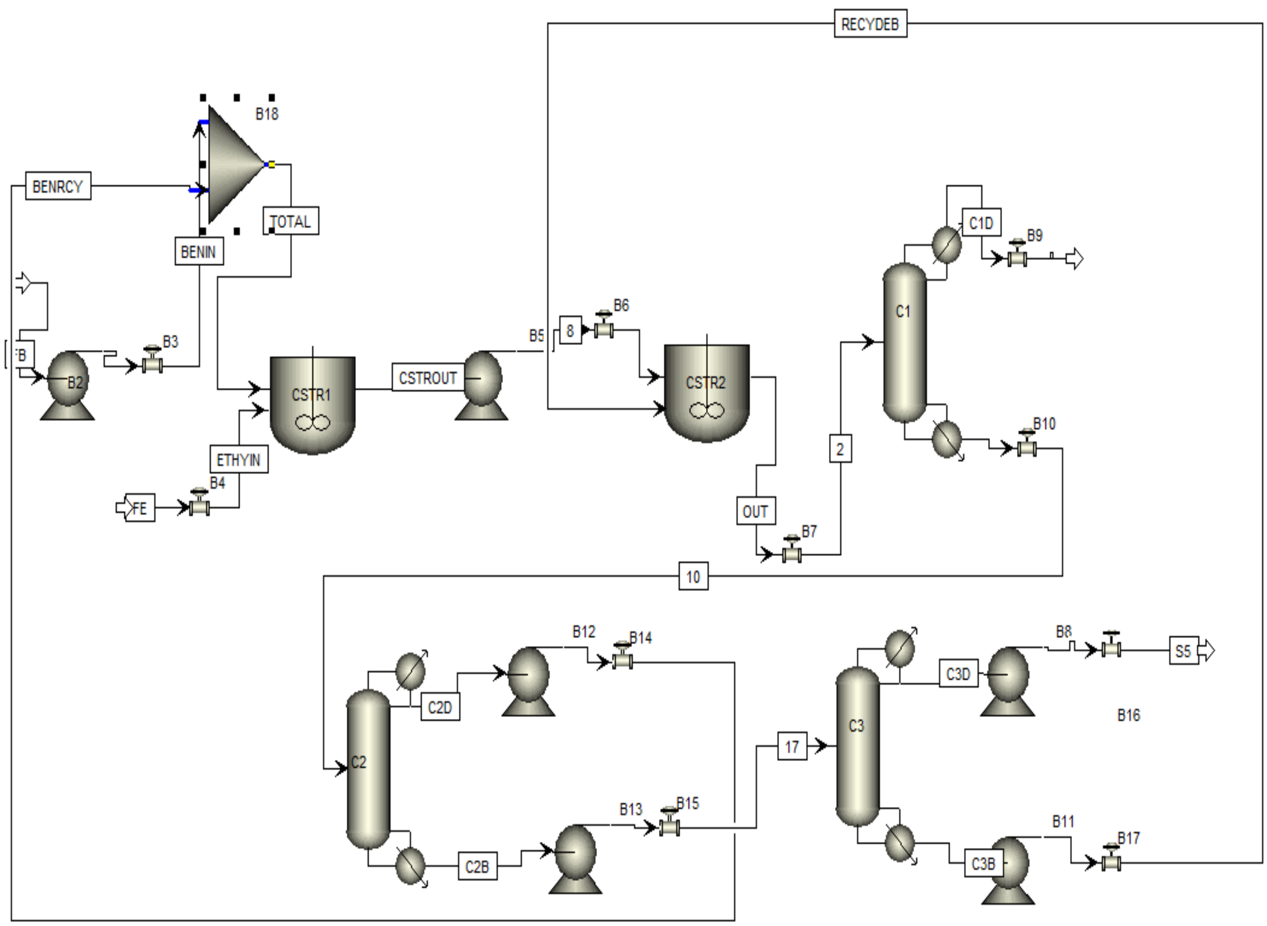
CHE352: SIMULATION LAB 8

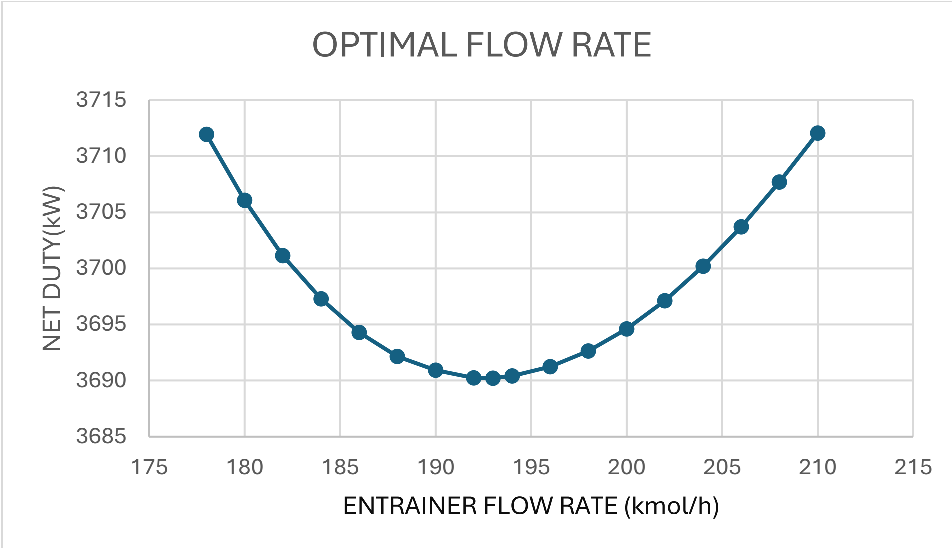
Name: Bhavishya Gupta

Roll No- 220295



Question 1

Sensitivity 1: Optimum Entrainer rate was determined by varying the net entrainer rate over net duty of the columns.



