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Aspen Hysys Simulation for LPG Production Optimization In Deethanizer Column: Case Study in Delayed Coking Unit

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ABSTRACT - The global petroleum refining industry faces increasing pressure to optimize resource utilization while ensuring environmental sustainability. This challenge is further intensified by the rising demand for lighter, cleaner fuels and heavier crude oil feedstocks. The Delayed Coking Unit (DCU) plays an important role in refining processes by converting vacuum residue into valuable products such as Liquefied Petroleum Gas (LPG), diesel, naphtha, and green coke. The LPG market, currently valued at $113.7 billion, is projected to grow to $165.1 billion by 2033. Within this process, the deethanizer column utilizes pressurized distillation to separate ethane (C2) from LPG. According to evaluation results, the column's feed flow was recorded at 83.7 tons per day, with a feed temperature of 102.61°C and a top column pressure of 18.84 kg/cm². The feed composition data was obtained through laboratory analysis. According to the calculation, the theoretical tray number was 17, the reflux ratio was 0.9936, and the total tray efficiency was 56.57%. The optimization of deethanizer column operating conditions was carried out by increasing the bottom product yield, which aimed to determine the optimum point with the greatest LPG yield. Based on a trial-and-error using Aspen Hysys V14 software, the optimum conditions were identified when the column was operated at 110°C reboiler temperature and reflux ratio 2, which could increase LPG yield to 73.21 tons/day with 98.1% w/w purity. Economically, the profit increased from $18,444,932.92/year to $22,640,582.13/year.

Keywords: deethanizer, evaluation, optimization, yield, profit.

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INTRODUCTION

The petroleum refining industry faces significant challenges in maintaining competitiveness in the global fuel market. An important factor that should be put into consideration is optimizing the utilization of existing petroleum resources while ensuring environmental sustainability. This has led to an increased focus on upgrading heavy residues, specifically as crude oils become heavier and there is an increase in the demand for lighter, cleaner fuels (Harji et al. 2005). Among various upgrading technologies, the Delayed Coking Unit

(DCU) has proven to be an important solution, and this unit converts heavy residues, such as vacuum residue, into lighter and higher-value products. The operational flexibility nature of this process allows refineries to process diverse feedstocks, due to the decrease in the demand for residual fuels while converting previously low-value or environmentally problematic streams into valuable products (Debiase & Elliott 1982). In addition, DCU integrates effectively with other technologies and can serve as the primary upgrading process in a refinery. This unit is capable of producing LPG) diesel, naphtha, and green coke (Sawarkar et al. 2007).

Green coke is defined as a byproduct obtained from DCU at temperatures of 480-520°C, and the characteristics include a deep black color and a solid texture similar to coal. In addition, it has a very low ash content (approximately 0.10%) and a relatively low sulfur content (around 0.50%), with a high calorific value (about 7,500-8,500 kcal/gram), which is higher than coal (Gao et al. 2024).

According to Figure 1, in 2023, the market value of LPG was estimated at $113.7 billion, and it is forecasted to increase to $165.1 billion by 2033, with a compound annual growth rate (CAGR) of 3.9%. This growth is driven by the rising global demand for LPG, recognized as a clean and efficient fuel for household, transportation, and industrial applications. It highlights LPG's strategic role as a future energy solution supporting sustainability and efficiency (Market Research 2023). One of the essential components of DCU is the deethanizer column, which separates off-gas (C1-C2) from LPG (C3-C4). However, one of the challenges is the presence of propane (C3) in the off-gas, which reduces the yield of LPG. This shows the need for further evaluation of the process and optimization of the operating conditions in the deethanizer column to obtain the optimum amount of LPG product and fulfill the required specifications. Therefore, to address the increasing demand for LPG (as shown in Figure 1), a comprehensive evaluation and optimization effort is required in DCU, particularly in the deethanizer column, to ensure that LPG output can be maximized both in terms of volume and quality (Sembiring et al. 2020).

This research focuses on optimizing the bottom product yield of the deethanizer column. To achieve this, a series of simulations were conducted using Hysys software to evaluate the feasibility and efficiency of the process. In addition, other tools such as Aspen Plus and Pro/II were also commonly used for process simulations. However, these tools have certain limitations. Aspen Plus is less optimal for dynamic simulations, as it requires additional modules, and the accuracy in modeling hydrocarbon processes is lower than Hysys. Meanwhile, Pro/II is more limited to steady-state simulations and is less flexible when modeling multi-component distillation. Hysys, developed

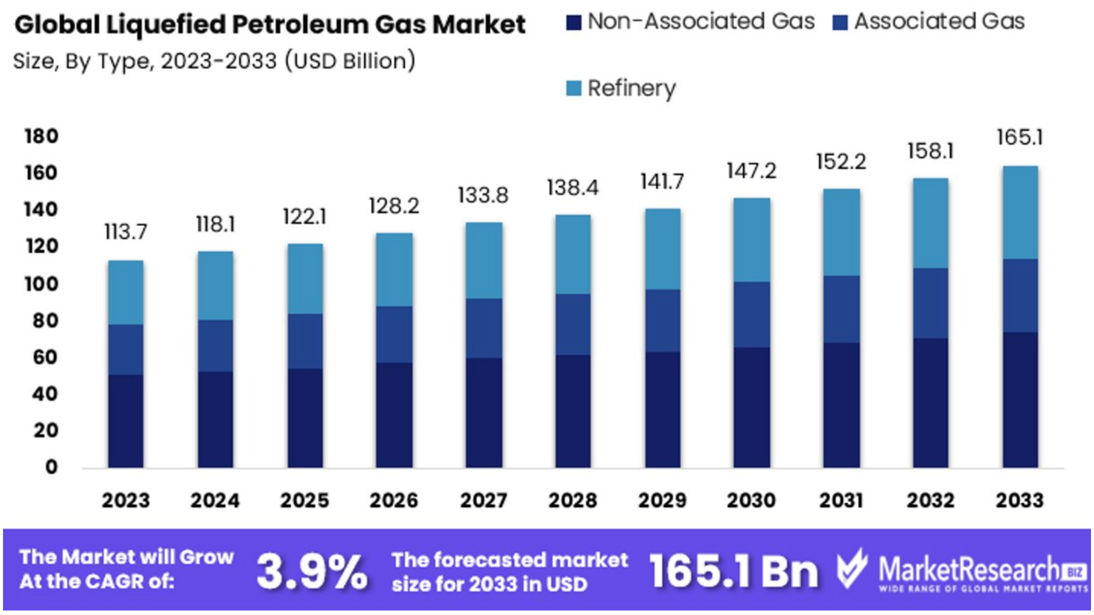

Figure 1
LPG global market (2023-2033) (Market Research 2023)

by Aspen Technology Inc., is software capable of modeling process systems in detail, making it easier to solve complex calculations (Haydary 2018).

