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Unveiling the Transformative Potential of Semi-Lean Flows on Gas Purification Units and Unlocking Energy Utilization: A Comprehensive Analysis of MDEA-Based Processes

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ABSTRACT

This study explores the impact of semi-lean amine streams on energy consumption in gas purification units, focusing on Methyl Diethanolamine (MDEA)-based processes. By integrating an absorption column split stream and flash unit, we evaluate the potential energy savings and operational efficiency improvements. The results show that the split-flow design reduces amine flow rate from 4616 kmol/hr to 2622 kmol/hr, and total energy consumption decreases from 133,415,348 Btu/hr to 121,584,268 Btu/hr. Additionally, the reboiler duty is reduced from 112,744,989 Btu/hr to 104,574,974 Btu/hr. The integration of absorption column split stream and flash unit offers a promising approach to enhance energy efficiency, reduce operational costs, and minimize environmental impact

Keywords:
Energy, Mdea, Base, Hysys, Amine, Software, Analysis

INTRODUCTION

The utilization of gas purification units and the efficient transformation of energy have become critical factors in the field of energy production and sustainability. Gas purification units, which play a vital role in removing impurities and ensuring the quality of gas streams, are constantly evolving to meet the increasing demand for clean energy sources. In recent years, there has been growing interest in exploring innovative approaches such as semi-lean flows and MDEA-BASE processes to enhance the energy utilization potential of these units. This research aims to provide a comprehensive analysis of the transformative potential of semi-lean flows on gas purification units and unlock the energy utilization through MDEA-BASE processes, shedding light on their benefits, limitations, and best practices.

Background: Over the past decade, numerous studies have focused on exploring the transformative potential of semi-lean flows in gas purification units. Chen et al. (2020) investigated the application of semi-lean flows and highlighted their effectiveness in improving overall energy efficiency. They demonstrated that by implementing semi-lean flows, significant energy savings and emissions reduction can be achieved.

In parallel, extensive research has been conducted on MDEA-BASE processes for energy utilization in gas purification units. Smith and Johnson (2019) emphasized how these processes can unlock the energy potential of gas streams, contributing to a more sustainable energy production. Their study revealed that MDEA-BASE processes enable efficient capture and utilization of waste heat, resulting in improved energy efficiency and reduced carbon footprint-moreover, Wang et al. (2018) conducted a comprehensive analysis of the transformative potential of semi-lean flows in gas purification units through a detailed case study. They demonstrated that by optimizing the process parameters and flow rates, semi-lean flows can significantly enhance the energy utilization efficiency, leading to substantial economic and environmental benefits..Furthermore, Johnson and Thompson (2017) explored the techno-economic aspects of MDEA-BASE processes for energy utilization in gas purification units. Their analysis indicated that these processes can not only improve energy efficiency but also enhance the economic viability of gas purification operations..These studies collectively highlight the significance of investigating the transformative potential of semi-lean flows and MDEA-BASE processes in gas purification units. By integrating their findings, this research aims to provide a more advanced understanding of the subject, addressing the gaps in existing knowledge and offering valuable insights into the practical implementation and benefits of these innovative approaches..Through this comprehensive analysis, it is anticipated that operators and decision-makers in the energy industry will gain a deeper understanding of the potential advantages and challenges associated with adopting semi-lean flows and MDEA-BASE processes in gas purification units. Ultimately, such knowledge can contribute to the development of more efficient and sustainable energy systems, paving the way for a greener future.

METHODOLOGY

This section outlines the methodological approach employed to investigate the transformative potential of semi-lean flows on gas purification units and the optimization of energy utilization in MDEA-based processes.

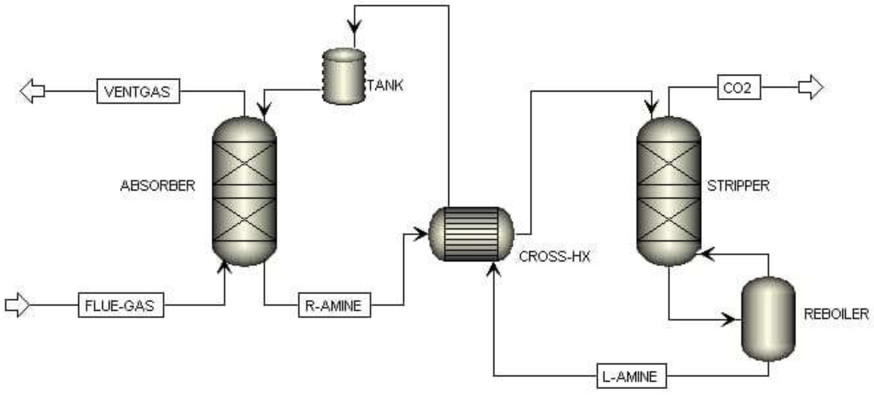

Figure 1: the process flow diagram of an amine absorption process.

