

Modeling of Absorption - Stripping Network for Non-ideal Hydrocarbon Mixtures

A Thesis

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the Degree of Master of Science in
Chemical Engineering**

By

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CERTIFICATION

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ABSTRACT

The present work is concerned with constructing a simulation computer program of multi – component absorption – stripping network through the use of rigorous method based on Otto Burningham sum- rates method by using MAT LAB 6.5 package . Two hydrocarbon systems A and B were studied.

The design of equilibrium stage models requires thermodynamic data such as the equilibrium constant and vapor and liquid enthalpies. In this study, the data are predicted by using cubic equation of state namely Peng Robinson equation of state and Soave Redlich Kwong equation of state. The Antoine vapor pressure equation was used to calculate the latent heat of vaporization.

The results obtained using SRK-EOS for thermodynamic calculation were compared with results obtained by other references [1, 2] to give the accuracy of the simulation computer program. For the absorber, three hydrocarbon systems A, B, and C were studied and for system C the accuracy of the computer program was 98%, while for the stripper two hydrocarbon systems A and B were studied and for system A the accuracy of the computer program was 99.5%.

In this work PR-EOS was used this is because using PR-EOS gives better results in fractional absorbed and stripped for absorption and stripping processes and their networks.

The effect of many process variables on the performance of absorption –stripping network were studied. These variables include; number of stages, wet gas feed temperature, operating pressure, and type of the solvent. The effect of the process variables was studied through the total vapor and liquid flow rate profiles, temperature profiles, fraction stripped and vapor mole fraction.

The best effect obtained for absorption – stripping network for system A and B , is by decreasing the number of stages the fraction stripped down to 48.18% for system A and 50% for system B , increasing wet gas feed temperature the fraction stripped down to 48.194 % for system A and 49% for system B, decreasing the operating pressure the fraction stripped down to 47.7% for system A and 49.7% for system B and increasing the carbon number of the solvent the fraction stripped down to 48.4% for system A and 49.75% for system B.

CONTENTS

Contents	Page
ABSTRACT	I
CONTENTS	III
NOMENCLATURE	VII
Chapter One : Introduction	
1.1 .Introduction	1
Chapter Two: Literature Survey	
2.1. Introduction	3
2.2. Absorption – stripping network	3
2.3. Types of absorption– stripping network	4
2.4.Thermodynamic models of multi -component multi stage absorption – stripping network	6
2.4.1. Equation of state	7
2.4.1.1.Compressibility factor	10
2.4.1.1.1.Three parameter correlation	10
2.4.2.Vapor –Liquid Equilibrium (VLE) for multi component mixture	12
2.4.3. Ideal solution	12
2.4.4. Enthalpy	13
2.4.5. Enthalpy of vaporization	14
2.4.6. Residual enthalpy	14
2.4.7.Fugacityand Fugacity coefficient	14

2.4.8. Equilibrium constant	15
2.5. Absorption- Stripping network design method	16
2.5.1. Short-Cut method	16
2.5.2. Rigorous method	17
Chapter Three : Theoretical Aspect	
3.1. introduction	20
3.2. Design procedure for absorption – stripping network	20
3.2.1. method of analysis	20
3.2.2. Specification of variable.	21
3.2.3. Selection of the equation of state	27
3.2.3.1. Peng Robinson (PR EOS)	28
3.2.3.2. Peng Robinson EOS parameters	28
3.2.3.3. PR EOS mixing rules	29
3.2.3.4. Peng Robinson compressibility factor	30
3.2.3.5. Residual enthalpies of PR EOS	31
3.2.3.6. Peng Robinson (EOS) fugacity coefficient	31
3.2.4. Actual enthalpies of gas and liquid phases	31
3.2.4.1. Ideal gas enthalpy	32
3.2.4.2. Enthalpy of vaporization	32
3.3. Rigorous design method	34
3.3.1. Equation tearing procedure	34
3.3.2. Tri- diagonal matrix algorithm	38
3.3.3. Sum rate method (SR)	41
3.3.4. Rigorous method computer program	45
3.3.5. The enthalpy of partial derivatives	46
Chapter Four: Results and Discussions	

4.1. Introduction	49
4.2. Comparison between the present work and references	49
4.3. General discussion	54
4.3.1. Discussion of absorption results	54
4.3.2. Discussion of stripping results	60
4.4. Effect of process variables on the performance of the multi component absorption, stripping and absorption-stripping network:	64
4.4.1. Absorption process	64
4.4.1.1. Effect of changing number of stage	65
4.4.1.2. Effect of changing wet gas feed temperature	69
4.4.1.3. Effect of changing operating pressure	73
4.4.1.4. Effect of changing type of solvent	77
4.4.2. Stripping process	81
4.4.2.1. Effect of changing number of stage	81
4.4.2.2. Effect of changing rich oil temperature	85
4.4.2.3. Effect of changing operating pressure	89
4.4.2.4. Effect of changing the type of solvent in the rich oil	93
4.5. Absorption – stripping network	96
4.5.1. Effects on the Absorption-Stripping network	97
4.5.1.1. Effect of changing number of stage	97
4.5.1.2. Effect of changing wet gas feed temperature	101
4.5.1.3. Effect of changing operating pressure	105
4.5.1.4. Effect of changing type of solvent	109

Chapter Five: Conclusions and Suggestion

5.1. Conclusions	114
5.1.1. Absorption column	114
5.1.2. Stripping column	115
5.1.3. Absorption –Stripping network	116
5.2. Suggestion of the future work	117

References	118
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Appendices

Appendix A-I

Appendix A-II

Appendix A-III

Appendix B

Appendix C

NOMENCLATURE

Symbols	Definition
A,B	Parameters of Peng Robinson equation of state, equations(3-1)&(3-2)
A1,A2,A3	Constants of Antoine vapor pressure equation, equation. (3-22)
A, B,C	Three gases hydrocarbon
A,B,C,D	Constants of ideal gas specific heat , equation.(2-19):Tri diagonal matrix parameter
a	Fraction absorbed
a, b	parameters of Vander Waals equation of state, equations (2-4)
BP	Bubble point method
BWR	Benedict-Webb-Rubin equation of state
Comp.	Component
Cp	Specific heat, equation. (2-19) J/mole.K
CPU	Central process unit
Cyc	Cyclo
E	Phase equilibrium equation, equation (3-29)
EOS	Equation of state
F	Feed flow rate mole/ sec
f	Fugacity N/m ²
G, g, h	Parameters of Riedel Plank-Miller equation
H	Enthalpy J/mole
K	Equilibrium constant ,equation .(2-13)

k	Interaction parameters, equation. (3-8)	
L	Liquid flow rate	mole/sec
M	Material balance equation , equation .(3-28)	
MESH	Material balance ,equilibrium ,mole fraction summations ,enthalpy balance equations , equations (3-28) through(3-32)	
N	Number of stages	
n	Number of moles	
no.	Number	
P	Pressure	N/m ²
PR	Peng Robinson equation of state	
Q	Heat transfer rate/sec	J /sec
R	Gas constant =8.314	J/mole.K
S	Mole fraction summations equations (3-30),(3-31)	
s	Stripping factor	
SR	Sum rates method	
SRK	Soave -Redlich- Kwong equation of state.	
T	Temperature	K
U	Liquid side stream flow rate	mole/sec
V	Vapor flow rate : Volume	mole/sec M ³
VLE	Vapor -liquid equilibrium	
W	Vapor side stream flow rate, mole/sec	
x	Liquid mole fraction	
y	Vapor mole fraction	
Z	Compressibility factor	
z	Feed mole fraction	

Greek

Letters

γ	Activity coefficient	
Δ	Change or difference	
λ	Latent heat of vaporization	J/mole
ϕ	Fugacity coefficient ,equations.(2-26),(3-16)	
μ	Chemical potential	
ω	A centric factor ,equation.(2-7)	

Subscript

b	Boiling
c	Critical
f	Feed
I	component I in the mixture
j	Component j in the mixture
k	Trial number
m	Stage number
r	Reduced
V	Vapor phase
v	Vaporization

Superscript

g	Gas phase
id	Ideal solution
ig	Ideal gas
V	Vapor phase
L	Liquid phase
o	Pure component
R	Residual

Chapter One

Introduction

1.1. Introduction:

The separation of liquid and gaseous multi component mixtures into pure components or into fractions of desired composition is one of the most important functions of chemical engineering [1]. Absorption – stripping network are most widely used in both chemical and petrochemical industries, and there are many techniques, which are employed to develop the equation to predict their performance.

The calculations of chemical engineering processes, especially separation processes, require thermodynamic data on the materials being considered, therefore; the main problem in the design of multi component absorption – stripping network is obtaining vapor – liquid equilibrium data and thermodynamic data of the material [1].

The concept of the equilibrium stages based upon presumption that the phases leaving the stages are thermodynamically in equilibrium, but the knowledge of phase equilibrium is necessary for understanding the processes in a separation unit and for computation of the final state in an equilibrium stage.

In this study, many thermodynamic calculations occur to obtain the (K-value and H enthalpies) by using equation of state. So as Peng Robinson equation of state is used for this purpose. A rigorous method used to design absorption – stripping network, which is based on sum rate method. This method used material balance, equilibrium relation and energy balance to determine the absorption fraction for each components and stage temperature.

Many variables have been considered in this work which affects the performance of absorption- stripping network, absorption and stripping processes such as number of stage, feed temperature, operating pressure and solvent.

The aim of this work is employing different thermodynamic equations of state, namely PR-EOS and SRK-EOS to develop a computer program in MAT LAB 6.5 based on Otto – Buninghum Sum-rate method for simulating multi-component absorption- stripping networks and to compare the results obtained from the developed computer program with those obtained from other researcher [1, 2].

The performance of the absorber, stripper and their networks were studied by changing the number of stage, wet gas feed temperature, operating pressure and the carbon number of the solvent and their effects on the vapor flow rate profiles liquid flow rate profiles and temperature profiles , fraction absorbed and stripped and vapor mole fraction.

Chapter Two

Literature Survey

2.1. Introduction:

Absorption is the separation process which involves the transfer of one or more materials from the gas phase to the liquid solvent, the physical phenomenon of absorption involves no chemical change present in the system. Most, frequently, however, the considerable vapor (**solute**) is separated from the solvent and the solvent circulated to the process. The operation of removing the absorbed solute from the solvent is normally referred to as stripping. The absorption and stripping processes plant has the purpose of purifying raw material, intermediate, and product. This chemical process is widely used in chemical industry [3].

The procedure to design and simulate multi component absorption – stripping network is divided into two main parts ,first is the prediction of thermodynamic properties (**K- values, vapor and liquid enthalpies**)of materials being considered , and second is the application of the design method for non –ideal systems (**rigorous method**).

2.2. Absorption–Stripping network:

Absorption is the physical process that involves transfer of one or more components from the gas phase into a liquid solvent. In some cases, a portion of the solvent may be transferred to the gas phase, but this is an incidental effect, rather than the main intent of the absorption process [1].

Generally, the solvents used are expensive, so they are processed to remove the absorbed gas and then returned to the system. This solvent –recovery process is called stripping .So as the absorbers are frequently connected with strippers to permit re- generation and re–cycle of absorbent.

The unidirectional of material creates thermal effects. Where the material transferred undergoes a phase change, and the heat of vaporization or condensation are involved along with smaller heat of solution. In absorption, most of the heat released as the gas components condense into the liquid phase must appear as sensible heat in the liquid ,therefore, the temperature of the liquid phase rises as it passes down the column ,and the temperature of vapor phase decreases as it rises through the column . The effect is opposite in stripping column , where the heat of vaporization of the light components as they pass from the liquid to the gas phase is supplied from the sensible heat content of the liquid phase . When the small amount of material is transferred, the temperature changes will be negligible [4].

2.3. Types of Absorption –Stripping network:

There are different types of absorbent recovery so as:

1. Absorbent recovery schemes by using steam or inert gas stripping, as shown in Fig (2.1) where the lean solvent enters the top of the absorber and follows downwards in counter current contact with the rising vapor stream (**rich gas**).The solvent with the material leaving the bottom of the column is called rich oil, and the gas leaving the top of the column so – called the lean gas. The lean oil enters the stripper for solvent recovery. So as the rich oil is separated, generally at elevated temperature and ambient pressure, by contacting liquid feed with the stripping gas instead of the liquid solvent in absorption process [5].

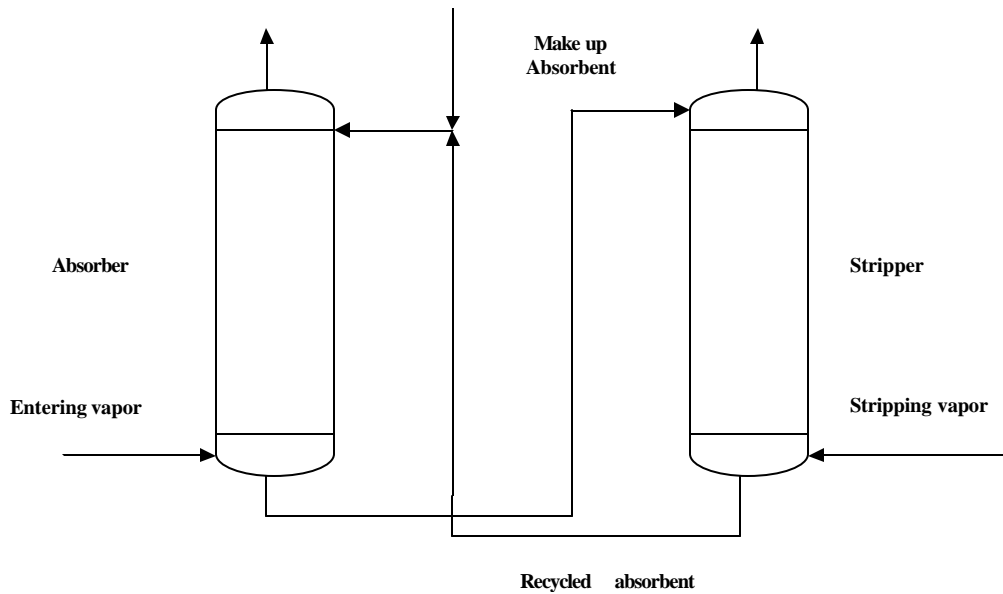


Fig. (2.1) Absorption –stripping network by using steam or inert gas stripping

2. Absorbent recovery schemes by using re – boiled stripping as shown in Fig. (2-2) which is used if bottom product from stripper is thermally stable , it may be re – boiled without using stripping agent so – called re-boiled absorption [5] .

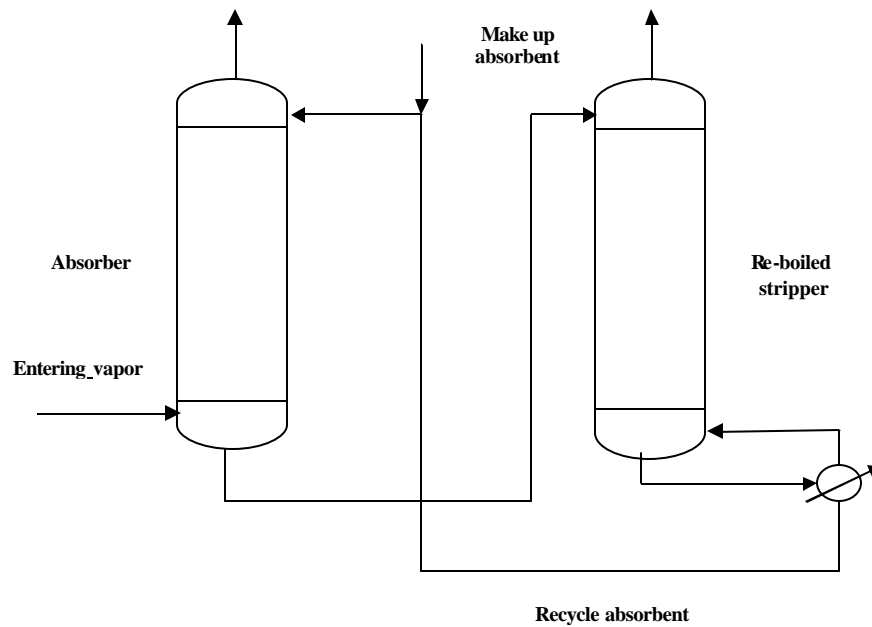


Fig. (2.2) absorption-stripping network by using re -boiled stripping

3. Absorbent recovery schemes by using the distillation as shown in Fig. (2.3) which is used if the bottom product of the distillation column is stable when the condensation of vapor leaving the top of distillation is not readily accomplished, an absorbent may be introduced to the top tray in place of reflux, then the resulting operation is called re-boiled absorption [5].

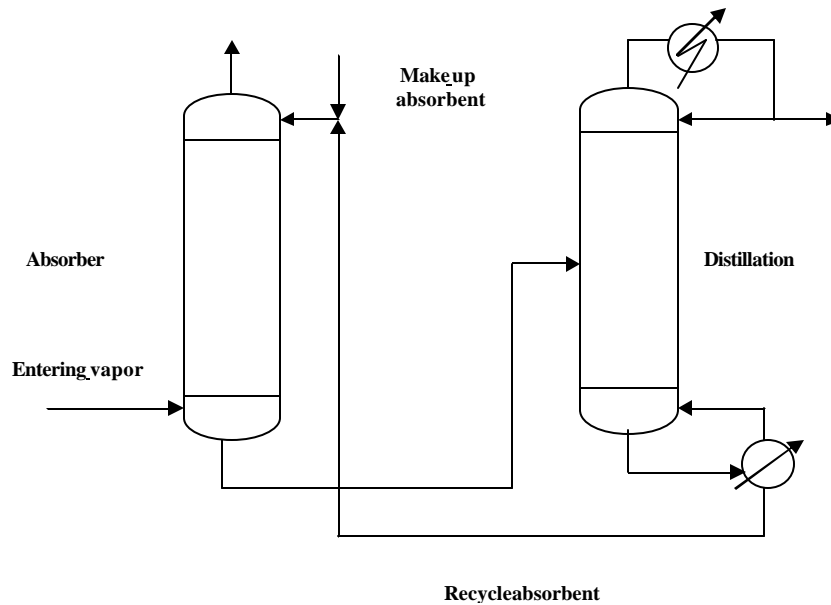


Fig. (2.3) Absorption – Stripping network by using distillation

2.4. Thermodynamic models of multi -component multi stage absorption – stripping network [6]:

The selection of thermodynamic model for the prediction of enthalpy and phase equilibrium (**K**) is fundamental to process modeling.

The primary area of interest for thermodynamic model selection involves two phase liquid – liquid system, such as extraction and extractive distillation. Vapor – liquid system, such as distillation, stripping and absorption.

All these thermodynamic properties in a consistent manner from (**PVT**) relationship, which are usually referred to as equation of state (**EOS**). The equation of state have the widest application for distillation ,absorption , and stripping calculations .

2.4.1. Equation of state:

An equation of state (**EOS**) relates the quantity and volume of gas to the temperature and pressure. The ideal gas law is the simplest (**EOS**) [7]:

$$PV=nRT \quad (2-1)$$

As the system temperature decreases and the pressure increases deviations from the ideal gas (**EOS**) results. There are many equation of state [8] available for predicting non – ideal gas behavior and another method incorporate a compressibility factor into the ideal gas law [6]. The earliest equation of state may be the ideal gas law, which results from Boyle's laws [9]:

$$Z = \frac{PV}{RT} = 1 \quad (2-2)$$

This is valid for real gas for pressure up to 3 atm.

In **1873** the first equations of state (**EOS**) was developed by Van der Waals which is given as [10, 11]:

$$P = \frac{RT}{(V - b)} - \frac{a}{V^2} \quad (2-3)$$

The two parameters (**a**) and (**b**) are interaction force between the molecules and for the actual volumes of the molecules, respectively.

In 1901, virial equation of state has a theoretical basis and has the form of an infinite power series of volume, which is not convenient for practical use [8].

$$Z = 1 + \frac{B}{V} + \frac{C}{V^2} + \frac{D}{V^3} + \dots \quad (2-4)$$

The virial coefficient **B**, **C**, **D**, etc in equation (2-4) are dependent only on temperature. This equation used for vapor phase property calculations truncated after the second or third term [12].

Benedict – Webb - Rubin (**BWR**) (**EOS**) is of the same form as the virial equation of state extended fifth virial coefficient (**BWR**)(**EOS**) is accurate for gases containing a single species or a gas mixture with dominant component (**e.g. natural gas and provides considerable precision**)[6]. Cubic equation of state that represents an equation linear in pressure and cubic in volume and is equivalent to the virial equation truncated at the third virial coefficient [6].

One of the most successful modifications [12] was that made by Redlich and Kwong (1949). Redlich and Kwong modified the Van-der –Waals equation by the term (a/v^2) as follows:

$$Z = \frac{V}{(V-b)} - \frac{(a/T^{0.5})}{RT(V+b)} \quad (2-5)$$

At that time, a numerous modified Redlich–Kwong (**RK**) equations have been proposed by Redlich and Dunloop, 1963; Chuen and Prausnitz, 1967; Wilson, 1969; Zudkevitch and Joffe, 1970 [13].

The most widely used cubic equation of state is the Soave modifications of Redlich-Kwong (**SRK**) in 1972 equation which is a modification for the Van der Waals original equation [6]:

$$P = \frac{RT}{(V-b)} - \frac{a \cdot a}{V(V+b)} \quad (2-6)$$

The Soave Redlich Kwong (**SRK**) equation has rapidly gained acceptance by the hydrocarbon processing industry because of the relative simplicity of the equation itself as compared with the more complicated (**BWRS**) equation, Starling and Powers, 1970; Lin et al .1972 and because of its capability for generating reasonably accurate equilibrium ratios in (**VLE**) calculations[13].

The successful modification have been indeed by Soave in (1973) [14], subsequently, by Peng and Robinson [9, 13] in 1976. The (**SRK**) and (**PR**) equations of state are recommended for computing the properties of both gas and liquid phase pure components and mixtures.

Many modifications have been proposed in the intervening years , particularly in 1970 's , some of these equations are ; Fuller(1976) ,Martin (1976)[10] and Lu [10]et al .(1977) , Harmens and Knapp[8] .

The development in the line, Beattie and Bridgman [12] in 1927, proposed a five – constant (**EOS**), which is the first satisfactory EOS for the quantitative description of the real gas behavior. Many investigators, among them Starling and Han in 1973 who had accomplished a most successful generalization of the equation. Then Lee and Kesler [15] in 1975 proposed the use of two equations of state similar in form to the BWR –EOS, one for simple fluid and another for a reference fluid, the Lee Kesler correlation makes use of acentric factor.

Generally, the wide use of high – speed computers, simplicity is still highly desired for easy applications of the equation to complex problem .However, the simplest form of (**EOS**) that has found extremely valuable application in phase equilibrium predictions, is demonstrated by Soave and by Peng – Robinson.

The **PR -EOS** is currently considered the most general and simple analytical EOS, which can be used to accurately predict thermodynamic properties, especially

vapor – liquid equilibrium, properties. The **PR- EOS** is easier to solve because of its newest introduction and comparative simplicity [16].

2.4. 1.1. Compressibility factor: [17]

Compressibility factor (**EOS**) retains the simplicity of the ideal gas law but is applicable over a much wider range of conditions.

Compressibility factor is expressed as (**Z**) factor for non ideal gas as follows:

$$Z = \frac{PV}{RT} \quad (2-7)$$

It depends on gas temperature and pressure and has three parameters correlation, reduced temperature (**T_r**), reduced pressure (**P_r**), and acentric factor (**?**).

2.4.1.1.1. Three parameter correlation:

The compressibility factor is often correlated with reduced temperature (**T_r**); pressure (**P_r**) [18], as

$$Z = f(T_r, P_r) \quad (2-8)$$

Equation (2-8) is a two parameter (**EOS**); the two Parameters are (**T_r**) and (**P_r**) is expressed as follows:

$$T_r = \frac{T}{T_c} \quad \text{And,} \quad P_r = \frac{P}{P_c}$$

In 1951, Meissner and Seferian first proposed to use critical compressibility factor as third parameter. In 1954, Riedel observed that the slope of reduced vapor pressure of fluid at the critical point $\left(\frac{\partial P_{n P_r}}{\partial T_r} \right)$ so as it is considered as a third parameter called Reidel's parameter. In 1955, Pitzer proposed another third parameter known as acentric factor (**?**) [9].

Pitzer introduced the acentric factor (ω) and it has gained widest acceptance in both academic and industrial areas. Acentric factor is defined as [14]:

$$\omega = -\log P_{vPr}(at T_r=0.7) - 1.000 \quad (2-10)$$

Pitzer noted that all vapor pressure data for the simple fluid (Ar, Kr, Xe) lie on the same line when plotted as $\log p_{vPr}$ vs. $1/T_r$ and that line passes through $\log p_{vPr} = -1.000$ at $T_r = 0.7$. This is given in fig (2-4). For the simple fluid ($\omega \sim 0.0$) for all other non-polar substances and equation (2-8) becomes [17]:

$$Z = f(T_r, P_r, \omega) \quad (2-11)$$

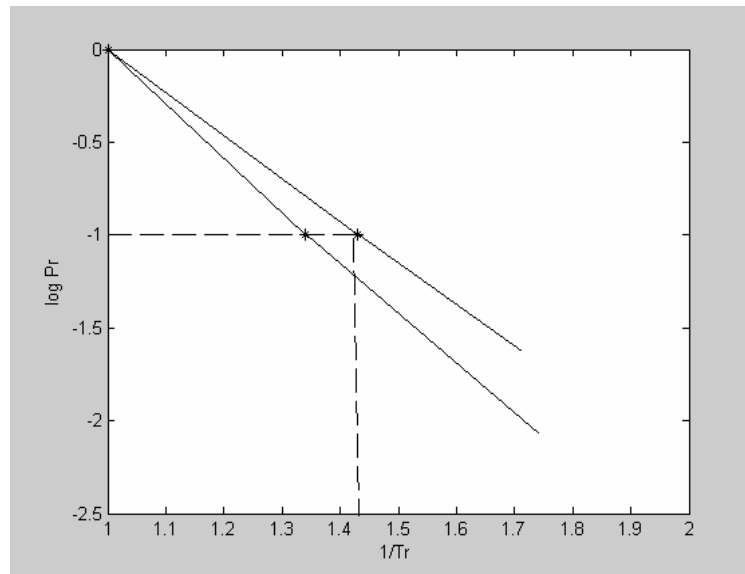


Fig (2-4) Approximate temperature depended on reduced vapor pressure

2.4.2. Vapor –liquid equilibrium (VLE) for multi component mixtures [20]:

(VLE) calculations are usually carried out for separation processes, with various form of **EOS**. The thermodynamic treatment of multi component phase equilibrium is based on the concept of chemical potential (μ).

A liquid phase and vapor phase are in equilibrium when the temperature and pressure of each component is the same in both phases.

The starting point of all **VLE** calculations is the equilibrium

$$T^v = T^L \quad (2-12)$$

$$P^v = P^L \quad (2-13)$$

$$f_i^v = f_i^L \quad (2-14)$$

2.4.3. Ideal solution:

The system which form ideal vapor and liquid mixtures at any pressure are unfortunately, only minority in the total number of systems in which the design engineer must work, usually homolog series compounds, such as paraffin and olefin hydrocarbons can safely be considered to form ideal mixtures and then only at moderate pressure (up to 10.2 atm) [4] and the activity coefficient for ideal mixture become unity so ($\gamma_i=1.0$).

The ideal gas mixture is imaginary gas mixture and every component of the ideal gas mixture obeys the ideal gas law .equation (2-1) in pure state as well as in mixture environment. However, the real gases do not obey the ideal gas law except at very low pressures.

2.4.4. Enthalpy:

The enthalpies for pure species or mixtures at temperature T and pressure P are given as follows [5]:

For gas phase

$$H_v = \left[\sum_{i=1}^c y_i H_{vi}^\circ \right] + [H_v - H_v^\circ] \quad (2-15)$$

For liquid phase

$$H_L = \left[\sum_{i=1}^c x_i H_{vi}^\circ \right] + [H_L - H_v^\circ] \quad (2-16)$$

H_v° : The ideal gas state enthalpy

The ideal gas state enthalpy can be obtained by the integration of the specific heat of gases. The specific heat of gases is given as a polynomial with temperature used as variable:

$$Cp_v^\circ = A + BT + CT^2 + DT^3 \quad (2-17)$$

The integration of equation (2-17) gives the equation of ideal gas enthalpy at any temperature T referred to a datum temperature T_o .

$$\begin{aligned} H_v^\circ &= \int_{T_o}^T Cp_v^\circ dT \\ &= A(T - T_o) + \frac{B}{2}(T^2 - T_o^2) + \frac{C}{3}(T^3 - T_o^3) + \frac{D}{4}(T^4 - T_o^4) \end{aligned} \quad (2-18)$$

Where A, B, C, and D constant can be found in appendix A -III [18, 21, 22].

For ideal gas solution equation (2-15) becomes:

$$H_v^{id} = \sum_{i=1}^c y_i H_{vi}^\circ \quad (2-19)$$

And for ideal liquid solution equation (2-16) becomes:

$$H_L^{id} = \sum_{i=1}^c (x_i H_{vi}^\circ - l_i) \quad (2-20)$$

2.4.5. Enthalpy of vaporization: [9]

The enthalpy of vaporization or the latent heat of vaporization is the difference between the enthalpy of the saturated vapor and the enthalpy of saturated liquid at the same temperature.

2.4.6. Residual enthalpy: [5, 14]

Residual enthalpy H^R is defined thermodynamically as the degree of deviation from the ideal gas state at the same temperature, volume, and composition.

In order to obtain the residual enthalpy by using EOS the following expression is used.

$$H^R = H - H^{id} \quad (2-21)$$

2.4.7. Fugacity and fugacity coefficient:

The concept of fugacity was derived to provide a measure of departure of a substance from its zero pressure state, and the fugacity of an ideal gas equal to pressure [5].

It is convenient to represent the departure from both types of ideality (**ideal gas law and ideal gas solution**) by the definitions of the mixture fugacity coefficient [5]:

$$f_i^v = \frac{f_i^v}{y_i P} \quad (2-22)$$

$$f_i^L = \frac{f_i^L}{x_i P} \quad (2-23)$$

For ideal gas behavior $f_i^v \rightarrow P_i$ and $f_i^v = 1.0$ for ideal solution behavior

$$f_i^L \rightarrow x_i f_i^\circ \text{ and } f_i^L = \frac{f_i^\circ}{P}.$$

The fugacity coefficient can be calculated by using EOS [23]:

$$f_i = \text{Exp} \left[\frac{1}{RT} \int_v^\infty \left[\left(\frac{\partial P}{\partial n_i} \right)_{T,v,n_i} - \frac{RT}{V} \right] \partial V - \ln Z \right] \quad (2-24)$$

And when $f_i^l = f_i^v$ as in equation (2-14), so the fugacity can be expressed in term of fugacity coefficient as follows [24]:

$$f_i^v y_i P_i = f_i^L x_i P_i \quad (2-25)$$

2.4.8. Equilibrium constant:

The K- values of all the thermodynamic information is related in complex way to temperature, pressure, and compositions of vapor and liquid; however when the K-values depend not only on the temperature and pressure but also on the phase composition, their calculation is inherently more difficult [14].

Therefore the equation that expressed the equilibrium constant given as:

$$K_i = \frac{y_i}{x_i} = \frac{f_i^L}{f_i^v} \quad (2-26)$$

For mixture containing polar components, the equation (2-25) is replaced by:

$$f_i^v y_i P = g_i x_i f_i^\circ \quad (2-27)$$

And the K-values become:

$$K_i = \frac{g_i f_i^\circ}{f_i^v P} \quad (2-28)$$

So for liquid phase use the activity coefficient is used and for vapor phase the fugacity coefficient is used. And it can be calculated by using charts and graphs available for most materials.

2.5. Absorption –Stripping network design method: [3]

Short –cut methods generally provide good estimates of these parameters for use in a rigorous computer solution of the multi component absorption – stripping network.

The rigorous solutions save expensive computer time than the short – cut method. However, a short – cut method can not be used in the design of non – ideal systems because it is based on the assumptions involving ideality and constant phase rates in the column .As a results rigorous calculation methods are more accurate and convenient to give the temperature, composition and stream flow rates in each stage.

2.5.1. Short –cut method:

It is also called group methods. Most of short – cut methods were developed for the design of separation columns for hydrocarbon systems in the petroleum and petrochemical industries.

It is used to get a first estimation of the top and bottom temperatures and flow rates. Approximate calculation procedures have been developed to relate compositions of streams entering columns to the number of equilibrium stage required [4]. This method does not consider detailed changes in temperatures and composition in the individual stages.

Absorption –stripping columns for non – ideal systems must therefore be designed by rigorous procedures. Therefore short – cut method used to quick solution of pin point the optimum conditions.

Kresmer [25] originated the group method. He derived over all species material balance for multistage counter current absorber. Subsequent articles by Souder and Brown [26], Horton and Franklin [27], and Edmister [28] improved the method.

2.5.2. Rigorous method:

Final design of multistage equipment for conducting multi component separations requires determination of temperature, pressure, stream flow rates, stream compositions, heat rates and mass transfer rates at each stage. This is made by solving material balance, energy (**enthalpy**) balance, and equilibrium relation for each stage. The relations are non linear algebraic equations that interact strongly. Consequently, solution procedures are relatively difficult and tedious. However, once the procedures are programmed for a high – speed digital computer solutions are achieved rapidly and almost routinely [5].

Early attempt to solve **MESH** equation or equivalent forms of these equations resulted in the classical stage - by-stage, equation - by -equation calculation procedures of Lives-Matheson [29] in 1932 and Thiele-Geddes [24] in 1933 based on equation tearing for solving simple fractionators with one feed and two products. The Thiele –Geddes method was found often to be numerically unstable when attempts to program it for digital computer. However, Holland and co- workers [30] developed an improved Thiele-Geddes procedure called Theta method, which has been applied with considerable success.

The Lewis – Matheson method is also an equation – tearing procedure. It was formulated to determine stage requirements for specifications of the separation of two key component, reflux ratio and feed stage location criterion. The Lewis – Matheson method was widely used for hand calculations, but it also proved often to be numerically unstable when implemented on a digital computer.

In 1964, Friday and Smith [31] systematically analyzed a number of tearing techniques for solving the **MESH** equations. They showed that no one technique could solve all types of problems .For separators where the feed contain only components of similar volatility (**narrow –boiling case**) and for feed containing components of widely different volatility(**wide-boiling case**) or solubility . The **BP** method was shown to be subject to failure and a so – called sum – rates (**SR**) method was suggested.

Rather than, an equation by equation solution procedure Amundson and Pontinen [32] in a significant development in 1958, showed that the equation of material balance and the equation of equilibrium constant relationship of the MESH equations could be combined and solved component by component from simultaneous linear equation sets for all N stages by an equation tearing procedure using the same tear variable as the Thiele –Geddes method, Although too tedious for hand calculations. Such equation sets are readily solved with a digital computer.

McNesse [33] presented methods which successfully solve absorber type problems .These methods are based on the so – called SR procedure which uses stage energy imbalance to correct temperature profiles .

In 1961, Sujata was the first who developed a procedure for rigorous tray – by – tray calculations for absorption and stripping systems .and that procedure is suitable for solution by digital computer [3] .

A comparison of short –cut and tray – by – tray methods was recently carried out by Maddox (1982) for the absorption of propane from multi component light –hydrocarbon gas streams, and they compared the effect of temperature on the quantity absorbed by applying the Kresmer – Brown equation, also they carried out a comparison of the Edmister and Sujata tray – by – tray method [3].

Henley [5] gave a comparison between Kresmer – Brown short – cut method and Edmister short – cut method with **SR** method based on Burningham – Otto algorithm for absorption of heavier components from hydrocarbon gas stream.

Generally, the **SR** method is valid for both absorption and stripping network, because it depends on the material and energy balance, and the equilibrium relations. For absorption and stripping system the same final equations (**MESH-equations**) were attained, but the use of these equations differs. For absorbers the feed is considered as a gas phase and the solvent used to absorb the desired component. While in the strippers, the feed is liquid phase and the stripping agent that is used to strip the undesired components from the solvent in gas phase. In addition the conditions that are used for each process will affect the behavior of the **MESH** equations.

Nakkash and AL-Zubaidy [34] studied the simulation of ideal multi-component absorption of hydrocarbon systems, and carried out a comparison between Edmister short-cut methods with Burningham-Otto SR methods. He also studied the effect of various parameters upon the fractional absorbed.

Nakkash and AL-Mula [35] studied the simulation of multi component absorption and stripping for non ideal hydrocarbon systems using SRK-EOS for thermodynamic calculations and rigorous SR method for design calculations. She also studied the influence of various parameters upon the fractional absorbed and stripped.

Chapter Three

Theoretical Aspect

3.1 Introduction:

In this work non-ideal mixture are considered ;therefore thermodynamic properties of non-ideal mixtures are considered in order to make a design analysis for multi - component absorption – stripping network by using the Mat Lab computer program .

The design method that is used for predicting the performance of multi-component absorption – stripping network is the rigorous method and the thermodynamic properties of non – ideal mixture are needed for the design method so it valid by using equation of state which is valid for vapor and liquid phases, the Peng Robinson equation of state is used for this purpose.

3.2. Design procedure for absorption – stripping network:

The design procedure of multi-component multi-stage absorption – stripping network is divided into:

3.2.1. Method of analysis:

The analysis emphasizes to develop the computer programs in MAT.LAB version 6.5 languages to simulate the multi-component absorption – stripping network and their combination.

In this work, the developed computer program was applied to simulate multi component hydrocarbon systems absorption, stripping and their networks using three hydrocarbon systems. The material and energy balances with equilibrium relations were carried out for each column using the developed

computer program in MAT.LAB version 6.5 language (for rigorous method Otto-Burningham SR method). This program was used for predicting final compositions, temperatures, vapor and liquid profiles for each system, and studying the effect of some process variables on these design specifications.

3.2.2. Specification of variables:

The variables considered for the process systems are:

1. Wet gas flow rate and compositions.
2. Lean oil flow rate and compositions.
3. Ratio of lean oil to wet gas flow rate.
4. Temperatures of wet gas and lean oil streams.
5. Thermodynamic properties of wet gas and lean oil streams.
6. Number of theoretical stages.
7. Operation pressure.

Systems **A** and **B** were used to studying the performance of absorption – stripping networks. Table (3.1a, b) and Fig. (3.1) for system A and Table (3.2a, b) and Fig. (3.2) for system B. System C was chosen for studying the performance of absorption process using Peng Robinson equation of state Table (3.3).

The physical properties for each component of these systems considered are given in Appendix A-I.

The results of the developed computer program for system (A, B and C) were compared with results obtained by the other references [1, 2, 3, 21].

Different process variables were studied for absorption process:

1. Effect of number of theoretical stages.
2. Effect of wet gas feed temperature.
3. Effect of operating pressure.
4. Effect of the type of solvent used.

For stripping process are:

1. Effect of number of theoretical stages.
2. Effect of rich oil inlet temperature.
3. Effect of operating pressure.
4. Effect of the type of solvent in rich oil used.

And for absorption – stripping network:

1. Effect of number of theoretical stage of absorber on the network.
2. Effect of wet gas feed temperature of the absorber on the network.
3. Effect of operating pressure of the absorber on the network.
4. Effect of the type of solvent of the absorber on the network.

Table (3.1a) Data for absorber of system A [21]

Component	Wet gas flow rate (g mole/sec)	Secondary lean oil flow rates (g mole/sec)	Lean oil flow rate (g mole/sec)
C ₁	45.4	1.639	0.0
C ₂	5.044	0.378	0.0
C ₃	3.153	0.5045	0.0
nC ₄	1.892	0.5045	0.0
nC ₅	1.261	0.631	0.0
nC ₁₂ (oil)	0.0	17.025	31.528
Wet gas rate (v_f) = 56.75 g mole/sec Lean oil rate (L_{ol}) = 31.528 g mole/sec Secondary lean oil rate (L_{o2}) = 20.682 g mole/sec Wet gas temperature (T_f) = 305.372 K Lean oil temperature (T_{ol}) = 299.816 K Secondary lean oil temperature (T_{o2}) = 299.816 K Column pressure (P) = 27.2108 a t m Number of stage (N) = 8 Inter cooling rate (Q) = 43958.33 J/sec			

Table (3.1b) Data for stripper of system A [2]

component	Rich oil flow rate (g mole/sec)
C ₁	7.691
C ₂	4.02
C ₃	3.630
nC ₄	2.3965
nC ₅	1.892
nC ₁₂ (oil)	48.553
steam	0.0
Wet gas flow rate: steam(v_f) = 15 g mole/sec Rich oil flow rate (L_o) = 68.1825 g mole/sec Stripping gas temperature (T_f) = 350 K Rich oil temperature (T_o) = 309 K Column pressure (P) = 1 atm Number of stage (N) = 8	

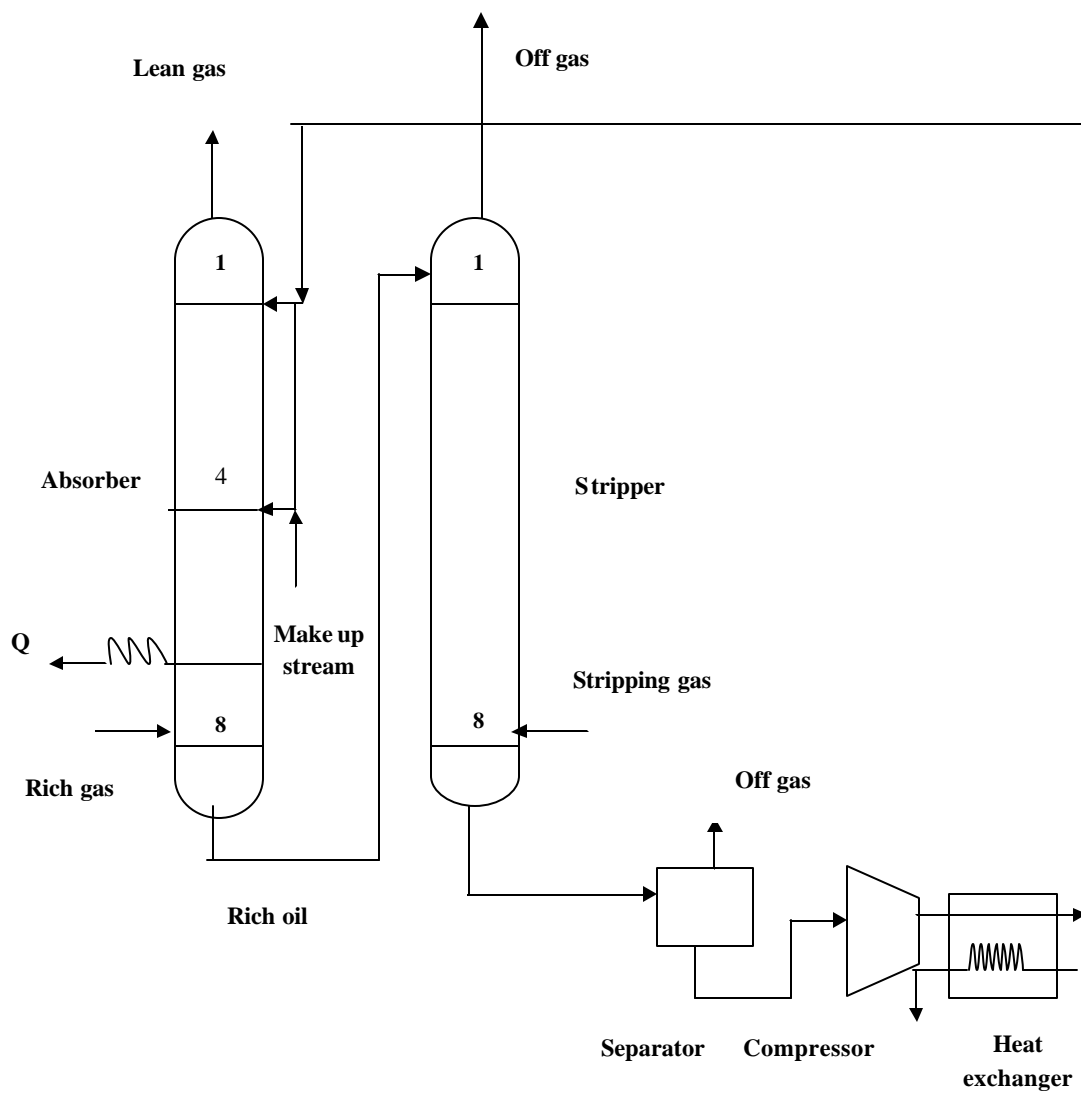


Fig. (3.1): Absorption – Stripping network of system A

Table (3.2a) Data for absorber and stripper of system B [21]

Component	Wet gas flow rate (g mole/sec)	Lean oil flow rate (g mole/sec)
CO₂	3.077	0.103
C₁	38.890	4.281
C₂	2.320	0.848
C₃	2.875	1.236
iC₄	0.706	0.362
nC₄	1.362	1.062
C₅⁺ (taken as C6)	1.210	1.691
nC₈	0.0	42.119
Wet gas rate (v_f) =50.44 g mole/sec Lean oil rate (L_{oil}) =51.705 g mole/sec Wet gas temperature (T_f) =300 K Lean oil temperature (T_o) =300 K Column pressure (P) = 21.068 a t m Number of stage (N) =6		

Component	Rich oil flow rate (g mole/sec)
CO₂	1.48
C₁	5.28
C₂	1.445
C₃	3.548
iC₄	1.031
nC₄	2.281
C₅⁺ (taken as C6)	2.794
nC₈(oil)	42.042
steam	0.0
Wet gas flow rate : steam (v_f) =15 g mole/sec Rich oil flow rate (L_o) =68.1825 g mole/sec Stripping gas temperature (T_f) =350 K Rich oil temperature (T_o) =350 K Column pressure (P) =1 a t m Number of stage (N) =8	

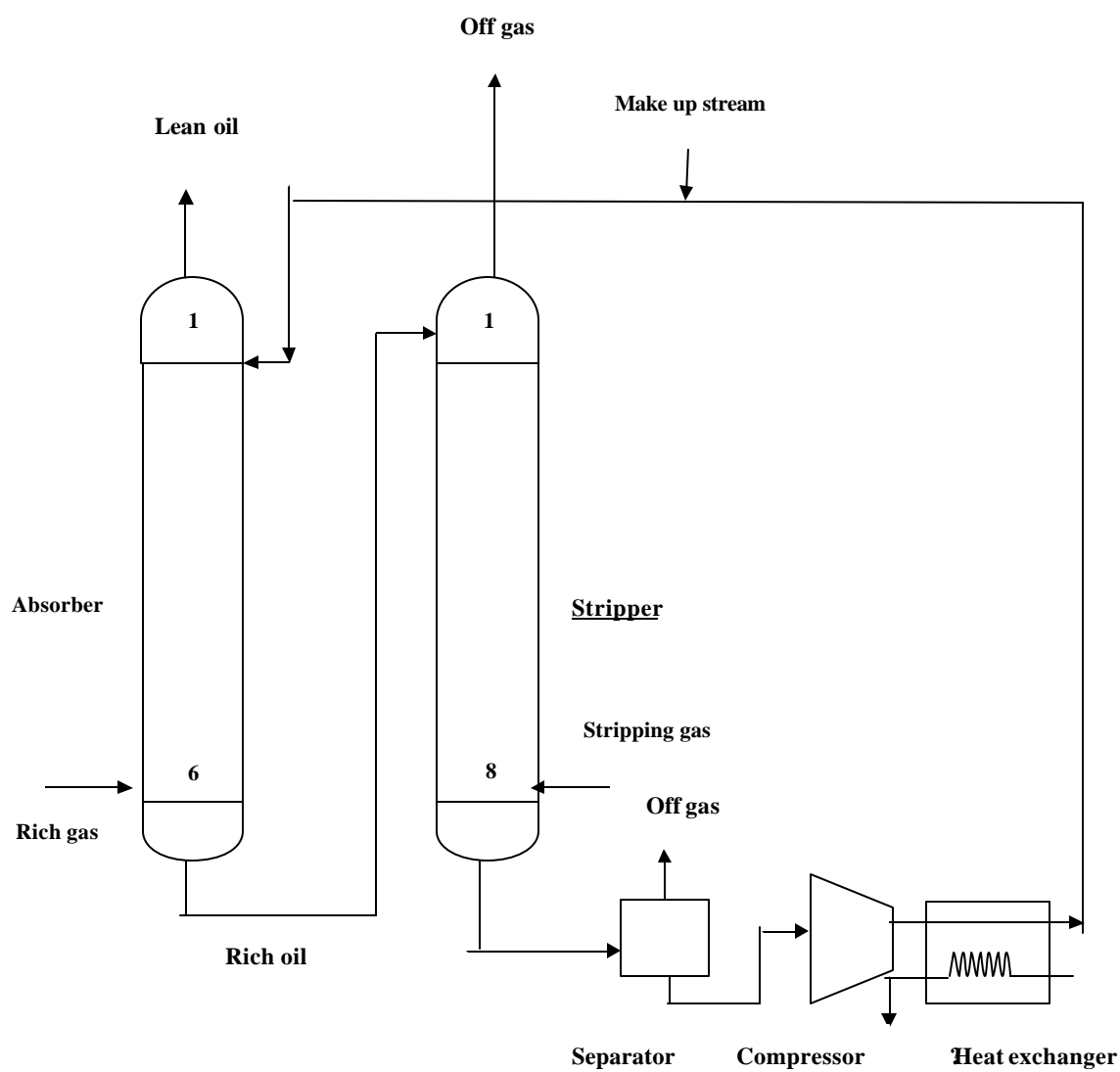


Fig. (3.2): Absorption – Stripping network system B

Table (3.3) Data for absorber of system C [3]

Component	Wet gas flow rate (g mole/sec)	Lean oil flow rate (g mole/sec)
N₂	2.9031	0.0
CO₂	15.8383	0.0
C₁	181.0917	0.0
C₂	23.1704	0.0
C₃	7.6284	0.0
iC₄	0.7478	0.0
nC₄	1.0593	0.0
iC₅	0.18663	0.0
nC₅	0.1286	0.0
C₆	5.2966*1E-2	0.0
C₇	8.8277*1E-3	0.0
nC₈(oil)	0.0	18.9166
Wet gas rate (v_f) =232.816 g mole/sec Lean oil rate (L_{oil}) =18.9166 g mole/sec Wet gas temperature (T_f) =255.372K Lean oil temperature (T_o) =255.372 K Column pressure (P) = 68.0272a t m Number of stage (N) =6		

3.2.3. Selection of equation of state:

The most popular class is formed " Cubic equation of state" which ,if expanded , would contain volume terms raised to either the first ,second , or third power [36].The cubic equations are Van der Waals , Redlich Kwong (RK), Soave Redlich Kwong (SRK) and Peng Robinson (PR) equations .

The Redlich Kwong (RK) equation of state modified by Soave Redlich Kwong (SRK) and the Peng Robinson (PR) equations are two of the currently popular equations.

The Peng Robinson equation has rapidly gained acceptance by the hydrocarbon processing industry. Because of the relative simplicity of the equation itself and because of its applicability for a large number of test mixtures; therefore in this study the PR-EOS was chosen for calculating the thermodynamic properties of the process design.

3.2.3.1. Peng Robinson (PR EOS):

A new modification of Redlich Kwong (RK) equation of state is given by Peng Robinson equation by making the attraction parameters as a function of reduced temperature and reduced pressure, and introducing the acentric factor as a third parameter to improve the prediction of enthalpy and phase equilibrium .

3.2.3.2. Peng Robinson EOS parameter [37]:

The Peng Robinson equation is:

$$P = \frac{RT}{V - b} - \frac{a}{[V(V + b)] + b[V - b]} \quad (3-1)$$

The PR-EOS parameters are: [10]

$$a_i = 0.457235 \frac{P_{ri}}{T_{ri}^2} \quad (3-2)$$

$$b_i = 0.077796 \frac{P_{ri}}{T_{ri}^2} \quad (3-3)$$

Where $P_{ri} = \frac{P}{P_{ci}}$ and $T_{ri} = \frac{T}{T_{ci}}$

And

$$a_i = \left[1 + m_i \left(1 - T_{ri}^{0.5} \right) \right]^2 \quad (3-4)$$

$$m_i = \left[0.37646 + 1.54226w_i - 0.26992w_i^2 \right] \quad (3-5)$$

Where

i refers to component i

The properties T_c and P_c and α can be found for each component are given in appendix A-I.

3.2.3.3. PR EOS mixing rules [5, 19, 37]:

The equation of state are generally developed for pure fluid first, and then extended to mixtures. The mixture extension requires so – called "mixing rules " , which simply means of calculating mixture parameters equivalent to those of pure substances .The mixing rules of PR-EOS for vapor phase are :

$$a = \sum_{i=1}^c \sum_{j=1}^c y_i y_j a_{ij} \quad (3-6)$$

Where;

$$a_{ij} = (a_i a_j)^{0.5} \quad (3-7a)$$

$$b = \sum_{i=1}^c y_i b_i \quad (3-7b)$$

The Peng Robinson equation of state (**EOS**) can be applied to light gases if the binary interaction parameter (k_{ij}) is incorporated into a revision of equation (3-6) given as:

$$a_{ij} = (1 - k_{ij}) (a_i a_j)^{0.5} \quad (3-8)$$

The key of obtaining a good representation of experimental data is by fitting single binary interaction parameter k_{ij} , to each set of binary data.

In this study, the value of (k_{ij}) are assumed zero value for hydrocarbon – hydrocarbon pairs and for other pairs the (k_{ij}) value assumed constant because the (k_{ij}) as function of temperature, pressure, and compositions for each binary pairs are rarely available in literature.

3.2.3.4. Peng Robinson compressibility factor:

To calculate the compressibility factor (Z) using Peng Robinson equation [5, 19]:

$$Z^3 - (1 - B)Z^2 + (A - 2B - B^3)Z - (AB - B^2 - B^3) = 0 \quad (3-9)$$

The (Z) factor for liquid and gas phases are calculated from above equation iteratively using Newton Raphson method. And the solution of this equation gives three roots, the valid root is the highest and the lowest one, for a gaseous and a liquid phase, respectively. The middle root is of no significance and the problem by calculating the compressibility factors through the following equation [14].

For gas phase:

$$V_{i+1} = \frac{RT}{P} + b - \frac{a(V - b_i)}{T^{0.5}PV_i(V_i + b)} \quad (3-10)$$

For liquid phase:

$$V_{i+1} = \frac{1}{C} \left(V_i^3 - \frac{R}{T} V_i^2 - \frac{ab}{T^{0.5}P} \right) \quad (3-11)$$

Where

$$C = b^2 + \frac{bRT}{P} - \frac{a}{T^{0.5}P} \quad (3-12)$$

These equations are used for evaluating the volume of gas and liquid phase.

The first assumption for volume of gases is $V_o = \frac{RT}{P_o}$ and for liquid is $V_o = b$.

The values of (a) and (b) are calculated by using (**PR-EOS**) as follows:

$$a = 0.457235 \frac{(RT_c)^2}{P_c} \quad (3-13)$$

$$b = 0.077796 \frac{RT_c}{P_c} \quad (3-14)$$

And the compressibility factor calculated by using equation (2-7).

$$Z = \frac{PV}{RT} \quad (2-7)$$

3.2.3.5. Residual enthalpies of Peng Robinson (EOS) [19]:

The following equation is used to calculate the residual enthalpies for vapor and liquid phases with appropriate phase composition and compressibility factor are used:

$$H^R = RT \left[Z - 1 - \frac{1}{2^{1.5} B} \sum_{i=1}^c \sum_{j=1}^c y_i y_j A_{ij} \left[1 - \frac{m_i T_{ri}^{0.5}}{2a_i^{0.5}} - \frac{m_j T_{ri}^{0.5}}{2a_j^{0.5}} \right] \ln \left[\frac{Z + (2^{0.5} + 1)B}{Z - (2^{0.5} - 1)B} \right] \right] \quad (3-15)$$

3.2.3.6. Peng Robinson (PR EOS) Fugacity coefficient[19]:

PR fugacity coefficients equation (for vapor and liquid phases) is:

$$f_i = EXP \left[(Z - 1) \frac{b_i}{b} - \ln(Z - B) - \frac{A}{2^{1.5} B} \left(\frac{2A_i^{0.5}}{A} - \frac{B_i}{B} \right) \ln \left[\frac{Z + (2^{0.5} + 1)b}{Z - (2^{0.5} - 1)b} \right] \right] \quad (3-16)$$

The PR –EOS is valid for both liquid and vapor phases and due to the fact that the fugacity for both phases is equal at equilibrium ,equation (2-14) , the equilibrium constant can be calculated using the fugacity coefficient of liquid and vapor phases as in the equation (2-26).

$$K_i = \frac{y_i}{x_i} = \frac{f_i^L}{f_i^v} \quad (2-26)$$

3.2.4. Actual enthalpies of gas and liquid phases [14]:

The actual enthalpies of gas and liquid are necessary to calculate three types of enthalpies H_v^o , $?$, H^R .

For non ideal system the actual enthalpies equal to the sum of ideal enthalpy and residual enthalpy. In this study, the actual enthalpies are calculated relative to a datum of ideal gas at reference temperature equal to (0 K) and 1 atm.

3.2.4.1. Ideal gas enthalpy (H_v[°]) [14]:

The ideal gas enthalpy is calculated from equation (2-18)

$$\begin{aligned} H_v^\circ &= \int_{T_o}^T C_{p_v}^\circ dT \\ &= A(T - T_o) + \frac{B}{2}(T^2 - T_o^2) + \frac{C}{3}(T^3 - T_o^3) + \frac{D}{4}(T^4 - T_o^4) \end{aligned} \quad (2-18)$$

The constant (A), (B), (C), and (D) for the component being considered in this study are given in appendix A-III.

3.2.4.2. Enthalpy of vaporization (?H_v) [14]:

Various methods have been proposed for estimating the latent heat of vaporization or the enthalpy of vaporization (?H_v).

In this study, two methods are chosen for calculating the enthalpies of vaporization, these two methods are:

I. Chen modification to Pitzer acentric – factor correlation :

Chen [38] had obtained a generalized correlation relating the vapor – pressure and temperature to the enthalpy of vaporization as follows:

$$\Delta H_v = \frac{T(7.9T_r - 7.82 - 7.11 \log P_{vPr})}{(1.07 - T_r)} \quad (3-17)$$

In this study, Riedel – Plank – Miller [4] equation is used to calculate vapor-pressure, which gives good results and it is relatively easy to use, and the form of this equation is given as follows:

$$\log P_{vPr} = \left(\frac{-G}{T_r} \right) \left[1 - T_r^2 - g(1 - T_r)^3 \right] \quad (3-18)$$

$$G = 0.2271 + 0.425 h \quad (3-19)$$

$$h = T_{br} \left[\ln \left(\frac{P_c}{1 - T_{br}} \right) \right] \quad (3-20)$$

Where: $T_{br} = \frac{T}{T_b}$

$$g = \frac{\left[\left(\frac{h}{G} \right) - (1 + T_{br}) \right]}{(1 - T_{br})^2} \quad (3-21)$$

II. Antoine vapor –pressure equation:

One of the most satisfactory methods in this field is the estimation of the latent heat of vaporization from vapor- pressure equation.

In this study , Antoine vapor- pressure equation is used and mainly considered in the calculations. It is more satisfactory and accurate than Chen's equation , Antoine vapor – pressure equation has the form [5, 14]:

$$\ln P_{vP_i} = A_1 - \frac{A_2}{T + A_3} \quad (3-22)$$

The constant A_1 , A_2 and A_3 are Antoine constants are given for each component in Appendix A-II where T in F° .

The starting point to evaluate the latent heat of vaporization is by applying the classical thermodynamic equation for ideal solution at low pressures [5]:

$$l_i = RT^2 \left(\frac{\partial \ln P_{vP_i}}{\partial T} \right) \quad (3-23)$$

And from Antoine equation:

$$\frac{\partial \ln P_{vP_i}}{\partial T} = \frac{A_2}{(T + A_3)^2} \quad (3-24)$$

The final equation of the latent heat of vaporization that is used in this study by substituting equation (3-24) into (3-23) is:

$$l_i = \frac{A_2 R T^2}{(T + A_3)^2} \quad (3-25)$$

Where T in (°R) and ? (BTU/lbmol). The following expression was obtained from the above equation (3-25) in order to calculate the latent heat of vaporization in SI unit:

$$l_i = \frac{R A_2 (1.8 T)^2}{(1.8 T - 459.67 + A_3)^2} \times \frac{1055}{454} \quad (3-26)$$

Where T in K , R=1.987Btu/lbmole. °R, and ? in J/mole.

3.3. Rigorous design method: [12]

By using Rigorous method the compositions, temperature, flow rate profiles, and heat transfer at each stage were determined .

3.3.1. Equation tearing procedure : [5]

Consider a general, continuous, steady –stage vapor – liquid separator consisting of a number of stage arranged in a counter current cascade .Assuming that phase equilibrium is achieved at each stage, no chemical reactions occur, and entrainment of liquid drop in vapor and the vapor bubble in liquid are negligible. Fig. (3.3) represented the equilibrium stage j for a vapor – liquid separator.

Entering stage j can be one single or two phase feed of molal flow rate F_j , with over all composition in mole fractions $Z_{i,j}$ of component i , temperature T_{Fj} , pressure P_{Fj} , and corresponding overall molar enthalpy h_{Fj} . Feed pressure is assumed equal to or greater than stage pressure P_j . Any excess feed pressure ($P_F - P_j$) is reduced to zero adiabatically across value F.

Also the liquid entering stage j from stage j-1 above , if any , of molar flow rate L_{j-1} , with composition in mole fractions $X_{i,j-1}$, enthalpy $h_{L,j-1}$, temperature T_{j-1} , and pressure P_{j-1} , which is equal to or less than the pressure of hydrostatic head

change across head L . Similarly , from stage $j+1$ below enter stage of molal flow rate V_{j+1} , with composition $Y_{i,j+1}$, enthalpy H_{vj+1} , temperature T_{j+1} and pressure P_{j+1} can enter stage j . Any excess pressure $(P_{j+1} - P_j)$ is reduced to zero adiabatically across value V .

Leaving stage j is vapor of intensive properties $Y_{i,j}, h_{vj}, T_j$, and P_j .This stream can be divided into a vapor side stream of molar flow rate W_j and enter stage stream of molar flow rate V_j to be sent to stage $j-1$ or , if $j=1$ to leave the column as product . Also leaving stage j is liquid intensive properties $X_{i,j}$, H_{Lj} , T_j , and P_j when is in equilibrium with vapor ($V_j + W_j$). This liquid can be product stream of molal flow rate L_j to be sent to stage $j+1$ or, if $j=N$, to leave multi stage separator as a product. Heat can be transferred at a rate Q_i from (+) or to (-) stage j to simulate stage inter coolers, inter heaters, condensers, or boilers.

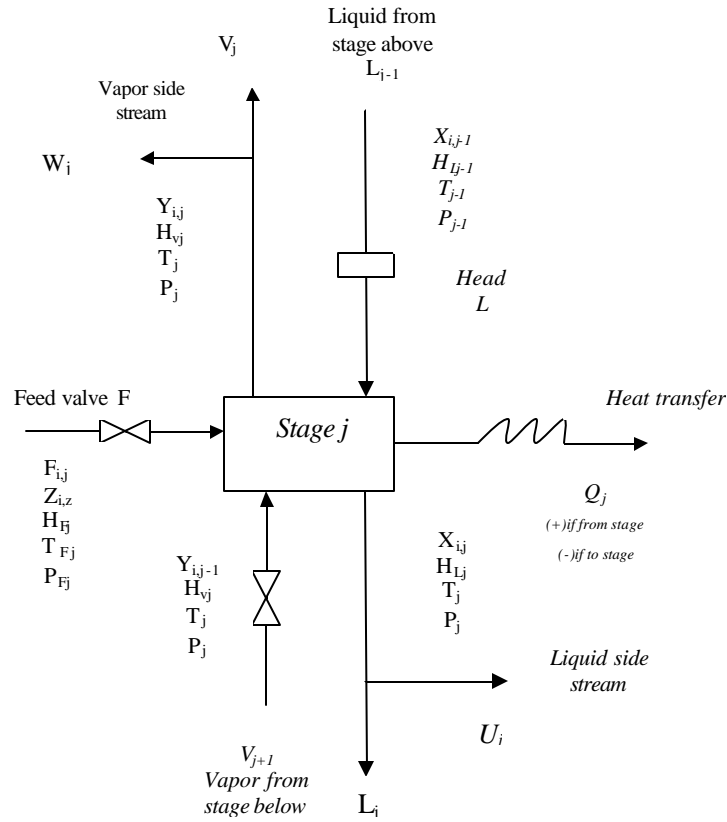


Fig. (3.3) General equilibrium stage

The following indexed equations expressed as:

1. M – equations , material balance for each component :

$$M_{i,j} = L_{j-1} X_{i,j-1} + V_{j+1} Y_{i,j+1} - F_j Z_{i,j} - (L_j - U_j) X_{i,j} - (V_j + W_j) Y_{i,j} = 0 \quad (3-27)$$

2.E- equations , phase equilibrium relation for each component :

$$E_{i,j} = Y_{i,j} - K_{i,j} X_{i,j} = 0 \quad (3-28)$$

$K_{i,j}$: the phase equilibrium ratio .

3.S-equation , mole fraction summations :

$$(SY)_j = \sum_{i=1}^c Y_{i,j} - 1.0 = 0 \quad (3-29)$$

$$(SX)_j = \sum_{i=1}^c X_{i,j} - 1.0 = 0 \quad (3-30)$$

4.H-equation , energy balance :

$$H_j = L_{j-1}h_{L_{j-1}} + V_{j+1}h_{V_{j+1}} + F_jh_{F_j} - (L_j + U_j)h_{L_j} - (V_j + W_j)h_{V_j} - Q_j = 0 \quad (3-31)$$

Where the kinetic and potential energy are ignored

In general, the K- value and the enthalpies of liquid and vapor of MESH equation are functions of temperature, pressure, and composition at each stage.

$$K_{i,j} = K_{i,j}(T_j, P_j, X_j, Y_j) \quad (3-32)$$

$$H_{V_j} = H_{V_j}(T_j, P_j, Y_j) \quad (3-33)$$

$$H_{L_j} = H_{L_j}(T_j, P_j, X_j) \quad (3-34)$$

The MESH equations are non linear equations that must be solved by iterative technique .

3.3.2. Tri-diagonal matrix algorithm: [5]

The key to the success of the BP and the SR tearing procedures is the tri diagonal matrix that results from M-equations (3-27) when they are torn from the other equations by selecting T_j and V_j as the tear variables, which leaves the modified M-equations linear in the unknown liquid mole fractions. This set of equations for each component is solved by a highly efficient and reliable algorithm due to Thomas as applied by Wang and Henke [39].

