ENGINEERING *for* SUSTAINABILITY

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DYNAMIC SIMULATION AND OPTIMIZATION OF CO_2 ABSORPTION FROM ETHANE GAS IN ABSORPTION TOWER USING ASPEN-HYSYS PROC ESS SIMULATOR SOFTWARE

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Abstract

The aim of this research is to improve the sweetening processes of ethane gas in 9 and 10 south pars using DEA solvent. For this purpose of this work, Aspen-Hysys software was used for the dynamic simulation and amine Pkg equation was chosen from the fluid property package for calculating the thermodynamic properties of the process. The absorber configuration was according to the design and manufacture company. This research shows that pressure variation does not have any considerable changes on absorption process, while both amine inlet temperature and volumetric flow rate increment enhances the absorption tower efficiency. The effect of temperature was very significant as shown by the dynamic study plots. The optimum condition for CO_2 absorption from a stream of ethane gas with molar flow rate of 2118 kgmol $h^{-1}$was 75 m^3h^{-1} of amine at 30 ^oC and 24 bar. This optimized condition is economical, safe and feasible.

Keywords: Dynamic Simulation; Absorption Tower; Optimization; ASPEN- HYSYS Software.

INTRODUCTION

The natural gas extracted from independent gas wells usually contains large percentage of methane gas, some quantity of ethane with little quantity of other hydrocarbons like propane and butane gas [1, 2]. Other impurities such as steam, hydrogen sulfide, carbon dioxide, sulphur dioxide and helium gases in varying quantities depending on the types and location of wells are also present. Generally, in situ natural gas does not always meet industrial requirements for use in energy generation, chemical and/or petrochemical industries due to the presence of the impurities [3]. Consequently, there is need for refining processes to eliminate some of the impurities to enhance its usability. Ethane gas, which is valuable composition of natural gas is a feedstock for olefin plant and must be purge of CO_2 before it can be used. The purging process known as "sweetening process of ethane gas" can be achieved by absorbing the CO_2 into diethanol amine (DEA) solvent [4]. The aim of this work is to study the effects of operational variables in the removal of CO_2 from the ethane gas stream of South Pars Gas Phases 9 and 10 Absorption Tower using Aspen-Hysys (process simulator) dynamic simulation to facilitate the determination of the feed optimal conditions.

VARIOUS METHOD OF GAS PURIFICATION

Two Types Of Gas Purification

1. Absorption in rigid phase

Adsorption or absorption in rigid phase is one of the gas purification methods in which the acidic gas and other impurities associated with it are transferred onto the solid surface due to concentrations gradient. Absorption phenomenon occurs between absorbent and impurities due to molecular attraction force. In this processes formation or breaking of chemical bond does not take place and the processes is considered physical.

2. Absorption in liquid phase

The most usual method of gas sweetening processes in refineries and gas treatment plants is absorbing the impurities in a liquid phase. Absorption processes in liquid are divided into two types - physical and chemical. In physical absorption, gas flows through a liquid phase where the impurities are absorbed into the bulk of a liquid that has affinity for the impurities; the gases can then be desorbed from the liquid phase.The important advantage of this method is low energy consumption, and in addition to that, the solvent used can be reused again [5]. The chemical absorption process is mostly used in commercial gas purification process with diethanol amine (DEA) and monoethanol amine (MEA) as the commonest absorbents. Triethanol amine can also be used but it is not popularly accepted because it has relatively higher molecular weight, less activity and lack of stability. Generally, alkaline amine solutions are used as an absorber in liquid phase chemical absorption; hence this method is used in this study.

Chemistry Of The Processes

There are different reactions between amine and acid gases in different conditions. Generally in the first steps, H_2S reacts with amines via H^+ transfer, while CO_2 reacts with amine in two different reactions; in the first, it react with Amine to form acid carbonic salt and in the second, reaction occurs when the CO_2 is dissolved in water and form bi carbonate ion. The reactions are as follows:

$$H_2S + \text{Amine} \longleftrightarrow [\text{Amine}]\,H^+ + HS^- \quad (1)$$

$$CO_2 + H_2O + [\text{Amine}] \longleftrightarrow [\text{Amine}]\,COOH^+ + OH^- \quad (2)$$

$$CO_2 + H_2O + R_2NCH_3 \longleftrightarrow R_2NCH_4^+ + HCO_3^- \quad (3)$$

The reaction of CO_2 with amine is slow, but the reaction with H_2S is fast. Therefore, it is assumed that H_2S absorption occurs in gas phase while CO_2 absorption occurs in liquid phase [5].

