Current Work on SO_3 Emissions from Selective Catalytic Reduction Systems

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Overview of Presentation

- Review of effects of system and operating parameters on SO_3 conversion and removal
- Three case studies of measured SO_3 balances in operating plants
- Overview of SO_3 mitigation methods
- Conclusions

Selective Catalytic Reduction System Introduction

- Increased SO_3 production due to selective catalyst reduction systems
- Wide spread US deployment of SCR systems for NOx control
- Catalyst operation with US fuels i.e. high sulfur, PRB and pet coke blends not known based on European and Japan experience,.
- Increased SO_3 production due to selective catalyst reduction systems

Plant Flue Gas System

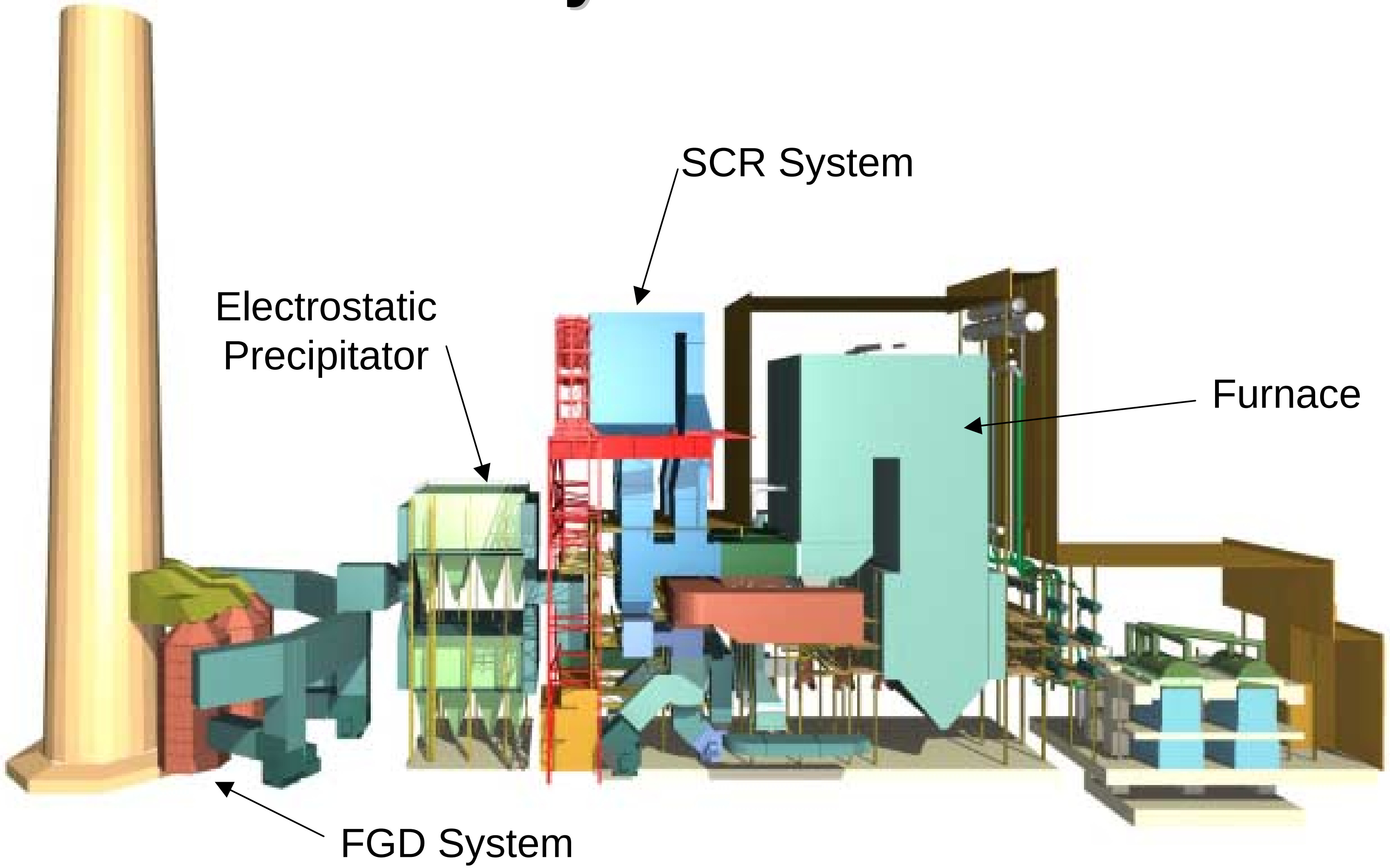
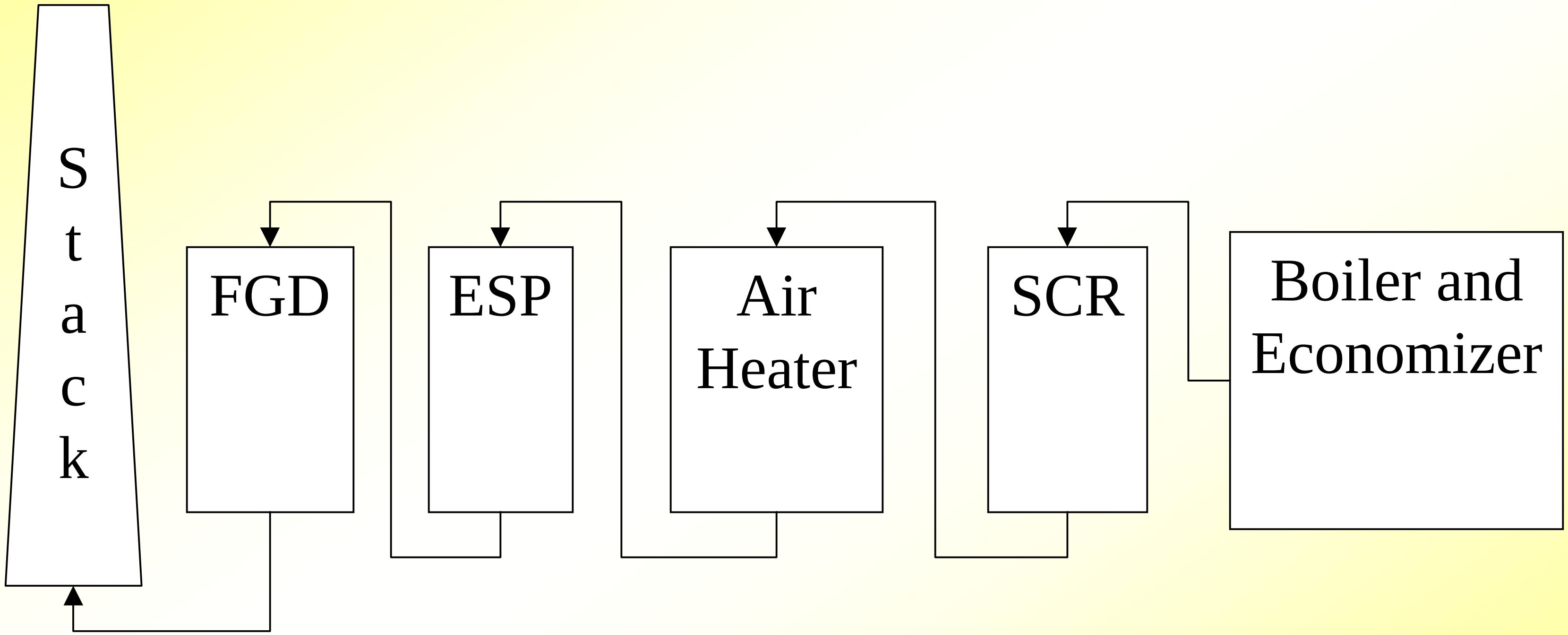


