Problem 1

A distillation column is used to separate 100 mol/h of a mixture made of two compounds A and C. The feed mixture consists of equal parts of saturated vapor and liquid, with a molar composition of 35% A. It is intended to obtain a distillate with a molar composition of 93% A and a residue with a molar composition of 97.8% C. The reflux ratio is equal to 4.

a) How many equilibrium stages are needed in each section of the column?

b) What is the optimal plate for the feed inlet?

c) Determine the minimum reflux ratio (Rmin).

d) Determine the minimum number of theoretical plates required (Nmin).

Problem 1

A distillation column is used to separate 100 mol/h of a mixture made of two compounds A and C. The feed mixture consists of equal parts of saturated vapor and liquid, with a molar composition of 35% A. It is intended to obtain a distillate with a molar composition of 93% A and a residue with a molar composition of 97.8% C. The reflux ratio is equal to 4.

a) How many equilibrium stages are needed in each section of the column?

b) Qual é o prato óptimo para a introdução da alimentação?

c) Determine a razão de refluxo mínima, R_{min}

d) Determine o número mínimo de pratos teóricos necessários, N_{min}

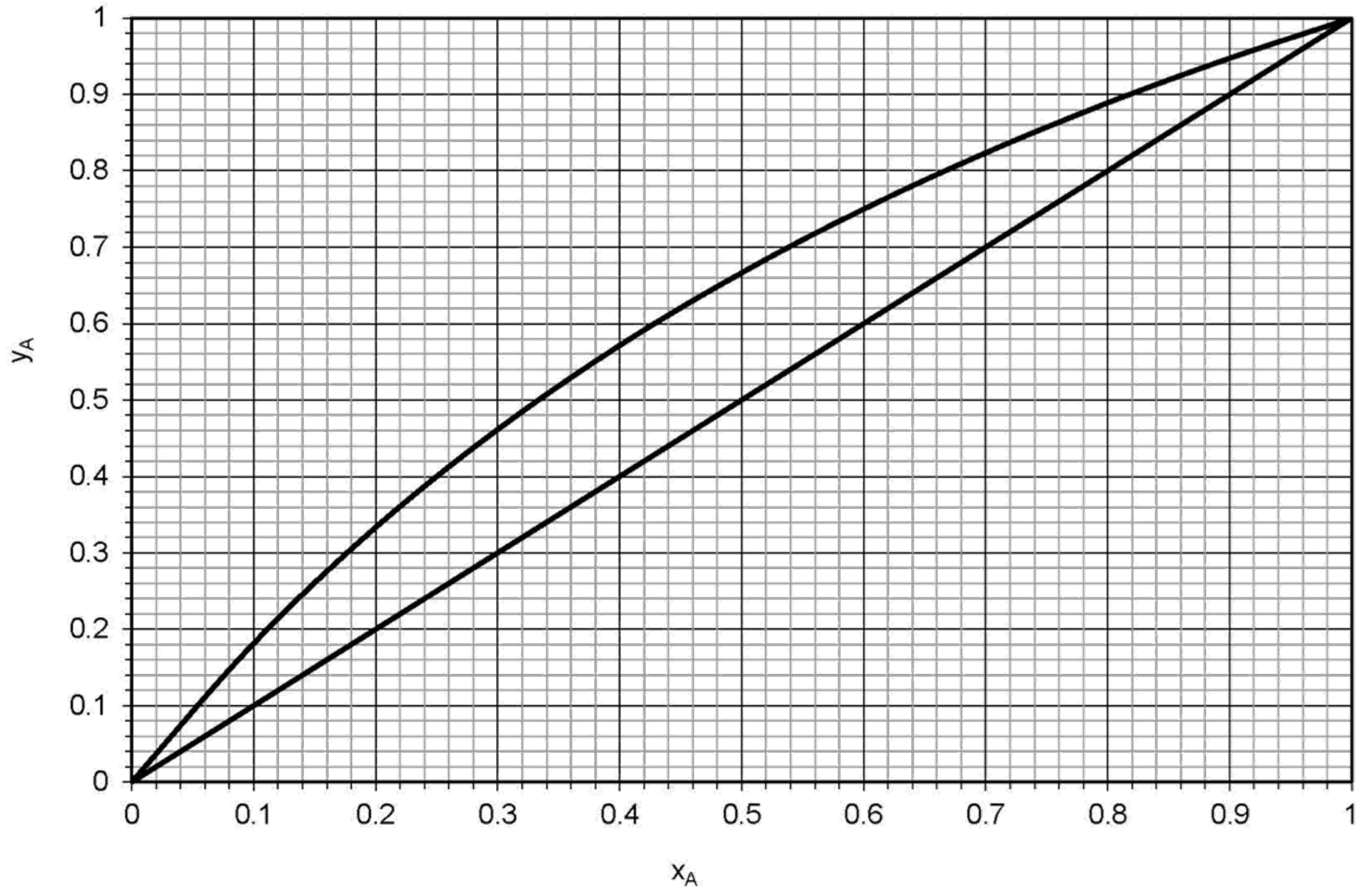
e) Calcule o declive da linha operatória da alimentação se esta for constituída por:

i) líquido saturado

ii) vapor saturado

iii) Vapor sobreaquecido, passando duas moles de líquido para o vapor por cada 10 moles de alimentação

Equilibrium curve



Equations needed

OL ≡ Operating Line

① Overall mass balance

$$F = B + D$$

$$F\,x_F = B\,x_B + D\,x_D$$

$$i = \frac{\bar{L} - L}{F}$$

$$R = L/D$$

$$V = L + D$$

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

② Enriching OL

$$y_{n+1} = \frac{R}{R+1}x_n + \frac{x_D}{R+1}$$

$$\begin{cases} y_{n+1}\big|_{x_n = x_D} = x_D \\ y_{n+1}\big|_{x_n = 0} = \dfrac{x_D}{R+1} \end{cases}$$

③ Feed OL

$$y_i = \frac{i}{i-1}x_i - \frac{x_F}{i-1}$$

$$\begin{cases} y_i\big|_{x_i = x_F} = x_F \\ y_i\big|_{x_i = 0} = -\dfrac{x_F}{i-1} \end{cases}$$

④ Stripping OL

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

$$y_{m+1}\big|_{x_m = x_B} = x_B$$

⑤ The three OL's intersect in a single point

- F: $L_F = V_F = 50\%$ F
- F = 100 mol/h
- $x_F = 0.35$; $x_D = 0.93$; $x_B = 0.022$
- R = 4

① **Overall mass balance**

$$F = B + D$$

$$F\,x_F = B\,x_B + D\,x_D$$

A distillation column is used to separate 100 mol/h of a mixture made of two compounds A and C. The feed mixture consists of equal parts of saturated vapor and liquid, with a molar composition of 35% A. It is intended to obtain a distillate with a molar composition of 93% A and a residue with a molar composition of 97.8% C. The reflux ratio is equal to 4.

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- R = 4

① Overall mass balance

$$F = B + D$$

$$F\,x_F = B\,x_B + D\,x_D$$

D = 36.12 mol/h

B = 63.88 mol/h

A distillation column is used to separate 100 mol/h of a mixture made of two compounds A and C. The feed mixture consists of equal parts of saturated vapor and liquid, with a molar composition of 35% A. It is intended to obtain a distillate with a molar composition of 93% A and a residue with a molar composition of 97.8% C. The reflux ratio is equal to 4.

Input data

- $x_F = 0.35$
- $x_D = 0.93$; $x_B = 0.022$

- $R = 4$

② Enriching OL

$$\boxed{y_{n+1} = \frac{R}{R+1} x_n + \frac{x_D}{R+1}}$$

$$\begin{cases} y_{n+1}\big|_{x_n = x_D} = x_D \\ y_{n+1}\big|_{x_n = 0} = \dfrac{x_D}{R+1} \end{cases}$$

③ Feed OL

$$\boxed{y_i = \frac{i}{i-1} x_i - \frac{x_F}{i-1}}$$

$$\begin{cases} y_i\big|_{x_i = x_F} = x_F \\ y_i\big|_{x_i = 0} = -\dfrac{x_F}{i-1} \end{cases}$$

④ Stripping OL

$$\boxed{y_{m+1} = \frac{\bar{L}}{\bar{V}} x_m - \frac{B x_B}{\bar{V}}}$$

$$y_{m+1}\big|_{x_m = x_B} = x_B$$

⑤ The three OL's intersect in a single point

- $x_F = 0.35$
- $x_D = 0.93; x_B = 0.022$

- $R = 4$

Input data

② Enriching OL

$$\boxed{y_{n+1} = \frac{R}{R+1} x_n + \frac{x_D}{R+1}}$$

$$\begin{cases} y_{n+1}\big|_{x_n = x_D} = x_D \\ y_{n+1}\big|_{x_n = 0} = \dfrac{x_D}{R+1} \end{cases}$$

$$\begin{cases} y_{n+1}\big|_{x_n = 0.93} = 0.93 \\ y_{n+1}\big|_{x_n = 0} = 0.186 \end{cases}$$

- $x_F = 0.35$
- $x_D = 0.93$; $x_B = 0.022$

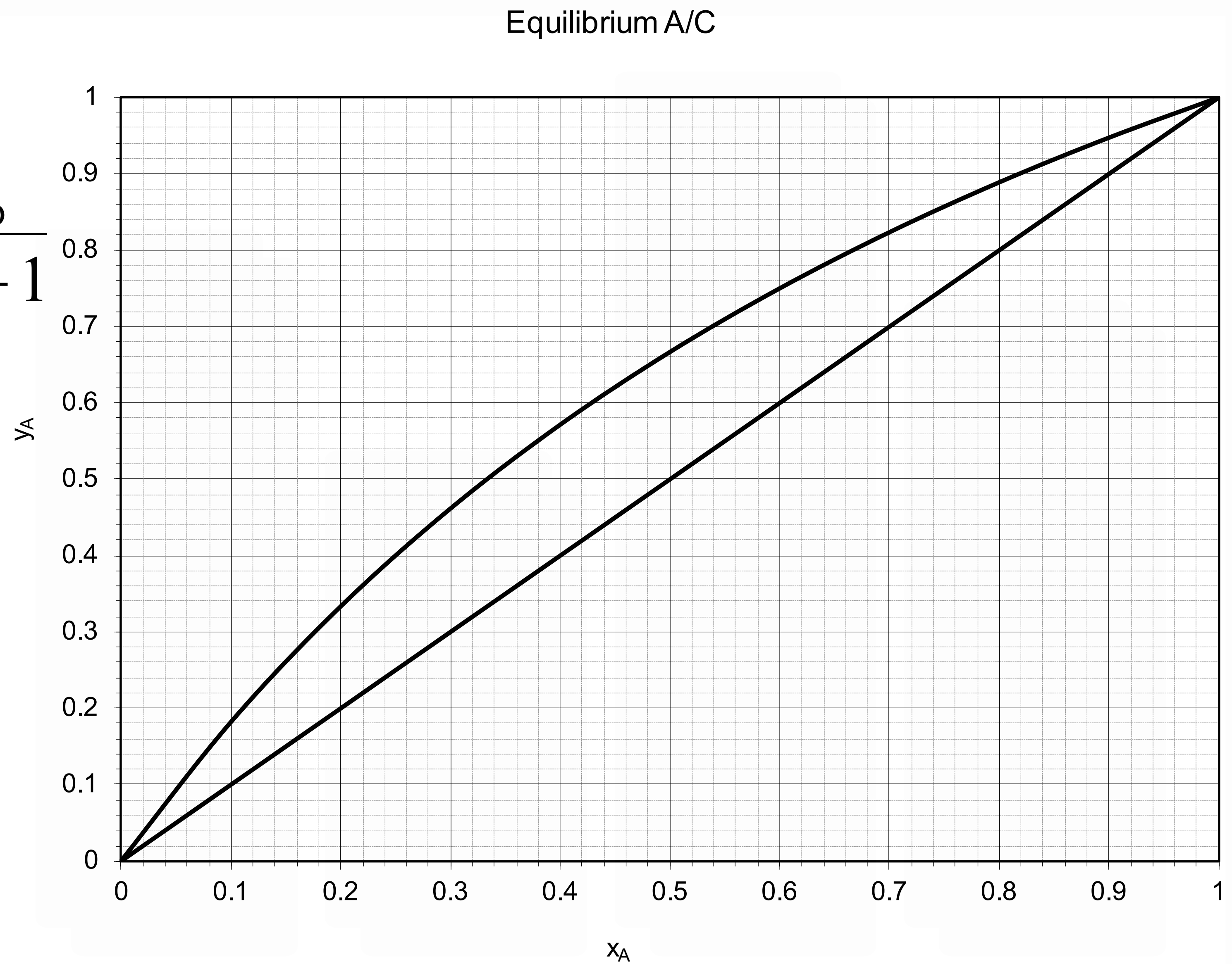
- $R = 4$

Enriching OL

②

$$y_{n+1} = \frac{R}{R+1} x_n + \frac{x_D}{R+1}$$

$$\begin{cases} y_{n+1}\Big|_{x_n=0.93} = 0.93 \\ y_{n+1}\Big|_{x_n=0} = 0.186 \end{cases}$$



Enriching OL

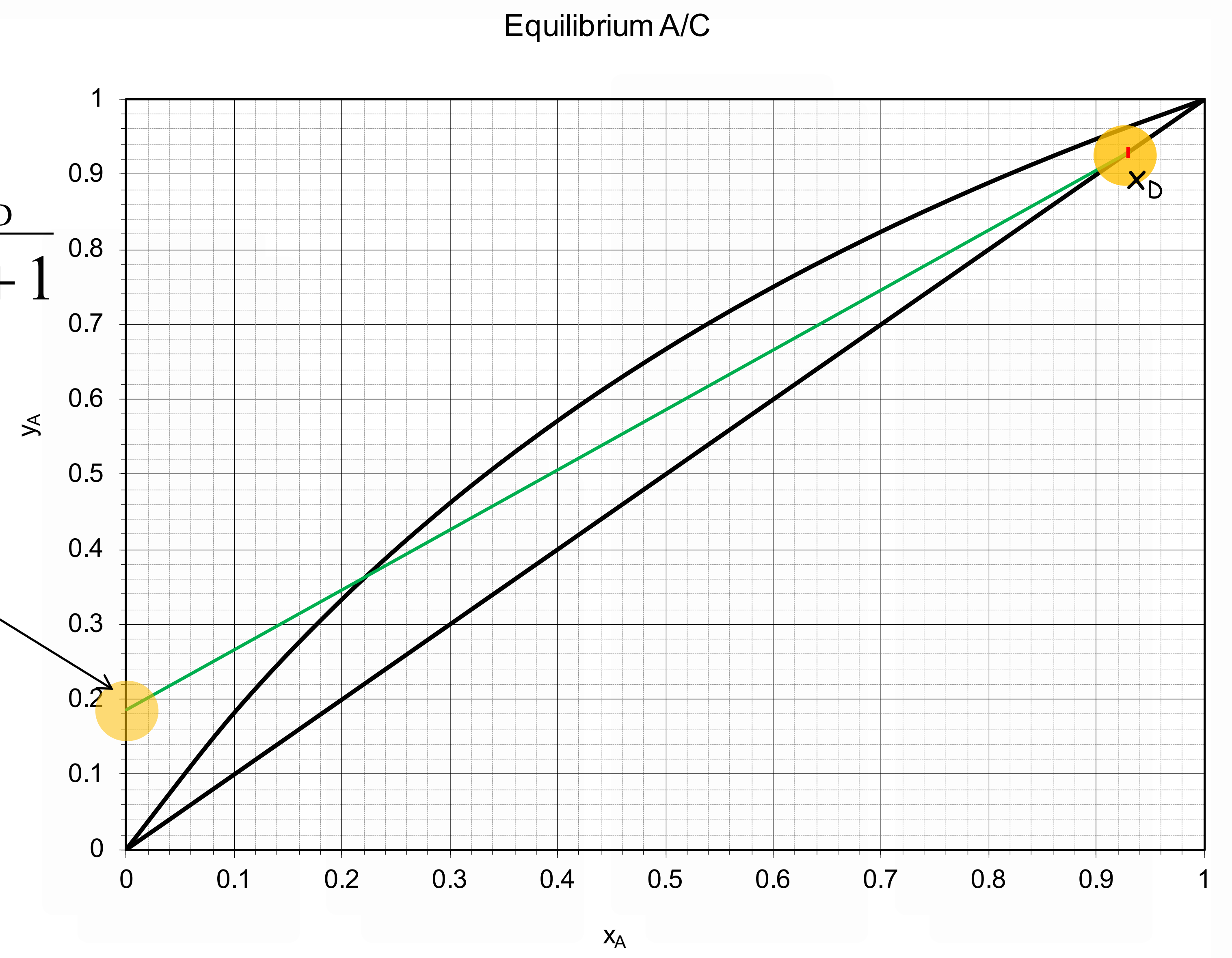
- $x_F = 0.35$
- $x_D = 0.93$; $x_B = 0.022$

- $R = 4$

②

$$y_{n+1} = \frac{R}{R+1} x_n + \frac{x_D}{R+1}$$

$$\begin{cases} y_{n+1}\Big|_{x_n=0.93} = 0.93 \\ y_{n+1}\Big|_{x_n=0} = 0.186 \end{cases}$$



- $x_F = 0.35$
- $x_D = 0.93$; $x_B = 0.022$

- $R = 4$

Input data

③ Feed OL

$$\boxed{y_i = \frac{i}{i-1}x_i - \frac{x_F}{i-1}}$$

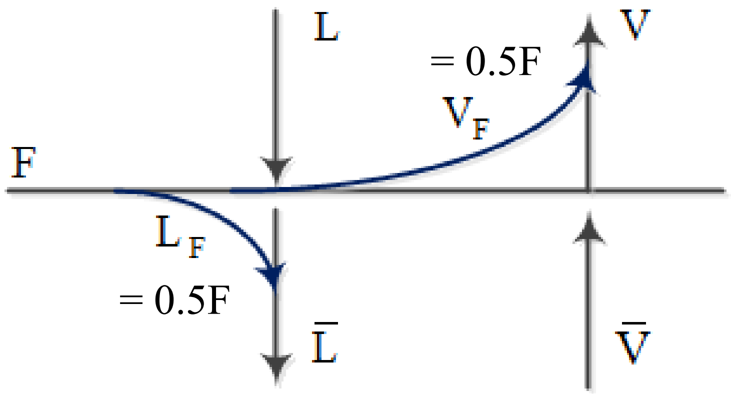
$$\begin{cases} y_i\big|_{x_i = x_F} = x_F \\ y_i\big|_{x_i = 0} = -\dfrac{x_F}{i-1} \end{cases}$$

$$\boxed{i = \frac{\bar{L} - L}{F}}$$

③ Feed OL

$$\boxed{y_i = \frac{i}{i-1} x_i - \frac{x_F}{i-1}}$$

F has 50% vapor and 50% liquid



$\bar{L} = L + 0.5F$

$$i = \frac{(L + 0.5F) - L}{F} = 0.5$$

$$\frac{i}{i-1} = \frac{0.5}{0.5-1} = -1$$

- $x_F = 0.35$
- $x_D = 0.93; x_B = 0.022$

- $R = 4$

- $i = 0.5$

Input data

③ **Feed OL**

$$\boxed{y_i = \frac{i}{i-1}x_i - \frac{x_F}{i-1}}$$

$$\begin{cases} y_i\Big|_{x_i = x_F} = x_F \\ y_i\Big|_{x_i = 0} = -\dfrac{x_F}{i-1} \end{cases}$$

$$\Rightarrow \begin{cases} y_i\Big|_{x_i = 0.35} = 0.35 \\ y_i\Big|_{x_i = 0} = 0.7 \end{cases}$$

Feed OL

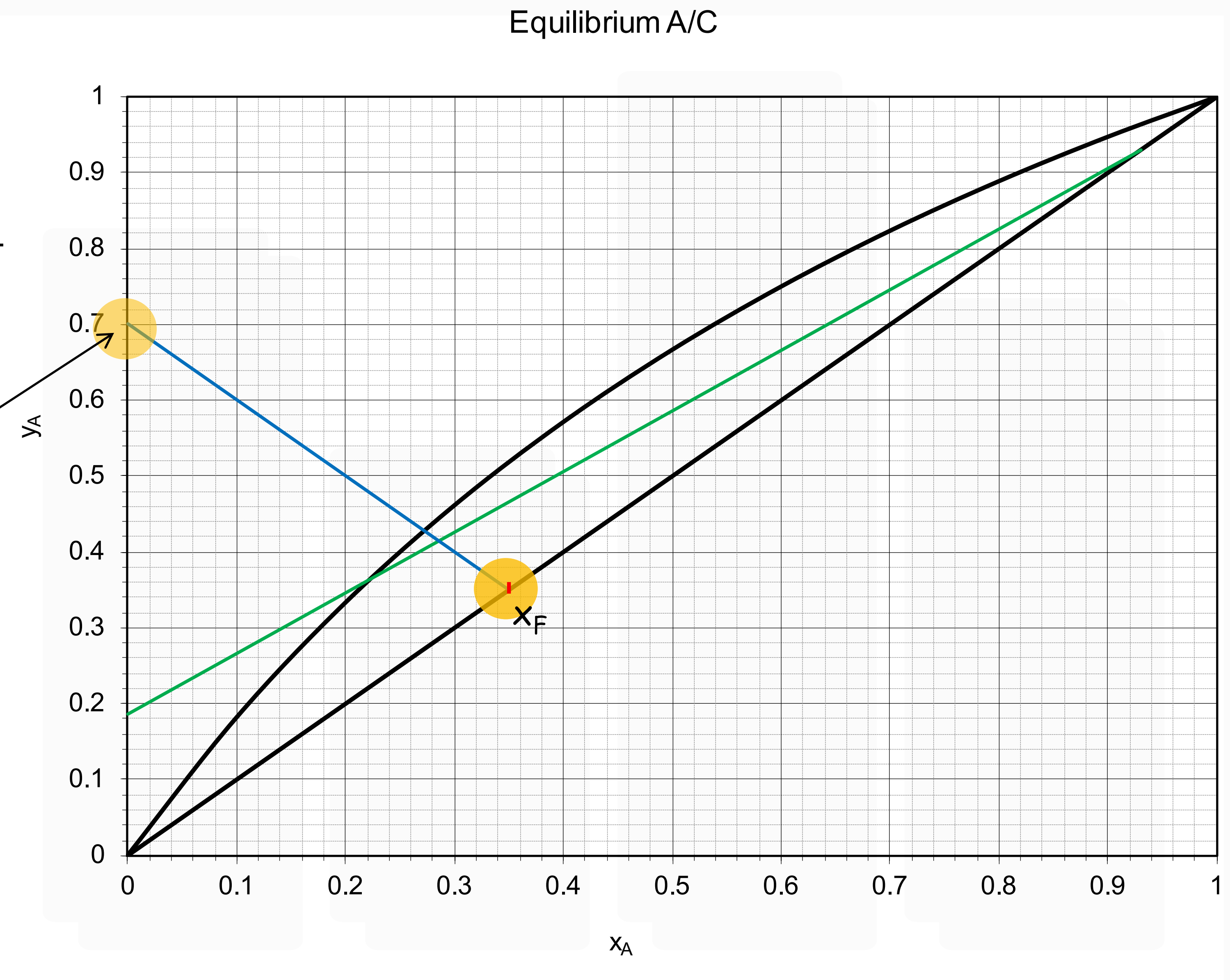
- $x_F = 0.35$
- $x_D = 0.93$; $x_B = 0.022$