Fluid packages in process simulation software, such as Aspen Hysys, are collections of mathematical models and parameters that enable the modeling of the thermodynamic behavior of fluid mixtures under various operating conditions. The equation used in this research is Peng-Robinson, which is generally more suitable for calculations involving vapor-liquid equilibrium and liquid density in hydrocarbon components (Gutierrez et al. 2014).

METHODOLOGY

This research was carried out from 01 to 31 August 2024. The materials used in the preparation of deethanizer column optimization are heavy oil complex process flow diagram, deethanizer column design data, deethanizer column operating condition log sheet, and laboratory analysis data of feed, top product, and bottom product of deethanizer column.

The tools used to prepare the optimization of the deethanizer column included a laptop, MS Office software (MS Word, MS Excel, and MS PowerPoint), and Aspen Hysys to process the data obtained. Additional equipment, including personal protective equipment (safety helmets, wear packs, safety shoes, masks, etc.), is used in the refinery.

The subject of the optimization process is the bottom product yield of the deethanizer column. This process started by evaluating the actual efficiency of the equipment and then optimizing the operating conditions to obtain the optimum bottom product yield, considering the independent and dependent variables. The independent variables used are the reboiler temperature and reflux ratio, while the dependent variable is the LPG Mixed specification, consisting of Bottom Product Purity (min. 97% vol. of C_3 and C_4), Bottom Product Yield, Vapour Pressure (max. 145 psig), and H_2S content. In order to support the optimization process from an economic point of view, a comparison of the bottom product yield after optimization with the previous one is carried out, taking into account the increase in revenue achieved after optimization.

RESULT AND DISCUSSION

Column performance evaluation

Deethanizer column is a pressurized distillation column with an operating pressure of 18.84 kg/cm². This column uses the principle of binary mixed distillation as it separates only two components, with the top product being off-gas and the bottom product being LPG. The column uses a 30-valve tray as the tray type. The following are the design data of the deethanizer column.

Table 1
Equipment design data

Deethanizer Column	
Column Shape	Cylindrical
Column Orientation	Vertical
Column Diameter (m)	1.1
Number of Tray (pcs)	30
Type of Tray	Valve
Tray Spacing (cm)	0.55
Design Temp. (ºC)	120
Design Press. (kg/cm^2)	25
Top Column Temp. (ºC)	40-80
Bottom Column Temp. (ºC)	100-120
Feed Temp. (ºC)	50-60
Top Column Press. (kg/cm^2)	18

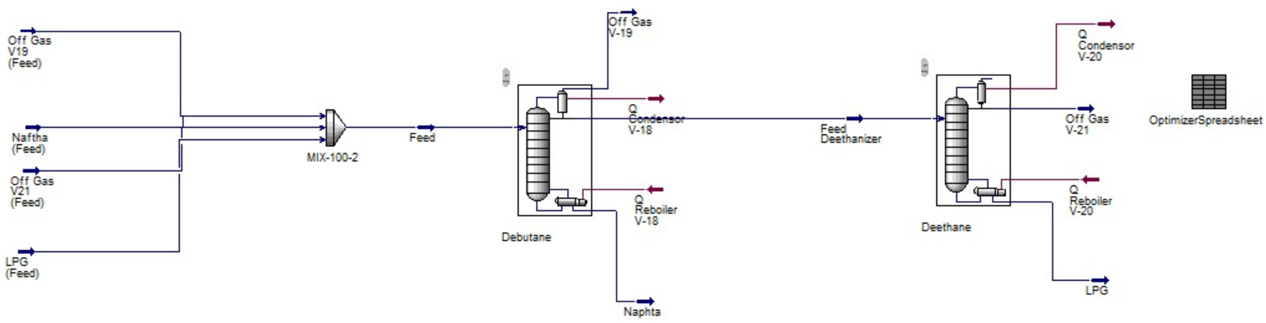

Figure 2
Deethanizer simulation on aspen hysys V14

Operating data is collected to ensure that the data obtained is representative and relevant to actual conditions. The data collected includes various important variables in column operation such as pressure, temperature, and flow rate. The following is the actual data of the operating conditions of the deethanizer column during the period 1-31 August 2024.

Table 2
Operating condition data

Deethanizer Column	
Column Top Temp. (°C)	48.06
Column Bottom Temp. (°C)	113.05
Feed Temp. (°C)	50.28
Column Top Press. (kg/cm^2)	18.84
Column Bottom Press. (kg/cm^2)	18.74
Feed Press. (kg/cm^2)	25.93
Top Product Flowrate (m^3/hour)	1.831
Bottom Product Flowrate (m^3/hour)	4.626
Reflux Flowrate (m^3/hour)	6.457
Feed Flowrate (m^3/hour)	1.688

To determine the feed and product composition, product testing is carried out in the laboratory to determine whether the composition of the top and bottom column products meets the specified specifications. The following is the data from the laboratory analysis of the deethanizer column.

Table 3
Flow composition data

Component	Vol%		
	Top Product	Bottom Product	Feed
Methane	12.84	0.00	2.12
Ethane	36.47	0.17	6.15
Ethene	3.42	0.00	0.56
Propane	31.93	28.96	29.45
Propene	15.05	9.26	10.21
i-Butane	0.10	6.51	5.45
i-Butene	0.05	33.46	27.95
n-Butane	0.04	5.27	4.41
t-Butene	0.00	2.63	2.20

Table 3
Flow composition data (Continued)

Component	Vol%		
	Top Product	Bottom Product	Feed
1-Butene	0.08	12.12	10.14
cis-Butene	0.00	1.63	1.36
i-Pentane	0.00	0.00	0.00
n-Pentane	0.00	0.00	0.00
n-Hexane	0.00	0.00	0.00
Total	100.00	100.00	100.00

Based on Table 3, it can be observed that the top product of the column consists mainly of C_2 components, where the product will be used as fuel gas. The bottom product of the column consists of the C_{3+} component, which is LPG.

