Tutorial - 5

$$\text{MW of feed} = \frac{1}{\frac{0.3}{34} + \frac{0.7}{18}} = 22.02\ g$$

$F = 5000\ kg/h = 227.05\ kmol/h$.

$$x_D = \frac{\frac{0.88}{34}}{\frac{0.88}{34} + \frac{0.12}{18}} = 0.7416$$

$$x_B = \frac{\frac{0.04}{34}}{\frac{0.04}{34} + \frac{0.96}{18}} = 0.016$$

$$x_F = \frac{0.30/34}{0.3/34 + 0.7/18} = 0.1436$$

H_{V_1} = enthalpy of vapour @ $x = x_D$
($x = x_D$ because "complete/total condenser")

$\Rightarrow H_{V1} = 48865$ kJ/kmol (interpolation)

$H_F = 4790$ kJ/kmol (given)

H_{L0} = enthalpy of liquid @ $x = x_D$ (interpolation)
$= 8840$ kJ/kmol.

$$\frac{L}{L_0} = \frac{H_D' - H_{V1}}{H_D' - H_{L0}} \text{ ; Given } R = 1.$$

$\Rightarrow H_D' = 2H_{V1} - H_{L0}$ ~~88391~~ ~~88822~~ kJ/kmol

$=$ ~~13144~~

$= 88822$ kJ/kmol

In the enthalpy concentration diagram, if a line through (H_f, x_f), $(H_{D'}, x_D)$ passes through $(H_{B'}, x_B)$

Using this property we get $H_{B'} = -13141$ kJ/kmol.

To obtain operating lines, we recognise that a line passing through D' cutting $H_L - xy$ curve at (x_L, y_L) & cutting $H_V - xy$ curve at (x_V, y_V) means that the point (x_L, y_V) lies on the stripping section OL.

Analogously using lines through B' we obtain the rectification operating line.

We then perform the stepping process to obtain

a) 10 total stages, 1 is a partial reboiler

$\Rightarrow$ 9 ideal trays are required.

b) H_D = enthalpy of liquid at $x = x_D$

$= 8839.1$ kJ/kmol $(= H_{LO})$

H_B = enthalpy of liquid at $x = x_B$

$= 7361.9$ kJ/kmol

$D = F \times \left(\frac{x_F - x_B}{x_D - x_B}\right) = 39.93$ kmol/h

$B = F - D = 187.122$ kmol/h

Energy balance at condenser:

$$Q_C = D(H_D' - H_D)$$

$$= \boxed{3.19 \times 10^6 \text{ kJ/kmol}}$$

Energy balance at partial reboiler:

$$Q_B = BH_B + V_{m+1}H_{V_{m+1}} - L_m H_{L_m}$$

or an easier way!

total energy balance:

$$Q_B + FH_f = Q_C + D\cancel{x}H_D + BH_B.$$

$$\Rightarrow Q_B = Q_C + DH_D + BH_B - FH_F$$

$$\Rightarrow Q_B = 3.836 \times 10^6 \text{ kJ/kmol}.$$

$$= \boxed{3.84 \times 10^6 \text{ kJ/kmol.}}$$

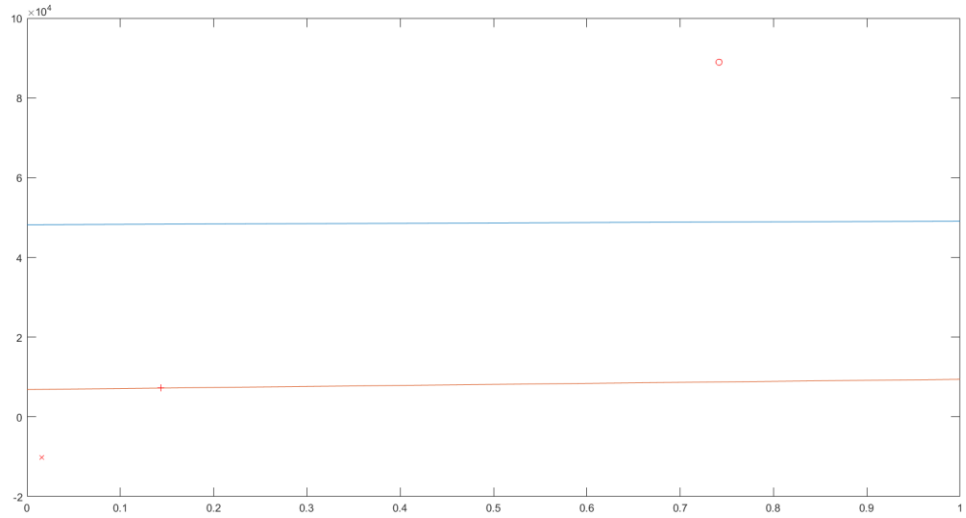
MATLAB CODE

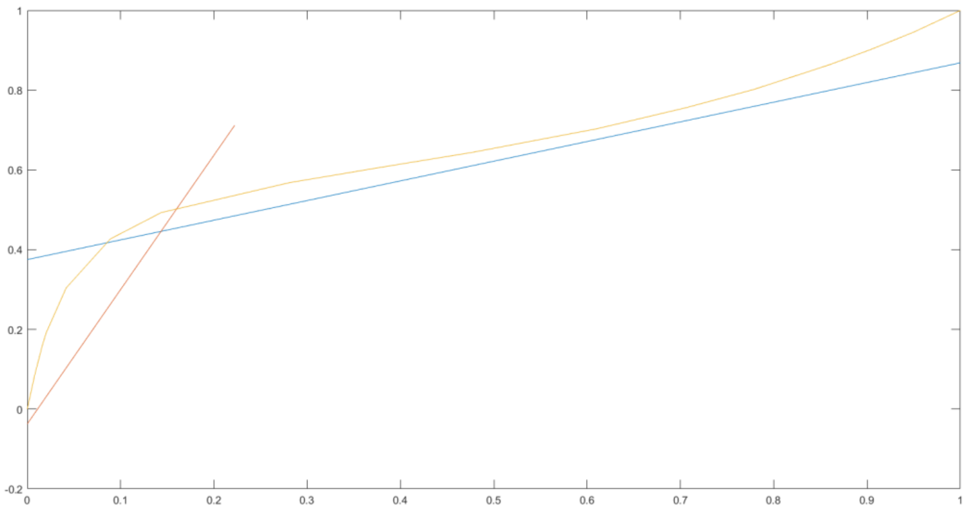
```
close all; clear;
%Given data
x = [0 0.0417 0.0891 0.146 0.207 0.281 0.37 0.477 0.61
0.779 1];
HL = [7540 7125 6880 6915 7097 7397 7750 8105 8471 8945
9523];
HV = [48150 48250 48300 48328 48436 48450 48450 48631
48694 48950];
%composition in terms of mole fractions
xD = 0.7416;
xB = 0.016;
xF = 0.1436;
%Flow rates
F = 227.05;
D = 227.05*(xB-xF)/(xB-xD);
B = F-D;
%Enthalpy-Concentration curves(linear regression)
hlcurve = polyfit(x,HL,1);
hvcurve = polyfit(x(1:length(HV)),HV,1);
%Enthalpy-Concentration curves(splines)
hv_spline = spline(x(1:10),HV);
hl_spline = spline(x,HL);
Hv1 = spline(x(1:10),HV,xD);
Hlo = spline(x,HL,xD);%Since total condenser, same comp
as incoming v1
%Using the reflux ratio to get HD'
Hd = 2*Hv1-Hlo;%NOTE: This is Hd'
Hf = 4790;
%Determining Hb by extrapolating teh Hd-Hf line
Hb = Hf + (xB-xF)*(Hd-Hf)/(xD-xF);%NOTE: This is Hb'
a = linspace(0,1,10);
plot(a,polyval(hvcurve,a),a,polyval(hlcurve,a),xB,Hb,'rx'
,xF,Hf,'r+',xD,Hd,'ro');
%Eqbm data
xeqbm = [0 0.00792 0.016 0.0202 0.0417 0.0891 0.1436
0.281 0.37 0.477 0.61 0.641 0.706 0.779 0.86 0.904 0.95
1];
yeqbm = [0 0.0850 0.1585 0.191 0.304 0.427 0.493 0.568
0.603 0.644 0.703 0.72 0.756 0.802 0.864 0.902 0.9456 1];
pp = spline(yeqbm,xeqbm);
%Rectification line
m = linspace((Hd-Hf)/(xD-xF),(Hd-Hf)/(xD-xF)*10,10);
fnrl = @(x)(m.*(x-xD)+Hd - polyval(hlcurve,x));
fnrl2 = @(y)(m.*(y-xD)+Hd - polyval(hvcurve,y));
x_RL = fsolve(fnrl,zeros(1,10));
```