- $R = 4$
- $i = 0.5$

③

$$y_i = \frac{i}{i-1}x_i - \frac{x_F}{i-1}$$

$$\begin{cases} y_i\big|_{x_i=0.35} = 0.35 \\ y_i\big|_{x_i=0} = 0.7 \end{cases}$$



- $x_F = 0.35$
- $x_D = 0.93$; $x_B = 0.022$

- $R = 4$

Input data

④ Stripping OL

$$\boxed{y_{m+1} = \frac{\bar{L}}{\bar{V}} x_m - \frac{B x_B}{\bar{V}}}$$

$$y_{m+1}\Big|_{x_m = x_B} = x_B$$

$$\Rightarrow \quad y_{m+1}\big|_{x_m=0.022} = 0.022$$

⑤ The three OL's intersect in a single point

Stripping OL

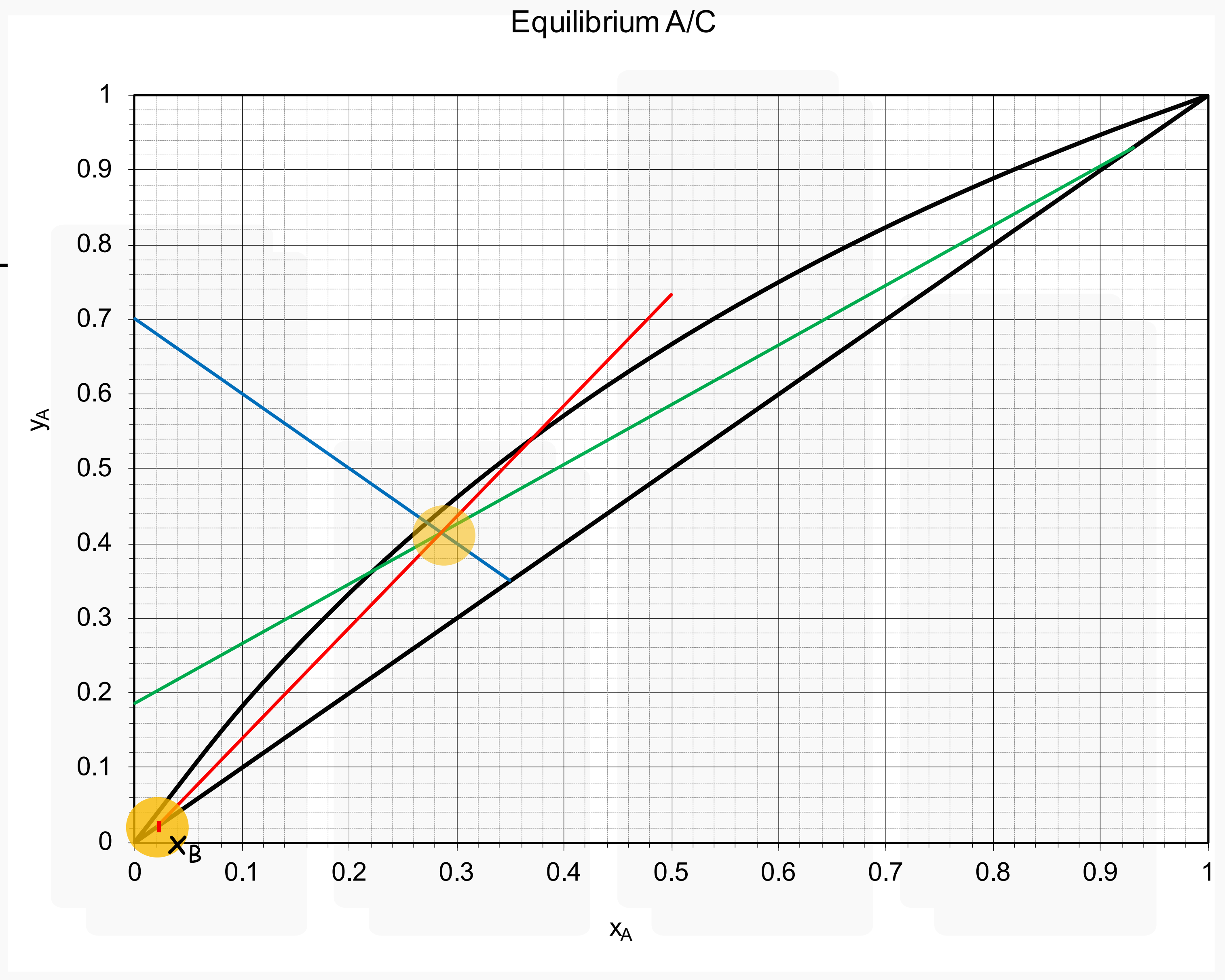
- $x_F = 0.35$
- $x_D = 0.93$; $x_B = 0.022$

- $R = 4$
- $i = 0.5$

④

$$y_{m+1} = \frac{\overline{L}}{\overline{V}} x_m - \frac{B x_B}{\overline{V}}$$

$y_{m+1}|_{x_m=0.022} = 0.022$



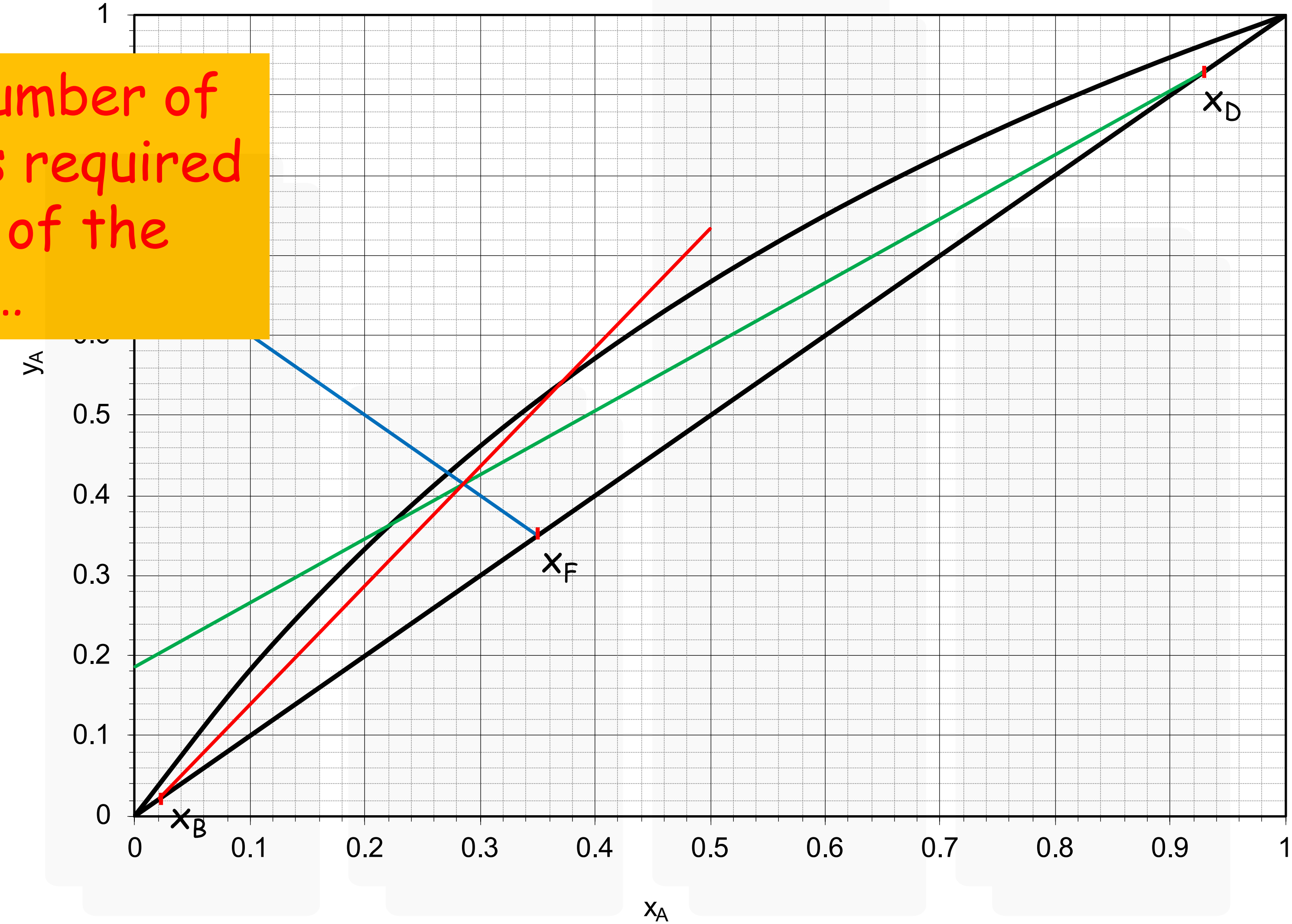
⑤

The three OL's interset in a single point!

- $x_F = 0.35$
- $x_D = 0.93$; $x_B = 0.022$

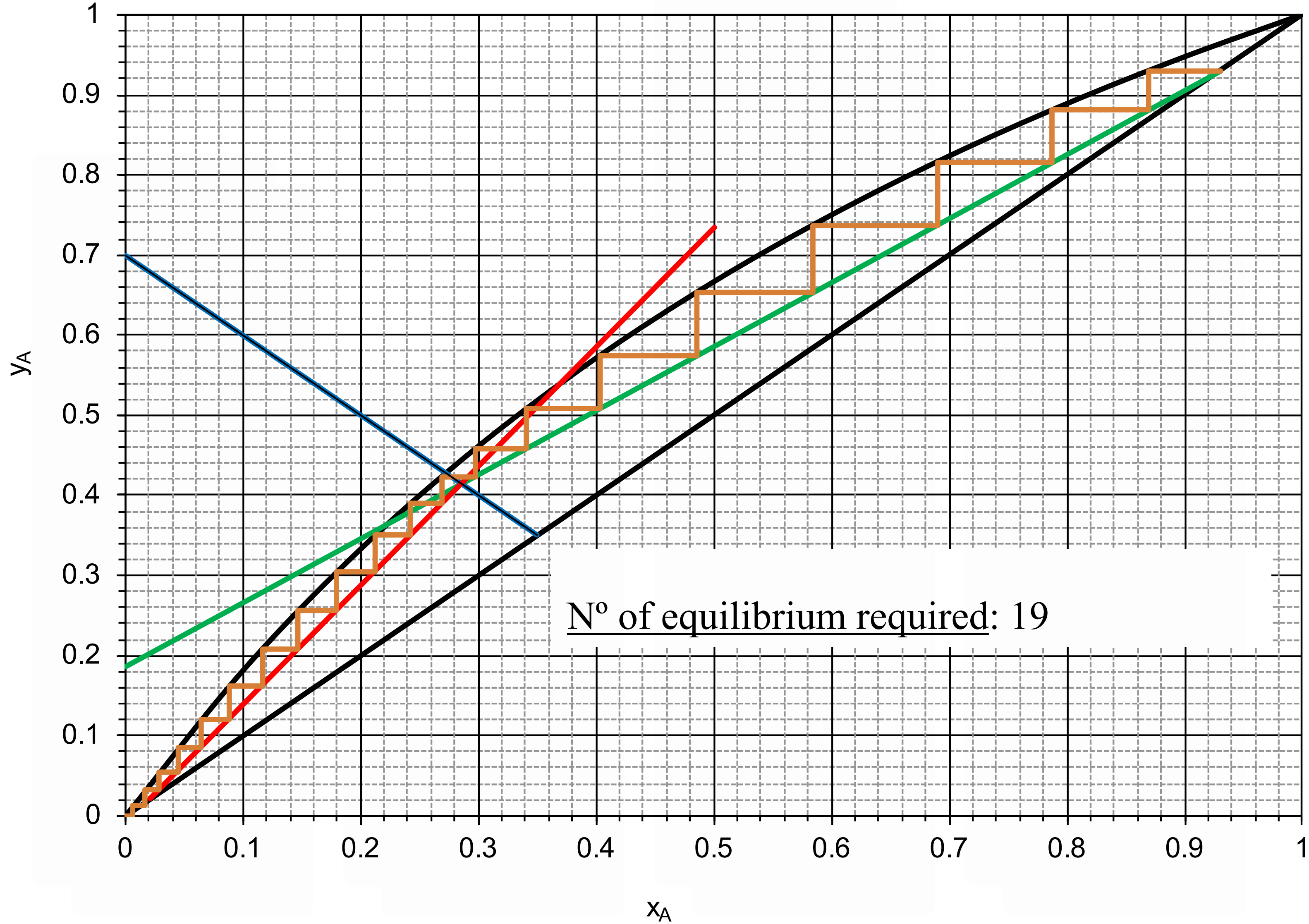
- $R = 4$
- $i = 0.5$

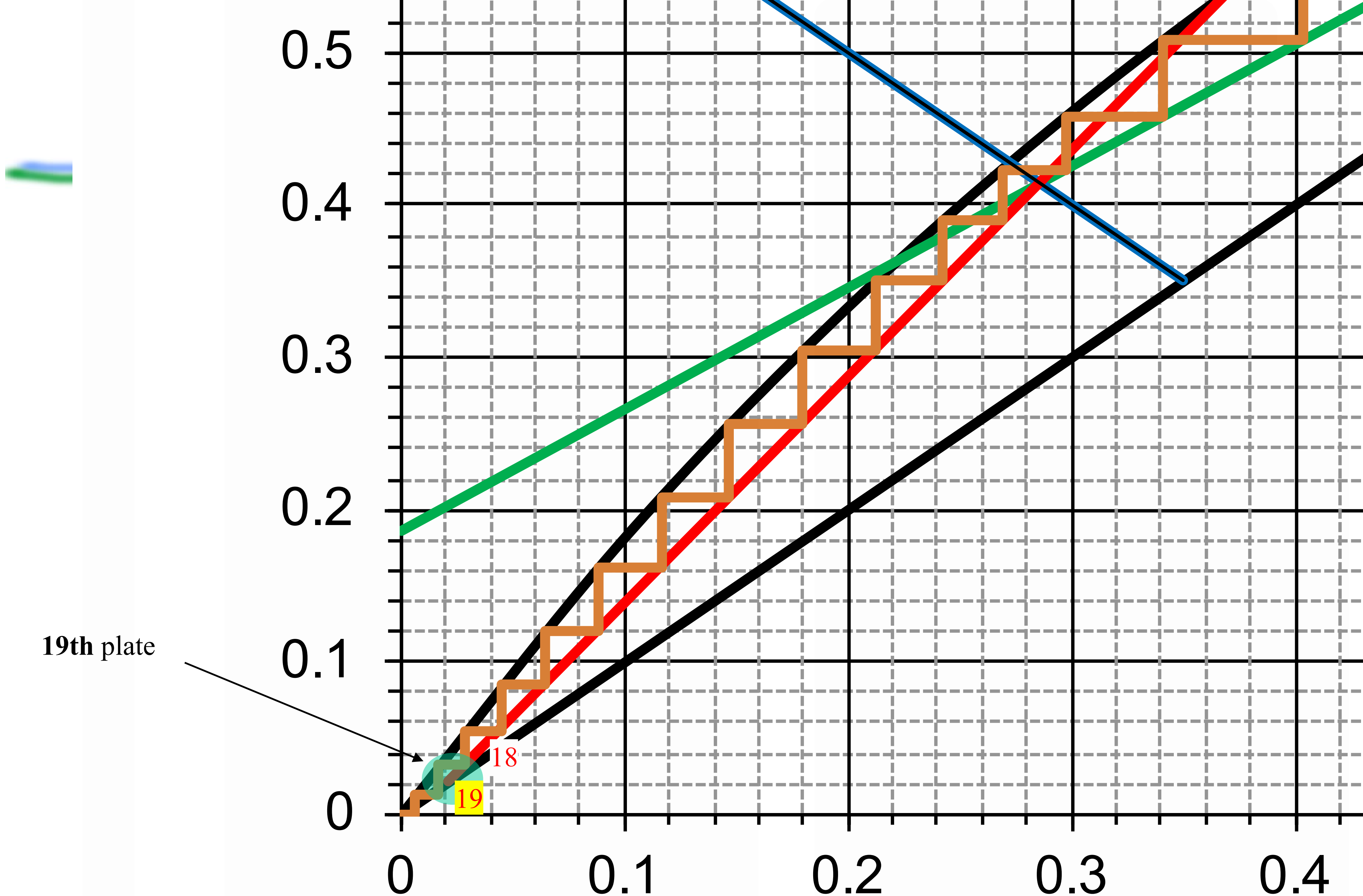
Determine the number of equilibrium stages required by the method of the triangles…



- $x_F = 0.35$
- $x_D = 0.93$; $x_B = 0.022$

- $R = 4$
- $i = 0.5$





0.5
0.4
0.3
0.2
0.1
0
0
0.1
0.2
0.3
0.4
19th plate
18
19

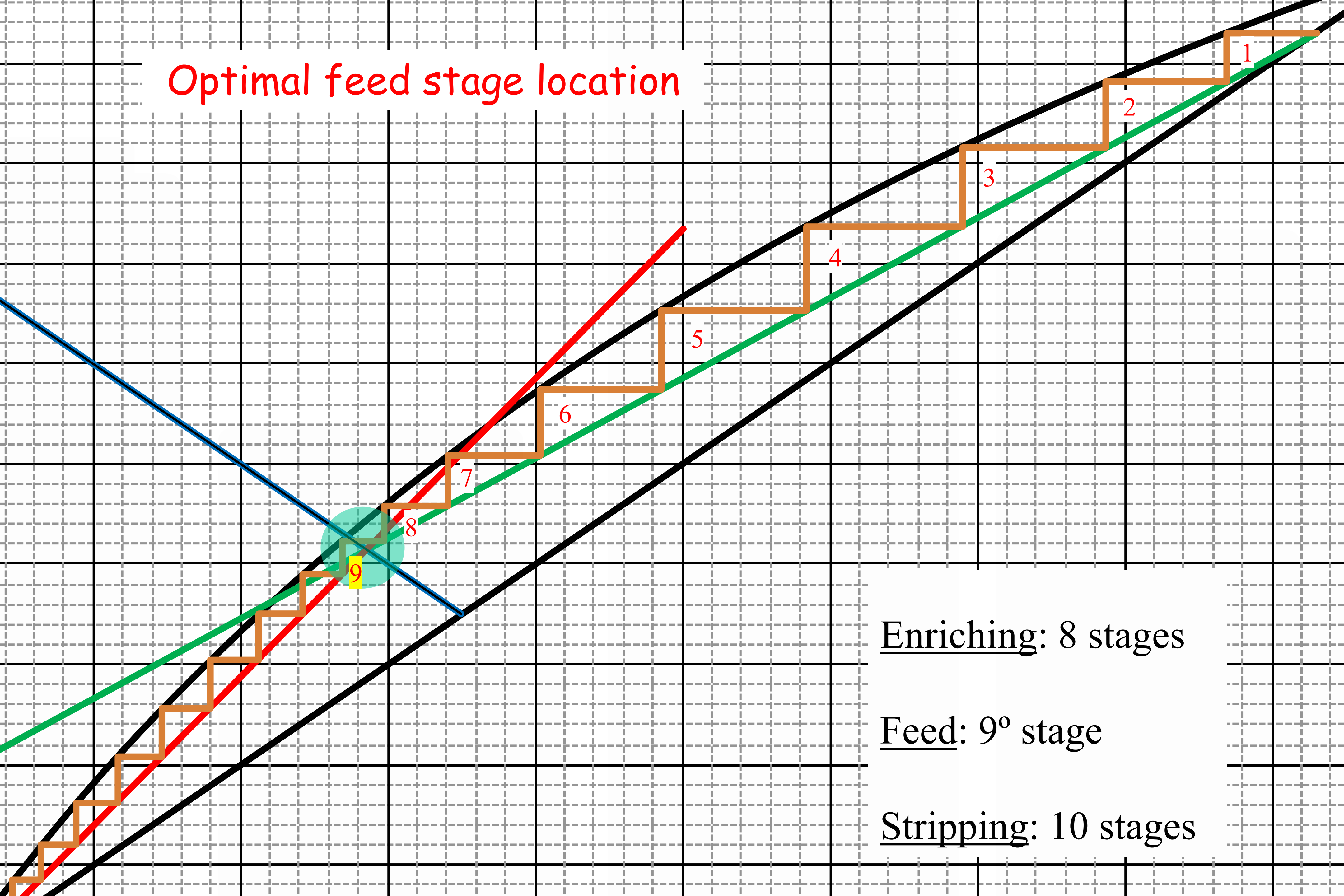
Problema 1

A distillation column is used to separate 100 mol/h of a mixture made of two compounds A and C. The feed mixture consists of equal parts of saturated vapor and liquid, with a molar composition of 35% A. It is intended to obtain a distillate with a molar composition of 93% A and a residue with a molar composition of 97.8% C. The reflux ratio is equal to 4.

a) How many equilibrium stages are needed in each section of the column?

b) What is the optimal plate for the feed inlet?

Optimal feed stage location



Enriching: 8 stages

Feed: 9º stage

Stripping: 10 stages

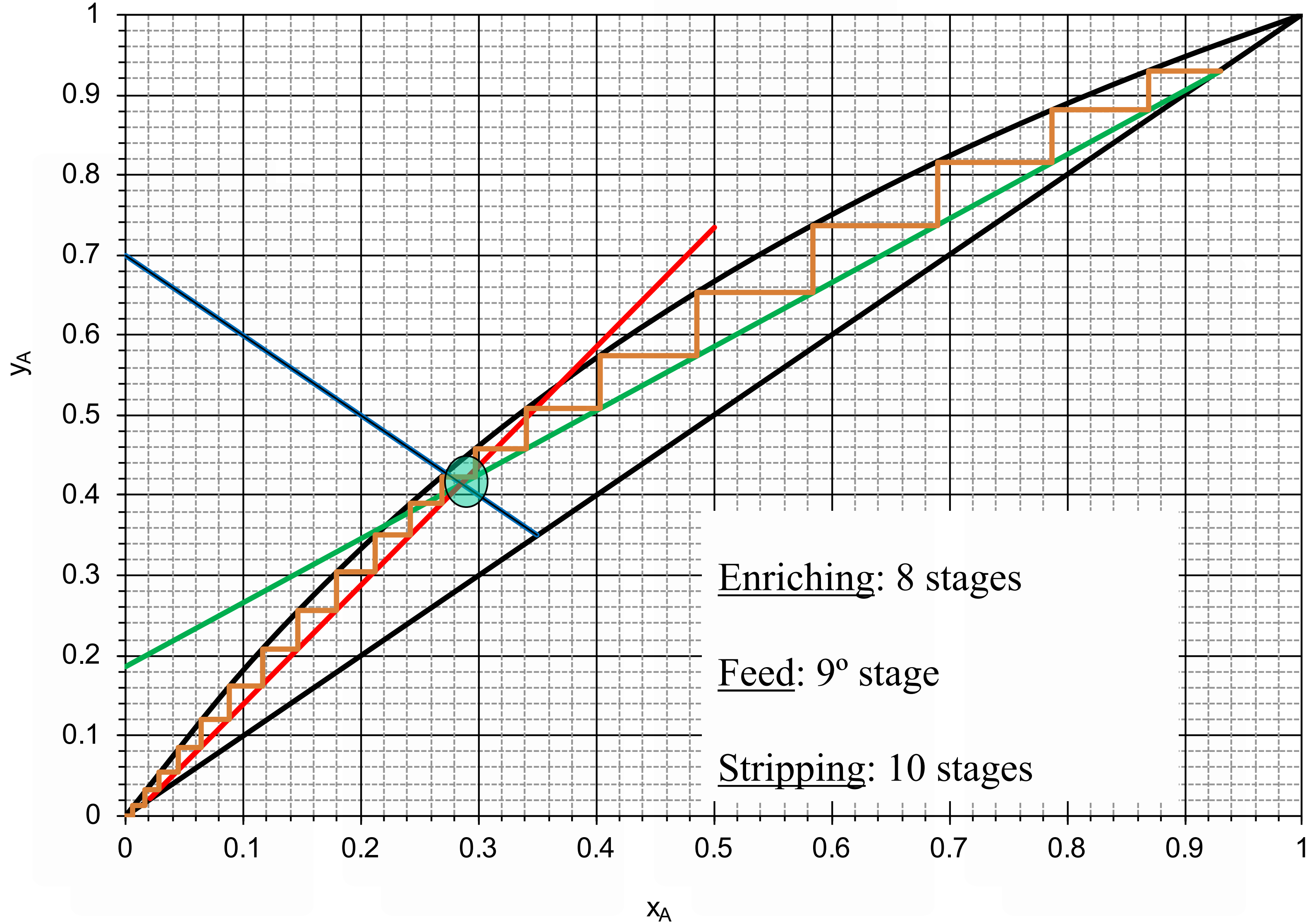
Optimal feed stage location

$F = 100$ mol/h

$x_F = 0.35$; $x_D = 0.93$

$x_B = 0.022$

$i = 0.5$; $R = 4$



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a) How many equilibrium stages are needed in each section of the column?

