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Simulation and feasibility analysis of structured packing replacement in absorption column of natural gas dehydration process: A case study for Farashband gas processing plant, Iran

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ABSTRACT

Application of structured packing in separation processes like natural gas dehydration has been increased since last few years. Replacement of the existing trayed column with that of structured packing can enhance the capacity and performance of the natural gas dehydration process. In this work, the natural gas dehydration plant of Farashband gas processing plant has been simulated. The profile of concentration, temperature and pressure in absorption column was obtained. A computer program, prepared with Visual Basic, has been proposed to calculate the height equivalent to a theoretical plate (HETP) of structured packing. The effect of some important parameters of inlet Tri-ethylene glycol (TEG) and natural gas on the performance of absorption column have been analyzed. Results show that revamp of trays with structured packing, can reduce outlet natural gas dew point and improve the positive effect of other parameters on the performance of dehydration unit. Moreover, the most significant factors affecting the HETP were investigated which were less than 15% effective. Finally, the cost of the modification project for the absorption column in the Farashband gas processing plant was calculated. The cost is evaluated 202,909 $ in this case and replacing was found economically justifiable.

1. Introduction

1.1. The gas dehydration process

The presence of water vapor in natural gas can cause serious problems such as hydrate formation or freezing (which results pipe plugging), corrosion (especially in the presence of H_2S and CO_2) and reduction of combustion efficiency (Rohani, 2009). Hydrate formation stems from the presence of water vapor in the gas mixture of methane, ethane and propane which in turn contributes to many problems in the process of gas production and is regarded as one the most important limitations in the natural gas treatment and transition industry (Dendy Sloan). In the gas dehydration unit, separation of water from the gas stream via dew point adjustment not only prevents the hydrate formation and pipeline blockage, but also decreases the probability of equipment corrosion (Mokhatab and Poe, 2006).

There are several methods for gas dehydration, including: absorption with solvent, adsorption, gas permeation with membrane and gas refrigeration (Siming, 1999). Among these methods, absorption has been used on an industrial scale for many years (Siming, 1999).

The glycols are effective liquid desiccants which are widely utilized in the dehydration process as absorbent. Some benefits of glycols usage are their high hygroscopic property, low vapor pressure, high boiling point, and low solubility in natural gas (Khosravanipour Mostafazadeh et al., 2009). The four types of glycols that have been utilized for natural gas dehydration are ethylene glycol (EG), diethylene glycol (DEG), triethylene glycol (TEG), and tetra ethylene glycol (T4EG). The standard method for the natural gas dehydration is the absorption of water using triethylene glycol (Khosravanipour Mostafazadeh et al., 2009).

The advantages of TEG compared to the other glycols are: 1) Lower vapor pressure 2) Higher resistance to degradation 3) Lower viscosity.

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Glycol has been used for dehydration since the first of the 20th century (Kohl and Nielsen, 1997; Wieninger, 1991; Pearce et al., 1972; Paymooni et al., 2011; Smith, 1993) but, limited researches have been conducted to improve absorber trays yields and investigate the equations of state to predict thermodynamic behavior of water-glycol system (Scauzillo, 1961; Twu et al., 2005; Erik, 2003). In 2009, Khosravanipour Mostafazadeh et al. (2009) investigated Vapor-Liquid Equilibria of Water + Triethylene Glycol (TEG) and Water + TEG + Toluene at 85 kPa. In 1999, Koch-Glitsch studied improvement of TEG and natural gas contact in packed towers (Koch, 1999). Also, in 2011 Paymooni et al. (2011) investigated the Enhancement in Triethylene Glycol (TEG) Purity via Hydrocarbon Solvent Injection to a TEG + Water System in a Batch Distillation Column.

The absorption column of a natural gas dehydration unit has been simulated by H. Pirzade and absorber charts were plotted (Pirzadeh, 2003). The desorption system of the Farashband gas processing plant dehydration unit was simulated by M. Jooshghani in 2004 (Joshghani, 2004). Natural gas dehydration in packed towers has been investigated by S. Khayami; he also studied the influence of various factors on absorption rate (Khayami, 2004).

In recent years, most research has been done in response to the environmental debate. Today prevention of light and volatile compounds (benzene, toluene, Ethyl Benzene and xylene (BTEX)) emission is highly regarded (Break, 2000; Darwish, 2004). On the other hand, from the economic viewpoint, glycol waste and hydrocarbon emission have been studied (Choi et al., 1992; Gupta, 1996; Grizzle, 1993).

