International Science and Technology Journal
المجلة الدولية للعلوم والتقنية

Volume 33 العدد
Part 2 المجلد
January 2024 يناير

المجلة الدولية للعلوم والتقنية
International Science and Technology Journal
ISTJ

تم استلام الورقة بتاريخ: 27/ 2023/12م وتم نشرها على الموقع بتاريخ: 28/ 2024/1م

Enhancement performance of sweetening gas process unit by using different concentration of amine ratios

Zakaria Sihaib, Abdulwahed Shglabow, Alkouni Ejlail

Chemical engineering department, Higher Institute of Science and Technology in Zawia

zakariasihaib@yahoo.com , shglabowabdulwahed@gmail.com

Alkouni33@gmail.com

Abstract:

Natural gas in the Mellitah plant contains impurities such as CO_2 and H_2S. These impurities are undesirable and cause many technical problems. To overcome these problems, an MDEA solution is used with an increase of 100 mm in the height of the absorption column to increase the residence time instead of 50 mm in the original design, which resulted in an increase in cost. The aim of this paper is to use other amines such as DEA, which is a good candidate that can be mixed to MDEA solution doping to increase the reaction rate of MDEA solution with the CO_2 sweetening process put under investigation using Aspen HYSYS v.11 as a simulator. In addition, an optimization study was performed by mixing different concentrations of DEA with MDEA and the concentration of each mixture is considered a simulated scenario to achieve the best absorption.

Results showed the best possible scenario at the current operational conditions is when the amine feed stream is at a concentration of 39% MDEA and 1% DEA, where it showed better gas quality as the absorption of CO_2 and H_2S where more efficient. Furthermore, the estimated duty required according the simulator was less by 4.46×10^4 kw.

Keywords: natural gas sweetening, Mellitah gas plant, MEA, DEA, MDEA process simulation, Aspen HYSYS V11.

تم استلام الورقة بتاريخ: 27/ 2023/12م وتم نشرها على الموقع بتاريخ: 28/ 2024/1م

تحسين أداء وحدة عملية تحلية الغاز باستخدام نسب مختلفة من الأمين

زكريا صهيب، عبد الواحد شقلابو، الكوني جليل
قسم الهندسة الكيميائية- المعهد العالي للعلوم والتقنية بالزاوية

zakariasihaib@yahoo.com, shglabowabdulwahed@gmail.com
Alkouni33@gmail.com

الملخص:
الغاز الطبيعي في مجمع مليته يحتوي على شوائب مثل ثاني أكسيد الكربون و كبريتيد الهيدروجين. هذه الشوائب غير مرغوب فيها وتسبب العديد من المشاكل الفنية مثل لتأكل والتلوث البيئي. ولتغلب على هذه المشاكل يتم استخدام محلولMDEA مع زيادة 100 مم في ارتفاع عمود الامتصاص لزيادة زمن المكوث بدلاً من 50 مم في التصميم الأصلي مما ترتب عليه زيادة في التكلفة. الهدف من هذه الورقة هو استخدام أمينات أخري مثل DEAوهو مرشح جيد يمكن إضافته وخلطه إلى محلول MDEA كمنشطات لزيادة معدل تفاعل محلول MDEA مع عملية تحلية غاز ثاني أكسيد الكربون بمحطة مليته للغاز تم وضعها قيد التحقيق باستخدام برنامج Aspen HYSYS v.11 كجهاز محاكاة. بالإضافة إلى ذلك، تم إجراء دراسة تحسين عن طريق مزج تراكيز مختلفة من DEA مع MDEAويعتبر تركيز كل خليط سيناريو تم محاكاته لتحقيق أفضل امتصاص.
لقد أظهرت النتائج المتحصل عليها من عملية المحاكاة إن أفضل سيناريو ممكن في ظل ظروف التشغيل الحالية لوحدة تحلية غاز مليته هو عندما يكون تيار تغذية الأمين بتركيز 39 %MDEA و 1 %DEA حيث حقق أفضل جودة وكفاءة لامتصاص غاز CO_2 و H_2S وأقل استهلاك للطاقة بقيمة $4.46*10^4$ كيلو وات.

الكلمات المفتاحية: تحلية الغاز الطبيعي، مصنع مليته للغاز، مونو إيثانول أمين، داي إيثانول أمين، ميثايل داي إيثانول أمين.