Minimum Entrainer flow rate: 193.507 kmol/h of Benzene recycle rate from column 2 to CSTR 1

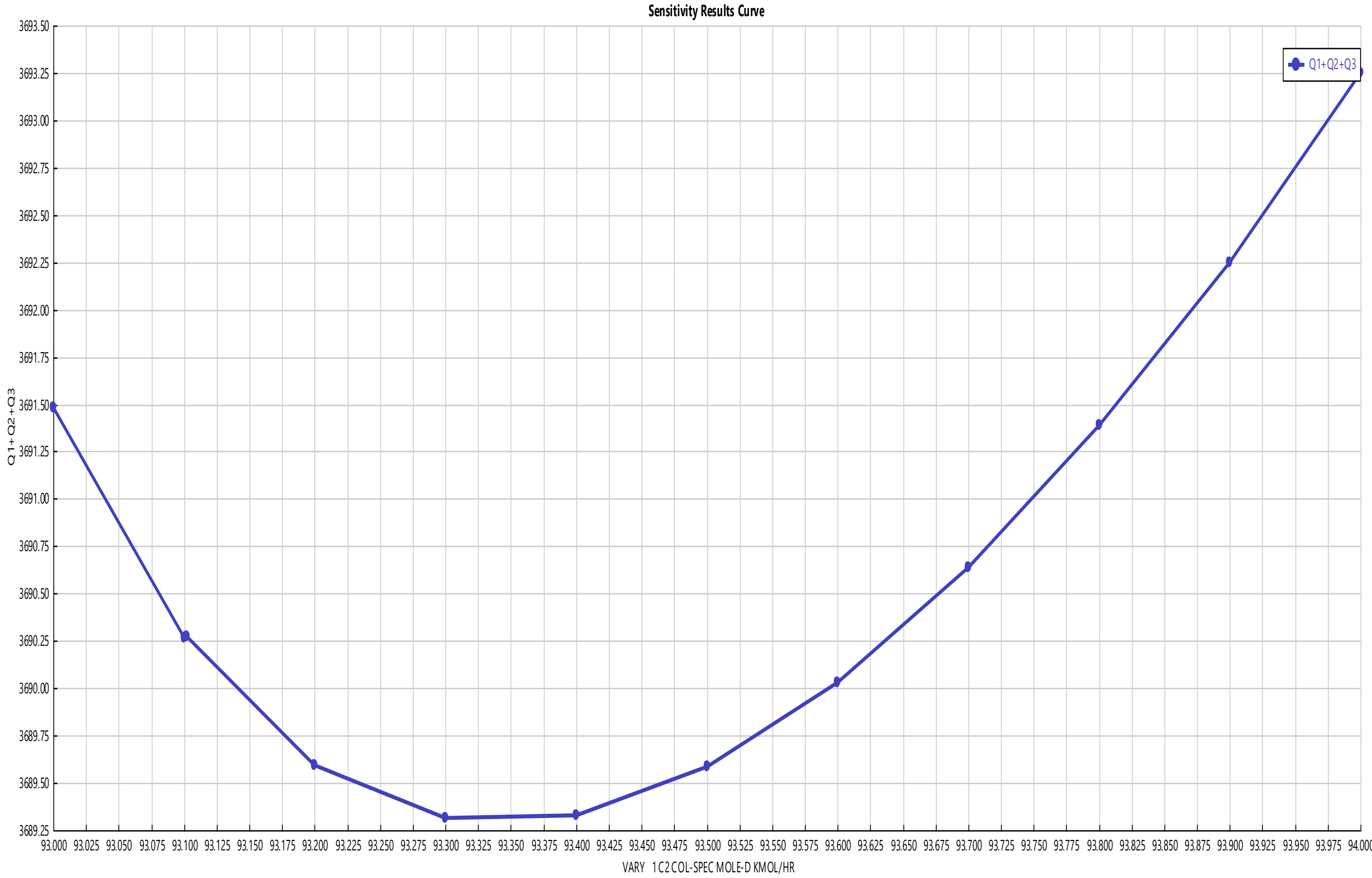
Benzene flow rate in entrainer: 192.448 kmol/h

Recycled Benzene from rad-frac: 92.241 kmol/h

Fresh Makeup Benzene: 100.207 kmol/h

Minimum Overall Energy consumed: 3690.219 kW

<u>Sensitivity 2</u>: Total duty was further minimised by varying the distillate rate of the second column

