REINHOLD ENVIRONMENTAL Ltd.

2019 NOx-Combustion-CCR Round Table Presentation

February 11 & 12, 2019, in Salt Lake City, Utah / Hosted by PacifiCorp

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Combined Cycle SCR Systems

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2019 Reinhold NO_x-Combustion-CCR Round Table

February 11, 2019

Salt Lake City, Utah

FERCo

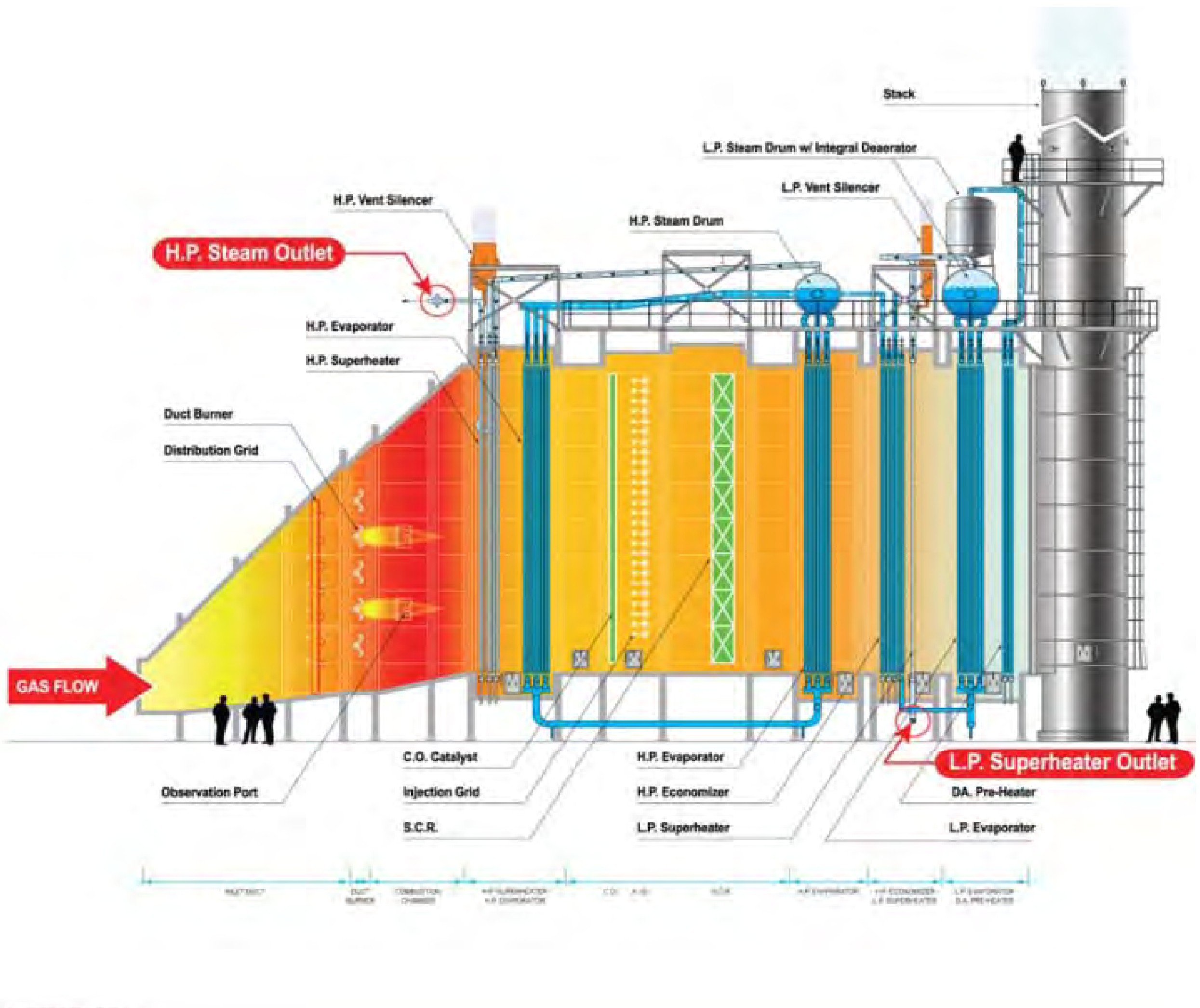
MP313

Todays Topics

Topics

- **Catalyst Sizing**
- **AIG Tuning; How Done and Importance**
- **Flue Gas Bypass**
- **Combined Cycle SCR Operating Temperatures; Issues**
- **NO_2 Effects with SCR; Issues**
- **Dual Function Catalyst; What is it and how can it be used**

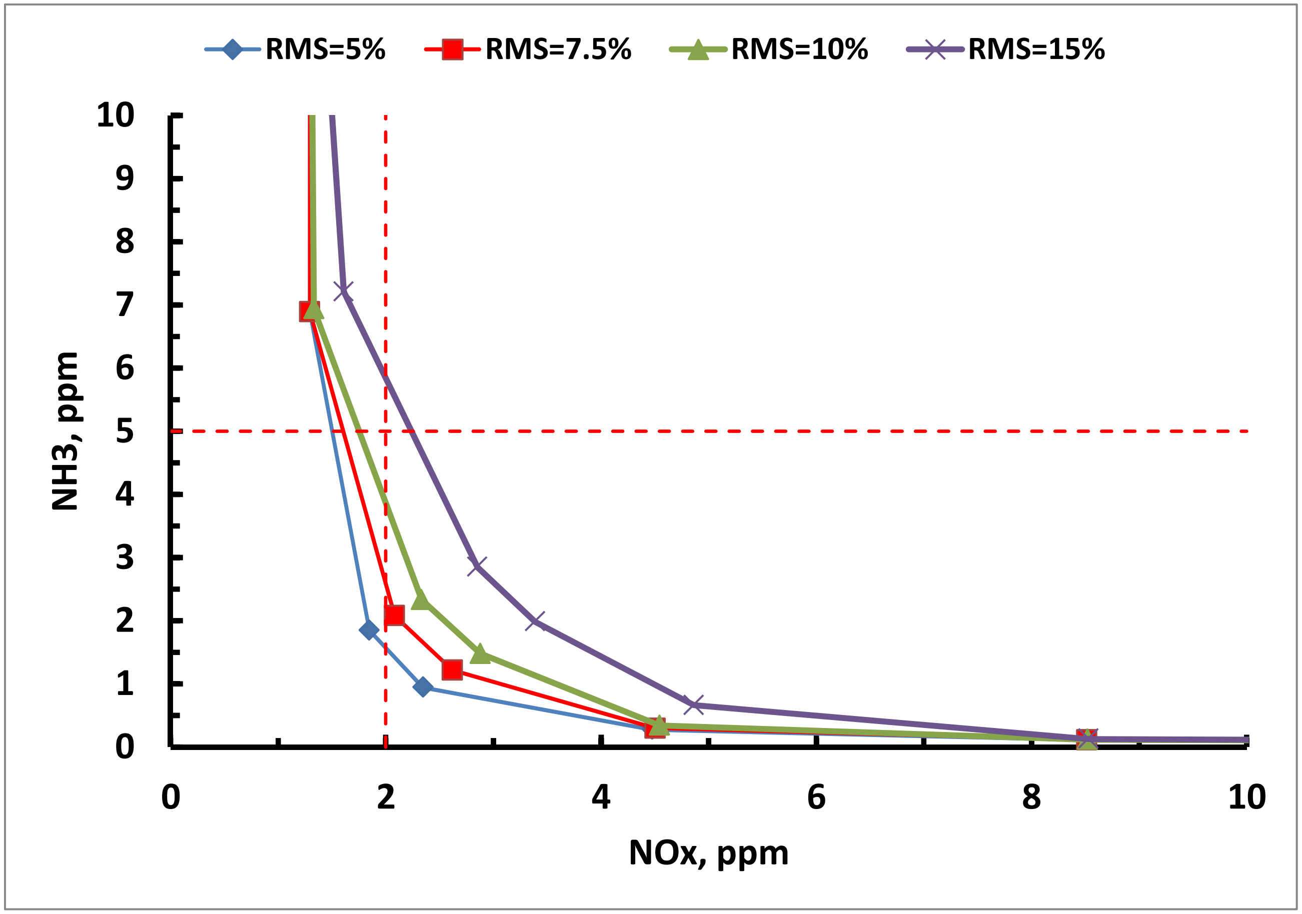
Combined Cycle Gas Turbine SCR



Was Enough Catalyst Installed?

