Natural gas sweetening process simulation and optimization: a case study of the Khurmala field in Iraqi Kurdistan

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Abstract

Natural gas is the most important and popular fossil fuel in the current era and in the future as well. However, because natural gas exists in deep underground reservoirs it may contain several non-hydrocarbon components, for example, hydrogen sulphide and carbon dioxide. These impurities are undesirable compounds and cause several technical problems, for example, corrosion and environmental pollution. Recently, the Iraqi Kurdistan region has achieved huge development in many fields, for example, education, economic and in the oil and gas industries. Khurmala dome is located in southwest Erbil-Kurdistan region. The Kurdistan region government has paid great attention to this dome to provide fuel for the Kurdistan region. Currently, the Khurmala associated natural gas is flaring at the field and there is a plan to recover and trade this gas and to use it either as feedstock to the power station or to sell it on the global market. However, laboratory analysis has shown that the Khurmala natural gas has huge quantities of H_2S (about 5.3%) and CO_2 (about 4.4%). Therefore, this study aims to simulate the prospective Khurmala gas sweetening process by using the latest version of the Aspen HYSYS V. 7.3 program. The simulation work is based on the gas sweetening process using DEA solution and it has achieved high acid gas removal, for instance, H_2S concentration in sweet gas stream was about 4 ppm at 400 m^3/hr DEA solution circulation rate. In addition, the simulation work has also achieved process optimization by using several amine types and blends for example, MEA and MDEA. It has also studied some of the critical amine process factors for each amine type, such as the amine circulation rate and amine

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concentration. The optimization work found that the use of DEA 35% w/w may be considered to be the most recommended process.

Keywords: natural gas sweetening, Khurmala dome, MEA, DEA, MDEA process simulation, Aspen HYSYS V.7.3, process optimization.

Nomenclature

RMM	Relative Molecular Weight	H_2S	Hydrogen sulfide
CO_2	Carbon dioxide	DEA	Diethanolamine
MEA	Monoethanolamine	MDEA	Methyldiethanolamine

1 Introduction

The demand of natural gas in recent decades has been dramatic. Natural gas plays a huge rule in the recent world economy and development. However, natural gas usually contains several impurities for instance, acid gases that it need to be removed from natural gas to meet the gas pipelines specifications. Stewart and Arnold [1] noted that gas contracts regulation restrict H_2S content about 4 ppm and CO_2 about 2% in natural gas stream. Indeed, Khurmala dome is the northernmost dome of the Kirkuk oil fields structure. Moreover, the dome is located approximately 20 kilometres by 8 kilometres. However, the dome has not developed until 2003. Nowadays Khurmala field is considered as main fuel source for Iraqi Kurdistan region KAR. Khurmala associated natural gas is currently flaring at the field. There is a plan to recover and trade this gas to use it either as feedstock to power station or to sell it on the global market. However, the laboratory analysis has showed that the Khurmala natural gas has huge quantities of H_2S (about 5.3%) and CO_2 (about 4.4%). There are several processes to remove acid gases from raw natural gas for instance, solid bed process and chemical solvent process. Amine solutions are used to remove the hydrogen sulphide and carbon dioxide. This process is known simply as the 'amine process', Gas sweetening by amine process has been considered as the most popular process in gas processing industries. Therefore, this study will adopt amine process to remove acid gases from Khurmala natural gas.

2 Basic amine process description

Amine process is considered as the most successful and common process in gas industry field. Indeed, this process is utilized alkanamine solution as a chemical solvent to remove acid gases from natural gas stream. Moreover, alkanamine possess high affinity toward acid gases and there are several types of amines that are used in amine process for example, monoethanolamine (MEA) and diethanolamine (DEA). Amine process is consisting of several operation units for instance, contactor tower, regenerator tower and heat exchanger. Figure 1 shows the typical amine process.

