Statistical Process Control of Debutanizer Column

by

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13825

Dissertation submitted in partial fulfillment of

the requirements for the

Bachelor of Engineering (Hons)

(Chemical Engineering)

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CERTIFICATION OF APPROVAL

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Approved by,

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(Nasser B M Ramli)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

May 2014

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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(JACKIE KOH)

ABSTRACT

Distillation process in distillation column is a challenging process as it is subjected to disturbances and interruptions that sometime cannot be controlled or predicted. The main concern in any distillation column or process is the quality of the main product produced. To control and monitor the quality of the main product also proves as a challenge. The right implementation of control strategies could help the distillation column to produce conforming product with desired quality. Therefore, Statistical Process Control (SPC) is introduced with the aim to identify the variations affecting the process, thus controlling and monitoring the quality of the end product of distillation column. The relationship between the product compositions and the process variables also being investigated using the statistical method. The debutanizer column at PETRONAS Penapisan Terengganu Sdn Bhd (PPTSB), an oil refinery plant will be the subject for this SPC research. The methodology to implement SPC is constructed and Individual Control Charts will be used to determine the state of the process. The finding of this project shows that the Manipulate Variables and Temperature Variable have the most significant relationship with the top product composition. The quality of the top product also affected by the changes made in the manipulated variables as shown on each of the individual. The findings are very helpful in suggesting what variables are crucial to be taken care of to maintain the quality of the product.

Keywords: *Statistical Process Control, Debutanizer Column, Final Year Project*

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CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Distillation is a separation process that separates a mixture based on differences in volatility of components in a boiling liquid mixture. The components in a liquid solution are separated by distillation with regards to the components distribution in vapor and liquid phase (Geankoplis, 2003). It is a physical separation process which is different than a chemical process that using chemical reactions. Distillation is used in many applications for separation but found its widest application in oil and gas and petrochemical industries. In petroleum/oil refineries for example, crude oil as the feedstock of the refineries is separate to various fractions to produce petroleum products and other using vapor-liquid separation process in a distillation column/tower.

The distillation column is definitely the most important component in distillation unit. The separation process between mixtures happens inside the distillation column and produces two type of product, which are the top product and bottom product. Most of the time, the top product will be the main product of the separation and the bottom product will undergo another separation to obtained another desired product. However, some of the aforementioned products will be recycled back into the column as reflux. This is where the distillation process in distillation column gets complicated.

Distillation process in refinery plant is usually operated in continuous steady state. In continuous steady state operation, the amount of product being distilled is normally will be the same with the amount of feed being added. This will be different if there are interruptions in the process such as changes in the feed, heat, pressure, or temperature. This will affect the separation process inside the distillation column.

It is not easy to maintain the stability in the process and definitely same goes to the quality of the product as it is correlated. The separation process in distillation column proves to be complicated and difficult to be handled as it is complex and highly un-predictive in nature. In addition, Mohamed Ramli, Hussain, Mohamed Jan, and Abdullah (2014) describes the PETRONAS Penapisan Terengganu Sdn Bhd (PPTSB) debutanizer column as “a challenging process as it deals with non-linearity, is highly multivariable process, involves a great deal of interaction between the variables, has lag in many of the control system, all of which makes it a difficult system to be modeled by linear techniques”.

To maintain the stability and desired quality that meets the customers’ requirement will be a challenging process. Therefore, the best control strategy is needed to be implemented in the distillation column to manage the stability and the product quality. The process stability can be managed by the process model or corrective actions by the controller. The product quality however proves to be the hardest to control.

Therefore, Statistical Process Control (SPC) is introduced with the aim to control and manage the product quality. Quality has a broad definitions but all of it comes to a single statement which is to meet the specification given by the customer. SPC was pioneered by Dr. Walter Shewhart in the early 1920s back in the Bell Laboratories. It was not until after the World War II, where W. Edwards Deming introduces the application of SPC to Japanese industry. From then on, SPC is widely used until now. SPC as a method of quality control which is widely used and most popular in manufacturing industries but it is not limited to only manufacturing processes.

In response to the challenges in controlling and monitoring the quality of the end product of the debutanizer column, SPC is introduced as a quality control strategy. In this study, the relationship between the process variables and the top product will be investigated. The effect of this relationship is then compared to the process in order to identify if it has an impact toward the process. The process can be either in control or out of control.

1.2 Problem Statement

A distillation column such as the debutanizer column is a challenging process to control especially the quality of its end product. Monitoring and controlling the quality of debutanizer column end product is a challenge especially for a control engineer. The variations in the distillation process are often the challenge that needed to be tackled as the variation is inversely proportional to the quality. By reducing the variation in the process, quality of the end product can be controlled within the specification limit. The relationship between the process variables and the top product compositions also needed to be analyzed to observe the effect of the process variables towards the quality of the product especially on the top product compositions.

Therefore, this project addresses several focuses:

1. Is there a relationship between each of the process variable and the top product compositions that eventually affecting the quality?
2. Is the relationship affecting the process?

1.3 Objectives

The objectives of the project are as follows:

- To implement Statistical Process Control techniques/tools to analyze the debutanizer column top product quality.
- To investigate the relationship between the process variables and the top product compositions.
- To analyze the variables using control chart.

1.4 Scope of study

This study will focus on the application of Statistical Process Control (SPC) on the Debutanizer Column top product quality. This includes the descriptive and inferential statistic, and the use of control charts. Real plant data of debutanizer column obtained from the PETRONAS Penapisan Terengganu Sdn. Bhd. (PPTSB) will be used as the analysis data inputs. The analyzing method is statistical method with the help of Statistical Packages for the Social Sciences (SPSS) software, prominent software for statistical analysis.

1.5 Relevancy of the Project

Quality of the product is the most important in any production industries. To maintain a certain quality of the product, controlling and monitoring the quality is crucial. Challenging distillation process contributes to the variability of the product quality in a debutanizer column. With the introduction of Statistical Process Control or SPC to control and monitor the main product quality, it is desired to improve the process capability and at the same time maintained the desired quality. The success of the SPC implementation during this project could benefits on future, real implementation to any distillation column.

1.6 Feasibility of the Project

The time allocated for the project is adequate to be completed in time. The area of the project covers in within the area of expect of the Supervisor which the author seeks guidance and help. The data information for the project was obtained and readily used as the case study for SPC application.

CHAPTER 2

LITERATURE REVIEW

2.1 Statistical Process Control (SPC)

Statistical Process Control (SPC) has been widely used since the World War II both in the United Kingdom (UK) and the United States of America (USA) but as industries converted to peacetime production, SPC lost its importance in the industries (Wetherill & Brown, 1991). However, when taught to the Japanese by W. E. Deming in the 1950s, they have applied it to their industry widely and prove that SPC saves money and attracts customers. Competition between industries becomes bigger since the application of SPC in Japan and it has forced UK and USA to introduce it to their industries in order to compete with the Japanese. Up until now, SPC have gained the interest in industries for quality control and improvements.

SPC in general is a quality control technique which uses the statistical method. Control Chart is commonly used as SPC tools to monitor and controlling the process. It helps to monitor and control the variations in the process that eventually affects the quality of the product. However, according to Oakland (2008), SPC is not really about statistics or control, it is about competitiveness. Quality, delivery and price are the three main issues that always revolve around the competition between industries. If the quality is right, the delivery and price performance will be competitive too (Oakland, 2008). Therefore, there is a relationship between the SPC methods and the result or quality of the desired product.

2.1.1 Statistics, Process, and Control

These three words (statistic, process, and control) are crucial in understanding SPC and using it effectively.

A process is where a set of inputs is transformed into outputs (Oakland, 2008). Normally, the quality of production is determined by the process that produces the output. By knowing on how the process works and what process factors affect the output, the quality can be improved and the source of the factors can be eliminated or reduced. According to Oakland (2008), each process may be analyzed by an examination of the inputs and outputs. The examination will determine the action necessary to improve quality. This can be done using SPC which gather and analyze data of the process to understand and improve it. Better improvement on the process can leads to better quality product. Although quality can be different in definition by the industries, but in general, it can be defined as meeting the requirements of the customers. Therefore, better quality product leads to the satisfaction of the customers.

On the other hand, statistics or statistical methods help to quantify variations. Fundamentally, SPC is about understanding and managing variation (Stapenhurst, 2013). Variations exist almost in every process not only in production or manufacturing. Variations in form of data can be analyzed using graphical analysis such as Cumulative Sum plot, Histogram, moving-average charts, etc as part of process capability analysis. With the help of quantitative methods and statistical tools to quantify variations, it can be eliminated or reduced by identifying the causes.

Last but not least, control. All processes can be monitored and brought ‘under control’ by gathering and using data (Oakland, 2008). The process’ performance is measured and feedback is required for corrective action where necessary to make it ‘in control’. But in every process, there are variations and this is where control comes in. Variations can be categories into two which are *common cause variation* and *special cause variation*. *Common cause variation* is non-assignable or random source of variation. It can be considered normal to the process as it is consistently act on the process. Stapenhurst (2013) added that the process is said to be in state of statistical control or in control although it was subjected to only *common cause variation*. The *special cause variation* is different as it is assignable and not always occurs or present in the process. When it occurs, the process is said to be not in a state of statistical control or out of control. This can happen with *special cause variation*, or both *common cause variation* and *special cause variation*. It is important for SPC to monitor and manage the various so that it cannot affect the process and eventually affects the quality of the product.

2.1.2 The SPC and its Applications

Control chart is proven as the most prominent SPC tools when it comes to monitoring and controlling variations (Driesen, 2004). Control chart enable visual and statistical analysis of a data for practitioner in descriptive and inferential tools. As descriptive tool, the control chart help practitioner to see and visualize the patterns in production process, whereas as inferential tools, control chart established baseline and applying probability test to distinguish *special cause variations* from *common cause variations*. Control Chart will be further discussed later in this chapter.

The application of SPC has been used in many industries nowadays but not limited only to production or manufacturing industries. SPC also widely used in healthcare and at some point, in an organization for better performances.

Ipek, Ankara, and Ozdag (1999) wrote a technical note entitled ‘The Application of Statistical Process Control’ to show how control chart is used to find the causes of the quality changes of the concentrates and examines if the process is ‘in control’ or otherwise. The finding using control chart shows that the process is ‘in control’ but found also few causes that contribute to the poor quality of the concentrates. Ipek et al. then make a suggestion based on the findings using control chart to increase the quality.

Smith et al. (2013) shows that the SPC also can be used in monitoring and improving the outcomes of cardiac surgery performances. In his article entitle ‘Use of Graphical Statistical Process Control Tools to Monitor and Improve Outcomes in Cardiac Surgery’ concluded that the use of SPC tools such as the Cumulative Sum (CUSUM) charts, Exponentially Weighted Moving Average (EWMA) charts and Funnel Plots, facilitate near “real-time” performance monitoring by allowing early detection and intervention in altered performance. This proves that SPC is working effectively even though it was outside of the common use in manufacturing.

SPC is proven to be effective in monitoring, controlling and improving the quality of the desired outcome especially using the control chart and other statistical methods. Wheeler (2010) proclaimed that SPC is not a theory anymore as it has been proven time after time.

2.2 Control Charts

The heart of SPC is definitely the Control Charts. Ipek et al. (1999) describes the control charts as "the most effective means for controlling process control system via statistical methods in an economical and secure way". Control charts have been used to analyze and monitor the variations in the process effectively.

The pioneer control charts were developed by Shewhart back in the 1920s and known as Shewhart control charts. The Shewhart charts can be divided into two categories: Attributes Control Charts and Variable Control Charts (Christobek, 2001). When countable sets of measurement provided, the Attributes Control Charts is used. On the hand, if the set of measurement is from a continuous distribution or from a process, Variables Control Charts is used.

The most common Attributes Control Charts are the c-chart and p-chart. c-chart deals with the number of defects and nonconformities while, p-chart deals with fraction or proportions of the defects.

Since this project deals with variations in the process and having a continuous data, Variables Control Charts is most suitable to be used. Some examples of Variable Control Charts are Mean or X-bar chart, range or R chart and individuals chart.

The assumption on using control charts was that the data were normally distributed and independent (Ibrahim, 1996). Based on this assumption, the probability of falling in certain ranges for the data can be predicted. Therefore, the state of the process data, either 'in control' or 'out of control' can be defined from the control charts.

2.2.1 X-bar and R Chart

X-bar and R chart are common type of variable control chart and it is using a set or more of measured data. It is often used to monitor the data when samples are collected at regular intervals. Most of the time, X-bar and R charts is used together (Oakland, 2008).

X-bar or mean chart is simply a plot of the mean of the sample of data taken from the process. While R or range chart is a plot of range between samples.

To construct X-bar chart, the mean of the each samples must be known. The mean, $\bar{X}$ is calculated using the formula below

$$\bar{X} = \frac{\sum_{i=1}^{n} Xi}{n}$$

Where

i = Item number

n = Total number of item in the sample

Since the central tendency of a process is unknown, the mean of the sample means can be used to estimate it. The mean of sample means, $\bar{\bar{X}}$ simply the average of all samples mean.

$$\bar{\bar{X}} = \frac{\sum_{j=1}^{m} \bar{X}j}{m}$$

Where

j = Sample number

m = Total number of sample

The range, R is the difference between the highest and the lowest numbers in the sample. R-bar, $\bar{R}$ is the mean of the R of each sample.

$$R = Xmax - Xmin$$

$$\overline{R} = \frac{\sum_{j=1}^{m} Rj}{m}$$

Where

X_{max} = Highest number in the sample

X_{min} = Lowest number in the sample

The Control Limit is calculated for both charts. The $\overline{\overline{X}}$ will be the central line (CL) for X-bar chart, and $\overline{R}$ will be the CL for r chart. The general equations for control limit are as follows:

$$\text{Upper Control Limit for } \overline{X} = \overline{\overline{X}} + A2\overline{R}$$

$$\text{Lower Control Limit for } \overline{X} = \overline{\overline{X}} - A2\overline{R}$$

$$\text{Upper Control Limit for } R = D4\overline{R}$$

$$\text{Lower Control Limit for } R = D3\overline{R}$$

The factors A2, D3 and D4 can be obtained from Table 1. Figure 1 show the common X-bar and R chart used together.

Table 1: Factor determining from $\overline{R}$ the three sigma Control Limits for $\overline{X}$ and R chart (adapted from Statistical Quality Control, p.562, by E. L. Grant and R. Leavenworth, 1964, New York: McGraw-Hill)

Number of Observations in Subgroup n	Factor for $\overline{X}$ Chart A_2	Factors for R Chart: Lower Control Limit D_3	Factors for R Chart: Upper Control Limit D_4
2	1.88	0	3.27
3	1.02	0	2.57
4	0.73	0	2.28
5	0.58	0	2.11
6	0.48	0	2.00
7	0.42	0.08	1.92
8	0.37	0.14	1.86
9	0.34	0.18	1.82
10	0.31	0.22	1.78
11	0.29	0.26	1.74
12	0.27	0.28	1.72
13	0.25	0.31	1.69
14	0.24	0.33	1.67
15	0.22	0.35	1.65
16	0.21	0.36	1.64
17	0.20	0.38	1.62
18	0.19	0.39	1.61
19	0.19	0.40	1.60
20	0.18	0.41	1.59

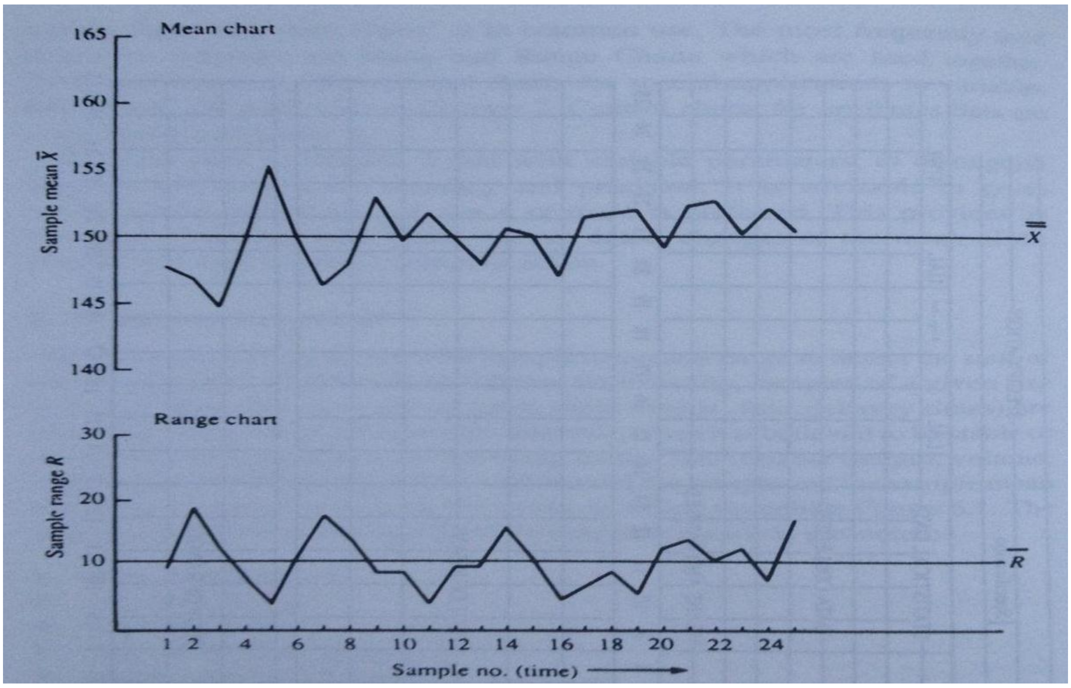

Figure 1: X-bar and R Chart (adapted from Statistical Process Control, p.108, by Oakland J. S., 2008)

2.2.2 Individuals Chart

Another control charts for variable can be used is the individuals chart. This chart is much more simpler than the Shewhart chart. Ussually, an individual chart is used for a one-time or one sample of data (Oakland, 2008). Only the individuals value are plotted instead of means of sample. This is different than the Shewhart chart which plots the means of sample.

The individual chart consist of centreline (CL), action lines such as Upper Action Line (UAL) and Lower Action Lines (LAL) or control limits such as Upper Control Line (UCL) and Lower Control Lines (LCL). The actions or control line can be placed at two or three standard deviations from the centreline.

Both the Shewhart charts and Individual chart can explain on the state of the process either it is in control or out of control. Based on the state of the process, the quality can be monitored and controlled.

Accoding to Oakland (2008), there were other control charts used for special applications to variable data. Run charts, Median, mid range and multi-vari charts, Moving mean, moving range and exponentially weighted moving average (EWMA) charts, control charts for standard deviation, are few of the examples of alternative control charts for variables.

2.3 Debutanizer Column

PETRONAS Penapisan Terengganu Sdn Bhd (PPTSB) debutanizer column is located at the Crude Distillation Unit where the crude oil as the main feedstock is transformed to petroleum products, liquefied petroleum gas (LPG), naphtha and low sulphur waxy residue. Mohamed Ramli et al. (2014) identified the debutanizer column as the main column which is responsible in producing the main product, LPG. The feed of the debutanizer is coming from the deethanizer column bottom product and the LPG is produced as the overhead product. The manipulated variables for the debutanizer column are the feed flow rate, reflux flow rate and reboiler flow rate, whereas the measure variables are the feed flow, debutanizer receiver overhead pressure (Pressure 1), LPG flow to storage (Flow 2), Light Naphtha flow to storage (Flow 1), debutanizer condenser level (Level 2), debutanizer level (Level 1) and reboiler outlet temperature to column. Figure 2 shows the debutanizer column configuration and **Table 2** shows the column specification obtained from Mohamed Ramli et al. technical paper.

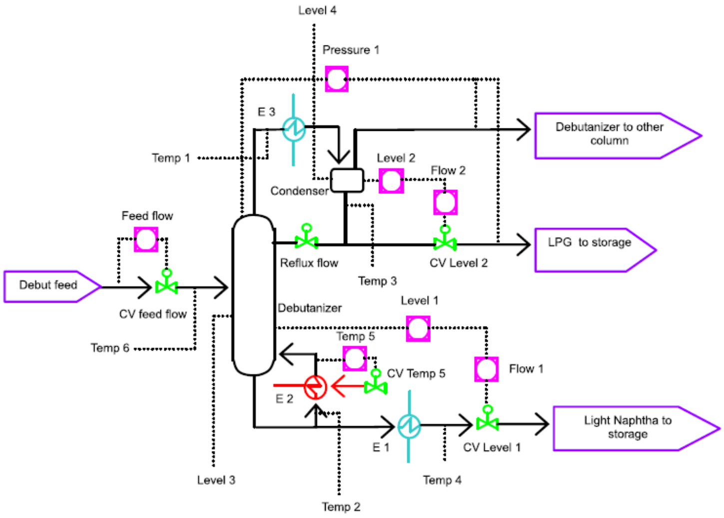

Figure 2: Debutanizer column configuration (Mohamed Ramli et al., 2014)

Table 2: Debutanizer column specification (Mohamed Ramili et al., 2014)

Number of tray of the column	35
Feed tray – stage number	23
Type of tray use	Valve
Column diameter	1.3 m
Column height	23.95 m
Condenser type	Partial
Feed mass flow rate	44106 kg/hr
Feed temperature	113^{o}C
Feed pressure	823.8 kPa
Overhead vapor mass flow rate	11286 kg/hr
Overhead liquid mass flow rate	5040 kg/hr
Condenser pressure	823.8 kPa
Reboiler pressure	853.2 kPa

CHAPTER 3

METHODOLOGY

3.1 Research Methodology and Project Activities

The project started with preliminary research and literature reviews to grasp the full understanding on the Statistical Process Control (SPC) techniques. The research involves with the study of the SPC, the nature of distillation column, and the software that is used in the project.

From preliminary research and literature reviews, the project procedure/methodology is constructed to fit the project relevancy and feasibility. Figure 3 shows the flowchart of the project methodology in brief.

This project is using a real plant data consisting the process variables and compositions. These data were obtained from PETRONAS Penapisan Terengganu Sdn Bhd (PPTSB) debutanizer column as inputs for SPC analysis. The data will be analyzed in descriptive analysis, inferential analysis, and control charts with the aid of Microsoft Excel and Statistical Package for the Social Science (SPSS) software.

In descriptive analysis, the data will be analyzed to get the value for maximum and minimum, mean, standard error of mean, standard deviation, variance, skewness and kurtosis. The data distribution will be displayed using the histogram to describe it.

For inferential analysis, the multivariable data will be analyzed using various statistical methods in order to come out with an inference or conclusion from the data. Statistical methods such as Paired t-Test, Analysis of Variance (ANOVA), Correlations, Scatter plots, Chi-square test, and Regression will be used.

Last but not least, the last statistical method is the control charts. Individual chart is chosen as control chart as the data exhibits only one-time set of data.

The flowchart of the methodology is as shown below:

Preliminary Research and Literature Review

↓

Study on:

a. Statistical Process Control
b. Fractionation/Distillation Column
c. SPSS Software

↓

Using SPSS Software to analyze the data

a. Descriptive analysis
b. Inferential analysis
c. Control charts

↓

Discussion on the finding of the analysis

↓

Conclusion on the finding

Figure 3: Flowchart of the Methodology

3.2 Software Used

Below are the software used in this project:

Table 3: List of Software Used

No	Software	Version	Descriptions
1	Microsoft Word	2010	Microsoft Word or Word is used in this project for documentation and report writing.
2	Microsoft Excel	2010	Microsoft Excel or Excel is used in this project for data analysis.
3	IBM SPSS Statistics	V22	SPSS is used in this project for statistical analysis.

3.3 Project Milestone and Gantt Chart

The project schedule as shown in Table 4 and Table 5 are in the form of gantt chart for better monitoring of the project progress and the activities. The schedule is feasible and structured to follow the timeline given to complete the project.

There are few milestones stated in the gantt chart to enable the project completed in time.

Table 4: Gantt Chart for FYP I

No	Activities\Week	FYP I (Semester 7)													
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1	Title Selection														
2	Preliminary Research Work and Preparing Proposal														
3	Submission of extended Proposal (Wed, 26th Feb)														
4	Proposal Defense (5-7th March)														
5	Project Work/ Analysis Commence - Familiarization on SPSS Software - Descriptive Statistic - Histograms - Paired T-test - ANOVA - Preparing for Interim report														
6	Submission of Interim Report (Draft) (Wed, 9th April)														
7	Submission of Interim Report (Final) (Mon, 21st April)														
8	Project Work Continues														

Key milestone

Table 5: Gantt Chart for FYP II

No	Activities\Week	FYP II (Semester 8)													
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1	Project Work/ Analysis Continues														
	- Correlations	●													
	- Scatter Plots		●												
	- Chi-square Test			●											
	- Regression				●										
	- Control Charts						●								
	- Prepare for Progress Report							●							
2	Submission of Progress Report								●						
3	Project Work Continues														
	- Discussion on the findings									●					
	- Conclusion of the project										●				
	- Preparing Poster & Dissertation										●				
4	Pre – SEDEX										●				
5	Submission of Dissertation (Softbound)												●		
6	Oral Presentation (Viva)													●	
7	Submission of Dissertation (Hardbound)														●

● Key Milestones

CHAPTER 4

RESULTS AND DISCUSSIONS

Over the period of the study, the data from PETRONAS Penapisan Terengganu Sdn Bhd (PPTSB) Debutanizer Column is analyzed using statistical methods which correspond to the statistical process control tools as mentioned in Chapter 3. In this chapter, the result of the analysis is discussed.

4.1 Descriptive Statistic

Descriptive statistic is used to describe and explore the data obtained. This enables us to summarize the data such as what is the data average (mean), range, standard deviation and variance as presented on Table 6.

The debutanizer top product compositions analyzed are Propane (C3), i-Butane (iC4), n-Butane (nC4), i-Pentane (iC5), and n-Pentane (nC5). The process variables analyzed are flow rates, temperature, level, and pressure as mentioned in Chapter 2 of this report. There are 301 values for each compositions and process variables.

The range (R) and standard deviation (σ) tells how spread the data. Range is the difference between the maximum and minimum value in the set of data. Standard deviation the other hand is the square root of the variance of the data, which also responsible in measuring the deviation of the data from the mean. The higher the value of R and σ, the more the data is spread.

It can be seen that in Table 6, variables with larger R value also have large σ value and vice versa. The data is said to have a better distribution if the set has lower R and σ value. However, very large R and σ value can affect the process ultimately leads to 'out of control' process.

