Optimization of Process Design and Operating Parameters of H_2S Removal Unit to Reduce Lean Amine Inlet Temperature of Amine Contactor at Upstream Oil and Gas Subsidiary SI

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ABSTRACT - Upstream Oil and Gas Subsidiary SI is a natural gas processing company that operates an H_2S removal unit to convert natural gas rich in CO_2 and H₂S into sweet gas. The main problem of this unit is the high temperature of lean amine entering the Amine Contactor. The purpose of this study is to determine the factors of high lean amine temperatures, evaluate the lean amine cooler, amine regenerator overhead cooler, and plate exchanger performance, and determine the optimal process design configuration and operating parameters. The method used is the simulation of the H_2S removal unit with Aspen HYSYS, followed by a comparative analysis between simulation data and equipment design data. The independent variables of this study include Reboiler duty, reflux ratio, and heat transfer area in the Plate Exchanger, with the main dependent variable being lean amine temperature. The results showed that the high lean amine temperature was caused by a decrease in the performance of the Lean Amine cooler and amine regenerator overhead cooler, as seen from the UA and LMTD values of the simulation results which were smaller than the design. In contrast, the Plate Exchanger still functions well with a UA value greater than the design. Optimization was carried out by adjusting the process design and operating parameters of the H_2S removal unit. The optimized design involves bypass reflux from the regenerator to the rich amine stream entering the rich/lean amine exchanger and increasing the heat transfer surface area of the plate exchanger to 62.17 m². The influential operating parameters are reboiler duty, liquid flow rate to the mixer, and plate exchanger heat transfer surface area. Optimal operating conditions were achieved at a Reboiler duty of 1,642 kW, a liquid flow rate of 1.4 m³/h, the reflux to Mixer ratio is 100%, and a heat transfer surface area of 62.17 m². In addition, it can be concluded that the optimization of process design and operating parameters successfully reduced the lean amine inlet temperature of the Amine Contactor.

Keywords: H_2S removal unit, lean amine temperature, operating parameters, optimization, process design.

INTRODUCTION

Upstream Oil and Gas Subsidiary SI is a company that processes natural gas. The company is located in an industrial area in Gresik, East Java. The company has a gas processing facility (Kurniawan 2024). This facility functions to process natural gas into sales gas (Mujiyanti 2018). There are several process units that play an important role in the gas processing facility (Kementerian Pendidikan dan Kebudayaan Republik Indonesia 2015). One of the process units that has a critical role in natural gas processing is the H_2S removal unit (Abdel-Aal 2003). This unit aims to process natural gas rich in acid gases like CO_2 and H_2S into sweet gas (Aziz et al. 2023). The H_2S removal unit at Upstream Oil and Gas Subsidiary SI uses an absorption-regeneration process with amine solvents. The operating conditions of the H_2S removal unit must always be maintained at certain limits (Fatimura & Fitriyanti 2018). This is because if the operating conditions of the H_2S removal unit are not maintained, it can interfere with the process in the H_2S removal unit (Sugihardjo 2022).

Based on available information, there is a problem in the H_2S removal unit. The problem is the high lean amine's temperature when it enters the Amine Contactor. Figure 1 shows that from January to February 2024, the lean amine's temperature as it enters the Amine Contactor was, on average, above 44°C. The highest temperature reached ± 46.5°C. Of course, this is not good for the absorption process. The optimal absorption process occurs at low temperatures and high pressure. In addition, the absorption process with amine solvents is a chemical absorption process, and the reaction is exothermic (Halimah et al. 2017). The outlet of the Amine Contactor will experience an increase in temperature; if the outlet temperature of the Amine Contactor is too high, it can cause the evaporation of the water content in the amine solvent, so more make-up demine water is needed (Jones 2016). For the Amine Contactor outlet, the gas temperature graph can be seen in Figure 2.

