REINHOLD ENVIRONMENTAL Ltd.

2012 NOx-Combustion Round Table & Expo Presentation

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SCR/SNCR and the Importance of Combustion Optimization

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Introduction to STEAG

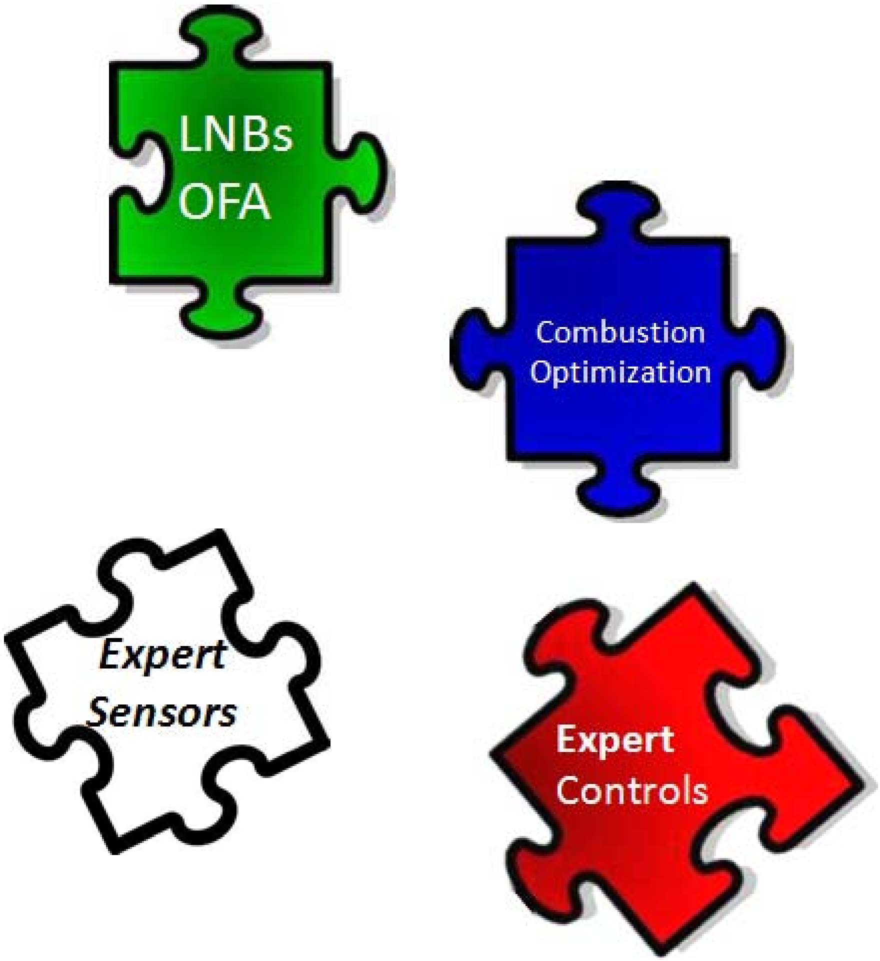
- STEAG has more than 70 years of experience in the business of coal-fired generation.
- In Germany, STEAG operates 10 bituminous coal-fired stations with a total capacity of about 11,000 MW.
- Our units use combinations of low NO_x burners, overfire air, SNCR and SCR technology for controlling NO_x emissions.
- Our fleet has a total of 28 SCR units that been operating for more the 25 years.

Walsum Unit 10

Where are NO_x Rules Leading?

- Cross-State Air Pollution Rule (CSAPR) will ultimately create a need for additional NO_x emissions reductions from coal-fired units.
- CSAPR will cause NO_x allowance prices to increase creating a market incentive for additional cost-effective NO_x reductions.
- In the interim, the objective remains the same – to operate existing systems in a reliable and **cost-effective** manner. Minimize adverse impacts to plant operation.

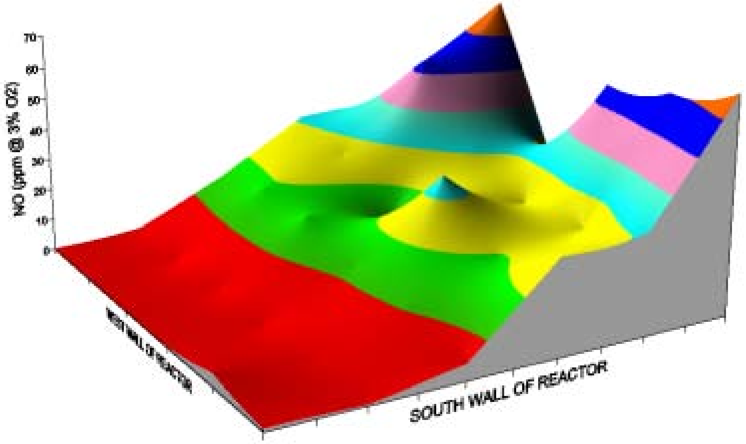
How do these pieces fit together to achieve cost-effective NO_x control?



Does reducing NO_x emission always require the addition of another piece to this puzzle ?

What STEAG has Learned: Focus on the Fundamentals

- Our experience has proven that **Combustion Optimization** is critical to achieve optimal performance of the SCR and SNCR systems.
- Don’t depend solely on sensor and control systems for optimization.
- In Germany, we have our own testing services group focused exclusively on boiler, SCR and SNCR performance optimization.
- In the US, we have test teams that apply the same services for utility customers.



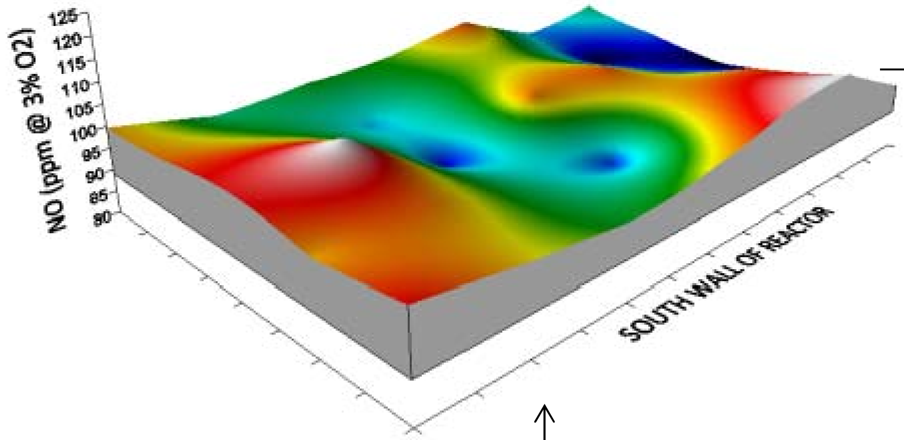
How Does Combustion Optimization Impact SCR Performance?

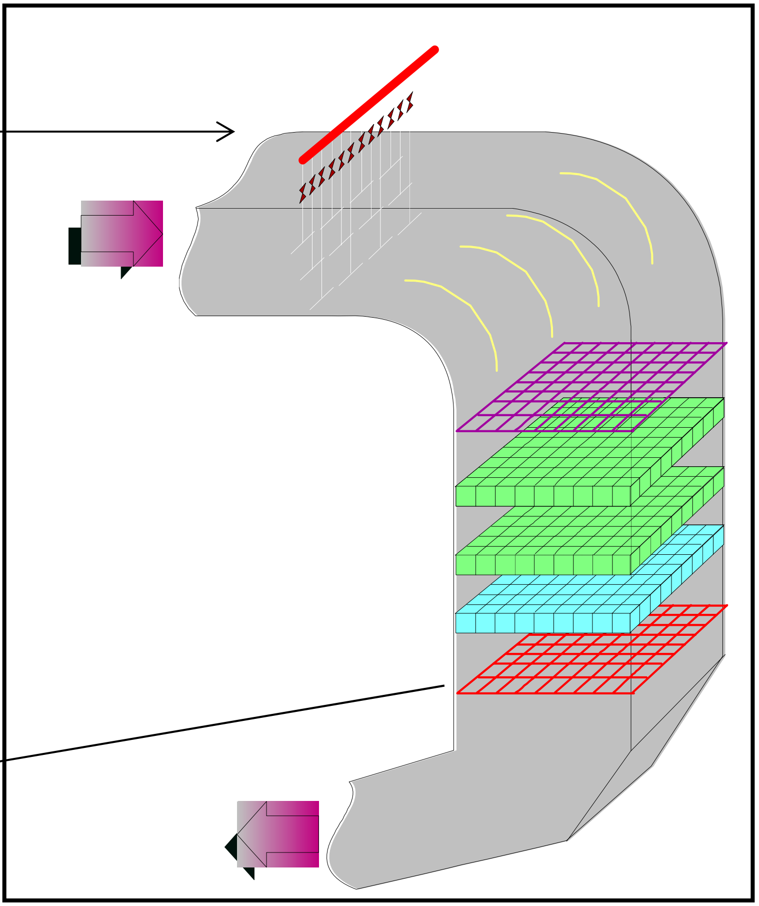
- If the SCR can achieve 90% NO_x removal, why worry about combustion optimization anymore?

- STEAG's own experience has proven:
  - 5% to 10% increased NO_x removal prior to the SCR can reduce reagent cost by more than $100,000 annually.
  - NO_x imbalances at the SCR outlet are often related to furnace imbalances rather than ammonia distribution issues.
  - Combustion optimization can eliminate regions of very low NO_x at the SCR outlet and imbalance between reactors that contribute disproportionately to ammonia slip.
  - Reduce SO_2 to SO_3 conversion rate
  - Reduce ammonia in ash.

