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Optimization of Heavy Key Composition of Distillate in Deisobutanizer Column Using Aspen Hysys with Flow Rate Reflux and Reboiler Temperature in Alkylation Unit at Company PEP

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ABSTRACT - The mass fraction of specific components is used to determine the product quality in distillation column process. Therefore, there is a need for sophisticated optimization strategies to identify ideal reflux flow rates and reboiler temperatures during operation. In distillation column, the most influential variables are reflux flow rate and reboiler temperature, which means the quantity and quality of distillate heavy fraction must remain below 3%. Simulation through Aspen Hysys identified optimal operating conditions at a 200 tons/day reflux flow rate and reboiler temperature of 72.58°C, decreasing from 3.38% to 2.19% by company standards. Following this optimization, an analysis of energy savings was conducted to compare actual field conditions and optimization at energy consumption levels of 2,989 kW and 1,688 kW, respectively. Energy savings were 1,301 kW in deisobutanizer column, downstream equipment, and depropanizer column feed pump. The energy required for deisobutanizer column pump was reduced from 0.907 kW to 0.88 kW after optimization, with a significant decrease in depropanizer column. The results showed an overall figure of the positive impact of optimizing operations in the central distillation column.

Keywords: distillation, optimization, heavy key in distillate, energy saving.

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INTRODUCTION

Energy consumption is one of the numerous aspects that increase yearly in Indonesia (Syahrir, 2020). It is mainly driven by petroleum, resulting in the need for expertise in problem-solving, especially in oil and gas processing. The expertise is required for the conversion of petroleum into finished products, as well as meeting the specified quantity and quality of fuel needed in the community. The processing of petroleum by both the government and private sector across Indonesia aims to meet domestic energy supply needs. According to the General Directorate of Oil and Gas (2021), approximately 99% of the refinery processing carried out in the country is handled by Pertamina, with private company managing the rest.

The Central Bureau of Statistics (2021) reported that the consumption of LPG by Indonesians was gradually increasing, compelling company with the requisite skills to meet this demand. Data from the General Directorate of Foreign Trade (2021) reported a threefold increase in LPG imports over the last decade, reaching 6.34 million tons in 2021. Despite domestic LPG production amounting to approximately 1.9 million tons, Company PEP contributes 0.6% or 1.4 tons. Therefore, Indonesia heavily depends on imports to fulfill LPG needs. This portrays the collective inability of Indonesian company to meet the nation LPG demand, focusing on the importance of pursuing objectives that enhance equipment performance and durability.

Another important problem that needs to be addressed is the widespread use of Freon refrigerant, commonly referred to as AC fuel, for cooling indoor environments. Freon contains Hydro Chloro Fluoro Carbons (HCFC), which is extremely dangerous, particularly when used daily. In addition, the chlorine component causes the depletion of the ozone layer, potentially leading to increased global warming. This was proven by the diverse Freon types, such as R12 and R22, which have a GWP (Global Warming Potential et al.) index of 8500 and 1900, respectively (Patompong et al., 2018).

Gas plant is an important unit in company that processes natural gas into non-BBM products such as LPG and refrigerant (MC-22) to meet the daily needs of Indonesians. The proposal of MC-22 refrigerant products marks the first step in reducing the acceleration of global warming because it does not contain HCFC (Khairini, 2020).

Deisobutanizer column is a critical component in the production process. It is a pressurized distillation column used to separate light (isobutane) and heavy-key (n-butane) fractions. The n-butane and heavier fractions were marketed as LPG, while the isobutane and light fractions proceeded to the next column for further processing.

The separation isolates propane and other heavy fractions, essential for producing MC-22 product, an environmentally friendly product. Additionally, the extracted i-C4 is further recycled in deisobutanizer column. Optimizing theperformance of this column is essential to prevent any adverse impacts, specifically considering the significant role of the resulting products, including MC-22, in reducing global warming and meeting the natural gas consumption needs of Indonesians (Khairini, 2020). Distillation column is a major energy consumer, with approximately 50% allocated to cooling the condenser and heating reboiler. This enormous energy requirement leads to significant production costs for the company, specifically considering the expenses associated with adjusting operating conditions such as reflux flow rate and reboiler temperature to achieve and maintain the desired composition of the heavy key in distillate. As a result, precise control becomes a critical priority.

Company PEP (2010), stated that the main problem was the heavy key (n-butane) contained in distillate exceeded the designated limit of the company. The evaluation process results showed that n-butane concentration should not exceed 3% based on manufacturing design specifications. However, the actual levels are approximately 4%, posing a risk to the quality of the top product. The extensive operating conditions in the field require substantial energy for cooling and heating, resulting in increased operating costs.

Optimization is a strategic method to achieve desired results or solve problems effectively. It becomes indispensable when decision-makers must select the best course of action from several alternatives based on specific considerations or criteria. Optimization entails maximizing profits in response to related challenges and minimizing energy consumption to achieve the most efficient state. This process aims to achieve optimal conditions that lead to favorable economic outcomes and reduce total expenses or costs per unit of time.