Catalyst Sizing for Combined Cycles

Current Catalyst Volume (Catalyst Cost~0.2% of the units capital cost)



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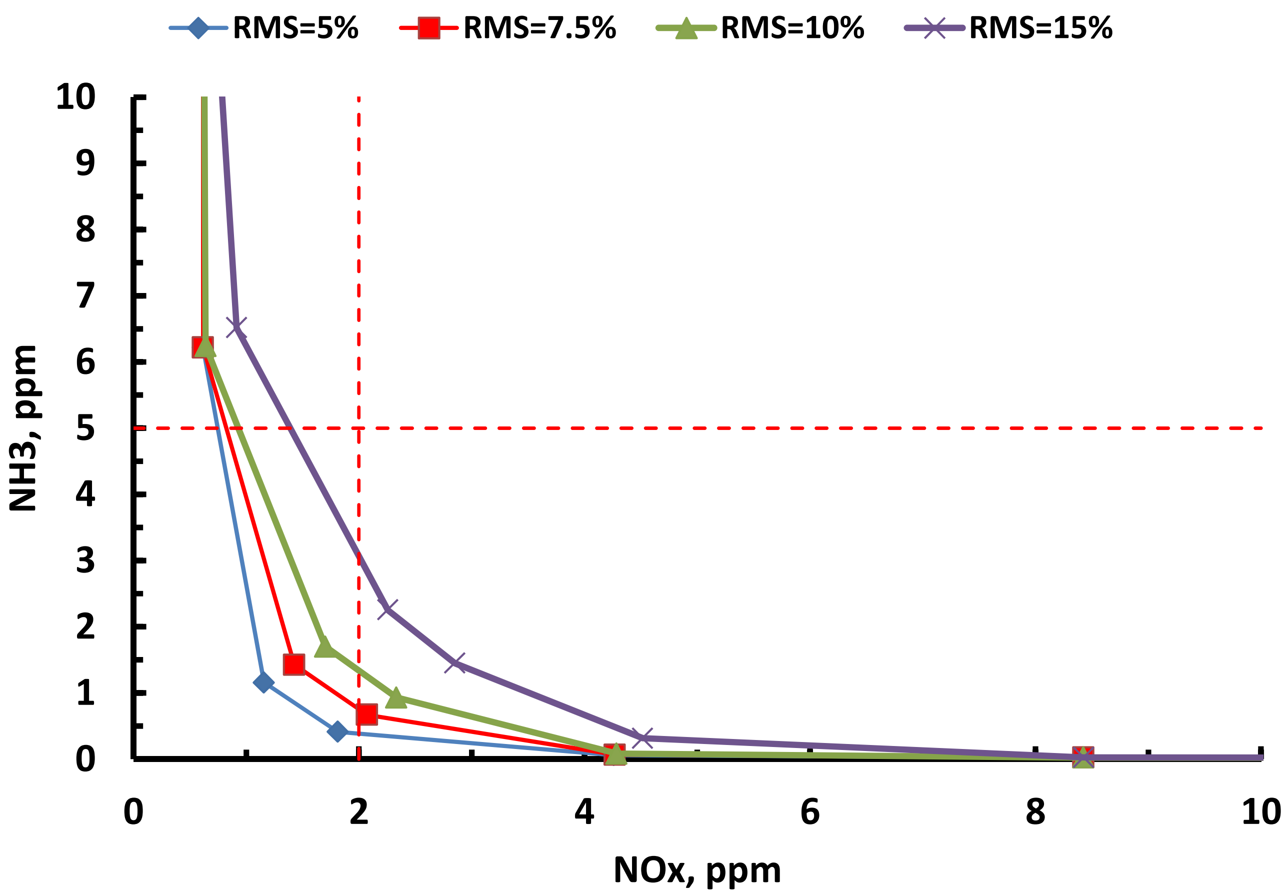
Catalyst Sizing for Combined Cycles

25% More Catalyst (adds ~0.05% of the project capital cost)