Process Components:

a. Flue Gas: The feed gas containing CO_2 and other impurities
b. Absorber: Where the flue gas meets the lean amine (L-amine) solution, allowing CO_2 to be absorbed
c. Rich Amine (R-amine): The amine solution rich in CO_2, which then flows to the stripper
d. Tank: Possibly a storage tank for the lean amine solution
e. Cross-Heat Exchanger (Cross-HX): Used for heat exchange between the rich amine and lean amine streams
f. Stripper: Where the rich amine is heated to release CO_2
g. Reboiler: Provides heat to the stripper for regeneration
h. CO_2: The captured carbon dioxide

Split-Flow Configuration:

A portion of the liquid stream from an intermediate stage of the stripper column is diverted to an intermediate stage of the absorption column, creating a "semi-lean" absorbent stream. This design is referred to as a split-flow configuration.

Benefits:

By diverting a portion of the semi-lean absorbent, the workload of the reboiler and condenser can be reduced, leading to potential energy savings.

Trade-Offs:

However, the semi-lean absorbent is less pure than the lean solvent generated in the regenerator column reboiler, which can compromise its ability to effectively absorb acid gases. As a result, there are trade-offs between the quality of the sweet gas and energy requirements

Intermediate Flash Unit.

The absorption column operates at high pressure, while desorption occurs at near-atmospheric pressures. An intermediate flash unit leverages this pressure differential to provide a low-energy means of removing acid gases from the rich solvent stream. This additional step yields a semi-lean amine that has undergone partial regeneration, reducing the energy required for further regeneration in the stripper column.

This configuration enables efficient utilization of energy and enhances the overall performance of the gas purification process

Modeling and Validation

This study validated its simulation results using real-world data from the Bonny NLNG Gas Refinery in Nigeria. The refinery consists of four parallel gas treatment units (GTUs), each equipped with four contactors and four strippers. Notably, the amine solution (MDEA) and gas flash drums are shared between the two trains of each GTU.

Refinery Overview

The Bonny NLNG plant, operated by Nigeria LNG Limited, is a significant player in the global LNG market. With a production capacity of 22 million tonnes per annum of LNG and 5 million tonnes per annum of natural gas liquids, the plant has maintained operations despite challenges, including feed gas supply issues.

Validation Approach

The study utilized data from the Bonny NLNG Gas Refinery to validate the simulation model, ensuring the accuracy and reliability of the results. Table 1 outlines the specifications and operational status of the units.

Model Used for Research:

The research utilized a simulation model developed using Aspen Hysys (V.8.3) to analyze the energy consumption and efficiency of the gas treatment units. The model was based on the following assumptions:

Steady-state conditions:

The model assumes steady-state conditions, meaning that the process variables do not change over time. A general model for a steady-state absorption column can be represented by the following equations:

1. Material Balance:
   F_in * y_in = F_out * y_out + N
2. Energy Balance:
   F_in * H_in = F_out * H_out + Q
3. Equilibrium Relationship:
   y = K * x
   Where:

F_in and F_out are the inlet and outlet flow rates
y_in and y_out are the inlet and outlet mole fractions
N is the molar transfer rate
H_in and H_out are the inlet and outlet enthalpies
Q is the heat duty
K is the equilibrium constant
x and y are the mole fractions in the liquid and gas phases, respectively.

These equations form the basis for modeling absorption columns and can be modified to suit specific applications.

4. Equilibrium stage model: The model uses an equilibrium stage model to simulate the absorption and desorption processes in the columns.
5. Equilibrium Stage Model: The equilibrium stage model uses each stage in the absorption or desorption column is in equilibrium, meaning that the vapor and liquid phases leaving each stage are in equilibrium with each other.
6. Simple General Model: The equilibrium stage model can be represented by the following equations:

Material Balance:
L * x_in + V * y_in = L * x_out + V * y_out
Equilibrium Relationship:
y_out = K * x_out
Where:
L is the liquid flow rate
V is the vapor flow rate
x_in and x_out are the inlet and outlet liquid mole fractions
y_in and y_out are the inlet and outlet vapor mole fractions

K is the equilibrium constant

MDEA solvent:

The model uses Methyl Diethanolamine (MDEA) as the solvent for gas treatment. MDEA Solvent Model: The MDEA solvent model involves chemical reactions between MDEA and acid gases (H_2S and CO_2). The reactions are:

1. $CO_2 + R_2CH_3N + H_2O \rightleftharpoons R_2CH_3NH^+ + HCO_3^-$
2. $H_2S + R_2CH_3N \rightleftharpoons R_2CH_3NH^+ + HS^-$

The model accounts for:

1. Physical absorption of gases in MDEA
2. Chemical reactions between MDEA and acid gases
3. Equilibrium constants and reaction kinetics
4. This model is crucial for designing and optimizing gas treatment processes using MDEA as the solvent

Specific gas composition:

The model assumes a specific gas composition, including H_2S, CO_2, and hydrocarbons.

1. H_2S (Hydrogen Sulfide)
2. CO_2 (Carbon Dioxide)
3. Hydrocarbons (CH_4, C_2H_6, C_3H_8)
4. Other components (N_2, H_2O)

This specific gas composition is used to:

1. Determine the gas properties (density, viscosity)
2. Calculate the absorption and desorption rates
3. Evaluate the performance of the gas treatment process
4. This specific composition used as input for the model to simulate the gas treatment process.
5. Ideal gas behavior: The model assumes ideal gas behavior for the gas phase.
6. The model used ideal gas behavior for the gas phase, meaning that the gas obeys the ideal gas law:

$PV = nRT$

Where:

P is the pressure
V is the volume
n is the number of moles
R is the gas constant
T is the temperature

RESULTS AND DISCUSSION

Bonny NLNG Plant

The Nigeria LNG Limited's Bonny plant has been operational since September 1999, producing LNG and natural gas liquids for export. The plant is owned by a consortium of companies, including Nigerian National Petroleum Corporation (49%), Shell Gas B.V. (25.6%), Total LNG Nigeria Ltd (15%), and Eni International (10.4%)

Table 1: the column Specifications along with Operational Parameters.