Based on the challenges, the main objectives of the research include, first, investigating the effect of varying reflux flow rate and reboiler temperature on the composition of heavy keys in distillate. Second, to understand the impact of optimization process on the company potential profit and energy savings in the 1-1 deisobutanizer column. The successful optimization implementation in the column served as a guideline for improved operational performance of all equipment used in the process. It is an essential reference for improving product purity above and below the column while adhering to industry standards and maximizing energy efficiency.

METHODOLOGY

This research adopted a method focused on identifying the main process variables, namely reboiler temperature and reflux flow rate. The variables were simulated using Hysys software to assess the impact on the issues discussed in paragraph seven of the introduction. In addition, specific reactants were used, namely spen propane propylene and res butane butylene from the polypropylene and polymerization units, ensuring it was not subjected to reactions in other process units. The two reactants were mixed to form the primary raw material for this process. The feasibility and sustainability of the proposed optimization process were evaluated through a comprehensive review of existing economic research. Detailed insights into the composition of the feed, top, and bottom products, as well as the operating conditions of each unit, are provided in the discussion section.

Preparation

In this stage, relevant literature was reviewed before the field observation phase. Furthermore, operating condition data were collected, including temperature, pressure, and flow rate, which served as benchmarks for subsequent simulations. The data collection process lasted one month, from November 25 to December 25, 2022. Manufacturing design and window data from the tool and operating mode are detailed in the discussion section. However, this unit operates in two distinct modes. First, the reactor operation mode focuses on producing LOMC and HOMC products. Second is the redistillation mode, where the final products are musicool and LPG. In the research period, the unit exclusively operated in the redistilation mode, which only used distillation to manufacture the products.

Implementation

The modeling of distillation column started after obtaining the relevant data. The selected unit is a binner de-isobutane - n-butane distillation column that uses a liquid vapor structure. Figure 2 shows the modeling of the Binner distillation column system. The process design modeling was performed using the Aspen HYSYS 12.0 software application to achieve steady-state conditions. Subsequently, validation was carried out to ensure accuracy by comparing the obtained results with PFD (process flow diagram) data. Distillation process is carried out based on the difference in boiling points of the mixture, requiring comprehensive analysis comprising the law of mass balance, components, and energy (both mass and energy balance). In terms of composition, the focus is on the ethanol-propanol separation process.

Optimization of operating conditions prioritizes parameters demanding the most energy, namely the reflux and heat flow rates in reboiler. Moreover, controlling product purity is achievable through adjustments to these parameters. Determining parameters includes identifying variables that affect optimization process to achieve the desired product purity.

Optimization can be performed by identifying the variables significantly influencing the purity and yield of bottom and top products. This process uses a case study method, focusing on independent variables, namely reboiler temperature and reflux flow rate. However, through iterative experimentation with these variables, optimal settings can be determined, leading to improved separation efficiency and energy savings.

Completion

In the final stage, optimization results obtained through Hysys simulations were examined. The results were compared with the manual data received, company design standards, and energy savings obtained before optimization. This thorough comparison led to a successful conclusion regarding the research subject and suggestions to address any shortcomings encountered in the performance analysis results.