1. Introduction.

Many types of cleaning processes have been developed and tested for gas sweetening based on both chemical and/or physical

تم استلام الورقة بتاريخ: 27/ 2023/12م وتم نشرها على الموقع بتاريخ: 28/ 2024/1م

principles. Methods for gas sweetening can be divided into two categories: adsorption and absorption processes. Adsorption is a physical/chemical method where the gas is concentrated on the surface of a solid or liquid to remove impurities. The absorption process is performed by either dissolution, which is a physical process or by reactions with other compounds, which are chemical processes. [1]

1.1. Acid gas removal phenomena.

CO_2 capture in amine solvents is based on the reversible transfer of CO_2 from the gas phase into the liquid phase where it reacts with the amine solvent (reactive absorption). There are three main physical or chemical phenomena take place in the CO_2 capture process [2]:

1. Hydrodynamics: amine solvent and flue gas flow in counter current through the column packing. Their intimate contact is maximized by using appropriate column packing in order to increase the specific interfacial area between gas and liquid and thus to enhance the CO_2 transfer.

2. Mass transfer: at the phase interface, CO_2 is transferred from the flue gas into the amine solvent. However, the mass transfer may be slowed down due to physical diffusivity limitations.

3. Chemical reaction: CO_2 chemically reacts with the amine solvent, which enhances the CO_2 mass transfer. However, the reaction may be slowed down by chemical kinetics limitations.

1.2. Amine Process.

In the gas processing industry absorption with chemical solvents has been used commercially for the removal of acid gas impurities from natural gas. The currently preferred chemical solvent technology for acid gas removal is chemical absorption of acid gases by amine-based absorbents, figure (1) shows that the typical amine peocess. Alkanolamines, are the most commonly used category of amine chemical solvents used for acid gas removal. Chemical absorption of CO_2 with alkanolamines as solvent has been used in a large variety of industries over years. Natural gas treating, production of hydrogen and ammonia from synthesis gas and CO_2 capture from combustion gases are among the biggest industries that are utilized

تم استلام الورقة بتاريخ: 27/ 12/2023م وتم نشرها على الموقع بتاريخ: 28/ 1/2024م

chemical absorption of CO_2 with alkanolamines [3]. Removal of acid gas from process gas with alkanolamines has been developed in 1930's [3]. Nowadays, aqueous solutions of MEA and MDEA are the most commonly used solvents for gas sweetening. The use of blend amines is also increasing, since it reduces the operating costs and improves products quality (Kim et al. 2008). It is notable that MDEA is advantageous over other amines due to selective removal of H_2S from its mixture with CO_2. The selectivity of absorption is due to the higher rate of the reaction of MDEA with H_2S than the reaction of MDEA with CO_2 [4]. H_2S has H+ that can give directly to MDEA; the proton transfer reaction is always fast and spontaneous. Moreover, comparing to other amines, MDEA is more stable, less volatile and less corrosive, it has lower heat of reaction and higher absorption capacity [4].

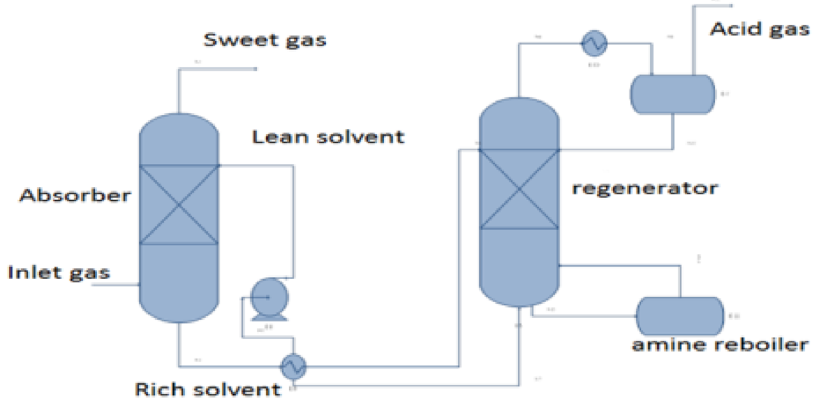

Figure 1. Process flow diagram of Mellitah gas plant.

1.3. Problem statement.

Mellitah gas plant uses the MDEA solution as a solvent for gas sweetening process with a concentration of 50%. The typical operating problem occurs in Acid Gas Removal Unit (AGRU) using MDEA solution are poor absorption rate, and high regeneration duty. Moreover, foaming, corrosion and solvent losses. MDEA

تم استلام الورقة بتاريخ: 27/ 12/2023م وتم نشرها على الموقع بتاريخ: 28/ 1/2024م

solution is used with an increase of 100 mm in the height of the absorption column to increase the residence time instead of 50 mm in the original design, which resulted in an increase in cost.
Even there are many research works that have been done based on Mellitah gas plant as a case study focusing on the simulation of the unit, optimization of the existing process, using other types of amine solution, this research will focus on the study of the possible MDEA based blends with DEA as activator to check the ability of increasing the absorption rate, while taking in the consideration its effect on the other operating parameter.