By substituting equation (3-28) into (3-27) to eliminate $Y_{i,j}$ and $Y_{i,j+1}$ to give :

$$L_{j-1}X_{i,j-1} + V_{j+1}K_{i,j+1}X_{i,j+1} + F_{i,j}Z_{i,j} - (L_j - U_j)X_{i,j} - (V_j + W_j)K_{i,j}X_{i,j} = 0 \quad (3-35)$$

Next equation (3-27) is assumed over the C components and over stage 1 through j and combined with equation (3-29), (3-30), and $Z_{i,j} - 1.0 = 0$ to give a total material balance over stage 1 through j.

$$L_j = V_{j+1} + \sum_{m=1}^j (F_m - U_m - W_m) - V_1 \quad (3-36)$$

By substituting equations (3-36) into (3-27) to eliminate L_o , the results for each component and each stage is as follows:

$$A_j X_{i,j-1} + B_j X_{i,j} + C_j X_{i,j+1} = D_j \quad (3-37)$$

Where:

$$A_j = V_j + \sum_{m=1}^{j-1} (F_m - W_m - U_m) - V_1 \quad 2 \leq j \leq N \quad (3-38)$$

$$B_j = - \left[V_{j+1} + \sum_{m=1}^i (F_m - W_m - U_m) - V_1 + U_j + (V_j + W_j) K_{ij} \right] \quad 1 \leq j \leq N \quad (3-39)$$

$$C_j = V_{j+1} K_{i,j+1} \quad 1 \leq j \leq N-1 \quad (3-40)$$

$$D_j = -F_j Z_{i,j} \quad 1 \leq j \leq N \quad (3-41)$$

With $X_{i,0}=0$, $V_{n+1}=0$, $W_1=0$, and $U_n=0$, as indicated in Fig (3.4).

The modified M – equations are linearized in terms of unknown components $X_{i,j}$ by selecting unknowns V_j and T_j as tear variables and using values of vector X_j and Y_j from the previous iteration to compute values of $K_{i,j}$ for the current iteration . In this manner all values of A_j , B_j , and C_j can be estimated. Values of D_j are fixed by feed specifications further more, they can be partitioned into C sets, one for each component, and solved separately for the values of X_i , which pertains to all j values of $X_{i,j}$ for the particular species i . Each set of N – equation is called tri –diagonal matrix equation, which has the form as shown in Fig (3.5 a) for a five – stage example in which, for convenience, the sub script i has been dropped from the coefficient B , C , and D .

For this type of sparse matrix equation, one can apply a highly efficient version of the Gaussian elimination procedure called “Thomas algorithm” which avoids matrix inversion, dominates the need to store the zero coefficients in the matrix, almost always avoids buildup of truncation errors because usually none of steps involves – subtraction of nearly equal quantities and rarely produces negative

values of $X_{i,j}$. Thus, the Thomas algorithm begins by a form the top row, to give the following replacement shown in Fig. (3.5b) for row 1:

$$p_1 = \frac{C_1}{B_1} \quad (3-42)$$

$$q_1 = \frac{D_1}{B_1} \quad (3-43)$$

$$X_{i,j} = q_1 - p_1 X_{i,j} \quad (3-44)$$

Thus , the coefficients in the matrix become $B_1 \rightarrow 1$, $C_1 \rightarrow p_1$, and $D_1 \rightarrow q_1$, where \rightarrow means "is replaced by".

$$\begin{bmatrix} B_1 & C_1 & 0 & 0 & 0 \\ A_1 & B_2 & C_2 & 0 & 0 \\ 0 & A_3 & B_3 & C_3 & 0 \\ 0 & 0 & A_4 & B_4 & C_4 \\ 0 & 0 & 0 & A_5 & B_5 \end{bmatrix} \begin{bmatrix} X_1 \\ X_2 \\ X_3 \\ X_4 \\ X_5 \end{bmatrix} = \begin{bmatrix} D_1 \\ D_2 \\ D_3 \\ D_4 \\ D_5 \end{bmatrix} \quad (a)$$

$$\begin{bmatrix} 1 & p_1 & 0 & 0 & 0 \\ 0 & 1 & p_2 & 0 & 0 \\ 0 & 0 & 1 & p_3 & 0 \\ 0 & 0 & 0 & 1 & p_4 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} X_1 \\ X_2 \\ X_3 \\ X_4 \\ X_5 \end{bmatrix} = \begin{bmatrix} q_1 \\ q_2 \\ q_3 \\ q_4 \\ q_5 \end{bmatrix} \quad (b)$$

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} X_1 \\ X_2 \\ X_3 \\ X_4 \\ X_5 \end{bmatrix} = \begin{bmatrix} r_1 \\ r_2 \\ r_3 \\ r_4 \\ r_5 \end{bmatrix} \quad (c)$$

Fig. (3.5) Tri-diagonal – matrix equation for a column with five theoretical stages

(a) original equation

(b) after forward elimination

(c) after backward elimination

For all subsequent rows:

$$P_j = \frac{D_j - A_j q_{j-1}}{B_j - A_j P_{j-1}} \quad (3-45)$$

$$P_j = \frac{C_j}{B_j - A_j P_{j-1}} \quad (3-46)$$

$$X_{i,j} = q_j - P_j X_{i,j-1} + 1 \quad (3-47)$$

With $A_j \neq 0$, $B_j \neq 1$, $C_j \neq P_j$

$D_j \neq q_i$ only of P_j and q_j need be stored.

At the Bottom row for component i, isolates

$$X_{i,N} = q_N \quad (4-48)$$

The remaining values of x_j for species i are computed recursively by backward substitution:

$$X_{i,j-1} = q_{j-1} - P_{j-1} X_{i,j} = r_{j-1} \quad (3-49)$$

3.3.3. Sum rates (SR) method:

The chemical components present in most absorbers and strippers cover a relatively wide range of volatility. The BP method of solving the MESH equation will fail because calculation of stage temperature by bubble –point determination is too sensitive to liquid – phase composition and the stage energy balance is much more sensitive to stages temperatures than to inter stage flow rates. In this case, Friday and Smith [31] showed that an alternative procedure devised by Sujata [40] could be successfully applied.

This procedure, termed the sum-rates (SR) method, was further developed in conjunction with the tri-diagonal matrix formulation for the modified M equations by Burningham [5, 21].

It is important to specify the necessary number of independent variable in advance. For absorbers and strippers the specification consist of conditions and stage locations for all feeds, pressure at any stage, total flow rates of any side streams, heat transfer rates to or from any stage, and number of stage.

An initial set of tear variables T_j and V_j is assumed to initiate the calculations. For most cases it is sufficient to assume a set of V_j values based on the assumption of constant molal inter stage flows, working up from the bottom of the column using specified vapor feeds and set T_j values are obtained by linear interpolation between the top and bottom stage temperature.

Values of $X_{i,j}$ are obtained by solving equation (3-38) through equation (3-41) by the Thomas algorithm. These values of $X_{i,j}$ are corrected to provide better values of the assumed iteration variables for the next trial, therefore for each iteration, the computed set of $X_{i,j}$ values for each stage will, in general, not satisfy the summation constraint given by equation (3-30). The values of $X_{i,j}$ can be normalized using the following relation:-

$$(X_{i,j})_{normalized} = \frac{X_{i,j}}{\sum_{i=1}^C X_{i,j}} \quad (3-50)$$

The new inter stage liquid rates can be obtained by multiplying the previous inter stage, liquid rates by corresponding un-normalized liquid mole fraction .Summation computed from the tri- diagonal matrix algorithm.

$$L_j^{(K+1)} = L_j^{(K)} \sum_{i=1}^C X_{i,j} \quad (3-51)$$

Where K is the iteration number the values of $L_j^{(k)}$ are obtained from Values of $V_j^{(k)}$ by equation (3-36). Corresponding values of $V_j^{(k+1)}$ are obtained from a total material balance, which is derived by summing equation(3-27) over the C components, combining the results obtained with equation (3-29) and (3-30) and summing the result over stage j through N to give:-

$$V_j = L_{j-1} - L_N + \sum_{m=1}^N (Fm - Um - Wm) \quad (3-52)$$

Normalizing values of $X_{i,j}$ are next calculated from equation (3-50) corresponding values of $y_{i,j}$ are computed from equation (3-28).

A new set of values for stage temperature T_j is obtained solving simultaneous set of energy balance relation for the N stages given by equation (3-30).

The temperatures are embedded in the specific enthalpies corresponding to the unspecified specific vapor and liquid flow rates. In general, these enthalpies are non linear in temperature. Therefore an iterative solution procedure such as Newton-Raphson method is required. In the Newton-Raphson method, the simultaneous non linear equations are written in the form.

$$f_i\{x_1, x_2, \dots, x_n\} = 0 \quad i=1, 2 \dots n \quad (3-53)$$

Initial guesses, marked by asterisks, are provided for the n variables and each function is expanded about these guesses in a Taylor's series that is terminated after the first derivatives to give:

$$0 = f_i\{x_1, x_2, \dots, x_n\} \approx f_i\{x_1^*, x_2^*, \dots, x_n^*\} + \left. \frac{\partial f_i}{\partial x_1} \right|_* \Delta x_1 + \left. \frac{\partial f_i}{\partial x_2} \right|_* \Delta x_2 + \dots + \left. \frac{\partial f_i}{\partial x_n} \right|_* \Delta x_n \quad (3-54)$$

Where $\Delta x_j = x_j - x_j^*$ and x_j^* are the initial tear variables. Equations (3-54) are linear and can be solved directly for the correction Δx_j . If the corrections are found to be zero, the guesses are corrected and equation (3-53) is solved; if not, the corrections are added to the guesses to provide a new set of guesses that are applied to equation (3-54). The procedure is repeated until all the corrections and thus the functions, become zero to within some tolerance. In recursion form equation (3-54) are:

$$\sum_{j=1}^n \left[\left(\frac{\partial f_i}{\partial x_j} \right)^k \Delta x_j^{(k)} \right] = -f_i^{(k)} \quad i=1, 2 \dots n \quad (3-55)$$

$$x_j^{(k+1)} = x_j^k - \Delta x_j^{(k)} \quad j=1, 2 \dots n \quad (3-56)$$

As applied Newton –Raphson to solve a new set of T_j values from energy equation [equation. (3-31)], the recursion energy equation for Newton-Raphson method is:

$$\left(\frac{\partial H_j}{\partial T_{j-1}}\right)^{(k)} \Delta T_{j-1}^{(k)} + \left(\frac{\partial H_j}{\partial T_j}\right)^{(k)} \Delta T_j^{(k)} + \left(\frac{\partial H_j}{\partial T_{j+1}}\right)^{(k)} \Delta T_{j+1}^{(k)} = -H_j \quad (3-57)$$

Where:-

$$\Delta T^{(K)} = T_j^{(K+1)} - T_j^{(K)} \quad (3-58)$$

$$\frac{\partial H_j}{\partial T_{j-1}} = L_{j-1} \frac{\partial H_{j-1}}{\partial T_{j-1}} \quad (3-59)$$

$$\frac{\partial H_j}{\partial T_j} = -(L_j + U_j) \frac{\partial H_{2j}}{\partial T_j} - (V_j + W_j) \frac{\partial H_{vj}}{\partial T_j} \quad (3-60)$$

$$\frac{\partial H_j}{\partial T_{j+1}} = V_{j+1} \frac{\partial H_{vj+1}}{\partial T_{j+1}} \quad (3-61)$$

Equation (3-57) indicates that the error in heat balance for one stage was caused by the errors in that stage, the stage above, and the stage below.

The N relation is given by equation (3-59) from tri-diagonal matrix equation that is identical to equations (3-38), (3-39), and (3-40), thus:

$$A_j \Delta T_{j-1} + B_j \Delta T_j + C_j \Delta T_{j+1} = D_j \quad (3-62)$$

Where,

$$A_j = L_{j-1} \frac{\partial H_{2j-1}}{\partial T_{j-1}} \quad 2 < j < N \quad (3-63)$$

$$B_j = (L_j + U_j) \frac{\partial H_{Lj}}{\partial T_j} - (V_j + W_j) \frac{\partial H_{vj}}{\partial T_j} \quad 1 < j < N \quad (3-64)$$

$$C_j = V_{j+1} \frac{\partial H_{vj+1}}{\partial T_{j+1}} \quad 1 < j < N-1 \quad (3-65)$$

$$D_j = -H_j \quad 1 < j < N \quad (3-66)$$

The matrix of partial derivatives is called “Jacobin correction matrix”. The Thomas algorithm can be employed to solve for the set of corrections $\Delta T_j^{(k)}$, thus:

$$\Delta T_j = q_N \quad j=N \quad (3-67)$$

And in general,

$$\Delta T_j = q_j - p_j \Delta T_j \quad 1 \leq j \leq N-1 \quad (3-68)$$

Where p_j and q_j are defined by equations (3-45) and (3-46), new set of T_j can be determined from:

$$\Delta T_j^{(k+1)} = T_j^{(k)} + \Delta T_j^{(k)} \quad (3-69)$$

When all the corrections $\Delta T_j^{(k)}$ have approached zero, the resulting values of T_j are used with the following criterion (to determine whether convergence has been achieved):

$$\sum_{j=1}^N \left[\frac{T_j^k - T_j^{(k-1)}}{T_j^{(k)}} \right]^2 + \sum_{j=1}^N \left[\frac{V_j^k - V_j^{(k-1)}}{V_j^k} \right]^2 \leq 10^{-7} N \quad (3-70)$$

But Wang and Hanks [42] use:

$$\sum_{j=1}^N \left[T_j^{(k)} - T_j^{(k-1)} \right]^2 \leq 0.01 N \quad (3-71)$$

If the convergence is not achieved before beginning new k iteration, one can adjust of V_j and T_j . Rapid convergence is generally observed for the SR method.

3.3.4. Rigorous method computer program:

A computer program is developed for rigorous method for absorption – stripping system which is written in Mat lab language. A listing of the program of rigorous method is given in (Appendix C attended in compact disk)

The developed computer program based on the ‘Burningham – Otto SR method’ (that discussed previously) which calculates:

- 1- Stream composition for each stage.

- 2- Stream flow rates for each stage.
- 3- Temperatures profile for each stage.
- 4- Recovery fraction in wet gas stream.

The thermodynamic properties (K-values with vapor and liquid enthalpies) were calculated by using Peng- Robinson equation of state and Soave Redlich Kwong equation of state that programmed using MAT LAB 6.5.

3.3.5. The Enthalpy partial derivatives:

The partial Derivatives of enthalpies for liquids and vapor with respect to temperature are given as follows;

1. Ideal enthalpies derivatives:

By Differentiation equation (2-18) and combining the result with equation (2-19), as follows:

For ideal vapor

$$\frac{\partial H_{vi}^{id}}{\partial T} = \sum_{i=1}^C Y_i \frac{\partial H_{vi}}{\partial T} \quad (3-72)$$

For ideal liquid the differentiation of equation (2-20) as follows:

$$\frac{\partial H_{Li}^{id}}{\partial T} = \sum_{i=1}^c x_i \left[\frac{\partial H_{vi}^{\circ}}{\partial T} + \left(\frac{\partial I_i}{\partial T} \right) \right] \quad (3-73)$$

2. Enthalpy of vaporization (or Latent heat of vaporization) derivatives:

The Term $\frac{\partial \Delta H_v}{\partial T}$ or $\frac{\partial I}{\partial T}$ can be calculated either from:

I. Chen modification for Pitzer acentric factor correlation:

The derivation of equation (3-17) is given as:

$$\frac{\partial \Delta H_v}{\partial T} = \frac{(1.07 - T_r) \left[(7.9T_r - 7.82 - 7.11 \log P_{vP_r}) + T \left(\frac{7.9}{T_c} - 7.11 \frac{\partial \log P_{vP_r}}{\partial T} \right) - (-T_r (7.9T_r - 7.82 - 7.11 \log p_{vP_r})) \right]}{(1.07 - T_r)^2} \quad (3-74)$$

Where;

$$\begin{aligned} \frac{\partial \log P_{vP_r}}{\partial T} &= \left(-\frac{G}{T_r} \right) \left[-\frac{2T}{T_c} + 3g(1 - T_r)^2 \left(-\frac{1}{T_c} \right) \right] + \frac{-G(-T_c)}{T^2} [1 - T_r^2 + g(1 - T_r)^3] \\ &= \left(-\frac{G}{T_r} \right) \left[-\frac{2T}{T_c^2} - \frac{3g}{T_c} (1 - T_r)^2 \right] - \left[\frac{\log P_{vP_r}}{T} \right] \end{aligned} \quad (3-75)$$

II. Antoine vapor pressure:

The derivation of the Antoine equation [equation (3-25)] is as follows:

$$\frac{\partial I}{\partial T} = \frac{2(T + A_3)^2 RA_2 T - 2RA_2 T^2 (T + A_3)}{(T + A_3)^4} = \frac{2RTA_2 (T + A_3 - T)}{(T + A_3)^3} = \frac{2RTA_2 A_3}{(T + A_3)^3} \quad (3-76)$$

3. Residual enthalpy derivatives:

The residual enthalpy partial derivatives with respect to temperature for Peng Robinson equation of state is obtained by derivation of equations (3-1) through equation (3-15) For example, for gas phase:

$$\begin{aligned}
\frac{\partial H^R}{\partial T} = & R \left[Z - 1 - \left[\frac{1}{2^{1.5} B} \ln \left[\frac{Z + (2^{0.5} + 1)B}{Z - (2^{0.5} - 1)B} \right] \sum_{i=1}^c \sum_{j=1}^c Y_i Y_j A_{ij} \left[1 - \left(\frac{m_i T_{ri}^{0.5}}{2a_i^{0.5}} \right) - \left(\frac{m_j T_{rj}^{0.5}}{2a_j^{0.5}} \right) \right] \right] \right] \\
& + \left[(RT) \left[\frac{\partial Z}{\partial T} - \frac{1}{2^{1.5} B} \ln \left[\frac{Z + (2^{0.5} + 1)B}{Z - (2^{0.5} - 1)B} \right] \frac{\partial}{\partial T} \left[\sum_{i=1}^c \sum_{j=1}^c Y_i Y_j A_{ij} \left[1 - \left(\frac{m_i T_{ri}^{0.5}}{2a_i^{0.5}} \right) - \left(\frac{m_j T_{rj}^{0.5}}{2a_j^{0.5}} \right) \right] \right] \right] \right] \\
& - \left[\sum_{i=1}^c \sum_{j=1}^c Y_i Y_j A_{ij} \left[1 - \left(\frac{m_i T_{ri}^{0.5}}{2a_i^{0.5}} \right) - \left(\frac{m_j T_{rj}^{0.5}}{2a_j^{0.5}} \right) \right] \left[\frac{1}{2^{1.5} B} \frac{\partial}{\partial T} \left[\ln \left[\frac{Z + (2^{0.5} + 1)B}{Z - (2^{0.5} - 1)B} \right] \right] + \left[\ln \left[\frac{Z + (2^{0.5} + 1)B}{Z - (2^{0.5} - 1)B} \right] \frac{\partial}{\partial T} \left(\frac{1}{B} \right) \right] \right] \right] \right] \quad (3-77)
\end{aligned}$$

Where:

$$\frac{\partial a_i}{\partial T} = 2 \left[1 + m_i (1 - T_{ri}^{0.5}) \right] \left(\frac{-0.5 m_i}{\sqrt{T_c} \sqrt{T}} \right) = \frac{-m_i \sqrt{a_i}}{\sqrt{T_c} T} \quad (3-78)$$

$$\frac{\partial A_i}{\partial T} = 0.457235 P_{ri} \left[\frac{\partial a_i / \partial T}{T_{ri}^2} - \frac{2a_i}{T_{ri}^2 T} \right] \quad (3-79)$$

$$\frac{\partial B_i}{\partial T} = -0.077796 \frac{P_{ri} T_c}{T^2} = -\frac{B_i}{T} \quad (3-80)$$

$$\frac{\partial B}{\partial T} = \sum_{i=1}^c Y_i \frac{\partial B_i}{\partial T} \quad (3-81)$$

$$\frac{\partial A_{ij}}{\partial T} = \left[0.5 (1 - K_{ij}) (A_i A_j)^{-0.5} \left(A_i \frac{\partial A_j}{\partial T} + A_j \frac{\partial A_i}{\partial T} \right) \right] \quad (3-82)$$

$$\frac{\partial A}{\partial T} = \sum_{i=1}^c \sum_{j=1}^c Y_i Y_j \frac{\partial A_{ij}}{\partial T} \quad (3-83)$$

The derivation of equation (3-9) is as follows:

$$Z^3 - (1 - B)Z^2 + (A - 2B - B^3)Z - (AB - B^2 - B^3) = 0 \quad (3-9)$$

$$\begin{aligned}
& 3Z^2 \frac{\partial Z}{\partial T} + 2ZB \frac{\partial Z}{\partial T} - 2Z \frac{\partial Z}{\partial T} + Z^2 \frac{\partial B}{\partial T} + (A - 2B - B^3) \frac{\partial Z}{\partial T} \\
& + Z \left(\frac{\partial A}{\partial T} - 2 \frac{\partial B}{\partial T} - 3B^2 \frac{\partial B}{\partial T} \right) - A \frac{\partial B}{\partial T} - B \frac{\partial A}{\partial T} + 2B \frac{\partial B}{\partial T} - 3B^2 \frac{\partial B}{\partial T} = 0
\end{aligned} \tag{3-84}$$

$$\frac{\partial Z}{\partial T} = \frac{\left[Z^2 \frac{\partial B}{\partial T} + Z \left(\frac{\partial A}{\partial T} - 2 \frac{\partial B}{\partial T} - 3B^2 \frac{\partial B}{\partial T} \right) - A \frac{\partial B}{\partial T} - B \frac{\partial A}{\partial T} + 2B \frac{\partial B}{\partial T} - 3B^2 \frac{\partial B}{\partial T} \right]}{3Z^2 + 2ZB - 2Z + (A - 2B - B^3)} \tag{3-85}$$

$$\begin{aligned}
& \frac{\partial}{\partial T} \left(\ln \left[\frac{Z + (2^{0.5} + 1)B}{Z - (2^{0.5} - 1)B} \right] \right) = \\
& \frac{Z - (2^{0.5} - 1)B}{Z + (2^{0.5} + 1)B} * \left[\frac{(Z - (2^{0.5} - 1)B) \left(\frac{\partial Z}{\partial T} + (2^{0.5} + 1) \frac{\partial B}{\partial T} \right)}{(Z - (2^{0.5} - 1)B)^2} \right] - \left[(Z + (2^{0.5} + 1)B) \left(\frac{\partial Z}{\partial T} - (2^{0.5} - 1) \frac{\partial B}{\partial T} \right) \right]
\end{aligned} \tag{3-86}$$

$$\frac{\partial}{\partial T} \left(\frac{1}{B} \right) = \frac{-1}{B^2} \frac{\partial B}{\partial T} \tag{3-87}$$

$$\frac{\partial}{\partial T} \left(\frac{m_i T_{ri}^{0.5}}{2\alpha_i^{0.5}} \right) = \frac{m_i}{2} \frac{\left[\alpha_i^{0.5} \frac{0.5T^{-0.5}}{T_c^{0.5}} - 0.5\alpha_i^{-0.5} T_{ri}^{0.5} \frac{\partial \alpha_i}{\partial T} \right]}{\alpha_i} = \frac{m_i}{4} \left[\left(\frac{1}{\sqrt{TT_c \alpha_i}} \right) - \left(\frac{T_{ri}^{0.5} \left(\frac{\partial \alpha_i}{\partial T} \right)}{\alpha_i^{1.5}} \right) \right] \tag{3-88}$$

$$\begin{aligned}
& \frac{\partial}{\partial T} \left[\sum_{i=1}^c \sum_{j=1}^c Y_i Y_j A_{ij} \left(1 - \frac{m_i T_{ri}^{0.5}}{2\alpha_i^{0.5}} - \frac{m_j T_{rj}^{0.5}}{2\alpha_j^{0.5}} \right) \right] = \\
& \sum_{i=1}^c \sum_{j=1}^c Y_i Y_j \left[\left(A_{ij} \left(\frac{\partial}{\partial T} \left(\frac{m_i T_{ri}^{0.5}}{2\alpha_i^{0.5}} \right) \right) - \left(\frac{\partial}{\partial T} \left(\frac{m_j T_{rj}^{0.5}}{2\alpha_j^{0.5}} \right) \right) \right) + \left(\frac{\partial A_{ij}}{\partial T} \left(1 - \frac{m_i T_{ri}^{0.5}}{2\alpha_i^{0.5}} - \frac{m_j T_{rj}^{0.5}}{2\alpha_j^{0.5}} \right) \right) \right]
\end{aligned} \tag{3-89}$$

Chapter Four

Results and Discussion

4.1. Introduction:

In the previous chapter the analysis and the design method for the multi component multistage absorption – stripping network were considered.

In this chapter the final results of the total vapor and total liquid flow rates profiles, vapor and liquid fractions profiles, temperatures profiles , fraction absorbed and stripped and amount of water used for cooling the liquid solvent from the stripper were obtained by using MAT LAB version 6.5 computer programs .

The effects of some process variables on the performance of absorption, stripping and absorption – stripping network such as (number of stages, temperature, operating pressure, and solvent) were studied.

The accuracy of the developed model and simulation computer program were checked and compared with references [1, 2] because the experimental data are not available.

4.2. Comparison between the present work and references:

In the present work, and preliminary step, a developed computer program using Mat Lab 6.5 was constructed using Peng Robinson and Soave Redlich Kwong equation of states for thermodynamic calculations and SR –method for the design calculation for absorption, stripping and their networks.

The results obtained for the fraction absorbed of system C using Soave Redlich Kwong equation are given in Table (4-1) were compared with AL-Mula [2] and. Maddox [2], the results are approximately identical with AL-Mula [2] . The difference is due to the fact that in the present work MAT LAB 6.5 computer

program was used, while AL-Mula [2] used QUICK BASIC computer program. But with results obtained by Maddox [1] the differences is due to the computation method and to the solvent used. In Maddox [1] petroleum fractions were used as solvents while in the present work n-octane is used as a solvent. And this comparison gives the accuracy of the developed computer program.

Table (4-1) comparison between the present work and other references of the fraction absorbed by using SRK EOS of absorber system C

Component	Fraction absorbed (a %)		
	R.N. Maddox [1]	AL-Mula[2]	Present work
N ₂	4.52	4.52	4.492
CO ₂	31.97	31.99	31.73
C ₁	10.12	10.13	10.065
C ₂	36.66	36.68	36.40
C ₃	76.32	76.32	75.94
iC ₄	96.43	96.42	96.29
nC ₄	98.95	98.95	98.906
iC ₅	99.96	99.96	99.961
nC ₅	99.99	99.99	99.989
C ₆	99.999	99.999	99.999
C ₇	100.0	100.0	100.0

Table (4-2) show the fraction absorbed for system A using PR-EOS. The results compared with SRK-EOS and show there is 0.0010 % increase in the fraction absorbed of the C₃ while the total vapor and liquid flow rate profiles and temperature profile are approximately identical. Fig. (4 -1).

Table (4-2) Comparison between the results obtained by using PR-EOS and SRK-EOS for system A

component	Fraction absorbed (a %)	
	PR-EOS	SRK-EOS
C ₁	11.660	11.652
C ₂	47.179	47.072
C ₃	91.405	91.313
nC ₄	99.607	99.600
nC ₅	99.979	99.978

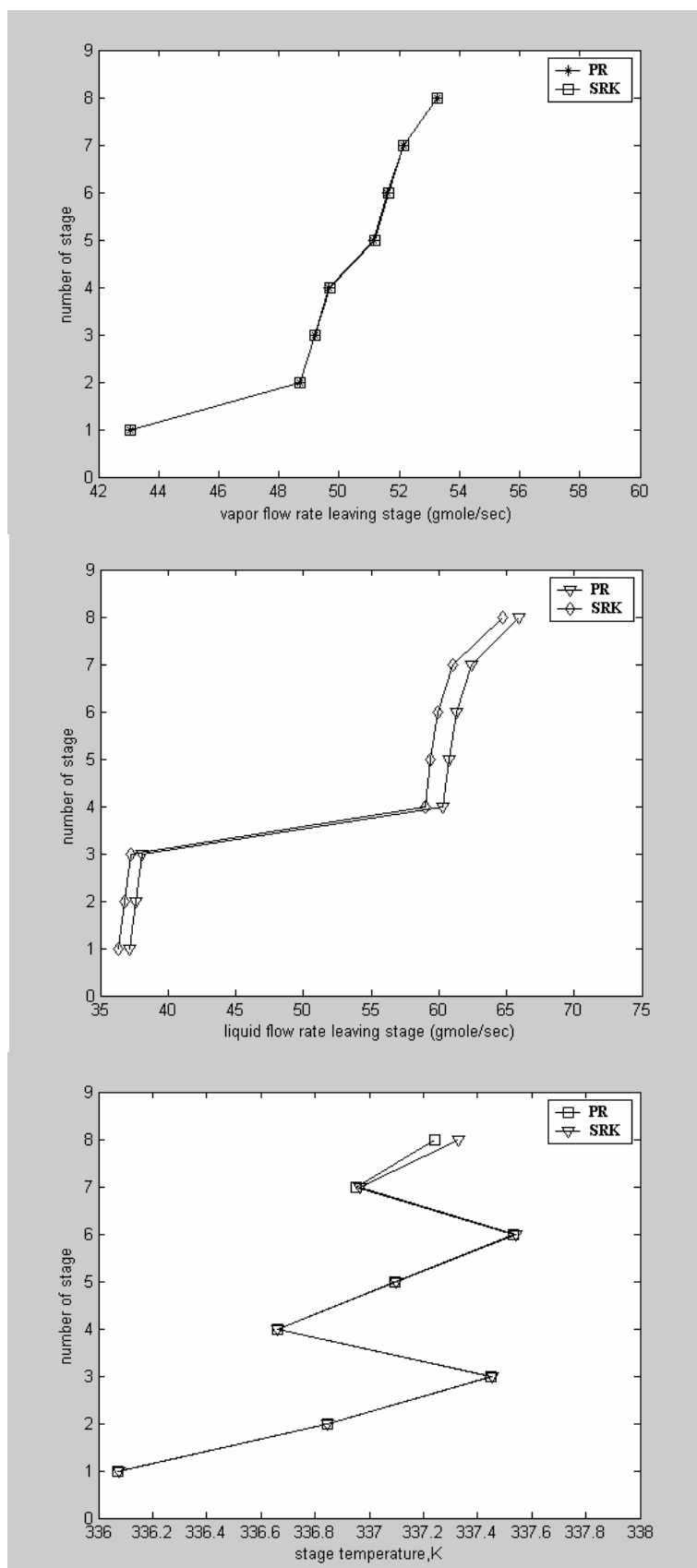


Fig. (4.1) Comparison between the results obtained by using PR and SRK equation of state in the computer program of absorber system A

Table (4-3) shows a comparison of the fraction stripped of the present work for system A using SRK-EOS with that of AL-Mula [2]. The results obtained are approximately identical. The only difference is due to the fact that in the present work MAT LAB 6.5 was used while AL-Mula used QUICK BASIC.

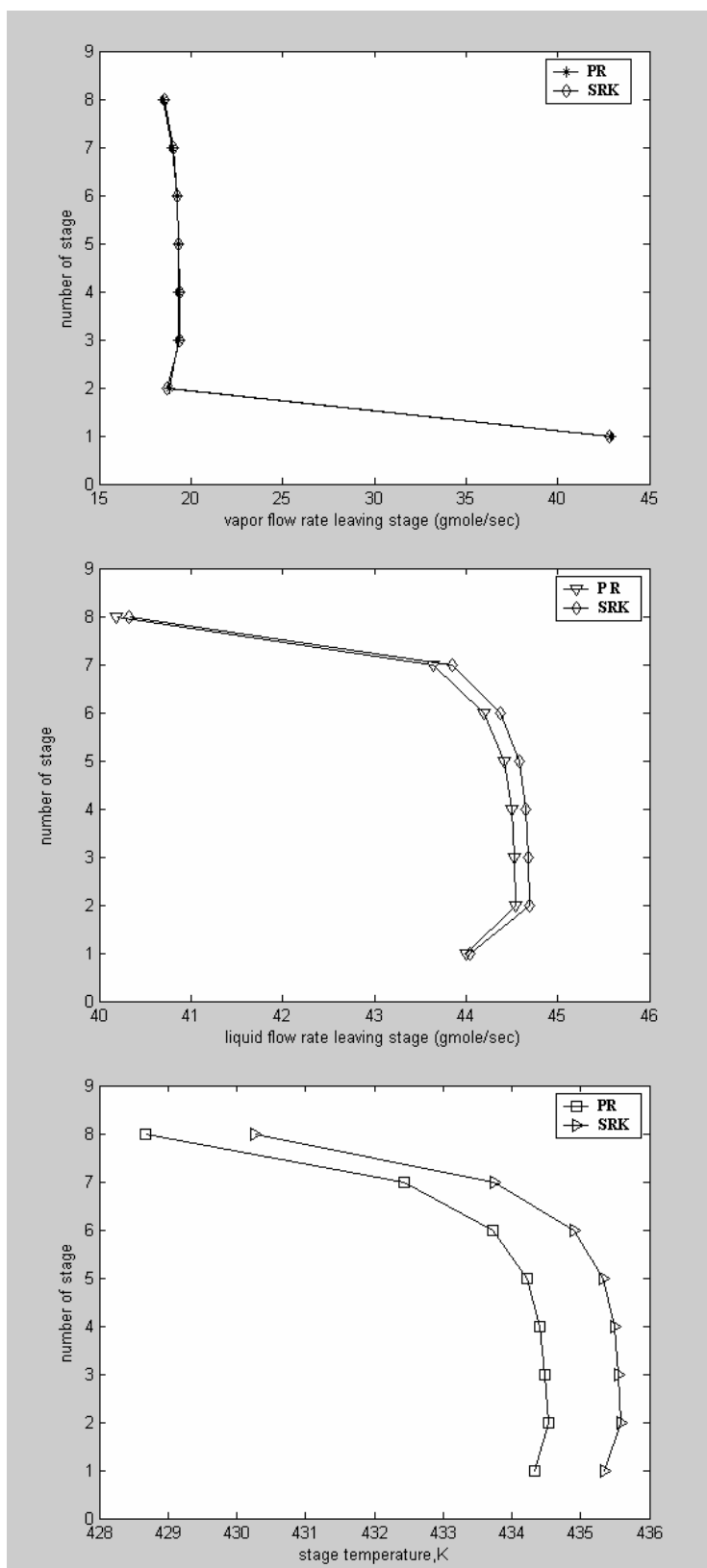
Table (4.3) Comparison between the present work and other references by using SRK equation of state for fraction stripped of stripper system A

component	Fraction stripped (s %)	
	Present work	AL-Mula[2]
C ₁	100.00	100.00
C ₂	100.00	100.00
C ₃	100.00	100.00
nC ₄	100.00	100.00
nC ₅	99.999	99.999
Oil	19.984	19.994

Table (4-4) shows the fraction stripped for system A using PR-EOS and SRK-EOS. The results show that there is 4.7×10^{-4} % decrease in the fraction stripped of oil. Fig. (4-2) shows the total vapor and liquid flow rates profiles these are approximately identical while the temperature profiles decreases, this is because of the reduction in the fraction stripped.

Table (4.4) Comparison between the PR and SRK equation of state for the fraction stripped of stripper system A

component	Fraction stripped (s %)	
	PR EOS	SRK EOS
C ₁	100.00	100.00
C ₂	100.00	100.00
C ₃	100.00	100.00
nC ₄	100.00	100.00
nC ₅	99.999	99.999
Oil	20.023	19.984



(a)

(b)

(c)

Fig. (4.2) Comparison between the results obtained by using P- R and SRK equation of state of stripper system A

4.3. General discussion:

The general discussion of absorber and stripper results:

4.3.1. Discussion of absorption results:

Systems A, B, and C for absorption process. Tables (3-1a), (3-2a) and (3-3) are chosen for general discussion. The results obtained from the developed computer program for system A, B and C show that the vapor flow rates profiles decrease as it passes up the column, the wet gas enters at the bottom of the column and its amount decrease when it passes up the column due to the transfer of the gases present in the vapor phase throughout the column, Figs. (4-3a), (4-4a), and (4-5a). Therefore, the liquid flow rate profiles increases as it passes down the column. The previous figures show that the bulk of overall absorption occurs at the two terminal stages (top and bottom); this can be observed as a dip on these stages Figs. (4-3b), (4-4 b), and (4-5 b).

For system A, Figs. (4-3 a, b) shows that a large decrease and increase in the total vapor and liquid flow rate profiles, respectively take place in stage 4 this is due to the entering of the secondary oil feed which causes an increase in the absorption ability of the liquid.

Figures (4-3c),(4-4c) and(4-5c) show that the temperature profile increases from the top to the bottom due to the increase in the rate of absorption, i.e., increasing the heat of absorption, in addition to the entering of the wet gas at the bottom of the stage at higher temperature, and Fig. (4-3c) shows a decrease in the temperature profile that occurs in stage 4 and stage 7 this is due to the entry of the secondary feed oil at lower temperature and the inter cooling stage respectively.

For system C, Fig. (4-5c) shows an irregular temperature profile due to small ratio of lean oil to wet gas (L_o/V_f), therefore the temperature profile increases

in the top stage 1 and 2, because of the maximum (L/V) ratio and then the temperature profile begins to fall due to the decrease in the ratio below these stages.

Figure (4-6) for systems A, B, and C shows that the vapor fraction profiles for the light components (C_1 and C_2) decreases at the two top stages due to the increase in the degree of absorption, and the absorption of the component heavier than C_3 occurs through out the column but mainly at the bottom stages.

Figure(4-6 a) for system A shows that the vapor fraction profiles for the heavy components decrease after passing the secondary feed oil due to increase in the fraction absorbed of these components .

Table (4-4) for systems A, B, and C shows that the fraction absorbed by the lean oil of the light gases is less than that of heavy gases this because of the similarity in chemical nature between the lean oil and the heavy gases.

Table (4.4a) Fraction absorbed of system A, B and C

Fraction absorbed (a %)					
System A		System B		System C	
component	a%	component	a%	component	a%
C_1	11.660	CO_2	41.884	N_2	4.776
C_2	47.179	C_1	0.9555	CO_2	31.548
C_3	91.405	C_2	21.679	C_1	10.427
nC_4	99.607	C_3	78.209	C_2	36.624
nC_5	99.979	iC_4	89.221	C_3	75.330
		nC_4	88.485	iC_4	95.834
		C_{5+}	97.693	nC_4	98.685
				iC_5	99.946
				nC_5	99.984
				nC_6	99.999
				nC_7	97.693

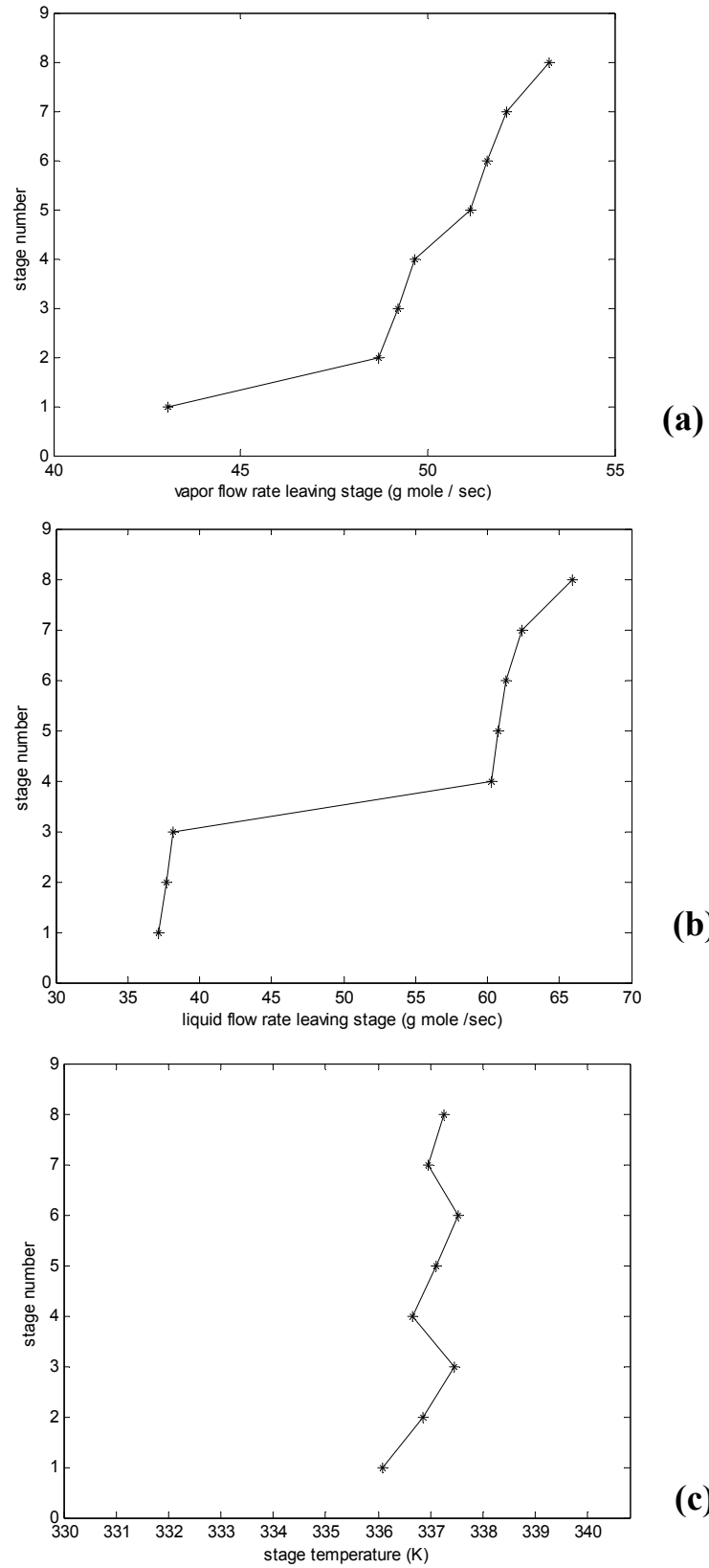


Fig. (4.3) Vapor, liquid flow rate and stage temperatures for absorber system A

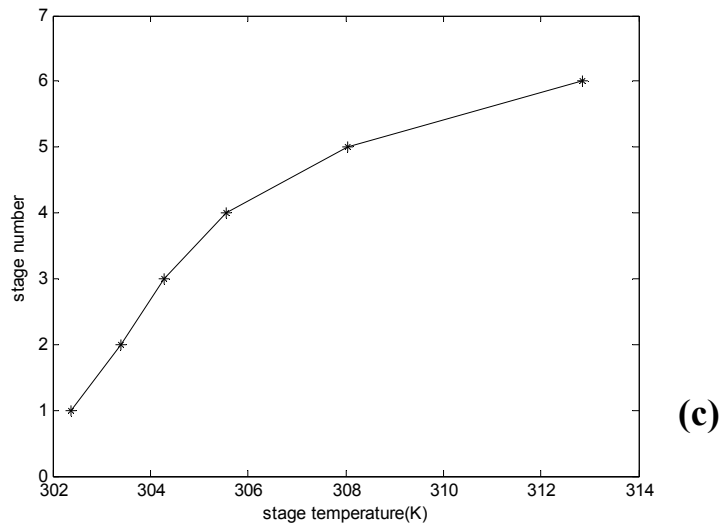
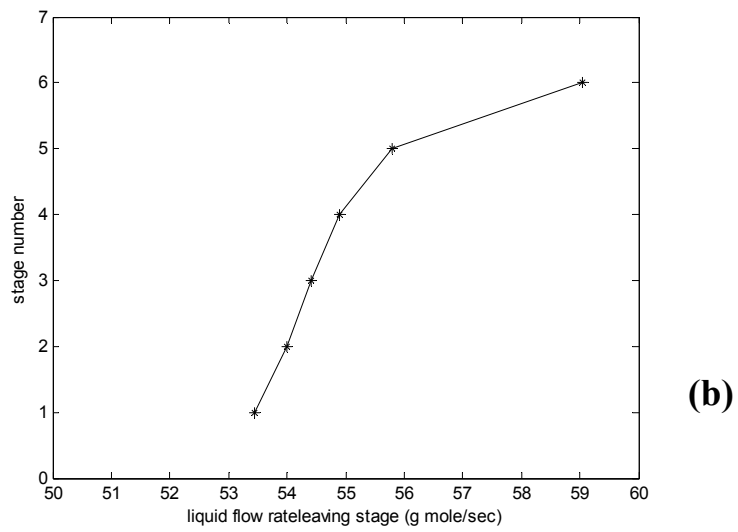
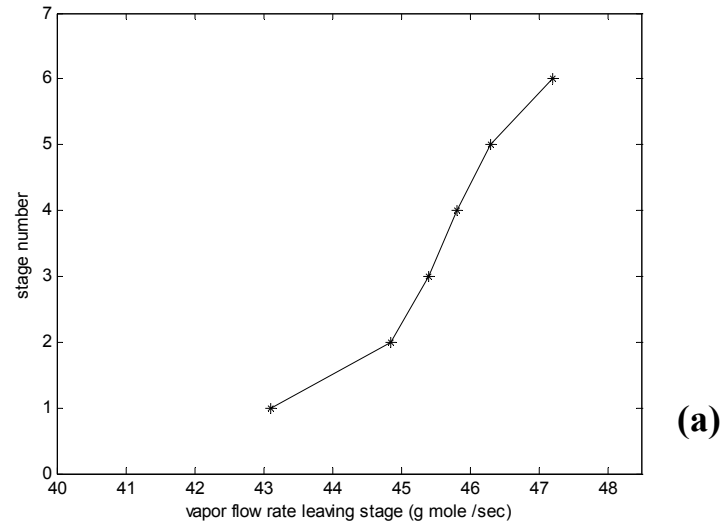


Fig. (4.4) Vapor, liquid flow rates, and stage temperature for absorber system B

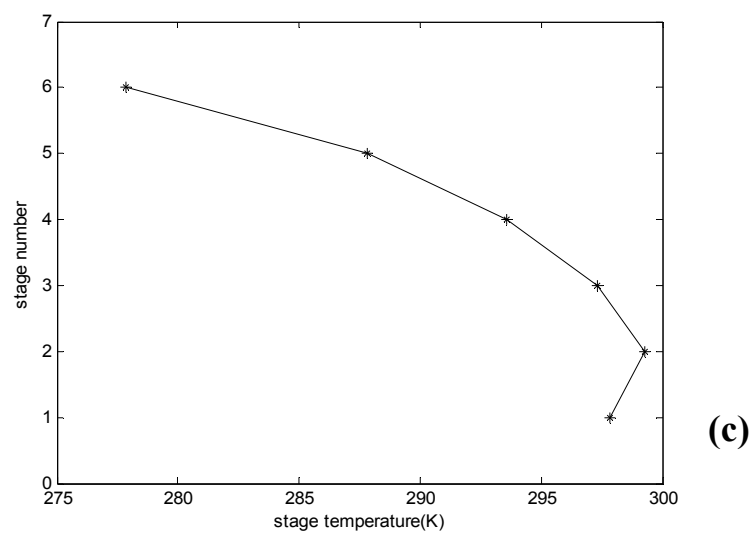
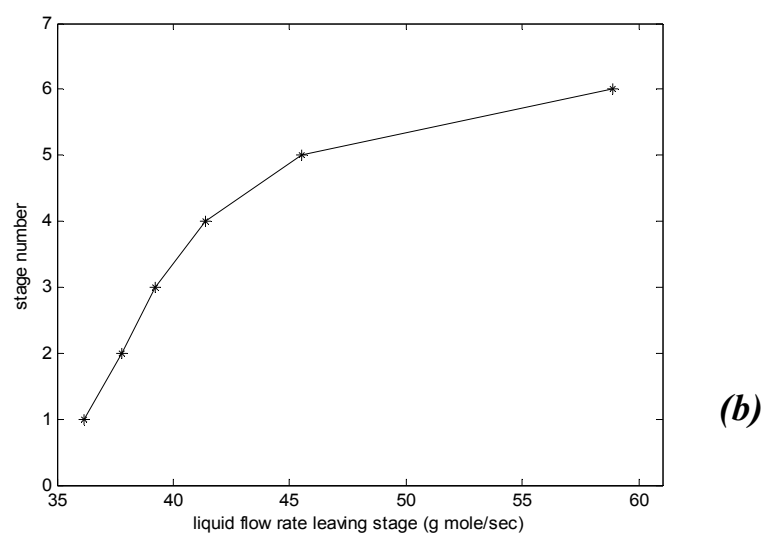
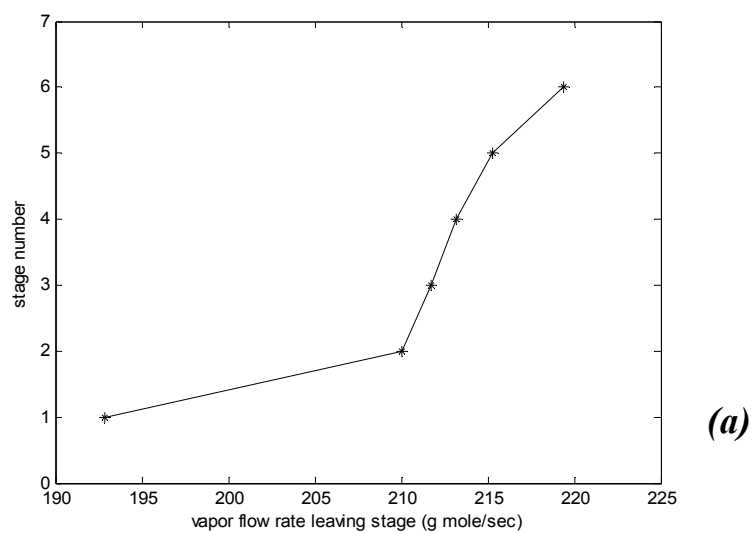
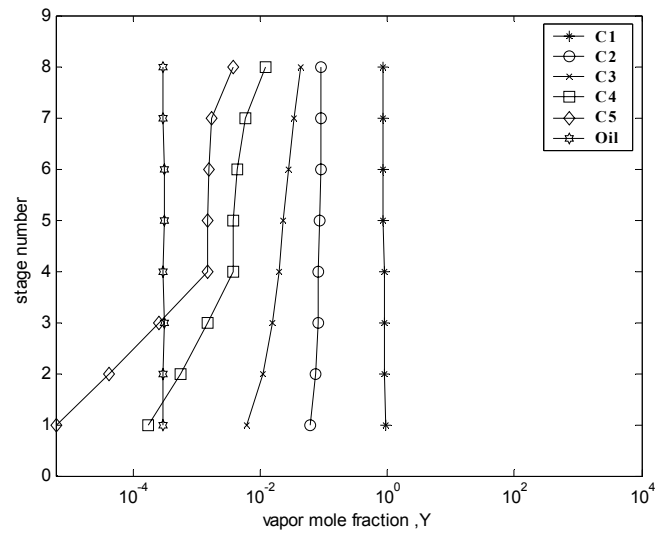
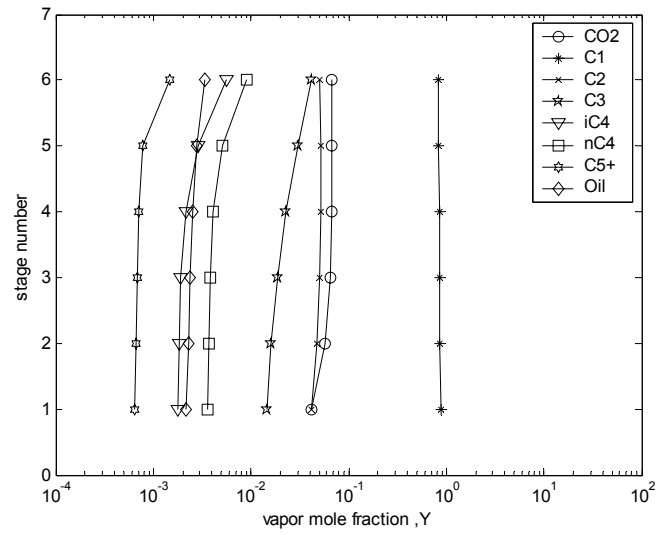


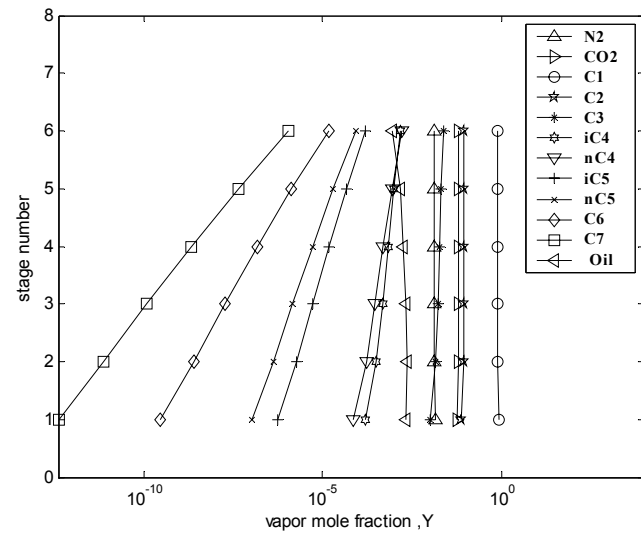
Fig. (4.5) Vapor, liquid flow rates, and stage temperatures for absorber of system C



(a)



(b)



(c)

Fig. (4.6) Vapor mole fraction profiles for absorber of system A, B and C

4.3.2 Discussion of stripper results:

Systems A, and B for stripper process Tables (3-1b) and (3-2b) are chosen for general discussion. The results obtained from the developed computer program for systems A and B show that the total vapor flow rate profile is slowly increased as it passes up the column and this increase become sharp at the two terminal top stages Figs. (4-7 a) and (4-8a). This is because at these stages a first contact between rich oil feed and vapor phase is achieved and the degree of stripping is high for the liquid component take place from the rich oil to the vapor phase. Therefore the liquid flow rate profile is decreased as it passes down the column, where the rich oil feed enters the column at the top stage and its amount decreases due to transfer of the components from the liquid to the vapor phase Figs. (4-7 b) and (4-8b). These figures show that the bulk over all stripping take place at the two terminal stages (top and bottom), this can be observed as a dip on these stages.

The temperature profiles decreases from the top to the bottom, because the sensible heat content of the liquid phase is decreased as it passes down the column, and the heat of vaporization of liquid component is supplied from sensible heat of liquid Figs. (4-7c) and (4-8c). Figures (4-9a, b) for system A and B, respectively show that the liquid composition profiles decreases sharply for the light components, but for the heavy components the liquid composition profiles are slowly decreased and the main decrease take place at the two terminal(7-8) bottom stages. The rates of stripping of the component lighter than C_3 is very high and occurs through out the column, but for the heavier components are less than that for light components and also occur through out the column but mainly at the bottom stages. Table(4-5) shows that the stripping fraction of light components are higher than the heavy components because the boiling point of the light components is lower and their evaporation can occur at lower temperature than the heavier components .

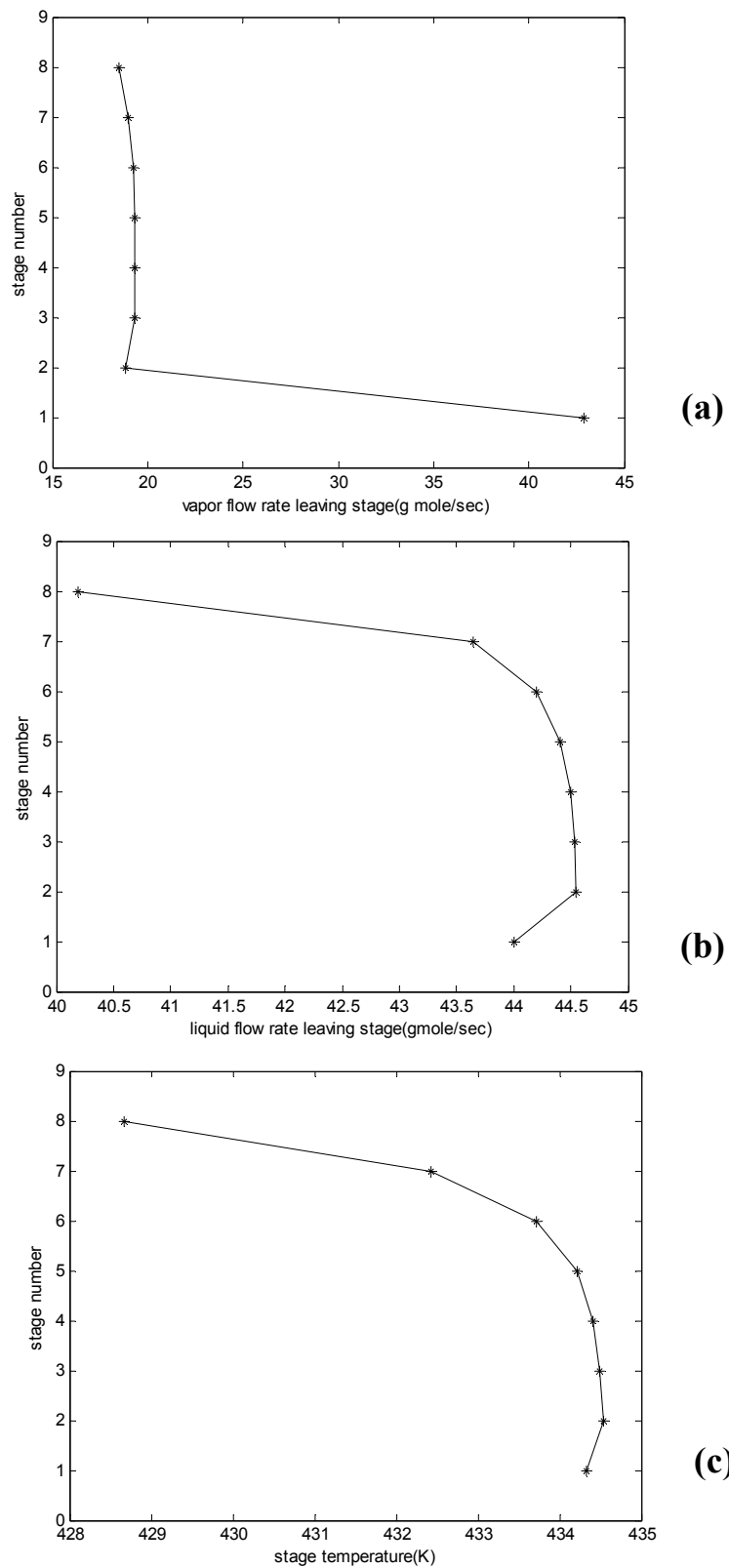


Fig. (4-7) Vapor, liquid flow rates and stage temperatures for stripper of system A

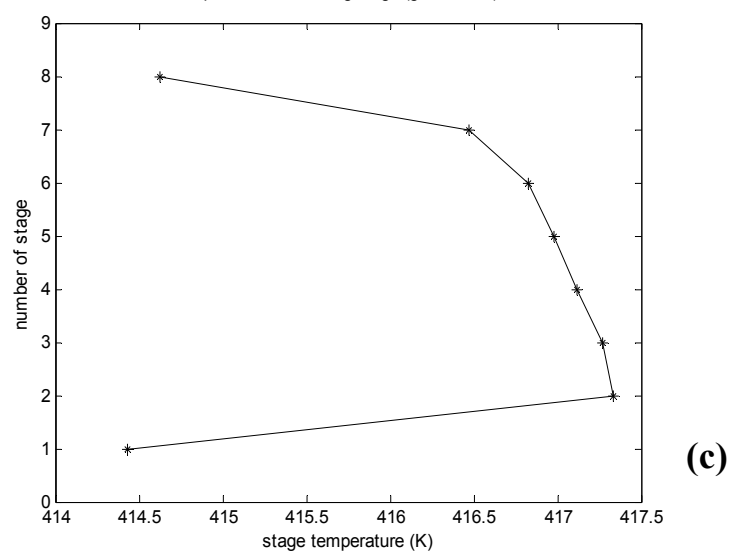
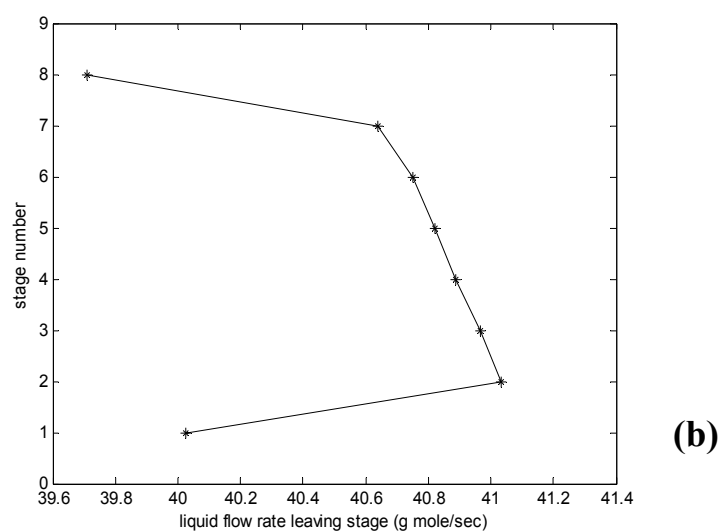
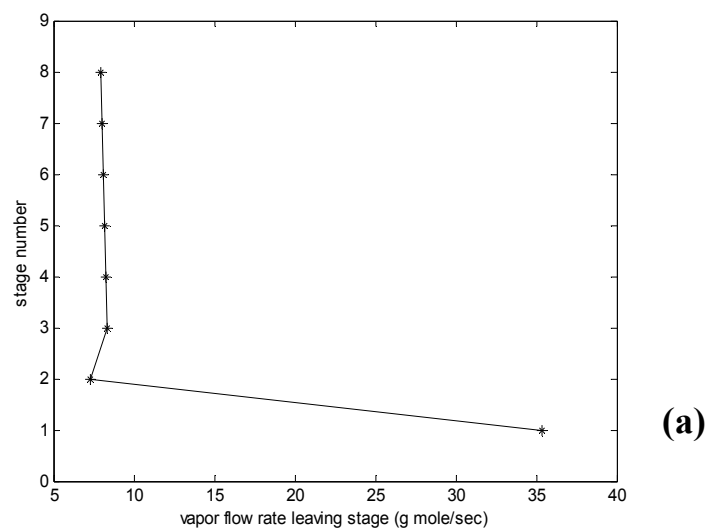


Fig. (4-8) Vapor, liquid flow rates and stage temperatures for stripper of system B

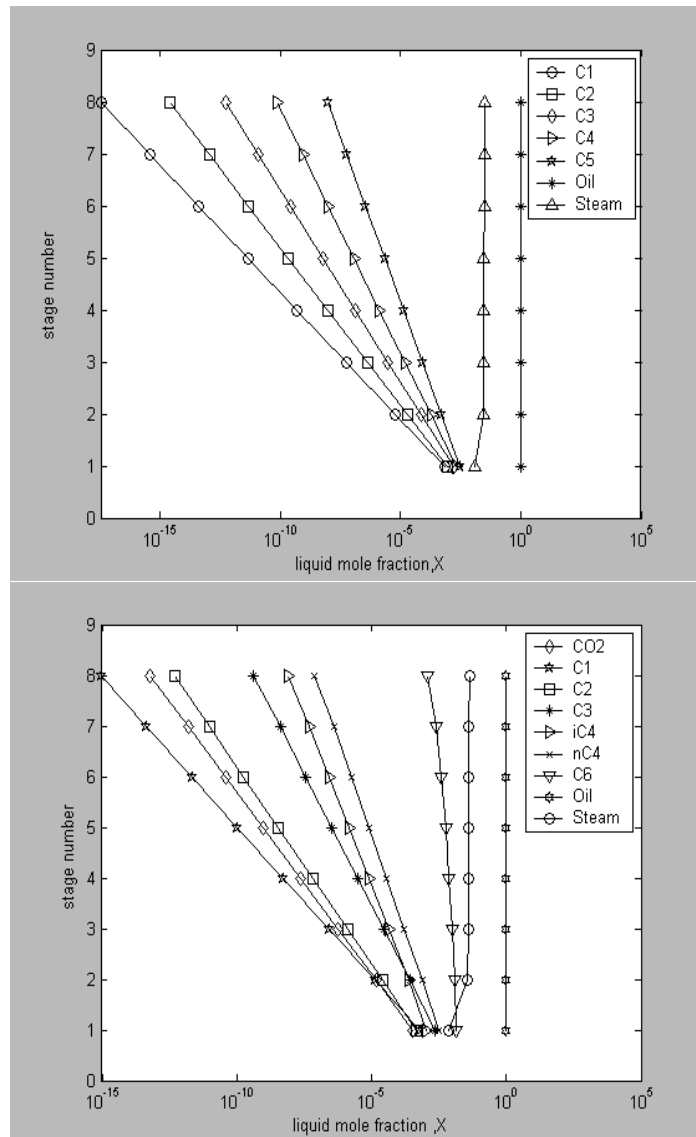


Fig. (4.9) Liquid mole fraction for stripper of system A and B

Table (4.5) Fraction stripped for the stripper systems A and B

Fraction stripped(s %)			
System A		System B	
component	S%	component	S%
C ₁	100.00	CO ₂	100.00
C ₂	100.00	C ₁	100.00
C ₃	100.00	C ₂	100.00
C ₄	100.00	C ₃	100.00
C ₅	99.999	iC ₄	99.999
Oil	20.023	nC ₄	99.999
		C ₆	98.290
		Oil	9.786

4.4. Effect of process variables on the performance of the multi component absorption, stripping and absorption-stripping network:

In this study the effect of changing some of the process variables such as number of stage , operating pressure , feed temperature and the lean oil (solvent) on the performance of absorption and stripping column and their networks.

The effect of these variables on the vapor and liquid flow rate profiles , temperature profiles , vapor fraction profiles , and the fraction absorbed (a%)for absorption process and fraction strip(s%) for stripping process for each component were considered:

4.4.1. Absorption process:

Before studying the effect of the process variables the following points must be considered:

1. The effect of the changing process variable is studied under constant of other variables.

2. For system A, the secondary lean oil is used in this process and this enters in at stage 4.
3. Inter cooling effect used in system A in the stage number 7.

4.4.1.1. Effect of changing the number of stage:

Figure (4-10 a,b) for system A, and Figs.(1a, b)and (2a, b)for system B, and C (Appendix B attended in compact disk) show that increasing the number of stages will decrease the total vapor flow rate profiles at constant wet gas flow rate. The effect of increasing the number of stages on the vapor flow rate profiles is very small at the first stage while it was more significant in the bottom stages. Therefore increasing the number of stage will decrease the liquid flow rate profiles at constant lean oil rates and the effect is very small at the first stage then it will be more significant at the bottom stages.

Figure (4-10c) for system A and Figs. (1c) and (2c) for system B and C (Appendix B attended in compact disk) show that increase of the number of stages will decrease the temperature profiles and this is due to the decrease in the rate of the absorption for the components present in the vapor phase.