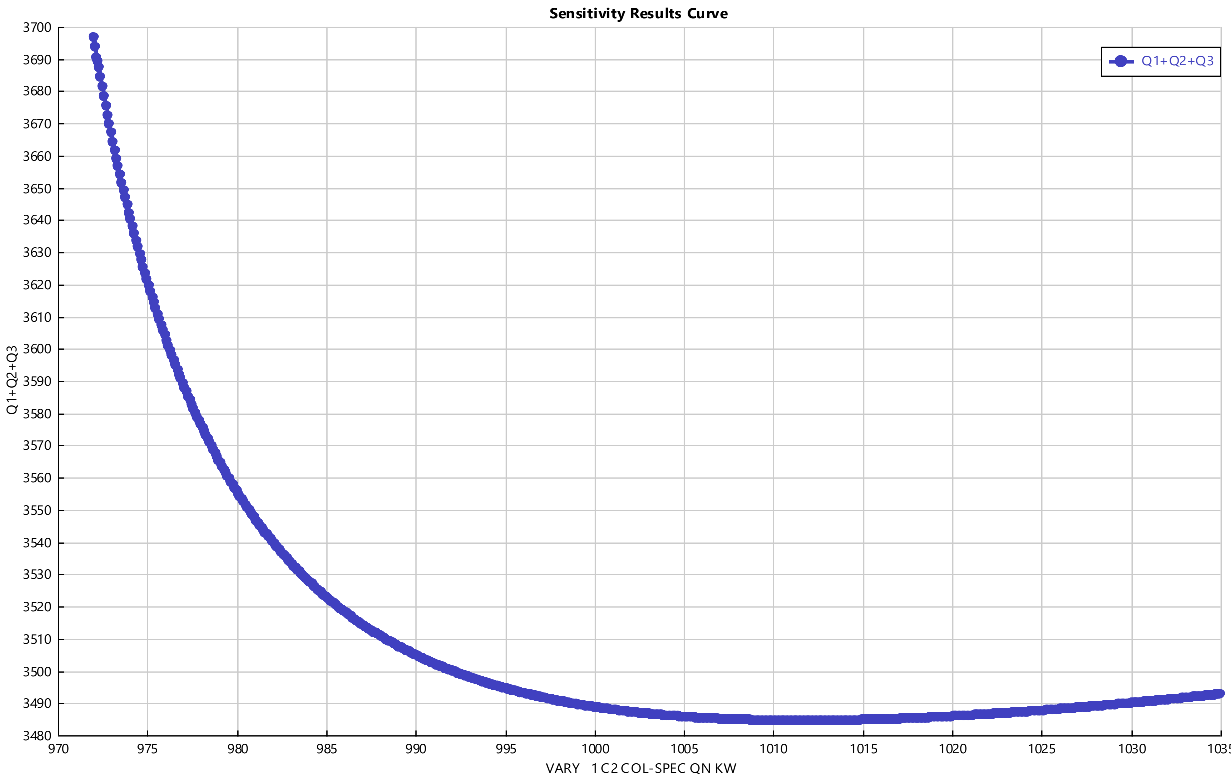


Minimum Overall Energy consumed: 3689.311 kW

DOF Controlled: Benzene Purity in “BENRCY” stream

Final Value: 0.989

<u>Sensitivity 3:</u> Duty was again reduced by varying the reboiler duty of the second column

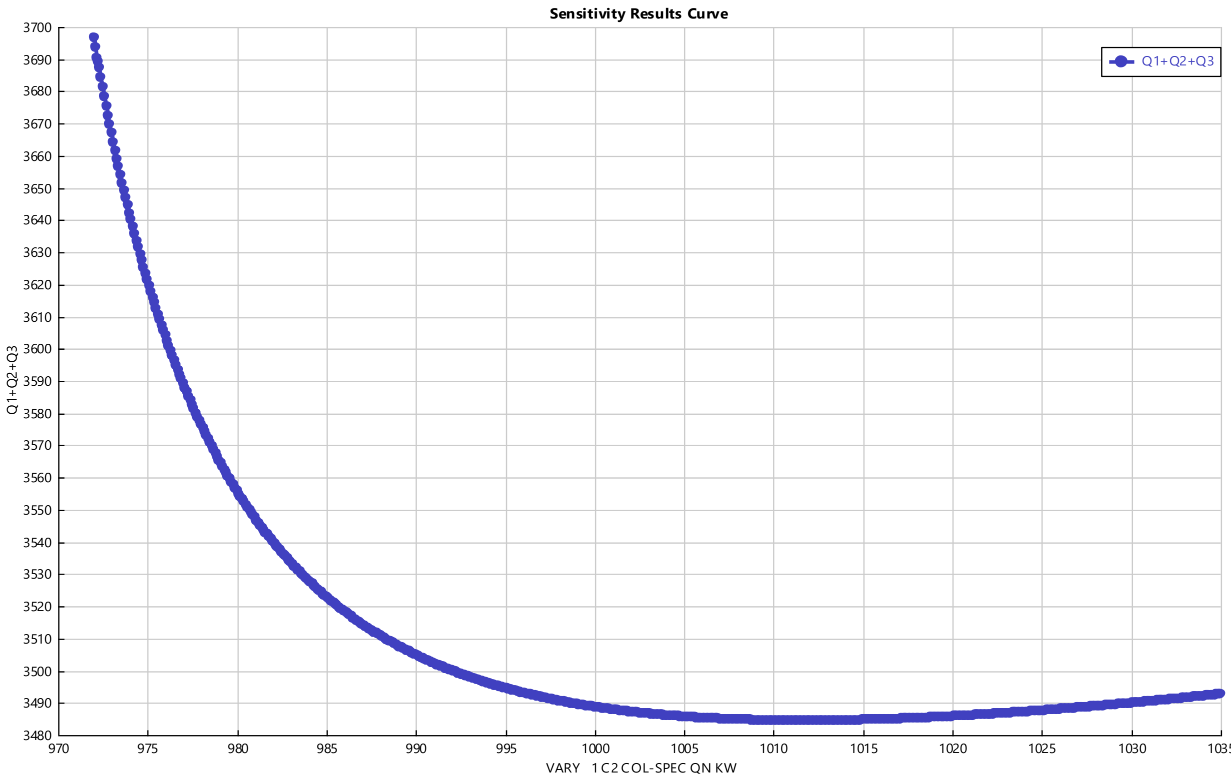


Minimum Overall Energy consumed: 3484.453 kW

DOF Controlled: Benzene Impurity in “C2B” stream

Final Value: 6.86×10^{-5}

<u>Sensitivity 4:</u> Duty was again reduced by varying the distillate to feed ratio of the third column