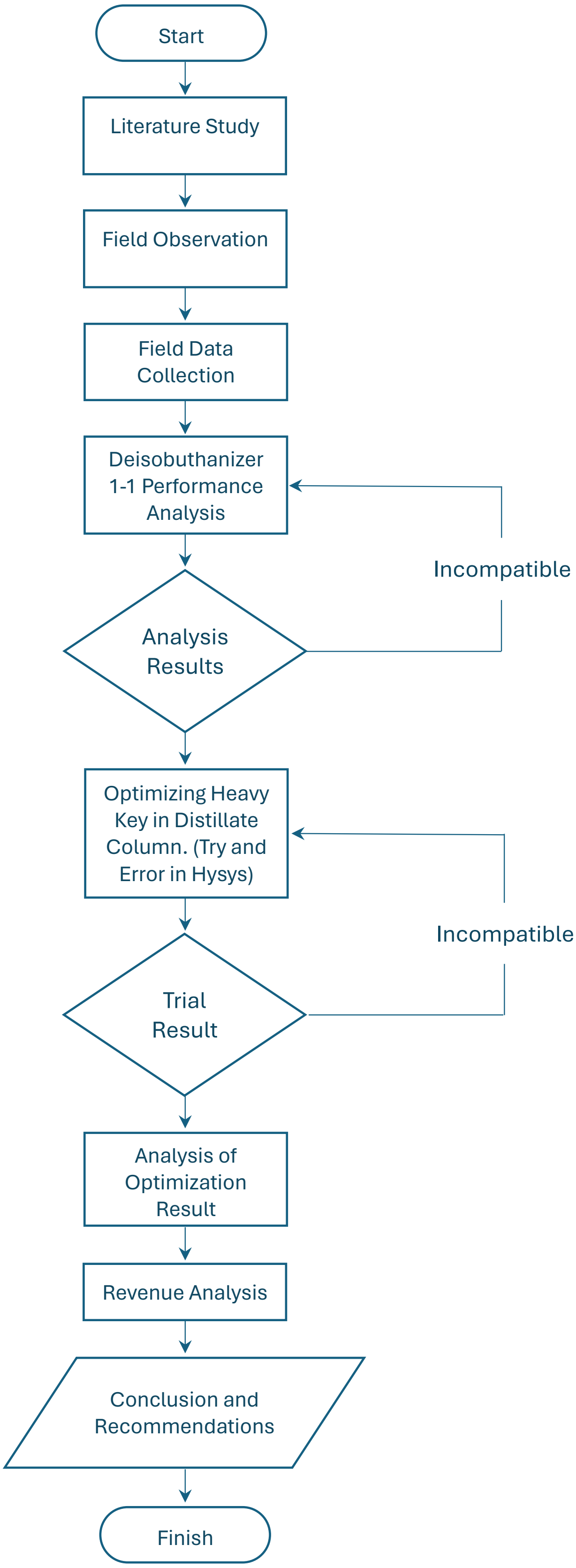

Figure 1
Research method flowchart

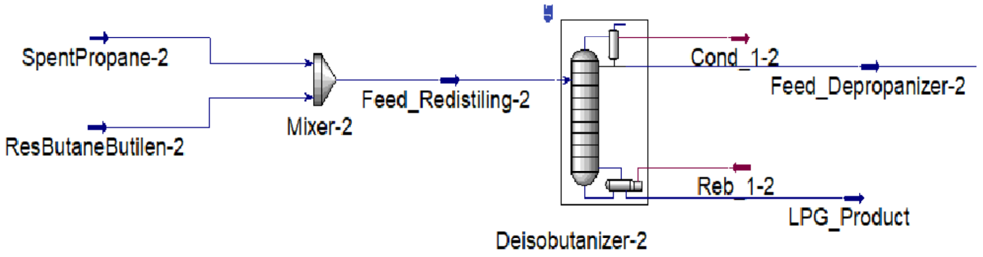

Figure 2
Binner distillation column modeling

RESULT AND DISCUSSION

Data collection for evaluating and optimizing the performance of deisobutanizer column was based on summarized information stored in the control room. Table 1 shows the actual operating conditions averaged over one month, alongside manufacturing design data and the operating window.

Table 1
Design data of deisobutanizer column

Deisobutanizer Column		
Item	**Value**	**Units**
Column Shape	Cylinder	-
Column Position	Vertical	-
Column Material	C.S	-
Column Diameter	2	m
Column Height	40	m
Number of Trays	60	Pcs
Plate Tray Type	Valve	-
Tray Spacing	0.5	m
Flow Type	C.S	-
Design Temperature	204,4	°C
Design Pressure	10,5	Kg/cm^2
Heavy Key in Distillate	3	%
Light Key in Distillate	0,05	%

The design data for the operating window, when Alkylation Unit is in Redistilation mode, is shown in Table 2.

Table 2
Window operation design data deisobutanizer column

Window Operating Design Data		
Item	**Value**	**Units**
Feed flow rate	30 - 90	Ton/Day
Feed Temperature	27 – 30	°C
Top Temperature	35 – 50	°C
Bottom Temperature	60 – 70	°C
Top Pressure	8.8	Kg/cm^2
Bottom Pressure	8.7	Kg/cm^2

Table 3 shows the actual average operating conditions for one month.

Table 3
Actual operating conditions deisobutanizer column

Item	**Temperature**	**Pressure**	**Flowrate**
	°C	**Kg/cm^2**	**Ton/day**
Feed	35	5	51.49
Top column	56	8.45	35.32
Bottom	73	8.36	16.62
Reflux	56	8.45	383

	Operating Duty	
Item	**Units**	**Value**
Reboiler	kW	1475
Condenser	kW	1514

The laboratory test data describing the composition of the feed, top, and bottom products of the column under non-optimized conditions are shown in Table 4.

Table 4
Deisobutanizer column feed and product composition data

Component	Feed Redistilation %Mass	Top Product %Mass	Bottom Product %Mass
Propane	4.75	6.96	-
Propene	0.10	0.14	-
i-Butane	51.74	75.82	0.03
n-Butane	9.98	3.38	24.33
13-Butadiene	0.05	0.07	0.00
M-Acetylene	0.01	0.02	0.00
tr2-Butene	16.57	4.60	42.26
Iso-Butylene	5.47	7.97	0.09
Cis-Butylene	9.19	0.23	28.44
tr2-Pentene	0.09	-	0.29
n-Pentane	0.04	-	0.12
1-Butene	0.61	0.89	0.02
i-Pentane	1.41	-	4.43