The increase of the number of the stages will increase the surface and time of contact between the vapor and liquid phases and increases in the fraction absorbed as shown in Table(4-6a , b, c)]for system A, B , and C respectively.

Figure(4-11) for system A and Figs.(3)and (4) for system B, and C (Appendix B attended in compact disk) show that increasing in the number of stages causes a small decrease in the vapor mole fraction profiles due to the small increase in the degree of absorption for each component.

Table (4.6a) Effect of change number of stages of the absorber on the fraction absorbed for system A

Component	Fraction Absorbed (a %)		
	N=8	N=10	N=12
C1	11.660	11.651	11.649
C2	47.179	47.522	47.604
C3	91.405	92.733	93.354
nC4	99.607	99.618	99.621
nC5	99.979	99.979	99.979

Table (4.6 b) Effect of change number of stages of the absorber on the fraction absorbed for system B

Component	Fraction absorbed (a %)		
	N=6	N=9	N=10
CO2	41.884	41.978	41.985
C1	0.955	0.949	0.948
C2	21.679	21.844	21.860
C3	78.209	79.100	79.174
iC4	89.221	89.286	89.291
nC4	88.485	88.540	88.544
C6	97.693	97.704	97.705

Table (4.6 c) Effect of change number of stages of the absorber on the fraction absorbed for system C

Component	Fraction absorbed (a %)		
	N=6	N=8	N=10
N2	4.776	4.8164	4.841
CO2	31.548	31.857	32.029
C1	10.427	10.526	10.579
C2	36.624	36.978	37.177
C3	75.330	76.409	76.928
iC4	95.834	97.213	97.939
nC4	98.685	99.394	99.691
iC5	99.946	99.992	99.998
nC5	99.984	99.998	99.999
C6	99.999	99.99	100.00
C7	97.6930	100.00	100.00

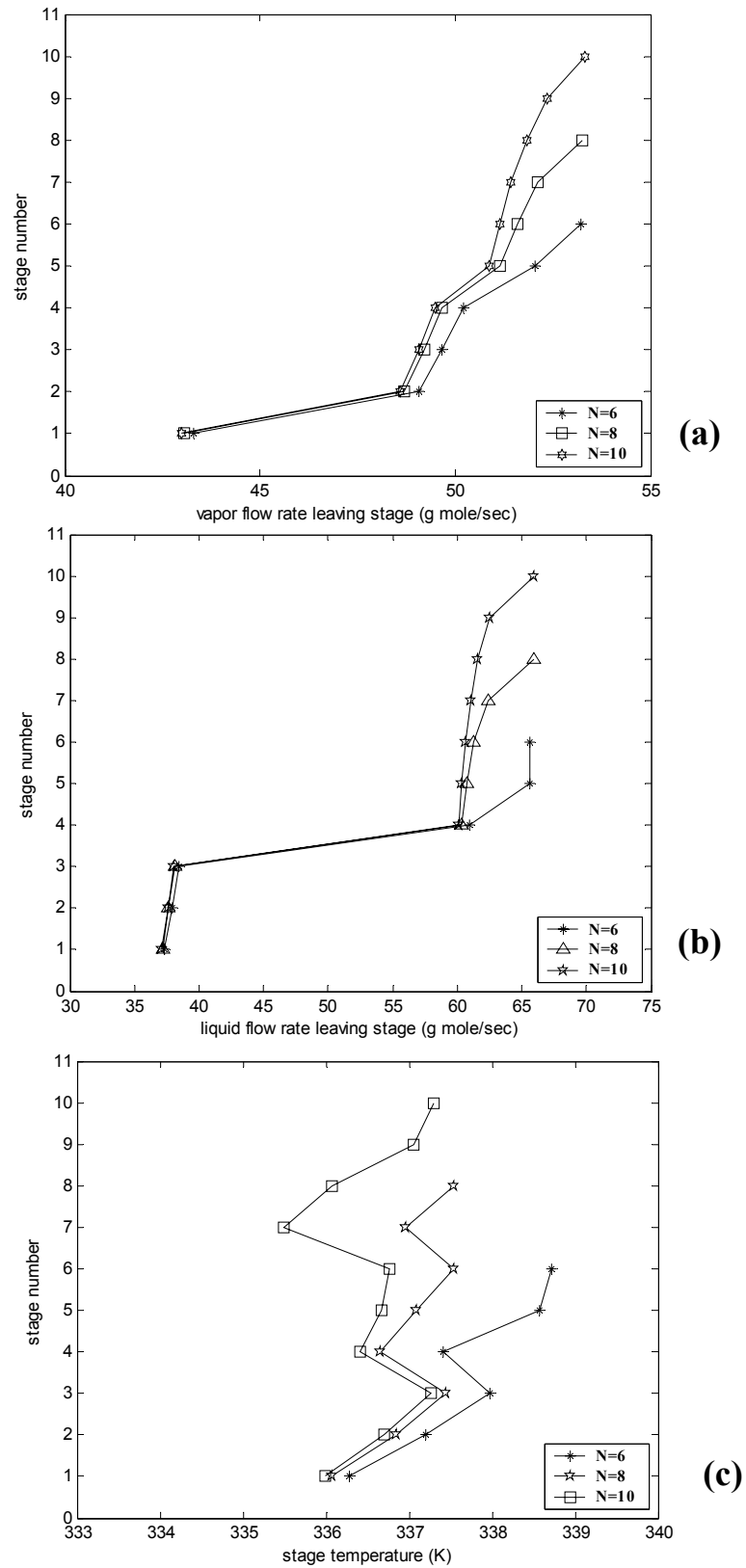
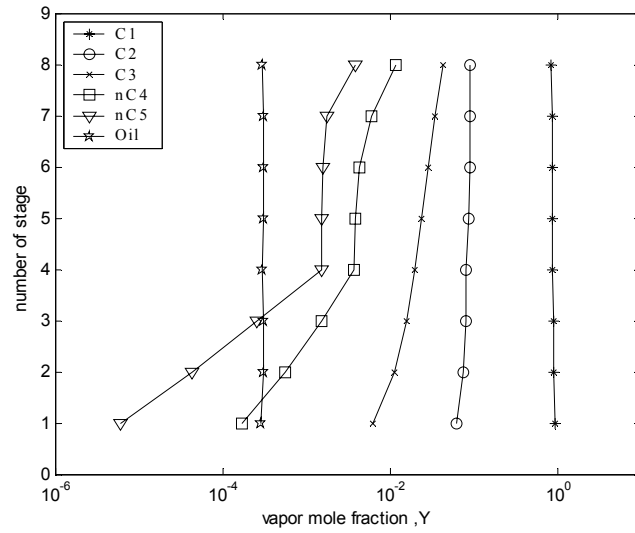
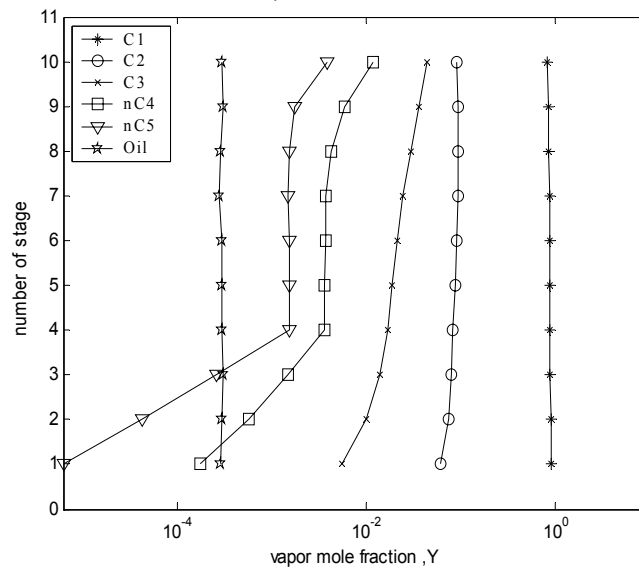


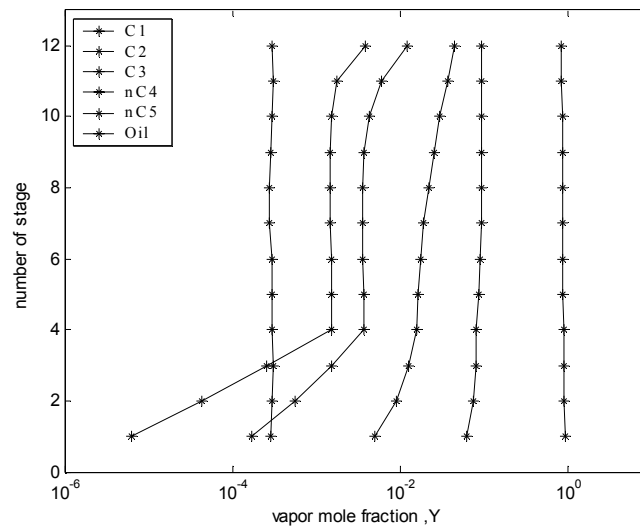
Fig. (4.10) Effect change the number of stages on the vapor, liquid flow rates and stage temperatures for absorber system A



N=8



N=10



N=12

Fig. (4-11) Effect of change number of stage on the vapor mole fraction of the absorber system A

4.4.1. 2 .Effect of changing the inlet wet gas temperature:

Figures (4-12 a, b) for system A and Figs. (5a, b) and (6a, b) for system B and C (Appendix B attended in compact disk) show that increasing the wet gas feed temperature will increase the total vapor flow rate profiles at constant wet gas. This increase very small in the first stages and it will be more significant in the bottom stages while increase in the feed temperature will decrease the liquid flow rate profiles but this decrease is very small that can be ignored.

The increasing of the feed temperature will increase the temperature profiles Figs. (4-12c) for system A and Figs.(5c) and (6c) for system B, and C (Appendix B attended in compact disk) and decreases the fractional absorbed Table (4-7) for system A, B and C and there is no large effect on the vapor mole fraction profiles Fig. (4-13) for system A and Figs(7) and(8) for system B and C (Appendix B attended in compact disk). This is due to the decrease in the rate of absorption for the component present in the vapor phase.

Table (4-7a) Effect of change wet gas feed temperature of the absorber on the fraction absorbed of system A

Component	Fraction Absorbed (a %)		
	$T_f=305.372K$	$T_f=315 K$	$T_f=325K$
C_1	11.660	11.565	11.468
C_2	47.179	46.792	46.389
C_3	91.405	91.289	91.174
nC_4	99.607	99.603	99.601
nC_5	99.9790	99.978	99.978

Table (4-7b) Effect of change wet gas feed temperature of the absorber on the fraction absorbed of system B

Component	Fraction absorbed (a %)		
	$T_f=300K$	$T_f=305K$	$T_f=310K$
CO_2	41.884	38.621	35.704
C_1	0.955	0.554	0.179
C_2	21.679	17.647	14.010
C_3	78.209	75.233	71.860
iC_4	89.221	87.725	86.076
nC_4	88.485	86.771	84.872
C_6	97.6930	97.209	96.645

Table (4-7c) Effect of change wet gas feed temperature of the absorber on the fraction absorbed of system C

Component	Fraction absorbed (a %)		
	$T_f=255.3722K$	$T_f=260K$	$T_f=265K$
N_2	4.776	4.477	4.204
CO_2	31.548	29.423	27.359
C_1	10.427	9.757	9.126
C_2	36.624	34.300	32.029
C_3	75.330	72.122	68.962
iC_4	95.834	94.558	92.946
nC_4	98.685	98.162	97.440
iC_5	99.946	99.917	99.871
nC_5	99.984	99.975	99.961
C_6	99.999	99.999	99.999
C_7	99.999	99.999	99.999

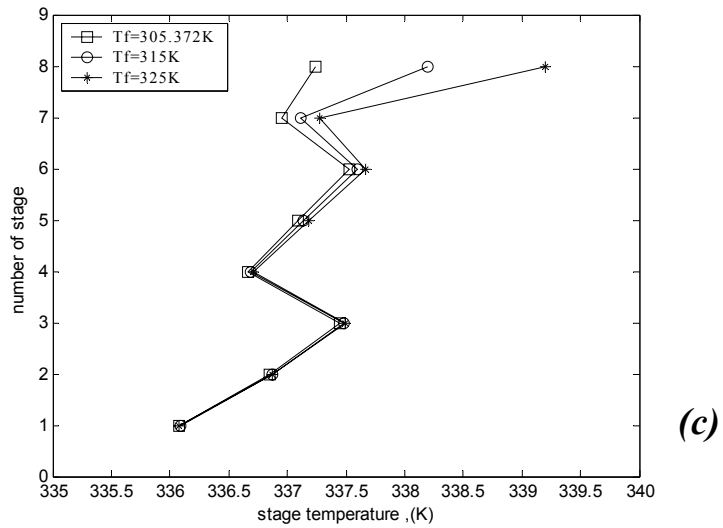
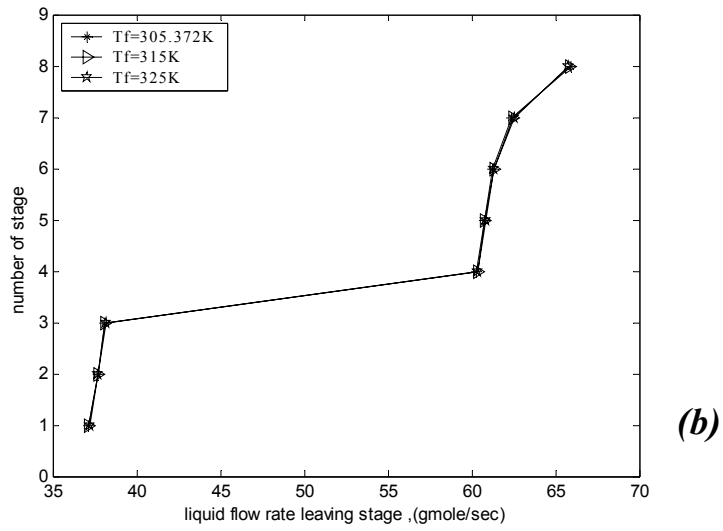
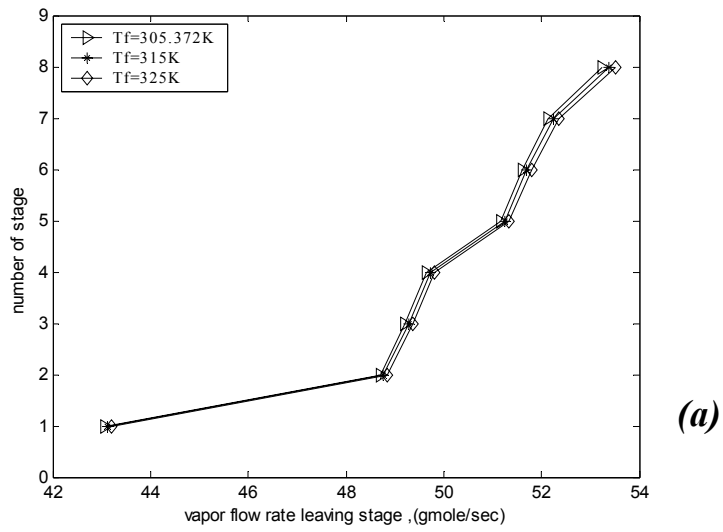
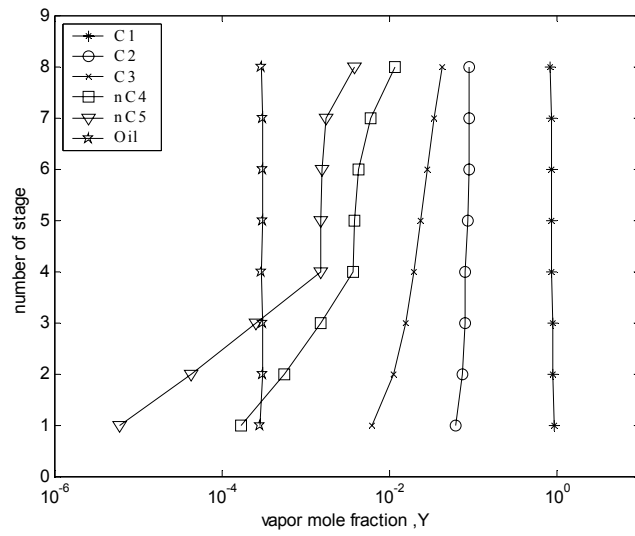
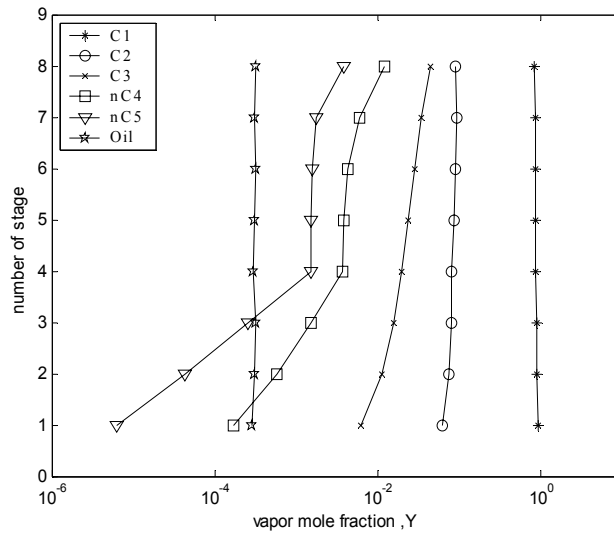


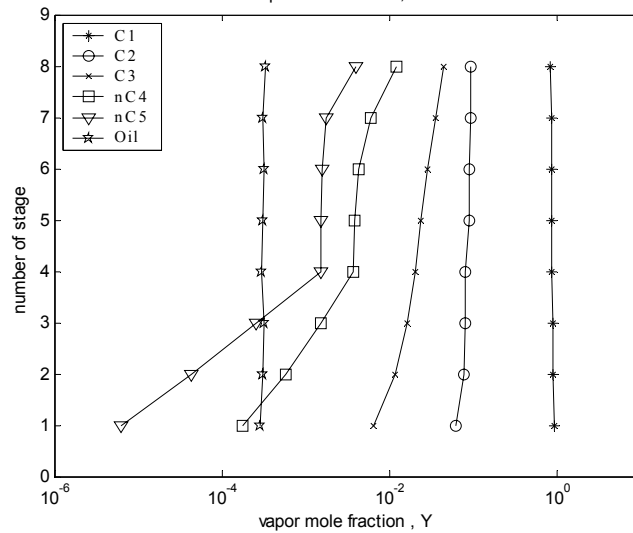
Fig. (4-12) Effect of change feed temperature on the vapor, liquid flow rates and stage temperatures of absorber system A



$T_f=305.372K$
(a)



$T_f=315K$
(b)



$T_f=325K$
(c)

Fig. (4-13) Effect of change feed temperature on the vapor mole fraction profiles of absorber system A

4.4.1. 3. Effect of changing the operating pressure:

Figure (4-14a, b) for system A and Figs.(9a,b) and(10a,b) for system B and C (Appendix B attended in compact disk), show that increasing the operating pressure will decrease the vapor flow rate profiles at constant wet gas . The increase is significant for the first stages, while the liquid flow rate profiles will increase at constant lean oil and this increase is approximately identical in the stage 3 and 4 when the secondary feed oil enter the column for system A Fig. (4 -13 b).

The increase in the operating pressure will increase the temperature profiles Fig. (4-13c) for system A and Figs. (9c) and (10c) for system B and C (Appendix B attended in compact disk), therefore the fractional absorbed will increase as in Table (4-8). While the vapor mole fraction will be decreased as in Figs. (4-15) for system A and Figs. (11) and (12) for system B and C (Appendix B attended in compact disk), this is due to the increase of the rate of absorption for the component present in the vapor phase.

Table (4-8a) Effect of change operating pressure of the absorber on the fraction absorbed of system A

Component	Fraction Absorbed (a %)		
	P=27.20atm	P=30atm	P=32atm
C ₁	11.660	13.452	14.758
C ₂	47.179	52.409	56.045
C ₃	91.405	93.766	94.997
nC ₄	99.607	99.718	99.774
nC ₅	99.979	99.984	99.987

Table (4-8b) Effect of change operating pressure of the absorber on the fraction absorbed of system B

Component	Fraction absorbed (a %)		
	P=21.068atm	P=23atm	P=25atm
CO ₂	41.884	45.838	49.840
C ₁	0.955	2.176	3.455
C ₂	21.679	26.530	31.357
C ₃	78.209	80.051	81.622
iC ₄	89.221	89.975	90.637
nC ₄	88.485	89.263	89.946
C ₆	97.693	97.803	97.898

Table (4-8c) Effect of change operating pressure of the absorber on the fraction absorbed of system C

Component	Fraction absorbed (a %)		
	P=68.0272atm	P=70atm	P=71atm
N ₂	4.776	4.926	5.068
CO ₂	31.548	32.002	32.423
C ₁	10.427	10.695	10.936
C ₂	36.624	37.064	37.470
C ₃	75.330	95.831	75.781
iC ₄	95.834	98.673	95.828
nC ₄	98.685	99.944	98.662
iC ₅	99.946	99.984	99.942
nC ₅	99.984	99.999	99.983
C ₆	99.999	99.999	99.999
C ₇	97.693	95.831	99.999

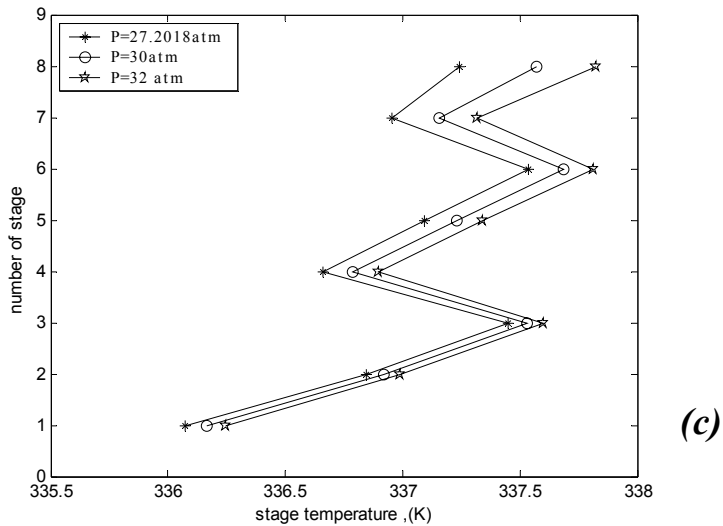
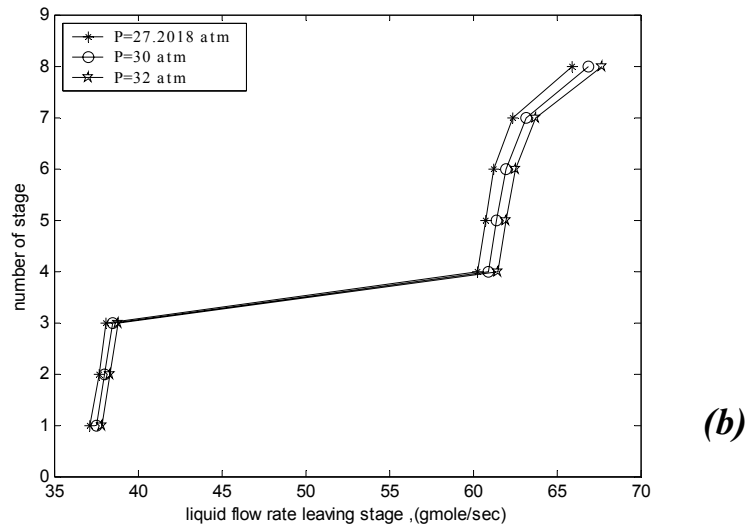
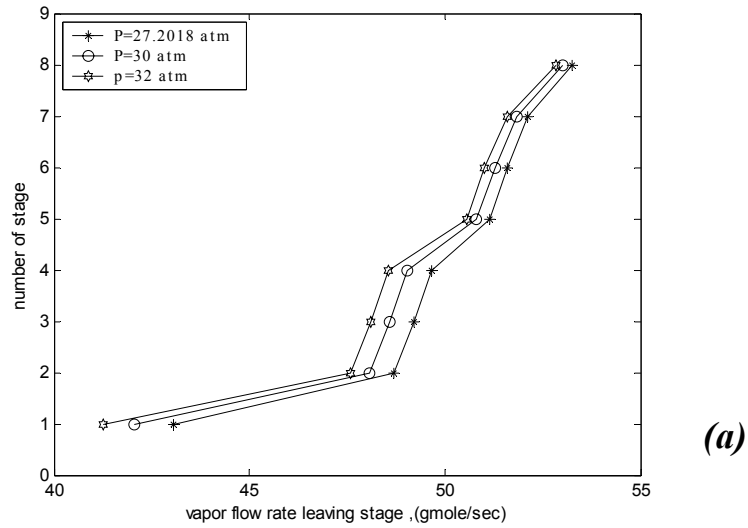
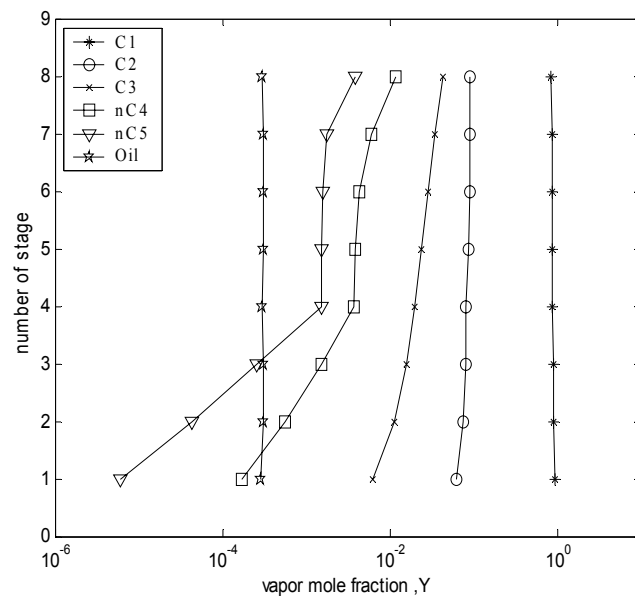
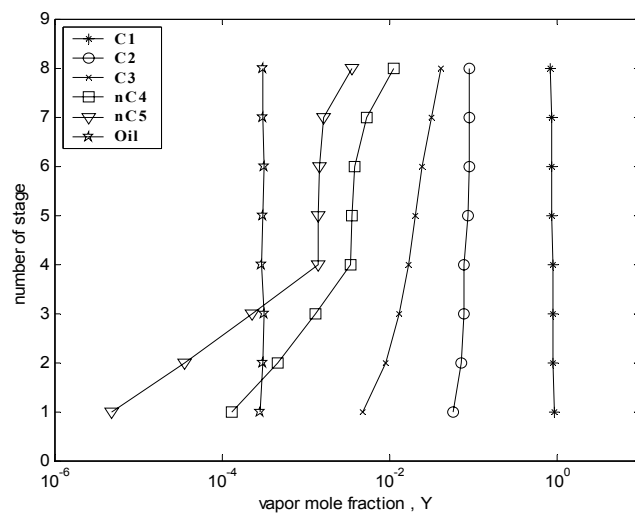


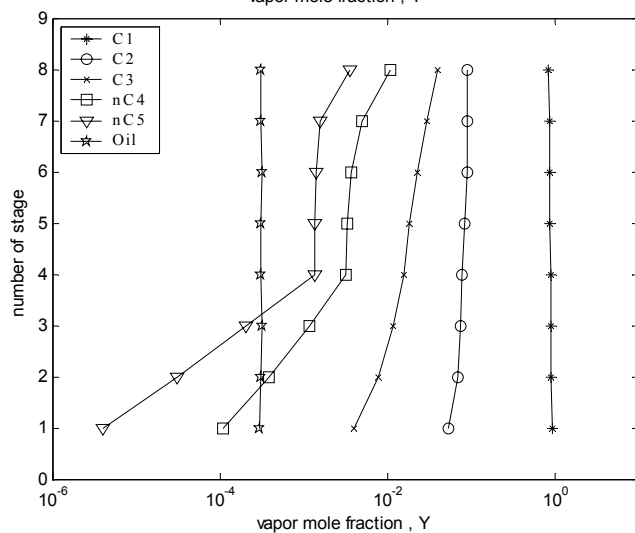
Fig. (4-14) Effect of change operating pressure on the vapor, liquid flow rates of absorber system A



P=27.2018 atm



P=30 atm



P=32 atm

Fig. (4-15) Effect of change operating pressure of vapor mole fraction profiles of absorber system A

4.4.1. 4. Effect of changing the solvent:

In this study different solvents were used nC_8 , nC_{10} , nC_{12} for systems A, B and C [28, 39].

Figure (4-16a, b) for system A and Figs.(11a, b) and(12 a, b) for system B and C (Appendix B attended in compact disk), show that the total vapor flow rates profiles decreases and the total liquid flow rate increases when the carbon number of the solvents is increased. The decrease in vapor flow rate profile is due to the increase in the solvent ability for absorbing components from the vapor phase with increasing the carbon number of the solvent Fig. (4-16a) for system A, and therefore the liquid flow rate increase Fig. (4-16b) for system A and the effect of the solvents in the vapor and liquid flow rate profiles is not significant and the curves are approximately identical.

Figure (4-16c) for system A and Figs. (11c) and (12c) for system B and C (Appendix B attended in compact disk), show that the temperature profile decreases with increasing the carbon number of the solvent this is due to the decrease in the heat of absorption for each component as results of increasing the similarity between these component and the solvent used in chemical nature.

Figure (4-17) for system A and Figs.(13) and(14) for system B and C (Appendix B attended in compact disk) show that the vapor fraction profiles decrease with increasing the carbon number of the solvent, this is because of increasing the fraction absorbed of the solvent for these components Tables (4-9) of system A, B, and C, respectively.

Table (4-9a) Effect of change solvent on the fraction absorbed for absorber system A

Component	Fraction Absorbed (a %)		
	nC₈	nC₁₀	nC₁₂
C₁	8.365	10.992	11.660
C₂	35.541	43.607	47.179
C₃	77.974	88.016	91.405
nC₄	98.267	99.354	99.607
nC₅	99.872	99.961	99.979

Table (4-9b) Effect of change solvent on the fraction absorbed for absorber system B

component	Fraction absorbed (a %)		
	nC₈	nC₁₀	nC₁₂
CO₂	49.840	54.008	55.707
C₁	3.455	5.903	6.571
C₂	31.357	38.677	40.949
C₃	81.622	83.457	83.928
iC₄	90.637	91.586	91.822
nC₄	89.946	90.729	90.949
C₆	97.898	98.061	98.112

Table (4-9c) Effect of change solvent on the fraction absorbed for absorber system C

Component	Fraction absorbed (a %)		
	nC₈	nC₁₀	nC₁₂
N₂	4.776	4.551	4.633
CO₂	31.548	30.833	31.230
C₁	10.437	10.035	10.178
C₂	36.624	35.846	36.486
C₃	75.330	75.524	77.732
iC₄	95.834	96.382	97.375
nC₄	98.685	98.953	99.301
iC₅	99.946	99.963	99.978
nC₅	99.984	99.990	99.994
C₆	99.999	99.999	99.999
C₇	99.999	100.00	100.000

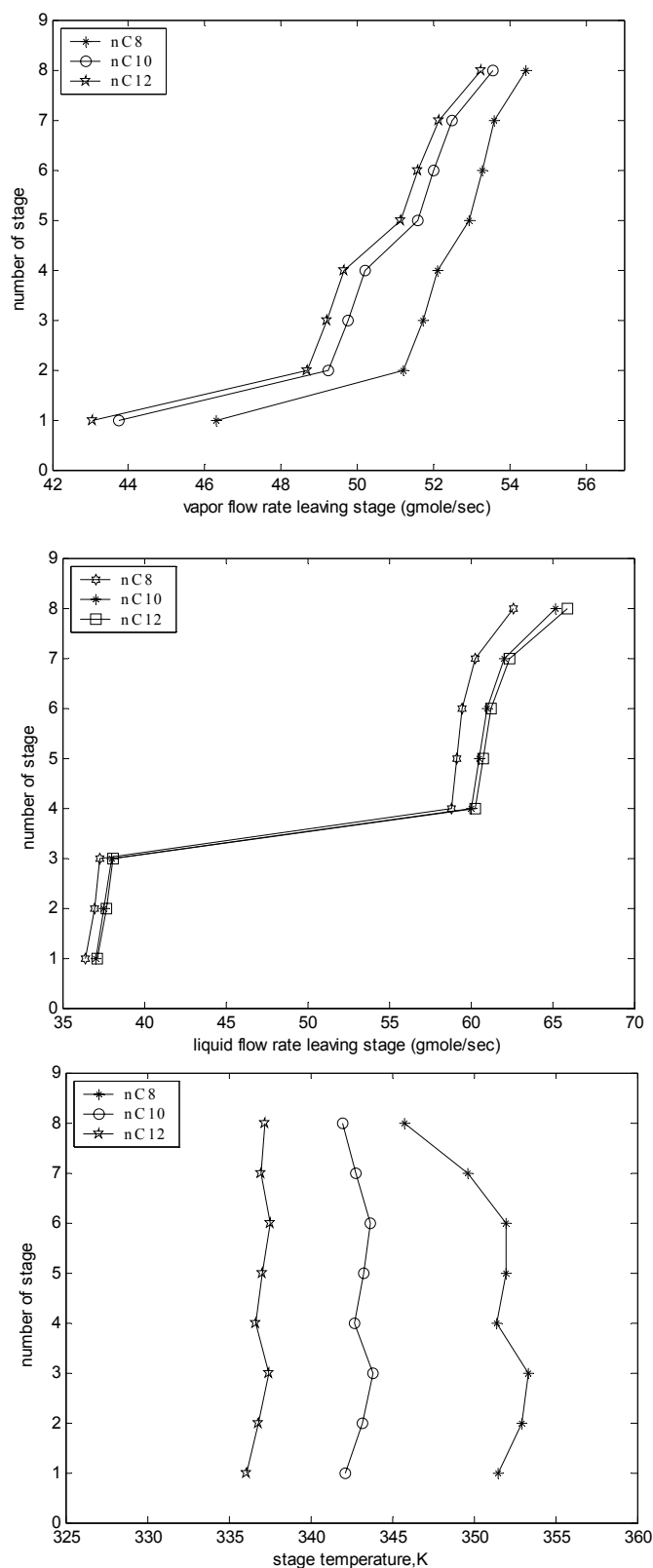
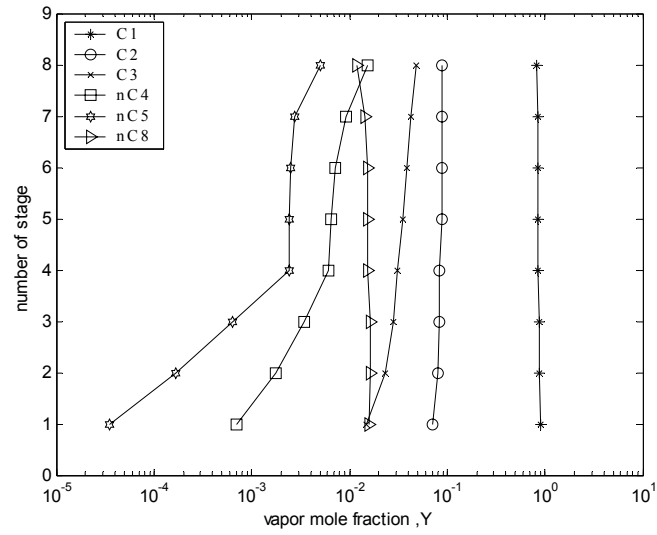
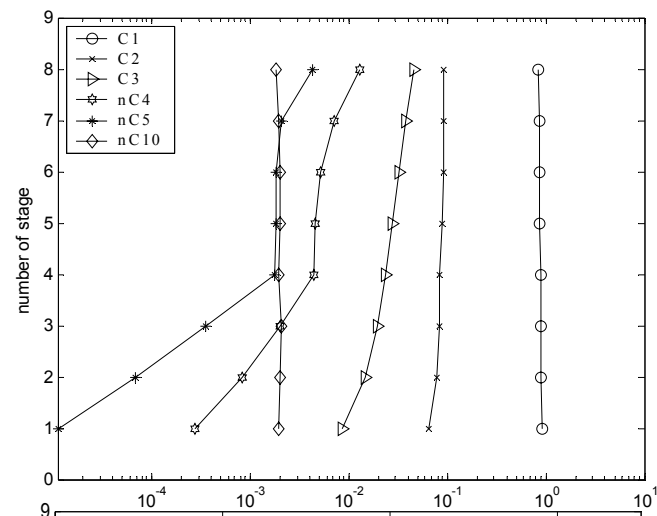


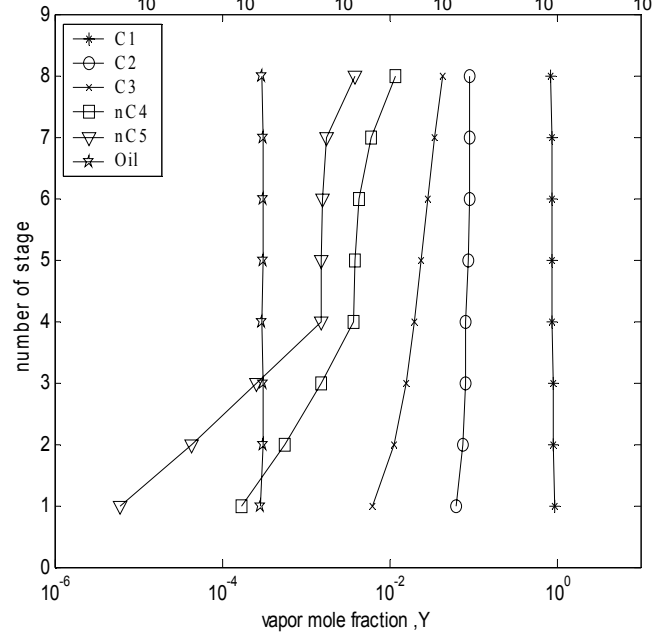
Fig. (4-16) Effect of change solvent on the vapor, liquid flow rates and stage temperatures of absorber system A



nC_8 (solvent)
(a)



nC_{10} (solvent)
(b)



nC_{12} (solvent)
(c)

Fig. (4-17) Effect of change solvent on the vapor mole fraction of the absorber system A

4.4.2. Stripping process:

The effects of several process variables on the performance of stripper were studied for stripper systems A and B to obtain the best solvent recovery process. The process variables studied are:

1. Effect of changing number of stage.
2. Effect of changing the rich oil feed temperature.
3. Effect of changing the operating pressure.
4. Effect of changing solvent.

4.4.2. 1. Effect of changing number of stage:

Figure (4-18 a, b) for system A and Figs.(15 a, b) for system B (Appendix B attended in compact disk) ,show that increasing the number of stage will increase the total vapor and liquid flow rate profiles at constant wet gas and lean oil flow rate and this increase is significant at the first stage .

This will increase the stage temperature profile Fig. (4-18c) for system A and Fig. (15c) for system B (Appendix B attended in compact disk). While this decreases the vapor mole fraction profiles Figs. (4-19) for system A and Figs. (16) for system B (Appendix B attended in compact disk). This will cause a small increase in fraction stripped due to increasing the surface and the time for the contact between the liquid and gas phases Table (4-10 a, b).

Table (4-10a) Effect of change number of stage on the fraction stripped for stripper system A

Component	Fraction stripped (s %)		
	N=8	N=10	N=12
C₁	100.00	100.00	100.00
C₂	100.00	100.00	100.00
C₃	100.00	100.00	100.00
C₄	100.00	100.00	100.00
C₅	99.9998	99.999	100.00
Oil	20.023	20.026	20.023

Table (4-10b) Effect of change number of stage on the fraction stripped for stripper system B

Component	Fraction stripped (s %)		
	N=8	N=10	N=12
CO₂	100.00	100.00	99.999
C₁	100.00	100.00	100.00
C₂	100.00	100.00	100.000
C₃	100.00	100.00	100.00
iC₄	99.999	99.999	100.00
nC₄	99.9998	99.9993	100.00
C₆	98.2905	98.8265	99.163
Oil	9.786	9.790	9.792

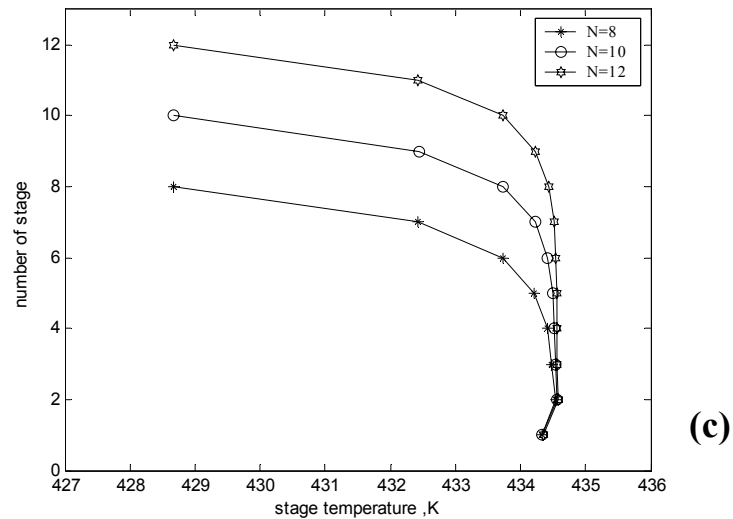
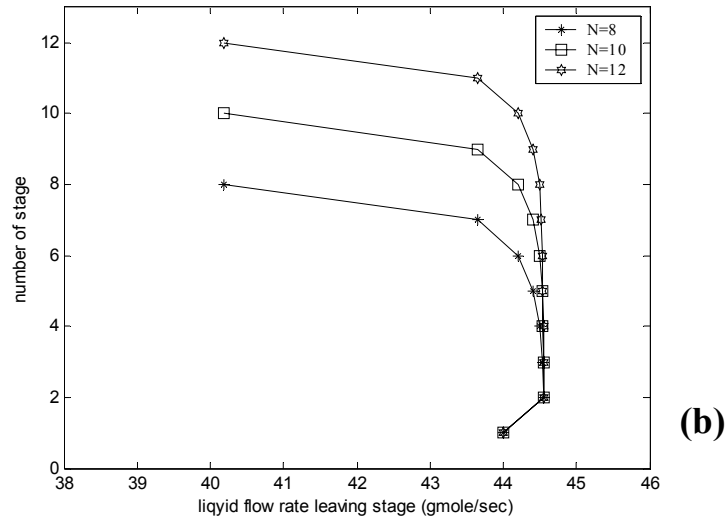
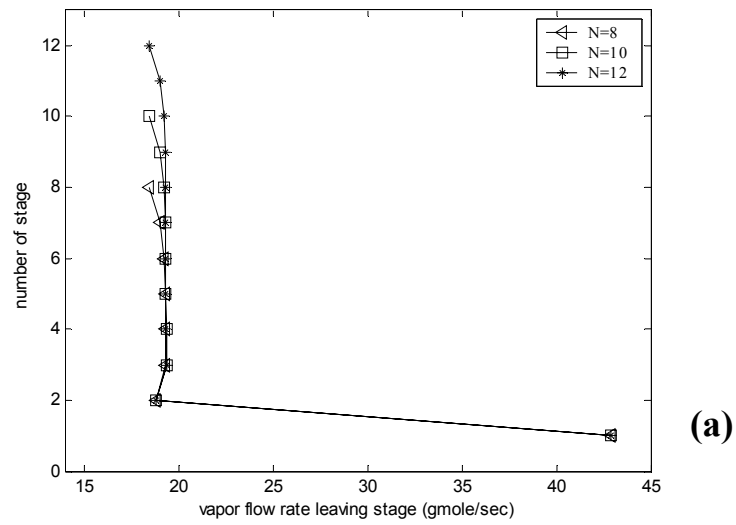
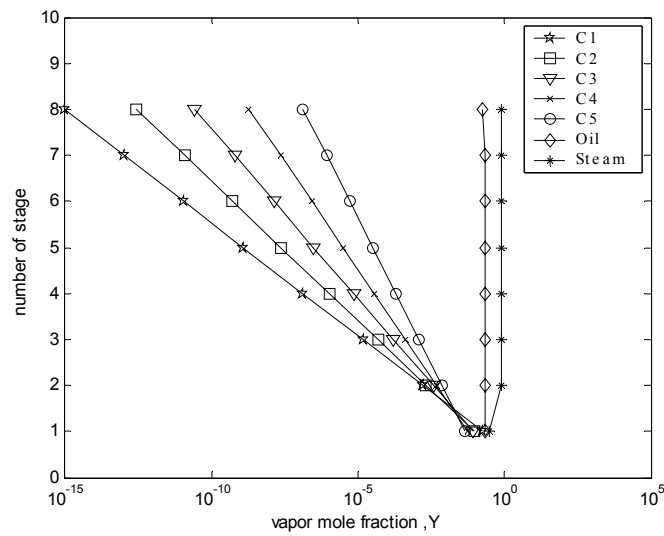
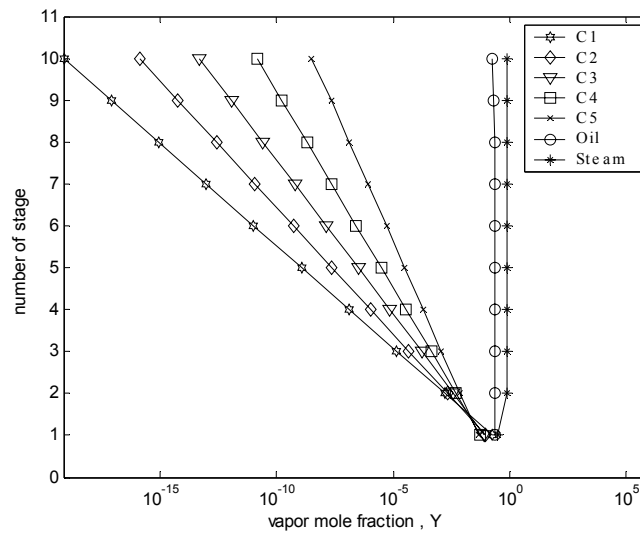


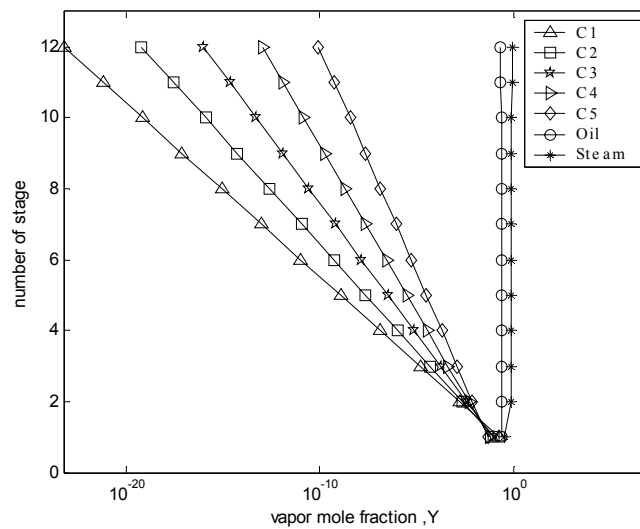
Fig.(4-18) Effect of change number of stage on the vapor, liquid flow rates profiles for stripper system A



(a)
 $N=8$



(b)
 $N=10$



(a)
 $N=12$

Fig. (4-19) Effect of change number of stage on the vapor mole fraction for stripper system A

4.4.2. 2. Effect of changing the rich oil temperature:

Figure(4-20a,b)for system A and Figs.(17a,b)for system B (Appendix B attended in compact disk), show that increasing the rich oil temperature will increase the total vapor flow rate profiles and this is sharply increased at the top stages. While the liquid flow rate profiles will decrease at constant wet gas and lean oil.

Figure (4-20c) for system A and Fig. (17c) for system B (Appendix B attended in compact disk), show that increasing of the rich oil temperature will increase the stage temperature profiles and this increasing is very significant.

The increasing of the rich oil temperature will increase the vapor fraction profiles Figs. (4-21) for system A and Figs. (18) for system B (Appendix B attended in compact disk). due to increase the fraction stripped Table (4-11) for system A and B and this will increase the rate of evaporation of the component in the liquid phase and decrease the condensation rate for the stripping gas in the liquid phase.

Table (4-11 a) Effect of change the rich oil temperature on the fraction stripped of stripper system A

Component	Fraction stripped (s %)		
	T=445K	T=450K	T=455K
C1	100.00	100.00	100.00
C2	100.00	100.00	100.00
C3	100.00	100.00	100.00
C4	100.00	100.00	100.00
C5	99.999	99.9998	99.99
Oil	16.914	20.023	23.594

Table (4-11 b) Effect of change the rich oil temperature on the fraction stripped of stripper system B

Component	Fraction stripped (s %)		
	T _o =450K	T _o =455K	T _o =460K
CO2	100.00	100.00	100.00
C1	100.00	100.00	100.00
C2	100.00	100.00	100.00
C3	100.00	100.00	100.00
iC4	99.999	99.999	99.999
nC4	99.9998	99.999	99.999
C6	98.2905	98.888	99.2999
Oil	9.786	11.203	12.725

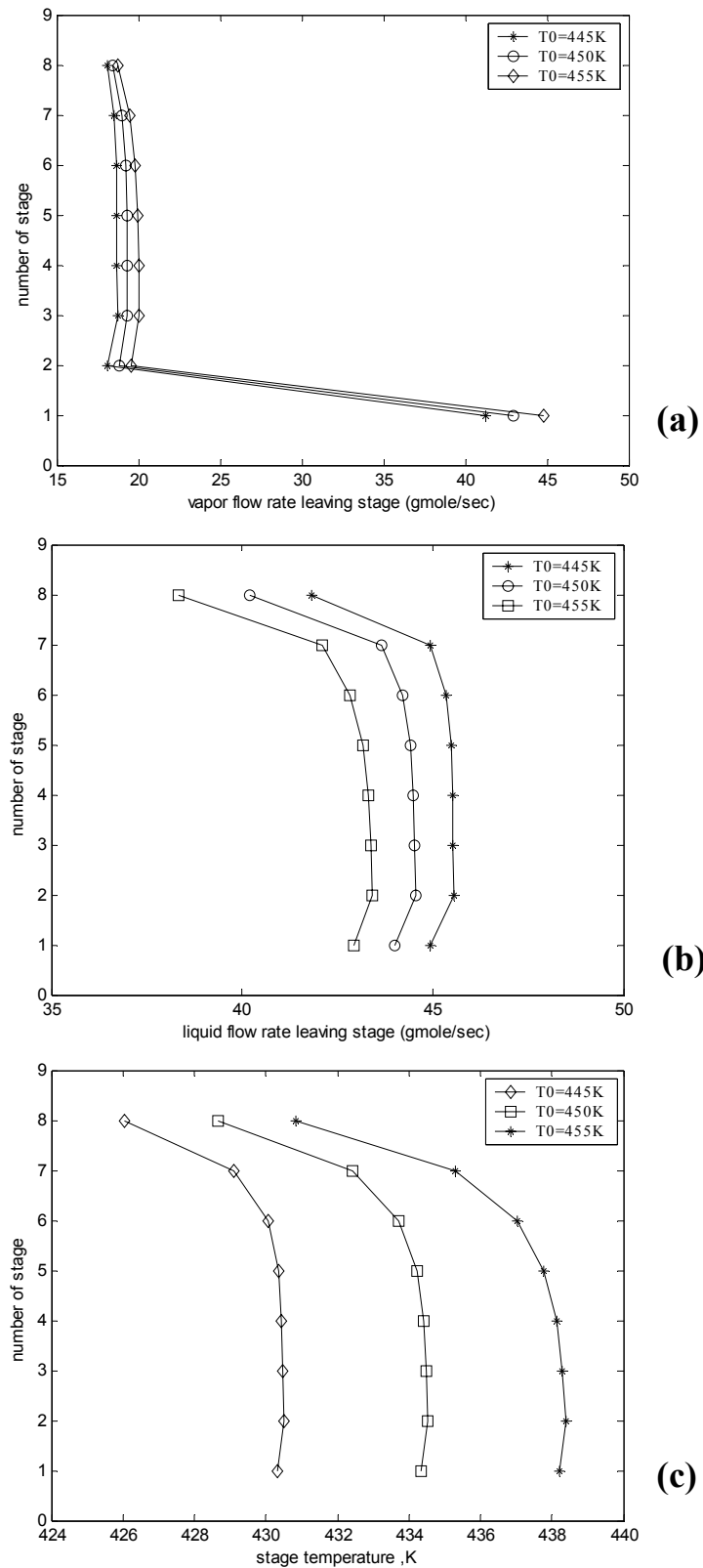
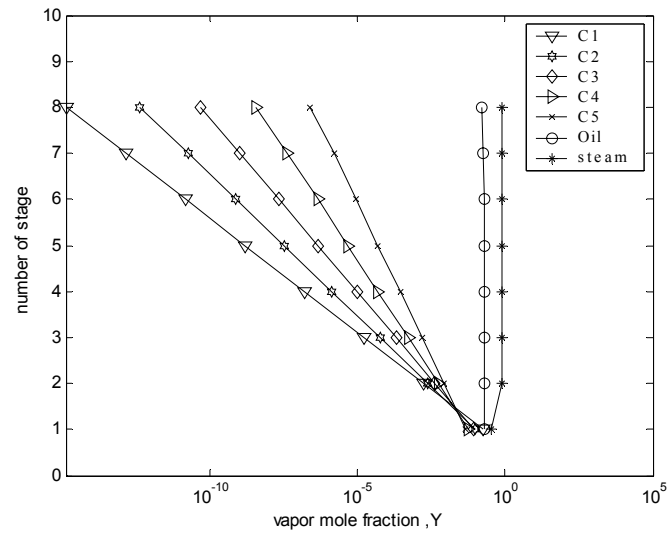
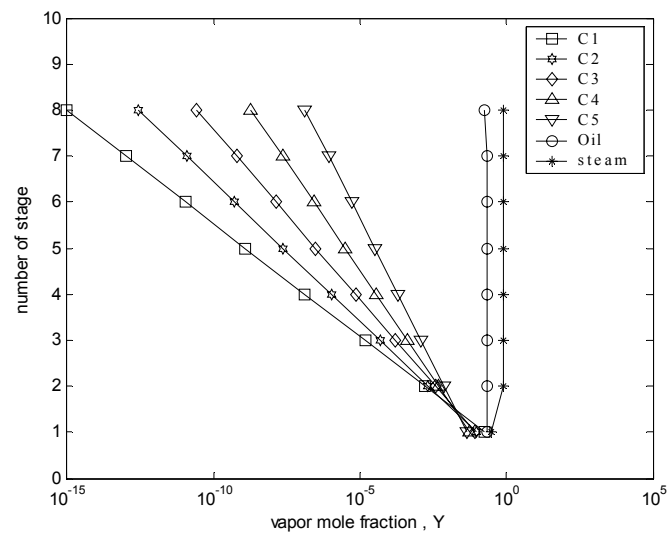


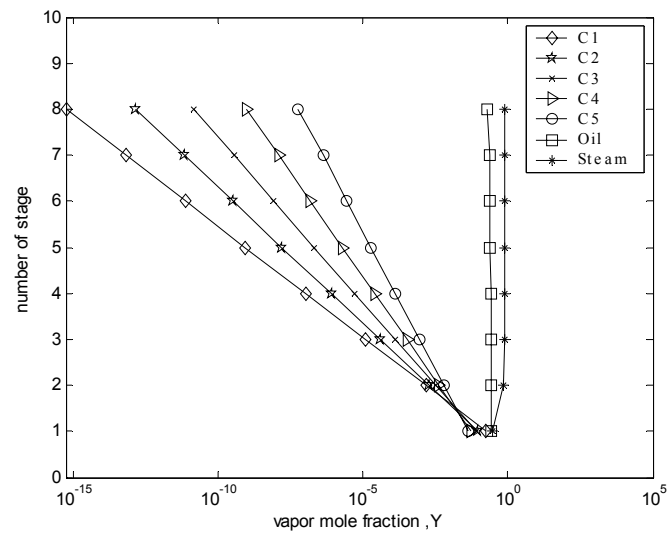
Fig. (4-20) Effect of change rich oil temperature on the vapor, liquid flow rates and stage temperatures for stripper system A



$T_0=445K$



$T_0=450K$



$T_0=455K$

Fig. (4-21) Effect of changing rich oil temperature on the vapor mole fraction profiles for stripper system A

4.4.2. 3. Effect of changing operating pressure:

Figure (4-21a, b) for system A and Figs. (20a, b) for system B in (Appendix B attended in compact disk) show that increasing the operating pressure will decrease the total vapor flow rate profiles at constant wet gas . While the total liquid flow rate profiles will increase at constant rich oil. The effect of increasing the operating pressure is significant on the first stage.

The increase of the operating pressure will increase the stage temperature profiles Fig. (21c) for system A and Fig. (20c) for system B (Appendix B attended in compact disk) and decrease the fraction stripped Table (4-12). This increase of operating pressure due to the increase of the vapor mole fraction Fig. (4-22) for system A and Figs. (21) for system B (Appendix B attended in compact disk) and this increase of the column pressure will decrease the components ability in the liquid phase to evaporate especially the heavy components, while this increase will increase the stripping gas ability to condense or to be absorbed by the liquid phase.

Table (4-12a) Effect of change operating pressure on the fraction stripped of the stripper system A

Component	Fraction stripped (s %)		
	P=1atm	P=2atm	P=3atm
C ₁	100.00	100.00	100.00
C ₂	100.00	100.00	100.00
C ₃	100.00	99.999	99.999
C ₄	100.00	99.999	99.995
C ₅	99.999	99.988	99.656
Oil	20.0233	9. 843	6.3456

Table (4-12b) Effect of change operating pressure on the fraction stripped of the stripper system B

Component	Fraction stripped (s %)		
	P=1atm	P=2atm	P=2.5atm
CO ₂	100.00	100.00	99.999
C ₁	100.00	100.00	100.00
C ₂	100.00	99.999	99.999
C ₃	100.00	99.9998	99.9989
iC ₄	99.999	99.992	99.951
nC ₄	99.999	99.971	99.836
C ₆	98.290	83.218	74.745
Oil	9.786	5.558	4.544

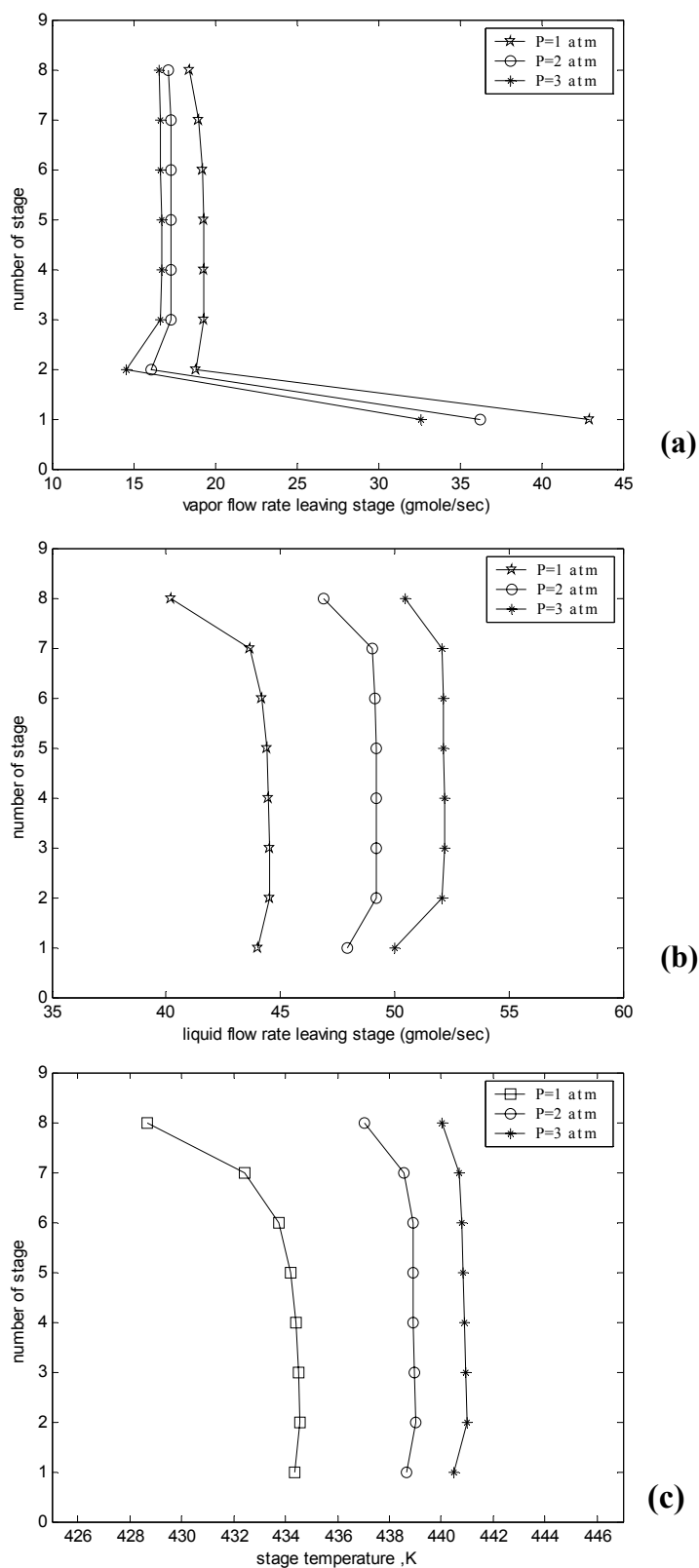
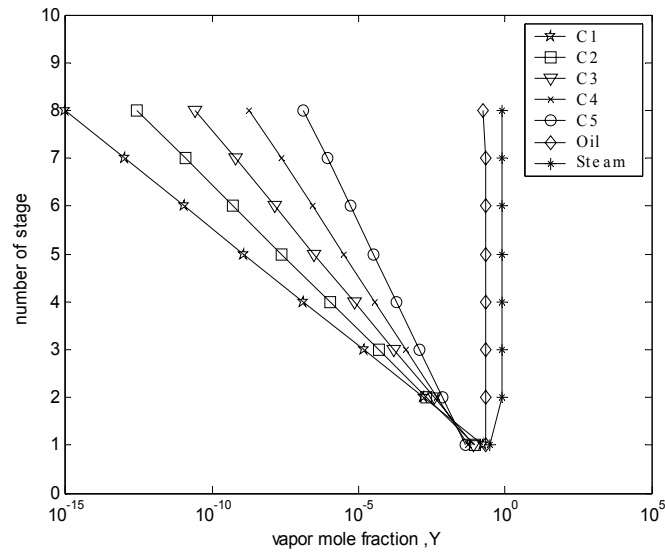
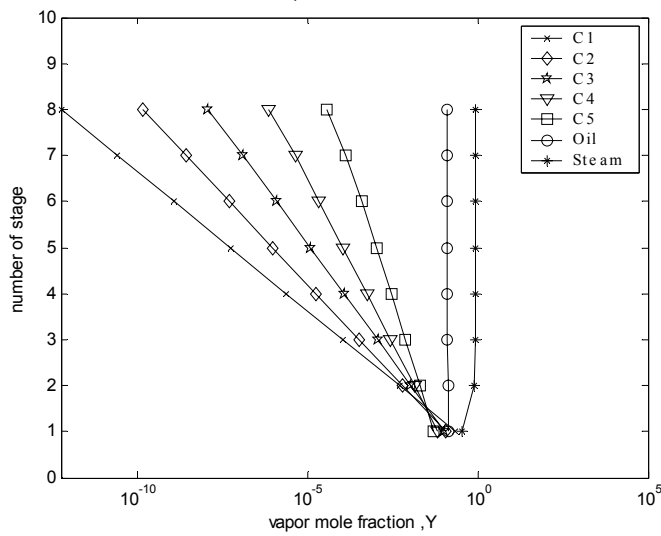


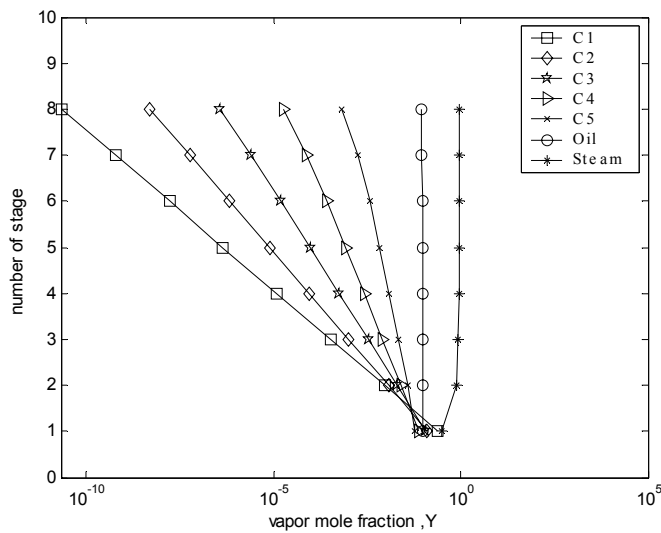
Fig. (4-22) Effect of change operating pressure on the vapor, liquid flow rate and stage temperatures for stripper system A



**P=1 atm
(a)**



**P=2 atm
(b)**



**P=3 atm
(c)**

Fig. (4-23) Effect of change operating pressure on the vapor mole fraction profiles of stripper system A

4.4.2. 4. Effect of changing solvent of the rich oil:

In this study different solvents were used, nC_{10} and nC_{12} for system A and B [2].

Figures (4-24a,b) for system A and Figs.(22a, b) for system B (Appendix B attended in compact disk), show that the total vapor flow rate and the total liquid flow rate decreases when the carbon number of the solvent are increased. The decrease in vapor and liquid flow rate profiles are due to increasing the solvent ability for stripped of the component from the liquid phase with increasing the carbon number of the solvent and the decreasing in the total liquid flow is significant from the first stage.

Figure (4-24c) for system A and Fig. (22c) for system B (Appendix B attended in compact disk), show that the temperature profiles decreases with increasing the carbon number of the solvent this is due to the decrease in the evaporation rate of the component in the liquid phase and decrease the condensation rate for the stripping gas in that liquid phase and this decrease is very sharp in the last stage.

Figure (4-25) for system A and Fig.(23)for system B (Appendix B attended in compact disk), show that the vapor mole fraction profiles decrease with increasing the carbon number of the solvent, this is because of the decrease of the fraction stripped of the solvent for these components Tables (4-13) of system A and B.