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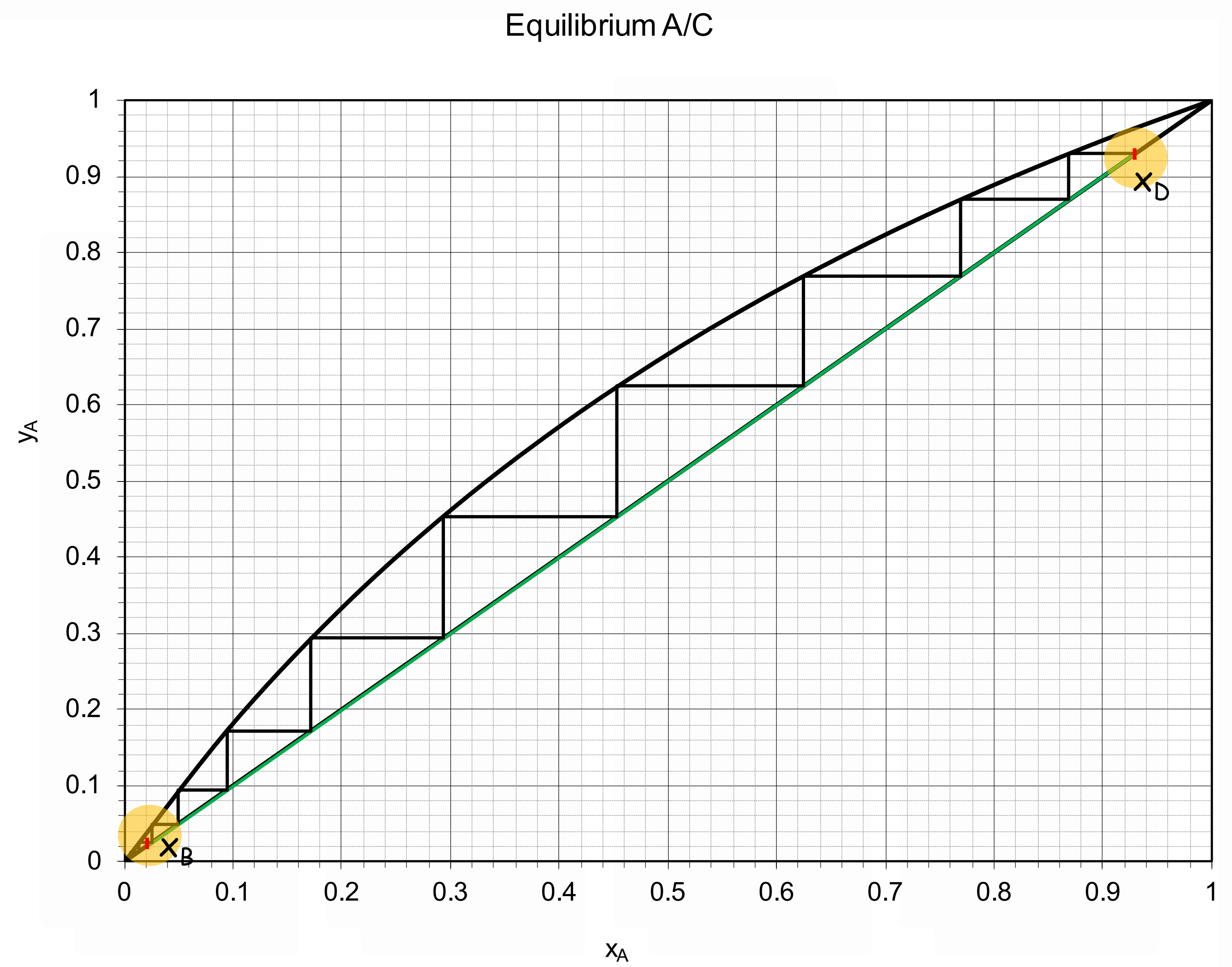
c) Determine the minimum reflux ratio (Rmin).

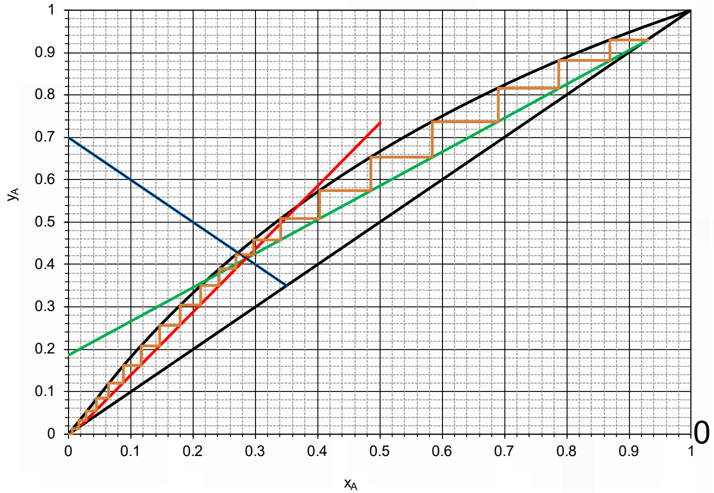
d) Determine the minimum number of theoretical plates required (Nmin).

Minimum number of stages

Total reflux

$N_{min} = 9$





Minimum Reflux Ratio

Infinite number of equilibrium stages

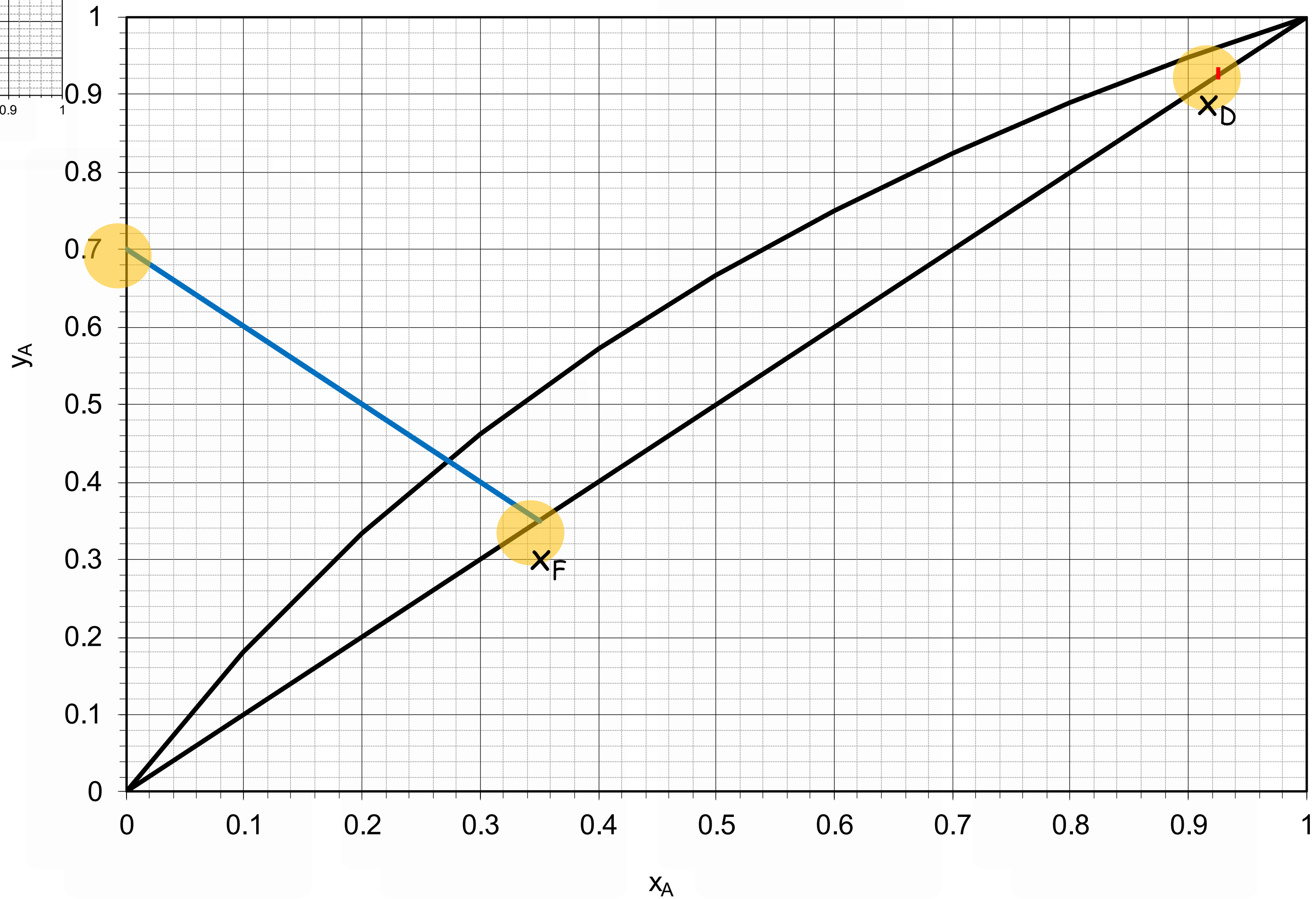
$x_F = 0.35$

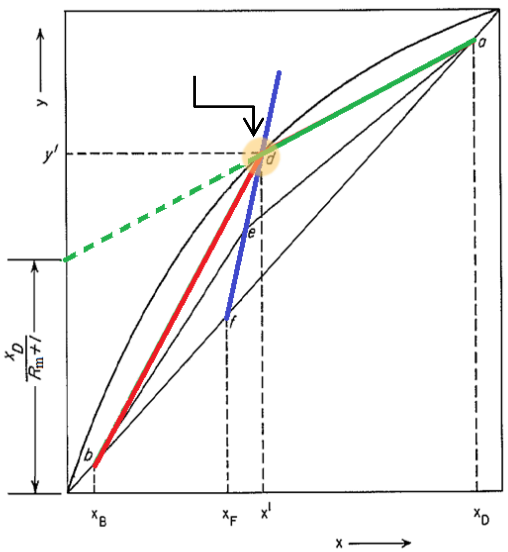
$x_D = 0.93$

$x_B = 0.022$

$i = 0.5$

$$y_{n+1} = \frac{R_{\min}}{R_{\min}+1} x_n + \frac{x_D}{R_{\min}+1}$$





Minimum Reflux Ratio

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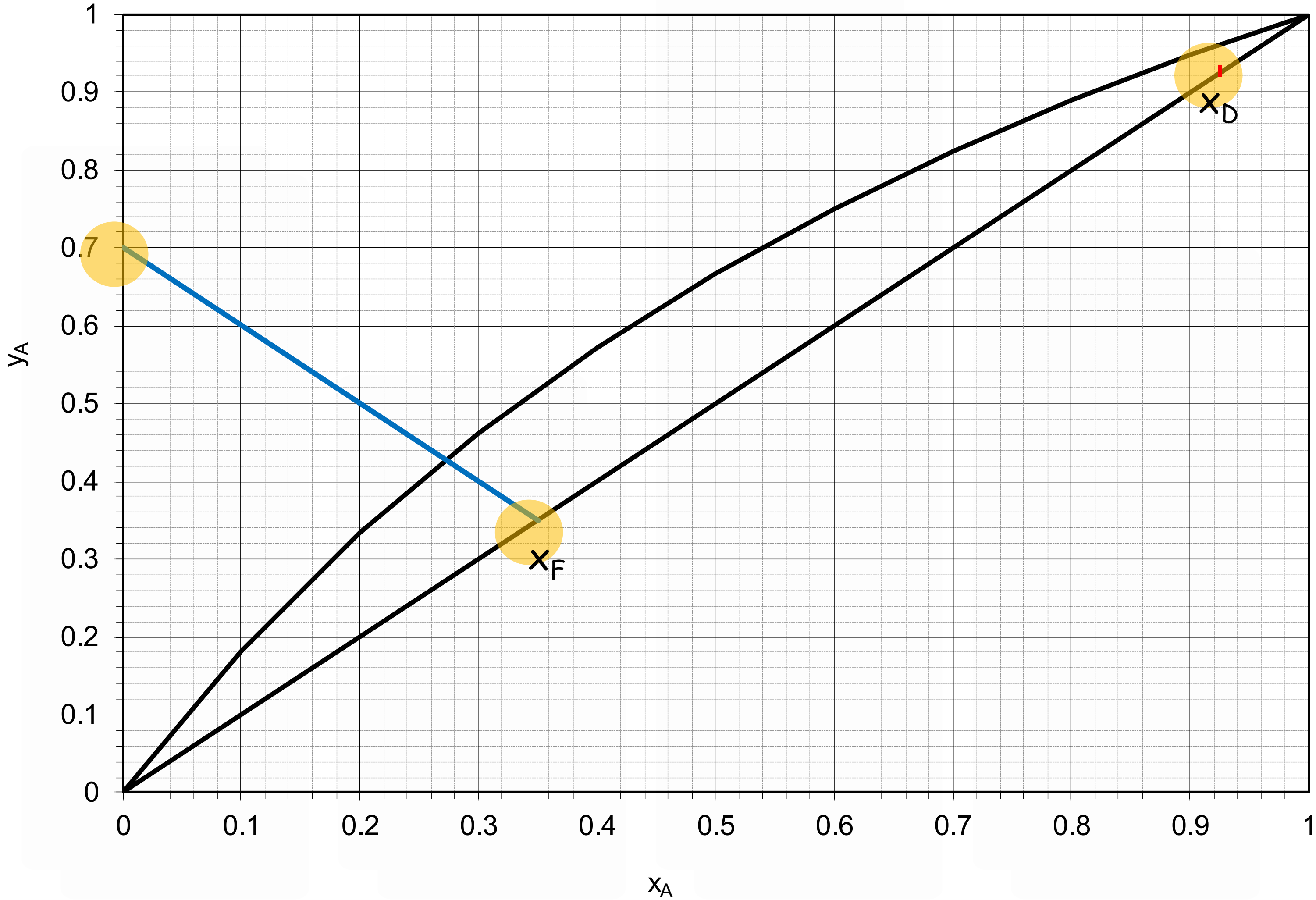
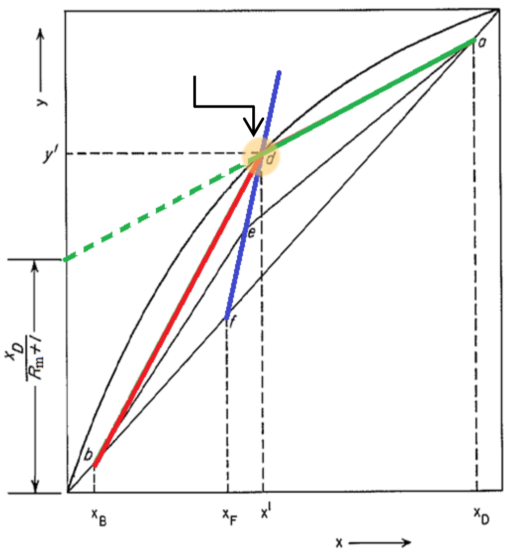
$$y_{n+1} = \frac{R_{min}}{R_{min}+1} x_n + \frac{x_D}{R_{min}+1}$$



Minimum Reflux Ratio

Infinite number of equilibrium stages



$x_F = 0.35$

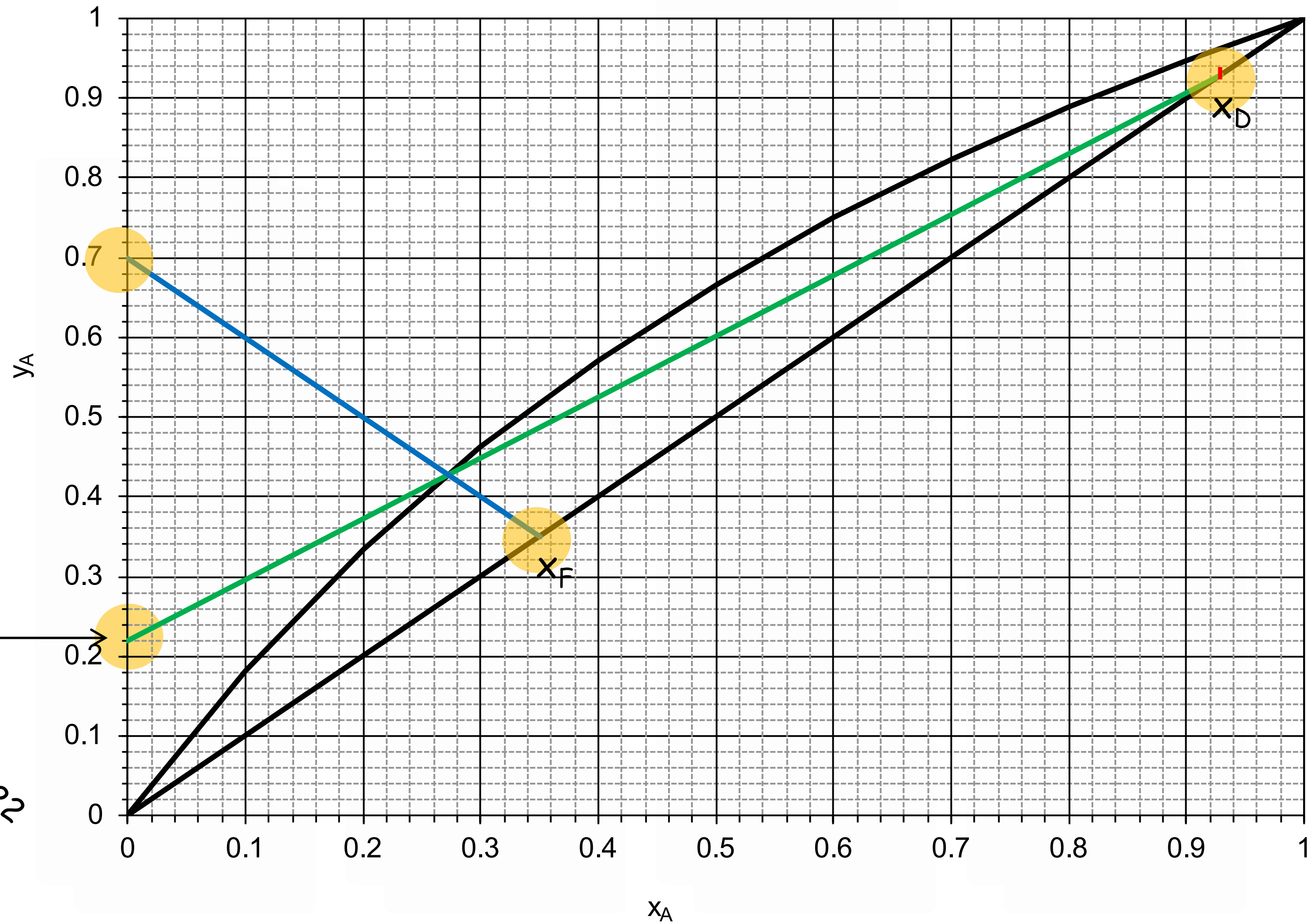
$x_D = 0.93$

$x_B = 0.022$

$i = 0.5$

$$y_{n+1} = \frac{R_{min}}{R_{min}+1}x_n + \underbrace{\frac{x_D}{R_{min}+1}}_{=0.22}$$

=> $R_{min} = 3.2$



Why so many equilibrium stages??

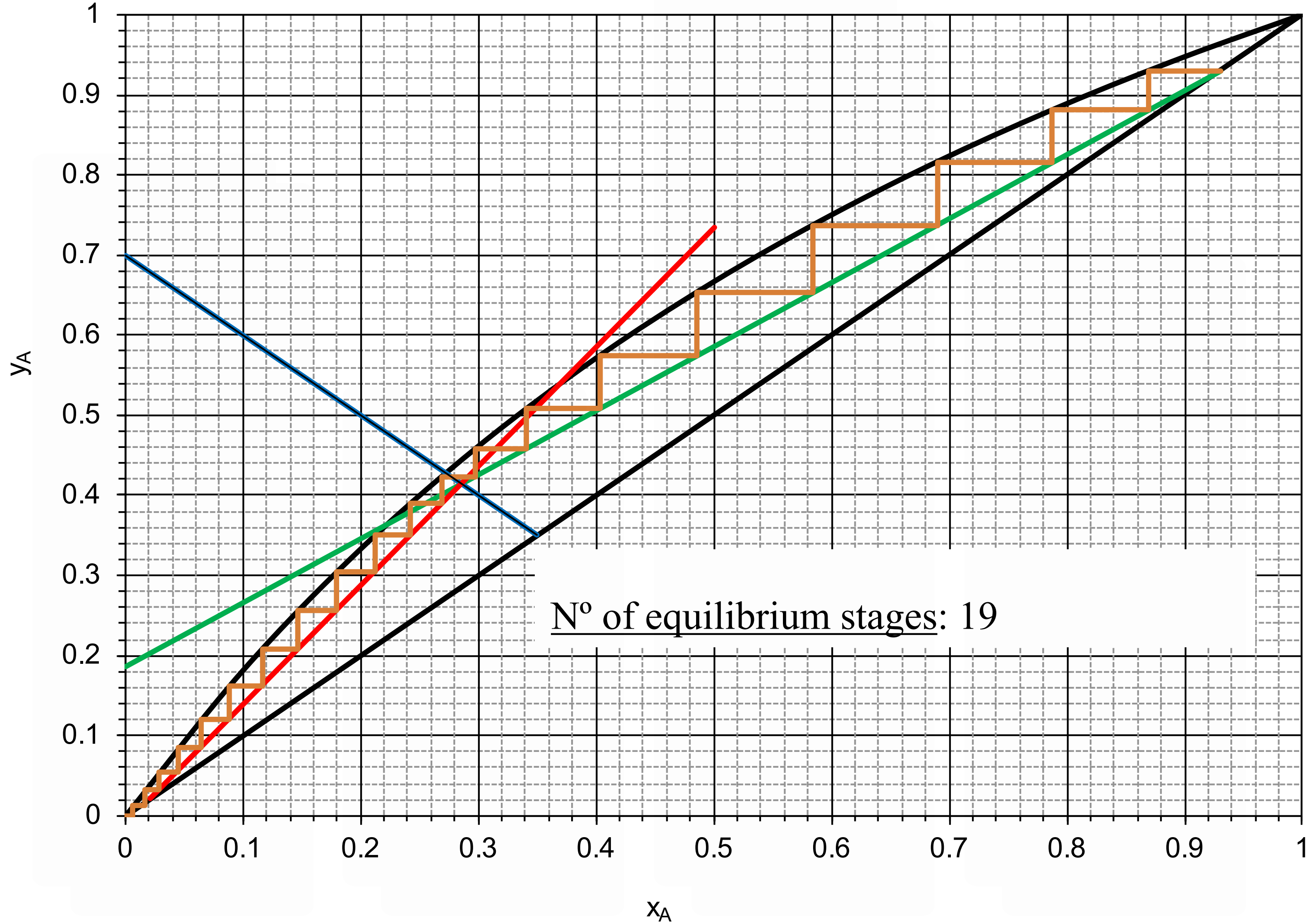
$F = 100$ mol/h

$x_F = 0.35$; $x_D = 0.93$

$x_B = 0.022$

$i = 0.5$; $R = 4$

$R_{min} = 3.2$



Why so many equilibrium stages??

