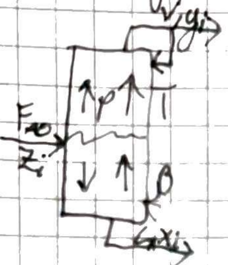
Exercise 2 - Distillation

① Design 1: $F_{A0} = 200\ mol/h$ at T_b $x_{F,H} = 0{,}42$, $x_{F,E} = 0{,}58$



$P = 101{,}32\ kPa$ $R = 2{,}5 = L_T/D$, Sat liq => $q = 1$

$x_{D,H} = 0{,}97$, $x_{D,E} = 0{,}03$, $x_{B,H} = 0{,}011$ $x_{B,E} = 0{,}989$

Assuming that there is a total condenser

We have the massbalances

$B = F_{A0} - D$ and $Bx_{B,H} = F_{A0}x_{F,H} - Dx_{D,H}$

This gives the equation

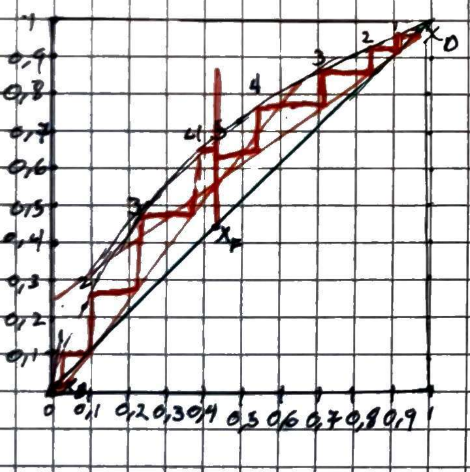
$(F - D)x_{B,H} = Fx_{F,H} - Dx_{D,H}$

$200 \cdot 0{,}011 - D \cdot 0{,}011 = 200 \cdot 0{,}42 - D \cdot 0{,}97$

$2{,}2 - 0{,}011D = 84 - 0{,}97D$

$0{,}959D = 81{,}8$ => $D = 85{,}297$

=> $B = F_{A0} - D = 200 - 85{,}297 = \underline{114{,}703\ mol/h}$



$q = 1$

T: $y = \frac{R}{R+1}x + \frac{x_D}{R+1} = 0{,}714x + 0{,}277$

N = 9 eq

N = 8 tray

Feed tray = #5

i) $V_B = L_B - B = L_T + q \cdot F_{A0} - B$ $\quad R = \frac{L}{D}$

$= R \cdot D + q F_{A0} - B$

$= R \cdot D + q \cdot F - F_{A0} + D$

$= D(R+1) + F_{A0}(q-1)$

ii) $Q = V_B \cdot \Delta H_{vap}$

Given the fact that $x_{B,H} <<< x_{B,E}$ we use ΔH_{vap} for ethylbenzene

We find V_B from the eq in i)

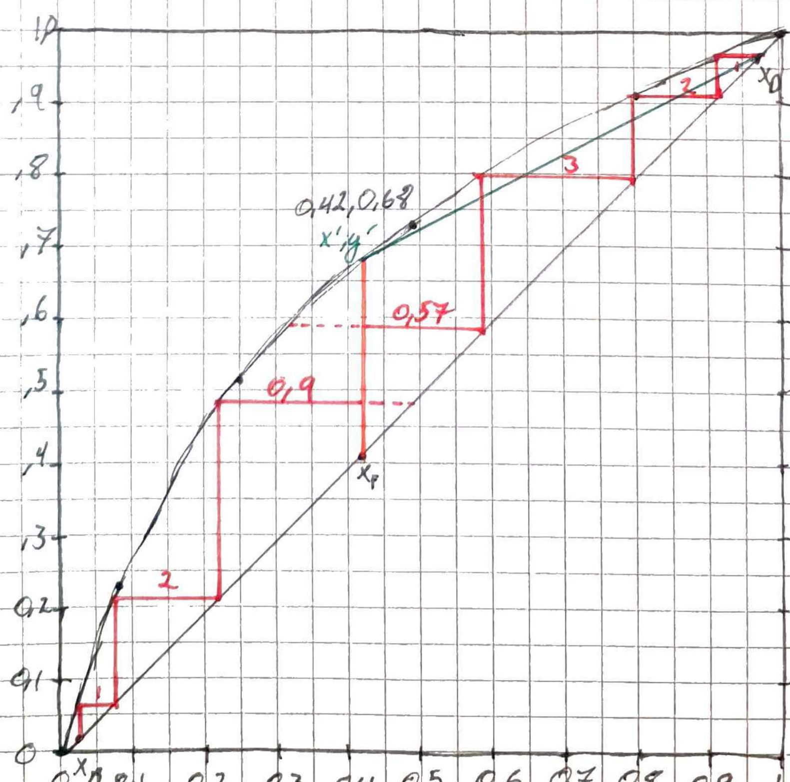
$Q = (D(R+1) + F(q-1)) \cdot \Delta H_{vap,E}$