SCR and Combustion Tuning Process

Correlate Emission Measurements to Spatial Position



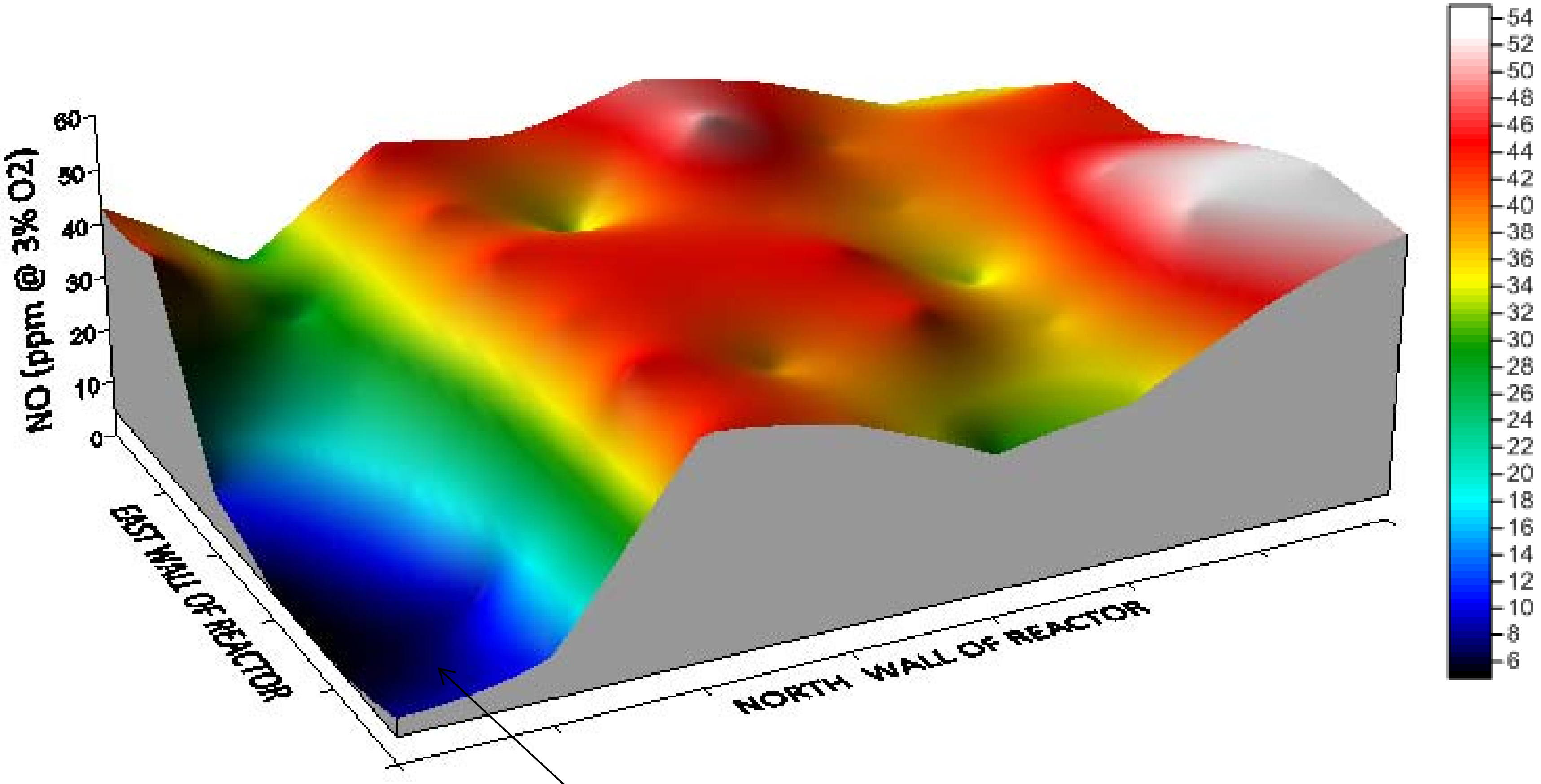


Install Spatial Sample Grid at Economizer and SCR Outlet

Measure O_2, CO and NO_x

As-Found Nitric Oxide Profile at the SCR Outlet

Average NO = 37 ppm @ 3% O_2

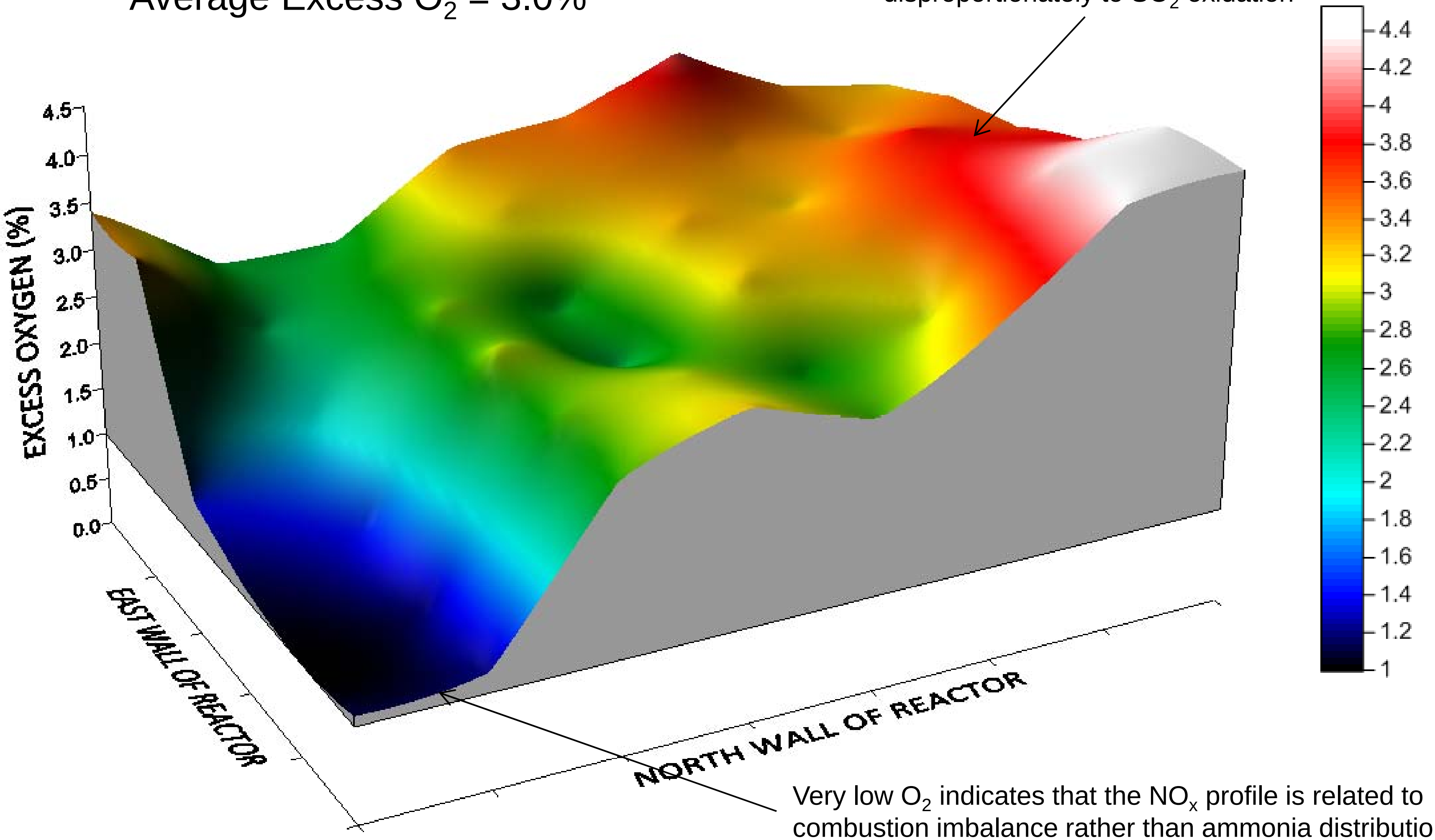


NO values as low as 0 ppm →High NH_3 Slip

Excess Oxygen Profile at the SCR Outlet

Average Excess O_2 = 3.0%

Regions of high O_2 will contribute disproportionately to SO_2 oxidation



Very low O_2 indicates that the NO_x profile is related to combustion imbalance rather than ammonia distribution.