Performance analysis

The data comparison process requires comparing two or more variables to discern differences, influences, similarities, or patterns in operation. The numerical comparison method was adopted because it compares the results obtained from the field data operation with the manufacturing design and column reference manual (Christie and Geankoplis, 1983). The operating conditions in the unit are critical factors closely associated with the physical and chemical properties of the process. In distillation column, these conditions refer to the variables controlled during process operations, which significantly affect the efficiency and quality of the separated mixture. Understanding and managing the operating conditions is important, as it enables the effective control of the parameters, leading to achieving the desired separation objectives (Winkle, 1967). Table 3 shows the actual operating conditions averaged over one month obtained from fieldwork practices. The results implied that the unit requires 2,989 kW of energy to function due to the enormous reflux flow and high reboiler temperature. In addition, a critical aspect of the Binner distillation column consists of heavy (n-butane) and light keys (i-butane), with limited concentration at the top and bottom of the column. The performance analysis shows that the n-butane contained in distillate exceeded the factory design limit of 3%, as shown in Table 4. This focuses on the need for optimization to prevent adverse effects on the composition and quality of the top product, which could subsequently impact the bottom processes, resulting in losses. Graphs generated from Hysys results compared actual field conditions with the research results. These graphs, also known as satisfactory operation, are often used in columns for real-time performance monitoring and control. In the operation of distillation column, several factors, such as weeping, flooding, and entrainment, can affect separation efficiency. The generated graph is shown in Figure 3. The distillation column operates safely without any indication of the previously mentioned problems. Thiswas attributed to the balanced liquid/Vapour ratio, which ensures the vapor and liquid flow rates are in equilibrium. The balance prevents any potential problems that could hinder the performance of distillation column.

Determination of optimum operating conditions

Company frequently uses the optimum point software to evaluate the performance of equipment and operational units. The dependent variable to be optimized is the n-butane content in distillate, closely associated to influential operating parameters both theoretically and in the field. This variable is relatively easy to control and does not negatively impact the company. Optimizing this variable improves tool life and energy savings compared to the conditions before optimization (Usman and Haans, 2017).

To address the identified problems, research was carried out by adjusting the operating conditions of the reflux flow rate and reboiler temperature using the trial and error method. This includes using the case study function in Hysys to optimize the heavy key contained in distillate. The results of the trial method generated through Hysys modeling comprised 144 iterations with different variations. The reflux flow rate ranges from 8,325 to 16,030 kg/day with a 700 kg/day interval, while reboiler temperature was in 64 to 75°C, at an interval of 1°C. To determine the optimum point among the 144 iterations, a method was applied based on the results of the experiments that generate profits for the company, focusing on economic calculations.

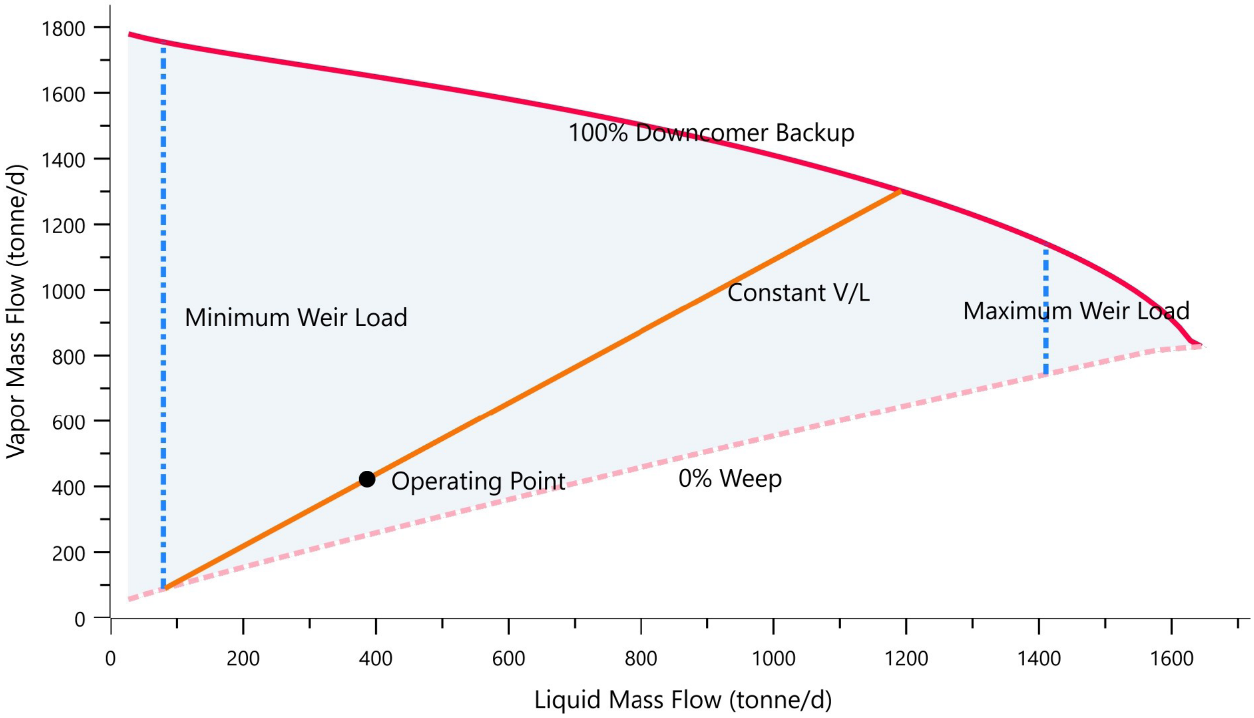

Figure 3
Static factory operating actual conditions deisobutanizer column

Table 5
Column operating cost

Item	Units	Price
Feed	USD/Kg	16.3
LPG	USD/Kg	1.25
MC-22	USD/Kg	10.67
Heating Oil	USD/kW	0.34
Cooling Water	USD/kW	0.106

The first method used to determine the optimal point included performing cost calculations for each optimization variable. This complex process includes applying formulas and considering various factors and parameters to comprehensively analyze optimization variables.

$$Profit = Income - Cost \qquad (1)$$

$$Income = \ (P_{LPG} *\ Q_{Bottom} * Purity_{Bottom}) + (P_{MC-22} *\ Q_{Top} * Purity_{Top})$$

$$Cost = \ (P_{Feed} * Q_{Feed}) + (P_{HeatOil} *\ Reb_{Duty}) + (P_{Cooller} * Coller_{Duty})$$

The given equation was used to ascertain that 96 out of 144 trials were unprofitable for the company, eliminating the results obtained. The remaining 48 trials were proven to be profitable and were retained for further analysis.

