Lab Report 2

Name: Shalin Jain, Shree Kumar Sundaray, Shridam Mahajan, Shubham Kumar Gupta, Shubham Raj

Roll No.: 180107055, 180107056, 180107057, 180107058, 180107059

Group: 11

Problem 1: A binary mixture is to be distilled in a distillation column to give a distillate of xD = 0.98 and a bottoms composition of xB = 0.01. The feed composition is zF = 0.5 and the reflux ratio is R = 2.7. The feed is a mixture of vapor and liquid and q = 1. The equilibrium equation is given by $y = \alpha x/(1+(1-\alpha)x)$ with $\alpha = 2.5$. Determine the location of the feed stage and the number of total stages, and plot the equilibrium curve, q-line, and the operating lines as a function of liquid-phase mole fraction.

Problem 2: A 41-stage column with the overhead condenser as stage 1, the feed stage as stage 21, and the reboiler as stage 41 is used to distil a binary mixture. The relative volatility, α, is 2.5. The feed rate is F = 1 mol/min, the feed composition is zF = 0.5, and the feed condition is q = 1 (bubble-point liquid). The flow rate of the distillate leaving the column is 0.5 mol/min. Plot the steady-state liquid composition profile along the stages for the reflux flow rate of R = 2.4, 2.7, and 3.0 mol/min.

Solution 1:

First we write the equilibrium line through the equation provided. The following code in script q1equilibgrp11.m does that:-

```
% McCabe and Thiele Graphical Method for Binary Distillation
% Function equilib, called by main program, gives the
% relationship between liquid and vapor mole fractions
% for the low boiling component of binary mixture
% with constant relative volatility alpha=2.45

function f=q1equilibgrp11(x)
global y
alpha=2.45;
f=y-alpha*x/(1+(alpha-1)*x);
end
```

Then we draw the rectifying, stripping operating lines along with the q line to get the number of stages and the feed stage thus applying the Mcabe-Thiele through the following code in q1maingrp11.m:-

```
global y
for i=1:11
   y=0.1*(i-1);
   ye(i)=0.1*(i-1);
   xe(i)=fzero('q1equilibgrp11',0.5);
end

xd=0.9;
xb=0.1;
zf=0.5;
R=1.5;
q=0.8;

yi=(zf+xd*q/R)/(1+q/R);
xi=(-(q-1)*(1-R/(R+1))*xd-zf)/((q-1)*R/(R+1)-q);

figure(1);
hold on;

plot(xe,ye,'r');
set(line([0  1],[0  1]),'Color',[0 1 0]);
set(line([xd xi],[xd yi]),'Color',[1 0 1]);
set(line([zf xi],[zf yi]),'Color',[1 0 1]);
set(line([xb xi],[xb yi]),'Color',[1 0 1]);

% Rectifying section

i=1;
xp(1)=xd;
yp(1)=xd;
y=xd;
while (xp(i)>xi)
   xp(i+1)=fzero('q1equilibgrp11',0.5);
   yp(i+1)=R/(R+1)*xp(i+1)+xd/(R+1);
   y=yp(i+1);
   set(line([xp(i) xp(i+1)],[yp(i) yp(i)]),'Color',[0 0 1]);
```

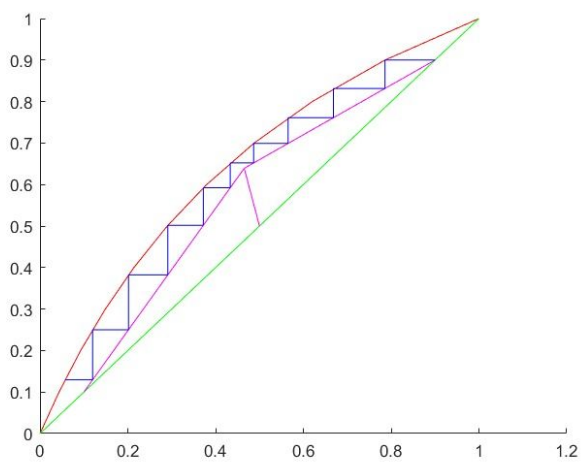
```
    if (xp(i+1)>xi)
        set(line([xp(i+1) xp(i+1)],[yp(i) yp(i+1)]),'Color',[0 0 1]);
    end
        i=i+1;
end
feedn = i-1;
% Stripping section

SS=(yi-xb)/(xi-xb);
yp(i)=SS*(xp(i)-xb)+xb;
y=yp(i);
set(line([xp(i) xp(i)],[yp(i-1) yp(i)]),'Color',[0 0 1]);

while (xp(i)>xb)
    xp(i+1)=fzero('q1equilibgrp11',0.5);
    yp(i+1)=SS*(xp(i+1)-xb)+xb;
    y=yp(i+1);
    set(line([xp(i) xp(i+1)],[yp(i) yp(i)]),'Color',[0 0 1]);
    if (xp(i+1)>xb)
        set(line([xp(i+1) xp(i+1)],[yp(i) yp(i+1)]),'Color',[0 0 1]);
    end
    i=i+1;
end
totaln = i-1;
hold off;
```