Table 6: Descriptive Statistic

	N	Range	Minimum	Maximum	Mean		Std. Deviation	Variance	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
Feed Flow	301	22	50	72	62.57	.629	10.905	118.926	-.290	.140	-1.929	.280
Reboiler Flow	301	3.0	141.5	144.5	142.181	.0629	1.0915	1.191	1.109	.140	-.483	.280
Reflux Flow	301	1.999001	20.299999	22.299000	21.09363068	.055810586	.968277475	.938	.422	.140	-1.813	.280
Debutanizer top temp	301	1.1750	57.7083	58.8833	58.500996	.0112138	.1945514	.038	-1.167	.140	2.750	.280
Debutanizer bottom temp	301	.983337	138.600006	139.583344	139.16348423	.008786698	.152443505	.023	-.376	.140	1.639	.280
Debutanizer receiver bottom temp	301	3.119353	32.206203	35.325556	33.58836350	.035161752	.610033603	.372	.195	.140	.195	.280
Light naphtha temp	301	1.583336	38.908333	40.491669	39.61292878	.010030428	.174021424	.030	.560	.140	5.221	.280
Reboiler outlet temp	301	46.178000	94.551000	140.729000	115.76065781	.735121710	12.753884990	162.662	-.049	.140	-1.220	.280
Debutanizer feed temp	301	8.580552	107.622157	116.202710	110.85372048	.107810802	1.870447513	3.499	.707	.140	.420	.280
Debutanizer receiver level	301	6.424999	57.141666	63.566666	59.99197109	.037131285	.644203711	.415	.164	.140	7.615	.280
Debutanizer level	301	5.291668	57.108334	62.400002	60.22937427	.039016590	.676912540	.458	-.965	.140	5.380	.280
Debutanizer level indicator	301	12.853602	56.061479	68.915081	62.95628984	.139953736	2.428106562	5.896	.050	.140	-.042	.280
Condenser level indicator	301	22.577714	44.753287	67.331001	57.99590042	.254856689	4.421598302	19.551	-.521	.140	.525	.280

Light naphtha flow	301	5.400002	27.208332	32.608334	29.14839423	.032096606	.556855305	.310	1.529	.140	11.124	.280
LPG flow to storage	301	2.870833	5.195833	8.066667	6.76428571	.023881660	.414331315	.172	-.019	.140	1.396	.280
Debutanizer overhead pressure	301	212.031000	715.800000	927.831000	850.69804319	3.363755246	58.358972362	3405.770	-.618	.140	-1.386	.280
propane	301	.2914	.0565	.3480	.175584	.0039026	.0677070	.005	.817	.140	-.038	.280
i-butane	301	.1978	.1308	.3286	.233832	.0021052	.0365243	.001	.566	.140	-.540	.280
n-butane	301	.0983	.0930	.1914	.138282	.0010323	.0179095	.000	.893	.140	.112	.280
i-pentane	301	.0678	.0682	.1360	.095813	.0007678	.0133205	.000	1.271	.140	1.603	.280
n-pentane	301	.0975	.0690	.1665	.112789	.0010190	.0176792	.000	1.012	.140	2.093	.280
Valid N (listwise)	301											

4.2 Histogram

Histogram is the one of the best way to illustrate the descriptive statistic of the data analyzed especially the frequency distribution. The histograms are discussed based on the skewness and kurtosis obtained from Table 6. 8 out of 21 variables are showing negative skewness and kurtosis.

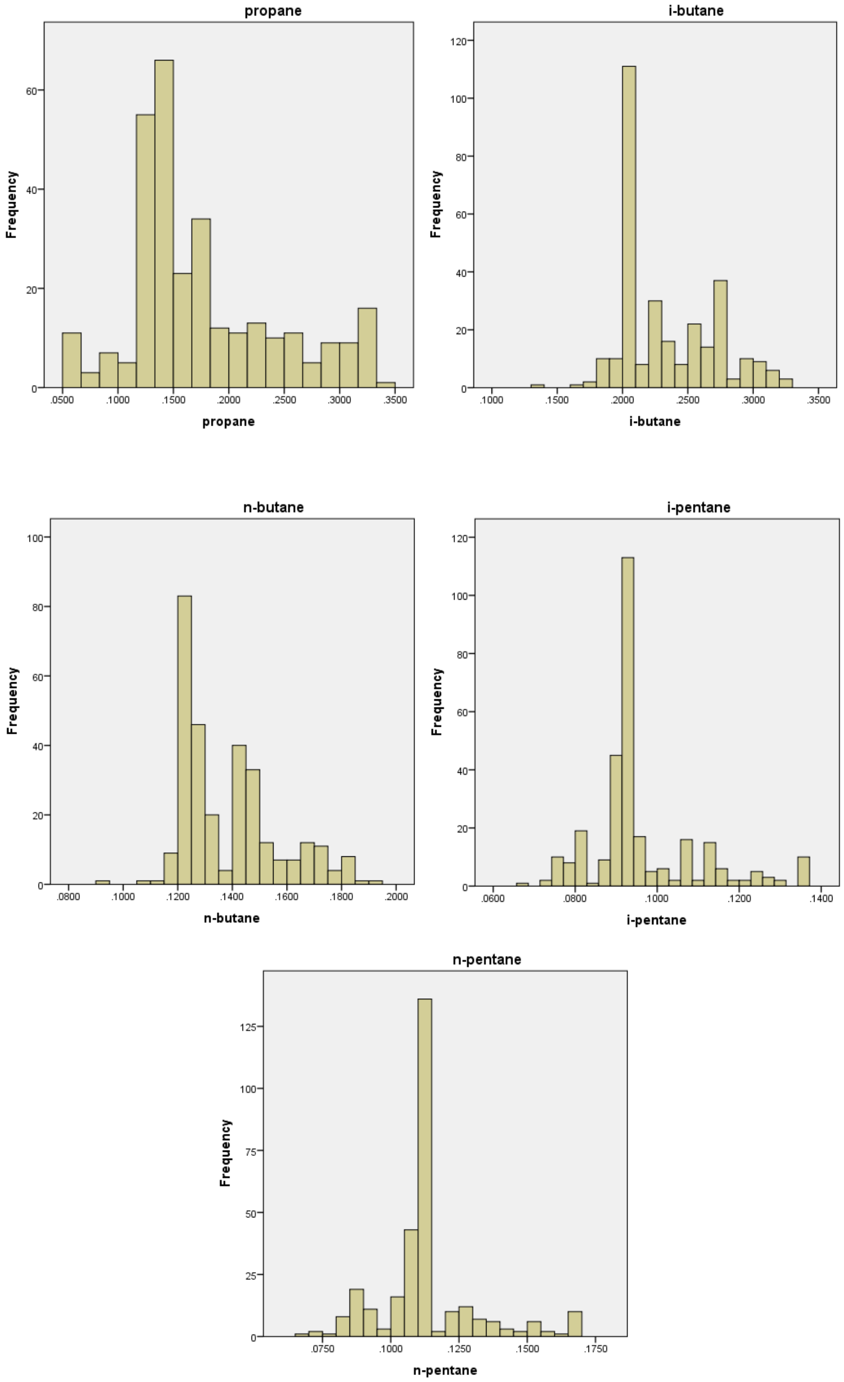

Figure 4 : Histogram of the Compositions

Figure 4 shows the histogram of the debutanizer top product compositions. From Table 6, it can be seen that all the compositions have a positive skewness. Propane (C3), i-Butane (iC4), n-Butane (nC4), i-Pentane (iC5) and n-Pentane (nC5) has skewness of 0.817, 0.566, 0.893, 1.271 and 1.012 respectively. As a result, all the histogram of the compositions is skewed to the right and creating an asymmetrical distribution. As the skewness value getting higher, the distribution will have a long ‘tail’ to the right as indicated by iC5 and nC5 histogram.

However, C3 and iC4 have a negative kurtosis while nC4, iC5 and nC5 have a positive kurtosis. Negative kurtosis suggests that the data have a ‘flat’ distribution, while positive kurtosis suggests that the data have a ‘peaked’ distribution.

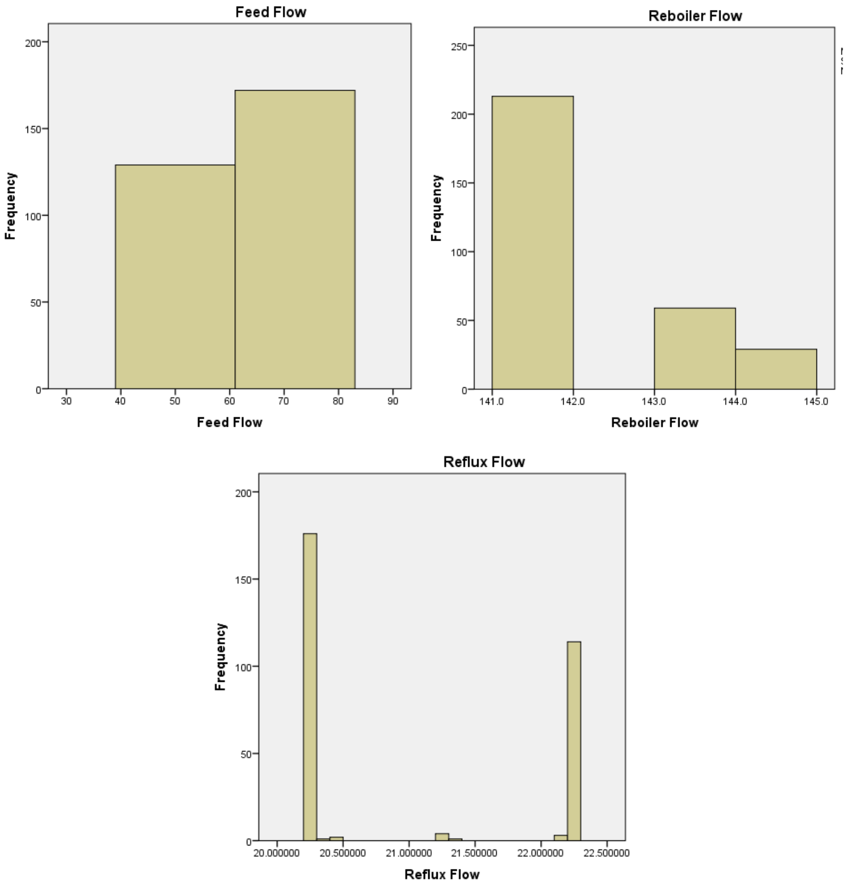

Figure 5: Histogram of the Manipulated Variables

Figure 5 show the histogram of the manipulated variables which are the Feed flow rates, Reboiler flow rates, and Reflux flow rates. All three histogram have negative Kurtosis which indicates flat distribution among the data. Only feed flow rates histogram is skewed to the left as it haves a negative skewness.

4.3 Statistical Analysis

There are few statistical methods used for the statistical analysis on the data provided. Correlations, Chi-Square Test and Regression are used to analyze the relationship between the process variables and the product compositions. On the other hand, t-Test and Analysis of Variance (ANOVA) used to test the significant of the relationship. Nonparametric techniques also used to analyze the data. Last but not least, individual chart is used as control chart to observe the state of the data especially on the top product compositions.

4.3.1 Correlations and Scatter Plots

Pearson's Correlation or Correlation can be used to measure the relationship between two variables whether it have an association or not. Scatter plot is a representation of the relationship or the correlation between the two variables. In this method, we can examine whether both of the variable is responding to each other and have a significant relationship.

The variables is said to have a stronger relationship when the Pearson Correlation coefficients, r is near to +1 or -1. It depends on the relationship between the two variables whether it is a positive (r is greater than 0) or negative (r is lesser than 0) which can be illustrated by the Scatter plots. If r is equal to 0, it indicates that there is no relationship between the two variables.

The correlation examines the relationship as follows:

a) Manipulated Variables and Compositions
b) Temperature Variables and Compositions
c) Level Variables and Compositions
d) Flow Variables and Compositions
e) Pressure Variable and Compositions

The manipulated variables are as follows:

MV 1 : Feed Flow

MV 2 : Reboiler Flow

MV 3 : Reflux Flow

Table 7: Summary of Pearson's Correlation between Top Product Compositions and Manipulated Variables

		MV 1	MV 2	MV 3
Pearson's Correlation Coefficients (r)	C3	**-0.157**	**-0.201**	**-0.411**
	iC4	**-0.102**	**-0.192**	**-0.396**
	nC4	0.023	**-0.151**	**-0.226**
	iC5	**0.198**	0.078	**0.179**
	nC5	**0.198**	**0.120**	**0.236**

The Pearson's Correlations coefficients (r) are significant when the p value is less than the alpha value, which is $\alpha = 0.05$. The bold values (in black) are the values that are significant ($p<0.05$). Appendix II shows the correlation results.

The highest r value between the correlation of the MVs and the compositions are -0.411, which is a negative correlation. This is the correlation between the MV 3 and the Propane (C3). As a result, the changes in value of MV 3 have more effect on C3 than the other compositions. This however considered as a medium relationship between the MVs and the compositions.

From Table 7, the Pearson's correlation coefficients show that almost all the data have significant relationship. The relationship however is not strong based on the r value. Although the r value did not characterize the relationship, it can be seen that in the scatter plots in Figure 6 that the relationship is not a linear relationship. The scatter plots show many outliers that able to produce a significant correlation coefficient even though the relationship is not linear.

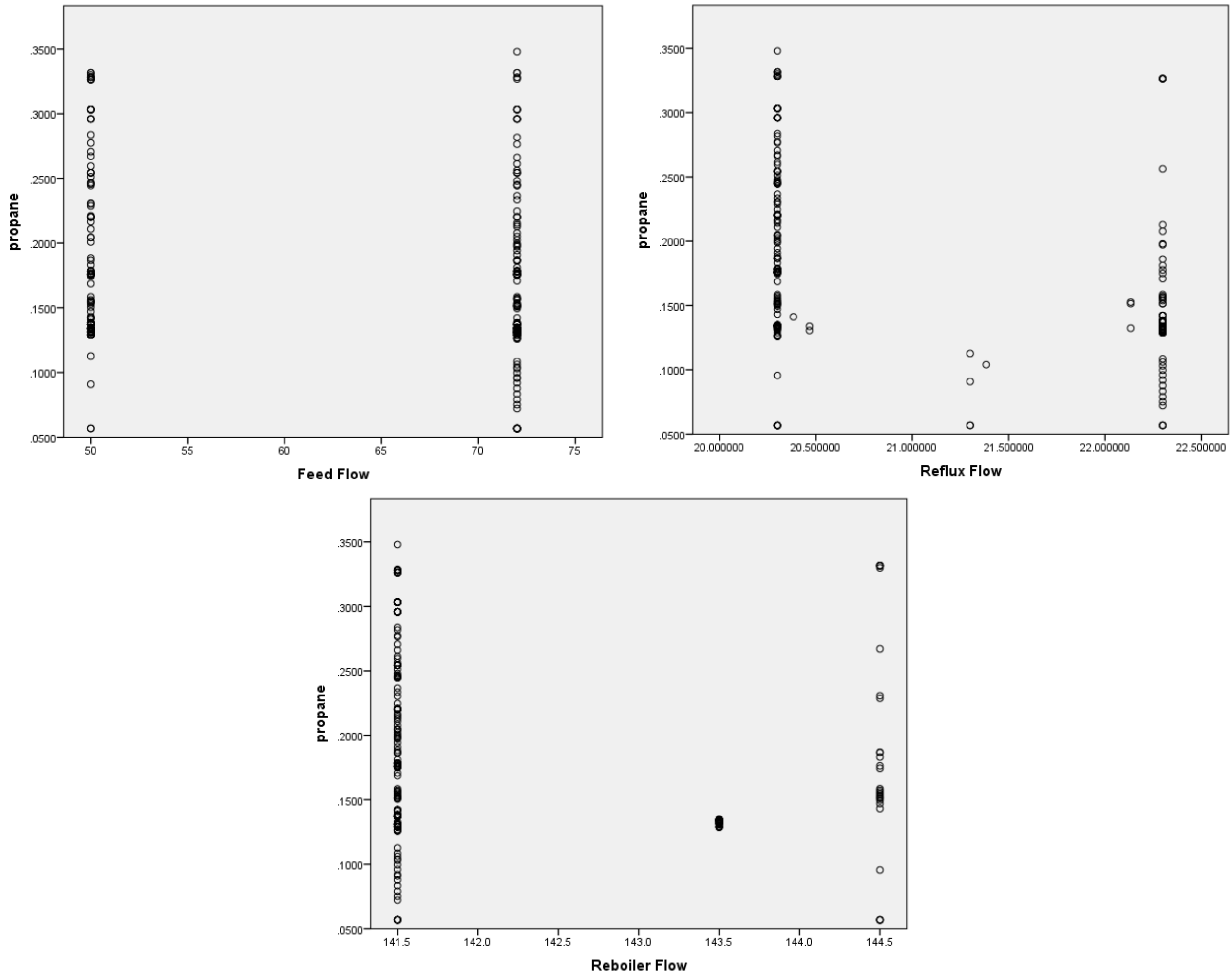

Figure 6: Scatter Plots of C3 vs MVs

The temperature variables are as follow:

TEMP 1 : Debutanizer Top Temperature

TEMP 2 : Debutanizer Bottom Temperature

TEMP 3 : Debutanizer Receiver Bottom Temperature

TEMP 4 : Light Naptha Temperature

TEMP 5 : Reboiler Outlet Temperature

TEMP 6 : Debutanizer Feed Temperature

Table 8: Summary of Pearson's Correlation between Top Product Compositions and Temperature Variables

		TEMP 1	TEMP 2	TEMP 3	TEMP 4	TEMP 5	TEMP 6
Pearson's Correlation Coefficients (r)	C3	-0.058	0.075	**0.156**	**0.161**	**0.127**	-0.011
	iC4	-0.048	**0.188**	**0.125**	**0.261**	**0.124**	**-0.129**
	nC4	-0.056	**0.177**	**0.180**	**0.431**	**0.282**	**-0.177**
	iC5	**0.224**	0.005	0.109	**0.332**	**0.339**	-0.069
	nC5	**0.225**	-0.056	0.055	**0.223**	**0.268**	-0.008

Based on the correlation result between temperature variables and compositions, it can be seen that the highest r value is 0.431, a positive correlation between TEMP 4 and nC4. The result also shows that TEMP 4 and TEMP 5 have most significant r value with the compositions the most compare to the other temperature variables.

There is no strong relationship detected based on the r value although 0.431 is the highest r value obtained. However, it does suggesting a medium relationship between the temperature variables and the compositions especially TEMP 4 and TEMP 5 and the compositions. Although the scatter plots of this correlation in APPENDIX III showing a nonlinear relationship, the changes in temperature variables does have effects on the compositions.

The level variables are as follow:

LEVEL 1 : Debutanizer Level

LEVEL 2 : Debutanizer Condenser Level

LEVEL 3 : Debutanizer Level Indicator

LEVEL 4 : Condenser Level Indicator

Table 9: Summary of Pearson's Correlation between Top Product Compositions and Level Variables

		LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4
Pearson's Correlation Coefficients (r)	C3	0.08	-0.084	**-0.095**	**0.198**
	iC4	0.053	0.022	-0.08	**0.270**
	nC4	0.013	0.086	-0.032	**0.316**
	iC5	-0.083	**0.107**	**0.116**	**0.127**
	nC5	**-0.098**	0.094	**0.139**	0.025

The correlation result between the Level variables and the compositions also showing a less strong relationship compare with the MVs and temperatures correlation result. The highest r value is 0.316 indicates a positive correlation between LEVEL 4 and nC4. LEVEL 4 have the most significant r values in which it haves more effects on the compositions than other level variables.

The flow variables are as follow:

FLOW 1 : Light Naphtha flow to storage

FLOW 2 : LPG Flow to storage

Table 10: Summary of Pearson's Correlation between Top Product Compositions and Flow Variables

		FLOW 1	FLOW 2
Pearson's Correlation Coefficients (r)	C3	0.09	0.005
	iC4	0.077	0.071
	nC4	0.079	0.01
	iC5	-0.011	**-0.098**
	nC5	-0.032	**-0.108**

With highest r value of -0.108, a negavite correlation between the FLOW 2 and nC5, the correlation shows the relationship between the Flow variables and the compositions are weak. The other r values also showing a weak relationship. The scatter plots in APPENDIX III also shows a nonlinear relationship between the flow variables and compositions.

The pressure variables is

PRESSURE 1 : Debutanizer Receiver Overhead Pressure

Table 11: Summary of Pearson's Correlation between Top Product Compositions and Pressure Variable

		PRESSURE 1
Pearson’s Correlation Coefficients (r)	C3	**0.29**
	iC4	**0.108**
	nC4	0.058
	iC5	0.0
	nC5	-0.003

The same relationship also can be seen on the correlation between the Pressure variable and the compositions which indicates a weak relationship with the compositions. The highest r value is 0.29, a positive correlation of PRESSURE 1 and C3. Others showing a lower r value therefore a less strong relationship.

Based on the correlation analysis, MVs and Temperature variables have the most significant relationship with the compositions. Although the relationship is not linear, both MVs and temperature variables have effects on the compositions.

4.3.2 Regression Analysis

The regression analysis enables us to generate equations that can be used to predict the value of the dependent variable (compositions). From the correlation analysis and scatter plots, the relationship between the process variables and compositions is either not linear or have a weak linear relationship. Therefore, a Linear Regression might not be useful or able to correctly predict the dependent variable using linear equation. Other regression equations such as quadratic, cubic, logarithmic, and exponential were obtained. The equations also needed to be significant ($p<0.05$) and simple in order to be selected. A linear equation can be selected if it is significant and simpler than other equations. It is important for the equation to be significant ($p<0.05$) in order to correctly predict the dependent variables value from the independent variable values. APPENDIX IV shows the result of the regression analysis.

The equations are as follow:

[C3] = 0.236 – 0.001[MV1]

[C3] = 0.417 - 0.059(ln[MV1])

[C3] = 1.949 – 0.012[MV2]

[C3] = 9.027 – 1.786(ln[MV2])

[C3] = 0.782 – 0.029[MV3]

[C3] = 2.043 - 0.613(ln[MV3])

[iC4] = 1.145 – 0.006[MV2]

[iC4] = 4.785 – 0.918(ln[MV2])

[iC4] = 0.549 – 0.015[MV3]

[iC4] = 1.205 – 0.319(ln[MV3])

[nC4] = 0.491 – 0.002[MV2]

[nC4] = 1.906 – 0.357(ln[MV2])

[nC4] = 0.226 – 0.04[MV3]

[iC5] = 0.036 + 0.001(ln[MV1])

[iC5] = 0.044 + 0.02[MV3]

[nC5] = 0.033 + 0.019(ln[MV1])

[nC5] = -0.163 + 0.02[MV2]

[nC5] = 0.022 + 0.004[MV3]

[C3] = -0.405 + 0.017[TEMP3]

[C3] = -2.299 + 0.062[TEMP 4]

[C3] = 0.097 – 0.001[TEMP 5]

[iC4] = -6.02 _ 0.45[TEMP2]

[iC4] = -0.017 + 0.007[TEMP3]

[iC4] = -1.938 +0.055[TEMP 4]

[iC4] = 0.04 + 0.041(ln[TEMP 5])

[iC4] = -28.864 + 0.525[TEMP 6] – 0.002[TEMP6]^{2}

$[nC4] = -2.757 + 0.021[TEMP2]$

$[nC4] = -0.039 + 0.005[TEMP3]$

$[nC4] = -1.547 + 0.043[TEMP\ 4]$

$[nC4] = -0.067 + 0.43(\ln[TEMP\ 5])$

$[nC4] = 0.326 – 0.002[TEMP\ 6]$

$[iC5] = -0.802 + 0.015[TEMP1]$

$[iC5] = -0.911 + 0.025[TEMP4]$

$[iC5] = -0.086 + 0.038(\ln[TEMP\ 5])$

$[nC5] = -1.085 + 0.2[TEMP1]$

$[nC5] = -0.787 + 0.023\ [TEMP\ 4]$

$[nC5] = -0.078 + 0.4(\ln[TEMP\ 5])$

$[C3] = -.001 + 0.003[LEVEL4]$

$[iC4] = -1.925 + 0.07[LEVEL3] – 0.001[LEVEL3]^2$

$[iC4] = 0.104 + 0.002[LEVEL4]$

$[nC4] = -1.905 + 0.65[LEVEL3] – 0.001[LEVEL3]^2$

$[nC4] = 0.064 + 0.001[LEVEL4]$

$[iC5] = 4.785 – 0.154[LEVEL1] + 0.001[LEVEL1]^2$

$[iC5] = 0.025 + EXP(0.022[LEVEL2])$

$[iC5] = -0.965 + 0.033[LEVEL3] + 0.001[LEVEL3]^2$

$[iC5] = 0.01 + 0.021(\ln[LEVEL4])$

$[nC5] = 8.274 – 0.269[LEVEL1] + 0.002[LEVEL1]^2$

$[nC5] = 0.049 – 0.01[LEVEL3]$

$[iC4] = -0.708 + 0.273[FLOW2] – 0.02[FLOW2]^2$

$[nC4] = -0.136 + 0.061[FLOW2]$

$[C3] = -1.692 + 0.277(\ln[PRESSURE\ 1])$

$[nC4] = -0.966 + 0.003[PRESSURE1] – (1.57 \times 10^{-6})\ [PRESSURE1]^2$

$[iC5] = -1.986 + 0.005[PRESSURE1] – (3.01 \times 10^{-6})\ [PRESSURE1]^2$

$[nC5] = -2.381 + 0.006[PRESSURE1] – (3.61 \times 10^{-6})\ [PRESSURE1]^2$

Equation 1: Regression Equations

4.3.3 Paired t-test and Analysis of Variance (ANOVA)

Paired t-test and ANOVA is used to test the significant of the relationship between the process variables and the compositions on mean basis. APPENDIX V and APPENDIX VI show the results of the Paired t-Test and ANOVA respectively.

The t-Test is used to determine whether there is a significant difference between the two variables investigated. The null hypothesis is there is no significant difference between the two variables. Based on the t-test result on APPENDIX V, it can be seen that the p value is less than 0.05 for all case, therefore the null hypothesis is rejected. This indicates that there is a significant difference between the two variables.

The null hypothesis for ANOVA is also the same with t-test. However, some of the result did not reject the null hypothesis which indicates that there is a significant difference between the two variables. The failure to reject the null hypothesis ($p>0.05$) is because ANOVA take account on the possibility of a linear relationship between the variables. Although almost all scatter plots of process variables vs compositions showing a nonlinear relationship, ANOVA detected a possible linear relationship (medium relationship as observed in the correlations analysis) between the two variables investigated. In regression analysis also, it is observed that linear equation is possible for some of the relationship based on the ANOVA significant result ($p<0.05$).

4.3.4 Chi-square Test

Chi-square test can be used to convey the existence or nonexistence of the relationships between the variables investigated. However, it cannot determine the strength of the relationship.

The process variables and compositions were subjected to Chi-square test. However it did not give correct results as it violates the assumption for conducting a chi-square test. As seen in Table **12**, 98.7% of the data have counts less than 5. In order to do the chi-square test, the counts must be more than 5 and none less than 1 (minimum expected count is 0.43). Therefore chi-square test is not suitable to be used.

Table 12: Chi-Square Tests C3 and Feed Flow

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	158.156[a]	158	.482
Likelihood Ratio	213.224	158	.002
Linear-by-Linear Association	7.367	1	.007
N of Valid Cases	301		

a. 314 cells (98.7%) have expected count less than 5. The minimum expected count is .43.

4.3.5 Non-parametric Techniques

Nonparametric techniques involve free distributions and less assumption as alternative on the previous test/analysis done. In this analysis, only Friedman Test and Spearman Rank-order Correlation were used to analyze the relationship between the process variables and the compositions.

4.3.5.1 Friedman Test

Table 13: Friedman Test Ranks

	Mean Rank
Feed Flow	13.89
Reboiler Flow	20.00
Reflux Flow	7.00
Debutanizer top temp	12.04
Debutanizer bottom temp	18.97
Debutanizer receiver bottom temp	9.00
Light naphtha temp	10.00
Reboiler outlet temp	17.66
Debutanizer feed temp	17.36
Debutanizer receiver level	13.55
Debutanizer level	13.83
Debutanizer level indicator	14.96
Condenser level indicator	12.73
Light naphtha flow	8.00
LPG flow to storage	6.00
Debutanizer overhead pressure	21.00
propane	3.81

i-butane	4.87
n-butane	3.07
i-pentane	1.10
n-pentane	2.15

Table 14: Friedman Test Statistics

N	301
Chi-Square	5907.514
df	20
Asymp. Sig.	.000

Friedman test is used to compare two or more related samples, in this case, the association between the two variables. The null hypothesis is still the same as in t-test. Based on Table 14, the p value is less than 0.05. This rejects the null hypothesis. There is a significant difference between the two variables investigated which suggesting an association or relationship between the variables.

4.3.5.2 Spearman's Rank-order Correlation

The Spearman's Rank-order Correlation is an alternative to the Correlation analysis. The Spearman's Correlation Coefficients also indicates the strength of the relationship between the process variables and the compositions. The + and - sign indicates the direction of the relationship. As the coefficients reaching +1 or -1, the relationship is considered as strong relationship. If the coefficient is equal to 0, there is no relationship between the investigated variables. Bold values in the tables indicate that the values are significant as $p < 0.05$.

The highest coefficient obtained is 0.534, a positive relationship between the TEMP 4 and nC4. It can be seen that MVs and Temperature again showing more association with the compositions. The same findings can be detected in the Pearson's Correlations analysis.

