REINHOLD ENVIRONMENTAL Ltd.

2016 NOx-Combustion-CCR Round Table Presentation

February 1 & 2, 2016, in Orlando, FL / Hosted by OUC

Cycling on Coal Fired SCR's
February 1, 2016

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Agenda

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Cycling

Impacts on the Plant

What can the Plant Do?

As of Jan. 1th, 2016 we are …

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steag
Essen, Germany

EnergyCapital Partners
Short Hills, NJ (USA)

steag
Kings Mountain, NC (USA)

CoaLogix® | SCR TECH A CoaLogix Company
Charlotte, NC (USA)

50% 50%

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Cycling

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Why has cycling become so prevalent?

- **Natural Gas Prices**
- **Renewables**
- **Recession in United States**
- **Carbon Concerns**

Historical Natural Gas Pricing

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Historical Crude Oil Pricing

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Renewables

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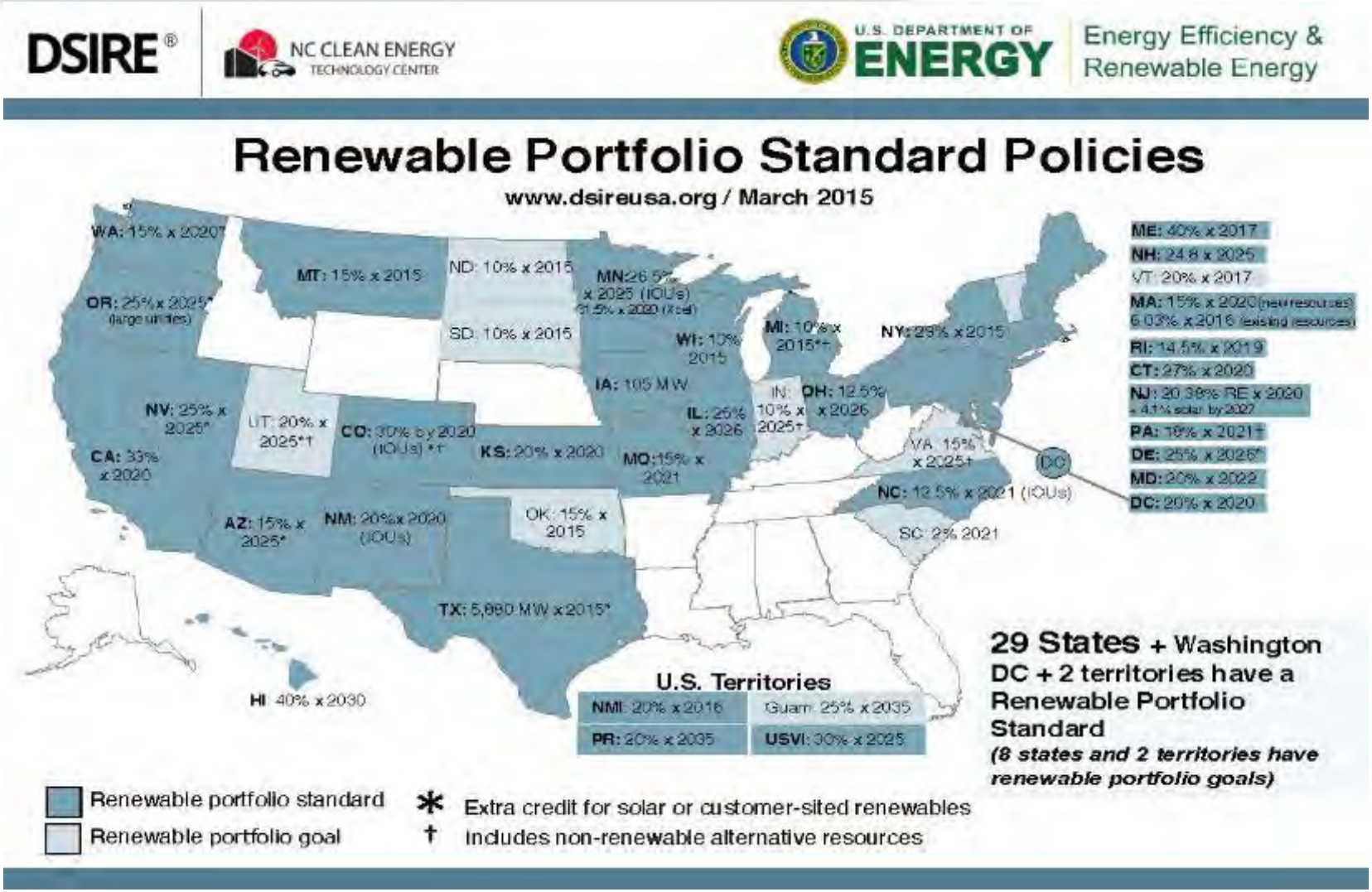

http://www.seia.org/policy/renewable-energy-deployment/renewable-energy-standards

Recession in the United States

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Carbon Concerns

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- **2010** • Proposed Settlement of GHG
- **2012** • Carbon Pollution Standards for New Power Plants
- **2014** • Proposed Standards for Modified and Reconstructed Power Plants
- **2015** • Proposed Federal Plan for the Clean Power Plan

Source: http://www.epa.gov/cleanpowerplan/clean-power-plan-existing-power-plants#federal-plan