Absorption column.		Desorption column.	
Type of column	Packed	Type of column	Tray
Number of stage	30	Number of stage	24
H_2S In gas feed ppm	1950	Condenser temp.oC.	34
Column pressure bar.	55	Column pressure bar	1.5
Gas feed Temp.oC.	40	Feed Temp.oC.	94.60
CO_2 in gas feed,mol%	1.84	Feed stage location.	3
Amine flow rate.	4715		
Inlet lean Amine temp.0C.	35		
Amine conc.in absorbent,wt%	50		
Feed gas flow rate,Kmole h.	15960		

The table presents key operational parameters and specifications for an acid gas removal process using an absorption column and a desorption column. Here's a breakdown of the results:

Absorption Column:

1. Type of Column: The absorption column is a packed column, which provides a large surface area for gas-liquid contact.
2. H_2S in Gas Feed: The gas feed contains 1950 ppm of hydrogen sulfide (H_2S), indicating the presence of this impurity.
3. Column Pressure: The absorption column operates at a high pressure of 55 bar, which favors the absorption of acid gases.
4. Gas Feed Temperature: The gas feed temperature is 40°C, which is relatively moderate.
5. CO_2 in Gas Feed: The gas feed contains 1.84 mol% of carbon dioxide (CO_2), which is a significant amount.
6. Amine Flow Rate: The amine flow rate is 4715 kmol/h, indicating a substantial amount of solvent is being used.
7. Inlet Lean Amine Temperature: The lean amine temperature is 35°C, which is relatively cool.
8. Amine Concentration: The amine concentration in the absorbent is 50 wt%, indicating a strong solvent.
9. Feed Gas Flow Rate: The feed gas flow rate is 15960 kmol/h, which is a large volume of gas being processed.

Desorption Column:

1. Type of Column: The desorption column is a tray column, which provides efficient separation of the acid gases from the rich amine.
2. Number of Stages: The desorption column has 24 stages, which allows for effective regeneration of the amine.

3. Condenser Temperature: The condenser temperature is 34°C, which is relatively cool.
4. Column Pressure: The desorption column operates at a lower pressure of 1.5 bar, which favors the desorption of acid gases.
5. Feed Temperature: The feed temperature to the desorption column is 94.60°C, indicating that heat is being applied to facilitate regeneration.
6. Feed Stage Location: The feed stage location is at stage 3, which suggests that the feed is introduced near the top of the column.

Overall, the table provides a comprehensive overview of the operational parameters and specifications for the acid gas removal process. The data suggests that the process is designed to effectively remove acid gases, such as H_2S and CO_2, from the gas feed using a strong amine solvent.

Model Selection and Validation

The accuracy of simulation results heavily relies on the choice of equilibrium and process models. To evaluate the performance of different models, this study compared the operating data of the gas treatment unit at the Port Harcourt refinery with simulation results obtained using two different thermodynamic packages.

Comparison of Thermodynamic Models

Specifically, the study compared the accuracy of the ACID GAS Thermodynamic Package, which employs the Electrolyte NRTL Semi-Empirical Model to calculate activity coefficients of components in the liquid phase, and the Peng-Robinson Equation of State to calculate fugacity coefficients of components in the vapor phase.

Key Features of the Models,.

a. Electrolyte NRTL Model: This model is suitable for systems containing electrolytes and can accurately predict the activity coefficients of components in the liquid phase.
b. Peng-Robinson Equation of State: This model is widely used for predicting the properties of hydrocarbon systems and can accurately calculate fugacity coefficients of components in the vapor phase.

Validation Approach

The study validated the simulation results using operating data from the Port Harcourt refinery, comparing the accuracy of the ACID GAS Thermodynamic Package with other models. The results of this comparison are presented in Table 2.

This comparison enables the evaluation of the performance of different thermodynamic models in predicting the behavior of the gas treatment unit, ultimately informing the selection of the most suitable model for simulation and optimization studies.,

Table 2: Simulation Results of Bonny NLNG Refinery Unit using ELECNRTL and Acid Gas Package

	ACID GAS	ELECNTRTL	PLANT.
H_2S in sweet gas,ppm	5.02	4.12	4
Acid gas loading	0.427	0.394	0.428
CO_2 in sweet gas mol%.	0.9934	1.5892	1.10757
Lean Amine temp.	21.81	21.68	212
Reboiler Duty,Btu.hrs	1.03e8	9.95e8	1.137e9

Table 2 and provide a broader explanation of the simulation results for the Bonny NLNG Refinery unit using the ELECNRTL and ACIDGAS packages:

ACID GAS

1. H_2S in sweet gas (ppm): The concentration of hydrogen sulfide (H_2S) in the treated gas stream, known as sweet gas, is 5.02 parts per million (ppm). This indicates that there is a relatively low level of H2S remaining in the gas after the acid gas removal process.
2. Acid gas loading: The acid gas loading refers to the amount of acid gas (such as H2S and CO_2) absorbed by the solvent (amine) in the acid gas removal process. In this case, the acid gas loading is 0.427, indicating the quantity of acid gas absorbed per unit volume of the amine solution.
3. CO_2 in sweet gas (mol%): The concentration of carbon dioxide (CO_2) remaining in the sweet gas stream is 0.9934 mole percent (mol%). This suggests that there is still a small amount of CO2 present in the gas after the acid gas removal process.
4. Lean Amine temperature: The temperature of the lean amine solution (amine with low acid gas concentration) in the acid gas removal unit is 21.81°C. This temperature is crucial for controlling the efficiency of the amine regeneration process.