Table 15: Summary of Spearman's Correlation between Top Product Compositions and Manipulated Variable

		MV 1	MV 2	MV 3
Spearman Correlation Coefficients	C3	**-0.173**	**-0.24**	**-0.491**
	iC4	-0.06	**-0.2**	**-0.458**
	nC4	0.052	**-0.179**	**-0.326**
	iC5	**0.207**	**0.168**	**0.206**
	nC5	**0.223**	**0.215**	**0.364**

Table 16: Summary of Spearman's Correlation between Top Product Compositions and Temperature Variable

		TEMP 1	TEMP 2	TEMP 3	TEMP 4	TEMP 5	TEMP 6
Spearman Correlation Coefficients	C3	-0.033	-0.046	**0.12**	**0.234**	**0.194**	**0.127**
	iC4	**-0.170**	**0.181**	**0.126**	**0.315**	0.1	-0.11
	nC4	-0.018	**0.214**	**0.19**	**0.534**	**0.291**	**-0.152**
	iC5	**0.177**	**0.183**	-0.01	**0.184**	0.107	**-0.174**
	nC5	**0.19**	0.047	-0.001	0.066	0.083	**-0.126**

Table 17: Summary of Spearman's Correlation between Top Product Compositions and Level Variables

		LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4
Spearman Correlation Coefficients	C3	0.016	-0.069	-0.096	**0.229**
	iC4	0.027	0.044	**-0.123**	**0.177**
	nC4	-0.048	0.103	-0.077	**0.191**
	iC5	-0.061	**0.139**	0.11	0.043
	nC5	-0.039	**0.179**	**0.116**	-0.073

Table 18: Summary of Spearman's Correlation between Top Product Compositions and Flow Variables

		FLOW 1	FLOW 2
Spearman Correlation Coefficients	C3	0.059	0.039
	iC4	0.019	**0.168**
	nC4	0.019	0.098
	iC5	**-0.161**	0.016
	nC5	**-0.181**	0.006

Table 19: Summary of Spearman's Correlation between Top Product Compositions and Pressure Variable

		PRESSURE 1
Spearman Correlation Coefficients	C3	**0.355**
	iC4	0.0
	nC4	**-0.125**
	iC5	**-0.393**
	nC5	**-0.266**

4.3.6 Control Charts (Individual Charts)

Individual chart is selected as control chart because the data obtained is just a one-time data. It is the simplest variable chart which has Upper Control Limit (UCL) and Lower Control Limit (LCL). The control limit is placed three standard deviations (from the Centreline (CL). The CL can be the mean or target value of the variable.

Based to the data used, the manipulated variables (MVs) are manipulated few times to see the changes on the compositions and other process variables. As the values of the MVs changing, the values of other variables also changing accordingly. The Individual Chart explain the state of the variable either in control (within UCL and LCL) or out of control (out of UCL and LCL) after the changes.

According to all the individual charts, all the compositions variables are not in control since many of the values are exceeding the UCL and LCL as indicate by the red dots. The red dots are showing the value that is in violation with the control chart. This happened when the value are exceeding the three sigma or the control limist (UCL and LCL). The green dots indicate that there is no violation and the values are inside the control limits.

Propane, i-Butane and n-Butane individual charts showing a similar trend. Many of the values are outside of the control limits, and at some point, it stabilizes along the CL. Individual charts for i-Pentane and n-Pentane also showing a similar trends but different than the other three charts aforementioned. The charts have fewer points outside the control limits compare to the other three charts. At some point also, the values are stabilizing along the CL. The violations might be because of the changes made on the manipulated variable. It causes sudden changes on the compositions. The compositions then slowly stabilizing inside the control limits. It might be because of the corrective action taken by the controller to bring the process under the control.

As the MVs changes, this requires the compositions to react based on the changes. From the individual charts, it can be seen that Propane, i-Butane, and n-Butane is highly affected by the changes in the MVs compare to i-Pentane and n-Pentane.

When the process is out of control, it is best to take action to bring back the process in control.

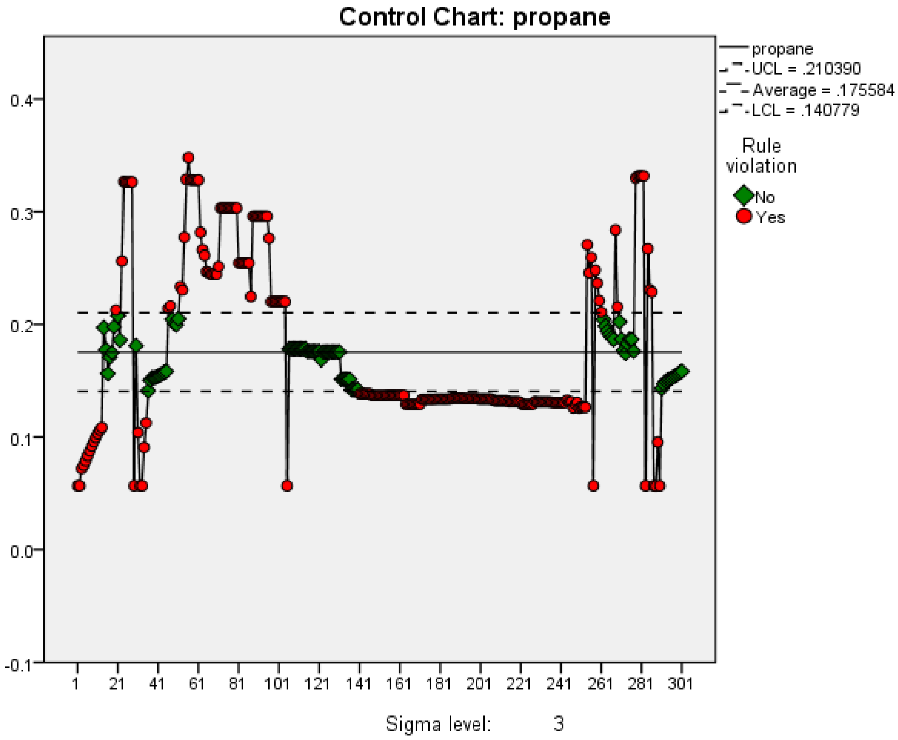

Figure 7: Propane Individual Chart

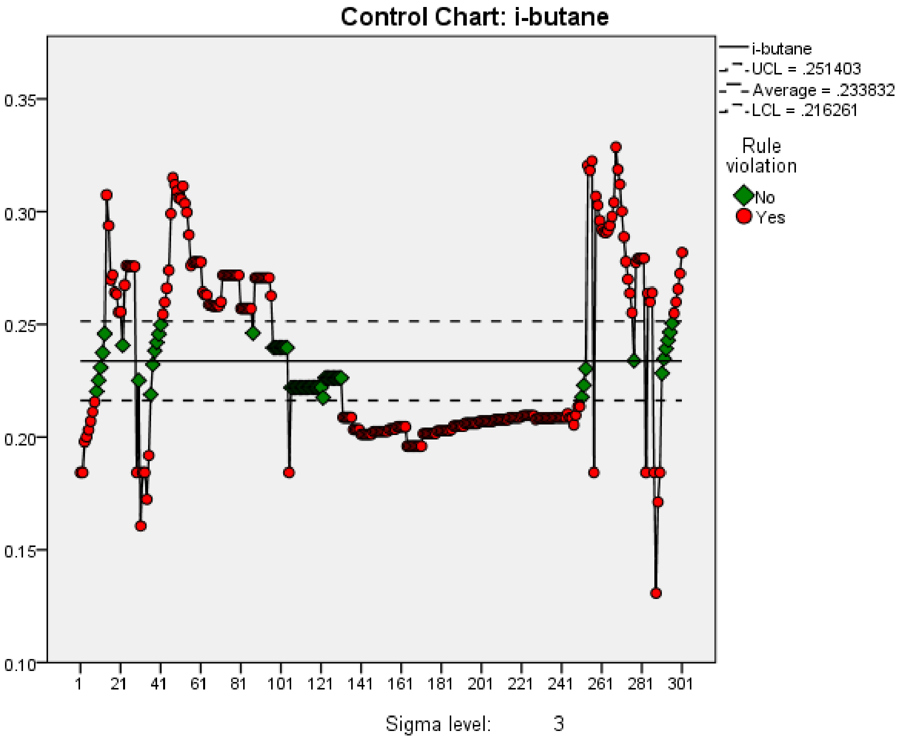

Figure 8: i-Butane Individual Chart

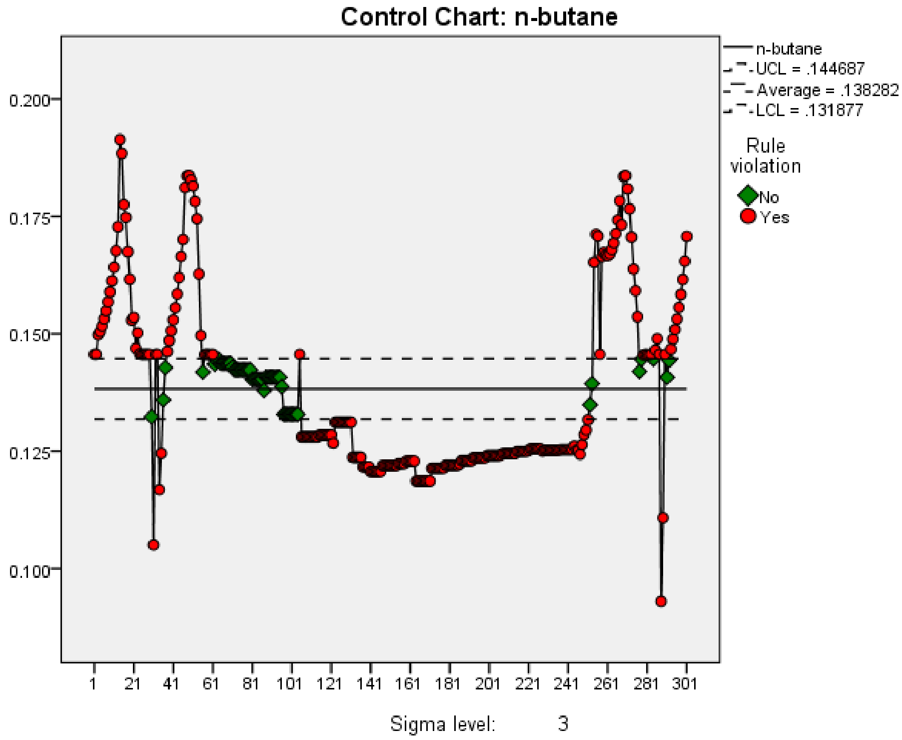

Figure 9: n-Butane Individual Chart

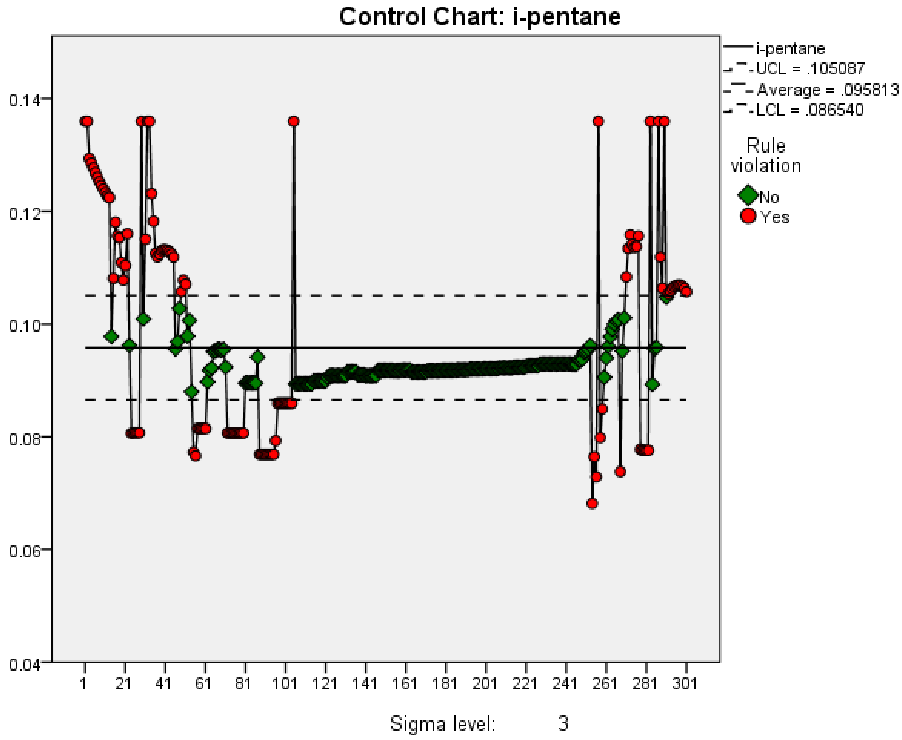

Figure 10: i-Pentane Individual Chart

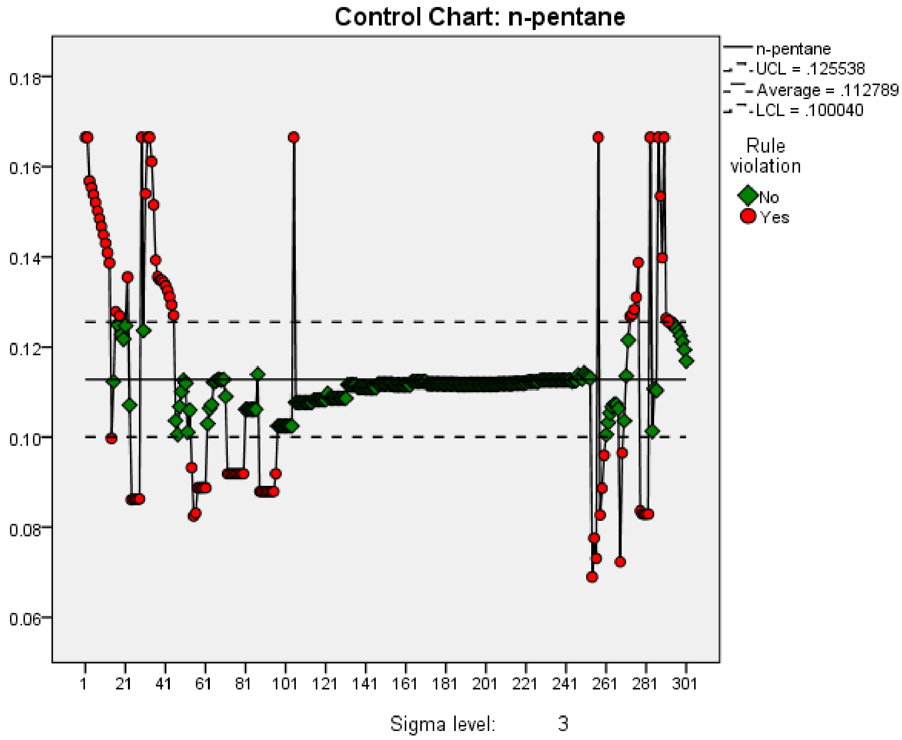

Figure 11: n-Pentane Individual Chart

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

This project focuses on the application of Statistical Process Control on a distillation column, specifically on the debutanizer column which produces the main product, Liquefied Petroleum Gas (LPG). The interest is mostly on the relationship between the process variables and the product compositions.

Statistical Process Control is an interesting and proven method for monitoring, controlling and improving quality of desired product. To apply it in debutanizer column would enable us to see the variations effects on the process using statistical method especially on the relationship between the process variables and the top product compositions. Control charts especially individuals chart is used to observe the state of the process especially on the compositions. The methodologies for this project were constructed to follow the timeline given for completion as well as comply with the objectives that have been stated.

The result shows that there is small relationship between the variables analyzed. Most of the relationships are weak based on the Pearson's Correlations and Spearman's Correlation analysis. However it does not indicate that the process variables did not interact or associate with the compositions. From the individual charts, it can be seen that the changes in the manipulated variables haves effects on the compositions.

It is just a matter of the strength of the relationship between the variables to observe if it is affecting the product quality. The stronger the relationship, the more process variables affects the quality which are the top product composition.

From the statistical analysis, the manipulated variables (MVs) and the temperature variables have the most significant and medium relationship with the compositions.

Therefore, it is best to monitor and control the MVs as well as the temperature variables to obtain the desired quality of the top product.

The way forward for this project is to investigate the variations that affecting the top product quality. It is no doubt that SPC is very crucial in understanding the process especially on the quality but also the possible variations that affecting the quality of the top product. In order to do that, a few samples of each of the variables have to be taken. This is to ensure this project have the mean of samples to plot the Shewhart chart or Mean and Range chart which is a prominent SPC tool for quality. Therefore, with the Shewhart chart or Mean and Range Chart, the top product quality can be further analyzed, monitored and controlled.

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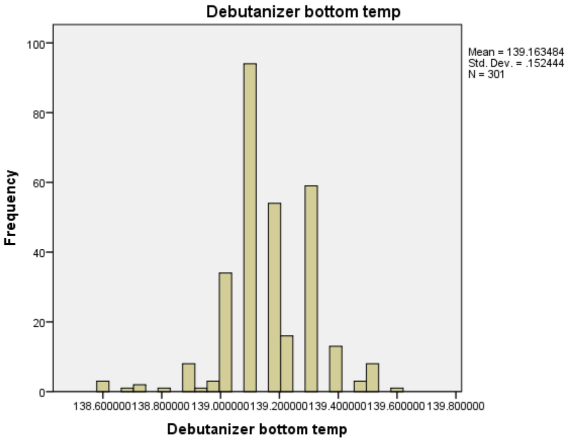
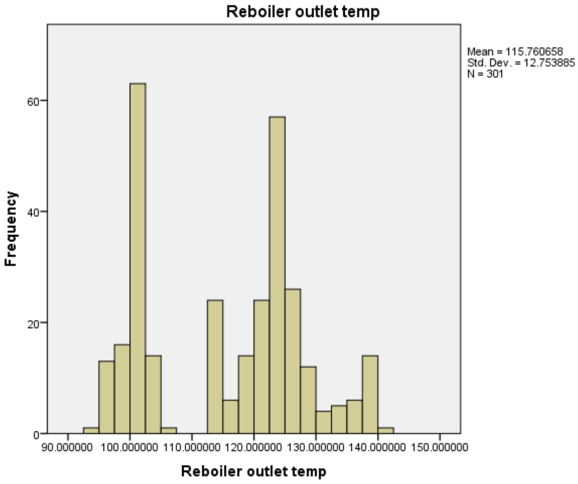
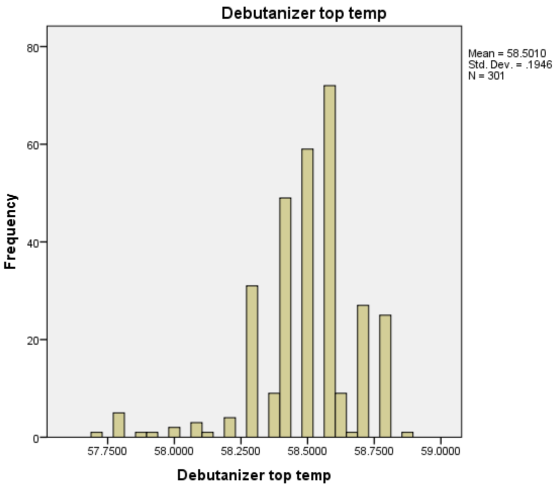
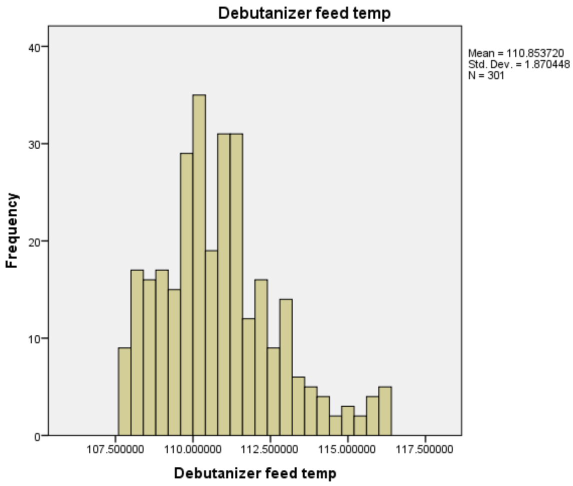
APPENDIX I

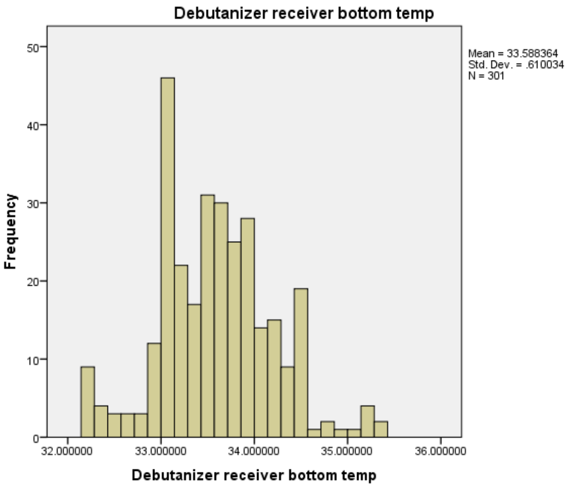
HISTOGRAM

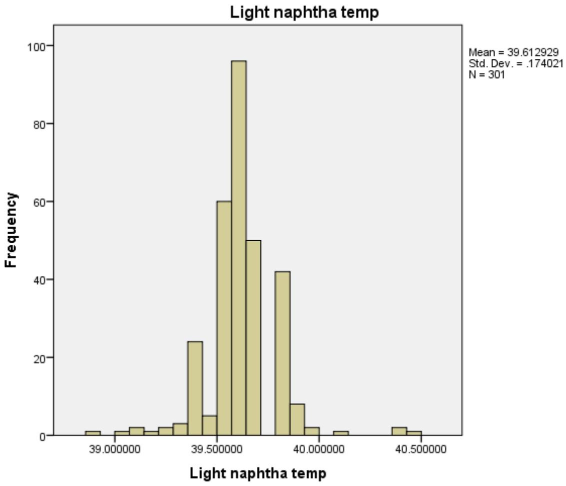


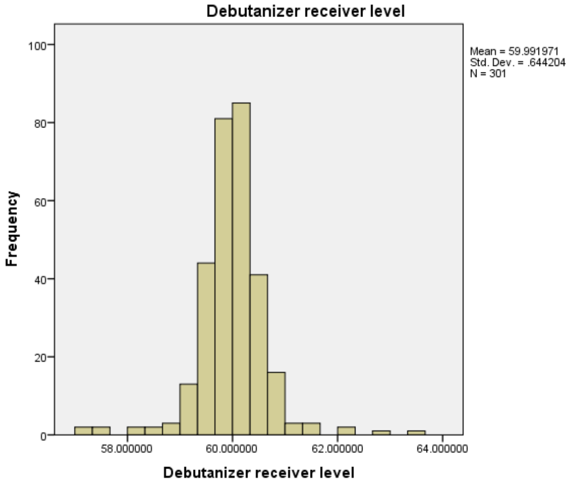








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Mean = 59.991971
Std. Dev. = .644204
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60
80
100
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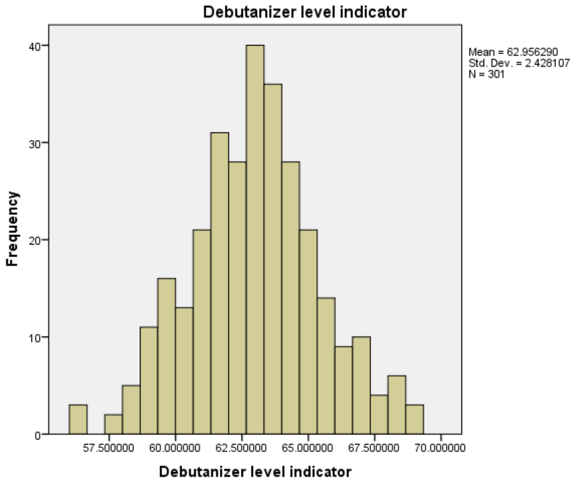
60.000000
62.000000
64.000000
Debutanizer receiver level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Std. Dev. = 2.428107
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30
40
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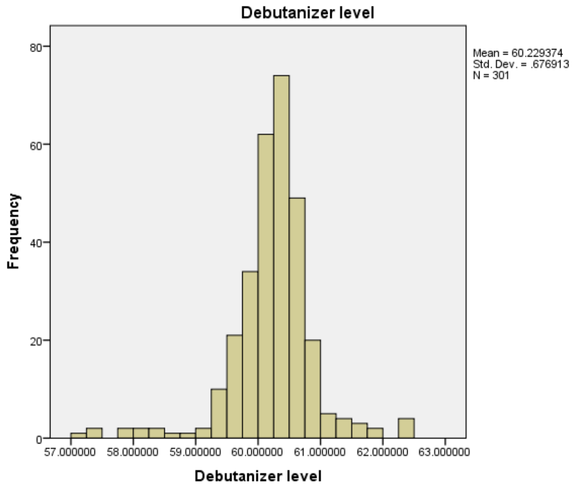
62.500000
65.000000
67.500000
70.000000
Debutanizer level indicator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60
80
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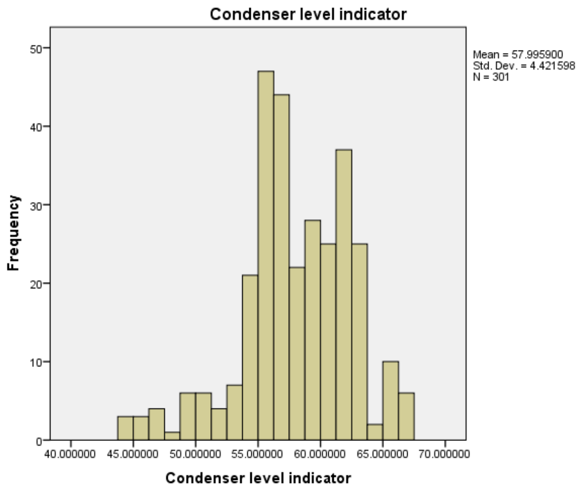
58.000000
59.000000
60.000000
61.000000
62.000000
63.000000
Debutanizer level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Std. Dev. = 4.421598
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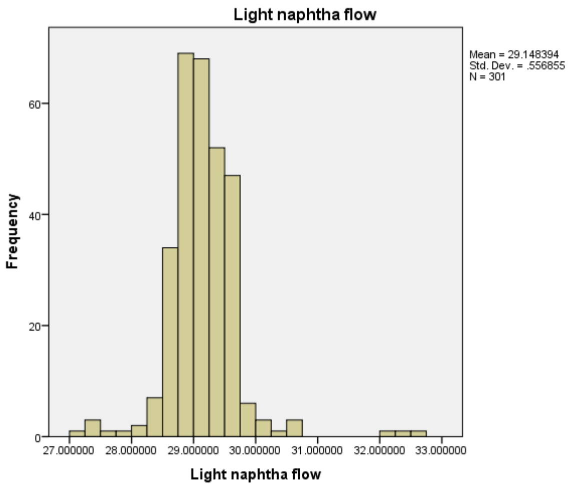
45.000000
50.000000
55.000000
60.000000
65.000000
70.000000
Condenser level indicator


Light naphtha flow
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Std. Dev. = .556855
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60
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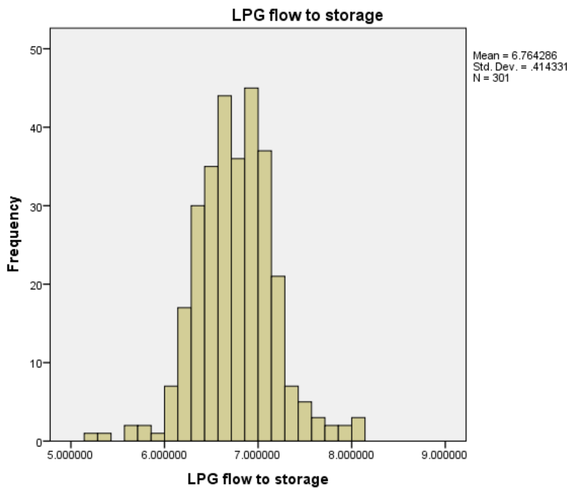
28.000000
29.000000
30.000000
31.000000
32.000000
33.000000
Light naphtha flow


