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CH3030 AMT TUTORIAL - 6

① Given data:

$z_F = 0.1$, $x_B = 0.01$, $x_D = 0.8$

Feed is bubble-point liquid.

$\Rightarrow q = 1$

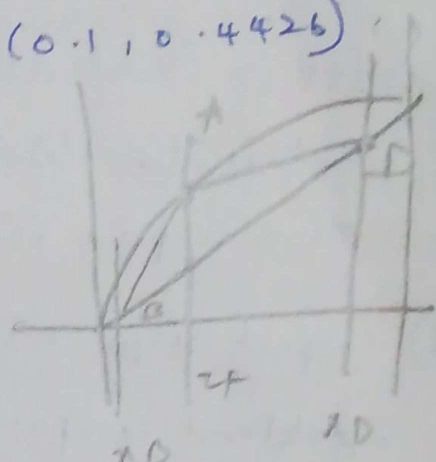
$\Rightarrow$ the q-line is simply a vertical line passing through (z_F, z_F)

Step i): Finding R_{min}.

→ Find the intersection between q-line ($x = 0.1$) and the eqbm curve

→ Intersection is found to be: $A(0.1, 0.4426)$

→ The line joining $D(x_D, x_D)$ to A has slope $= \frac{R_{min}}{R_{min}+1}$



$\Rightarrow R_{min} = \frac{m_{min}}{1 - m_{min}}$

$= \underline{1.043}$

Step ii) Finding R and doing the stepping by constructing operating lines.

→ $R = 1.5\, R_{min} = \underline{1.5645}$

→ ~~Stripping~~ Rectification section operating line: slope $= \frac{R}{R+1}$ and passes through (x_D, x_D)

$\Rightarrow$ eqn is $(y - x_D) = \left(\frac{R}{R+1}\right)(x - x_D)$

$\Rightarrow y = 0.6101x + 0.3119$

→ Join point B(x_B, x_B) and the intersection of the q-line. This is the stripping operating line.

$\boxed{y = 4.03x - 0.303.}$

→ 8 the lines are plotted in MATLAB and the figure is attached

→ Stepping is done in ~~matlab~~ MATLAB

Procedure :

a) Start from $y = x_D$, $x = x_D$.

b) fix ~~x~~ y and move left to the ~~corresponding~~ corresponding point on the equilibrium curve.

c) fix x and drop to the point on ~~stripping~~ Rectification line if $x > z_F$ or to the point on stripping line if $x < z_F$.

d) Repeat steps b to c till the ~~x~~ desired bottoms composition ($x_B = 0.01$) is achieved

~~(i.e. y x Repeat till.~~

(i.e. stop only when $y <= 0.01$)

a) We find that there are 14 theoritical stages in rectification

13 theoritical stages in stripping

⇒ 17 theoritical stages.

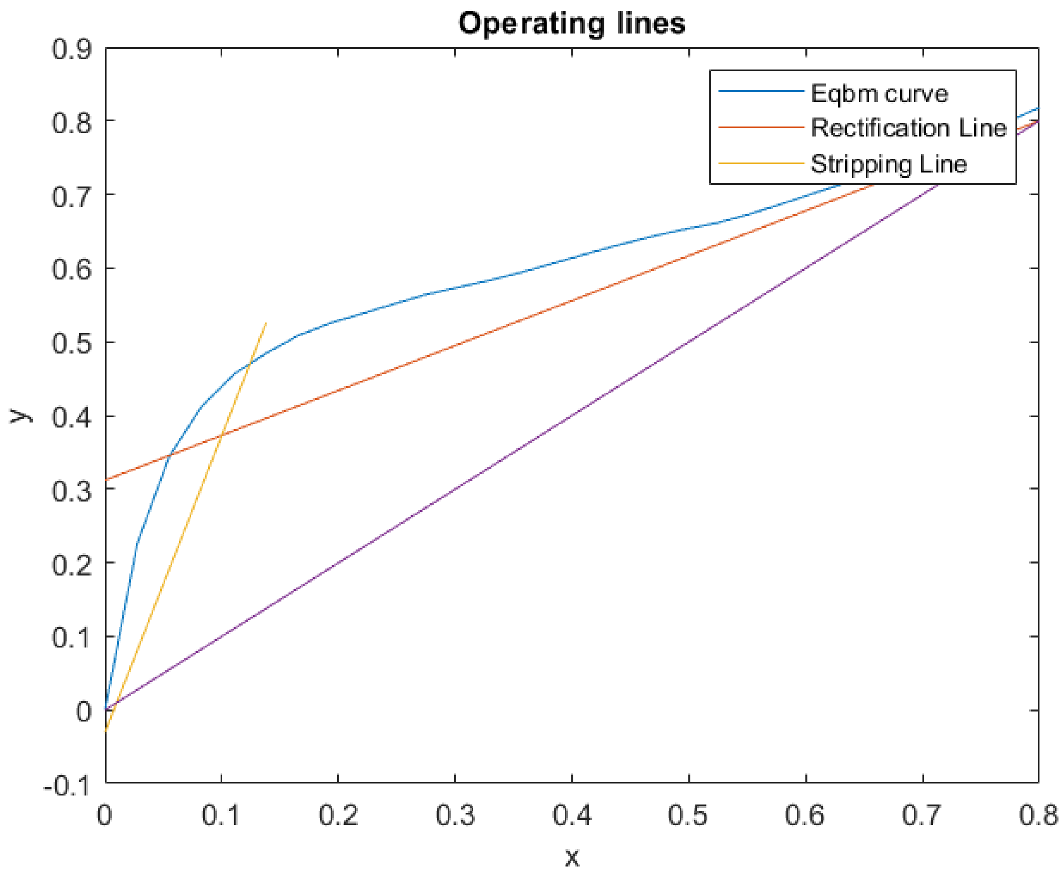
But the last stage in stripping section is PARTIAL REBOILER

