Second Scientific Conference on Modern Technologies in Oil Refining
In 14-16/5/2013

Simulation and Optimization of Depropanizer Using Hysys Simulation Package

Dr. Nidhal M. Abdul Razzak Al-Azzawi
Senior lecturer, Chemical Engineering Department,University of Technology / Baghdad
Email:uotechnology.edu.iq/dep-chem-eng/mtor2013.htm

ABSTRACT

A new depropanizer is designed for the revamped petrochemical complex PC1 in Basrah. Conventional fractionation column is used to match the design of the existing plant. The feed to the new depropanizer is the bottom product of the revamped deethanizer of the ethylene plant. Hysys package (3.2) is used for the short-cut method, rigorous model and tray sizing. Different variables have been studied such as total number of stages, reflux ratio, feed location and feed temperature. The optimum number of stages is found to be (55) stages and the feed location is at tray 25th from top, with feed temperature of 32ºC. The tray layout and sizing is estimated using Hysys, all trays are forced to have the same design so that the column maintains the same diameter throughout its height.

Key Words: Simulation, Propylene, Optimization, Tray layout, Petrochemicals, Distillation.

الخلاصة

تصميم جهاز فصل البروبانات لوحدة الأثيلين المطوّرة في مجمع البتروكيمياويات – البصرة. أختير جهاز فصل تقليدي ليتماشى مع الأجهزة الموجودة حاليا في وحدة الأثيلين. المغذي لهذا الجهاز هو الناتج السفلي لجهاز فصل الأيثان. استخدم برنامج هايسس 3.2 للحصول على أفضل الظروف التشغيلية في موديل الحالة المستقرة واسلوب المحاكاة الصارم المعتمد على النمذجة الحديثة. تم دراسة تأثير عدة متغيرات وهي عدد الصواني، نسبة الراجع، درجة حرارة المغذي وموقع المغذي وتم الحصول على افضل الظروف التشغيلية، وذلك في ان يكون عدد الصواني الأمثل هو 55 صينية ونسبة الراجع=1 وان يكون المغذي بدرجة حرارة 32 درجة مؤية وموقعه على الصينية 25 من الأعلى. كذلك استخدم البرنامج لاجراء الحسابات الأولية للتصميم باستخدام الطريقة المختصرة لايجاد اقل نسبة راجع واقل عدد صواني بالاضافة الى حساب قطر البرج وتصميم الصواني.

https://doi.org/10.30684/etj.31.18A.7
2412-0758/University of Technology-Iraq, Baghdad, Iraq

الكلمات الدالة: المحاكاة، البروبلين، الأختيار ألمثل، تصميم الصواني، البتروكيمياويات، التقطير

INTRODUCTION

Working from Iraq's significant potentials for a dynamic petrochemical and plastic industry, the downstream petrochemical industries were limited by the country's long isolation from world market. The sector of the petrochemicals can be revitalized with some investment. Basic infrastructure already exists and can be rehabilitated and expanded.

A revamp study to the ethylene plant at Basrah petrochemical complex PC1 was proposed by Linde [1] and Al-Azzawi [7] for the existing plant to achieve co-cracking of LPG with ethylene in order to produce polymer grade propylene. The net bottom of the revamped deethanizer must be depropanized because of the higher yield of propylene. The top product from the depropanizer (mixed C_3's) must be sent to selective hydrogenation reactor to increase the yield of propylene. The effluent from the reactor must be sent to propylene/propane fractionator to produce polymer grade propylene, and propane is recycled to the cracking furnace. The depropanizer and propylene fractionator are not constructed because of the low yield of propylene in the existing plant.

In this work, a new depropanizer is designed for the revamped ethylene unit by simulating the data gained from the revamped deethanizer to complete the objective of introducing new feedstock to the existing ethylene plant. The simulation and design are conducted using Hysys package. Hysys incorporates a number of significant features including an innovative separation model that allows accurate simulation and understanding of the liquid and gas separations that occur in oil and gas plants.

Following are the results of a study that is prepared to assess the financial viability of propylene production unit at (PC1). First, the various uses and the demand history for high purity propylene are presented. Next, the financial aspects for the importance of producing propylene in Iraq are discussed. Finally, simulation and design of a new depropanizer for the revamped ethylene plant are conducted. This study includes the optimization and simulation of a conventional distillation with different operating variables.

PROPYLENE

World-wide demand of propylene has been rising steadily over the last 20 years. The consumption of propylene in 2011 was 79 million tones and it is expected to reach 97.5 million tons in 2015 [2], with a majority of the increase in demand occurring in Asia. Propylene prices that were high in 2010 (approximately \$0.6/lb.) have continued to increase and are projected to remain between (\$0.7 – 0.8/lb.) in

https://doi.org/10.30684/etj.31.18A.7
2412-0758/University of Technology-Iraq, Baghdad, Iraq

North_America [2]. In Europe, propylene went above ethylene for the first time ever during 2010. Since 2001, the price differential of ethylene over propylene has steadily eroded until it reversed in 2010. The price of propylene also has risen above that of ethylene in North East Asia [4, 5, 6, 8].

Propylene is the primary ethylene co-product from steam cracking of hydrocarbons, such as ethane, propane, naphtha and gasoil. Lower molecular weight feedstock (e.g. ethane and propane) yield a higher percentage of ethylene. Heavy molecular weight feedstock like naphtha, LPG and gasoil, are used to obtain more propylene. The propylene produced from an ethylene steam cracker is of sufficient purity to produce polymer grade propylene. In the FCC units, the propylene is produced as a dilute stream in propane. In the case of visbreaking and coking the propylene yields are lower and quality often unacceptable other than for refining fuel. Propylene comes in three grades; polymer grade (99.5% minimum purity), chemical grade (93 – 94% minimum purity) and refinery grade (60 – 70% purity).

Propylene is the feedstock for many important chemicals and is used to make plastics and fibers as polypropylene (thermoplastic) and acrylic, it is also used to manufacture plenty of consumer products such as; food packaging, table ware, washing machine parts, outdoor furniture, building components, automotive components, pharmaceuticals, cosmetics, skin-care and sun screen products [5]. Worldwide demand for propylene is distributed as follow [12]:

Polypropylene	52%
Acrylonitrile	12%
Oxo Alcohols	10%
Propylene Oxide	8%
Cumene	6%
Isopropyl Alcohol	4%
Acrylic Acid	3%
Others	5%

The petrochemical industry has been, and always will be, driven by the availability of competitive raw material, first coal then oil and now natural gas. As plastic manufacturers continue to find new uses of polymers, demands for its most basic building blocks, namely ethylene and propylene, will continue to escalate the price of monomers. Another issue is the higher prices of crude oil and petroleum gases in US, Japan, Europe, Canada and Asia impact on the petrochemical industry higher cost of ethylene and propane as well as higher cost for fuel, steam and electricity which raises the cost of producing ethylene and propylene. Great efforts will continue by these countries to seek-out the lowest sources of production [3].

Middle East countries have extensive hydrocarbon resources and geographically well suited to supply these products. These countries are expanding their petrochemical operations in an effort to diversity their industries and strengthen their domestic economics. In terms of future development, the Middle East is at the center of strong global growth [3]. Saudi Arabia, Iran, Qatar and most of the Arabian

https://doi.org/10.30684/etj.31.18A.7
2412-0758/University of Technology-Iraq, Baghdad, Iraq

Gulf countries are expanding their petrochemical business, because the industry's center of gravity moves from West to East. Iraq has significant potential to become a major player in both energy exports and petrochemical production. Feedstock's advantages in Iraq should fuel a powerful and continuing upsurge in petrochemical industries to divert Iraq's economy from just exporting oil to industrialization.

Iraq poised to become game-changer for the world’s oil markets. Iraq’s energy sector holds the key to the country’s future prosperity and can make a major contribution to the stability and security of global energy markets. Natural gas can play a much more important role in Iraq’s future and a vital first step will be to reduce the amount of gas that is currently flared. Once domestic needs are met, Iraq can provide a cost competitive source of gas supply to US and European market, neighboring countries and to Asia [9].

THE DEPROPANIZER

As noted previously, depropanizer was not constructed in the existing ethylene plant at Basrah PC1 because of the low yield of propylene. Even though Lummus[13] (the Construction Company of the petrochemical complex) made a material and energy balance for the un-constructed yet depropanizer. Their data is simulated using Hysys to ensure the accuracy of the simulation package. The results were pretty good and it is tabulated in appendix A.

Simulating the data gained from the revamped deethanizer is of high importance to complete the objective of introducing new feedstock to the existing ethylene plant in Basrah PC1. The feed comes from the revamped deethanizer, as bottom product, which contains C_3^+. The feed composition of the depropanizer is given in table 1. The column operates at a fixed pressure of 10 bars to reduce fouling in the bottom section of the tower[10]. The feed pressure produces a flash (split between vapor and liquid), depending on its temperature. Heat Q_r is provided at the bottom of the column by low pressure steam, and extracted at its top by condenser Q_c.