Diagram of Basis Flue Gas System



Visible SO_3 Plume From WFGD Equipped Plant

Parameters Affecting SO_3 Production and Capture in Furnace

- Slagging and fouling characteristics of coal
- Sulfur content of fuel
- Furnace type, wet bottom, cyclone or dry bottom
- Alkali content of fuel
- Furnace exit gas temperatures, equilibrium concentration and reaction kinetics
- Furnace gas retention times, kinetic formation rate

Parameters Affecting SO_2 to SO_3 Conversion In SCR System Catalyst

- SCR reactor operating temperature, strong function - increased inlet temperatures increases SO_3 conversion
- SO_2 inlet concentration, increased inlet SO_2 decreases SO_2 to SO_3 percent conversion rate
- NH_3 inlet concentrations and NH_3/NO_x ratios, increased NH_3 decreases SO_3 conversion
- O_2, H_2O and NO_x inlet concentrations, weak functions in coal fired operating ranges

Parameters Affecting SO_3 Capture in Air Heaters and Electrostatic Precipitator (ESP)

- Type of air heater, regenerative or tubular
- Operating flue gas and air temperatures
- Fly ash alkali content with respect to inlet SO_3 concentration
- Air leakage rates affecting gas temperatures
- Type of ESP, cold or hot

Parameters Affecting SO_3 Capture in FGD Systems

- Type of FGD system, wet, semi-dry or dry
- Absorber configuration, counter or concurrent flow
- Absorber gas velocities and pressure loss
- Absorber inlet temperature
- Absorber operating parameters - L/G

Seven Large-Effect Parameters Effecting Stack Opacity

- **Wind Speed at top of Stack**
- **Stack Exit Diameter**
- **Exit Velocity of Stack**
- **Sulfuric Acid Vapor Concentration**
- **Fine Geometric Mass Mean Diameter**
- **Fine Geometric Standard Deviation**
- **Fine Particle Concentration**

Reference: EPRI Report TR-104425

Case Study Low Sulfur Bituminous Coal (< 1.5%)

Plant Operating Parameters

- Furnace SO_2 to SO_3 conversion 0.33 to 1.8% (furnace type and ash alkali dependent)
- Regenerative air heater SO_3 capture rate 25 to 70% (temperature and ash alkali dependent)
- Tubular air heater SO_3 capture rate ~10%
- ESP SO_3 capture rate 0 to 20%

Case Study PRB Coal
Plant Operating Parameters

- Furnace SO_2 to SO_3 conversion 0.1%
- Air heater SO_3 capture rate ~0%
- ESP SO_3 capture rate ~0%
- SO_3 concentrations are within the resolution of the test measurement equipment