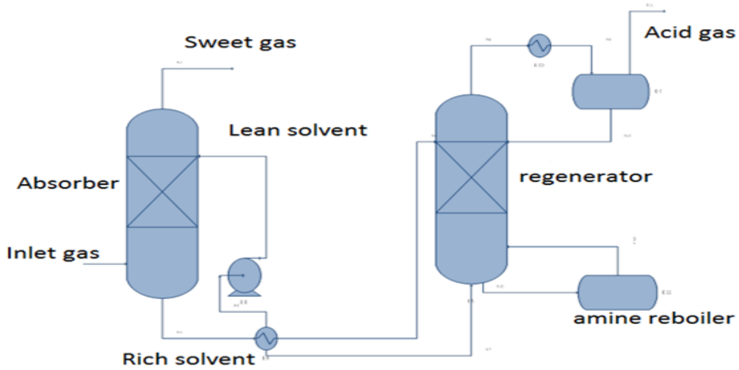

Figure 1: General flow diagram for gas sweetening process by amine solution.

The chemical reaction of amines with H_2S and CO_2 are given below:

$2RNH_2 + H_2S = (RNH_3)_2S$
$2RNH_2 + CO_2 = RNHCOONH_3R$ R= mono, di, tri-Ethanol.

3 Khurmala gas composition and water content calculations

The Khurmala gas stream composition and operating conditions are show in table 1. The gas composition is based on dry basis. It is very important to calculate the water content in the gas before process design or simulation.

Table 1: Khurmala raw natural gas compositions and operation conditions.

Laboratory name	Core laborites international B.V.	Component	Mole%
Location	Abu Dhabi Branch	H_2S	5.38
Field	Khurmala-Erbil	CO_2	4.48
Sample NO.	1 Cylinder (S-012)	N_2	0.11
Test data	14-03-2010	CH_4	63.35
Sample type	Natural gas	C_2H_6	13.9
Flow rate	120,000 stdm^3/hr	C_3H_8	6.03
Gas density	0.65 Kg/m^3	i-C_4H_{10}	1.36
Gas SG (Air=1.0)	0.67	n-C_4H_{10}	2.44
Pressure	7000 K.pa	i-C_5H_{12}	1.03
Temperature °C	38 C°	n-C_5H_{14}	0.73
Max. ambient temperature °C	38 C°	C_6H_{14}	1.19

Natural gas water content can be estimated by adopting the McKetta-Wehe Chart [2]. The water content in the raw natural gas is about 1000kg/MMstd.m^3= 128.265 kg/hr. Table 2 shows the natural gas composition with water content.

Table 2: Khurmala natural gas compositions and quantities (wet basis).

Component	Mole%	RMM	Kmole/hr	Kg/hr	Mole%
H_2S	5.38	34.076	288.03426	9815.056	5.372849
CO_2	4.48	44.01	239.85009	10555.8	4.474045
N_2	0.11	28.02	5.8891764	165.0147	0.109854
CH_4	63.35	16.02	3391.6302	54333.92	63.26579
C_2H_6	13.9	30.07	744.17775	22377.42	13.88152
C_3H_8	6.03	44.09	322.83394	14233.75	6.021985
i-C_4H_{10}	1.36	58.123	72.811636	4232.031	1.358192
n-C_4H_{10}	2.44	58.123	130.63264	7592.761	2.436757
i-C_5H_{12}	1.03	72.15	55.144106	3978.647	1.028631
n-C_5H_{14}	0.73	72.15	39.082716	2819.818	0.72903
C_6H_{14}	1.19	86.177	63.710181	5490.352	1.188418
H_2O	-	18	7.1258541	128.2654	0.132922
Total	100		5360.9226	135722.8	100

4 Steady state simulation and optimization

The expected Khurmala amine gas sweetening plant is simulated by using the latest version of Aspen HYSYS V.7.3. The DEA is utilized as an aqueous absorbent to absorb acid gases from sour gas stream. The first step of simulation work could be done by providing the program by gas stream compositions from table 2 and choosing amine fluid package as shown in figure 2.