Generation Profile

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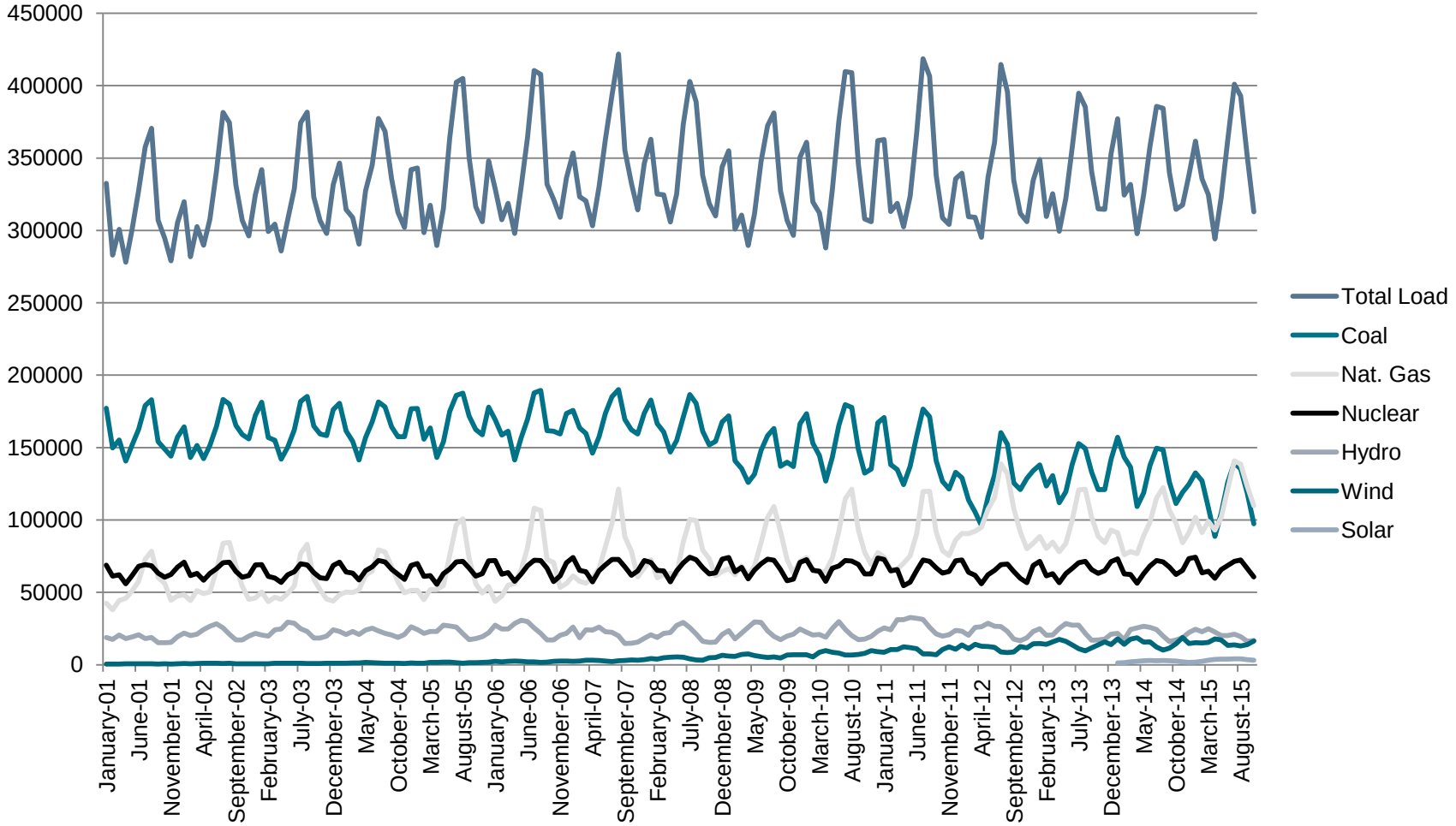
Energy Generation in United States



Coal Fired Plant Operators

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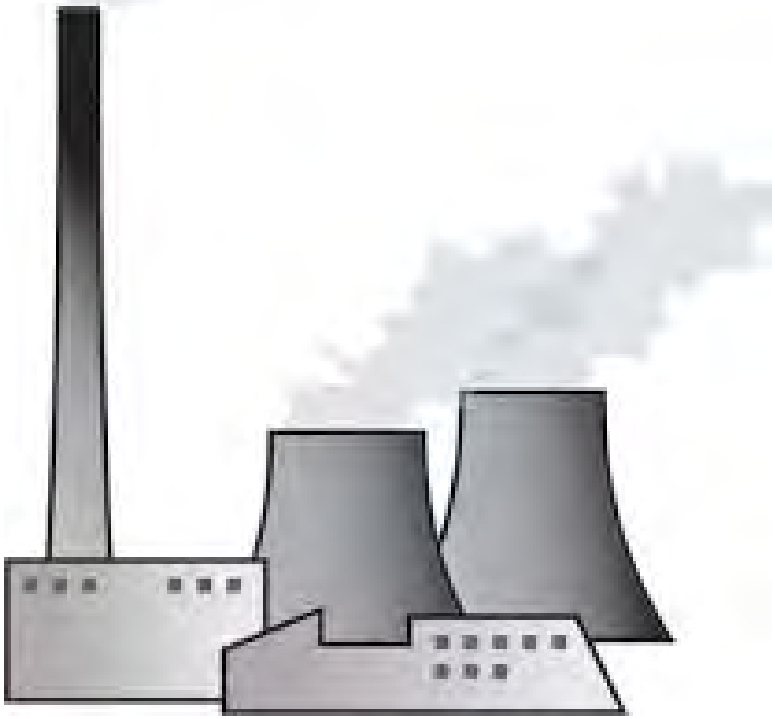
Adjust to cyclical operation!