Table 6
Calculate the economics of optimization variables

Number Of Trials No	Independent Variable		Overall Profit USD/Kg
	Reflux Flow Rate Kg/h	Reboiler Temperature °C	
9	8325	72	662.1881
10	8325	72	1626.9208
11	8325	74	4077.7044
12	8325	75	5238.1534
21	9025	72	570.8484
22	9025	73	1939.8799
23	9025	74	4006.2246
24	9025	75	5164.4892
33	9725	72	496.8516

34	9725	73	1398.0766
35	9725	74	3939.6591
36	9725	75	5097.7528
45	10430	72	441.9612
46	10430	73	1239.6039
47	10430	74	3883.0023
48	10430	75	5041.4609
57	11130	72	396.7922
58	11130	73	1521.9853
59	11130	74	3836.3999
60	11130	75	4995.2375
69	11830	72	361.1796
70	11830	73	1401.9670
71	11830	74	3789.7556
72	11830	75	4948.5937
81	12530	72	324.9895
82	12530	73	1248.8092
83	12530	74	3743.3531
84	12530	75	4901.4691
93	13230	72	288.6669
94	13230	73	1610.0096
95	13230	74	3705.8920
96	13230	75	4853.8605
105	13930	72	251.9890
106	13930	73	1574.2098
107	13930	74	3668.7709
108	13930	75	4816.9895
117	14630	72	214.8687
118	14630	73	1357.5891
119	14630	74	3631.3999
120	14630	75	4769.2210
129	15330	72	188.2442
130	15330	73	1138.6812
131	15330	74	3593.9662
132	15330	75	4731.8970
141	16030	72	150.9859
142	16030	73	1458.5786
143	16030	74	3556.2204
144	16030	75	4694.4203

The second method required eliminating the trial results of optimization variables exceeding the company manufacturing design standards, particularly where the n-butane in distillate was greater than 3%. The results of the elimination process successfully led to the removal of 25 optimization variables in Table 6, where the outcomes failed to meet the company design standards.

Table 7
Composition data heavy key in distillate

Number	Independent Variable		Heavy Key
Of Trials	Reflux Flow Rate	Reboiler Temperature	In Top Product
No	Kg/h	°C	%Mol
9	8325	72	0.62
10	8325	72	2.19
21	9025	72	0.42
33	9725	72	0.30
34	9725	73	1.71
45	10430	72	0.23
46	10430	73	1.34
57	11130	72	0.18
58	11130	73	2.17
69	11830	72	0.14
70	11830	73	1.89
81	12530	72	0.12
82	12530	73	1.56
93	13230	72	0.10
94	13230	73	2.65
105	13930	72	0.08
106	13930	73	2.62
117	14630	72	0.07
118	14630	73	2.12
129	15330	72	0.06

130	15330	73	1.55
141	16030	72	0.06
142		73	2.58

The elimination of optimization variables in Table 7 led to the final stage, in which the optimal point was determined. The aim was to identify the point that maximizes profit while minimizing energy consumption and operational conditions. Table 8 shows that the optimum point was identified as the 10th trial.

Table 8
Optimum point determination

Number	Utility		Overall
Of Trials	Reboiler Duty	Condenser Duty	Profit
No	kW.h	kW.h	USD/Kg
9	853.3	811.9	662.19
10	864	823	1,630.85
21	914.2	872.8	570.85
33	975.4	933.9	496.85
34	987.8	947.1	1,398.08
45	1037	995.2	441.96
46	1048	1008	1,239.60
57	1098	1057	396.79
58	1114	1073	1,521.99
69	1160	1118	361.18
70	1174	1134	1,401.97
81	1222	1180	324.99
82	1243	1201	1,248.81
93	1283	1242	288.67
94	1298	1258	1,610.01
105	1345	1303	251.99
106	1358	1319	1,574.21
117	1407	1365	214.87
118	1420	1381	1,357.59
129	1469	1427	188.24
130	1492	1449	1,138.68
141	1531	1488	150.99
142	1554	1511	1,458.58

The 10th optimization variable experiment was conducted under a reflux flow rate of 8325 Kg/h and a resulting reboiler temperature of approximately 73^{o}C, leading to a profit of $ 1,630.85. The results are considered optimal because it met the standard composition of HK and LK contents at the top and bottom of the column. Furthermore, minimal reboiler and cooler load reduces operating costs and durability of the equipment or unit, producing significant benefits for the company.