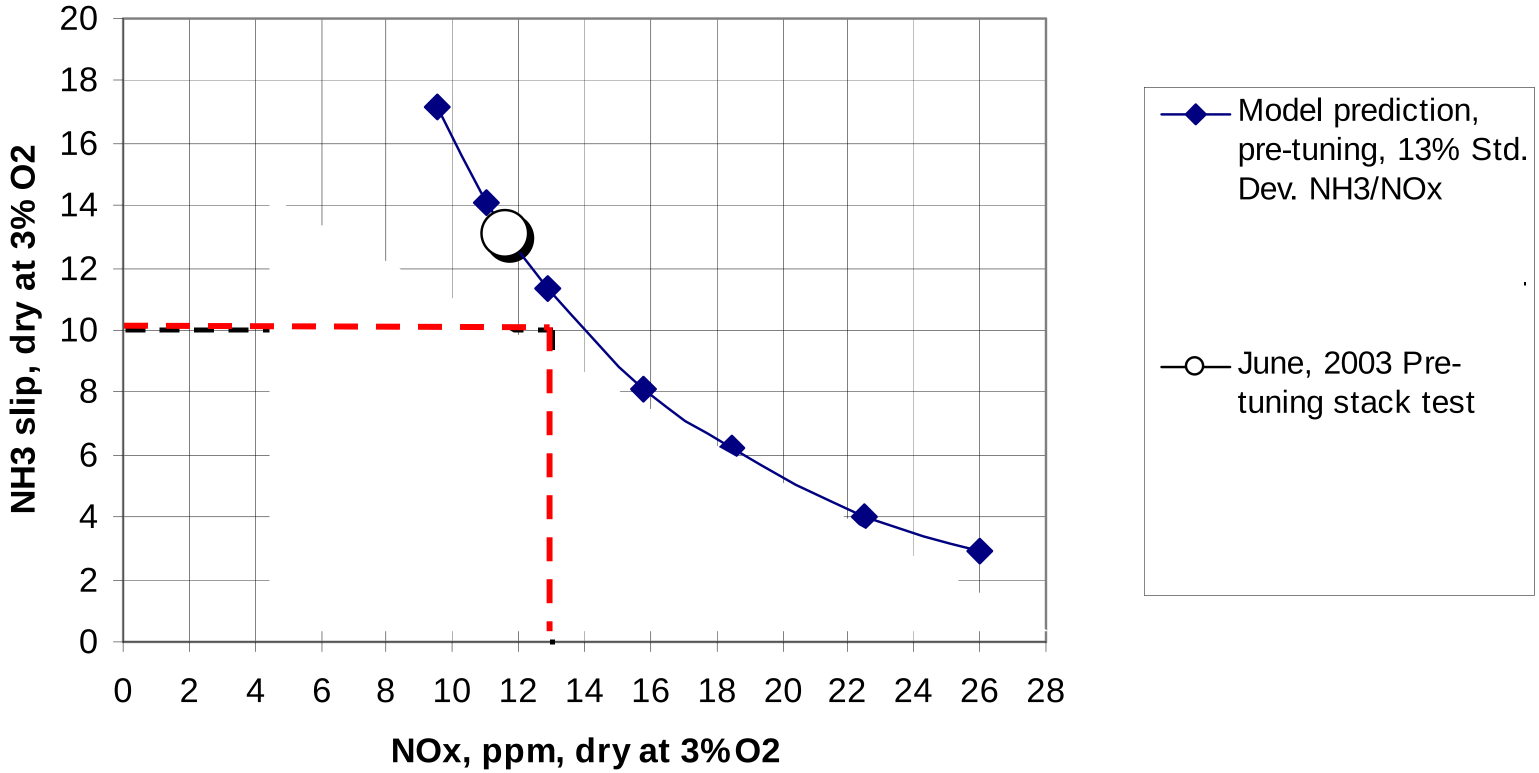


AIG Design & Tuning

- **Importance**
- **Issues**
- **Impacts of AIG Design**

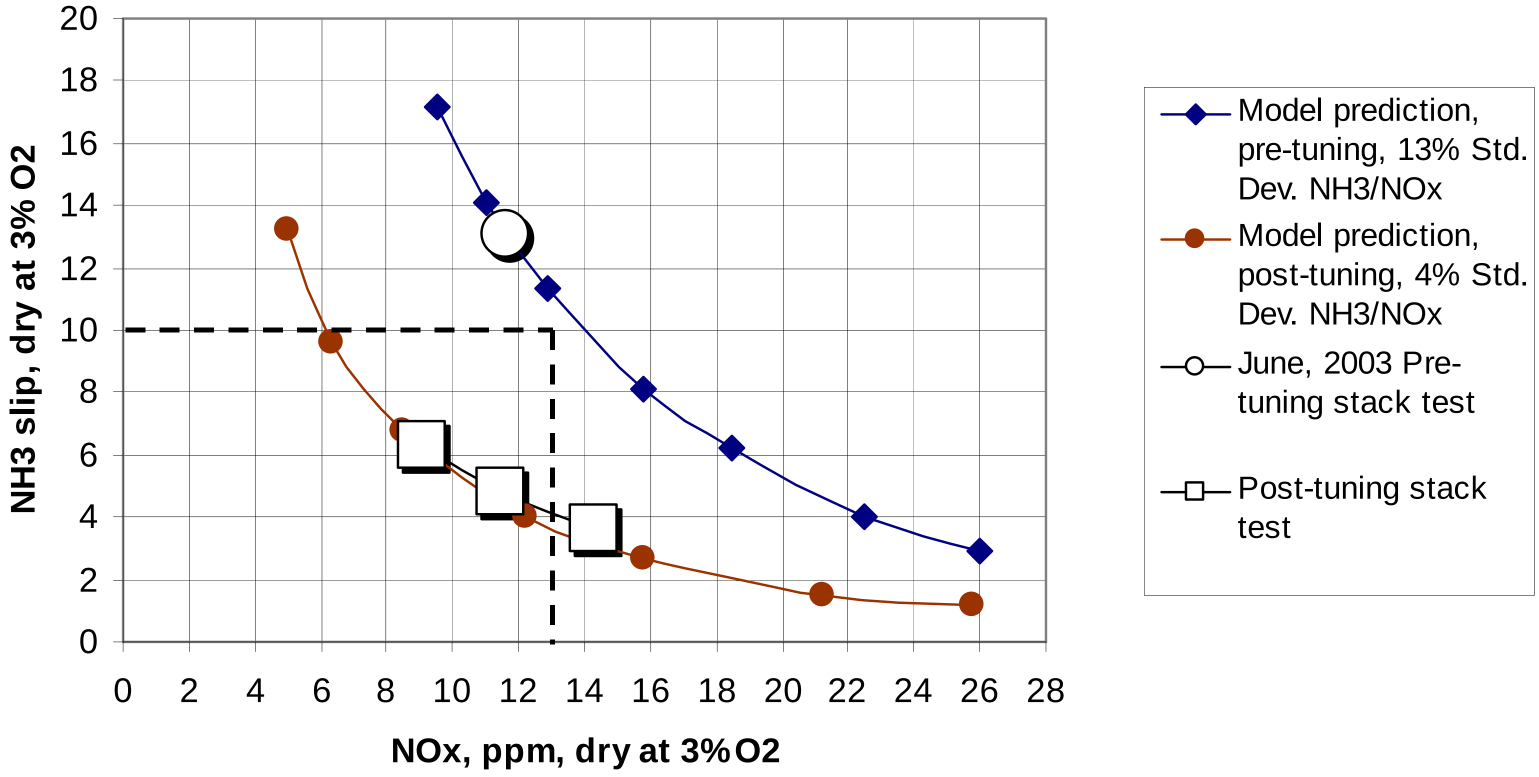
How Important is the NH_3/NO_x Distribution

AIG Tuning at South Bay 1: 141MW Boiler (2003)



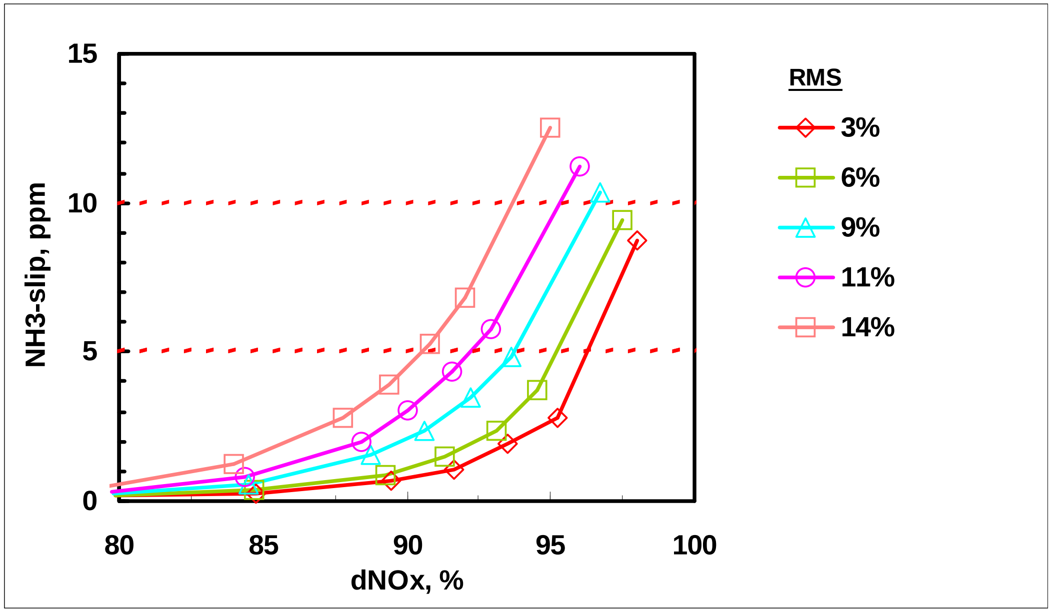
How Important is the NH_3/NO_x Distribution

AIG Tuning at South Bay 1: 141MW Boiler (2003)