It is evident from Figure 2 that the average gas outlet temperature is above 49°C, and the highest temperature is 53°C. This temperature can vaporize most of the water in the amine solvent, damaging the amine solvent's composition (Giffari et al. 2021). Therefore, the temperature must be maintained under certain conditions so that the absorption process can run well. In this case, the company has tried to reduce the temperature of the lean amine entering the Amine Contactor by increasing the performance of the Lean Amine Cooler duty. However, the efforts were unsuccessful because, based on information from the operator, the duty of the lean amine cooler has been maximized. So, it can be seen that there is a problem with the performance of the Plate Exchanger and Cooler in the H_2S removal unit.
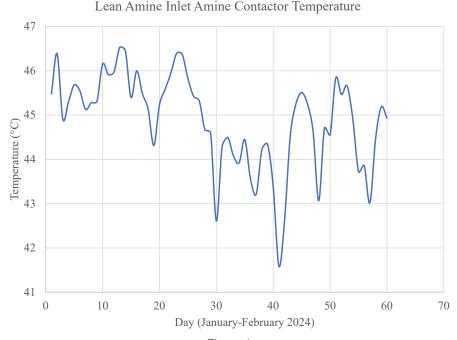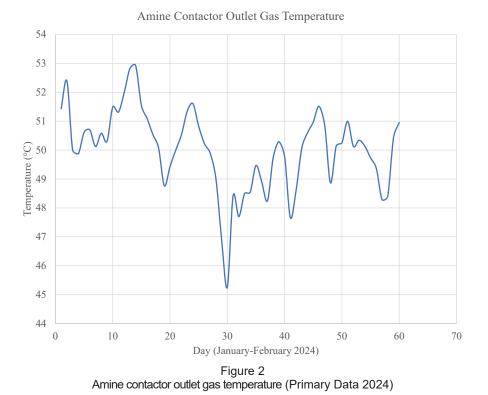

Figure 1
Temperature chart of lean amine inlet amine contactor (Primary Data 2024)

Figure 2
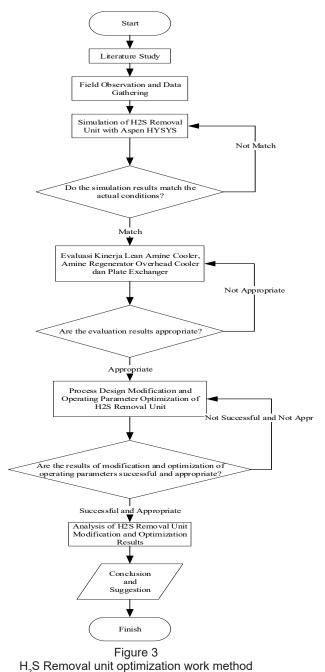Amine contactor outlet gas temperature (Primary Data 2024)

To solve this problem, an evaluation is needed to determine the cause of high lean amine temperatures and optimization to overcome high lean amine temperatures. If this is not done, it can disrupt the absorption process in the H_2S removal unit. Evaluation is aimed at the Lean Amine Cooler, Amine Regenerator Overhead Cooler, and Plate Exchanger to determine the performance of these equipment. Furthermore, optimization was carried out by adjusting the process design and operating parameters in the H_2S removal unit. Thus, it is possible to lower the lean amine temperature so that the process in the H_2S removal unit can run well. Therefore, researchers are interested in optimizing this unit. The objectives of this study are to determine the cause of the high temperature of lean amine inlet Amine Contactor, evaluate the performance of the Lean Amine Cooler, Amine Regenerator Overhead Cooler, and Plate Exchanger, get the proper process design configuration for the H_2S removal unit and determine the operating parameters that are influential in reducing the temperature of lean amine inlet Amine Contactor and get the optimum operating conditions.

METHODOLOGY

The object of this study is the H_2S removal unit located in the Gas Processing Facility Upstream Oil and Gas Subsidiary SI. The main process equipment reviewed are Amine Contactor, Amine Regenerator, Plate Exchanger, Lean Amine Cooler, and Amine Regenerator Overhead Cooler. The variables in this study include independent variables, namely Reboiler duty, reflux ratio, and heat transfer area in Plate Exchangers. The dependent variables are Regenerator top and bottom temperatures, flowrate and H_2S loading of lean amine out Regenerator, liquid flowrate from Amine Reflux Drum, Amine Regenerator Overhead Cooler duty, Regenerator inlet liquid temperature and volume, Mixer inlet liquid temperature and volume, lean amine out Plate Exchanger temperature, rich amine out Plate Exchanger temperature, Lean Amine Cooler duty, lean amine temperature inlet Amine Contactor, Amine Contactor out gas temperature and H_2S composition in sweet gas. For three months, this study was carried out, from January 2024 to March 2024. The objective function of this optimization is to lower the lean amine temperature inlet Amine Contactor. Meanwhile, the limiting function is the H_2S removal unit design operating condition data. The working method of this research seen in Figure 3.