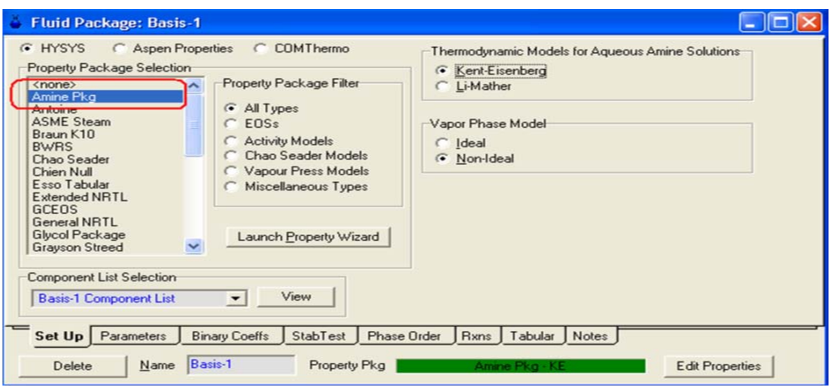

Figure 2: HYSYS fluid package menu.

It is quite important to use an inlet gas separator to remove any undesirable impurities such as, solid particulates and liquids. Amine contactor is also an important part of the sweetening plant and it also needs some specifications for example, streams temperature and pressure. Figure 3 shows the amine contactor

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menu. Rich amine needs to be regenerated and that could be achieved by installing an amine regenerator after amine heat exchanger. Figure 4 shows the amine regenerator menu and a simulation is run successfully.

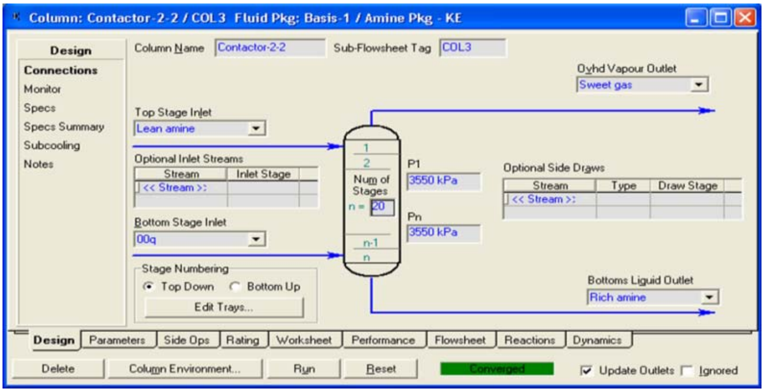

Figure 3: Amine contactor menu.

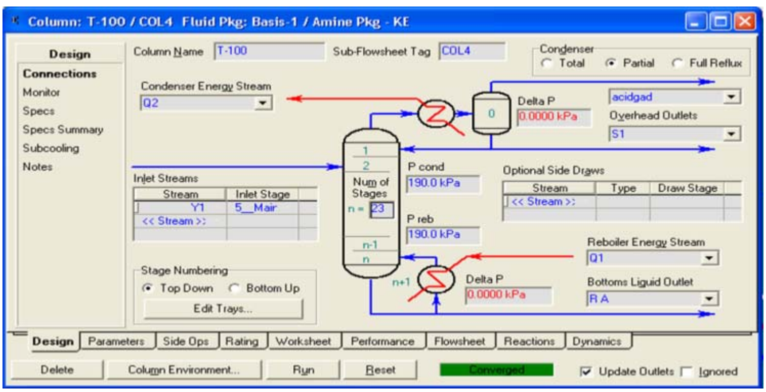

Figure 4: Amine regenerator menu.

Figure 5 shows the process flow diagram of Khurmala gas sweetening plant. Installation of a flash tank for rich amine may be very useful in order to avoid any technical problems that might be caused by rich amine impurities. Moreover, the ADJUST function is also important to adjust the mass flow rate of lean amine with the H_2S molar fraction in sweet gas stream. In addition, water make up 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. The water make up stream will maintain the concentration of amine solution in the process. The simulation process is done and the process achieved high acid gas removal which will be discussed in results and discussions.