Table (4-13a) Effect of change solvent of the rich oil on the fraction stripped of the stripper system A

Component	Fraction stripped (s %)	
	nC ₁₀	nC ₁₂
C ₁	100.00	100.00
C ₂	100.00	100.00
C ₃	100.00	100.00
C ₄	100.00	100.00
C ₅	99.999	99.999
Oil	20.3628	20.0233

Table (4-13b) Effect of change solvent of the rich oil on the fraction stripped of the stripper system B

Component	Fraction stripped (s %)	
	nC ₁₀	nC ₁₂
CO ₂	100.000	100.00
C ₁	100.000	100.00
C ₂	100.000	100.00
C ₃	100.000	100.00
iC ₄	99.999	99.999
nC ₄	99.999	99.999
C ₆	97.594	98.290
Oil	18.751	9.7862

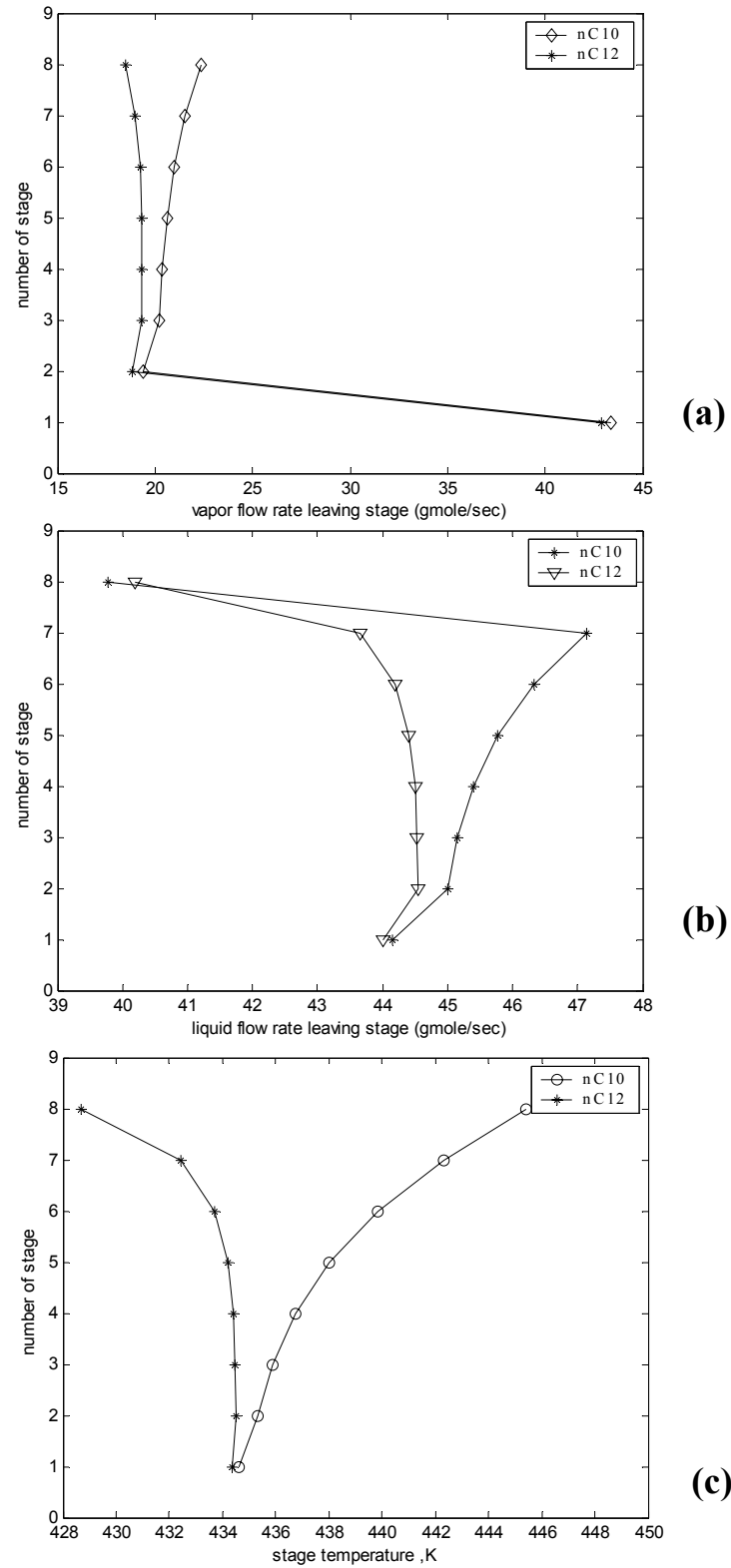
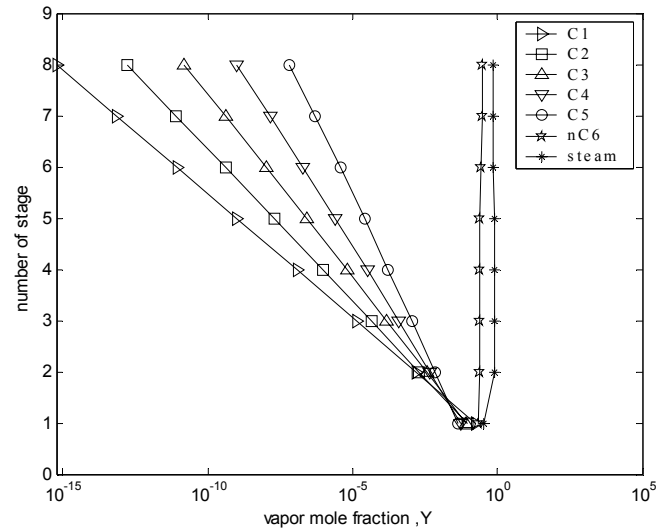
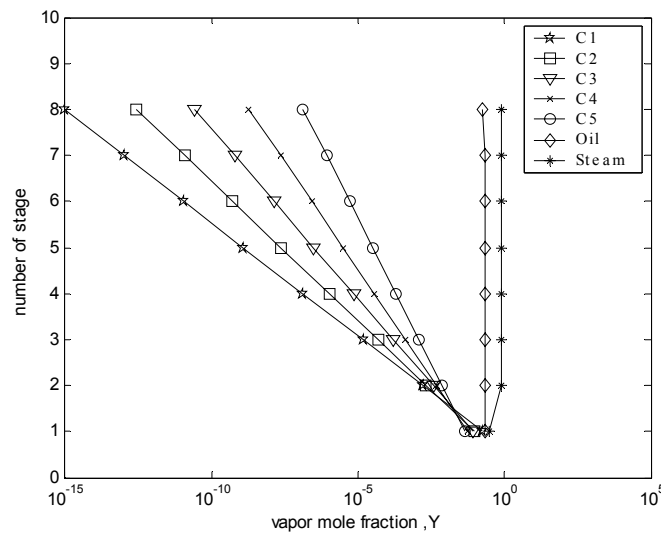


Fig. (4-24) Effect of change solvent of rich oil on the vapor, liquid flow rates and stage temperatures of the stripper system A



nC₁₀ (solvent)
(a)



nC₁₂ (solvent)
(b)

Fig. (4-25) Effect of change solvent of the rich oil on the vapor mole fraction profiles for stripper system A

4.5. Absorption -Stripping network:

In order to simulate the absorption –stripping network for system A and B , the bottom product from the absorber (rich oil) will be the feed of the stripper , and the bottom product of the stripper (lean oil) is recycled to the absorber . Therefore, the bottom product of the stripper must have the same specifications of the lean oil fed to the absorber. There is a loss in the amount of the solvent used in the absorber due to evaporation through out the two processes. And the lean oil exit from

stripper must be cooled to the temperature of the absorber feed by using a heat exchanger that uses water for this cooling.

4.5.1. Effects on the absorption – stripping network process:

The effect of changing the number of stages, wet gas feed temperature, operating pressure and the type of solvent of the absorber on the performance of absorption – stripping network were studied for system A and B.

4.5.1. 1. Effect of changing number of stage:

By changing the number of stages of system A and B of the absorber there will be some effect on the stripper of the network, Figure (4-26) for system A and Fig. (23) for system B (Appendix B attended in compact disk), show that increasing the number of the stages in the absorber will increase the total vapor flow rate profile and decrease total liquid flow rate profile of the stripper at constant wet gas and lean oil Fig. (4-26a, b). The effect of increasing the number of stages on the total vapor flow rate is very small in the first stages, then it will be more significant for system A Fig (4-26a), but for the liquid flow rate the increase is very large from the first stages of system A Fig. (4-26b)

Figure (4-26c) for system A and Fig. (23c) for system B (Appendix B attended in compact disk), show that increasing the number of stages of the absorber will increase the temperature profiles of the stripper and this increase is very large and significant for the first stages.

The increase number of stages in the absorber will decrease the vapor mole fraction on the stripper but these decrease very small Figs. (4-27) for system A and Fig. (24) for system B (Appendix B attended in compact disk). While the increasing number of stage of the absorber will increase the fractions stripped Tables (4-14a, b) for system A and B.

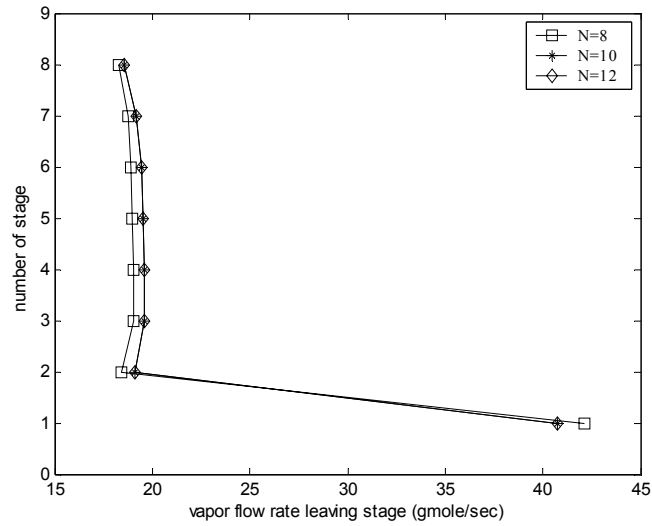
Increasing the number of stages will increase the amount of the water used for cooling the exit stream from the stripper in the network Table (4-15a, b) for system A and B.

Table (4-14a) Effect of change number of stages of absorber in the fraction stripped of stripper in the network A

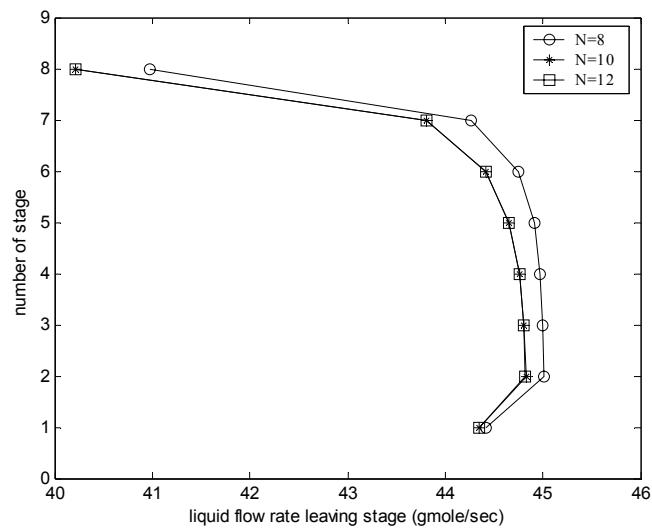
component	Fraction stripped (s %)		
	N=8	N=10	N=12
C1	100.000	100.00	100.00
C2	100.000	100.00	100.00
C3	100.000	100.00	100.00
C4	100.000	100.00	100.00
C5	99.999	99.999	99.999
Oil	18.508	19.909	19.906

Table (4-14b) Effect of change number of stages of absorber in the fraction stripped of stripper in the network B

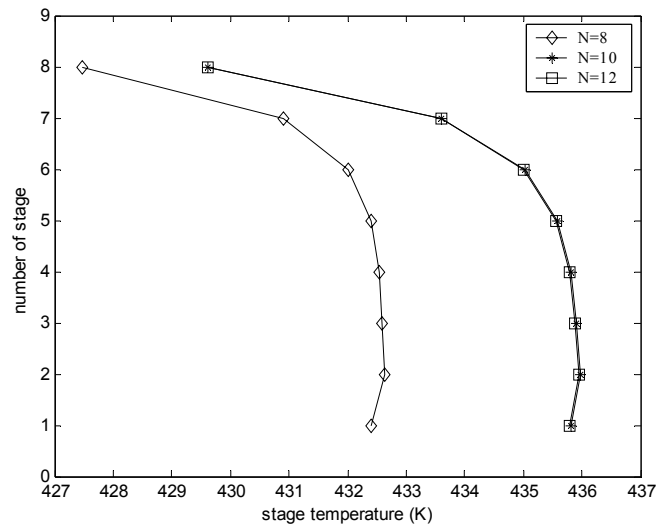
component	Fraction stripped (s %)		
	N=6	N=8	N=10
CO ₂	100.000	100.000	100.000
C ₁	100.000	100.000	100.000
C ₂	100.000	100.000	100.000
C ₃	100.000	100.000	100.000
iC ₄	99.999	99.999	99.999
nC ₄	99.999	99.999	99.999
C ₆	99.477	99.476	99.476
Oil	11.417	11.416	11.416



(a)

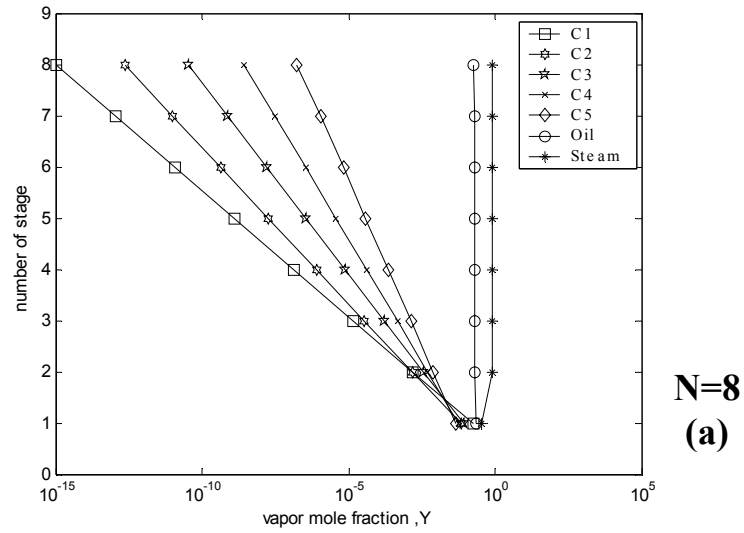


(b)

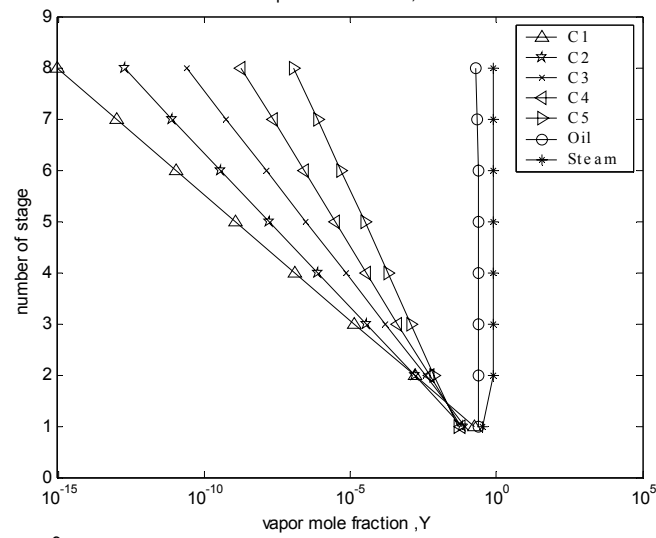


(c)

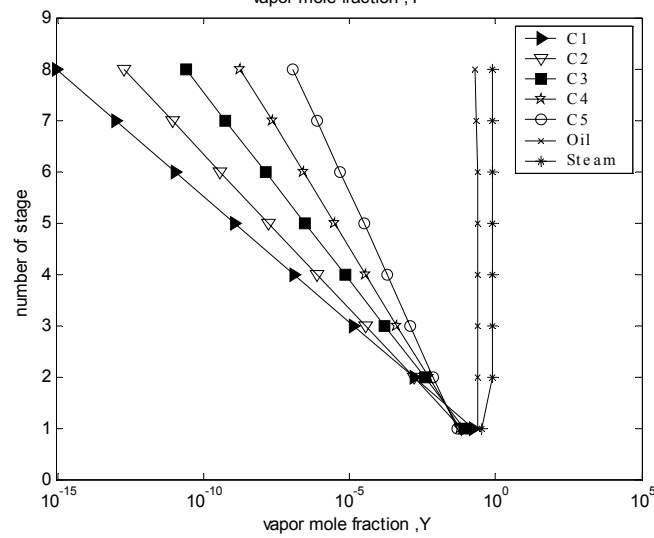
Fig. (4-26) Effect of change number of stages for absorber on the vapor, liquid flow rates and stage temperatures of the stripper in the network system A



N=8
(a)



N=10
(b)



N=12
(c)

Fig. (4-27) Effect of change number of stages on the vapor mole fraction profiles for stripper system A

Table (4-15a) Effect of change number of stages of the absorber on the water flow rate using to cool exit stream of the stripper system A

Number of stage	Water flow rate need for each component (mole/sec)
8	5.713
10	5.784
12	5.783

Table (4-15b) Effect of change number of stages of the absorber on the water flow rate using to cool exit stream of the stripper system B

Number of stage	Water flow rate need for each component (mole/sec)
6	3.341
8	3.340
10	3.340

4.5.1. 2. Effect of changing wet gas feed temperature:

By changing the wet gas feed temperature of the absorber some effects can be considered on the stripper as in Fig. (4-28) for system A and Fig. (25) for system B (Appendix B attended in compact disk). Increasing the wet gas temperature will increase the vapor flow rate and decrease the liquid flow rate profiles at constant wet gas and rich oil respectively. This increases in the vapor flow rate and decreases in the liquid flow rate are very small in the first stages but it get more significance at the bottom stages Figs. (4-27a, b) for system A and Figs. (25a, b) for system B in (Appendix B attended in compact disk).

The increase of the wet gas feed temperature of the absorber will increase the temperature profiles of the stripper Fig. (4-27c) for system A and Fig. (25c) for system B (Appendix B attended in compact disk). While the fraction stripped of

system A is unstable for increasing wet gas feed temperature so increasing then decreasing and for system B the fraction stripped will decrease Table (4-16) for system A and B and the vapor mole fraction increase Fig.(4-28) for system A and Fig.(26) for system B (Appendix B attended in compact disk).

Increasing the wet gas feed temperature of the absorber will increase the water flow rate used for cooling the exit stream from the stripper and recycled to the absorber Tables (4-17 a, b) for system A and B respectively.

Table (4-16a) Effect of change feed temperature of absorber on the fraction stripped of the stripper of the network system A

Component	Fraction stripped (s %)		
	$T_f=305.372K$	$T_f=315K$	$T_f=325K$
C1	100.00	100.00	100.00
C2	100.00	100.00	100.00
C3	100.00	100.00	100.00
C4	100.00	100.00	100.00
C5	99.999	99.999	99.999
Oil	18.508	19.905	19.893

Table (4-16b) Effect of change feed temperature of absorber on the fraction stripped of the stripper of the network system B

component	Fraction stripped (s %)		
	$T_f=300K$	$T_f=305K$	$T_f=310K$
CO ₂	100.000	100.000	100.000
C ₁	100.000	100.000	100.000
C ₂	100.000	100.000	100.000
C ₃	100.000	100.000	100.000
iC ₄	99.999	99.999	99.999
nC ₄	99.999	99.999	99.999
C ₆	99.477	99.498	99.518
Oil	11.417	11.398	11.380

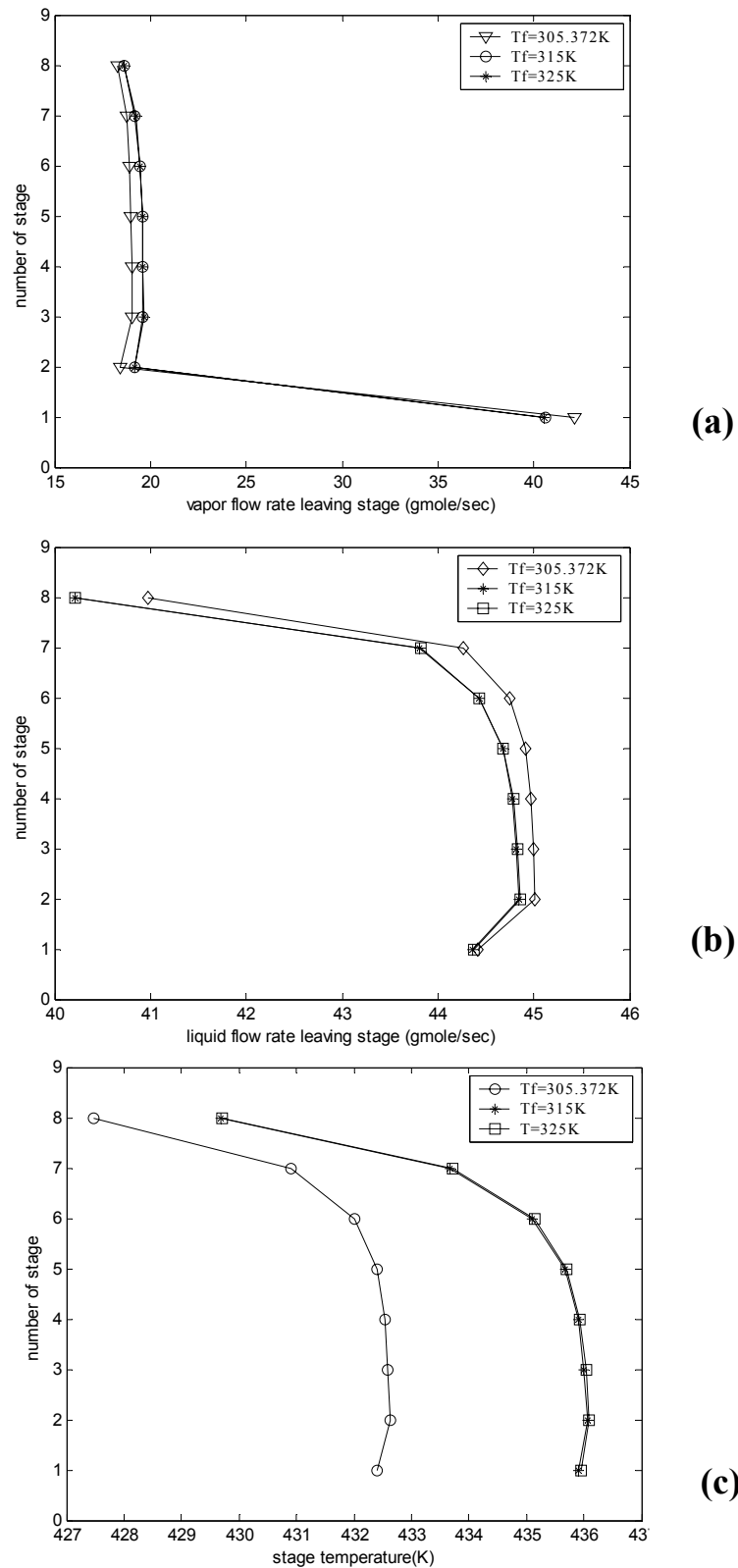
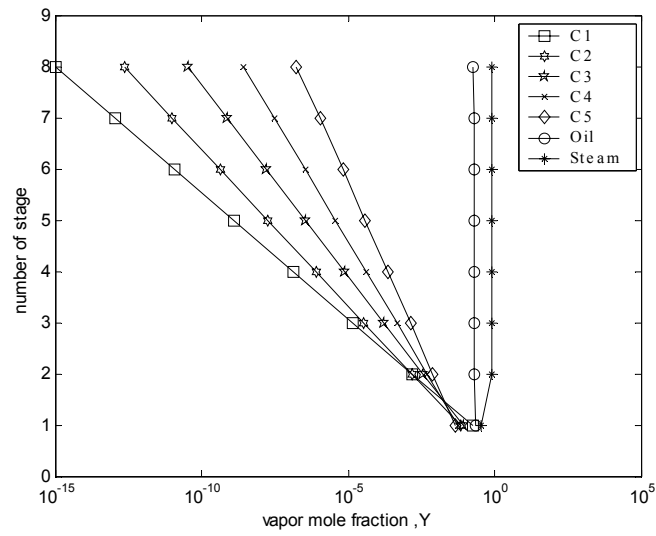
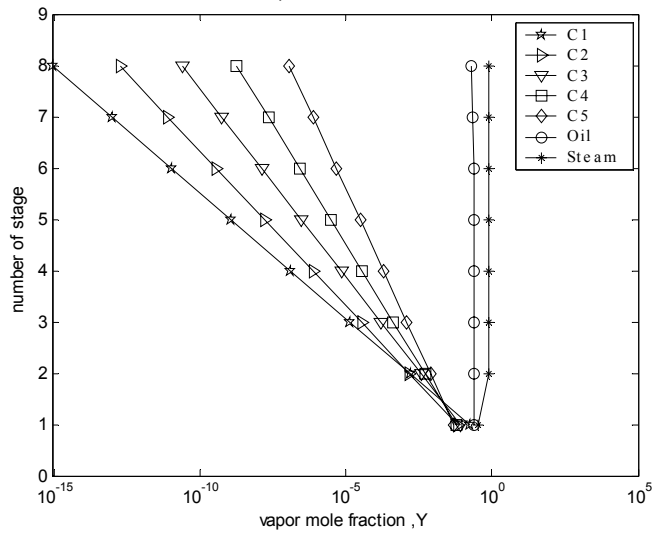


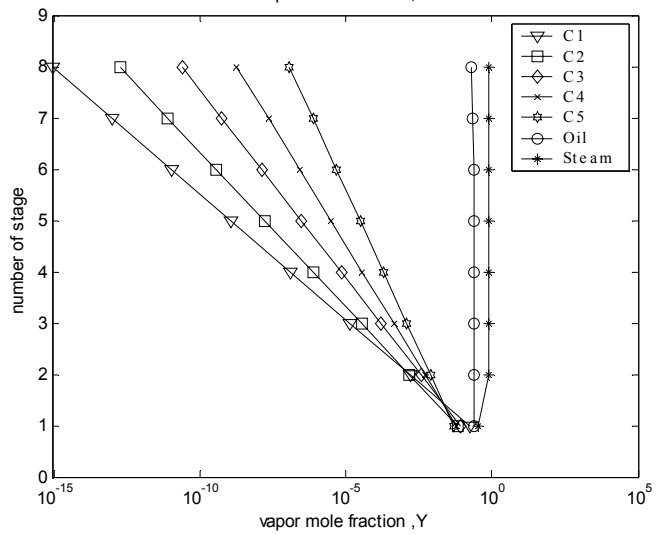
Fig. (4-28) Effect of change feed temperature for absorber on the vapor liquid flow rates and stage temperatures of the stripper of the network system A



$T_f=305.372\text{ K}$
(a)



$T_f=315\text{ K}$
(b)



$T_f=325\text{ K}$
(c)

Fig. (4-29) Effect of change feed temperature of absorber on the vapor mole fraction profiles of the stripper of the network system A

Table (4-17a) Effect of change wet gas feed temperature of absorber on the water flow rate used to cool exit stream of the stripper of the network system A

Wet gas temperature(K)	Water flow rate need for each component (mole/sec)
305.37	5.713
315	5.789
325	5.791

Table (4-17b) Effect of change wet gas feed temperature of absorber on the water flow rate used to cool exit stream of the stripper of the network system B

Wet gas temperature(K)	Water flow rate need for each component (mole/sec)
300	3.341
305	3.349
310	3.356

4.5.1. 3. Effect of changing operating pressure:

By changing the operating pressure of the absorber system A and B some effects can be considered Fig.(4-30)for system A and Fig.(27) for system B (Appendix B attended in compact disk), increasing the operating pressure in the absorber will increase the total vapor flow rate profile of the stripper and decrease the total liquid flow rate profile. The effect of increasing total vapor flow rate is very small that can be ignored Fig. (4-30a) for system A and Fig. (27a) for system B. The total liquid flow rate will decrease, then it will be more significant for the first stages, Fig. (4-30b) for system A and Fig. (27b) for system B.

Figure(4-30c) and Fig. (27c) show that increasing the operating pressure of the absorber will increase the stage temperature profiles of the stripper, this is due to

the decrease of the vapor mole fraction Fig.(4-31) for system A and Fig.(28)for system B .

Table (4-18) for system A and B show that increasing the operating pressure of the absorber will increase the fraction stripped of the stripper. This is due to the increase in the evaporation rate of the component in the liquid phase and the decrease of the condensation rate for the stripping gas in that liquid phase.

Tables (4-19) for system A and B show that increasing the operating pressure of the absorber will decrease the water flow rate that is used to cooling the exit stream from the stripper

Table (4-18a) Effect of change operating pressure of the absorber on the fraction stripped of the stripper on the network A

Component	Fraction stripped (s %)		
	P=27 atm	P=30 atm	P=32 atm
C1	100.00	100.00	100.00
C2	100.00	100.00	100.00
C3	100.00	100.00	100.00
C4	100.00	100.00	100.00
C5	99.999	99.999	99.999
Oil	18.508	20.099	20.249

Table (4-18b) Effect of change operating pressure of the absorber on the fraction stripped of the stripper on the network B

component	Fraction stripped (s %)		
	P=21.068atm	P=23atm	P=25atm
CO ₂	100.000	100.000	100.000
C ₁	100.000	100.000	100.000
C ₂	100.000	100.000	100.000
C ₃	100.000	100.000	100.000
iC ₄	99.999	99.999	99.999
nC ₄	99.999	99.999	99.999
C ₆	99.477	99.451	99.423
Oil	11.417	11.477	11.534

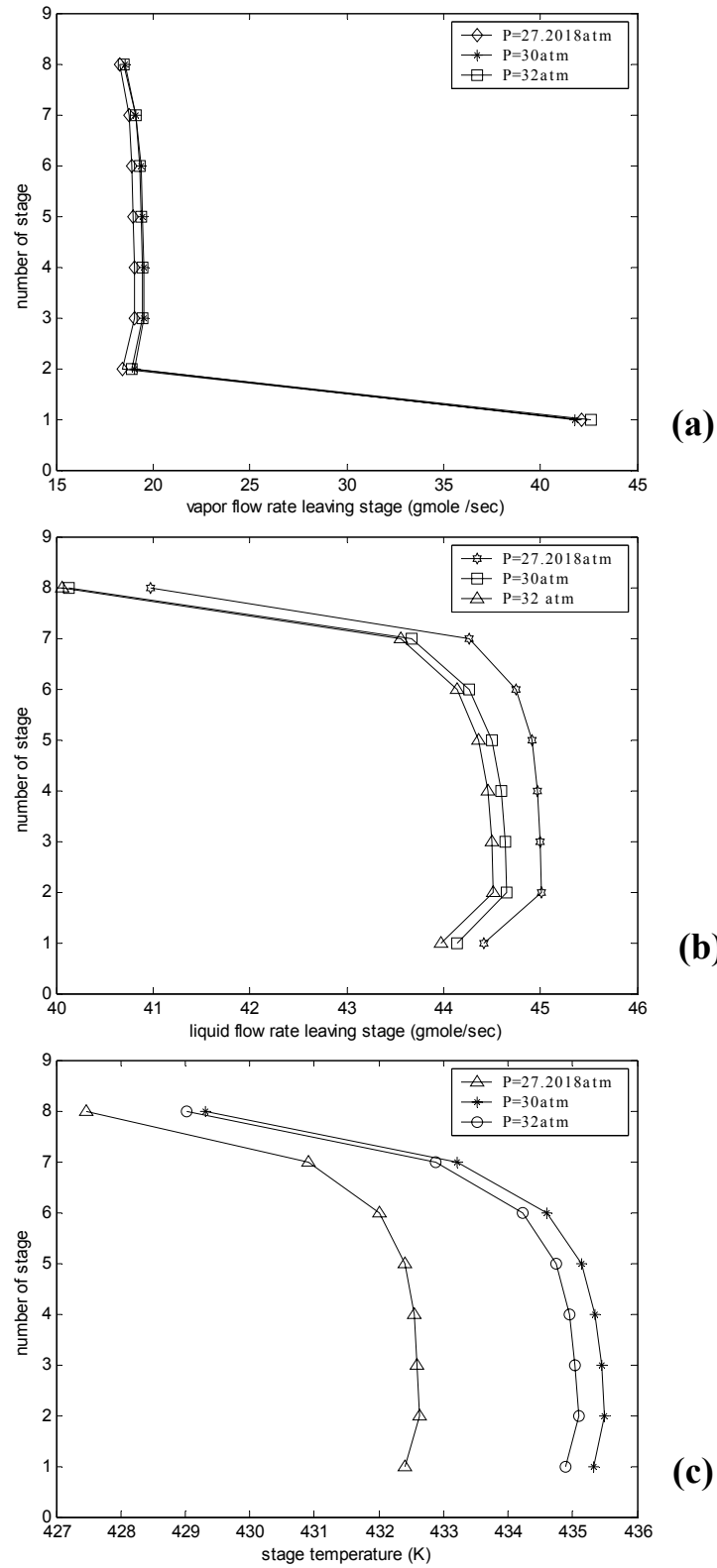
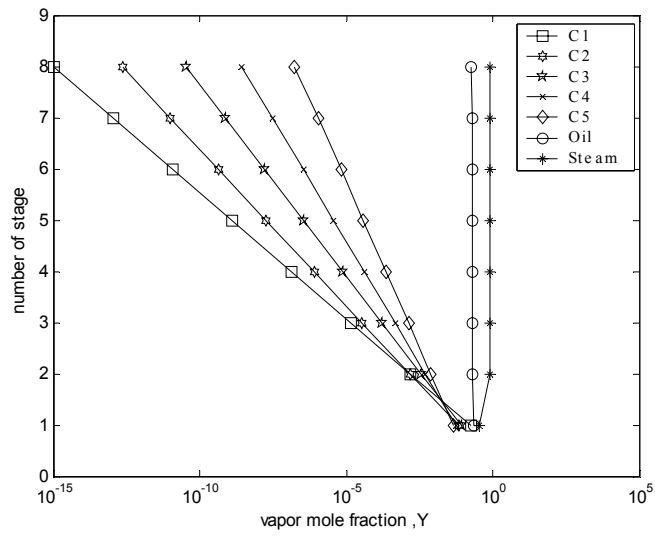
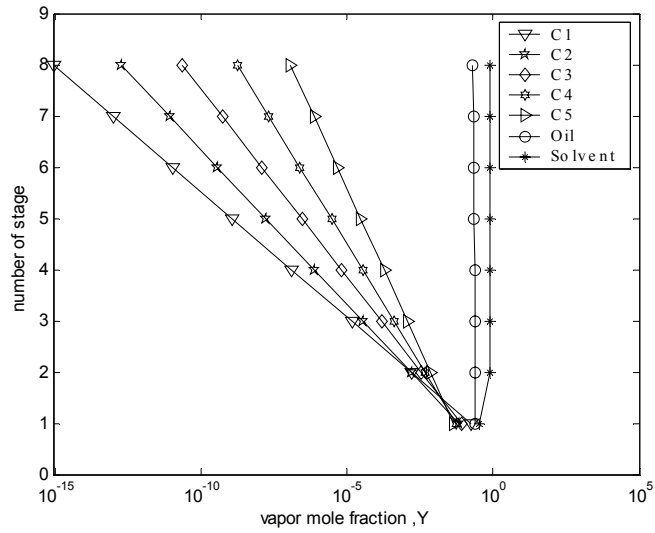


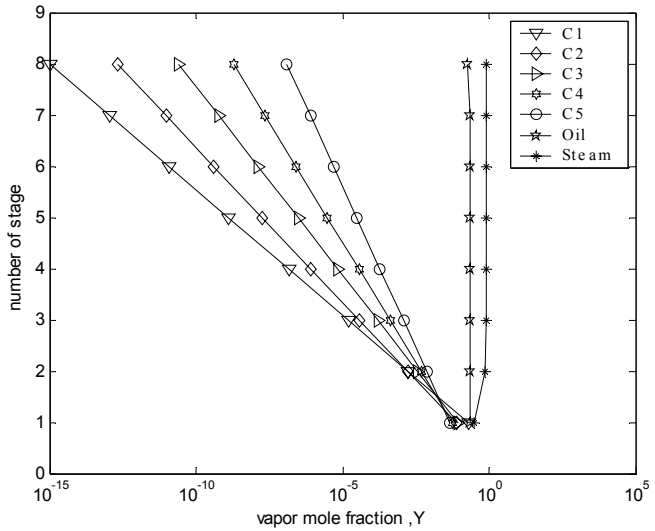
Fig. (4-30) Effect of change operating pressure for the absorber on the vapor, liquid flow rates and stage temperatures of the stripper in the network system A



**P=27.327atm
(a)**



**P=30atm
(b)**



**P=32 atm
(c)**

Fig. (4-31) Effect of change operating pressure of absorber on the vapor mole fraction profiles of the stripper in the network system A

Table (4-19a) Effect of change operating pressure of the absorber on the water flow rates used to cool the exit stream from the stripper on the network A

Operating pressure (atm)	Water flow rate need for each component (mole/sec)
27.327	5.713
30	5.747
32	5.717

Table (4-19b) Effect of change operating pressure of the absorber on the Water flow rates used to cool the exit stream from the stripper on the network B

Operating pressure(atm)	Water flow rate need for each component (mole/sec)
21.068	3.313
23	3.298
25	3.283

4.5.1. 4. Effect of changing solvent:

In this study nC_8 , nC_{10} and nC_{12} , were considered as solvents for system A and B [1, 21]. Changing the type of solvent in the absorber will effect on the performance of the stripper.

Figures(4-32a,b) for system A and Fig.(29a, b) for system B (Appendix B attended in compact disk) show that the vapor flow rate profiles of the stripper decrease when the carbon number of the solvent of the absorber are increased while the liquid flow rate profiles of the stripper will increase . And the effect of decreasing vapor flow rate is very small in the first two stages (1, 2) but it's significant in the bottom stages Fig. (4-32a) for system A and Fig. (29a) for system

B. Therefore the increase of liquid flow rate profiles is significant for the first stages Fig. (4-32b) for system A and Fig. (29b) for system B (Appendix B attended in compact disk).

Figure (4-32c) for system A and Fig. (29c) for system B (Appendix B attended in compact disk) show that the temperature profiles of the stripper decrease with increasing the carbon number of the solvent of the absorber this is due to the decrease in the evaporation rate of the component in the liquid phase and the decrease in condensation rate for the stripping gas in that liquid phase.

Figure (4-25) for system A and Fig.(23)for system B (Appendix B attended in compact disk) show that the vapor mole fraction profiles of the stripper decrease with increasing the carbon number of the solvent of the absorber, this is because of the decrease of the fraction stripped of the solvent for these components Tables (4-20) of system A and B.

The increase of the carbon number of the solvent of the absorber will decreases water flow rate used for cooling the exit stream of the stripper Tables (4-21) for system A and B respectively.

Table (4-20a) Effect of change solvent of the absorber on the fraction stripped of the stripper on the network A

Component	Fraction stripped (s %)		
	nC8	nC10	nC12
C1	100.00	100.00	100.00
C2	100.00	100.00	100.00
C3	100.00	100.00	100.00
C4	100.00	100.00	100.00
C5	99.999	99.999	99.999
Oil	19.706	19.864	18.508

Table (4-20b) Effect of change solvent of the absorber on the fraction stripped of the stripper on the network B

component	Fraction stripped (s %)		
	nC ₈	nC ₁₀	nC ₁₂
CO ₂	100.00	100.00	100.00
C ₁	100.00	100.00	100.00
C ₂	100.00	100.00	100.00
C ₃	100.00	100.00	100.00
iC ₄	99.999	99.999	99.999
nC ₄	99.999	99.999	99.999
C ₆	99.477	99.437	99.426
Oil	11.417	11.507	11.531

Table (4-21a) Effect of change operating pressure of the absorber on the water flow rates used to cool the exit stream of the stripper on the network A

Type of solvent	Water flow rate need for each component (mole/sec)
nC ₈	5.795
nC ₁₀	5.800
nC ₁₂	5.713

Table (4-21b) Effect of change operating pressure of the absorber on the water flow rates used to cool the exit stream of the stripper on the network B

Number of stage	Water flow rate need for each component (mole/sec)
nC ₈	3.411
nC ₁₀	3.331
nC ₁₂	3.313

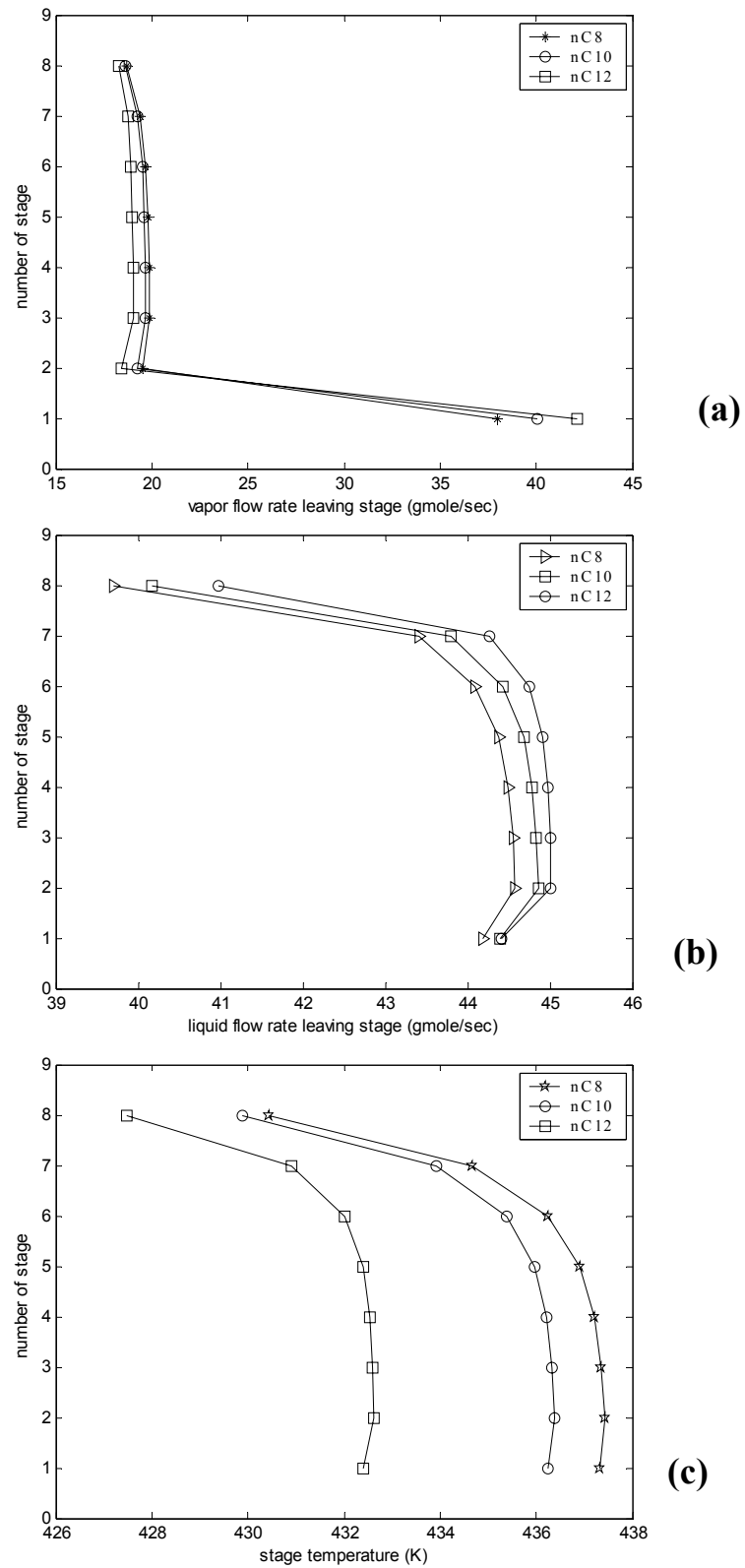
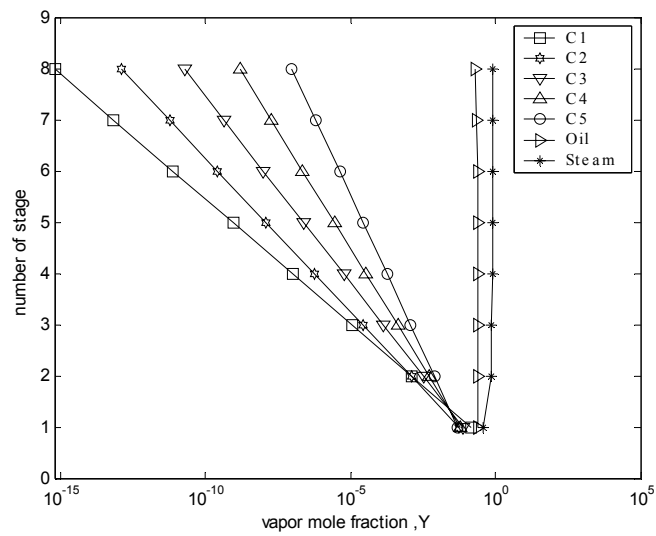
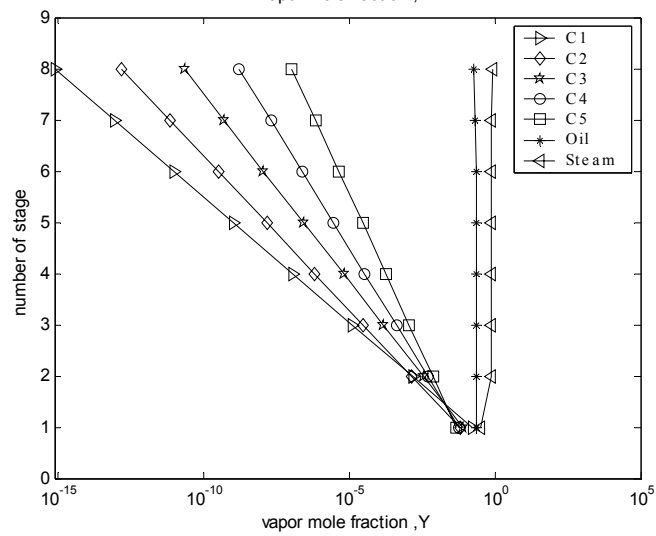


Fig. (4-32) Effect of change solvent of the absorber on the vapor, liquid flow rates and stage temperatures for stripper on the network system

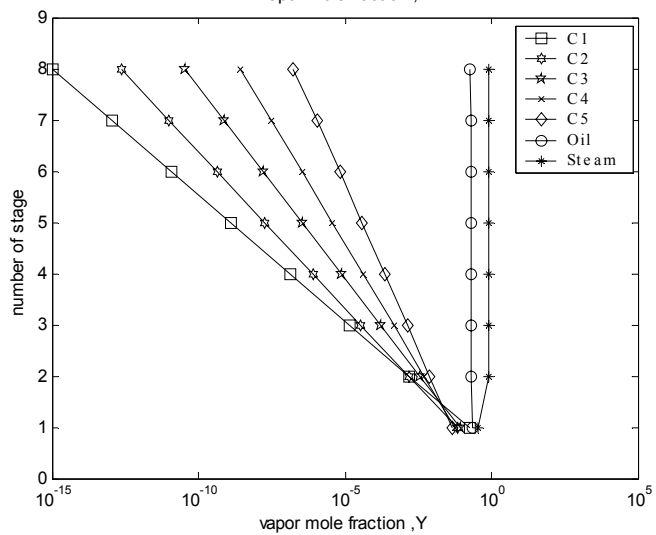
A



**nC8
(a)**



**nC10
(b)**



**nC12
(c)**

Fig. (4-33) Effect of change solvent of the absorber on the vapor mole fraction profiles of the stripper in the network system A

Chapter Five

Conclusions and Suggestion

5.1. Conclusions:

The following conclusions have been drawn from this work:

5.1.1. Absorption column:

- 1.** The results obtained from the developed computer program using SRK EOS give identical with AL-Mula [2] and Maddox [39] for the desired product and this give the accuracy of the developed computer program.
- 2.** Using PR EOS gives better results of the fractional absorbed of the desired product than SRK EOS.
- 3.** There are some effect of process variables on the performance of absorption column , such as:
 - a.** The increase of the number of stages will decrease the total vapor and liquid flow rate profiles, temperature profiles and vapor mole fraction but the fraction absorbed increased.
 - b.** Increasing the wet gas feed temperature will increase the total vapor flow rate and temperature profiles , while the total liquid flow rate and fraction absorbed and vapor mole fraction decreases.
 - c.** Increasing the operating pressure will decrease the total vapor flow rate and the vapor mole fraction and increase the total liquid flow rate profiles, fraction absorbed and temperature profiles.
 - d.** The increase of the type of solvent will decrease the total vapor flow rate profiles, fraction absorbed and vapor mole fraction and increase the total liquid flow rate profiles and temperature profiles.

The best effect of changing the variables for system A is by increasing the operating pressure to $P = 32\text{atm}$ and number of stage = 8 that gave the best percent fraction absorbed of C_3 is 94.99% .

5.1.2. Stripper column:

1. The results obtained from the developed computer program using SRK EOS gave identical with AL-Mula [2] for the desired product and this give the accuracy of the developed computer program.
2. Using PR EOS gives better results of the fractional stripped of the desired product than SRK-EOS.
3. There are some effect of process variables on the performance of stripping process , such as:
 - a. Increasing the number of stages will increase the total vapor and liquid flow rate profiles, temperature profiles and fractions stripped and decrease the vapor mole fraction.
 - b. Increasing rich oil temperature will increase the total vapor flow rate profiles, temperature profiles, vapor mole fraction and fraction stripped and decrease liquid flow rate profiles.
 - c. Increasing of operating pressure will decrease the total vapor flow rate and increase the total liquid flow rate profiles, temperature profiles, vapor mole fraction and fraction stripped.
 - d. Increasing of carbon number of solvent on the rich oil will decrease the total vapor and liquid flow rate profiles, temperature profiles, vapor mole fraction and fraction stripped.

The best effect of changing the variables for system A is by increasing carbon number of the solvent in rich oil such as at carbon number C_{12} and number of stage = 8 gave the percent fractionstripped of oil = 20.02% .

5.1.3. Absorption-Stripping network:

The effect of variables on the performance absorption stripping network is:

- a.** Increasing the number of stages of the absorber will increase the total vapor flow rate profiles, temperature profiles and the fraction stripped on the stripper of the network system.
- b.** Increasing wet gas feed temperature of the absorber will increase the total vapor flow rate profiles and temperature profiles , while the fraction stripped will decrease on the stripper of the network .
- c.** Increasing operating pressure of the absorber will increase the total vapor flow rate profiles, temperature profiles and fraction stripped on the stripper, while it decrease the liquid flow rate profiles of the network.
- d.** The vapor flow rate profiles, temperature profiles and fraction stripped will decrease when the number of carbon used as solvent of the absorber increase while the liquid flow rate profile increase in the network.
- e.** Amount of the water used in the absorption – stripping network for cooling the liquid stream leaving the stripper that is recycled to the absorber changes when the process variables of the absorber was changed.

The best effect of changing process design in the performance of absorption - stripping network for system A is by changing the type of solvent of the absorber that decreases percent fraction stripped from 19.70% of nC_8 to 18.51% of nC_{12} of the oil is and the water used for cooling the exist stream is decrease from 20.847Kg/hr of nC_8 to 20.55 Kg/hr of nC_{12} .

5.2. Recommendation:

The following recommendations are suggested:

1. Studying another process variable for absorber – stripper network, such as lean oil and wet gas feed composition, inter cooling for the absorber and by changing the process variables of the stripper and absorber such as by changing number of stages of the absorber and changing the number of stages of the stripper in the some time .
2. Modification of the computer program of absorber –stripping network by combination in the same column that is called re-boiled column.
3. Modification of the computer program for systems containing high polar components by adding the activity coefficient calculation to the VLE relations.
4. Application of the computer program to industrial systems and comparing the theoretical results obtained by the computer program with experimental results.
5. Modified the computer program by comparing the results obtained by network with multi-component distillation according to energy requirements and cost estimation.

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Appendices

- **Appendix A:** Physical and thermodynamics properties.
- **Appendix B:** Computer programs.
- **Appendix C:** Figures of the results chapter four.

Appendix A

Appendix A-I Table (1): physical properties of the component				
Component	T _b (K)	T _c (K)	P _c (K)	w
N ₂	77.4	126.2	33.9	0.039
CO ₂	194.65	304.1	73.8	0.239
C ₁	111.6	190.4	46	0.011
C ₂	184.6	305.4	48.8	0.099
C ₃	231.1	369.8	42.5	0.153
iC ₄	261.4	408.2	36.5	0.183
nC ₄	272.7	425.2	38	0.199
iC ₅	301	460.4	33.7	0.227
nC ₅	309.2	469.7	33.7	0.251
C ₆	341.9	507.5	30.1	0.299
C ₇	371.6	540.3	27.7	0.3403
C ₈	398.8	568.8	29.4	0.398
C ₁₀	447.3	617.7	21.2	0.489
C ₁₂	489.5	658.2	18.2	0.575

Appendix A-II**Table (2): Antoine constant**

component	A1	A2	A3
N ₂	5.316656	1184.797	454.5328
CO ₂	6.470323	3521.259	455.869
C ₁	5.14135	1742.638	452.974
C ₂	5.383894	2847.921	434.898
C ₃	5.353418	3371.084	414.488
iC ₄	5.611805	3870.419	409.949
nC ₄	5.741624	4126.385	409.5179
iC ₅	5.49978	4221.154	387.287
nC ₅	5.853654	4598.287	394.4148
C ₆	6.039243	5085.758	382.794
C ₇	5.98627	5278.902	359.5259
C ₈	6.4141	5947.491	360.26
C ₁₀	6.33557	6213.998	317.6512
C ₁₂	6.561135	6739.22	292.574

Appendix A-III

Table (3): Coefficient of the specific heat

component	A	B	C	D
N₂	3.11E+01	-1.36E-02	2.68E-05	-1.17E-08
CO₂	1.98E+01	7.34E-02	-5.60E-05	-1.72E-08
C₁	1.93E+01	5.21E-02	1.20E-05	-1.13E-08
C₂	5.41	1.78E-01	-6.94E-05	8.71E-09
C₃	-4.224	3.06E-01	-1.59E-04	3.22E-08
iC₄	-1.39	3.85E-01	-1.85E-04	2.90E-08
nC₄	9.487	3.31E-01	-1.11E-04	-2.82E-09
iC₅	-9.53	5.07E-01	-2.73E-04	5.72E-08
nC₅	-3.63	4.85E-01	-1.85E-04	5.31E-08
C₆	-4.41	5.82E-01	-3.12E-04	6.49E-08
C₇	-5.15	6.76E-01	-3.65E-04	7.66E-08
C₈	-6.10	7.71E-01	-4.20E-04	8.86E-08
C₁₀	-7.91	9.61E-01	-5.29E-04	1.13E-07
C₁₂	-9.33	1.149	-6.35E-04	1.36E-07

Appendix B

Computer program

1. Computer program for network system A

For absorber:

```

dc;
clear all

t111 = clock;

% @@@@ RIGOROUS METHOD
% @@@@ RIGOROUS METHOD
% *****
% THIS PROGRAMME IS USED FOR EVALUATING THE PERFORMANCE OF
% MULTICOMPONENT
% MULTISTAGE ABSORPTION PROBLEMES BY (SR) METHOD FOR
% CALCULATING
% THE TEMPERATURE, FLOW RATE & CONCENTRATION PROFILES
% THROUGHOUT THE COLUMN
% *****
% " THE NUMBER OF COMPONENTS & NUMBER OF STAGES"; NC, N
NC = 6;
N = 8;
SYf = 0;
SXo = 0;
Q = zeros(1,N);
X = zeros(NC,N);
% -----
% ##### RIGOROUS CALCULATION #####
% F = zeros(1,N);
% W = F; U = F; SWV = F; SWL = F;
%
% Ti = zeros(1,N);
% Vi = Ti; Li = Ti; A = Ti; B = Ti; C = Ti; D = Ti;
% pox = Ti; qox = Ti; TN = Ti; T = Ti; P = Ti; L = Ti; V = Ti;
%
% MAS = zeros(N,N);
% MAS1 = MAS; ENT = MAS;
%
% Yf = zeros(1,NC);
% Xo = Yf; Lco = Yf; Vfc = Yf; RECF = Yf;
%
% Vc = zeros(NC, N);
% Y = Vc; X = Vc; Z = Vc; Lc = Vc;
%===== without define C$(NC)
DT = zeros(1,N+1);
% ##### SRK FOR FEED #####

```



```

X = zeros(NC,N);
% HVYo = zeros(1,NC);
% Prf = zeros(1,NC);
% Trf = Prf; Pro = Prf; Tro = Prf; Ho = Prf;
% SSf = Prf; SSo = Prf; Sf = Prf; So = Prf; Mi = Prf; aR = Prf; bR = Prf;
% AC1 = Prf; AC2 = Prf; AC3 = Prf; AC4 = Prf; A2 = Prf; A3 = Prf; Afi = Prf; Bfi = Prf;
% Aoi = Prf; Boi = Prf; HVYo = Prf; HVXo = Prf;

% Afi = zeros(NC, NC);
% Aoi = zeros(NC, NC);
% ##### SRK FOR EACH STAGE #####
Kij = zeros(NC,NC);
% AX = zeros(1,N);
% AY = AX; BX = AX; BY = AX;
% ZL = AX; ZV = AX; FV = AX; FL = AX; ZV1 = AX; ZL1 = AX;
% HVVo = AX; HVLo = AX; HV = AX; HL = AX; HVT = AX; HLT = AX;
% VV = AX; VVY = AX; VYV = AX; LL = AX; XLX = AX; LXL = AX;
% PC = AX; TC = AX; ww = AX; SY = AX; SX = AX;
%
% Ai = zeros(NC, N);
% Bi = Ai; S = Ai; Hoi = Ai;
% HVo = Ai; OL = Ai; OV = Ai; Ke = Ai; SS = Ai;
% YY = Ai; YYY = Ai; XX = Ai; XXX = Ai; Pr = Ai; Tr = Ai;
% ##### DERIVATIVES #####
% DAi = zeros(NC, N);
% DBi = DAi; DBX = DAi; DBY = DAi; DAX = DAi; DAY = DAi; DHoi = DAi;
% DHVo = DAi; DSS = DAi; DS = DAi;
%
% Kij = zeros(NC,NC);
%
% DZV = zeros(1,N);
% DZL = DZV; DJJX = DZV; DJJY = DZV;
% DHVVo = DZV; DHVLo = DZV; HLDT = DZV; HVDT = DZV;
% DYVY = DZV; DXLX = DZV; DSY = DZV; DSX = DZV;
% -----
% THE STE OF READING MAX. ERROR(ER) ,MAX. NUMBER OF ITRATION;[Num]
ER = 1e-3*N;
Num = 30;
% -----
R = 8.314;
Tref = 0;
Rb = 4.6173;
% -----
% THE STE OF READING THE TEMRETAURE, FLOWRATES OF FEEDS
% [Vf,Lo,Tf,T0] & THE RESSUR OF THE COLUMN,[]
% -----
Vf = 450*(454/3600);
Lo1 = 250*(454/3600);
Lo2 = 164*(454/3600);
Tf = (90-32)/1.8 + 273.15;
T0 = (80-32)/1.8 + 273.15;
p = (101325/14.7)*400;
Q(7) = 150000*(1055/3600);

```

```

% -----
% STEP OF READING THE WET GAS COMPONENTS
% -----
NC = 6;
C_S = strcat('C1', 'C2', 'C3', 'nC4', 'nC5','oil');
fprintf('\n');
for I = 1:NC,

    fprintf('%s',C_S(I,:));
end;

for J = 1 : N,

    SWL(J) = 0;    SWV(J) = 0;

    if (J == 1)
        SWL(J) = 1;    SWV(J) = 0;
        elseif (J==4)
            SWL(J) = 1;    SWV(J) = 0;

    end;

    if (J == N)
        SWL(J) = 0;    SWV(J) = 1;
    end;
end;

% -----
% STEP OF READING Fj,Wj,Uj
% -----
% ===== Page No. 1 =====
for I = 1 : N,
    F(I) = 0; W(I) = 0; U(I) = 0;
    if (I == 1)
        F(I) = Lo1; W(I) = 0; U(I) = 0;
    end;
    if(I==4)
        F(I)=Lo2;W(I)=0;U(I)=0;
    end;
    if (I == N)
        F(I) = Vf; W(I) = 0; U(I) = 0;
    end;
end;

% "-----"
% STEP OF READING THE COMP.FEED FLOWRATE ;(Vfc,Lco)
fprintf('\n-----');

Lco1 = [0,0,0,0,0,250];
Lco2=[13,3,4,4,5,135]
Vfc = [360,40,25,15,10,0];

Lco1(6) = Lco1(6) * (454 / 3600);

```

```

for I = 1 : NC
    Lco2(I)=Lco2(I)*(454/3600);
    Vfc(I) = Vfc(I) * (454 / 3600);
end;
% -----
% STEP FOR READING CRITICAL PROPERTIES
% -----
TC = [190.4 ,305.4 ,369.8 ,425.2 ,469.7 ,658.2 ];
PC = [4600000,4880000,4250000,3800000,3370000,1820000];
ww = [.011,0.099 ,0.153 ,.199 ,.251 ,0.575 ];

% -----
% STEP FOR READING INTERACTION COEFFICIENTS
% -----

% 'FOR I = 1 TO 2
% 'FOR J = 1 TO NC
% 'IF I = J THEN Kij(I, J) = 0: GOTO 7
% 'READ Kij(I, J)
% '7 REM
% 'PRINT "Kij("; I; ","; J; ")="; Kij(I, J)
% 'NEXT J, I
% 'DATA -.025,.02,.06,.08,.08,.08,.08,.08,.08,.08
% 'DATA -.025,.12,.15,.15,.15,.15,.15,.15,.15,.15
AC1 = [ 1.925e+1, 5.409, -4.224, 9.487, -3.626, -9.328 ];
AC2 = [ 5.213E-2 ,1.781E-1 ,3.063E-1 ,3.313E-1 ,4.873E-1 ,1.149];

AC3 = [ 1.197E-5 ,-6.938E-5 ,-1.586E-4 ,-1.108E-4 ,-1.846E-4 ,-6.347E-4];

AC4 = [ -1.132E-8 ,8.713E-9 ,3.215E-8 ,-2.822E-9 ,5.305E-8 ,1.359E-7];
% =====
% READING THE ANTIONE CONSTANTS
% =====
A1 = [5.14135,5.383894,5.353418,5.741624,5.853654,6.561135];
A2 = [1742.638,2847.921,3371.084,4126.385,4598.287,6739.22];
A3=[452.974,434.898,414.488,409.5179,394.4148,292.574]

% -----
% CALCULATION OF FEED'S CONCENTRATION (Xo1,Xo2,Yf)
% -----
for I = 1 : NC,
    Xo1(I) = Lco1(I)/Lo1;
    Xo2(I)=Lco2(I)/Lo2;
    Yf(I) = Vfc(I) / Vf;
end;

% -----
% THE STEP OF READING THE CONCENTRATION OF FEEDS;[Zi,j]
% -----
for I = 1 : NC,
for J = 1 : N,
    Z(I, J) = 0;

```

```

if J == 1
    Z(I, J) = Xo1(I);
end;
if J==4
    Z(I,J)=Xo2(I);
end;

if J == N
    Z(I, J) = Yf(I);
end;

end;
end;
% -----
% END OF READING
% *****
% -----
% THE STEP OF CALCULATION THE ENTHALPIES OF FEEDS (HFi)
% -----
% % % % % GOSUB 250
step_250S1
% REM -----
% REM STEP OF INITIAL ASSUMTION OF VAPOR,LIQUID AND TEMPETAURE
PROFILES
% REM (Vj,Lj,Tj)
% REM -----
% REM INTTIAL TERMINAL OF TEMP.& FLOW RATES FROM SHORT- CUT
METHOD IS:-
% REM -----
Ti(1) = T0;
Ti(N) = Tf;
for I = 1 : N,
    P(I) = p;
    Vi(I) = Vf;
    if (I ~= 1) && (I ~= N)
        DT1 = (Ti(N) - Ti(1)) / (N - 1);
        Ti(I) = DT1 + Ti(I - 1);
    end;
end;

end;

for I = 1 : N,
    V(I) = Vi(I);
    T(I) = Ti(I);
end;

for Kf = 1 : N,
for If = 1 : NC,
    X(If, Kf) = Xo2(If);
    Y(If, Kf) = Yf(If);
end;
end;

```

IT = 1;

```
%=====
%=====
step_15S1
%=====
%=====

% 15 REM %%%%%%%%%% BEGINING OF ITREATION PROCEDURE
%%%%%%%%%
% % REM -----
% fprintf('ITREATION NUMBER = %f',IT);
%
fprintf('=====
=====');
% fprintf('STAGE \t TEMP.\t V');
%
fprintf('_____
');
);
%
% for J = 1 : N,
% fprintf('%f\t %f\t %f\t',J,T(J),V(J));
% end;
% % -----
% % CALCULATION OF K-VALUES & ENTHALPIES FOR EACH STAGE
% % -----
% GOSUB 260
% % -----
% % CALCULATION OF CONCENTRATION PROFILES (Xi,j)
% % -----
% GOSUB 270
% % 'PRINT "-----"
% % 'PRINT " THE CONCENTRATION PROFILES of ALL COPONENTS; X(i,j)"
% % 'PRINT "-----"
% % 'FOR K = 1 TO N: PRINT SPC(8); K; : NEXT K: PRINT
% % 'PRINT "-----"
% % 'FOR I = 1 TO NC: PRINT ; C$(I); SPC(5);
% % 'FOR J = 1 TO N
% % 'PRINT USING "#.####"; X(I, J); SPC(5);
% % 'NEXT J: PRINT : NEXT I
% % 'PRINT " ----- NORMALIZATION STEP----- "
% for J = 1 : N,
%   S1 = 0;
%   for I = 1 : NC,
%     S1 = S1 + X(I, J);
%   end;
%   SUMX(J) = S1;
%   fprintf('SUMX(%g)= %f',J,SUMX(J));
% end;
% % 'INPUT FG
```

```

% % 'PRINT "THE CONCENTRATION PROFILES OF ALL COMP. AFTER
NORMALIZATION X(i, j)"
% % 'PRINT "-----"
% % 'FOR K = 1 TO N: PRINT SPC(8); K; : NEXT K: PRINT
% % 'PRINT "-----"
% for I = 1 : NC;
%   %'PRINT C$(I); SPC(5);
%   for J = 1 : N,
%     X(I, J) = X(I, J) / SUMX(J);
%     %'PRINT USING "#.#####"; X(I, J); SPC(5);
%   end;
%   %'PRINT
% end;
% % 'PRINT "-----"
% % 'PRINT "THE VAPOR MOLE FRACTION BEFOR NORMALIZATION IS Y(i,j) "
% % 'PRINT "-----"
% % 'FOR K = 1 TO N: PRINT SPC(8); K; : NEXT K
% % 'PRINT "-----"
% for I = 1 : NC,
%   %'PRINT C$(I); SPC(5);
%   for J = 1 : N,
%     Y(I, J) = Ke(I, J) * X(I, J);
%     % 'PRINT USING "#.#####"; Y(I, J); SPC(5);
%   end;
%   %'PRINT
% end;
%
% for J = 1 : N,
%   S1 = 0;
%   for I = 1 : NC,
%     S1 = S1 + Y(I, J);
%   end;
%   SUMY(J) = S1;
%   fprintf('SUMY = %f', SUMY(J));
% end;
% % 'PRINT "-----"
% % 'PRINT "THE Y(i,j) AFTER NORMALIZATION IS :-"
% % 'PRINT "-----"
% % 'FOR K = 1 TO N: PRINT SPC(9); K; : NEXT K
% % 'PRINT "-----"
% for I = 1 : NC,
%   %'PRINT C$(I); SPC(5);
%   for J = 1 : N,
%     Y(I, J) = Y(I, J) / SUMY(J);
%     %'PRINT USING "#.#####"; Y(I, J); SPC(5);
%   end;
%   %'PRINT
% end;
% % -----
% % THE END OF NORMALIZATION STEP
% % *****
% % ESTIMATING LIQUID FLOWRATE
% % -----