After obtaining actual data and laboratory analysis, mass balance is calculated. This calculation ensures that no mass is lost during the distillation process by determining the total mass of the incoming and outgoing streams and their component fractions. The following is the total mass balance of the deethanizer column.

Table 4
Mass balance

Component	Output		Input
	Top (kg/h)	Bottom (kg/h)	Feed (kg/h)
Methane	109.1064	0.0000	109.1064
Ethane	581.0774	4.5640	585.6414
Ethene	50.8542	0.0006	50.8548
Propane	746.0631	1134.0988	1880.1619
Propene	335.6244	345.9676	681.5920
i-Butane	2.9739	335.8906	338.8645
i-Butene	1.2616	262.4381	263.6996
n-Butane	1.6697	1727.0501	1728.7198
t-Butene	0.1037	130.9874	131.0911
1-Butene	2.3873	604.1389	606.5262
cis-Butene	0.0396	81.0741	81.1138
i-Pentane	0.0000	0.0151	0.0151
n-Pentane	0.0000	0.0005	0.0005
n-Hexane	0.0000	0.0000	0.0000
Total	1831.1613	4626.2258	6457.3871

Based on Table 4, the mass of the incoming feed is equal to the mass of the outgoing product, indicating that the system operates efficiently and maintains mass balance.

After obtaining the operating data of the deethanizer column, the reflux mole value can be calculated to determine the ratio between the amount of liquid returned to the column and the amount of product removed from the column. The reflux mole value plays an important role in influencing the separation efficiency and product quality, specifically in maintaining the composition of LPG at the bottom of the column and the off-gas at the top. The following is the reflux mass balance calculation for the deethanizer column (Sidabutar et al. 2020):

$$\begin{aligned} Reflux\ flowrate\ (m^3/h) &= 1.68 \\ Reflux\ flowrate\ (kg/h) &= 1688.19 \\ MW\ top\ product\ (kg/kgmol) &= 48.8432 \\ Reflux\ mole\ (kgmol/h) &= \frac{Reflux\ flowrate}{MW\ top\ product} \\ Reflux\ mole\ (kgmol/h) &= \frac{1688.19}{48.8432} \\ Reflux\ mole\ (kgmol/h) &= 48.8432 \end{aligned} \tag{1}$$

The minimum reflux ratio (Rm) is critical in the operation of a distillation column, as it determines the minimum reflux required to achieve the desired separation. Higher refluxes tend to improve product quality but also tend to increase the energy consumed. On the other hand, reflux ratios below this minimum may lead to reduced separation efficiency and product quality. The following is the calculation of the minimum reflux ratio of the deethanizer column (Zakharov et al. 2021):

$$\begin{aligned} R_m + 1 &= \frac{\Sigma\ (\alpha_i * x_{iT})}{(\alpha_i - \theta)} \\ R_m + 1 &= 0.0722 \\ R_m &= 0.9728 \end{aligned} \tag{2}$$

The minimum tray shows the minimum number of trays required to achieve the desired target product purity in the top and bottom products of the distillation column. This shows that the column effectively separates the components of the feed mixture (Peccini et al. 2023).

Table 5
Mole fraction

Component	Top	Bottom
Methane	0.1284	0.0000
Ethane	0.3647	0.0017
Ethene	0.0342	0.0000
Propane	0.3193	0.2896
Propene	0.1505	0.0926
i-Butane	0.0010	0.0651
i-Butene	0.0004	0.0527
n-Butane	0.0005	0.3346
t-Butene	0.0000	0.0263
1-Butene	0.0008	0.1212
cis-Butene	0.0000	0.0163
i-Pentane	0.0000	0.0000
n-Pentane	0.0000	0.0000
n-Hexane	0.0000	0.0000
Total	1.0000	1.0000

According to Table 5, the composition of the light key (x_{LKT}) and heavy key (x_{HKT}) in the top product is 0.3647 and 0.3193 respectively, while the composition of the light key (x_{LKB}) and heavy key (x_{HKB}) in the bottom product is 0.0000 and 0.0926, respectively. The following is the minimum tray calculation of the deethanizer column.

$$\begin{aligned} N_m &= \frac{Log\ \{\left(\frac{x_{LKT}}{x_{HKT}}\right) * \left(\frac{x_{HKB}}{x_{LKB}}\right)\}}{Log(\alpha)_{avg}} \\ N_m &= \frac{Log\ \{\left(\frac{x_{LKT}}{x_{HKT}}\right) * \left(\frac{x_{HKB}}{x_{LKB}}\right)\}}{Log(\alpha)LK_{avg}} \\ N_m &= \frac{Log\ \{\left(\frac{0.3647}{0.3193}\right) * \left(\frac{0.0926}{0.0000}\right)\}}{Log(3.3170)} \\ N_m &= 4.3913\ (4\ pcs) \end{aligned} \tag{3}$$

The operating reflux is the ratio between the flow rate of liquid returned to the column and the flow rate of distillate product removed from the column. The following is the calculation of the operational reflux of the deethanizer column (Yousuo & Erefagha Rufus 2020):

Table 6
Top product and reflux flow

Section	Flow Molar kgmole/h
Top (T)	52.9796
Reflux (L)	48.8432

$$\begin{aligned} Operating\ reflux\ (R_{ops}) &= \frac{L}{T} \\ Operating\ reflux\ (R_{ops}) &= \frac{48.8432}{52.9796} \\ Operating\ reflux\ (R_{ops}) &= 0.9219 \end{aligned} \tag{4}$$

After the operating recycle is obtained, the recycle ratio is determined, indicating the proportion of recycled material relative to the minimum amount required for optimal operation. The following is the calculation of the reflux ratio of the deethanizer column (Artika et al. 2023):

$$Reflux\ ratio\ (R) = \frac{R_{ops}}{R_m}$$
$$Reflux\ ratio\ (R) = \frac{0.9219}{0.9728} \quad (5)$$
$$Reflux\ ratio\ (R) = 0{,}9936$$

The theoretical tray is the number of trays required from an ideal distillation column model, assuming each tray operates at maximum efficiency and all mass transfer is optimal. The following is the theoretical tray calculation of the deethanizer column (Amalia et al. 2023):

$$\frac{R - R_m}{R+1} = \frac{0.9936-0.9728}{0.9936+1}$$
$$\frac{R - R_m}{R+1} = 0.0330 \quad (6)$$

Then, this number is matched with Gilliland's graph to get the theoretical tray equation.