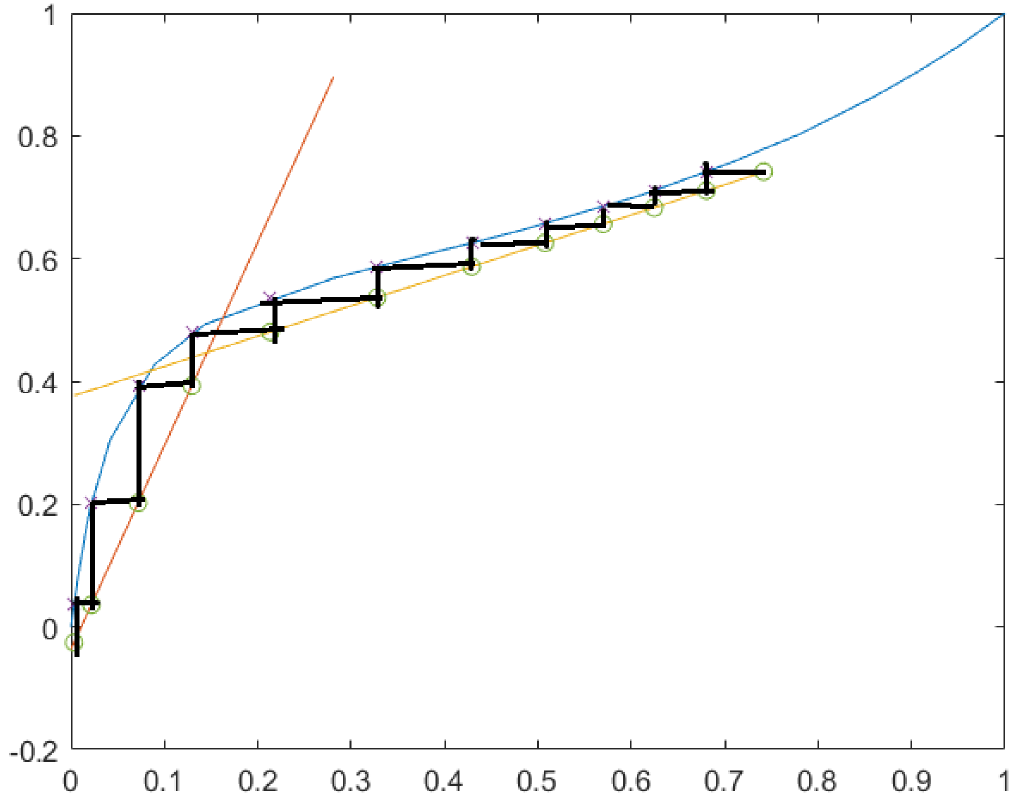
```
y_RL = fsolve(fnrl2,zeros(1,10));
RL_eqn = polyfit(x_RL,y_RL,1);
RL = @(x)(polyval(RL_eqn,x));
%Stripping line
m = linspace((Hb-Hf)/(xB-xF),(Hb-Hf)/(xB-xF)*10,10);
fnol = @(x)(m.*(x-xB)+Hb - ppval(hl_spline,x));
fnol2 = @(y)(m.*(y-xB)+Hb-ppval(hv_spline,y));
x_SL = fsolve(fnol,zeros(1,10));
y_SL = fsolve(fnol2,zeros(1,10));
SL_eqn = polyfit(x_SL,y_SL,1);
SL = @(x)(polyval(SL_eqn,x));
xcoords = linspace(0,1,10);
figure();
plot(xcoords,RL(xcoords),xcoords(1:3),SL(xcoords(1:3)),xe
qbm,yeqbm);
%Stepping process
i = 0;
y_c = xD;
x_intersection = fsolve(@(x)(SL(x)-RL(x)),0);
y_inters = RL(x_intersection);
x_c = 0;
xcoords = zeros(1,7);
ycoords = zeros(1,7);
xcoords2 = zeros(1,8);
ycoords2 = zeros(1,8);
xcoords2(1)= xD;
ycoords2(1) = xD;
while y_c >= xB
    i=i+1;
    x_c = ppval(pp,y_c);
    xcoords(i) = x_c;
    xcoords2(i+1) = x_c;
    ycoords(i)=y_c;
    if x_c >= x_intersection
        y_c = RL(x_c);
    else
        y_c = SL(x_c);
    end
    ycoords2(i+1) = y_c;
end
figure();
plot(xeqbm,yeqbm,x(1:6),SL(x(1:6)),xcoords2,RL(xcoords2),
xcoords,ycoords,'x',xcoords2,ycoords2,'o');
%Actual Enthalpy calculation
Hda = spline(x,HL,xD);
Hba = spline(x,HL,xB);
%Flow rate calculations
```

```
D = F*(xF-xB)/(xD-xB);
B = F - D;
%Heat duties
Qc = D*(Hd-Hda);
QB = Qc + D*Hda+B*Hba-F*Hf;
```

MATLAB PLOTS



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0.4
0.2
0
-0.2
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1