Minimum Overall Energy consumed: 3483.458 kW

DOF Controlled: EB Impurity in "RECYDEB" stream

Final Value: 0.0012214

Most Dominant Degree of Freedom: Benzene Impurity in Colum 2 bottoms controlled by Column 2 reboiler duty (as this is the case that affected column 2 the most).

Question 2

Overall Material balance: -

Stream	Total Flow (kmol/h)	Ethane mole fraction	Ethylene mole fraction	Benzene mole fraction	Diethyl Benzene mole fraction	Ethyl Benzene mole fraction
Feed	105.26	0.05	0.95	0	0	0
Makeup	100.207	0	0	1	0	0
Distillate: column 1	5.56054	0.946	0.000109	0.05333	5.786×10^{-9}	6.485×10^{-5}

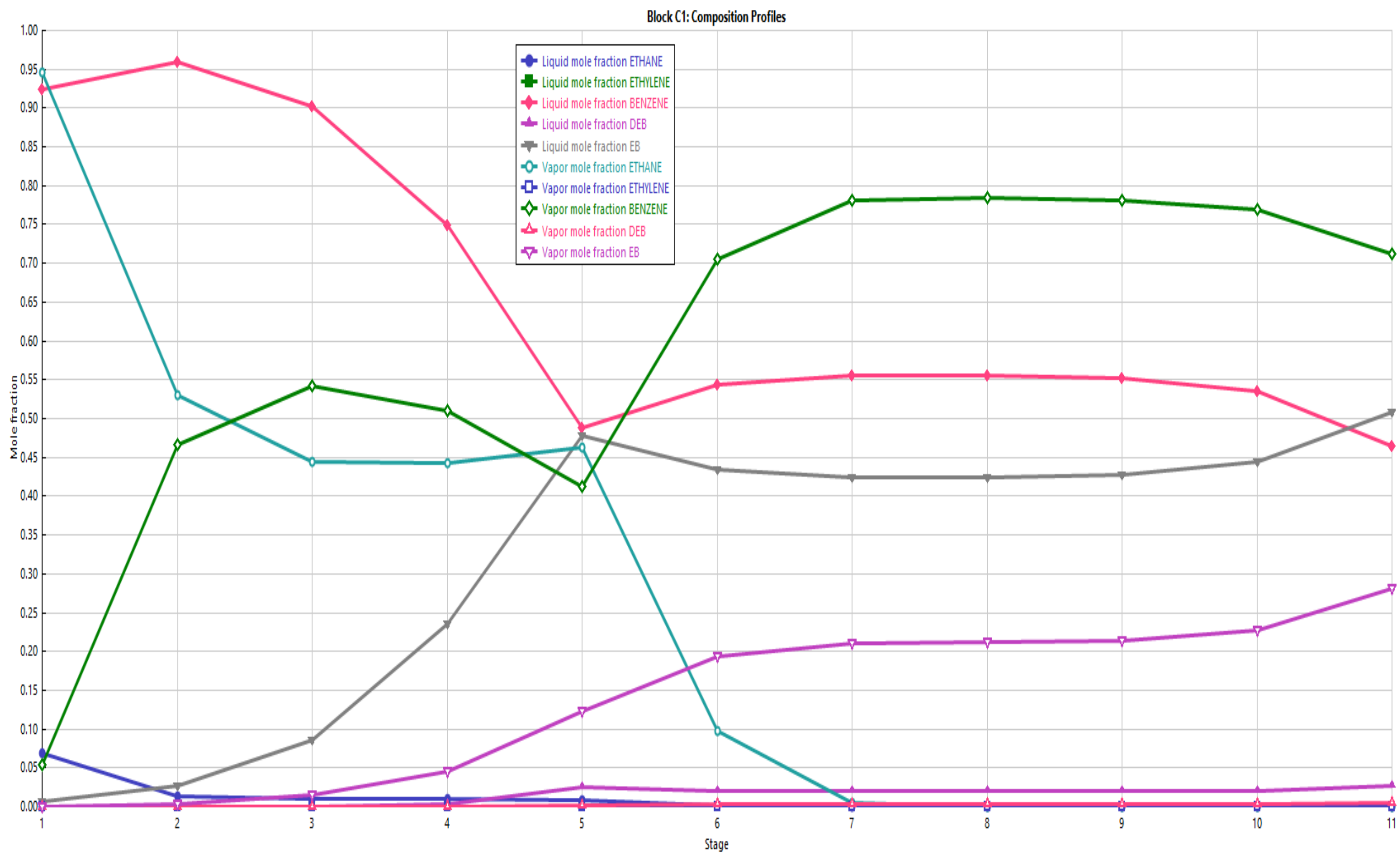
Distillate: column 3	99.9106	0	0	7.219×10^{-5}	0.000927804	0.999
Loss of moles in conversion during reaction	99.996	_	_	_		