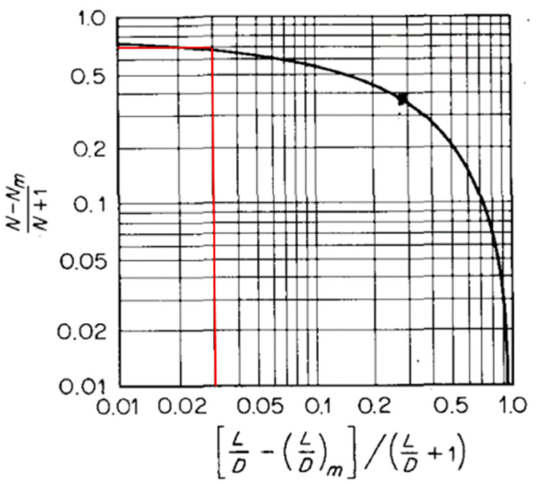

Figure 3
Gilliland's graph

Based on Figure 3, it can be stated that the equation ($N-N_m/N+1$) has a value of 0.7.

$$\frac{N - N_m}{N+1} = 0.7$$
$$0.7N + 0.7 = N - 4.3913$$
$$0.3N = 5.0913 \quad (7)$$
$$N = 16.9711\ (17\ pcs)$$

After determining the theoretical tray, a tray efficiency calculation evaluates its performance under actual operating conditions compared to ideal theoretical conditions. The following is the calculation of the deethanizer column tray efficiency.

$$\eta\ (\%) = \frac{N}{N_a}$$
$$\eta\ (\%) = \frac{17}{30} \quad (8)$$
$$\eta\ (\%) = 56.57\%$$

Based on the calculations above, the deethanizer column is still in a condition suitable for operation. However, the efficiency value is close to the minimum efficiency limit, which shows that the column is already in a condition close to its effective performance limit. Therefore, to maintain the performance and efficiency of the column operation, it is recommended that repairs or maintenance be carried out on the column.

Besides tray efficiency, the percentage recovery on the column is also calculated. Percentage recovery expresses the effectiveness of the column in recovering or separating components from a mixture during the separation process. In this context, the components to be separated are C_3 and C_4. The following is the calculation of the percent recovery of the bottom product in the deethanizer column (Agustina 2020):

Table 7
Pre-optimization C_3 and C_4 flow

	Feed	Product Off Gas	Product LPG
Propane (kg/h)	1172.5291	1144.0321	28.4970
Propene (kg/h)	377.4083	374.9729	2.4354
i-Butane (kg/h)	316.8616	84.7334	232.1282
i-Butene (kg/h)	264.7551	56.0204	208.7346
n-Butane kg/h)	1729.3872	181.4071	1547.9801
t-Butene (kg/h)	163.3272	15.3365	147.9907
1-Butene kg/h)	615.7252	121.2444	494.4808
cis-Butene (kg/h)	15.8357	1.1914	14.6444
Total	4655.8293	1978.9382	2676.8912

$$\%\ Recovery = \frac{C_3 + C_4\ in\ bottom\ prod.}{C_3 + C_4\ in\ feed}\ x\ 100\%$$
$$\%\ Recovery = \frac{2676.8912\ kg/jam}{4655.8293\ kg/jam}\ x\ 100\% \quad (9)$$
$$\%\ Recovery = 57.50\%$$

Pre-optimization internal column condition

After obtaining the tray efficiency and percentage recovery, a process simulation was carried out to determine the actual internal conditions of the column. The simulation was carried out using Aspen Hysys V14 software. The following is the internal condition of the deethanizer column:

According to Figure 4, the weeping limit is shown by the pink dashed line, while the flooding limit is shown by the solid red line. The position of the operating point between these two limits shows that the liquid and vapor flow in each tray is in the optimum range, without experiencing flow problems that cause weeping (a condition where liquid seeps through the tray holes with little vapor interaction) or flooding (a condition where vapor interferes excessively with liquid flow, causing a build-up of liquid in the tray) (Mehairbi et al. 2020)

Column performance optimization

In the deethanizer column, the high-value product is LPG (bottom product). To achieve the minimum specification target and maximum profit, optimization is focused on increasing the bottom product yield. Reboiler temperature and reflux ratio are two important parameters in the distillation process that significantly affect yield and product quality. Higher reboiler temperature increases the amount of vapor at the bottom of the column, which can improve heavy component separation and bottom product yield. However, if the temperature is too high, light components may be carried to the bottom, reducing the purity of the top product. The reflux ratio, which is the proportion of liquid returned to the column relative to the amount withdrawn as a product, plays a crucial role in the separation process. A higher reflux ratio improves the purity of the top product by increasing the number of distillation cycles but reduces the yield of the bottom product because more liquid is returned to the column. On the other hand, reducing the reflux ratio can increase the yield of the bottom product but can reduce the purity of the product (Rahima & Dewi 2020). Increasing the reflux ratio also affects the liquid/vapor (L/V) ratio in the enrichment section of the column, improving liquid/vapor contact, increasing separation efficiency, and reducing the number of equilibration stages required to achieve the desired product quality. Proper adjustment of reboiler temperature and reflux ratio, considering their effect on L/V and number of equilibration stages, is essential for optimum distillation process efficiency. This not only improves yield and product quality but also ensures efficient energy consumption, contributing to the economics of the operation (Biasi et al. 2020).