F = 100 mol/h

$x_F = 0.35$; $x_D = 0.93$

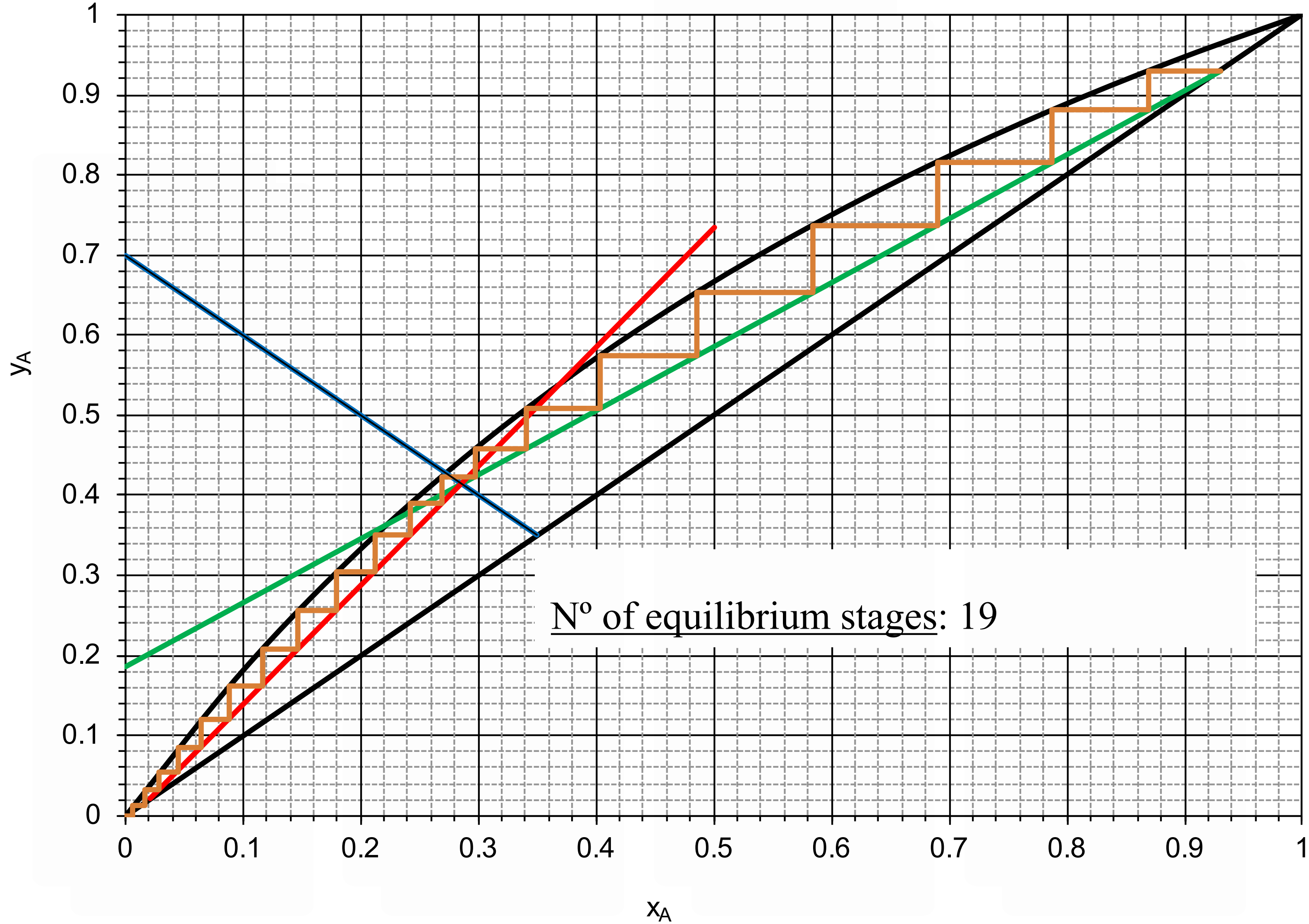
$x_B = 0.022$

i = 0.5; R = 4

$R_{min} = 3.2$

$R \cong R_{min}$

LO's are very near the equilibrium line!



Problem 2

It is intended to design a distillation column to operate continuously. The column will be used to separate a mixture containing 15.67% CS2 and 84.3% CCl4, to give a distillate with 91% CS2 and a residue with 97.3% CCl4 (all percentages are by weight). Assume a reflux of 3.16 and a total efficiency of 70%. The feed enters at 290 K, having a specific heat of 225.4 J/(mol.K), a boiling point of 336 K and a latent heat of vaporization of 25 900 J/mol. Determine the number of actual stages of the column.

$M(CS_2) = 76$ g/mol), $M(CCl_4) = 154$ g/mol

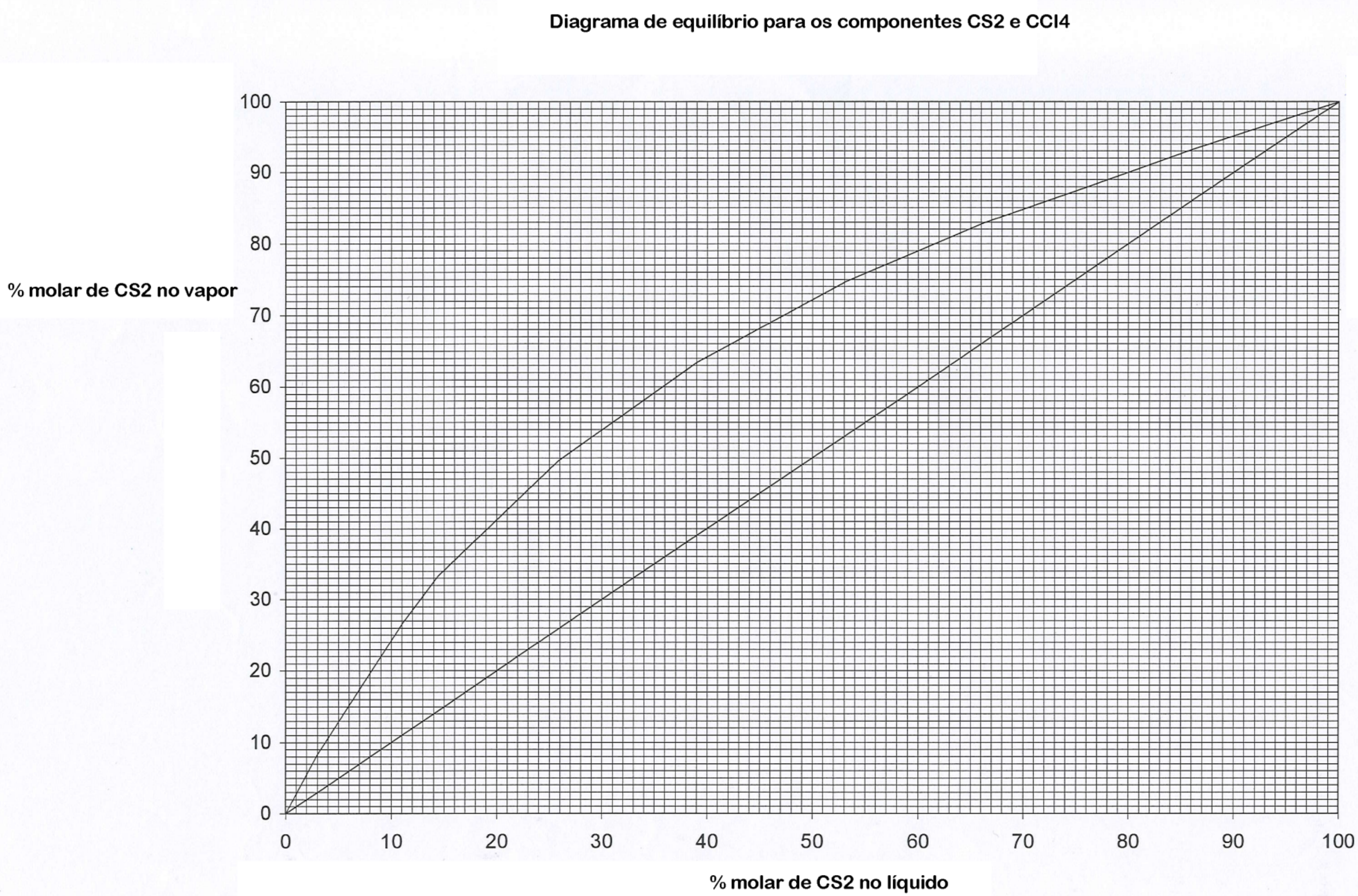


Diagrama de equilíbrio para os componentes CS2 e CCl4
% molar de CS2 no vapor
% molar de CS2 no líquido
0
10
20
30
40
50
60
70
80
90
100

Enriching OL

$$y_{n+1} = \frac{R}{R+1} x_n + \frac{x_D}{R+1}$$

Feed OL

$$y_i = \frac{i}{i-1} x_i - \frac{x_F}{i-1}$$

- $x_F = 15.67\%$ p/p
- $x_D = 91\%$ p/p
- $x_B = 97.3\%$ p/p
- $R = 3.16$

- $T_F = 290K$
- $c_{pF} = 1.7$ kJ/kg.K
- $T_{sat} = 336K$
- $\Delta H_{vap} = 25.9$ kJ/mol

- $M(CS_2) = 76$ g/mol
- $M(CCl_4) = 154$ g/mol

$$F = B + D$$

$$F z_F = B x_B + D x_D$$

$$R = L/D$$

$$V = L + D$$

$$\bar{V} = \bar{L} - B$$

Mass units → molar units!

- $x_F = 0.274$ mol/mol
- $x_D = 0.953$ mol/mol
- $x_B = 0.053$ mol/mol

- $x_F = 0.274$ mol/mol
- $x_D = 0.953$ mol/mol
- $x_B = 0.053$ mol/mol
- $R = 3.16$

Enriching OL

$$\boxed{y_{n+1} = \frac{R}{R+1} x_n + \frac{x_D}{R+1}}$$

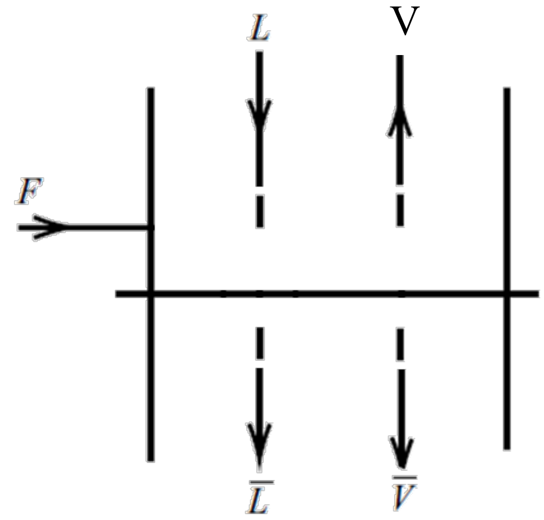
$$\Rightarrow \quad y_{n+1} = 0.76\, x_n + 0.23$$

③ Operating line of feed

$$y_i = \frac{i}{i-1}x_i - \frac{x_F}{i-1}$$

$$i = \frac{\bar{L} - L}{F}$$

The feed enters at 290 K, having a specific heat of 225.4 J/(mol.K), a boiling point of 336 K and a latent heat of vaporization of 25 900 J/mol



- Temperature: 290K
- Specific heat: 225.4 J/(mol.K)
- Boiling point: 336 K
- Enthalpy of vaporization: 25 900 J/mol

$T_{feed} < T_{saturated\ liquid}$

Subcooled liquid!

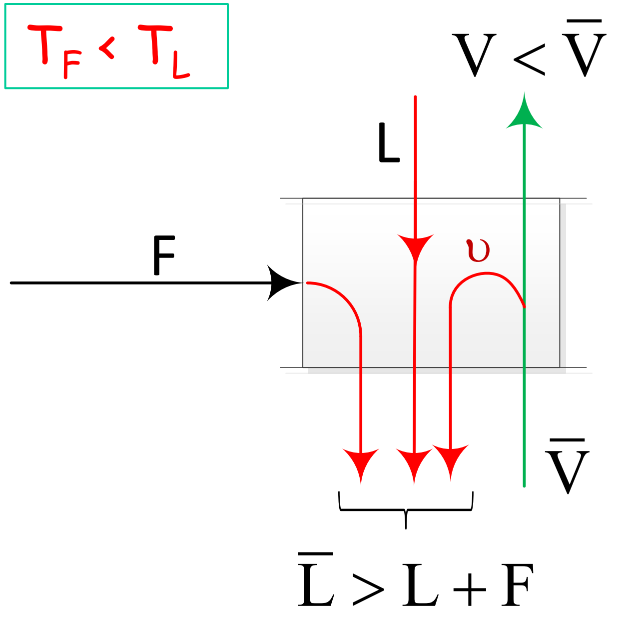
③ Operating line of feed

$$y_i = \frac{i}{i-1}x_i - \frac{x_F}{i-1}$$

$$i = \frac{\bar{L} - L}{F}$$

- Temperature: 290K
- Specific heat: 225.4 J/(mol.K)
- Boiling point: 336 K
- Enthalpy of vaporization: 25 900 J/mol

$T_F < T_L$



How to estimate υ? → Energy balance to the feed plate

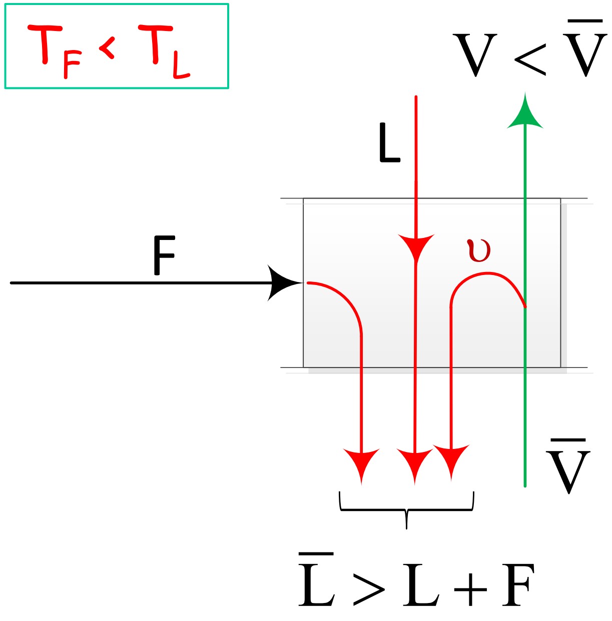
③ Operating line of feed

$$y_i = \frac{i}{i-1} x_i - \frac{x_F}{i-1}$$

$$i = \frac{\bar{L} - L}{F}$$

- Temperature: 290K
- Specific heat: 225.4 J/(mol.K)
- Boiling point: 336 K
- Enthalpy of vaporization: 25 900 J/mol

$T_F < T_L$



Energy balance to the feed plate

$$\boxed{F\, c_p^{líq}\, \Delta T = n_V \lambda_m}$$

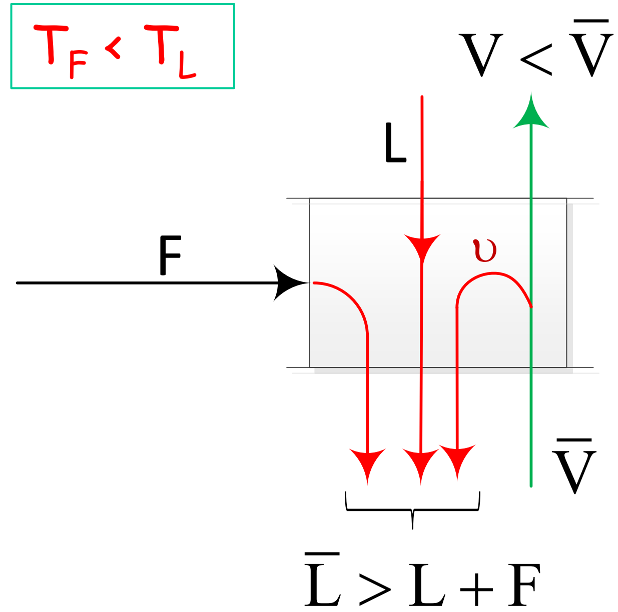
$$n_V = \frac{c_p^{líq}\, \Delta T}{\lambda_m} F$$

③ Operating line of feed

$$y_i = \frac{i}{i-1}x_i - \frac{x_F}{i-1}$$

$$i = \frac{\bar{L} - L}{F}$$

$T_F < T_L$



- Temperature: 290K
- Specific heat: 225.4 J/(mol.K)
- Boiling point: 336 K
- Enthalpy of vaporization: 25 900 J/mol

$$n_V = \frac{c_p^{líq}\,\Delta T}{\lambda_m}F$$

$$\Rightarrow \quad n_V = \frac{225.4\,Jmol^{-1}K^{-1} \times (336K - 290K)}{25900Jmol^{-1}}F$$

$$\Rightarrow \quad n_V = 0.4F$$

③ Operating line of feed

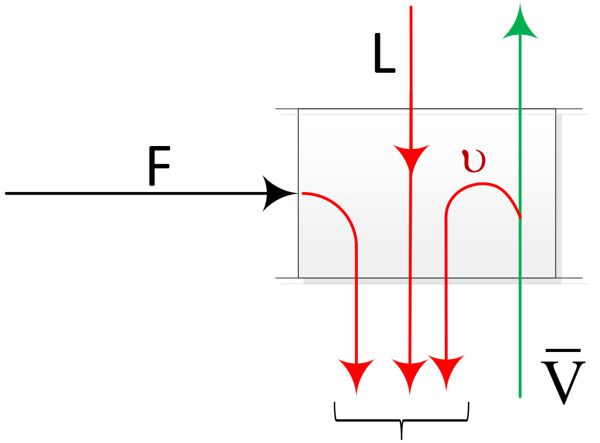
$$y_i = \frac{i}{i-1}x_i - \frac{x_F}{i-1}$$

$$i = \frac{\bar{L} - L}{F}$$

- Temperature: 290K
- Specific heat: 225.4 J/(mol.K)
- Boiling point: 336 K
- Enthalpy of vaporization: 25 900 J/mol

$T_F < T_L$

$V < \bar{V}$



$\bar{L} > L + F$

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

$$\upsilon = 0.4F$$

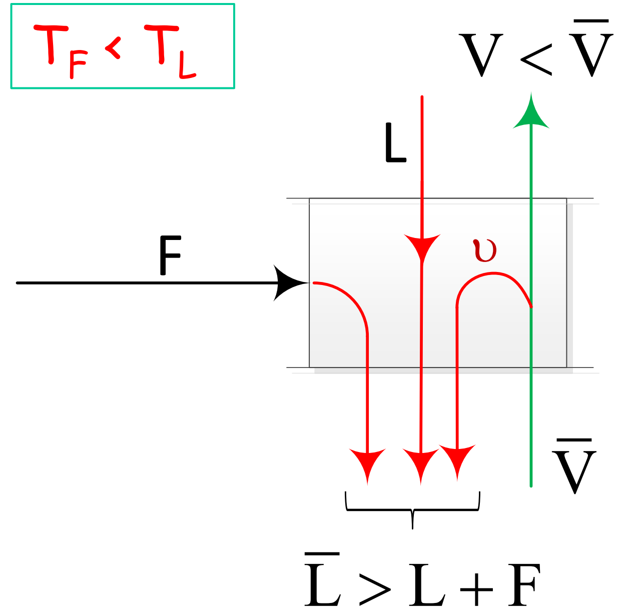
$$\Rightarrow \quad i = \frac{(L + F + 0.4F) - L}{F} = 1.4$$

③ Operating line of feed

$$y_i = \frac{i}{i-1}x_i - \frac{x_F}{i-1}$$

$$i = \frac{\bar{L} - L}{F}$$

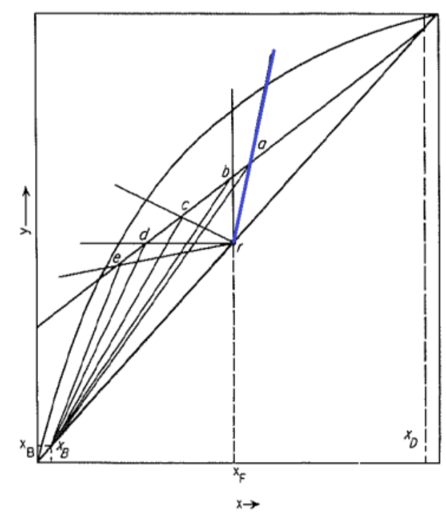
- Temperature: 290K
- Specific heat: 225.4 J/(mol.K)
- Boiling point: 336 K
- Enthalpy of vaporization: 25 900 J/mol



Subcooled liquid!