Based on Figure 3, this research begins with conducting literature studies, field observations, and collecting the necessary field data. Then, an overview of the H_2S removal unit was undertaken to determine

the process in the unit. After that, a simulation of the H_2S removal unit is made where the simulation results must be close to the actual conditions (Michael 2021). If the results are appropriate, then proceed to evaluate the performance of the Lean Amine Cooler, Amine Regenerator Overhead Cooler, and Plate Exchanger. The next step is to modify the process design and optimize the operating parameters of the H_2S removal unit. The optimum conditions are analyzed if the modification and optimization are successful and the results are appropriate (Fuqoha 2012). After that, conclusions and suggestions are drawn on the H_2S removal unit optimization results.

The analysis method used in this optimization simulates the H_2S removal unit, followed by an analysis by comparing the simulation data and the equipment design data. H_2S removal unit simulation results must be close to actual conditions (Sopurta et al. 2014). Which aims to evaluate the performance of the Lean Amine Cooler, Amine Regenerator Overhead Cooler, and Plate Exchanger. Then, after modifying and optimizing the H_2S removal unit, the optimum conditions will be found by comparing the optimization data with the design data. If an optimum condition has been found, the optimization is declared successful and can be used as a recommendation for the company.

Figure 3
H_2S Removal unit optimization work method

RESULT AND DISCUSSION

Brief Description of H₂S Removal Unit Process

The process gas enters Amine Contactor Inlet KO Drum 135-V-01 and will be separated between liquid hydrocarbons and hydrocarbon gas. Liquid goes to the Liquid Separator while hydrocarbon gas enters Amine Contactor 135-V-06, where an exothermic process occurs with a temperature of 28.5°C and a pressure of 45.7 barg. In the Amine Contactor, sweet gas goes to the Amine Overhead Gas Knock Drum 135-V-09 with a temperature of 44.5°C and a pressure of 45.7 barg. After that, sweet gas goes to the TEG Regeneration System. Liquid from Knock Drum enters Amine Flash Drum 135-V-10, and rich amine enters Amine Flash Drum 135-V-10 with a temperature of 30.9°C and a pressure of 6 barg (full vacuum).

After that, rich amine from Flash Drum enters Rich Amine Filter 135-W-04. Then, from the Rich Amine Filter, enter the Rich Amine Exchanger 135-H-02 A/B. Then, it goes to Amine Regenerator 135-V-07 with a temperature of 94.7°C and a pressure of 0.8 barg (full vacuum). Then, the rich amine will be resolved into lean amine and acid gas. Acid gas goes from the Amine Regenerator Overhead Cooler (fin fan) to the Amine Reflux Drum 135-V-11. Amine is pumped to the Regenerator using the Reflux Pump, or amine enters the Amine Drain Vessel 135-V-14. In the Regenerator, there is an Amine Reboiler. Lean amine is pumped with a Hot Lean Amine Pump to the Lean Amine Exchanger. Lean amine goes to the Lean Amine Cooler then to Lean Amine Filter, Carbon Filter, and to Amine Surge Vessel. Then lean amine is pumped with a Lean Amine Pump 135-P-01 A/B with a pressure of 42.8 barg and a capacity of 45.5 m³/hr.

H₂S Removal Unit Simulation

Several data sets must be used to simulate the H₂S removal unit using Aspen HYSYS. These data are operating condition data, natural gas and amine composition data, design data, and mechanical design data of the H₂S removal unit (Adikharisma 2014). These data will be input to Aspen HYSYS (Yaws, 1999). Daily data is recapitulated for operating conditions from January 01, 2024, to February 29, 2024. Meanwhile, natural gas and amine composition data are monthly from January 2024 to February 2024. The following shows the average operating condition data and average natural gas and amine composition data used in the H₂S removal unit simulation:

Operating Condition Data

Table 1
H₂S removal unit average operating condition data
(Primary Data 2024)