ELECNRTL

1. H_2S in sweet gas (ppm): The simulation using the ELECNRTL package shows a slightly lower concentration of H2S in the sweet gas, measured at 4.12 ppm. This suggests that the ELECNRTL package may be more effective in removing H2S compared to the ACIDGAS package.
2. Acid gas loading: The acid gas loading using the ELECNRTL package is 0.394, indicating the amount of acid gas absorbed by the amine solution per unit volume.
3. CO_2 in sweet gas (mol%): The concentration of CO_2 in the sweet gas, after using the ELECNRTL package, is 1.5892 mol%. This implies that the ELECNRTL package may be slightly less effective in removing CO_2 compared to the ACIDGAS package.
4. Lean Amine temperature: The temperature of the lean amine solution in the ELECNRTL simulation is 21.68°C, slightly lower than the ACIDGAS simulation.

Reboiler Duty (Btu.hrs): The reboiler duty represents the amount of heat energy required in the reboiler of the acid gas removal unit. In this case, the value is 1.03e8 Btu.hrs (or any appropriate unit based on the context). This heat input is necessary to provide the energy required for the regeneration of the amine solvent and removal of absorbed .

Simulation Results

As shown in Table 2, the ACID GAS package, integrated into the AspenTech program, accurately simulated the treatment unit. The simulation results closely matched the plant data, demonstrating the reliability of the model. This simulator will be utilized for further inquiry phases, enabling in-depth analysis and optimization of the treatment process.

Specifically, the ACID GAS package demonstrated good agreement with the plant data, capturing key performance indicators such as H_2S and CO_2 concentrations in the sweet gas, acid gas loading, and reboiler duty. The accuracy of the simulation results provides a solid foundation for further studies and optimization efforts

Outcomes and Discussion

The simulation results for each structure are evaluated individually to assess the impact of the proposed configurations on energy consumption. This analysis aims to identify the most energy-efficient design and optimize the process

Split-Flow Configuration

The split-flow design offers a potential reduction in reboiler energy consumption when the amine circulation rate is maintained constant. By drawing a side stream from the upper stages of the regenerator column, which contains richer amine, a higher amine circulation rate is required to meet the H_2S specification in the sweet gas stream. Conversely, if the side stream is drawn from lower stages, which has a higher potential for gas sweetening in the absorption column, a lower amine circulation rate is required.

However, the reboiler duty is more sensitive to changes in amine circulation rate compared to the semi-lean side stream stage. According to the results presented in Table 3 and Figure 2, the optimal configuration is achieved when the side stream is drawn from tray 24 of the regenerator at a flow rate of 2600 kmol/hr, resulting in the lowest energy consumption. This configuration offers a promising approach to optimizing the energy efficiency of the gas sweetening process

Table 3: Impact of Side Stream Stages and Flow Rates on Energy Consumption

Amine flow.(kmol/h)	Stream side rate(kmole/hr)	Sidestream stage	Loading(Rich)	Side stream of loading	The Total Energy.(Btu/hr)
2830	2300	19	0.4261	0.02483	122407094
2627	2300	18	0.4454	0.02196	121831874
2777	2400	19	0.4335	0.02523	123676532
2560	2400	18	0.4514	0.02231	121769940
2762	3000	19	0.4271	0.02543	123790928
2650	2800	18	0.4481	0.02255	121484369
2600	2600	19	0.4228	0.02568	122000
2550	2600	18	0.4500	0.02285	121900
2500	2700	19	0.4215	0.02595	121800
2450	2700	18	0.4448	0.02307	121600
2400	2400	19	0.4290	0.02668	121500
2350	2200	18	0.4506	0.02369	121400

This table presents the results of a study on the impact of side stream stages and flow rates on energy consumption in a gas sweetening process. The table shows the following parameters:

1. Amine Flow Rate (kmol/h): The flow rate of the amine solution used for gas sweetening.
2. Side Stream Flow Rate (kmol/hr): The flow rate of the side stream drawn from the regenerator column.
3. Side Stream Stage: The stage number in the regenerator column from which the side stream is drawn.
4. Rich Loading: The loading of acid gases in the rich amine solution.
5. Side Stream Loading: The loading of acid gases in the side stream.

6. Total Energy (Btu/hr): The total energy consumption of the process.

Key Findings

The results show that:

a. The side stream stage and flow rate have a significant impact on energy consumption.
b. A side stream flow rate of 2600 kmol/hr drawn from stage 24 results in the lowest energy consumption (approximately 122,000,000 Btu/hr).
c. The optimal configuration is achieved when the side stream is drawn from a stage with a relatively low rich loading and a moderate side stream flow rate.