1.4. Objective.

The aims of this project are to study the sweetening unit in Mellitah gas plant as a case study, where will simulate at the current operational conditions using Aspen HYSYS software as a simulator. Perform a sensitivity analysis to investigate and select the main operating parameters that has a strong influence on the process performance. Implementation of the enhancement methodology on the base case by mean of using a blend of MDEA with DEA at different concentrations. Identify the optimum blend of amine to enhance the performance of the gas sweetening process at Mellitah gas plant based on obtained results.

2. Process of feed condition with the compositions.

The sources of data considered in this study was a combination of plant data and related publications. The feed condition and its composition are shown in Table 1. The required specifications of the sweet gas stream are 2% mol. of CO_2 and 5 ppm of H_2S [5,6,7].

Table1. Feed condition and its composition.

Condition		
Temperature .C°	30	
Pressure. Kpa	3950	
Molar flow. Kg mol/h	14388	
Composition		
Compounds	**Mole %**	**Molar flow rate (kgmol/h)**
H_2O	0.02	2.42
Nitrogen	4.59	660.63
CO_2	15.71	2260.45

H_2S	1.29	185.64
Methane	70.12	10088.95
Ethane	4.46	641.94
Propane	1.8	259.23
i-Butane	0.4	56.97
n-Butane	0.66	95.43
i-pentane	0.29	41.83
n-pentane	0.28	40.79
n-hexane	0.25	35.56
n-heptane	0.13	18.16

2.1. Process Description.

Once the base case is completed, the optimization procedure is applied in order to improve the plant performance by using a blend of MDEA & DEA. Many trails were done to investigate the possible scenarios that can be applied, where the Five scenarios considered are shown in Table 2.

Table2. Considered scenarios for optimization

Scenario No.	H_2O	MDEA	DEA
Scenario 1	50%	50%	0%
Scenario 2	50%	48%	2%
Scenario 3	50%	49%	1%
Scenario 4	60%	38%	2%
Scenario 5	60%	39%	1%

Scenario 1: Simulation of existing plant is performed with the actual operating conditions, where the MDEA is used as a solvent with a concentration of 50%wt.

Scenario 2 and scenario 3: The overall concentration is kept at 50%wt, but in this case, the amine blend of MDEA & DEA is used.

Scenario 4 and scenario 5: The overall concentration is decreased to 40%wt, and again the amine blend of MDEA & DEA is used and investigated.

3. Results and Discussion.

The effect of the amine flow rate on the CO_2 & H_2S concentration in the sweet gas and reboiler duty was studied and the results are shown in figures (2) & (3). It can be seen that the concentration of acid gases is decreased to less than about 1% mol. by increasing the

تم استلام الورقة بتاريخ: 27/ 2023/12م   وتم نشرها على الموقع بتاريخ: 28/ 2024/1م

amine flow rate to 4 times of normal, because the increase in the amine flow rate will increase the amine residence time inside the column .while the reboiler duty is increased to the double, due to the increase of the amount of amine that need to be regenerated.

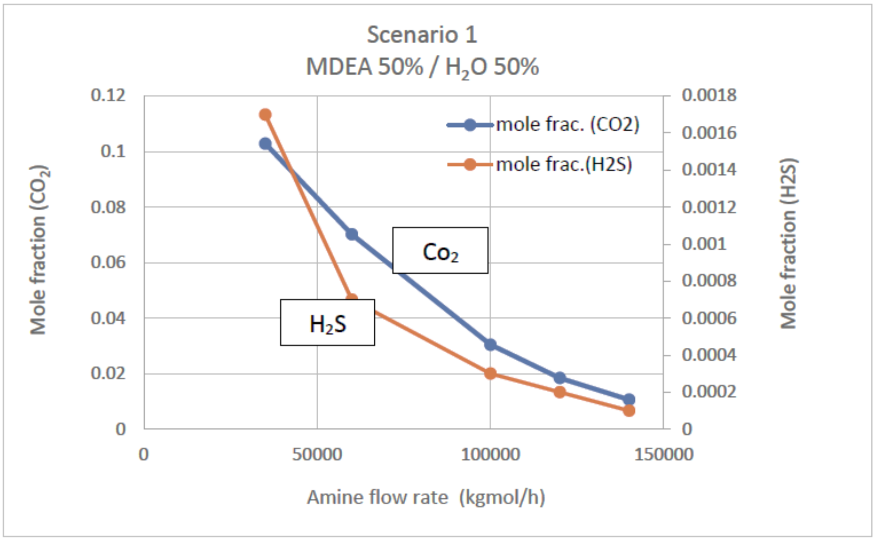

Figure 2.Effect of amine flow rate on acid gas concentration.