Overall Operational Energy Balance: -

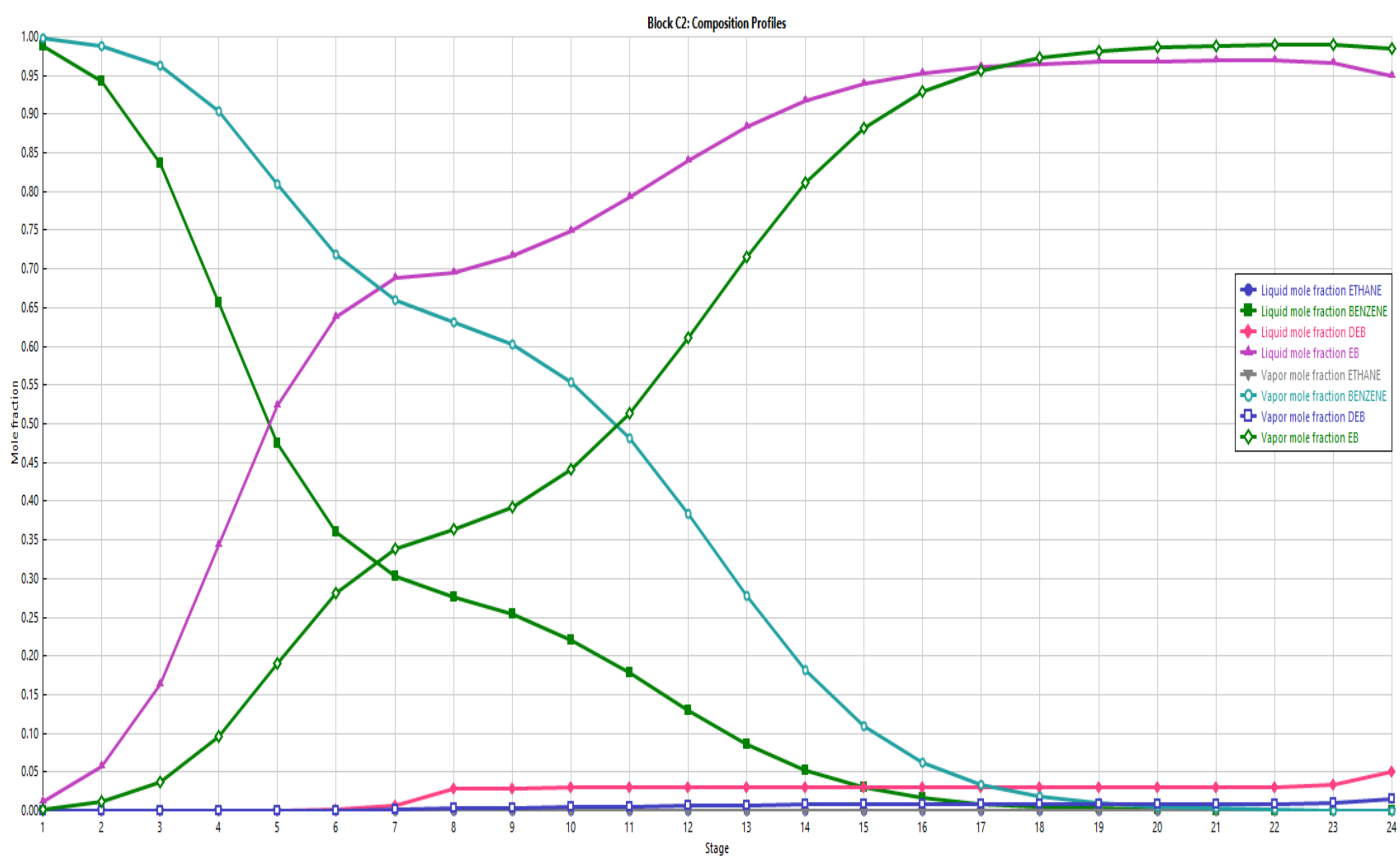
Equipment	Net Duty (kW)
Column 1: Reboiler	636.028
Column 2: Reboiler	1011.8
Column 3: Reboiler	1835.6312
Column 1: Condenser	-60.255
Column 2: Condenser	-1862.333
Column 3: Condenser	-1881.9029