Effect of O_2 on SO_2 to SO_3 Oxidation

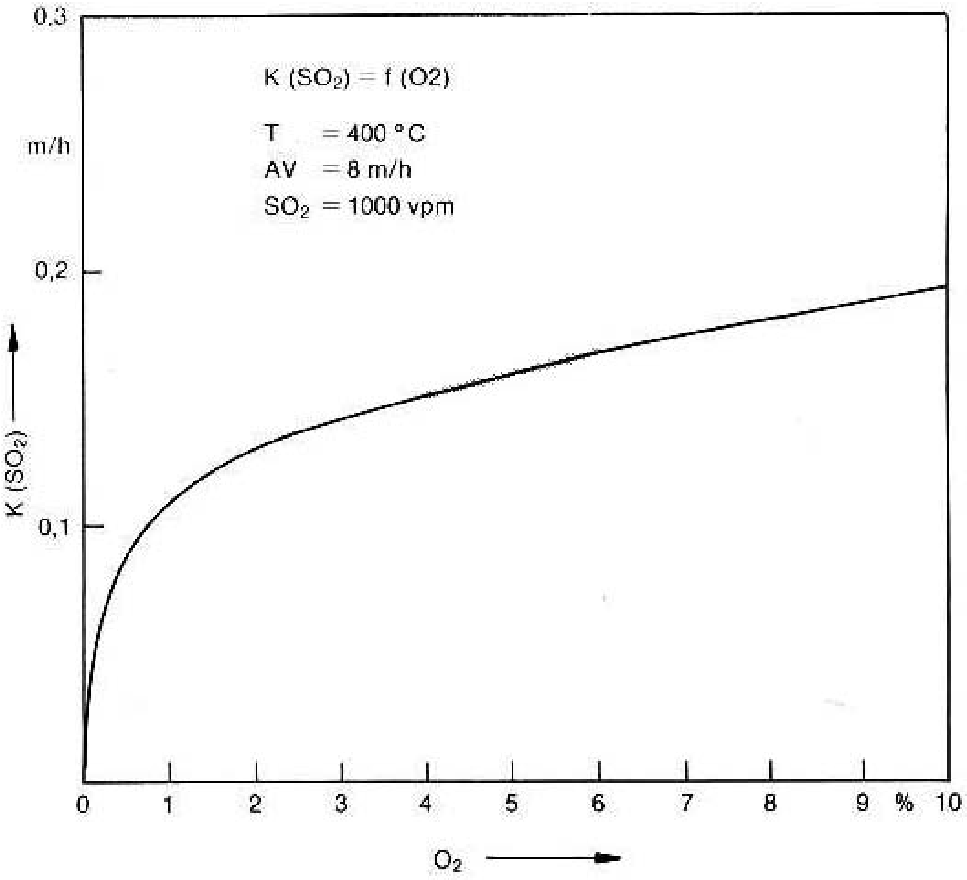


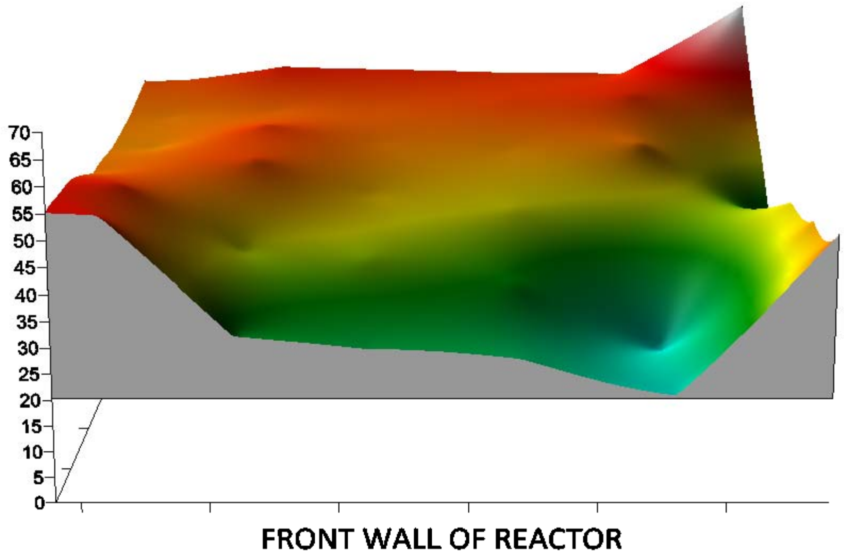
Figure 5

Effect of O2 Concentration on SO2 Conversion Constant

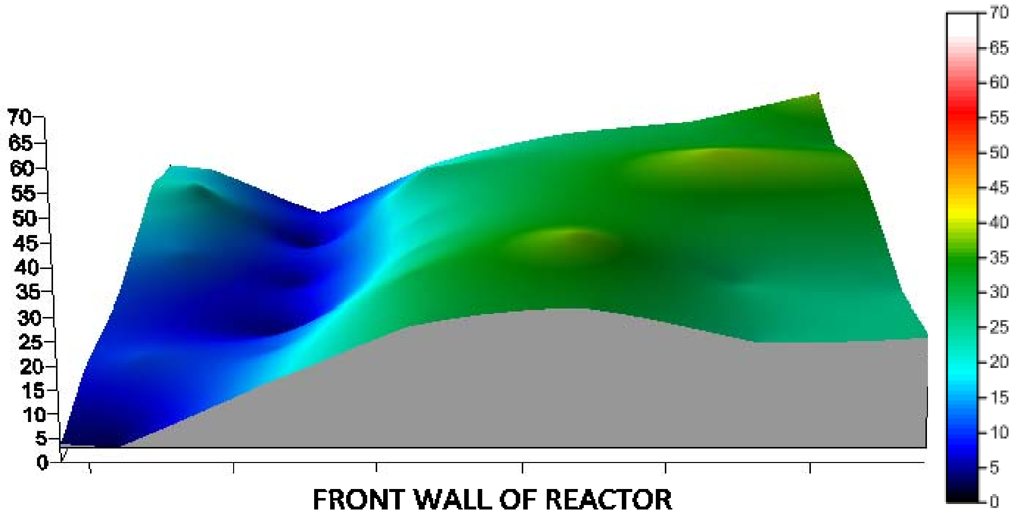
Furnace O_2 imbalance contributes to both higher NH_3 slip and higher SO_3 concentrations.

Furnace Imbalance Creates AIG Tuning Issues – 2 Reactors

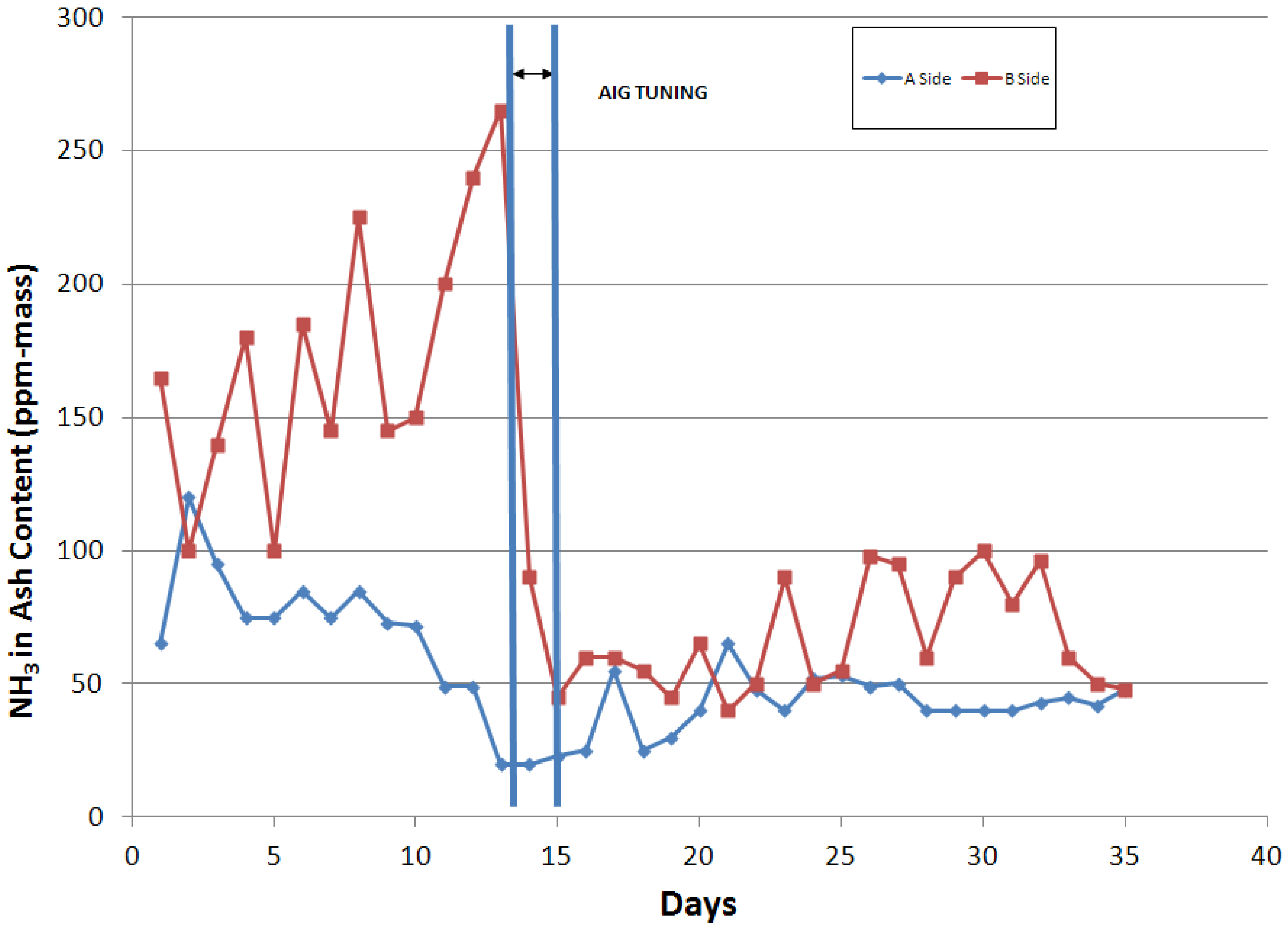
A SIDE REACTOR
45 ppm NO_x @ 3% O_2
Average Excess O_2 = 4.2%
88% Reduction