The vapor – liquid equilibrium on the tower trays is calculated using Peng Robenson Fluid Package from Hysys Environment. Peng Robenson equation of state becomes one of the most widely used in industry for correlating mixtures containing hydrocarbons[11]. There are two assumptions for this simulation; first, the state of the process model for simulation is normally considered to be steady-state when the optimal manipulated variables are searched. Second, the model of the process simulator is conducted by simple K-value and a Jacobian Matrix is solved using inside-out method. In the simulator, the controlled variables are the propane mole fraction in the bottom product of the depropanizer is specified to be (0.0078), Reflux ratio, number of trays, feed temperature, propylene composition in distillate and feed location. The major considerations for the simulation are zero mole fraction of isobutane in the top product, and as minimum as possible heat duties of the reboiler and the condenser.

Table (1) Flow rate and composition of the feed stream

https://doi.org/10.30684/etj.31.18A.7
2412-0758/University of Technology-Iraq, Baghdad, Iraq

to the depropanizer.

Component	Flow rate kmole/hr	Mole Fraction
C_2H_6	2.399	0.0165
C_3H_6	77.64	0.5347
C_3H_8	21.9	0.1508
C_3H_4	1.29	0.0089
i-C_4H_{10}	32.09	0.2210
i-C_5H_{12}	4.15	0.0286
n-C_5H_{12}	5.74	0.0395
Total molar rate kmole/hr	145.2	1
Total mass rate kg/hr	9620.81	
Pressure bar	10	

The overhead stream must contain zero isobutane because this component affects the hydrogenation step before propylene-propane splitter. We have to find the minimum reflux ratio and the minimum number of stage to accomplish the separation at total reflux.

Hysys has separate calculations for shortcut method. This calculation has been conducted before steady state simulation of depropanizer. Propylene is assumed to be the light key-component and propane is the heavy key-component. Hysys asked about other data to be supplied such as feed pressure = 10 bar, feed flow rate = 145.2 kmole/hr, feed temperature 38ºC, propylene composition in the bottom product = 0.001 and propane composition in the distillate = 0.21. The results for the short-cut method are shown in Table 2.

With this information it is possible to conduct preliminary simulation based on equilibrium stage model or steady state model in Hysys, Constant pressure operation is assumed.

RESULTS AND DISCUSSION

First consideration is to assume a certain number of stages (50, 55 and 60) and for each assumption the reflux ratio is changed (0.8, 0.9, 1.0, 1.05, 1.1 and 2) and the results are drawn in Figures (1, 2, and 3).

Figure (1), shows the propylene mole fraction in distillate for different reflux ratio for each number of stages. Higher composition can be reached at reflux ratio = 1 and N = 60.

Figure (2), shows the condenser duty for different reflux ratio at each number of stages, as reflux ratio increased, the condenser duty is increased and the condenser duty is higher for N=60 for all reflux ratios.

Figure (3) shows the reboiler duty for different reflux ratio at each number of stages. It shows the same trend as for the condenser duty but with higher values.

https://doi.org/10.30684/etj.31.18A.7
2412-0758/University of Technology-Iraq, Baghdad, Iraq

From the simulation results at reflux ratio 0.8 & 0.9 for each number of stages, it is noted that a fraction of isobutane appears in the top product which is not preferred, as mentioned before. The isobutane disappears from the top product when reflux ratio increased to 1 and also for the higher values.

Table (2) Results for the short-cut Method.

Component	Mole Frac.Feed	Mole Frac.Distillate	Mole Frac.Bottom
C_2H_6	0.0165	0.0233	0
C_3H_6	0.5347	0.7549	0.001
C_3H_8	0.1508	0.2099	0.0078
C_3H_4	0.0089	0.0119	0.0017
i-C_4H_{10}	0.221	0	0.7564
i-C_5H_{12}	0.028	0	0.0978
n-C_5H_{12}	0.0395	0	0.1353
Flow rate kmole/hr.	145.2	102.8	42.42
Mass flow kg/hr	6935	4338	2598
Heat duty kcal/hr		$6.167x10^5$	$3.184x10^5$
Temp..C°	38	6.479	66.11
Pressure bar	10	7.19	8.25
External Reflux Ratio		0.6	
Minimum Reflux Ratio		0.155	
Minimum No. of stages		45	
Optimal feed tray		5-6 from top	

https://doi.org/10.30684/etj.31.18A.7
2412-0758/University of Technology-Iraq, Baghdad, Iraq

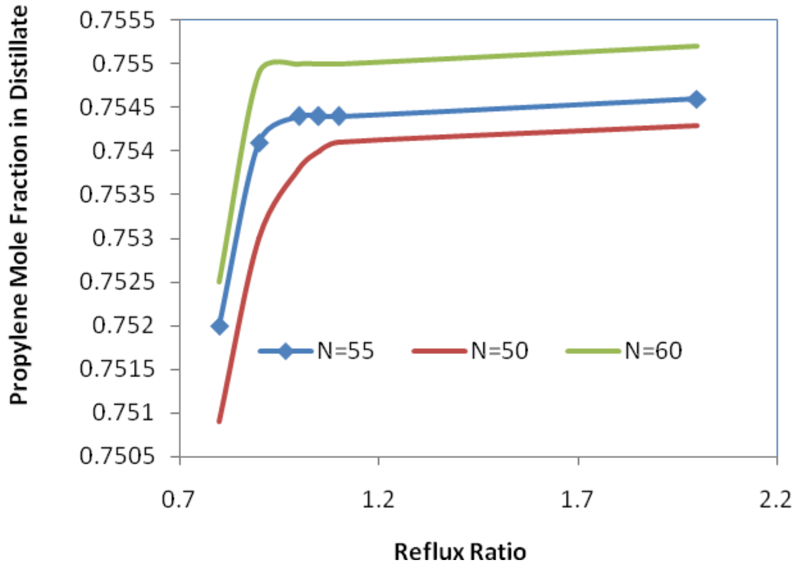


Figure (1) Propylene Profile vs. Reflux Ratio at Different Number of Trays.

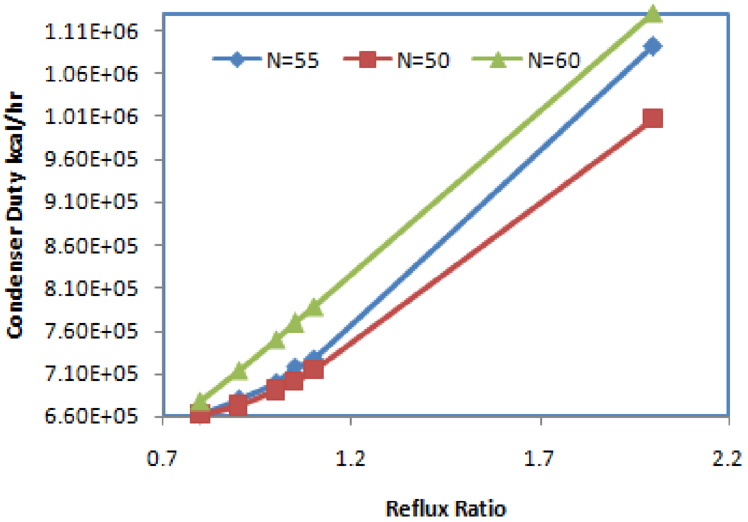


Figure (2) Condenser Duty vs. Reflux Ratio at Different Number of Trays.

https://doi.org/10.30684/etj.31.18A.7
2412-0758/University of Technology-Iraq, Baghdad, Iraq

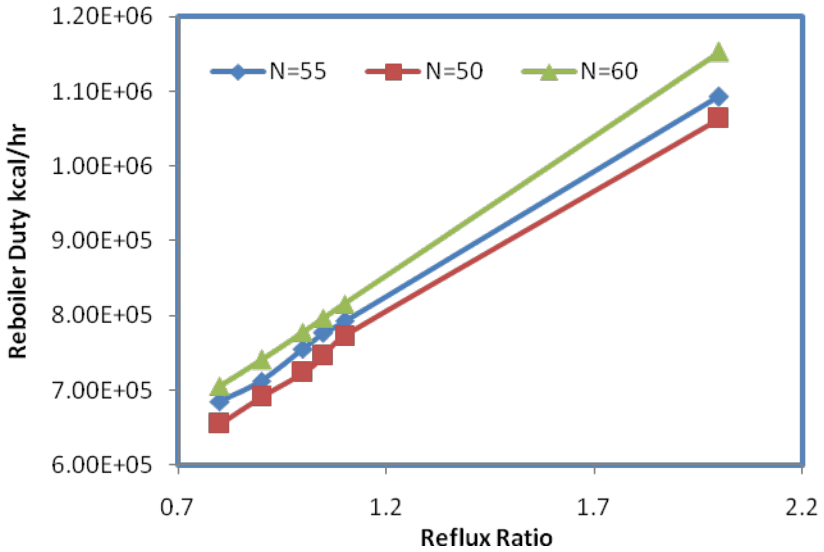
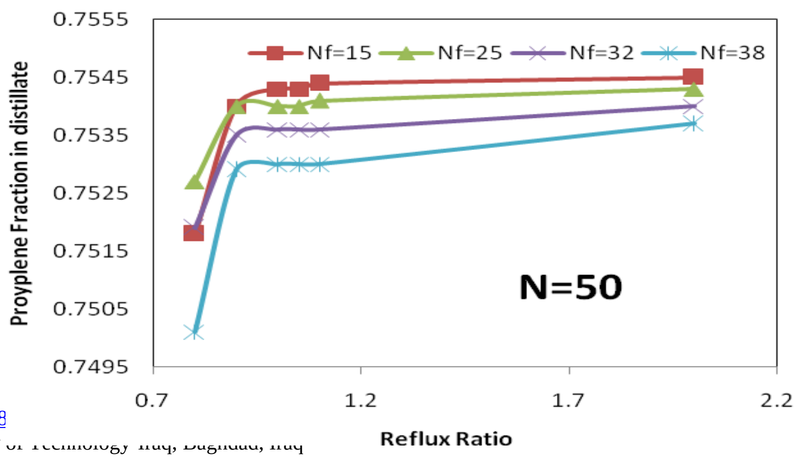


Figure (3) Reboiler Duty vs. Reflux Ratio at Different Number of Trays.