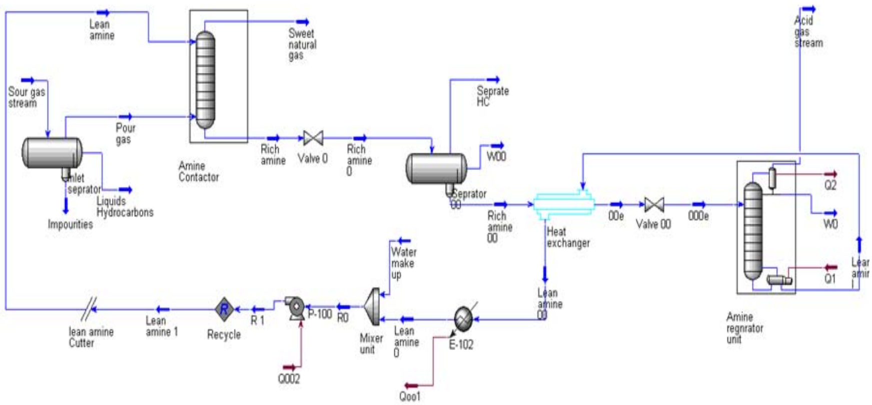

Figure 5: Process flow diagram of Khurmala gas sweetening plant.

4.1 Process optimization

The aim of this optimization work to study the effect of using various types of amine and amine blends on the amine plant performance. Therefore, optimization section will apply various amines with different concentrations that can be achieved by entering to simulation tools and changing sour gas stream compositions (for instance, change or remove DEA component and its molar or weight fraction in lean amine menu). The following steps are carried out for the process optimization.

Experiment 1: Using 10 % MEA for Khurmala gas sweetening plant by maintaining same operation conditions for instance, sour gas stream pressure and temperature and lean amine temperature and pressure. Then the results will be recorded for H_2S, CO_2 and H_2O in sweet gas stream which will be applied in MS Excel with other optimization results [3].

Experiment 2: Investigating 25% DEA for same simulation program and find out the acid gas composition and H_2O content in sweet gas stream.

Experiment 3: Investigating 40 % MDEA.

Experiment 4: Investigating with 40 % MDEA and 10% MEA.

Experiment 5: Investigating with 30% MDEA and 10% DEA.

5 Results and discussions

First, the study used 35% DEA amine solution to achieve the sweetening process and it has achieved acceptable sweetening results.

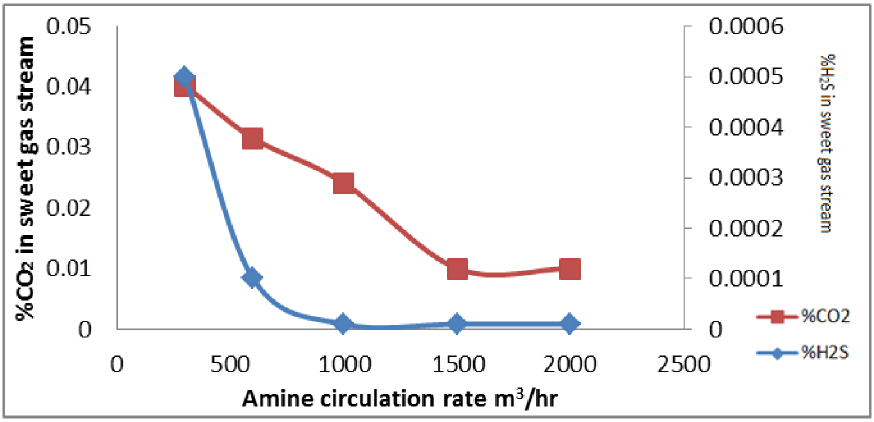

Figure 6: Effects of 35% DEA circulation rate on acid gas mole fraction in sweet gas stream.

Figure 6 shows that the increase in the 35% DEA circulation rate will lead to increase the acid gas removal. At 350 m^3/hr amine circulation rate the H_2S amount in sweet gas was about 5 ppm. When the amine rate was 400 m^3/hr it gave 4 ppm H_2S in the sweet gas stream and it achieves the optimum liquid residence time on tray. In contrast, that the rich amine stream temperature is decreased by increasing amine rate that may be because the increase in the circulation rate will decrease the amine residence time inside the column as shown in figure 7. However, the economical aspect should be considered for amine process as the increase of amine circulation rate will lead to an increase in the process operation cost.