Process Variable	Value	Units
Lean Amine Pressure Inlet Amine Contactor	33.85	Barg
Lean Amine Flow Inlet Amine Contactor	24.91	m³/hr
Sales Gas Flow	22.85	MMSCFD
GPF Fuel Gas Flow	1.77	MMSCFD
LPGF Fuel Gas Flow	1.23	MMSCFD
Amine Overhead Gas KO Drum Pressure Outlet	33.62	bag
Acid Gas Pressure Outlet Amine Flash Drum	4.02	barg
Amine Reflux Drum Outlet Pressure	0.39	barg
Lean Amine Flow Inlet Amine Surge Vessel	31	m³/hr
Reflux Flow from Amine Reflux Drum	1.6	m³/hr
Amine Reboiler Heating Medium Flow	75.62	m³/hr
Hot Lean Amine Flow	25.56	m³/hr
Temperature at Amine Contactor Tray 4	47	°C
Temperature at Amine Contactor Tray 9	52.99	°C
Temperature at Bottom Amine Contactor	44.75	°C
Temperature at Amine Contactor Tray 1	49.53	°C
Temperature at Amine Contactor Tray 12	48.88	°C
Gas Temperature Inlet Amine Contactor	34.25	°C
Gas Temperature Outlet Amine Contactor	50.02	°C
Lean Amine Temperature Inlet Amine Contactor	44.88	°C
Gas Temperature Outlet Amine Regenerator	98.54	°C
Amine Regenerator Bottom Temperature	118.2	°C
Amine Flash Drum Inlet Temperature	41.93	°C
Rich Amine Temperature Outlet Amine Exchanger	94.72	°C

Table 1 (continued)
H_2S removal unit average operating condition data
(Primary Data 2024)

Process Variable	Value	Units
Amine Temperature Inlet Amine Regenerator	91.01	°C
Temperature at Amine Regenerator Trays 7 & 8	111.18	°C
Temperature at Amine Regenerator Tray 15 & 16	118.01	°C
Temperature Outlet Amine Regenerator Overhead Cooler	32.73	°C
Analyzer H_2S in Treated Gas	5.33	ppm

Table 1 above is the average data of H_2S removal unit operating conditions. The data will be used as input in the simulation of the H_2S removal unit in Aspen HYSYS.

Natural Gas Composition Data

Table 2
Average natural gas composition data
(Primary Data 2024)

Composition	% mol or ppm
C_1	77.2335 % mol
C_2	7.0905 % mol
C_3	5.8145 % mol
iC_4	1.311 % mol
nC_4	1.4205 % mol
iC_5	0.354 % mol
nC_5	0.2135 % mol
C_{6+}	0.224 % mol
N_2	2.4005 % mol
CO_2	3.938 % mol
H_2S	410 ppm

Table 2 above shows the average natural gas composition data processed in the H_2S removal unit. This data will be used as input in the simulation of the H_2S removal unit in Aspen HYSYS.
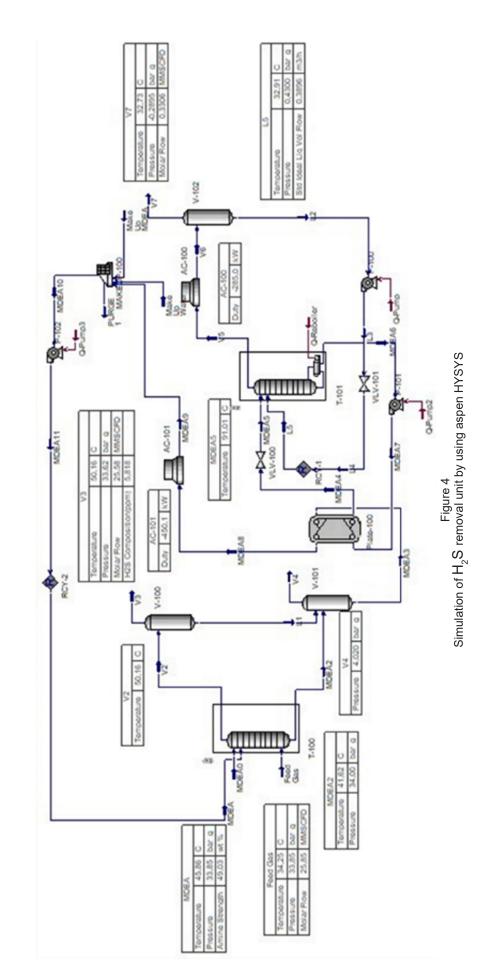
Amine Composition Data

Table 3
Amine composition mean data
(Primary Data 2024)

Composition	% wt or ppm
MDEA	42.885 % wt
HC	11.9 ppm
H_2O	57.11381 % wt

Table 3 above shows the average amine composition data used in the H_2S removal unit. This data will be used as input in the simulation of the H_2S removal unit in Aspen HYSYS.