B SIDE REACTOR
24 ppm NO_x @ 3% O_2
Average Excess O_2 = 3.0%
92% Reduction



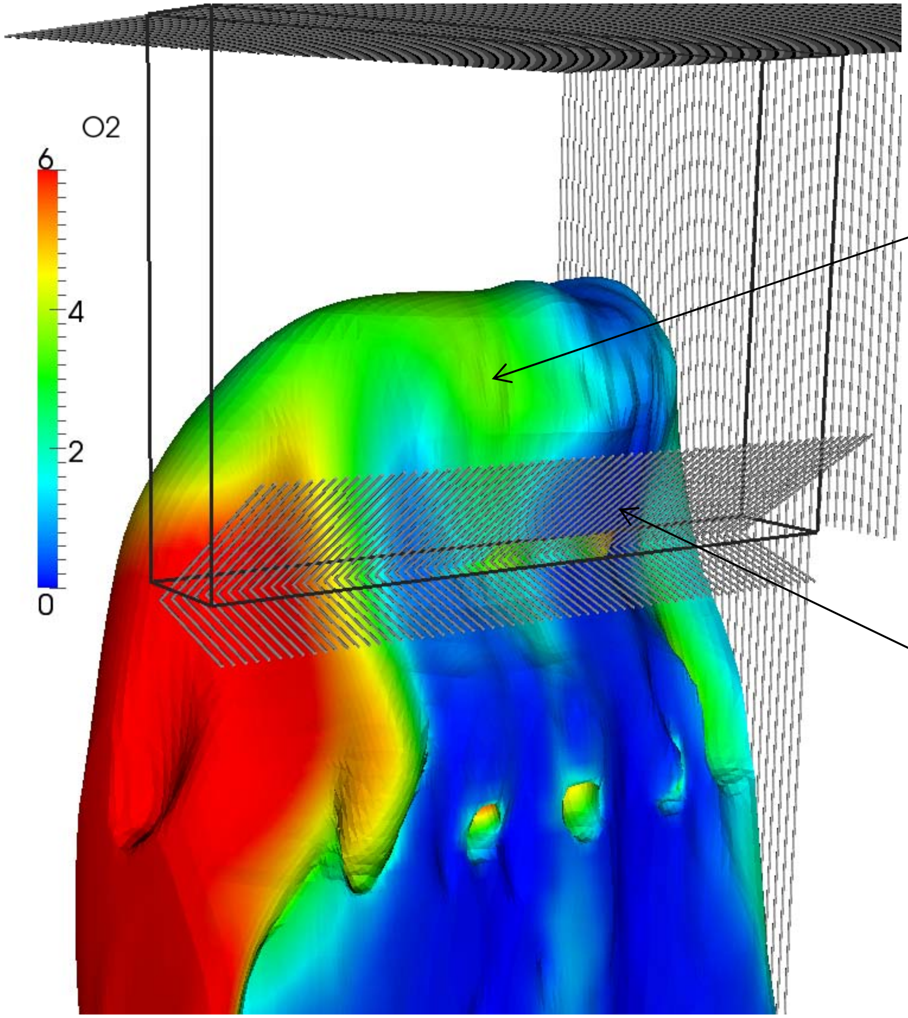
Benefit of Boiler and AIG Tuning on NH_3 Slip



Operating Problems Can Be Solved by Combustion Optimization

- *Furnace Slagging*
- *Opacity*
- *Wall corrosion*

Air/Fuel Imbalances Can Increase Slag and Raise NO_x

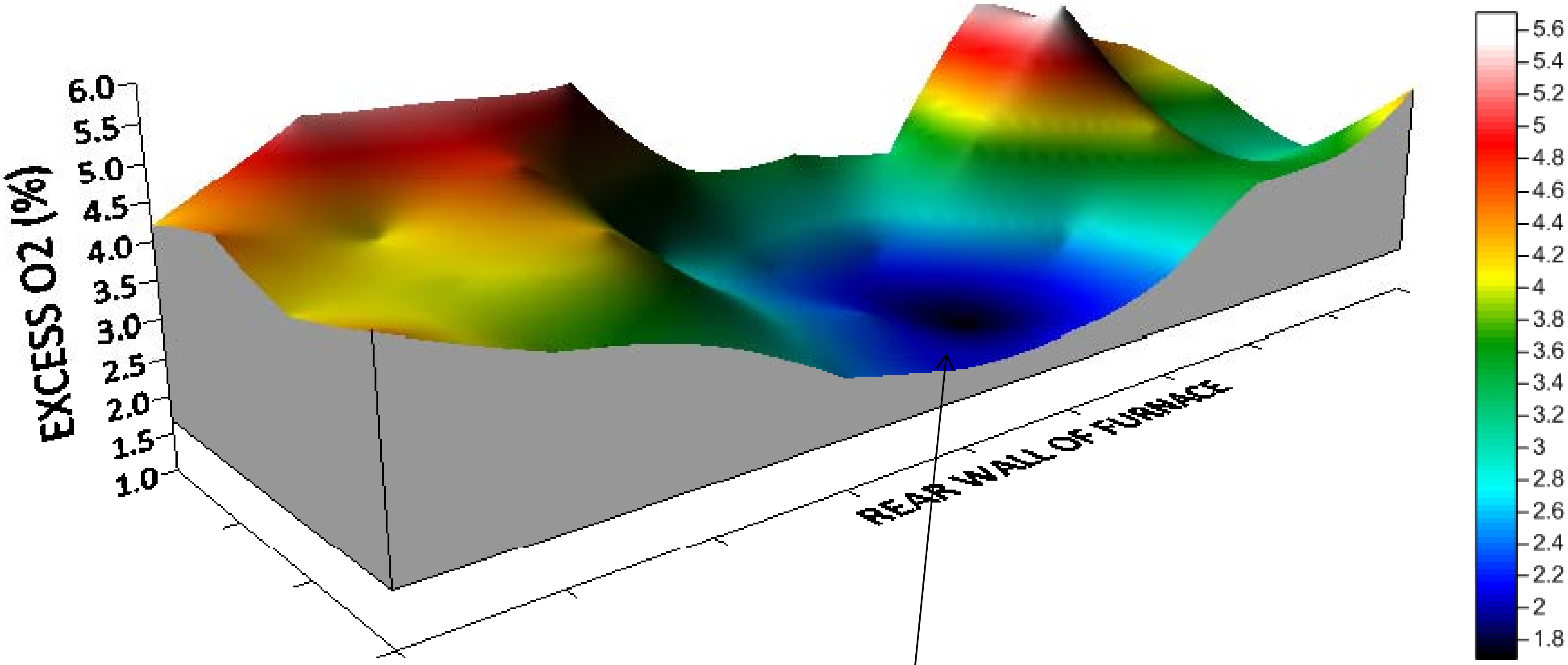


Volume represents regions where the flue gas temperature exceeds the ash softening temperature of 2450 F.

Substoichiometric regions create reducing ash fusion temperature characteristics – ash fusion temperature decreases to 2180 F.

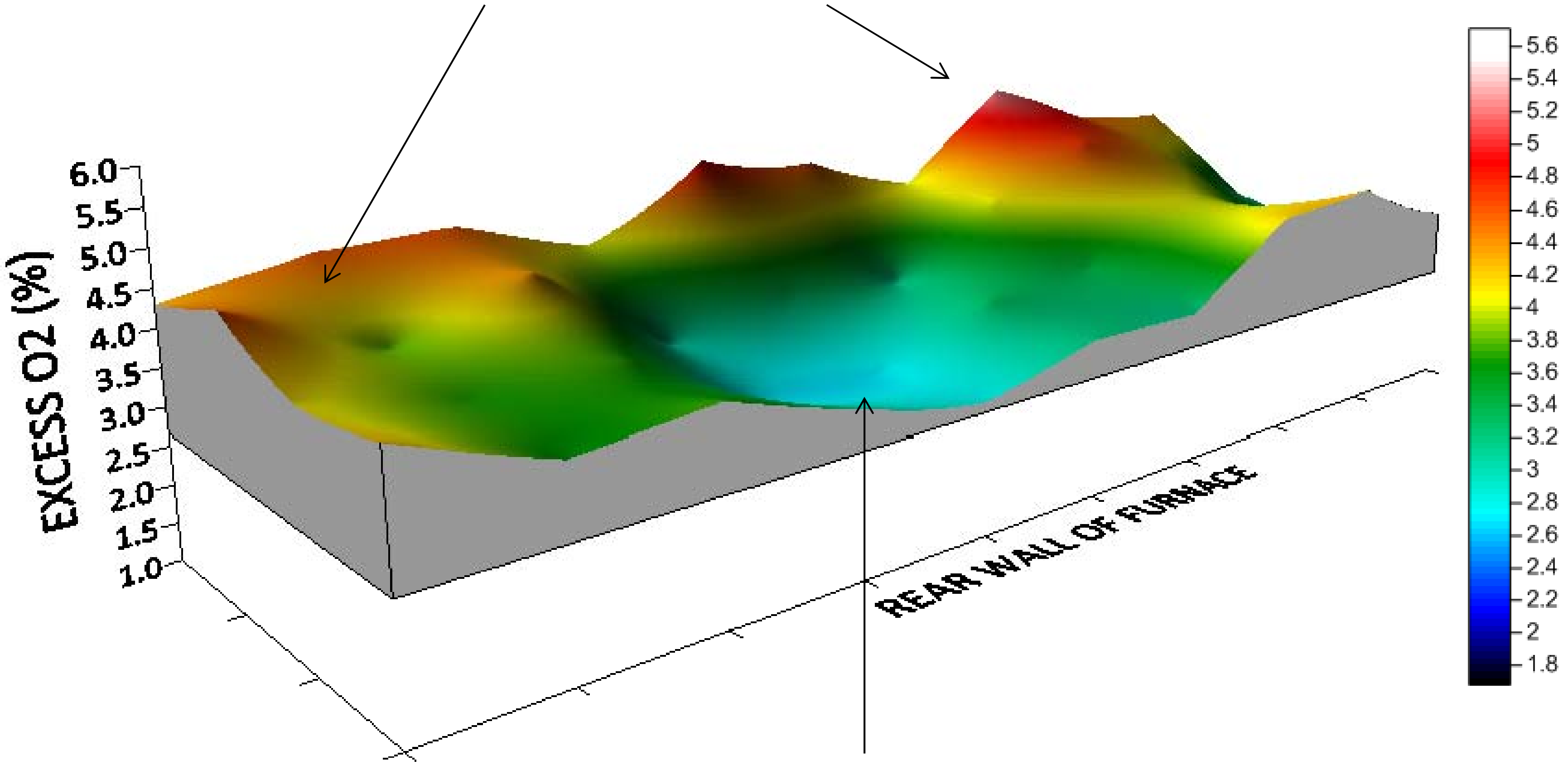
As-Found Furnace Excess O_2 Profile

Average Excess O_2 = 3.8%



Very low O_2 related to poor distribution in secondary air
Tendency is to raise total air flow to minimize slag.