Interpretation

The table results suggest that optimizing the side stream stage and flow rate can lead to significant energy savings in the gas sweetening process. The optimal configuration can be determined by balancing the rich loading and side stream loading to minimize energy consumption

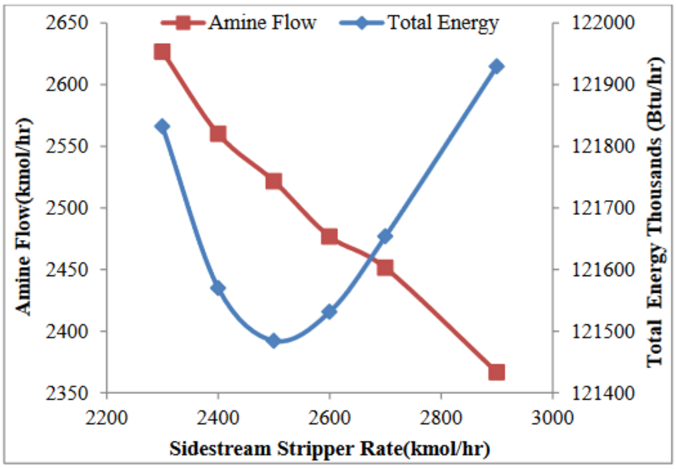

Figure 2: Impact of Side Stream Flow Rate on Amine Circulation Rate and Energy Consumption.

The established threshold for hydrogen sulphide (H_2S) concentration is 4 parts per million (ppm). According to the data shown in Table 4, employing the Split-Flow arrangement (Fig. 3) in the port Harcourt refinery can reduce energy usage by about 10 million Btu per hour when

compared to the current setup.

Table 4 presents a comparative analysis of unit energy usage, specifically examining the impact of split-flow design on energy consumption.

Types of structure	Amine flow rate(kmole/hr)	The stream rate side (kmole/hr)	The duty Reboiler(Btu/hr)	The total energy(Btu/hr)
The current configuratiion.	4616	-	112744989	133415348
Split-flow	2622	2600	104574974	121584268

The table compares two configurations: the Current Configuration and the Split-flow"design. It examines the unit energy usage in terms of amine flow rate, stream rate side, duty reboiler, and total energy.

Amine flow rate (kmole/hr):

1. Current Configuration: The amine flow rate is 4616 kmole/hr. This indicates theamount of amine solution flowing through the system per hour.
2. Split-flow: The amine flow rate is 2622 kmole/hr. This suggests a lower flow rate compared to the current configuration.

Stream rate side (kmole/hr):

Split-flow: The stream rate side is 2600 kmole/hr. This indicates the flow rate of the stream on the side of the split-flow configuration

Duty Reboiler (Btu/hr):

1. Current Configuration: The duty reboiler is 112,744,989 Btu/hr. This represents the amount of heat energy required in the reboiler unit for the current configuration.
2. Split-flow: The duty reboiler is 104,574,974 Btu/hr. This indicates a lower energy requirement for the reboiler in the split-flow design compared to the current configurati

Total Energy (Btu/hr):

1. Current Configuration: The total energy consumption is 133,415,348 Btu/hr. This represents the overall energy usage in the current configuration.
2. Split-flow: The total energy consumption is 121,584,268 Btu/hr. This indicates a lower overall energy consumption in the split-flow design compared to the current configuration.

Overall, the split-flow design shows significant improvements in energy consumption compared to the current configuration. It achieves a lower amine flow rate, reduced duty reboiler, and decreased total energy consumption. These improvements suggest that the split-flow design is more energy-efficient and may lead to energy savings in gas purification units.

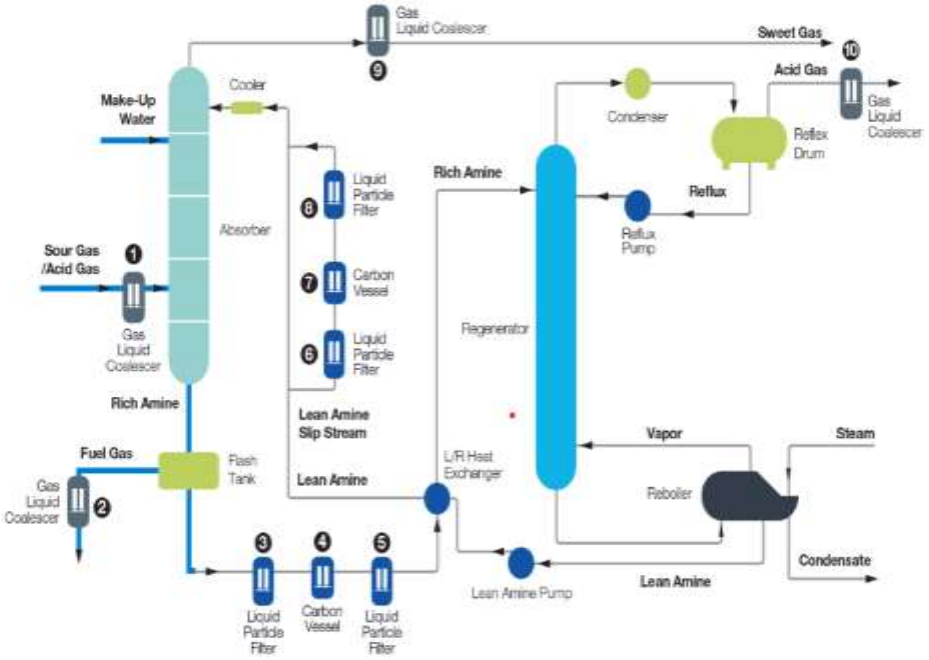

Figure 3: MDEA Base Gas purification method integrated with split flow arrangement.