The feed location is studied at each number of stages and different reflux ratio. For number of stages N=50, Figure (4) shows the variation of the propylene composition in distillation with reflux ratio. Higher composition can be reached for feed location at stage 15 from the top, but for most reflux ratios a fraction of isobutane appeared, except for R=1.1 and higher, hence this location is not preferred. For feed location at 25th stage from top, it is found that only when R=0.8, the isobutane appears in the top product, and this is also observed for feed location at 32nd stage and 38th.

Figure (5) and Figure (6) show the heat duty for each feed location for N=50 as the feed moves to the top the reboiler, and condenser duties are increased. But at lower reflux ratio they have approximated values. The same has been done for each number of stages and they all show the same trends as for N=50, but the results are not shown. From all above, the optimum reflux ratio was found to be R=1.



https://doi.org/10.3068
2412-0758/University of Technology-Iraq, Baghdad, Iraq

Figure (4) Propylene Composition in Distillate vs. Reflux Ratio at Different Feed Location for N=50.

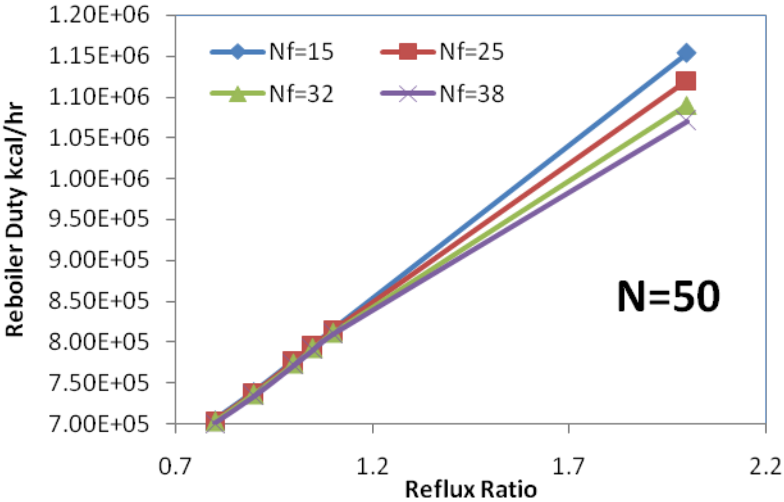


Figure (5) Reboiler Duty vs. Reflux Ratio at Different Feed Location for N=50.

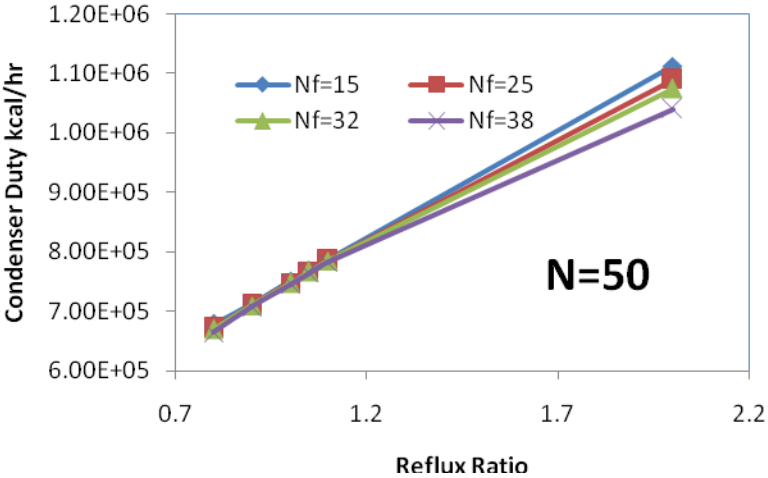


Figure (6) Condenser Duty vs. Reflux Ratio at Different Feed Location at N=50.

https://doi.org/10.30684/etj.31.18A.7
2412-0758/University of Technology-Iraq, Baghdad, Iraq

For the chosen reflux ratio, a comparison between the numbers of the stages is carried out. For each number of stages with fixed R=1, the propylene composition in distillate, the reboiler and condenser duty are plotted against feed location to choose the optimum number of stages and the best feed location. Figures 7 & 8 show the propylene mole fraction in the distillate, the reboiler and condenser duty against feed location at N=50. Location at 25th stage from the top gives higher composition which is equal to 0.75, and heat duty Q_c= 7.49x10^5 kcal/hr and Q_r=7.76x10^5 kcal/hr

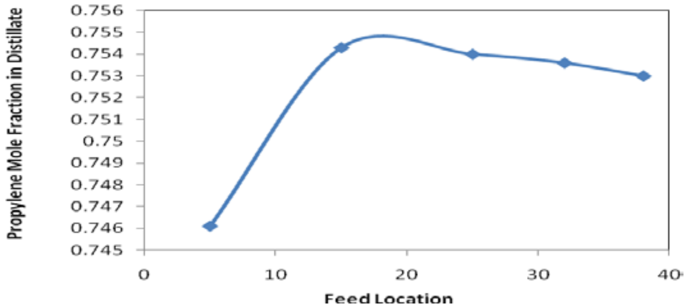


Figure (7) Feed Location vs. Propylene Composition in Distillate for N=50 and R=1.

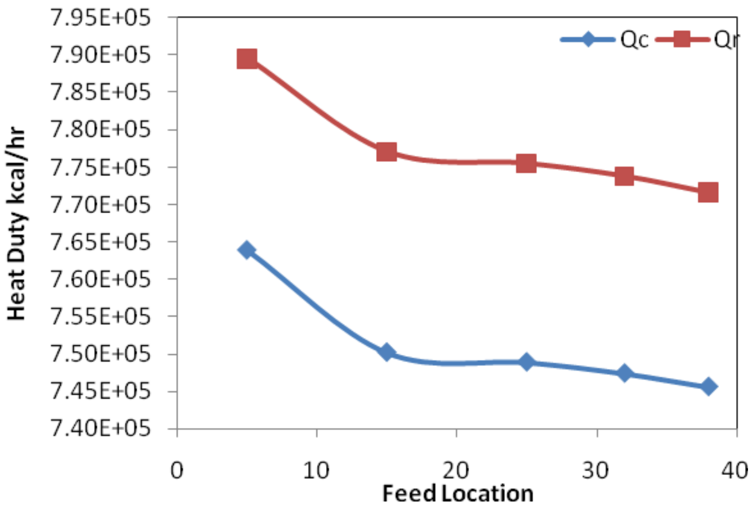


Figure (8) Feed Location vs. Heat Duty for N=50 and R=1

https://doi.org/10.30684/etj.31.18A.7
2412-0758/University of Technology-Iraq, Baghdad, Iraq

Figure (9 & 10) show the same variables but for N=55. The feed location at stage 25 also gives higher propylene composition equal to 0.7542, Q_c=7.5x10^5 kcal/hr and Q_r=7.74x10^5 kcal/hr.

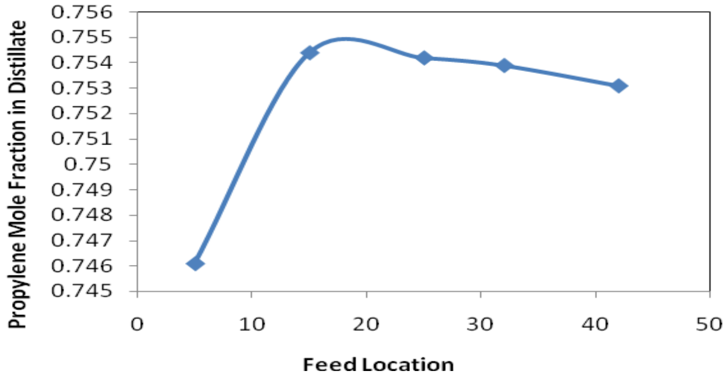


Figure (9) Feed Location vs. Propylene Composition in Distillate at N=55 and R=1.