Operational Impacts on SCR

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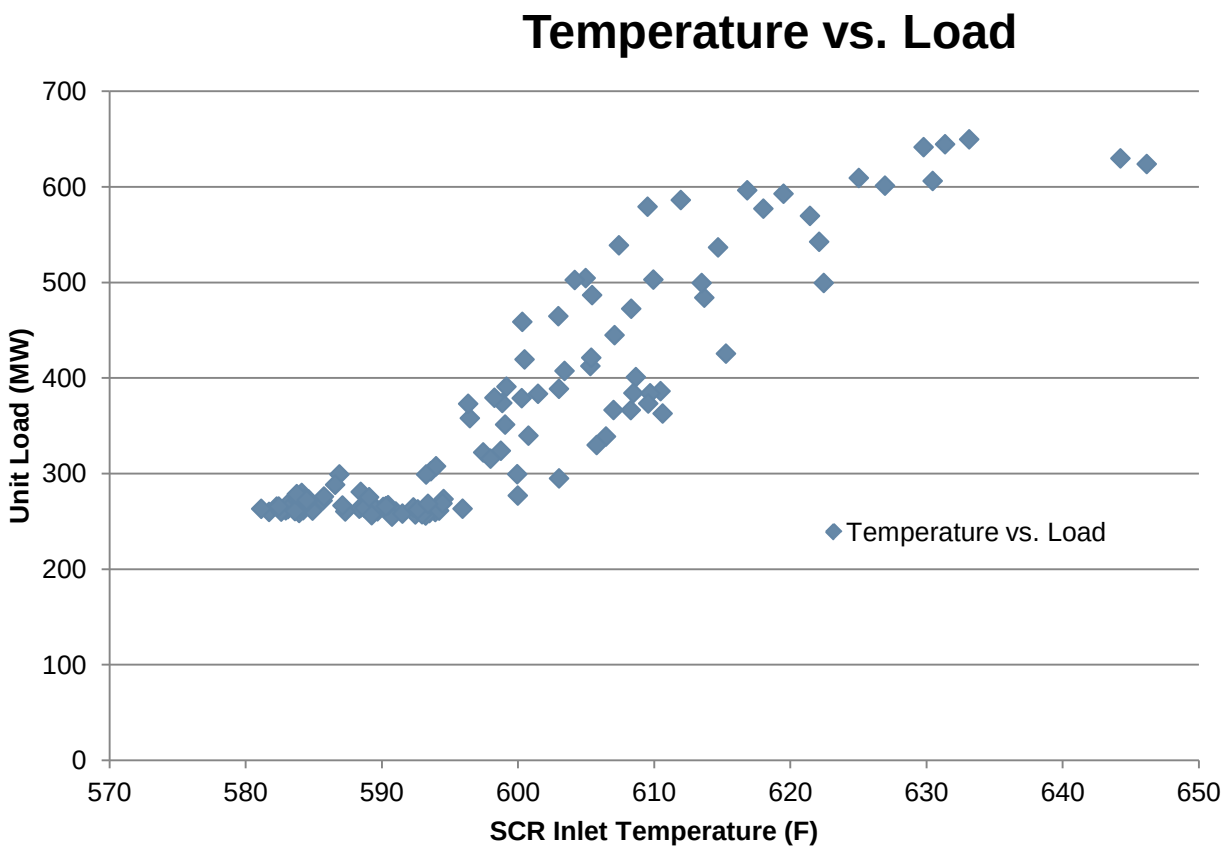
- Lower SCR Temperatures
- Lower Flue Gas Velocities
- Ash Deposition on Catalyst
- ABS Formation
- SO_2 Oxidation Rate Changes
- Ammonia Slip Potential
- Mercury Oxidation Rate Changes
- Lower NO_X and SO_X Concentrations

Flue Gas Temperatures

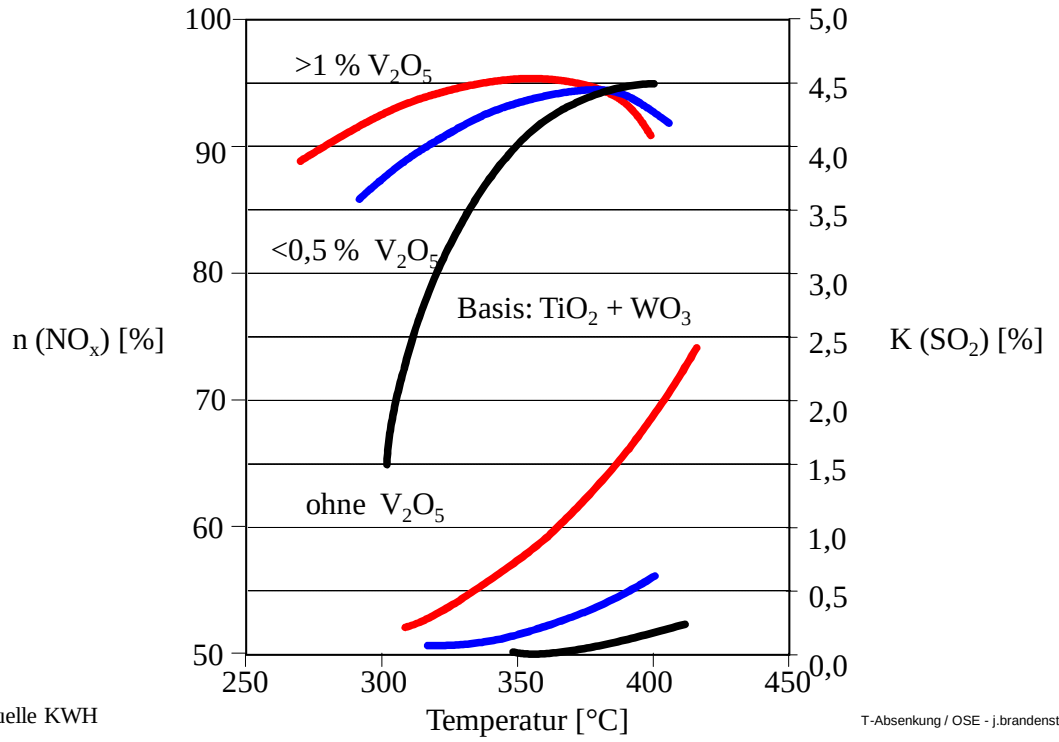
- **Load drops include drops in temperature across the SCR**
- **Degree of change varies from unit to unit**



Flue Gas Temperatures

Why Not Worry?