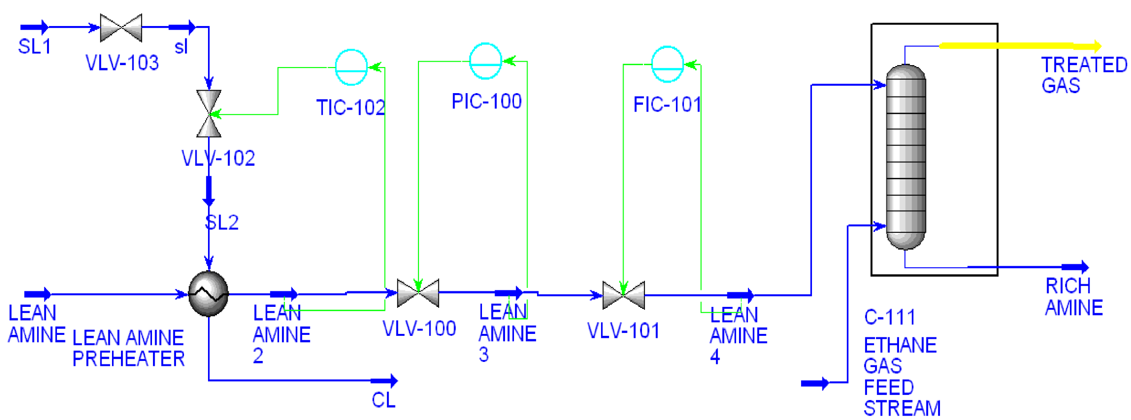

Fig.1 Process Flow Diagram for the Dynamic simulation of CO_2 absorption from Ethane Gas Stream

Process Simulation

The absorption tower in this study has 28 valve-type trays. The tower gas feed rate is 2118 kg molh^{-1}. The mole fraction of the feed is ethane, 0.9194; methane, 0.0092; H_2S, 0.000048 and CO_2, 0.054. The molar flow of CO_2 in the feed stream is 113.7 kg mol/h and represents the quantity to be absorbed by amine. The feed enters the tower at a temperature of 37^{o}C and a pressure of 24.4 atm. Diethanol amine (38% w/w) is used as the absorption liquid and it enters the tower at a temperature of 55.40^{o}C and a pressure of 24.1bar with a flow rate of 5142.291 kg molh^{-1}.

Effect Of Amine Inlet Temperature On Absorption Tower Performance

In order to understand the effect of amine temperature on the process, the amine temperature is simulated in the dynamic simulation environment at 44.97, 55.38 and 58.54 ^oC. The simulation results are shown in Fig.((1)-(3)). The results showed that increase in the amine inlet temperature increases the outlet gas flow rate and consequently higher removal of CO_2 from the ethane gas stream. The flow rate at the three studied temperature is 1967, 2015, and 2025 kgmol/h, respectively and the amount of CO_2 removed is 0.0016, 0.0042 and 0.0055 kgmol/h. this observation is due to the increase in the reaction rate between the amine and CO_2 gas as depicted in Eq. 2-3.