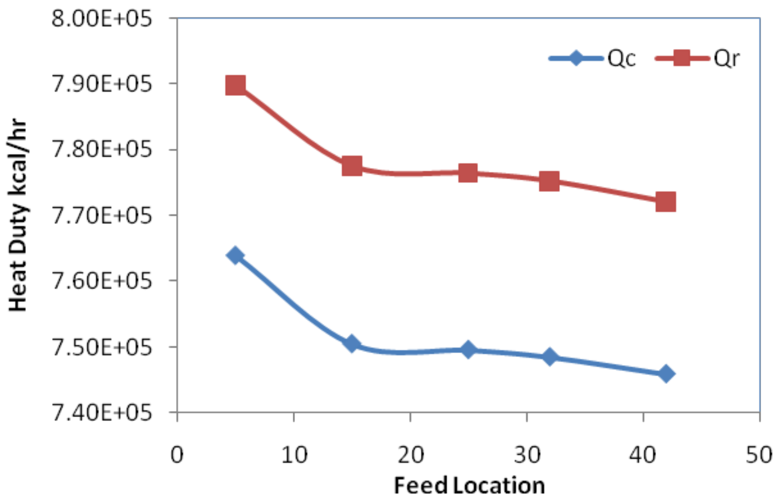


Figure (10) Feed Location vs. Heat Duty for N=55 and R=1.

Figure (11 & 12) show the same variables for N=60. It is found that the optimum location for the feed is 25th from top, which gives propylene composition =0.7548, Q_c=7.48x10^5 kcal/hr and Q_r=7.776x10^5 kcal/hr.

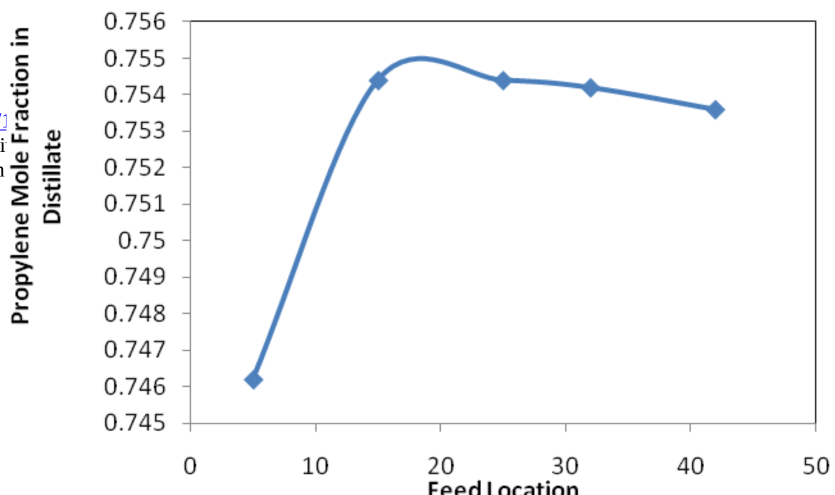


Figure (11) Feed Location vs. Propylene Composition in Distillate for N=60 and R=1.

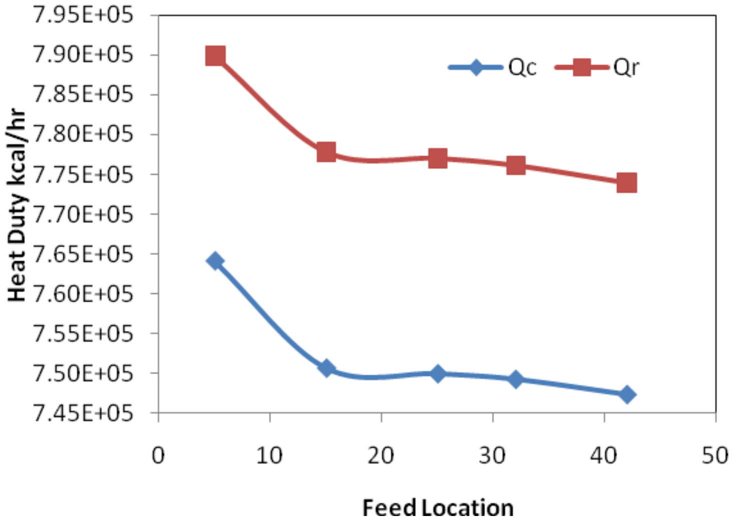


Figure (12) Feed Location vs. Heat Duty for N=60 and R=1.

https://doi.org/10.30684/etj.31.18A.7
2412-0758/University of Technology-Iraq, Baghdad, Iraq

From all above values, and taking into consideration that isobutane does not exist in the top product, the optimum number of stages is 55, which gives the average values of propylene composition in distillate and the heat duties.

In the above studied cases, the feed temperature was fixed at 30ºC. For the chosen configuration, which was found after many trials, the feed temperature has been changed to find its optimum value. The results are shown in table -3.

Table (3) Simulation results for different feed temp. kcal/hr mole fraction.

Feed Temp. Cº	f_v	Propylene mole Fraction in Distillate	Isobutane mole Fraction in Distillate	Q_r kcal/hr	Q_c kcal/hr
30	0	0.7542	0	$7.5x10^5$	$7.74x10^5$
32	0.0847	0.7540	0	$7.244x10^5$	$7.494x10^5$
38	0.5116	0.7465	0.0097	$7.6x10^5$	$4.871x10^5$
40	0.7158	0.727	0.0352	$7.9x10^5$	$3.905x10^5$

From Table (3) the optimum feed temperature is 32ºC. The optimum design variables for the depropanizer are N=55, feed location=25th from top and feed temperature =32ºC. Appendix B gives the full design for the chosen column with all specifications and the PFD using Hysys printout resultes.Table-4 shows the process flow data sheet for the depropanizer which was designed.

To complete the design, Hysys utilities are used for tray sizing. Hysys has a utility program to perform a mechanical design of distillation columns; both tray and packed. Three types of trays are offered; valve tray, sieve tray and bubble cap tray. Valve tray was chosen for the depropanizer. The column diameter is estimated to be (0.762 m) with maximum flooding of 73%, all the important results for tray sizing are shown in appendix C.

Table(4) Process Flow Data Sheet for the Designed Depropanizer.

Component	Feed	Distillate	Vapor to Condenser	Reflux to Column	Bottom	Vapor from Reboile
C_2H_6	2.399	2.399	4.798	2.399	0	0
C_3H_6	77.64	77.447	154.9	77.447	0.1933	1.754
C_3H_8	21.9	21.568	43.14	21.568	0.3318	2.967
C_3H_4	1.29	1.2749	2.55	1.275	0.0151	0.139
i-C_4H_{10}	32.09	0	0	0	32.09	150.4
i-C_5H_{12}	4.15	0	0	0	4.15	8.174
n-C_5H_{12}	5.74	0	0	0	5.74	9.5
Total						

https://doi.org/10.30684/etj.31.18A.7
2412-0758/University of Technology-Iraq, Baghdad, Iraq

kmole/hr	145.2	102.689	205.388	102.689	45.42	172.934
kg/hr	6935	4333	8667	4333	2602	10229.3
Mwt. avge.	47.762	42.199	41.635	42.199	61.198	59.15
Temp. C°	32	12.57	12.569	12.569	72.36	72.36
P bar	10	8.5	8.5	8.5	9.5	9.5
Vapor Frac f_v	0.0847	0	1	0	0	1
Total Number of Stages		55				
Feed Location		25^{th} from top				
Reflux Ratio		1.0				
Reboiler Duty kcal/hr		$7.244\text{x}10^5$				
Condenser Duty kcal/hr		$7.494\text{x}10^5$				

CONCLUSIONS

Based on the process design optimization, the following may be concluded:

1. The short-cut method is important for primary design prior to performing the rigorous tray-to-tray calculations, because the preliminary calculations give an idea of what is reasonable, such as minimum reflux ratio and minimum number of stages. It is found that the minimum reflux ratio is 0.155 and minimum number of stages is 45.
2. The optimum number of stages for the depropanizer is found to be 55 stages. The feed location is at stage 25^{th} from top, and the feed temperature is 32ºC. These values are chosen from the simulation results. This configuration gives zero concentration of isobutane in the propylene-propane top product and fairly acceptable heat duty compared to other configurations. The presence of isobutane in top product of the depropanizer affects the catalyst and the reaction of the hydrogenator, to increase the yield of propylene before the propylene propane splitter.
3. Hysys has been tested for the same data of the designed, yet unimplemented, depropanizer of Lummus Company (1976), the results have shown good compatibility with Lummus results.
4. Hysys is also used for tray sizing, and the valve-trays have been chosen. Other efficient packages for the tray design can be used as well, which offer new tray technology, such as Ultra-capacity tray, Superfrac tray, Flexi tray …etc.