- **Temperatures are generally above minimum temperature for DeNOx reaction to occur**



Quelle KWH

T-Absenkung / OSE - j.brandenstein

Flue Gas Temperatures

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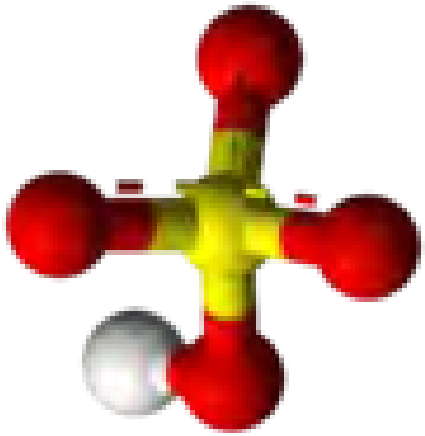
Why Worry?

- Generally based on formation of ammonium salts
- For coal fired power plants, the concern is



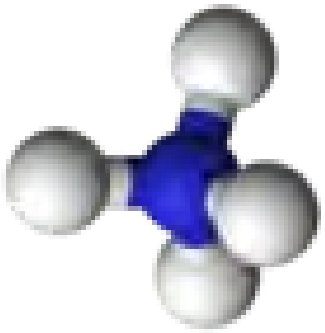
Ammonium Bisulfate

$$NH_3 + SO_3 + H_2O \longrightarrow NH_4HSO_4$$

or

Ammonium Sulfate

$$2NH_3 + SO_3 + H_2O \longrightarrow (NH_4)_2SO_4$$



Ammonium Pore Condensation

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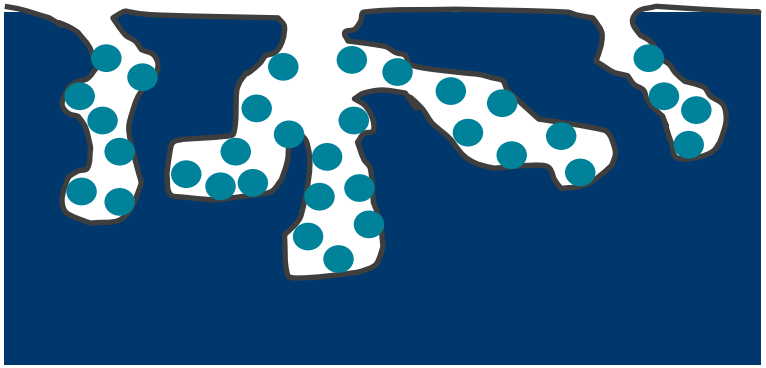
Above Dew Point Temperature

$$4NO + 4NH_3 + O_2 \rightarrow 4N_2 + 6H_2O$$

$$2SO_2 + O_2 \rightarrow 2SO_3$$



Below Dew Point Temperature

$$4NO + 4NH_3 + O_2 \rightarrow 4N_2 + 6H_2O$$

$$2SO_2 + O_2 \rightarrow 2SO_3$$

$$2NH_3 + SO_3 + H_2O \leftrightarrow (NH_4)_2SO_4$$

Ammonium Pore Condensation

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- Fills in the pores and blocks the active sites
- Is dependent on the minimum temperature in flue gas – not average
- Higher than the minimum because of capillary forces in the pore structure
- However, this process is generally reversible!

Flue Gas Flow Rate

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Flow rate decreases help with removal efficiency:

- Longer residence time
- Linear, area and space velocities are decreased

$$A_V = \frac{\dot{V}_{FG}}{S_A}$$

$$SV = \frac{\dot{V}_{FG}}{V_{Cat}}$$

All have a positive impact on the SCR reactor performance

Lower linear velocity also results in:

- Lower pressure drop
- Lower erosion

Flue Gas Flow Rate – Ash Deposits

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Ash Buildup on Catalyst During Low Load

Ash sweepers can offer a solution for eliminating ash buildup problems

Flue Gas Flow Rate

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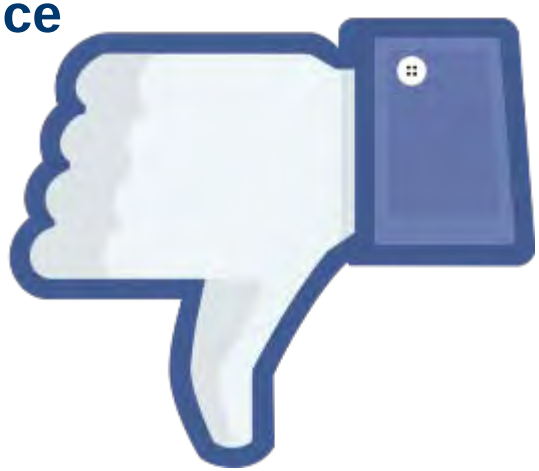
Ash buildup leads to less surface area

- **Linear, area and space velocities are increased!**
- **Residence time is decreased!**