$i = 1.4$

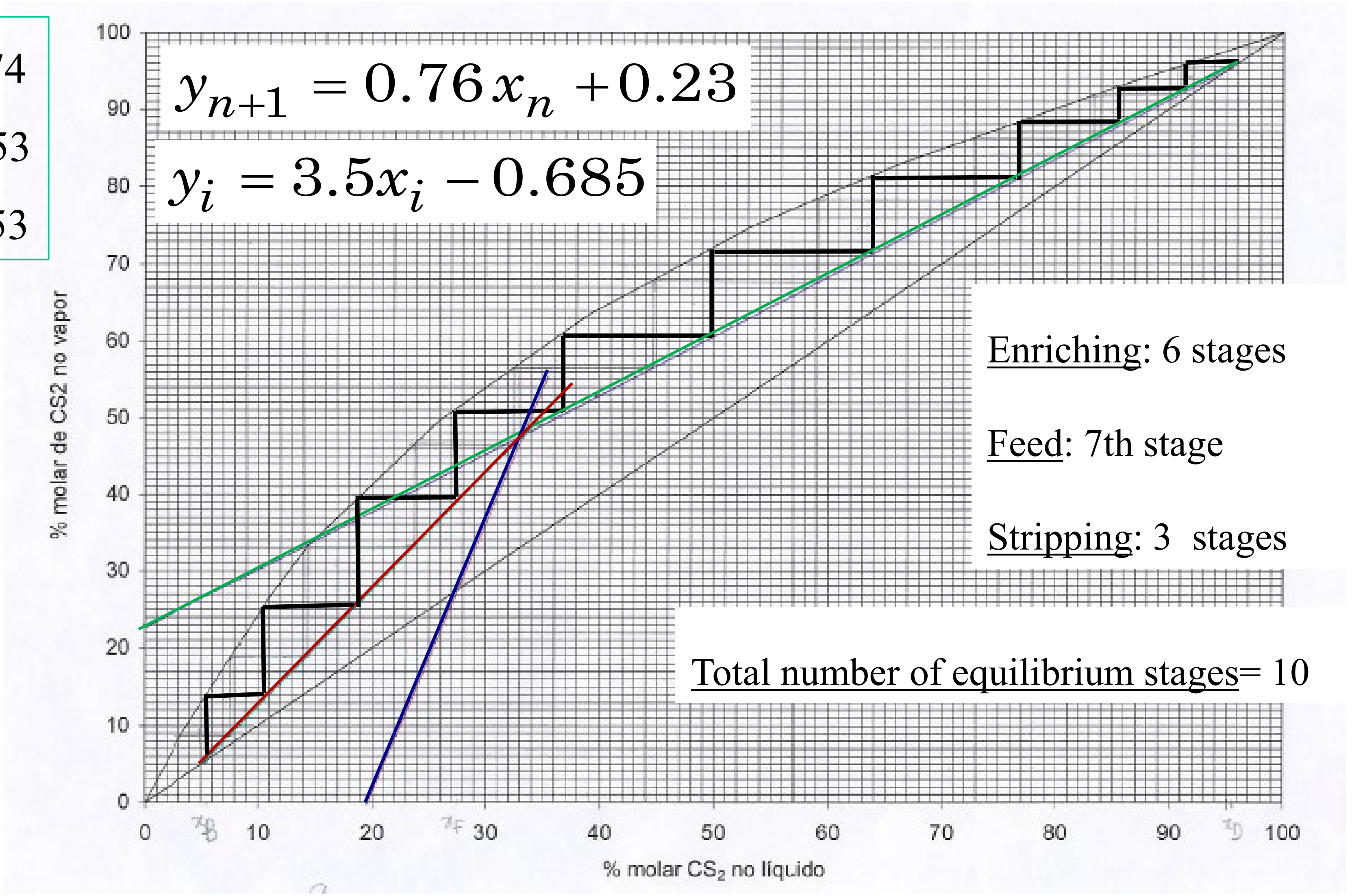
$$\boxed{y_i = 3.5x_i - 0.685}$$



e.g.: $y_i = 0 \Rightarrow x_i = 0.196$

Number of equilibrium stages

- $x_F = 0.274$
- $x_D = 0.953$
- $x_B = 0.053$

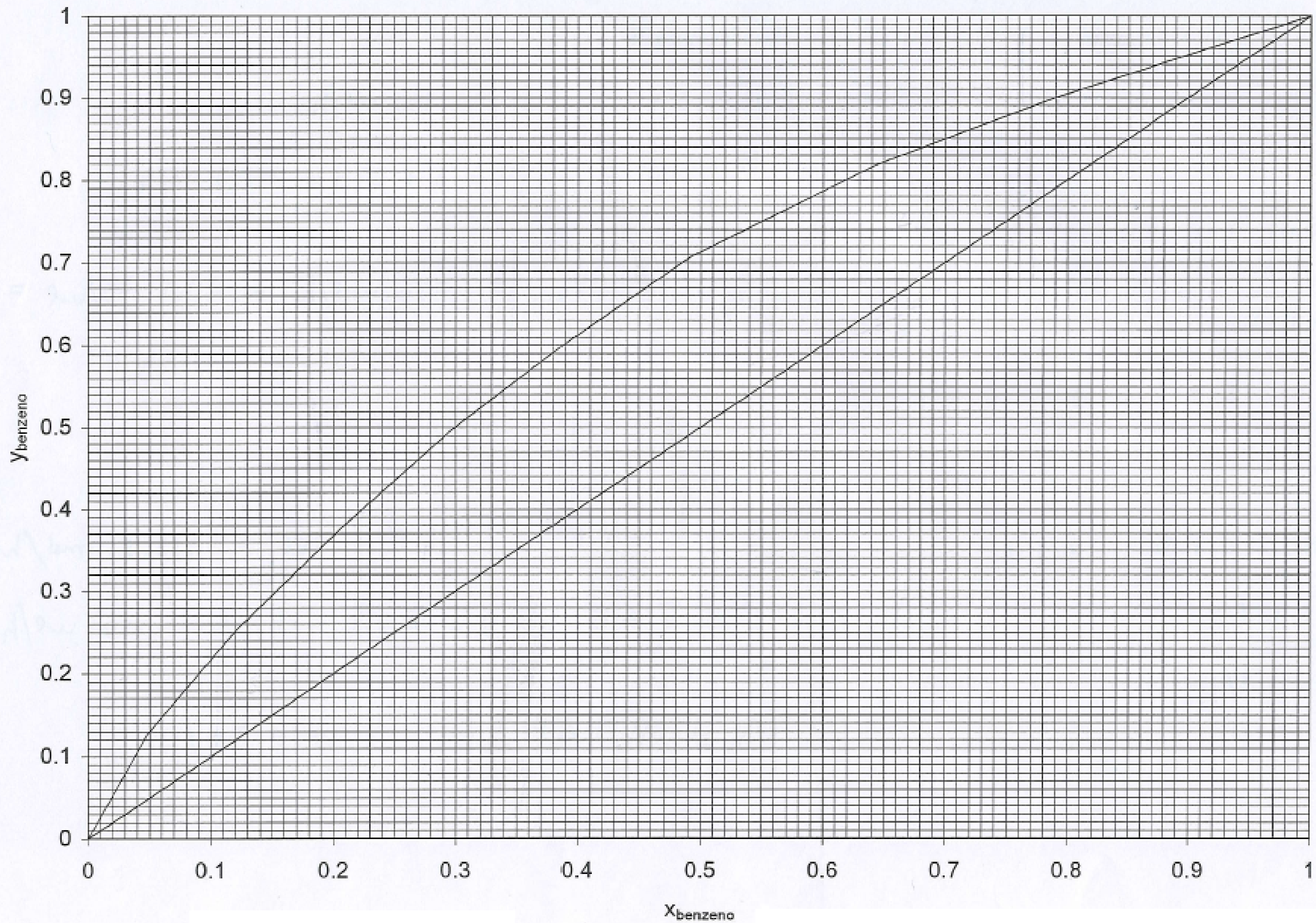


Problema 3

It is intended to separate a mixture of benzene and toluene, which contains 40% benzene, to give a distillate with 90% in benzene and a residue with 10% in benzene. The feed is heated to the boiling temperature before entering the column. The column is operated with a reflux ratio of 2.2 times greater than the minimum.

a) Determine the number of theoretical plates required.

b) What is the optimal stage for the feed inlet?



1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
$y_{benzeno}$
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
$x_{benzeno}$

It is intended to separate a mixture of benzene and toluene, which contains 40% benzene, to give a distillate with 90% in benzene and a residue with 10% in benzene. The feed is heated to the boiling temperature before entering the column. The column is operated with a reflux ratio of 2.2 times greater than the minimum.

$$\boxed{R = L/D}$$

$$\boxed{i = \frac{\bar{L} - L}{F}}$$

- $x_F = 0.4$
- $x_D = 0.9$
- $x_B = 0.1$
- $R = 2.2 \times R_{min}$

① Feed operating line

$$\boxed{y_i = \frac{i}{i-1} x_i - \frac{x_F}{i-1}}$$

② Enriching Operating line

$$\boxed{y_{n+1} = \frac{R}{R+1} x_n + \frac{x_D}{R+1}}$$

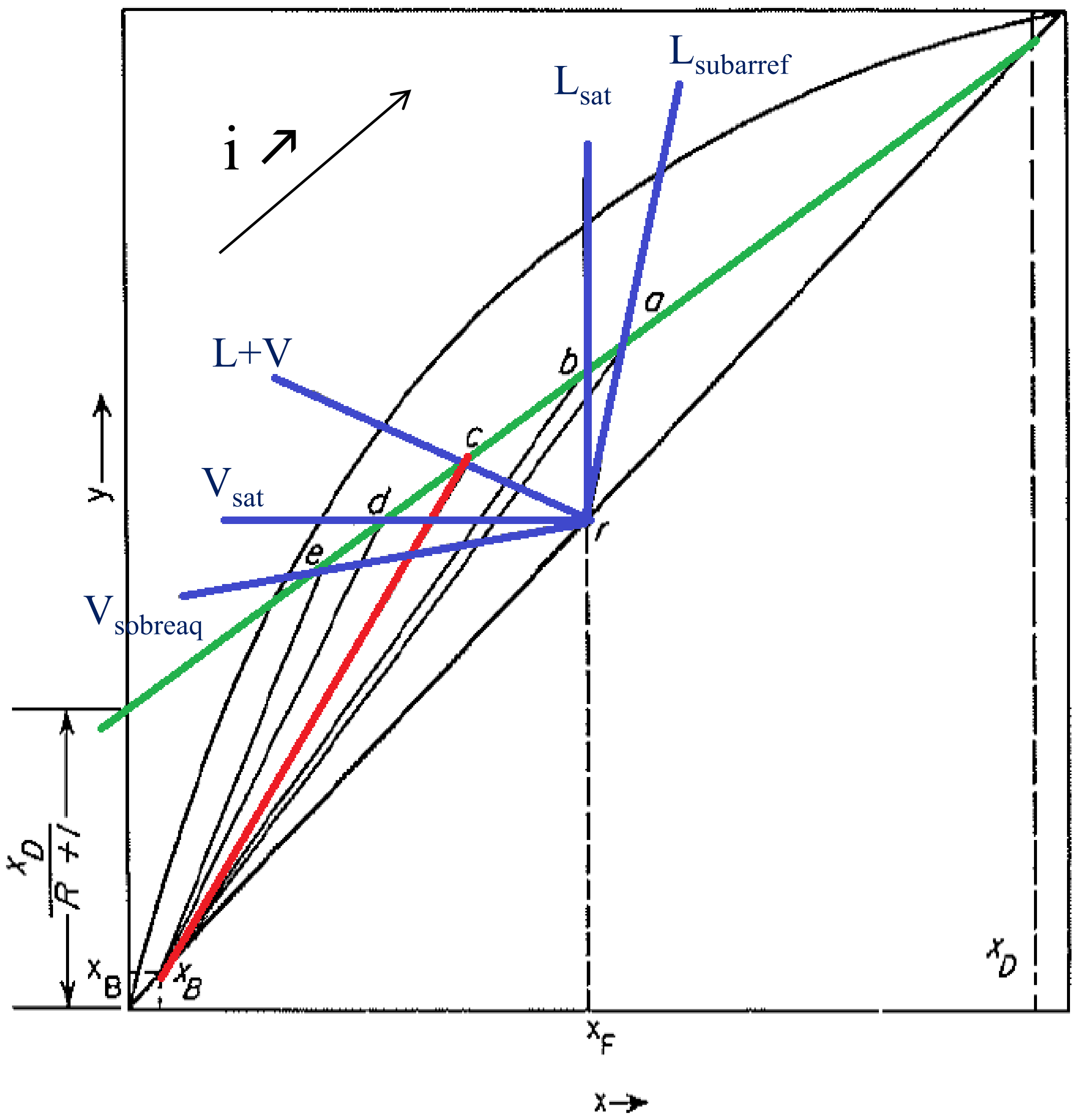
Feed OL

$$i = \frac{\bar{L} - L}{F}$$

$$y_i = \frac{i}{i-1} x_i - \frac{x_F}{i-1}$$

The feed is heated to the boiling temperature before entering the column

$i = \frac{\bar{L} - L}{F}$	i	$\frac{i}{i-1}$
a) Subcooled liquid	i > 1	> 0
b) Saturated liquid	i = 1	∞
c) L+V	0 < i < 1	< 0
d) Saturated vapor	i = 0	0
e) Superheated vapor	i < 0	> 0



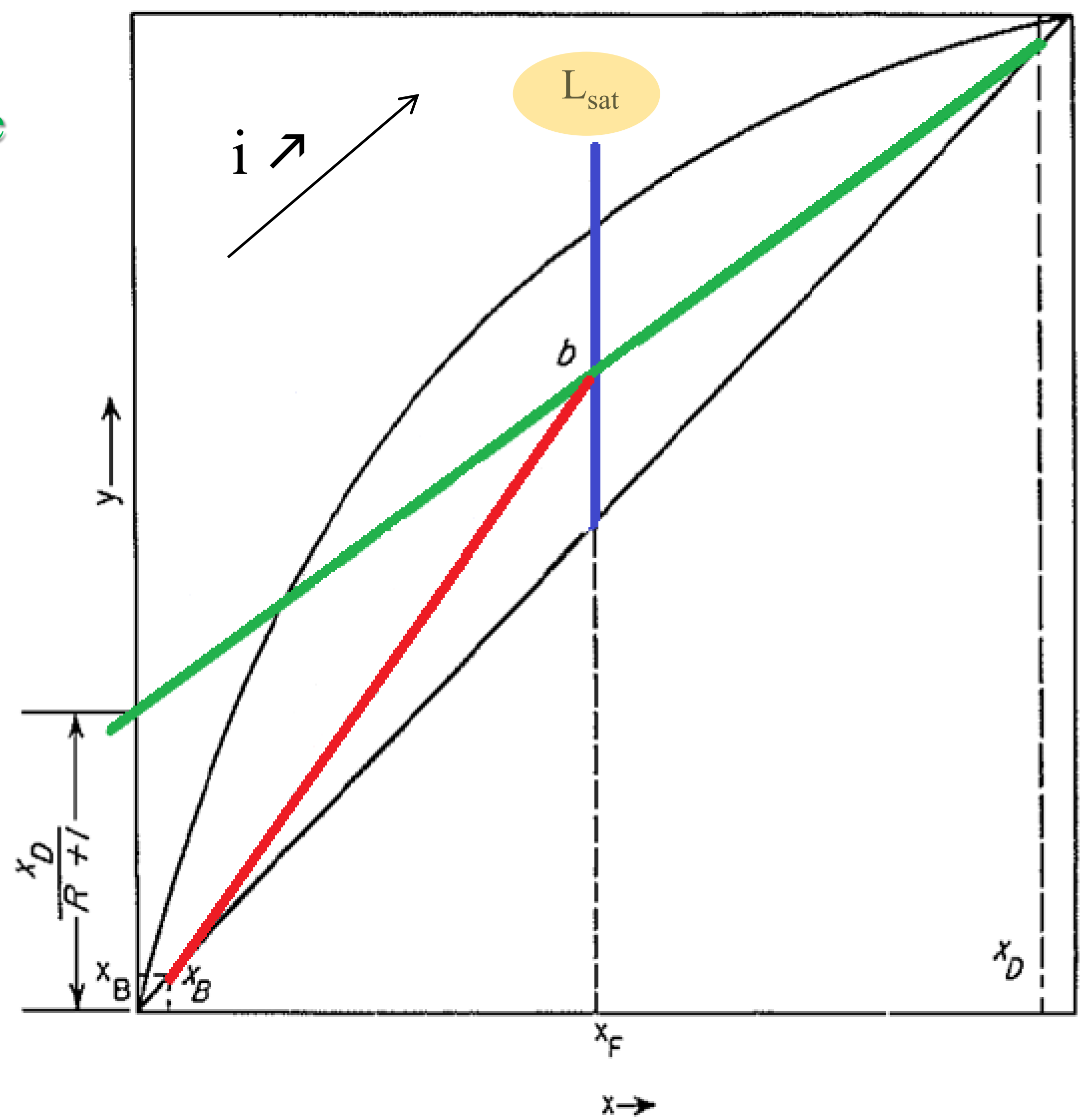
Feed OL

$$i = \frac{\bar{L} - L}{F}$$

$$y_i = \frac{i}{i-1} x_i - \frac{x_F}{i-1}$$

The feed is heated to the boiling temperature before entering the column

Saturated Liquid!



$$i = \frac{\bar{L} - L}{F}$$

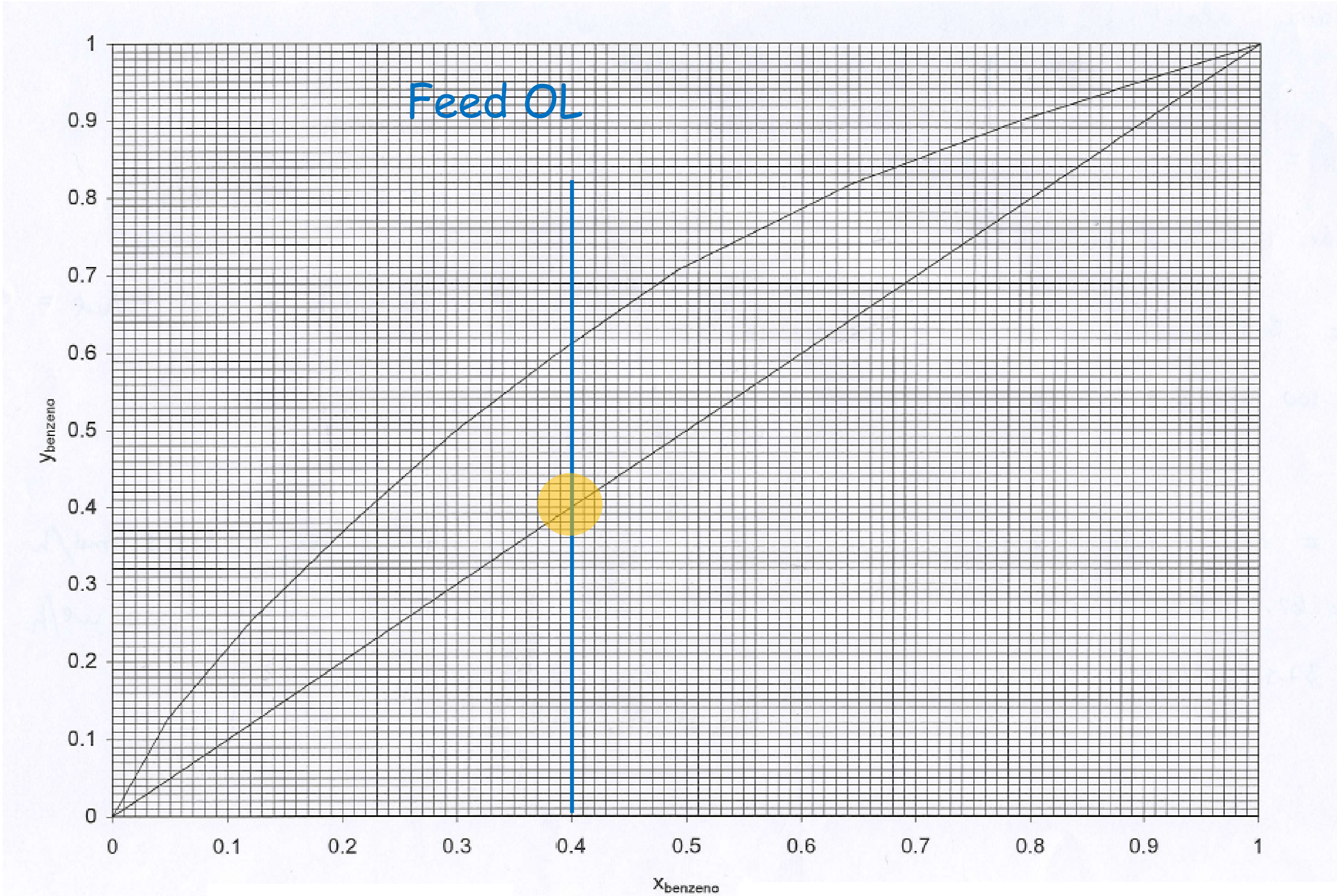
	i	$\frac{i}{i-1}$
a) Subcooled liquid	i > 1	> 0
b) Saturated liquid	i = 1	∞
c) L+V	0 < i < 1	< 0
d) Saturated vapor	i = 0	0
e) Superheated vapor	i < 0	> 0