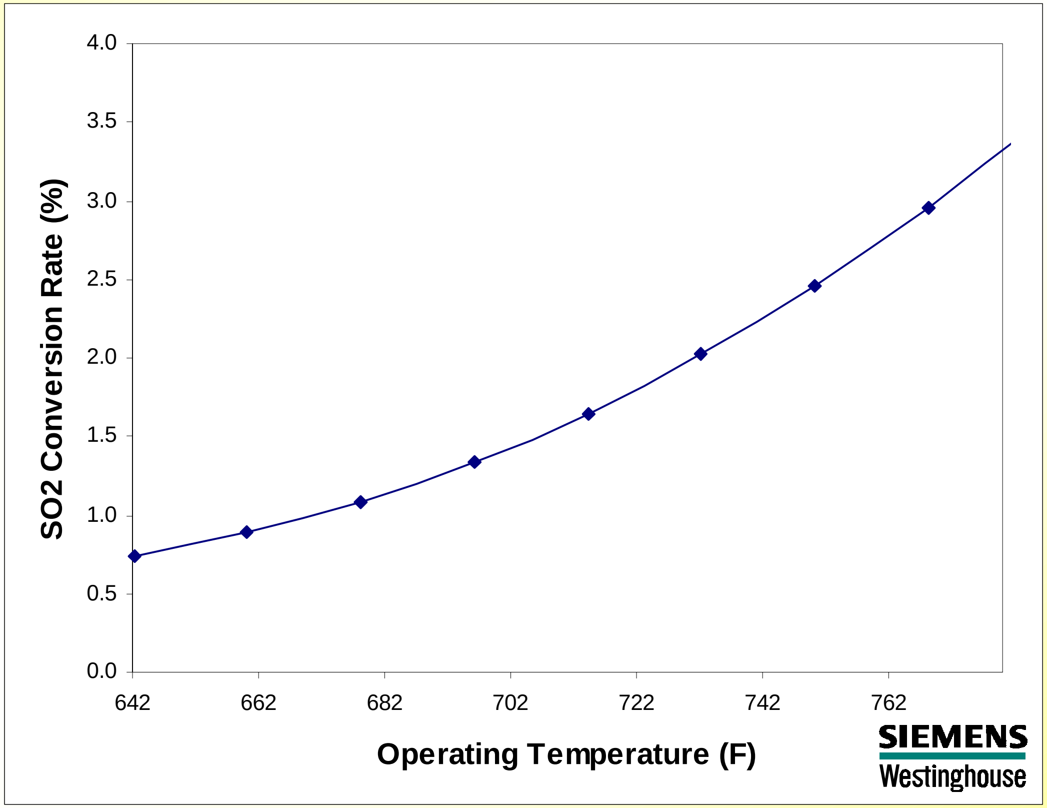
Case Study High Sulfur Coal (> 2.5) Plant Operating Parameters

- Furnace SO_2 to SO_3 conversion 0.8 to 1.25%
- Air heater SO_3 capture rate 15 to 35% (temperature dependent)
- ESP SO_3 capture rate 0 to 5%
- WFGD SO_3 capture rate 40 to 50%

Mitigation Methods

- Furnace alkali addition, MgO injection or limestone addition to fuel.
- SCR catalyst temperature control, design or operating
- Ammonia injection after air heater
- Alkali injection after air heater

Mitigation Methods
SCR Inlet Temperature Control



Mitigation Methods
Ammonia injection after air heater

- Proven effective in full scale operation between 8 to 30 ppm NH_3 injected with 95% SO_3 removal rates, reference EPRI report.
- Injection rates of NH_3 less than 1.0 molar ratio to the SO_3
- Increase ammonia bisulfate (sticky ash) formation
- Decrease particle loading on ESP due to agglomeration
- May result in ESP fouling

