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Amine Aerosol Characterization by Phase Doppler Interferometry

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Abstract

Preventing emission of gaseous and aerosol pollutants is a crucial function of CO_2 capture systems using aqueous amine solvents. Aerosols, not volatility or entrainment, constitute the largest source of amine loss. This effort presents a means of understanding the dynamics of high-density aerosol fields in gas-liquid contacting devices by developing an *in situ* particle analysis technique called Phase Doppler Interferometry (PDI). Particle size distributions (PSDs) and total particle densities were measured and compared directly to hot-gas Fourier Transform Infrared Spectroscopy (FTIR) on bench- and pilot-scale apparatuses for two amine systems: piperazine (PZ) and monoethanolamine (MEA). A post-processing algorithm integrated PSDs (between 0.1 to 12 μm) and used the total particle density (up to 10^7 part./cm^3) to calculate the total mass of aerosol liquid per unit volume of gas (total phase concentration). Assuming a constant amine concentration in the aerosol liquid by sampling day, the integrated PDI data matched FTIR measurements within 40%. Unit operation changes are clearly visible in the average aerosol diameter and total density. The total particle density and the average diameter were found to be inversely related in pilot plant sampling; the condensable mass is constant in the gas phase.

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Keywords: Aerosol; Phase Doppler Interferometry, FTIR, Amines, Emissions

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1. Introduction

1.1. Aerosol Emissions from Amine Plants

Alkanolamine absorption/stripping is a robust and mature technology used for acid gas removal from industrial sources. However, recent pilot plant studies scrubbing CO_2 from coal-fired flue gas have observed much higher amine and degradation product emission than that predicted by solvent equilibrium. Amine contained in an entrained aerosol phase was discovered to be the cause of the increased emission. SO_3 content in the flue gas, the location and absolute magnitude of the temperature bulge in the absorption section, the number of absorption beds or total column height, the use of solvent intercooling, and amine content in the water wash solution have all been identified as important parameters influencing amine slippage in the aerosol phase [1, 2, 3]. Suppression of aerosol emissions presents a significant technological challenge not only due to the increased capital and operating cost of removal devices, but also in estimating, characterizing, and reporting of emissions in both the gaseous and droplet phases.

The approach of the work at the University of Texas at Austin has been to develop an understanding of the dynamics of aerosol populations in gas-liquid contact devices in order to predict their behavior and thereby conceptualize and implement lower cost removal devices. To meet those objectives, a two-front methodology of experimental measurements and computer-based modeling has been ongoing. This work focuses on developing a transportable, *in situ* measurement technique for characterizing high-density aerosol fields at variable process scales to feed into modeling studies.

1.2. Aerosol Measurement

Amine-containing aerosols can originate from a variety of sources: physical entrainment of solvent, homogeneous nucleation of amine with other gaseous species, and heterogeneous nucleation/condensation on preformed nuclei such as hygroscopic particulate, and most importantly, H_2SO_4 mist formed by reaction and subsequent condensation of SO_3 and H_2O. Due to the rapid dynamics of aerosol populations (a combination of nucleation, coagulation, and condensation), particle distributions, in the size, number of distribution modes, and total density, can span several orders of magnitude.

Available literature data has shown total particle densities ranging from 10^4 to 10^9 part./cm^3 for sizes ranging from 6 nm up to 10+ microns [2, 4]. However, the exact nature of the aerosols present in the process is uncertain due to the large discrepancies between direct comparisons of aerosol analytical methods [2]. Measurement inconsistencies are caused by the combination of sampling efficiency and instrument limitations (relative humidity, resolution, accuracy, and measurement errors) [5].

Generally, aerosol analyzers fall into two categories: *in situ* and *ex situ*. *In situ* analyzers are broadly defined as those measurement types that do not destructively interfere with the sampled media and *ex situ* measurements involve selective partitioning of the aerosol field by mobility mechanisms to yield sizing and density information. A true *in situ* measurement accurately captures the properties of the process aerosols and measurement error is restricted to instrument error, while *ex situ* measurement accuracy relies on the ability to sample particles without biasing their *in situ* properties. A review of *ex situ* particle loss mechanisms and equations can be found in the dissertation by Fulk [5].

Following an extensive review of commercially available particle analyzers, PDI was determined to be the best available particle analyzer because it is capable of making *in situ* measurements of high-density aerosols in fully saturated gases [5]. Therefore, PDI, in theory, does not require extractive sampling or dilution, meaning the sample seen by the instrument is identical to that in the process duct. Additionally, this work is the only study to use *in situ* techniques for full particle phase analysis at CO_2 capture systems.

1.3. Work Objectives

The purpose of this work is to demonstrate PDI as a field-ready technique for characterizing aerosolized amine emissions from CO_2 capture plants scrubbing with aqueous amines. PSDs and total particle densities will be directly