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Improved performance of the natural-gas-sweetening Benfield-HiPure process using process simulation

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ABSTRACT

Natural gas processing plants are an essential part of the energy industry, providing clean burning fuels and valuable chemical feedstock. The importance and complexity of gas processing plants have increased over the years, leading to improvements in energy efficiency and integration with petrochemical plants. These improvements are aided by the use of computer simulation models as tools for designing, troubleshooting, and optimizing gas treating plants. This work discusses the major optimization techniques based on the Benfield HiPure process at Abu Dhabi Gas Liquefaction Company Limited (ADGAS) and the use of a process simulation tool, ProMax®. At ADGAS' Train 3 plant in Das Island, high pressure natural gas containing 6 to 7 mol % acid gas first comes into contact with a 30 wt. % Potassium carbonate (K_2CO_3) solution promoted with 3 wt. % diethanolamine (DEA). The gas is then contacted with a 20 wt. % DEA solution downstream. The results from the simulations show a close match with the plant operating data. The simulation model was then used to explore the effect of changes in process parameters on ADGAS' plant performance.

1. Introduction

ADGAS (Abu Dhabi Gas Company), a part of ADNOC (Abu Dhabi National Oil Company) group, is known for the production of Liquefied Natural Gas (LNG) since 1977. ADGAS operates three LNG Trains. The first two trains, (Trains 1 & 2) have been in operation since 1977, each with a capacity of 180 tons per hour of LNG. The third train (Train 3) was commissioned in 1994 and is capable of producing 380 tons per hour of LNG [1]. The Train# 3 gas sweetening plant is a “Benfield HiPure” design supplied by UOP, and is a hybrid arrangement of the basic Benfield and Amine units [5].

Carbon dioxide and hydrogen sulfide removal from natural gas is a key step in the liquefied natural gas (LNG) process, in particular for sour gas streams containing significant concentrations of these acid gases. This plant is seeking sweet gas which contains no more than 5 ppmv and 50 ppmv of H_2S and CO_2, respectively [1]. Higher acid gas concentrations will directly affect the quality of LNG product and/or pose serious operational problems to the cryogenic columns. Failure to remove carbon dioxide can cause freeze-out on surfaces inside heat exchangers or plug lines which may lead to safety hazards and/or reduced operation efficiency. In the presence of water, CO_2 and H_2S also form acids which cause corrosion of process equipment [2–4]. Therefore, removal of these contaminants is an operational necessity in any LNG producing plant.

The Benfield HiPure design was described in 1974 by Benson and Parrish [5]. It uses two independent but compatible circulating solutions to remove acid gases (H_2S & CO_2) from natural gas. In the first stage, the bulk of the acid gas is removed in a carbonate absorption system, where hot potassium carbonate promoted with diethanolamine (DEA) is employed as the solvent. In the second stage, the remaining acid gases are removed in an amine absorption system using DEA as the solvent. The DEA system provides the final trim removal of the acid gases to achieve the required sweet gas specification of less than 5 ppmv H_2S and 50 ppmv CO_2. The integrated schematic of the Benfield HiPure process is shown in Fig. 1.

The hot potassium carbonate absorption system comprises a split flow absorber and a regenerator with no side draws. The carbonate absorber and regenerator are both tall vertical packed bed columns. The treated gas from the carbonate absorber is fed directly into the amine absorber.

The DEA amine system comprises an absorber and a stripper, both tall columns using a packed bed arrangement. After absorbing the acid gases, the rich solution from the absorber is pumped to the DEA regenerator. The regenerator has no condenser, and the overhead gas is fed to the middle of the carbonate regenerator, which does have a condenser. Liquid from the carbonate regenerator condenser is fed to the top of the