A display of simulation results of the H_2S removal unit using Aspen HYSYS can be seen in Figure 4. The simulation results have described the actual situation (Aulia 2022). This simulation can be used to evaluate the performance of the Lean Amine Cooler, Amine Regenerator Overhead Cooler and Plate Exchanger and can be used as a basis for modifying the design of the H_2S removal unit.

Based on the simulation results, it can be seen that the process equipment related to the lean amine temperature inlet Amine Contactor is a Plate Exchanger, Amine Regenerator Overhead Cooler, and Lean Amine Cooler. Researchers suspect there are problems with these three equipment, so if the performance of these equipment decreases, it can cause heat transfer in these equipment not to run optimally. As a result, the lean amine temperature becomes higher. In addition, weather factors can affect the performance of the fin fan Cooler, such as the air temperature around the Upstream Oil and Gas Subsidiary SI. A more detailed discussion related to the performance of the Plate Exchanger, Amine Regenerator Overhead Cooler, and Lean Amine Cooler can be seen in the next discussion.

Optimization of Process Design and Operating Parameters of H2S Removal Unit to Reduce Lean Amine Inlet Temperature of Amine Contactor at Upstream Oil and Gas Subsidiary SI (Budi Sulistiyo Nugroho et al.)

Figure 4
Simulation of H$_2$S removal unit by using aspen HYSYS

Performance Evaluation of Lean Amine Cooler, Amine Regenerator Overhead Cooler, and Plate Exchanger

Evaluation of the Lean Amine Cooler, Amine Regenerator Overhead Cooler, and Plate Exchanger is intended to determine the performance of the three equipment and to answer the cause of the high temperature of lean amine inlet Amine Contactor (Mahfud & Sabara 2018). The following displays the evaluation findings for the Lean Amine Cooler, Amine Regenerator Overhead Cooler, and Plate Exchanger.

Table 4
Lean amine cooler performance evaluation

Parameter	Simulation	Design	Description
UA (W/°C)	24,967.91	58,287.75	Smaller than design indicates poor Cooler performance
Duty (W)	450,097.03	645,000	Duty has not been used at all
LMTD (°C)	0.38	14	There is a huge difference

According to Table 4, the simulated UA value is smaller than the design, which indicates that the performance of the Lean Amine Cooler is not good. In addition, the Lean Amine Cooler duty is only used 450.10 kW out of 645 kW which means that the Lean Amine Cooler should be able to perform the lean amine cooling process. There is also the LMTD factor which can indicate the performance of the Lean Amine Cooler, LMTD which has a significant difference indicates poor Lean Amine Cooler performance (McCabe et al. 1993).

Table 5
Performance evaluation of amine regenerator overhead cooler

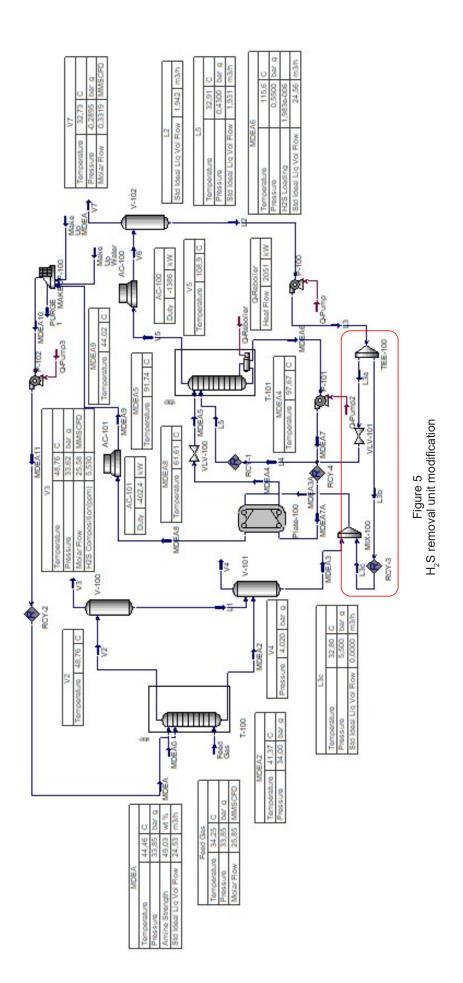| Parameter	Simulation	Design	Description
UA (W/°C)	22,333.75	44,635.55	Smaller than design indicates poor Cooler performance
Duty (W)	285,019.61	1,066.300	Duty has not been used all
LMTD (°C)	-3.96	29.1	There is a vast difference.