Ash buildup has a negative impact on performance

$$A_V = \frac{\dot{V}_{FG}}{S_A} \qquad SV = \frac{\dot{V}_{FG}}{V_{Cat}}$$



Higher linear velocity also results in:

- **Higher pressure drop**
- **Higher erosion**

Flue Gas Flow Rate

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Plugging of Catalyst Can Lead to Erosion

Ammonia Slip Issues

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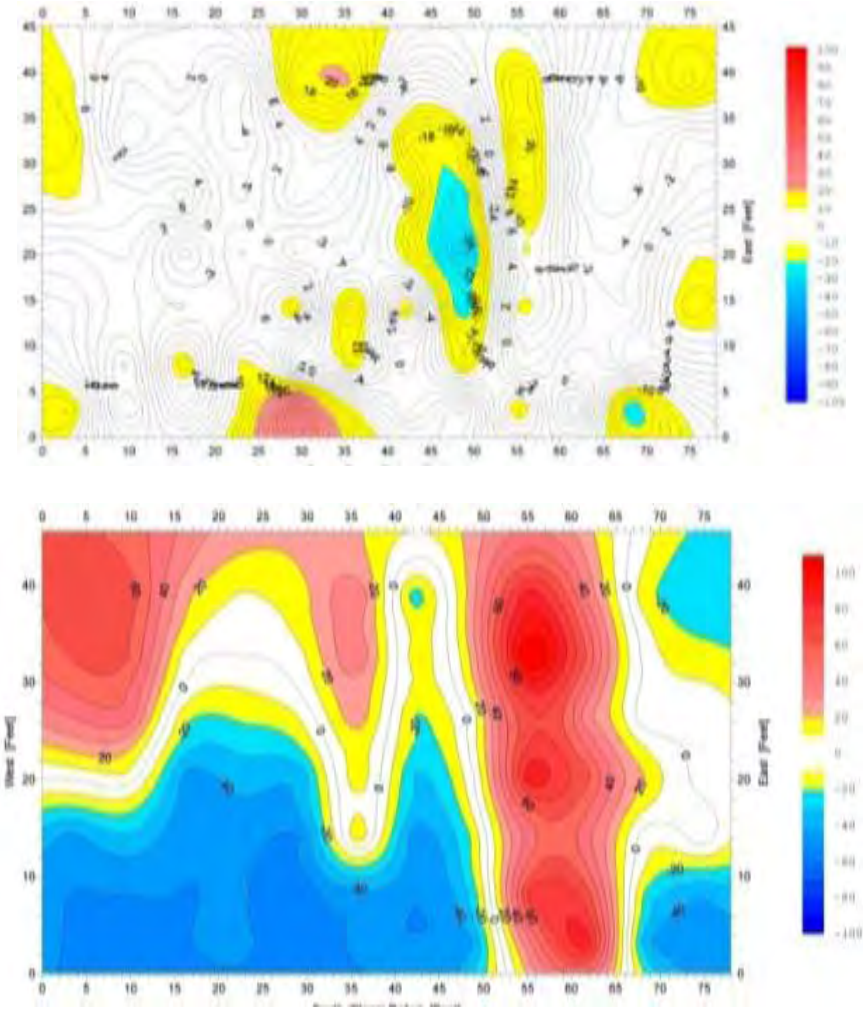
- **Unit is generally tuned at full load and design NOx removal efficiency**
- **NO_X profile can change with reduced load operation and different mill / burner combinations**
- **Ammonia slip can occur**



SO_2 to SO_3 Conversion

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- SO_2 oxidation decreases with temperature
- At low temperatures, conversion rates become less of an issue
- Even though longer residence time, temperatures are too low to impact.