Question 3

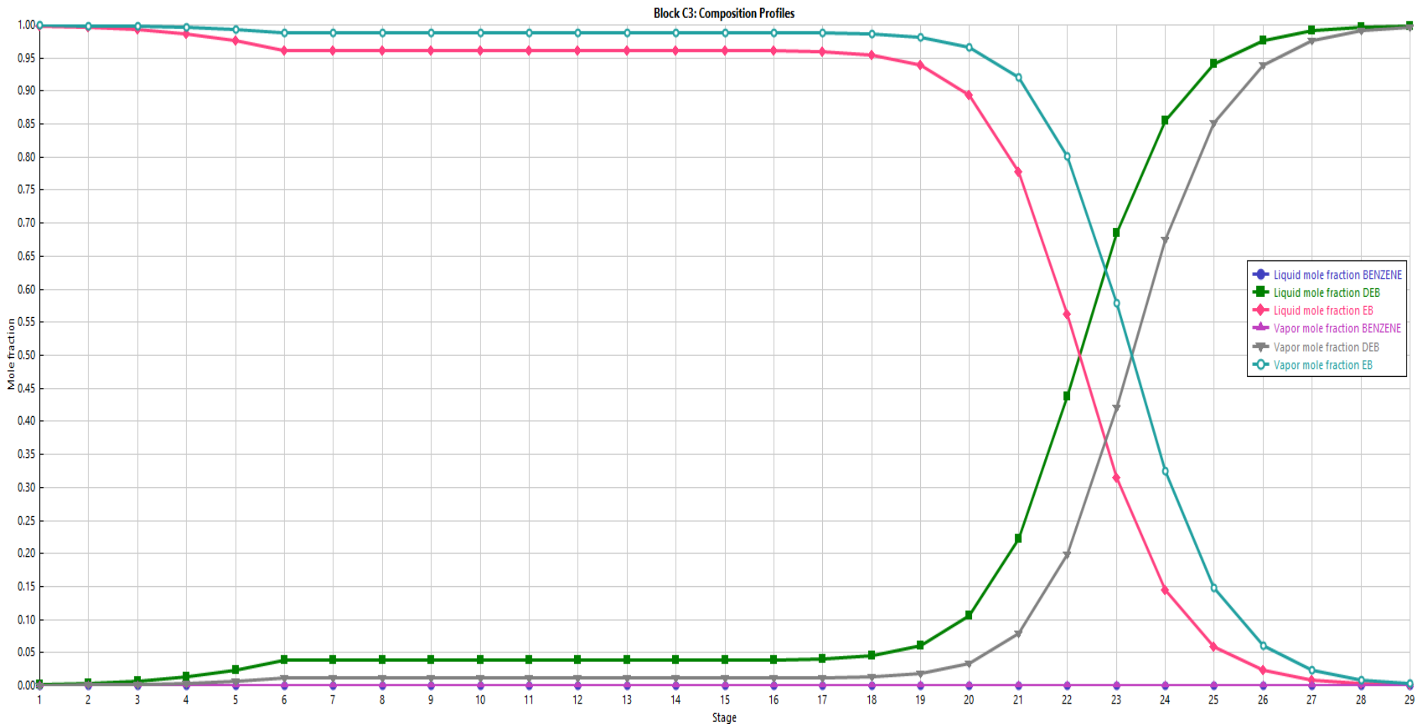
Composition profile column C1:-



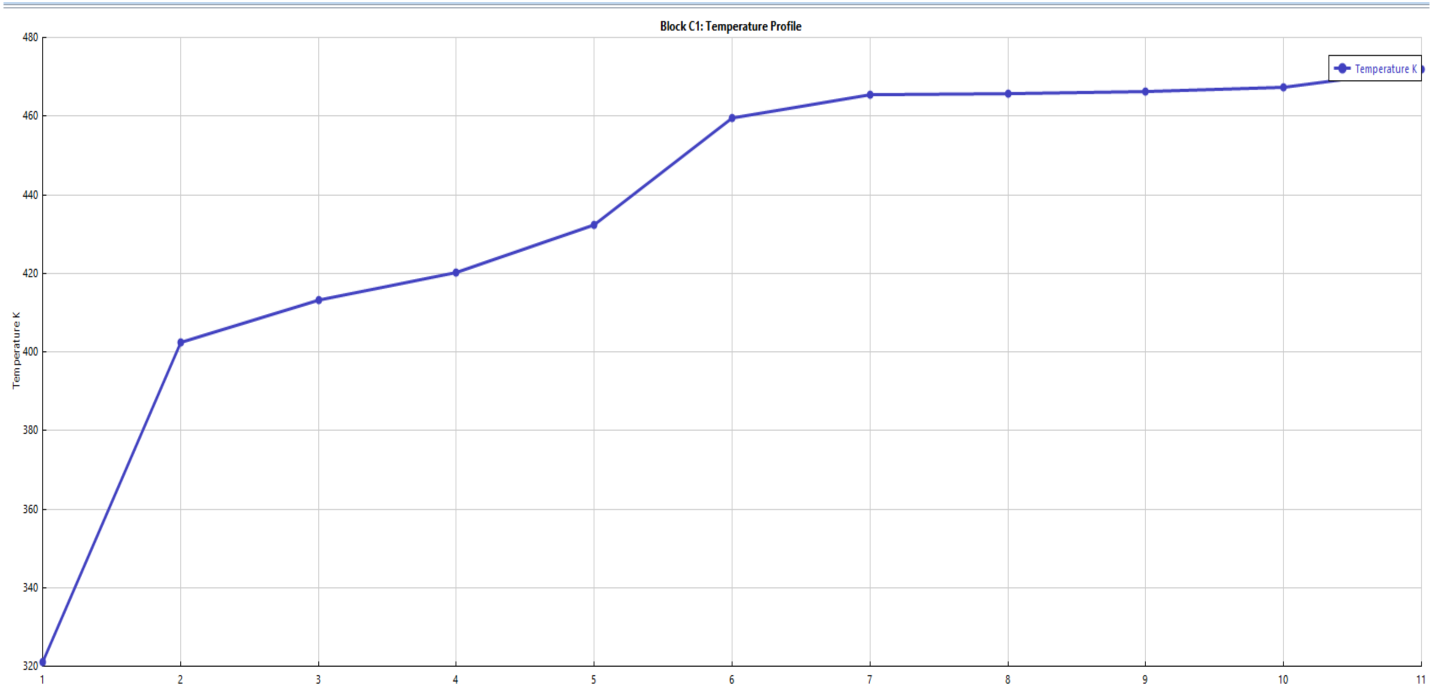
Composition profile column C2:-



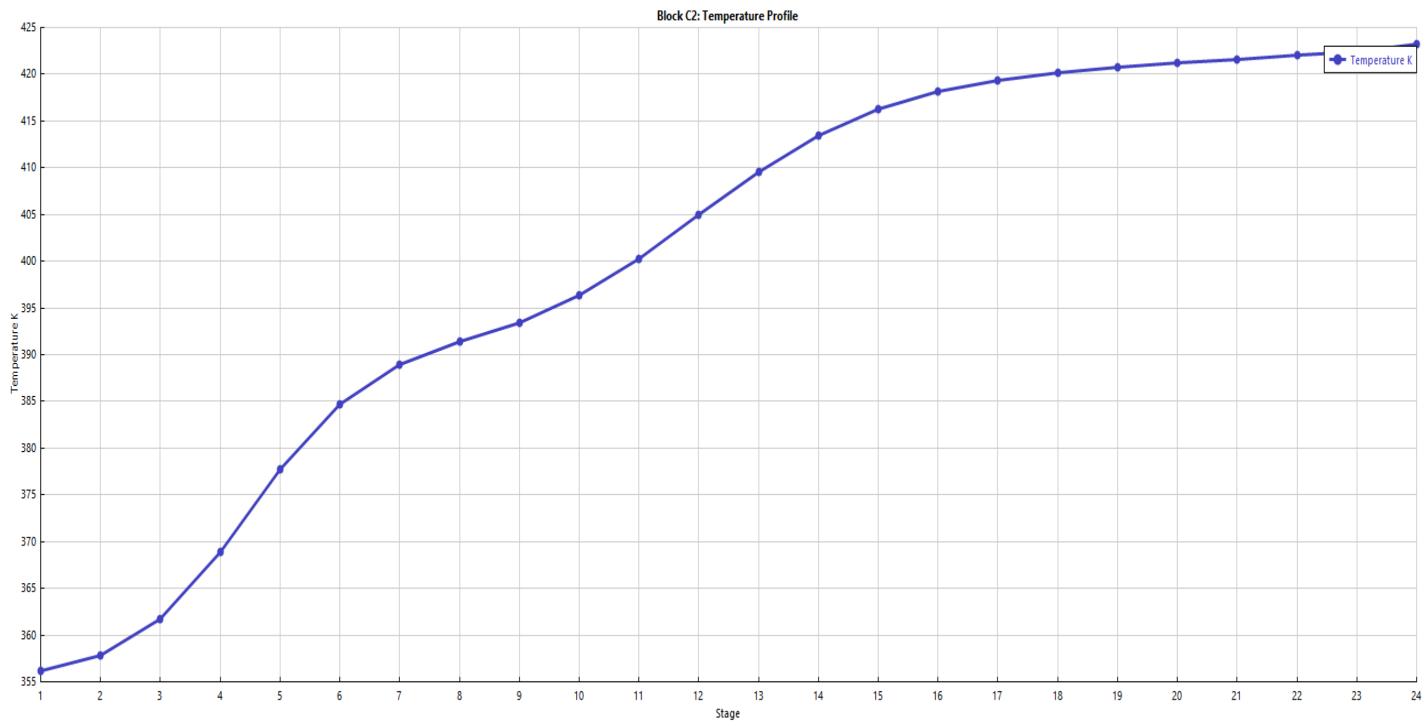
Composition profile column C3:-



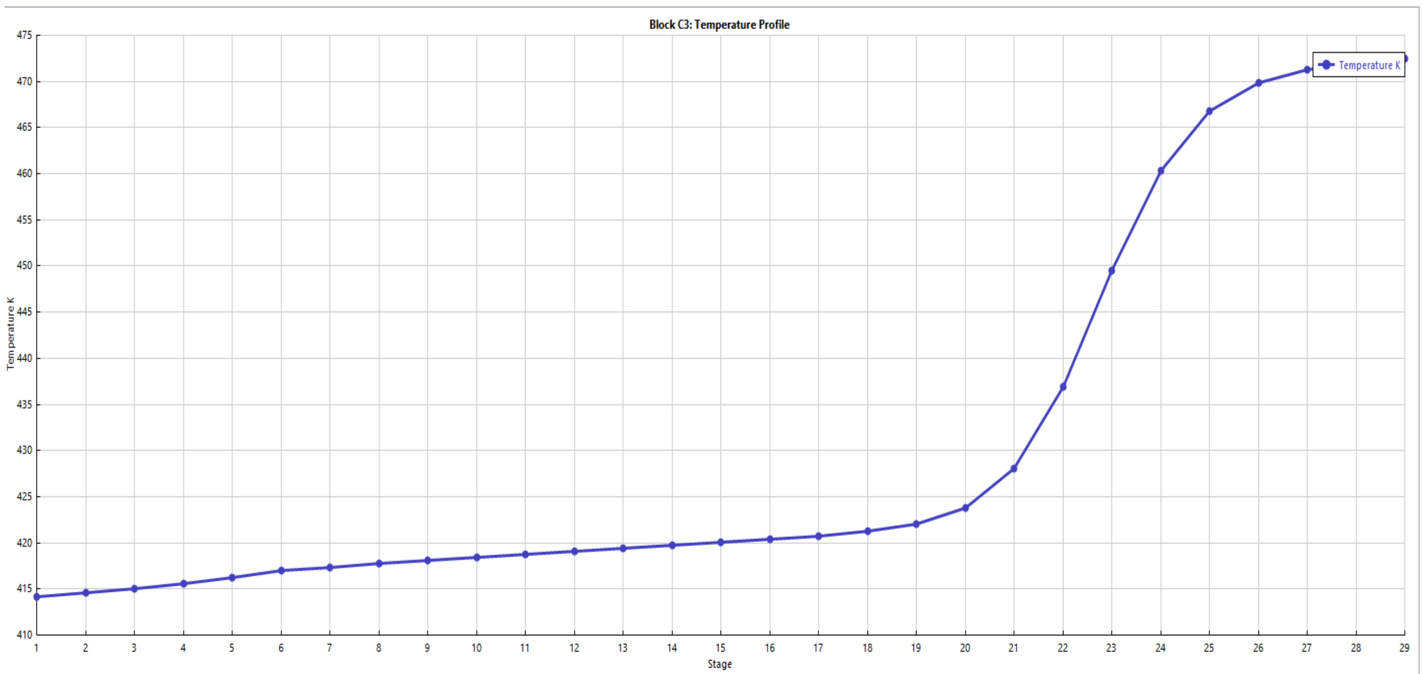
Temperature profile column C1:-



Temperature profile column C2:-



Temperature profile column C3:-



Question 4

Column	No of trays	Reboiler type	Condenser type	Condensor duty (kW)	Reboiler duty (kW)	Reboiler temp difference (K)	Steam used in reboiler	Condenser temp difference (K)	Steam used in condensor	Diameter (m)	Tray space (m)
C1	11	Partial	Partial	-60.255	636.028	4.778	Hp	81.245	Cooling water	0.6694617	0.6096
C2	24	Partial	Total	-1862.333	1011.8	0.855	Mp	1.688	Cooling water	1.2173070 8	0.6096
C3	29	Partial	Total	-1881.90291	1835.63115	0.482	Hp	0.431	Cooling water	1.3080559 4	0.6096

Column	Column Cost (*1.0e+05$)	Tray Cost (*1.0e+03$)	Condensor cap cost (*1.0e+06$)	Reboiler Cap cost (*1.0e+06$)	Total capital cost (*1.0e+06$)
C1	0.5521	0.1137	0.0087	0.1946	0.2586