Comparison between Actual and Optimized Conditions of Deisobutanizer Column

Data comparison requires examining two or more variables to identify differences, similarities, or patterns during operation. The numerical comparison method, entailed comparing the results obtained from the field and after optimization, to process the data. This sub-chapter focused on the comparison between actual condition data and optimization results.

Table 9
Actual and optimal operating conditions of deisobutanizer column

Item	Units	Conditions	
		Actual	Optimal
Feed Flowrate	Ton/day	51.49	51.49
Top Flowrate	Ton/day	35.32	34.27
Bottom Flowrate	Ton/day	16.62	17.67
Reflux Flowrate	Ton/day	383	200
Feed Temperature	°C	35	35
Top Temperature	°C	56	55
Bottom Temperature	°C	73	72
Reflux Temperature	°C	56	55
Feed Pressure	Kg/cm^2	5	5
Top Pressure	Kg/cm^2	8.45	8.45
Bottom Pressure	Kg/cm^2	8.36	8.36
Reflux Pressure	Kg/cm^2	8.45	8.45
Reboiler Duty	Kw	1475	823
Condenser Duty	Kw	1514	865

The data in Table 9 shows significant differences between the current and optimum operating conditions of deisobutanizer column. The differences mainly include the temperature and reflux flow rate at the top of the column as well as the performance of reboiler and condenser. The higher temperature at the top of the column poses a risk of increasing heavy fraction content, such as n-butane, beyond the manufacturing design limit. This could lead to contamination of the top product, resulting in reduced purity, increased load on the next column, and diminished bottom product yield during separation. This was found in the actual conditions, where the temperature of the top column was higher, and a difference in reflux flow rate was detected compared to the optimal conditions. However, a high reflux flow rate is considered advantageous for effective separation. The increased temperature of the top column can lead to the rise of heavy fraction, posing a risk of contaminating the product. In this case, the weight of the heavy fraction content exceeded 3% of the design limit, depicting potential contamination. Additionally, the significant reflux flow rate contributes to substantial energy consumption, which is evident in the large reboiler and condenser loads under actual and optimal conditions. Maintaining the current operating conditions of deisobutanizer column reduces the efficiency, resulting in lower product quality and increased utility production costs. Therefore, the optimum operating conditions with a reflux flow rate and reboiler temperature of 200 tons/day and 73°C produces a high-purity product with decreased energy consumption.

The isobutane and propane were concentrated in the top product, while n-butane and heavier compounds were found at the bottom. This is consistent with the difference in boiling point between isobutane and n-butane, with isobutane having a lower boiling point.

Table 10
Actual and optimal composition product of deisobutanizer column

Component	Top Product		Bottom Product	
	%Mass			
	Actual	Optimal	Actual	Optimal
Propane	6.96	7.17	-	-
Propene	0.14	0.15	-	-
i-Butane	75.82	77.97	0.03	0.03
n-Butane	3.38	2.19	24.33	25.25
13-Butadiene	0.07	0.07	-	-
M-Acetylene	0.02	0.02	-	-
tr2-Butene	4.60	4.60	42.26	42.45
Iso-Butylene	7.97	7.89	0.09	0.07
Cis-Butylene	0.23	0.32	28.44	26.58
tr2-Pentene	-	-	0.29	0.27
n-Pentane	-	-	0.12	0.11
1-Butene	0.89	0.89	0.02	0.01
i-Pentane	-	-	4.43	4.16

Reviewing the actual data with optimization results in Table 10, it was discovered that optimization process successfully restored the product composition. However, the reboiler temperature is a critical factor that influences the composition of the heavy (n-butane) and light keys (iso-butane). An increase in reboiler temperature leads to the evaporation of heavier components, due to the higher boiling points compared to the lighter ones. This causes potential contamination, disruption of the top product and distillation column performance. Additionally, adjustments to the bottom temperature was required to balance variations in reboiler temperature. Increasing the reflux enhances the separation efficiency, stabilizes the temperature at the top of the column and reduces the loss of valuable components.

The results obtained are consistent with the research conducted by Moudy (2016) that optimizing reboiler temperature and reflux flow rate significantly improved the purity of the separation process in distillation column. These two operating variables strongly influence the fractions of the top and bottom components. Furthermore, Muhammad Fuad (2015) stated that the separation process in the distillation column depended on the maintenance of optimal temperature and pressure. This is particularly crucial given the low boiling point of the feed component, requiring the maintenance of pressure conditions above atmospheric pressure to avoid deviation.

Significant changes in the fractions of the separated components is affected by slight differences in the reflux flow rate and reboiler temperature set points. Therefore, this research focused on the need for proper set point optimization during distillation column operation. An in-depth knowledge of the relationship between reboiler temperature, reflux flow rate, and component fractions is critical for achieving optimal separation efficiency.

The magnitude of the flow rate has a significant impact on component separation, with higher flow rates enhancing separation, while increasing the load on both condenser and reboiler. The operating temperature is a crucial factor in the separation process as it affects the retention time, a critical parameter in distillation. In addition, retention time determines the efficiency of component separation from the mixture (Novrizal, Lisna & Yayun, 2013).