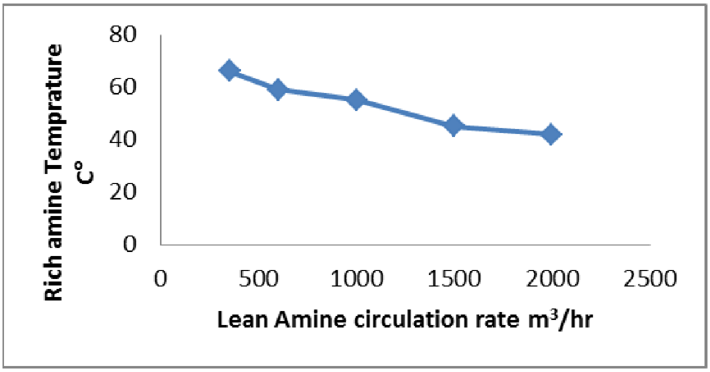

Figure 7: The relationship between 35% DEA rate and rich amine temperature.

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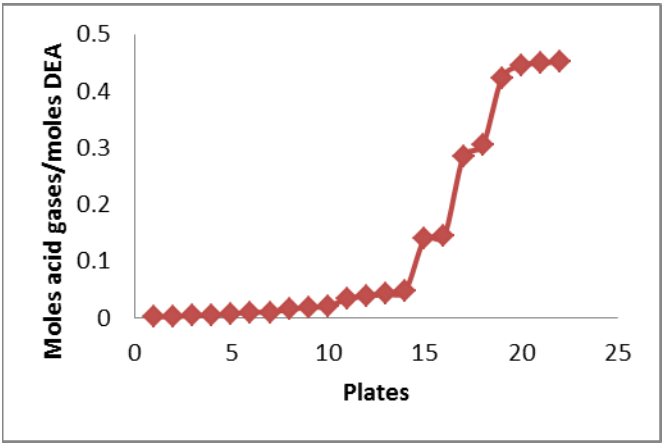

Figure 8: The effect of increasing the absorber plates on acid gas loading for 35% DEA case.

It can be that by increasing contactor plates the acid gas loading is increased because the capacity of the contactor will increase and more acid gas may be absorbed. After pate number twenty the loading stays constant. As a result, twenty trays are considered as ideal for the amine contactor as it gives an optimum acid gases removal.

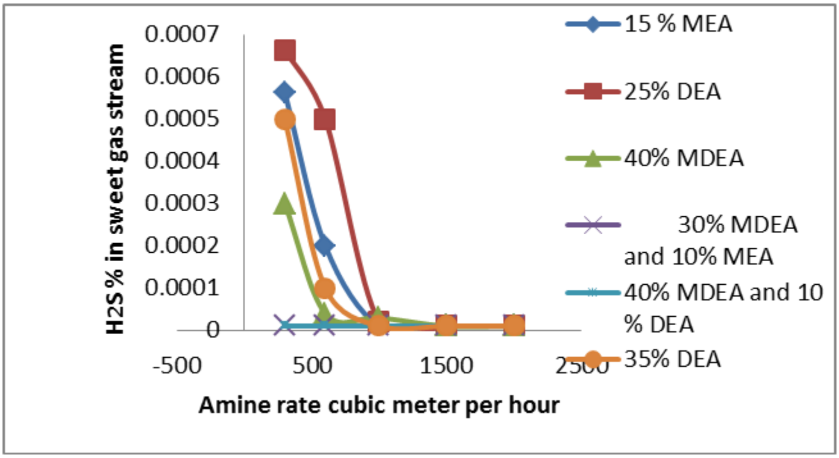

Figure 9: Relationship between amine rate and H_2S mole percentage in sweet gas stream for various amine types and blends.

Figure 9 shows that the removal of H_2S from gas stream is increased by increasing amine circulation rate for all amine types. However, increasing amine circulation rate is increased the process operation cost. Hence, using 40% MEDA with 10% DEA gives an optimum H_2S removal and lowest amine circulation rate. However, 40% MEDA may be considered as very high percentage and lead to amine process corrosion. Thus, the plant corrosion should also be considered in design work.