REFERENCES

[1]. Linde Company, Documents & Manuals, PC1, Basra (2002).

https://doi.org/10.30684/etj.31.18A.7
2412-0758/University of Technology-Iraq, Baghdad, Iraq

[2]. Palmer, R.E., Nijhawan, S. and Andrzejewski; "A Financial Analysis for the Recovery of High Purity Propylene from Refinery LPG" Digital Refining, April 2012, Mustang Engineering.
[3]. Almady, M.; "Growth of the Middle East Petrochemical Industry", International Petrochemical Conference NPRA, 2004.
[4]. Richardson, J.; "Propylene Prices to remain Elevated versus Ethylene" ICIS Chemical Business, vol. 282, issue 7, 2011.
[5]. Wang, and Judith; "Asia C_3 Hits High on Firm Crude and Derivatives", ICIS, Chemical Business, vol.282, issue 7, 2012.
[6]. Lemos, William, etc "October Contracts for US Propylene, PP increase again", ICIS, Chemical Business, vol.282, issue 11, 2012.
[7]. Al-Azzawi, N.; "Optimal Design Variables for Low Temperature Distillation Columns in the Ethylene Plant at PC1-Basra, for Revamping" PhD Thesis, University of Technology, Iraq (2007).
[8]. Beacham, W.; "Republic of Iraq-Industrial Development Authority, ICIS, Chemical Business, July 2011".
[9]. Shahid, A.; "Iraq poised to become Game-Changer for World Oil Markets' Global Arab Network, 2012.
[10]. Karl Strok; "Integrated low pressure Depropanizer/ Debutanizer Column" United States Patent No. US6291743 B1 Houston, TX (US).
[11]. Seader. J.D. and Henly, E.J.; "Separation Process Principals" John Wiley and Sons Inc. New York 1998.
[12]. Hwee, PehSoo and Feliza; "Propylene", ICIS Chemical Business, vol 281, issue 16, 2012.
[13]. Lummus Company, Operation Manuals, PC1, Basra (1976).

APPENDICES

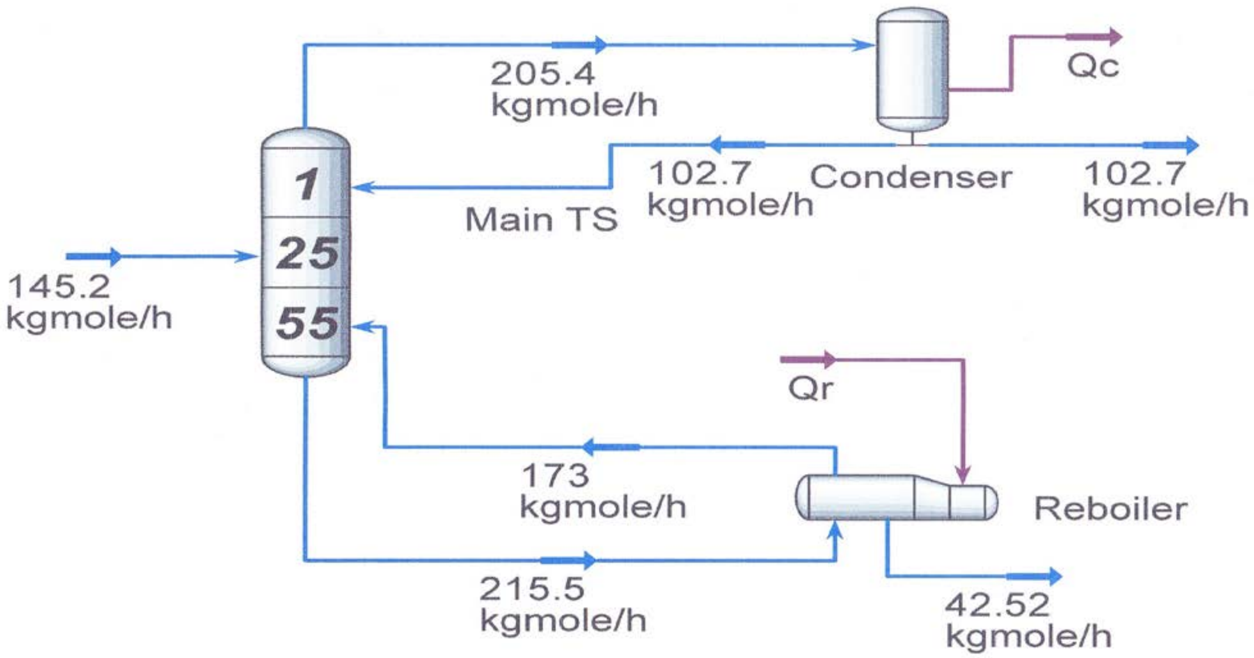
Appendix A: Composition of the design results for the "Lummus" depropanizer (1976) and Hysys simulation results.

Comp.	X_f	Lummus X_D	Hysys X_D	Lummus X_W	Hysys X_W
C_2H_6	0.0032	0.0045	0.0043	0	0
C_3H_6	0.5920	0.8239	0.8245	0.0052	0.0055
C_3H_8	0.1155	0.1544	0.1532	0.0218	0.02
C_3H_4	0.0099	0.0119	0.0110	0.0054	0.0065
$i\text{-}C_4H_{10}$	0.0037	0.0003	0.0002	0.0125	0.0123
C_4H_8	0.0274	0.0008	0.0011	0.0945	0.0927
C_4H_6	0.1379	0.0039	0.0045	0.4799	0.4727
$n\text{-}C_4H_{10}$	0.0298	0.0003	0.0002	0.1021	0.1034
$i\text{-}C_5H_{12}$	0.0282	0	0	0.0935	0.1007

https://doi.org/10.30684/etj.31.18A.7
2412-0758/University of Technology-Iraq, Baghdad, Iraq

n-C_5H_{12}	**0.0523**	**0**	**0**	**0.1851**	**0.1862**
Molar flow kmol/hr	**61.29**	**42.82**	**44.11**	**18.47**	**17.18**
Mass flow kg/hr	**2896**	**1814.28**	**1872**	**1104.7**	**1023**
Mwt	**47.25**	**42.37**	**42.44**	**59.81**	**59.55**
Temp. C°	**31.4**	**11.7**	**12.5**	**72.9**	**76.65**
P bar	**8.47**	**7.19**	**8.113**	**8.25**	**9.103**
Reflux Ratio	**1.2**				
Number of stages	**26**				
Feed location	**4^{th} from top**				
Q_C kcal/hr	**Lummus = $3.253x10^5$**		**Hysys = $3.518x10^5$**		
Q_r kcal/hr	**Lummus = $2.768x10^5$**		**Hysys = $2.891x10^5$**		

Appendix B:Hysys report documents for the whole design of the depropanizer of N=55, Feed Location 25^{th} from top and Feed Temperature = 32 C°



https://doi.org/10.30684/etj.31.18A.7
2412-0758/University of Technology-Iraq, Baghdad, Iraq

HYSIM's Development Team Calgary, Alberta CANADA	Case Name:	D:\ÇáÈÍË ÇáãÊÚÑ\New Research Depro ÇáÃÖÇÖí.hsc
	Unit Set:	EuroSI
	Date/Time:	Sat Mar 30 16:14:24 2013

Distillation: DEPROPANIZER @Main

CONNECTIONS

Inlet Stream

STREAM NAME	Stage	FROM UNIT OPERATION
Qr	Reboiler	
Feed	25__Main TS	

Outlet Stream

STREAM NAME	Stage	TO UNIT OPERATION
Qc	Condenser	
buta	Reboiler	
propa	Condenser	

SPECS

Column Specification Parameters

Reflux Ratio

Stage:	Condenser	Flow Basis:	Molar	Liquid Specification:	---

Reflux Rate

Stage:	Condenser	Flow Basis:	Molar	Liquid Specification:	---

Btms Prod Rate

Stream:	buta	Flow Basis:	Molar

Distillate Rate

Stream:	propa	Flow Basis:	Molar

Comp Fraction

Stage:	Condenser	Flow Basis:	Mole Fraction	Phase:	Liquid
Components:		i-Butane			

Comp Fraction - 2

Stage:	Reboiler	Flow Basis:	Mole Fraction	Phase:	Liquid
Components:		Propane			

Temperature

Stage:	16__Main TS

MONITOR

Specifications Summary

	Specified Value	Current Value	Wt. Error	Wt. Tol.	Abs. Tol.	Active	Estimate	Used
Reflux Ratio	1.000	1.000	1.414e-008	1.000e-002	1.000e-002	On	On	On
Reflux Rate	---	102.7 kgmole/h	---	1.000e-002	1.000 kgmole/h	Off	On	Off
Btms Prod Rate	---	42.52 kgmole/h	---	1.000e-002	1.000 kgmole/h	Off	On	Off
Distillate Rate	102.0 kgmole/h	102.7 kgmole/h	6.755e-003	1.000e-002	1.000 kgmole/h	Off	On	Off
Comp Fraction	1.000e-004	9.365e-007	-0.8091	1.000e-002	1.000e-003	Off	On	Off
Comp Fraction - 2	7.800e-003	7.803e-003	1.742e-004	1.000e-002	1.000e-003	On	On	On
Temperature	35.00 C	16.06 C	-3.788e-002	1.000e-002	1.000 C	Off	On	Off

