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Optimization of natural gas treatment for the removal of CO_2 and H_2S in a novel alkaline-DEA hybrid scrubber ☆

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ABSTRACT

Contaminated natural gas when carelessly handled, often poses human and equipment related problems ranging from lung and skin infections to corrosion, equipment fouling/failure and reduction in gas quality owing to the presence of acid gases. In this work, four natural gas (NG) samples were treated to remove CO_2 and H_2S using 10–50% Di-Ethanolamine (DEA) solutions mixed with 5% w/w 0.1 M calcium hydroxide. The treatment process gave increased acid gas removal at increased DEA concentrations. Based on the simulation results, cost effective treatment of the gas samples, require 0.1 M $Ca(OH)_2$ and DEA mixed solutions in the range of 27.4–30%. The optimum mixture concentration for the gas treatment was found to be 30% $Ca(OH)_2$-DEA hybrid solution with feed gas flow rate of 830 kscf/h. In terms of pressure energy consumption, pumping the hybrid mix at 830 kscf/h will save pressure energy as compared to pumping the feed gas at 1024.58 kscf/h since the lower and upper limit feed gas flow rates gave similar results. The optimum pressure for NG treatment was found to be in the range of 2–2.7 bar (2–2.7*10^5 kgm^{-1} s^{-2}).

1. Introduction

The risks posed by CO_2, H_2S and other impurities in Natural Gas (NG) are increasingly alarming owing to their negative consequences in humans, equipment and the environment. Natural gas may be classified as sweet or sour. It comprises of methane, ethane, propane, isobutene, n-butane, nitrogen, CO_2, O_2, isopentane, n-pentane, hexane and H_2 [1]. Other gases include helium, hydrogen sulphide and mercaptans which give the gas its characteristic odour. CO_2 and H_2S are the major pollutants in NG. For easy/safe transportation, <50 ppm CO_2 is desired [2]. CO_2 and H_2S can be trapped using amine solvents, absorption equipment and membranes [3]. Other contaminants, such as carbonyl sulphide, mercaptans, ethane, pentane etc., are usually removed via distillation and absorption. Gas purification depends on the target-solute solubility, partial vapour pressures of the constituents and the spent heat during solvent recovery [4,5]. Absorption of CO_2 from flue gas using several alcohol-amine solvents has been reported [6]. According to Fang and Zhu [7], the use of amines, carbonates, aqueous ammonia, polymer membranes, ionic liquids and enzymes are recent advances in gas treatment operations. Acid gas removal from contaminated gas depends on the desired application; in internal combustion engines, a CH_4 concentration >90% is friendly [8,9]. High CO_2 in NG reduces engine power [10,11], while ~3500 ppm H_2S in gaseous fuels may cause internal corrosion of engines [12]. High amount of CO_2 also reduces the burn-rate of natural gas [3]. Transportation of significant amounts of H_2S can cause pipeline corrosion [13], leakages, fire explosions and loss of aquatic and human lives [14] hence, the gas must be treated prior transportation [15]. In selecting a solvent for gas treatment, one must consider its solubility, viscosity, solvent corrosivity, density, thermal stability, % H_2S/CO_2 in feed gas, process economics and solvent recovery [16,17]. According to reports from National Energy Laboratory, the recommended residual sulphur threshold in NG is 0.1 ppm [18]. One popular amine for acid gas absorption is Di-ethanolamine (DEA) with formula $HN(CH_2CH_2OH)_2$ [19,20]. Natural gas contains significant quantities of H_2S and CO_2 [21] thus, controlling these contaminants is critical in quantifying the risks associated with equipment fouling. Natural gas liquefies at −161 °C and 1 atm which necessitates CO_2 removal [22,23].

Fig. 1 illustrates a traditional gas treatment process (i.e. the Rectisol process) where cold CH_3OH is used to absorb acid gases from

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