The deethanizer column receives its feed from the top product of the preceding debutanizer column. To ensure efficient separation in the deethanizer, the feed entering the debutanizer column should be free of C5 and heavier fractions, allowing the process to

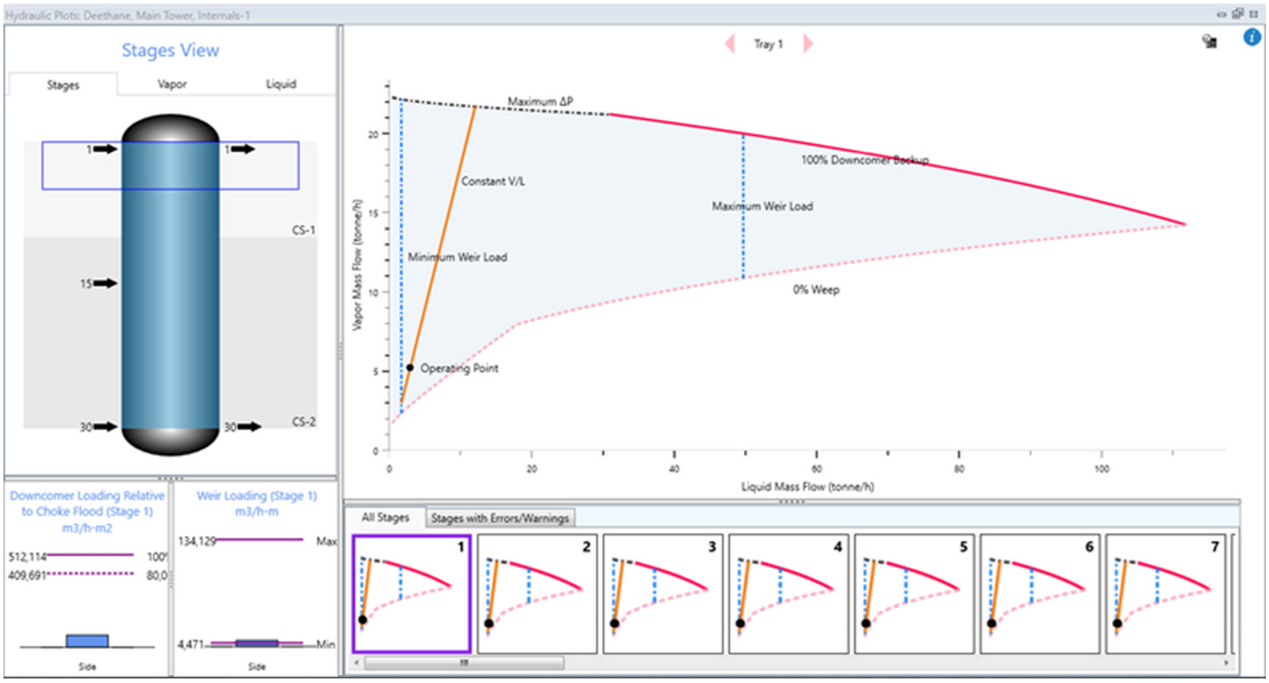

Figure 4
Pre-optimization internal column

focus on separating LPG and off-gas. With operating conditions at 113 reboiler, reflux ratio of 0.99, and pressure of 20 kg/cm2, the variables of reboiler temperature and reflux ratio will be used to determine the optimal product yield and the largest profit. The reboiler temperature is used to control the amount of top product produced. Additionally, the higher the temperature, the more steam is formed, and the more top product is produced. Meanwhile, the reflux ratio acts as a flow purity regulator, the return flow to the column is expected to interact further with the vapor to optimize the separation of heavy and light fractions (Susmiati et al. 2021).

Determination of optimum operating condition

The independent variable, reboiler temperature, is controlled by adjusting Low-Pressure (LP) steam flow. LP steam is utilized as the heating medium for the bottom section of the column. On the other hand, the reflux ratio is the ratio between the amount of liquid returned to the distillation column (as reflux) and the amount of liquid taken as distillate.

The solution for the optimization of the deethanizer column is based on trial-and-error on the dependent quantity (reboiler temperature and reflux ratio), by examining the dependent quantity (purity) which is kept at the minimum requirement, and the data obtained produces the greatest profit.

The trial was conducted by adjusting the independent variables, reboiler temperature in the range of 110 - 120°C with an interval of 0.2°C, and reflux ratio in the range of 1-2 with an interval of 0.1. The dependent variables considered are product purity, product yield, reboiler capacity, and condenser capacity. The trial data obtained are 561 data. The following are the trial results obtained using Aspen Hysys:

Table 8
Trial-and-error data

Number of Trials	Reflux Ratio	Btms Prod Rate	Reboiler Temp	LPG Mixed Comp	C_{5+} Comp	H_2S Comp	Vapour Press	
		m^3/h	°C				kg/cm^2_g	psig
1	1.0	5.125	110.0	0.979	0.0209	0.0000000063	3.734	53.109
30	1.0	2.694	115.8	0.961	0.0395	0.0000000000	2.768	39.369
408	1.7	0.956	120.0	0.888	0.1116	0.0000000000	2.482	35.301
475	1.9	5.390	113.0	0.980	0.0199	0.0000000008	3.082	43.835
511	2.0	5.649	110.0	0.981	0.0190	0.0000000030	3.698	52.597
561	2.0	0.970	120.0	0.890	0.1101	0.0000000000	2.479	35.259