PROFILES

General Parameters

Sub-Flow Sheet:	DEPROPANIZER (COL1)	Number of Stages:	55

Profile Estimates

	Temperature (C)	Net Liquid (kgmole/h)	Net Vapour (kgmole/h)
Condenser	12.58	102.8	1.132e-018
1__Main TS	14.02	103.0	205.6
2__Main TS	14.43	103.0	205.7
3__Main TS	14.55	103.0	205.6
4__Main TS	14.63	103.0	205.8
5__Main TS	14.81	102.9	205.7
6__Main TS	15.00	102.7	205.6

https://doi.org/10.30684/etj.31.18A.7
2412-0758/University of Technology-Iraq, Baghdad, Iraq

HYPROTECH	HYSIM's Development Team Calgary, Alberta CANADA	Case Name:	D:\ÇáÈÍË ÇáäãÊÚÑ\New Research Depro ÇáÃÖÇÖí.hsc
		Unit Set:	EuroSI
		Date/Time:	Sat Mar 30 16:14:24 2013

Distillation: DEPROPANIZER @Main (continued)

Profile Estimates

	Temperature (C)	Net Liquid (kgmole/h)	Net Vapour (kgmole/h)
7__Main TS	15.25	102.5	205.5
8__Main TS	15.59	102.1	205.2
9__Main TS	16.07	101.5	204.8
10__Main TS	16.74	100.6	204.2
11__Main TS	17.67	99.46	203.4
12__Main TS	18.86	98.11	202.2
13__Main TS	20.30	96.63	200.9
14__Main TS	21.93	94.94	199.4
15__Main TS	23.80	92.48	197.7
16__Main TS	26.42	220.0	195.3
17__Main TS	26.88	220.4	177.6
18__Main TS	16.89	101.4	204.7
19__Main TS	17.58	100.5	204.1
20__Main TS	18.52	99.36	203.2
21__Main TS	19.72	98.02	202.0
22__Main TS	27.15	220.6	178.0
23__Main TS	27.36	220.8	178.2
24__Main TS	27.54	221.0	178.4
25__Main TS	27.73	221.2	178.6
26__Main TS	27.91	221.3	178.7
27__Main TS	28.10	221.5	178.9
28__Main TS	28.30	221.6	179.0
29__Main TS	28.50	221.8	179.2
30__Main TS	28.70	221.9	179.3
31__Main TS	28.90	222.1	179.5
32__Main TS	29.11	222.2	179.6
33__Main TS	29.33	222.4	179.8
34__Main TS	29.55	222.5	179.9
35__Main TS	29.77	222.7	180.1
36__Main TS	30.00	222.9	180.3
37__Main TS	30.24	223.0	180.4
38__Main TS	30.49	223.2	180.6
39__Main TS	30.75	223.3	180.7
40__Main TS	31.05	223.4	180.9
41__Main TS	31.41	223.5	181.0
42__Main TS	31.87	223.4	181.0
43__Main TS	32.52	223.1	181.0
44__Main TS	33.50	222.5	180.7
45__Main TS	35.00	221.5	180.1
46__Main TS	37.26	220.1	179.1
47__Main TS	40.47	218.5	177.6
48__Main TS	44.57	217.4	176.1
49__Main TS	49.17	217.2	175.0
50__Main TS	53.67	217.9	174.8
51__Main TS	57.55	219.1	175.4
52__Main TS	60.60	220.2	176.6
53__Main TS	62.93	220.8	177.8
54__Main TS	64.97	219.9	178.4
55__Main TS	67.59	215.7	177.4
Reboiler	72.49	42.43	173.3

PROPERTIES

Properties : Feed

	Overall	Vapour Phase	Liquid Phase		
Vapour/Phase Fraction	0.0847	0.0847	0.9153		
Temperature: (C)	32.00	32.00	32.00		
Pressure: (bar)	10.00	10.00	10.00		
Molar Flow (kgmole/h)	145.2	12.30	132.9		
Mass Flow (kg/h)	6935	540.2	6395		

Hyprotech Ltd. HYSYS.Plant v2.2 (Build 3797) Page 2 of 6

Licensed to: HYSIM's Development Team

https://doi.or
2412-0758/University of Technology-Iraq, Baghdad, Iraq

HYSIM's Development Team Calgary, Alberta CANADA	Case Name:	D:\ÇáÈÍË ÇáäåÈÜÑ\New Research Depro ÇáÃÖÇÓí.hsc
	Unit Set:	EuroSI
	Date/Time:	Sat Mar 30 16:14:24 2013

Distillation: DEPROPANIZER @Main (continued)

Properties : Feed

	Overall	Vapour Phase	Liquid Phase
Liquid Volume Flow (m3/h)	12.92	1.041	11.87
Molar Enthalpy (kcal/kgmole)	-1.428e+004	-5603	-1.508e+004
Mass Enthalpy (kcal/kg)	-298.9	-127.6	-313.4
Molar Entropy (kJ/kgmole-C)	66.57	104.9	63.02
Mass Entropy (kJ/kg-C)	1.394	2.390	1.310
Heat Flow (kcal/h)	-2.073e+006	-6.894e+004	-2.004e+006
Molar Density (kgmole/m3)	3.790	0.4734	10.79
Mass Density (kg/m3)	181.0	20.79	519.1
Std Liquid Mass Density (kg/m3)	542.4	524.1	544.0
Molar Heat Capacity (kJ/kgmole-C)	123.7	78.72	127.9
Mass Heat Capacity (kJ/kg-C)	2.591	1.793	2.658
Thermal Conductivity (W/m-K)	---	1.890e-002	9.633e-002
Viscosity (cP)	---	9.101e-003	0.1006
Surface Tension (dyne/cm)	---	---	7.212
Molecular Weight	47.76	43.91	48.12
Z Factor	---	0.8326	3.654e-002

Properties : propa

	Overall	Vapour Phase	Liquid Phase
Vapour/Phase Fraction	0.0000	0.0000	1.0000
Temperature: (C)	12.57	12.57	12.57
Pressure: (bar)	8.500	8.500	8.500
Molar Flow (kgmole/h)	102.7	0.0000	102.7
Mass Flow (kg/h)	4333	0.0000	4333
Liquid Volume Flow (m3/h)	8.414	0.0000	8.414
Molar Enthalpy (kcal/kgmole)	-5499	-2223	-5499
Mass Enthalpy (kcal/kg)	-130.3	-53.40	-130.3
Molar Entropy (kJ/kgmole-C)	38.26	94.23	38.26
Mass Entropy (kJ/kg-C)	0.9066	2.263	0.9066
Heat Flow (kcal/h)	-5.647e+005	0.0000	-5.647e+005
Molar Density (kgmole/m3)	12.36	0.4228	12.36
Mass Density (kg/m3)	521.7	17.60	521.7
Std Liquid Mass Density (kg/m3)	517.9	513.2	517.9
Molar Heat Capacity (kJ/kgmole-C)	110.4	69.84	110.4
Mass Heat Capacity (kJ/kg-C)	2.615	1.677	2.615
Thermal Conductivity (W/m-K)	0.1122	1.714e-002	0.1122
Viscosity (cP)	8.683e-002	8.585e-003	8.683e-002
Surface Tension (dyne/cm)	8.175	---	8.175
Molecular Weight	42.20	41.64	42.20
Z Factor	2.894e-002	0.8463	2.894e-002

Properties : buta

	Overall	Vapour Phase	Liquid Phase
Vapour/Phase Fraction	0.0000	0.0000	1.0000
Temperature: (C)	72.36	72.36	72.36
Pressure: (bar)	9.500	9.500	9.500
Molar Flow (kgmole/h)	42.52	0.0000	42.52
Mass Flow (kg/h)	2602	0.0000	2602
Liquid Volume Flow (m3/h)	4.502	0.0000	4.502
Molar Enthalpy (kcal/kgmole)	-3.607e+004	-3.117e+004	-3.607e+004
Mass Enthalpy (kcal/kg)	-589.3	-527.1	-589.3
Molar Entropy (kJ/kgmole-C)	107.8	156.7	107.8
Mass Entropy (kJ/kg-C)	1.762	2.650	1.762
Heat Flow (kcal/h)	-1.534e+006	0.0000	-1.534e+006
Molar Density (kgmole/m3)	8.266	0.4093	8.266
Mass Density (kg/m3)	505.9	24.21	505.9
Std Liquid Mass Density (kg/m3)	580.4	570.1	580.4
Molar Heat Capacity (kJ/kgmole-C)	172.9	122.3	172.9
Mass Heat Capacity (kJ/kg-C)	2.825	2.068	2.825
Thermal Conductivity (W/m-K)	7.222e-002	2.114e-002	7.222e-002
Viscosity (cP)	0.1152	9.204e-003	0.1152
Surface Tension (dyne/cm)	6.092	---	6.092

Hyprotech Ltd. HYSYS.Plant v2.2 (Build 3797) Page 3 of 6

Licensed to: HYSIM's Development Team

HYPROTECH	HYSIM's Development Team Calgary, Alberta CANADA	Case Name:	D:\ÇáÈÍË ÇáäãÊÙÑ\New Research Depro ÇáÃÓÇÓí.hsc
		Unit Set:	EuroSI
		Date/Time:	Sat Mar 30 16:14:24 2013