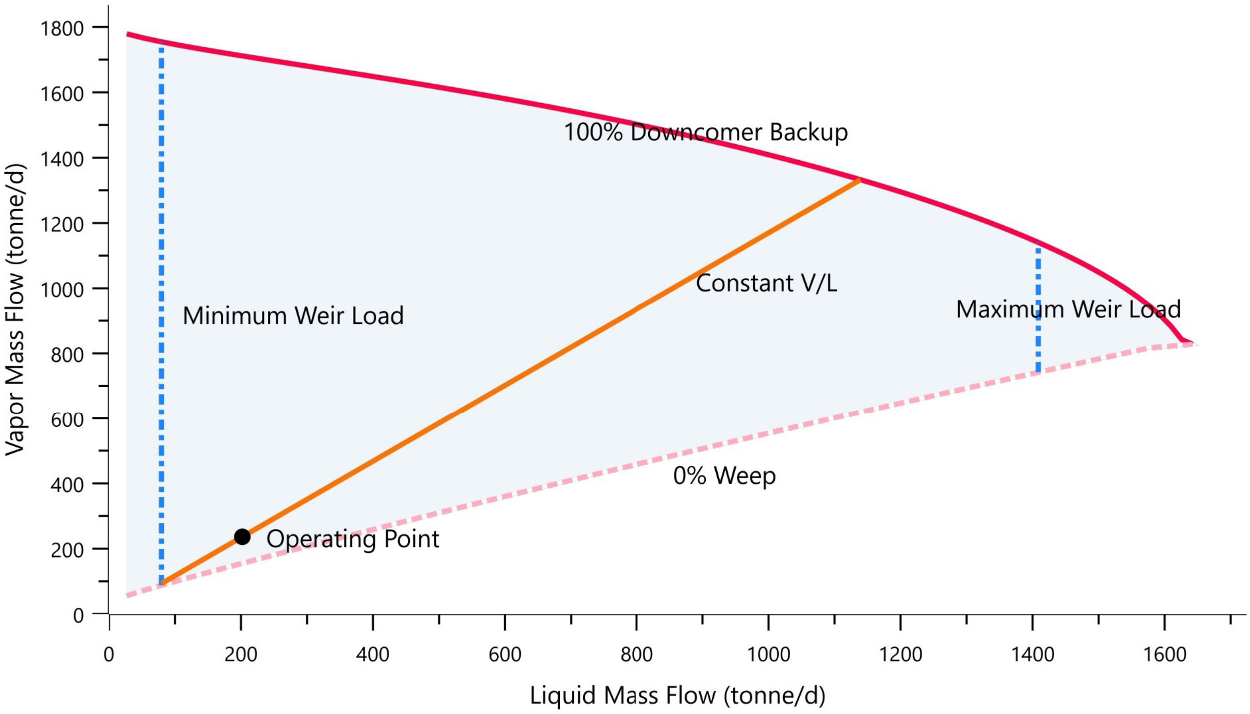

Figure 4
Static factory operating optimal conditions deisobutanizer column

The analysis comparing post and pre-optimization troubleshooting based on the Static factory operation graph, none of the issues namely flooding, weeping, or dumping depicted reduced separation efficiency. However, there was a decrease in the ratio of steam to liquid flow rate, as shown in Figure 4.

Effect of Optimization on Alkylation Unit

The research on operating system, focused on the independent variables and the effect on the deisobutanizer column. However, in Alkylation unit operated using redistilling modes, several tools, including depropanizer column, depropanizer feed pump, and hot oil furnace, operated alongside deisobutanizer column. Any change made to the operating conditions of one tool, during optimization process can affect the others. These changes are shown in the following table.

Table 11 shows the pump operating conditions are important variables, where an increase in pressure is required to proceed to thenext stage. In Alkylation unit, depropanizer feed pump is used to increase the pressure, which effectively lowers the boiling point of the compound to be separated. The procedure reduces the need for excessively high heat during processing. The distillate flow rate is greater in the actual section compared to the optimization results. This requires increased flow rate from the suction pump to reach the desired pressure, resulting in greater power or energy requirements. Additionally, both the inlet and outlet temperatures increased in the actual and optimization conditions.

Table 11
Depropanizer feed pump operating conditions

Dec	Units	Actual		Optimal	
		In	Out	In	Out
Flowrate	Ton/ Day	35.33		34.27	
Pressure	Kg/ cm2	8.45	17	8.45	17
Temperature	°C	55.6	56.55	55.22	56.2
NPSHa	M	0.008675		0.008102	
Power	KW	0.907		0.88	

Following deisobutanizer column, depropanizer plays a crucial role in separating C3 based on the weight fraction. The top product contributes to an environmentally friendly refrigerant, while the bottom functions as a recycle for the previous column, namely deisobutanizer. This subchapter discussed the impact of optimizing deisobutanizer column on depropanizer, examining both operating conditions and the percentage of recycling.

Operating conditions are variables that often experience instability when there is a change in flow rate, temperature, or other conditions because it has a strong relationship. Changes in one condition can have a significant impact on the other variables. The following research stated on the operating conditions of depropanizer column before and after optimization.