$= (85{,}297 (2{,}5+1) + F(1-1)) 35{,}6$

$= \left(\frac{85{,}297}{3600}(2{,}5+1)\right) 35{,}6$

$= 2{,}95 \text{ kW}$

iii)



$\left(\frac{L}{V}\right)_{min} = \frac{x_{D,H} - y'}{x_{D,H} - x'}$

$= \frac{0{,}97 - 0{,}68}{0{,}97 - 0{,}42}$

$= 0{,}527$

$R_{min} = \frac{(L/V)_{min}}{1 - (L/V)_{min}}$

$= 1{,}114$

↙ eq from i)

$V_{min} = D(R_{min}+1) + F_{A0}(q-1)$

$= 85{,}297 \cdot (1{,}114 + 1) = 180{,}32$

Design 2:

$R = 1{,}2\, R_{min} = 1{,}2 \cdot 1{,}114 = 1{,}3368$

$V = D(R+1) + F_{10}(q-1)$

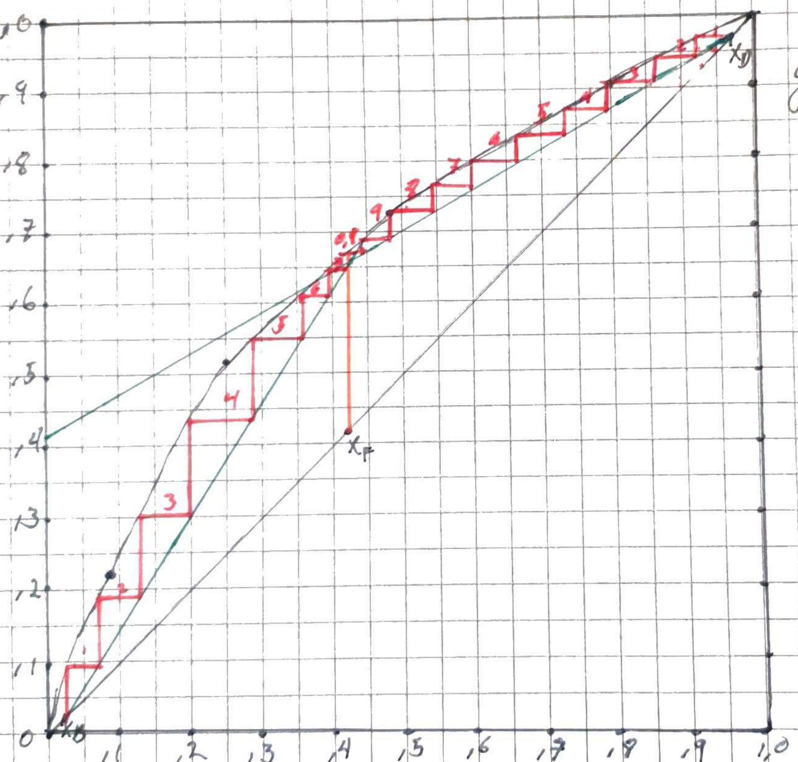
$= 85{,}297(1{,}3368+1) = 199{,}32$

$\frac{199{,}32}{180{,}32} = 1{,}105\, V_{min} = \underline{1{,}1\, V_{min}}$

- $Q = V_B \cdot \Delta H_{vap}$

$= \frac{199{,}32 \cdot 35{,}6}{3600}$

$= \underline{1{,}97\, kW}$



$y = \frac{R}{R+1} x + \frac{x_D}{R+1}$

