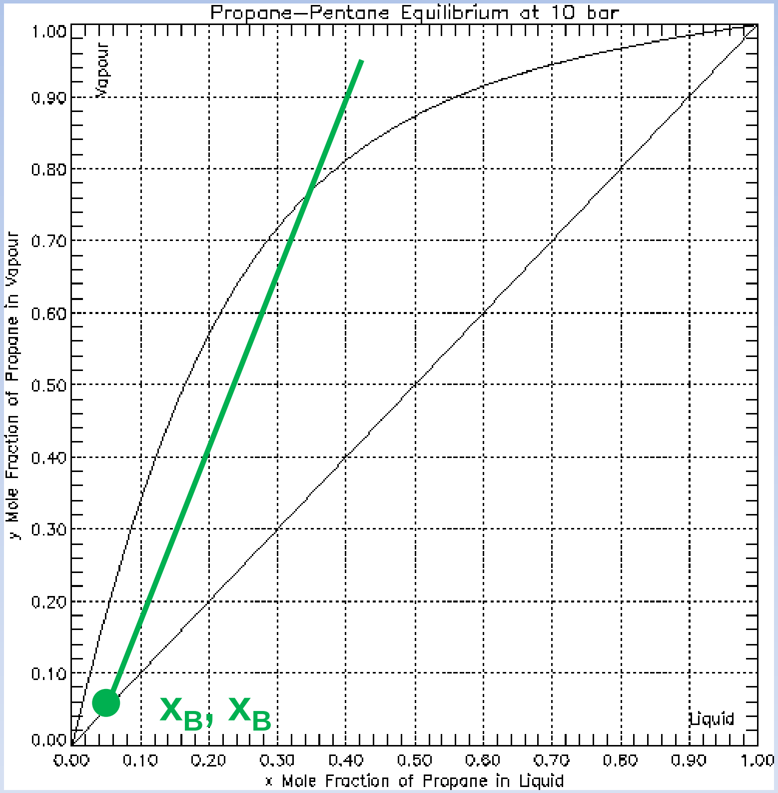


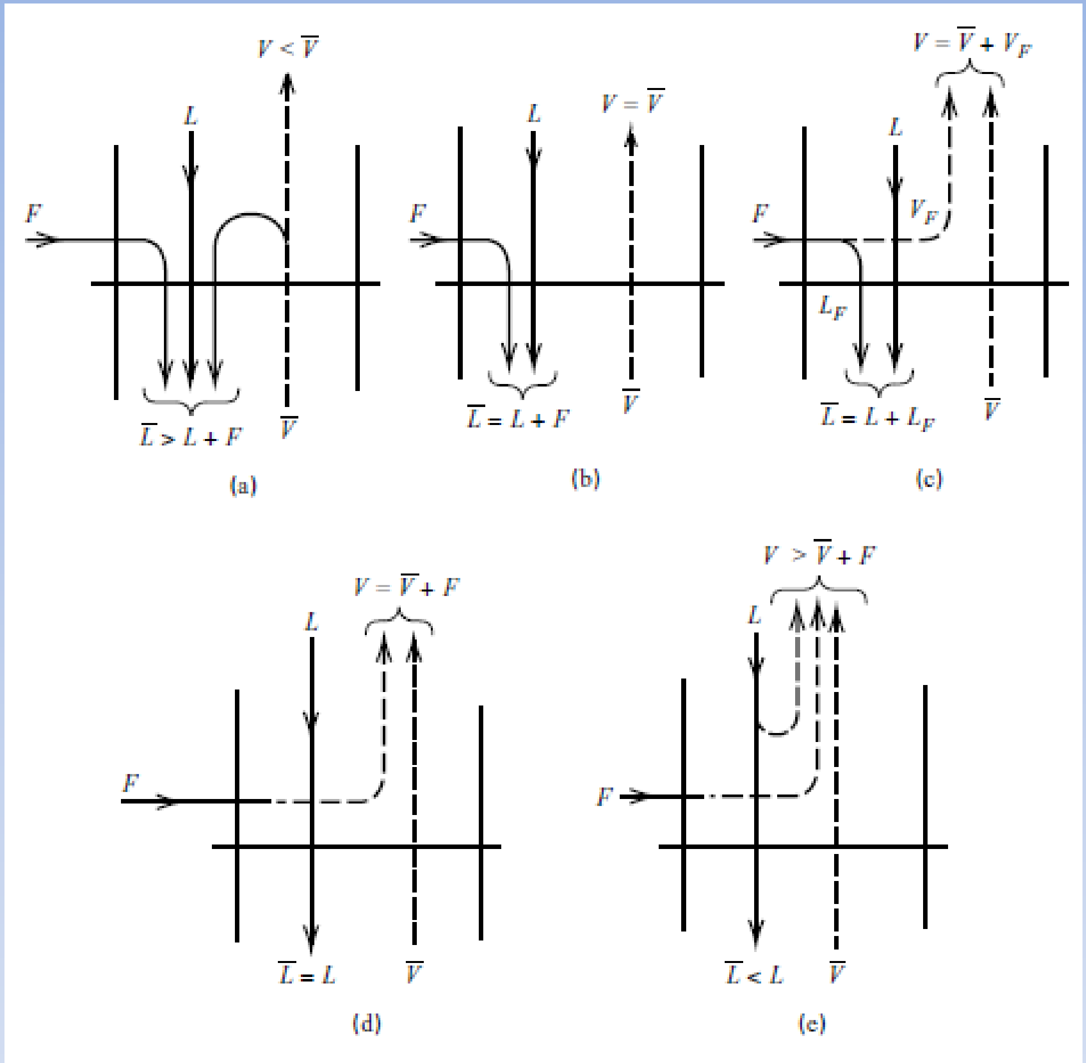


$$b)\ \overline{V} = \overline{L} - B$$

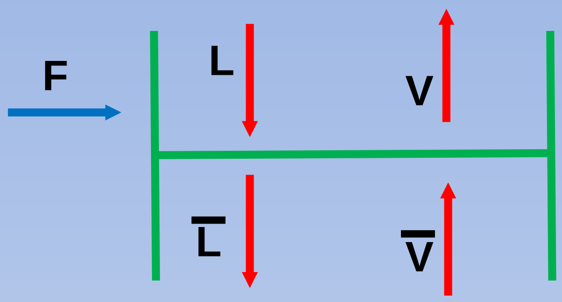
$$\bar{V}y_{m+1} = \bar{L}_n x_m - Bx_B$$

$$y_{m+1} = (\bar{L}/\bar{V})x_m - (B/\bar{V})x_B$$





(a) Liquido sottoraffreddato;
(b) Liquido saturo;
(c) Misto liquido e vapore;
(d) Vapore saturo;
(e) Vapore surriscaldato.



$$F + L + \bar{V} = \bar{L} + V$$

$$FH_F + LH_L + \bar{V}H_V = \bar{L}H_L + VH_V$$

$$\left(\bar{L} - L\right)H_L = \left(\bar{V} - V\right)H_V + FH_F$$

$$\frac{\left(\bar{L} - L\right)H_L}{F} = \frac{\left(\bar{V} - V\right)H_V}{F} + H_F$$

$$\frac{\left(\bar{L} - L\right)H_L}{F} = \frac{\left(\bar{L} - L\right)H_V}{F} + H_F - H_V$$

$$\frac{\left(\bar{L} - L\right)}{F} = \frac{H_V - H_F}{H_V - H_L}$$

$$q = \frac{\left(\bar{L} - L\right)}{F} = \frac{H_V - H_F}{H_V - H_L}$$