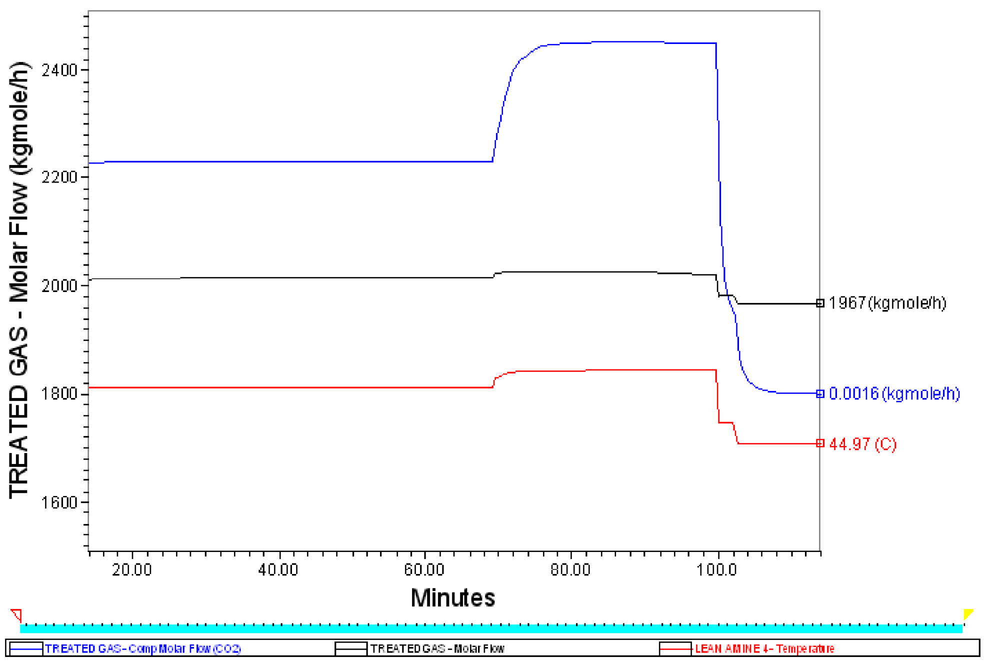

Fig.1: Tower performance at amine inlet temperature of 44.97^oC

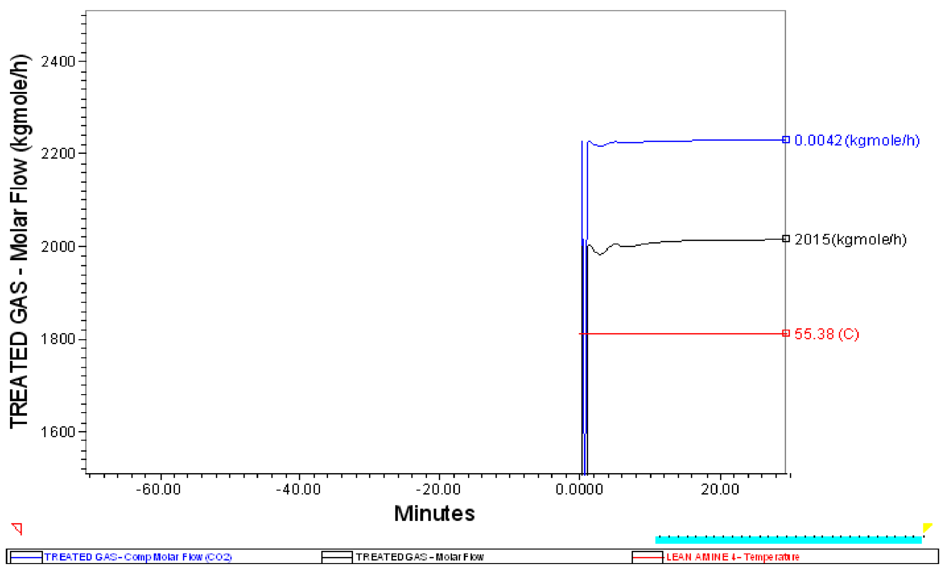

Fig.2: Tower performance at amine inlet temperature of 55.38°C

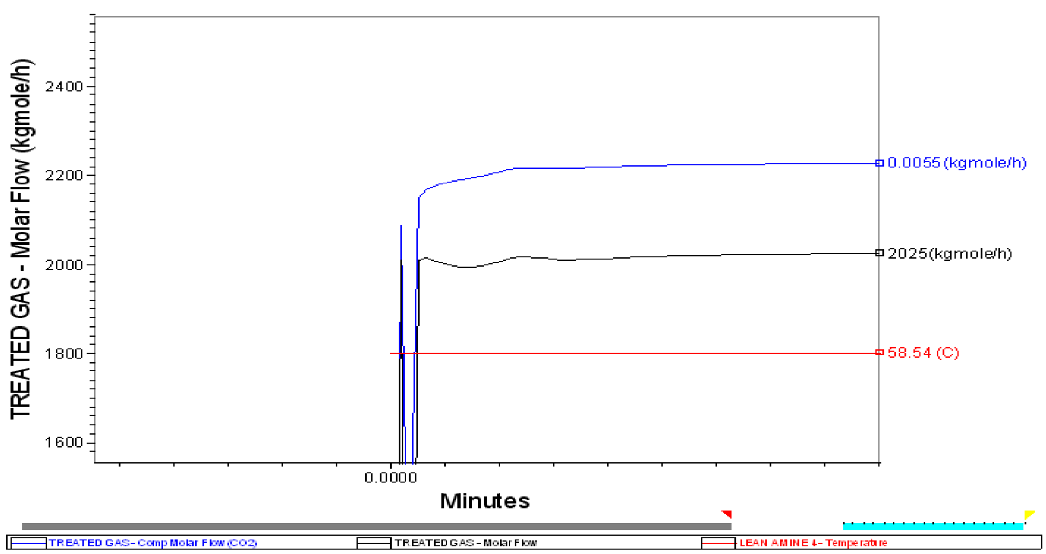

Fig. 3: Tower performance at amine inlet temperature of 58.54°C

Table 1: Composition of the absorption tower inlet and outlet streams

Composition	**Ethane Inlet Stream** Mole Fractions	**Amine Inlet Stream** Mole Fractions	**Amine Outlet Stream** Mole Fractions	**Treated Gas Outlet Stream** Mole Fractions
CO_2	0.0537	0.0011	0.0228	0.0000
H_2S	0.0000	0.0001	0.0001	0.0000
H_2O	0.0000	0.9035	0.8833	0.0062
DEAmine	0.0000	0.0953	0.0935	0.0000
Methane	0.0092	0.0000	0.0000	0.0097
Ethane	0.9194	0.0000	0.0003	0.9656
Propane	0.0176	0.0000	0.0000	0.0185

Analysis of Optimal Conditions

In this part of the work, the optimization of operational parameters is studied. In order to achieve this objective, amine inlet flow rate, pressure, and temperature were simulated and optimized to enhance the performance efficiency of the tower. Optimal values of the operational parameter were obtained. Table.1 shows the composition of the absorption tower at the optimized condition.

The Effect of Amine Flow on Tower Performance

Fig. 4 shows the effect of amine volumetric flow rate on the tower performance. The amine volumetric flow rate is assigned as the independent variable, while the monitored molar flow rate of CO_2 and ethane in the treated gas stream are assigned the dependent variables. The volumetric flow rate was increased from 60 to 150 $m^3\ h^{-1}$ and the result showed that increment in the amine volumetric flow rate drastically increases the absorption rate of CO_2 from 60 up to 75 $m^3\ h^{-1}$. Beyond 75 $m^3\ h^{-1}$, there is no absorption of CO_2 gas anymore. At this condition, it can be concluded that the absorption process has attained equilibrium based on the prevailing operating conditions and composition of the components. It is worthy of mention too that the molar flow rate of ethane gas in the treated gas stream slightly reduced from 1947 to 1945.7 kg mole h^{-1}. This is due to equilibrium and solubility factors as part of the ethane gas were mass transferred with the CO_2 into the amine stream during the absorption of CO_2. The optimal amine volumetric flow rate observed is 75 m^3h^{-1}.