∴ Totally $\boxed{\text{13 above + 2 below}}$ = 15 theoritical plates

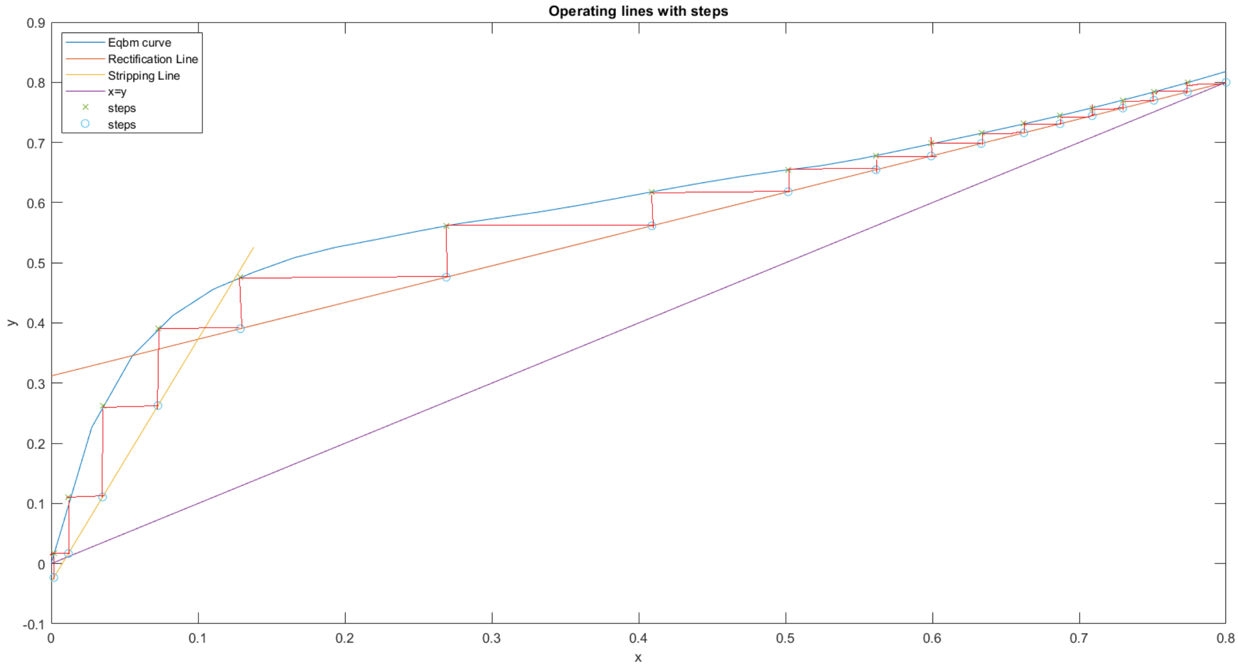
= $\boxed{\text{15 plates reqd.}}$

Question 1-plots

Operating lines



Number of stages (stepping)



1 b) Since H is given in terms of overall Mass Transfer Coefficient, $N_{OG} = \int_{y_1}^{y_2} \frac{dy}{y^* - y}$.

For obtaining y^*, we just fix the x coordinate of a point on the operating line and find the corresponding y-coordinate in the eqbm curve.

Thus we can find multiple such points and then integrate numerically

Intersection of the operating lines $\equiv (0.1, 0.373)$

Limits of Integral

i) Rectification section: $y_1 = 0.373$,

$y_2 = 0.8$ $(= x_D)$

ii) Stripping section: $y_1 = 0.098$ (this is the purity at which vapour from the partial reboiler enters)

$y_2 = 0.373$.

~~y_1, stripping is found as~~

y_1, stripping = y_{eqbm} at $x = x_B = 0.01$

Note that to generate points ~~at~~ (y, y^*) it is easier to know the ~~y~~ x-coordinates and find y using operating line equation and y^* using eqbm curve

So these eqns are numerically integrated in MATLAB.
using (y, y^*) generated for a set of x-coordinates.

One small manipulation is needed only in x_1, stripping
(otherwise $x_2 = y_2$ & $x_1 = y_1$)

In that case I use the stripping line equation to get x_1 from y_1

Upon integration with 30 points for each section),

NTU, above = 14.152 ~~≈ 14 15 units~~

NTU, below = 2.230 ~~or 3 units~~.

b) NTU above = 14.15 ~ 15

Subtracting one for feed,

NTU above = 15 − 1 = 14 units

NTU below = 2.23 ~ 3.