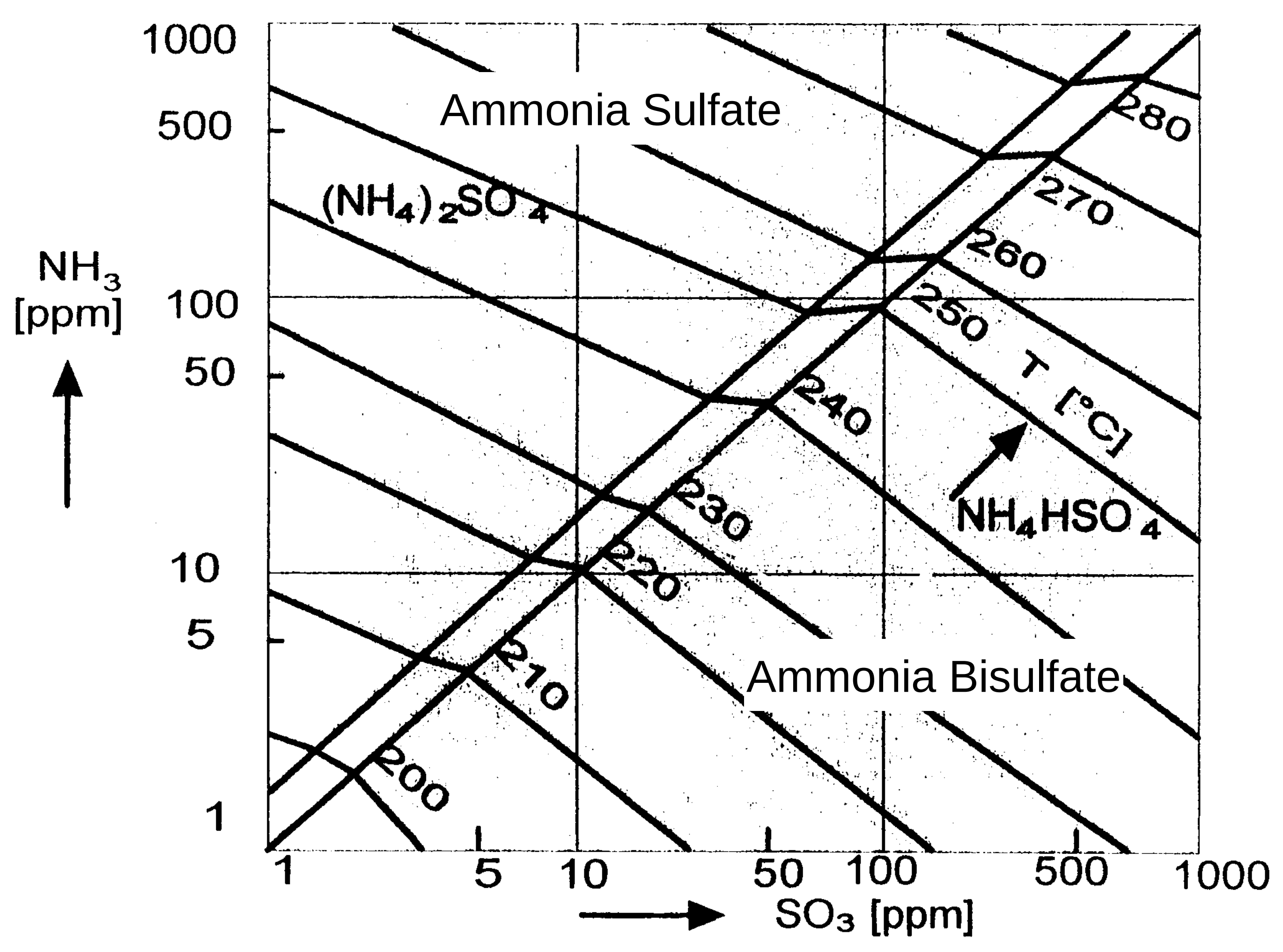
Mitigation Methods
Ammonia injection after air heater

- Injection rates of NH_3 1.0 to 2.0 molar ratio to the SO_3
- Increases ammonia sulfate formation and reduces ammonia bisulfate (sticky ash) formation
- Increase particle loading of ESP due to salt formation
- May result in increased fine particle emission