Distillation: DEPROPANIZER @Main (continued)

Properties : buta

	Overall	Vapour Phase	Liquid Phase		
Molecular Weight	61.20	59.14	61.20		
Z Factor	4.001e-002	0.8079	4.001e-002		

SUMMARY

Tray Summary

Flow Basis: Molar | Reflux Ratio: 1.000

	Temp. (C)	Pressure (bar)	Liquid (kgmole/h)	Vapour (kgmole/h)	Feeds (kgmole/h)		Draws (kgmole/h)		Duties (kcal/h)
Condenser	12.57	8.500	102.7	---	---		102.7	L	-7.494e+005
1__Main TS	14.00	8.500	102.9	205.4					---
2__Main TS	14.39	8.519	103.0	205.6					---
3__Main TS	14.55	8.537	103.0	205.6					---
4__Main TS	14.66	8.556	103.0	205.7					---
5__Main TS	14.75	8.574	103.0	205.7					---
6__Main TS	14.84	8.593	103.0	205.7					---
7__Main TS	14.92	8.611	103.0	205.7					---
8__Main TS	15.01	8.630	103.1	205.7					---
9__Main TS	15.09	8.648	103.1	205.8					---
10__Main TS	15.18	8.667	103.1	205.8					---
11__Main TS	15.27	8.685	103.1	205.8					---
12__Main TS	15.38	8.704	103.0	205.8					---
13__Main TS	15.49	8.722	103.0	205.7					---
14__Main TS	15.63	8.741	102.9	205.7					---
15__Main TS	15.81	8.759	102.7	205.6					---
16__Main TS	16.06	8.778	102.5	205.4					---
17__Main TS	16.40	8.796	102.0	205.2					---
18__Main TS	16.89	8.815	101.4	204.7					---
19__Main TS	17.58	8.833	100.5	204.1					---
20__Main TS	18.52	8.852	99.36	203.2					---
21__Main TS	19.72	8.870	98.02	202.0					---
22__Main TS	21.14	8.889	96.57	200.7					---
23__Main TS	22.74	8.907	94.92	199.3					---
24__Main TS	24.57	8.926	92.50	197.6					---
25__Main TS	27.13	8.944	220.8	195.2	145.2	M			---
26__Main TS	27.58	8.963	221.2	178.3					---
27__Main TS	27.85	8.981	221.4	178.7					---
28__Main TS	28.04	9.000	221.6	178.9					---
29__Main TS	28.22	9.019	221.7	179.1					---
30__Main TS	28.40	9.037	221.9	179.2					---
31__Main TS	28.58	9.056	222.0	179.3					---
32__Main TS	28.76	9.074	222.2	179.5					---
33__Main TS	28.94	9.093	222.3	179.6					---
34__Main TS	29.13	9.111	222.5	179.8					---
35__Main TS	29.33	9.130	222.6	179.9					---
36__Main TS	29.53	9.148	222.7	180.1					---
37__Main TS	29.74	9.167	222.9	180.2					---
38__Main TS	29.96	9.185	223.0	180.4					---
39__Main TS	30.20	9.204	223.1	180.5					---
40__Main TS	30.46	9.222	223.2	180.6					---
41__Main TS	30.78	9.241	223.3	180.7					---
42__Main TS	31.19	9.259	223.2	180.7					---
43__Main TS	31.77	9.278	222.9	180.7					---
44__Main TS	32.63	9.296	222.4	180.4					---
45__Main TS	33.97	9.315	221.4	179.9					---
46__Main TS	36.04	9.333	220.0	178.9					---
47__Main TS	39.06	9.352	218.4	177.5					---
48__Main TS	43.07	9.370	217.2	175.9					---
49__Main TS	47.72	9.389	216.7	174.6					---
50__Main TS	52.42	9.407	217.3	174.2					---
51__Main TS	56.57	9.426	218.5	174.8					---

Hyprotech Ltd. HYSYS.Plant v2.2 (Build 3797) Page 4 of 6

Licensed to: HYSIM's Development Team

HYPROTECH

HYSIM's Development Team
Calgary, Alberta
CANADA

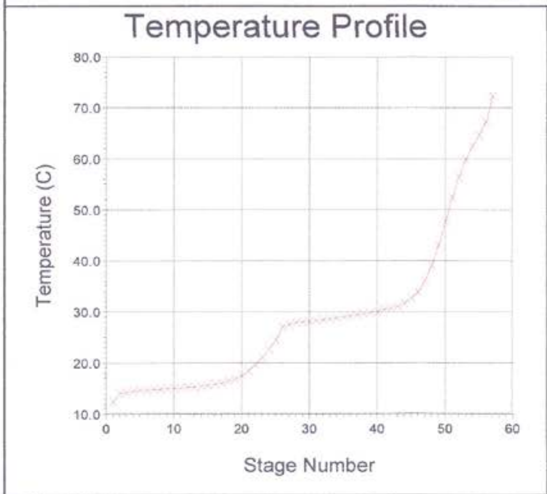
Case Name:	D:\ÇaÈÍÉ ÇáãâÊÙÑ\New Research Depro ÇáÃÓÇÓi.hsc
Unit Set:	EuroSI
Date/Time:	Sat Mar 30 16:14:24 2013

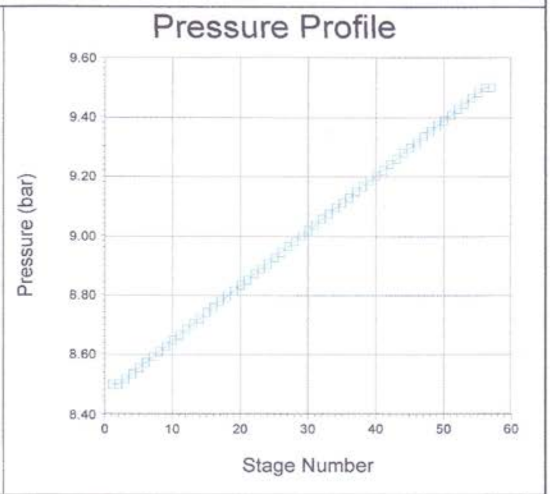
Distillation: DEPROPANIZER @Main (continued)

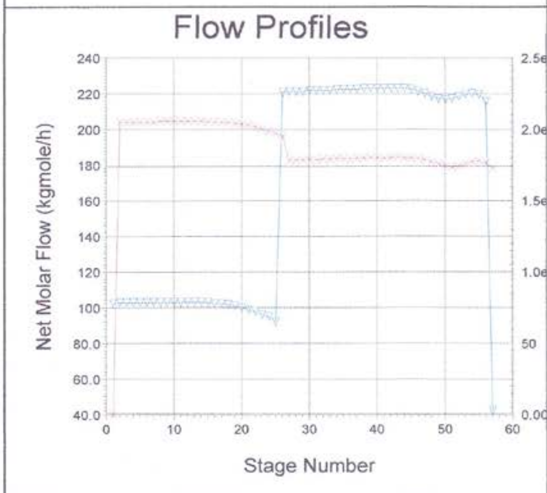
Tray Summary

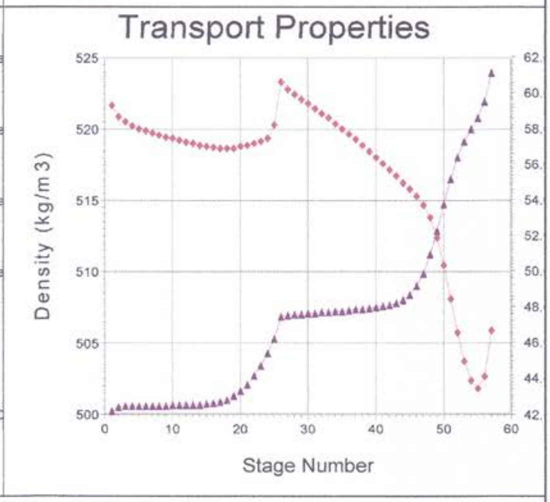
	Temp. (C)	Pressure (bar)	Liquid (kgmole/h)	Vapour (kgmole/h)	Feeds (kgmole/h)		Draws (kgmole/h)		Duties (kcal/h)
52__Main TS	59.89	9.444	219.7	176.0					---
53__Main TS	62.46	9.463	220.4	177.2					---
54__Main TS	64.66	9.481	219.6	177.9					---
55__Main TS	67.39	9.500	215.5	177.0					---
Reboiler	72.36	9.500	---	173.0	---		42.52	L	7.244e+005