```

```

% for J = 1 : N,
%   S = 0;
%   for M = 1 : J,
%     S = S + F(M) - U(M) - W(M);
%   end;
%   if J == N
%     L(J) = S - V(1);
%   else
%     L(J) = V(J + 1) + S - V(1);
%   end;
% end;
%
% for I = 1 : N
%   fprintf('L= %g',L(I));
% end;
% % -----
% % ESTIMATION OF THE NEW LIQUID FLOW RATES BY THE SUM-RATE
RELATION
% % -----
% for J = 1 : N,
%   L(J) = L(J) * SUMX(J);
% end;
% fprintf('-----');
% % ----- THE NEW VAPOR FLOW RATE-----
% for J = 1 : N,
%   S = 0;
%   for M = J : N,
%     S = S + F(M) - W(M) - U(M);
%   end;
%   V(J) = L(J - 1) - L(N) + S
%   if J == 1
%     V(J) = -L(N) + S;
%   end;
% end;
%
%
% fprintf(' THE NEW LIQ.AND VAP. FLOW RATE');
% fprintf('-----');
% fprintf('Vi= \tV= \tL=');
% fprintf('-----');
% for J = 1 : N,
%   fprintf('%f\t%f\t%f',Vi(J), V(J), L(J));
% end;
% % -----
% % -----BEGAIN OF ENARGY BALANCE-----
% % THE STEP OF CALCULATION OF THE COEFFICIENTES OF TRIDIAGONAL
MATRIX
% % THIS MATRIX AISO KNOWN AS JACOBIAN MATRIX
% % THIS STEP CONTIANS THE SOLUTION OF THIS MATRIX BY
% % GSUSS METHOD FOR OBTAINING THE NEW TEMPERATURE PROFILES(Tj)
% % -----
% fprintf('-----');
% fprintf(' BEGAIN OF ENARGY BALANCE');

```

```

% fprintf('-----');
%
% GOSUB 280
%
% % -----
% % CALCULATION OF NEW TEMPERATURE (TNj)
% % -----
% for J = 1 : N,
%   TN(J) = T(J) + DT(J);
%   fprintf('STAGE = %f \t T NEW = %f',J,TN(J));
% end;
% % -----
% % CONVERGENCE CHECK STEPS
% % -----
%   RR = 0;
%   S2 = 0;
%   S3 = 0;
%   for J = 1 : N,
%     RR = RR + (TN(J) - T(J)) ^ 2;
%   end;

while ((RR > ER) && (IT < 500 ))
  fprintf('\n ERROR = %f \t ITRATION NUMBER = %f ',RR,IT);
  % 'INPUT RFD
  fprintf('\n*****');
  fprintf('\nTHE ITRATION MUST BE RETURNED');
  fprintf('\n*****');
  IT = IT + 1;
  for J = 1 : N,
    T(J) = TN(J);
  end;
  step_15S1

end;
% % % % % GOSUB 290
% -----
% fprintf('\n DIVERGEN ACCUR ');
% fprintf('\n -----');
% -----
% THE CONVEGENCE ACCURE
% -----
% step_290S1

% %===== ((1))=====
% plot(Z,Y(:,1),'-bs','LineWidth',1,...
%       'MarkerEdgeColor','k',...
%       'MarkerFaceColor','r',...
%       'MarkerSize',3)

```



```

% W = F; U = F; SWV = F; SWL = F;
%
% Ti = zeros(1,N);
% Vi = Ti; Li = Ti; A = Ti; B = Ti; C = Ti; D = Ti;
% pox= Ti; qox = Ti; TN = Ti; T = Ti; P = Ti; L = Ti; V = Ti;
%
% MAS = zeros(N,N);
% MAS1 = MAS; ENT = MAS;
%
% Yf = zeros(1,NC);
% Xo = Yf; Lco = Yf; Vfc = Yf; RECF = Yf;
%
% Vc = zeros(NC, N);
% Y = Vc; X = Vc; Z = Vc; Lc = Vc;
%===== without define C$(NC)
DT = zeros(1,N+1);
% ##### SRK FOR FEED #####
X= zeros(NC,N);
% HVYo = zeros(1,NC);
% Prf = zeros(1,NC);
% Trf = Prf; Pro = Prf; Tro = Prf; Ho = Prf;
% SSf = Prf; SSo = Prf; Sf = Prf; So = Prf; Mi = Prf; aR = Prf; bR = Prf;
% AC1 = Prf; AC2 = Prf; AC3 = Prf; AC4 = Prf; A2 = Prf; A3 = Prf; Afi = Prf; Bfi = Prf;
% Aoi = Prf; Boi = Prf; HVYo = Prf; HVXo = Prf;

% Afij = zeros(NC, NC);
% Aoi = zeros(NC, NC);
% ##### SRK FOR EACH STAGE #####
Kij = zeros(NC,NC);
% AX = zeros(1,N);
% AY = AX; BX = AX; BY = AX;
% ZL = AX; ZV = AX; FV = AX; FL = AX; ZV1 = AX; ZL1 = AX;
% HVVo = AX; HVLo = AX; HV = AX; HL = AX; HVT = AX; HLT = AX;
% VV = AX; VVY = AX; VVY = AX; LL = AX; XLX = AX; LXL = AX;
% PC = AX; TC = AX; ww = AX; SY = AX; SX = AX;
%
% Ai = zeros(NC, N);
% Bi = Ai; S = Ai; Hoi = Ai;
% HVo = Ai; OL = Ai; OV = Ai; Ke = Ai; SS = Ai;
% YY = Ai; YYY = Ai; XX = Ai; XXX = Ai; Pr = Ai; Tr = Ai;
% ##### DERIVATIVES #####
% DAi = zeros(NC, N);
% DBi = DAi; DBX = DAi; DBY = DAi; DAX = DAi; DAY = DAi; DHoi = DAi;
% DHVo = DAi; DSS = DAi; DS = DAi;
%
% Kij = zeros(NC,NC);
%
% DZV = zeros(1,N);
% DZL = DZV; DJJX = DZV; DJJY = DZV;
% DHVVo = DZV; DHVLo = DZV; HLDT = DZV; HVDT = DZV;
% DYVY = DZV; DXLX = DZV; DSY = DZV; DSX = DZV;
% -----
% THE STE OF READING MAX. ERROR(ER) ,MAX. NUMBER OF ITRATION;[Num]

```

```

ER = 1e-3*N;
Num = 30;
% -----
R = 8.314;
Tref = 0;
Rb = 4.6173;
% -----
% THE STE OF READING THE TEMPERATURE, FLOWRATES OF FEEDS
% [Vf,Lo,Tf,T0] & THE PRESSURE OF THE COLUMN,[]
% -----
Vf = 15;
Lo = 68.1126;
Tf = 500;
T0 = 450;
p = 101325;
% -----
% STEP OF READING THE WET GAS COMPONENTS
% -----
% NC = 7;
C_S = strcat('C1', 'C2', 'C3', 'C4', 'C5', 'oil', 'steam');
fprintf('\n');
for I = 1:NC,

    fprintf('%s', C_S(I,:));
end;

for J = 1 : N,

    SWL(J) = 0;    SWV(J) = 0;

    if (J == 1)
        SWL(J) = 1;    SWV(J) = 0;
    end;

    if (J == N)
        SWL(J) = 0;    SWV(J) = 1;
    end;
end;

% -----
% STEP OF READING Fj, Wj, Uj
% -----
% ===== Page No. 1 =====
for I = 1 : N,
    F(I) = 0; W(I) = 0; U(I) = 0;
    if (I == 1)
        F(I) = Lo; W(I) = 0; U(I) = 0;
    end;

    if (I == N)
        F(I) = Vf; W(I) = 0; U(I) = 0;
    end;
end;

```

```

% "-----"
% STEP OF READING THE COMP.FEED FLOWRATE ;(Vfc,Lco)
fprintf('\n-----');
Lco = [6.933141 , 2.758254 , 3.386262 , 2.388677 , ,0];
Vfc = [0,0,0,0,0,15];
% -----
% STEP FOR READING CRITICAL PROPERTIES
% -----
TC = [190.4 ,305.4 ,369.8 ,425.2 ,469.7 ,658.2,647.3 ];
PC = [4600000,4880000,4250000,3800000,3370000,1820000,22120000 ];
ww = [0.011,0.099 ,0.153 ,.199 ,.251 ,0.575 ,.3477 ];

% -----
% STEP FOR READING INTERACTION COEFFICIENTS
% -----

% 'FOR I = 1 TO 2
% 'FOR J = 1 TO NC
% 'IF I = J THEN Kij(I, J) = 0: GOTO 7
% 'READ Kij(I, J)
% '7 REM
% 'PRINT "Kij("; I; ","; J; ")="; Kij(I, J)
% 'NEXT J, I
% 'DATA -.025,.02,.06,.08,.08,.08,.08,.08,.08,.08
% 'DATA -.025,.12,.15,.15,.15,.15,.15,.15,.15,.15
AC1 = [ 1.925e+1, 5.409, -4.224, 9.487, -3.626, -9.328,3.224E+1];
AC2 = [ 5.213E-2 ,1.781E-1 ,3.063E-1 ,3.313E-1 ,4.873E-1 ,1.149,1.924E-3];

AC3 = [ 1.197E-5 ,-6.938E-5 ,-1.586E-4 ,-1.108E-4 ,-2.58E-4 ,-6.347E-4,1.055E-5];

AC4 = [ -1.132E-8 ,8.713E-9 ,3.215E-8 ,-2.822E-9 ,5.305E-8 ,1.359E-7,-3.596E-9];

% =====
% READING THE ANTIONE CONSTANTS
% =====
A2 = [5.14135,452.974,2847.921,5.353418,414.488,4126.385,5.853654,394.4148,6739.22,7173.79
];
A3 =
[1742.638,5.383894,434.898,3371.084,5.741624,409.5179,4598.287,6.561135,292.574,389.4747];
% -----
% CALCULATION OF FEED'S CONCENTRATION (Xo,Yf)
% -----
for I = 1 : NC,
Xo(I) = Lco(I)/Lo;
Yf(I) = Vfc(I) / Vf;
end;
% -----
% THE STEP OF READING THE CONCENTRATION OF FEEDS;[Zi,j]
% -----
for I = 1 : NC,
for J = 1 : N,

```

```

    Z(I, J) = 0;

if J == 1
    Z(I, J) = Xo(I);
end;

if J == N
    Z(I, J) = Yf(I);
end;

end;
end;
% -----
% END OF READING
% *****
% -----
% THE STEP OF CALCULATION THE ENTHALPIES OF FEEDS (HFi)
% -----
% % % % % GOSUB 250
step_250S2
% REM -----
% REM STEP OF INITIAL ASSUMTION OF VAPOR, LIQUID AND TEMPETAURE
PROFILES
% REM (Vj, Lj, Tj)
% REM -----
% REM INTITAL TERMINAL OF TEMP. & FLOW RATES FROM SHORT- CUT
METHOD IS:-
% REM -----
Ti(1) = T0;
Ti(N) = Tf;
for I = 1 : N,
    P(I) = p;
    Vi(I) = Vf;
    if (I ~= 1) && (I ~= N)
        DT1 = (Ti(N) - Ti(1)) / (N - 1);
        Ti(I) = DT1 + Ti(I - 1);
    end;
end;

end;

for I = 1 : N,
    V(I) = Vi(I);
    T(I) = Ti(I);
end;

for Kf = 1 : N,
for If = 1 : NC,
    X(If, Kf) = Xo(If);
    Y(If, Kf) = Yf(If);
end;
end;

IT = 1;

```

```

%=====
%=====
step_15S2
%=====
%=====

% 15 REM %%%%%%%%%% BEGINING OF ITREATION PROCEDURE
%%%%%%%%%
% % REM -----
% fprintf('ITREATION NUMBER = %f',IT);
%
fprintf('=====
=====');
% fprintf('STAGE \t TEMP.\t V');
%
fprintf('_____
');
);
%
% for J = 1 : N,
% fprintf('%f\t %f\t %f\t',J,T(J),V(J));
% end;
% % -----
% % CALCULATION OF K-VALUES & ENTHALPIES FOR EACH STAGE
% % -----
% GOSUB 260
% % -----
% % CALCULATION OF CONCENTRATION PROFILES (Xi,j)
% % -----
% GOSUB 270
% % 'PRINT "-----"
% % 'PRINT " THE CONCENTRATION PROFILES of ALL COPONENTS; X(i,j)"
% % 'PRINT "-----"
% % 'FOR K = 1 TO N: PRINT SPC(8); K; : NEXT K: PRINT
% % 'PRINT "-----"
% % 'FOR I = 1 TO NC: PRINT ; C$(I); SPC(5);
% % 'FOR J = 1 TO N
% % 'PRINT USING "#.####"; X(I, J); SPC(5);
% % 'NEXT J: PRINT : NEXT I
% % 'PRINT " ----- NORMALIZATION STEP-----"
% for J = 1 : N,
%   S1 = 0;
%   for I = 1 : NC,
%     S1 = S1 + X(I, J);
%   end;
%   SUMX(J) = S1;
%   fprintf('SUMX(%g)= %f',J,SUMX(J));
% end;
% % 'INPUT FG
% % 'PRINT "THE CONCENTRATION PROFILES OF ALL COMP. AFTER
NORMALIZATION X(i, j)"
% % 'PRINT "-----"

```

```

% % 'FOR K = 1 TO N: PRINT SPC(8); K; : NEXT K: PRINT
% % 'PRINT "-----"
% for I = 1 : NC;
%   %'PRINT C$(I); SPC(5);
%   for J = 1 : N,
%     X(I, J) = X(I, J) / SUMX(J);
%     %'PRINT USING "#.####"; X(I, J); SPC(5);
%   end;
%   %'PRINT
% end;
% % 'PRINT "-----"
% % 'PRINT "THE VAPOR MOLE FRACTION BEFOR NORMALIZATION IS Y(i,j) "
% % 'PRINT "-----"
% % 'FOR K = 1 TO N: PRINT SPC(8); K; : NEXT K
% % 'PRINT "-----"
% for I = 1 : NC,
%   %'PRINT C$(I); SPC(5);
%   for J = 1 : N,
%     Y(I, J) = Ke(I, J) * X(I, J);
%     %'PRINT USING "#.#####"; Y(I, J); SPC(5);
%   end;
%   %'PRINT
% end;
%
% for J = 1 : N,
%   S1 = 0;
%   for I = 1 : NC,
%     S1 = S1 + Y(I, J);
%   end;
%   SUMY(J) = S1;
%   fprintf('SUMY = %f', SUMY(J));
% end;
% % 'PRINT "-----"
% % 'PRINT "THE Y(i,j) AFTER NORMALIZATION IS :-"
% % 'PRINT "-----"
% % 'FOR K = 1 TO N: PRINT SPC(9); K; : NEXT K
% % 'PRINT "-----"
% for I = 1 : NC,
%   %'PRINT C$(I); SPC(5);
%   for J = 1 : N,
%     Y(I, J) = Y(I, J) / SUMY(J);
%     %'PRINT USING "#.####"; Y(I, J); SPC(5);
%   end;
%   %'PRINT
% end;
% % -----
% % THE END OF NORMALIZATION STEP
% % *****
% % ESTIMATING LIQUID FLOWRATE
% % -----
% for J = 1 : N,
%   S = 0;
%   for M = 1 : J,

```

```

%   S = S + F(M) - U(M) - W(M);
% end;
%   if J == N
%       L(J) = S - V(1);
%   else
%       L(J) = V(J + 1) + S - V(1);
%   end;
% end;
%
% for I = 1 : N
%   fprintf('L= %g',L(I));
% end;
% % -----
% % ESTIMATION OF THE NEW LIQUID FLOW RATES BY THE SUM-RATE
RELATION
% % -----
% for J = 1 : N,
%   L(J) = L(J) * SUMX(J);
% end;
% fprintf('-----');
% % ----- THE NEW VAPOR FLOW RATE-----
% for J = 1 : N,
%   S = 0;
%   for M = J : N,
%     S = S + F(M) - W(M) - U(M);
%   end;
%   V(J) = L(J - 1) - L(N) + S
%   if J == 1
%     V(J) = -L(N) + S;
%   end;
% end;
%
%
% fprintf(' THE NEW LIQ.AND VAP. FLOW RATE');
% fprintf('-----');
% fprintf('Vi= \tV= \tL=');
% fprintf('-----');
% for J = 1 : N,
%   fprintf('%f\t%f\t%f',Vi(J), V(J), L(J));
% end;
% % -----
% % -----BEGAIN OF ENARGY BALANCE-----
% % THE STEP OF CALCULATION OF THE COEFFICIENTES OF TRIDIAGONAL
MATRIX
% % THIS MATRIX AISO KNOWN AS JACOBIAN MATRIX
% % THIS STEP CONTIANS THE SOLUTION OF THIS MATRIX BY
% % GSUSS METHOD FOR OBTAINING THE NEW TEMPERATURE PROFILES(Tj)
% % -----
% fprintf('-----');
% fprintf(' BEGAIN OF ENARGY BALANCE');
% fprintf('-----');
%
% GOSUB 280

```



```

%
% % -----
% % CALCULATION OF NEW TEMPERATURE (TNj)
% % -----
% for J = 1 : N,
%   TN(J) = T(J) + DT(J);
%   fprintf('STAGE = %f \t T NEW = %f',J,TN(J));
% end;
% % -----
% % CONVERGENCE CHECK STEPS
% % -----
%   RR = 0;
%   S2 = 0;
%   S3 = 0;
%   for J = 1 : N,
%     RR = RR + (TN(J) - T(J)) ^ 2;
%   end;

while ((RR > ER) && (IT < 500 ))
    fprintf('\n ERROR = %f \t ITRATION NUMBER = %f ',RR,IT);
    % 'INPUT RFD
    fprintf('\n*****');
    fprintf('\nTHE ITRATION MUST BE RETURNED');
    fprintf('\n*****');
    IT = IT + 1;
    for J = 1 : N,
        T(J) = TN(J);
    end;
    step_15S2

end;
% % % % % GOSUB 290
% -----
%   fprintf('\n DIVERGEN ACCUR ');
%   fprintf('\n -----');
% -----
% THE CONVEGENCE ACCURE
% -----
%   step_290S2

% %===== ((1))=====
% plot(Z,Y(:,1),'-bs','LineWidth',1,...
%       'MarkerEdgeColor','k',...
%       'MarkerFaceColor','r',...
%       'MarkerSize',3)
% hold,
%
% plot(Z,Y(:,2*N+2),'-d','LineWidth',1,...

```

```

%      'MarkerEdgeColor','k',...
%      'MarkerFaceColor','g',...
%      'MarkerSize',5)
%
% plot(Z,Y(:,2*N+3),'-','LineWidth',1,...
%      'MarkerEdgeColor','k',...
%      'MarkerFaceColor','b',...
%      'MarkerSize',5)
%
% h = legend('j_1(z)','u(z)','\psi_o(z)',2);
%
%
% % title(['At N =',num2str(N),' , \rho = ',num2str(ro), ' , C_i = ',num2str(Cc),...
% %      ' , \psi_1_i = ',num2str(Epsai1)])
% grid on
% xlabel('z')
% ylabel('')

f_time = etime(clock,t111);
fprintf('\nThe final time is = %f second',f_time);

for I = 1:NC,
    CPi(I) = AC1(I) + (AC2(I) * TN(1)) + (AC3(I) * TN(1)*TN(1)) + (AC4(I) *TN(1)^3);
    CPw = 4180;
    TO = ((80-32)/1.8)+273.15;
    Tref = 0;
    M(I) = (Lc(I,1)*CPi(I) * (TN(1)-Tref))/(CPw*(TO-Tref));
    fprintf('\nTHE VALUE OF M = %f',M(I));
end;

```

2. Computer program of network system B

For Absorber:

```
dc;
clear all

t111 = clock;

% @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ RIGOROUS METHOD
% @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @
% *****
% THIS PROGRAMME IS USED FOR EVALUATING THE PERFORMANCE OF
% MULTICOMPONENT
% MULTISTAGE ABSORPTION PROBLEMES BY (SR) METHOD FOR
% CALCULATING
% THE TEMPERATURE, FLOW RATE & CONCENTRATION PROFILES
% THROUGHOUT THE COLUMN
% *****
% " THE NUMBER OF COMPONENTS & NUMBER OF STAGES"; NC, N
NC = 8;
N = 6;
SYf = 0;
SXo = 0;
Q = zeros(1,N);
X = zeros(NC,N);
% -----
% ##### RIGOROUS CALCULATION #####
% F = zeros(1,N);
% W = F; U = F; SWV = F; SWL = F;
%
% Ti = zeros(1,N);
% Vi = Ti; Li = Ti; A = Ti; B = Ti; C = Ti; D = Ti;
% pox = Ti; qox = Ti; TN = Ti; T = Ti; P = Ti; L = Ti; V = Ti;
%
% MAS = zeros(N,N);
% MAS1 = MAS; ENT = MAS;
%
% Yf = zeros(1,NC);
% Xo = Yf; Lco = Yf; Vfc = Yf; RECF = Yf;
%
% Vc = zeros(NC, N);
% Y = Vc; X = Vc; Z = Vc; Lc = Vc;
% ===== without define C$(NC)
DT = zeros(1,N+1);
% ##### SRK FOR FEED #####
X = zeros(NC,N);
% HVYo = zeros(1,NC);
% Prf = zeros(1,NC);
% Trf = Prf; Pro = Prf; Tro = Prf; Ho = Prf;
% SSf = Prf; SSo = Prf; Sf = Prf; So = Prf; Mi = Prf; aR = Prf; bR = Prf;
% AC1 = Prf; AC2 = Prf; AC3 = Prf; AC4 = Prf; A2 = Prf; A3 = Prf; Afi = Prf; Bfi = Prf;
```

```

% Aoi = Prf; Boi = Prf; HVYo = Prf; HVXo = Prf;

% Afij = zeros(NC, NC);
% Aoi = zeros(NC, NC);
% ##### SRK FOR EACH STAGE #####
% Kij = zeros(NC,NC);
% AX = zeros(1,N);
% AY = AX; BX = AX; BY = AX;
% ZL = AX; ZV = AX; FV = AX; FL = AX; ZV1 = AX; ZL1 = AX;
% HVVo = AX; HVLo = AX; HV = AX; HL = AX; HVT = AX; HLT = AX;
% VV = AX; VVY = AX; VVYV = AX; LL = AX; XLX = AX; LXL = AX;
% PC = AX; TC = AX; ww = AX; SY = AX; SX = AX;
%
% Ai = zeros(NC, N);
% Bi = Ai; S = Ai; Hoi = Ai;
% HVo = Ai; OL = Ai; OV = Ai; Ke = Ai; SS = Ai;
% YY = Ai; YYY = Ai; XX = Ai; XXX = Ai; Pr = Ai; Tr = Ai;
% ##### DERIVATIVES #####
% DAi = zeros(NC, N);
% DBi = DAi; DBX = DAi; DBY = DAi; DAX = DAi; DAY = DAi; DHoi = DAi;
% DHVo = DAi; DSS = DAi; DS = DAi;
%
% Kij = zeros(NC,NC);
%
% DZV = zeros(1,N);
% DZL = DZV; DJJX = DZV; DJJY = DZV;
% DHVVo = DZV; DHVLo = DZV; HLDT = DZV; HVDT = DZV;
% DYVY = DZV; DXLX = DZV; DSY = DZV; DSX = DZV;
% -----
% THE STE OF READING MAX. ERROR(ER) ,MAX. NUMBER OF ITRATION;[Num]
ER = 1e-5*N;
Num = 30;
% -----
R = 8.314;
Tref = 0;
Rb = 4.6173;
% -----
% THE STE OF READING THE TEMRETAURE, FLOWRATES OF FEEDS
% [Vf,Lo,Tf,T0] & THE RESSUR OF THE COLUMN,[]
% -----
Vf = 50.44;
Lo = 51.705;
Tf = 300;
T0 = Tf;
p = 21.068 * 101325 ;
% -----
% STEP OF READING THE WET GAS COMPONENTS
% -----
NC = 8;
C_S = strvcats('CO2', 'C1', 'C2', 'C3', 'iC4', 'nC4', 'C6', 'nC8');
fprintf('\n');
for I = 1:NC,

```

```

fprintf('%s',C_S(I,:));
end;

for J = 1 : N,

    SWL(J) = 0;    SWV(J) = 0;

    if (J == 1)
        SWL(J) = 1;    SWV(J) = 0;
    end;

    if (J == N)
        SWL(J) = 0;    SWV(J) = 1;
    end;
end;

% -----
% STEP OF READING Fj,Wj,Uj
% -----
% ===== Page No. 1 =====
for I = 1 : N,
    F(I) = 0; W(I) = 0; U(I) = 0;
    if (I == 1)
        F(I) = Lo; W(I) = 0; U(I) = 0;
    end;

    if (I == N)
        F(I) = Vf; W(I) = 0; U(I) = 0;
    end;
end;

% "-----"
% STEP OF READING THE COMP.FEED FLOWRATE ;(Vfc,Lco)
fprintf('\n-----');

Vfc = [3.077,38.890,2.320,2.875,0.706,1.362,1.210,0.0];
Lco = [.103,4.281,.848,1.236,.362,1.065,1.691,42.119];
% Lco(12) = Lco(12) * (454 / 3600);
% for I = 1 : NC
% Vfc(I) = Vfc(I) * (454 / 3600);
% end;
% -----
% STEP FOR READING CRITICAL PROPERTIES
% -----
TC = [304.1 ,190.4 ,305.4 ,369.8 ,408.2 ,425.2 ,507.5 ,568.8 ];
PC = [7380000,4600000,4880000,4250000,3650000,3800000,3010000,2900000 ];
ww = [0.239,0.011,0.099,0.153,0.183,0.199,0.299,0.398];

% -----
% STEP FOR READING INTERACTION COEFFICIENTS
% -----

% 'FOR I = 1 TO 2

```

```

% 'FOR J = 1 TO NC
% 'IF I = J THEN Kij(I, J) = 0: GOTO 7
% 'READ Kij(I, J)
% '7 REM
% 'PRINT "Kij("; I; ","; J; ")="; Kij(I, J)
% 'NEXT J, I
% 'DATA -.025,.02,.06,.08,.08,.08,.08,.08,.08
% 'DATA -.025,.12,.15,.15,.15,.15,.15,.15,.15
AC1 = [ 1.98e+1, 1.925e+1, 5.409, -4.224, -1.39, 9.487, -4.413, -6.096 ];
AC2 = [ 7.344E-2 ,5.213E-2 ,1.781E-1 ,3.063E-1 ,3.847E-1 ,3.313E-1 ,5.82E-1 ,...
7.712e-1 ];
AC3 = [-5.602E-5 ,1.197E-5 ,-6.938E-5 ,-1.586E-4 ,-1.846E-4 ,-1.108E-4 ,...
-3.119E-4 ,-4.195e-4 ];
AC4 = [ 1.715E-8 ,-1.132E-8 ,8.713E-9 ,3.215E-8 ,2.895E-8 ,-2.822E-9 ,...
6.494E-8 ,8.855e-8 ];

% =====
% READING THE ANTIONE CONSTANTS
% =====
A2 = [ 3521.259, 1742.638, 2847.921, 3371.084, 3870.419, 4126.385, 5085.758, 5947.491 ];
A3 = [ 455.869 , 452.974 , 434.898 , 414.488 , 409.949 , 409.5179, 382.794 , 360.26 ];

% -----
% CALCULATION OF FEED'S CONCENTRATION (Xo,Yf)
% -----
% Xo(8) = Lco(8) / Lo;
for I = 1 : NC,
    Xo(I) = Lco(I) / Lo;
    Yf(I) = Vfc(I) / Vf;
end;
% -----
% THE STEP OF READING THE CONCENTRATION OF FEEDS;[Zi,j]
% -----
for I = 1 : NC,
for J = 1 : N,
    Z(I, J) = 0;

    if J == 1
        Z(I, J) = Xo(I);
    end;

    if J == N
        Z(I, J) = Yf(I);
    end;

end;
end;
% -----
% END OF READING
% *****
% -----
% THE STEP OF CALCULATION THE ENTHALPIES OF FEEDS (HFi)
% -----

```

```

%%%%%%%%% GOSUB 250
step_250S1
% REM -----
% REM STEP OF INITIAL ASSUMTION OF VAPOR,LIQUID AND TEMPETAURE
PROFILES
% REM          (Vj,Lj,Tj)
% REM -----
% REM INTITIAL TERMINAL OF TEMP.& FLOW RATES FROM SHORT- CUT
METHOD IS:-
% REM -----
  Ti(1) = T0;
  Ti(N) = Tf;
for I = 1 : N,
  P(I) = p;
  Vi(I) = Vf;
  if (I ~= 1) && (I ~= N)
    DT1 = (Ti(N) - Ti(1)) / (N - 1);
    Ti(I) = DT1 + Ti(I - 1);
  end;

end;

for I = 1 : N,
  V(I) = Vi(I);
  T(I) = Ti(I);
end;

for Kf = 1 : N,
for If = 1 : NC,
  X(If, Kf) = Xo(If);
  Y(If, Kf) = Yf(If);
end;
end;

IT = 1;

%=====
%=====
step_15S1
%=====
%=====

% 15 REM %%%%%%%%%% BEGINING OF ITREATION PROCEDURE
%%%%%%%%%
% % REM -----
% fprintf('ITREATION NUMBER = %f',IT);
%
fprintf('=====
=====');
% fprintf('STAGE \t TEMP.\t V');

```

```

%
fprintf('_____
');
%
% for J = 1 : N,
% fprintf('%f\t %f\t %f\t',J,T(J),V(J));
% end;
% % -----
% % CALCULATION OF K-VALUES & ENTHALPIES FOR EACH STAGE
% % -----
% GOSUB 260
% % -----
% % CALCULATION OF CONCENTRATION PROFILES (Xi,j)
% % -----
% GOSUB 270
% % 'PRINT "-----"
% % 'PRINT " THE CONCENTRATION PROFILES of ALL COPONENTS; X(i,j)"
% % 'PRINT "-----"
% % 'FOR K = 1 TO N: PRINT SPC(8); K; : NEXT K: PRINT
% % 'PRINT "-----"
% % 'FOR I = 1 TO NC: PRINT ; C$(I); SPC(5);
% % 'FOR J = 1 TO N
% % 'PRINT USING "#.####"; X(I, J); SPC(5);
% % 'NEXT J: PRINT : NEXT I
% % 'PRINT "-----NORMALIZATION STEP-----"
% for J = 1 : N,
%   S1 = 0;
%   for I = 1 : NC,
%     S1 = S1 + X(I, J);
%   end;
%   SUMX(J) = S1;
%   fprintf('SUMX(%g)= %f',J,SUMX(J));
% end;
% % 'INPUT FG
% % 'PRINT "THE CONCENTRATION PROFILES OF ALL COMP. AFTER
NORMALIZATION X(i, j)"
% % 'PRINT "-----"
% % 'FOR K = 1 TO N: PRINT SPC(8); K; : NEXT K: PRINT
% % 'PRINT "-----"
% for I = 1 : NC;
%   %'PRINT C$(I); SPC(5);
%   for J = 1 : N,
%     X(I, J) = X(I, J) / SUMX(J);
%     %'PRINT USING "#.####"; X(I, J); SPC(5);
%   end;
%   %'PRINT
% end;
% % 'PRINT "-----"
% % 'PRINT "THE VAPOR MOLE FRACTION BEFOR NORMALIZATION IS Y(i,j) "
% % 'PRINT "-----"
% % 'FOR K = 1 TO N: PRINT SPC(8); K; : NEXT K
% % 'PRINT "-----"
% for I = 1 : NC,

```



```

%    %'PRINT C$(I); SPC(5);
%    for J = 1 : N,
%        Y(I, J) = Ke(I, J) * X(I, J);
%        % 'PRINT USING "#.#####"; Y(I, J); SPC(5);
%    end;
%    %'PRINT
%end;
%
%    for J = 1 : N,
%        S1 = 0;
%        for I = 1 : NC,
%            S1 = S1 + Y(I, J);
%        end;
%        SUMY(J) = S1;
%        fprintf('SUMY = %f', SUMY(J));
%    end;
%    % 'PRINT "-----"
%    % 'PRINT "THE Y(i,j) AFTER NORMALIZATION IS :-"
%    % 'PRINT "-----"
%    % 'FOR K = 1 TO N: PRINT SPC(9); K; : NEXT K
%    % 'PRINT "-----"
%    for I = 1 : NC,
%        %'PRINT C$(I); SPC(5);
%        for J = 1 : N,
%            Y(I, J) = Y(I, J) / SUMY(J);
%            % 'PRINT USING "#.#####"; Y(I, J); SPC(5);
%        end;
%        %'PRINT
%    end;
%    % -----
%    % THE END OF NORMALIZATION STEP
%    % *****
%    % ESTIMATING LIQUID FLOWRATE
%    % -----
%    for J = 1 : N,
%        S = 0;
%        for M = 1 : J,
%            S = S + F(M) - U(M) - W(M);
%        end;
%        if J == N
%            L(J) = S - V(1);
%        else
%            L(J) = V(J + 1) + S - V(1);
%        end;
%    end;
%
%    for I = 1 : N
%        fprintf('L= %g', L(I));
%    end;
%    % -----
%    % ESTIMATION OF THE NEW LIQUID FLOW RATES BY THE SUM-RATE
%    % RELATION
%    % -----

```

```

% for J = 1 : N,
%   L(J) = L(J) * SUMX(J);
% end;
% fprintf('-----');
% % ----- THE NEW VAPOR FLOW RATE -----
% for J = 1 : N,
%   S = 0;
%   for M = J : N,
%     S = S + F(M) - W(M) - U(M);
%   end;
%   V(J) = L(J - 1) - L(N) + S
%   if J == 1
%     V(J) = -L(N) + S;
%   end;
% end;
%
%
% fprintf(' THE NEW LIQ.AND VAP. FLOW RATE');
% fprintf('-----');
% fprintf('Vi= \tV= \tL=');
% fprintf('-----');
% for J = 1 : N,
%   fprintf('%f \t %f \t %f',Vi(J), V(J), L(J));
% end;
% % -----
% % ----- BEGAIN OF ENARGY BALANCE -----
% % THE STEP OF CALCULATION OF THE COEFFICIENTES OF TRIDIAGONAL
% % MATRIX
% % THIS MATRIX ALSO KNOWN AS JACOBIAN MATRIX
% % THIS STEP CONTIANS THE SOLUTION OF THIS MATRIX BY
% % GSUSS METHOD FOR OBTAINING THE NEW TEMPERATURE PROFILES(Tj)
% % -----
% fprintf('-----');
% fprintf(' BEGAIN OF ENARGY BALANCE');
% fprintf('-----');
%
% GOSUB 280
%
% % -----
% % CALCULATION OF NEW TEMPERATURE (TNj)
% % -----
% for J = 1 : N,
%   TN(J) = T(J) + DT(J);
%   fprintf('STAGE = %f \t T NEW = %f',J,TN(J));
% end;
% % -----
% % CONVERGENCE CHECK STEPS
% % -----
%   RR = 0;
%   S2 = 0;
%   S3 = 0;
%   for J = 1 : N,
%     RR = RR + (TN(J) - T(J)) ^ 2;

```

```

% end;

while ((RR > ER) && (IT < 500 ))
    fprintf('\n ERROR = %f\t ITRATION NUMBER = %f ',RR,IT);
    % 'INPUT RFD
    fprintf('\n*****');
    fprintf('\nTHE ITRATION MUST BE RETURNED');
    fprintf('\n*****');
    IT = IT + 1;
    for J = 1 : N,
        T(J) = TN(J);
    end;
    step_15S1

end;
%%%%%% GOSUB 290
% -----
fprintf('\n DIVERGEN ACCUR ');
fprintf('\n -----');
% -----
% THE CONVEGENCE ACCURE
% -----
step_290S 1

% %===== ((1))=====
% plot(Z,Y(:,1),'-bs','LineWidth',1,...
%         'MarkerEdgeColor','k',...
%         'MarkerFaceColor','r',...
%         'MarkerSize',3)
% hold,
%
% plot(Z,Y(:,2*N+2),'-d','LineWidth',1,...
%         'MarkerEdgeColor','k',...
%         'MarkerFaceColor','g',...
%         'MarkerSize',5)
%
% plot(Z,Y(:,2*N+3),'-*','LineWidth',1,...
%         'MarkerEdgeColor','k',...
%         'MarkerFaceColor','b',...
%         'MarkerSize',5)
%
% h = legend('j_1(z)','u(z)','\psi_o(z)',2);
%
%
% % title(['At N =',num2str(N),' , \rho = ',num2str(ro), ' , C_i = ',num2str(Cc),...
% %         ' , \psi_1_i = ',num2str(Epsai1)])
% grid on
% xlabel('z')

```

```
f_time = etime(clock,t111);
fprintf('\nThe final time is = %f second',f_time);
RFS = input('\nRFS = ');
RIGOROUS_METHOD_final
```

```
clc;
clear all
```

```
% @@@@ RIGOROUS METHOD
@@@@@
% *****
% THIS PROGRAMME IS USED FOR EVALUATING THE PERFORMANCE OF
MULTICOMPONENT
% MULTISTAGE ABSORPTION PROBLEMES BY (SR) METHOD FOR
CALCULATING
% THE TEMPERATURE,FLOW RATE & CONCENTRATION PROFILES
THROUGHOUT THE COLUMN
% *****
% " THE NUMBER OF COMPONENTS & NUMBER OF STAGES"; NC,N
NC = 9;
N = 8;
SYf = 0;
SXo = 0;
Q = zeros(1,N);
X= zeros(NC,N);
% -----
% ##### RIGOROUS CALCULATION #####
% F = zeros(1,N);
% W = F; U = F; SWV = F; SWL = F;
%
% Ti = zeros(1,N);
% Vi = Ti; Li = Ti; A = Ti; B = Ti; C = Ti; D = Ti;
% pox= Ti; qox = Ti; TN = Ti; T = Ti; P = Ti; L = Ti; V = Ti;
%
% MAS = zeros(N,N);
% MAS1 = MAS; ENT = MAS;
%
% Yf = zeros(1,NC);
% Xo = Yf; Lco = Yf; Vfc = Yf; RECF = Yf;
%
% Vc = zeros(NC, N);
% Y = Vc; X = Vc; Z = Vc; Lc = Vc;
%===== without define C$(NC)
DT = zeros(1,N+1);
% ##### SRK FOR FEED #####
X= zeros(NC,N);
% HVYo = zeros(1,NC);
```

```

% Prf = zeros(1,NC);
% Trf = Prf; Pro = Prf; Tro = Prf; Ho = Prf;
% SSf = Prf; SSo = Prf; Sf = Prf; So = Prf; Mi = Prf; aR = Prf; bR = Prf;
% AC1 = Prf; AC2 = Prf; AC3 = Prf; AC4 = Prf; A2 = Prf; A3 = Prf; Afi = Prf; Bfi = Prf;
% Aoi = Prf; Boi = Prf; HVYo = Prf; HVXo = Prf;

% Afi = zeros(NC, NC);
% Aoi = zeros(NC, NC);
% ##### SRK FOR EACH STAGE #####
  Kij = zeros(NC,NC);
% AX = zeros(1,N);
% AY = AX; BX = AX; BY = AX;
% ZL = AX; ZV = AX; FV = AX; FL = AX; ZV1 = AX; ZL1 = AX;
% HVVo = AX; HVLo = AX; HV = AX; HL = AX; HVT = AX; HLT = AX;
% VV = AX; VVY = AX; VYV = AX; LL = AX; XLX = AX; LXL = AX;
% PC = AX; TC = AX; ww = AX; SY = AX; SX = AX;
%
% Ai = zeros(NC, N);
% Bi = Ai; S = Ai; Hoi = Ai;
% HVo = Ai; OL = Ai; OV = Ai; Ke = Ai; SS = Ai;
% YY = Ai; YYY = Ai; XX = Ai; XXX = Ai; Pr = Ai; Tr = Ai;
% ##### DERIVATIVES #####
% DAi = zeros(NC, N);
% DBi = DAi; DBX = DAi; DBY = DAi; DAX = DAi; DAY = DAi; DHoi = DAi;
% DHVo = DAi; DSS = DAi; DS = DAi;
%
% Kij = zeros(NC,NC);
%
% DZV = zeros(1,N);
% DZL = DZV; DJJX = DZV; DJJY = DZV;
% DHVVo = DZV; DHVLo = DZV; HLDT = DZV; HVDT = DZV;
% DYVY = DZV; DXLX = DZV; DSY = DZV; DSX = DZV;
% -----
% THE STE OF READING MAX. ERROR(ER) ,MAX. NUMBER OF ITRATION;[Num]
ER = 1e-3*N;
Num = 30;
% -----
R    = 8.314;
Tref = 0;
Rb   = 4.6173;
% -----
% THE STE OF READING THE TEMRETAURE, FLOWRATES OF FEEDS
% [Vf,Lo,Tf,T0] & THE RESSUR OF THE COLUMN,[]
% -----
Vf = 7;
Lo = 59.040069;
Tf = 500;
T0 = 450;
p = 101325;
% -----
% STEP OF READING THE WET GAS COMPONENTS
% -----
% NC = 9;

```

```

C_S = strcat( 'CO2', 'C1', 'C2', 'C3', 'iC4', 'nC4', 'C6','oil','steam');
fprintf('\n');
for I = 1:NC,

    fprintf('%s',C_S(I,:));
end;

for J = 1 : N,

    SWL(J) = 0;    SWV(J) = 0;

    if (J == 1)
        SWL(J) = 1;    SWV(J) = 0;
    end;

    if (J == N)
        SWL(J) = 0;    SWV(J) = 1;
    end;
end;

% -----
% STEP OF READING Fj,Wj,Uj
% -----
% ===== Page No. 1 =====
for I = 1 : N,
    F(I) = 0; W(I) = 0; U(I) = 0;
    if (I == 1)
        F(I) = Lo; W(I) = 0; U(I) = 0;
    end;

    if (I == N)
        F(I) = Vf; W(I) = 0; U(I) = 0;
    end;
end;

% "-----"
% STEP OF READING THE COMP.FEED FLOWRATE ;(Vfc,Lco)
fprintf('\n-----');
Lco = [1.391787,4.652606,1.350957,3.48512,0.991904,2.270170,2.873086,42.025047,0];
Vfc = [0,0,0,0,0,0,0,7];

% -----
% STEP FOR READING CRITICAL PROPERTIES
% -----
TC = [304.1 ,190.4 ,305.4 ,369.8 ,408.2 ,425.2 ,507.5 ,658.2,647.3  ];
PC = [7380000,4600000,4880000,4250000,3650000,3800000,3010000,1820000,22120000 ];
ww = [0.177,0,0.1064,0.1538,0.1825,0.1954,0.2972,0.575 ,.3477  ];

% -----
% STEP FOR READING INTERACTION COEFFICIENTS

```

```

% -----

% 'FOR I = 1 TO 2
% 'FOR J = 1 TO NC
% 'IF I = J THEN Kij(I, J) = 0: GOTO 7
% 'READ Kij(I, J)
% '7 REM
% 'PRINT "Kij("; I; ", "; J; ")="; Kij(I, J)
% 'NEXT J, I
% 'DATA -.025,.02,.06,.08,.08,.08,.08,.08,.08,.08
% 'DATA -.025,.12,.15,.15,.15,.15,.15,.15,.15,.15
AC1 = [ 1.98e+1, 1.925e+1, 5.409, -4.224, -1.39, 9.487, -4.413, -9.328, 3.224E+1];
AC2 = [ 7.344E-2 ,5.213E-2 ,1.781E-1 ,3.063E-1 ,3.847E-1 ,3.313E-1 ,5.82E-1 ,...
1.149 ,1.924E-3];

AC3 = [ -5.602E-5 ,1.197E-5 ,-6.938E-5 ,-1.586E-4 ,-1.846E-4 ,-1.108E-4 ,...
-3.119E-4 ,-6.347E-4,1.055E-5];

AC4 = [ 1.715E-8 ,-1.132E-8 ,8.713E-9 ,3.215E-8 ,2.895E-8 ,-2.822E-9 ,...
6.494E-8 ,1.359E-7 ,-3.596E-9];

% =====
% READING THE ANTIONE CONSTANTS
% =====
A2 = [ 3521.259, 1742.638, 2847.921, 3371.084, 3870.419, 4126.385, 5085.758, 6739.22,7173.79
];
A3 = [ 455.869 , 452.974 , 434.898 , 414.488 , 409.949 , 409.5179, 382.794 , 292.574,389.4747];
% -----
% CALCULATION OF FEED'S CONCENTRATION (Xo,Yf)
% -----
for I = 1 : NC,
Xo(I) = Lco(I)/Lo;
Yf(I) = Vfc(I) / Vf;
end;
% -----
% THE STEP OF READING THE CONCENTRATION OF FEEDS;[Zi,j]
% -----
for I = 1 : NC,
for J = 1 : N,
Z(I, J) = 0;

if J == 1
Z(I, J) = Xo(I);
end;

if J == N
Z(I, J) = Yf(I);
end;

end;
end;
% -----

```

```

% END OF READING
% *****
% -----
% THE STEP OF CALCULATION THE ENTHALPIES OF FEEDS (HFi)
% -----
% % % % % GOSUB 250
step_250
% REM -----
% REM STEP OF INITIAL ASSUMTION OF VAPOR, LIQUID AND TEMPETAURE
PROFILES
% REM (Vj,Lj,Tj)
% REM -----
% REM INTITAL TERMINAL OF TEMP.& FLOW RATES FROM SHORT- CUT
METHOD IS:-
% REM -----
Ti(1) = T0;
Ti(N) = Tf;
for I = 1 : N,
P(I) = p;
Vi(I) = Vf;
if (I ~= 1) && (I ~= N)
DT1 = (Ti(N) - Ti(1)) / (N - 1);
Ti(I) = DT1 + Ti(I - 1);
end;

end;

for I = 1 : N,
V(I) = Vi(I);
T(I) = Ti(I);
end;

for Kf = 1 : N,
for If = 1 : NC,
X(If, Kf) = Xo(If);
Y(If, Kf) = Yf(If);
end;
end;

IT = 1;

%=====
%=====
step_15
%=====
%=====

% 15 REM % % % % % % % % % % % % % % BEGINING OF ITREATION PROCEDURE
% % % % % % % % % % % % % %
% % REM -----
% fprintf('ITREATION NUMBER = %f',IT);

```



```

%
fprintf('=====')
=====);
% fprintf('STAGE \t TEMP.\t V');
%
fprintf('_____')
);
%
% for J = 1 : N,
% fprintf('%f\t %f\t %f\t',J,T(J),V(J));
% end;
% % -----
% % CALCULATION OF K-VALUES & ENTHALPIES FOR EACH STAGE
% % -----
% GOSUB 260
% % -----
% % CALCULATION OF CONCENTRATION PROFILES (Xi,j)
% % -----
% GOSUB 270
% % 'PRINT "-----"
% % 'PRINT " THE CONCENTRATION PROFILES of ALL COPONENTS; X(i,j)"
% % 'PRINT "-----"
% % 'FOR K = 1 TO N: PRINT SPC(8); K; : NEXT K: PRINT
% % 'PRINT "-----"
% % 'FOR I = 1 TO NC: PRINT ; C$(I); SPC(5);
% % 'FOR J = 1 TO N
% % 'PRINT USING "#.####"; X(I, J); SPC(5);
% % 'NEXT J: PRINT : NEXT I
% % 'PRINT "-----NORMALIZATION STEP-----"
% for J = 1 : N,
%   S1 = 0;
%   for I = 1 : NC,
%     S1 = S1 + X(I, J);
%   end;
%   SUMX(J) = S1;
%   fprintf('SUMX(%g)= %f',J,SUMX(J));
% end;
% % 'INPUT FG
% % 'PRINT "THE CONCENTRATION PROFILES OF ALL COMP. AFTER
NORMALIZATION X(i, j)"
% % 'PRINT "-----"
% % 'FOR K = 1 TO N: PRINT SPC(8); K; : NEXT K: PRINT
% % 'PRINT "-----"
% for I = 1 : NC;
%   %'PRINT C$(I); SPC(5);
%   for J = 1 : N,
%     X(I, J) = X(I, J) / SUMX(J);
%     %'PRINT USING "#.####"; X(I, J); SPC(5);
%   end;
%   %'PRINT
% end;
% % 'PRINT "-----"
% % 'PRINT "THE VAPOR MOLE FRACTION BEFOR NORMALIZATION IS Y(i,j) "

```

```

% % 'PRINT "-----"
% % 'FOR K = 1 TO N: PRINT SPC(8); K; : NEXT K
% % 'PRINT "-----"
% for I = 1 : NC,
%   %'PRINT C$(I); SPC(5);
%   for J = 1 : N,
%     Y(I, J) = Ke(I, J) * X(I, J);
%     % 'PRINT USING "#.#####"; Y(I, J); SPC(5);
%   end;
%   %'PRINT
% end;
%
% for J = 1 : N,
%   S1 = 0;
%   for I = 1 : NC,
%     S1 = S1 + Y(I, J);
%   end;
%   SUMY(J) = S1;
%   fprintf('SUMY = %f', SUMY(J));
% end;
% % 'PRINT "-----"
% % 'PRINT "THE Y(i,j) AFTER NORMALIZATION IS :-"
% % 'PRINT "-----"
% % 'FOR K = 1 TO N: PRINT SPC(9); K; : NEXT K
% % 'PRINT "-----"
% for I = 1 : NC,
%   %'PRINT C$(I); SPC(5);
%   for J = 1 : N,
%     Y(I, J) = Y(I, J) / SUMY(J);
%     % 'PRINT USING "#.#####"; Y(I, J); SPC(5);
%   end;
%   %'PRINT
% end;
% % -----
% % THE END OF NORMALIZATION STEP
% % *****
% % ESTIMATING LIQUID FLOWRATE
% % -----
% for J = 1 : N,
%   S = 0;
%   for M = 1 : J,
%     S = S + F(M) - U(M) - W(M);
%   end;
%   if J == N
%     L(J) = S - V(1);
%   else
%     L(J) = V(J + 1) + S - V(1);
%   end;
% end;
%
% for I = 1 : N
%   fprintf('L= %g', L(I));
% end;

```

```

% % -----
% % ESTIMATION OF THE NEW LIQUID FLOW RATES BY THE SUM-RATE
RELATION
% % -----
% for J = 1 : N,
%   L(J) = L(J) * SUMX(J);
% end;
% fprintf('-----');
% % ----- THE NEW VAPOR FLOW RATE -----
% for J = 1 : N,
%   S = 0;
%   for M = J : N,
%     S = S + F(M) - W(M) - U(M);
%   end;
%   V(J) = L(J - 1) - L(N) + S
%   if J == 1
%     V(J) = -L(N) + S;
%   end;
% end;
%
%
% fprintf(' THE NEW LIQ.AND VAP. FLOW RATE');
% fprintf('-----');
% fprintf('Vi= \tV= \tL=');
% fprintf('-----');
% for J = 1 : N,
%   fprintf('%f \t %f \t %f',Vi(J), V(J), L(J));
% end;
% % -----
% % ----- BEGAIN OF ENARGY BALANCE -----
% % THE STEP OF CALCULATION OF THE COEFFICIENTES OF TRIDIAGONAL
MATRIX
% % THIS MATRIX ALSO KNOWN AS JACOBIAN MATRIX
% % THIS STEP CONTIANS THE SOLUTION OF THIS MATRIX BY
% % GSUSS METHOD FOR OBTAINING THE NEW TEMPERATURE PROFILES(Tj)
% % -----
% fprintf('-----');
% fprintf(' BEGAIN OF ENARGY BALANCE');
% fprintf('-----');
%
% GOSUB 280
%
% % -----
% % CALCULATION OF NEW TEMPERATURE (TNj)
% % -----
% for J = 1 : N,
%   TN(J) = T(J) + DT(J);
%   fprintf('STAGE = %f \t T NEW = %f',J,TN(J));
% end;
% % -----
% % CONVERGENCE CHECK STEPS
% % -----
% RR = 0;

```

```

% S2 = 0;
% S3 = 0;
% for J = 1 : N,
% RR = RR + (TN(J) - T(J)) ^ 2;
% end;

while ((RR > ER) && (IT < 500 ))
    fprintf('\n ERROR = %f\t ITRATION NUMBER = %f ',RR,IT);
    % INPUT RFD
    fprintf('\n*****');
    fprintf('\nTHE ITRATION MUST BE RETURNED');
    fprintf('\n*****');
    IT = IT + 1;
    for J = 1 : N,
        T(J) = TN(J);
    end;
    step_15

end;

%%%%%% GOSUB 290
% -----
fprintf('\n DIVERGEN ACCUR ');
fprintf('\n -----');
% -----
% THE CONVEGENCE ACCURE
% -----
step_290

% %===== ((1))=====
% plot(Z,Y(:,1),'-bs','LineWidth',1,...
%      'MarkerEdgeColor','k',...
%      'MarkerFaceColor','r',...
%      'MarkerSize',3)
% hold,
%
% plot(Z,Y(:,2*N+2),'-d','LineWidth',1,...
%      'MarkerEdgeColor','k',...
%      'MarkerFaceColor','g',...
%      'MarkerSize',5)
%
% plot(Z,Y(:,2*N+3),'-*','LineWidth',1,...
%      'MarkerEdgeColor','k',...
%      'MarkerFaceColor','b',...
%      'MarkerSize',5)
%
% h = legend('j_1(z)','u(z)','\psi_o(z)',2);
%
%
```

```

% % title(['At N =',num2str(N),' , \rho = ',num2str(ro), ' , C_i = ',num2str(Cc),...
% %      ' , \psi_1_i = ',num2str(Epsai1)])
% grid on
% xlabel('z')
% ylabel('')

f_time = etime(clock,t111);
fprintf('\nThe final time is = %f second',f_time);
for I = 1:NC,
    CPi(I) = AC1(I) + (AC2(I) * TN(1)) + (AC3(I) * TN(1)*TN(1)) + (AC4(I) *TN(1)^3);
    CPw = 4180;
    TO = 450;
    Tref = 0;
    M(I) = (Lc(I,1)*CPi(I) * (TN(1)-Tref))/(CPw*(TO-Tref));
fprintf('\nTHE VALUE OF M = %f',M(I));
end;

```

3. Computer Program For Absorber System A Using PR-EOS

```

dc;
clear all

t111 = clock;

% @@@@ RIGOROUS METHOD
% @@@@ RIGOROUS METHOD
% *****
% THIS PROGRAMME IS USED FOR EVALUATING THE PERFORMANCE OF
% MULTICOMPONENT
% MULTISTAGE ABSORPTION PROBLEMES BY (SR) METHOD FOR
% CALCULATING
% THE TEMPERATURE, FLOW RATE & CONCENTRATION PROFILES
% THROUGHOUT THE COLUMN
% *****
% " THE NUMBER OF COMPONENTS & NUMBER OF STAGES"; NC, N
NC = 6;
N = 8;
SYf = 0;
SXo = 0;
Q = zeros(1,N);
X = zeros(NC,N);
% -----
% ##### RIGOROUS CALCULATION #####
% F = zeros(1,N);
% W = F; U = F; SWV = F; SWL = F;
%
% Ti = zeros(1,N);
% Vi = Ti; Li = Ti; A = Ti; B = Ti; C = Ti; D = Ti;
% pox = Ti; qox = Ti; TN = Ti; T = Ti; P = Ti; L = Ti; V = Ti;
%
% MAS = zeros(N,N);
% MAS1 = MAS; ENT = MAS;
%
% Yf = zeros(1,NC);
% Xo = Yf; Lco = Yf; Vfc = Yf; RECF = Yf;
%
% Vc = zeros(NC, N);
% Y = Vc; X = Vc; Z = Vc; Lc = Vc;
% ===== without define C$(NC)
DT = zeros(1,N+1);
% ##### SRK FOR FEED #####
X = zeros(NC,N);
% HVYo = zeros(1,NC);
% Prf = zeros(1,NC);
% Trf = Prf; Pro = Prf; Tro = Prf; Ho = Prf;
% SSf = Prf; SSo = Prf; Sf = Prf; So = Prf; Mi = Prf; aR = Prf; bR = Prf;
% AC1 = Prf; AC2 = Prf; AC3 = Prf; AC4 = Prf; A2 = Prf; A3 = Prf; Afi = Prf; Bfi = Prf;
% Aoi = Prf; Boi = Prf; HVYo = Prf; HVXo = Prf;

```

```

% Afij = zeros(NC, NC);
% Aoij = zeros(NC, NC);
% ##### SRK FOR EACH STAGE #####
  Kij = zeros(NC,NC);
% AX = zeros(1,N);
% AY = AX; BX = AX; BY = AX;
% ZL = AX; ZV = AX; FV = AX; FL = AX; ZV1 = AX; ZL1 = AX;
% HVVo = AX; HVLo = AX; HV = AX; HL = AX; HVT = AX; HLT = AX;
% VV = AX; YVY = AX; VYV = AX; LL = AX; XLX = AX; LXL = AX;
% PC = AX; TC = AX; ww = AX; SY = AX; SX = AX;
%
% Ai = zeros(NC, N);
% Bi = Ai; S = Ai; Hoi = Ai;
% HVo = Ai; OL = Ai; OV = Ai; Ke = Ai; SS = Ai;
% YY = Ai; YYY = Ai; XX = Ai; XXX = Ai; Pr = Ai; Tr = Ai;
% ##### DERIVATIVES #####
% DAi = zeros(NC, N);
% DBi = DAi; DBX = DAi; DBY = DAi; DAX = DAi; DAY = DAi; DHoi = DAi;
% DHVo = DAi; DSS = DAi; DS = DAi;
%
% Kij = zeros(NC,NC);
%
% DZV = zeros(1,N);
% DZL = DZV; DJJX = DZV; DJJY = DZV;
% DHVVo = DZV; DHVLo = DZV; HLDT = DZV; HVDT = DZV;
% DYVY = DZV; DXLX = DZV; DSY = DZV; DSX = DZV;
% -----
% THE STE OF READING MAX. ERROR(ER) ,MAX. NUMBER OF ITRATION;[Num]
ER = 1e-3*N;
Num = 30;
% -----
R    = 8.314;
Tref = 0;
Rb   = 4.6173;
% -----
% THE STE OF READING THE TEMRETAURE, FLOWRATES OF FEEDS
% [Vf,Lo,Tf,T0] & THE RESSUR OF THE COLUMN,[]
% -----
Vf = 450*(454/3600);
Lo1 = 250*(454/3600);
Lo2 = 164*(454/3600);
% Tf = ((90-32)/1.8)+273.15;
for Tf=305.375:
  T0 = ((80-32)/1.8)+273.15;
  p = (101325/14.7)*400;
  Q(7) = 150000*(1055/3600);
% -----
% STEP OF READING THE WET GAS COMPONENTS
% -----
NC = 6;
C_S = strvcat('C1', 'C2', 'C3', 'nC4', 'nC5','oil');
fprintf('\n');

```

```

for I = 1:NC,

fprintf('%s',C_S(I,:));
end;

for J = 1 : N,

    SWL(J) = 0;    SWV(J) = 0;

    if (J == 1)
        SWL(J) = 1;    SWV(J) = 0;
        elseif (J==4)
            SWL(J) = 1;    SWV(J) = 0;

    end;

    if (J == N)
        SWL(J) = 0;    SWV(J) = 1;
    end;
end;

% -----
% STEP OF READING Fj,Wj,Uj
% -----
% ===== Page No. 1 =====
for I = 1 : N,
    F(I) = 0; W(I) = 0; U(I) = 0;
    if (I == 1)
        F(I) = Lo1; W(I) = 0; U(I) = 0;
    end;
    if(I==4)
        F(I)=Lo2;W(I)=0;U(I)=0;
    end;
    if (I == N)
        F(I) = Vf; W(I) = 0; U(I) = 0;
    end;
end;

% "-----"
% STEP OF READING THE COMP.FEED FLOWRATE ;(Vfc,Lco)
fprintf('\n-----');

Lco1 = [0,0,0,0,0,250];
Lco2=[13,3,4,4,5,135]
Vfc = [360,40,25,15,10,0];

Lco1(6) = Lco1(6) * (454 / 3600);

for I = 1 : NC
    Lco2(I)=Lco2(I)*(454/3600);
    Vfc(I) = Vfc(I) * (454 / 3600);
end;
% -----

```



```

% STEP FOR READING CRITICAL PROPERTIES
% -----
TC = [190.4 ,305.4 ,369.8 ,425.2 ,469.7 ,658.2 ];
PC = [4600000,4880000,4250000,3800000,3370000,1820000];
ww = [.011,0.099 ,0.153 ,.199 ,.251 ,0.575   ];

% -----
% STEP FOR READING INTERACTION COEFFICIENTS
% -----

% 'FOR I = 1 TO 2
% 'FOR J = 1 TO NC
% 'IF I = J THEN Kij(I, J) = 0: GOTO 7
% 'READ Kij(I, J)
% '7 REM
% 'PRINT "Kij("; I; ","; J; ")="; Kij(I, J)
% 'NEXT J, I
% 'DATA -.025,.02,.06,.08,.08,.08,.08,.08,.08,.08
% 'DATA -.025,.12,.15,.15,.15,.15,.15,.15,.15,.15
AC1 = [ 1.925e+1, 5.409, -4.224, 9.487, -3.626, -9.328   ];
AC2 = [ 5.213E-2 ,1.781E-1 ,3.063E-1 ,3.313E-1 ,4.873E-1 ,1.149];

AC3 = [ 1.197E-5 ,-6.938E-5 ,-1.586E-4 ,-1.108E-4 ,-1.846E-4 ,-6.347E-4];

AC4 = [ -1.132E-8 ,8.713E-9 ,3.215E-8 ,-2.822E-9 ,5.305E-8 ,1.359E-7];
% =====
% READING THE ANTIONE CONSTANTS
% =====
A1 = [5.14135,5.383894,5.353418,5.741624,5.853654,6.561135];
A2 = [1742.638,2847.921,3371.084,4126.385,4598.287,6739.22];
A3=[452.974,434.898,414.488,409.5179,394.4148,292.574]

% -----
% CALCULATION OF FEED'S CONCENTRATION (Xo1,Xo2,Yf)
% -----
for I = 1 : NC,
Xo1(I) = Lco1(I)/Lo1;
Xo2(I)=Lco2(I)/Lo2;
Yf(I) = Vfc(I) / Vf;
end;

% -----
% THE STEP OF READING THE CONCENTRATION OF FEEDS;[Zi,j]
% -----
for I = 1 : NC,
for J = 1 : N,
Z(I, J) = 0;

if J == 1
Z(I, J) = Xo1(I);
end;
if J==4
Z(I,J)=Xo2(I);

```

```

end;

if J == N
    Z(I, J) = Yf(I);
end;

end;
end;
% -----
% END OF READING
% *****
% -----
% THE STEP OF CALCULATION THE ENTHALPIES OF FEEDS (HFi)
% -----
% % % % % GOSUB 250
step_250
% REM -----
% REM STEP OF INITIAL ASSUMTION OF VAPOR, LIQUID AND TEMPETAURE
% REM PROFILES
% REM (Vj, Lj, Tj)
% REM -----
% REM INTTIAL TERMINAL OF TEMP. & FLOW RATES FROM SHORT- CUT
% REM METHOD IS:-
% REM -----
Ti(1) = T0;
Ti(N) = Tf;
for I = 1 : N,
    P(I) = p;
    Vi(I) = Vf;
    if (I ~= 1) && (I ~= N)
        DT1 = (Ti(N) - Ti(1)) / (N - 1);
        Ti(I) = DT1 + Ti(I - 1);
    end;
end;

end;

for I = 1 : N,
    V(I) = Vi(I);
    T(I) = Ti(I);
end;

for Kf = 1 : N,
for If = 1 : NC,
    X(If, Kf) = Xo2(If);
    Y(If, Kf) = Yf(If);
end;
end;

IT = 1;

%=====
%=====

```

```

step_15
%=====
%=====

% 15 REM %%%%%%%%%% BEGINING OF ITREATION PROCEDURE
% % REM -----
% fprintf('ITREATION NUMBER = %f',IT);
%
fprintf('=====
=====');
% fprintf('STAGE \t TEMP.\t V');
%
fprintf('_____
');
);
%
% for J = 1 : N,
% fprintf('%f\t %f\t %f\t',J,T(J),V(J));
% end;
% % -----
% % CALCULATION OF K-VALUES & ENTHALPIES FOR EACH STAGE
% % -----
% GOSUB 260
% % -----
% % CALCULATION OF CONCENTRATION PROFILES (Xi,j)
% % -----
% GOSUB 270
% % 'PRINT "-----"
% % 'PRINT " THE CONCENTRATION PROFILES of ALL COPONENTS; X(i,j)"
% % 'PRINT "-----"
% % 'FOR K = 1 TO N: PRINT SPC(8); K; : NEXT K: PRINT
% % 'PRINT "-----"
% % 'FOR I = 1 TO NC: PRINT ; C$(I); SPC(5);
% % 'FOR J = 1 TO N
% % 'PRINT USING "#.####"; X(I, J); SPC(5);
% % 'NEXT J: PRINT : NEXT I
% % 'PRINT " ----- NORMALIZATION STEP-----"
% for J = 1 : N,
%   S1 = 0;
%   for I = 1 : NC,
%     S1 = S1 + X(I, J);
%   end;
%   SUMX(J) = S1;
%   fprintf('SUMX(%g)= %f',J,SUMX(J));
% end;
% % 'INPUT FG
% % 'PRINT "THE CONCENTRATION PROFILES OF ALL COMP. AFTER
NORMALIZATION X(i, j)"
% % 'PRINT "-----"
% % 'FOR K = 1 TO N: PRINT SPC(8); K; : NEXT K: PRINT
% % 'PRINT "-----"
% for I = 1 : NC;
%   %'PRINT C$(I); SPC(5);