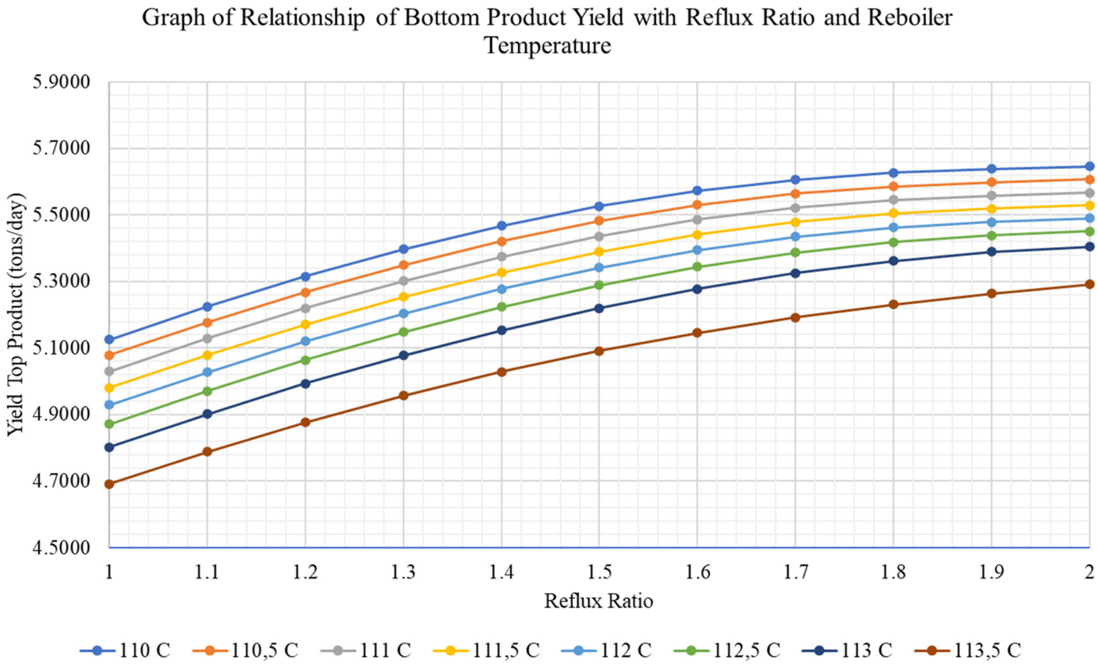

Figure 5
LPG product yield vs. reboiler temperature and reflux ratio graph

Based on Figure 5, it can be observed that the optimum point based on LPG product yield is located in the reboiler temperature of 110°C at reflux ratio 2.

After obtaining the trial data, it is processed to determine the optimum point revenue value. To determine the cost-effective condition, it is necessary to calculate the maximum profit with the appropriate product specifications. The profit is obtained by eliminating the cost of feed, pumping (reboiler and reflux), steam, and cooling water from the selling price of the product (LPG).

From trial-and-error data, an optimum point for the highest profit is at a reboiler temperature of 110°C and a reflux ratio of 2. The following is a comparison of operating costs and revenue between actual and post-optimization conditions:

Based on Table 11, it was found that the revenue increased from $18,444,932.92/year to $22,640,582.13/year. In other words, there was a 22.74% increase in profit from the pre-optimization.

The process optimization resulted in several significant changes compared to the actual conditions, showing an overall improvement in process performance. First, the reboiler temperature was reduced from 113.05°C to 110°C, a decrease of 3.05°C. This decrease in temperature can reduce energy consumption, which is consistent with the thermodynamic theory that a decrease in operating temperature can reduce heat demand in the reboiler. The reflux ratio has been increased from 0.99 to

Table 9
Actual vs. optimized capacity

Condition	**Capacity**		
	Feed	**Reboiler**	**Condenser**
Actual	Rp12,798,621	Rp12,013,987	-
Optimization	Rp12,798,621	Rp12,488,287	-

Actual vs. optimized income

Condition	**Income**	
	Off Gas	**LPG**
Actual	-	Rp809,404,467
Optimization	-	Rp988,349,040

Table 10
Actual vs. optimized income

Condition	**Profit Conversion**		
	Rp/Day	**Rp/Year**	**USD/Year**
Actual	Rp784,591,859	Rp286,376,028,521	$18,444,932.92
Optimization	Rp963,062,132	Rp351,517,678,131	$22,640,582.13

Table 11
Actual vs. optimized operating condition

Condition	**Reboiler Temp.**	**Refluks Rate**	**Pressure**	**Purity**	**Feed**	**Product LPG**	**Product Off Gas**
	°C	**tons/day**	**kg/cm²g**	**%Mass**	**tons/day**	**tons/day**	**tons/day**
Actual	113.05	0.99	18.74	97.7	83.7	59.96	23.73
Optimization	110	2	20	98.1	83.69	73.21	10.48

2. This increase means that the separation of the components in the distillation column has been improved. Theoretically, increasing the reflux ratio means that more liquid is returned to the column, increasing contact between the liquid and vapor phases and improving the purity of the final product (Sidabutar et al., 2020).

The pressure in the system also increased from 18.74 kg/cm² to 20 kg/cm². This increase in pressure enhances the distillation process by widening the boiling point difference between components. This aligns with the fundamental principle of distillation, where higher pressure can improve the efficiency of separating more easily vaporized components (Schack et al., 2020).

Product purity also increased from 97.7% to 98.1%, showing an improvement in the quality of the product produced. According to distillation theory, improved purity is usually the result of properly optimizing operating variables such as temperature, pressure, and reflux, which contribute to a more effective separation process. The purity obtained after optimizing meets the specifications.

LPG production increased significantly from 59.96 tons/day to 73.21 tons/day, an increase of 13.25 tons/day. This increase in production is a result of higher process efficiency and improved separation of the desired fractions. Meanwhile, off-gas production decreased from 23.73 tons/day to 10.48 tons/day, a decrease of 13.25 tons/day. This decrease in off-gas shows that more product is successfully converted to LPG, following the principle of mass efficiency in industrial processes.

As a result, the optimization process shows significant improvements in energy efficiency, product quality, and waste reduction. These outcomes are in line with the fundamental principles of distillation and process optimization theory.

In addition to optimizing for revenue value, it is also necessary to know the operating conditions after optimization to ensure that the operating conditions are running well and without interference. The following is the percent recovery of the bottom product obtained after optimization:

In comparison, the actual percent recovery (before optimization) is 57.50%, while 69.26% is achieved after optimization. Therefore, it can be stated that the C_3 and C_4 components that were successfully recovered increased by 11.76%, leading to an increase in the bottom product yield.