Results for solution 1 which are displayed by running **q1maingrp11.m** :-

y



x

Solution 2:-

The script q2dist_ssgrp11.m sets the field values of the structures DIST_PAR for the given operating conditions. Then the function q2dist_ssgrp11() is called to calculate the steady state compositions which are used as initial values.

The input argument DIST_PAR is a structure variable consisting of parameter fields : DIST_PAR.alpha, DIST_PAR.ns (total stages), DIST_PAR.nf (feed stage), DIST_PAR.feed and etc. Thus all the variables values have been taken from this struct.

```
function f = q2dist_ssgrp11(x,R)
global DIST_PAR ;
DIST_PAR = [2.5 41 21 1 0.5 1 R R+0.5];

% input
alpha =DIST_PAR(1) ; % relative volatility
ns = DIST_PAR(2) ; % total stages
nf = DIST_PAR(3); % feed stage
feed = DIST_PAR(4); % feed flow rate
zfeed = DIST_PAR(5); % feed composition
qf = DIST_PAR(6) ; % feed condition
reflux = DIST_PAR(7); % reflux rate
vapor = DIST_PAR(8);
% rectifying & stripping liquid flowrates
lr = reflux;
ls = reflux + feed*qf;
% rectifying & stripping vapor flowrates
vs = vapor;
vr = vs + feed*(1-qf);
% distilate and bottom rates
dist = vr - reflux;
lbot = ls - vs;
if dist < 0
disp('error in specifications, distilate flow <0')
return
end
if lbot < 0
disp('error in specifications, stripping section')
```

```
disp (' ')
disp('liquid flowrate is negative')
return
end
% zero function vector
f = zeros(ns, 1);
y = zeros(ns, 1);
% equilibrium vapor compositions
for i=1:ns
  y(i)=(alpha*x(i) )/(1-(1-alpha) *x(i));
end
% MATERIAL BALANCES
% overhead receiver
f(1)=(vr*y(2)-(dist+reflux)*x(1));
% rectifying (top) section
for i=2:nf-1
  f(i)=lr*x(i-1)+vr*y(i+1)-lr*x(i)-vr*y(i);
end
% feed stage
f(nf) = lr*x(nf-1)+vs*y(nf+1)-ls*x(nf) -vr*y(nf)+feed*zfeed;
% stripping (bottom) section
for i=nf+1:ns-1
  f(i)=ls*x(i-1)+vs*y(i+1)-ls*x(i) -vs*y(i);
end
% reboiler
f(ns)=(ls*x(ns-1)-lbot*x(ns)-vs*y (ns));
end
```

Now this function is called in q2maingrp11.m to solve the system of differential equations.

```
x0 = 0.5*ones(41,1);
R = [2.4 2.7 3.0];
nr = 3;
x = [];
for i = 1:nr
   a=fsolve (@(x)q2dist_ssgrp11(x,R (i)),x0) ;
   x = [x, a] ;
end
n=1:41;
```

```
figure(2);
plot (n,x, '-*')
title ('alpha = 2.5');
xlabel ('number of stages');
ylabel ('light composition');
legend('R=2.4','R=2.7','R=3')
```

The plot obtained is shown below which is obtained by running q2maingrp11.m script :- (Result)