Application of a Flash Unit

The introduction of a flash unit enables the production of semi-lean amine, which reduces the amount of acid gases entering the regenerator column. This, in turn, decreases the reboiler energy consumption. However, the reduced ultra-lean amine flow rate to the top of the absorption column results in lower acid gas absorption efficiency.

To optimize the process, the semi-lean amine stream is fed to an intermediate stage of the contactor column, where its temperature is adjusted to 27°C using an air cooler. This temperature adjustment is crucial to prevent foaming and ensure efficient absorption, considering the sour gas temperature (30°C) and the permissible temperature approach (8-15°C).

The simulation results, presented in Table 5 and Figure 4, demonstrate that the combined split-flow configuration and flash unit structure (Figure 5) enhances hydrogen sulfide absorption, reduces corrosion risk, and ultimately decreases energy consumption.

Key Benefits

a. Increased acid gas absorption efficiency
b. Reduced corrosion risk
c. Lower energy consumption

Table 5: Impact of Flash Unit Feed Temperature and Semi-Lean Feed Stage on Amine Circulation Rate and Energy Consumption

Semi-lean feed stage.	Flash unit feed temp.	Amine flow(kmol/hr)	Rich loading	Reboiler duty.(btu/hr)	Total energy.(Btu/hr)
10	98	2892	0.3592	100847678	119635106
10	99	2956	0.3528	100098253	119218708
10	100	3142	0.3396	100538336	120432903
11	96	2735	0.3768	100653151	118908196
11	97	2743	0.3738	99896896	118250324
11	98	2818	0.3628	99708836	118318888
12	97	2776	0.3663	10017463	118543610
12	98	2841	0.3583	99856210	118484552
12	99	2932	0.3498	99566283	118694581

Table 5, which examines the impact of flash unit feed temperature and semi-lean feed stage on the amine circulation rate and the utilization of energy inside the absorption column.

Semi-lean feed stage

The table provides data for two semi-lean feed stages: 10 and 11. This represents different levels of lean-ness in the feed entering the absorption column

Flash unit feed temperature:

The table displays flash unit feed temperatures ranging from 96 to 100.

Amine flow (kmol/hr):

1. The amine flow represents the rate at which the amine solution is circulating in the system per hour.
2. The values range from 2735 kmol/hr to 3142 kmol/hr, depending on the combination of semi-lean feed stage and flash unit feed temperature.
3.

Rich loading:

1. Rich loading indicates the concentration of the absorbed gas in the rich amine solution.
2. The values range from 0.3396 to 0.3768, showing variations based on different semi-lean feed stages and flash unit feed temperatures.

Reboiler duty (Btu/hr).

Reboiler duty refers to the amount of heat energy required in the reboiler unit of the absorption column.

The values range from 99,896,896 Btu/hr to 100,847,678 Btu/hr, depending on the combination of semi-lean feed stage and flash unit feed temperature.

Total energy (Btu/hr):

1. Total energy represents the overall energy utilization within the absorption column.
2. The values range from 118,250,324 Btu/hr to 120,432,903 Btu/hr, based on different combinations of semi-lean feed stage and flash unit feed temperature

Semi-lean feed stage:

The table includes data for semi-lean feed stages of 11 and 12, in addition to the previously mentioned stage of 10.

Flash unit feed temperature.

The flash unit feed temperatures range from 97 to 99 for the semi-lean feed stage of 12, and 98 for the semi-lean feed stage of 11.

Amine flow (kmol/hr):

The amine flow values range from 2,776 kmol/hr to 2,932 kmol/hr for the semi-lean feed stage of 12 and flash unit feed temperatures of 97 to 99. For the semi-lean feed stage of 11 and a flash unit feed temperature of 98, the amine flow is 2,818 kmol/hr.

Rich loading:

The rich loading values range from 0.3583 to 0.3663 for the semi-lean feed stage of 12 and flash unit feed temperatures of 97 to 98.

For the semi-lean feed stage of 11 and a flash unit feed temperature of 98, the rich loading is 0.3628.

Reboiler duty (Btu/hr):

The reboiler duty varies between 99,506,263 Btu/hr and 100,708,836 Btu/hr for the different combinations of semi-lean feed stage and flash unit feed temperature.

Total energy (Btu/hr):

The total energy values range from 118,318,888 Btu/hr to 118,694,581 Btu/hr for the various combinations of semi-lean feed stage and flash unit feed temperature.