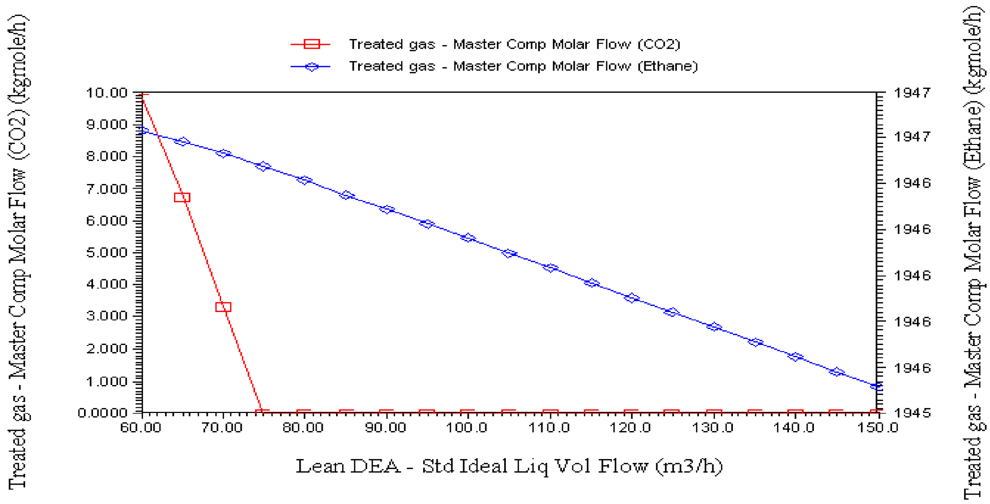

Fig. 4: Effect of amine volumetric flow rate on the tower performance

The Effect of Amine Temperature On Tower Performance

The result of changing amine inlet temperature is shown on Fig. 5. Ethane and CO_2 molar flows were taken as the dependent variables, while the temperature was the independent variable. The minimum quadratic plot showed that initial increase in temperature decreased the absorption rate up to the turning point and further increment beyond that point increases the absorption efficiency of the tower. Maximum absorption of 0.024 kg mole h^{-1} was observed at a temperature of 30^oC. Increase in the temperature from 30 to 53^oC showed a decrease in absorption of CO_2 gas. Further increment in temperature above 53 to 70^oC progressively showed increase in the absorption of CO_2. Similarly, a small increase (almost negligible) in the quantity of ethane gas was observed at the treated gas stream. The enhanced absorption observed in the temperature range of 53 to 70^oC may due to thermal partition created by temperature increment that break the weak force of attraction between absorbed CO_2 and associated ethane molecules that were initially in equilibrium [6]. The absorption at 53 to 70^oC is comparably lower to that at 30^oC, hence it can be concluded that the tower can be best operated at lower temperature which will not only save both initial and operational cost, but also reduce the risk of operation at elevated temperature.