C2	1.9203	0.8925	1.0012	0.8051	1.9992
C3	2.4136	1.1884	2.4481	1.7210	4.4117

TCC = 6.6696*10^6 $

YOC = 1.0686*10^6 $ (from circulating fluid used in reb and con of all columns)

PBP = 3 years

TAC = 3.2918*10^6 $

Appendix:

Code Used for Calculating TAC (MATLAB): -

```
clc
clear all
close all

col_data=[11 9 -60.255    636.028      4.778  81.245 0.669461701  0.6096;
24     23 -1862.33394      1011.8 0.855  1.688  1.217307083  0.6096;
29     28 -1881.90291      1835.63115   0.482  0.431  1.308055935  0.6096
];

% [NO OF TRAYS      EFFECTIVE_NO_FO_TRAYS      CONDENSOR DUTY      REBOILER
% DUTY REBOILER TEMP DIFFERENCE   CONDENSER TEMP DIFFERENCE DIAMETER      TRAY SPACE]

%[C1;C2;C3]

Colm_cost=zeros(1,3);
for i=1:3
```

```
Colm_cost(i)=17640*col_data(i,7)^1.066*(0.6096*col_data(i,2)+1.2*0.6096*(col_data(i,1
)-col_data(i,2)))^0.8092;
end

Tray_cost=zeros(1,3);
for i=1:3
    A=pi*col_data(i,7)^2/4;
    Cp=exp(2.994+0.446*log(A)+0.396*log(A)^2);
    N=col_data(i,2);
    if N<20
    Fq=exp(0.477+0.085*log(N)-0.347*log(N)^2);
    else
        Fq=1;
