Journal of Loss Prevention in the Process Industries 41 (2016) 169–177

Contents lists available at ScienceDirect

Journal of Loss Prevention in the Process Industries

journal homepage: www.elsevier.com/locate/jlp

Some notes on process intensification of amine based gas sweetening process for better temperature distribution in contactor to reduce the amount of amine as a result of corrosion and foaming

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ARTICLE INFO

Article history:
Received 6 August 2015
Received in revised form
7 February 2016
Accepted 16 March 2016
Available online 18 March 2016

Keywords:
Gas sweetening
Supersonic separation
H_2S
Corrosion
Multi-lean amine flow pattern
CFD

ABSTRACT

The conventional processes of acid gas removal from natural gas have the disadvantages of low acid gas loading capacity, high equipment corrosion rate and energy demand. To address these issues and to better control of corrosion and temperature in the contactor, the temperature based techniques such as supersonic gas separation, mixed amines and multi-lean amine streams processes are simulated and proposed using computational fluid dynamics and process simulator software, respectively. The results of multi-lean amine streams approach confirmed a lower corrosion and temperature along the contactor and proposed a promising process.

1. Introduction

The removal of acid gases, namely H_2S and CO_2, from natural gas is essential for environmental, operational and health reasons (Tavan et al., 2013; Tavan and Hossein, 2013; Tavan and Tavan, 2014). Removal of acid gas from natural gas is always performed by amine solutions (Noeres et al., 2003; Plaza et al., 2010a; Yildirim et al., 2012; Ali et al., 2000; Notz et al., 2012; Plaza et al., 2010b). The main disadvantage of conventional gas sweetening process with amine solution lies in its high external energy input required to fulfill the desired purification (i.e., high steam consumption). Moreover, 25% of the maintenance expenditure is devoted to corrosion control, in gas sweetening plants (Tavan et al., 2013; Tavan and Hossein, 2013; Tavan and Tavan, 2014).

In order to address these issues, some techniques such as using membrane, hydrates, ammonia and ethanol sweetening processes are previously proposed (Ahmad et al., 2012; Zeng et al., 2013; Niu et al., 2013; Harboua et al., 2014). However, these processes have the disadvantages of low acid gas loading capacity, high equipment corrosion rate and many requiring modifications in existing plant. Hence, it can be said that these processes need more investigations and developing a novel process with low required energy and high absorption capacity is crucial.

It is emphasized that corrosion-related problems cost the gas industry millions of dollars leading to low production as well as damaged equipments. Moreover, thermally degraded products of amine (i.e., heat stable amine salts, oxygen and CO_2 presence in amine solution) are previously reported as the main cause of corrosion problems (Davoudi et al., 2014). Although, Davoudi et al. (2014) in their article recognized the all sources of corrosion in a gas sweetening plant, they did not mention any recommendation or a new costless process to control corrosion in the plant. Since,

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http://dx.doi.org/10.1016/j.jlp.2016.03.019
0950-4230/

the absorption process is an exothermic reaction, study of stages temperature in contactor column and maximum temperature of this column would give useful information about the reactive absorption process. As we believe lower temperature cause lower corrosion, some economical alternatives with low modification in the existing plant are recommended to better temperature distribution along the contactor column. In addition, in this research, two author-based indicators including foaming tendency as a results of corrosion and rich amine loading (RAL) as criterion of acid gas corrosion are reported for the processes. Moreover, supersonic gas separation as a cryogenic process is investigated and an innovative process based on the split flow process, called "multi-lean amine streams", is proposed the led to better temperature distribution and corrosion control in the amine contactors. Today, computer-aided process simulation is almost recognized as an essential tool in the process industries. Process simulator is a model-based representation of a chemical process in the software platform. This software simultaneously solves the mass and energy balance equations around unit operation equipments to find a stable operating point with the help of knowing chemical and physical properties of pure components and their mixtures and possible reactions. Hence, all properties of an Iranian gas well, the Khangiran gas refinery Company, are considered for the simulation due to higher acid gas content in the inlet sour gas stream. Therefore, this paper summarizes the various processes available and suitable for removal of acid gas from natural gas to meet the pipeline stringent specifications, aiming good temperature distribution and resulting in lower corrosion rate along the absorber.

2. Simulation

2.1. HYSYS simulations

Table 1 shows the compositional analysis of several natural gases in Iran. It is obvious that natural gas often contains acid gases in variable concentrations. Typically in Iran, acid gas concentration varies from low amount in ppm (e.g. Parsian gas treating Company) to near 50% concentrations (e.g. Masjed Solyeman gas treating Company). Also due to economic source of CO_2, mainly for enhanced oil recovery (EOR) operations in the aged gas reservoirs, acid gas concentration varies from well to well. Generally, acid gas pipeline specifications are 4.0 ppm for H_2S and 2 mol % of CO_2 with dew point of less than -10 °C at 45 kg/cm^2.