Table 5 shows that the simulated UA value is smaller than the design, indicating the performance of the Amine Regenerator Overhead Cooler is not good. In addition, the duty used is only 285.02 kW out of 1,066.3 kW. This means that the Cooler is still capable of cooling to its maximum temperature. The LMTD value is also far from the design which indicates that the performance of the Amine Regenerator Overhead Cooler is not good (McCabe et al., 1993).

Table 6
Plate exchanger performance evaluation

Parameter	Simulation	Design	Description
UA (W/°C)	56,505.55	55,469.39	Larger than design, Plate Exchanger performance in good condition

According to Table 6, it is evident that the Plate Exchanger performance is in good condition because the simulation UA value is greater than the design. So, it can be said that only a small amount of fouling in the Plate Exchanger inhibits heat transfer. Since only the Lean Amine Cooler and Amine Regenerator Overhead Cooler perform poorly, researchers recommend maintenance and cleaning of the two Coolers. Fouling may hinder heat transfer in the Cooler (Smith et al. 2005). In addition, the fin fan can be checked to see whether it is damaged which can reduce the cooling power of the cooler (Wuryanti 2016). There is also a weather factor. If the weather is hot, the cooling air used will cause the cooling process by the Cooler fin fan to be less than optimal and vice versa.

Figure 5
H$_2$S removal unit modification

H$_2$S Removal Unit Process Modification

After knowing the cause of the high lean amine inlet temperature of the Amine Contactor and having also been given recommendations related to the problematic equipment, the researcher tried to find other alternatives to reduce the lean amine inlet temperature of the Amine Contactor. The alternative formulated was to create a reflux bypass from the Regenerator to the rich amine stream entering the Rich/Lean Amine Exchanger and add heat transfer surface area in the Plate Exchanger (Alexander n.t.). This process modification uses the existing design base but there is only the addition of bypass flow and heat transfer surface area in the Plate Exchanger in this case the addition of the number of plates. The increase in the number of plates is based on the number of plates which now only amounts to 83 plates while the Plate Exchanger capacity is 109 plates. That is, if the number of plates is filled to 109 plates, it can increase the heat transfer surface area from 50.2 m^2 to 62.17 m^2. The display of the modified H$_2$S removal unit seen in Figure 5.

It is evident from Figure 5 that there are additional components in the modified H$_2$S removal unit, namely, Splitter and Mixer. In the simulation, it can be seen that the output of the Reflux Pump will be divided into two streams with a specific flow ratio (shown in the red box). The flow partly flows to the Amine Regenerator and partly flows to the Mixer inlet Rich/Lean Amine Exchanger. The purpose of this H$_2$S removal unit modification is to reduce the outlet temperature of the Rich/Lean Amine Exchanger so that the outlet temperature of the Lean Amine Cooler will drop. In this case, the assumption used in the simulation is the performance of the Lean Amine Cooler which is considered the same as the field situation. So that later the outlet temperature of the Lean Amine Cooler can be known when the performance of the Lean Amine Cooler is still the same as the field situation (Rahmatika et al. 2019).

From the simulation results, it can be seen that the simulation has converged, which means that the simulation was successful. Based on the review of the researchers, there is an influence of the results of the modification of the H$_2$S removal unit with the temperature of the lean amine inlet Amine Contactor. The effect is a decrease in the temperature of the lean amine inlet Amine Contactor. However, the reduction in temperature needs to be studied again by means of trials of certain variables to find the optimum conditions. The optimum condition of the H$_2$S removal unit will be determined in the following discussion.

