The Effects of Amine Type and Lean Amine Temperature on Gas Sweetening Processes: A Case Study and Simulation

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Abstract—**In the North Gas Company (NGC) in Kirkuk, Iraq, sour gas stream is loaded with considerable amounts of H_2S and CO_2 of 2.95% and 2.54%, respectively. A DEA amine system is currently used to reduce these sour component concentrations below 5 ppm and 2% for H_2S and CO_2, respectively. This study used Bryan Research and Engineering's ProMax® process simulation software to optimize this amine sweetening system by adopting other amine types and blends, such as methyldiethanolamine (MDEA). It could be argued that a 50 wt% MDEA solution circulated at 414 m³/h was determined to be the optimum operating conditions. This design met sweet gas specifications and minimized the reboiler duty to 38 MW, 30.9% reduction in steam consumption. The experimental simulation work is also examined the effects of lean solvent temperature on the gas sweetening process efficiency and performance and find out that the lean amine temperature within the range of 43–48°C in all sceneries give acceptable sweetening results.**

***Index Terms*—Gas sweetening, Lean amine temperature, Mixed amine, Natural gas industry, North gas company, Process simulation.**

I. Introduction

The raw natural gas can contain significant amounts of sour components, for instance, H_2S and CO_2 after it is produced (Abdel-Aal, Aggour and Fahim, 2003). The "sour gas" must be treated, or "sweetened," before pipeline transport to lower the risk of corrosion in the presence of water, lower toxicity from H_2S, and to increase the heating value reduced by CO_2 (Stewart and Arnold, 2011). In fact, chemical solvent absorption remains the most widely adopted technology (Sorensen, 2018). The most common form of natural gas sweetening is the use of alkanolamines in solution as a chemical solvent to absorb and remove sour gas components (Wang and Economides, 2013).

Amine molecules are similar to ammonia molecules (NH_3) with one or several of the hydrogen atoms replaced with a substituent (Bryan Research & Engineering, LLC, 2020). Amines can be classified as primary, secondary, or tertiary depending on the number of hydrogen atoms (Fig. 1).

The following chemical reaction sets show the significant interactions of amines with H_2S and CO_2 during the sweetening process (Maddox and Morgan, 1998):

H_2S:

$$H_2S \leftrightarrow H^+ + HS^- \quad (1)$$

$$HS^- \leftrightarrow H^+ + S^{2-} \quad (2)$$

$$H^+ + RH_2N \leftrightarrow RH_2NH^+ \quad (3)$$

CO_2 with primary mines:

$$CO_2 + H_2O \leftrightarrow H^+ + HCO_3^- \quad (4)$$

$$HCO_3^- + RH_2N \leftrightarrow RHNCOO^- + H_2O \quad (5)$$

$$CO_2 + RH_2N \leftrightarrow RHNCOO^- + H^+ \quad (6)$$

$$H^+ + RH_2N \leftrightarrow RH_2NH^+ \quad (7)$$

CO_2 with tertiary amines:

$$CO_2 + H_2O \leftrightarrow H^+ + HCO_3^- \quad (4)$$

$$H^+ + R_3N \leftrightarrow R_3NH^+ \quad (8)$$

Examples of primary, secondary, or tertiary amines are MEA, DEA, and MDEA, respectively.

Indeed, the amine type may consider an important factor in the gas sweetening process (Abdulrahman, et al., 2017). However, other parameters such as lean amine temperature

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are also important to be examined as the parameter that used to control the absorber temperature (Sarker, 2016). In fact, the lean amine temperature might affect several factors, for example, the loading of acid gases by the lean amine (acid gases continent in sweet gas stream/ overhead), foaming that could be caused by impurities contents in the rich amine solution, for instance, condensate hydrocarbons, hydrate formation, and amine pump duty (Bryan Research and Engineering, Inc.- Technical Papers, 2020).

II. Amine Process at North Gas Company

The North Gas Company (NGC) processes the most of the associated gas in Iraq's northern oil fields. The studied NGC system in the Kirkuk Field (Fig. 2) uses a standard configuration for amine gas sweetening with an absorption section (left) and the regeneration section (right).

