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SO_3 Generator for Testing Amine Aerosol

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1. Introduction

Amine aerosol emission is a significant environmental, safety and economic problem for amine based CO_2 capture plants. Aerosol nuclei, which could be a combination of fly ash, SO_2 or sulfuric acid in the flue gas pass through the absorber and wash column while collecting water and CO_2 loaded amine. Conventional water wash columns are ineffective at removing the amine once it is captured in the aerosol. A good understanding and quantification of the growth mechanisms of these aerosols in the absorber and water wash is therefore imperative. Certain bench scale columns and pilot-plants where aerosol observation and quantification are to be carried out use a synthetic gas which lacks aerosol nuclei, hence the need for an aerosol nuclei generator.

The production of SO_3 aerosol nuclei, which is the preferred nuclei source for testing at pilot plant operations, has however been met with several challenges. In reviewing the methods of producing SO_3 aerosol nuclei for bench and pilot plant amine emissions testing, we have designed two new systems which have not been previously used for aerosol nuclei injection purposes. The first system will oxidize SO_2 over a heated vanadium pentoxide catalyst bed, while the second generates atomic oxygen via a dielectric barrier discharge (DBD), which then oxidizes the incoming SO_2 in air feed. These SO_3 generating systems will be used for 3 weeks in April at the UT-SRP pilot plant as well as in August at the NCCC pilot plant in Alabama. This paper aims at bench-marking results from these two newly designed systems against a previously used Liquid Vaporizer Injector (LVI). Comparisons are made in terms of the design, performance, energy and safety requirements of the SO_3 generating systems.

2. Experimental Setup

The catalyst bed and DBD generators both make use of 8% SO_2 in air feed to produce SO_3 which on injection, rapidly hydrolyses in water vapor saturated environments to form sulfuric acid nuclei. The generators are designed for over 50% conversion with ranges of 2–30 ppmv SO_3 for both bench and pilot scale testing. The pilot-scale testing is designed for a flue gas flow rate of 10–20 m^3/min, while the bench scale at 0.05–0.125 m^3/min.
The catalyst bed system uses a Carbolite HST 12/900 furnace with a heated length of 36”, which allows enough catalyst mass to have very high SO_2 oxidation rates at the bench scale and moderate rates at the pilot scale. With a

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bed diameter of 1” and a catalyst bulk density of 0.61 kg/L, a catalyst mass of 0.28 kg is required for a single-pass SO_3 generator at the bench scale. On the pilot scale, a 2” diameter bed of the same length allows a catalyst mass of 1.14 kg. Preliminary modeling results displayed higher conversions at lower flow rates for both the bench-scale and pilot-plant ranges. The optimum temperature for the bench scale was found to be 440–460ºC, while that for the pilot scale was 520–560ºC.

The major drawback with the operation of the catalyst bed system is that it could take 15 to 60 minutes to reach steady state. This results in a large SO_2 inventory for start-up and poses safety concerns on the venting of the exit stream during start-up and shut-down operations. Also, the vanadium pentoxide catalyst is harmful to gastrointestinal and respiratory systems, requiring extra care to ensure that the catalyst is contained and not allowed to form a powder that would be easily inhaled or ingested.

The DBD system has previously been applied in FGD systems for removing SO_2 from flue gas and collecting the SO_3 produced over water, but has not been directly applied for producing aerosol nuclei for injection purposes. It involves a plasma-assisted oxidation of SO_2 to SO_3 with a coaxial dielectric-barrier discharge used to generate the atomic oxygen.

The DBD experimental setup consists of a tubular reactor with a high voltage power supply. The power supply has an output of up to 300 Watts and independent voltage control of 40kv pk-pk. The single tube reactor has a quartz glass tube of 0.5” diameter and wall thickness of 0.04”, wrapped with an aluminium foil serving as low voltage electrode. A stainless-steel rod of 1/8” diameter centred inside the quartz tube serves as the high voltage electrode. The setup has a total capacitive load of 34pf per meter and a discharge gap of 0.144”.

The previously used LVI system feeds a liquid solution of sulfuric acid and water through a vaporizer and injects the solution into the process stream. It was designed for 350–2000 ppmv of Sulfuric acid in 1 cubic feet per minute of carrier gas, which on injection into the pilot flue gas stream dilutes to 1–5 ppmv. The LVI while being successful at concentration demonstration tests on the bench scale, failed at the pilot plant stage in March 2015 UT-SRP Pilot plant campaign. H_2SO_4 was injected at 10–13.7 ppm for only a total of 160 minutes over the duration of the campaign, after which the eductor eventually plugged and ceased operating.

3. Conclusions

Results from the previously used LVI system were marred due to the highly corrosive nature of H_2SO_4 and the subsequent plugging of the eductor which led to inconsistent and pulsating stream of aerosol.
While the catalyst bed solves the LVI corrosion problem with the use of a catalyst bed, it still provides considerable start-up time delay. The DBD, though more energy intensive, is considered the cleanest alternative of the three because of its relative ease to turn on/off, thereby offering complete control in the injection of aerosol nuclei.