LPG flow to storage
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Std. Dev. = .414331
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30
40
50
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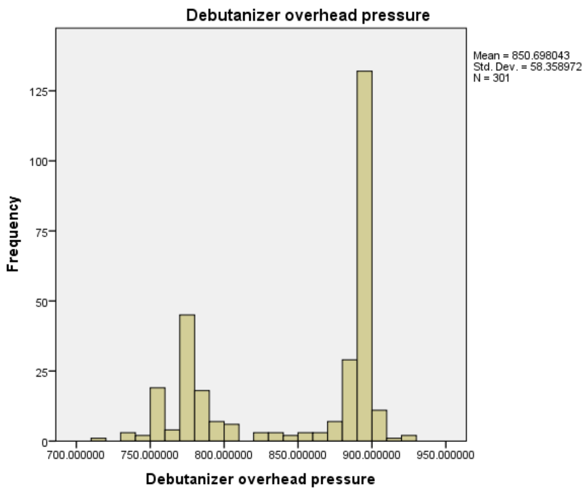
6.000000
7.000000
8.000000
9.000000
LPG flow to storage


Debutanizer overhead pressure
Mean = 850.698043
Std. Dev. = 58.358972
N = 301
Frequency
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75
100
125
700.000000
750.000000
800.000000
850.000000
900.000000
950.000000
Debutanizer overhead pressure

APPENDIX II

PEARSON'S CORRELATIONS

Correlations

		Feed Flow	Reboiler Flow	Reflux Flow	Debutanizer top temp	Debutanizer bottom temp	Debutanizer receiver bottom temp	Light naphtha temp	Reboiler outlet temp	Debutanizer feed temp
Feed Flow	Pearson Correlation	1	-.106*	.086	-.013	.033	.134*	.077	.028	-.088
	Sig. (1-tailed)		.034	.069	.412	.284	.010	.092	.314	.064
	N	301	301	301	301	301	301	301	301	301
Reboiler Flow	Pearson Correlation	-.106*	1	-.010	-.099*	-.156**	-.519**	-.190**	-.349**	.130*
	Sig. (1-tailed)	.034		.429	.043	.003	.000	.000	.000	.012
	N	301	301	301	301	301	301	301	301	301
Reflux Flow	Pearson Correlation	.086	-.010	1	.060	-.124*	.355**	-.015	.206**	-.327**
	Sig. (1-tailed)	.069	.429		.151	.016	.000	.394	.000	.000
	N	301	301	301	301	301	301	301	301	301
Debutanizer top temp	Pearson Correlation	-.013	-.099*	.060	1	-.271**	.142**	.295**	.515**	.374**
	Sig. (1-tailed)	.412	.043	.151		.000	.007	.000	.000	.000
	N	301	301	301	301	301	301	301	301	301
Debutanizer bottom temp	Pearson Correlation	.033	-.156**	-.124*	-.271**	1	-.019	-.017	-.105*	-.268**

	Sig. (1-tailed)	.284	.003	.016	.000		.369	.384	.034	.000
	N	301	301	301	301	301	301	301	301	301
Debutanizer receiver bottom temp	Pearson Correlation	.134*	-.519**	.355**	.142**	-.019	1	.301**	.565**	-.471**
	Sig. (1-tailed)	.010	.000	.000	.007	.369		.000	.000	.000
	N	301	301	301	301	301	301	301	301	301
Light naphtha temp	Pearson Correlation	.077	-.190**	-.015	.295**	-.017	.301**	1	.574**	-.203**
	Sig. (1-tailed)	.092	.000	.394	.000	.384	.000		.000	.000
	N	301	301	301	301	301	301	301	301	301
Reboiler outlet temp	Pearson Correlation	.028	-.349**	.206**	.515**	-.105*	.565**	.574**	1	.020
	Sig. (1-tailed)	.314	.000	.000	.000	.034	.000	.000		.364
	N	301	301	301	301	301	301	301	301	301
Debutanizer feed temp	Pearson Correlation	-.088	.130*	-.327**	.374**	-.268**	-.471**	-.203**	.020	1
	Sig. (1-tailed)	.064	.012	.000	.000	.000	.000	.000	.364	
	N	301	301	301	301	301	301	301	301	301
Debutanizer receiver level	Pearson Correlation	.034	.020	.015	-.081	.382**	-.012	-.266**	.043	-.013
	Sig. (1-tailed)	.277	.367	.400	.080	.000	.419	.000	.231	.413
	N	301	301	301	301	301	301	301	301	301
Debutanizer level	Pearson Correlation	.025	.051	.327**	.092	-.406**	.122*	-.001	.050	-.225**

	Sig. (1-tailed)	.336	.190	.000	.056	.000	.017	.494	.195	.000
	N	301	301	301	301	301	301	301	301	301
Debutanizer level indicator	Pearson Correlation	-.049	-.150**	-.001	.401**	.069	-.231**	.073	.136**	.124*
	Sig. (1-tailed)	.198	.005	.492	.000	.118	.000	.102	.009	.016
	N	301	301	301	301	301	301	301	301	301
Condenser level indicator	Pearson Correlation	.016	-.212**	-.161**	-.042	.225**	.197**	.223**	.337**	.043
	Sig. (1-tailed)	.389	.000	.002	.232	.000	.000	.000	.000	.227
	N	301	301	301	301	301	301	301	301	301
Light naphtha flow	Pearson Correlation	.009	.128*	-.086	.028	.239**	-.068	.331**	.143**	-.120*
	Sig. (1-tailed)	.440	.013	.069	.316	.000	.119	.000	.006	.019
	N	301	301	301	301	301	301	301	301	301
LPG flow to storage	Pearson Correlation	-.038	.056	.131*	-.274**	-.078	-.020	-.409**	-.360**	-.093
	Sig. (1-tailed)	.258	.167	.012	.000	.088	.368	.000	.000	.053
	N	301	301	301	301	301	301	301	301	301
Debutanizer overhead pressure	Pearson Correlation	-.029	-.274**	.044	.437**	-.339**	.424**	.356**	.775**	.158**
	Sig. (1-tailed)	.305	.000	.221	.000	.000	.000	.000	.000	.003
	N	301	301	301	301	301	301	301	301	301
propane	Pearson Correlation	-.157**	-.201**	-.411**	-.058	.075	.156**	.161**	.127*	-.011

	Sig. (1-tailed)	.003	.000	.000	.160	.097	.003	.003	.014	.428
	N	301	301	301	301	301	301	301	301	301
i-butane	Pearson Correlation	-.102*	-.192**	-.396**	-.048	.188**	.125*	.261**	.124*	-.129*
	Sig. (1-tailed)	.039	.000	.000	.203	.001	.015	.000	.016	.012
	N	301	301	301	301	301	301	301	301	301
n-butane	Pearson Correlation	.023	-.151**	-.226**	.056	.177**	.180**	.413**	.282**	-.177**
	Sig. (1-tailed)	.344	.004	.000	.165	.001	.001	.000	.000	.001
	N	301	301	301	301	301	301	301	301	301
i-pentane	Pearson Correlation	.198**	.078	.179**	.224**	.005	.109*	.332**	.339**	-.069
	Sig. (1-tailed)	.000	.089	.001	.000	.466	.029	.000	.000	.116
	N	301	301	301	301	301	301	301	301	301
n-pentane	Pearson Correlation	.198**	.120*	.236**	.225**	-.056	.055	.223**	.268**	-.008
	Sig. (1-tailed)	.000	.019	.000	.000	.168	.170	.000	.000	.442
	N	301	301	301	301	301	301	301	301	301

Correlations

		Debutanizer receiver level	Debutanizer level	Debutanizer level indicator	Condenser level indicator	Light naphtha flow	LPG flow to storage	Debutanizer overhead pressure	propane	i-butane	n-butane
Feed Flow	Pearson Correlation	.034	.025	-.049	.016	.009	-.038	-.029	-.157**	-.102*	.023
	Sig. (1-tailed)	.277	.336	.198	.389	.440	.258	.305	.003	.039	.344
	N	301	301	301	301	301	301	301	301	301	301
Reboiler Flow	Pearson Correlation	.020	.051	-.150**	-.212**	.128*	.056	-.274**	-.201**	-.192**	-.151**
	Sig. (1-tailed)	.367	.190	.005	.000	.013	.167	.000	.000	.000	.004
	N	301	301	301	301	301	301	301	301	301	301
Reflux Flow	Pearson Correlation	.015	.327**	-.001	-.161**	-.086	.131*	.044	-.411**	-.396**	-.226**
	Sig. (1-tailed)	.400	.000	.492	.002	.069	.012	.221	.000	.000	.000
	N	301	301	301	301	301	301	301	301	301	301
Debutanizer top temp	Pearson Correlation	-.081	.092	.401**	-.042	.028	-.274**	.437**	-.058	-.048	.056
	Sig. (1-tailed)	.080	.056	.000	.232	.316	.000	.000	.160	.203	.165
	N	301	301	301	301	301	301	301	301	301	301
Debutanizer bottom temp	Pearson Correlation	.382**	-.406**	.069	.225**	.239**	-.078	-.339**	.075	.188**	.177**

	Sig. (1-tailed)	.000	.000	.118	.000	.000	.088	.000	.097	.001	.001
	N	301	301	301	301	301	301	301	301	301	301
Debutanizer receiver bottom temp	Pearson Correlation	-.012	.122*	-.231**	.197**	-.068	-.020	.424**	.156**	.125*	.180**
	Sig. (1-tailed)	.419	.017	.000	.000	.119	.368	.000	.003	.015	.001
	N	301	301	301	301	301	301	301	301	301	301
Light naphtha temp	Pearson Correlation	-.266**	-.001	.073	.223**	.331**	-.409**	.356**	.161**	.261**	.413**
	Sig. (1-tailed)	.000	.494	.102	.000	.000	.000	.000	.003	.000	.000
	N	301	301	301	301	301	301	301	301	301	301
Reboiler outlet temp	Pearson Correlation	.043	.050	.136**	.337**	.143**	-.360**	.775**	.127*	.124*	.282**
	Sig. (1-tailed)	.231	.195	.009	.000	.006	.000	.000	.014	.016	.000
	N	301	301	301	301	301	301	301	301	301	301
Debutanizer feed temp	Pearson Correlation	-.013	-.225**	.124*	.043	-.120*	-.093	.158**	-.011	-.129*	-.177**
	Sig. (1-tailed)	.413	.000	.016	.227	.019	.053	.003	.428	.012	.001
	N	301	301	301	301	301	301	301	301	301	301
Debutanizer receiver level	Pearson Correlation	1	-.294**	.033	.012	.524**	-.157**	-.036	.080	.053	.013
	Sig. (1-tailed)		.000	.285	.420	.000	.003	.265	.083	.180	.413
	N	301	301	301	301	301	301	301	301	301	301
Debutanizer level	Pearson Correlation	-.294**	1	.075	-.143**	-.284**	.520**	.106*	-.084	.022	.086

	Sig. (1-tailed)	.000		.097	.007	.000	.000	.033	.072	.352	.069
	N	301	301	301	301	301	301	301	301	301	301
Debutanizer level indicator	Pearson Correlation	.033	.075	1	-.191**	-.005	-.219**	.037	-.095*	-.080	-.032
	Sig. (1-tailed)	.285	.097		.000	.465	.000	.260	.050	.083	.292
	N	301	301	301	301	301	301	301	301	301	301
Condenser level indicator	Pearson Correlation	.012	-.143**	-.191**	1	-.043	-.198**	.152**	.198**	.270**	.316**
	Sig. (1-tailed)	.420	.007	.000		.230	.000	.004	.000	.000	.000
	N	301	301	301	301	301	301	301	301	301	301
Light naphtha flow	Pearson Correlation	.524**	-.284**	-.005	-.043	1	-.446**	.059	.090	.077	.079
	Sig. (1-tailed)	.000	.000	.465	.230		.000	.155	.059	.091	.086
	N	301	301	301	301	301	301	301	301	301	301
LPG flow to storage	Pearson Correlation	-.157**	.520**	-.219**	-.198**	-.446**	1	-.215**	.005	.071	.010
	Sig. (1-tailed)	.003	.000	.000	.000	.000		.000	.462	.111	.433
	N	301	301	301	301	301	301	301	301	301	301
Debutanizer overhead pressure	Pearson Correlation	-.036	.106*	.037	.152**	.059	-.215**	1	.290**	.108*	.058
	Sig. (1-tailed)	.265	.033	.260	.004	.155	.000		.000	.031	.159
	N	301	301	301	301	301	301	301	301	301	301
propane	Pearson Correlation	.080	-.084	-.095*	.198**	.090	.005	.290**	1	.774**	.350**

	Sig. (1-tailed)	.083	.072	.050	.000	.059	.462	.000		.000	.000
	N	301	301	301	301	301	301	301	301	301	301
i-butane	Pearson Correlation	.053	.022	-.080	.270**	.077	.071	.108*	.774**	1	.828**
	Sig. (1-tailed)	.180	.352	.083	.000	.091	.111	.031	.000		.000
	N	301	301	301	301	301	301	301	301	301	301
n-butane	Pearson Correlation	.013	.086	-.032	.316**	.079	.010	.058	.350**	.828**	1
	Sig. (1-tailed)	.413	.069	.292	.000	.086	.433	.159	.000	.000	
	N	301	301	301	301	301	301	301	301	301	301
i-pentane	Pearson Correlation	-.083	.107*	.116*	.127*	-.011	-.098*	.000	-.622**	-.246**	.309**
	Sig. (1-tailed)	.075	.031	.022	.014	.427	.045	.500	.000	.000	.000
	N	301	301	301	301	301	301	301	301	301	301
n-pentane	Pearson Correlation	-.098*	.094	.139**	.025	-.032	-.108*	-.003	-.763**	-.532**	-.012
	Sig. (1-tailed)	.045	.052	.008	.335	.289	.031	.478	.000	.000	.419
	N	301	301	301	301	301	301	301	301	301	301

Correlations

		i-pentane	n-pentane
Feed Flow	Pearson Correlation	.198**	.198**
	Sig. (1-tailed)	.000	.000
	N	301	301
Reboiler Flow	Pearson Correlation	.078	.120*
	Sig. (1-tailed)	.089	.019
	N	301	301
Reflux Flow	Pearson Correlation	.179**	.236**
	Sig. (1-tailed)	.001	.000
	N	301	301
Debutanizer top temp	Pearson Correlation	.224**	.225**
	Sig. (1-tailed)	.000	.000
	N	301	301
Debutanizer bottom temp	Pearson Correlation	.005	-.056
	Sig. (1-tailed)	.466	.168
	N	301	301
Debutanizer receiver bottom temp	Pearson Correlation	.109*	.055
	Sig. (1-tailed)	.029	.170
	N	301	301
Light naphtha temp	Pearson Correlation	.332**	.223**
	Sig. (1-tailed)	.000	.000
	N	301	301
Reboiler outlet temp	Pearson Correlation	.339**	.268**
	Sig. (1-tailed)	.000	.000

	N	301	301
Debutanizer feed temp	Pearson Correlation	-.069	-.008
	Sig. (1-tailed)	.116	.442
	N	301	301
Debutanizer receiver level	Pearson Correlation	-.083	-.098*
	Sig. (1-tailed)	.075	.045
	N	301	301
Debutanizer level	Pearson Correlation	.107*	.094
	Sig. (1-tailed)	.031	.052
	N	301	301
Debutanizer level indicator	Pearson Correlation	.116*	.139**
	Sig. (1-tailed)	.022	.008
	N	301	301
Condenser level indicator	Pearson Correlation	.127*	.025
	Sig. (1-tailed)	.014	.335
	N	301	301
Light naphtha flow	Pearson Correlation	-.011	-.032
	Sig. (1-tailed)	.427	.289
	N	301	301
LPG flow to storage	Pearson Correlation	-.098*	-.108*
	Sig. (1-tailed)	.045	.031
	N	301	301
Debutanizer overhead pressure	Pearson Correlation	.000	-.003
	Sig. (1-tailed)	.500	.478
	N	301	301

propane	Pearson Correlation	-.622**	-.763**
	Sig. (1-tailed)	.000	.000
	N	301	301
i-butane	Pearson Correlation	-.246**	-.532**
	Sig. (1-tailed)	.000	.000
	N	301	301
n-butane	Pearson Correlation	.309**	-.012
	Sig. (1-tailed)	.000	.419
	N	301	301
i-pentane	Pearson Correlation	1	.944**
	Sig. (1-tailed)		.000
	N	301	301
n-pentane	Pearson Correlation	.944**	1
	Sig. (1-tailed)	.000	
	N	301	301

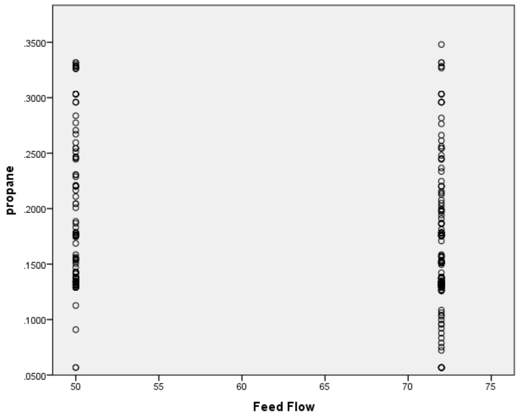
*. Correlation is significant at the 0.05 level (1-tailed).

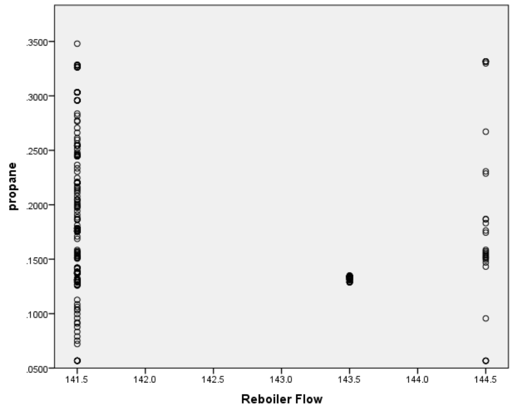
**. Correlation is significant at the 0.01 level (1-tailed).

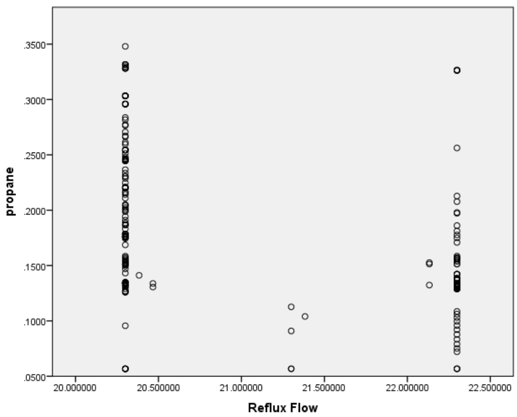
APPENDIX III

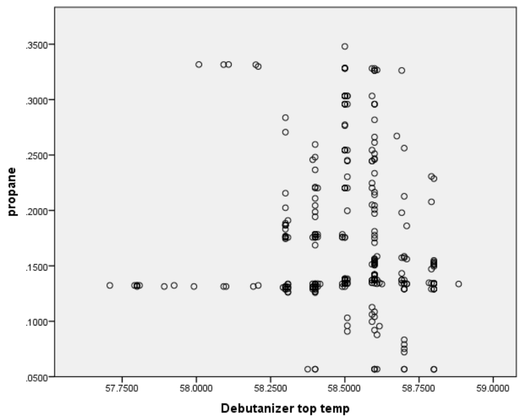
SCATTER PLOTS

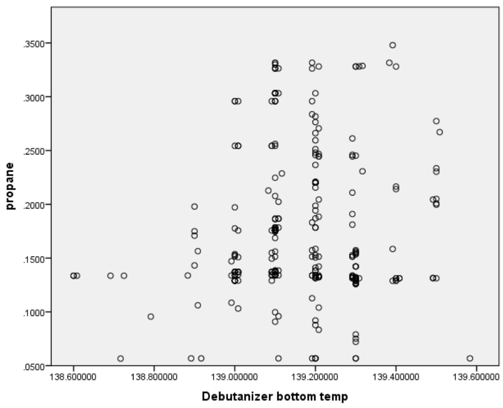
C3 vs Variables

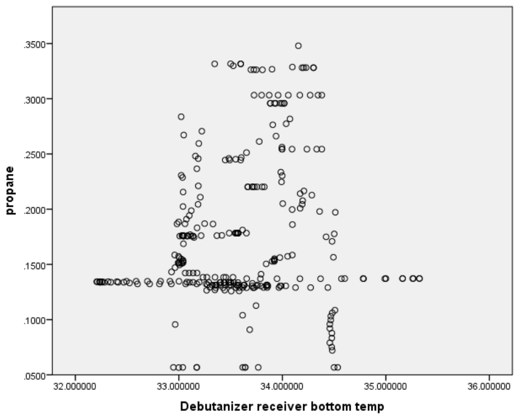


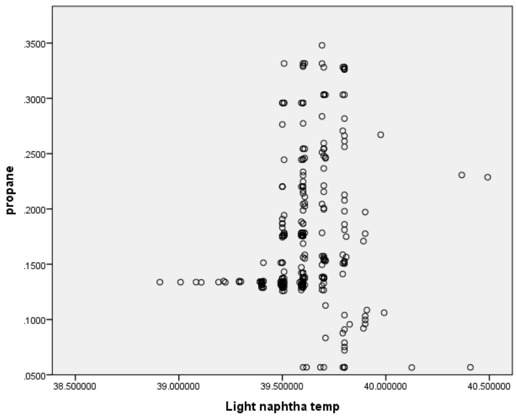


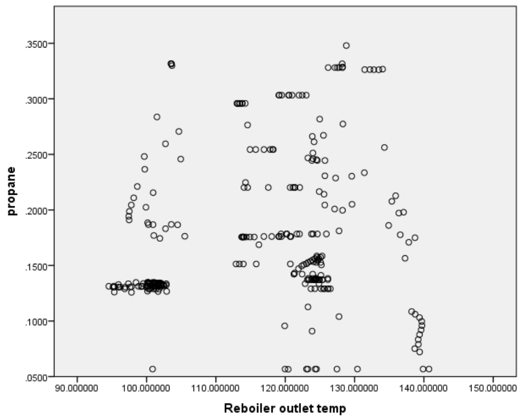


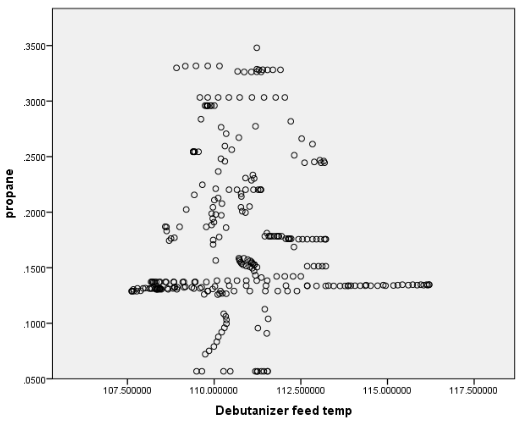







propane
.3500
.3000
.2500
.2000
.1500
.1000
.0500
38.500000
39.000000
39.500000
40.000000
40.500000
Light naphtha temp


propane
.3500
.3000
.2500
.2000
.1500
.1000
.0500
90.000000
100.000000
110.000000
120.000000
130.000000
140.000000
150.000000
Reboiler outlet temp


propane
.3500
.3000
.2500
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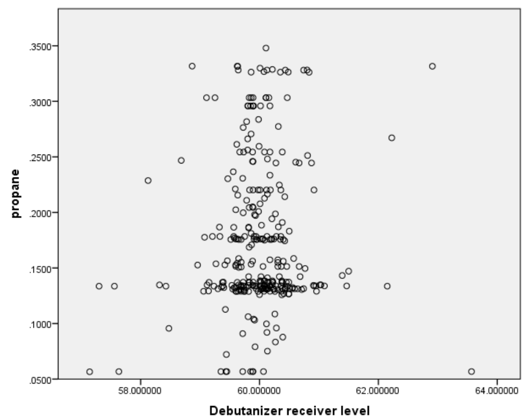
.1500
.1000
.0500
107.500000
110.000000
112.500000
115.000000
117.500000
Debutanizer feed temp


propane
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.2500
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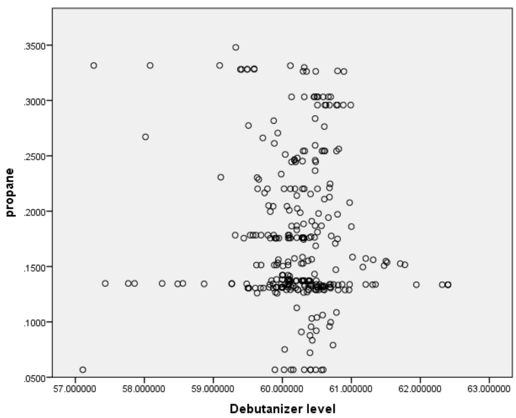
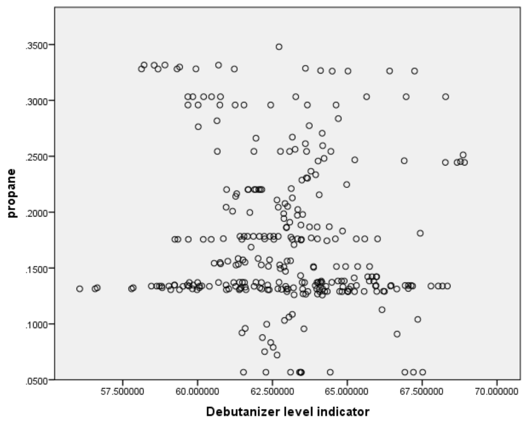
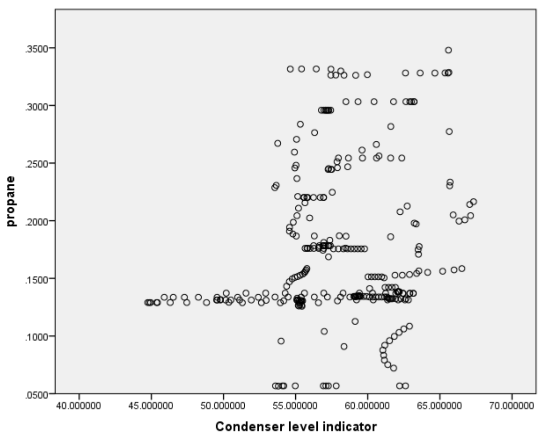
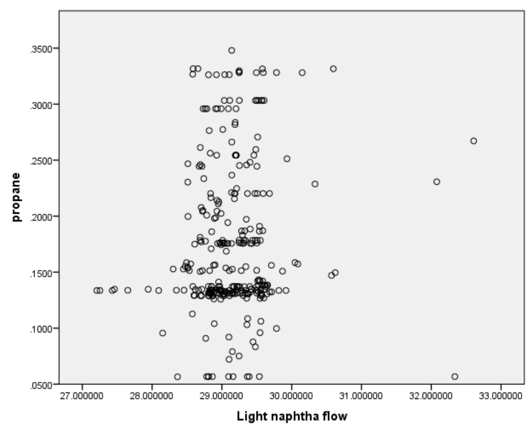
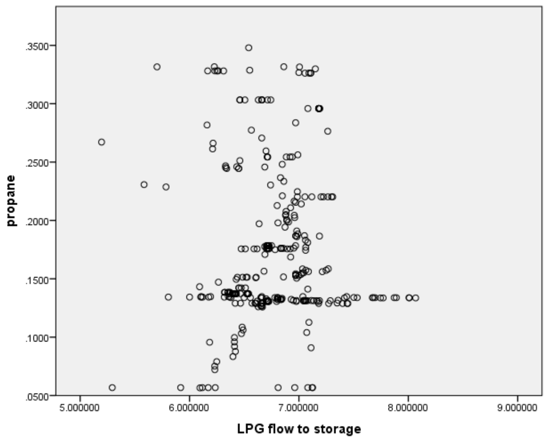
.1500
.1000
.0500
58.000000
60.000000
62.000000
64.000000
Debutanizer receiver level