Absorption section: Sour gas comes in contact with the amine solution in the absorber column. Sour components are removed in the following way:

a. The bulk removal of the acid gas occurs in the bottom absorber sections where the column temperature is highest. This is commonly referred to as the absorption column's "temperature bulge."
b. The final purification, or polishing, occurs midway through the column height.
c. The column's top acts as a water wash section to prevent amine carry-over into the exiting sweet gas stream. This lost amine increases operational costs and can cause damage in following dehydration units.

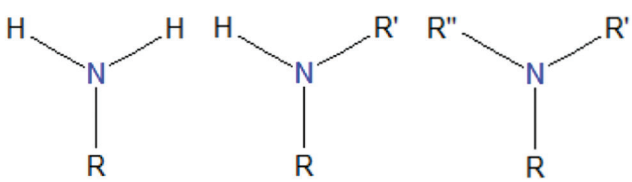

Fig. 1. Primary (left), secondary (middle), and tertiary (right) amine.

Regeneration section: Rich amine solution exits the bottom of the absorber and enters the regeneration column. Steam is used to strip the sour components from the amine solution. The lean amine solution is drawn from the regenerator's bottom and circulated back to the absorption column. The H_2S and CO_2 stream, or "Acid Gas" stream, exits the column's top and is sent to a sulfur recovery unit.

III. *NGC Gas Composition*

NGC gas stream compositions and operating conditions are shown in Tables I and II, respectively. Hexanes plus (C6+) were modeled as the n-Hexane component.

TABLE I
NGC dry basis natural gas compositions

Component	Mole%
H_2S	2.95
CO_2	2.54
Methane	71.56
Ethane	12.83
Propane	6.48
i-Butane	0.83
n-Butane	1.61
i-Pentane	0.51
n-Pentane	0.46
C_6+	0.23

TABLE II
Operation conditions (NGC)

North Gas Company (NGC) Kirkuk	
Sample No.	Stream 1000
Sample type	Natural gas
Flow rate	334.783 MMSCFD
Pressure	27.5 bar
Temperature	42 °C
DEA	28.55 wt%
DEA circulation rate	800 m^3/h
Reboiler duty	55 W

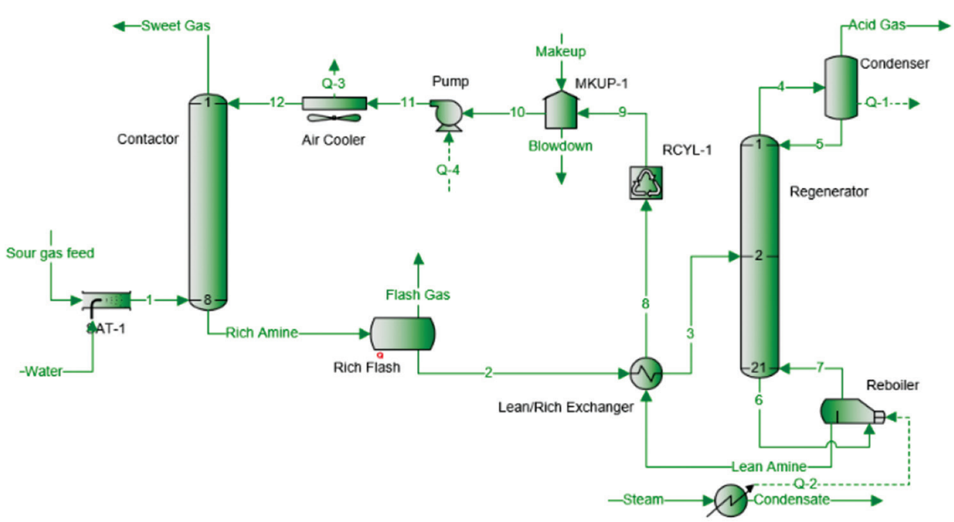

Fig. 2. ProMax® simulation of NGC amine sweetening process.