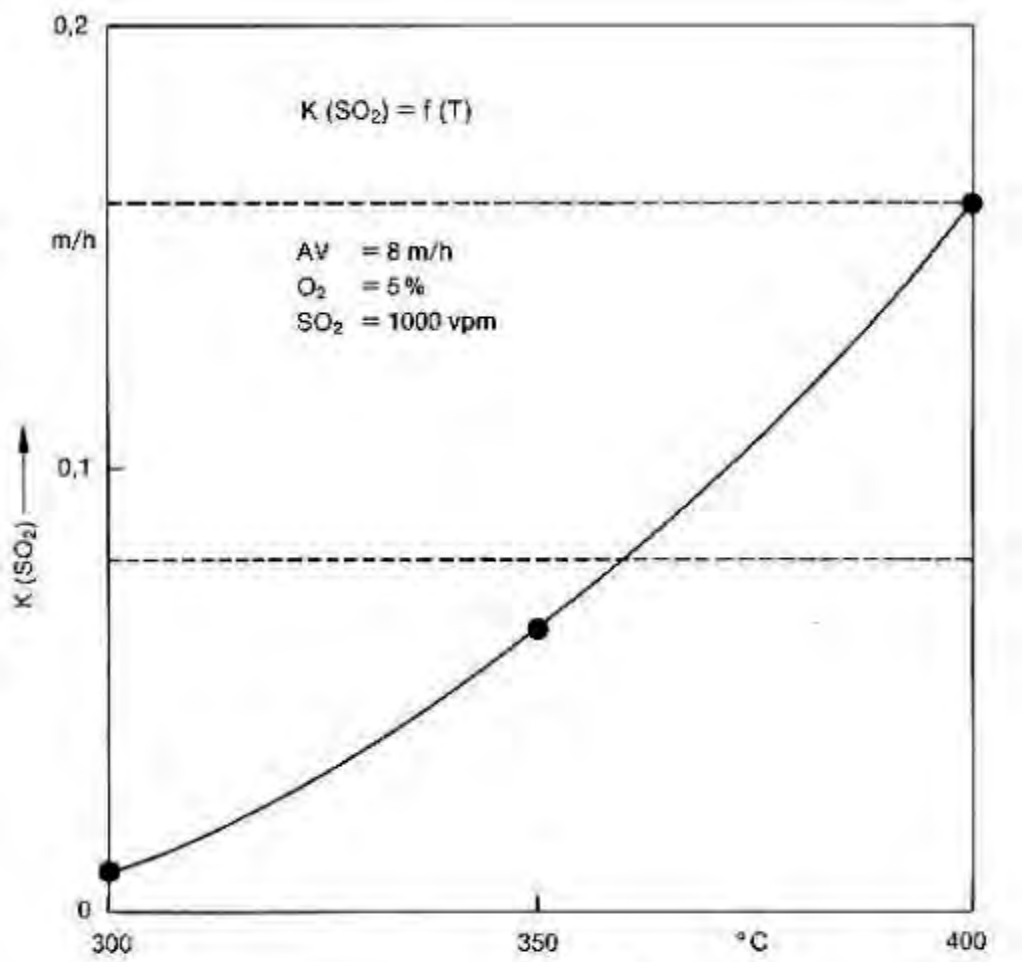
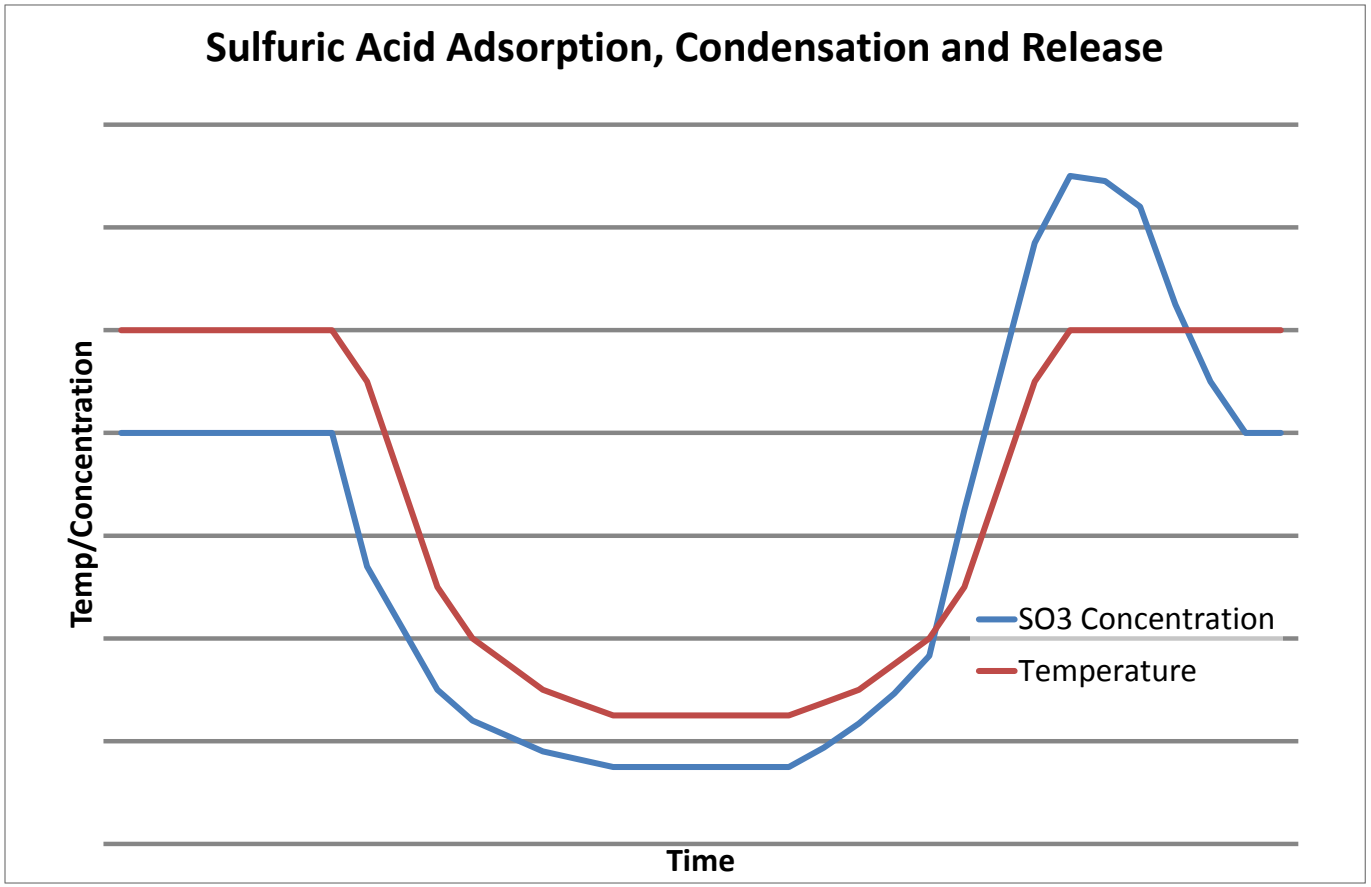


Figure 4
Effect of Temperature on SO2 Conversion Constant

SO_3 Concentration over Temperature



Corrosion in the SCR

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SCR Side Reactions

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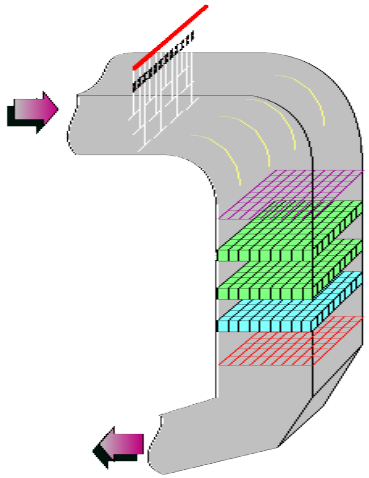
Undesired Side Reactions in the Air Heater:



- **SO_3 condensation:**

$$SO_3 + H_2O + O_2 \rightarrow H_2SO_4$$

- **Ammonium Bisulfate ABS formation:**

$$NH_3 + SO_3 + H_2O \rightarrow NH_4HSO_4$$

Mercury Oxidation

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Impacts of Mercury Oxidation on Temperature and Flow:

- **Oxidation rate increases with temperature decrease**
- **Hg oxidation increases due to lower A_V**
- **Lower ammonia values increases Hg oxidation**

What Can Be Done?

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SCR Temperatures

- **Economizer bypass operation / maintenance**
- **Static mixers to evenly distribute the temperature and gas concentrations**
- **Determine what is the actual minimum operating temperature**
- **Operate at lower temperatures and allow the ABS build up in the catalyst pores, if the ABS can be 'burned off' again at full load**

Improve Temperature Distribution

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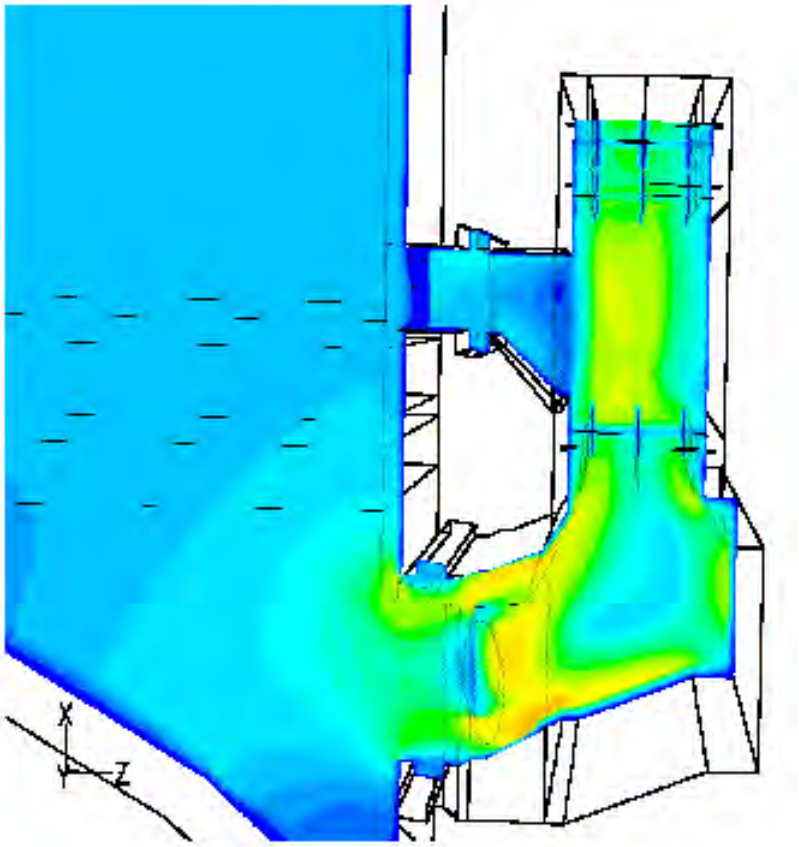
Economizer Bypass Installation / Maintenance



Static Mixers

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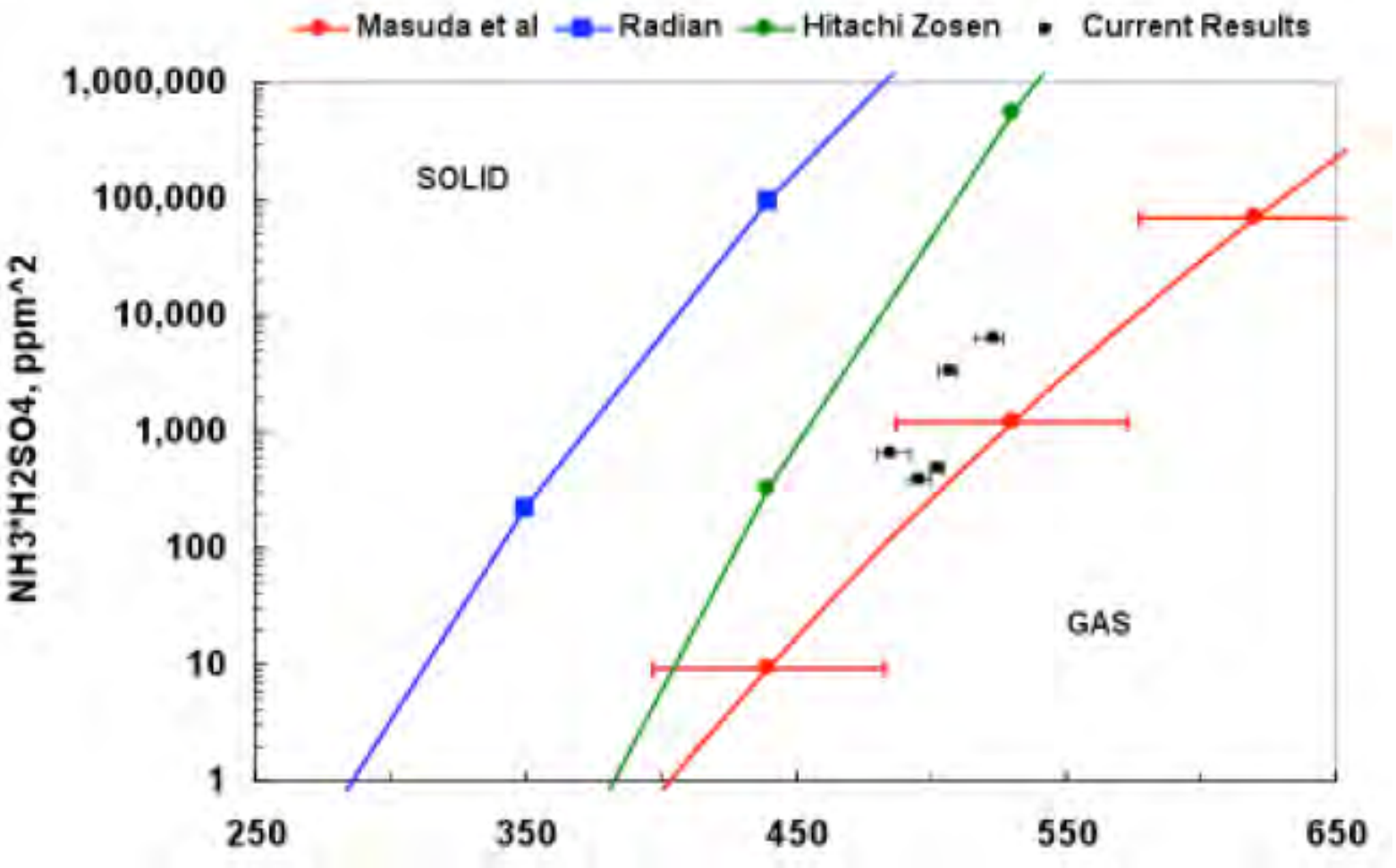
Addition of Static Mixers Upstream to Even Distribution

