

**Title:** Observation of SO<sub>3</sub> Behavior in a Pilot-Scale Combustor

**Author:** Stanley J. Miller  
smiller@eerc.und.nodak.edu  
Telephone: (701) 777-5210  
Fax: (701) 777-5181  
Energy & Environmental Research Center  
PO Box 9018  
Grand Forks, ND 58202-9018

### Summary

After years of experience dealing with SO<sub>3</sub> in coal-fired boilers, fundamental questions remain that make predicting its formation and fate difficult. The amount formed appears to be defined within empirical limits, but as the flue gas cools, H<sub>2</sub>SO<sub>4</sub> may follow several paths. When saturation conditions exist, the abundance of fine particles provides nucleation sites for the condensed acid, but the amount of acid sorbed also depends on the fly ash chemistry. In addition, upon further cooling or if insufficient fine particles are available, homogeneous nucleation may occur, leading to a submicron fume. Since the mass-transfer characteristics of the vapor and aerosol are different, separate approaches may be required to either measure or control these forms. The interaction of SO<sub>3</sub> with fly ash is of great interest because of the effect of SO<sub>3</sub> on resistivity, cohesive properties, and corrosive character of the ash. Data indicate that SO<sub>3</sub> can sorb onto the ash and affect these dust properties at much higher temperatures than where SO<sub>3</sub> condensation is expected. Because of these possibilities, observations must be carefully analyzed to develop a better understanding of the mechanisms that define SO<sub>3</sub> behavior.

Extensive testing has been completed at the Energy & Environmental Research Center (EERC) to investigate the effects of SO<sub>3</sub> on ash properties and dust collectibility. Results for several coals show that for some nonalkaline ash, the affinity of the ash for SO<sub>3</sub> is low and large amounts of SO<sub>3</sub> are required to lower resistivity. In contrast, a small amount of SO<sub>3</sub> was highly effective in lowering the resistivity of a high-alkalinity ash. This is surprising, because an anticipated effect would be neutralization of the acid by ash components without a significant change in resistivity.

A number of tests were conducted with both SO<sub>3</sub> and ammonia conditioning. In most cases, the addition of ammonia enhanced the effectiveness of SO<sub>3</sub>, both by decreasing the amount of SO<sub>3</sub> required and by extending the upper temperature where SO<sub>3</sub> could lower resistivity. However, the addition of ammonia has a significant effect on the cohesive properties of the ash. Tensile strength and porosity measurements of the ash show that the addition of SO<sub>3</sub> alone may increase stickiness, but when small amounts of ammonia are present, the dust becomes much more cohesive. A concern is that the ash might become so cohesive that dust buildup on the electrodes of an electrostatic precipitator (ESP) could occur. However, some increase in tensile strength may be beneficial, helping to reduce rapping reentrainment. Since the

ideal cohesive properties for optimum ESP performance are not well known, the benefit of ammonia in addition to  $\text{SO}_3$  is difficult to predict.

In cases where  $\text{SO}_3$  needs to be reduced, an approach to control is to neutralize it with ammonia. However, in addition to its effect on cohesive properties of the dust, the ammonia may react with the  $\text{SO}_3$  to form submicron particles that are difficult to collect. In cases with a large enough ESP or a baghouse, adding ammonia could be feasible, but for a small ESP, opacity could increase with the increase in fine particles. Wet scrubbers might appear to be a good approach to  $\text{SO}_3$  control. Clearly a scrubber will neutralize any  $\text{SO}_3$  or acid mist that contacts the low-pH liquid. The problem is that once the  $\text{SO}_3$  is in the form of an aerosol, there is poor mass transfer to the liquid. A scrubber will not collect acid mist any better than it collects fine ash particles. A fraction of the particles is collected by diffusion, interception, and impaction, but most pass through the scrubber uncollected. A scrubber may make opacity much worse because the rapid quench can cause significant acid condensation, which passes through the scrubber. If the scrubber were not present, much of the  $\text{SO}_3$  would remain in vapor form and have no effect on opacity. The best approach to controlling  $\text{SO}_3$  in coal-fired boilers is unclear.