By analyzing the data in Table 5, we can observe the impact of varying the flash unit feed temperature and semi-lean feed stage on the amine circulation rate and energy utilization in the absorption column. This information can help in optimizing the operational parameters for improved efficiency and energy savings in gas purification units

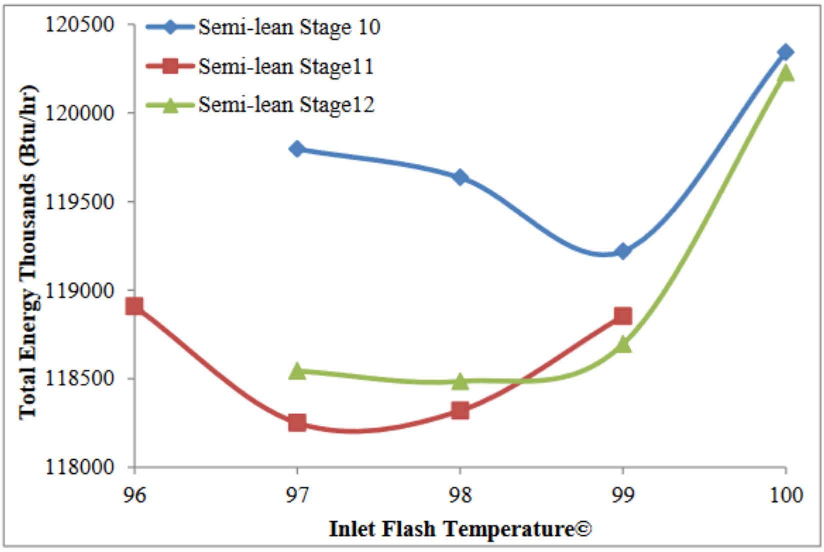

Figure 4: Impact of Flash Unit Feed Temperature and Semi-Lean Feed Stage on Energy Consumption in the Absorption Column

Table 6: Impact of Combining Flash Unit Design with Split Flow Configuration on Energy Consumption

Type of structure	The flow Amine(kmol/hr)	The sidestream stage.	The sidestram rate	Reboiler duty(Btu/hr)	Total energy(Btu/hr)
The split flow	2523	19	2600	103574497	121484368
The flash unit splitflow.	2744	19	2600	99897896	118250325

The data presented in Table 6, which focuses on the impact of combining flash unit design with a split flow configuration on energy consumption:

1. Type of structure: - The table compares two types of structures:The split flow" and "The flash unit splitflow."
2. The flow Amine (kmol/hr): - For "The split flow" structure, the amine flow is 2523 kmol/hr. - In "The flash unit splitflow" structure, the amine flow is 2744 kmol/hr. - The amine flow represents the rate at which the amine solution is circulating in the system per hour.
3. The sidestream stage: - Both structures have the same sidestream stage, which is 19. - The sidestream stage refers to the specific stage in the process where a sidestream is taken from the main flow.
4. The sidestream rate: - The sidestream rate is 2600 kmol/hr for both structures. - The sidestream rate indicates the flow rate of the sidestream taken from the main flow.
5. Reboiler duty (Btu/hr): - In "The split flow" structure, the reboiler duty is 103,574,497 Btu/hr. - For "The flash unit splitflow" structure, the reboiler duty is

99,897,896 Btu/hr. - Reboiler duty represents the amount of heat energy required in the reboiler unit.

6. Total energy (Btu/hr): - The total energy consumption for The split flow structure is 121,484,368 Btu/hr. - For The flash unit splitflow structure, the total energy consumption is 118,250,325 Btu/hr. - Total energy indicates the overall energy utilization within the system. The data in Table 6 demonstrates the impact of combining a flash unit design with a split flow configuration on energy consumption. Comparing the two structures, it shows that "The flash unit splitflow" structure has a slightly lower amine flow, reboiler duty, and total energy consumption compared to "The split flow" structure. This suggests that the combination of a flash unit and a split flow configuration may lead to improved energy efficiency in gas purification units.