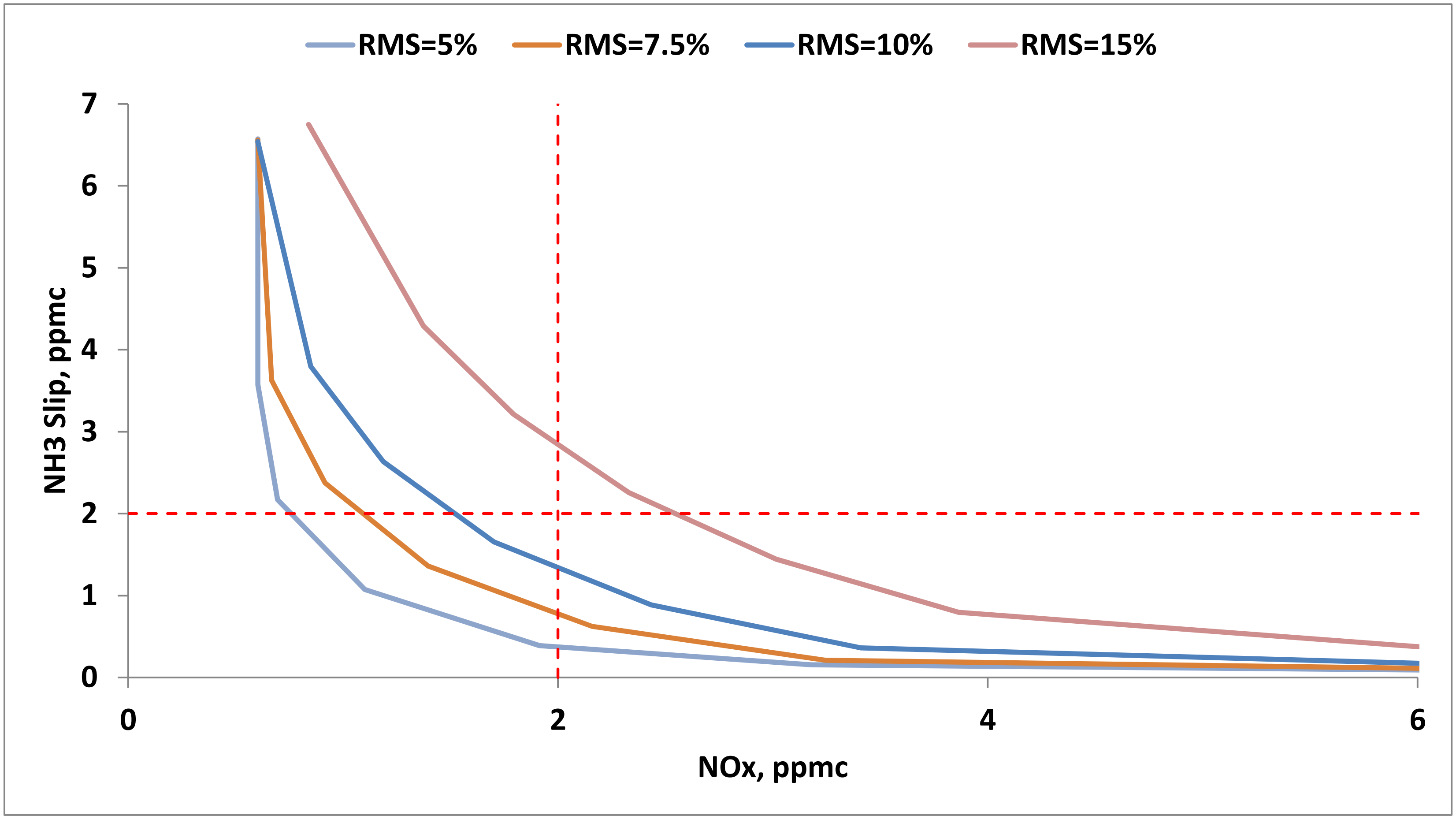


AIG Tuning: Why is it important?

- **Performance Improvement (can be as important as the catalyst quantity)**
- **Becoming More Important as Emission Limits Decrease**
- **Catalyst Guarantees are Usually based on a given NH_3/NO_x Uniformity (RMS); need to quantify the RMS**



What Happens if (or when!) NH_3 Slip Limits Reduced to 2ppm?



AIG Tuning: How is it Done

$$NH_{3_{in_i}} = (NO_{x_{in_i}} - NO_{x_{out_i}}) + NH_{3_{slip_i}}$$

Method 1:

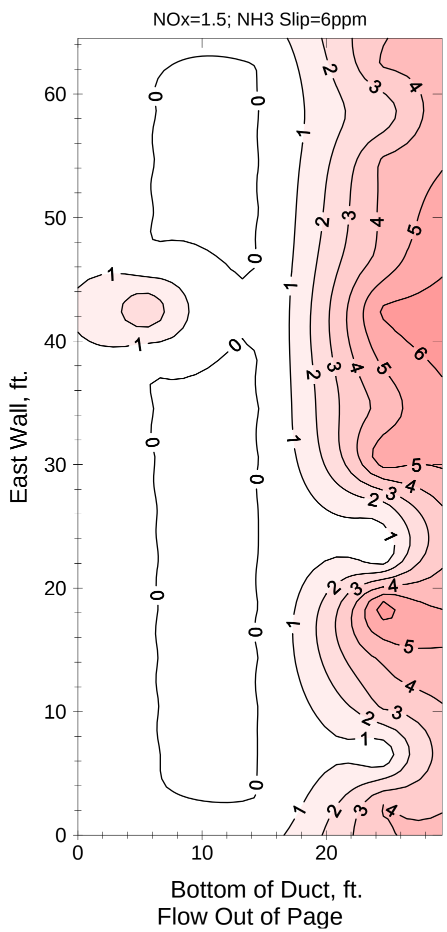
- **Tune at reduced NH_3 injection rate**
- **Local NH_3 slip = 0**
- **Just need to measure NO_x at the exit**

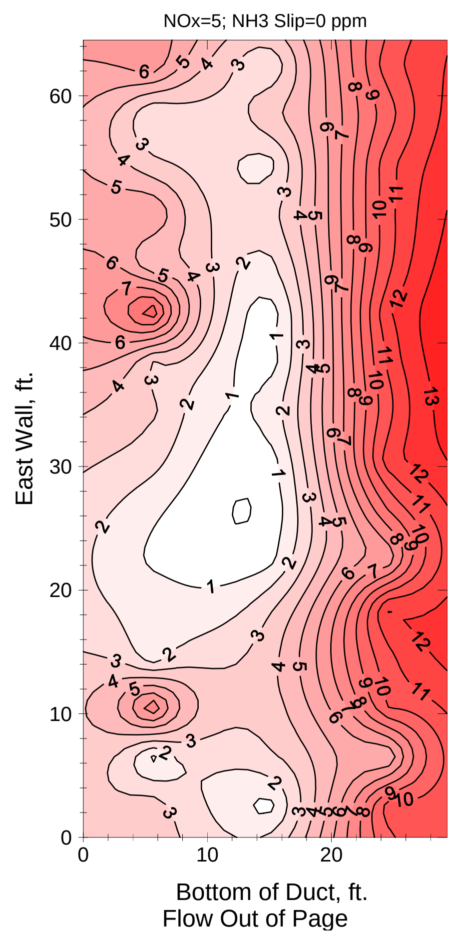
$$\left(\frac{NH_3}{NO_x}\right)_i = \frac{NO_{x_{in_i}} - NO_{x_{out_i}}}{NO_{x_{in_i}}}$$

- **For the NO_x-in turn off NH_3**
- **For GTs, NO_x-in is basically uniform so can measure one point upstream**
- **Are there issues with this approach?**
- **Yes**

Why Tune at Reduce NH3 Injection?

