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Investigation of carbon dioxide capture with aqueous piperazine on a post combustion pilot plant–Part I: Energetic review of the process

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ABSTRACT

37.6 wt% piperazine (7 molal) was investigated in a PCC-test facility on the power plant in Dürnrohr, Austria. Through the use of real power plant flue gas and the well-conceived dimensions of the test facility, industry-related conditions for full scale applications can be provided. Deviations from measurement results, generated on other test facilities in which piperazine was tested, are discussed scientifically. The specific energy consumption for solvent regeneration can be reduced to 3.17 GJ/t_{CO2} (without absorber intercooler and multi-stage flash), resulting in an energy saving of 14% in comparison to 30 wt% MEA. The low CO_2 absorption heat of piperazine and the low sensible heat are crucial for the low energy consumption. The optimal solvent flow rate is 20% lower in comparison to that of 30 wt% MEA, resulting in less pumping and cooling demand.

Especially for the regenerated solvent there is a risk of solidification. Even a small temperature reduction of the regenerated solvent in operation can lead to failure. A sudden system failure leads to a rapid solidification. Endangered areas have to be trace heated.

A detailed parameter study and an emission measurement on the pilot plant will be presented in Part II of this paper.

1. Introduction

Carbon dioxide capture and storage (CCS) is an important contribution to reducing greenhouse gas emissions and stopping global warming. At low partial pressures of CO_2, aqueous amines are the most suitable solvents for the absorption and desorption process for post combustion CO_2 capture (PCC) (Kohl and Nielsen, 1997). Compared to other CCS techniques like pre combustion capture or oxy-fuel technology, PCC is a mature process and can be implemented on a large scale in a relatively short time (Mangalapally and Hasse, 2011). However, the capital requirements and especially the operation cost of PCC remain high. This complicates the implementation of the absorption/desorption process with aqueous amine solutions for large scale PCC-plants (Davis, 2006).

A 30 wt% aqueous solution of monoethanolamine (MEA) is the benchmark solvent of the PCC-process. Several system extensions, such as vapor re-compression and absorber intercooling (Fisher et al., 2005; Knudsen et al., 2011) enable a reduction of the energy consumption. By taking into account the properties of the solvent and setting the optimal operation parameters, large energy savings are possible (Oexmann and Kather, 2010). Nevertheless, the energy required for the process with MEA is still high. Moreover, MEA is highly corrosive, foams by pollution and degrades under the influence of O_2, NO_x, SO_2 (Notz, 2009) and high temperature.

In order to improve the process, it is important to find new more efficient solvents. Using concentrated piperazine (PZ) is an alternative to the standard MEA-based process. Extensive laboratory based research has indicated that aqueous PZ solutions possess the following benefits under laboratory conditions (Freeman et al., 2010, 2009; Rochelle et al., 2011):

- Double CO_2 absorption rate in comparison to MEA.
- Nearly double CO_2 absorption capacity compared to MEA.
- Thermal stability up to a temperature of 150 °C.

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