H$_2$S Removal Unit Operating Parameter Optimization

Optimization of H$_2$S removal unit operating parameters is intended to obtain optimum operating conditions in the H2S removal unit in order to reduce the temperature of lean amine inlet Amine Contactor (Edgar et al. 2001). This optimization is carried out by trial and error on Aspen HYSYS simulation where a trial of Reboiler duty from 1026-2052 kW, reflux ratio to Regenerator and Mixer 100%, 80%, 60%, 40%, 20% and 0%, and Plate Exchanger surface area 50.2 m^2 and 62.17 m^2. From the results of trial and error, the most optimum condition will be sought, with the objective function being the low lean amine inlet temperature of the Amine Contactor. The constraints used in the optimization are the H$_2$S removal unit design operating conditions. The following shows the results of the optimization of H$_2$S removal unit operating parameters:

Table 7
H_2S removal unit operating parameter optimization results

Parameter	Actual	Design	Optimization	Description
Reboiler Duty (kW)	1,026	Max. 3,893.4	1,642	Meet
Reflux Ratio (To Regenerator, %)	100	Max. 100	0	Design Optimization Results
Plate Exchanger Surface Area (m^2)	50.2	Max. 62.17	62.17	Meets
Regenerator Bottom Temperature (°C)	115.6	Max. 118.6	115.6	Meets
Regenerator Top Temperature (°C)	98.48	Min. 94.7	107.7	Meets
Flowrate Lean Amine Out Regenerator (m^3/h)	24.56	Max. 48.2	24.58	Meets
H2S Loading Lean Amine Out Regenerator	0.00006955	-	0.00000577	Meets
Liquid Flowrate from Amine Reflux Drum (m^3/h)	0.3883	Max. 1.52	1.4	Meets
Liquid Temperature Inlet Regenerator (°C)	32.91	Max. 48.9	0	Design Optimization Results
Liquid Volume Inlet Regenerator (m^3/h)	0.3890	Max. 1.52	0	Design Optimization Result
Liquid Temperature Inlet Mixer (°C)	0	Max. 48.9	32.8	Design Optimization Result
Liquid Volume Inlet Mixer (m^3/h)	0	Max. 1.52	1.41	Design Optimization Result
Lean Amine Temperature Out Plate Exchanger (°C)	65.07	Max. 150	60.26	Meets
Rich Amine Temperature Out Plate Exchanger (°C)	94.72	Max. 150	95.54	Meets
Lean Amine Cooler Duty (kW)	450.20	Max. 645	384	Meets
Amine regenerator Overhead Cooler Duty (kW)	284.10	Max. 1,0066.3	1,002	Meets
Lean Amine Temperature Inlet Amine Contactor (°C)	45.92	Min. 41.63	43.8	Meets
Gas Temperature Out Amine Contactor (°C)	50.15	Min.44.1	48.12	Meets
H2S Composition in Sweet Gas (ppm)	6.262	16	5.504	Meets

According to Table 7, it is evident that there is an influence between the addition of Plate Exchanger surface area on the lean amine temperature of Plate Exchanger output, Lean Amine Cooler duty, lean amine temperature inlet Amine Contactor, and Amine Contactor output gas temperature. Adding a Plate Exchanger surface area of 62.17 m^2 will cause a decrease in Plate Exchanger output lean amine temperature, Lean Amine Cooler duty, lean amine temperature inlet Amine Contactor, and Amine Contactor output gas temperature. However, the addition of the Plate Exchanger surface area, results in an increase in the duty of the Amine Regenerator Overhead Cooler which is due to an increase in the rich amine temperature of the Plate Exchanger output (Christie & Geankoplis 1983).

From the previous explanation, it can be concluded that the increase in Reboiler duty, the increase in heat transfer surface area on the Plate Exchanger, and the more liquid flowing into the Mixer can reduce the Plate Exchanger output lean amine temperature, Lean Amine Cooler duty, lean amine temperature inlet Amine Contactor, and Amine Contactor output gas temperature. Thus, the independent variables that have been determined are appropriate for optimizing the operating parameters in the H$_2$S removal unit.

