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ScienceDirect

Energy Procedia 114 (2017) 906 – 929

Energy Procedia

13th International Conference on Greenhouse Gas Control Technologies, GHGT-13, 14-18 November 2016, Lausanne, Switzerland

Field Measurement of Amine Aerosol by FTIR and Phase Doppler Interferometry

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Abstract

The emission of volatile compounds is an environmental and economic concern for CO_2 capture by amine scrubbing. The condensation of amine species into aerosol is the main cause of volatile amine emissions. Current mitigation methods, including water wash, are not effective at preventing the atmospheric release of aerosol. This study focuses on the observation of aerosol at three amine scrubbing pilot plants.

Fourier Transform Infrared Spectrometry (FTIR) sampling was performed in a pilot plant at the University of Texas at Austin. SO_2 injection increased the emission of PZ solvent at a 1:1 molar ratio, and the injection of vaporized sulfuric acid increased amine emissions at a rate of 3 mols PZ/mol H_2SO_4. The slipstream pilot plant operated by the University of Kentucky utilized MEA to scrub CO_2 from the flue gas stream of a coal-fired power plant. Bypassing caustic pretreatment and allowing SO_2 to enter the absorber column increased MEA emissions. A 4% increase in the outlet CO_2 resulted in a 10% reduction of amine emissions. A simplified water wash system was found to be ineffective at curtailing aerosol emissions.

Phase Doppler Interferometry (PDI) and FTIR sampling were performed simultaneously at the National Carbon Capture Center. Using a blower between the water wash and absorber column instead of upstream of the absorber column resulted in a decrease in MEA emissions. The use of the intermediate blower instead of the upstream blower resulted in fewer, smaller aerosol drops. Decreasing the CO_2 removal resulted in reduced amine aerosol emissions. Lower CO_2 correlated with a lower aerosol concentration in the treated flue gas, but the aerosol sizes were significantly larger and resulted in overall increased amine emissions. Increasing the water wash temperature was found to increase average aerosol size and the amine concentration within the aerosol phase, resulting in an overall increase in amine emissions. By using the particle size distribution and aerosol concentration observed by PDI, the total liquid volume in the aerosol phase was calculated. Comparing this calculated quantity with the amine emissions observed using the FTIR allowed the approximate amine concentration in the aerosol phase to be determined.

Peer-review under responsibility of the organizing committee of GHGT-13.
doi:10.1016/j.egypro.2017.03.1234

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Peer-review under responsibility of the organizing committee of GHGT-13.

Keywords: Pilot Plant, amine aerosol, emissions, Fourier Transform Infrared Spectrometry, Phase Doppler Interferometry

1. Introduction

1.1. Amine aerosol losses

Amine solvent losses have been a significant issue at amine scrubbing pilot plants. Solvent lost through the absorber overhead represents an environmental and safety hazard, along with having undesirable economic implications. Amine losses can occur in the gas phase as a function of vapor pressure in the absorber column or as a mist composed of aerosol. A water wash is used to contact the gas phase with water or a solution unsaturated with amine, resulting in the transfer of the volatile amine from the gas phase to the liquid and mitigating gas phase losses. Washing steps are currently employed to mitigate the emission of amine degradation products, such as ammonia, from CO_2 capture facilities.

Aerosol emissions from absorber columns occur when aerosol nuclei are present in the incoming flue gas. Nuclei can be fly ash from the coal combustion process or submicron sulfuric acid drops produced from sulfur in the fuel. The nuclei collect water, amine, and CO_2 while traveling through the absorber. The water wash is ineffective at collecting aerosol smaller than 3 microns [1, 3, 4] because these small drops follow the gas streamline

1.2. Aerosol at Pilot Plants

Aerosol emissions have been reported at a number of amine scrubbing pilot plants. Mitsubishi Heavy Industries (MHI) found an increase of KS-1 and ethanolamine (MEA) emissions to be proportional to the inlet SO_3 to the absorber column [10]. MHI used inlet SO_3 removal and a series of wash beds and demisters to mitigate amine aerosol emissions.

SINTEF and the Netherlands Organization for Applied Scientific Research collaborated on a CO_2 capture pilot plant using 30 wt % MEA as the amine solvent [11–14]. FTIR measurements of amine emissions at the water wash outlet were found to be significantly higher than predicted by the process model. A Brownian Demister Unit (BDU) was installed downstream of the water wash and reduced emissions to the levels predicted in models. The steps taken show that aerosol, not entrainment or gas-phase losses, was responsible for the majority of amine emissions. Aerosol was found to be dependent on the maximum temperature in the absorber, the quantity of available nuclei for condensation, and the extent of temperature gradients in the absorber and water wash.

A 2012 pilot plant campaign at the National Carbon Capture Center experienced MEA emissions of over 100 ppm; amine vapor emissions were predicted to be less than 3 ppm [15]. The increased amine emissions were due to sulfuric acid aerosol with SO_3 forming the nuclei source. Amine emissions were found to increase with increasing SO_3 levels and with deactivation of the upper absorber bed, and to decrease with reductions in the water wash MEA content and the absorber column solvent temperature.

The CO_2 capture pilot plant at Karlsruhe Institute of Technology measured the loss of MEA through aerosol emissions. A condensation particle counter (CPC) was used to measure particulate concentration, with a soot generator and an SO_3 synthesis reactor to produce aerosol nuclei. The soot generator produced an aerosol