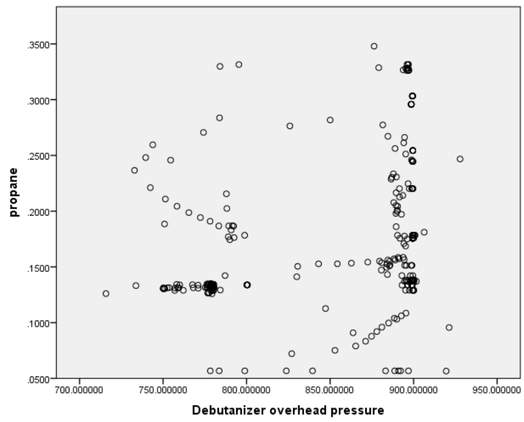

propane
.3500
.3000
.2500
.2000
.1500
.1000
.0500
57.000000
58.000000
59.000000
60.000000
61.000000
62.000000
63.000000
Debutanizer level


propane
.3500
.3000
.2500
.2000
.1500
.1000
.0500
57.500000
60.000000
62.500000
65.000000
67.500000
70.000000
Debutanizer level indicator

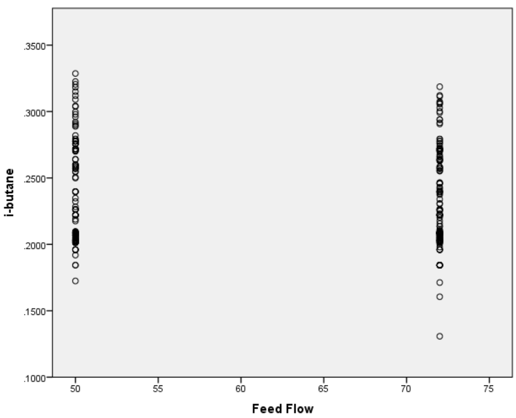

propane
.3500
.3000
.2500
.2000
.1500
.1000
.0500
40.000000
45.000000
50.000000
55.000000
60.000000
65.000000
70.000000
Condenser level indicator

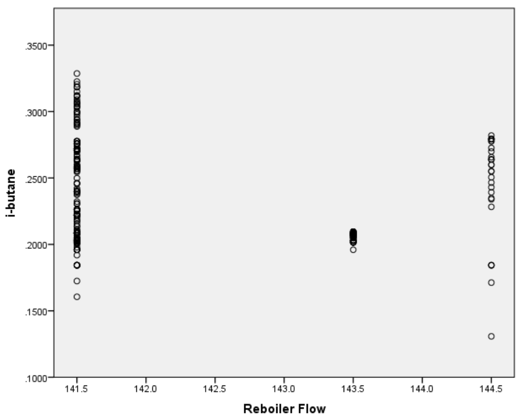

propane
.3500
.3000
.2500
.2000
.1500
.1000
.0500
27.000000
28.000000
29.000000
30.000000
31.000000
32.000000
33.000000
Light naphtha flow

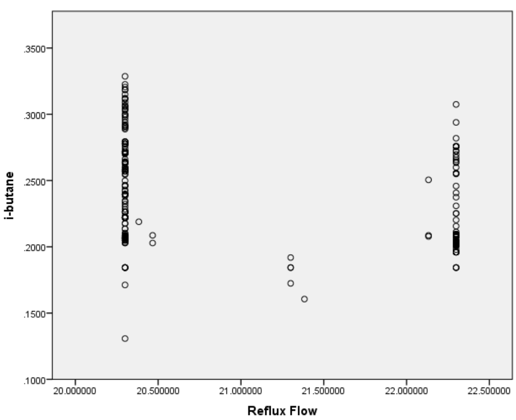


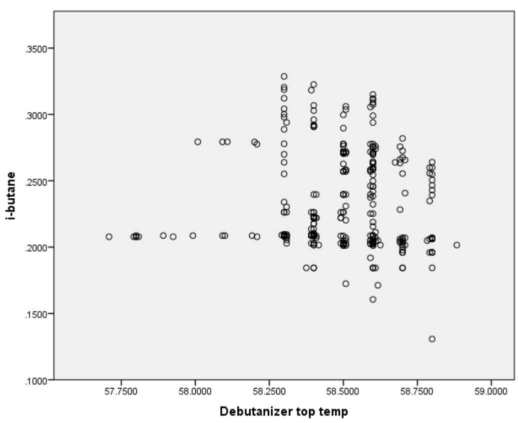


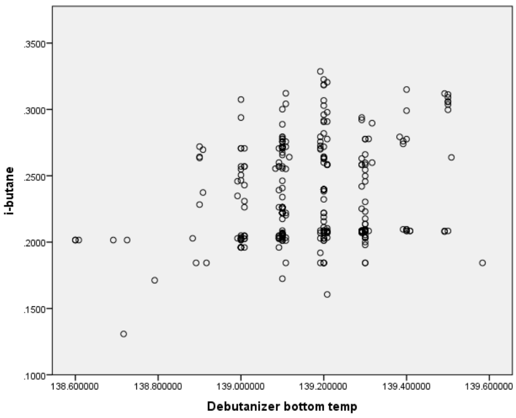
iC4 vs Variables



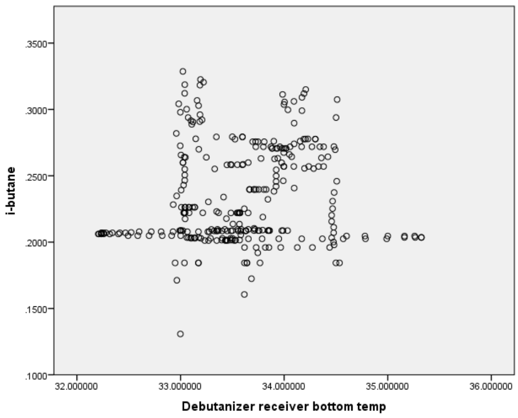








i-butane
.3500
.3000
.2500
.2000
.1500
.1000
138.600000
138.800000
139.000000
139.200000
139.400000
139.600000
Debutanizer bottom temp



i-butane
.3500
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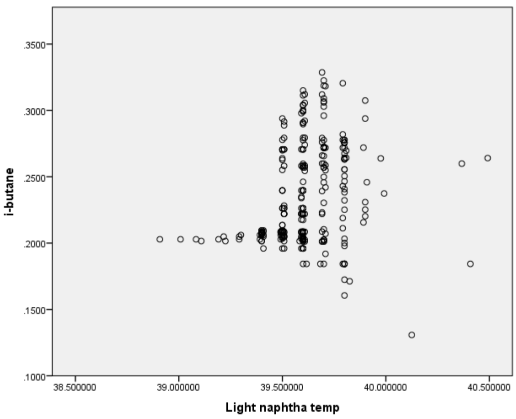
.2500
.2000
.1500
.1000
32.000000
33.000000
34.000000
35.000000
36.000000
Debutanizer receiver bottom temp



i-butane
.3500
.3000
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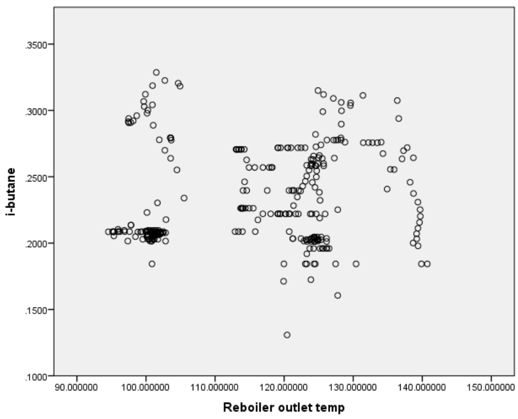
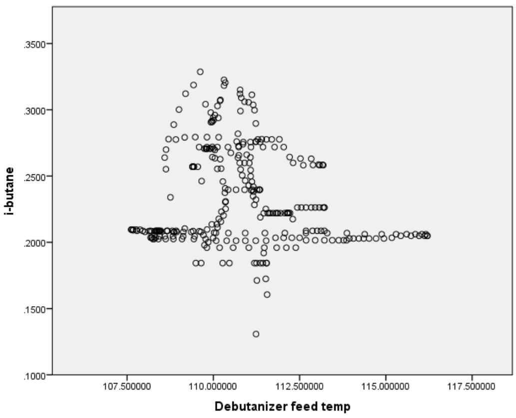
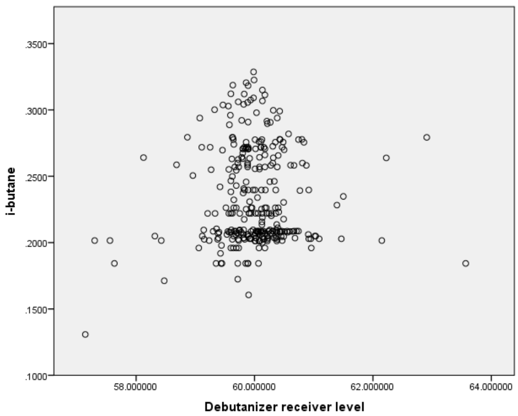
.2000
.1500
.1000
38.500000
39.000000
39.500000
40.000000
40.500000
Light naphtha temp



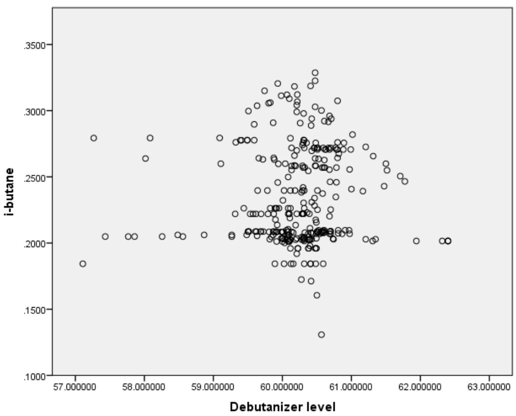
i-butane
.3500
.3000
.2500
.2000
.1500
.1000
90.000000
100.000000
110.000000
120.000000
130.000000
140.000000
150.000000
Reboiler outlet temp



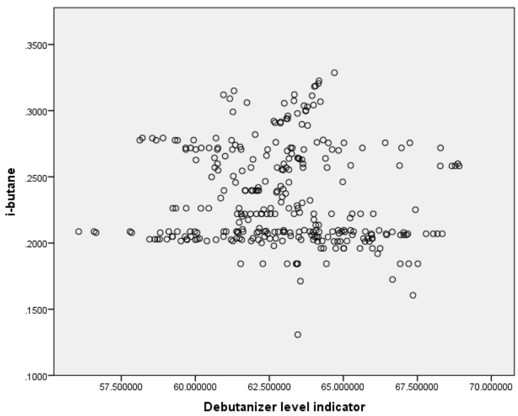
i-butane
.3500
.3000
.2500
.2000
.1500
.1000
107.500000
110.000000
112.500000
115.000000
117.500000
Debutanizer feed temp



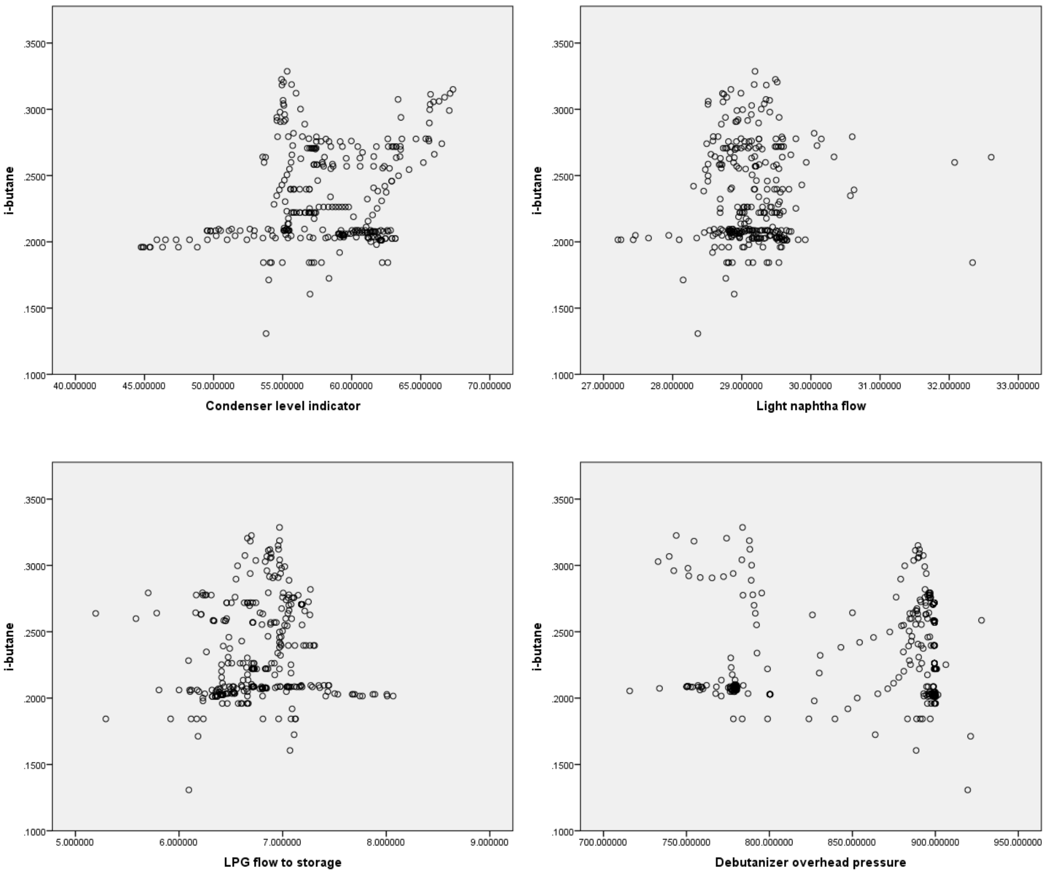
i-butane
.3500
.3000
.2500
.2000
.1500
.1000
58.000000
60.000000
62.000000
64.000000
Debutanizer receiver level



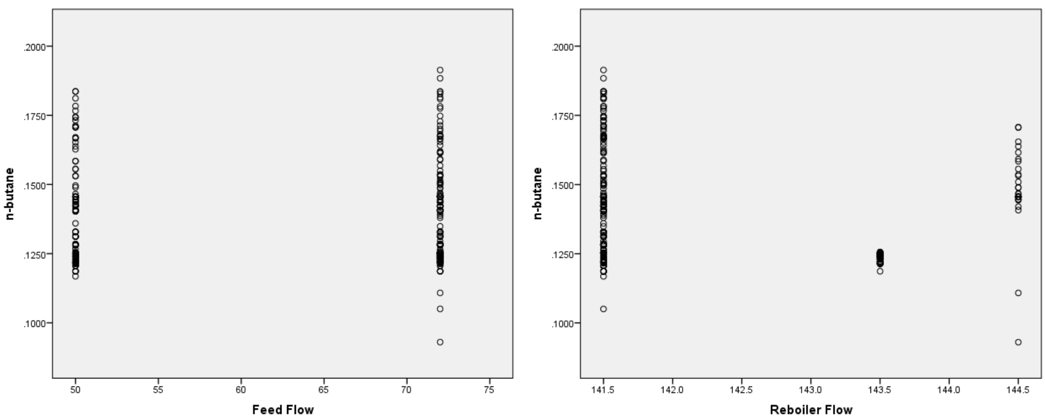
i-butane
.3500
.3000
.2500
.2000
.1500
.1000
57.000000
58.000000
59.000000
60.000000
61.000000
62.000000
63.000000
Debutanizer level

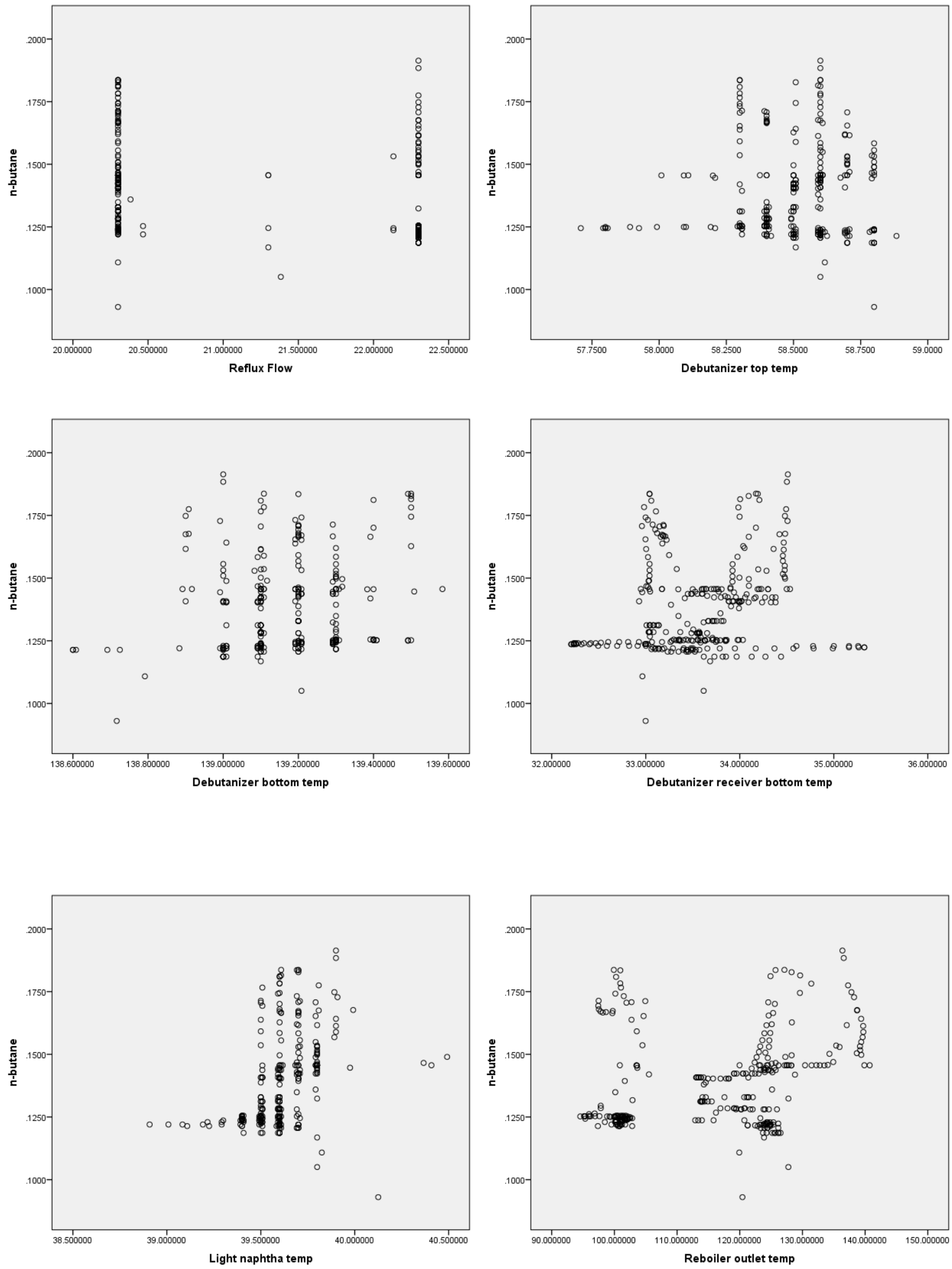


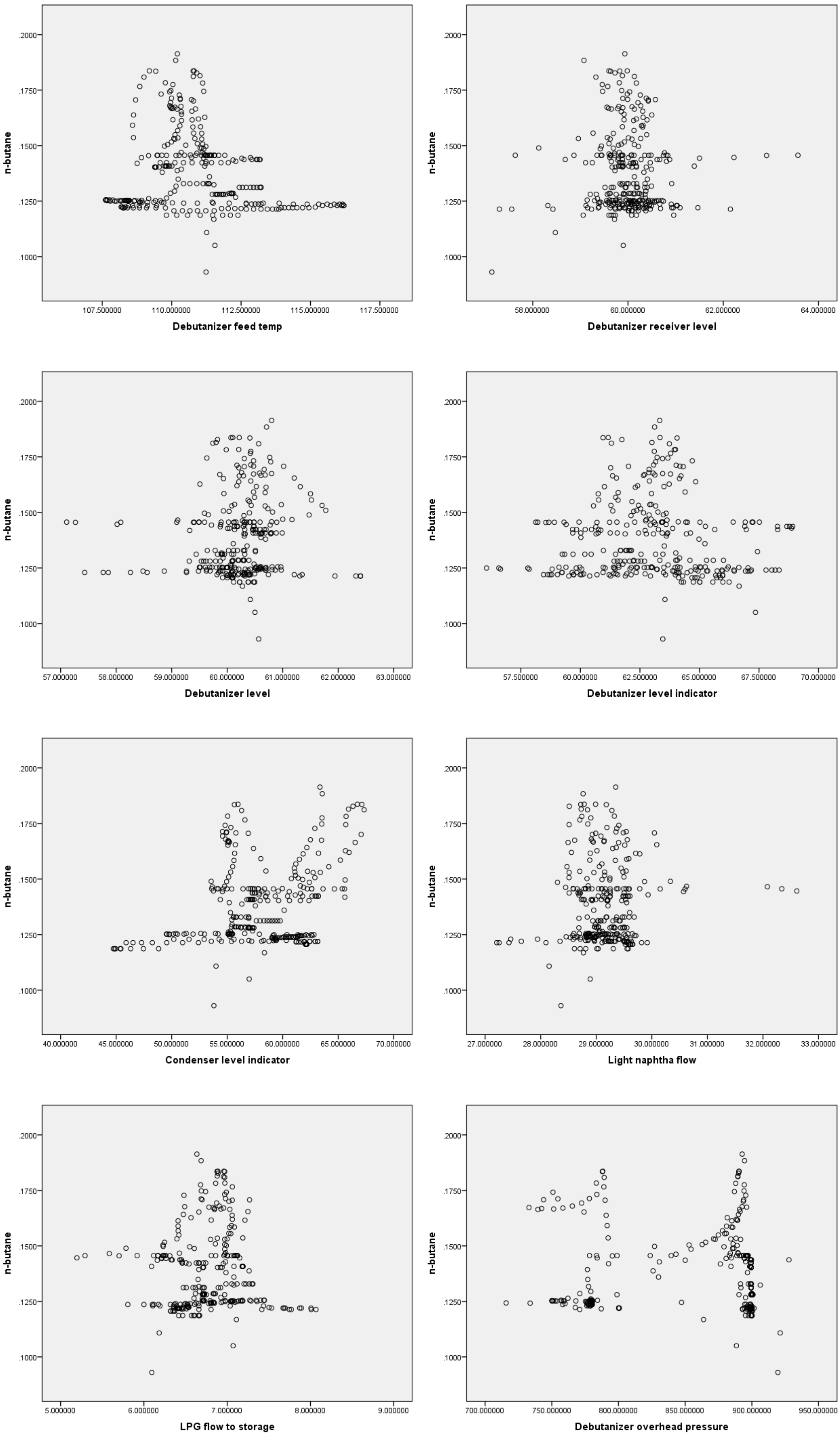
i-butane
.3500
.3000
.2500
.2000
.1500
.1000
57.500000
60.000000
62.500000
65.000000
67.500000
70.000000
Debutanizer level indicator