TRAY by TRAY PROPERTIES PLOTS



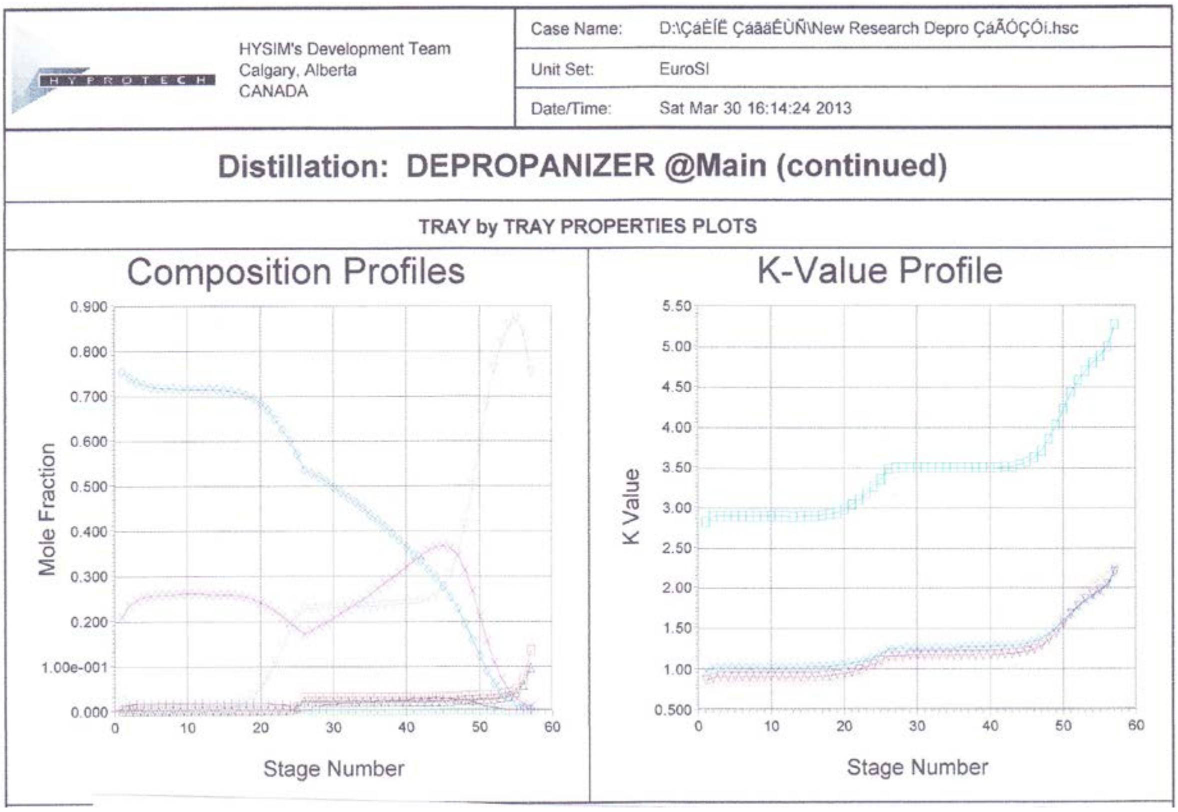






Hyprotech Ltd. HYSYS.Plant v2.2 (Build 3797) Page 5 of 6
Licensed to: HYSIM's Development Team

ht
2412-0758/University of Technology-Iraq, Baghdad, Iraq



https://doi.org/10.30684/etj.31.18A.7
2412-0758/University of Technology-Iraq, Baghdad, Iraq

Appendix C

HYSIM's Development Team Calgary, Alberta CANADA	Case Name: D:\ÇáÈÍË ÇáãåÊÚÑ\New Research Depro ÇáÃÓÇÓí.hsc
	Unit Set: EuroSI
	Date/Time: Sat Mar 30 16:06:08 2013

Tray Sizing: Tray Sizing-1

SETUP

Tray Section:	Main TS @COL1	Liquid Draw:	0.00 %	Sieve Tray Flooding Method:	Minimum Csb

	Section_1			
Section Start	1__Main TS			
Section End	55__Main TS			
Internals	Valve			
Mode	Design			
Active	Off			
Status	Complete			
Design Limit	Flooding			
Limiting Stage	25__Main TS			

SPECIFICATIONS

	Section_1		
Section Start	1__Main TS		
Section End	55__Main TS		
Internals	Valve		
Mode	Design		
Number of Flow Paths	---		
Section Diameter (m)	---		
Tray for Properties	---		
Tray Spacing (mm)	609.6		
Tray Thickness (mm)	3.175		
Foaming Factor	1.000		
Max Delta P (ht of liq)	152.4 mm		
Max Flooding (%)	85.00		
Packing Correlation	---		
HETP (m)	---		
Packing Type			

TRAY INTERNALS

	Section_1			
Section Start	1__Main TS			
Section End	55__Main TS			
Internals	Valve			
Sieve Hole Pitch (mm)	---			
Sieve Hole Diameter (mm)	---			
Valve Mat'l Density (kg/m3)	8220			
Valve Mat'l Thickness (mm)	1.524			
Hole Area (% of AA) (%)	15.30			
Valve Orifice Type	Straight			
Valve Design Manual	Glitsch			
Bubble Cap Slot Height (mm)	---			
Side Weir Type	Straight			
Weir Height (mm)	50.80			
Max Weir Loading (m3/h-m)	89.42			
Downcomer Type	Vertical			
Downcomer Clearance (mm)	38.10			
Max DC Backup (%)	50.00			
Side DC Top Width (mm)	---			
Side DC Bottom Width (mm)	---			
Centre DC Top Width (mm)	---			
Centre DC Bottom Width (mm)	---			
O.C. DC Top Width (mm)	---			
O.C. DC Bottom Width (mm)	---			
O.S. DC Top Width (mm)	---			
O.S. DC Bottom Width (mm)	---			

TRAY RESULTS

	Section_1			

Hyprotech Ltd. HYSYS.Plant v2.2 (Build 3797) Page 1 of 11
Licensed to: HYSIM's Development Team

https://doi.org/10.30684/etj.31.18A.7
2412-0758/University of Technology-Iraq, Baghdad, Iraq

HYPROTECH	HYSIM's Development Team Calgary, Alberta CANADA	Case Name:	D:\ÇáÈÍË ÇáãäÊÙÑ\New Research Depro ÇáÃÓÇÓÌ.hsc
		Unit Set:	EuroSI
		Date/Time:	Sat Mar 30 16:06:08 2013

Tray Sizing: Tray Sizing-1 (continued)

Section Start		1__Main TS			
Section End		55__Main TS			
Internals		Valve			
Section Diameter	(m)	0.7620			
Max Flooding	(%)	73.02			
X-Sectional Area	(m2)	0.4560			
Section Height	(m)	33.53			
Section DeltaP	(bar)	0.2671			
NFP		1			
Flow Length	(mm)	444.5			
Flow Width	(mm)	716.3			
Max DC Backup	(%)	35.37			
Max Weir Load	(m3/h-m)	41.48			
Max DP/ Tray	(bar)	5.631e-003			
Tray Spacing	(mm)	609.6			
Total Weir Length	(mm)	618.9			
Weir Height	(mm)	50.80			
Active Area	(m2)	0.3184			
DC Clearance	(mm)	38.10			
DC Area	(m2)	6.883e-002			
Side Weir Length	(m)	0.6189			
Hole Area	(m2)	4.871e-002			
Estimated # of Holes/Valves		42			
Relief Area	(m2)	0.0000			
Relief - S	(mm)	---			
Relief - A	(mm)	---			
Relief - B	(mm)	---			
Side DC Top Width	(mm)	158.8			
Side DC Btm Width	(mm)	158.8			
Side DC Top Length	(m)	0.6189			
Side DC Btm Length	(m)	0.6189			
Side DC Top Area	(m2)	6.883e-002			
Side DC Btm Area	(m2)	6.883e-002			
Centre DC Top Width	(mm)	0.0000			
Centre DC Btm Width	(mm)	0.0000			
Centre DC Top Length	(m)	0.0000			
Centre DC Btm Length	(m)	0.0000			
Centre DC Top Area	(m2)	0.0000			
Centre DC Btm Area	(m2)	0.0000			
O.C. DC Top Width	(mm)	0.0000			
O.C. DC Btm Width	(mm)	0.0000			
O.C. DC Top Length	(m)	0.0000			
O.C. DC Btm Length	(m)	0.0000			
O.C. DC Top Area	(m2)	0.0000			
O.C. DC Btm Area	(m2)	0.0000			
O.S. DC Top Width	(mm)	0.0000			
O.S. DC Btm Width	(mm)	0.0000			
O.S. DC Top Length	(m)	0.0000			
O.S. DC Btm Length	(m)	0.0000			
O.S. DC Top Area	(m2)	0.0000			
O.S. DC Btm Area	(m2)	0.0000			

PACKED RESULTS

		Section_1		
Section Start		1__Main TS		
Section End		55__Main TS		
Internals		Valve		
Section Diameter	(m)	0.7620		
Max Flooding	(%)	73.02		
X-Sectional Area	(m2)	0.4560		
Section Height	(m)	33.53		
Section DeltaP	(bar)	0.2671		

Hyprotech Ltd. HYSYS.Plant v2.2 (Build 3797) Page 2 of 11

Licensed to: HYSIM's Development Team

https://doi.org/10.30684/etj.31.18A.7
2412-0758/University of Technology-Iraq, Baghdad, Iraq