Table 12
Post-optimization C_3 and C_4 flow

	Feed	Product Off Gas	Product LPG
Propane (kg/h)	1172.5291	1047.4940	125.0352
Propene (kg/h)	377.4083	369.8920	7.5163
i-Butane (kg/h)	316.8616	4.5442	312.3174
i-Butene (kg/h)	264.7551	2.1162	262.6389
n-Butane (kg/h)	1729.3872	2.9398	1726.4474
t-Butene (kg/h)	163.3272	0.2355	163.0917
1-Butene (kg/h)	615.7252	4.0727	611.6525
cis-Butene (kg/h)	15.8357	0.0150	15.8208
Total	4655.8293	1431.3094	3224.5201

$$\% \, Recovery = \frac{C_3 + C_4 \, in \, bottom \, prod.}{C_3 + C_4 \, in \, feed} \, x \, 100\%$$
$$\% \, Recovery = \frac{3224.5201 \, kg/jam}{4655.8293 \, kg/jam} \, x \, 100\% \quad (10)$$
$$\% \, Recovery = 69.26\%$$

The simulation results show that there is no sign of weeping or flooding on each tray. This can be seen from the fact that all operating points are between the weeping and flooding boundaries. In addition, the comparison of operating points before and after optimization has better results. The operating points are further away from the flooding and weeping lines. Therefore, it can be concluded that the column works optimally without experiencing any problems in its operation in the post-optimization condition and has better satisfactory results.

CONCLUSIONS

In conclusion, based on the analysis presented in Aspen Hysys Simulation for LPG Production Optimization in Deethanizer Column: A Case Study in DCU showed that LPG yield was influenced by

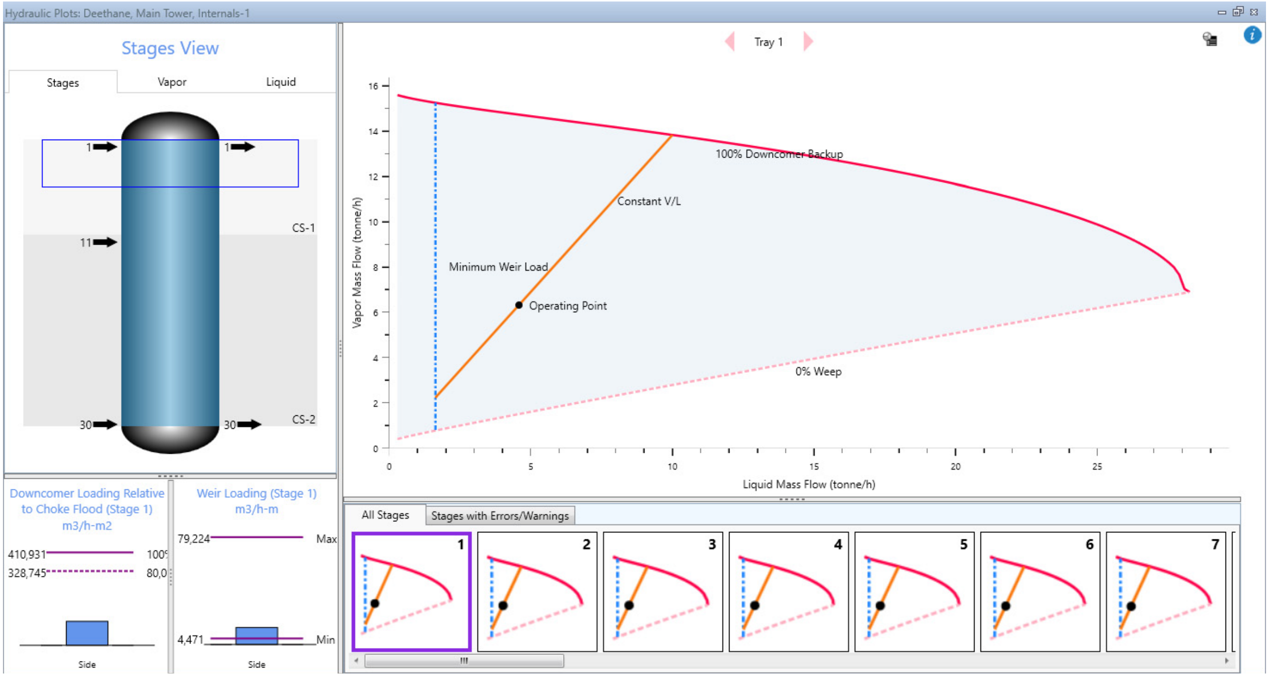

Figure 6
Post-optimization internal column

several factors, such as reflux ratio and reboiler temperature, closely related to the quality and quantity of the product produced. After the evaluation, the actual overall tray efficiency was 56.57%. The column can recover C_3 and C_4 components of the bottom product obtained from the feed by 57.50%. The bottom product (LPG) had a purity of 97.7%. After simulating the process using Aspen Hysys V14 software, it was found that under actual conditions neither weeping nor flooding occurred. After using the trial-and-error method, 561 data was obtained. Based on these data, optimization calculations were carried out regarding the point that generates the highest yield and the products in line with the specifications. Additionally, the most optimal point was at a reboiler temperature of 110°C with a reflux ratio of 2. From these conditions, the percentage of C_3 and C_4 recovery in the bottom product increased to 69.26%. The bottom product yield increased from 59.96 tons/day to 73.21 tons/day, which was 22.10% higher than the actual condition. In other words, there was an increase in the LPG production rate of 13.25 tons/day. The purity of the bottom product increased to 98.1%. However, the top product yield (off-gas) decreased from 23.73 tons/day to 10.48 tons/day. Economically, the profit increased from $18,444,932.92/year to $22,640,582.13/year, and there was an increase in profit of $4,195,649.21/year (22.74% compared to actual conditions).

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GLOSSARY OF TERMS

Symbol	Definition	Unit
R_m	Minimum reflux ratio	-
N_m	Minimum tray calculation	pcs
x_{LKT}	Composition of light key in top product	-
x_{HKT}	Composition of heavy key in top product	-
x_{LKB}	Composition of light key in bottom product	-
x_{HKB}	Composition of heavy key in bottom product	-
R_{ops}	Operating reflux ratio	-
R	Reflux ratio	-
N	Theoretical tray	pcs
η	Tray efficiency	%

REFERENCES

Agustina, N, 2020, Validation Method for Determination of Niclosamide Monohydrate in Veterinary Medicine Using Uv-Vis Spectrophotometry. Jurnal Ilmiah Farmako Bahari, 11(2), 153–160. www.journal.uniga.ac.id.

