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Research Article

Performance Comparison of Different Separation Systems for H_2 Recovery from Catalytic Reforming Unit Off-Gas Streams

The performance of pressure swing adsorption (PSA), membrane separation, and gas absorption systems for H_2 recovery from refinery off-gas stream was studied by simulation-based data. The PSA process was simulated using adsorbents of silica gel and activated carbon for removing heavy and light hydrocarbons. The mole fraction profiles of all components and the relationship between hydrogen purity and recovery as a function of feed pressure were examined. The solution-diffusion model was applied for modeling and simulation of a one-stage membrane process. The gas absorption process with a tower tray was simulated at subzero temperature and the correlation between hydrogen purity and recovery as a function of tower pressure and temperature was evaluated at different solvent flow rates.

Keywords: Gas absorption, Gas permeation, Hydrogen recovery, Pressure swing adsorption

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1 Introduction

Hydrogen is considered a valuable gas in the refineries and industry. The most common applications of hydrogen are in hydrotreating and hydroprocessing units for desulfurization of fuels. Consequently, the hydrogen demand in industry has enhanced due to new environmental regulations for production of clean fuels. Furthermore, hydrogen can be used as a fuel directly in fuel cells. Fuel cells convert chemical energy to electrical energy by combining hydrogen from the fuel with oxygen from the air, thus providing a clean and constant source of electricity unlike some other renewable energy. Therefore, in the past decades, environmentalists have promoted hydrogen as the solution to the problems of air pollution and global warming [1]. Consequently, today it is urgent to construct additional units for hydrogen production.

Hydrogen recovery from reactor exhaust gas streams (off-gas) of refineries is one of the low-cost methods for hydrogen production [2]. This stream consists of hydrogen and hydrocarbons gases, so a separation process is necessary to remove impurities from this stream. Typically, most of the make-up hydrogen in refineries is supplied from a catalytic reforming unit (CRU) [3]. This unit is used to produce high-octane and aromatic products by dehydrogenation of the hydrocarbon molecules in which significant amounts of hydrogen gas is also obtained as by-product stream. This by-product stream is termed CRU off-gas stream. In some refineries, a part of this stream is transferred to the refinery fuel system. If the amount of hydrogen in this stream is remarkable, it would be economical to build a unit for recovering this amount of hydrogen which is called hydrogen recovery unit (HRU). The HRU produces two separate gas streams from the reactor exhaust gas of CRU, namely, pure hydrogen and tail-gas stream. The tail-gas stream includes C_1^+ and can be sent to the refinery fuel gas system. Also, purified hydrogen could be used in a hydroprocessing unit or in other applications. The recovered hydrogen could be combined with the make-up hydrogen to enhance the purity to 0.94–0.96 and then could be recycled to the hydroprocessing unit [4]. Pressure swing adsorption (PSA), membrane separation, and gas absorption processes are three methods that can be applied for hydrogen purification.

PSA is a cyclical separation process based on adsorption and is used for purification of gases like hydrogen in industry. In this process, the impurities are adsorbed by absorbents at high pressure and subsequently rejected at low pressure. For hydrogen recovery from off-gas streams, gases of C_1^+ hydrocarbons are adsorbed by the adsorbents and pure hydrogen is supplied. Depending on the purpose of separation, different adsorbents are used in PSA beds. For hydrogen recovery from off-gas streams, activated carbon and silica gel are appropriate candidates as adsorbents. PSA is able to provide almost pure hydrogen as product [5]. To have a continuous pure product flow, it is necessary to use more than one adsorption bed in the

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