$= 0{,}57x + 0{,}42$

$N = 9{,}8 + 7 = \underline{16{,}8}$

- Design #1 will use more energy but need less steps/hight than Design #2.

will cost more to construct #2, but it will have lower operational cost in form of energy.

(2) $F = 100$ kmol/h sat.vap => $q = 1$

$y_{F,A} = 0{,}4$ $y_{F,B} = 0{,}6$ $P = 101{,}32$ kPa $R = 4$

$x_{D,A} = 0{,}9$ $x_{D,B} = 0{,}1$

a) $F = D + W$ $F = D + W$

$F y_{F,A} = D x_{D,A} + W x_{W,A}$ $F y_{F,B} = D x_{D,B} + W x_{W,B}$

Assuming constant molar flow $L = W$

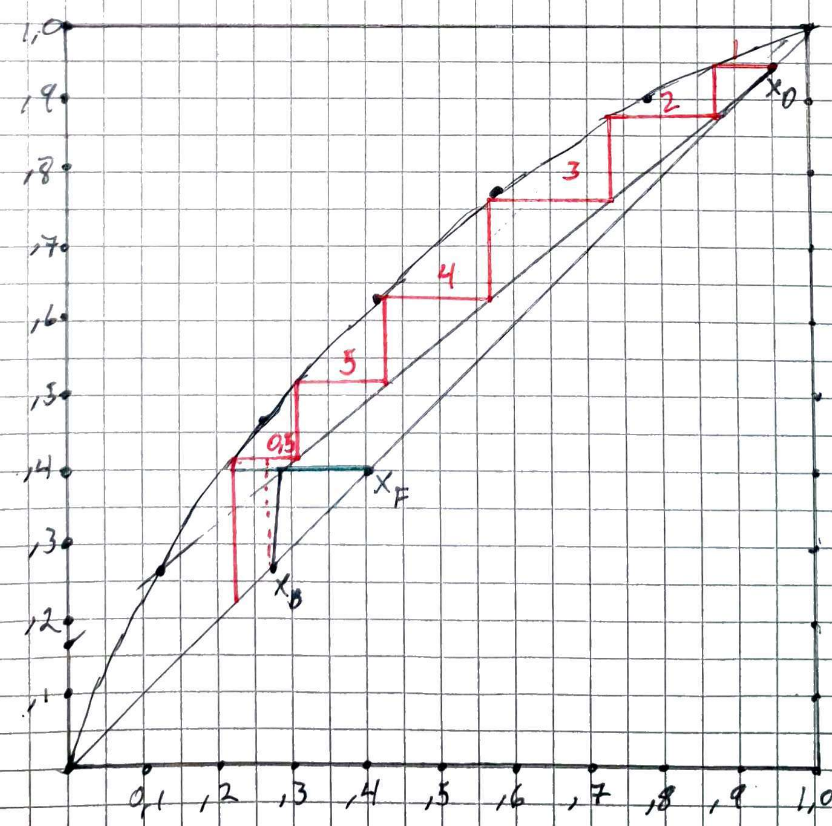
$R = \frac{W}{D} = 4$ $W = 4D$

$F = D + 4D = 5D$ $\frac{100}{5} = D = \underline{20}$

$W = 80$

$40 = 18 + 80 x_{W,A}$ => $\underline{x_{W,A} = 0{,}275}$

b) Sat.vap => $q = 0$



$y = \frac{R}{R+1} x + \frac{x_D}{R+1}$

$= \frac{R}{R+1} x +$

$\underline{N = 5{,}5}$