Subtracting one for feed,

NTU below = 2 units

∴ Total number of transfer units = 14 + 2
(including feed) = $\boxed{16 \text{ units}}$

c) We obtained 16 ~~theoriti~~ theoritical plates including the feed in part (a).

Efficiency = 0.8.

$$\Rightarrow \frac{\text{No. of theoritical plates}}{\text{No. of actual plates}} = 0.8.$$

$$\Rightarrow \text{No. of actual plates} = \frac{\text{No. of theoritical plates}}{0.8}$$

$\Rightarrow$ Number of actual plates $= \frac{16}{0.8} = 20$ plates.

$\therefore$ Height of plated section $= (20-1) \times$ ~~200~~ ~~18~~ 18 in

(if we have n plates, we have (n-1) gaps b/w plates) $= 342$ ~~m~~. inches

$= \boxed{8.839 m.}$

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c) We have totally $14 + 3 + 1 = 18$ transfer units

Height of bed $=$ NTU $\times$ HTU

$= 18 \times 1.2$ feet

$= 21.6$ feet

$= 6.584$ m.

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d) We have totally $14 + 2 + 1 = 17$ transfer units
$\downarrow$ (feed)

$\Rightarrow$ Height of bed $=$ NTU $\times$ HTU

$= 17 \times 1.2$

$= \boxed{20.4 \text{ feet}}$

$= 6.218$ m

(here I have rounded off the NTU to nearest integer ; since it is height if we can simply use the Integral value. In that case we get a less conservative value of $16.38 \times 1.2 = \underline{19.66 \text{ feet} \sim 5.99 m}$)

Code

```
clear; close all;
%Given data
xeqbm =
[0,0.019,0.0721,0.0966,0.1238,0.1661,0.2337,0.2608,0.3273
,0.3965,0.5079,0.5198,0.5732,0.6763,0.7472,0.8943];
yeqbm =
[0,0.17,0.3891,0.4375,0.4704,0.5089,0.5445,0.558,0.5826,0
.6122,0.6564,0.6599,0.6841,0.7385,0.7815,0.8943];
pp = spline(xeqbm,yeqbm);
xD = 0.8;
xB = 0.01;
zF = 0.1;

%Rmin evaluation
m_min = (0.8-ppval(pp,0.1))/(0.8-0.1);
Rmin = m_min/(-m_min+1);
R = 1.5*Rmin;
OL = @(x) (R/(R+1).*(x-0.8)+0.8);
ycoord = OL(0.1);
x = linspace(0,0.8,30);
%Getting stripping section operating line
m_s = (ycoord-0.01)/(0.1-0.01);
SL = @(x)(m_s.*(x-0.01) + 0.01);
figure();
plot(x,ppval(pp,x),x,OL(x),x(1:6),SL(x(1:6)),x,x);
title('Operating lines');
legend('Eqbm curve','Rectification Line','Stripping
Line');
xlabel('x');
ylabel('y');
%Stepping process
i=0;%Step counter
y = xD;
PP = spline(yeqbm,xeqbm);
xcoords = zeros(1,7);
ycoords = zeros(1,7);
xcoords2 = zeros(1,8);
ycoords2 = zeros(1,8);
xcoords2(1)= xD;
ycoords2(1) = xD;
while y >= 0.01
    i = i + 1;
    x = ppval(PP,y);
    xcoords(i) = x;
    xcoords2(i+1)=x;
```

```
    ycoords(i) = y;
    if x > 0.1
        y = OL(x);
    else
        y = SL(x);
    end
    ycoords2(i+1) = y;
end
%Plotting the steps
x = linspace(0,0.8,30);
figure();
plot(x,ppval(pp,x),x,OL(x),x(1:6),SL(x(1:6)),x,x);
title('Operating lines with steps');
xlabel('x');
ylabel('y');
hold on;
plot(xcoords,ycoords,'x',xcoords2,ycoords2,'o');
lgd = legend('Eqbm curve','Rectification Line','Stripping
Line','x=y','steps','steps');
lgd.Location = 'northwest';
hold off;
%Part b
%choose (x,y) along the RL, get y*; evaluate 1/(y*-y) &
integrate
x_above = linspace(0.10,0.8,30);
y_star_above = ppval(pp,x_above);
y_above = OL(x_above);
f_above = 1./(y_star_above-y_above);
NTU_above = trapz(y_above,f_above);
%Evaluating x,y at the tray just before the partial
reboiler
y_start = ppval(pp,xB);
fun = @(x)(SL(x)-0.098);
x_start = fsolve(fun,0);
%choose (x,y) along the SL, get y*; evaluate 1/(y*-y) &
integrate
x_below2 = linspace(x_start,zF,30);
y_star_below2 = ppval(pp,x_below2);
y_below2 = SL(x_below2);
f_below2 = 1./(y_star_below2-y_below2);
NTU_below2 = trapz(y_below2,f_below2);
```