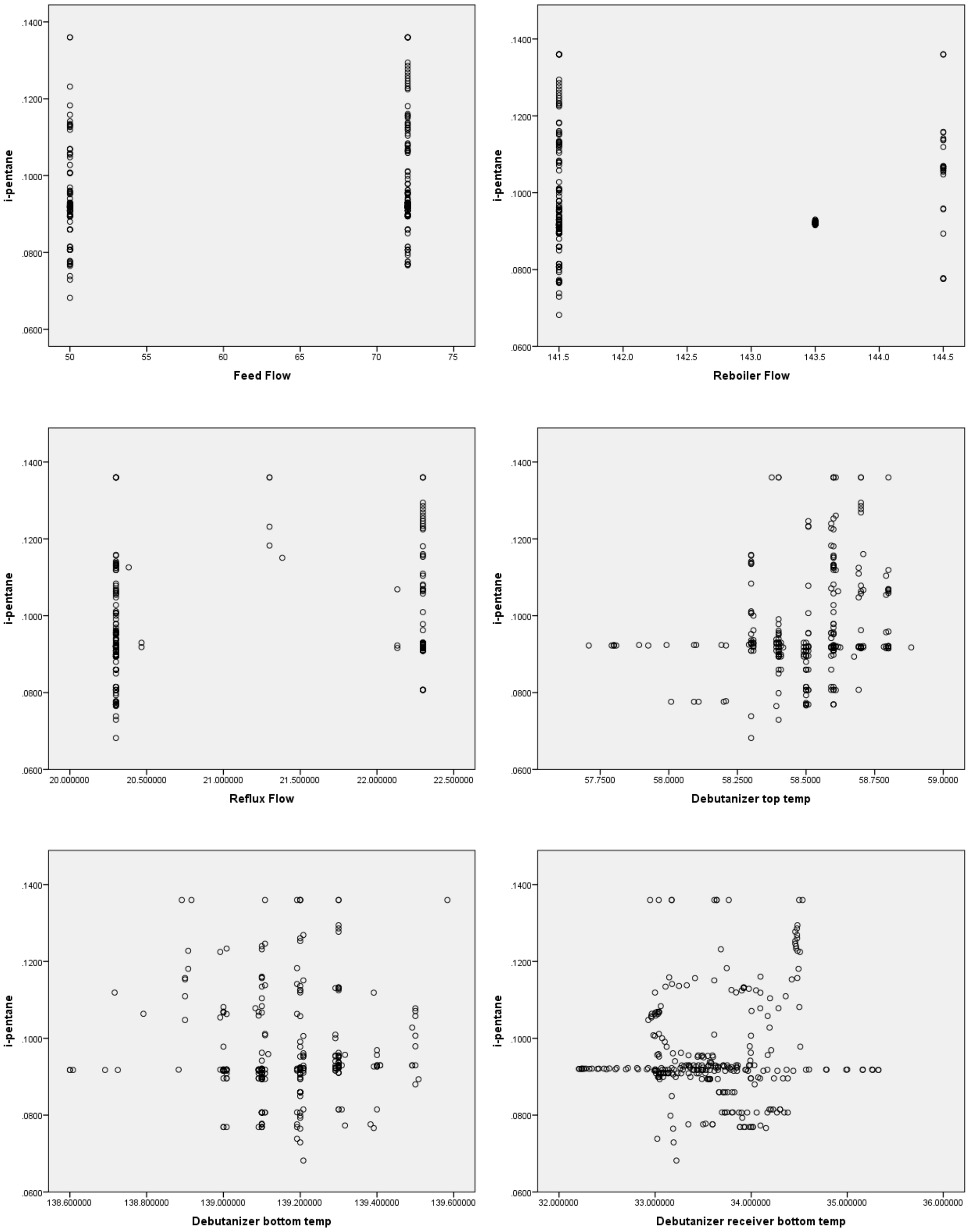
nC4 vs Variables

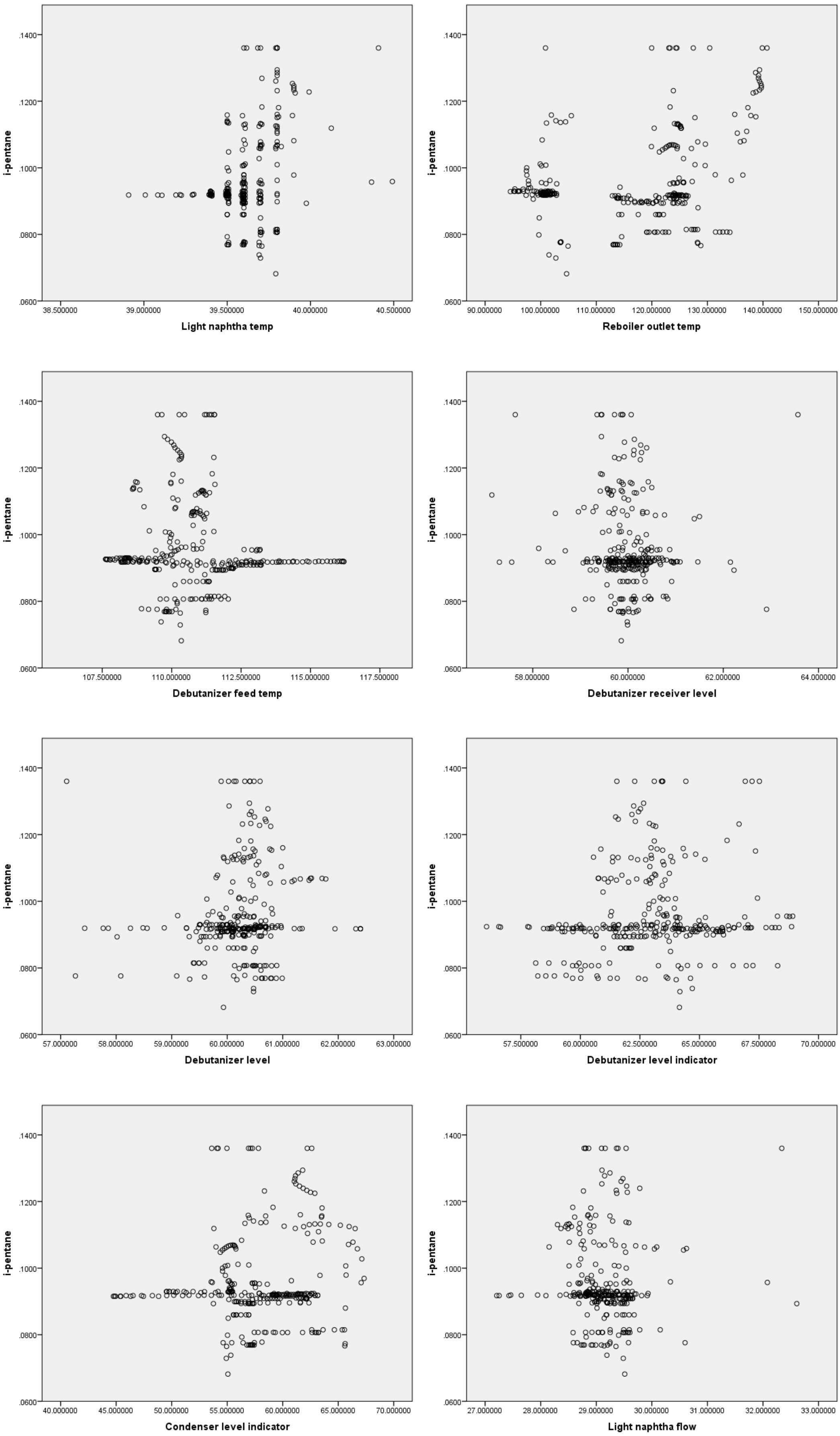


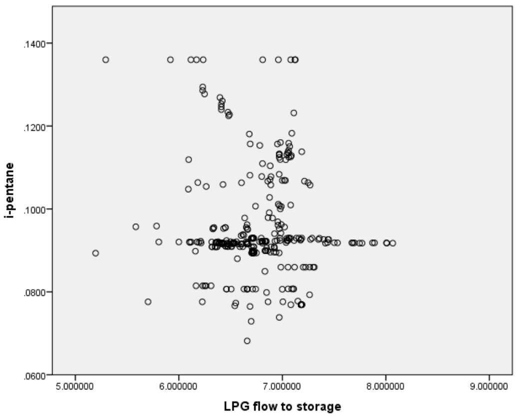

n-butane
.2000
.1750
.1500
.1250
.1000
20.000000
20.500000
21.000000
21.500000
22.000000
22.500000
Reflux Flow
57.7500
58.0000
58.2500
58.5000
58.7500
59.0000
Debutanizer top temp
138.600000
138.800000
139.000000
139.200000
139.400000
139.600000
Debutanizer bottom temp
32.000000
33.000000
34.000000
35.000000
36.000000
Debutanizer receiver bottom temp
38.500000
39.000000
39.500000
40.000000
40.500000
Light naphtha temp
90.000000
100.000000
110.000000
120.000000
130.000000
140.000000
150.000000
Reboiler outlet temp

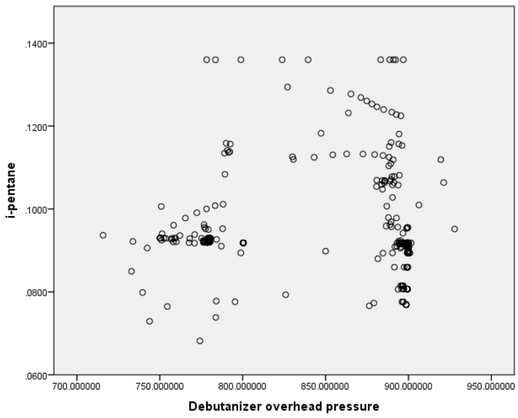

n-butane
.2000
.1750
.1500
.1250
.1000
107.500000
110.000000
112.500000
115.000000
117.500000
Debutanizer feed temp
58.000000
60.000000
62.000000
64.000000
Debutanizer receiver level
57.000000
58.000000
59.000000
60.000000
61.000000
62.000000
63.000000
Debutanizer level
57.500000
60.000000
62.500000
65.000000
67.500000
70.000000
Debutanizer level indicator
40.000000
45.000000
50.000000
55.000000
60.000000
65.000000
70.000000
Condenser level indicator
27.000000
28.000000
29.000000
30.000000
31.000000
32.000000
33.000000
Light naphtha flow
5.000000
6.000000
7.000000
8.000000
9.000000
LPG flow to storage
700.000000
750.000000
800.000000
850.000000
900.000000
950.000000
Debutanizer overhead pressure

iC5 vs Variables

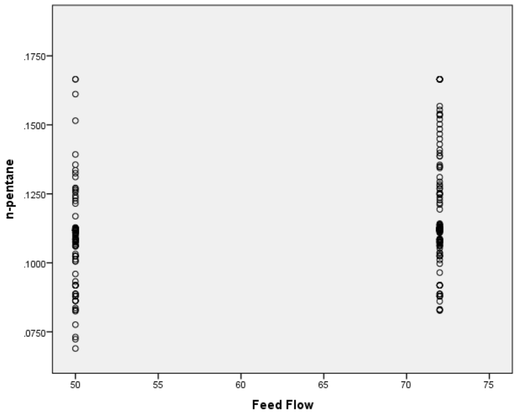


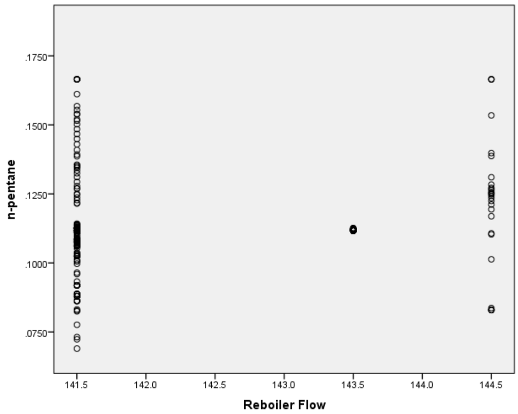

i-pentane
.0600
.0800
.1000
.1200
.1400
Light naphtha temp
38.500000
39.000000
39.500000
40.000000
40.500000
Reboiler outlet temp
90.000000
100.000000
110.000000
120.000000
130.000000
140.000000
150.000000
Debutanizer feed temp
107.500000
110.000000
112.500000
115.000000
117.500000
Debutanizer receiver level
58.000000
60.000000
62.000000
64.000000
Debutanizer level
57.000000
58.000000
59.000000
60.000000
61.000000
62.000000
63.000000
Debutanizer level indicator
57.500000
60.000000
62.500000
65.000000
67.500000
70.000000
Condenser level indicator
40.000000
45.000000
50.000000
55.000000
60.000000
65.000000
70.000000
Light naphtha flow
27.000000
28.000000
29.000000
30.000000
31.000000
32.000000
33.000000

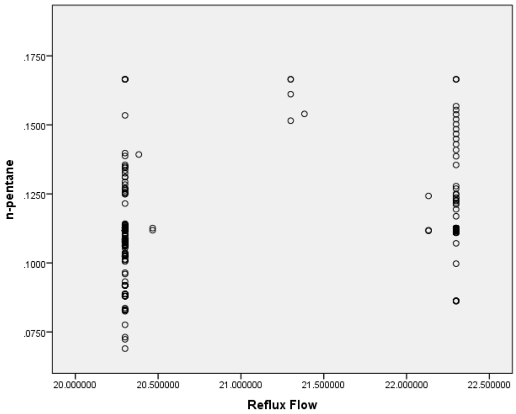


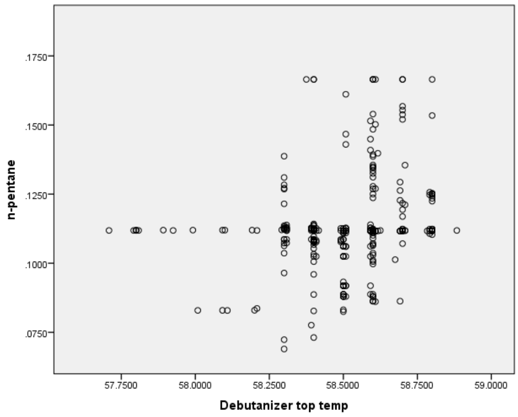


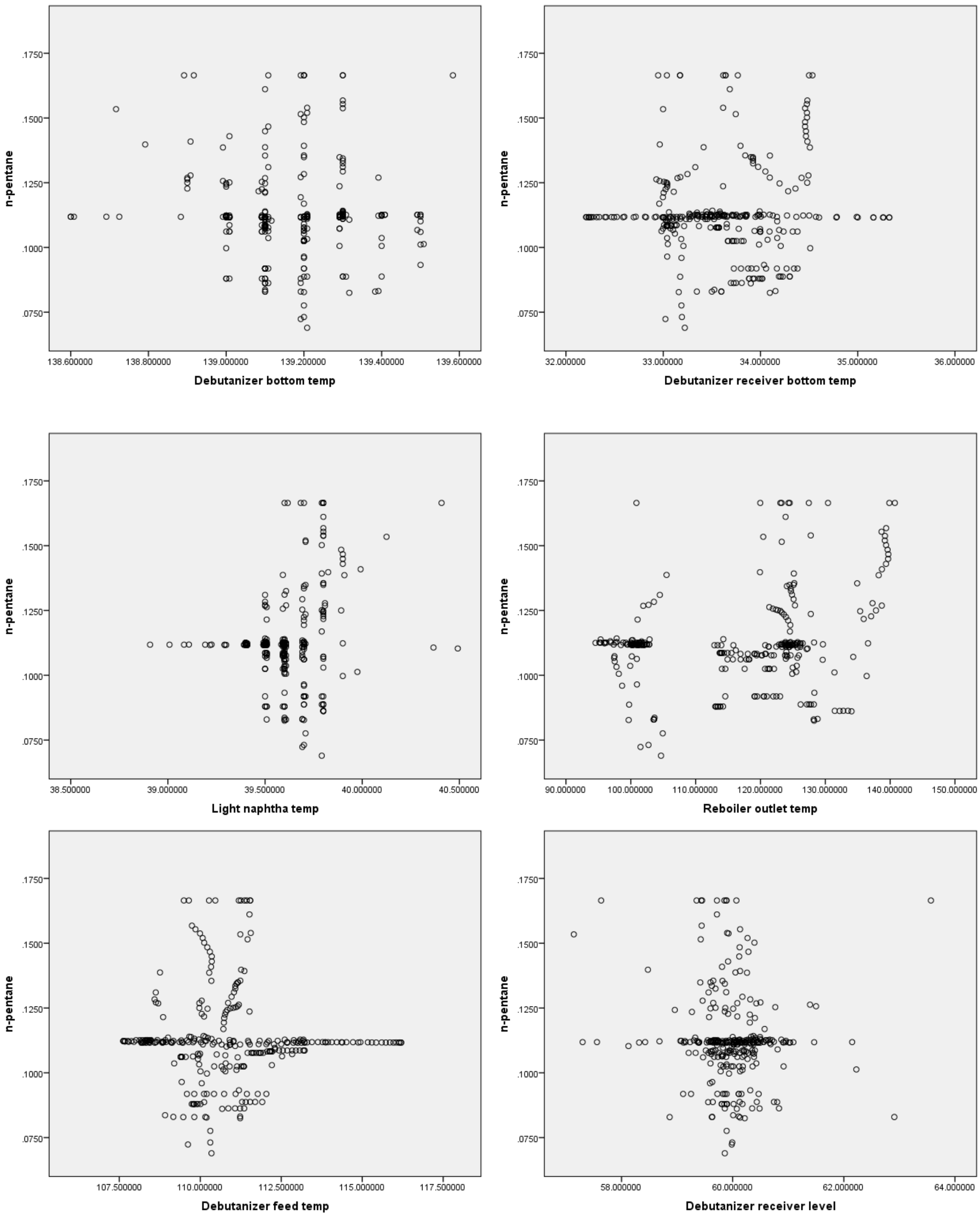
nC5 vs Variables



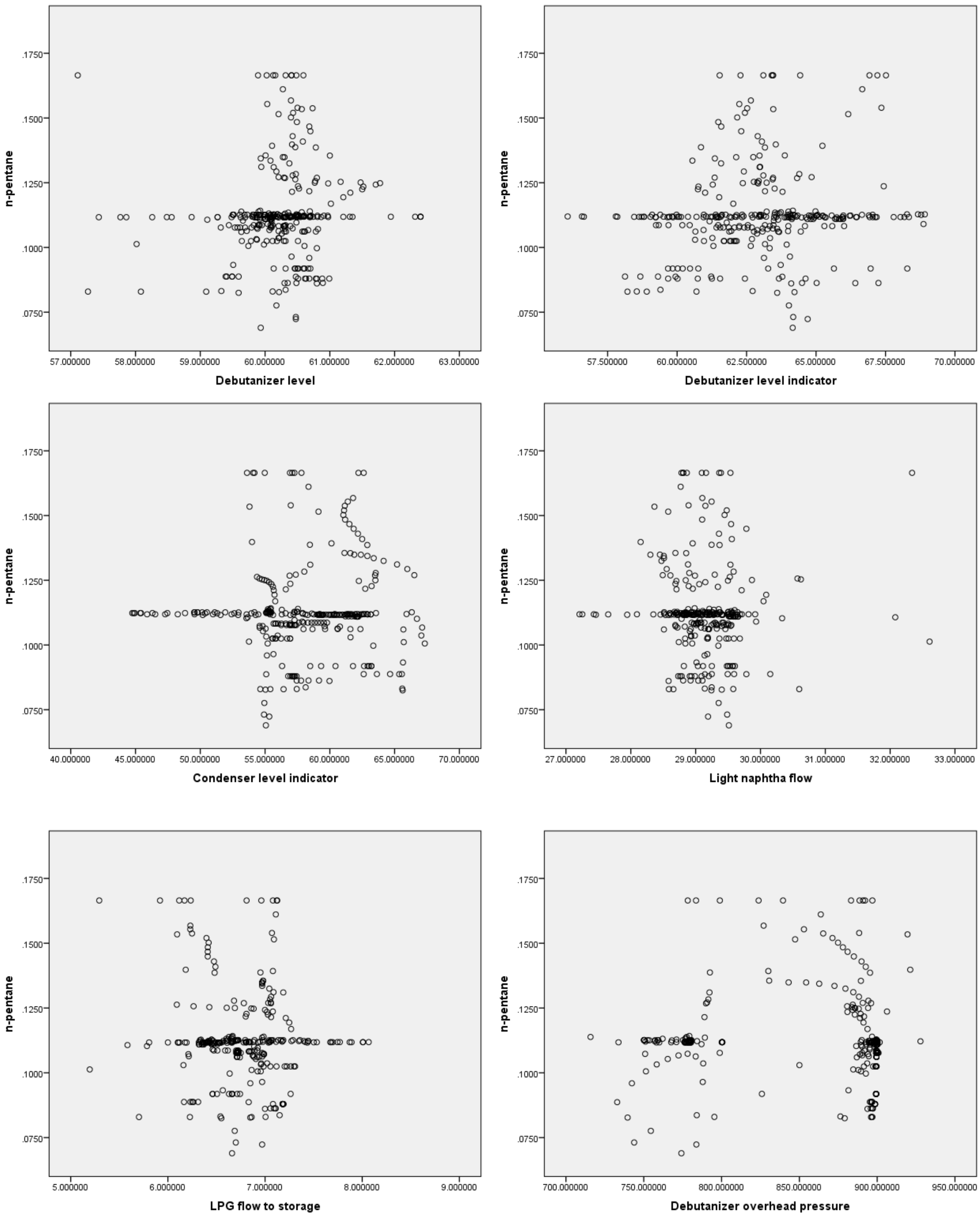








n-pentane
.1750
.1500
.1250
.1000
.0750
138.600000
138.800000
139.000000
139.200000
139.400000
139.600000
Debutanizer bottom temp
32.000000
33.000000
34.000000
35.000000
36.000000
Debutanizer receiver bottom temp
38.500000
39.000000
39.500000
40.000000
40.500000
Light naphtha temp
90.000000
100.000000
110.000000
120.000000
130.000000
140.000000
150.000000
Reboiler outlet temp
107.500000
110.000000
112.500000
115.000000
117.500000
Debutanizer feed temp
58.000000
60.000000
62.000000
64.000000
Debutanizer receiver level


n-pentane
Debutanizer level
n-pentane
Debutanizer level indicator
n-pentane
Condenser level indicator
n-pentane
Light naphtha flow
n-pentane
LPG flow to storage
n-pentane
Debutanizer overhead pressure

APPENDIX IV

REGRESSION

Dependent Variables: Compositions

Independent Variables: Manipulated Variables

Model Summary and Parameter Estimates

Dependent Variable: propane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.025	7.527	1	299	.006	.236	-.001		
Logarithmic	.025	7.527	1	299	.006	.417	-.059		
Quadratic	.025	7.527	1	299	.006	.236	-.001	.000	
Cubic	.	.	.	.	.	.176	.000	.000	.000
Exponential	.029	9.009	1	299	.003	.239	-.006		

The independent variable is Feed Flow.

Model Summary and Parameter Estimates

Dependent Variable: propane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.040	12.604	1	299	.000	1.949	-.012		
Logarithmic	.041	12.667	1	299	.000	9.027	-1.786		
Quadratic	.040	12.604	1	299	.000	1.949	-.012	.000	
Cubic	.040	12.604	1	299	.000	1.949	-.012	.000	.000
Exponential	.040	12.333	1	299	.001	3754.731	-.071		

The independent variable is Reboiler Flow.

Model Summary and Parameter Estimates

Dependent Variable: propane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.169	60.802	1	299	.000	.782	-.029		
Logarithmic	.169	61.002	1	299	.000	2.043	-.613		
Quadratic	.169	60.802	1	299	.000	.782	-.029	.000	
Cubic	.169	60.802	1	299	.000	.782	-.029	.000	.000
Exponential	.159	56.662	1	299	.000	4.739	-.160		

The independent variable is Reflux Flow.

Model Summary and Parameter Estimates

Dependent Variable: i-butane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.010	3.135	1	299	.078	.255	.000		
Logarithmic	.010	3.135	1	299	.078	.319	-.021		
Quadratic	.010	3.135	1	299	.078	.255	.000	.000	
Cubic	.	.	.	.	.	.234	.000	.000	.000
Exponential	.010	3.073	1	299	.081	.252	-.001		

The independent variable is Feed Flow.

Model Summary and Parameter Estimates

Dependent Variable: i-butane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.037	11.383	1	299	.001	1.145	-.006		
Logarithmic	.037	11.466	1	299	.001	4.785	-.918		
Quadratic	.037	11.383	1	299	.001	1.145	-.006	.000	
Cubic	.037	11.383	1	299	.001	1.145	-.006	.000	.000
Exponential	.037	11.626	1	299	.001	10.881	-.027		

The independent variable is Reboiler Flow.

Model Summary and Parameter Estimates

Dependent Variable: i-butane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.157	55.699	1	299	.000	.549	-.015		
Logarithmic	.158	55.907	1	299	.000	1.205	-.319		
Quadratic	.157	55.699	1	299	.000	.549	-.015	.000	
Cubic	.157	55.699	1	299	.000	.549	-.015	.000	.000
Exponential	.156	55.176	1	299	.000	.860	-.062		

The independent variable is Reflux Flow.

Model Summary and Parameter Estimates

Dependent Variable: n-butane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.001	.161	1	299	.689	.136	3.808E-5		
Logarithmic	.001	.161	1	299	.689	.129	.002		
Quadratic	.001	.161	1	299	.689	.136	3.808E-5	.000	
Cubic	.	.	.	.	.	.138	.000	.000	.000
Exponential	.000	.133	1	299	.716	.135	.000		

The independent variable is Feed Flow.

Model Summary and Parameter Estimates

Dependent Variable: n-butane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.023	7.014	1	299	.009	.491	-.002		
Logarithmic	.023	7.090	1	299	.008	1.906	-.357		
Quadratic	.023	7.014	1	299	.009	.491	-.002	.000	
Cubic	.023	7.014	1	299	.009	.491	-.002	.000	.000
Exponential	.024	7.274	1	299	.007	1.665	-.018		

The independent variable is Reboiler Flow.

Model Summary and Parameter Estimates

Dependent Variable: n-butane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.051	16.055	1	299	.000	.226	-.004		
Logarithmic	.051	16.096	1	299	.000	.409	-.089		
Quadratic	.051	16.055	1	299	.000	.226	-.004	.000	
Cubic	.051	16.055	1	299	.000	.226	-.004	.000	.000
Exponential	.057	18.107	1	299	.000	.262	-.031		

The independent variable is Reflux Flow.

Model Summary and Parameter Estimates

Dependent Variable: i-pentane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.039	12.170	1	299	.001	.081	.000		
Logarithmic	.039	12.170	1	299	.001	.036	.015		
Quadratic	.039	12.170	1	299	.001	.088	.000	1.980E-6	
Cubic	.	.	.	.	.	.096	.000	.000	.000
Exponential	.040	12.320	1	299	.001	.082	.002		

The independent variable is Feed Flow.

Model Summary and Parameter Estimates

Dependent Variable: i-pentane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.006	1.823	1	299	.178	-.039	.001		
Logarithmic	.006	1.801	1	299	.181	-.573	.135		
Quadratic	.006	1.845	1	299	.175	.028	.000	3.347E-6	
Cubic	.006	1.868	1	299	.173	.051	.000	.000	1.572E-8
Exponential	.008	2.418	1	299	.121	.021	.011		

The independent variable is Reboiler Flow.

Model Summary and Parameter Estimates

Dependent Variable: i-pentane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.032	9.948	1	299	.002	.044	.002		
Logarithmic	.033	10.050	1	299	.002	-.065	.053		
Quadratic	.032	9.948	1	299	.002	.044	.002	.000	
Cubic	.032	9.948	1	299	.002	.044	.002	.000	.000
Exponential	.037	11.352	1	299	.001	.055	.026		

The independent variable is Reflux Flow.

Model Summary and Parameter Estimates

Dependent Variable: n-pentane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.039	12.233	1	299	.001	.093	.000		
Logarithmic	.039	12.233	1	299	.001	.033	.019		
Quadratic	.039	12.233	1	299	.001	.093	.000	.000	
Cubic	.	.	.	.	.	.113	.000	.000	.000
Exponential	.041	12.683	1	299	.000	.094	.003		

The independent variable is Feed Flow.

Model Summary and Parameter Estimates

Dependent Variable: n-pentane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.014	4.361	1	299	.038	-.163	.002		
Logarithmic	.014	4.343	1	299	.038	-1.259	.277		
Quadratic	.014	4.379	1	299	.037	-.025	.000	6.815E-6	
Cubic	.014	4.397	1	299	.037	.021	.000	.000	3.188E-8
Exponential	.017	5.318	1	299	.022	.008	.018		

The independent variable is Reboiler Flow.

Model Summary and Parameter Estimates

Dependent Variable: n-pentane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.056	17.650	1	299	.000	.022	.004		
Logarithmic	.056	17.821	1	299	.000	-.168	.092		
Quadratic	.056	17.650	1	299	.000	.022	.004	.000	
Cubic	.056	17.650	1	299	.000	.022	.004	.000	.000
Exponential	.065	20.897	1	299	.000	.048	.040		

The independent variable is Reflux Flow.

Dependent Variables: Compositions

Independent Variables: Temperature

Model Summary and Parameter Estimates

Dependent Variable: propane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.003	.994	1	299	.319	1.348	-.020		
Logarithmic	.003	.974	1	299	.324	4.888	-1.158		
Quadratic	.003	1.015	1	299	.315	.769	.000	.000	
Cubic	.003	1.035	1	299	.310	.576	.000	.000	-1.999E-6
Exponential	.006	1.866	1	299	.173	1572.778	-.157		

The independent variable is Debutanizer top temp.

Model Summary and Parameter Estimates

Dependent Variable: propane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.006	1.699	1	299	.193	-4.470	.033		
Logarithmic	.006	1.704	1	299	.193	-22.787	4.652		
Quadratic	.006	1.699	1	299	.193	-4.470	.033	.000	
Cubic	.006	1.699	1	299	.193	-4.470	.033	.000	.000
Exponential	.004	1.351	1	299	.246	8.178E-12	.170		

The independent variable is Debutanizer bottom temp.

Model Summary and Parameter Estimates

Dependent Variable: propane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.024	7.426	1	299	.007	-.405	.017		
Logarithmic	.025	7.729	1	299	.006	-1.907	.593		
Quadratic	.080	12.910	2	298	.000	-33.668	1.995	-.029	
Cubic	.080	13.016	2	298	.000	-22.680	1.011	.000	.000
Exponential	.010	3.159	1	299	.077	.018	.065		

The independent variable is Debutanizer receiver bottom temp.

Model Summary and Parameter Estimates

Dependent Variable: propane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.026	7.911	1	299	.005	-2.299	.062		
Logarithmic	.026	7.992	1	299	.005	-8.984	2.490		
Quadratic	.026	7.911	1	299	.005	-2.299	.062	.000	
Cubic	.046	7.162	2	298	.001	-129.750	4.883	.000	-.001
Exponential	.004	1.243	1	299	.266	.001	.143		

The independent variable is Light naphtha temp.

Model Summary and Parameter Estimates

Dependent Variable: propane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.016	4.932	1	299	.027	.097	.001		
Logarithmic	.020	6.049	1	299	.014	-.231	.086		
Quadratic	.102	16.870	2	298	.000	-1.723	.033	.000	
Cubic	.102	16.870	2	298	.000	-1.723	.033	.000	.000
Exponential	.003	.894	1	299	.345	.135	.002		

The independent variable is Reboiler outlet temp.

Model Summary and Parameter Estimates

Dependent Variable: propane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.000	.033	1	299	.855	.218	.000		
Logarithmic	.000	.016	1	299	.899	.315	-.030		
Quadratic	.077	12.423	2	298	.000	-48.257	.869	-.004	
Cubic	.077	12.347	2	298	.000	-31.948	.432	.000	-1.160E-5
Exponential	.000	.011	1	299	.915	.142	.001		

The independent variable is Debutanizer feed temp.

Model Summary and Parameter Estimates

Dependent Variable: i-butane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.002	.691	1	299	.406	.761	-.009		
Logarithmic	.002	.675	1	299	.412	2.350	-.520		
Quadratic	.002	.708	1	299	.401	.501	.000	-7.812E-5	
Cubic	.002	.724	1	299	.395	.415	.000	.000	-9.024E-7
Exponential	.003	.812	1	299	.368	2.526	-.041		

The independent variable is Debutanizer top temp.