Feed OL

$$i = \frac{\bar{L} - L}{F}$$

$$y_i = \frac{i}{i-1} x_i - \frac{x_F}{i-1}$$

- $x_F = 0.4$
- $x_D = 0.9$
- $x_B = 0.1$
- $i = 1$

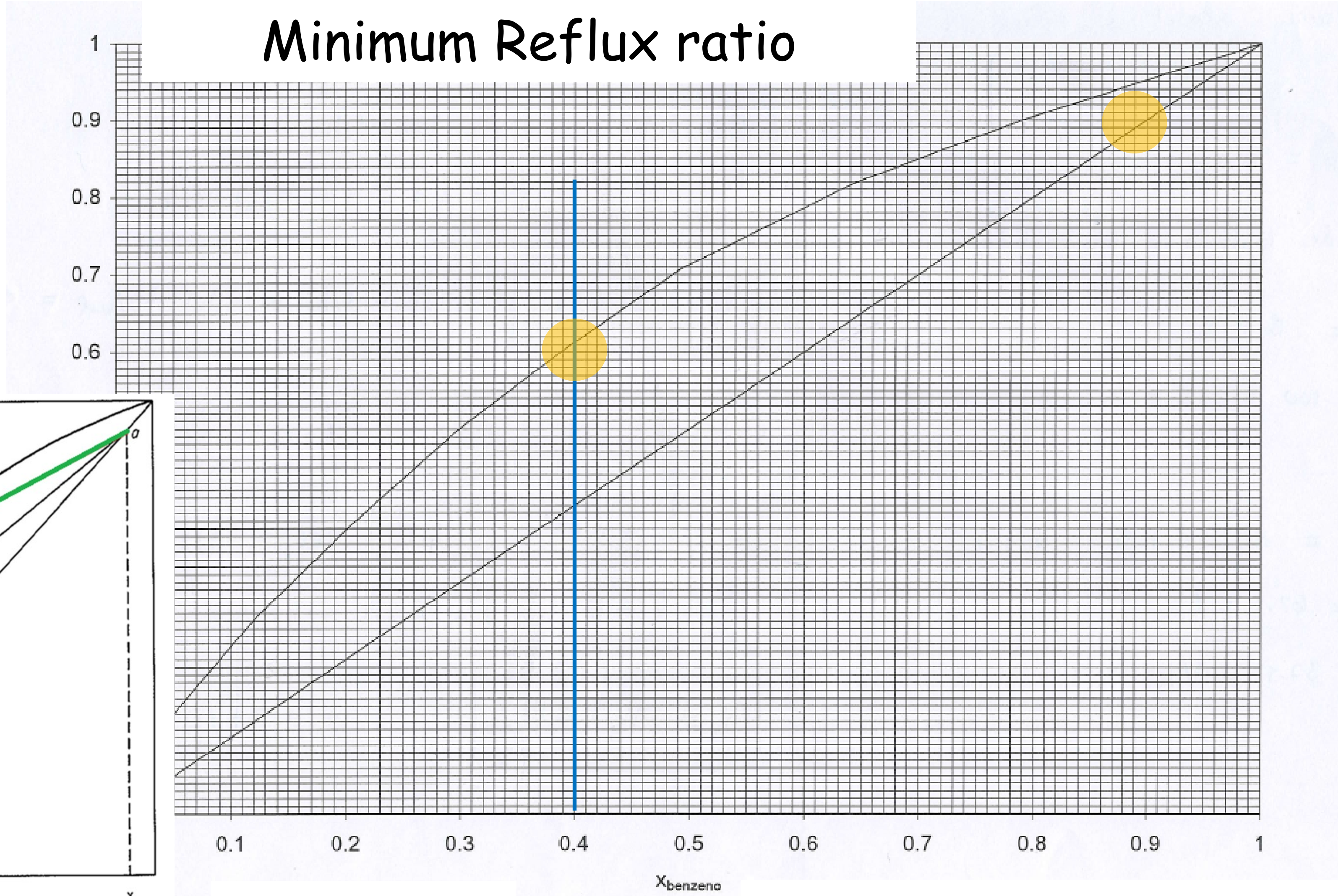


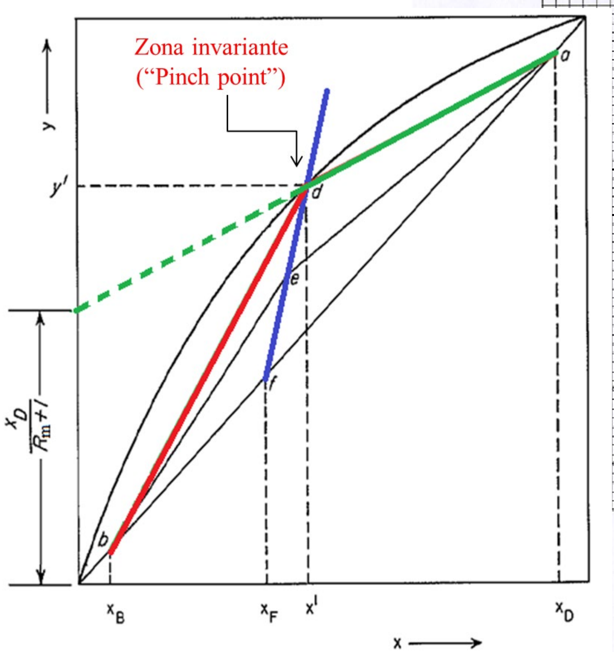
Enriching OL

$$y_{n+1} = \frac{R}{R+1} x_n + \frac{x_D}{R+1}$$

- $x_F = 0.4$
- $x_D = 0.9$
- $x_B = 0.1$
- $i = 1$

Minimum Reflux ratio



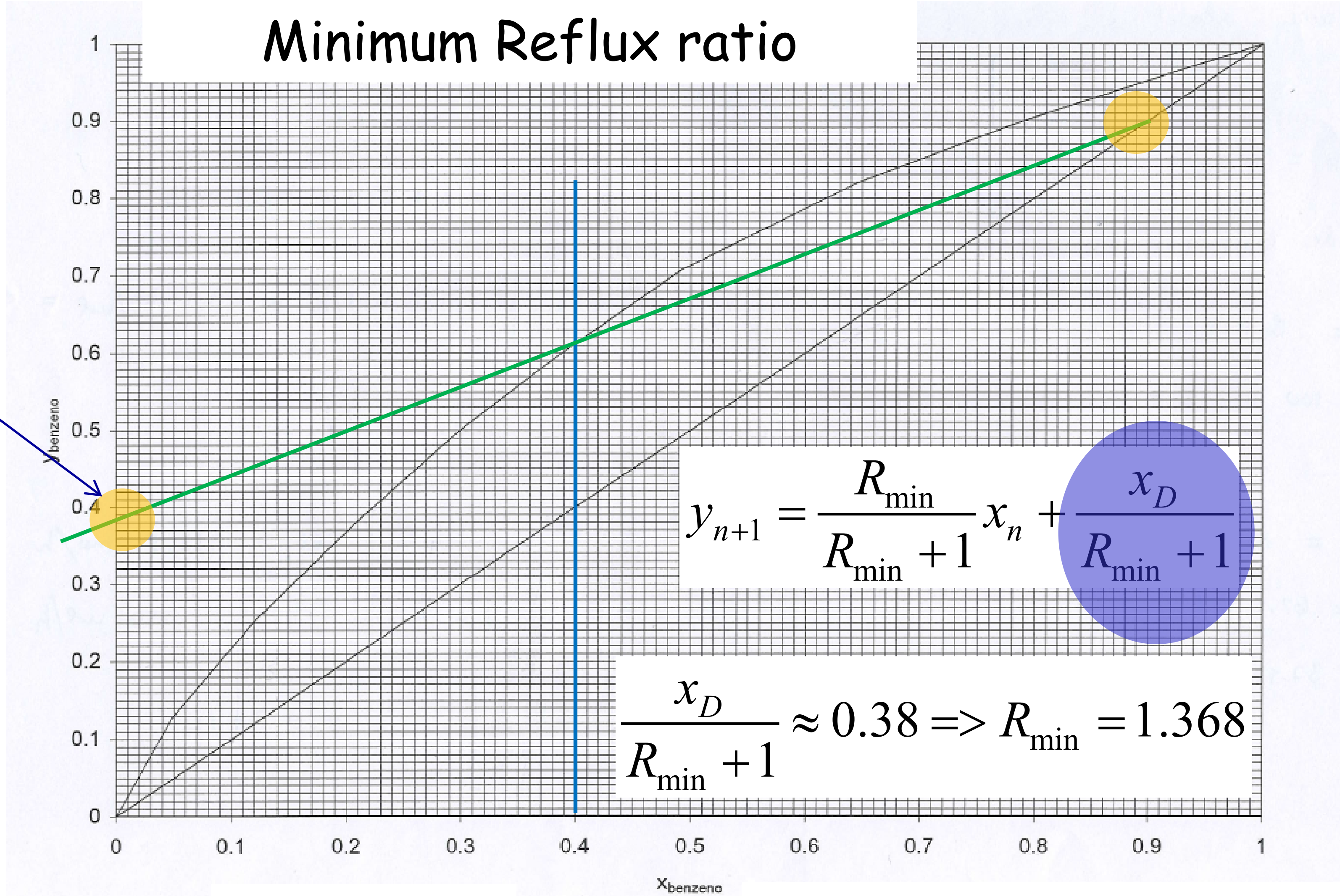


Enriching OL

$$y_{n+1} = \frac{R}{R+1} x_n + \frac{x_D}{R+1}$$

- $x_F = 0.4$
- $x_D = 0.9$
- $x_B = 0.1$
- $i = 1$

Minimum Reflux ratio



$$y_{n+1} = \frac{R_{\min}}{R_{\min}+1} x_n + \frac{x_D}{R_{\min}+1}$$

$$\frac{x_D}{R_{\min}+1} \approx 0.38 \Rightarrow R_{\min} = 1.368$$

Enriching OL

$$\boxed{y_{n+1} = \frac{R}{R+1} x_n + \frac{x_D}{R+1}}$$

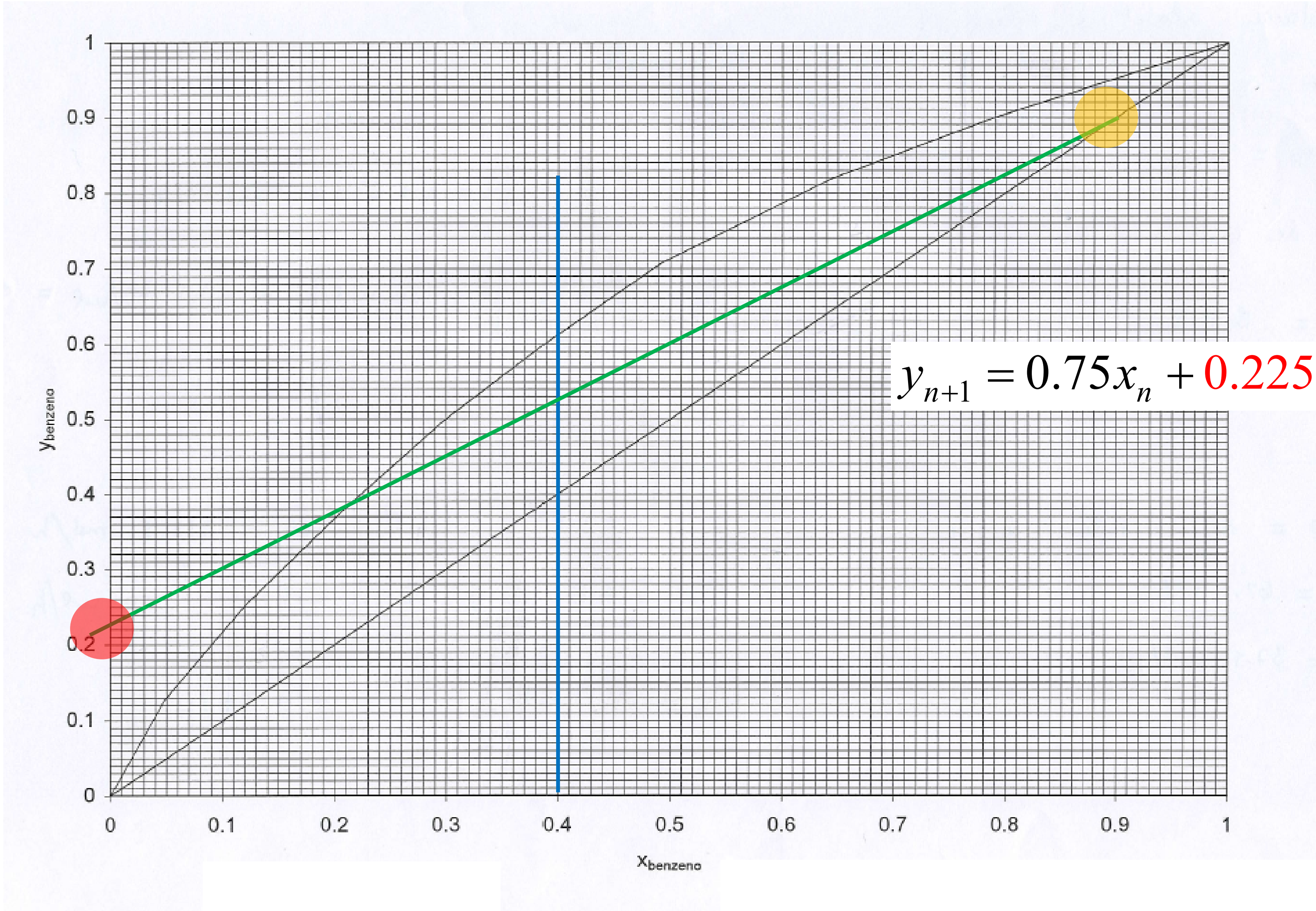
$R_{\min} = 1.368$ => $R = 2.2 \times R_{\min} = 3$

$$\Rightarrow \quad \boxed{y_{n+1} = 0.75 x_n + 0.225}$$

Enriching OL

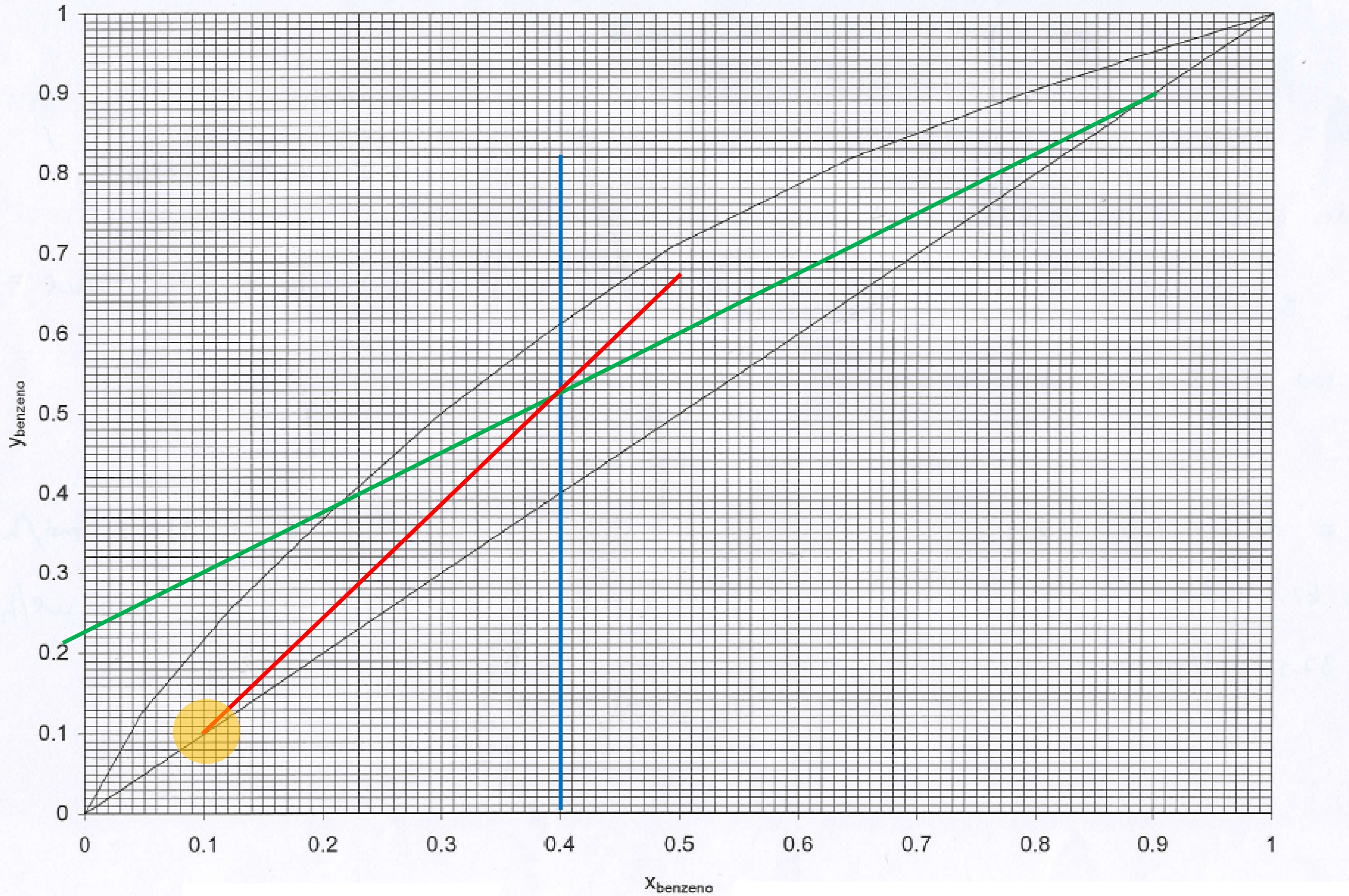
$$y_{n+1} = \frac{R}{R+1} x_n + \frac{x_D}{R+1}$$

- $x_F = 0.4$
- $x_D = 0.9$
- $x_B = 0.1$
- $i = 1$



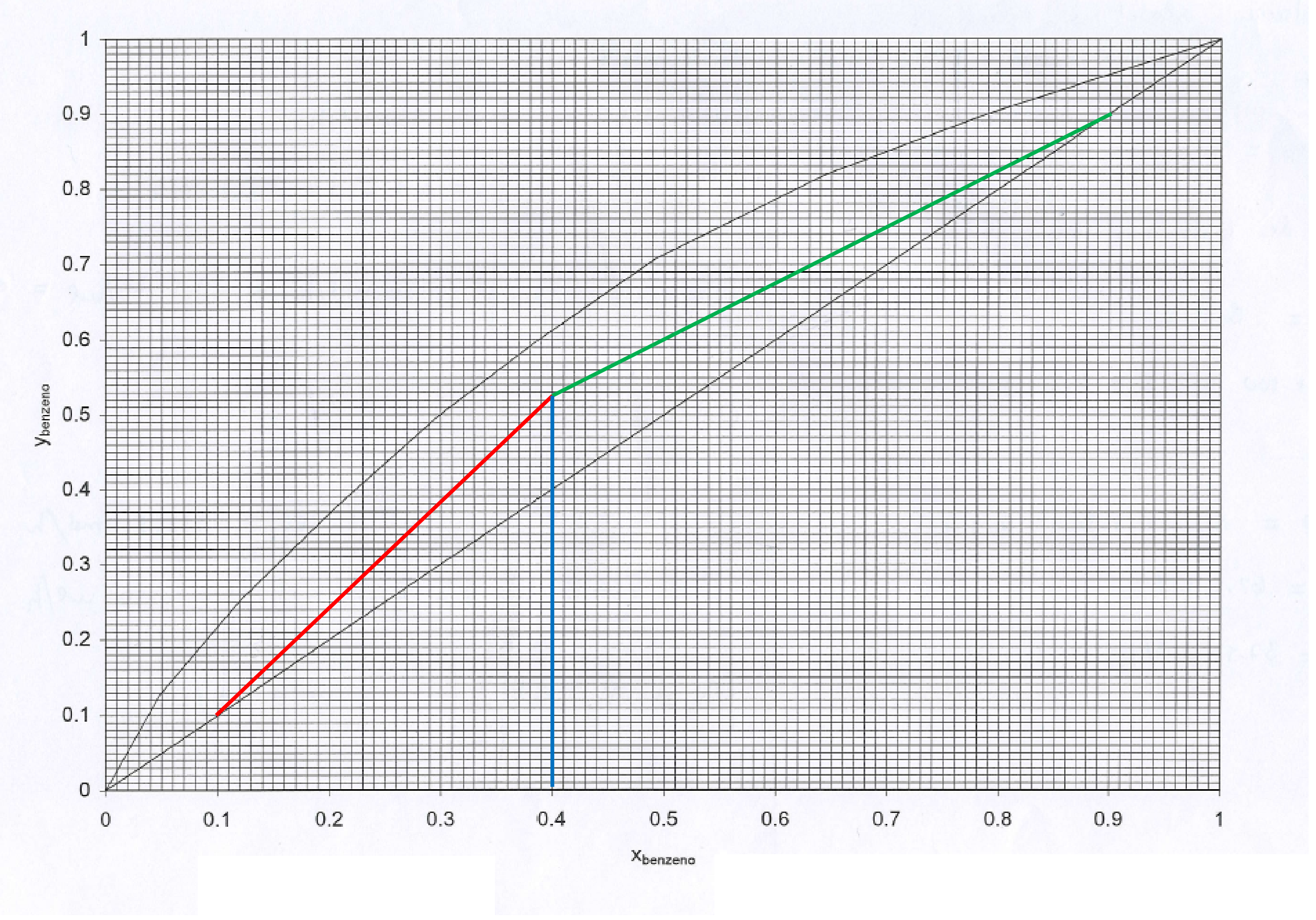
Stripping OL

- $x_F = 0.4$
- $x_D = 0.9$
- $x_B = 0.1$
- $i = 1$

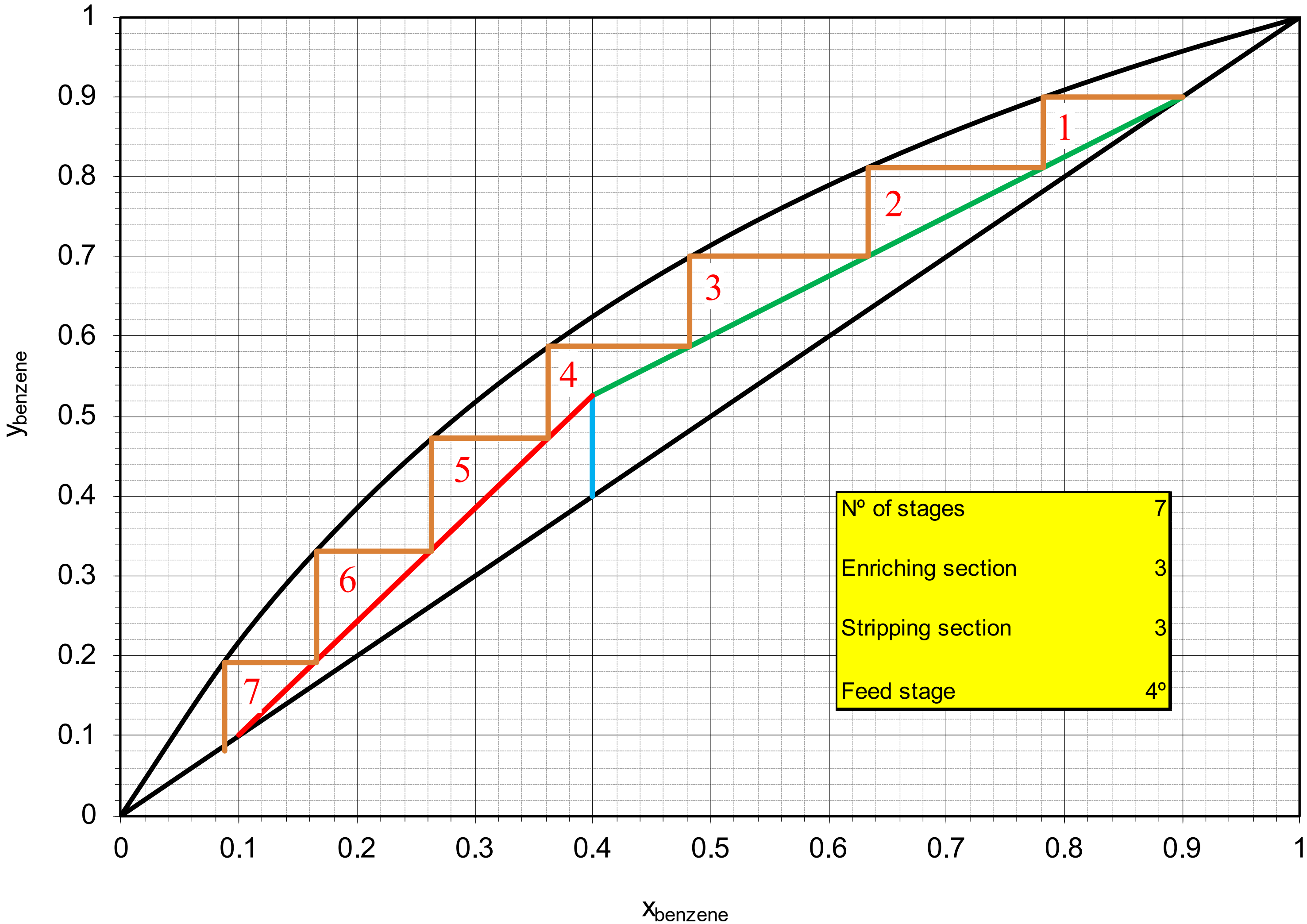


Calculate the number of equilibrium stages...