```

```

% for J = 1 : N,
%   X(I, J) = X(I, J) / SUMX(J);
%   %'PRINT USING "#.####"; X(I, J); SPC(5);
% end;
%   %'PRINT
% end;
% % 'PRINT "-----"
% % 'PRINT "THE VAPOR MOLE FRACTION BEFOR NORMALIZATION IS Y(i,j) "
% % 'PRINT "-----"
% % 'FOR K = 1 TO N: PRINT SPC(8); K; : NEXT K
% % 'PRINT "-----"
% for I = 1 : NC,
%   %'PRINT C$(I); SPC(5);
%   for J = 1 : N,
%     Y(I, J) = Ke(I, J) * X(I, J);
%     % 'PRINT USING "#.####"; Y(I, J); SPC(5);
%   end;
%   %'PRINT
% end;
%
% for J = 1 : N,
%   S1 = 0;
%   for I = 1 : NC,
%     S1 = S1 + Y(I, J);
%   end;
%   SUMY(J) = S1;
%   fprintf('SUMY = %f', SUMY(J));
% end;
% % 'PRINT "-----"
% % 'PRINT "THE Y(i,j) AFTER NORMALIZATION IS :-"
% % 'PRINT "-----"
% % 'FOR K = 1 TO N: PRINT SPC(9); K; : NEXT K
% % 'PRINT "-----"
% for I = 1 : NC,
%   %'PRINT C$(I); SPC(5);
%   for J = 1 : N,
%     Y(I, J) = Y(I, J) / SUMY(J);
%     %'PRINT USING "#.####"; Y(I, J); SPC(5);
%   end;
%   %'PRINT
% end;
% % -----
% % THE END OF NORMALIZATION STEP
% % *****
% % ESTIMATING LIQUID FLOWRATE
% % -----
% for J = 1 : N,
%   S = 0;
%   for M = 1 : J,
%     S = S + F(M) - U(M) - W(M);
%   end;
%   if J == N
%     L(J) = S - V(1);

```

```

%   else
%       L(J) = V(J + 1) + S - V(1);
%   end;
% end;
%
% for I = 1 : N
%     fprintf('L= %g',L(I));
% end;
% % -----
% % ESTIMATION OF THE NEW LIQUID FLOW RATES BY THE SUM-RATE
RELATION
% % -----
% for J = 1 : N,
%     L(J) = L(J) * SUMX(J);
% end;
% fprintf('-----');
% % ----- THE NEW VAPOR FLOW RATE-----
% for J = 1 : N,
%     S = 0;
%     for M = J : N,
%         S = S + F(M) - W(M) - U(M);
%     end;
%     V(J) = L(J - 1) - L(N) + S
%     if J == 1
%         V(J) = -L(N) + S;
%     end;
% end;
%
%
% fprintf(' THE NEW LIQ.AND VAP. FLOW RATE');
% fprintf('-----');
% fprintf('Vi= \tV= \tL=');
% fprintf('-----');
% for J = 1 : N,
%     fprintf('%f\t%f\t%f',Vi(J), V(J), L(J));
% end;
% % -----
% % -----BEGAIN OF ENARGY BALANCE-----
% % THE STEP OF CALCULATION OF THE COEFFICIENTES OF TRIDIAGONAL
MATRIX
% % THIS MATRIX AISO KNOWN AS JACOBIAN MATRIX
% % THIS STEP CONTIANS THE SOLUTION OF THIS MATRIX BY
% % GSUSS METHOD FOR OBTAINING THE NEW TEMPERATURE PROFILES(Tj)
% % -----
% fprintf('-----');
% fprintf(' BEGAIN OF ENARGY BALANCE');
% fprintf('-----');
%
% GOSUB 280
%
% % -----
% % CALCULATION OF NEW TEMPERATURE (TNj)
% % -----

```

```

% for J = 1 : N,
%   TN(J) = T(J) + DT(J);
%   fprintf('STAGE = %f \t T NEW = %f',J,TN(J));
% end;
% % -----
% % CONVERGENCE CHECK STEPS
% % -----
%   RR = 0;
%   S2 = 0;
%   S3 = 0;
%   for J = 1 : N,
%     RR = RR + (TN(J) - T(J)) ^ 2;
%   end;

while ((RR > ER) && (IT < 500 ))
  fprintf('\n ERROR = %f \t ITRATION NUMBER = %f ',RR,IT);
  % 'INPUT RFD
  fprintf('\n*****');
  fprintf('\nTHE ITRATION MUST BE RETURNED');
  fprintf('\n*****');
  IT = IT + 1;
  for J = 1 : N,
    T(J) = TN(J);
  end;
  step_15

end;
% % % % % GOSUB 290
% -----
  fprintf('\n DIVERGEN ACCUR ');
  fprintf('\n -----');
% -----
% THE CONVEGENCE ACCURE
% -----
  step_290

% %===== ((1))=====
% plot(Z,Y(:,1),'-bs','LineWidth',1,...
%       'MarkerEdgeColor','k',...
%       'MarkerFaceColor','r',...
%       'MarkerSize',3)
% hold,
%
% plot(Z,Y(:,2*N+2),'-d','LineWidth',1,...
%       'MarkerEdgeColor','k',...
%       'MarkerFaceColor','g',...
%       'MarkerSize',5)
%
```



```

% Vi = Ti; Li = Ti; A = Ti; B = Ti; C = Ti; D = Ti;
% pox= Ti; qox = Ti; TN = Ti; T = Ti; P = Ti; L = Ti; V = Ti;
%
% MAS = zeros(N,N);
% MAS1 = MAS; ENT = MAS;
%
% Yf = zeros(1,NC);
% Xo = Yf; Lco = Yf; Vfc = Yf; RECF = Yf;
%
% Vc = zeros(NC, N);
% Y = Vc; X = Vc; Z = Vc; Lc = Vc;
%===== without define C$(NC)
DT = zeros(1,N+1);
% ##### SRK FOR FEED #####
X = zeros(NC,N);
% HVYo = zeros(1,NC);
% Prf = zeros(1,NC);
% Trf = Prf; Pro = Prf; Tro = Prf; Ho = Prf;
% SSf = Prf; SSo = Prf; Sf = Prf; So = Prf; Mi = Prf; aR = Prf; bR = Prf;
% AC1 = Prf; AC2 = Prf; AC3 = Prf; AC4 = Prf; A2 = Prf; A3 = Prf; Afi = Prf; Bfi =
Prf;
% Aoi = Prf; Boi = Prf; HVYo = Prf; HVXo = Prf;

% Afi = zeros(NC, NC);
% Aoi = zeros(NC, NC);
% ##### SRK FOR EACH STAGE #####
Kij = zeros(NC,NC);
% AX = zeros(1,N);
% AY = AX; BX = AX; BY = AX;
% ZL = AX; ZV = AX; FV = AX; FL = AX; ZV1 = AX; ZL1 = AX;
% HVVo = AX; HVLo = AX; HV = AX; HL = AX; HVT = AX; HLT = AX;
% VV = AX; YVY = AX; VYV = AX; LL = AX; XLX = AX; LXL = AX;
% PC = AX; TC = AX; ww = AX; SY = AX; SX = AX;
%
% Ai = zeros(NC, N);
% Bi = Ai; S = Ai; Hoi = Ai;
% HVo = Ai; OL = Ai; OV = Ai; Ke = Ai; SS = Ai;
% YY = Ai; YYY = Ai; XX = Ai; XXX = Ai; Pr = Ai; Tr = Ai;
% ##### DERIVATIVES #####
% DAi = zeros(NC, N);
% DBi = DAi; DBX = DAi; DBY = DAi; DAX = DAi; DAY = DAi; DHoi = DAi;
% DHVo = DAi; DSS = DAi; DS = DAi;
%
% Kij = zeros(NC,NC);
%
% DZV = zeros(1,N);
% DZL = DZV; DJJX = DZV; DJJY = DZV;
% DHVVo = DZV; DHVLo = DZV; HLDt = DZV; HVDT = DZV;

```



```

% DYVY = DZV; DXLX = DZV; DSY = DZV; DSX = DZV;
% -----
% THE STE OF READING MAX. ERROR(ER) ,MAX. NUMBER OF
ITRATION;[Num]
ER = 1e-3*N;
Num = 30;
% -----
R    = 8.314;
Tref = 0;
Rb   = 4.6173;
% -----
% THE STE OF READING THE TEMRETAURE, FLOWRATES OF FEEDS
% [Vf,Lo,Tf,T0] & THE RESSUR OF THE COLUMN,[]
% -----
Vf = 450*(454/3600);
Lo1 = 250*(454/3600);
Lo2 = 164*(454/3600);
Tf = ((90-32)/1.8)+273.15;
T0 = ((80-32)/1.8)+273.15;
p = (101325/14.7)*400;
Q(7) = 150000*(1055/3600);
% -----
% STEP OF READING THE WET GAS COMPONENTS
% -----
NC = 6;
C_S = strvcat('C1', 'C2', 'C3', 'C4', 'C5', 'oil');
fprintf('\n');
for I = 1:NC,

    fprintf('%s', C_S(I,:));
end;

for J = 1 : N,

    SWL(J) = 0;    SWV(J) = 0;

    if (J == 1)
        SWL(J) = 1;    SWV(J) = 0;
        elseif (J==4)
            SWL(J) = 1;    SWV(J) = 0;

    end;

    if (J == N)
        SWL(J) = 0;    SWV(J) = 1;
    end;
end;

```

```

% -----
% STEP OF READING Fj,Wj,Uj
% -----
% ===== Page No. 1 =====
for I = 1 : N,
    F(I) = 0; W(I) = 0; U(I) = 0;
if (I == 1)
    F(I) = Lo1; W(I) = 0; U(I) = 0;
end;
if(I==4)
    F(I)=Lo2;W(I)=0;U(I)=0;
end;
if (I == N)
    F(I) = Vf; W(I) = 0; U(I) = 0;
end;
end;

% "-----"
% STEP OF READING THE COMP.FEED FLOWRATE ;(Vfc,Lco)
fprintf('\n-----');

Lco1 = [0,0,0,0,0,250];
Lco2=[13,3,4,4,5,135]
Vfc = [360,40,25,15,10,0];

Lco1(6) = Lco1(6) * (454 / 3600);
Lco2(4)=Lco2(4)*(454/3600);
for I = 1 : NC
    Vfc(I) = Vfc(I) * (454 / 3600);
end;
% -----
% STEP FOR READING CRITICAL PROPERTIES
% -----
TC = [190.4 ,305.4 ,369.8 ,425.2 ,469.7 ,658.2 ];
PC = [4600000,4880000,4250000,3800000,3370000,1820000];
ww = [.011,0.099 ,0.153 ,.199 ,.251 ,0.575 ];

% -----
% STEP FOR READING INTERACTION COEFFICIENTS
% -----

% 'FOR I = 1 TO 2
% 'FOR J = 1 TO NC
% 'IF I = J THEN Kij(I, J) = 0: GOTO 7
% 'READ Kij(I, J)
% '7 REM
% 'PRINT "Kij("; I; ", "; J; ")="; Kij(I, J)
% 'NEXT J, I

```

```

% 'DATA -.025,.02,.06,.08,.08,.08,.08,.08,.08,.08
% 'DATA -.025,.12,.15,.15,.15,.15,.15,.15,.15,.15
AC1 = [ 1.925e+1, 5.409, -4.224, 9.487, -3.626,-9.328      ];
AC2 = [ 5.213E-2 ,1.781E-1 ,3.063E-1 ,3.313E-1 ,4.873E-1 ,1.149];

AC3 = [ 1.197E-5 ,-6.938E-5 ,-1.586E-4 ,-1.108E-4 ,-2.58E-4 ,-6.347E-4];

AC4 = [ -1.132E-8 ,8.713E-9 ,3.215E-8 ,-2.822E-9 ,5.305E-8 ,1.359E-7];
% =====
% READING THE ANTIONE CONSTANTS
% =====
A1 = [5.14135,5.383894,5.353418,5.741624,5.853654,6.561135];
A2 = [1742.638,2847.921,3371.084,4126.385,4598.287,6739.22];
A3=[452.974,434.898,414.488,409.5179,394.4148,292.574]

% -----
% CALCULATION OF FEED'S CONCENTRATION (Xo,Yf)
% -----
Xo1(8) = Lco1(8) / Lo1;

for I = 1 : NC,
    Yf(I) = Vfc(I) / Vf;
end;
% -----
% THE STEP OF READING THE CONCENTRATION OF FEEDS;[Zi,j]
% -----
for I = 1 : NC,
    for J = 1 : N,
        Z(I, J) = 0;

        if J == 1
            Z(I, J) = Xo(I);
        end;

        if J == N
            Z(I, J) = Yf(I);
        end;

    end;
end;
% -----
% END OF READING
% *****
% -----
% THE STEP OF CALCULATION THE ENTHALPIES OF FEEDS (HFi)
% -----
%%%%%%%%% GOSUB 250
step_250

```

```

% REM -----
% REM STEP OF INITIAL ASSUMTION OF VAPOR,LIQUID AND
TEMPETAURE PROFILES
% REM          (Vj,Lj,Tj)
% REM -----
% REM INTITAL TERMINAL OF TEMP.& FLOW RATES FROM SHORT-
CUT METHOD IS:-
% REM -----
  Ti(1) = T0;
  Ti(N) = Tf;
  for I = 1 : N,
    P(I) = p;
    Vi(I) = Vf;
    if (I ~= 1) && (I ~= N)
      DT1 = (Ti(N) - Ti(1)) / (N - 1);
      Ti(I) = DT1 + Ti(I - 1);
    end;

  end;

  for I = 1 : N,
    V(I) = Vi(I);
    T(I) = Ti(I);
  end;

  for Kf = 1 : N,
    for If = 1 : NC,
      X(If, Kf) = Xo(If);
      Y(If, Kf) = Yf(If);
    end;
  end;

  IT = 1;

%=====
%=====
step_15
%=====
%=====

% 15 REM %%%%%%%%%% BEGINING OF ITREATION
PROCEDURE %%%%%%%%%%
% % REM -----
% fprintf('ITREATION NUMBER = %f',IT);
%
fprintf('=====
=====');

```

```

% fprintf('STAGE \t TEMP.\t V');
%
fprintf('_____');
%
% for J = 1 : N,
% fprintf('%f\t %f\t %f\t',J,T(J),V(J));
% end;
% % -----
% % CALCULATION OF K-VALUES & ENTHALPIES FOR EACH STAGE
% % -----
% GOSUB 260
% % -----
% % CALCULATION OF CONCENTRATION PROFILES (Xi,j)
% % -----
% GOSUB 270
% % 'PRINT "-----"
% % 'PRINT " THE CONCENTRATION PROFILES of ALL COPONENTS;
X(i,j)"
% % 'PRINT "-----"
% % 'FOR K = 1 TO N: PRINT SPC(8); K; : NEXT K: PRINT
% % 'PRINT "-----"
% % 'FOR I = 1 TO NC: PRINT ; C$(I); SPC(5);
% % 'FOR J = 1 TO N
% % 'PRINT USING "#.####"; X(I, J); SPC(5);
% % 'NEXT J: PRINT : NEXT I
% % 'PRINT " -----NORMALIZATION STEP-----"
% for J = 1 : N,
%   S1 = 0;
%   for I = 1 : NC,
%     S1 = S1 + X(I, J);
%   end;
%   SUMX(J) = S1;
%   fprintf('SUMX(%g)= %f',J,SUMX(J));
% end;
% % 'INPUT FG
% % 'PRINT "THE CONCENTRATION PROFILES OF ALL COMP. AFTER
NORMALIZATION X(i, j)"
% % 'PRINT "-----"
% % 'FOR K = 1 TO N: PRINT SPC(8); K; : NEXT K: PRINT
% % 'PRINT "-----"
% for I = 1 : NC;
%   %'PRINT C$(I); SPC(5);
%   for J = 1 : N,
%     X(I, J) = X(I, J) / SUMX(J);
%     %'PRINT USING "#.####"; X(I, J); SPC(5);
%   end;
%   %'PRINT

```

```

% end;
% % 'PRINT "-----"
% % 'PRINT "THE VAPOR MOLE FRACTION BEFOR NORMALIZATION IS
Y(i,j) "
% % 'PRINT "-----"
% % 'FOR K = 1 TO N: PRINT SPC(8); K; : NEXT K
% % 'PRINT "-----"
% for I = 1 : NC,
%   %'PRINT C$(I); SPC(5);
%   for J = 1 : N,
%     Y(I, J) = Ke(I, J) * X(I, J);
%     % 'PRINT USING "#.#####"; Y(I, J); SPC(5);
%   end;
%   %'PRINT
% end;
%
% for J = 1 : N,
%   S1 = 0;
%   for I = 1 : NC,
%     S1 = S1 + Y(I, J);
%   end;
%   SUMY(J) = S1;
%   fprintf('SUMY = %f', SUMY(J));
% end;
% % 'PRINT "-----"
% % 'PRINT "THE Y(i,j) AFTER NORMALIZATION IS :-"
% % 'PRINT "-----"
% % 'FOR K = 1 TO N: PRINT SPC(9); K; : NEXT K
% % 'PRINT "-----"
% for I = 1 : NC,
%   %'PRINT C$(I); SPC(5);
%   for J = 1 : N,
%     Y(I, J) = Y(I, J) / SUMY(J);
%     %'PRINT USING "#.#####"; Y(I, J); SPC(5);
%   end;
%   %'PRINT
% end;
% % -----
% % THE END OF NORMALIZATION STEP
% % *****
% % ESTIMATING LIQUID FLOWRATE
% % -----
% for J = 1 : N,
%   S = 0;
%   for M = 1 : J,
%     S = S + F(M) - U(M) - W(M);
%   end;
%   if J == N

```

```

%      L(J) = S - V(1);
%      else
%      L(J) = V(J + 1) + S - V(1);
%      end;
% end;
%
% for I = 1 : N
% fprintf('L= %g',L(I));
% end;
% % -----
% % ESTIMATION OF THE NEW LIQUID FLOW RATES BY THE SUM-RATE
RELATION
% % -----
% for J = 1 : N,
% L(J) = L(J) * SUMX(J);
% end;
% fprintf('-----');
% % ----- THE NEW VAPOR FLOW RATE-----
% for J = 1 : N,
% S = 0;
% for M = J : N,
% S = S + F(M) - W(M) - U(M);
% end;
% V(J) = L(J - 1) - L(N) + S
% if J == 1
% V(J) = -L(N) + S;
% end;
% end;
%
%
% fprintf(' THE NEW LIQ.AND VAP. FLOW RATE');
% fprintf('-----');
% fprintf('Vi= \tV= \tL=');
% fprintf('-----');
% for J = 1 : N,
% fprintf('%f \t %f \t %f',Vi(J), V(J), L(J));
% end;
% % -----
% % ----- BEGAIN OF ENARGY BALANCE-----
% % THE STEP OF CALCULATION OF THE COEFFICIENTES OF
TRIDIAGONAL MATRIX
% % THIS MATRIX AISO KNOWN AS JACOBIAN MATRIX
% % THIS STEP CONTIANS THE SOLUTION OF THIS MATRIX BY
% % GSUSS METHOD FOR OBTAINING THE NEW TEMPERATURE
PROFILES(Tj)
% % -----
% fprintf('-----');
% fprintf(' BEGAIN OF ENARGY BALANCE');

```

```

% fprintf('-----');
%
% GOSUB 280
%
% % -----
% % CALCULATION OF NEW TEMPERATURE (TNj)
% % -----
% for J = 1 : N,
%   TN(J) = T(J) + DT(J);
%   fprintf('STAGE = %f\t T NEW = %f',J,TN(J));
% end;
% % -----
% % CONVERGENCE CHECK STEPS
% % -----
%   RR = 0;
%   S2 = 0;
%   S3 = 0;
% for J = 1 : N,
%   RR = RR + (TN(J) - T(J)) ^ 2;
% end;

while ((RR > ER) && (IT < 500 ))
    fprintf('\n ERROR = %f\t ITERATION NUMBER = %f ',RR,IT);
    % 'INPUT RFD
    fprintf('\n*****');
    fprintf('\nTHE ITERATION MUST BE RETURNED');
    fprintf('\n*****');
    IT = IT + 1;
    for J = 1 : N,
        T(J) = TN(J);
    end;
    step_15

end;
% % % % % GOSUB 290
% -----
% fprintf('\n DIVERGEN ACCUR ');
% fprintf('\n -----');
% -----
% THE CONVEGENCE ACCURE
% -----
    step_290

```



```

% %===== ((1)) =====
% plot(Z,Y(:,1),'-bs','LineWidth',1,...
%       'MarkerEdgeColor','k',...
%       'MarkerFaceColor','r',...
%       'MarkerSize',3)
% hold,
%
% plot(Z,Y(:,2*N+2),'-d','LineWidth',1,...
%       'MarkerEdgeColor','k',...
%       'MarkerFaceColor','g',...
%       'MarkerSize',5)
%
% plot(Z,Y(:,2*N+3),'-*','LineWidth',1,...
%       'MarkerEdgeColor','k',...
%       'MarkerFaceColor','b',...
%       'MarkerSize',5)
%
% h = legend('j_1(z)','u(z)','\psi_o(z)',2);
%
%
% % title(['At N =',num2str(N),' , \rho = ',num2str(ro), ' , C_i = ',num2str(Cc),...
% %       ', \psi_1_i = ',num2str(Epsai1)])
% grid on
% xlabel('z')
% ylabel('')

f_time = etime(clock,t111);
fprintf('\nThe final time is = %f second',f_time);

```

5. Computer Program of The Absorber System B Using PR –EOS:

```

dc;
clear all

t111 = clock;

% @@@@ RIGOROUS METHOD
% @@@@ RIGOROUS METHOD
% *****
% THIS PROGRAMME IS USED FOR EVALUATING THE PERFORMANCE OF
% MULTICOMPONENT
% MULTISTAGE ABSORPTION PROBLEMES BY (SR) METHOD FOR
% CALCULATING
% THE TEMPERATURE, FLOW RATE & CONCENTRATION PROFILES
% THROUGHOUT THE COLUMN
% *****
% " THE NUMBER OF COMPONENTS & NUMBER OF STAGES"; NC, N
NC = 8;
N = 6;
SYf = 0;
SXo = 0;
Q = zeros(1,N);
X = zeros(NC,N);
% -----
% ##### RIGOROUS CALCULATION #####
% F = zeros(1,N);
% W = F; U = F; SWV = F; SWL = F;
%
% Ti = zeros(1,N);
% Vi = Ti; Li = Ti; A = Ti; B = Ti; C = Ti; D = Ti;
% pox = Ti; qox = Ti; TN = Ti; T = Ti; P = Ti; L = Ti; V = Ti;
%
% MAS = zeros(N,N);
% MAS1 = MAS; ENT = MAS;
%
% Yf = zeros(1,NC);
% Xo = Yf; Lco = Yf; Vfc = Yf; RECF = Yf;
%
% Vc = zeros(NC, N);
% Y = Vc; X = Vc; Z = Vc; Lc = Vc;
% ===== without define C$(NC)
DT = zeros(1,N+1);
% ##### SRK FOR FEED #####
X = zeros(NC,N);
% HVYo = zeros(1,NC);
% Prf = zeros(1,NC);
% Trf = Prf; Pro = Prf; Tro = Prf; Ho = Prf;
% SSf = Prf; SSo = Prf; Sf = Prf; So = Prf; Mi = Prf; aR = Prf; bR = Prf;
% AC1 = Prf; AC2 = Prf; AC3 = Prf; AC4 = Prf; A2 = Prf; A3 = Prf; Afi = Prf; Bfi = Prf;
% Aoi = Prf; Boi = Prf; HVYo = Prf; HVXo = Prf;

```

```

% Afij = zeros(NC, NC);
% Aoij = zeros(NC, NC);
% ##### SRK FOR EACH STAGE #####
  Kij = zeros(NC,NC);
% AX = zeros(1,N);
% AY = AX; BX = AX; BY = AX;
% ZL = AX; ZV = AX; FV = AX; FL = AX; ZV1 = AX; ZL1 = AX;
% HVVo = AX; HVLo = AX; HV = AX; HL = AX; HVT = AX; HLT = AX;
% VV = AX; YVY = AX; VYV = AX; LL = AX; XLX = AX; LXL = AX;
% PC = AX; TC = AX; ww = AX; SY = AX; SX = AX;
%
% Ai = zeros(NC, N);
% Bi = Ai; S = Ai; Hoi = Ai;
% HVo = Ai; OL = Ai; OV = Ai; Ke = Ai; SS = Ai;
% YY = Ai; YYY = Ai; XX = Ai; XXX = Ai; Pr = Ai; Tr = Ai;
% ##### DERIVATIVES #####
% DAi = zeros(NC, N);
% DBi = DAi; DBX = DAi; DBY = DAi; DAX = DAi; DAY = DAi; DHoi = DAi;
% DHVo = DAi; DSS = DAi; DS = DAi;
%
% Kij = zeros(NC,NC);
%
% DZV = zeros(1,N);
% DZL = DZV; DJJX = DZV; DJJY = DZV;
% DHVVo = DZV; DHVLo = DZV; HLDT = DZV; HVDT = DZV;
% DYVY = DZV; DXLX = DZV; DSY = DZV; DSX = DZV;
% -----
% THE STE OF READING MAX. ERROR(ER) ,MAX. NUMBER OF ITRATION;[Num]
ER = 1e-3*N;
Num = 30;
% -----
R    = 8.314;
Tref = 0;
Rb   = 4.6173;
% -----
% THE STE OF READING THE TEMRETAURE, FLOWRATES OF FEEDS
% [Vf,Lo,Tf,T0] & THE RESSUR OF THE COLUMN,[]
% -----
Vf = 50.44;
Lo = 51.705;
Tf = 300;
T0 = Tf;
p = 21.068 * 101325 ;
% -----
% STEP OF READING THE WET GAS COMPONENTS
% -----
NC = 8;
C_S = strvcats('CO2', 'C1', 'C2', 'C3', 'iC4', 'nC4', 'C6', 'nC8');
fprintf('\n');
for I = 1:NC,

fprintf('%s', C_S(I,:));

```

```

end;

for J = 1 : N,

    SWL(J) = 0;    SWV(J) = 0;

    if (J == 1)
        SWL(J) = 1;    SWV(J) = 0;
    end;

    if (J == N)
        SWL(J) = 0;    SWV(J) = 1;
    end;
end;

% -----
% STEP OF READING Fj,Wj,Uj
% -----
% ===== Page No. 1 =====
for I = 1 : N,
    F(I) = 0; W(I) = 0; U(I) = 0;
    if (I == 1)
        F(I) = Lo; W(I) = 0; U(I) = 0;
    end;

    if (I == N)
        F(I) = Vf; W(I) = 0; U(I) = 0;
    end;
end;

% "-----"
% STEP OF READING THE COMP.FEED FLOWRATE ;(Vfc,Lco)
fprintf('\n-----');

Vfc = [3.077,38.890,2.320,2.875,0.706,1.362,1.210,0.0];
Lco = [1.103,4.281,.848,1.236,.362,1.065,1.691,42.119];
% Lco(12) = Lco(12) * (454 / 3600);
% for I = 1 : NC
% Vfc(I) = Vfc(I) * (454 / 3600);
% end;
% -----
% STEP FOR READING CRITICAL PROPERTIES
% -----
TC = [304.1 ,190.4 ,305.4 ,369.8 ,408.2 ,425.2 ,507.5 ,568.8 ];
PC = [7380000,4600000,4880000,4250000,3650000,3800000,3010000,2900000 ];
ww = [0.239,0.011,0.099,0.153,0.183,0.199,0.299,0.398];

% -----
% STEP FOR READING INTERACTION COEFFICIENTS
% -----

% 'FOR I = 1 TO 2
% 'FOR J = 1 TO NC

```

```

% 'IF I = J THEN Kij(I, J) = 0: GOTO 7
% 'READ Kij(I, J)
% '7 REM
% 'PRINT "Kij("; I; ","; J; ")="; Kij(I, J)
% 'NEXT J, I
% 'DATA -.025,.02,.06,.08,.08,.08,.08,.08,.08,.08
% 'DATA -.025,.12,.15,.15,.15,.15,.15,.15,.15,.15
AC1 = [ 1.98e+1, 1.925e+1, 5.409, -4.224, -1.39, 9.487, -4.413, -6.096 ];
AC2 = [ 7.344E-2 ,5.213E-2 ,1.781E-1 ,3.063E-1 ,3.847E-1 ,3.313E-1 ,5.82E-1 ,...
7.712e-1 ];
AC3 = [-5.602E-5 ,1.197E-5 ,-6.938E-5 ,-1.586E-4 ,-1.846E-4 ,-1.108E-4 ,...
-3.119E-4 ,-4.195e ];
AC4 = [ -1.168E-8 ,1.715E-8 ,-1.132E-8 ,8.713E-9 ,3.215E-8 ,2.895E-8 ,-2.822E-9 ,5.723E-8
,5.305E-8 ,...
6.494E-8 ,7.658E-8 ,8.855E-8 ];

% =====
% READING THE ANTIONE CONSTANTS
% =====
A2 = [ 1184.797, 3521.259, 1742.638, 2847.921, 3371.084, 3870.419, 4126.385, 4221.154,
4598.287, 5085.758, 5278.902, 5947.491 ];
A3 = [ 454.5328, 455.869 , 452.974 , 434.898 , 414.488 , 409.949 , 409.5179, 387.287 , 394.4148,
382.794 , 359.5259, 360.26 ];

% -----
% CALCULATION OF FEED'S CONCENTRATION (Xo,Yf)
% -----
Xo(12) = Lco(12) / Lo;
for I = 1 : NC,
Yf(I) = Vfc(I) / Vf;
end;
% -----
% THE STEP OF READING THE CONCENTRATION OF FEEDS;[Zi,j]
% -----
for I = 1 : NC,
for J = 1 : N,
Z(I, J) = 0;

if J == 1
Z(I, J) = Xo(I);
end;

if J == N
Z(I, J) = Yf(I);
end;

end;
end;
% -----
% END OF READING
% *****
% -----
% THE STEP OF CALCULATION THE ENTHALPIES OF FEEDS (HFi)

```



```

%
fprintf('_____
');
%
% for J = 1 : N,
% fprintf('%f\t %f\t %f\t',J,T(J),V(J));
% end;
% % -----
% % CALCULATION OF K-VALUES & ENTHALPIES FOR EACH STAGE
% % -----
% GOSUB 260
% % -----
% % CALCULATION OF CONCENTRATION PROFILES (Xi,j)
% % -----
% GOSUB 270
% % 'PRINT "-----"
% % 'PRINT " THE CONCENTRATION PROFILES of ALL COPONENTS; X(i,j)"
% % 'PRINT "-----"
% % 'FOR K = 1 TO N: PRINT SPC(8); K; : NEXT K: PRINT
% % 'PRINT "-----"
% % 'FOR I = 1 TO NC: PRINT ; C$(I); SPC(5);
% % 'FOR J = 1 TO N
% % 'PRINT USING "#.####"; X(I, J); SPC(5);
% % 'NEXT J: PRINT : NEXT I
% % 'PRINT "-----NORMALIZATION STEP-----"
% for J = 1 : N,
%   S1 = 0;
%   for I = 1 : NC,
%     S1 = S1 + X(I, J);
%   end;
%   SUMX(J) = S1;
%   fprintf('SUMX(%g)= %f',J,SUMX(J));
% end;
% % 'INPUT FG
% % 'PRINT "THE CONCENTRATION PROFILES OF ALL COMP. AFTER
NORMALIZATION X(i, j)"
% % 'PRINT "-----"
% % 'FOR K = 1 TO N: PRINT SPC(8); K; : NEXT K: PRINT
% % 'PRINT "-----"
% for I = 1 : NC;
%   %'PRINT C$(I); SPC(5);
%   for J = 1 : N,
%     X(I, J) = X(I, J) / SUMX(J);
%     %'PRINT USING "#.####"; X(I, J); SPC(5);
%   end;
%   %'PRINT
% end;
% % 'PRINT "-----"
% % 'PRINT "THE VAPOR MOLE FRACTION BEFOR NORMALIZATION IS Y(i,j) "
% % 'PRINT "-----"
% % 'FOR K = 1 TO N: PRINT SPC(8); K; : NEXT K
% % 'PRINT "-----"
% for I = 1 : NC,

```

```

%   %'PRINT C$(I); SPC(5);
%   for J = 1 : N,
%       Y(I, J) = Ke(I, J) * X(I, J);
%       % 'PRINT USING "#.#####"; Y(I, J); SPC(5);
%   end;
%   %'PRINT
% end;
%
% for J = 1 : N,
%     S1 = 0;
%     for I = 1 : NC,
%         S1 = S1 + Y(I, J);
%     end;
%     SUMY(J) = S1;
%     fprintf('SUMY = %f', SUMY(J));
% end;
% % 'PRINT "-----"
% % 'PRINT "THE Y(i,j) AFTER NORMALIZATION IS :-"
% % 'PRINT "-----"
% % 'FOR K = 1 TO N: PRINT SPC(9); K; : NEXT K
% % 'PRINT "-----"
% for I = 1 : NC,
%     %'PRINT C$(I); SPC(5);
%     for J = 1 : N,
%         Y(I, J) = Y(I, J) / SUMY(J);
%         % 'PRINT USING "#.#####"; Y(I, J); SPC(5);
%     end;
%     %'PRINT
% end;
% % -----
% % THE END OF NORMALIZATION STEP
% % *****
% % ESTIMATING LIQUID FLOWRATE
% % -----
% for J = 1 : N,
%     S = 0;
%     for M = 1 : J,
%         S = S + F(M) - U(M) - W(M);
%     end;
%     if J == N
%         L(J) = S - V(1);
%     else
%         L(J) = V(J + 1) + S - V(1);
%     end;
% end;
%
% for I = 1 : N
%     fprintf('L= %g', L(I));
% end;
% % -----
% % ESTIMATION OF THE NEW LIQUID FLOW RATES BY THE SUM-RATE
% % RELATION
% % -----

```



```

% for J = 1 : N,
%   L(J) = L(J) * SUMX(J);
% end;
% fprintf('-----');
% % ----- THE NEW VAPOR FLOW RATE-----
% for J = 1 : N,
%   S = 0;
%   for M = J : N,
%     S = S + F(M) - W(M) - U(M);
%   end;
%   V(J) = L(J - 1) - L(N) + S
%   if J == 1
%     V(J) = -L(N) + S;
%   end;
% end;
%
%
% fprintf(' THE NEW LIQ.AND VAP. FLOW RATE');
% fprintf('-----');
% fprintf('Vi= \tV= \tL=');
% fprintf('-----');
% for J = 1 : N,
%   fprintf('%f \t %f \t %f',Vi(J), V(J), L(J));
% end;
% % -----
% % ----- BEGAIN OF ENARGY BALANCE-----
% % THE STEP OF CALCULATION OF THE COEFFICIENTES OF TRIDIAGONAL
% % MATRIX
% % THIS MATRIX ALSO KNOWN AS JACOBIAN MATRIX
% % THIS STEP CONTIANS THE SOLUTION OF THIS MATRIX BY
% % GSUSS METHOD FOR OBTAINING THE NEW TEMPERATURE PROFILES(Tj)
% % -----
% fprintf('-----');
% fprintf(' BEGAIN OF ENARGY BALANCE');
% fprintf('-----');
%
% GOSUB 280
%
% % -----
% % CALCULATION OF NEW TEMPERATURE (TNj)
% % -----
% for J = 1 : N,
%   TN(J) = T(J) + DT(J);
%   fprintf('STAGE = %f \t T NEW = %f',J,TN(J));
% end;
% % -----
% % CONVERGENCE CHECK STEPS
% % -----
%   RR = 0;
%   S2 = 0;
%   S3 = 0;
%   for J = 1 : N,
%     RR = RR + (TN(J) - T(J)) ^ 2;

```

```

% end;

while ((RR > ER) && (IT < 500 ))
    fprintf('\n ERROR = %f\t ITRATION NUMBER = %f ',RR,IT);
    % 'INPUT RFD
    fprintf('\n*****');
    fprintf('\nTHE ITRATION MUST BE RETURNED');
    fprintf('\n*****');
    IT = IT + 1;
    for J = 1 : N,
        T(J) = TN(J);
    end;
    step_15

end;

%%%%%% GOSUB 290
% -----
fprintf('\n DIVERGEN ACCUR ');
fprintf('\n -----');
% -----
% THE CONVEGENCE ACCURE
% -----
step_290

% %===== ((1))=====
% plot(Z,Y(:,1),'-bs','LineWidth',1,...
%         'MarkerEdgeColor','k',...
%         'MarkerFaceColor','r',...
%         'MarkerSize',3)
% hold,
%
% plot(Z,Y(:,2*N+2),'-d','LineWidth',1,...
%         'MarkerEdgeColor','k',...
%         'MarkerFaceColor','g',...
%         'MarkerSize',5)
%
% plot(Z,Y(:,2*N+3),'-*','LineWidth',1,...
%         'MarkerEdgeColor','k',...
%         'MarkerFaceColor','b',...
%         'MarkerSize',5)
%
% h = legend('j_1(z)','u(z)','\psi_o(z)',2);
%
%
% % title(['At N =',num2str(N),' , \rho = ',num2str(ro), ' , C_i = ',num2str(Cc),...
% %         ' , \psi_1_i = ',num2str(Epsai1)])
% grid on
% xlabel('z')

```

```
% ylabel('')
```

```
f_time = etime(clock,t111);
```

```
fprintf('\n\nThe final time is = %f second',f_time);
```



```

% AC1 = Prf; AC2 = Prf; AC3 = Prf; AC4 = Prf; A2 = Prf; A3 = Prf; Afi = Prf; Bfi = Prf;
% Aoi = Prf; Boi = Prf; HVYo = Prf; HVXo = Prf;

% Afi = zeros(NC, NC);
% Aoi = zeros(NC, NC);
% ##### SRK FOR EACH STAGE #####
% Kij = zeros(NC,NC);
% AX = zeros(1,N);
% AY = AX; BX = AX; BY = AX;
% ZL = AX; ZV = AX; FV = AX; FL = AX; ZV1 = AX; ZL1 = AX;
% HVVo = AX; HVLo = AX; HV = AX; HL = AX; HVT = AX; HLT = AX;
% VV = AX; VVY = AX; VYV = AX; LL = AX; XLX = AX; LXL = AX;
% PC = AX; TC = AX; ww = AX; SY = AX; SX = AX;
%
% Ai = zeros(NC, N);
% Bi = Ai; S = Ai; Hoi = Ai;
% HVo = Ai; OL = Ai; OV = Ai; Ke = Ai; SS = Ai;
% YY = Ai; YYY = Ai; XX = Ai; XXX = Ai; Pr = Ai; Tr = Ai;
% ##### DERIVATIVES #####
% DAi = zeros(NC, N);
% DBi = DAi; DBX = DAi; DBY = DAi; DAX = DAi; DAY = DAi; DHoi = DAi;
% DHVo = DAi; DSS = DAi; DS = DAi;
%
% Kij = zeros(NC,NC);
%
% DZV = zeros(1,N);
% DZL = DZV; DJJX = DZV; DJJY = DZV;
% DHVVo = DZV; DHVLo = DZV; HLDT = DZV; HVDT = DZV;
% DYVY = DZV; DXLX = DZV; DSY = DZV; DSX = DZV;
% -----
% THE STE OF READING MAX. ERROR(ER) ,MAX. NUMBER OF ITRATION;[Num]
ER = 1e-3*N;
Num = 30;
% -----
R = 8.314;
Tref = 0;
Rb = 4.6173;
% -----
% THE STE OF READING THE TEMRETAURE, FLOWRATES OF FEEDS
% [Vf,Lo,Tf,T0] & THE RESSUR OF THE COLUMN,[]
% -----
Vf = 1846.12 * (454 / 3600);
Lo = 150 * (454 / 3600);
Tf = ((0 - 32) / 1.8) + 273.15;
T0 = Tf;
p = 1000 * (101325 / 14.7);
% -----
% STEP OF READING THE WET GAS COMPONENTS
% -----
NC = 12;
C_S = strvcats('N2', 'CO2', 'C1', 'C2', 'C3', 'iC4', 'nC4', 'iC5', 'nC5', 'C6', 'C7', 'Oil(n-
octane)');
fprintf('\n');

```

```

for I = 1:NC,

    fprintf('%s',C_S(I,:));
end;

for J = 1 : N,

    SWL(J) = 0;    SWV(J) = 0;

    if (J == 1)
        SWL(J) = 1;    SWV(J) = 0;
    end;

    if (J == N)
        SWL(J) = 0;    SWV(J) = 1;
    end;
end;

% -----
% STEP OF READING Fj,Wj,Uj
% -----
% ===== Page No. 1 =====
for I = 1 : N,
    F(I) = 0; W(I) = 0; U(I) = 0;
    if (I == 1)
        F(I) = Lo; W(I) = 0; U(I) = 0;
    end;

    if (I == N)
        F(I) = Vf; W(I) = 0; U(I) = 0;
    end;
end;

% "-----"
% STEP OF READING THE COMP.FEED FLOWRATE ;(Vfc,Lco)
fprintf('\n-----');

Vfc = [23.02,125.59,1435.97,183.73,60.49,5.93,8.4,1.48,1.02,.42,.07,0];
Lco = [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 150];
Lco(12) = Lco(12) * (454 / 3600);
for I = 1 : NC
    Vfc(I) = Vfc(I) * (454 / 3600);
end;
% -----
% STEP FOR READING CRITICAL PROPERTIES
% -----
TC = [126.2 ,304.1 ,190.4 ,305.4 ,369.8 ,408.2 ,425.2 ,460.4 ,469.7 ,507.5 ,540.3 ,568.8
];
PC =
[3390000,7380000,4600000,4880000,4250000,3650000,3800000,3370000,3370000,3010000,2770
000,2490000 ];
ww = [.0206 ,.177 ,0 ,.01064 ,.1538 ,.01825 ,.01954,0.2104 ,.2387 ,.2972 ,.0.3403 ,.3992
];

```

```

% -----
% STEP FOR READING INTERACTION COEFFICIENTS
% -----

% 'FOR I = 1 TO 2
% 'FOR J = 1 TO NC
% 'IF I = J THEN Kij(I, J) = 0: GOTO 7
% 'READ Kij(I, J)
% '7 REM
% 'PRINT "Kij("; I; ","; J; ")="; Kij(I, J)
% 'NEXT J, I
% 'DATA -.025,.02,.06,.08,.08,.08,.08,.08,.08,.08
% 'DATA -.025,.12,.15,.15,.15,.15,.15,.15,.15
AC1 = [ 3.11e+1, 1.98e+1, 1.925e+1, 5.409, -4.224, -1.39, 9.487, -9.525, -3.626, -4.413, -5.146, -
6.096 ];
AC2 = [ -1.357E-2, 7.344E-2 ,5.213E-2 ,1.781E-1 ,3.063E-1 ,3.847E-1 ,3.313E-1 ,5.066E-1
,4.873E-1 ,5.82E-1 ,...
6.762E-1, 7.712E-1 ];
AC3 = [ 2.68E-5 ,-5.602E-5 ,1.197E-5 ,-6.938E-5 ,-1.586E-4 ,-1.846E-4 ,-1.108E-4 ,-2.729E-4 ,-
2.58E-4 ,...
-3.119E-4 ,-3.651E-4 ,-4.195E-4 ];
AC4 = [ -1.168E-8, 1.715E-8 ,-1.132E-8 ,8.713E-9 ,3.215E-8 ,2.895E-8 ,-2.822E-9 ,5.723E-8
,5.305E-8 ,...
6.494E-8 ,7.658E-8 ,8.855E-8 ];

% =====
% READING THE ANTIONE CONSTANTS
% =====
A2 = [ 1184.797, 3521.259, 1742.638, 2847.921, 3371.084, 3870.419, 4126.385, 4221.154,
4598.287, 5085.758, 5278.902, 5947.491 ];
A3 = [ 454.5328, 455.869 , 452.974 , 434.898 , 414.488 , 409.949 , 409.5179, 387.287 , 394.4148,
382.794 , 359.5259, 360.26 ];

% -----
% CALCULATION OF FEED'S CONCENTRATION (Xo,Yf)
% -----
Xo(12) = Lco(12) / Lo;
for I = 1 : NC,
Yf(I) = Vfc(I) / Vf;
end;
% -----
% THE STEP OF READING THE CONCENTRATION OF FEEDS;[Zi,j]
% -----
for I = 1 : NC,
for J = 1 : N,
Z(I, J) = 0;

if J == 1
Z(I, J) = Xo(I);
end;

if J == N

```

```

    Z(I, J) = Yf(I);
end;

end;
end;
% -----
% END OF READING
% *****
% -----
% THE STEP OF CALCULATION THE ENTHALPIES OF FEEDS (HFi)
% -----
% % % % % GOSUB 250
step_250
% REM -----
% REM STEP OF INITIAL ASSUMTION OF VAPOR, LIQUID AND TEMPETAURE
% REM PROFILES
% REM (Vj, Lj, Tj)
% REM -----
% REM INTITIAL TERMINAL OF TEMP. & FLOW RATES FROM SHORT- CUT
% REM METHOD IS:-
% REM -----
Ti(1) = T0;
Ti(N) = Tf;
for I = 1 : N,
    P(I) = p;
    Vi(I) = Vf;
    if (I ~= 1) && (I ~= N)
        DT1 = (Ti(N) - Ti(1)) / (N - 1);
        Ti(I) = DT1 + Ti(I - 1);
    end;
end;

end;

for I = 1 : N,
    V(I) = Vi(I);
    T(I) = Ti(I);
end;

for Kf = 1 : N,
for If = 1 : NC,
    X(If, Kf) = Xo(If);
    Y(If, Kf) = Yf(If);
end;
end;

IT = 1;

%=====
%=====
step_15
%=====
%=====

```



```

% 15 REM %%%%%%%%%% BEGINING OF ITREATION PROCEDURE
%%%%%%%%%
% REM -----
% fprintf('ITREATION NUMBER = %f',IT);
%
fprintf('=====');
% fprintf('STAGE \t TEMP.\t V');
%
fprintf('_____');
);
%
% for J = 1 : N,
% fprintf('%f\t %f\t %f\t',J,T(J),V(J));
% end;
% % -----
% % CALCULATION OF K-VALUES & ENTHALPIES FOR EACH STAGE
% % -----
% GOSUB 260
% % -----
% % CALCULATION OF CONCENTRATION PROFILES (Xi,j)
% % -----
% GOSUB 270
% % 'PRINT "-----"
% % 'PRINT " THE CONCENTRATION PROFILES of ALL COPONENTS; X(i,j)"
% % 'PRINT "-----"
% % 'FOR K = 1 TO N: PRINT SPC(8); K; : NEXT K: PRINT
% % 'PRINT "-----"
% % 'FOR I = 1 TO NC: PRINT ; C$(I); SPC(5);
% % 'FOR J = 1 TO N
% % 'PRINT USING "#.####"; X(I, J); SPC(5);
% % 'NEXT J: PRINT : NEXT I
% % 'PRINT " ----- NORMALIZATION STEP-----"
% for J = 1 : N,
%   S1 = 0;
%   for I = 1 : NC,
%     S1 = S1 + X(I, J);
%   end;
%   SUMX(J) = S1;
%   fprintf('SUMX(%g)= %f',J,SUMX(J));
% end;
% % 'INPUT FG
% % 'PRINT "THE CONCENTRATION PROFILES OF ALL COMP. AFTER
NORMALIZATION X(i, j)"
% % 'PRINT "-----"
% % 'FOR K = 1 TO N: PRINT SPC(8); K; : NEXT K: PRINT
% % 'PRINT "-----"
% for I = 1 : NC;
%   %'PRINT C$(I); SPC(5);
%   for J = 1 : N,
%     X(I, J) = X(I, J) / SUMX(J);
%     %'PRINT USING "#.####"; X(I, J); SPC(5);

```

```

% end;
%   %'PRINT
% end;
% % 'PRINT "-----"
% % 'PRINT "THE VAPOR MOLE FRACTION BEFOR NORMALIZATION IS Y(i,j) "
% % 'PRINT "-----"
% % 'FOR K = 1 TO N: PRINT SPC(8); K; : NEXT K
% % 'PRINT "-----"
% for I = 1 : NC,
%   %'PRINT C$(I); SPC(5);
%   for J = 1 : N,
%     Y(I, J) = Ke(I, J) * X(I, J);
%     % 'PRINT USING "#.#####"; Y(I, J); SPC(5);
%   end;
%   %'PRINT
% end;
%
% for J = 1 : N,
%   S1 = 0;
%   for I = 1 : NC,
%     S1 = S1 + Y(I, J);
%   end;
%   SUMY(J) = S1;
%   fprintf('SUMY = %f', SUMY(J));
% end;
% % 'PRINT "-----"
% % 'PRINT "THE Y(i,j) AFTER NORMALIZATION IS :-"
% % 'PRINT "-----"
% % 'FOR K = 1 TO N: PRINT SPC(9); K; : NEXT K
% % 'PRINT "-----"
% for I = 1 : NC,
%   %'PRINT C$(I); SPC(5);
%   for J = 1 : N,
%     Y(I, J) = Y(I, J) / SUMY(J);
%     % 'PRINT USING "#.#####"; Y(I, J); SPC(5);
%   end;
%   %'PRINT
% end;
% % -----
% % THE END OF NORMALIZATION STEP
% % *****
% % ESTIMATING LIQUID FLOWRATE
% % -----
% for J = 1 : N,
%   S = 0;
%   for M = 1 : J,
%     S = S + F(M) - U(M) - W(M);
%   end;
%   if J == N
%     L(J) = S - V(1);
%   else
%     L(J) = V(J + 1) + S - V(1);
%   end;

```

```

% end;
%
% for I = 1 : N
% fprintf('L= %g',L(I));
% end;
% % -----
% % ESTIMATION OF THE NEW LIQUID FLOW RATES BY THE SUM-RATE
RELATION
% % -----
% for J = 1 : N,
% L(J) = L(J) * SUMX(J);
% end;
% fprintf('-----');
% % ----- THE NEW VAPOR FLOW RATE-----
% for J = 1 : N,
% S = 0;
% for M = J : N,
% S = S + F(M) - W(M) - U(M);
% end;
% V(J) = L(J - 1) - L(N) + S
% if J == 1
% V(J) = -L(N) + S;
% end;
% end;
%
%
% fprintf(' THE NEW LIQ.AND VAP. FLOW RATE');
% fprintf('-----');
% fprintf('Vi= \tV= \tL=');
% fprintf('-----');
% for J = 1 : N,
% fprintf('%f\t%f\t%f',Vi(J), V(J), L(J));
% end;
% % -----
% % ----- BEGAIN OF ENARGY BALANCE-----
% % THE STEP OF CALCULATION OF THE COEFFICIENTES OF TRIDIAGONAL
MATRIX
% % THIS MATRIX AISO KNOWN AS JACOBIAN MATRIX
% % THIS STEP CONTIANS THE SOLUTION OF THIS MATRIX BY
% % GSUSS METHOD FOR OBTAINING THE NEW TEMPERATURE PROFILES(Tj)
% % -----
% fprintf('-----');
% fprintf(' BEGAIN OF ENARGY BALANCE');
% fprintf('-----');
%
% GOSUB 280
%
% % -----
% % CALCULATION OF NEW TEMPERATURE (TNj)
% % -----
% for J = 1 : N,
% TN(J) = T(J) + DT(J);
% fprintf('STAGE = %f \t T NEW = %f',J,TN(J));

```

```

% end;
% % -----
% % CONVERGENCE CHECK STEPS
% % -----
% RR = 0;
% S2 = 0;
% S3 = 0;
% for J = 1 : N,
% RR = RR + (TN(J) - T(J)) ^ 2;
% end;

while ((RR > ER) && (IT < 500 ))
    fprintf('\n ERROR = %f\t ITRATION NUMBER = %f ',RR,IT);
    % 'INPUT RFD
    fprintf('\n*****');
    fprintf('\nTHE ITRATION MUST BE RETURNED');
    fprintf('\n*****');
    IT = IT + 1;
    for J = 1 : N,
        T(J) = TN(J);
    end;
    step_15

end;

% % % % % GOSUB 290
% -----
    fprintf('\n DIVERGEN ACCUR ');
    fprintf('\n -----');
% -----
% THE CONVEGENCE ACCURE
% -----
    step_290


% %===== ((1))=====
% plot(Z,Y(:,1),'-bs','LineWidth',1,...
%     'MarkerEdgeColor','k',...
%     'MarkerFaceColor','r',...
%     'MarkerSize',3)
% hold,
%
% plot(Z,Y(:,2*N+2),'-d','LineWidth',1,...
%     'MarkerEdgeColor','k',...
%     'MarkerFaceColor','g',...
%     'MarkerSize',5)
%
% plot(Z,Y(:,2*N+3),'-*','LineWidth',1,...
%     'MarkerEdgeColor','k',...
%     'MarkerFaceColor','b',...

```

```

%           'MarkerSize',5)
%
% h = legend('j_1(z)','u(z)', '\psi_o(z)',2);
%
%
% % title(['At N =',num2str(N),' , \rho = ',num2str(ro), ' , C_i = ',num2str(Cc),...
% %       ' , \psi_1_i = ',num2str(Epsai1)])
% grid on
% xlabel('z')
% ylabel('')

f_time = etime(clock,t111);
fprintf('\nThe final time is = %f second',f_time);

```

7. Computer Program Of Stripper System A Using PR-EOS:

```
dc;
clear all
```

```
t111 = clock;
```

```
% @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ RIGOROUS METHOD
% @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @
% *****
% THIS PROGRAMME IS USED FOR EVALUATING THE PERFORMANCE OF
% MULTICOMPONENT
% MULTISTAGE STRIPPER PROBLEMS BY (SR) METHOD FOR CALCULATING
% THE TEMPERATURE, FLOW RATE & CONCENTRATION PROFILES
% THROUGHOUT THE COLUMN
% *****
% " THE NUMBER OF COMPONENTS & NUMBER OF STAGES"; NC, N
NC = 7;
N = 8;
SYf = 0;
SXo = 0;
Q = zeros(1,N);
X= zeros(NC,N);
% -----
% ##### RIGOROUS CALCULATION #####
% F = zeros(1,N);
% W = F; U = F; SWV = F; SWL = F;
%
% Ti = zeros(1,N);
% Vi = Ti; Li = Ti; A = Ti; B = Ti; C = Ti; D = Ti;
% pox= Ti; qox = Ti; TN = Ti; T = Ti; P = Ti; L = Ti; V = Ti;
%
% MAS = zeros(N,N);
% MAS1 = MAS; ENT = MAS;
%
% Yf = zeros(1,NC);
% Xo = Yf; Lco = Yf; Vfc = Yf; RECF = Yf;
%
% Vc = zeros(NC, N);
% Y = Vc; X = Vc; Z = Vc; Lc = Vc;
%===== without define C$(NC)
DT = zeros(1,N+1);
% ##### SRK FOR FEED #####
X= zeros(NC,N);
% HVYo = zeros(1,NC);
% Prf = zeros(1,NC);
% Trf = Prf; Pro = Prf; Tro = Prf; Ho = Prf;
% SSf = Prf; SSo = Prf; Sf = Prf; So = Prf; Mi = Prf; aR = Prf; bR = Prf;
% AC1 = Prf; AC2 = Prf; AC3 = Prf; AC4 = Prf; A2 = Prf; A3 = Prf; Afi = Prf; Bfi = Prf;
% Aoi = Prf; Boi = Prf; HVYo = Prf; HVXo = Prf;
```

```

% Afij = zeros(NC, NC);
% Aoij = zeros(NC, NC);
% ##### SRK FOR EACH STAGE #####
  Kij = zeros(NC,NC);
% AX = zeros(1,N);
% AY = AX; BX = AX; BY = AX;
% ZL = AX; ZV = AX; FV = AX; FL = AX; ZV1 = AX; ZL1 = AX;
% HVVo = AX; HVLo = AX; HV = AX; HL = AX; HVT = AX; HLT = AX;
% VV = AX; YVY = AX; VYV = AX; LL = AX; XLX = AX; LXL = AX;
% PC = AX; TC = AX; ww = AX; SY = AX; SX = AX;
%
% Ai = zeros(NC, N);
% Bi = Ai; S = Ai; Hoi = Ai;
% HVo = Ai; OL = Ai; OV = Ai; Ke = Ai; SS = Ai;
% YY = Ai; YYY = Ai; XX = Ai; XXX = Ai; Pr = Ai; Tr = Ai;
% ##### DERIVATIVES #####
% DAi = zeros(NC, N);
% DBi = DAi; DBX = DAi; DBY = DAi; DAX = DAi; DAY = DAi; DHoi = DAi;
% DHVo = DAi; DSS = DAi; DS = DAi;
%
% Kij = zeros(NC,NC);
%
% DZV = zeros(1,N);
% DZL = DZV; DJJX = DZV; DJJY = DZV;
% DHVVo = DZV; DHVLo = DZV; HLDT = DZV; HVDT = DZV;
% DYVY = DZV; DXLX = DZV; DSY = DZV; DSX = DZV;
% -----
% THE STE OF READING MAX. ERROR(ER) ,MAX. NUMBER OF ITRATION;[Num]
ER = 1e-3*N;
Num = 30;
% -----
R    = 8.314;
Tref = 0;
Rb   = 4.6173;
% -----
% THE STE OF READING THE TEMRETAURE, FLOWRATES OF FEEDS
% [Vf,Lo,Tf,T0] & THE RESSUR OF THE COLUMN,[]
% -----
Vf = 15;
Lo = 68.1126;
Tf = 500;
T0 = 450;
p = 101325;
% -----
% STEP OF READING THE WET GAS COMPONENTS
% -----
% NC = 7;
C_S = strvcats('C1', 'C2', 'C3', 'C4', 'C5', 'oil', 'steam');
fprintf('\n');
for I = 1:NC,

fprintf('%s', C_S(I,:));

```

```

end;

for J = 1 : N,

    SWL(J) = 0;    SWV(J) = 0;

    if (J == 1)
        SWL(J) = 1;    SWV(J) = 0;
    end;

    if (J == N)
        SWL(J) = 0;    SWV(J) = 1;
    end;
end;

% -----
% STEP OF READING Fj,Wj,Uj
% -----
% ===== Page No. 1 =====
for I = 1 : N,
    F(I) = 0; W(I) = 0; U(I) = 0;
    if (I == 1)
        F(I) = Lo; W(I) = 0; U(I) = 0;
    end;

    if (I == N)
        F(I) = Vf; W(I) = 0; U(I) = 0;
    end;
end;

% "-----"
% STEP OF READING THE COMP.FEED FLOWRATE ;(Vfc,Lco)
fprintf('\n-----');
Lco = [7.6045,4.03555,3.632,2.396111,1.896111,48.5527,0];
Vfc = [0,0,0,0,0,0,15];

% -----
% STEP FOR READING CRITICAL PROPERTIES
% -----
TC = [190.4 ,305.4 ,369.8 ,425.2 ,469.7 ,658.2,647.3 ];
PC = [4600000,4880000,4250000,3800000,3370000,1820000,22120000 ];
ww = [.011,0.099 ,0.153 ,.199 ,.251 ,0.575 ,.3477 ];

% -----
% STEP FOR READING INTERACTION COEFFICIENTS
% -----

% 'FOR I = 1 TO 2
% 'FOR J = 1 TO NC
% 'IF I = J THEN Kij(I, J) = 0: GOTO 7

```



```

% 'READ Kij(I, J)
% '7 REM
% 'PRINT "Kij("; I; ","; J; ")="; Kij(I, J)
% 'NEXT J, I
% 'DATA -.025,.02,.06,.08,.08,.08,.08,.08,.08,.08
% 'DATA -.025,.12,.15,.15,.15,.15,.15,.15,.15,.15
AC1 = [ 1.925e+1, 5.409, -4.224, 9.487, -3.626, -9.328, 3.224E+1];
AC2 = [ 5.213E-2 ,1.781E-1 ,3.063E-1 ,3.313E-1 ,4.873E-1 ,1.149,1.924E-3];

AC3 = [ 1.197E-5 ,-6.938E-5 ,-1.586E-4 ,-1.108E-4 ,-2.58E-4 ,-6.347E-4,1.055E-5];

AC4 = [ -1.132E-8 ,8.713E-9 ,3.215E-8 ,-2.822E-9 ,5.305E-8 ,1.359E-7,-3.596E-9];

% =====
% READING THE ANTIONE CONSTANTS
% =====
A2 = [5.14135,452.974,2847.921,5.353418,414.488,4126.385,5.853654,394.4148,6739.22,7173.79
];
A3 =
[1742.638,5.383894,434.898,3371.084,5.741624,409.5179,4598.287,6.561135,292.574,389.4747];
% -----
% CALCULATION OF FEED'S CONCENTRATION (Xo,Yf)
% -----
for I = 1 : NC,
Xo(I) = Lco(I)/Lo;
Yf(I) = Vfc(I) / Vf;
end;
% -----
% THE STEP OF READING THE CONCENTRATION OF FEEDS;[Zi,j]
% -----
for I = 1 : NC,
for J = 1 : N,
Z(I, J) = 0;

if J == 1
Z(I, J) = Xo(I);
end;

if J == N
Z(I, J) = Yf(I);
end;

end;
end;
% -----
% END OF READING
% *****
% -----
% THE STEP OF CALCULATION THE ENTHALPIES OF FEEDS (HFi)
% -----
%%%%%%%% GOSUB 250
step_250

```

```

% REM -----
% REM STEP OF INITIAL ASSUMPTION OF VAPOR, LIQUID AND TEMPERATURE
PROFILES
% REM (Vj, Lj, Tj)
% REM -----
% REM INITIAL TERMINAL OF TEMP. & FLOW RATES FROM SHORT-CUT
METHOD IS:-
% REM -----
Ti(1) = T0;
Ti(N) = Tf;
for I = 1 : N,
    P(I) = p;
    Vi(I) = Vf;
    if (I ~= 1) && (I ~= N)
        DT1 = (Ti(N) - Ti(1)) / (N - 1);
        Ti(I) = DT1 + Ti(I - 1);
    end;
end;

for I = 1 : N,
    V(I) = Vi(I);
    T(I) = Ti(I);
end;

for Kf = 1 : N,
    for If = 1 : NC,
        X(If, Kf) = Xo(If);
        Y(If, Kf) = Yf(If);
    end;
end;

IT = 1;

%=====
%=====
step_15
%=====
%=====

% 15 REM %%%%%%%%%% BEGINNING OF ITERATION PROCEDURE
%%%%%%%%%%
% REM -----
% fprintf('ITERATION NUMBER = %f', IT);
%
fprintf('=====
=====');
% fprintf('STAGE \t TEMP.\t V');
%
fprintf('_____
);
%
```

```

% for J = 1 : N,
% fprintf('%f\t %f\t %f\t',J,T(J),V(J));
% end;
% % -----
% % CALCULATION OF K-VALUES & ENTHALPIES FOR EACH STAGE
% % -----
% GOSUB 260
% % -----
% % CALCULATION OF CONCENTRATION PROFILES (Xi,j)
% % -----
% GOSUB 270
% % 'PRINT "-----"
% % 'PRINT " THE CONCENTRATION PROFILES of ALL COPONENTS; X(i,j)"
% % 'PRINT "-----"
% % 'FOR K = 1 TO N: PRINT SPC(8); K; : NEXT K: PRINT
% % 'PRINT "-----"
% % 'FOR I = 1 TO NC: PRINT ; C$(I); SPC(5);
% % 'FOR J = 1 TO N
% % 'PRINT USING "#.####"; X(I, J); SPC(5);
% % 'NEXT J: PRINT : NEXT I
% % 'PRINT "-----NORMALIZATION STEP-----"
% for J = 1 : N,
%   S1 = 0;
%   for I = 1 : NC,
%     S1 = S1 + X(I, J);
%   end;
%   SUMX(J) = S1;
%   fprintf('SUMX(%g)= %f',J,SUMX(J));
% end;
% % 'INPUT FG
% % 'PRINT "THE CONCENTRATION PROFILES OF ALL COMP. AFTER
NORMALIZATION X(i, j)"
% % 'PRINT "-----"
% % 'FOR K = 1 TO N: PRINT SPC(8); K; : NEXT K: PRINT
% % 'PRINT "-----"
%   for I = 1 : NC;
%     %'PRINT C$(I); SPC(5);
%     for J = 1 : N,
%       X(I, J) = X(I, J) / SUMX(J);
%       %'PRINT USING "#.####"; X(I, J); SPC(5);
%     end;
%     %'PRINT
%   end;
% % 'PRINT "-----"
% % 'PRINT "THE VAPOR MOLE FRACTION BEFOR NORMALIZATION IS Y(i,j) "
% % 'PRINT "-----"
% % 'FOR K = 1 TO N: PRINT SPC(8); K; : NEXT K
% % 'PRINT "-----"
% for I = 1 : NC,
%   %'PRINT C$(I); SPC(5);
%   for J = 1 : N,
%     Y(I, J) = Ke(I, J) * X(I, J);
%     % 'PRINT USING "#.####"; Y(I, J); SPC(5);

```

```

% end;
% %'PRINT
% end;
%
% for J = 1 : N,
%   S1 = 0;
%   for I = 1 : NC,
%     S1 = S1 + Y(I, J);
%   end;
%   SUMY(J) = S1;
%   fprintf('SUMY = %f', SUMY(J));
% end;
% % 'PRINT "-----"
% % 'PRINT "THE Y(i,j) AFTER NORMALIZATION IS :-"
% % 'PRINT "-----"
% % 'FOR K = 1 TO N: PRINT SPC(9); K; : NEXT K
% % 'PRINT "-----"
% for I = 1 : NC,
%   %'PRINT C$(I); SPC(5);
%   for J = 1 : N,
%     Y(I, J) = Y(I, J) / SUMY(J);
%     %'PRINT USING '#.#####'; Y(I, J); SPC(5);
%   end;
%   %'PRINT
% end;
% % -----
% % THE END OF NORMALIZATION STEP
% % *****
% % ESTIMATING LIQUID FLOWRATE
% % -----
% for J = 1 : N,
%   S = 0;
%   for M = 1 : J,
%     S = S + F(M) - U(M) - W(M);
%   end;
%   if J == N
%     L(J) = S - V(1);
%   else
%     L(J) = V(J + 1) + S - V(1);
%   end;
% end;
%
% for I = 1 : N
%   fprintf('L= %g', L(I));
% end;
% % -----
% % ESTIMATION OF THE NEW LIQUID FLOW RATES BY THE SUM-RATE
% % RELATION
% % -----
% for J = 1 : N,
%   L(J) = L(J) * SUMX(J);
% end;
% fprintf('-----');