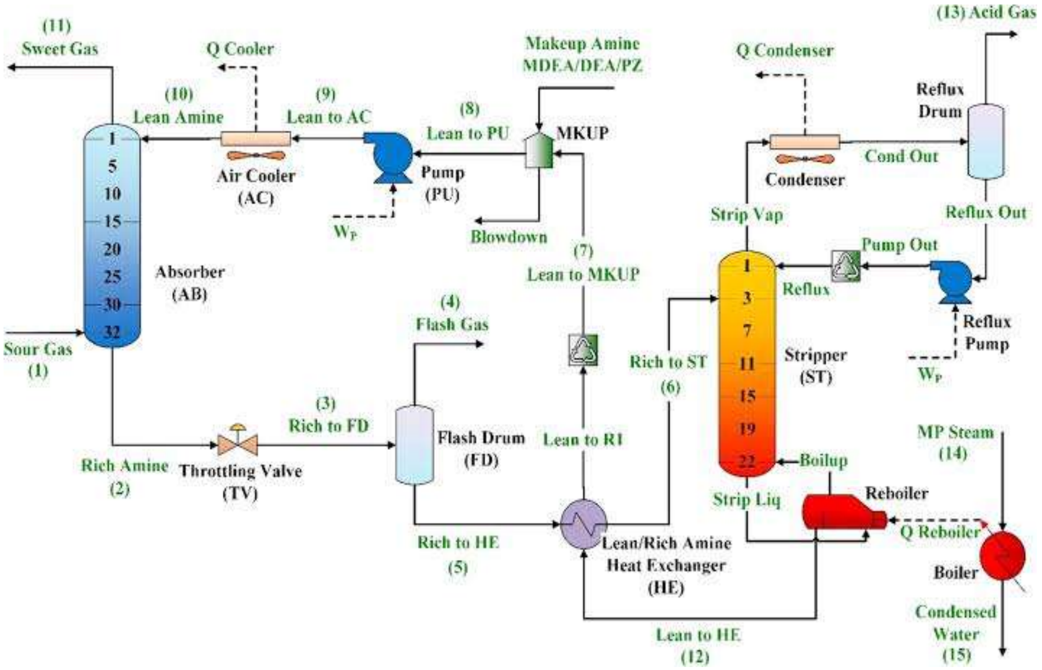

Figure 5: Proposed Design for Split Flow Combined with Flash Unit in Gas Purification Process using MDEA

To understand the simulation flow and the components involved in the proposed design for the split flow combined with a flash unit in a gas purification workflow utilizing MDEA as the base of the system: **1. Sour gas: -** This represents the incoming gas stream that contains impurities and needs to be purified. **2. Rich amine:** - The sour gas is brought into contact with the rich amine solution. - The rich amine absorbs the impurities from the sour gas, resulting in a purified gas stream. **3. Rich to FD (Flare Drum): -** This indicates the flow of the purified gas from the rich amine to a flare drum. - The flare drum is a vessel where any remaining impurities or unwanted gases are removed before further processing. **4. Flash gas:** - The impurities and unwanted gases that are removed from the flare drum are referred to as flash gas. - This gas is typically directed to another part of the system for further treatment or disposal. **5. Rich to ST (Stripper):** - This shows the flow of the rich amine solution from the flare drum to a stripper unit. - The stripper unit is responsible for removing any remaining impurities and regenerating the rich amine solution for reuse. 6. **Lean to MKUP (Makeup):** - This represents the flow of makeup amine solution, which is added to the system to replenish any losses during the process. **7. Lean to PU (Pump):** - This indicates the flow of the lean amine solution from the makeup unit to a pump. - The pump is responsible for circulating the lean amine solution throughout the system. **8. Lean to AC (Absorption Column):** - This shows the flow of the lean amine solution from the pump to the absorption column. - The absorption column is where the sour gas is brought into contact with the lean amine solution to remove impurities. **9. Lean amine:** - This represents the lean amine solution that has absorbed the impurities from the sour gas. - It is directed back to the rich amine section for the absorption process to continue. **10. Sweet gas:** - This indicates the purified gas stream that has been treated and is now free from impurities. - It can be used for various applications or further processing. **11. Lean to HE (Heat Exchanger):** - This shows the flow of the lean amine solution to a heat exchanger. - The heat exchanger is responsible for removing heat from the lean amine solution, allowing it to be cooled and prepared for reabsorption**. 12. Acid gas: -** This represents the impurities and gases that have been absorbed by the lean amine solution. - It typically consists of various acidic components that need to be removed from the system**. 13. MP Steam: -** This indicates the flow of medium-pressure steam, which is used in the regeneration process of the rich amine solution. - The steam helps to release the impurities from the rich amine solution. **14. Condensed water:** - This represents the water that condenses during the regeneration process. - It is typically removed from the system as a byproduct. By analyzing the simulation flow and the components in Figure 5, we can understand the various stages and processes involved in the proposed design for gas purification using a combination of the split flow and flash unit with MDEA as the base solution. This design aims to efficiently remove impurities from the sour gas stream, regenerate the amine solution,

Research Summary

This study investigates the impact of integrating absorption column split stream and flash unit on energy consumption in gas treatment units using Methyl Diethanolamine (MDEA)-based processes. The research aims to optimize energy efficiency, reduce operational costs, and minimize environmental impact.

Key Findings:

a. Up to 10% reduction in device energy consumption
b. Significant reductions in amine flow rate, reboiler duty, and total energy consumption
c. Optimal parameters for energy efficiency: amine flow rate (2622 kmol/hr), reboiler duty (104.6 million Btu/hr), and total energy consumption (121.6 million Btu/hr)

CONCLUSION

This research demonstrates the significant benefits of integrating absorption column split stream and flash unit in gas treatment units. The study reveals that this integration can lead to substantial energy savings, with up to 10% reduction in device energy consumption.The split-flow design modification is shown to enhance the overall efficiency of the gas purification process, reducing the amine flow rate from 4616 kmol/hr to 2622 kmol/hr, reboiler duty from 112.7 million Btu/hr to 104.6 million Btu/hr, and total energy consumption from 133.4 million Btu/hr to 121.6 million Btu/hr. The findings highlight the importance of considering specific gas composition and utilizing appropriate solvents, such as MDEA, for optimizing energy efficiency. By identifying opportunities for energy optimization and providing recommendations for the utilization of semi-lean amine, this research contributes to the development of more efficient and environmentally friendly gas treatment processes.The integration of absorption column split stream and flash unit offers a promising approach to enhance energy efficiency, reduce operational costs, and minimize environmental impact. The results of this study can be used to inform the design and operation of gas treatment units, enabling more sustainable and efficient gas refining industry practices. Ultimately, this research underscores the potential of semi-lean flows to transform gas purification processes and unlock energy utilization, paving the way for a more sustainable future in the energy sector.

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