Furnace O_2 Profile After Secondary Air Adjustments



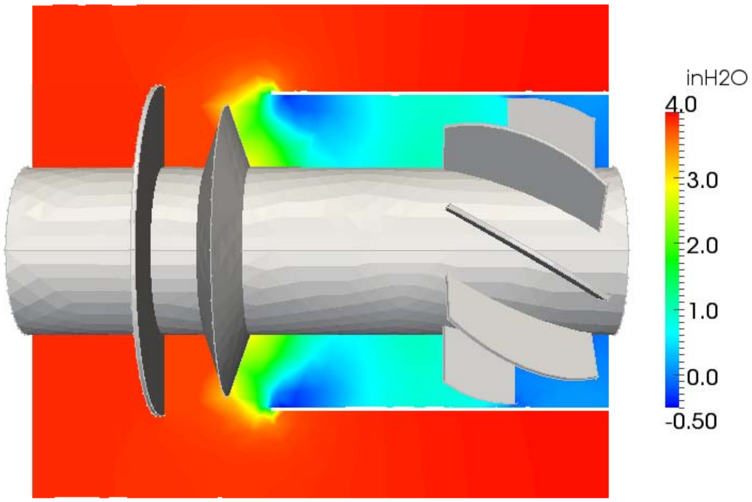
Average Excess O_2 = 3.8%

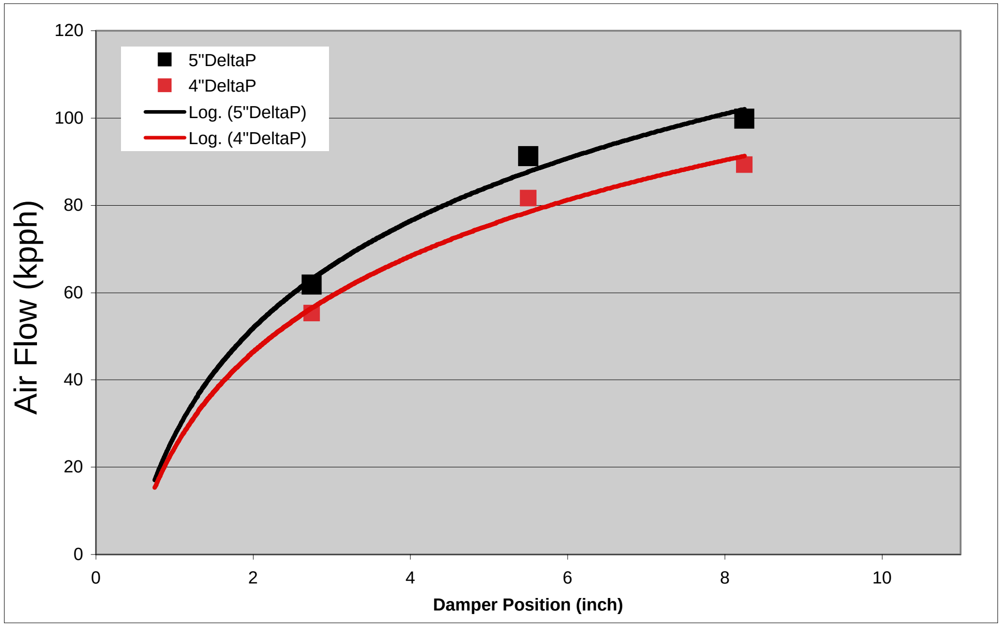
Air registers closed to push air into the middle

SA registers opened in the middle of the furnace

Advice on Secondary Air Damper Adjustments

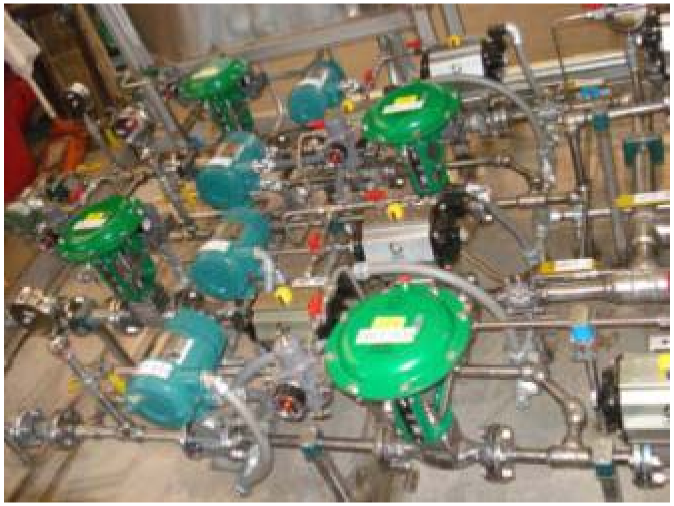
– **Flow is often not linear with damper position.**





STEAG SNCR Experience

- STEAG has over 20 years of experience with SNCR design and operation on coal-fired units. We operate SNCR system in Germany on units where SCR was not cost-effective.
- STEAG has designed and supplied SCNR systems for units ranging from 15 MW to 640 MW.
- Experience with systems utilizing both aqueous ammonia and urea solutions.
- SNCR fits a niche were SCR can not be cost justified and where cost-effective reduction are achievable.
- On coal units, SNCR can achieve 20% to 35% NO_x reduction.



SNCR Optimization

- **Technical Optimum**

– Maximizing NO_x Reduction

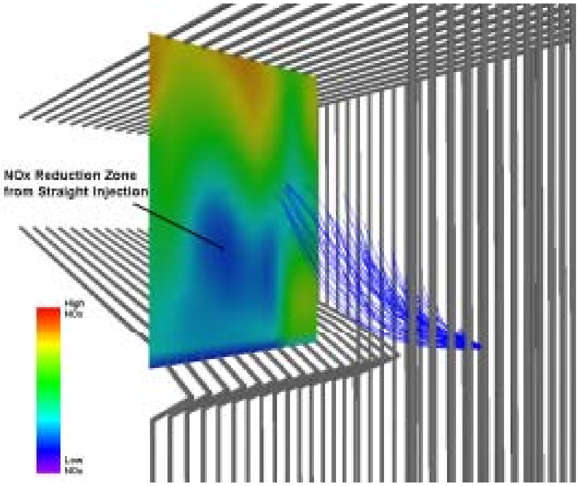
– Achieving acceptable ammonia slip level.

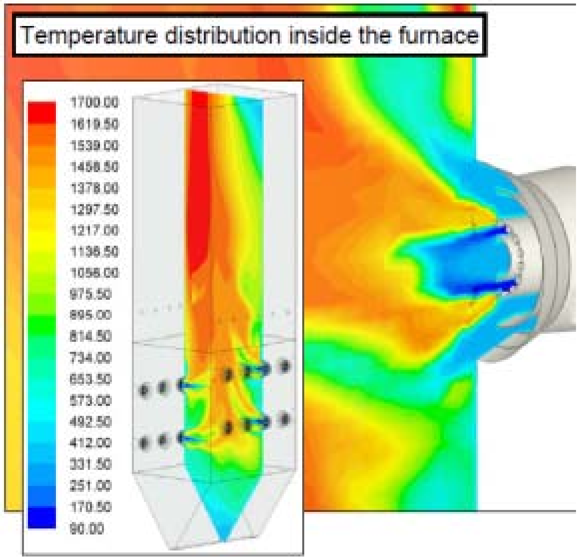
– Requires optimum distribution of reagent – spray characteristics and furnace elevation.

- **Economic Optimum**

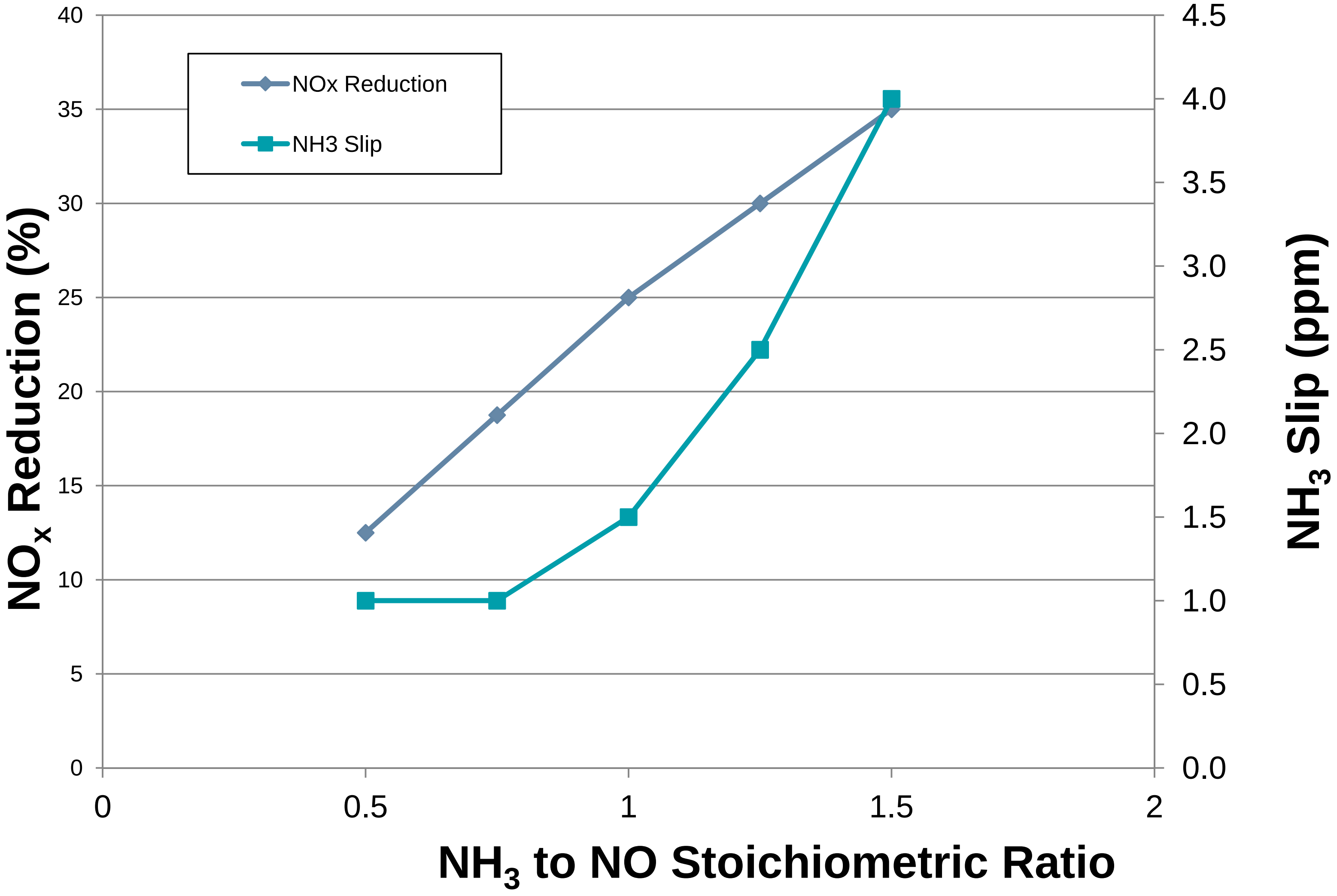
– Achieving cost-effectiveness ($ per ton of NO_x removed) which is less than the market price for a NO_x allowance.