```

```

% % ----- THE NEW VAPOR FLOW RATE-----
% for J = 1 : N,
%   S = 0;
%   for M = J : N,
%     S = S + F(M) - W(M) - U(M);
%   end;
%   V(J) = L(J - 1) - L(N) + S
%   if J == 1
%     V(J) = -L(N) + S;
%   end;
% end;
%
%
% fprintf(' THE NEW LIQ.AND VAP. FLOW RATE');
% fprintf('-----');
% fprintf('Vi= \tV= \tL=');
% fprintf('-----');
% for J = 1 : N,
%   fprintf('%f\t%f\t%f',Vi(J), V(J), L(J));
% end;
% % -----
% % -----BEGAIN OF ENARGY BALANCE-----
% % THE STEP OF CALCULATION OF THE COEFFICIENTES OF TRIDIAGONAL
% % MATRIX
% % THIS MATRIX AISO KNOWN AS JACOBIAN MATRIX
% % THIS STEP CONTIANS THE SOLUTION OF THIS MATRIX BY
% % GSUSS METHOD FOR OBTAINING THE NEW TEMPERATURE PROFILES(Tj)
% % -----
% fprintf('-----');
% fprintf(' BEGAIN OF ENARGY BALANCE');
% fprintf('-----');
%
% GOSUB 280
%
% % -----
% % CALCULATION OF NEW TEMPERATURE (TNj)
% % -----
% for J = 1 : N,
%   TN(J) = T(J) + DT(J);
%   fprintf('STAGE = %f \t T NEW = %f',J,TN(J));
% end;
% % -----
% % CONVERGENCE CHECK STEPS
% % -----
% RR = 0;
% S2 = 0;
% S3 = 0;
% for J = 1 : N,
%   RR = RR + (TN(J) - T(J)) ^ 2;
% end;

while ((RR > ER) && (IT < 500 ))
  fprintf('\n ERROR = %f\t ITRATION NUMBER = %f ',RR,IT);

```

```

% 'INPUT RFD
fprintf('\n*****');
fprintf('\nTHE ITERATION MUST BE RETURNED');
fprintf('\n*****');
IT = IT + 1;
for J = 1 : N,
    T(J) = TN(J);
end;
step_15

end;
%%%%%% GOSUB 290
% -----
fprintf('\n DIVERGEN ACCUR ');
fprintf('\n -----');
% -----
% THE CONVEGENCE ACCURE
% -----
step_290

% %===== (1) =====
% plot(Z,Y(:,1),'-bs','LineWidth',1,...
%      'MarkerEdgeColor','k',...
%      'MarkerFaceColor','r',...
%      'MarkerSize',3)
% hold,
%
% plot(Z,Y(:,2*N+2),'-d','LineWidth',1,...
%      'MarkerEdgeColor','k',...
%      'MarkerFaceColor','g',...
%      'MarkerSize',5)
%
% plot(Z,Y(:,2*N+3),'-*','LineWidth',1,...
%      'MarkerEdgeColor','k',...
%      'MarkerFaceColor','b',...
%      'MarkerSize',5)
%
% h = legend('j_1(z)','u(z)','\psi_o(z)',2);
%
%
% % title(['At N =',num2str(N),' , \rho = ',num2str(ro), ' , C_i = ',num2str(Cc),...
% %      ' , \psi_1_i = ',num2str(Epsai1)])
% grid on
% xlabel('z')
% ylabel('')

f_time = etime(clock,t111);
fprintf('\nThe final time is = %f second',f_time);

```

8. Computer Program OF The Stripper System B Using PR-EOS:

```

clc;
clear all

t111 = clock;

% @@@@ RIGOROUS METHOD
% @@@@ RIGOROUS METHOD
% *****
% THIS PROGRAMME IS USED FOR EVALUATING THE PERFORMANCE OF
% MULTICOMPONENT
% MULTISTAGE ABSORPTION PROBLEMES BY (SR) METHOD FOR
% CALCULATING
% THE TEMPERATURE, FLOW RATE & CONCENTRATION PROFILES
% THROUGHOUT THE COLUMN
% *****
% " THE NUMBER OF COMPONENTS & NUMBER OF STAGES"; NC, N
NC = 9;
N = 8;
SYf = 0;
SXo = 0;
Q = zeros(1,N);
X = zeros(NC,N);
% -----
% ##### RIGOROUS CALCULATION #####
% F = zeros(1,N);
% W = F; U = F; SWV = F; SWL = F;
%
% Ti = zeros(1,N);
% Vi = Ti; Li = Ti; A = Ti; B = Ti; C = Ti; D = Ti;
% pox = Ti; qox = Ti; TN = Ti; T = Ti; P = Ti; L = Ti; V = Ti;
%
% MAS = zeros(N,N);
% MAS1 = MAS; ENT = MAS;
%
% Yf = zeros(1,NC);
% Xo = Yf; Lco = Yf; Vfc = Yf; RECF = Yf;
%
% Vc = zeros(NC, N);
% Y = Vc; X = Vc; Z = Vc; Lc = Vc;
% ===== without define C$(NC)
DT = zeros(1,N+1);
% ##### SRK FOR FEED #####
X = zeros(NC,N);
% HVYo = zeros(1,NC);
% Prf = zeros(1,NC);
% Trf = Prf; Pro = Prf; Tro = Prf; Ho = Prf;
% SSf = Prf; SSo = Prf; Sf = Prf; So = Prf; Mi = Prf; aR = Prf; bR = Prf;
% AC1 = Prf; AC2 = Prf; AC3 = Prf; AC4 = Prf; A2 = Prf; A3 = Prf; Afi = Prf; Bfi = Prf;
% Aoi = Prf; Boi = Prf; HVYo = Prf; HVXo = Prf;

```

```

% Afij = zeros(NC, NC);
% Aoij = zeros(NC, NC);
% ##### SRK FOR EACH STAGE #####
    Kij = zeros(NC,NC);
% AX = zeros(1,N);
% AY = AX; BX = AX; BY = AX;
% ZL = AX; ZV = AX; FV = AX; FL = AX; ZV1 = AX; ZL1 = AX;
% HVVo = AX; HVLo = AX; HV = AX; HL = AX; HVT = AX; HLT = AX;
% VV = AX; YVY = AX; VYV = AX; LL = AX; XLX = AX; LXL = AX;
% PC = AX; TC = AX; ww = AX; SY = AX; SX = AX;
%
% Ai = zeros(NC, N);
% Bi = Ai; S = Ai; Hoi = Ai;
% HVo = Ai; OL = Ai; OV = Ai; Ke = Ai; SS = Ai;
% YY = Ai; YYY = Ai; XX = Ai; XXX = Ai; Pr = Ai; Tr = Ai;
% ##### DERIVATIVES #####
% DAi = zeros(NC, N);
% DBi = DAi; DBX = DAi; DBY = DAi; DAX = DAi; DAY = DAi; DHoi = DAi;
% DHVo = DAi; DSS = DAi; DS = DAi;
%
% Kij = zeros(NC,NC);
%
% DZV = zeros(1,N);
% DZL = DZV; DJJX = DZV; DJJY = DZV;
% DHVVo = DZV; DHVLo = DZV; HLDT = DZV; HVDT = DZV;
% DYVY = DZV; DXLX = DZV; DSY = DZV; DSX = DZV;
% -----
% THE STE OF READING MAX. ERROR(ER) ,MAX. NUMBER OF ITRATION;[Num]
ER = 1e-3*N;
Num = 30;
% -----
R    = 8.314;
Tref = 0;
Rb   = 4.6173;
% -----
% THE STE OF READING THE TEMRETAURE, FLOWRATES OF FEEDS
% [Vf,Lo,Tf,T0] & THE RESSUR OF THE COLUMN,[]
% -----
Vf = 7;
Lo = 68.1125;
Tf = 500;
T0 = 450;
p = 101325;
% -----
% STEP OF READING THE WET GAS COMPONENTS
% -----
% NC = 9;
C_S = strcat( 'CO2', 'C1', 'C2', 'C3', 'iC4', 'nC4', 'C6','oil','steam');
fprintf('\n');
for I = 1:NC,

fprintf('%s',C_S(I,:));

```



```

end;

for J = 1 : N,

    SWL(J) = 0;    SWV(J) = 0;

    if (J == 1)
        SWL(J) = 1;    SWV(J) = 0;
    end;

    if (J == N)
        SWL(J) = 0;    SWV(J) = 1;
    end;
end;

% -----
% STEP OF READING Fj,Wj,Uj
% -----
% ===== Page No. 1 =====
for I = 1 : N,
    F(I) = 0; W(I) = 0; U(I) = 0;
    if (I == 1)
        F(I) = Lo; W(I) = 0; U(I) = 0;
    end;

    if (I == N)
        F(I) = Vf; W(I) = 0; U(I) = 0;
    end;
end;

% "-----"
% STEP OF READING THE COMP.FEED FLOWRATE ;(Vfc,Lco)
fprintf('\n-----');
Lco = [1.48,5.28,1.445,3.548,1.031,2.281,2.794,42.042,0];
Vfc = [0,0,0,0,0,0,0,0,7];

% -----
% STEP FOR READING CRITICAL PROPERTIES
% -----
TC = [304.1 ,190.4 ,305.4 ,369.8 ,408.2 ,425.2 ,507.5 ,658.2,647.3 ];
PC = [7380000,4600000,4880000,4250000,3650000,3800000,3010000,1820000,22120000 ];
ww = [0.177,0,0.1064,0.1538,0.1825,0.1954,0.2972,0.575 ,.3477 ];

% -----
% STEP FOR READING INTERACTION COEFFICIENTS
% -----

% 'FOR I = 1 TO 2
% 'FOR J = 1 TO NC
% 'IF I = J THEN Kij(I, J) = 0: GOTO 7

```

```

% 'READ Kij(I, J)
% '7 REM
% 'PRINT "Kij("; I; ","; J; ")="; Kij(I, J)
% 'NEXT J, I
% 'DATA -.025,.02,.06,.08,.08,.08,.08,.08,.08,.08
% 'DATA -.025,.12,.15,.15,.15,.15,.15,.15,.15,.15
AC1 = [ 1.98e+1, 1.925e+1, 5.409, -4.224, -1.39, 9.487, -4.413, -9.328, 3.224E+1];
AC2 = [ 7.344E-2 ,5.213E-2 ,1.781E-1 ,3.063E-1 ,3.847E-1 ,3.313E-1 ,5.82E-1 ,...
1.149 ,1.924E-3];

AC3 = [ -5.602E-5 ,1.197E-5 ,-6.938E-5 ,-1.586E-4 ,-1.846E-4 ,-1.108E-4 ,...
-3.119E-4 ,-6.347E-4,1.055E-5];

AC4 = [ 1.715E-8 ,-1.132E-8 ,8.713E-9 ,3.215E-8 ,2.895E-8 ,-2.822E-9 ,...
6.494E-8 ,1.359E-7 ,-3.596E-9];

% =====
% READING THE ANTIONE CONSTANTS
% =====
A2 = [ 3521.259, 1742.638, 2847.921, 3371.084, 3870.419, 4126.385, 5085.758, 6739.22,,7173.79
];
A3 = [ 455.869 , 452.974 , 434.898 , 414.488 , 409.949 , 409.5179, 382.794 , 360.26,389.4747];
% -----
% CALCULATION OF FEED'S CONCENTRATION (Xo,Yf)
% -----
for I = 1 : NC,
Xo(I) = Lco(I)/Lo;
Yf(I) = Vfc(I) / Vf;
end;
% -----
% THE STEP OF READING THE CONCENTRATION OF FEEDS;[Zi,j]
% -----
for I = 1 : NC,
for J = 1 : N,
Z(I, J) = 0;

if J == 1
Z(I, J) = Xo(I);
end;

if J == N
Z(I, J) = Yf(I);
end;

end;
end;
% -----
% END OF READING
% *****
% -----
% THE STEP OF CALCULATION THE ENTHALPIES OF FEEDS (HFi)
% -----

```

```

%%%%%%%%% GOSUB 250
step_250
% REM -----
% REM STEP OF INITIAL ASSUMTION OF VAPOR,LIQUID AND TEMPETAURE
PROFILES
% REM          (Vj,Lj,Tj)
% REM -----
% REM INTITIAL TERMINAL OF TEMP.& FLOW RATES FROM SHORT- CUT
METHOD IS:-
% REM -----
  Ti(1) = T0;
  Ti(N) = Tf;
for I = 1 : N,
  P(I) = p;
  Vi(I) = Vf;
  if (I ~= 1) && (I ~= N)
    DT1 = (Ti(N) - Ti(1)) / (N - 1);
    Ti(I) = DT1 + Ti(I - 1);
  end;

end;

for I = 1 : N,
  V(I) = Vi(I);
  T(I) = Ti(I);
end;

for Kf = 1 : N,
for If = 1 : NC,
  X(If, Kf) = Xo(If);
  Y(If, Kf) = Yf(If);
end;
end;

IT = 1;

%=====
%=====
step_15
%=====
%=====

% 15 REM %%%%%%%%%% BEGINING OF ITREATION PROCEDURE
%%%%%%%%%
% % REM -----
% fprintf('ITREATION NUMBER = %f',IT);
%
fprintf('=====
=====');
% fprintf('STAGE \t TEMP.\t V');

```

```

%
fprintf('_____
');
%
% for J = 1 : N,
% fprintf('%f\t %f\t %f\t',J,T(J),V(J));
% end;
% % -----
% % CALCULATION OF K-VALUES & ENTHALPIES FOR EACH STAGE
% % -----
% GOSUB 260
% % -----
% % CALCULATION OF CONCENTRATION PROFILES (Xi,j)
% % -----
% GOSUB 270
% % 'PRINT "-----"
% % 'PRINT " THE CONCENTRATION PROFILES of ALL COPONENTS; X(i,j)"
% % 'PRINT "-----"
% % 'FOR K = 1 TO N: PRINT SPC(8); K; : NEXT K: PRINT
% % 'PRINT "-----"
% % 'FOR I = 1 TO NC: PRINT ; C$(I); SPC(5);
% % 'FOR J = 1 TO N
% % 'PRINT USING "#.####"; X(I, J); SPC(5);
% % 'NEXT J: PRINT : NEXT I
% % 'PRINT "-----NORMALIZATION STEP-----"
% for J = 1 : N,
%   S1 = 0;
%   for I = 1 : NC,
%     S1 = S1 + X(I, J);
%   end;
%   SUMX(J) = S1;
%   fprintf('SUMX(%g)= %f',J,SUMX(J));
% end;
% % 'INPUT FG
% % 'PRINT "THE CONCENTRATION PROFILES OF ALL COMP. AFTER
NORMALIZATION X(i, j)"
% % 'PRINT "-----"
% % 'FOR K = 1 TO N: PRINT SPC(8); K; : NEXT K: PRINT
% % 'PRINT "-----"
% for I = 1 : NC;
%   %'PRINT C$(I); SPC(5);
%   for J = 1 : N,
%     X(I, J) = X(I, J) / SUMX(J);
%     %'PRINT USING "#.####"; X(I, J); SPC(5);
%   end;
%   %'PRINT
% end;
% % 'PRINT "-----"
% % 'PRINT "THE VAPOR MOLE FRACTION BEFOR NORMALIZATION IS Y(i,j) "
% % 'PRINT "-----"
% % 'FOR K = 1 TO N: PRINT SPC(8); K; : NEXT K
% % 'PRINT "-----"
% for I = 1 : NC,

```

```

%   %'PRINT C$(I); SPC(5);
%   for J = 1 : N,
%       Y(I, J) = Ke(I, J) * X(I, J);
%       % 'PRINT USING "#.#####"; Y(I, J); SPC(5);
%   end;
%   %'PRINT
% end;
%
% for J = 1 : N,
%     S1 = 0;
%     for I = 1 : NC,
%         S1 = S1 + Y(I, J);
%     end;
%     SUMY(J) = S1;
%     fprintf('SUMY = %f', SUMY(J));
% end;
% % 'PRINT "-----"
% % 'PRINT "THE Y(i,j) AFTER NORMALIZATION IS :-"
% % 'PRINT "-----"
% % 'FOR K = 1 TO N: PRINT SPC(9); K; : NEXT K
% % 'PRINT "-----"
% for I = 1 : NC,
%     %'PRINT C$(I); SPC(5);
%     for J = 1 : N,
%         Y(I, J) = Y(I, J) / SUMY(J);
%         % 'PRINT USING "#.#####"; Y(I, J); SPC(5);
%     end;
%     %'PRINT
% end;
% % -----
% % THE END OF NORMALIZATION STEP
% % *****
% % ESTIMATING LIQUID FLOWRATE
% % -----
% for J = 1 : N,
%     S = 0;
%     for M = 1 : J,
%         S = S + F(M) - U(M) - W(M);
%     end;
%     if J == N
%         L(J) = S - V(1);
%     else
%         L(J) = V(J + 1) + S - V(1);
%     end;
% end;
%
% for I = 1 : N
%     fprintf('L= %g', L(I));
% end;
% % -----
% % ESTIMATION OF THE NEW LIQUID FLOW RATES BY THE SUM-RATE
% % RELATION
% % -----

```

```

% for J = 1 : N,
%   L(J) = L(J) * SUMX(J);
% end;
% fprintf('-----');
% % ----- THE NEW VAPOR FLOW RATE-----
% for J = 1 : N,
%   S = 0;
%   for M = J : N,
%     S = S + F(M) - W(M) - U(M);
%   end;
%   V(J) = L(J - 1) - L(N) + S
%   if J == 1
%     V(J) = -L(N) + S;
%   end;
% end;
%
%
% fprintf(' THE NEW LIQ.AND VAP. FLOW RATE');
% fprintf('-----');
% fprintf('Vi= \tV= \tL=');
% fprintf('-----');
% for J = 1 : N,
%   fprintf('%f \t %f \t %f',Vi(J), V(J), L(J));
% end;
% % -----
% % ----- BEGAIN OF ENARGY BALANCE-----
% % THE STEP OF CALCULATION OF THE COEFFICIENTES OF TRIDIAGONAL
% % MATRIX
% % THIS MATRIX ALSO KNOWN AS JACOBIAN MATRIX
% % THIS STEP CONTIANS THE SOLUTION OF THIS MATRIX BY
% % GSUSS METHOD FOR OBTAINING THE NEW TEMPERATURE PROFILES(Tj)
% % -----
% fprintf('-----');
% fprintf(' BEGAIN OF ENARGY BALANCE');
% fprintf('-----');
%
% GOSUB 280
%
% % -----
% % CALCULATION OF NEW TEMPERATURE (TNj)
% % -----
% for J = 1 : N,
%   TN(J) = T(J) + DT(J);
%   fprintf('STAGE = %f \t T NEW = %f',J,TN(J));
% end;
% % -----
% % CONVERGENCE CHECK STEPS
% % -----
%   RR = 0;
%   S2 = 0;
%   S3 = 0;
%   for J = 1 : N,
%     RR = RR + (TN(J) - T(J)) ^ 2;

```

```

% end;

while ((RR > ER) && (IT < 500 ))
    fprintf('\n ERROR = %f \t ITRATION NUMBER = %f ',RR,IT);
    % 'INPUT RFD
    fprintf('\n*****');
    fprintf('\nTHE ITRATION MUST BE RETURNED');
    fprintf('\n*****');
    IT = IT + 1;
    for J = 1 : N,
        T(J) = TN(J);
    end;
    step_15

end;
%%%%%% GOSUB 290
% -----
fprintf('\n DIVERGEN ACCUR ');
fprintf('\n -----');
% -----
% THE CONVEGENCE ACCURE
% -----
step_290

% %===== ((1))=====
% plot(Z,Y(:,1),'-bs','LineWidth',1,...
%         'MarkerEdgeColor','k',...
%         'MarkerFaceColor','r',...
%         'MarkerSize',3)
% hold,
%
% plot(Z,Y(:,2*N+2),'-d','LineWidth',1,...
%         'MarkerEdgeColor','k',...
%         'MarkerFaceColor','g',...
%         'MarkerSize',5)
%
% plot(Z,Y(:,2*N+3),'-*','LineWidth',1,...
%         'MarkerEdgeColor','k',...
%         'MarkerFaceColor','b',...
%         'MarkerSize',5)
%
% h = legend('j_1(z)','u(z)','\psi_o(z)',2);
%
%
% % title(['At N =',num2str(N),' , \rho = ',num2str(ro), ' , C_i = ',num2str(Cc),...
% %         ' , \psi_1_i = ',num2str(Epsai1)])
% grid on
% xlabel('z')

```

```
% ylabel('')
```

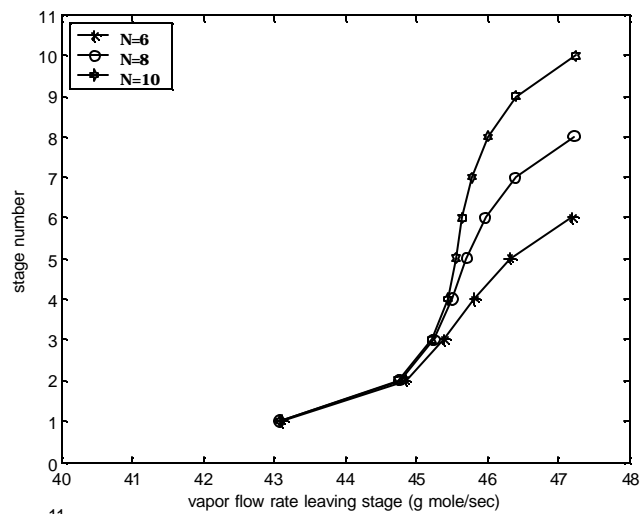
```
f_time = etime(clock,t111);
```

```
fprintf('\n\nThe final time is = %f second',f_time);
```

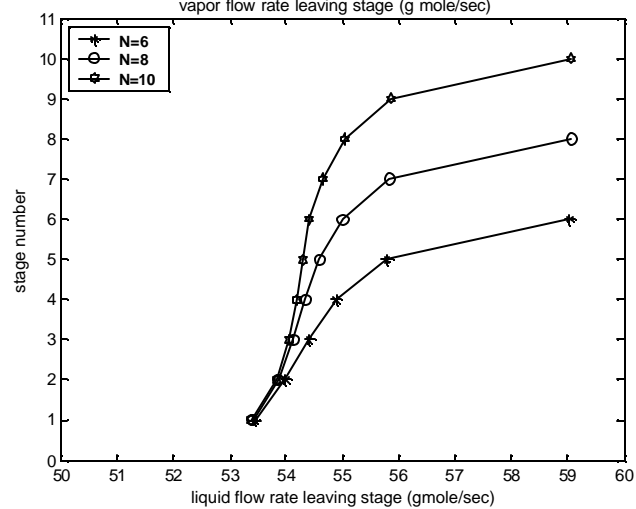

Appendix C

Figures of results obtained in chapter four:

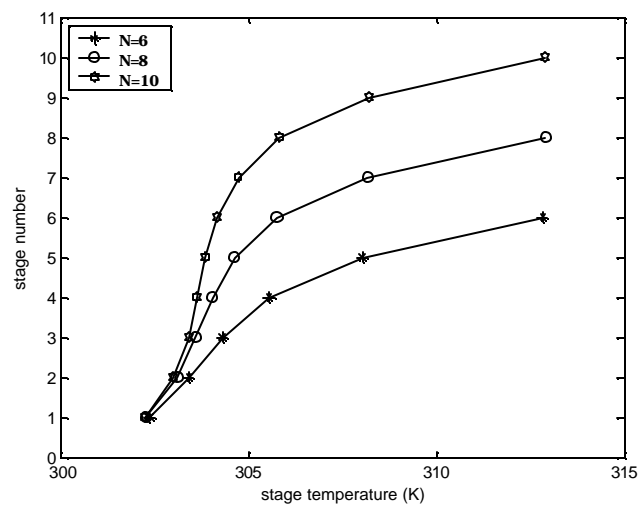
- For absorber system B and C.
- For stripper system B.
- For absorption – stripping network system B.



a)



(b)



(c)

Fig (1) Effect of change number of stage on the vapor, liquid flow rates and temperature profiles for absorber of system B

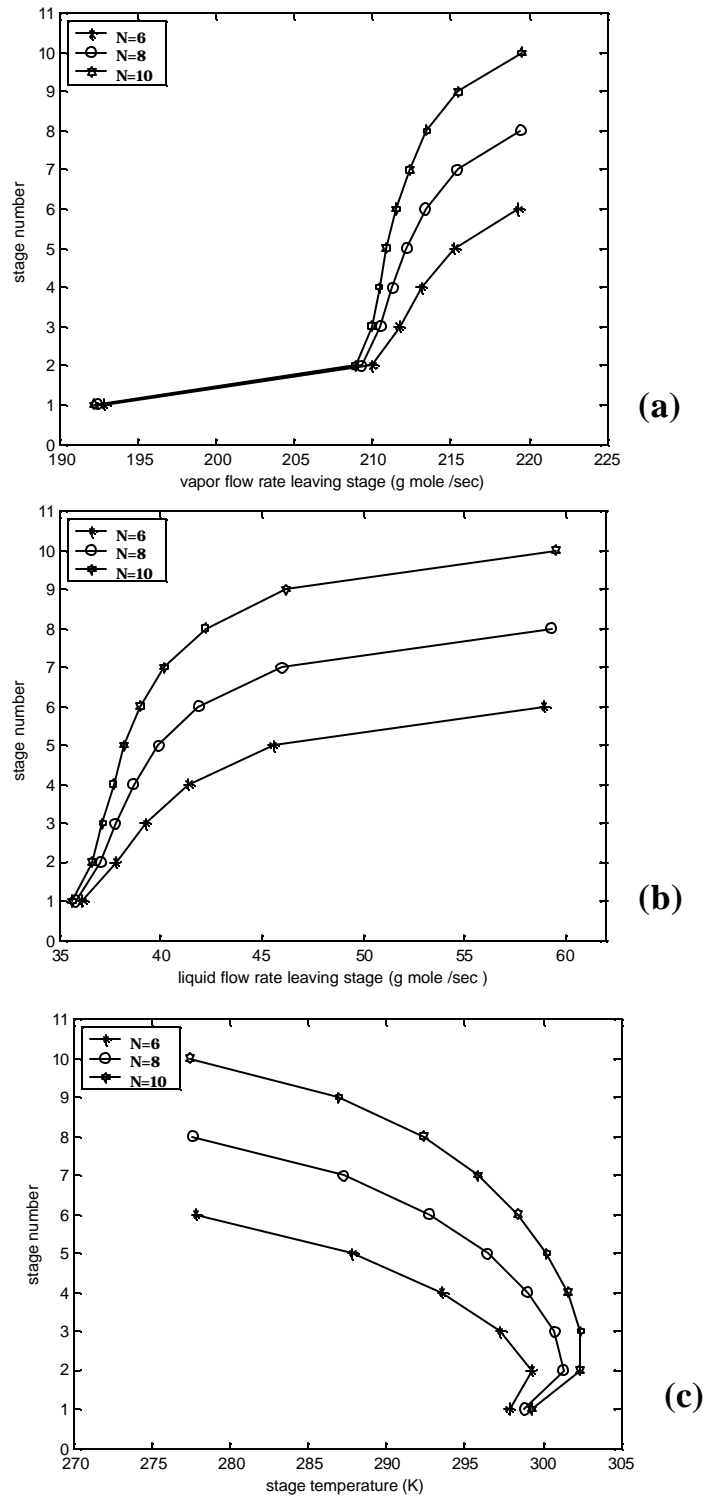
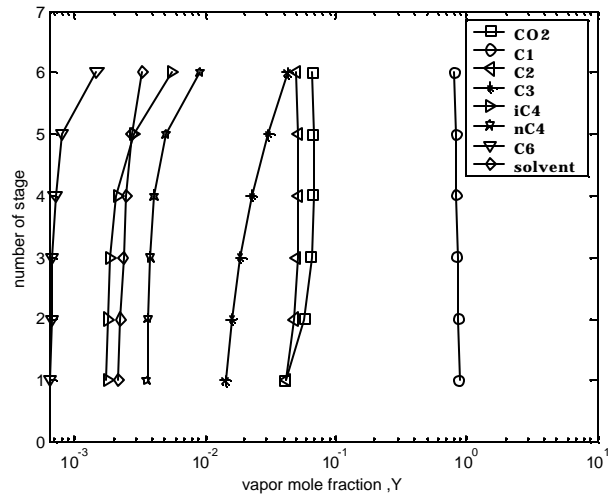
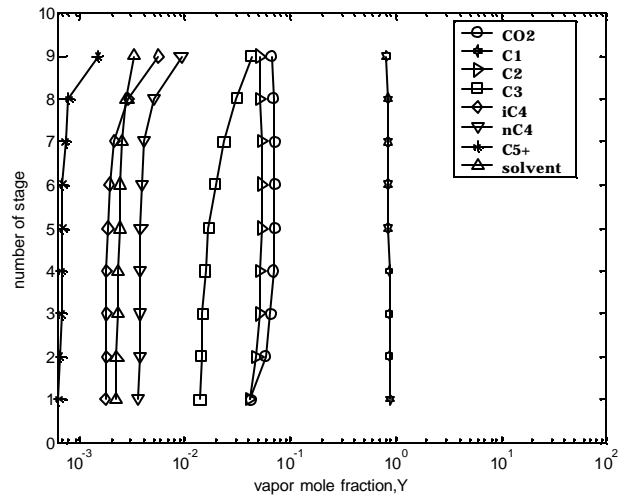


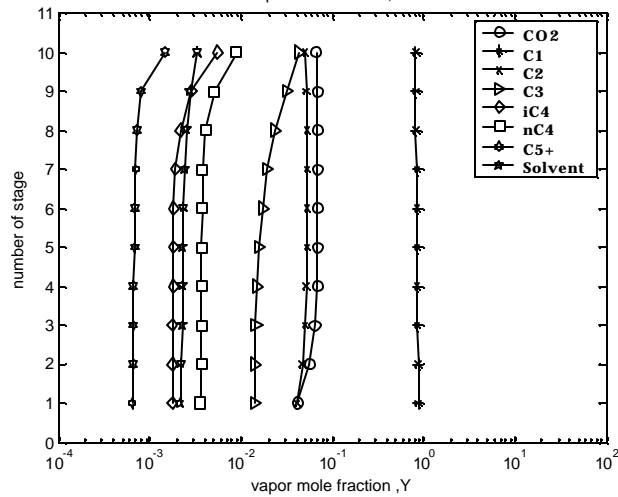
Fig (2) Effect of change number of stage of vapor, liquid flow rate profiles and temperature profile for absorber system C



N=6
(a)

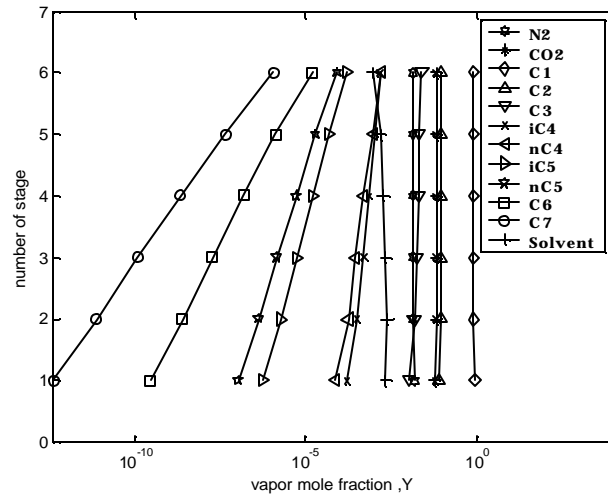


N=8
(b)

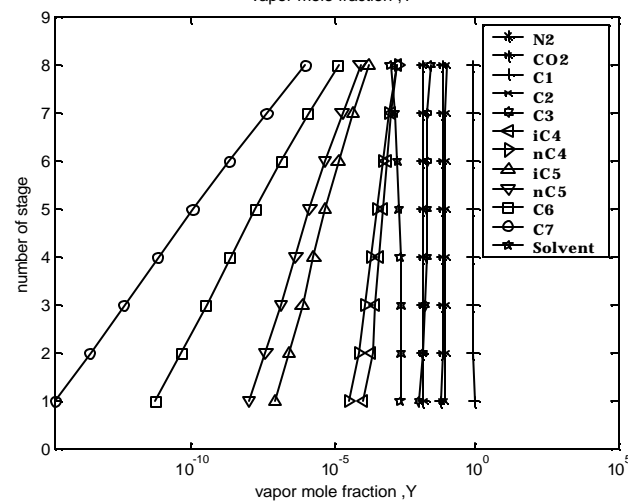


N=10
(c)

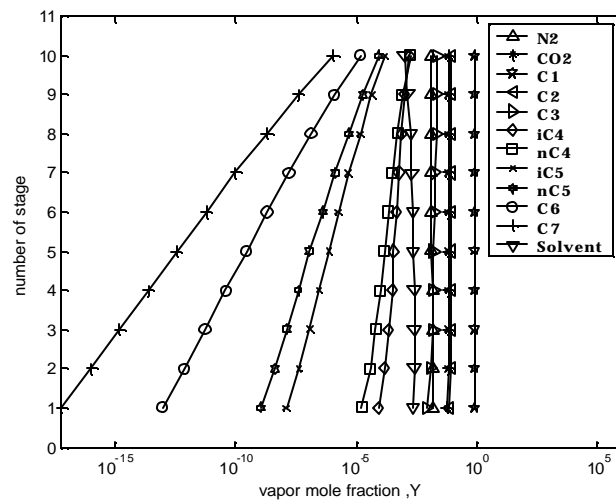
Fig (3) Effect of change number of stage on the vapor mole fraction of absorber system B



**N=6
(a)**



**N=8
(b)**



N=10(c)

Fig (4) Effect of change number of stage on the vapor mole fraction absorber system C

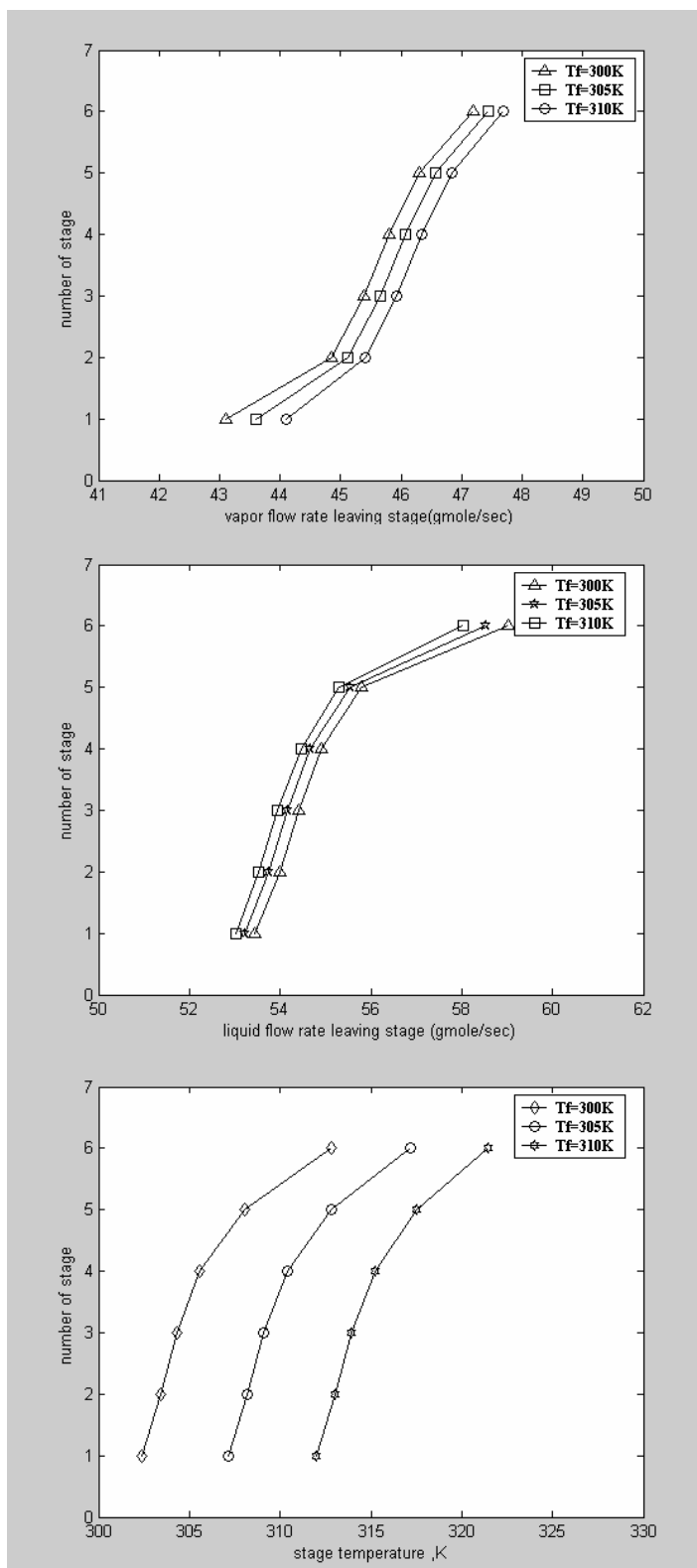


Fig (5) Effect of change wet gas feed temperature on vapor, liquid flow rate profiles and temperature profiles of absorber system B

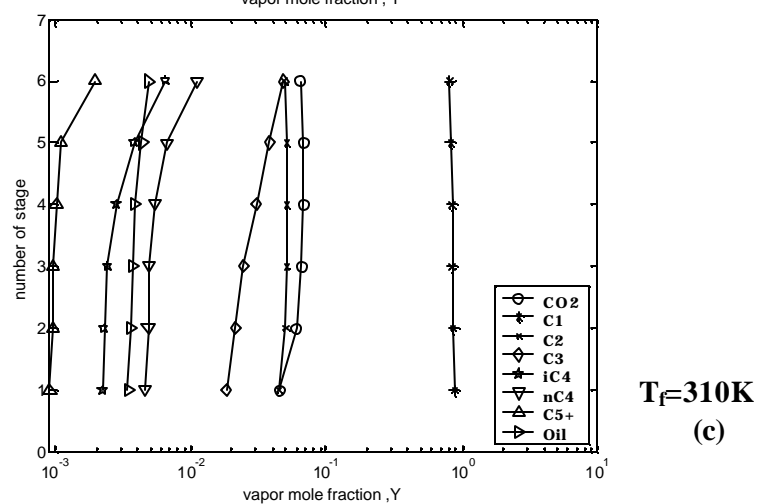
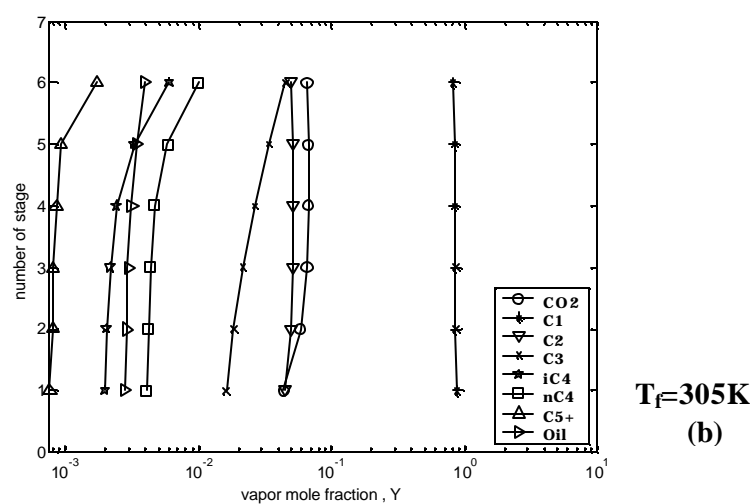
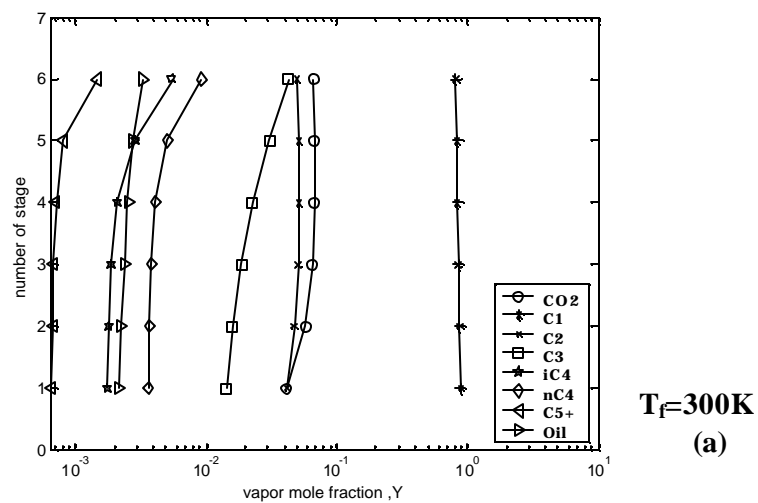
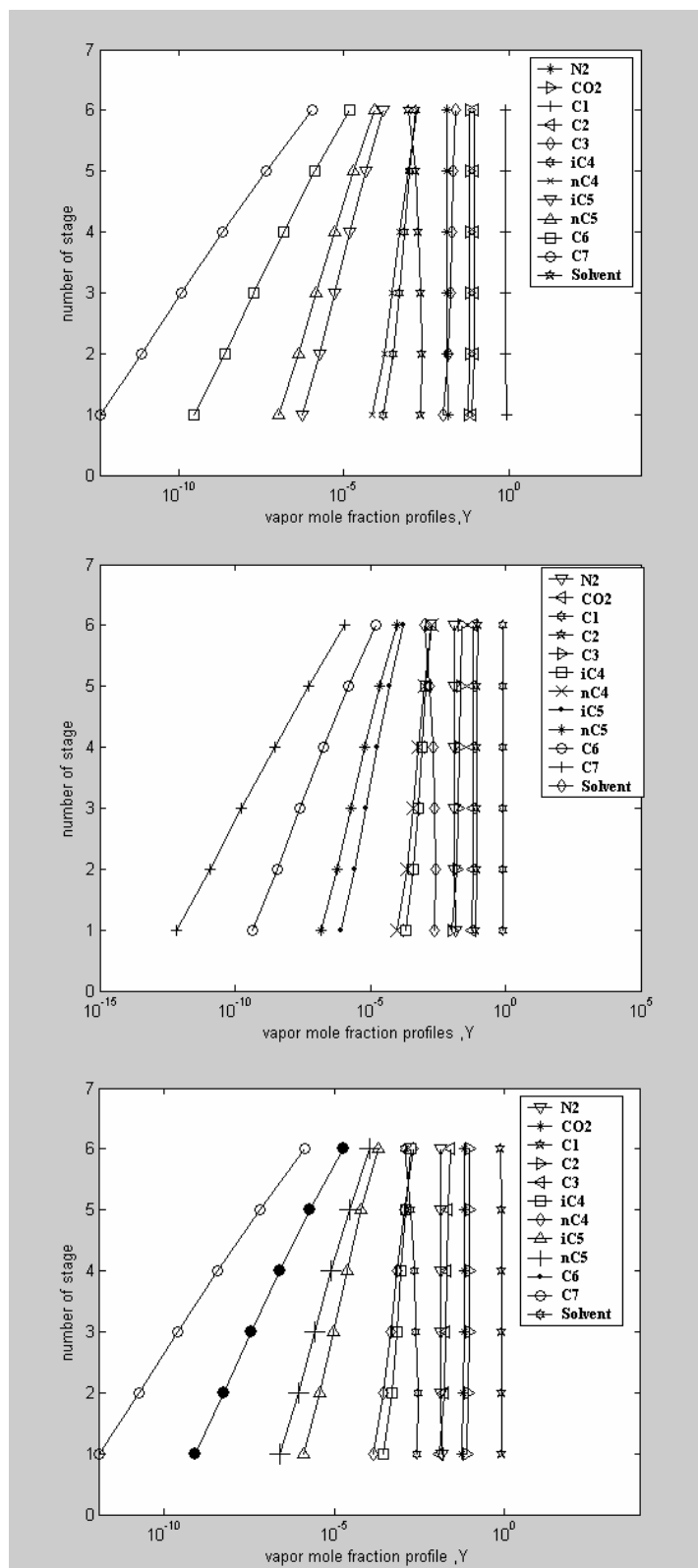


Fig (6) Effect of change wet gas temperature on the fraction mole fraction of absorber system B



$T_f=255.3722K$
(a)

$T_f=260K$
(b)

$T_f=265K$
(c)

Fig (6) Effect of change wet gas feed temperature on the vapor mole fraction of absorber system C

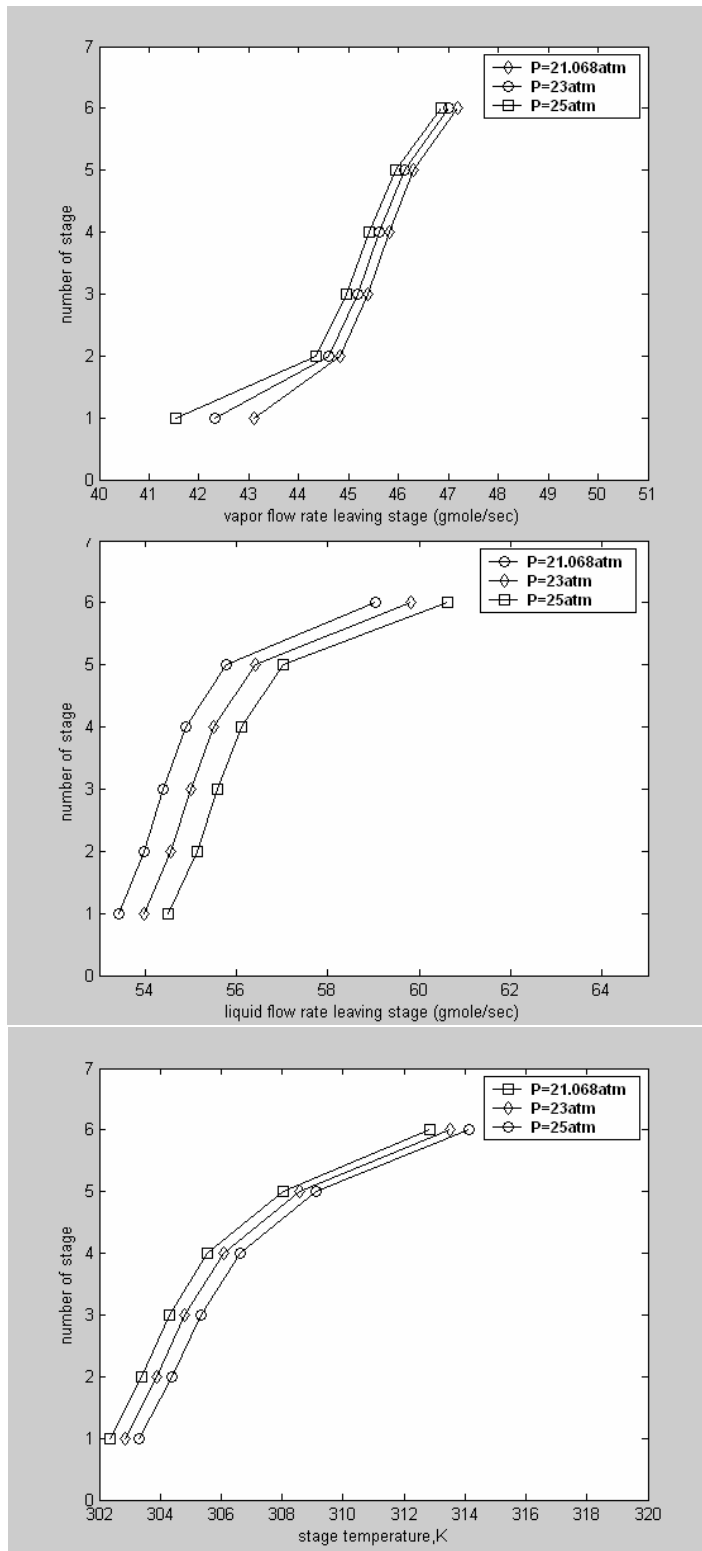
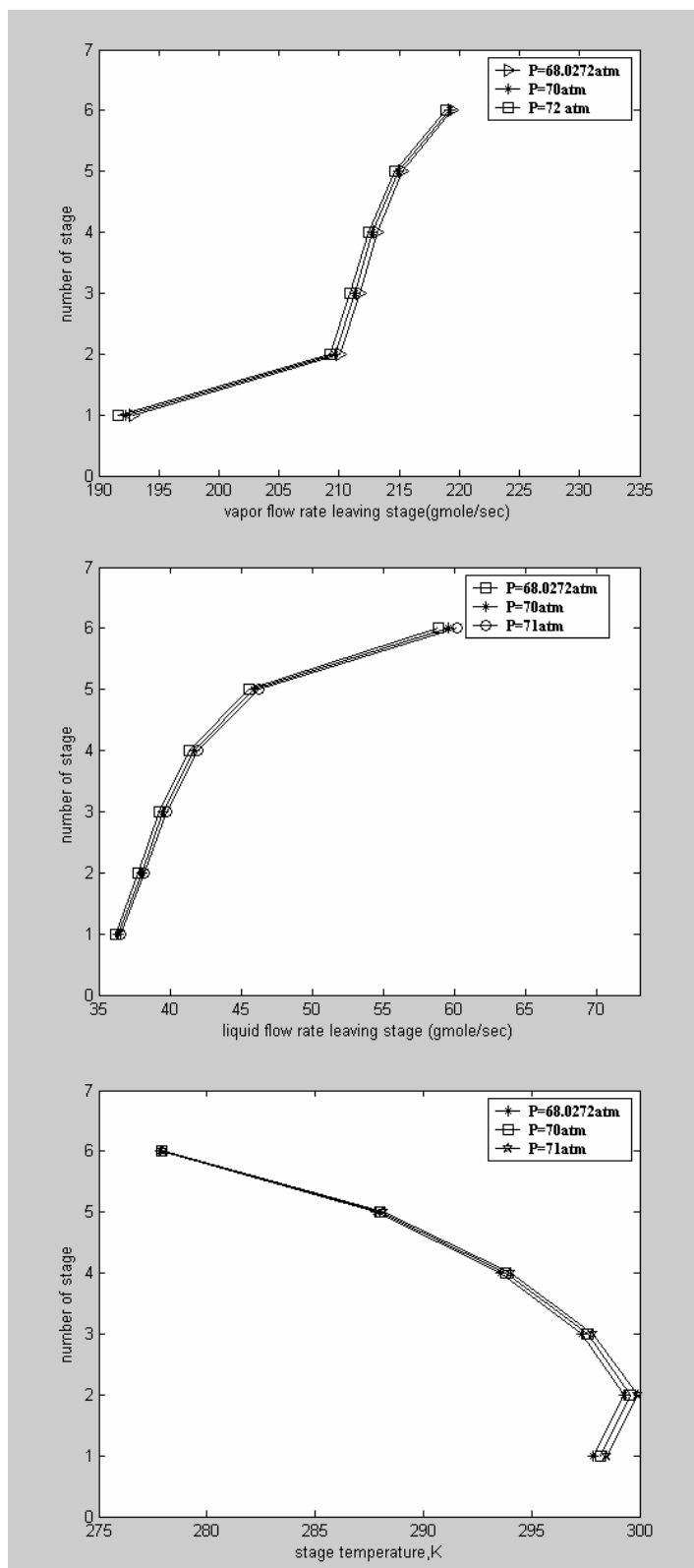


Fig (6) Effect of change operating pressure on the vapor, liquid flow rate profiles and temperature profiles system B

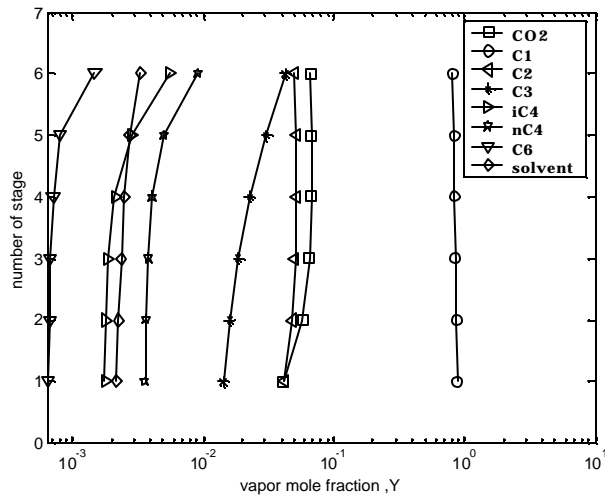


(a)

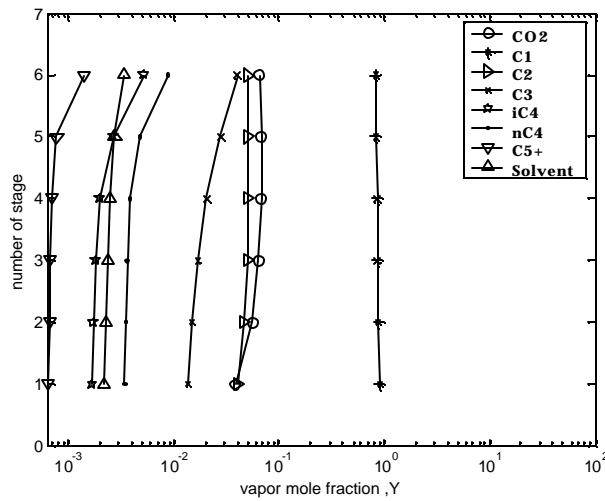
(b)

(c)

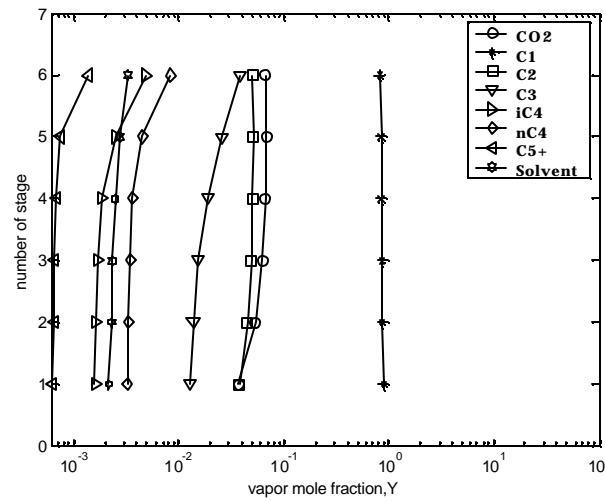
Fig (8) Effect of change operating pressure on the vapor, liquid flow rate profiles and temperature profile of the absorber system C



P=21.06 atm
(a)



P=23atm
(b)



P=25atm
(c)

Fig (9) Effect of change operating pressure on the vapor mole fraction of absorber system B

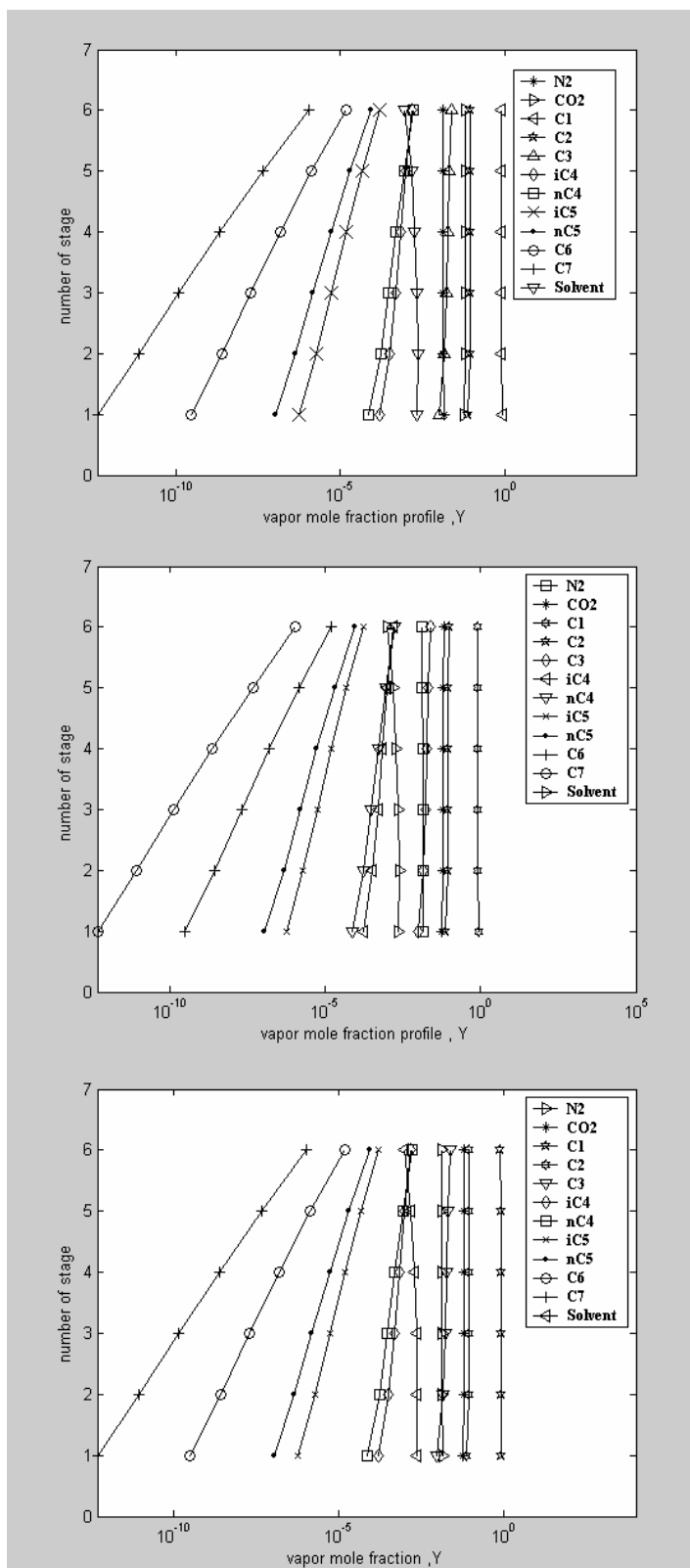


Fig (10) Effect of change operating pressure on the vapor mole fraction of the absorber system A

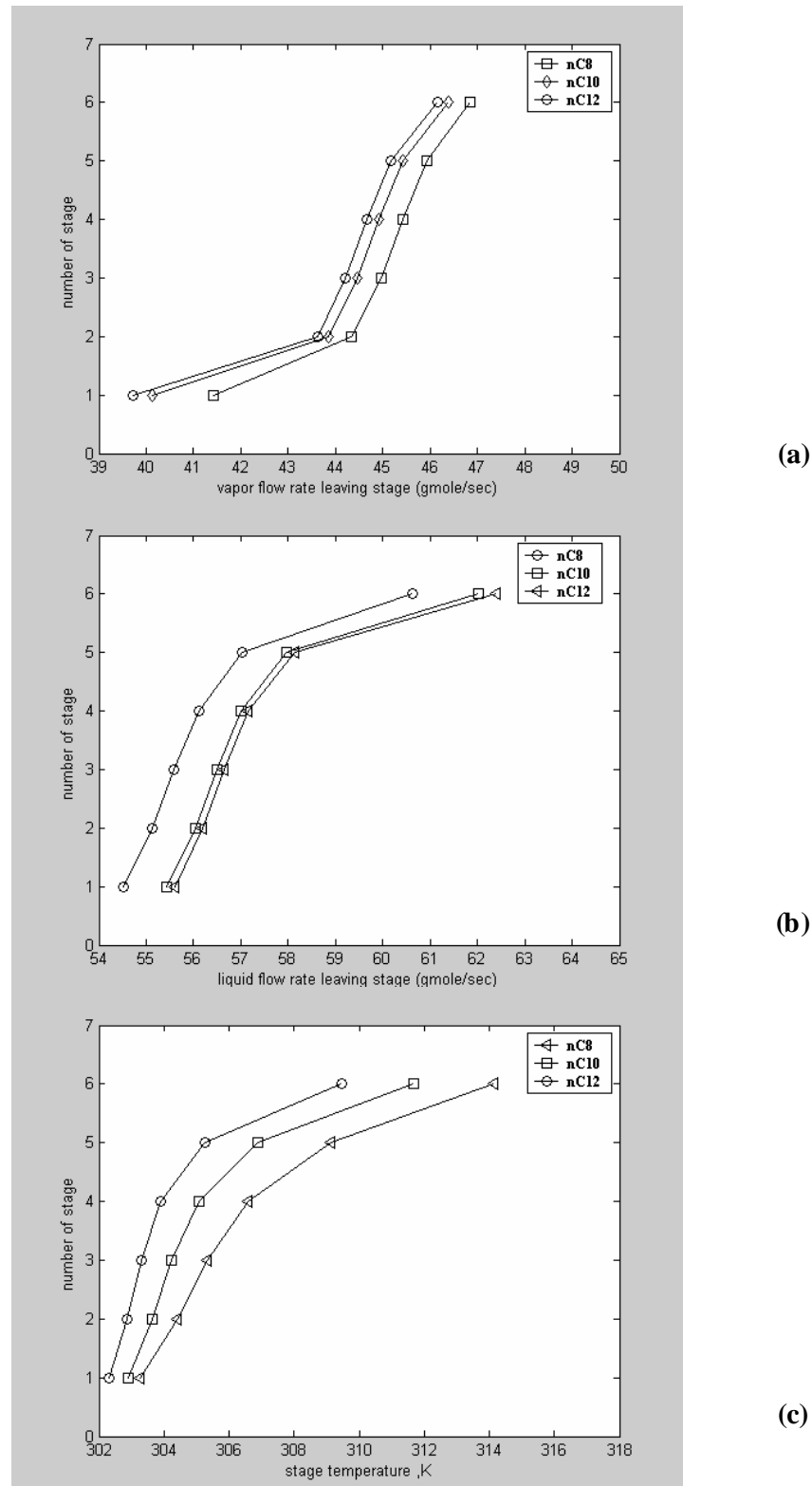


Fig (11) effect of change Solvent on the vapor, liquid flow rate profiles and temperature profiles of absorber system B

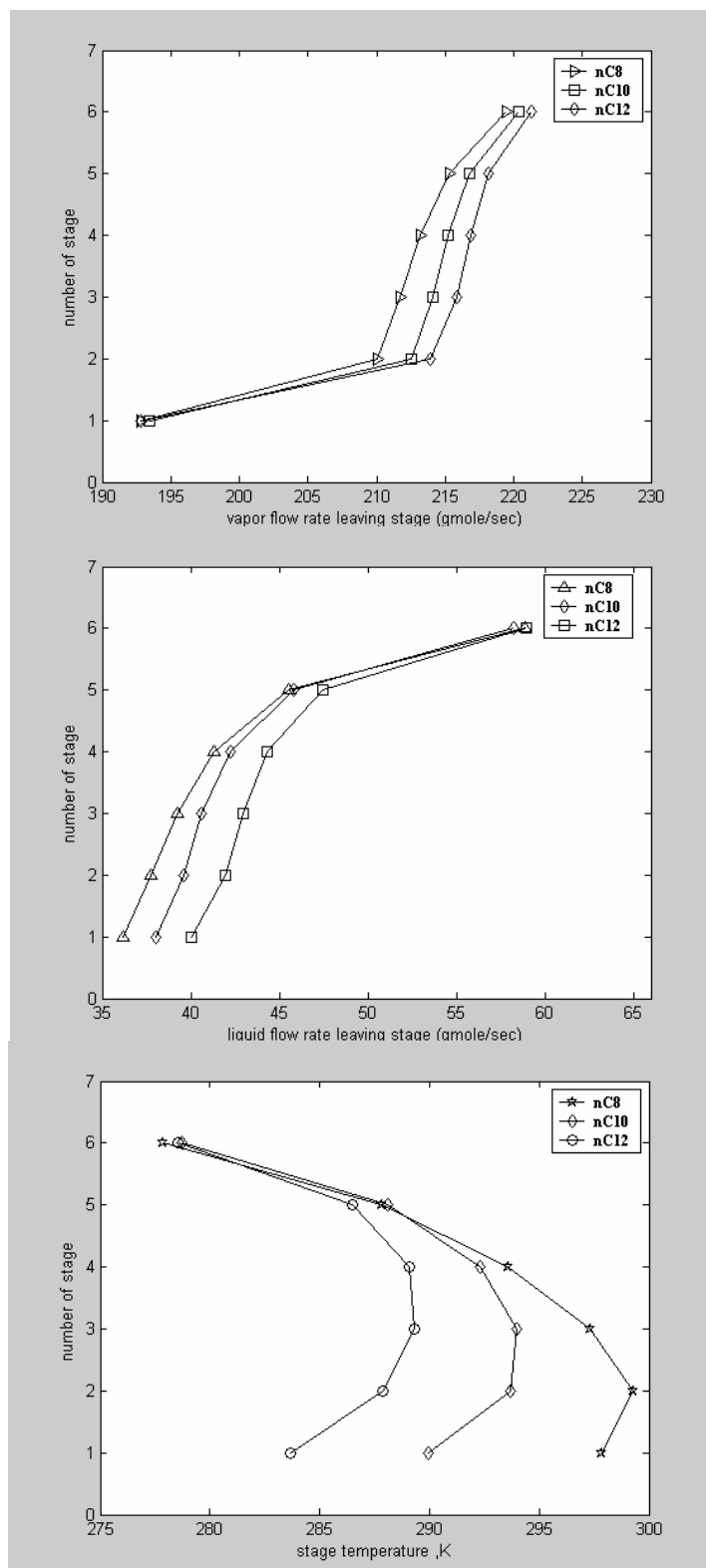


Fig (12) Effect of change solvent on the vapor, liquid flow rate profiles and temperature profiles of absorber system C