- **<u>Measure an Accurate RMS</u>**
- **<u>Get a Better Picture of the Distributions</u>**





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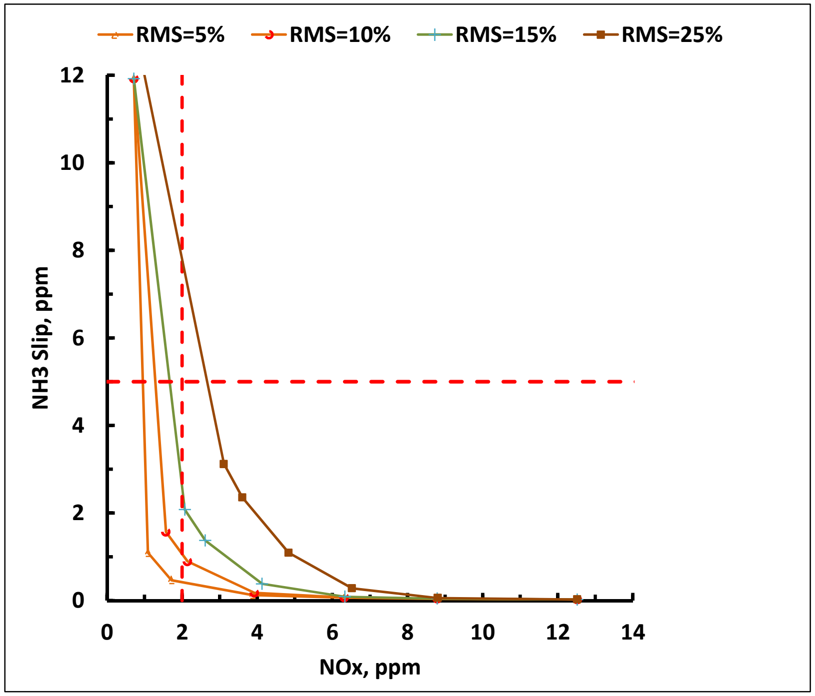
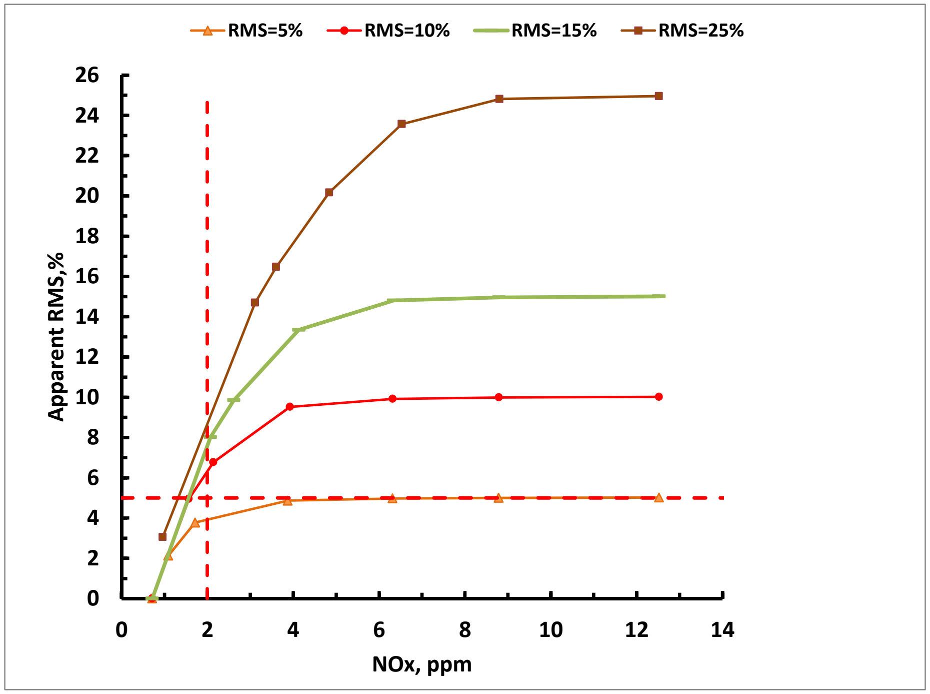
Tuning at Reduced NH_3 Injection Rate

- **For a Valid RMS Calculation, Local NH_3 Slip Needs to be Near Zero**
- **If NH_3 Slip is present, it is not accounted for in the RMS Calculation(i.e just calculating the RMS of the ΔNO_x)**
- **Thus, the RMS Value will be Artificially Low**

NH_3 slip vs NO_x



Apparent RMS vs NO_x



AIG Tuning: How is it Done

$$NH_{3_{in_i}} = NO_{x_{in_i}} - NO_{x_{out_i}} + NH_{3_{slip_i}}$$

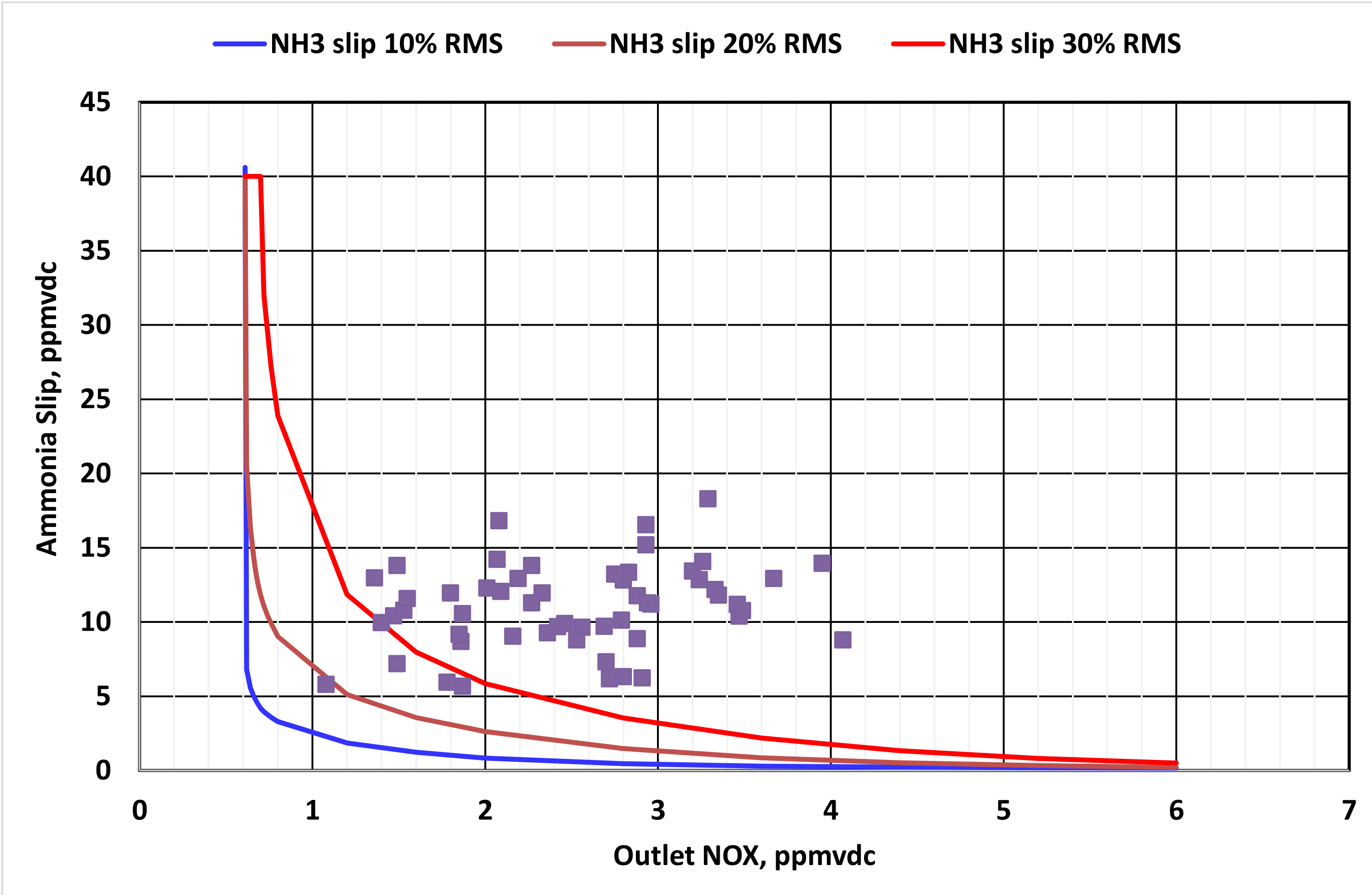
Method 2:

Use FTIR

- **Measure NO_x-in, NO_x-out, NH_3-in, NH_3-out**
- **$NH_{3(i)}/NO_{x(i)} = NH_{3\text{-}in(i)}/NO_{x\text{-}in(i)}$**

  Or
- **$NH_{3i}/NO_{x(i)} = (NO_{x\text{-}in(i)} - NO_{x\text{-}out(i)} + NH_{3\text{-}out(i)})/NO_{x\text{-}in(i)}$**
- **Are there issues with this approach?**
- **YES**

FTIR Measurements: Site 1



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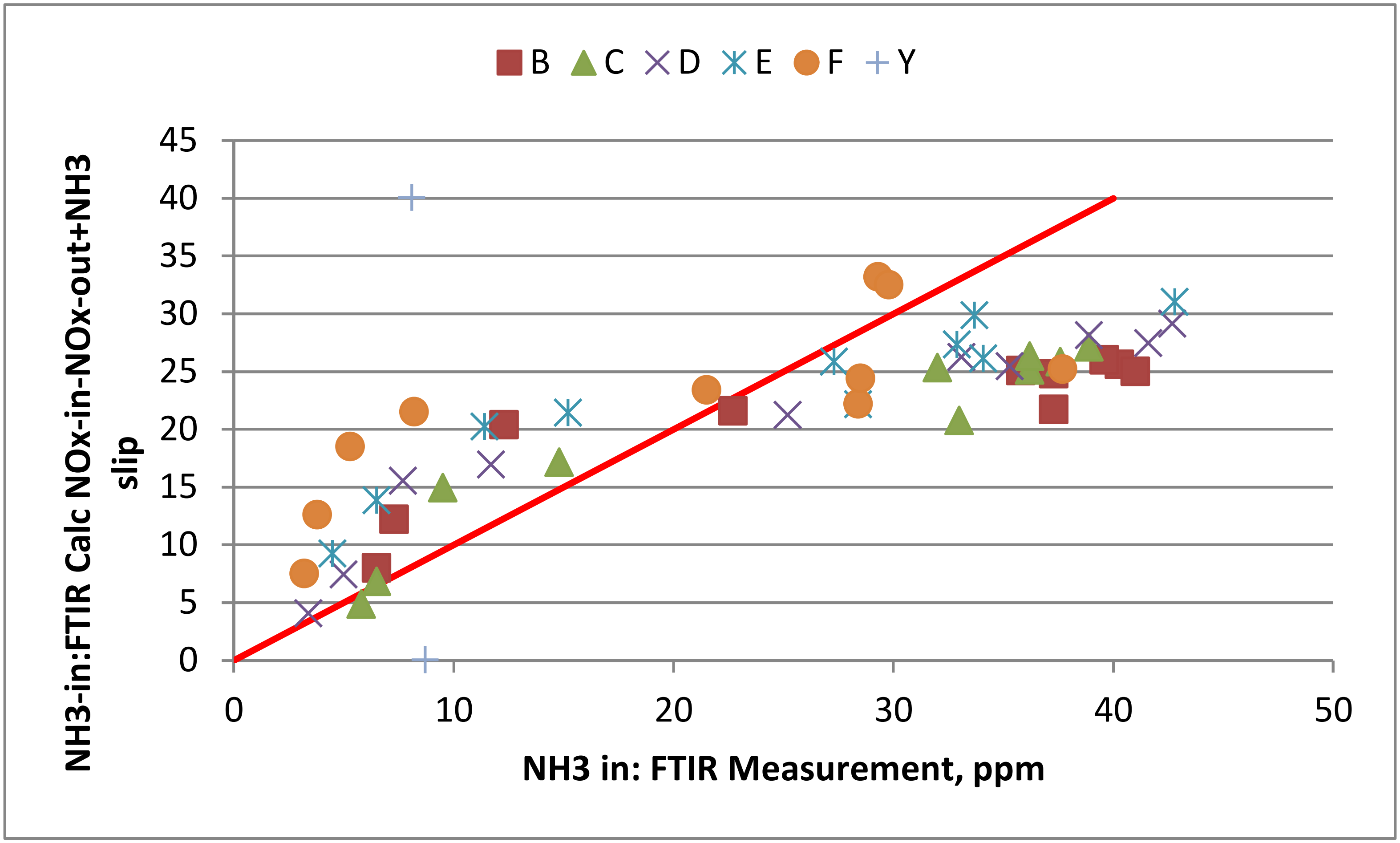
FTIR Measurements: Site 2



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SCR AIG Tuning

- **Tuning is Facilitated by Installing a Permanent Sample Grid at the Catalyst Exit *(Particularly for large GT-Combined Cycles)***
  - **Not feasible to manually traverse a large combined cycle system for AIG tuning**
  - **Typically need 36 to 60 probes depending on AIG design**

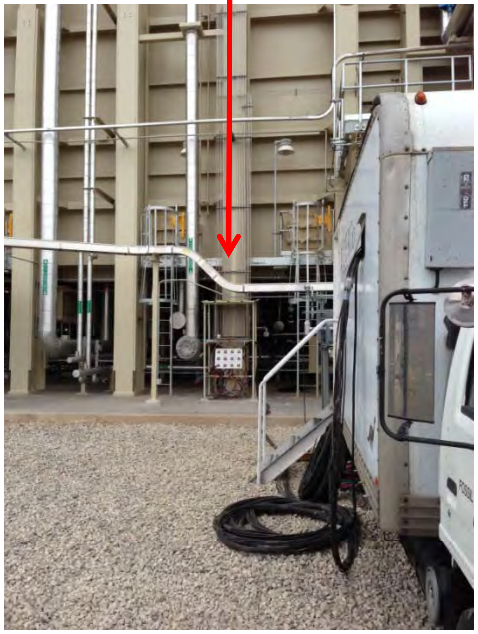
- **With Permanent Probes, Tuning can Typically be Completed in <u>One Day</u>**

- **The NO_x Profiles at the Exit of the Catalyst can also help Identify Bypass**

Outside View of a Permanent Sample Grid on a Large Combined Cycle

Sample probe exit ports

Sample probe lines brought down to grade



Permanent Sample Probes Should Be Installed

FERCo's Multipoint Instrumentation

- **Samples 48 points in 12 to 15 minutes (4 groups of 12)**
- **NO_x and O_2**

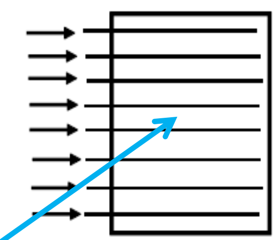
Recent AIG Tuning at Redding Electric

- **Multi-Point Sampling and Analysis**
  - **40-point sampling grid**

AIG Design Affects Tuning

- **No Adjustments:** **Some systems have no adjustment valves-**
  Bad Idea ! ! ! ***Best RMS ~17%***