- $x_F = 0.4$
- $x_D = 0.9$
- $x_B = 0.1$
- $i = 1$



- $x_F = 0.4$
- $x_D = 0.9$
- $x_B = 0.1$
- $i = 1$



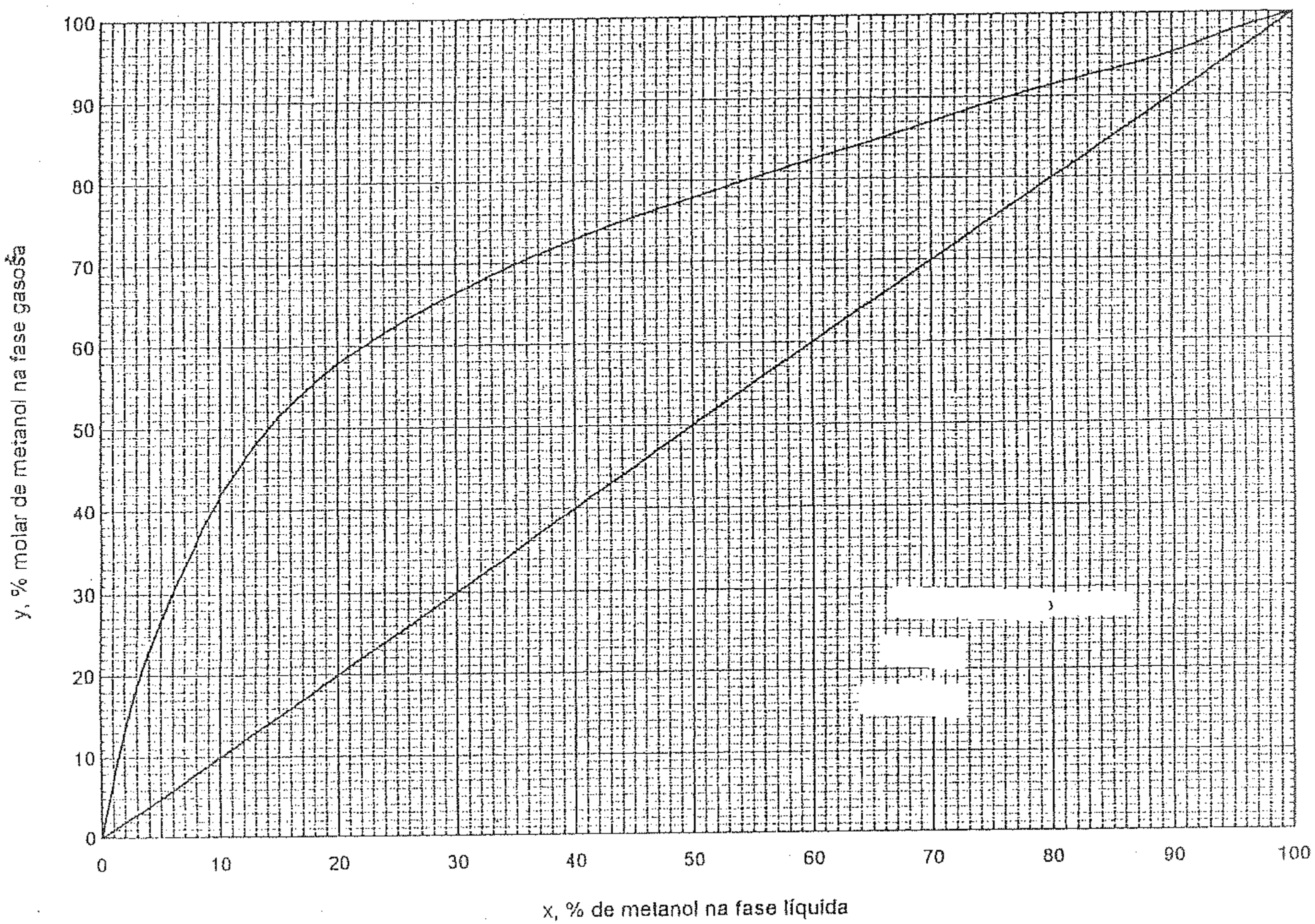
Problem 4

It is intended to distillate a batch of a methanol / water mixture having a molar percentage of methanol equal to 49%. The boiler is charged with 200 moles of the mixture and the distillation column has 3 theoretical plates and a total condenser. The system is operated with a constant reflux ratio equal to 0.64. At the end of the process, it remains in the boiler 106.6 moles of residue with a composition of 18 mol% in methanol. Calculate:

(a) the composition of the distillate obtained at the beginning

b) The composition of the distillate at the end of the process

Diagrama de equilíbrio
Sistema metanol/água



Multistage batch distillation

F = 200 mol

$x_F = 49\%$

$N = 3 + 1 = 4$

$R = 0.64$

$B_{final} = 107$ moles

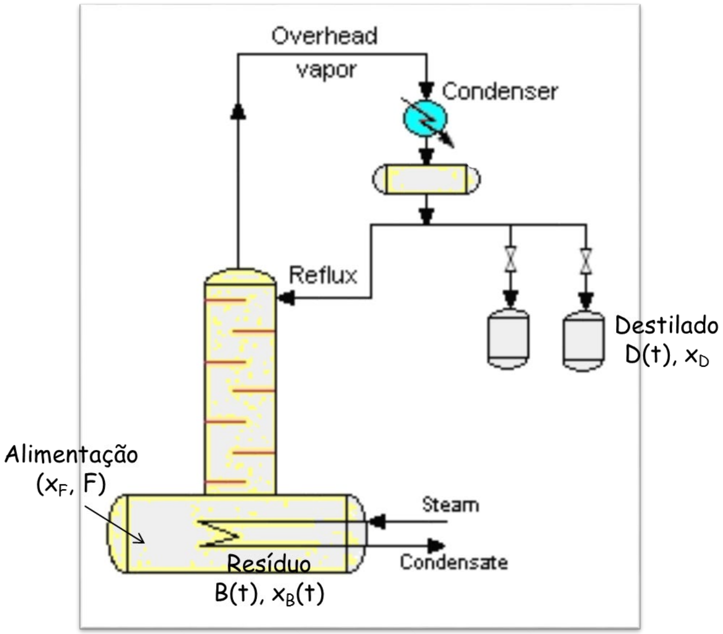
$x_{B,final} = 18\%$

Constant reflux ratio

x_F, $x_{B,final}$ and R known

Calculate:

1) $x_{D\ inicial}$
2) $x_{D\ final}$



$$y_{n+1} = \frac{R}{R+1} x_n + \frac{x_D}{R+1}$$

$$R = \frac{L(t)}{D(t)}$$

It is determined by adjusting the operating line along the process to have ALWAYS 4 stages between $x_{B,t}$ and $x_{D,t}$

☛ Disadvantage: x_D decreases with time

$x_F = 49\%$ $N = 4$ $F = 200$ moles

$x_{B,final} = 18\%$ $R = 0.64$ $B_{final} = 107$ moles

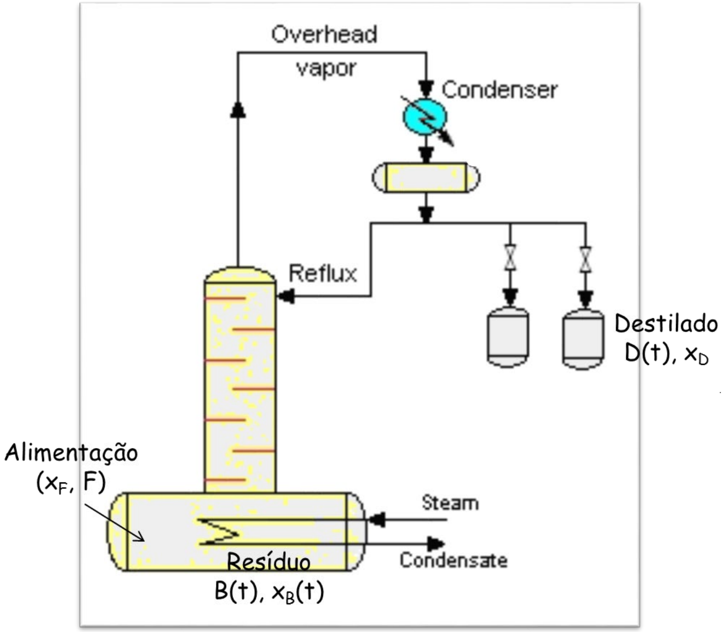
$$y_{n+1} = \frac{R}{R+1} x_n + \frac{x_D}{R+1}$$

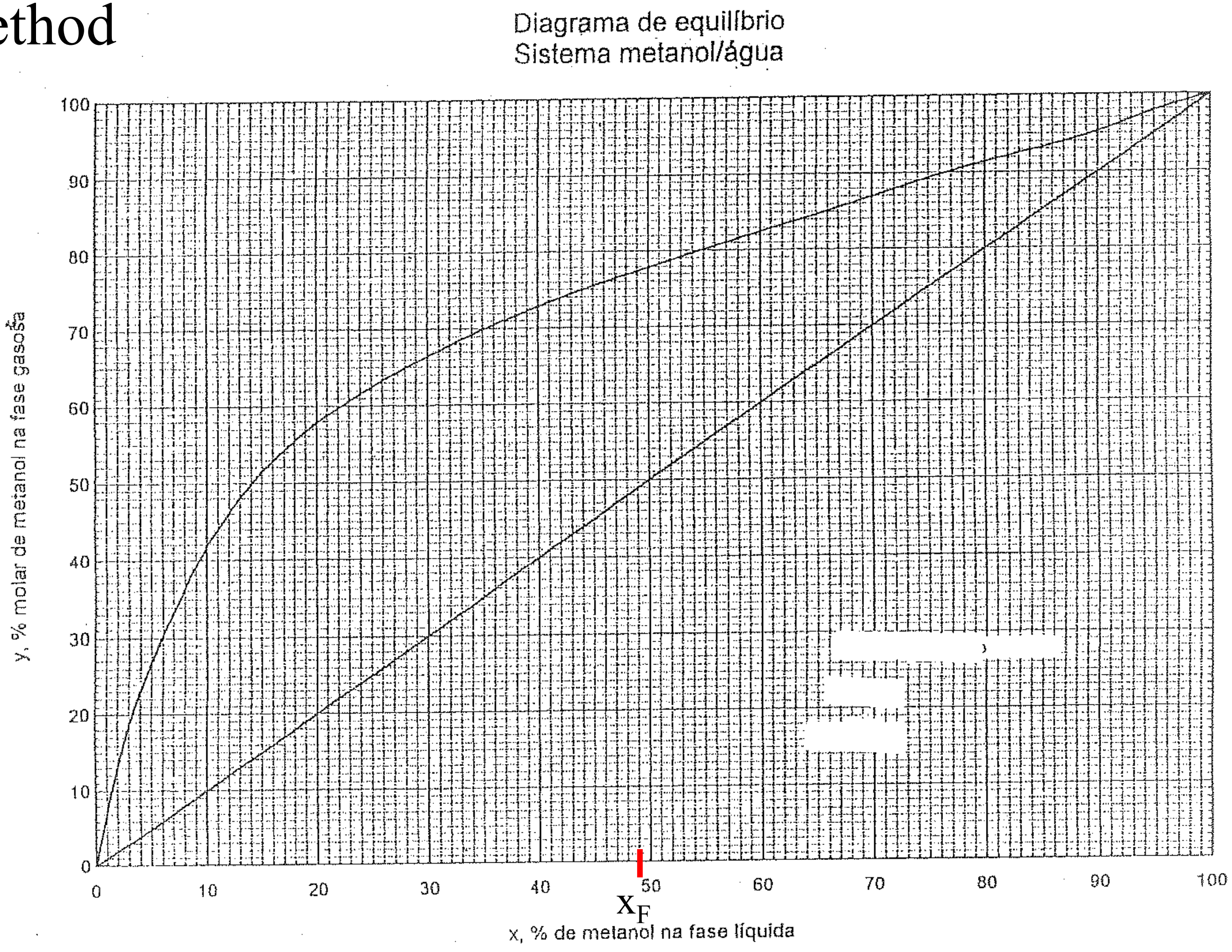
Iterative method

1) $x_{D\ inicial}$

If $x_D = 80\%$ =>

$$\frac{x_D}{R+1} = 49\%$$





$x_F = 49\%$ $\quad N = 4$ $\quad F = 200$ moles

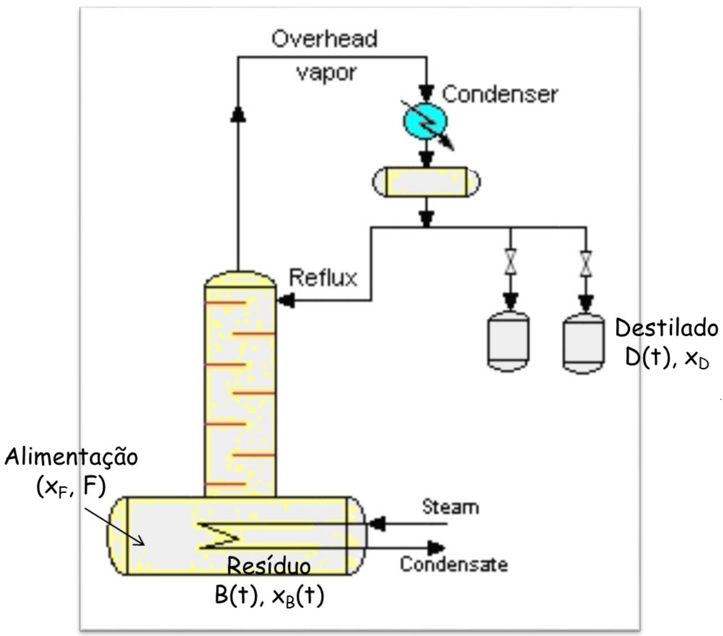
$x_{B,final} = 18\%$ $\quad R = 0.64$ $\quad B_{final} = 107$ moles

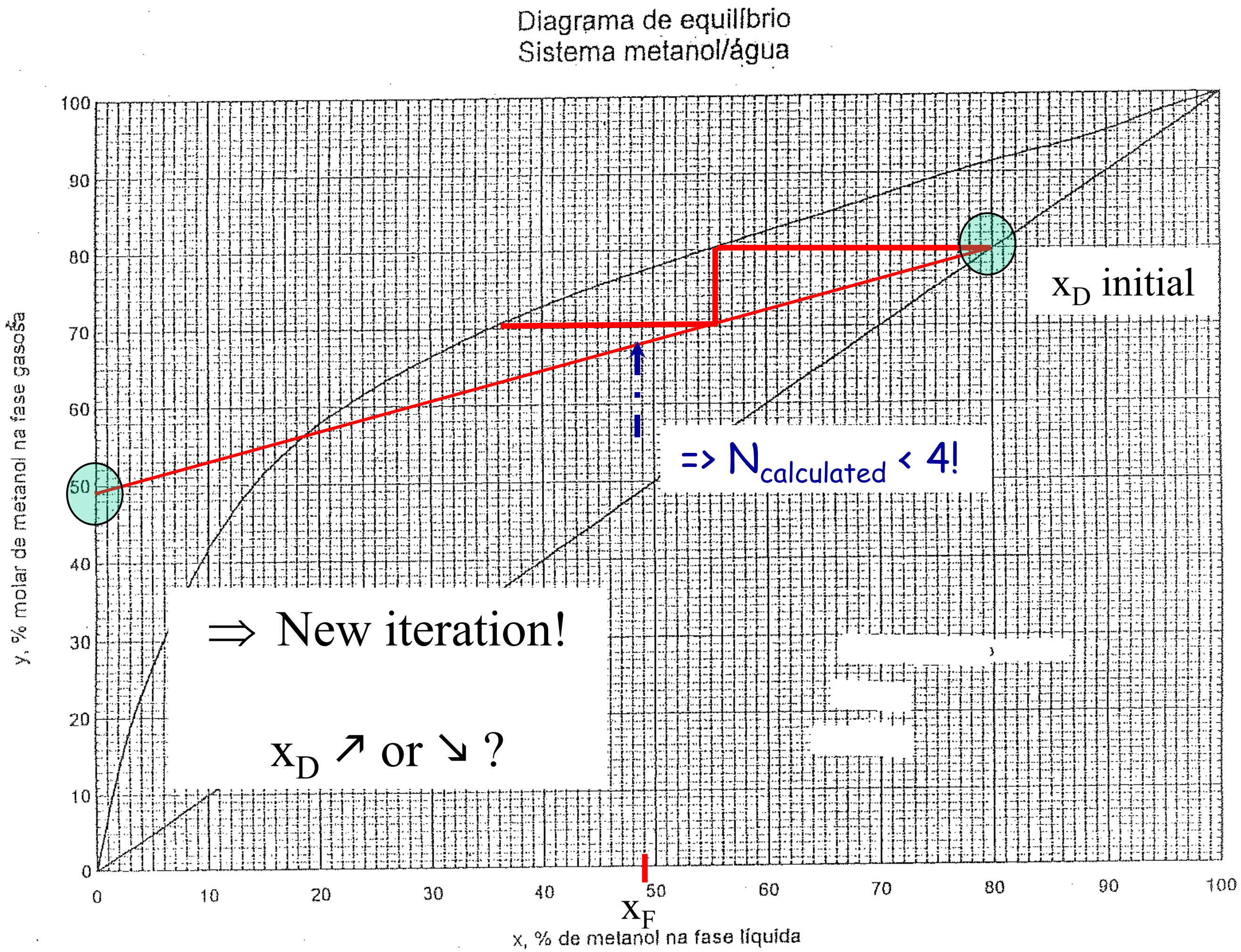
$$y_{n+1} = \frac{R}{R+1} x_n + \frac{x_D}{R+1}$$

1) x_{D} inicial

If $x_D = 80\%$ =>

$$\frac{x_D}{R+1} = 49\%$$





$x_F = 49\%$ $N = 4$ $F = 200$ moles

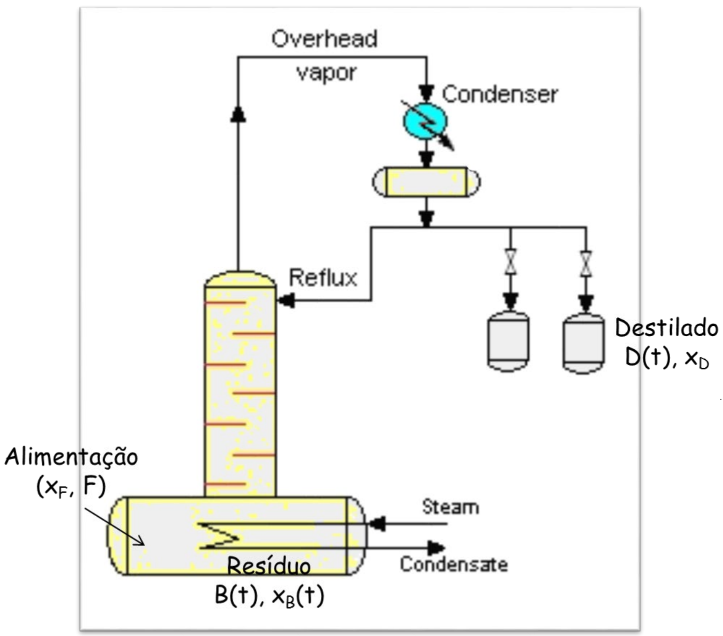
$x_{B,final} = 18\%$ $R = 0.64$ $B_{final} = 107$ moles

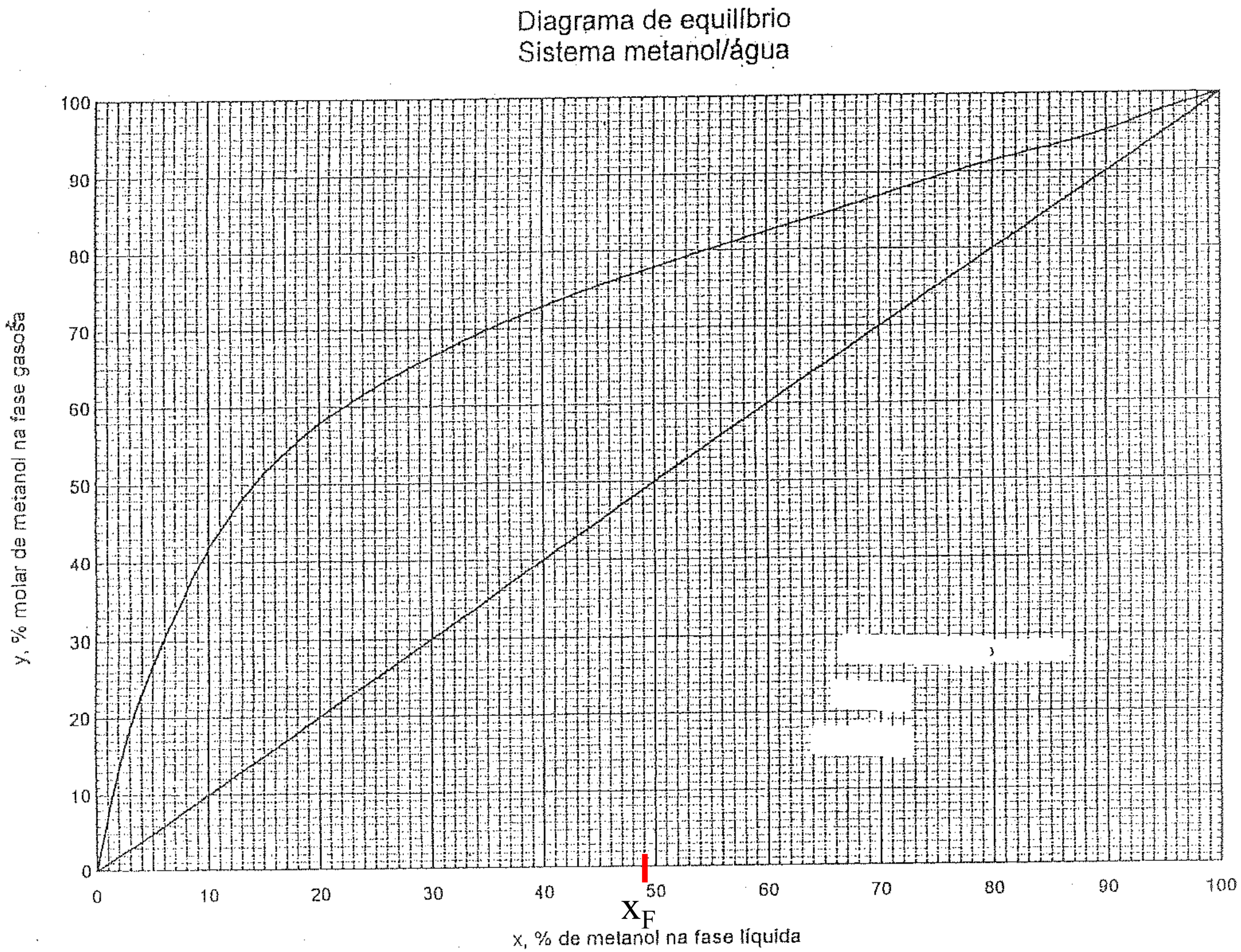
$$y_{n+1} = \frac{R}{R+1} x_n + \frac{x_D}{R+1}$$