In addition, Table 7 shows the optimum operating conditions for reducing the lean amine temperature inlet Amine Contactor. The optimum condition is the Reboiler duty of 1,642 kW, the Amine Reflux Drum output liquid flowrate is 1.4 m^3/hr, and the reflux ratio is all fed into the Mixer. With these optimum conditions, the Amine Regenerator Overhead Cooler duty obtained is 1,002 kW, the lean amine temperature output from the Plate Exchanger is 60.26°C, the rich amine temperature output from the Plate Exchanger is 95.54°C, the duty of the Lean Amine Cooler is 384 kW, the inlet temperature of the lean amine in the Amine Contactor is 43.8°C, the Amine Contactor outlet gas temperature is 48.12°C, and the H$_2$S composition is 5,504 ppm.

Compared with the design data sheet, the optimization result for the Reboiler duty is 1,642 kW while the design is 3.8934 MW, which means that not all of the Reboiler duty has been used so the optimization results are valid. For the Amine Reflux Drum output liquid flowrate parameter, the optimization result is 1.4 m^3/hr while the average capacity of the Amine Reflux Pump design is 1.52 m^3/hr. This means that the pump capacity can still pump liquid to the Mixer. In addition, the duty of the Amine Regenerator Overhead Cooler optimization result is 1,002 kW while the design is 1,066.3 kW. This means that the Cooler is still able to operate under optimized conditions. For the last parameter, namely the Lean Amine Cooler duty, the optimization condition is obtained at 384 kW while the design is 645 kW. This means the Cooler workload is still far from the maximum design limit and can still carry out the cooling process.

For the parameters of lean amine temperature output from the Plate Exchanger, lean amine temperature inlet Amine Contactor, and Amine Contactor outlet gas temperature when compared to actual data, there is a decrease from actual conditions which means that the optimization was successful. The output lean amine temperature from the Plate Exchanger optimization results is 60.26°C while the actual is 65.07°C. There is a decrease of 4.81°C in the output lean amine temperature from the Plate Exchanger. For the lean amine inlet temperature of the Amine Contactor, the optimization result is 43.8°C while the actual is 45.86°C, which means a temperature decrease of 2.06°C. In addition, for the Amine Contactor outlet gas temperature, the optimization results were obtained at 48.12°C while the actual was 50.16°C, which means there was a decrease in temperature of 2.04°C. From the discussion above, it can be concluded that the optimization of the process design and operating parameters of the H$_2$S removal unit was successfully carried out to reduce the temperature of the lean amine inlet Amine Contactor.

CONCLUSION

It is evident from the simulation results and the aforementioned analysis that the cause of the high lean amine inlet temperature of the Amine Contactor is a decrease in the performance of the Amine Regenerator Overhead Cooler and Lean Amine Cooler. The evaluation results of the Lean Amine Cooler and Amine Regenerator Overhead Cooler show poor performance because the simulated UA and LMTD values are smaller than the design UA and LMTD. While the performance of the Plate Exchanger is still in good condition because the simulated UA is greater than the designed UA. Optimization of process design and operating parameters of the H$_2$S removal unit was successfully carried out to reduce the lean amine inlet temperature of the Amine Contactor. The appropriate H$_2$S removal

unit process design configuration is to create a reflux bypass from the Regenerator to the rich amine stream entering the Rich/Lean Amine Exchanger and increase the heat transfer surface area of the Plate Exchanger to 62.17 m^2. The influential operating parameters are the duty of the Reboiler, the liquid flowrate flowing into the Mixer, and the addition of heat transfer surface area on the Plate Exchanger. The optimum H$_2$S removal operating condition is the Reboiler duty of 1,642 kW, the Amine Reflux Drum output liquid flowrate is 1.4 m^3/hr, the reflux ratio is all put into the Mixer, and the Plate Exchanger heat transfer surface area is 62.17 m^2.

The researcher also provided suggestions to the company in the form of installing a temperature indicator to measure the outlet air temperature of the Cooler, performing maintenance and cleaning of the Lean Amine Cooler and Amine Regenerator Cooler, making a reflux bypass from the Regenerator to the rich amine stream entering the Rich/Lean Amine Exchanger to get a lower lean amine temperature inlet Amine Contactor, and increasing the number of plates to 109 plates on the Plate Exchanger so that the heat transfer surface area becomes 62.17 m^2.

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GLOSSARY OF TERMS

Symbol	Desinition	Unit
MDEA	Methyl Diethanol Amine	
HC	Hydrocarbon	
UA	Heat Transfer Coefficient	W/^{o}C
LMTD	Log Mean Temperature Difference	^{o}C

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