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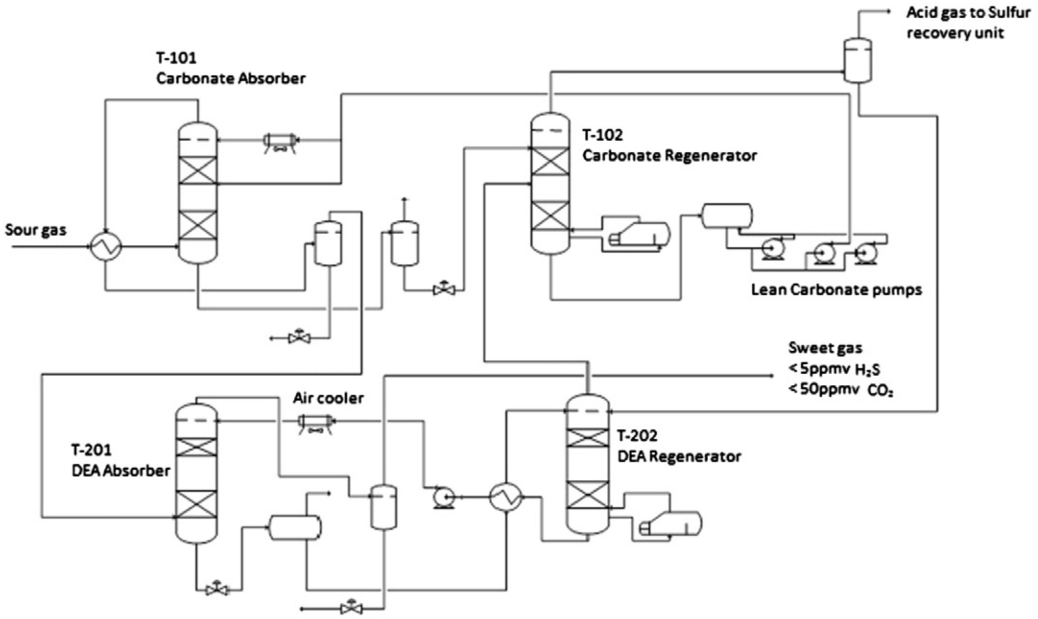

Fig. 1. ADGAS' gas sweetening unit-process schematic.

DEA regenerator as reflux. The exit gas from the DEA absorber (sweet gas) is passed on for further processing to produce LNG. The stripped acid gases (H_2S and CO_2) from both the carbonate and DEA regenerators proceed to a sulfur recovery unit (SRU), where the acid gases are processed to produce molten liquid sulfur.

The feed gas to Train 3 is high pressure gas of about 52 bar (g) with an average H_2S and CO_2 content of about 2.2% and 4.7%, respectively. The sweetened gas produced by this plant is about 0.4 ppmv H_2S and 19 ppmv CO_2, which meets the required design specifications [1].

Both the hot potassium carbonate and DEA absorbers operate at a pressure of about 50 bar(g) and the regenerators operate at lower pressures of about 0.8 bar(g). The necessary heat load for the regeneration is supplied through reboilers associated with each of the regenerators. Operating data and column internals are shown in Tables 1 and 2.

2. Process optimization through process simulation

Process optimization is the ultimate goal of process simulation. Simulation models help illuminate the bottlenecks in the processes and identify changes to help optimize plant performance. Process simulation can be described as a logical model for a chemical process that can be used to evaluate the process response for a given set of inputs. In a typical engineering process, process simulation provides the capability for the designer to understand the consequences of new design before the actual implementation of the process. This greatly minimizes the risks associated with implementation of less than optimum designs. Simulations also enable prediction of process responses to proposed changes in process parameters for proposed improvement projects [6,7].

Table 1
Typical operating data for ADGAS' Train 3 plant.

Parameter	Value
Feed gas flow rate (MMSCFD)	476.93
Feed gas temperature (°C)	25.03
Feed gas pressure (barg)	52.08
CO_2 feed gas composition (%)	4.67
H_2S feed gas composition (%)	2.11
Hot potassium carbonate unit	
Circulation rate (m^3/h)	Main: 343.50 Split: 1292.20
Lean solvent temperature (°C)	Main: 81.84 Split: 117
Lean solvent pressure (barg)	51.4
K_2CO_3 concentration (wt.%)	30
Promoter concentration (DEA) (wt.%)	3
Amine unit	
Circulation rate (m^3/h)	109.8
Lean solvent temperature (°C)	49.94
Lean solvent pressure (barg)	53.71
DEA concentration (wt.%)	20

Much work has been published on the modeling and simulation of both the hot potassium carbonate [3,8] and amine systems [2–4,10, 11]; however, limited studies have been available for the Benfield HiPure process [5]. This work focuses on the simulation of the ADGAS Train 3 plant using ProMax® modeling software due to its capabilities in modeling gas sweetening and other electrolytic processes [9]. ProMax was used to perform a parametric study to provide guidance for new operating conditions that can improve performance of the gas sweetening unit.

3. ADGAS Train#3 simulation model

The plant model is set up in ProMax using current operating conditions to set a benchmark, or base case, for the case studies. Since the

Table 2
Absorber configurations for ADGAS' Train 3 plant.

Hot potassium carbonate absorber	
Top section	
Column diameter (m)	3.581
Packing height (m)	9.144
Bed 1 packing type	#2.5 S.S mini rings
Bottom section	
Column diameter (m)	4.724
Packing height (m)	9.144
Bed 2 packing type	#3 S.S mini rings
Amine absorber	
Column diameter (m)	2.972
Packing height (m)	15.24
Packing type	#3 S.S mini rings