1.2. Methods of reducing dew point of exhaust gas from the absorption column

There are some methods for the TEG regeneration process to achieve reduced water content specifications and/or BTEX emissions, including: 1) Using stripping gas 2) Vacuum regeneration 3) Regeneration using solvent 4) Cold finger method (Reid, 1975; Erik and Tyvand, 2002) 5) Increasing the height of absorption column 6) Replacing the tray column with packed bed column:

One way to reduce dew point of output gas leads from the absorption column is replacing existing contactors (tray) by contactors with higher efficiency (Structured packing) which is the subject of this paper and will be discussed afterward.

1.3. Structured packing

During the last two decades, the application of the structured packing in mass transfer processes has been increasing (Wang et al., 2006). The first generation of the structured packing was manufactured from wire gauze. This type of packing was quite expensive compared to random packing. It was mainly used in the vacuum distillation where a large number of theoretical stages were required combined with an extremely low pressure drop. The development of sheet metal structured packing by Sulzer in the late 1970's revolutionized the packing industry. He made the structured packing more affordable and it became competitive with conventional internals (trays, random packing) (Erasmus, 2004).

The structured packing was made commercially available in the 1980's. Its distinct performance advantages became clear very quickly, which conduce to the modification of the mass transfer market over the succeeding 10 years. It is now considered as the most preferred packing for many applications.

In absorption processes, the best performance is usually obtained by packing techniques involving low pressure drop, good mass transfer efficiency, and high capacity. The important properties of an efficient packing seem to be a high effective area, good liquid distribution, good gas liquid mixing, low pressure drop, and a structure composed of a material of small thickness (Kohl and Nielsen, 1997).

The general tendency of chemical engineering is to achieve high efficiency and capacity of separation units at a minimal possible cost. A novel generation of column internals is introduced to improve the mass transfer operation in this regard. The structured packing is made of corrugated sheets which have gained wide acceptance (Sperandio et al., 1965; Sakata and February 15, 1972; Spiegel and Meier, 2003; Chen et al., 1982). The structured packing has been widely applied for mass transfer processes, and its applications in separation process have been developed during the past few years.

1.4. Replacing the tray column with the packed bed column

The Contactor is the most important mass transfer equipment in TEG dehydration since its performance has crucial impact on downstream processes. The typical contactor is equipped with internals like Vane Inlet Device (VID) for gas distribution, chimney tray for collection of liquid, trays/packing for mass transfer and demister to minimize TEG losses. Mass transfer in contactor can be achieved by using bubble cap, valve trays, sieve trays or the structured packing.

Usually, the column with the structured packing has shown better performance than tray column (Baniadam et al., 2009). Specific surface area of structured packing is between 100 and 750 m^2/m^3, and its void fraction is higher than 90% (Olujic et al., 1999).

High capacity, high mass transfer surface area, high turn down ratio, low pressure drop, and low liquid hold up are the advantages of the structured packing in comparison with trays or a random packing. Other benefits of the packed columns are shorter column height, mechanical simplicity, ease of installation and ability to be fabricated cost-effectively from corrosion-resistant materials, including plastics, ceramics and other nonmetals.

One of the constraints on the selection of the structured packing is the high cost per unit volume, which causes the capital investment to be more than that of random packing or tray (Rahimpour and Kashkooli, 2004). Moreover, sometimes trays are easier to clean compared to packing. But, the column capacity can increase at least 30–50% by replacing the existing tray columns with structured packing columns. In earlier days, bubble cap trays were commonly used in contactor. But in recent decade, due to the proven performance of the structured packing, TEG contactors are now designed or replaced with high capacity structured packing.

1.5. Farashband gas processing plant

Farashband gas processing plant is one of the oldest and important refineries in the southern part of Iran. It has been planted to dehydrate the produced gas and stabilize the accompanied condensate from Aghar and Dalan gas reservoirs. Every day around 1400 million standard cubic feet (MMscf) of gas is fed to this plant. The gas field of Aghar contains sour gas and the gas field of Dalan contains sweet gas. In summer, all of the gases from the Farashband processing plant are injected into the oil wells for recovery enhancement and in winter, the gas from Dalan (sweet gas) is used for general consumption and the gas from Aghar (sour gas) is injected to the oil wells. Also, the gas condensate of the gas processing plant (about 15,000 barrels/day) is sent to the Taheri harbor for exporting (Rahimpour and Jokar, 2012).