– Requires understanding the relationship between increased reagent use and increased NO_x reduction.



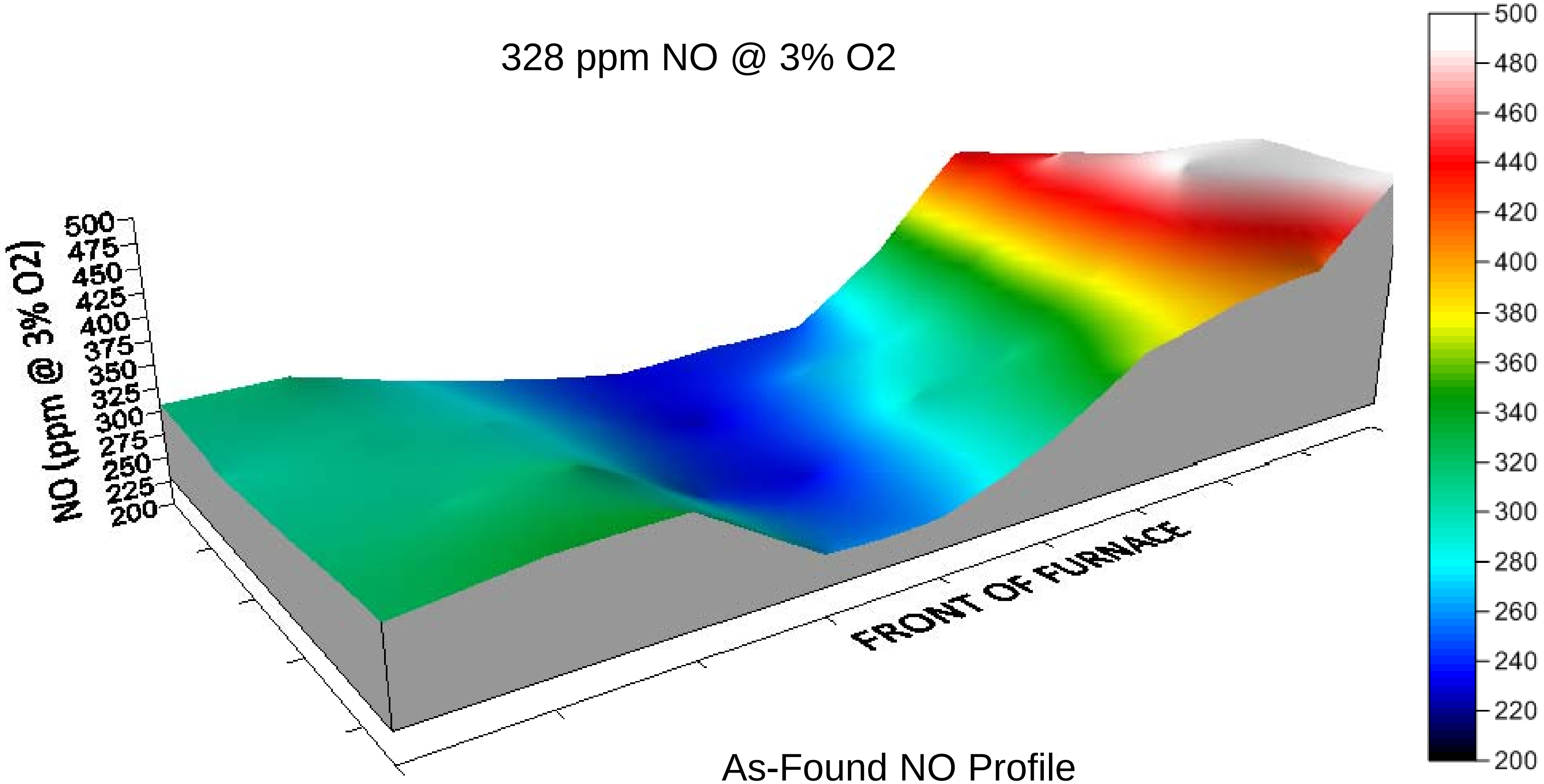


Typical SNCR Performance Characteristics



Problem with Combustion Imbalance on SNCR Optimization

328 ppm NO @ 3% O2

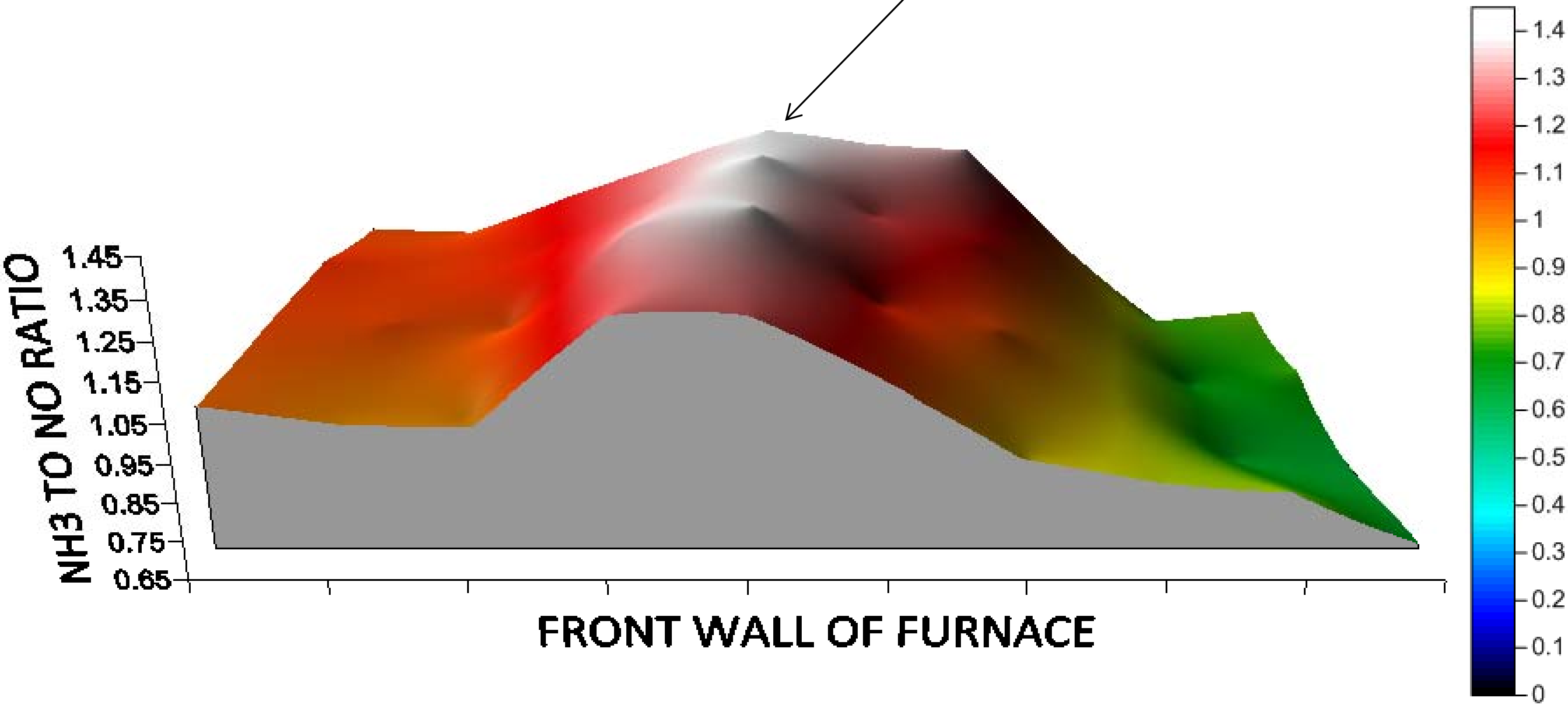


As-Found NO Profile

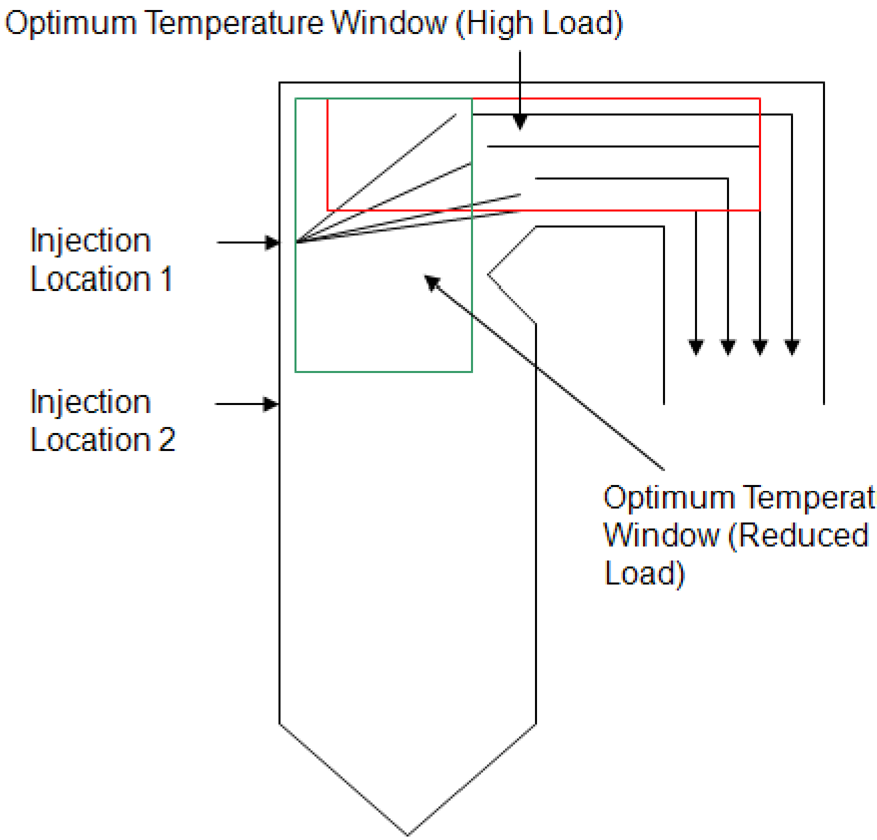
NH_3 to NO Distribution Profile Assuming Uniform Distribution of Reagent

NH_3 to NO Ratio of 1:1

High NH_3 to NO ration will lead to increase ammonia slip