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IV. Results and Discussion

The current NGC amine gas sweetening plant is simulated using ProMax simulator V. 5. The DEA and MDEA are utilized as an aqueous absorbent to absorb acid gases from the sour gas stream. The process simulation can be done by providing the ProMax program by gas stream compositions and operation conditions from Tables I and II, respectively, and choosing amine fluid package. The installing of an inlet gas separator is an important step (Shooshtari and Shahsavand, 2013). Moreover, an amine absorber tower is also an important unit of the sweetening process and it also needs some specifications, for instance, streams temperature and pressure. Furthermore, rich amine requires to bring regenerated and that can be done by installing an amine regenerator tower (Davoudi, et al., 2014). Furthermore, the installing a flash tank for rich amine may be very useful to avoid any technical problems that might be caused by rich amine impurities. Furthermore, water makeup stream should be added with a mixer to the process. Amine concentration may be built up in the process because of water losses with sweet gas (Poe and Mokhatab, 2017). Water makeup stream will maintain the amine solution concentration during the sweetening process.

An optimization study was performed on the NGC amine sweetening unit to determine the amine type and blend that minimizes the system's energy consumption. Three different amine solvent scenarios were evaluated:

1. 28.55 wt% DEA
2. 30 wt% MDEA and 10 wt% DEA
3. 50 wt% MDEA

1) Scenario 1: 28.55 wt% DEA

The first scenario represents the current operating conditions of the NGC amine system. Fig. 3 shows the relationship between the circulation rate of the 28.55 wt% DEA solvent solution and sweet gas H_2S and CO_2 concentrations. It could be argued that using of 28.55 wt% DEA at a circulation rate of 800 m^3/h is met the gas pipeline specifications in terms of H_2S and CO_2 concentrations.

The study also examined the effect of lean amine temperature on the sweetening process efficiency in the first process optimization scenario which is 28.55wt% DEA. Fig. 4 shows the relationship between the lean amine temperature of the 28.55 wt% DEA solvent solution and sweet gas H_2S and CO_2 concentrations. It is clear from Fig. 4 that the optimum value of lean amine temperature for the current scenario of amine type is 43°C.

2) Scenario 2: 30 wt% MDEA & 10 wt% DEA

Fig. 5 shows that the 30 wt% MDEA and 10 wt% DEA amine blend are able to achieve sweet gas specifications at a 510.5 m^3/h circulation rate and a 46.9 MW reboiler duty.

The study is also examined the effect of lean amine temperature on the sweetening efficiency process in the second process optimization scenario: 30 wt% MDEA and 10 wt% DEA mixture. Fig. 6 shows the relationship between the lean amine temperature of the 30 wt% MDEA and 10 wt% DEA amine blend solvent solution and sweet gas H_2S and CO_2 concentrations. As it is shown in Fig. 6, the optimum value of lean amine temperature for the 30 wt% MDEA and 10 wt% DEA mixture amine is 42°C.

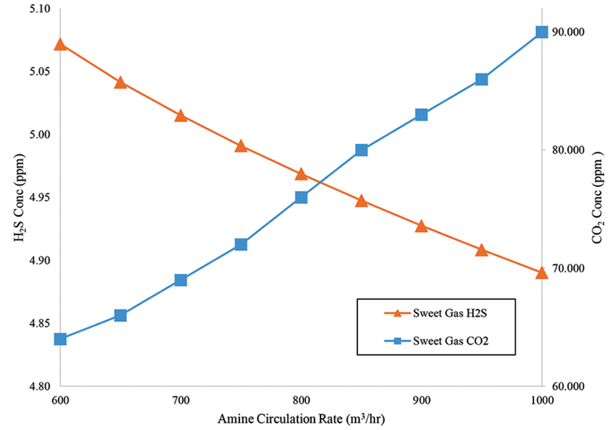

Fig. 3. H_2S and CO_2 removal with 28.55 wt% DEA.