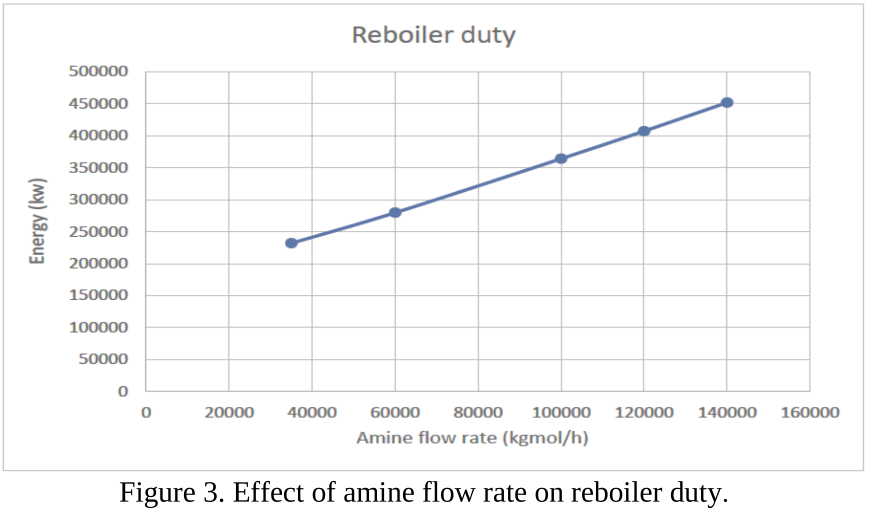

Figure 3. Effect of amine flow rate on reboiler duty.

تم استلام الورقة بتاريخ: 27/ 2023/12م وتم نشرها على الموقع بتاريخ: 28/ 2024/1م

3.1. Comparison between different scenarios.

Effect of the amine flow rate on the acid gas concentration and reboiler duty for all scenarios is shown in figure (4), where it is clearly seen that the results have a similar behavior in all cases.