It is noted that the Khangiran or Hashemi Nejhad gas treating Company located at Khorasan, province of Iran, previously used di-ethanolamine (DEA) as the solvent with concentration of 35 wt. %. The amount of acid gases are so high (more than 5 mol. %), which cause some serious problems like corrosion and formation of stable salts ultimately conducting to equipment plugging, amine lost and spending much more energy. To solve these problems, several methods have been previously proposed. Among them, replacement of DEA with methyl-di-ethanolamine (MDEA) received more attentions and this gas processing plant uses MDEA for gas sweetening units. The properties of inlet sour gas for this plant are presented in Table 1 and the studied process is illustrated in Fig. 1. The sweetening unit is simulated using all of the standard guidelines using HYSYS 3.1 software with the Amine package by Kent-Eisenberg model. The sour gas as the feed stream with the rate of 45 MMCMD is treated with MDEA and reaches to the pipeline specifications. The absorber (contactor) includes 20 stages operating at pressure of 67–72 barg. The regenerator column contains 20 stages where the rich amine stream enters to its 3rd tray and the pressure of this column is 0.8 barg. The output results of acid gas removal simulation are tabulated in Table 2 and it is seen that the simulation results are totally consistent with actual data.

Table 1
Typical compositional analysis of Iranian natural gases reservoirs.

Field	Kangan	Nar	Khangiran	Assaluyeh	Sarkhon
Components	Mole%	Mole%	Mole%	Mole%	Mole%
N_2	5.950	4.610	0.550	3.474	4.890
CO_2	1.830	1.460	6.410	1.860	0.650
H_2S	681 ppm	59.6 ppm	3.850	0.555	0.020
COS	–	–	17 ppm	3.1 ppm	–
C_1	85.290	87.980	88.350	85.086	87.760
C_2	4.140	3.650	0.560	5.448	3.750
C_3	1.320	1.090	0.009	1.991	1.390
i-C_4	0.290	0.240	0.020	0.379	0.320
n-C_4	0.400	0.320	0.030	0.573	0.480
i-C_5	0.200	0.160	0.020	0.178	0.190
n-C_5	0.140	0.110	0.020	0.159	0.150
C6+	0.440	0.380	0.010	0.273	0.210
RSH	59.6 ppm	17.1 ppm	–	159.4 ppm	–

2.2. Computational fluid dynamic (CFD)

Although, application of supersonic gas separation is investigated for natural gas dehydration, hydrocarbon dew point control, deep liquid recovery (Karimi and Abedinzadegan Abdi, 2009; Wen et al., 2011, 2012a; Yang et al., 2014a; Yang et al., 2014b; Rajaee Shooshtari and Shahsavand, 2013; Machado et al., 2012; Wen et al., 2012b; Twister, 2015), bulk H_2S and CO_2 removal is not well studied. In details, Wen et al. (2012a) studied water and hydrocarbon condensation founding that radial distribution of the gas parameters affects gas/liquid separation. Yang et al. (2014b) investigated the effect of pressure recovery coefficient (PRC) along the separator based on theoretical models and they observed that PRC depends on the gas adiabatic exponent and Mach number. Karimi and Abedinzadegan Abdi (2009) used a link between HYSYS and MATLAB and the effects of temperature and pressure are discussed in their research for selective water separation.

Unfortunately, most of the researchers are focused on pure and binary components, which cannot be extended for real conditions. Meanwhile most of the commercial softwares are unable to provide exact equilibrium flash calculations across the supersonic device due to very low temperature caused by adiabatic expansion. Hence, reliable software for equilibrium flash calculations is also required and the flows across supersonic device are very complicated requiring great attention. In the present study, feasibility of deep H_2S and CO_2 removal is particularly explored using CFD simulation (Computational Fluid Dynamics), and the author-made equilibrium flash calculation software for the sourest industrial gas treating plant in Iran. In this research, the geometry of supersonic device is designed to ensure the pipeline specifications for H_2S and CO_2 contents in sweet gas and effects of some parameters are investigated.

In this study, new supersonic equipment is designed involving Laval nozzle and diffuser. The Laval nozzle consists of three parts; converging part, throat area and diverging part. From the converging part to the throat area, the sonic velocity is reached and shock wave occurs. The flow pattern is then changed from supersonic to subsonic in the shock region and then remained kinetic energy is transformed to increase static pressure and temperature is also increased in diffuser. In current research, three designs of supersonic separator are created and the generated geometries are given in Table 3. For example, the "first design" of supersonic separator is 1141.6 mm long and the dimensions of the converging part are obtained using Eq. (1) and other characteristics are also