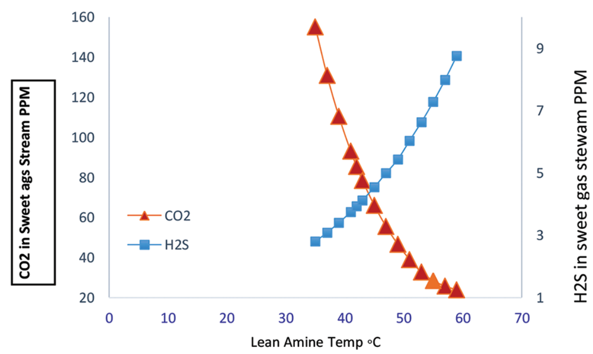

Fig. 4. The relationship between the lean amine temperature rate and the H_2S and CO_2 removal with 28.55 wt% DEA at 800 m^3/h DEA circulation rate.

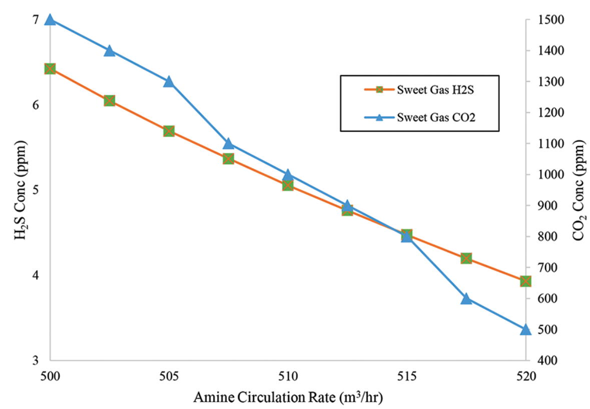

Fig. 5. H_2S and CO_2 removal with 30 wt% MDEA and 10 wt% DEA mixture.

3) Scenario 3: 50 wt% MDEA

The 50 wt% MDEA solution had the best performance of the three scenarios (Fig. 7). The 50% MDEA scenario met the sweet gas specifications at a solvent circulation rate of 414 m^3/h and a 38 MW reboiler duty.

The study also examined the effect of lean amine temperature on the third process optimization scenario which is 50 wt% MDEA. Fig. 8 shows the relationship between the lean amine temperature of the 50 wt% MDEA solvent

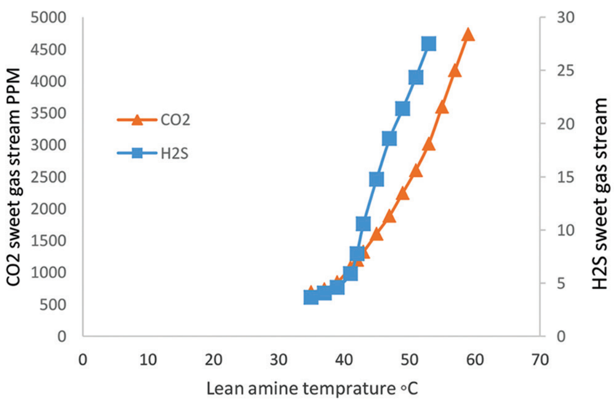

Fig. 6. The relationship between the lean amine temperature rate and the H_2S and CO_2 removal with 30 wt% MDEA and 10 wt% DEA mixture at a 510.5 m^3/h circulation rate.

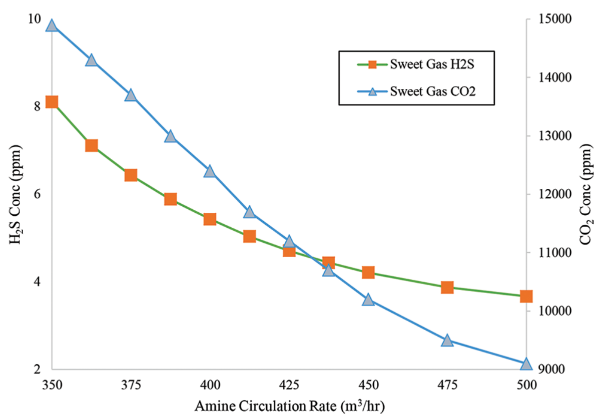

Fig. 7. H2S and CO2 removal with 50 wt% MDEA.