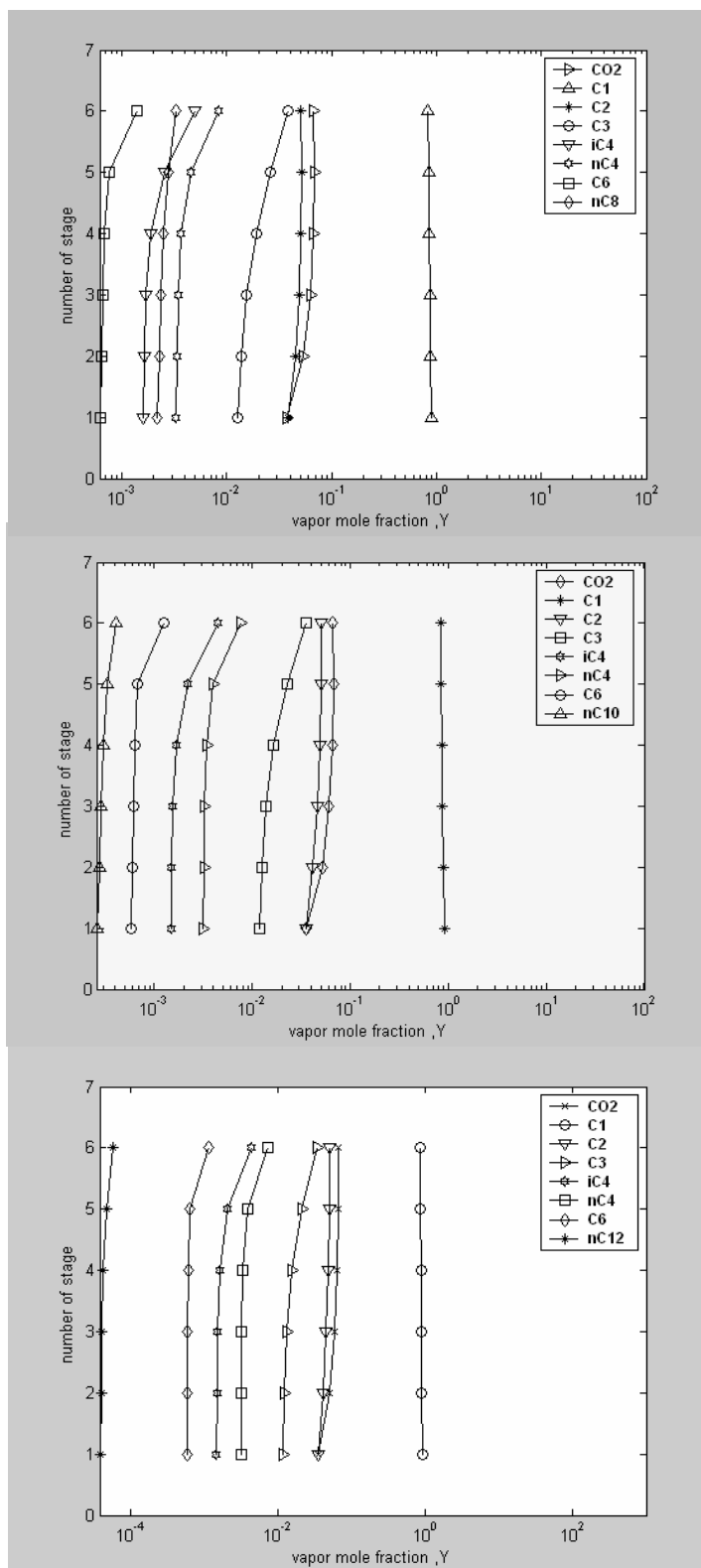
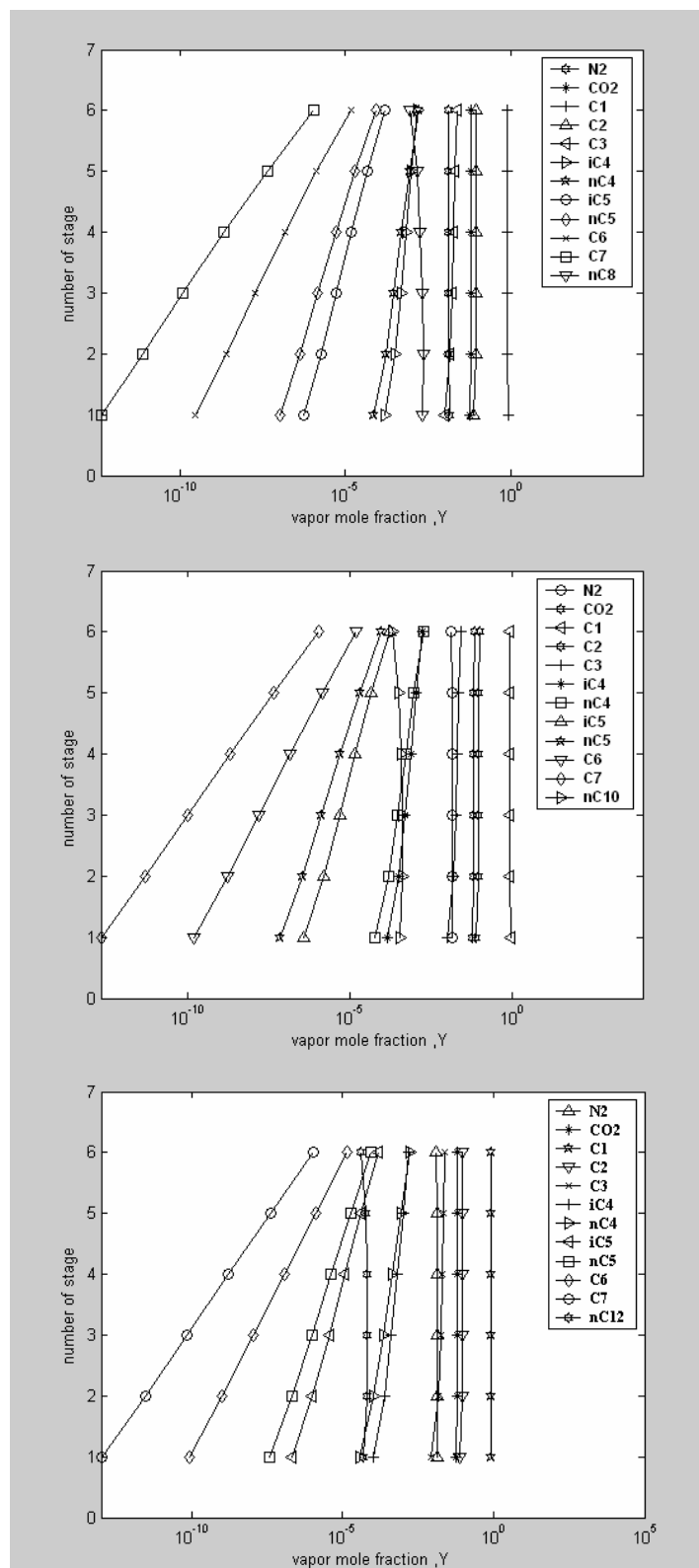


Fig (13) effect of change solvent on the vapor mole fraction of absorber system B



nC_8
(a)

nC_{10}
(b)

nC_{12}
(c)

Fig (14) effect of change solvent on the vapor mole fraction of absorber system C

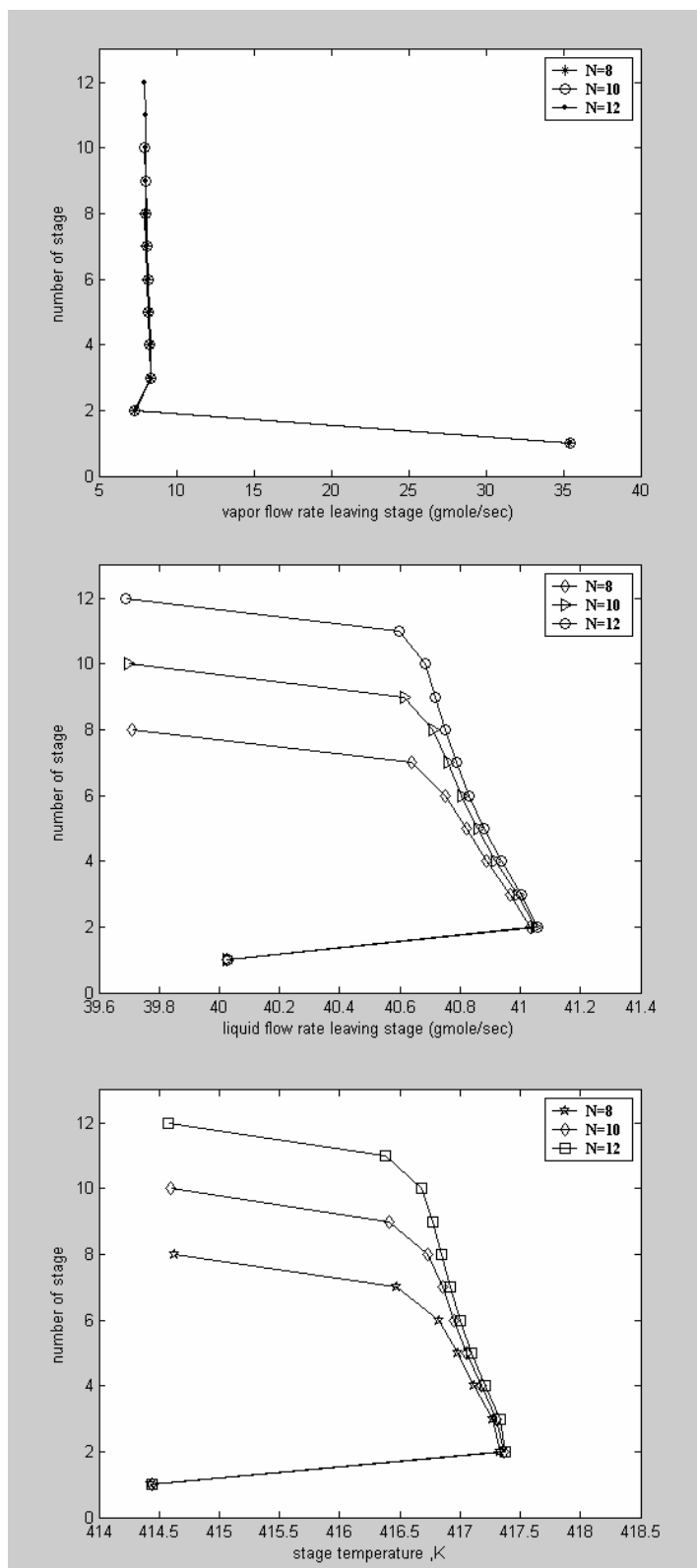
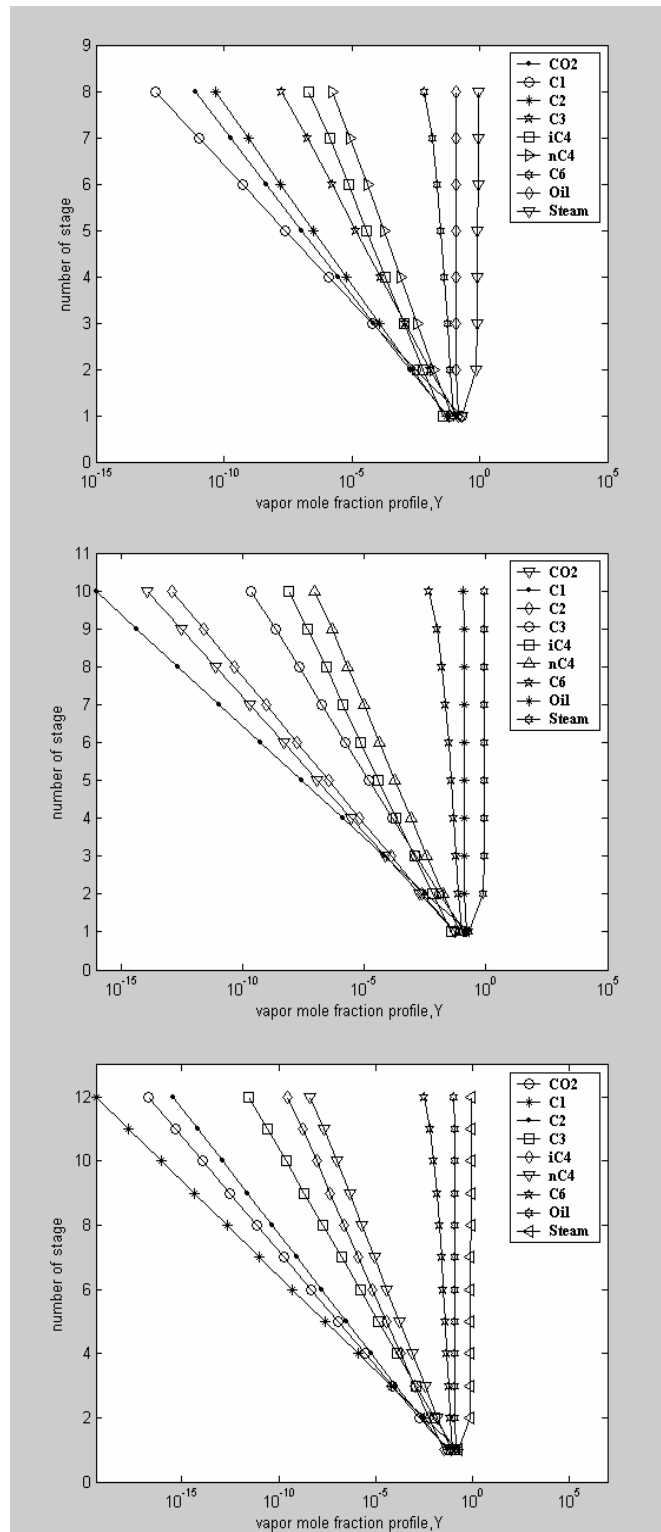


Fig (15) Effect of change number of stage on the vapor, liquid flow rate profiles and temperature profiles of the stripper system B



$N=8$
(a)

$N=10$
(b)

$N=12$
(c)

Fig (16) Effect of change number of stage on the vapor mole fraction on the stripper system B

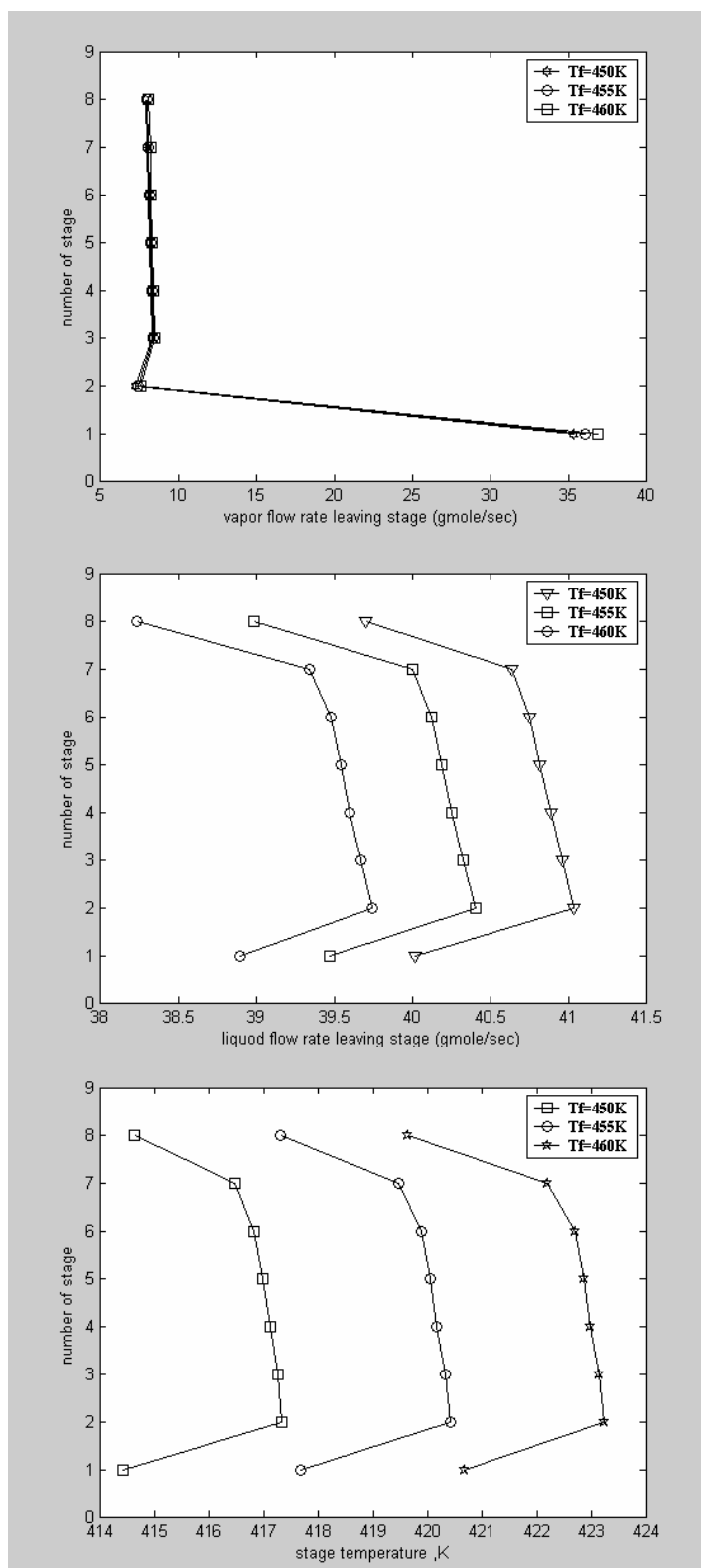


Fig (17) Effect of change rich oil temperature on the vapor, liquid flow rate profiles and temperature profiles of stripper system B

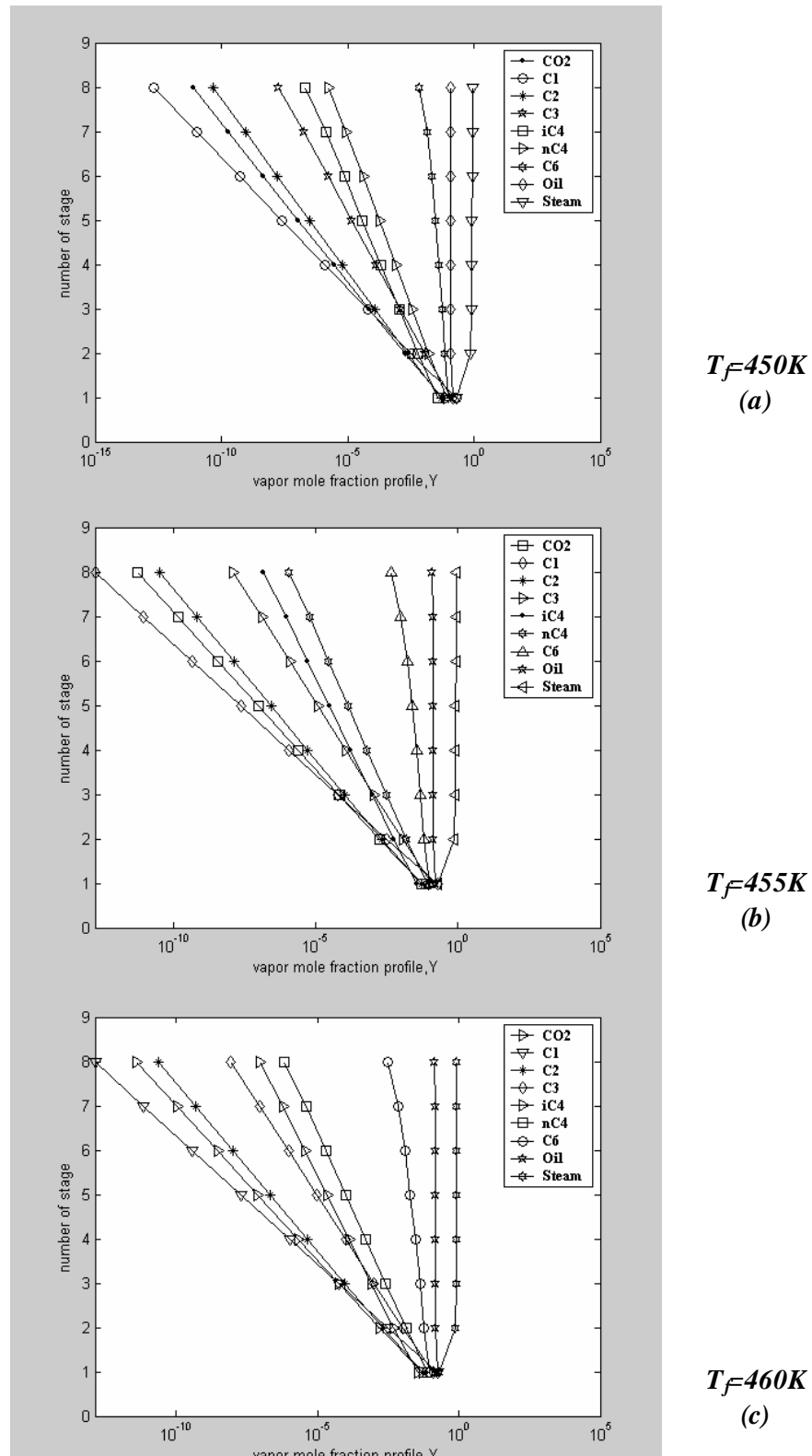


Fig (18) Effect of change rich oil temperature on the vapor mole fraction of stripper system B

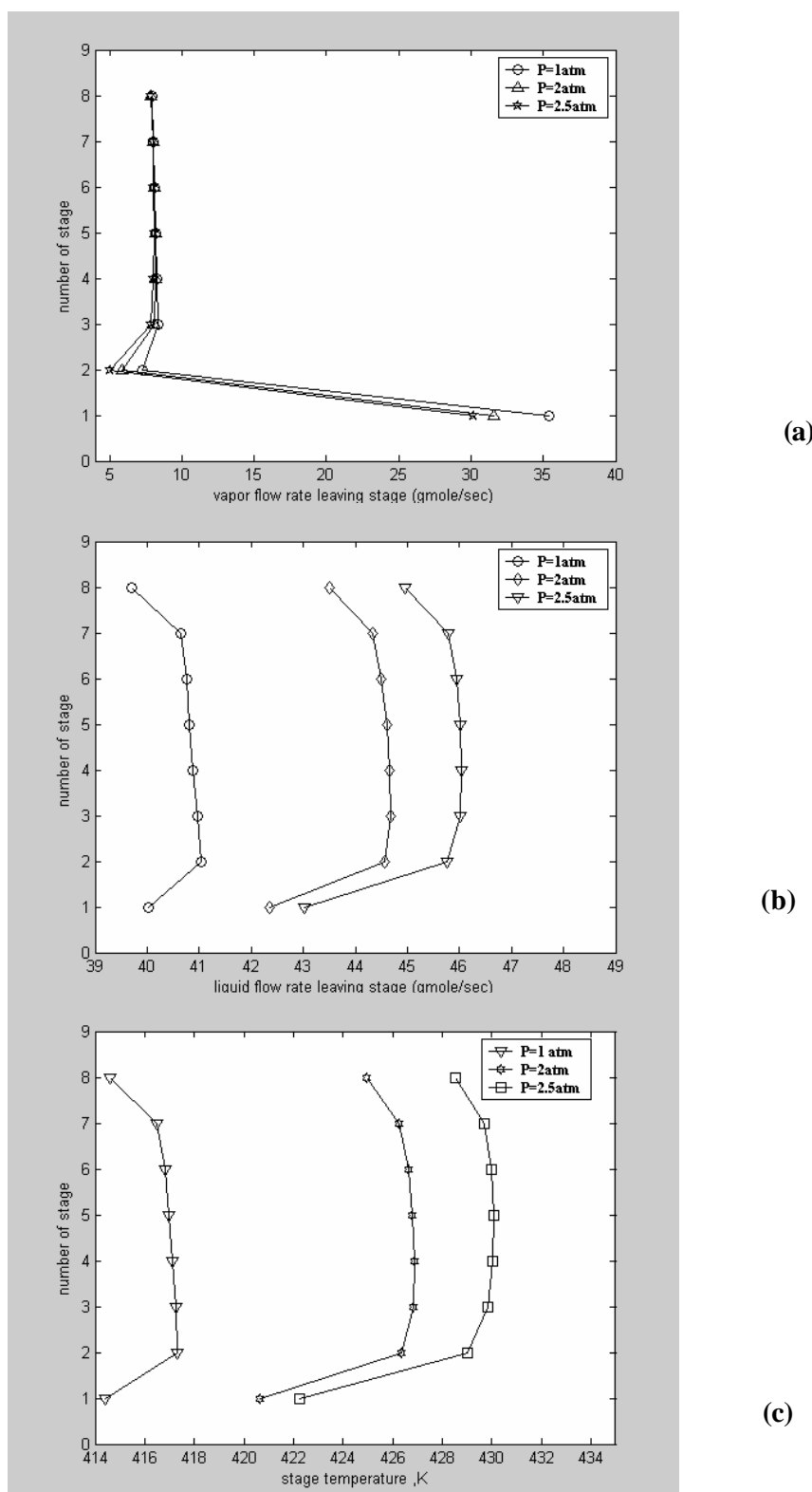
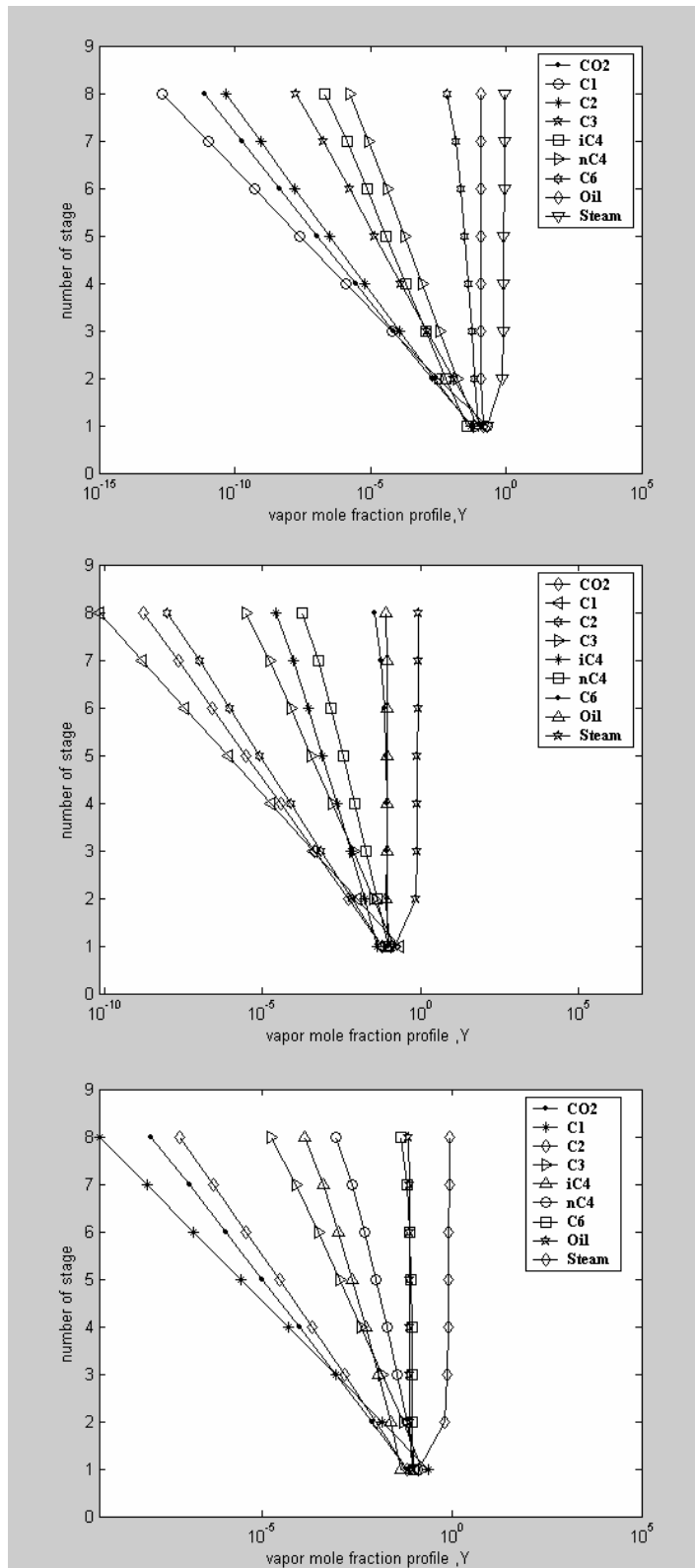


Fig (19) Effect of change operating pressure on the vapor, liquid flow rates profiles and temperature profiles of the stripper system B

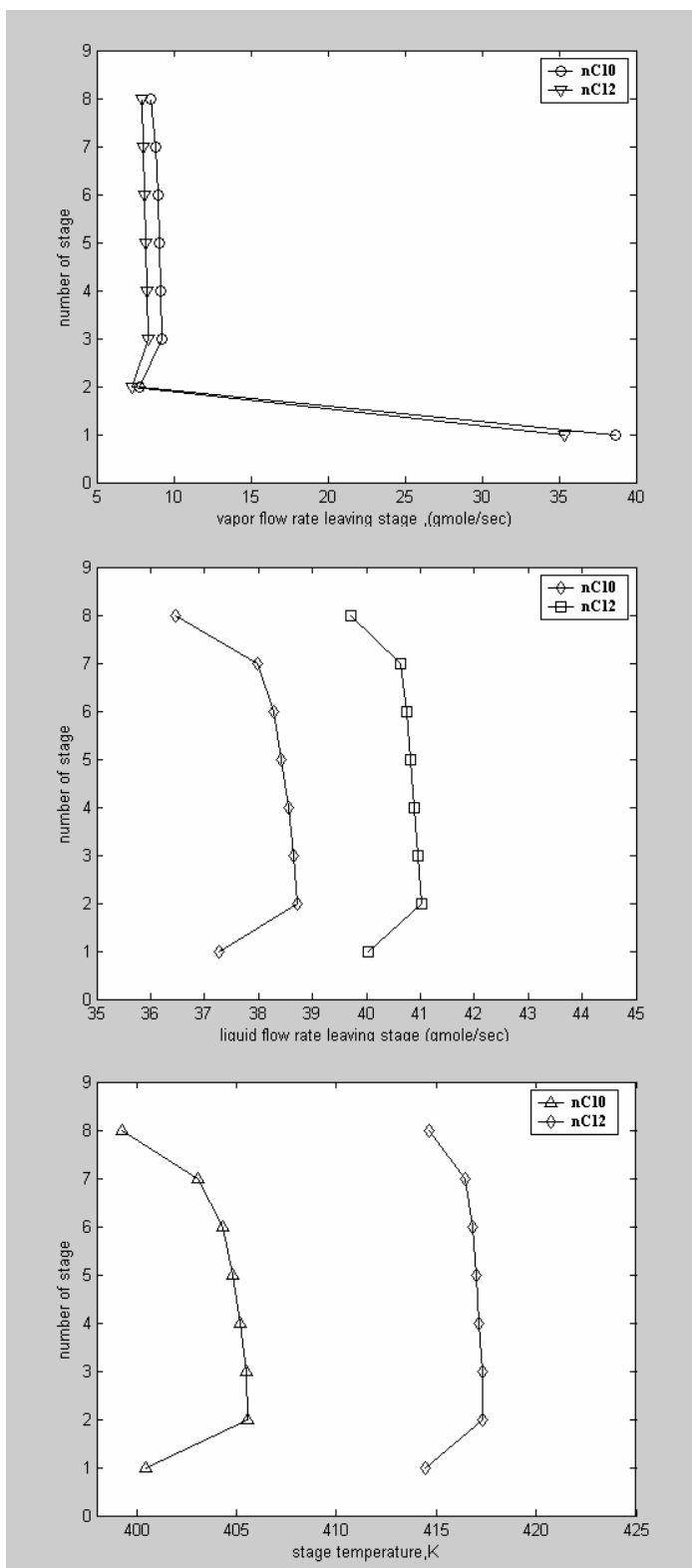


$P=1atm$
(a)

$P=2atm$
(b)

$P=2.5atm$
(c)

Fig (20) Effect of change operating pressure on the vapor mole fraction of stripper system B



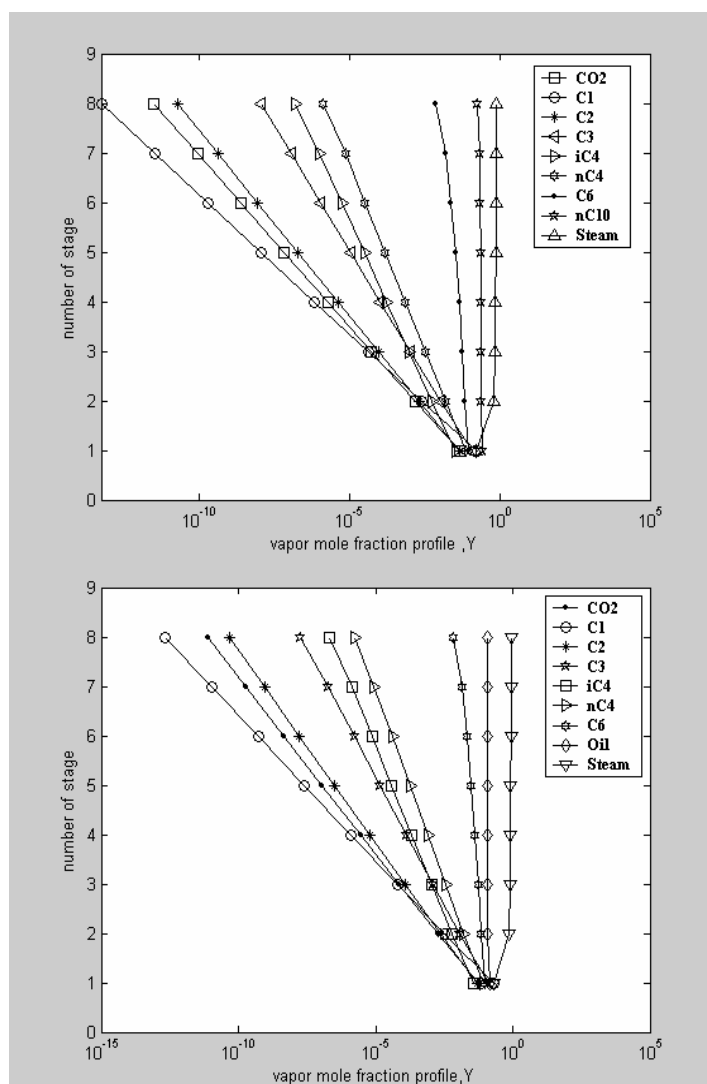


Fig (22) Effect of change solvent in the vapor mole fraction of Stripper system B

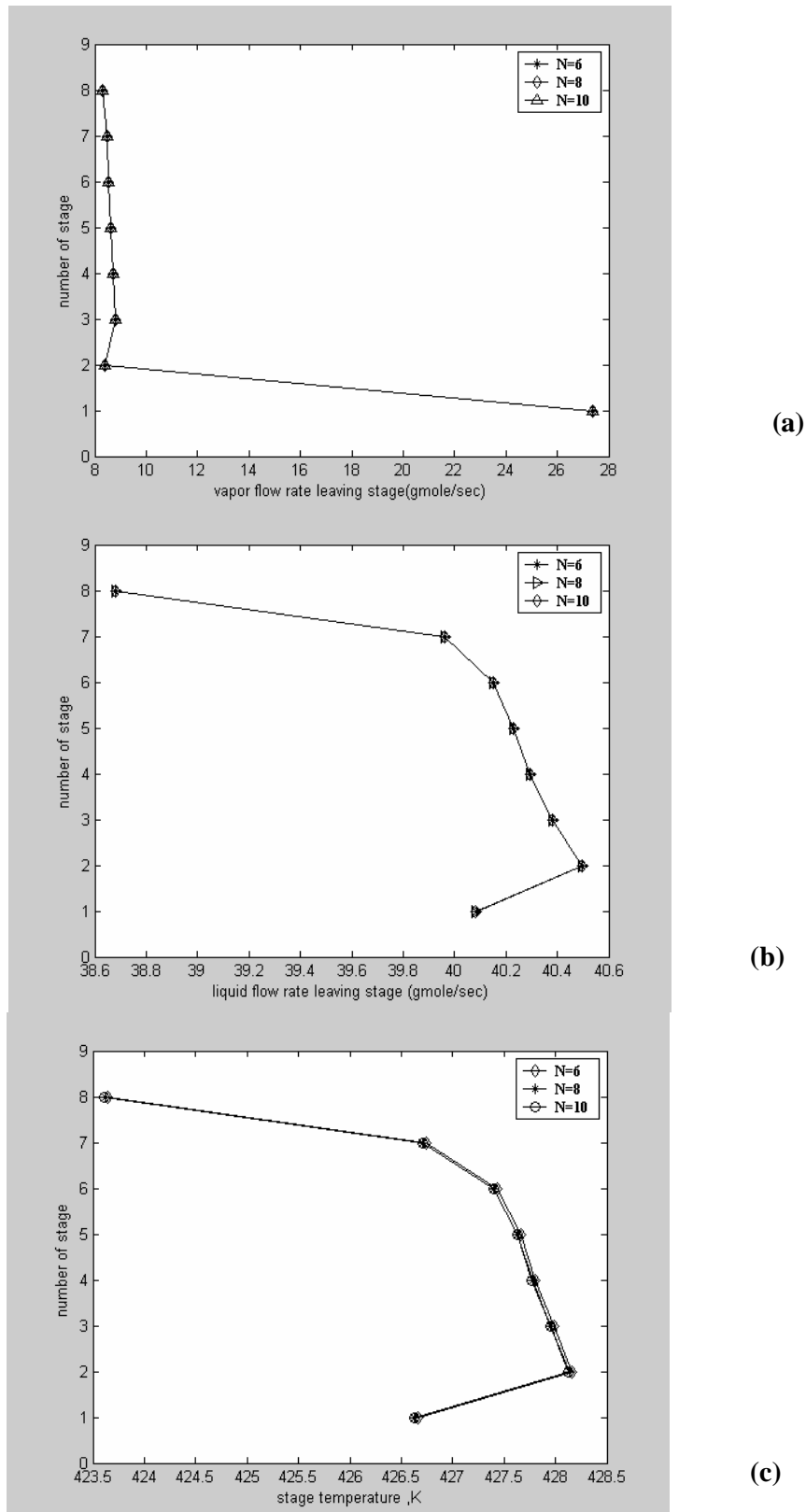


Fig (23) Effect of change number of stage of the absorber on the vapor, liquid flow rate and temperature profiles of the stripper on the network system B

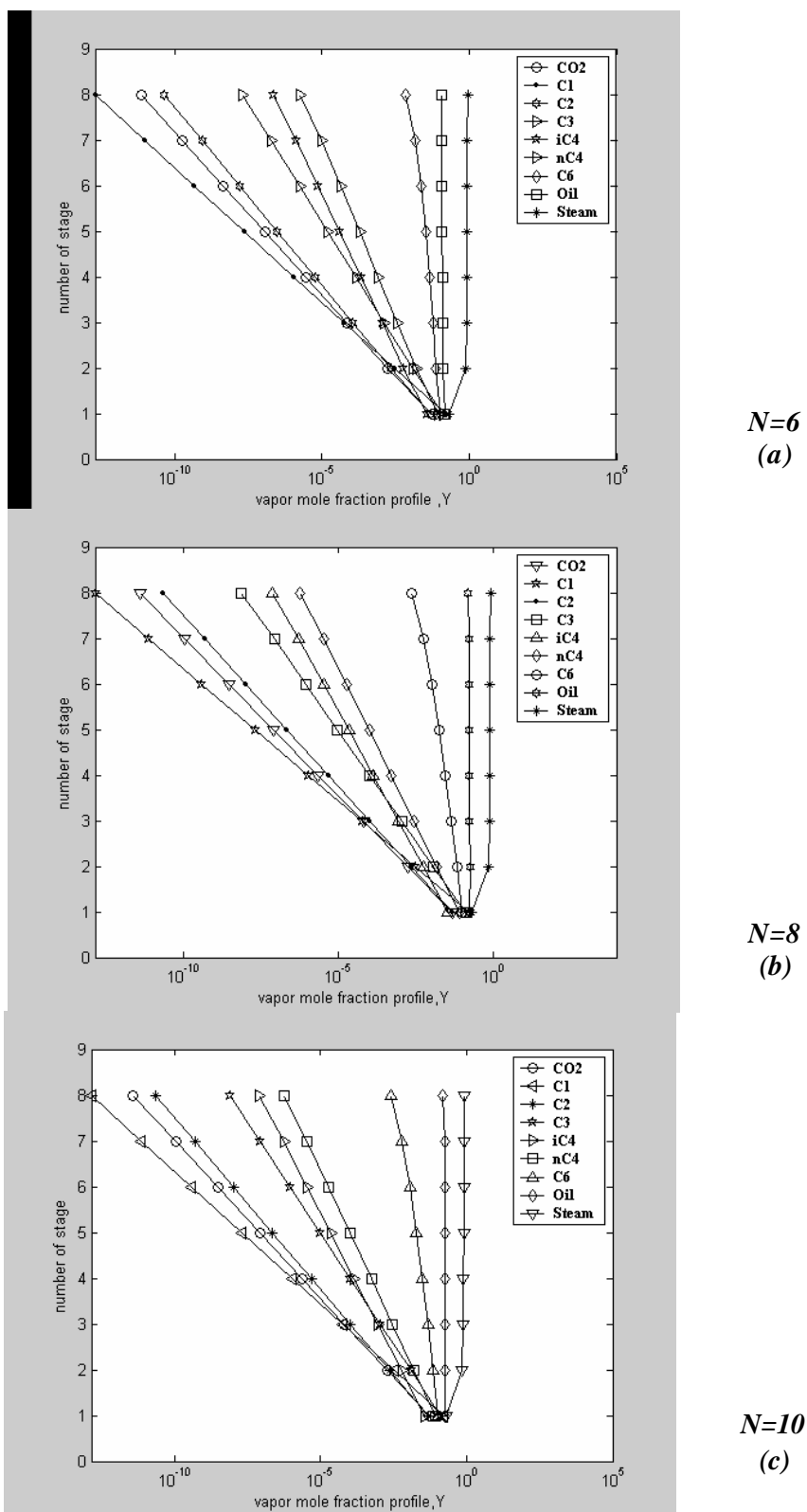


Fig (24) Effect of change number of stage of the absorber in the vapor mole fraction of the stripper on the network system B

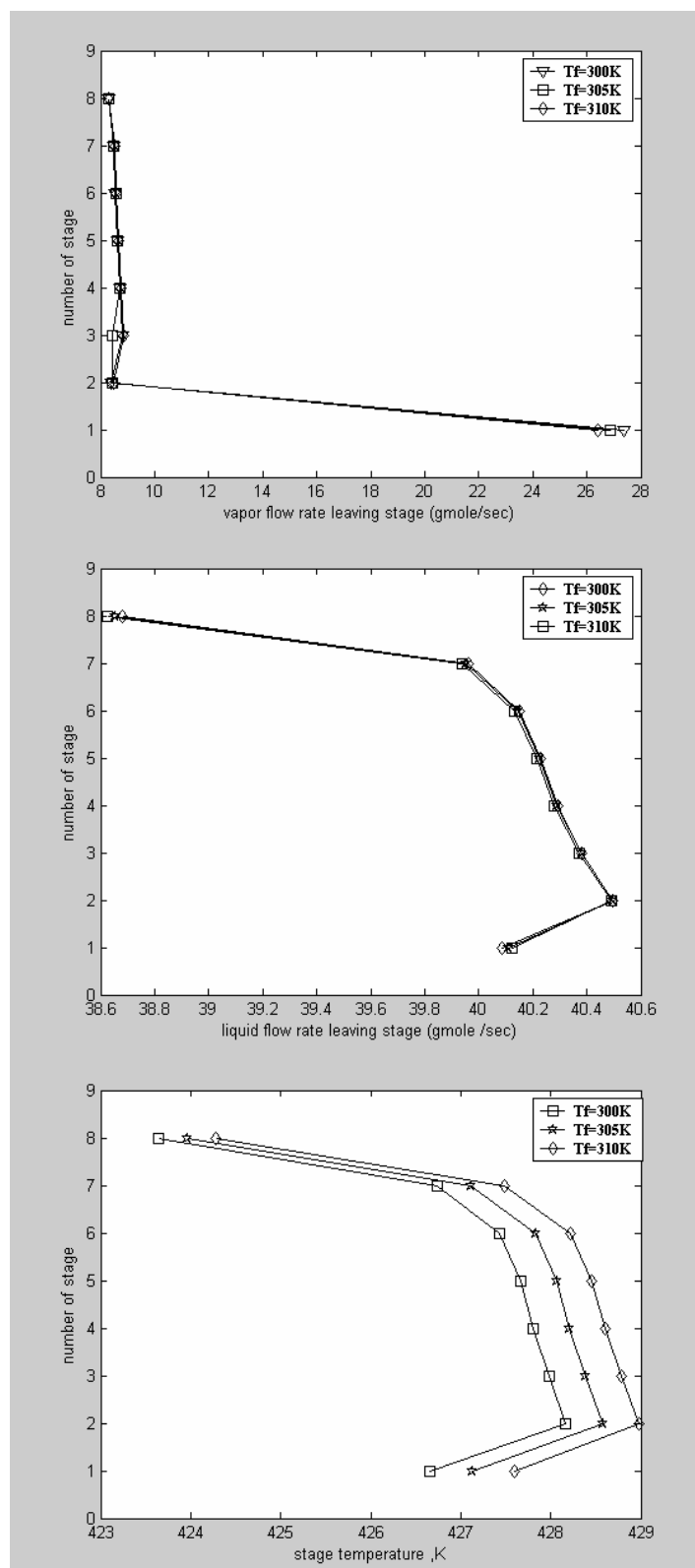


Fig (25) Effect of change feed temperature of the absorber on the vapor, liquid flow rate and temperature profile of the stripper on the network system B

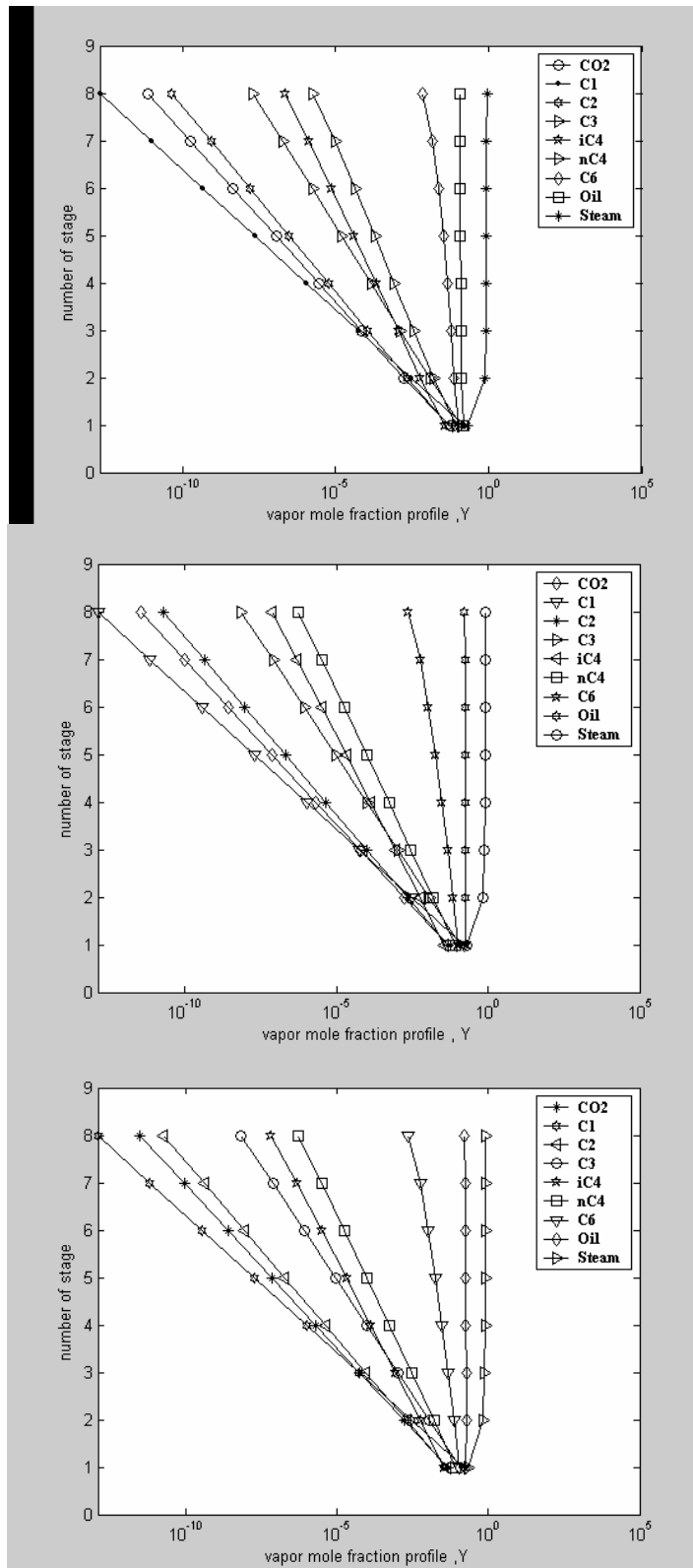


Fig (26) Effect of change wet gas feed temperature of the absorber on the vapor mole fraction of the stripper on the network system B

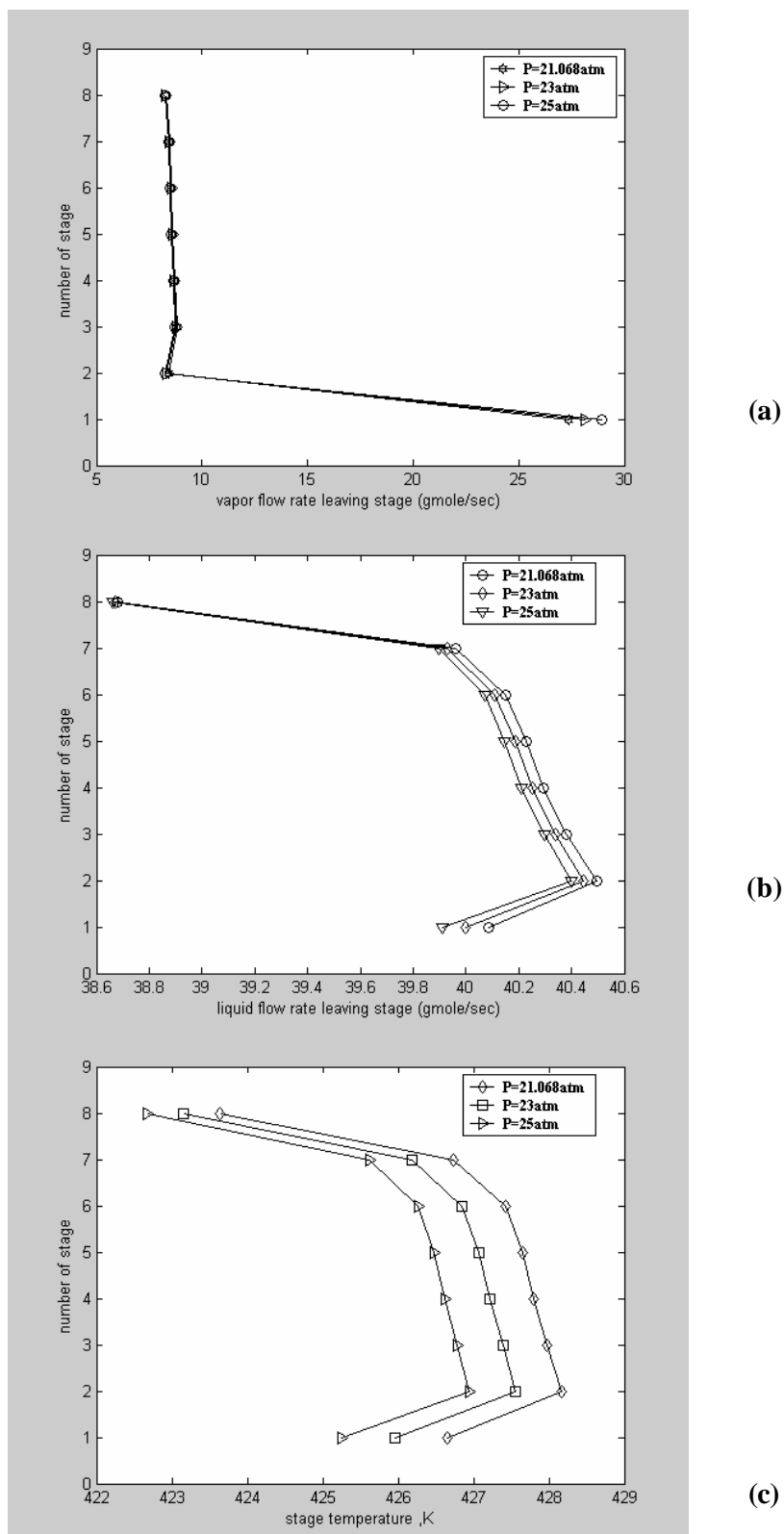


Fig (27) Effect of change operating pressure of the absorber on the vapor, liquid flow rate and temperature profiles of the stripper on the network system B

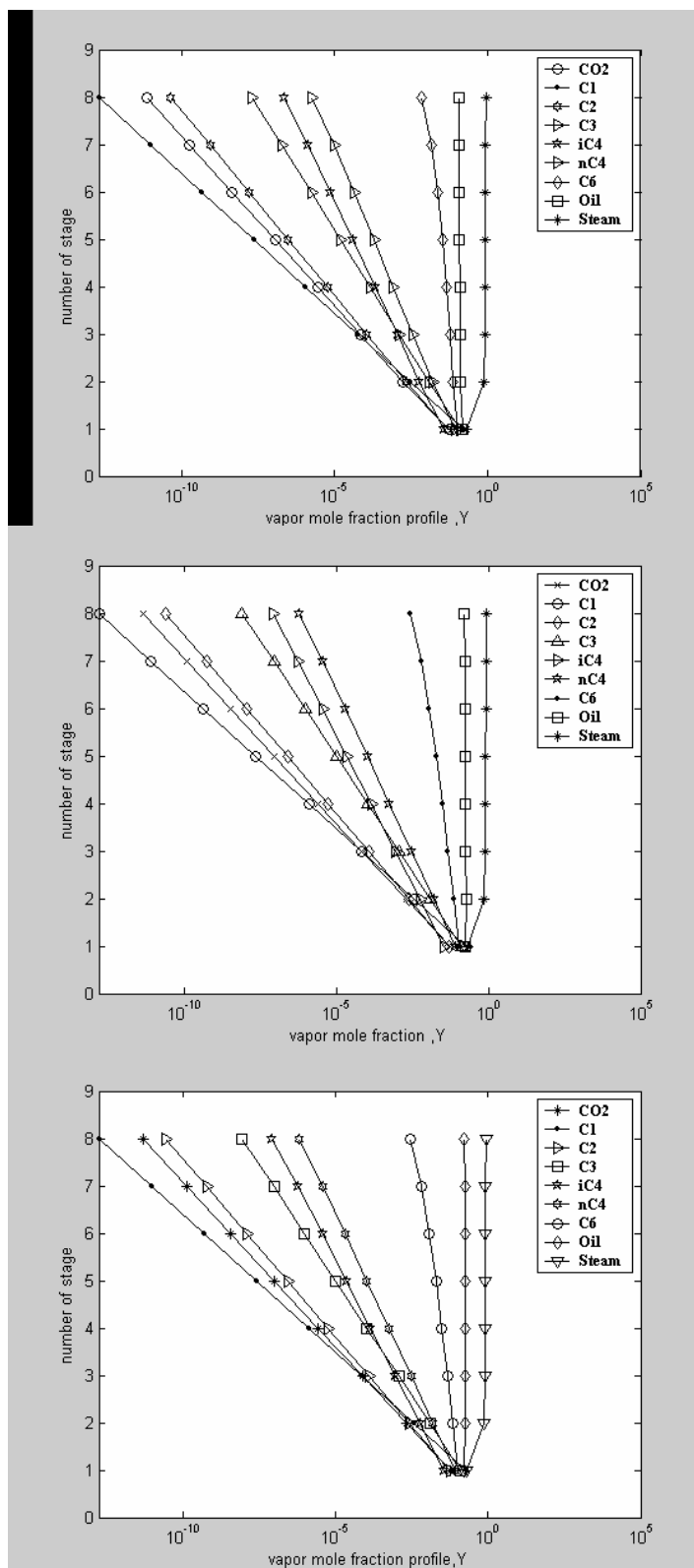


Fig (28) Effect of change operating pressure of the absorber on the vapor mole fraction profiles of the stripper on the network system B

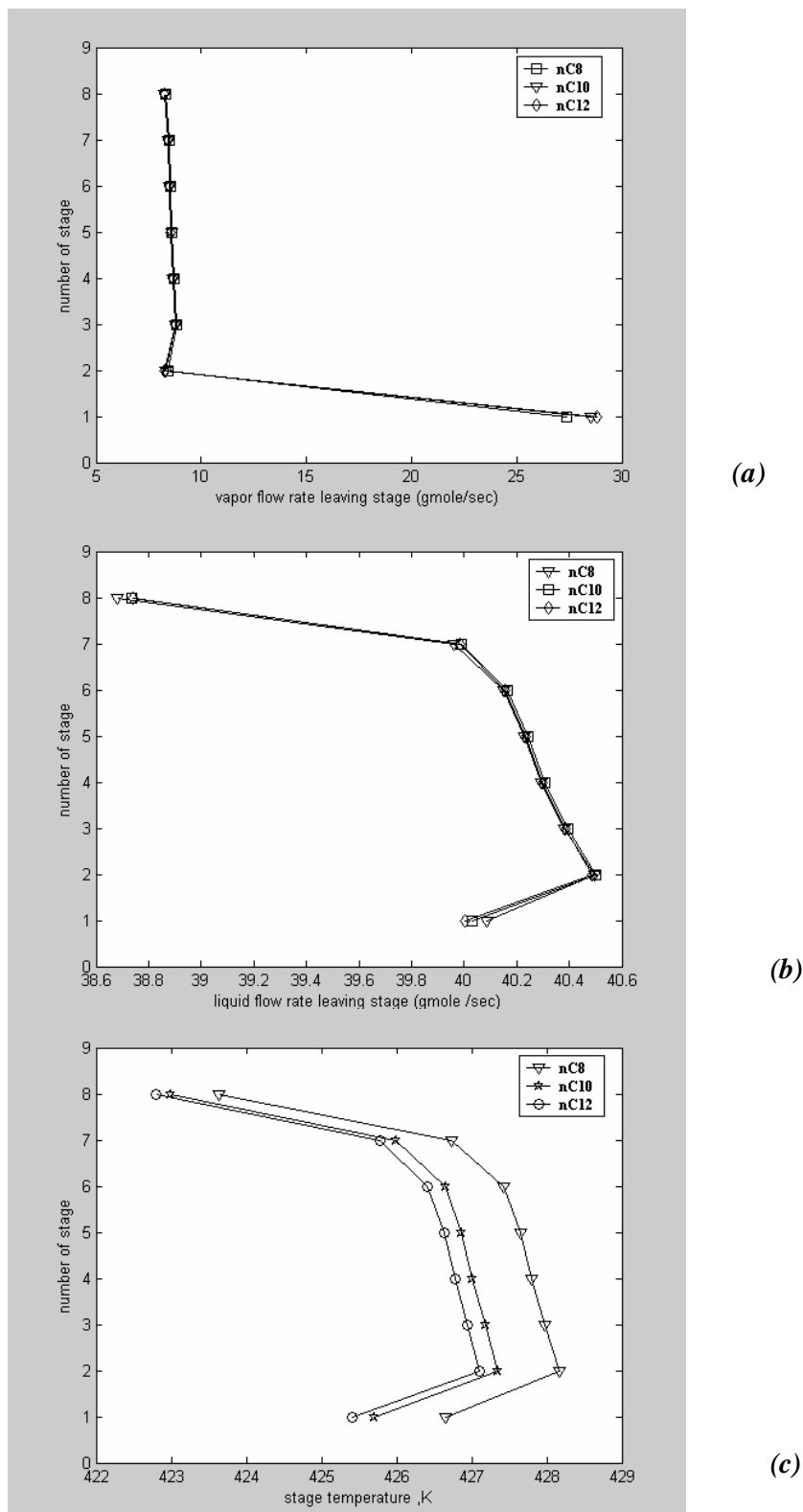


Fig (29) Effect of change solvent of absorber on the vapor, liquid and temperature profiles of the stripper on the network system B

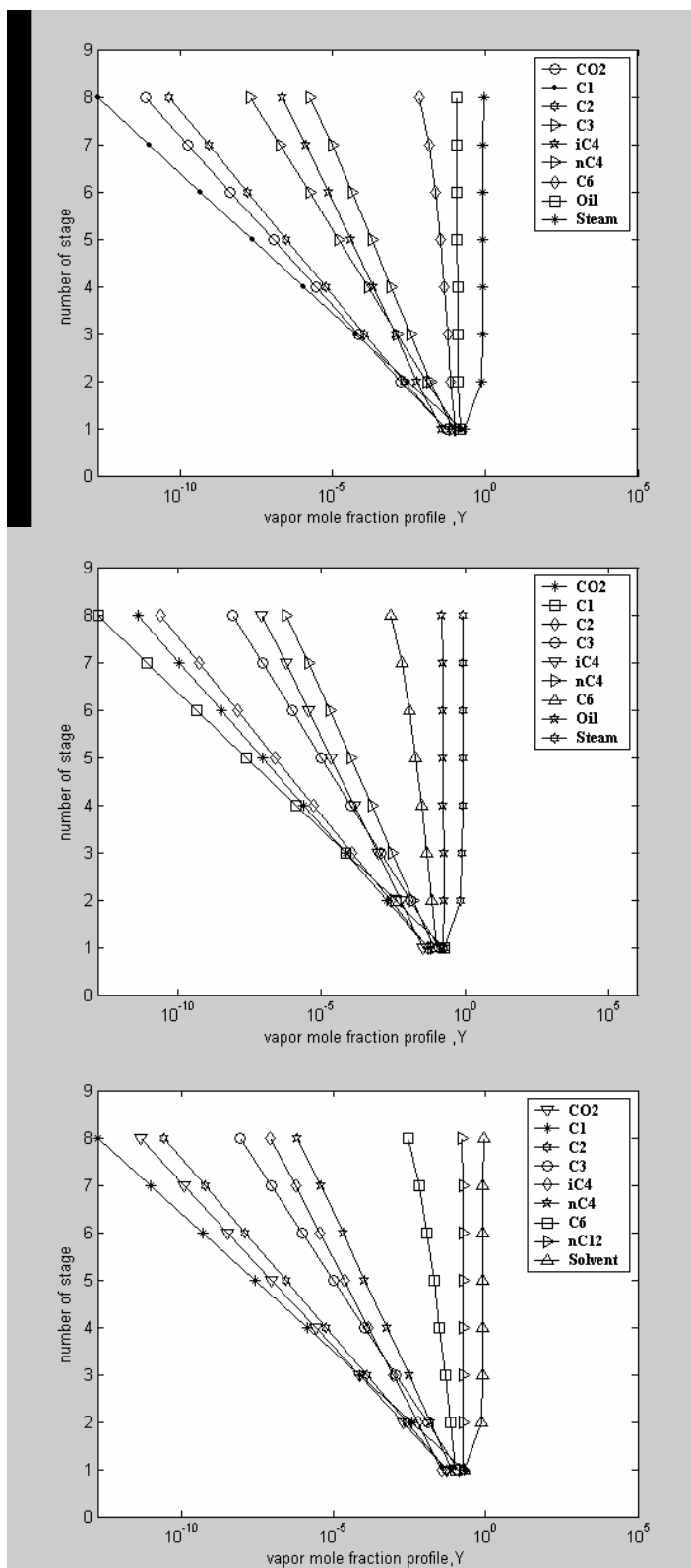


Fig (30) Effect of change solvent of the absorber on the vapor mole fraction of the stripper on the network B

الخلاصة

يهتم البحث بتطوير برنامج لتشكيل منظومة أبراج الأمتصاص و الانتزاع الفيزيائي متعددة المراحل من خلال استخدام طريقة دقيقة المبنية على طريقة Otto-Burningham لمجموع المعدلات باستخدام (MATLAB 6.5). ولهذا الغرض تم دراسة نظامين هايدروكاربونين غير مثالين.

من أجل تصميم منظومة متكاملة لأبراج الأمتصاص والانتزاع الفيزيائي فان هذا يتطلب الحصول على معلومات ثرموديناميكية الخاصة بحساب ثابت التوازن والمحتوى الحراري للطورين البخار والسائل ولهذا الغرض استخدمت المعادلات التكميلية باسم (SRK-EOS) و (PR-EOS) لحساب الخواص الثرموديناميكية ولحساب ضغط البخار السائل استخدمت (Antoine equation) وذلك من أجل حساب الحرارة الكامنة للتبخر.

النتائج التي حصل عليها باستخدام معادلة SRK-EOS المستخدم في الحسابات الثرموديناميكية قد قورنت مع النتائج الموجودة في المصادر اخرى [1,2] من أجل معرفة مدى دقة البرنامج المطور لمنظومة بالنسبة لأبراج الأمتصاص ثلاث أنظمة هايدروكاربونية (A و B و C) قد درست . وبالنسبة لنظام C فقد كانت صحة البرنامج بمقدار ٩٨ % اما بالنسبة لأبراج الانتزاع فقد تم دراسة نظامين هايدروكاربونين A و B لمعرفة مدى أنطباق البرنامج المطور وكانت صحة البرنامج بالنسبة لنظام A بمقدار ٩٩,٥ % .

في هذا البحث قد تم استخدام PR-EOS وذلك لأن استخدام هذه المعادلة تعطي نتائج افضل لنسبة الأمتصاص والانتزاع الفيزيائي في أبراج الأمتصاص والانتزاع الفيزيائي وكذلك لمنظومة.

قد تم دراسة تأثير عدة عوامل على اداء منظومة ابراج الامتصاص والانتزاع الفيزيائي وتتضمن هذه العوامل عدد المراحل ودرجة حرارة الغاز الداخل وضغط التشغيل ونوع المذيب وان

تأثير تغير هذه العوامل في ابراج الامتصاص على ابراج الانتزاع الفيزيائي من خلال توزيع معدل الجريان للبخر والسائل وتوزيع درجة الحرارة والكسور المولية للبخر ونسبة الانتزاع لكل مركب.

أفضل الظروف التي تم الحصول عليها لمنظومة أبراج الأمتصاص والأنتزاع الفيزيائي لنظامين A و B وذلك بتناقص عدد المراحل الذي يؤدي الى نقصان نسبة فقدان المذيب الى ٤٨,١٨% لنظام A و ٥٠% لنظام B وزيادة درجة الحرارة يؤدي الى نقصان نسبة فقدان المذيب الى ٤٨,١٩٨% لنظام A و ٤٩% لنظام B ونقصان ضغط التشغيل يؤدي الى نقصان نسبة فقدان المذيب الى ٤٧,٧% لنظام A و ٤٩,٧% لنظام B وزيادة العدد الكربوني لمذيب يؤدي الى نقصان نسبة فقدان المذيب الى ٤٨,٤% لنظام A و ٤٩,٧٥% لنظام B.

شكر و تقدير

أودُ أن أعبر عن خالص شكري وتقديري وأمتناني العميق للمشرفة الدكتورة ندى بهجت النقاش لما قدمته لي من توجيهات قيمة ونصائح سديدة طوال فترة إنجاز البحث.

أودُ أيضاً أن أشكر جميع أساتذة و موظفي قسم الهندسة الكيماوية في جامعة النهريين لإبدائهم المساعدة اللازمة أثناء هذا العمل .

ولا أنسى أن أتقدم بالشكر و الامتنان إلى من لازمني طوال فترة البحث وخلال أصعب الظروف إلى أعز من في الوجود إلى أبي و أمي وزوجي و جميع أفراد عائلتي فلهم جزيل الشكر و التقدير.

م/ نوار قادر الشرع

تشكيل منظومة أبراج الأمتصاص و الانتزاع الفيزيائي للمحاليل الهايدروكاربونية الغير مثالية

رسالة

مقدمة الى كلية الهندسة في جامعة النهرين
وهي جزء من متطلبات نيل درجة ماجستير علوم
في الهندسة الكيماوية

من قبل

نوار قادر الشرع

(بكالوريوس في الهندسة الكيماوية ٢٠٠٢)

١٤٢٦
٢٠٠٥

ربيع الآخر
أيار