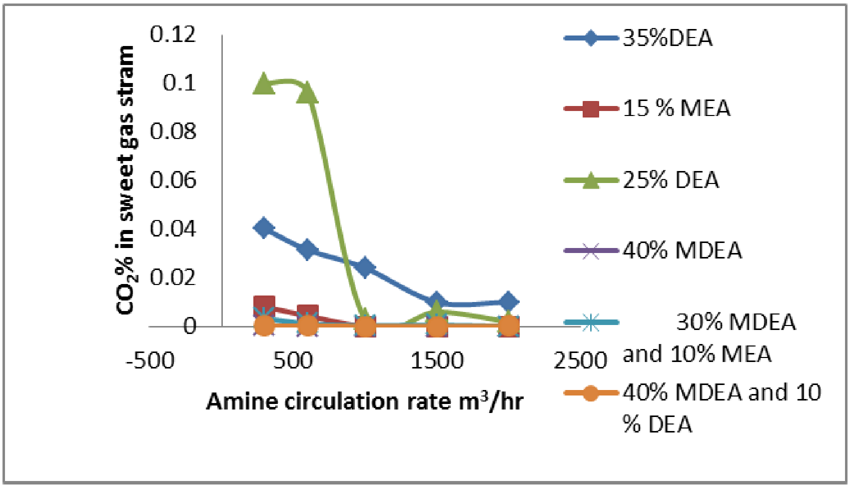

Figure 10: The relationship between amine circulation rate and CO_2 mole percentage in sweet gas stream for various amine types and blends.

From figure 10, it can be seen that MDEA and its blends (MDEA with DEA and MDEA with MEA) have high selectivity toward CO_2 and this is noted by many researchers [4].

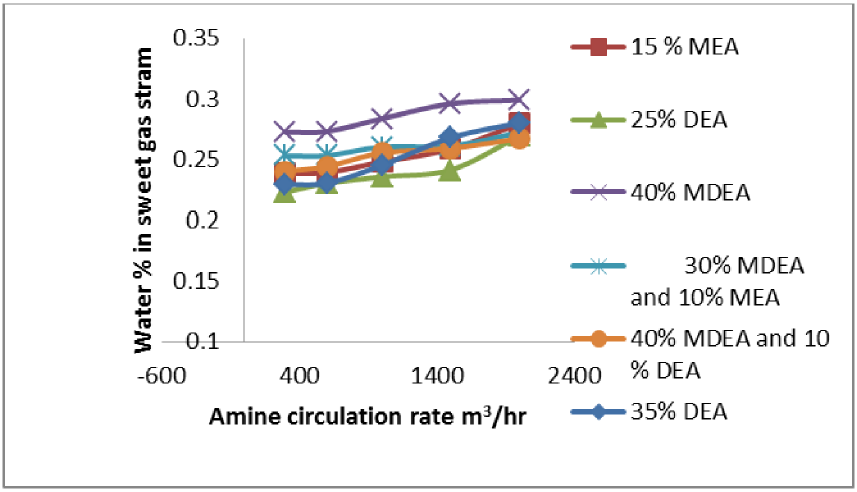

Figure 11: The relationship between water losses and amine rate.

Figure 11 shows the water loss in the sweet gas stream is increased by increasing amine circulation rate for all amine types and amine blends. However, 25% DEA shows the lowest water loss for almost all amine circulation rates. The water loss leads to various technical problems for example, amine loss and low amine concentration as well. Amine foaming may also be considered as the main responsible about this phenomenon.

6 Conclusion

This case study has achieved design calculations for gas sweetening process for Khurmala gas and simulated the process by using Aspen HYSYS V.7.3. The amine process is also optimized by applying several amine types and blends. The high amounts of acid gases in Khurmala gas problem can be solved by selection and installation of appropriate gas sweetening process. The simulation work has achieved high acid removal which meets the gas pipelines specifications for almost all amine types and blends. From the simulation work, 35% DEA with 400 m^3/hr circulation rate has achieved optimum gas removal and the processed natural gas stream has met the gas pipeline specification. It has been found that twenty trays achieved high acid gas loading for amine contactor tower. Several other process parameters such as water loss, acid gas removal and rich amine temperature are also investigated. From the process calculation and simulation process, it can be said that using 35% DEA is the most recommended for process. The study has found that amine blends are also gave good results and it could be considered for bulk CO_2 removal. Finally, there are other selection criteria that contributing in amine type selection such as cost and amine availably.

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