1) $x_{D\ inicial}$

If $x_D = 90\% \Rightarrow$

$$\frac{x_D}{R+1} = 55\%$$





$x_F = 49\%$ $N = 4$ $F = 200$ moles

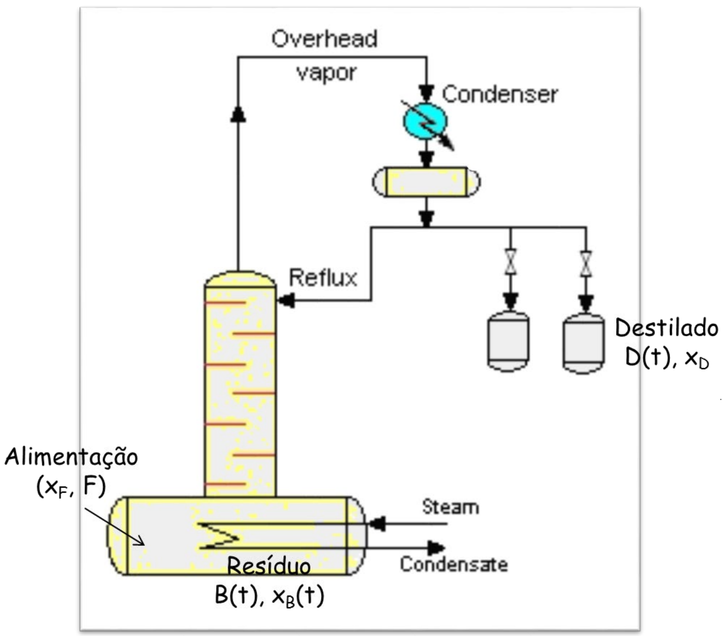
$x_{B,final} = 18\%$ $R = 0.64$ $B_{final} = 107$ moles

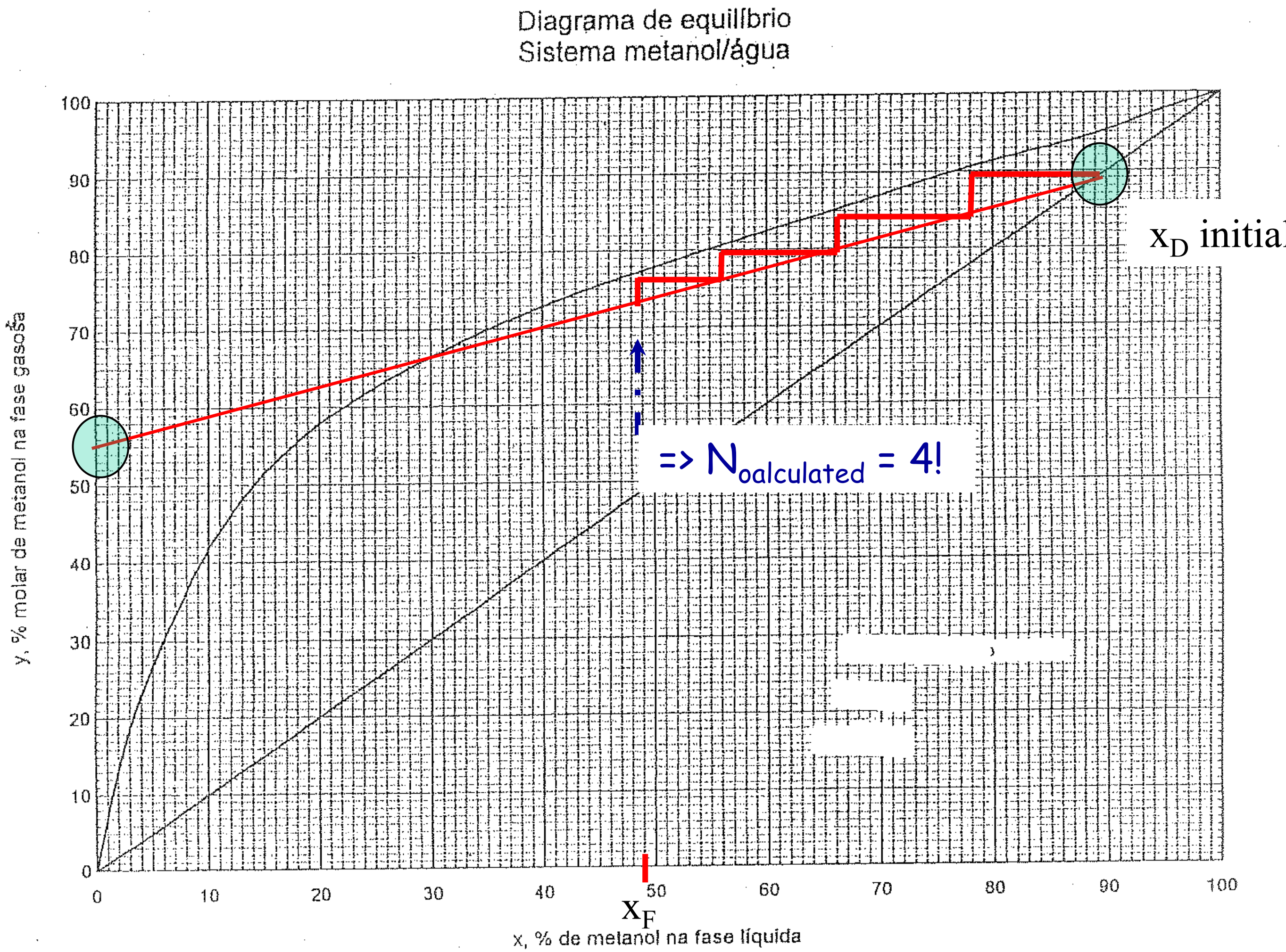
$$y_{n+1} = \frac{R}{R+1} x_n + \frac{x_D}{R+1}$$

1) $x_{D\ inicial}$

If $x_D = 90\% \Rightarrow$

$$\frac{x_D}{R+1} = 55\%$$





$x_F = 49\%$ $N = 4$ $F = 200$ moles

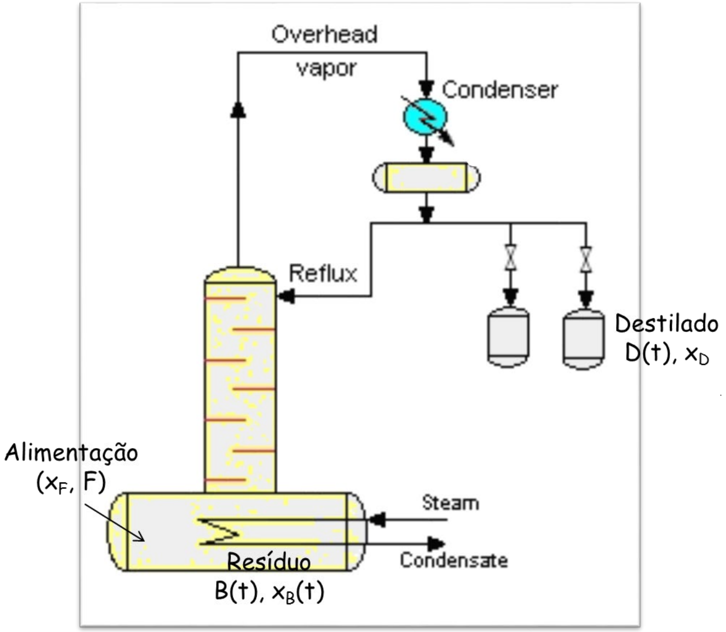
$x_{B,final} = 18\%$ $R = 0.64$ $B_{final} = 107$ moles

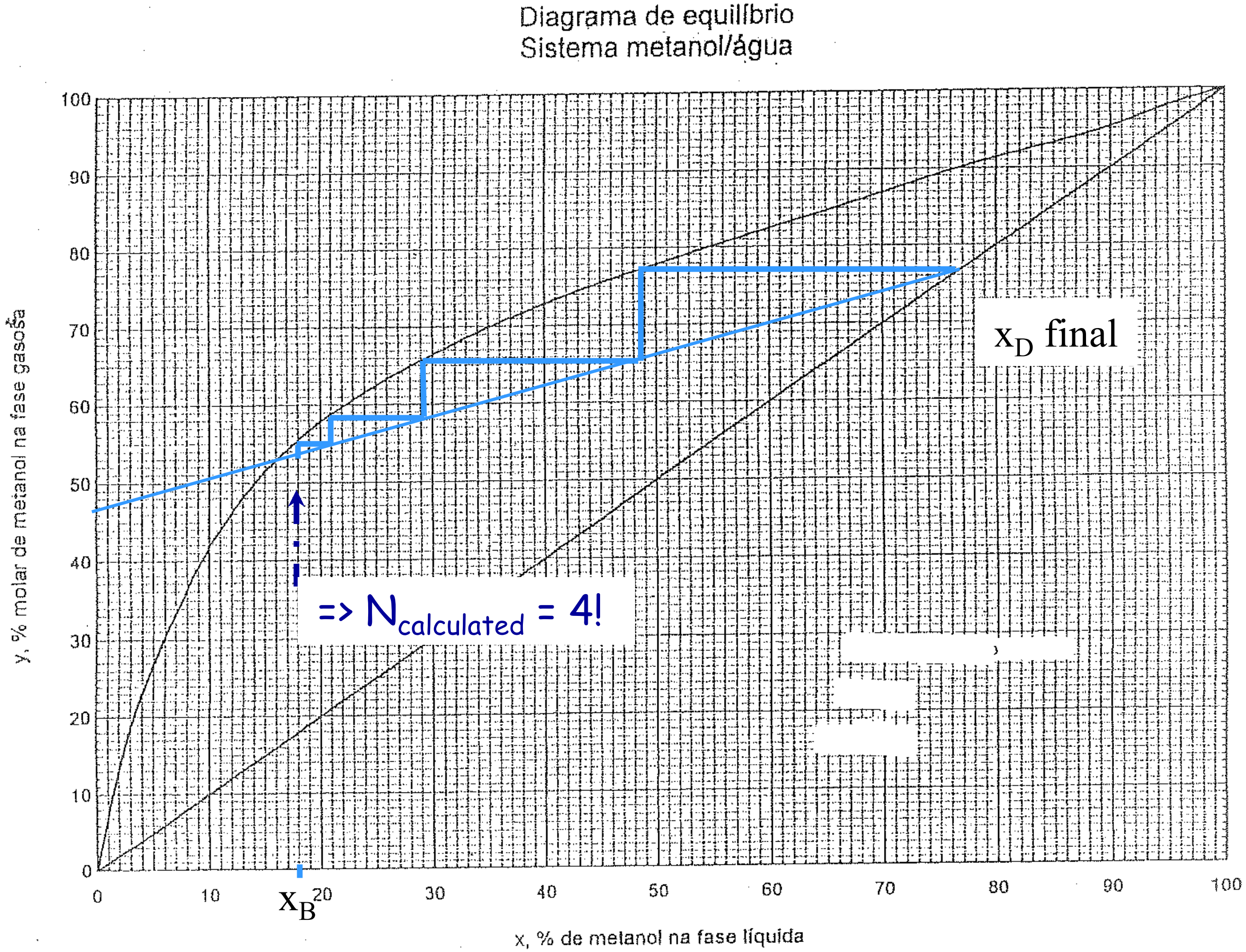
$$y_{n+1} = \frac{R}{R+1} x_n + \frac{x_D}{R+1}$$

2) $x_{D\ final}$

If $x_D = 77\%$ =>

$$\frac{x_D}{R+1} = 47\%$$





Problem 5

Considering the previous problem, now assume that the column will be operated by varying the reflux ratio (from $R_{initial} = 0.64$ to $R_{final} = 3.2$) to obtain a constant distillate composition ($x_D = 0.9$). Determine the final composition of the residue and the amount of distillate obtained in these conditions..

Multistage batch distillation

F = 200 mol

$x_F = 49\%$

N = 3+1 = 4

R = 0.64 a 3.2

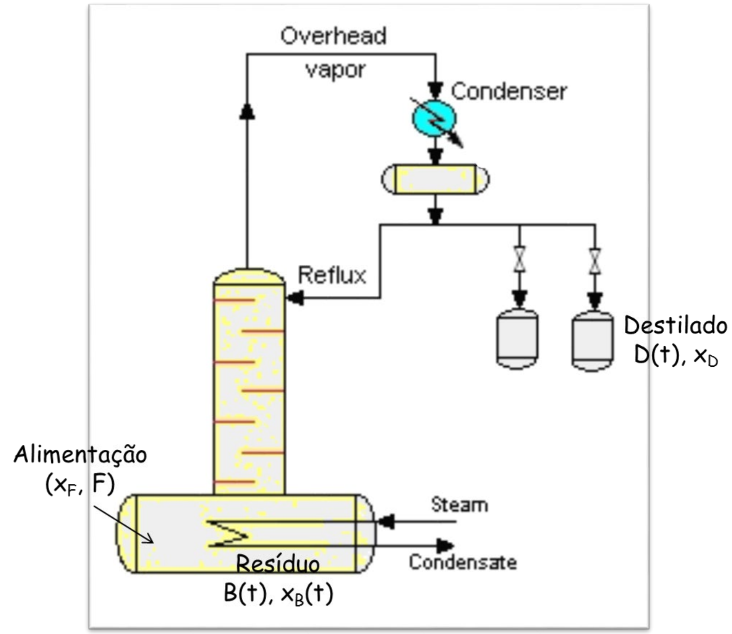
$x_D = 90\%$

Variable reflux ratio

x_F, x_D known

Calculate:

1) $x_{B\ final}$
2) D



$$y_{n+1} = \frac{R}{R+1} x_n + \frac{x_D}{R+1}$$

$$R(t) = \frac{L(t)}{D(t)}$$

R varies in order to keep constant the number of stages between x_D and x_B

$x_F = 49\%$ F = 200 moles $R_{inicial} = 0.64$

$x_D = 90\%$ N = 4 $R_{final} = 3.2$

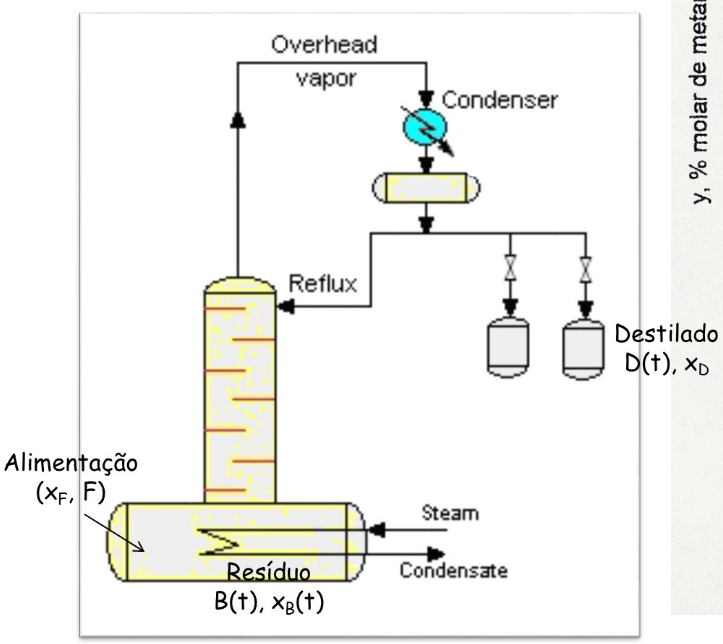
$$y_{n+1} = \frac{R}{R+1} x_n + \frac{x_D}{R+1}$$

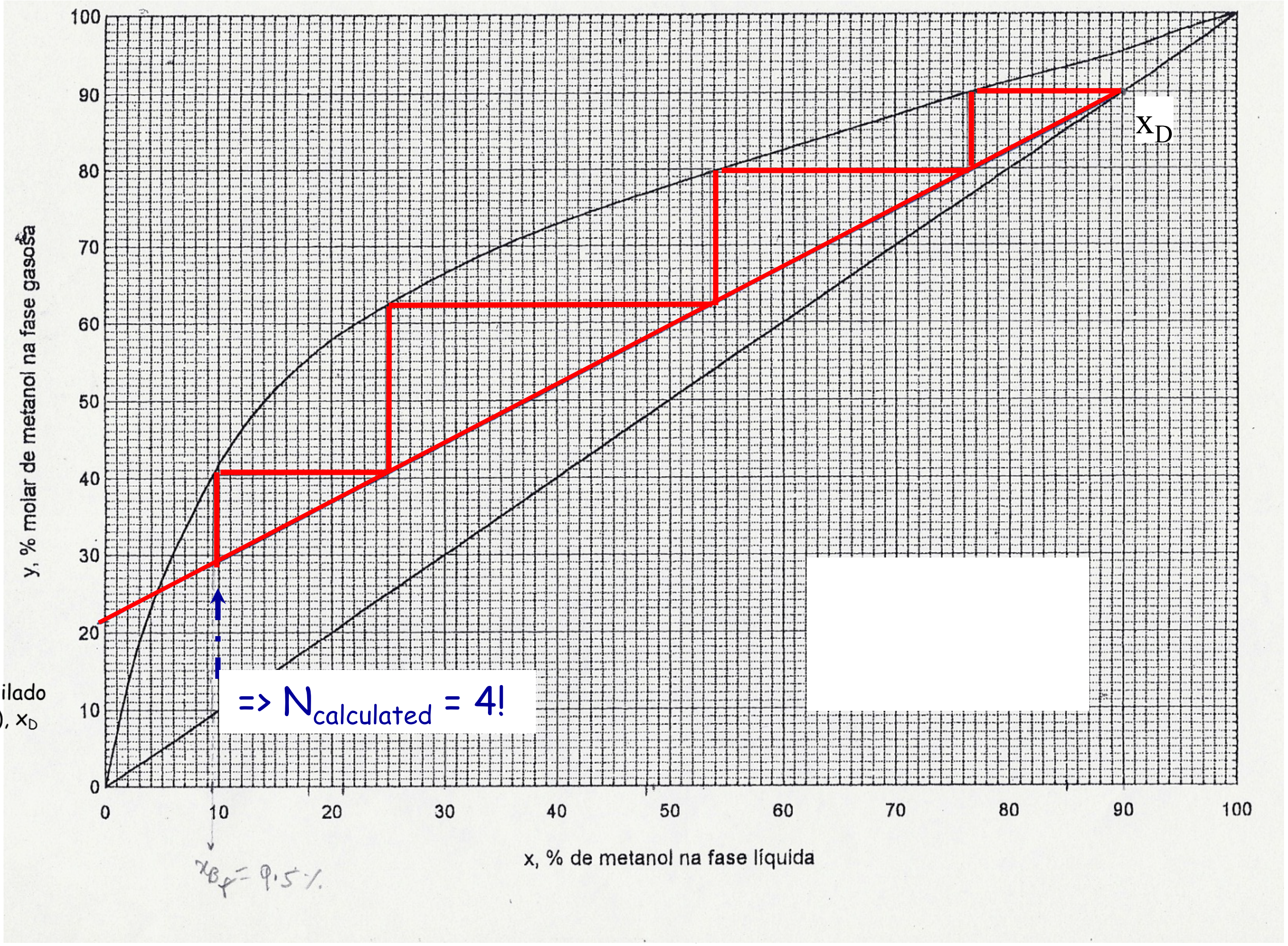
1) $x_{B\ final}$

$x_D = 90\%$; $R_{final} = 3.2$

$$\Rightarrow \frac{x_D}{R+1} = 21.4\%$$

For N = 4 => $x_{B\ final} = 9.5\%$





$x_F = 49\%$ $\quad$ F = 200 moles $\quad$ $R_{inicial} = 0.64$

$x_D = 90\%$ $\quad$ N = 4 $\quad$ $R_{final} = 3.2$

$$y_{n+1} = \frac{R}{R+1} x_n + \frac{x_D}{R+1}$$

1) $x_{B\ final}$

$x_D = 90\%$; $R_{final} = 3.2$

$$\Rightarrow \frac{x_D}{R+1} = 21.4\%$$

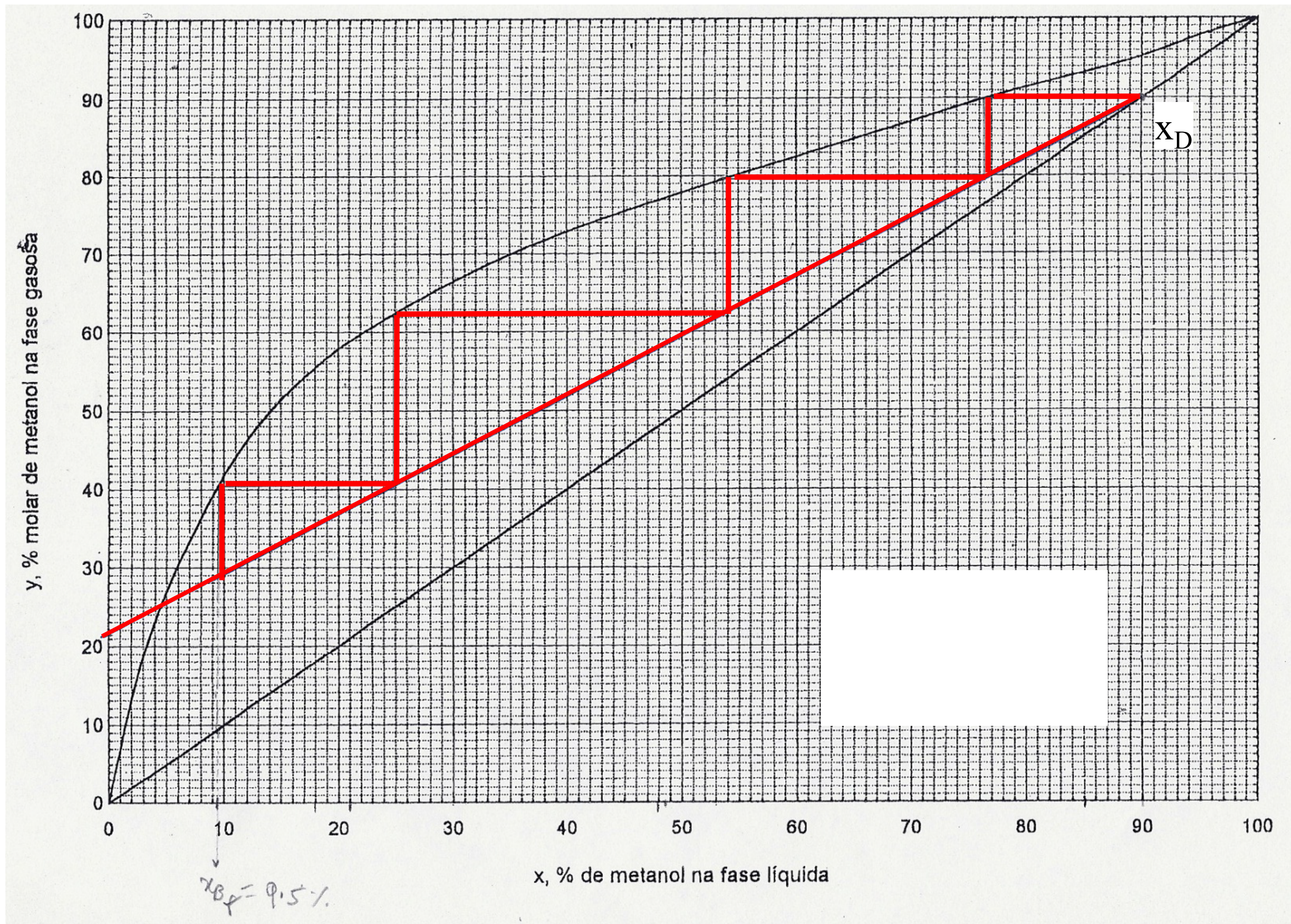
For N = 4 => $x_{B\ final} = 9.5\%$

2) D

$$\begin{cases} F = B + D \\ x_F F = x_{B_{final}} B + x_D D \end{cases}$$

=> D = 98.1 moles

=> B = 101.9 moles



$\therefore$ $B.x_B$ mol de metanol are left in the boiler = 9.7 moles