- **1-D: Commonly used design**



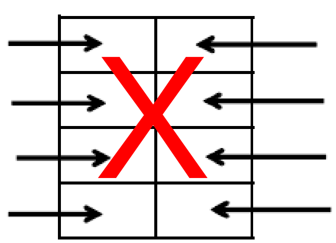
Struggle to get RMS ~10%

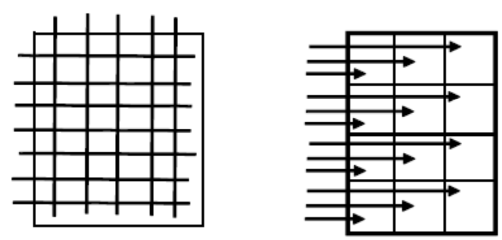
RMS ~5%

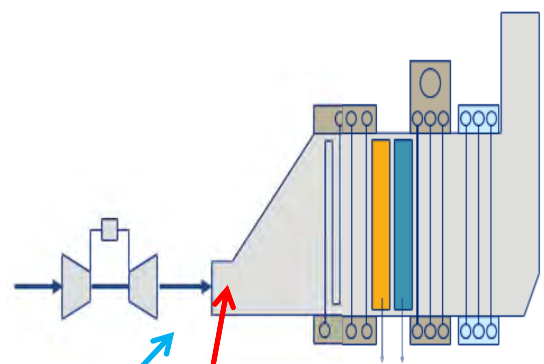
Better

Multi Zone:

Not Much Better Than







Reagent

RMS ~3-7%

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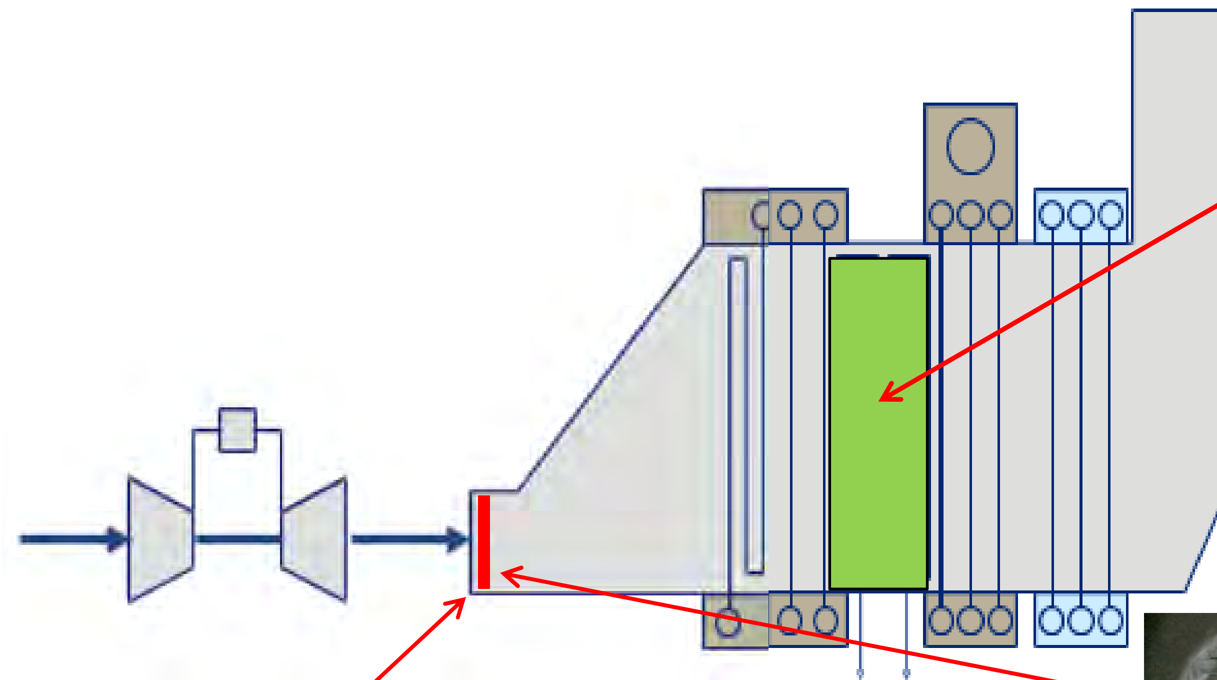
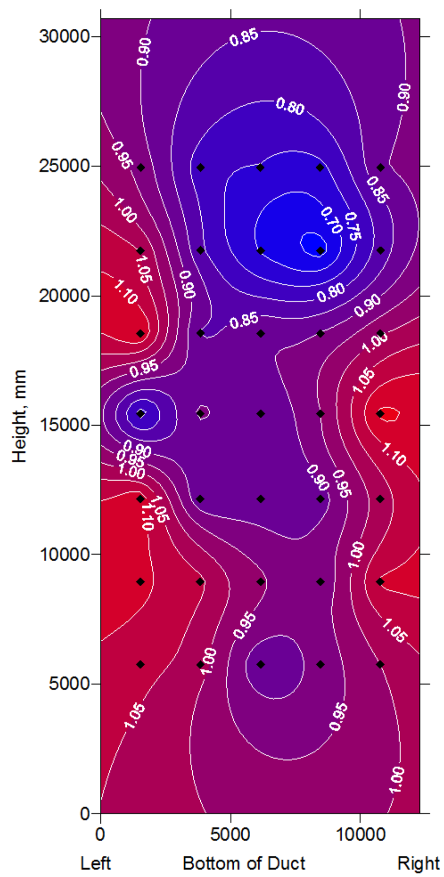
Direct Injection/Dual Function Catalyst

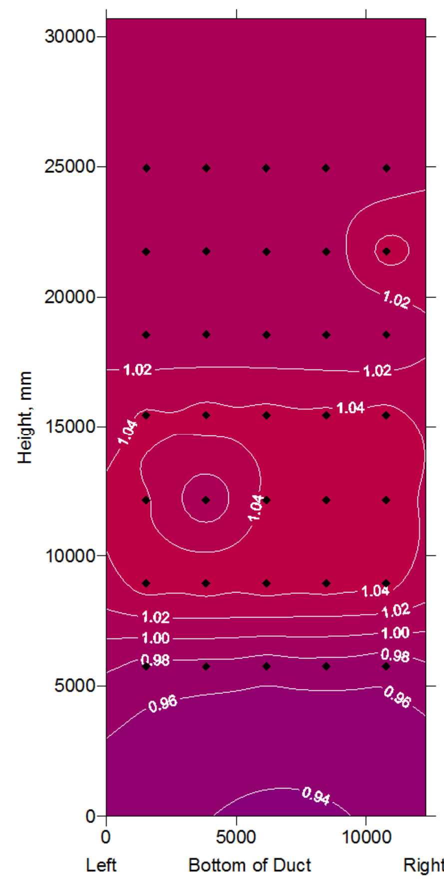


Direct Injection of Aqueous Ammonia @ Turbine Exhaust

As Found, RMS = 14%



Tuned, RMS = 3%



NO_2 Effects on SCR

How is NO_2 Formed

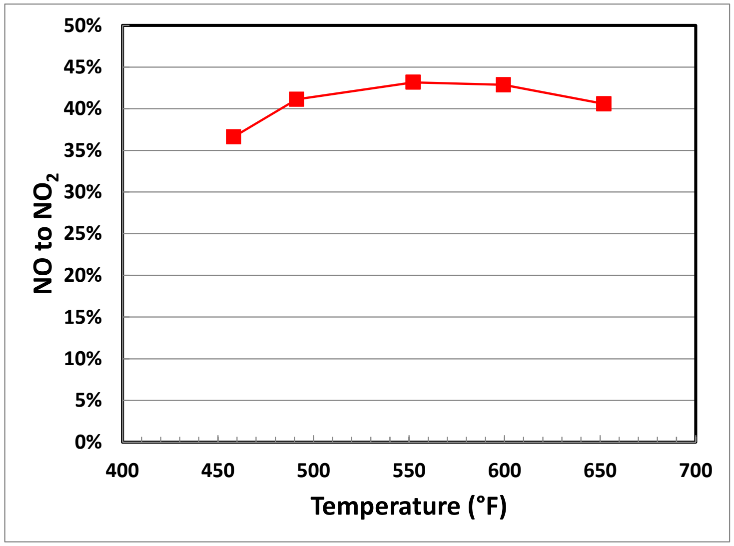
a. Gas Turbine Combustion Process

$NO + ½ O_2 = NO_2$ (X)

