Increased SO_3 and Ammonia Slip from SCR: Balancing Air Heater Deposits, Ammonia in Effluent Discharge, and SO_3 Plume

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SUMMARY

SCR results in ammonia (NH_3) slip and increased sulfur trioxide (SO_3) emissions, which will impact coal-fired plant operation – increased air heater deposits, NH_3 in the ash and FGD effluent discharge, and potential for a visible stack plume.

FORMATION AND FATE OF NH_3 AND SO_3

The NH_3 slip is generally limited to a maximum of 2 ppm and is removed in air heater deposits, flyash and FGD. The limited European literature reports that the bulk of the NH_3 slip is removed by flyash with little air heater deposits – based on low sulfur coals and generally low NH_3 slip. What the literature actually showed was that an equal percentage of NH_3 was removed in the air heater and the ESP – but that most of the regenerative air heater deposits were decomposed and recycled to the boiler as NOx.

SO_3 is formed in the boiler by oxidation of SO_2 on metal compounds in the ash on superheater tubes and in the SCR by oxidation of SO_2 on the catalyst. Boiler SO_3 is removed in the same places as NH_3 and also by condensation on the air heater surfaces. With SCR, there is additional SO_3 removal in the air heater as an acid condensate (higher acid dew point) and by reaction with the NH_3 slip. SO_3 "blue" plume has been reported from stacks with <10 ppm.

This "inherent" SO_3 removal in a power plant has shown a wide variability. It is not clear if the "inherent" removal percentage or the ppm of SO_3 removed stays the same, as the SO_3 increases significantly with SCR. If the fly ash has a larger capacity to ab/adsorb SO_3, then more boiler SO_3 would have been removed (inherent) before SCR was installed. Therefore, the fly ash and FGD would not be expected to remove the SCR-generated SO_3.

AIR HEATER DEPOSITS

The NH_3 slip reacts with the SO_3 to form ammonium solids in the air heater – ammonium bisulfate (ABS) has been the primary product detected after SCR. ABS is a sticky product which condenses on air heater elements/baskets below the ABS "initial formation temperature" (IFT) - ~350 F.

In the early 1980s, Radian developed thermodynamic and kinetic models for the formation of ABS. The analysis was used to develop an equation to predict ABS formation in regenerative air heaters and was compared to the SCR and SNCR applications at that time. The formation of significant NH_3 deposits in the air heater is dependent primarily on the NH_3 and SO_3 levels and the differential temperature between the IFT and air heater gas exit/cold end temperature. As the NH_3 and SO_3 increase, the IFT increases, with the SO_3 having a greater impact on the increase of the IFT.

The Radian numbers were calculated for the applications in the Radian report and for domestic applications (in the published literature). The "break point" between no/minimal deposits and deposits which impact air heater operation tended to be between Radian numbers of 5,000 and 7,000 for SCR and SNCR applications. There are no data for high sulfur coals with SCR:

- Low sulfur coals - For 1% sulfur, NH_3 slip should be < 6 ppm for SCR and 12 ppm for SNCR.
- Medium sulfur coals – For 1.5% sulfur, NH_3 slip should be < 4 ppm for SCR and 9 ppm for SNCR.
- High sulfur coals – For 3 % sulfur, NH_3 slip should be < 2 ppm for SCR and 5 ppm for SNCR.

SNCR tended to have air heater pluggage at a slightly lower Radian number than SCR, probably due to the uneven distribution of NH_3 slip, resulting in the areas of high slip.

AMMONIA IN EFFLUENT DISCHARGE

Since NH_3 is water soluble, it will eventually end up in the effluent discharge. The NH_3 in flyash and FGD will result in a steady steady-state NH_3 concentration in the effluent discharge and the air heater will result in a "slug" of NH_3 to the air heater chemical treatment pond:

- Worst Case – For 100% of the 2 ppm NH_3 slip in the air heater, flyash (sluice) and FGD, the NH_3 effluent concentrations are ~6,000 ppm, 2 ppm, and 10 ppm, respectively
- Early Operation Case – For the anticipated percentage of 0.5 ppm NH_3 slip in the air heater, flyash, and FGD, the NH_3 concentrations are 135 ppm (20% of slip), <0.5 ppm (70% of slip) and <1 ppm (10% of slip), respectively

For an ash landfill, the leachate will eventually contain NH_3, but with minimal water flow, and the NH_3 levels could be much higher than for an ash sluice system. For the air heater wash water, this NH_3 "slug" requires either treatment for the air heater wash water (air stripping at high pH) or blending small amounts over a long period to the ash/FGD pond. The shorter the blending period, the higher the NH_3 in the pond effluent.

SO_3 MITIGATION

SO_3 is converted to sulfuric acid vapor (H_2SO_4), as the gas cools from 900 F to 400 F. There are four general temperature ranges for SO_3/H_2SO_4 removal by alkali injection: In-furnace (>2500 F and ~2000 F) and in-ductwork (~650 F and ~300 F). For in-furnace injection, only the boiler SO_3 is removed – not the SCR-generated SO_3. Therefore, for in-furnace injection, the SO_3 after the SCR will be greater than the original boiler SO_3.

There has been limited testing for SO_3 removal - EPRI High Sulfur Test Center, Bruce Mansfield, and some unpublished data. There has been testing for SO_3 removal at three of these temperatures, but there do not appear to be any SO_3 removal tests at SCR outlet temperatures (~650 F). Lower in-furnace injection (>2500 F) results in "dead-burning" the alkali and requires a very high alkali stoichiometry. Stoichiometries <10 appear achievable for 90% SO_3 removal for upper furnace (~2000 F) and in-duct injection. Each 1.0 alkali stoichiometry for high sulfur coals with SCR is ~1% of the ash.

BALANCING AMMONIA SLIP AND SO_3

The key to the release of ammonia to the effluent discharge is the ammonia "spike" when the air heater is washed. A SO_3 removal system after the SCR will eliminate the potential for a visible SO_3 plume and will allow the balancing of NH_3 deposition between the air heater and the flyash.