Model Summary and Parameter Estimates

Dependent Variable: i-butane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.035	10.904	1	299	.001	-6.020	.045		
Logarithmic	.035	10.910	1	299	.001	-30.636	6.255		
Quadratic	.035	10.904	1	299	.001	-6.020	.045	.000	
Cubic	.035	10.904	1	299	.001	-6.020	.045	.000	.000
Exponential	.036	11.066	1	299	.001	8.246E-13	.189		

The independent variable is Debutanizer bottom temp.

Model Summary and Parameter Estimates

Dependent Variable: i-butane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.016	4.738	1	299	.030	-.017	.007		
Logarithmic	.016	4.942	1	299	.027	-.669	.257		
Quadratic	.056	8.868	2	298	.000	-15.360	.920	-.014	
Cubic	.057	8.931	2	298	.000	-10.283	.465	.000	.000
Exponential	.016	5.010	1	299	.026	.078	.032		

The independent variable is Debutanizer receiver bottom temp.

Model Summary and Parameter Estimates

Dependent Variable: i-butane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.068	21.892	1	299	.000	-1.938	.055		
Logarithmic	.069	22.056	1	299	.000	-7.793	2.182		
Quadratic	.068	21.892	1	299	.000	-1.938	.055	.000	
Cubic	.094	15.510	2	298	.000	-80.250	3.017	.000	-.001
Exponential	.060	19.167	1	299	.000	4.520E-5	.216		

The independent variable is Light naphtha temp.

Model Summary and Parameter Estimates

Dependent Variable: i-butane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.015	4.638	1	299	.032	.193	.000		
Logarithmic	.016	4.736	1	299	.030	.040	.041		
Quadratic	.016	2.444	2	298	.089	.094	.002	-7.493E-6	
Cubic	.016	2.444	2	298	.089	.094	.002	-7.493E-6	.000
Exponential	.016	4.749	1	299	.030	.194	.001		

The independent variable is Reboiler outlet temp.

Model Summary and Parameter Estimates

Dependent Variable: i-butane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.017	5.080	1	299	.025	.514	-.003		
Logarithmic	.016	4.794	1	299	.029	1.521	-.273		
Quadratic	.114	19.114	2	298	.000	-28.864	.525	-.002	
Cubic	.113	18.909	2	298	.000	-18.926	.259	.000	-7.010E-6
Exponential	.016	4.810	1	299	.029	.722	-.010		

The independent variable is Debutanizer feed temp.

Model Summary and Parameter Estimates

Dependent Variable: n-butane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.003	.948	1	299	.331	-.165	.005		
Logarithmic	.003	.961	1	299	.328	-1.099	.304		
Quadratic	.003	.948	1	299	.331	-.165	.005	.000	
Cubic	.003	.948	1	299	.331	-.165	.005	.000	.000
Exponential	.003	.898	1	299	.344	.018	.035		

The independent variable is Debutanizer top temp.

Model Summary and Parameter Estimates

Dependent Variable: n-butane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.031	9.678	1	299	.002	-2.757	.021		
Logarithmic	.031	9.675	1	299	.002	-14.145	2.894		
Quadratic	.031	9.681	1	299	.002	-1.310	.000	7.477E-5	
Cubic	.031	9.684	1	299	.002	-.827	.000	.000	3.583E-7
Exponential	.035	10.721	1	299	.001	9.228E-11	.152		

The independent variable is Debutanizer bottom temp.

Model Summary and Parameter Estimates

Dependent Variable: n-butane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.032	9.979	1	299	.002	-.039	.005		
Logarithmic	.033	10.162	1	299	.002	-.491	.179		
Quadratic	.048	7.433	2	298	.001	-4.647	.279	-.004	
Cubic	.048	7.475	2	298	.001	-3.134	.143	.000	-4.062E-5
Exponential	.034	10.570	1	299	.001	.039	.038		

The independent variable is Debutanizer receiver bottom temp.

Model Summary and Parameter Estimates

Dependent Variable: n-butane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.171	61.661	1	299	.000	-1.547	.043		
Logarithmic	.171	61.881	1	299	.000	-6.080	1.690		
Quadratic	.171	61.661	1	299	.000	-1.547	.043	.000	
Cubic	.183	33.433	2	298	.000	-27.924	1.040	.000	.000
Exponential	.175	63.311	1	299	.000	9.969E-7	.299		

The independent variable is Light naphtha temp.

Model Summary and Parameter Estimates

Dependent Variable: n-butane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.080	25.887	1	299	.000	.092	.000		
Logarithmic	.073	23.404	1	299	.000	-.067	.043		
Quadratic	.156	27.469	2	298	.000	.546	-.008	3.447E-5	
Cubic	.158	27.865	2	298	.000	.253	.000	-3.010E-5	1.824E-7
Exponential	.084	27.362	1	299	.000	.099	.003		

The independent variable is Reboiler outlet temp.

Model Summary and Parameter Estimates

Dependent Variable: n-butane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.031	9.684	1	299	.002	.326	-.002		
Logarithmic	.030	9.248	1	299	.003	1.009	-.185		
Quadratic	.144	24.965	2	298	.000	-15.163	.276	-.001	
Cubic	.142	24.661	2	298	.000	-9.912	.136	.000	-3.692E-6
Exponential	.031	9.692	1	299	.002	.506	-.012		

The independent variable is Debutanizer feed temp.

Model Summary and Parameter Estimates

Dependent Variable: i-pentane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.050	15.826	1	299	.000	-.802	.015		
Logarithmic	.050	15.775	1	299	.000	-3.546	.895		
Quadratic	.050	15.877	1	299	.000	-.355	.000	.000	
Cubic	.051	15.927	1	299	.000	-.206	.000	.000	1.505E-6
Exponential	.051	16.064	1	299	.000	1.325E-5	.152		

The independent variable is Debutanizer top temp.

Model Summary and Parameter Estimates

Dependent Variable: i-pentane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.000	.007	1	299	.931	.035	.000		
Logarithmic	.000	.007	1	299	.933	-.196	.059		
Quadratic	.000	.008	1	299	.930	.065	.000	1.597E-6	
Cubic	.000	.008	1	299	.928	.075	.000	.000	7.818E-9
Exponential	.000	.010	1	299	.921	.048	.005		

The independent variable is Debutanizer bottom temp.

Model Summary and Parameter Estimates

Dependent Variable: i-pentane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.012	3.616	1	299	.058	.016	.002		
Logarithmic	.012	3.573	1	299	.060	-.185	.080		
Quadratic	.014	2.136	2	298	.120	1.313	-.075	.001	
Cubic	.014	2.130	2	298	.121	.873	-.036	.000	1.125E-5
Exponential	.008	2.521	1	299	.113	.049	.020		

The independent variable is Debutanizer receiver bottom temp.

Model Summary and Parameter Estimates

Dependent Variable: i-pentane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.110	37.022	1	299	.000	-.911	.025		
Logarithmic	.110	36.916	1	299	.000	-3.607	1.006		
Quadratic	.110	37.123	1	299	.000	-.407	.000	.000	
Cubic	.115	19.404	2	298	.000	11.656	-.450	.000	.000
Exponential	.094	30.979	1	299	.000	1.040E-5	.230		

The independent variable is Light naphtha temp.

Model Summary and Parameter Estimates

Dependent Variable: i-pentane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.115	38.765	1	299	.000	.055	.000		
Logarithmic	.102	34.031	1	299	.000	-.086	.038		
Quadratic	.282	58.416	2	298	.000	.555	-.008	3.799E-5	
Cubic	.284	59.180	2	298	.000	.228	.000	-3.370E-5	2.020E-7
Exponential	.102	33.853	1	299	.000	.065	.003		

The independent variable is Reboiler outlet temp.

Model Summary and Parameter Estimates

Dependent Variable: i-pentane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.005	1.434	1	299	.232	.150	.000		
Logarithmic	.005	1.376	1	299	.242	.349	-.054		
Quadratic	.019	2.921	2	298	.055	-3.986	.074	.000	
Cubic	.019	2.892	2	298	.057	-2.584	.036	.000	-9.861E-7
Exponential	.004	1.143	1	299	.286	.153	-.004		

The independent variable is Debutanizer feed temp.

Model Summary and Parameter Estimates

Dependent Variable: n-pentane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.051	15.980	1	299	.000	-1.085	.020		
Logarithmic	.051	15.912	1	299	.000	-4.740	1.193		
Quadratic	.051	16.048	1	299	.000	-.488	.000	.000	
Cubic	.051	16.115	1	299	.000	-.289	.000	.000	2.009E-6
Exponential	.051	15.962	1	299	.000	3.983E-6	.175		

The independent variable is Debutanizer top temp.

Model Summary and Parameter Estimates

Dependent Variable: n-pentane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.003	.926	1	299	.337	1.010	-.006		
Logarithmic	.003	.929	1	299	.336	4.546	-.898		
Quadratic	.003	.926	1	299	.337	1.010	-.006	.000	
Cubic	.003	.926	1	299	.337	1.010	-.006	.000	.000
Exponential	.004	1.127	1	299	.289	527.908	-.061		

The independent variable is Debutanizer bottom temp.

Model Summary and Parameter Estimates

Dependent Variable: n-pentane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.003	.912	1	299	.340	.059	.002		
Logarithmic	.003	.878	1	299	.349	-.073	.053		
Quadratic	.009	1.362	2	298	.258	2.919	-.168	.003	
Cubic	.009	1.360	2	298	.258	1.962	-.083	.000	2.497E-5
Exponential	.001	.388	1	299	.534	.083	.009		

The independent variable is Debutanizer receiver bottom temp.

Model Summary and Parameter Estimates

Dependent Variable: n-pentane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.050	15.717	1	299	.000	-.787	.023		
Logarithmic	.050	15.624	1	299	.000	-3.191	.898		
Quadratic	.050	15.808	1	299	.000	-.338	.000	.000	
Cubic	.062	9.773	2	298	.000	24.520	-.934	.000	.000
Exponential	.030	9.314	1	299	.002	.000	.151		

The independent variable is Light naphtha temp.

Model Summary and Parameter Estimates

Dependent Variable: n-pentane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.072	23.119	1	299	.000	.070	.000		
Logarithmic	.064	20.563	1	299	.000	-.078	.040		
Quadratic	.164	29.277	2	298	.000	.564	-.008	3.753E-5	
Cubic	.166	29.658	2	298	.000	.242	.000	-3.318E-5	1.994E-7
Exponential	.057	18.089	1	299	.000	.080	.003		

The independent variable is Reboiler outlet temp.

Model Summary and Parameter Estimates

Dependent Variable: n-pentane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.000	.021	1	299	.884	.122	-7.958E-5		
Logarithmic	.000	.019	1	299	.890	.153	-.008		
Quadratic	.001	.192	2	298	.825	-1.472	.029	.000	
Cubic	.001	.191	2	298	.826	-.936	.014	.000	-3.815E-7
Exponential	.000	.003	1	299	.953	.108	.000		

The independent variable is Debutanizer feed temp.

Dependent Variables: Compositions

Independent Variables: Level

Model Summary and Parameter Estimates

Dependent Variable: propane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.006	1.923	1	299	.167	-.328	.008		
Logarithmic	.007	2.003	1	299	.158	-1.931	.515		
Quadratic	.016	2.485	2	298	.085	-19.511	.647	-.005	
Cubic	.016	2.485	2	298	.085	-19.511	.647	-.005	.000
Exponential	.008	2.499	1	299	.115	.006	.055		

The independent variable is Debutanizer receiver level.

Model Summary and Parameter Estimates

Dependent Variable: propane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.007	2.137	1	299	.145	.683	-.008		
Logarithmic	.007	2.107	1	299	.148	2.229	-.501		
Quadratic	.009	1.317	2	298	.269	-7.917	.279	-.002	
Cubic	.009	1.316	2	298	.270	-5.044	.135	.000	-1.332E-5
Exponential	.003	.947	1	299	.331	1.133	-.032		

The independent variable is Debutanizer level.

Model Summary and Parameter Estimates

Dependent Variable: propane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.009	2.725	1	299	.100	.342	-.003		
Logarithmic	.009	2.820	1	299	.094	.878	-.170		
Quadratic	.014	2.039	2	298	.132	2.534	-.072	.001	
Cubic	.014	2.092	2	298	.125	1.863	-.039	.000	3.039E-6
Exponential	.010	2.902	1	299	.089	.437	-.016		

The independent variable is Debutanizer level indicator.

Model Summary and Parameter Estimates

Dependent Variable: propane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.039	12.241	1	299	.001	-.001	.003		
Logarithmic	.040	12.555	1	299	.000	-.527	.173		
Quadratic	.041	6.360	2	298	.002	-.299	.014	-9.309E-5	
Cubic	.041	6.360	2	298	.002	-.299	.014	-9.309E-5	.000
Exponential	.032	9.867	1	299	.002	.066	.016		

The independent variable is Condenser level indicator.

Model Summary and Parameter Estimates

Dependent Variable: i-butane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.003	.844	1	299	.359	.053	.003		
Logarithmic	.003	.928	1	299	.336	-.541	.189		
Quadratic	.027	4.169	2	298	.016	-16.104	.541	-.004	
Cubic	.027	4.169	2	298	.016	-16.104	.541	-.004	.000
Exponential	.005	1.622	1	299	.204	.081	.017		

The independent variable is Debutanizer receiver level.

Model Summary and Parameter Estimates

Dependent Variable: i-butane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.000	.144	1	299	.704	.162	.001		
Logarithmic	.001	.155	1	299	.694	-.068	.074		
Quadratic	.004	.606	2	298	.546	-6.633	.228	-.002	
Cubic	.004	.616	2	298	.541	-4.410	.116	.000	-1.063E-5
Exponential	.001	.169	1	299	.682	.167	.005		

The independent variable is Debutanizer level.

Model Summary and Parameter Estimates

Dependent Variable: i-butane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.006	1.931	1	299	.166	.310	-.001		
Logarithmic	.006	1.764	1	299	.185	.534	-.072		
Quadratic	.022	3.411	2	298	.034	-1.925	.070	-.001	
Cubic	.022	3.332	2	298	.037	-1.160	.034	.000	-2.937E-6
Exponential	.008	2.460	1	299	.118	.331	-.006		

The independent variable is Debutanizer level indicator.

Model Summary and Parameter Estimates

Dependent Variable: i-butane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.073	23.597	1	299	.000	.104	.002		
Logarithmic	.072	23.334	1	299	.000	-.274	.125		
Quadratic	.075	11.998	2	298	.000	.254	-.003	4.653E-5	
Cubic	.076	12.275	2	298	.000	.231	.000	-3.937E-5	6.864E-7
Exponential	.076	24.451	1	299	.000	.133	.010		

The independent variable is Condenser level indicator.

Model Summary and Parameter Estimates

Dependent Variable: n-butane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.000	.049	1	299	.825	.117	.000		
Logarithmic	.000	.062	1	299	.804	.040	.024		
Quadratic	.009	1.385	2	298	.252	-4.706	.161	-.001	
Cubic	.009	1.385	2	298	.252	-4.706	.161	-.001	.000
Exponential	.001	.245	1	299	.621	.098	.006		

The independent variable is Debutanizer receiver level.

Model Summary and Parameter Estimates

Dependent Variable: n-butane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.007	2.207	1	299	.138	.002	.002		
Logarithmic	.007	2.233	1	299	.136	-.421	.136		
Quadratic	.009	1.327	2	298	.267	-2.157	.074	-.001	
Cubic	.009	1.342	2	298	.263	-1.486	.040	.000	-3.459E-6
Exponential	.007	1.984	1	299	.160	.056	.015		

The independent variable is Debutanizer level.

Model Summary and Parameter Estimates

Dependent Variable: n-butane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.001	.300	1	299	.584	.153	.000		
Logarithmic	.001	.190	1	299	.663	.187	-.012		
Quadratic	.057	9.062	2	298	.000	-1.905	.065	-.001	
Cubic	.057	8.934	2	298	.000	-1.214	.032	.000	-2.731E-6
Exponential	.001	.409	1	299	.523	.155	-.002		

The independent variable is Debutanizer level indicator.

Model Summary and Parameter Estimates

Dependent Variable: n-butane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.100	33.149	1	299	.000	.064	.001		
Logarithmic	.097	32.274	1	299	.000	-.151	.071		
Quadratic	.106	17.602	2	298	.000	.215	-.004	4.703E-5	
Cubic	.109	18.244	2	298	.000	.157	.000	-4.148E-5	6.137E-7
Exponential	.102	34.018	1	299	.000	.081	.009		

The independent variable is Condenser level indicator.

Model Summary and Parameter Estimates

Dependent Variable: i-pentane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.007	2.087	1	299	.150	.199	-.002		
Logarithmic	.007	2.187	1	299	.140	.529	-.106		
Quadratic	.022	3.307	2	298	.038	4.785	-.154	.001	
Cubic	.022	3.349	2	298	.036	3.277	-.079	.000	7.106E-6
Exponential	.007	2.113	1	299	.147	.263	-.017		

The independent variable is Debutanizer receiver level.

Model Summary and Parameter Estimates

Dependent Variable: i-pentane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.012	3.495	1	299	.063	-.032	.002		
Logarithmic	.011	3.474	1	299	.063	-.422	.126		
Quadratic	.012	1.797	2	298	.168	.760	-.024	.000	
Cubic	.012	1.789	2	298	.169	.459	-.010	.000	1.140E-6
Exponential	.013	4.020	1	299	.046	.025	.022		

The independent variable is Debutanizer level.

Model Summary and Parameter Estimates

Dependent Variable: i-pentane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.013	4.071	1	299	.045	.056	.001		
Logarithmic	.014	4.378	1	299	.037	-.076	.041		
Quadratic	.039	5.967	2	298	.003	-.965	.033	.000	
Cubic	.039	5.967	2	298	.003	-.965	.033	.000	.000
Exponential	.014	4.332	1	299	.038	.063	.006		

The independent variable is Debutanizer level indicator.

Model Summary and Parameter Estimates

Dependent Variable: i-pentane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.016	4.888	1	299	.028	.074	.000		
Logarithmic	.016	4.719	1	299	.031	.010	.021		
Quadratic	.017	2.618	2	298	.075	.124	-.001	1.570E-5	
Cubic	.017	2.629	2	298	.074	.099	.000	-1.007E-5	1.564E-7
Exponential	.015	4.417	1	299	.036	.077	.004		

The independent variable is Condenser level indicator.

Model Summary and Parameter Estimates

Dependent Variable: n-pentane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.010	2.889	1	299	.090	.274	-.003		
Logarithmic	.010	3.045	1	299	.082	.790	-.165		
Quadratic	.035	5.422	2	298	.005	8.274	-.269	.002	
Cubic	.035	5.450	2	298	.005	5.614	-.136	.000	1.233E-5
Exponential	.009	2.636	1	299	.106	.416	-.022		

The independent variable is Debutanizer receiver level.

Model Summary and Parameter Estimates

Dependent Variable: n-pentane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.009	2.653	1	299	.104	-.035	.002		
Logarithmic	.009	2.630	1	299	.106	-.486	.146		
Quadratic	.009	1.420	2	298	.243	1.364	-.044	.000	
Cubic	.009	1.412	2	298	.245	.859	-.020	.000	2.077E-6
Exponential	.011	3.330	1	299	.069	.027	.023		

The independent variable is Debutanizer level.

Model Summary and Parameter Estimates

Dependent Variable: n-pentane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.019	5.852	1	299	.016	.049	.001		
Logarithmic	.020	6.050	1	299	.014	-.154	.065		
Quadratic	.027	4.087	2	298	.018	-.692	.025	.000	
Cubic	.027	4.087	2	298	.018	-.692	.025	.000	.000
Exponential	.019	5.638	1	299	.018	.065	.008		

The independent variable is Debutanizer level indicator.

Model Summary and Parameter Estimates

Dependent Variable: n-pentane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.001	.182	1	299	.670	.107	9.872E-5		
Logarithmic	.001	.185	1	299	.667	.090	.006		
Quadratic	.001	.104	2	298	.901	.088	.001	-5.797E-6	
Cubic	.001	.115	2	298	.891	.090	.001	.000	-4.606E-8
Exponential	.000	.072	1	299	.788	.108	.001		

The independent variable is Condenser level indicator.

Dependent Variables: Compositions

Independent Variables: Flow

Model Summary and Parameter Estimates

Dependent Variable: propane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.008	2.446	1	299	.119	-.144	.011		
Logarithmic	.008	2.527	1	299	.113	-.932	.329		
Quadratic	.010	1.578	2	298	.208	-2.996	.204	-.003	
Cubic	.010	1.578	2	298	.208	-2.996	.204	-.003	.000
Exponential	.004	1.206	1	299	.273	.045	.044		

The independent variable is Light naphtha flow.

Model Summary and Parameter Estimates

Dependent Variable: propane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.000	.009	1	299	.925	.170	.001		
Logarithmic	.000	.027	1	299	.870	.156	.010		
Quadratic	.007	1.031	2	298	.358	-.643	.242	-.018	
Cubic	.008	1.190	2	298	.306	-.420	.132	.000	-.001
Exponential	.004	1.210	1	299	.272	.109	.059		

The independent variable is LPG flow to storage.

Model Summary and Parameter Estimates

Dependent Variable: i-butane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.006	1.796	1	299	.181	.086	.005		
Logarithmic	.006	1.884	1	299	.171	-.283	.153		
Quadratic	.010	1.465	2	298	.233	-1.857	.137	-.002	
Cubic	.010	1.465	2	298	.233	-1.857	.137	-.002	.000
Exponential	.008	2.287	1	299	.132	.115	.024		

The independent variable is Light naphtha flow.

Model Summary and Parameter Estimates

Dependent Variable: i-butane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.005	1.494	1	299	.223	.192	.006		
Logarithmic	.006	1.874	1	299	.172	.145	.047		
Quadratic	.034	5.209	2	298	.006	-.708	.273	-.020	
Cubic	.037	5.767	2	298	.003	-.452	.149	.000	-.001
Exponential	.006	1.737	1	299	.188	.191	.028		

The independent variable is LPG flow to storage.

Model Summary and Parameter Estimates

Dependent Variable: n-butane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.006	1.880	1	299	.171	.064	.003		
Logarithmic	.006	1.927	1	299	.166	-.118	.076		
Quadratic	.007	1.081	2	298	.341	-.415	.035	-.001	
Cubic	.007	1.081	2	298	.341	-.415	.035	-.001	.000
Exponential	.009	2.670	1	299	.103	.074	.021		

The independent variable is Light naphtha flow.

Model Summary and Parameter Estimates

Dependent Variable: n-butane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.000	.029	1	299	.865	.135	.000		
Logarithmic	.000	.086	1	299	.770	.129	.005		
Quadratic	.021	3.208	2	298	.042	-.241	.112	-.008	
Cubic	.024	3.668	2	298	.027	-.136	.061	.000	.000
Exponential	.000	.009	1	299	.923	.136	.002		

The independent variable is LPG flow to storage.

Model Summary and Parameter Estimates

Dependent Variable: i-pentane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.000	.034	1	299	.853	.103	.000		
Logarithmic	.000	.052	1	299	.819	.127	-.009		
Quadratic	.008	1.163	2	298	.314	1.112	-.069	.001	
Cubic	.008	1.199	2	298	.303	.782	-.035	.000	1.310E-5
Exponential	.000	.138	1	299	.710	.110	-.005		

The independent variable is Light naphtha flow.

Model Summary and Parameter Estimates

Dependent Variable: i-pentane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.010	2.897	1	299	.090	.117	-.003		
Logarithmic	.010	3.049	1	299	.082	.137	-.022		
Quadratic	.011	1.703	2	298	.184	.197	-.027	.002	
Cubic	.011	1.703	2	298	.184	.197	-.027	.002	.000
Exponential	.008	2.395	1	299	.123	.115	-.028		

The independent variable is LPG flow to storage.

Model Summary and Parameter Estimates

Dependent Variable: n-pentane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.001	.309	1	299	.579	.143	-.001		
Logarithmic	.001	.368	1	299	.545	.224	-.033		
Quadratic	.011	1.634	2	298	.197	1.661	-.104	.002	
Cubic	.011	1.663	2	298	.191	1.158	-.053	.000	1.961E-5
Exponential	.002	.603	1	299	.438	.159	-.012		

The independent variable is Light naphtha flow.

Model Summary and Parameter Estimates

Dependent Variable: n-pentane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.012	3.506	1	299	.062	.144	-.005		
Logarithmic	.013	3.829	1	299	.051	.174	-.032		
Quadratic	.019	2.918	2	298	.056	.368	-.071	.005	
Cubic	.019	2.921	2	298	.055	.295	-.038	.000	.000
Exponential	.009	2.578	1	299	.109	.140	-.034		

The independent variable is LPG flow to storage.

Dependent Variables: Compositions

Independent Variables: Pressure

Model Summary and Parameter Estimates

Dependent Variable: propane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.084	27.440	1	299	.000	-.111	.000		
Logarithmic	.083	26.916	1	299	.000	-1.692	.277		
Quadratic	.104	17.338	2	298	.000	3.882	-.009	5.787E-6	
Cubic	.104	17.326	2	298	.000	2.584	-.005	.000	2.344E-9
Exponential	.066	21.115	1	299	.000	.038	.002		

The independent variable is Debutanizer overhead pressure.

Model Summary and Parameter Estimates

Dependent Variable: i-butane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.012	3.533	1	299	.061	.176	6.763E-5		
Logarithmic	.011	3.477	1	299	.063	-.142	.056		
Quadratic	.013	1.989	2	298	.139	.762	-.001	8.494E-7	
Cubic	.013	1.938	2	298	.146	.526	-.001	.000	3.042E-10
Exponential	.014	4.119	1	299	.043	.178	.000		

The independent variable is Debutanizer overhead pressure.

Model Summary and Parameter Estimates

Dependent Variable: n-butane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.003	.999	1	299	.318	.123	1.771E-5		
Logarithmic	.004	1.081	1	299	.299	.035	.015		
Quadratic	.025	3.790	2	298	.024	-.966	.003	-1.579E-6	
Cubic	.027	4.161	2	298	.017	-.653	.001	.000	-6.750E-10
Exponential	.004	1.277	1	299	.259	.122	.000		

The independent variable is Debutanizer overhead pressure.

Model Summary and Parameter Estimates

Dependent Variable: i-pentane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.000	.000	1	299	1.000	.096	-1.019E-9		
Logarithmic	.000	.012	1	299	.912	.088	.001		
Quadratic	.142	24.613	2	298	.000	-1.986	.005	-3.018E-6	
Cubic	.151	26.477	2	298	.000	-.638	.000	3.211E-6	-2.565E-9
Exponential	.000	.031	1	299	.860	.097	-2.285E-5		

The independent variable is Debutanizer overhead pressure.

Model Summary and Parameter Estimates

Dependent Variable: n-pentane

Equation	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	.000	.003	1	299	.956	.114	-9.710E-7		
Logarithmic	.000	.002	1	299	.963	.108	.001		
Quadratic	.116	19.473	2	298	.000	-2.381	.006	-3.617E-6	
Cubic	.121	20.437	2	298	.000	-.757	.000	3.809E-6	-3.043E-9
Exponential	.000	.026	1	299	.872	.114	-2.419E-5		

The independent variable is Debutanizer overhead pressure.