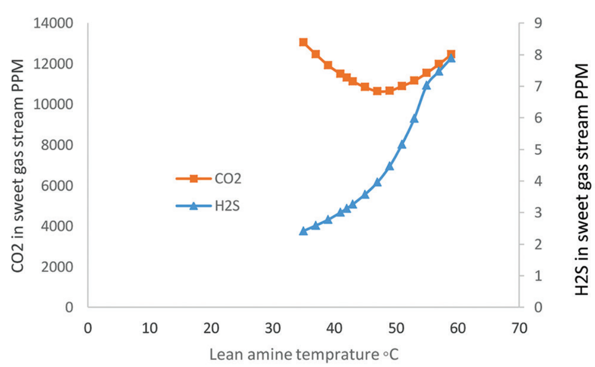

Fig. 8. The relationship between the lean amine temperature rate and the H_2S and CO_2 removal with 50 wt% MDEA at a 414 m^3/h circulation rate.

solution and sweet gas H_2S and CO_2 concentrations. It is clear from Fig. 8 that the optimum value of lean amine temperature for the 50 wt% MDEA is 45°C.

V. Conclusions

ProMax® was able to accurately model and optimize the amine system used by NGC. This work showed how the use of MDEA, can selectively absorb H_2S over CO_2 compare to DEA, a secondary amine. This was shown as required circulation rates and reboiler duties decreased with increasing MDEA concentrations. This study found that steam consumption could be reduced by 30.9% by changing from 28.55% DEA solvent to 50% MDEA solvent. Thus, it could be argued that a 50 wt% MDEA solution circulated at 414 m3/h was determined to be the optimum operating conditions. Moreover, the current study showed that the lean amine temperature also contributes to the sweetening process efficiency and performance. It can be stated that the lean amine temperature had a visible impact at all the three scenarios studied in the current work. It found that adopting lean amine temperature within the range of 43–48°C in all sceneries gives acceptable sweetening results.

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References

Abdel-Aal, H., Aggour, M. and Fahim, M., 2003. *Petroleum and Gas Field Processing*. Marcel Dekker, New York.

Abdulrahmanm, R.K., Zangana, M.H.S., Ali, K.S. and J.C. Slagle., 2017. *Utilizing Mixed Amines In Gas Sweetening Process: A Kirkuk Field Case Study And Simulation IEEE Conference Publication*. Available from: https://www.ieeexplore.ieee.org/document/8267616. [Last accessed on 2020 Dec 09].

Bre.com. 2020. Available from: https://www.bre.com/pdf/using-mixed-amine-solutions-for-gas-sweetening.pdf. [Last accessed on 2020 Feb 22].

Bre.com. 2020. *Bryan Research and Engineering, LLC*. Available from: https://www.bre.com. [Last accessed on 2020 Feb 14].

Davoudi, M., Safadoust, A., Mansoori, S.A. and Mottaghi, H., 2014. The impurities effect on thermal degradation and corrosivity of amine solution in South Pars gas sweetening plants. *Journal of Natural Gas Science and Engineering*, 19, pp.116-124.

Maddox, R. and Morgan, D., 1998. *Gas Conditioning and Processing*. Campbell Petroleum Series, Norman, Okla.

Poe, W. and Mokhatab, S., 2017. *Modeling, Control, And Optimization Of Natural Gas Processing Plants*. Gulf Professional, Amsterdam.

Sarker, N., 2016. Theoretical effect of concentration, circulation rate, stages, pressure and temperature of single amine and amine mixture solvents on gas sweetening performance. *Egyptian Journal of Petroleum*, 25(3), pp.343-354.

Shooshtari, S.R. and Shahsavand, A., 2013. Reliable prediction of condensation rates for purification of natural gas via supersonic separators. *Separation and Purification Technology*, 116, pp.458-470.

Sorensen, E., 2018. *Chemical Engineering Research and Design*. 1st ed. Institution of Chemical Engineers, London.

Stewart, M. and Arnold, K., 2011. *Gas Sweetening And Processing Field Manual*. Elsevier, Gulf Professional, Amsterdam.

Wang, X. and Economides, M., 2013. *Advanced Natural Gas Engineering*. Elsevier Science, Burlington.