Combustion Optimization Achieves Uniform NO Profile at SNCR Injection Locations

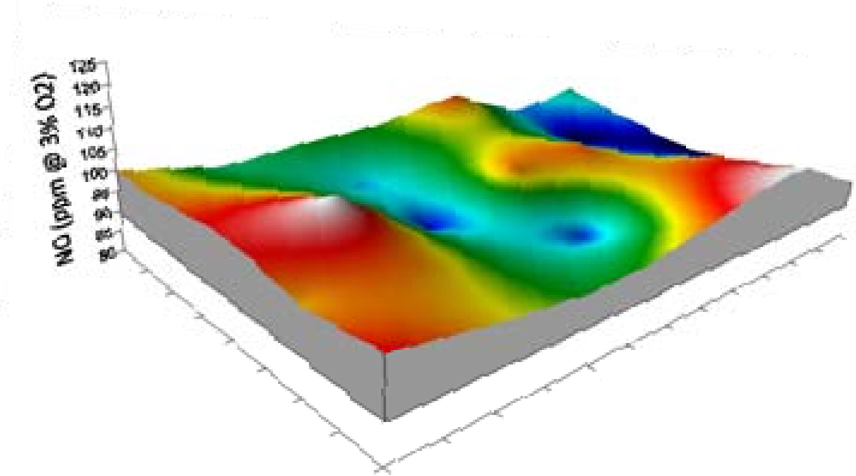


Optimum Temperature Window (High Load)

Injection Location 1

Injection Location 2

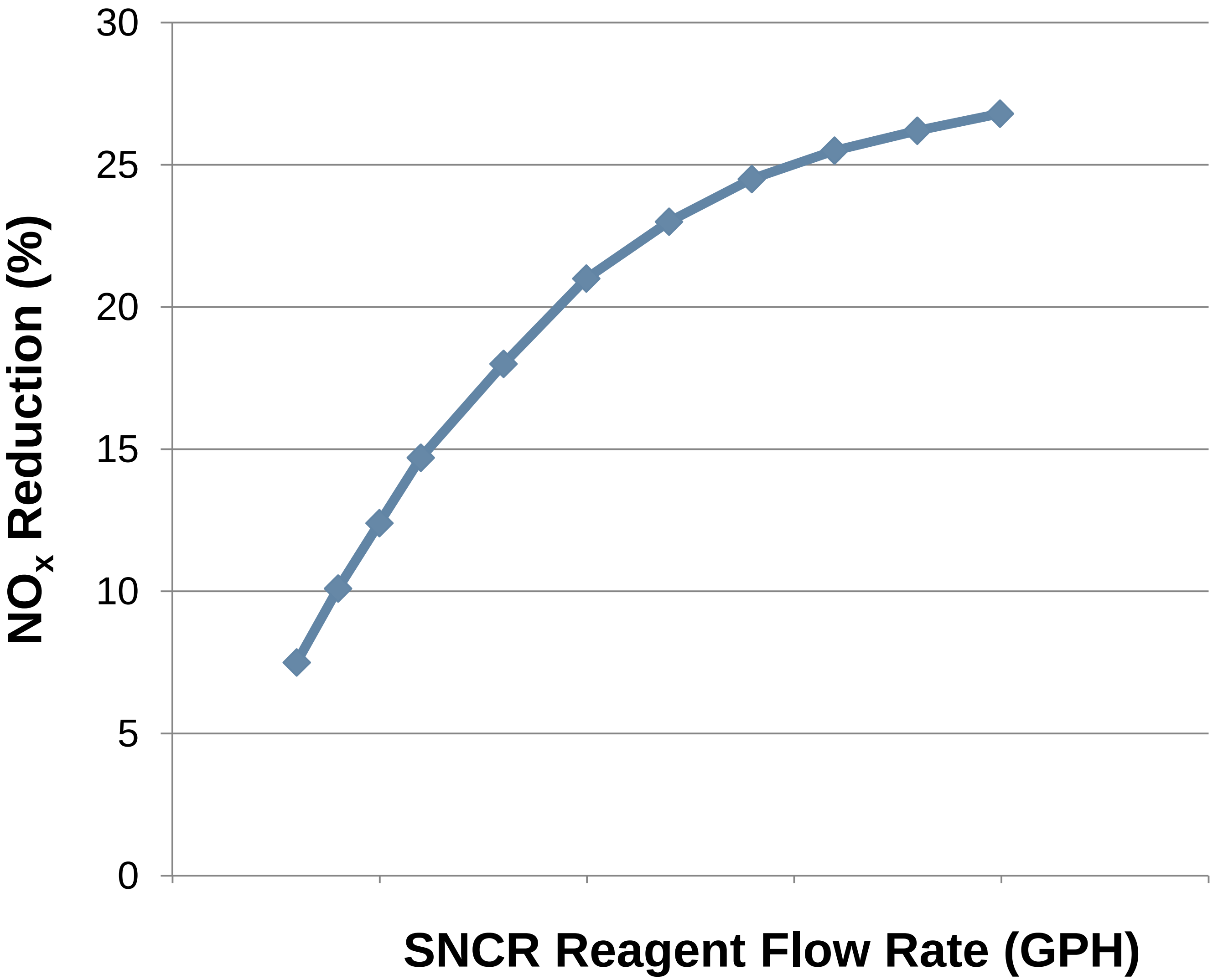
Optimum Temperature Window (Reduced Load)



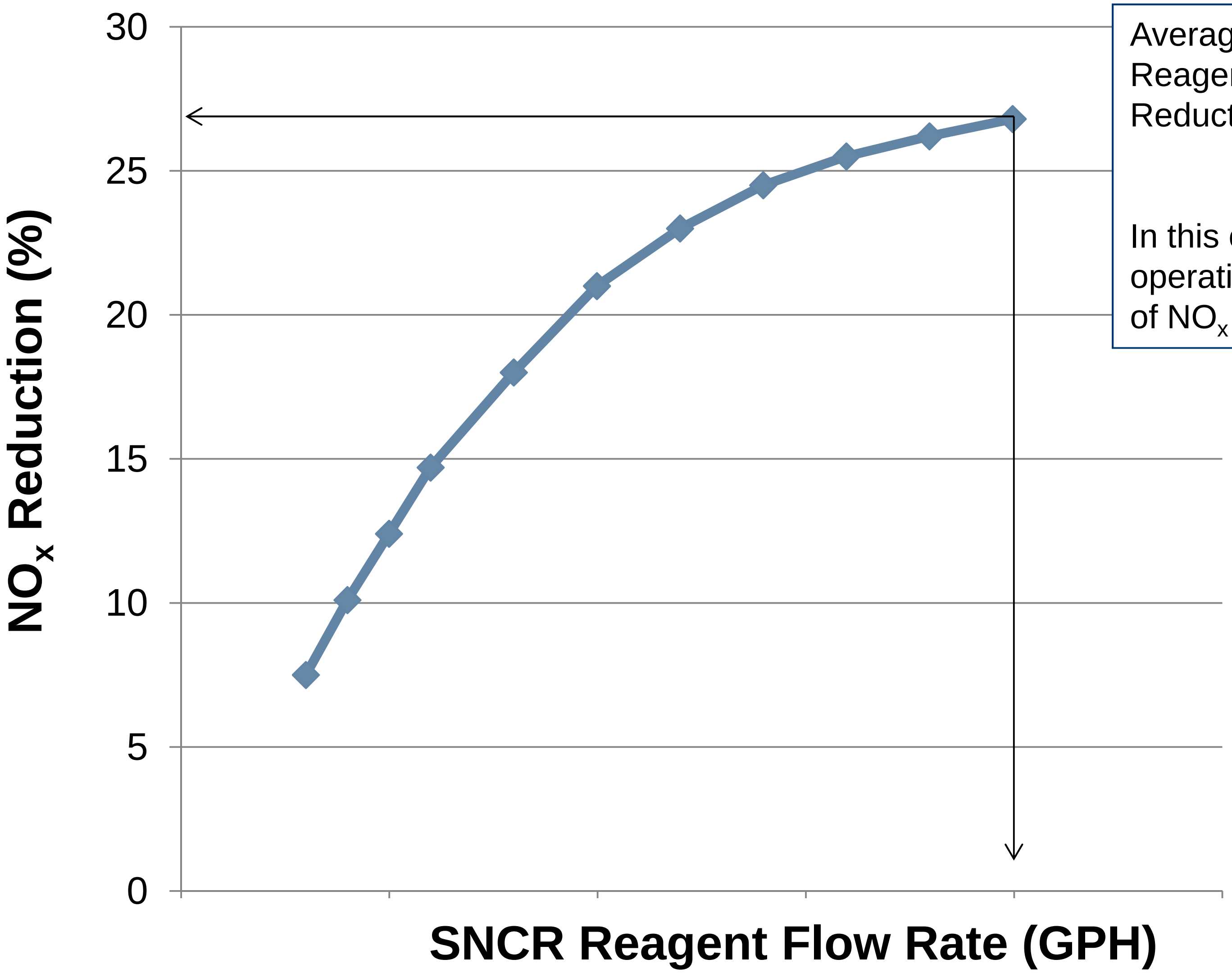
Economic Optimization

- Economic optimum with SNCR does not depend on achieving maximum NO_x reduction.
- Depends on identifying conditions where the NO_x reduction per gallon of reagent flow is maximized.