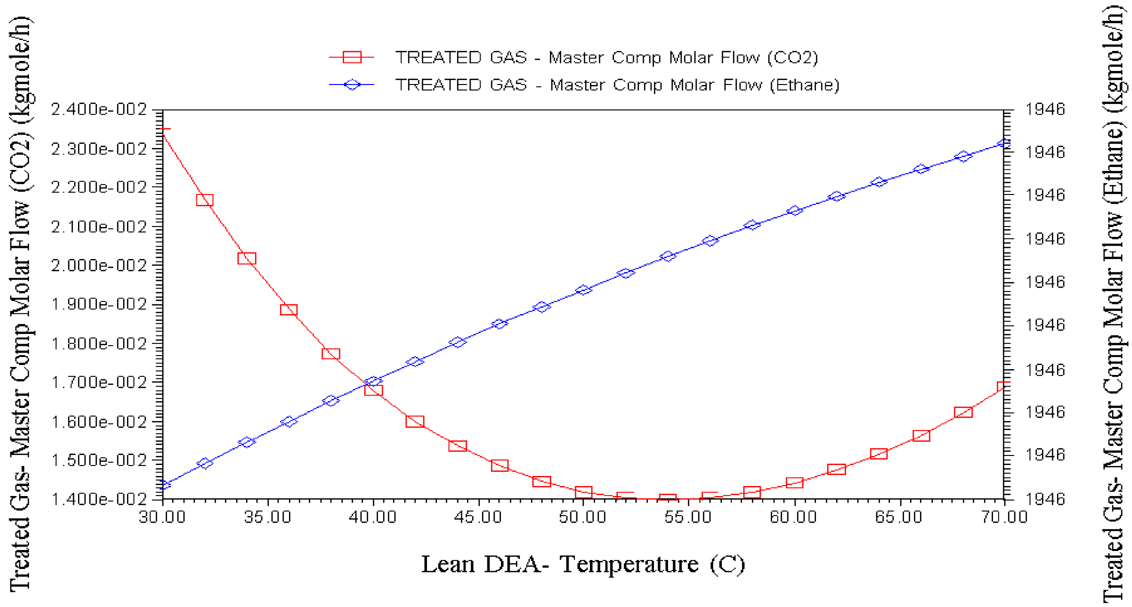

Fig. 5: Effect of amine inlet temperature on the tower performance

The Effect of Amine Inlet Pressure On Tower Performance

The effect of Amine inlet pressure is studied in the pressure range of 24 to 26bar and the response was plotted in Fig. 6. The result showed that pressure variation does not affect the absorption of CO_2 gas. The composition of both ethane and CO_2 was stable over the simulated range. This probably implied that amine has strong affinity for absorbing CO_2 gas without applying external pressure. Therefore, it can be concluded that the reaction between amine and CO_2 (Eq. 2-3) is rapid. For the purpose of economy and safety, the optimum pressure can be taken to be 24bar.

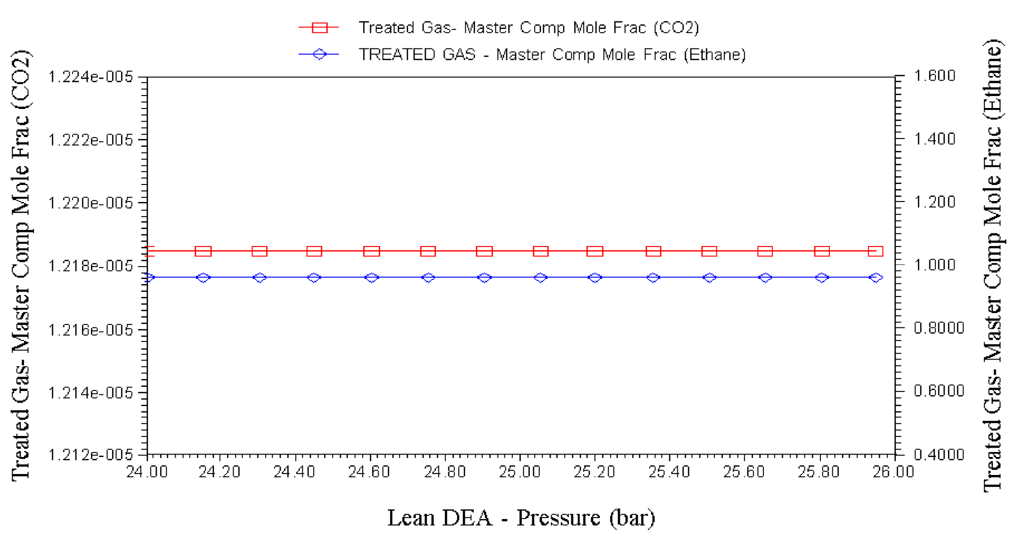

Fig.6: Effect of amine inlet pressure on the tower performance

CONCLUSIONS

In order to improve the sweetening operations of ethane gas in 9 and 10 phases of South pars, certain process variables like amine inlet temperature, pressure, and volumetric flow rate were simulated to evaluate the performance of the absorption tower. Both dynamic and optimization simulation results showed that temperature and volumetric flow rate increment enhances the absorption of CO_2, with observed optimal values of 30^oC and $75m^3h^{-1}$, respectively. The effect of pressure studies showed that Amine inlet pressure does not really affect the process. Therefore, the operation of the South Pars Gas Phases 9 and 10 absorption tower handling a gas feed rate of 2118 kg $molh^{-1}$ in a 28 valve-type trays absorption tower with amine (38% w/w) feed rate of 75 m^3h^{-1} at 30^oC and 24 bar is economical and technically viable.

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