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The Effect of In-situ Ammonium-Sulfur Aerosols on the Removal of SO₂, NO_x and Mercury from Combustion Flue Gas

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Ammonia-sulfur aerosols (mostly in the form of sulfates and sulfites) are formed as small aerosol particles with the mass mean diameter of ~0.14 μm when NH₃ is injected into a flue gas that contains both SO₃ and SO₂. Experiments conducted in our laboratory have shown the feasibility of SO_x, NO_x and mercury (Hg) removal by the action of these ammonia sulfur aerosols.

The removal of SO₂ (up to 3000 ppm) and NO_x (up to 1000 ppm) has been investigated in a bench-scale pulsed-corona enhanced wet electrostatic precipitator (ESP) with the optional injection of ammonia gas. Without ammonia, SO₂ can be easily removed up to 70% by water and corona discharge (45 kV) in the wet ESP. Ammonia injection improved the SO₂ removal to ~100%.

The NO_x removal results are as follows. In a simulated combustion flue gas with 3% O₂ and 800 ppm NO at 11.5 sec of gas residence time, the removal efficiency of NO was only 5%. Injecting NH₃ only (NH₃/NO_x molar ratio 1) at 76 watts corona power increased NO removal to 13%. With the presence of 2400 ppm SO₂ and 200 ppm ozone injection (no ammonia), NO removal increased to 35% due to oxidation, but total NO_x removal increased only to 17%. However, very high NO_x removals were measured in simulated combustion flue gas that contained ammonia, sulfur dioxide and ozone. The total NO_x removal efficiency was 79% when the ammonium sulfur aerosols were formed in the presence of 2400 ppm SO₂, 312 ppm O₃ and 2900 ppm NH₃.

It was determined that the ammonium sulfur aerosols produced from the reaction of ammonia and sulfur dioxide enhanced NO_x removal substantially. The aerosol formation itself is a SO₂ removal process that improves SO₂ removal to ~100%. The in-situ generated sub-micron aerosols are well spread in the flue gas, serve as a highly energetic and efficient adsorbent, and provide tremendous surface area to catalyze the De-NO_x chemical reactions. After the SO₂ and NO_x were separated from the gas phase, the final products, ammonium salt aerosols can be easily removed by conventional particle removal equipment such as an electrostatic precipitator or a bag house.

In the NH₃-SO₂ aerosol formation process, high molecular weight substances such as mercury may act as seeds for aerosol formation. Thus, mercury molecules in both

metallic and ionic forms are surrounded and captured by these aerosol particles and removed by an ESP or a bag house. This was confirmed by a test using a simulated flue gas containing SO₂ (2500 ppm) and elemental mercury (100 ppb). Ammonia injection was performed at a NH₃/SO₂ molar ratio = 2.0. The results, verified by an independent laboratory analysis of the collected solids, indicated >97% mercury capture by the aerosol particles at 23°C. Therefore, the sub-micron aerosol particles acted as a “super” sorbent for mercury capture.

Therefore, the advantages of the present method are:

1. **Simultaneous removal of NO_x and SO_x could be achieved** in a single pollution control device such as an ESP, which requires smaller installation spaces and investment costs than conventional combinations of FGD and catalytic De-NO_x processes.
2. **High NO_x removal efficiency (~80%) can be reached** by the catalyzing effect of in-situ ammonium sulfur aerosols.
3. **High coal sulfur content is not detrimental.** It not only removes ~100% of the SO₂, but also SO₂ is used as a source of the ammonium-sulfur sorbent. Although ammonia is needed for the formation of the sorbent, only SO₂ is consumed. (Ammonia could be recycled.) Unlike all other pollution control techniques, **high coal sulfur content is not detrimental.**
4. **Effective removal of condensables** including air toxics and volatile metals such as mercury: Due to the high surface activity of the sub-micron ammonium salts, many polar and non-polar compounds (e.g. dioxins and furans) would be “encapsulated” by ammonium salt aerosols and can be removed from flue gas well above their normal boiling points. The ammonium-salt aerosol particles act as a “super sorbent.”
5. **SO₃ is also utilized at a higher temperature** up to 230°C. Ammonia could be injected after the air pre-heater. The mercury containing particles can be easily captured by an existing particle control device such as an ESP or a bag house without significant modifications.