SNCR NO_x Reduction Profile at Full Load



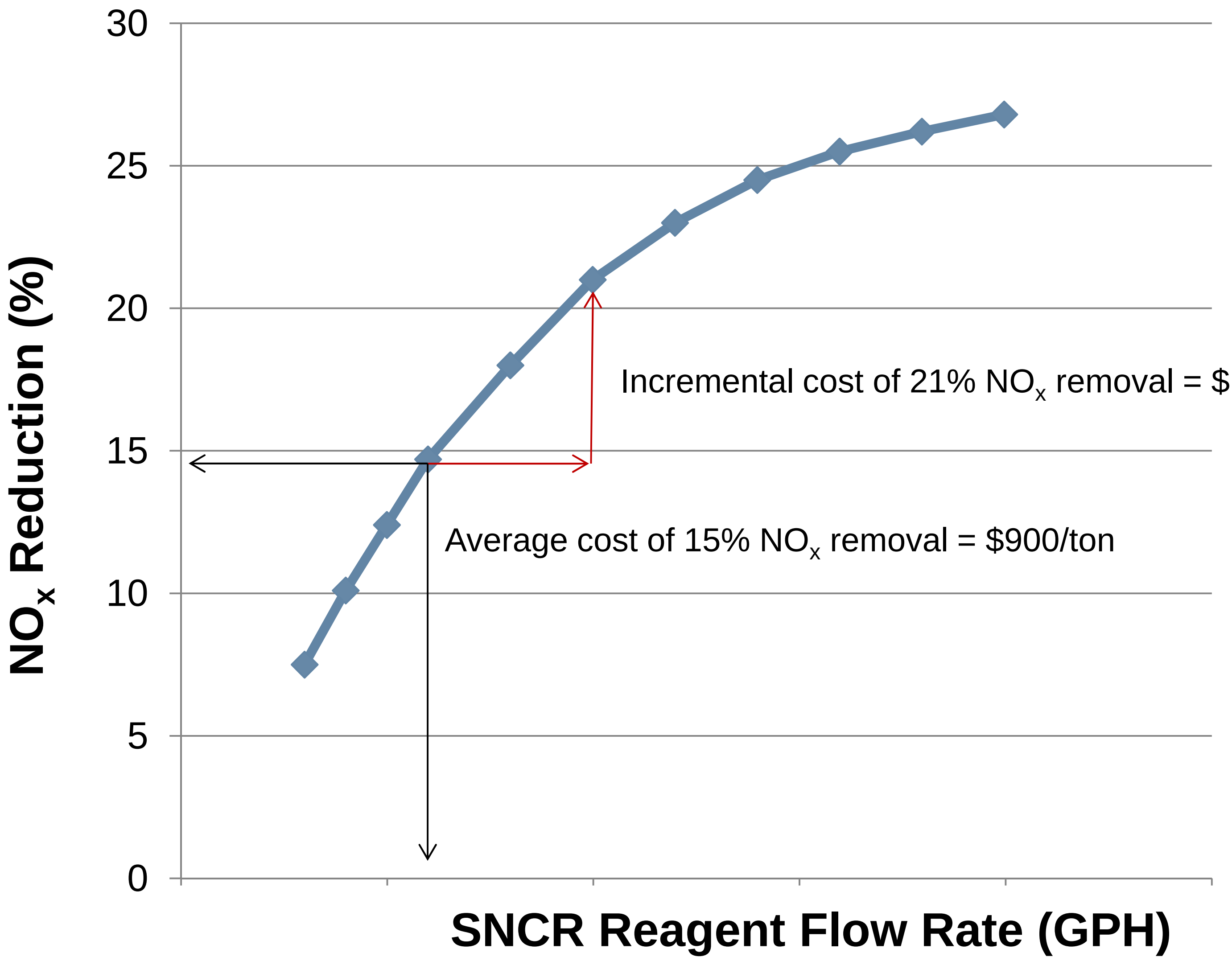
Average Cost-Effectiveness Measured at Full Load Operation



Average Cost Effectiveness = Reagent Cost ($)/27% NO$_x$ Reduction.

In this case the average operating cost was $1700/Ton of NO$_x$ removed.

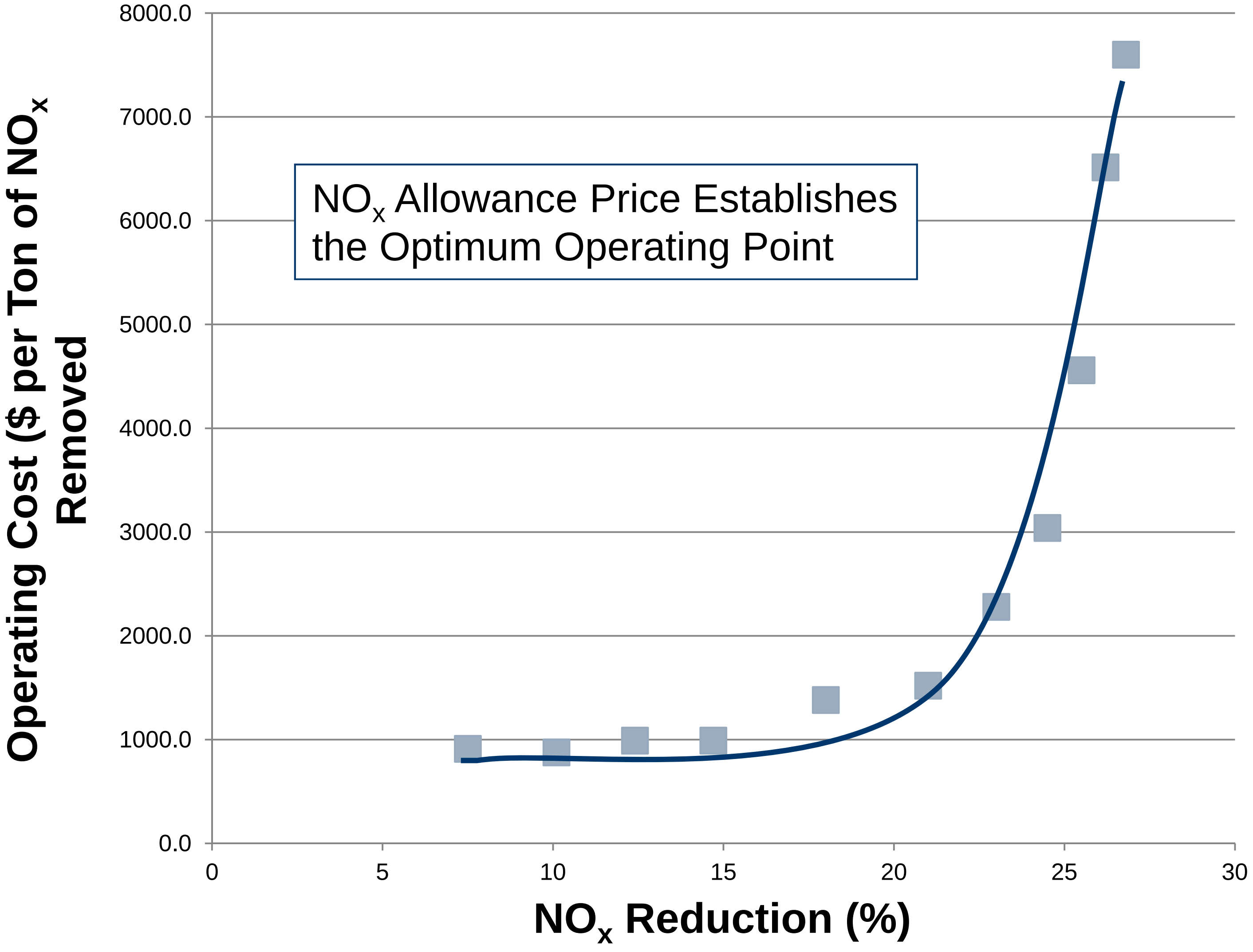
Incremental Cost-Effectiveness



Incremental cost of 21% NO$_x$ removal = $1450/ton

Average cost of 15% NO$_x$ removal = $900/ton

Incremental Cost-Effectiveness
Full Load



NO_x Allowance Price Establishes the Optimum Operating Point

Conclusions

- Don’t neglect combustion optimization expecting SCR or SNCR to achieve NO_x goals.
- Optimization can reduce reagent use and help to minimize ammonia slip and SO_3 formation characteristics.
- SNCR has to be operated cost-effectively which does not necessarily mean achieving maximum NO_x removal.
- Last, another expert sensor or control system is not a substitute for the fundamental goal of combustion uniformity.

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