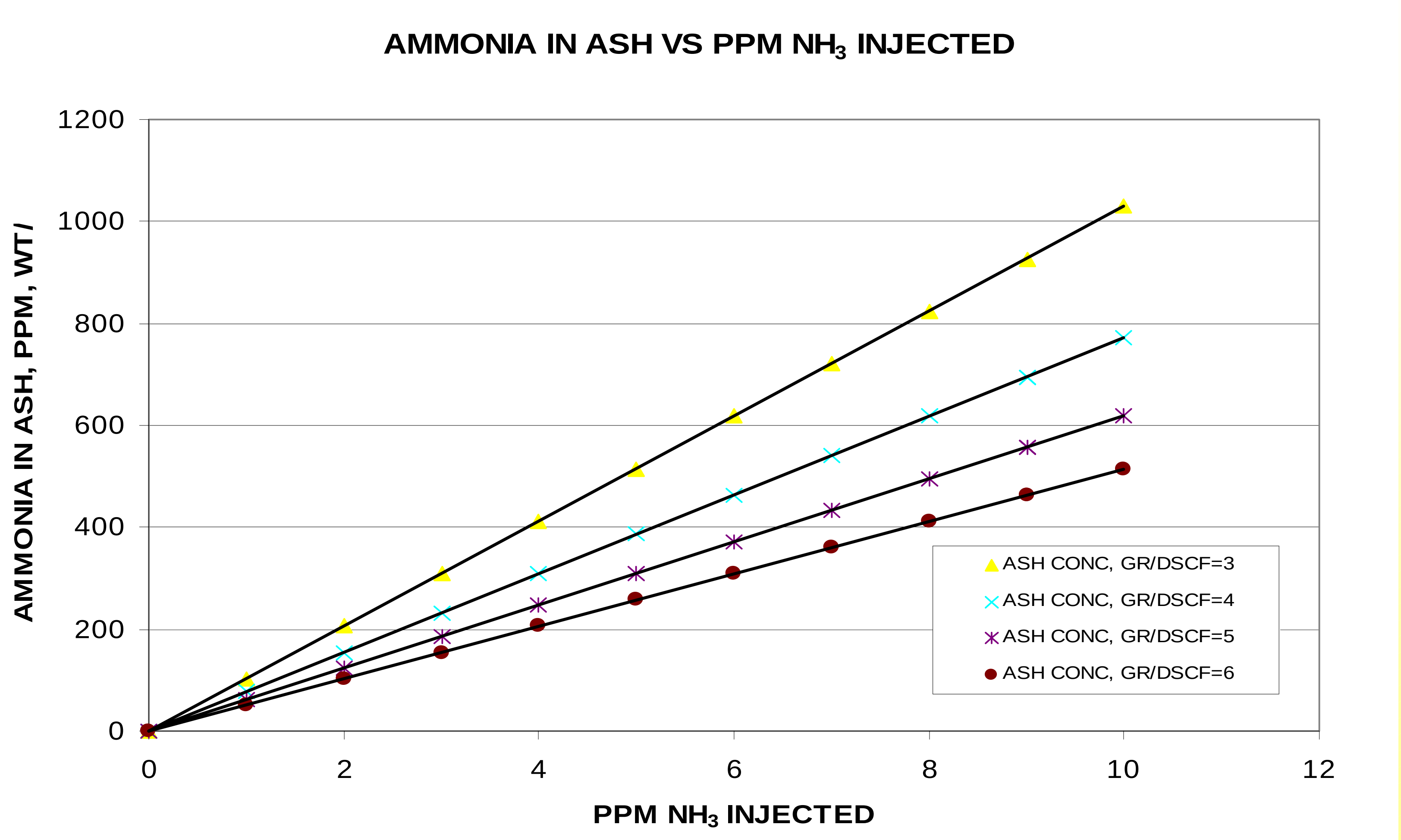
Mitigation Methods
Ammonia injection after air heater

- Adsorption of ammonia by flyash, similar to ammonia slip adsorption but without recycle to boiler. May effect ash sales and/or disposal.
- Wet ash systems are expected to have 0.0025%< ammonia by weight in sluicing water for 10 ppm ammonia injection with typical sluicing rates.

Ammonia Salt Formation Diagram



Post Air Heater Ammonia Injection Ash Adsorption



Hydrated lime injection before ESP

- **Proven effective in full scale test programs.**
- **Addition of water to the hydrated lime before ESP increased SO_3 removal rates.**
- **Design of injection system and understanding of flow distributions important to achieve uniform high removal efficiencies.**

On Going Development Work

- Air heater and ESP capture is a complex function of temperature and alkali content, models under development
- Data collection continues on FGD system capture, using European experience

Conclusions

- **Furnace SO_3 production and capture has been modeled for varying alkali and sulfur contents with success for dry bottom configurations**
- **Effect of furnace alkali injection and addition have been modeled with good success**
- **100% PRB and high PRB blends increase gaseous SO_3 removal in furnace, air heater and ESP**
- **SO_3 mitigation is possible and proven in the furnace and after air heaters**
- **Control of SO_3 emissions from SCR equipped units is possible with proper design, planning and mitigation as required**