APPENDIX V

PAIRED T-TEST

C3 – Variables

Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference: Lower	95% Confidence Interval of the Difference: Upper			
Pair 1 propane - Feed Flow	-62.3958443	10.9161214	.6291948	-63.6340386	-61.1576500	-99.168	300	.000
Pair 2 propane - Reboiler Flow	-142.0054788	1.1070602	.0638099	-142.1310505	-141.8799071	-2225.446	300	.000
Pair 3 propane - Reflux Flow	-20.918046385	.998020880	.057524967	-21.031249941	-20.804842828	-363.634	300	.000

Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference: Lower	95% Confidence Interval of the Difference: Upper			
Pair 1 propane - Debutanizer top temp	-58.3254122	.2096456	.0120838	-58.3491919	-58.3016325	-4826.755	300	.000
Pair 2 propane - Debutanizer bottom temp	-138.987899936	.162085681	.009342463	-139.006284997	-138.969514874	-14877.008	300	.000

Pair 3	propane - Debutanizer receiver bottom temp	-33.412779202	.603212500	.034768590	-33.481200416	-33.344357988	-961.005	300	.000
Pair 4	propane - Light naphtha temp	-39.437344478	.176307680	.010162206	-39.457342714	-39.417346243	-3880.786	300	.000
Pair 5	propane - Reboiler outlet temp	-115.585073509	12.745436776	.734634763	-117.030763471	-114.139383547	-157.337	300	.000
Pair 6	propane - Debutanizer feed temp	-110.678136177	1.872387399	.107922615	-110.890517417	-110.465754937	-1025.532	300	.000

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	95% Confidence Interval of the Difference Upper			
Pair 1	propane - Debutanizer receiver level	-59.816386790	.642346824	.037024255	-59.889246934	-59.743526647	-1615.600	300	.000
Pair 2	propane - Debutanizer level	-60.053789976	.685942550	.039537071	-60.131595097	-59.975984854	-1518.924	300	.000
Pair 3	propane - Debutanizer level indicator	-62.780705541	2.435473679	.140378369	-63.056956556	-62.504454526	-447.225	300	.000

Pair 4	propane - Condenser level indicator	-57.820316125	4.408670267	.254111530	-58.320382969	-57.320249280	-227.539	300	.000

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference: Lower	Upper			
Pair 1	propane - Light naphtha flow	-28.972809935	.554868474	.031982087	-29.035747580	-28.909872289	-905.907	300	.000
Pair 2	propane - LPG flow to storage	-6.588701407	.419460878	.024177323	-6.636280034	-6.541122780	-272.516	300	.000

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference: Lower	Upper			
Pair 1	propane - Debutanizer overhead pressure	-850.522458891	58.339378159	3.362625855	-857.139780436	-843.905137346	-252.934	300	.000

iC4 – Variables

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	95% Confidence Interval of the Difference Upper			
Pair 1	i-butane - Feed Flow	-62.3375966	10.9090878	.6287894	-63.5749931	-61.1002001	-99.139	300	.000
Pair 2	i-butane - Reboiler Flow	-141.9472311	1.0990341	.0633473	-142.0718924	-141.8225698	-2240.779	300	.000
Pair 3	i-butane - Reflux Flow	-20.859798676	.983323016	.056677796	-20.971335082	-20.748262270	-368.042	300	.000

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	95% Confidence Interval of the Difference Upper			
Pair 1	i-butane - Debutanizer top temp	-58.2671645	.1996667	.0115086	-58.2898123	-58.2445167	-5062.924	300	.000
Pair 2	i-butane - Debutanizer bottom temp	-138.929652227	.149947394	.008642824	-138.946660467	-138.912643988	-16074.567	300	.000

Pair 3	i-butane - Debutanizer receiver bottom temp	-33.354531493	.606555373	.034961270	-33.423331883	-33.285731104	-954.042	300	.000
Pair 4	i-butane - Light naphtha temp	-39.379096770	.168217625	.009695903	-39.398177366	-39.360016174	-4061.416	300	.000
Pair 5	i-butane - Reboiler outlet temp	-115.526825801	12.749422339	.734864487	-116.972967837	-114.080683764	-157.208	300	.000
Pair 6	i-butane - Debutanizer feed temp	-110.619888469	1.875517984	.108103059	-110.832624805	-110.407152133	-1023.282	300	.000

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	i-butane - Debutanizer receiver level	-59.758139082	.643301201	.037079265	-59.831107479	-59.685170685	-1611.632	300	.000
Pair 2	i-butane - Debutanizer level	-59.995542267	.677095823	.039027154	-60.072343922	-59.918740613	-1537.277	300	.000
Pair 3	i-butane - Debutanizer level indicator	-62.722457833	2.431305165	.140138100	-62.998236022	-62.446679644	-447.576	300	.000
Pair 4	i-butane - Condenser level indicator	-57.762068416	4.411860127	.254295390	-58.262497080	-57.261639753	-227.146	300	.000

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	i-butane - Light naphtha flow	-28.914562226	.555228674	.032002849	-28.977540729	-28.851583724	-903.500	300	.000
Pair 2	i-butane - LPG flow to storage	-6.530453699	.413364946	.023825959	-6.577340876	-6.483566522	-274.090	300	.000

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	i-butane - Debutanizer overhead pressure	-850.464211183	58.355036753	3.363528401	-857.083308851	-843.845113514	-252.849	300	.000

nC4 – Variables

Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			

Pair 1	n-butane - Feed Flow	-62.4331468	10.9049061	.6285483	-63.6700689	-61.1962246	-99.329	300	.000
Pair 2	n-butane - Reboiler Flow	-142.0427813	1.0943093	.0630749	-142.1669067	-141.9186559	-2251.969	300	.000
Pair 3	n-butane - Reflux Flow	-20.955348864	.972476886	.056052636	-21.065655015	-20.845042713	-373.851	300	.000

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	95% Confidence Interval of the Difference Upper			
Pair 1	n-butane - Debutanizer top temp	-58.3627147	.1943686	.0112032	-58.3847615	-58.3406678	-5209.460	300	.000
Pair 2	n-butane - Debutanizer bottom temp	-139.025202415	.150309369	.008663688	-139.042251713	-139.008153118	-16046.885	300	.000
Pair 3	n-butane - Debutanizer receiver bottom temp	-33.450081681	.607070798	.034990979	-33.518940535	-33.381222828	-955.963	300	.000

Pair 4	n-butane - Light naphtha temp	-39.474646958	.167412267	.009649483	-39.493636204	-39.455657712	-4090.856	300	.000
Pair 5	n-butane - Reboiler outlet temp	-115.622375989	12.748841132	.734830987	-117.068452100	-114.176299877	-157.346	300	.000
Pair 6	n-butane - Debutanizer feed temp	-110.715438657	1.873702560	.107998420	-110.927969073	-110.502908241	-1025.158	300	.000

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	n-butane - Debutanizer receiver level	-59.853689270	.644223959	.037132452	-59.926762334	-59.780616207	-1611.897	300	.000
Pair 2	n-butane - Debutanizer level	-60.091092455	.675615310	.038941819	-60.167726178	-60.014458732	-1543.099	300	.000
Pair 3	n-butane - Debutanizer level indicator	-62.818008021	2.428739948	.139990243	-63.093495242	-62.542520799	-448.731	300	.000
Pair 4	n-butane - Condenser level indicator	-57.857618605	4.415973164	.254532462	-58.358513802	-57.356723407	-227.309	300	.000

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	n-butane - Light naphtha flow	-29.010112414	.555726466	.032031541	-29.073147380	-28.947077448	-905.673	300	.000
Pair 2	n-butane - LPG flow to storage	-6.626003887	.414542336	.023893823	-6.673024613	-6.578983161	-277.310	300	.000

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	n-butane - Debutanizer overhead pressure	-850.559761371	58.357941637	3.363695836	-857.179188535	-843.940334207	-252.865	300	.000

iC5 – Variables

Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			

Pair 1	i-pentane - Feed Flow	-62.4756154	10.9026803	.6284200	-63.7122851	-61.2389457	-99.417	300	.000
Pair 2	i-pentane - Reboiler Flow	-142.0852500	1.0904987	.0628553	-142.2089431	-141.9615568	-2260.513	300	.000
Pair 3	i-pentane - Reflux Flow	-20.997817532	.965976132	.055677939	-21.107386315	-20.888248749	-377.130	300	.000

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	i-pentane - Debutanizer top temp	-58.4051833	.1920042	.0110669	-58.4269620	-58.3834047	-5277.448	300	.000
Pair 2	i-pentane - Debutanizer bottom temp	-139.067671083	.152958328	.008816371	-139.085020847	-139.050321319	-15773.799	300	.000
Pair 3	i-pentane - Debutanizer receiver bottom temp	-33.492550349	.608721588	.035086129	-33.561596448	-33.423504250	-954.581	300	.000

		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 4	i-pentane - Light naphtha temp	-39.517115626	.170064798	.009802372	-39.536405743	-39.497825508	-4031.383	300	.000
Pair 5	i-pentane - Reboiler outlet temp	-115.664844656	12.749378483	.734861959	-117.110981718	-114.218707594	-157.397	300	.000
Pair 6	i-pentane - Debutanizer feed temp	-110.757907325	1.871414897	.107866561	-110.970178256	-110.545636394	-1026.805	300	.000

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	i-pentane - Debutanizer receiver level	-59.896157938	.645449301	.037203079	-59.969369989	-59.822945886	-1609.979	300	.000
Pair 2	i-pentane - Debutanizer level	-60.133561123	.675610569	.038941546	-60.210194308	-60.056927938	-1544.201	300	.000
Pair 3	i-pentane - Debutanizer level indicator	-62.860476688	2.426598752	.139866827	-63.135721038	-62.585232339	-449.431	300	.000
Pair 4	i-pentane - Condenser level indicator	-57.900087272	4.419928613	.254760450	-58.401431129	-57.398743415	-227.273	300	.000

Paired Samples Test

	Paired Differences	t	df	Sig.

		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				(2-tailed)
					Lower	Upper			
Pair 1	i-pentane - Light naphtha flow	-29.052581082	.557156969	.032113994	-29.115778307	-28.989383857	-904.670	300	.000
Pair 2	i-pentane - LPG flow to storage	-6.668472554	.415847430	.023969047	-6.715641315	-6.621303794	-278.212	300	.000

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	i-pentane - Debutanizer overhead pressure	-850.602230038	58.358973942	3.363755337	-857.221774294	-843.982685782	-252.873	300	.000

nC5 – Variables

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	n-pentane - Feed Flow	-62.4586398	10.9018155	.6283702	-63.6952114	-61.2220682	-99.398	300	.000

Pair 2	n-pentane - Reboiler Flow	-142.0682744	1.0894765	.0627964	-142.1918516	-141.9446972	-2262.364	300	.000
Pair 3	n-pentane - Reflux Flow	-20.980841956	.964256596	.055578826	-21.090215696	-20.871468217	-377.497	300	.000

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	n-pentane - Debutanizer top temp	-58.3882078	.1913462	.0110290	-58.4099118	-58.3665037	-5294.056	300	.000
Pair 2	n-pentane - Debutanizer bottom temp	-139.050695507	.154437941	.008901655	-139.068213101	-139.033177913	-15620.769	300	.000
Pair 3	n-pentane - Debutanizer receiver bottom temp	-33.475574773	.609314474	.035120302	-33.544688122	-33.406461424	-953.169	300	.000
Pair 4	n-pentane - Light naphtha temp	-39.500140050	.170941423	.009852900	-39.519529601	-39.480750499	-4008.986	300	.000

Pair 5	n-pentane - Reboiler outlet temp	-115.647869080	12.749160063	.734849369	-117.093981367	-114.201756793	-157.376	300	.000
Pair 6	n-pentane - Debutanizer feed temp	-110.740931749	1.870679907	.107824197	-110.953119311	-110.528744186	-1027.051	300	.000

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	n-pentane - Debutanizer receiver level	-59.879182362	.646172721	.037244776	-59.952476470	-59.805888254	-1607.720	300	.000
Pair 2	n-pentane - Debutanizer level	-60.116585547	.675483815	.038934240	-60.193204355	-60.039966739	-1544.054	300	.000
Pair 3	n-pentane - Debutanizer level indicator	-62.843501112	2.425720258	.139816191	-63.118645816	-62.568356409	-449.472	300	.000
Pair 4	n-pentane - Condenser level indicator	-57.883111696	4.421197143	.254833567	-58.384599440	-57.381623953	-227.141	300	.000

Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			

Pair 1	n-pentane - Light naphtha flow	-29.035605506	.557703365	.032145488	-29.098864708	-28.972346304	-903.256	300	.000
Pair 2	n-pentane - LPG flow to storage	-6.651496978	.416605497	.024012742	-6.698751725	-6.604242232	-276.999	300	.000

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	n-pentane - Debutanizer overhead pressure	-850.585254462	58.359031704	3.363758666	-857.204805271	-843.965703654	-252.868	300	.000

APPENDIX VI

ANALYSIS OF VARIANCE (ANOVA)

Compositions – Manipulated Variables

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.034	1	.034	7.527	.006[b]
	Residual	1.341	299	.004		
	Total	1.375	300			

a. Dependent Variable: propane

b. Predictors: (Constant), Feed Flow

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.004	1	.004	3.135	.078[b]
	Residual	.396	299	.001		
	Total	.400	300			

a. Dependent Variable: i-butane

b. Predictors: (Constant), Feed Flow

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.000	1	.000	.161	.689[b]
	Residual	.096	299	.000		
	Total	.096	300			

a. Dependent Variable: n-butane

b. Predictors: (Constant), Feed Flow

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.002	1	.002	12.170	.001[b]
	Residual	.051	299	.000		
	Total	.053	300			

a. Dependent Variable: i-pentane

b. Predictors: (Constant), Feed Flow

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.004	1	.004	12.233	.001[b]
	Residual	.090	299	.000		
	Total	.094	300			

a. Dependent Variable: n-pentane

b. Predictors: (Constant), Feed Flow

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.056	1	.056	12.604	.000[b]
	Residual	1.320	299	.004		
	Total	1.375	300			

a. Dependent Variable: propane

b. Predictors: (Constant), Reboiler Flow

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.015	1	.015	11.383	.001[b]
	Residual	.386	299	.001		
	Total	.400	300			

a. Dependent Variable: i-butane

b. Predictors: (Constant), Reboiler Flow

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.002	1	.002	7.014	.009[b]
	Residual	.094	299	.000		
	Total	.096	300			

a. Dependent Variable: n-butane

b. Predictors: (Constant), Reboiler Flow

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.000	1	.000	1.823	.178[b]
	Residual	.053	299	.000		
	Total	.053	300			

a. Dependent Variable: i-pentane

b. Predictors: (Constant), Reboiler Flow

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.001	1	.001	4.361	.038[b]
	Residual	.092	299	.000		
	Total	.094	300			

a. Dependent Variable: n-pentane

b. Predictors: (Constant), Reboiler Flow

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.232	1	.232	60.802	.000[b]
	Residual	1.143	299	.004		
	Total	1.375	300			

a. Dependent Variable: propane

b. Predictors: (Constant), Reflux Flow

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.063	1	.063	55.699	.000[b]
	Residual	.337	299	.001		
	Total	.400	300			

a. Dependent Variable: i-butane

b. Predictors: (Constant), Reflux Flow

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.005	1	.005	16.055	.000[b]
	Residual	.091	299	.000		
	Total	.096	300			

a. Dependent Variable: n-butane

b. Predictors: (Constant), Reflux Flow

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.002	1	.002	9.948	.002[b]
	Residual	.052	299	.000		
	Total	.053	300			

a. Dependent Variable: i-pentane

b. Predictors: (Constant), Reflux Flow

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.005	1	.005	17.650	.000[b]
	Residual	.089	299	.000		
	Total	.094	300			

a. Dependent Variable: n-pentane

b. Predictors: (Constant), Reflux Flow

Compositions – Temperature Variables

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.005	1	.005	.994	.319[b]
	Residual	1.371	299	.005		
	Total	1.375	300			

a. Dependent Variable: propane

b. Predictors: (Constant), Debutanizer top temp

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.008	1	.008	1.699	.193[b]
	Residual	1.368	299	.005		
	Total	1.375	300			

a. Dependent Variable: propane

b. Predictors: (Constant), Debutanizer bottom temp

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.033	1	.033	7.426	.007[b]
	Residual	1.342	299	.004		
	Total	1.375	300			

a. Dependent Variable: propane

b. Predictors: (Constant), Debutanizer receiver bottom temp

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.035	1	.035	7.911	.005[b]
	Residual	1.340	299	.004		
	Total	1.375	300			

a. Dependent Variable: propane

b. Predictors: (Constant), Light naphtha temp

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.022	1	.022	4.932	.027[b]
	Residual	1.353	299	.005		
	Total	1.375	300			

a. Dependent Variable: propane

b. Predictors: (Constant), Reboiler outlet temp

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.000	1	.000	.033	.855[b]
	Residual	1.375	299	.005		
	Total	1.375	300			

a. Dependent Variable: propane

b. Predictors: (Constant), Debutanizer feed temp

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.001	1	.001	.691	.406[b]
	Residual	.399	299	.001		
	Total	.400	300			

a. Dependent Variable: i-butane

b. Predictors: (Constant), Debutanizer top temp

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.014	1	.014	10.904	.001[b]
	Residual	.386	299	.001		
	Total	.400	300			

a. Dependent Variable: i-butane

b. Predictors: (Constant), Debutanizer bottom temp

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.006	1	.006	4.738	.030[b]
	Residual	.394	299	.001		
	Total	.400	300			

a. Dependent Variable: i-butane

b. Predictors: (Constant), Debutanizer receiver bottom temp

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.027	1	.027	21.892	.000[b]
	Residual	.373	299	.001		
	Total	.400	300			

a. Dependent Variable: i-butane

b. Predictors: (Constant), Light naphtha temp

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.006	1	.006	4.638	.032[b]
	Residual	.394	299	.001		
	Total	.400	300			

a. Dependent Variable: i-butane

b. Predictors: (Constant), Reboiler outlet temp

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.007	1	.007	5.080	.025[b]
	Residual	.394	299	.001		
	Total	.400	300			

a. Dependent Variable: i-butane

b. Predictors: (Constant), Debutanizer feed temp

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.000	1	.000	.948	.331[b]
	Residual	.096	299	.000		
	Total	.096	300			

a. Dependent Variable: n-butane

b. Predictors: (Constant), Debutanizer top temp

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.003	1	.003	9.678	.002[b]
	Residual	.093	299	.000		
	Total	.096	300			

a. Dependent Variable: n-butane

b. Predictors: (Constant), Debutanizer bottom temp

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.003	1	.003	9.979	.002[b]
	Residual	.093	299	.000		
	Total	.096	300			

a. Dependent Variable: n-butane

b. Predictors: (Constant), Debutanizer receiver bottom temp

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.016	1	.016	61.661	.000[b]
	Residual	.080	299	.000		
	Total	.096	300			

a. Dependent Variable: n-butane

b. Predictors: (Constant), Light naphtha temp

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.008	1	.008	25.887	.000[b]
	Residual	.089	299	.000		
	Total	.096	300			

a. Dependent Variable: n-butane

b. Predictors: (Constant), Reboiler outlet temp

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.003	1	.003	9.684	.002[b]
	Residual	.093	299	.000		
	Total	.096	300			

a. Dependent Variable: n-butane

b. Predictors: (Constant), Debutanizer feed temp

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.003	1	.003	15.826	.000[b]
	Residual	.051	299	.000		
	Total	.053	300			

a. Dependent Variable: i-pentane

b. Predictors: (Constant), Debutanizer top temp

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.000	1	.000	.007	.931[b]
	Residual	.053	299	.000		
	Total	.053	300			

a. Dependent Variable: i-pentane

b. Predictors: (Constant), Debutanizer bottom temp

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.001	1	.001	3.616	.058[b]
	Residual	.053	299	.000		
	Total	.053	300			

a. Dependent Variable: i-pentane

b. Predictors: (Constant), Debutanizer receiver bottom temp

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.006	1	.006	37.022	.000[b]
	Residual	.047	299	.000		
	Total	.053	300			

a. Dependent Variable: i-pentane

b. Predictors: (Constant), Light naphtha temp

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.006	1	.006	38.765	.000[b]
	Residual	.047	299	.000		
	Total	.053	300			

a. Dependent Variable: i-pentane

b. Predictors: (Constant), Reboiler outlet temp

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.000	1	.000	1.434	.232[b]
	Residual	.053	299	.000		
	Total	.053	300			

a. Dependent Variable: i-pentane

b. Predictors: (Constant), Debutanizer feed temp

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.005	1	.005	15.980	.000[b]
	Residual	.089	299	.000		
	Total	.094	300			

a. Dependent Variable: n-pentane

b. Predictors: (Constant), Debutanizer top temp

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.000	1	.000	.926	.337[b]
	Residual	.093	299	.000		
	Total	.094	300			

a. Dependent Variable: n-pentane

b. Predictors: (Constant), Debutanizer bottom temp

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.000	1	.000	.912	.340[b]
	Residual	.093	299	.000		
	Total	.094	300			

a. Dependent Variable: n-pentane

b. Predictors: (Constant), Debutanizer receiver bottom temp

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.005	1	.005	15.717	.000[b]
	Residual	.089	299	.000		
	Total	.094	300			

a. Dependent Variable: n-pentane

b. Predictors: (Constant), Light naphtha temp

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.007	1	.007	23.119	.000[b]
	Residual	.087	299	.000		
	Total	.094	300			

a. Dependent Variable: n-pentane

b. Predictors: (Constant), Reboiler outlet temp

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.000	1	.000	.021	.884[b]
	Residual	.094	299	.000		
	Total	.094	300			

a. Dependent Variable: n-pentane

b. Predictors: (Constant), Debutanizer feed temp

Compositions – Level Variables

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.009	1	.009	1.923	.167[b]
	Residual	1.366	299	.005		
	Total	1.375	300			

a. Dependent Variable: propane

b. Predictors: (Constant), Debutanizer receiver level

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.010	1	.010	2.137	.145[b]
	Residual	1.366	299	.005		
	Total	1.375	300			

a. Dependent Variable: propane

b. Predictors: (Constant), Debutanizer level

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.012	1	.012	2.725	.100[b]
	Residual	1.363	299	.005		
	Total	1.375	300			

a. Dependent Variable: propane

b. Predictors: (Constant), Debutanizer level indicator

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.054	1	.054	12.241	.001[b]
	Residual	1.321	299	.004		
	Total	1.375	300			

a. Dependent Variable: propane

b. Predictors: (Constant), Condenser level indicator

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.001	1	.001	.844	.359[b]
	Residual	.399	299	.001		
	Total	.400	300			

a. Dependent Variable: i-butane

b. Predictors: (Constant), Debutanizer receiver level

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.000	1	.000	.144	.704[b]
	Residual	.400	299	.001		
	Total	.400	300			

a. Dependent Variable: i-butane

b. Predictors: (Constant), Debutanizer level

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.003	1	.003	1.931	.166[b]
	Residual	.398	299	.001		
	Total	.400	300			

a. Dependent Variable: i-butane

b. Predictors: (Constant), Debutanizer level indicator

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.029	1	.029	23.597	.000[b]
	Residual	.371	299	.001		
	Total	.400	300			

a. Dependent Variable: i-butane

b. Predictors: (Constant), Condenser level indicator

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.000	1	.000	.049	.825[b]
	Residual	.096	299	.000		
	Total	.096	300			

a. Dependent Variable: n-butane

b. Predictors: (Constant), Debutanizer receiver level

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.001	1	.001	2.207	.138[b]
	Residual	.096	299	.000		
	Total	.096	300			

a. Dependent Variable: n-butane

b. Predictors: (Constant), Debutanizer level

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.000	1	.000	.300	.584[b]
	Residual	.096	299	.000		
	Total	.096	300			

a. Dependent Variable: n-butane

b. Predictors: (Constant), Debutanizer level indicator

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.010	1	.010	33.149	.000[b]
	Residual	.087	299	.000		
	Total	.096	300			

a. Dependent Variable: n-butane

b. Predictors: (Constant), Condenser level indicator

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.000	1	.000	2.087	.150[b]
	Residual	.053	299	.000		
	Total	.053	300			

a. Dependent Variable: i-pentane

b. Predictors: (Constant), Debutanizer receiver level

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.001	1	.001	3.495	.063[b]
	Residual	.053	299	.000		
	Total	.053	300			

a. Dependent Variable: i-pentane

b. Predictors: (Constant), Debutanizer level

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.001	1	.001	4.071	.045[b]
	Residual	.053	299	.000		
	Total	.053	300			

a. Dependent Variable: i-pentane

b. Predictors: (Constant), Debutanizer level indicator

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.001	1	.001	4.888	.028[b]
	Residual	.052	299	.000		
	Total	.053	300			

a. Dependent Variable: i-pentane

b. Predictors: (Constant), Condenser level indicator

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.001	1	.001	2.889	.090[b]
	Residual	.093	299	.000		
	Total	.094	300			

a. Dependent Variable: n-pentane

b. Predictors: (Constant), Debutanizer receiver level

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.001	1	.001	2.653	.104[b]
	Residual	.093	299	.000		
	Total	.094	300			

a. Dependent Variable: n-pentane

b. Predictors: (Constant), Debutanizer level

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.002	1	.002	5.852	.016[b]
	Residual	.092	299	.000		
	Total	.094	300			

a. Dependent Variable: n-pentane

b. Predictors: (Constant), Debutanizer level indicator

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.000	1	.000	.182	.670[b]
	Residual	.094	299	.000		
	Total	.094	300			

a. Dependent Variable: n-pentane

b. Predictors: (Constant), Condenser level indicator

Compositions – Flow Variables

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.011	1	.011	2.446	.119[b]
	Residual	1.364	299	.005		
	Total	1.375	300			

a. Dependent Variable: propane

b. Predictors: (Constant), Light naphtha flow

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.000	1	.000	.009	.925[b]
	Residual	1.375	299	.005		
	Total	1.375	300			

a. Dependent Variable: propane

b. Predictors: (Constant), LPG flow to storage

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.002	1	.002	1.796	.181[b]
	Residual	.398	299	.001		
	Total	.400	300			

a. Dependent Variable: i-butane

b. Predictors: (Constant), Light naphtha flow

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.002	1	.002	1.494	.223[b]
	Residual	.398	299	.001		
	Total	.400	300			

a. Dependent Variable: i-butane

b. Predictors: (Constant), LPG flow to storage

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.001	1	.001	1.880	.171[b]
	Residual	.096	299	.000		
	Total	.096	300			

a. Dependent Variable: n-butane

b. Predictors: (Constant), Light naphtha flow

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.000	1	.000	.029	.865[b]
	Residual	.096	299	.000		
	Total	.096	300			

a. Dependent Variable: n-butane

b. Predictors: (Constant), LPG flow to storage

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.000	1	.000	.034	.853[b]
	Residual	.053	299	.000		
	Total	.053	300			

a. Dependent Variable: i-pentane

b. Predictors: (Constant), Light naphtha flow

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.001	1	.001	2.897	.090[b]
	Residual	.053	299	.000		
	Total	.053	300			

a. Dependent Variable: i-pentane

b. Predictors: (Constant), LPG flow to storage

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.000	1	.000	.309	.579[b]
	Residual	.094	299	.000		
	Total	.094	300			

a. Dependent Variable: n-pentane

b. Predictors: (Constant), Light naphtha flow

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.001	1	.001	3.506	.062[b]
	Residual	.093	299	.000		
	Total	.094	300			

a. Dependent Variable: n-pentane

b. Predictors: (Constant), LPG flow to storage

Compositions – Pressure Variable

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.116	1	.116	27.440	.000[b]
	Residual	1.260	299	.004		
	Total	1.375	300			

a. Dependent Variable: propane

b. Predictors: (Constant), Debutanizer overhead pressure

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.005	1	.005	3.533	.061[b]
	Residual	.396	299	.001		
	Total	.400	300			

a. Dependent Variable: i-butane

b. Predictors: (Constant), Debutanizer overhead pressure

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.000	1	.000	.999	.318[b]
	Residual	.096	299	.000		
	Total	.096	300			

a. Dependent Variable: n-butane

b. Predictors: (Constant), Debutanizer overhead pressure

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.000	1	.000	.000	1.000[b]
	Residual	.053	299	.000		
	Total	.053	300			

a. Dependent Variable: i-pentane

b. Predictors: (Constant), Debutanizer overhead pressure

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.000	1	.000	.003	.956[b]
	Residual	.094	299	.000		
	Total	.094	300			

a. Dependent Variable: n-pentane

b. Predictors: (Constant), Debutanizer overhead pressure