What Temperature to Operate?



Summary of Selective Catalytic Reduction System Operational Issues at Low Load. EPRI, Palo Alto, CA: 2010. 1021208

How Much SO_3 in Flue Gas?

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1. Minimum temperature generally set by how much SO_3 is in the flue gas
2. These have been generally set up based on original design
3. Potential to measure SO_3 concentration online in flue gas

Change in Minimum Operating Temperature

Flue Gas Flow

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Flow modeling to address fly ash deposition

Installation of ash sweepers to assist with cleaning

AIG Tuning

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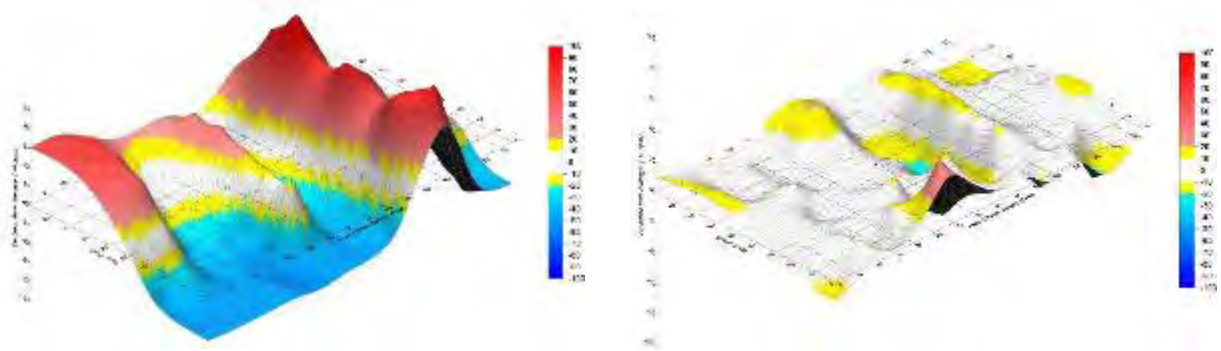
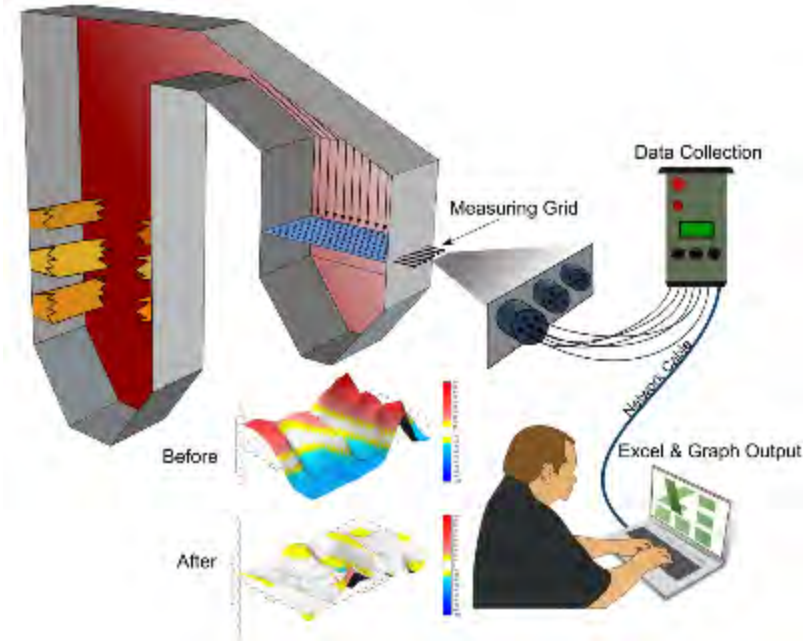
- Determine NOx profile at typical load range
- Tune reactor at low loads and compare to full load tuning
- Find optimum load for reactor tuning





Questions ?

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