Table 12 shows a comparison of the actual and optimization conditions of column 1-1, and the impact on subsequent operations. Optimization conditions operate at a lower state when compared to the actual one, resulting in minimized operating costs and energy consumption, which benefits the company financially and enhances equipment durability. Furthermore, optimization of deisobutanizer column leads to an increase in percentage yield of the top flow rate, compared to depropanizer.

Table 12
Actual and optimal operating conditions of depropanizer column

Item	Units	Conditions	
		Actual	Optimal
Feed Flowrate	Ton/day	35.33	51.49
Top Flowrate	Ton/day	0.1912	34.27
Bottom Flowrate	Ton/day	35.33	17.67
Reflux Flowrate	Ton/day	100	200
Feed Temperature	oC	56.55	56.11
Top Temperature	oC	49.11	50.83
Bottom Temperature	oC	92.29	92.30
Reflux Temperature	oC	49.11	50.83
Feed Pressure	Kg/cm^2	17.11	17.11
Top Pressure	Kg/cm^2	18.41	18.41
Bottom Pressure	Kg/cm^2	18.31	18.31
Reflux Pressure	Kg/cm^2	18.41	18.41
Reboiler Duty	kW	374	371
Condenser Duty	kW	330	326

The percent recovery is an evaluation of distillation column performance, depicting the expected percentage of components in the top and bottom products. Furthermore, more components are expected to be in the top product of the column, to obtain accurate results. The percentage recovery of C3 (propane/propylene) components captured before and after optimization was calculated using the following formula.

$$\%\,Recovery = \frac{Total\ Component\ in\ top\ (C3 + C3 =)}{Total\ Component\ top\ in\ feed(C3 + C3 =)} \times 100\%$$

Depropanizer column aims to separate C3 components (propane, propene), which predominantly appears at the top. To evaluate the separation efficiency, the percentage recovery of these components were calculated using the following formula:

$$\%\,Recovery = \frac{(0{,}0715 + 0{,}0267)\ ton/day}{(1{,}910 + 0{,}0368)ton\ /hours} \times 100\% = 5\,\%$$

Before optimization, the performance of depropanizer column, influenced by the previous column (deisobutanizer), was poor according to the actual data. Calculation show a minimal recovery of light key components in the overhead column, with approximately 95% in the bottom. This signifies a week recovery process in depropanizer column before optimization of column 1-1. The mass fraction distribution of distillation column under actual condition is shown in Figure 4. After optimization of the 1-1 deisobutanizer column, the percentage recovery of distillation column performance was calculated using the same formula as earlier mentioned.

$$\%\,Recovery = \frac{(0{,}2747 + 0{,}034)\ ton/day}{(1{,}901 + 0{,}0376)ton\ /hours} \times 100\% = 15\,\%$$

A significant improvement was detected when comparing the actual percentage recovery from depropanizer column before and after optimization of deisobutanizer. Prior to optimization, deisobutanizer column achieved only a 5% recovery, which increased to 15%. This showed that optimizing deisobutanizer column improved the separation efficiency of depropanizer.

The economic assessment is the final result of research conducted to measure the economic impact of a particular decision or policy. The main purpose was to assist decision-makers in evaluating performance in limited resources. Table 13 is a comparison of the resulting economic assessments.

The actual data have higher profits compared to optimization. In addition, the product composition specifications exceeded the standard design limits set by the company. This violation, in the form of heavy keys contained in the top column led to contamination of the overhead product, thereby increasing the separated load in the next column. The previous tables showed that the meeting of company standards by optimization would result in cost savings, prolonging the lifespan of the equipment in the unit and positively impact longevity.

CONCLUSION

In conclusion, the results of optimization research showed that minimizing the composition ofheavy key contained in the overhead product was achievable. This was influenced by the following variables bottom temperature and reflux flow rate. By adjusting the operating conditions of the reflux flow rate and reboiler temperature of 200 tons/day, and 72.8°C, in contrast to the initial values of 383 tons/day and 73.15°C, respectively, the heavy key composition in distillate was in line with the manufacturing design standards. Adhering to the standard composition of heavy key products in the top column less than 3%, led to a decrease in profit by $ 125. 708 kg/h compared to the actual operating conditions, but substantial energy savings of 1,301 Kw was achieved.

To ensure the optimal and safe operation of deisobutanizer column, many company should have facilitated data collection to support the evaluation and optimization of existing equipment. This would have included implementing advanced data collection systems to gather relevant operational information effectively. Furthermore, integrating indicators that had not beenconnected to CCL would had improved the control of process variables.

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GLOSSARY OF TERMS

Symbol	Definition
Light Key (LK)	A crucial component of light compounds, iso-butane possesses a low boiling point and will be distilled with the evaporated components to form distillate. In the context of this research, iso-butane serves as the light component in the main column (deisobutanizer).
Heavy Key (HK)	The heavy key component with a high boiling point is included with the remaining components in the residue and exits as the bottom product. In the context of this research, the heavy key component in the main column (deisobutanizer) is n-butane.
Static Factory Operating	This operational point allows for comparison between the ratios of liquid and vapor flow rates in order to analyze potential issues that may arise in distillation column, including weeping, dumping, flooding, and others.

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