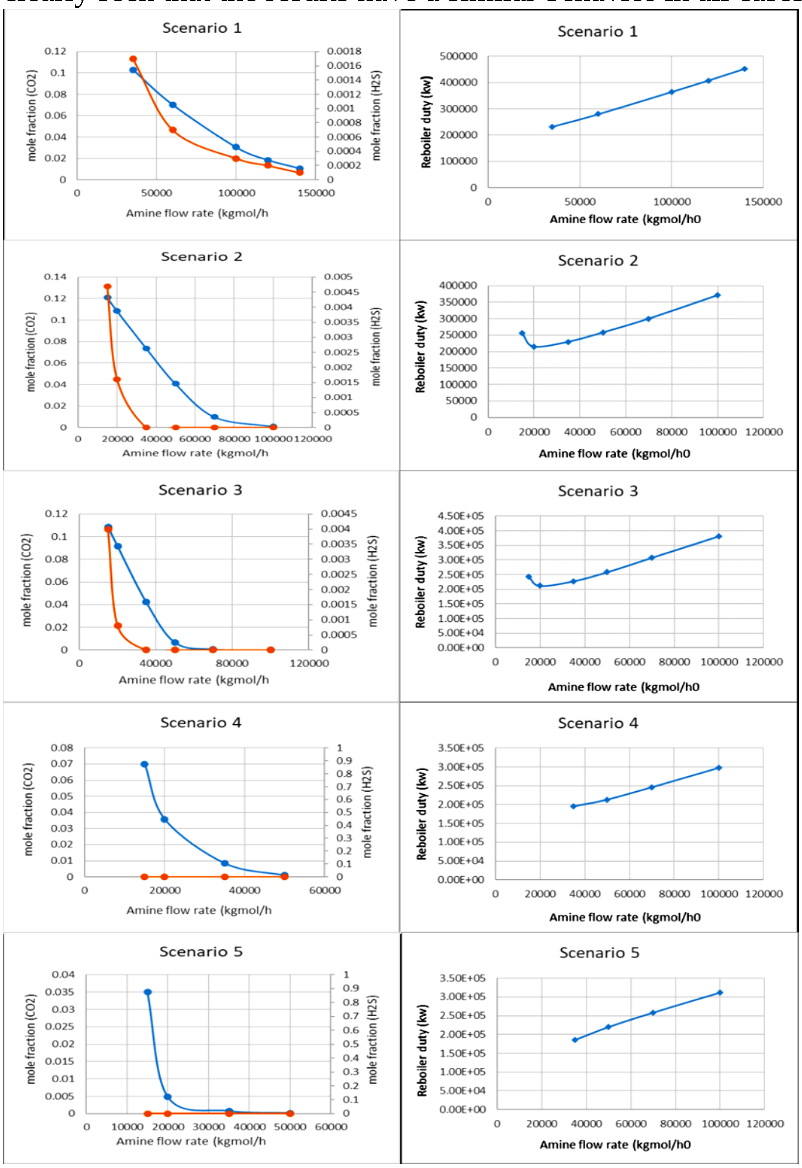

Figure 4. Comparison between different scenarios.

تم استلام الورقة بتاريخ: 27/ 2023/12م وتم نشرها على الموقع بتاريخ: 28/ 2024/1م

In order to have more understanding and clear vision of the effect of adding DEA on the absorption rate and reboiler duty, DEA with 1% and 2% has been investigated at amine strength of 50% and 40%, by fixing the amine flow rate at $3.5x10^4$ kgmol/h, and the results are shown in the Table 3.

Table 3. Comparison at fixed amine flow rate.

	CO_2 (Mol. Frac.)	H_2S (Mol. Frac.)	Reboiler duty (kw)
Scenario 1	0.1029	0.0017	$2.32x10^5$
Scenario 2	0.0737	0	$2.30x10^5$
Scenario 3	0.0423	0	$2.28x10^5$
Scenario 4	0.0701	0	$1.95x10^5$
Scenario 5	0.0350	0	$1.86x10^5$

4. Conclusion.

In the summary of the study, the CO_2 absorption in the gas-sweetening units of Mellitah complex using aqueous solutions containing MDEA and DEA as blends have been investigated using a process simulation software (Aaspen HYSYS V.11).

For the process optimization, five scenarios were defined based on the amine strength and fraction of the DEA as activator, and the results were compared to the standalone MDEA solutions at 50% wt. concentrations (scenario 1). The optimization and selection of the optimum scenario was done based on the reboiler duty in the regeneration column and concentration of CO_2 in the sweet gas.

The results show that all scenarios able to handle the process requirement at different amine flow rate and regeneration duty, where best possible scenario at the current operational conditions of Mellitah gas sweetening unit is when the amine feed stream is at a concentration of 39% MDEA and 1% DEA, where it showed better gas quality as the absorption of CO_2 and H_2S where more efficient. Furthermore, the estimated duty required according the simulator was less by $4.46x10^4$ kw.

تم استلام الورقة بتاريخ: 27/ 2023/12م وتم نشرها على الموقع بتاريخ: 28/ 2024/1م

Nomenclature

H_2S	Hydrogen sulfide	CO_2	Carbon dioxide
DEA	Diethanolamine	MEA	Monoethanolamine
MDEA	Methyldiethanolamine		

5. References.

[1] Negar Sadegh , “Acid Gas Removal from Natural Gas with Alkanolamines: A Modeling and Experimental Study”, Ph.D. Thesis, 2013.
[2] Grégoire L. "Optimal Design Of A CO2 Capture Unit With Assessment of Solvent Degradation.", Dissertation. Unversite De Liege, Dissertation,(2013).
[3] Bishnoi S, Rochelle GT. Absorption of carbon dioxide into aqueous piperazine: reaction kinetics, mass transfer and solubility, Chemical Engineering Science, 2000; 55(22): 5531- 5543.
[4] Samanta A, Bandyopadhyay SS. Kinetics and modeling of carbon dioxide absorption into aqueous solutions of piperazine. Chemical Engineering Science, 2007; 62(24), 7312-7319.
[5] Asma E. Etoumia , Mohamed R. Alhansha, “Performance Improvement of Gas Sweetening Units by Using a Blend of MDEA/PZ”, 2021.
[6] Najib M. Omar, “Simulation and Optimization of Gas Sweetening Process at Mellitah Gas Plant Using Different Blends of Amines”, 2017.
[7] Melitah Company, Operating manual, NOC Library.