Amalia, Y., Erdiyanti, F.S. & Dewajani, H., 2023, Analisa Jumlah Stage Teoritis Pada Kolom Distilasi Pabrik Plasticizer. DISTILAT: Jurnal Teknologi Separasi, 5(1), 13–18. https://doi.org/10.33795/distilat.v5i1.9.

Artika, D.I., Sudarminto, H.P. & Wahyudi, F., 2023, Perhitungan Reflux Pada Kolom Iii Stasiun Distilasi Di Pt X Lumajang. DISTILAT: Jurnal Teknologi Separasi, 8(3), 532–539. https://doi.org/10.33795/distilat.v8i3.477.

Biasi, L.C.K., Batista, F.R.M., Zemp, R.J. & Meirelles, A.J.A.. 2020, Influence of the Liquid or Vapor Split Ratios in Meta- or Parastillation Columns. Industrial & Engineering Chemistry Research, 59(34), 15317–15331. https://doi.org/10.1021/acs.iecr.0c01966.

Debiase, R. & Elliott, J.D., 1982, Delayed coking: latest trends. Hydrocarbon Process. https://api.semanticscholar.org/CorpusID:93617740.

Gao, L., Zhao, Y., Yang, J., Zhang, H. & Wang, Y., 2024, Structure and calcination characteristics of green coke in different parts of the delayed coking tower. Journal of Analytical and Applied Pyrolysis, 177, 106378. https://doi.org/https://doi.org/10.1016/j.jaap.2024.106378.

Gutierrez, J.P., Alberto Benítez, L., Martínez, J., Ruiz, L.A. & Erdmann, E., 2014, Thermodynamic Properties for the Simulation of Crude Oil Primary Refining. Journal of Engineering Research and Applications Www.Ijera.Com, 4(4), 190–194. www.ijera.com.

Harji, A., Henderson, R.& Rodwell, M., 2005, Consider modifying your refinery to handle heavy opportunity crude oils. In Hydrocarbon Processing (Vol. 84, Issue 9, p. 54). http://www.hydrocarbonprocessing.com/IssueArticle/2598855/Archive/Consider-modifying-your-refinery-to-handle-heavy-opportunity-crude-oils.html%5Cnhttps://ill.library.umkc.edu/illiad/illiad.dll?Action%3D10&Form%3D75&Value%3D320128.

Haydary, J., 2018, Introduction to Computer-Aided Process Design and Simulation. In Chemical Process Design and Simulation (pp. 1–14). https://doi.org/https://doi.org/10.1002/9781119311478.ch1.

Market Research, 2023, Liquefied Petroleum Gas [LPG] Market Report By Source (Non-Associated Gas, Associated Gas, Refinery), By Application (Residential, Commercialt, Industrial, Transportation, Others), By Distribution Channel (Direct Sales, Distributor Sales, Online Sales) By. https://marketresearch.biz/report/liquefied-petroleum-gas-lpg-market/.

Mehairbi, M., Mahri, S. & Dadach, Z.E., 2020, Simulation of Stripper Flooding Due to the Increase of Feed Flowrate. World Journal of Engineering and Technology, 08, 443–455. https://doi.org/10.4236/wjet.2020.83033.

Peccini, A., Jesus, L.F.S., Secchi, A.R., Bagajewicz, M. J. & Costa, A.L.H., 2023, Globally optimal distillation column design using set trimming and enumeration techniques. Computers and Chemical Engineering, 174(January). https://doi.org/10.1016/j.compchemeng.2023.108254.

Rahima, A.A. & Dewi, E.N., 2020, Simulasi Pengaruh Reflux Ratio Pada Proses Pemurnian Etil Asetat Dengan Distilasi Ekstraktif Menggunakan Chemcad. Jurnal Chemurgy, 4(1), 6. https://doi.org/10.30872/cmg.v4i1.4071.

Sawarkar, A.N., Pandit, A.B., Samant, S.D. & Joshi, J.B., 2007, Petroleum residue upgrading via delayed coking: A review. Canadian Journal of Chemical Engineering, 85(1), 1–24. https://doi.org/10.1002/cjce.5450850101.

Schack, D., Jastram, A., Liesche, G. & Sundmacher, K., 2020, Energy-Efficient Distillation Processes by Additional Heat Transfer Derived From the FluxMax Approach. Frontiers in Energy Research, 8. https://www.frontiersin.org/journals/energy-research/articles/10.3389/fenrg.2020.00134.

Sembiring, S., Panjaitan, R.L., Susianto, S. & Altway, A., 2020, Pemanfaatan Gas Alam sebagai LPG (Liquified Petroleum Gas). Jurnal Teknik ITS, 8(2). https://doi.org/10.12962/j23373539.v8i2.47079.

Sidabutar, I., Widyasanti, A., Nurjanah, S., Nurhadi, B., Rialita, T. & Lembong, E., 2020, kajian rasio refluks pada isolasi beberapa senyawa minyak nilam (Pogostemon cablin Benth) dengan metode distilasi fraksinasi. Jurnal Ilmiah Rekayasa Pertanian Dan Biosistem, 8, 71–78. https://doi.org/10.29303/jrpb.v8i1.160.

Susmiati, Y., Purwantana, B., Bintoro, N. & Rahayoe, S., 2021, Kinerja Internal Reboiler Tipe Vertical Tubular Baffle pada Proses Distilasi Etanol secara Batch. Jurnal Rekayasa Proses, 15(1), 59. https://doi.org/10.22146/jrekpros.65483.

Yousuo, O.N. & Erefagha Rufus, T., 2020, Determination Of The Actual Number Of Stages In A Binary Distillation Column Using Excel. International Journal of Advanced Research and Publications, 4(1), 37–41. http://www.ijarp.org/published-research-papers/jan2020/Determination-Of-The-Actual-Number-Of-Stages-In-A-Binary-Distillation-Column-Using-Excel.pdf.

Zakharov, M.K., Egorov, A.V. m& Podmetenny, A. A., 2021, Liquid mixtures separation and heat consumption in the process of distillation. Tonkie Khimicheskie Tekhnologii, 16(1), 7–15. https://doi.org/10.32362/2410-6593-2021-16-1-7-15.