    end
    Tray_cost(i)=Cp*N*1.8*Fq;
end

conden_cap_cost=zeros(1,3);
HTC_C=0.568;
for i=1:3
   delta_T=col_data(i,6);
   Q_cond=abs(col_data(i,3));
   A=Q_cond/(HTC_C*delta_T);
   conden_cap_cost(i)=7296*A^0.65;
end

reb_cap_cost=zeros(1,3);
HTC_R=0.852;
for i=1:3
   delta_T=col_data(i,5);
   Q_reb=col_data(i,4);
   A=Q_reb/(HTC_R*delta_T);
   reb_cap_cost(i)=7296*A^0.65;
end

reactor_cost=zeros(1,2);
for i=1:2
    V=200*10^-6;
    asp_rat=2;
    D=(V/asp_rat/pi*4)^(1/3);
    L=D*asp_rat;
    reactor_cost(i)=17640*D^1.066*L^0.802;
end

Total_Cap_cost_columns=Colm_cost+conden_cap_cost+Tray_cost+reb_cap_cost;

Total_Cap_cost_of_all=sum(Total_Cap_cost_columns)+sum(reactor_cost);

%% OPERATING COST

LPS_cost=7.78;%GJ^-1
MPS_cost=8.22;
HPS_cost=9.8;
CW_cost=0.354;
```

```
Cond_op_cost=CW_cost*sum(abs(col_data(:,3)))/10^6*365*24*60*60;

Reb_op_cost=(HPS_cost*(col_data(1,4)+col_data(3,4))+MPS_cost*col_data(2,4))/10^6*365*
24*60*60;

Total_op_cost=Cond_op_cost+Reb_op_cost;


TCC=Total_Cap_cost_of_all;
YOC=Total_op_cost;
PBP=3;
TAC=TCC/PBP+YOC;
```