Oxidation of Hydrocarbons at low temperatures, produces HO_2

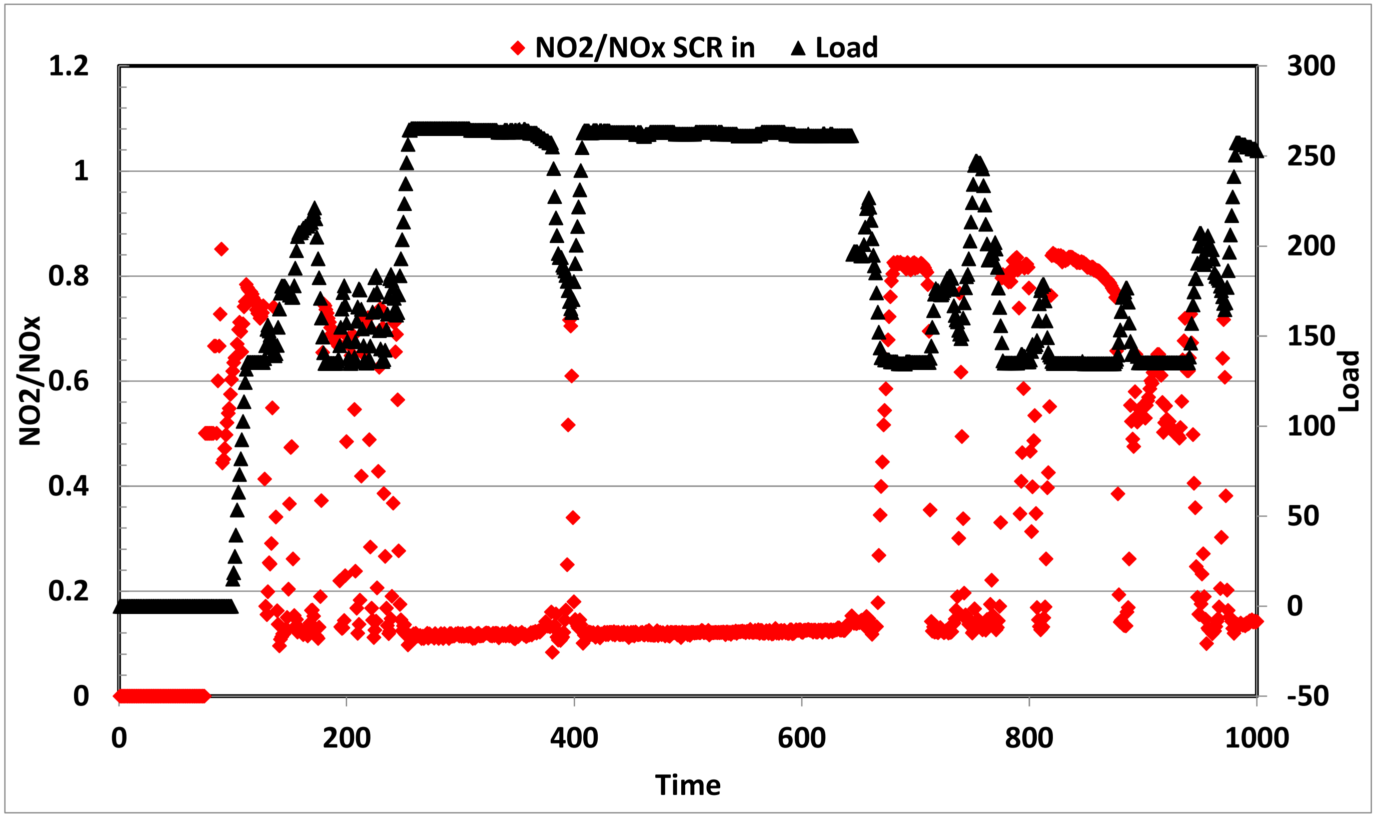
$NO + HO_2 = NO_2 + OH$

b. Oxidation of NO Across the CO Catalyst

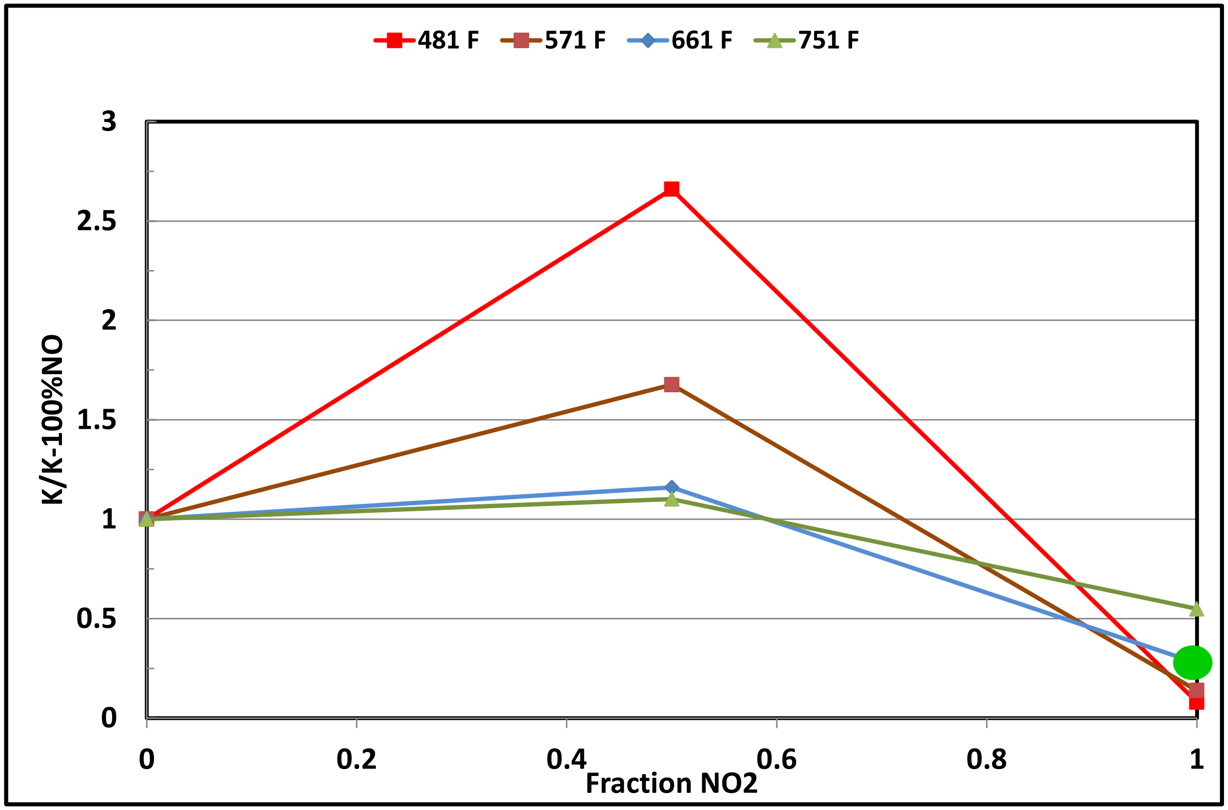


NO_2 Effects on SCR

Typical NO_2 Characteristics From A Gas Turbine



NO_2 Effects on SCR*



Impacts of NO_2

- **Up to 50% NO_2 increases Activity, particularly at lower temperature**
- **At NO_2>50% Activity decreases**
- **At NO_2> 80% Activity can be much lower than NO alone**
- ***This can increase the catalyst volume requirement if compliance is required at low loads***
- ***Response time at low loads (temperature) will also increase***

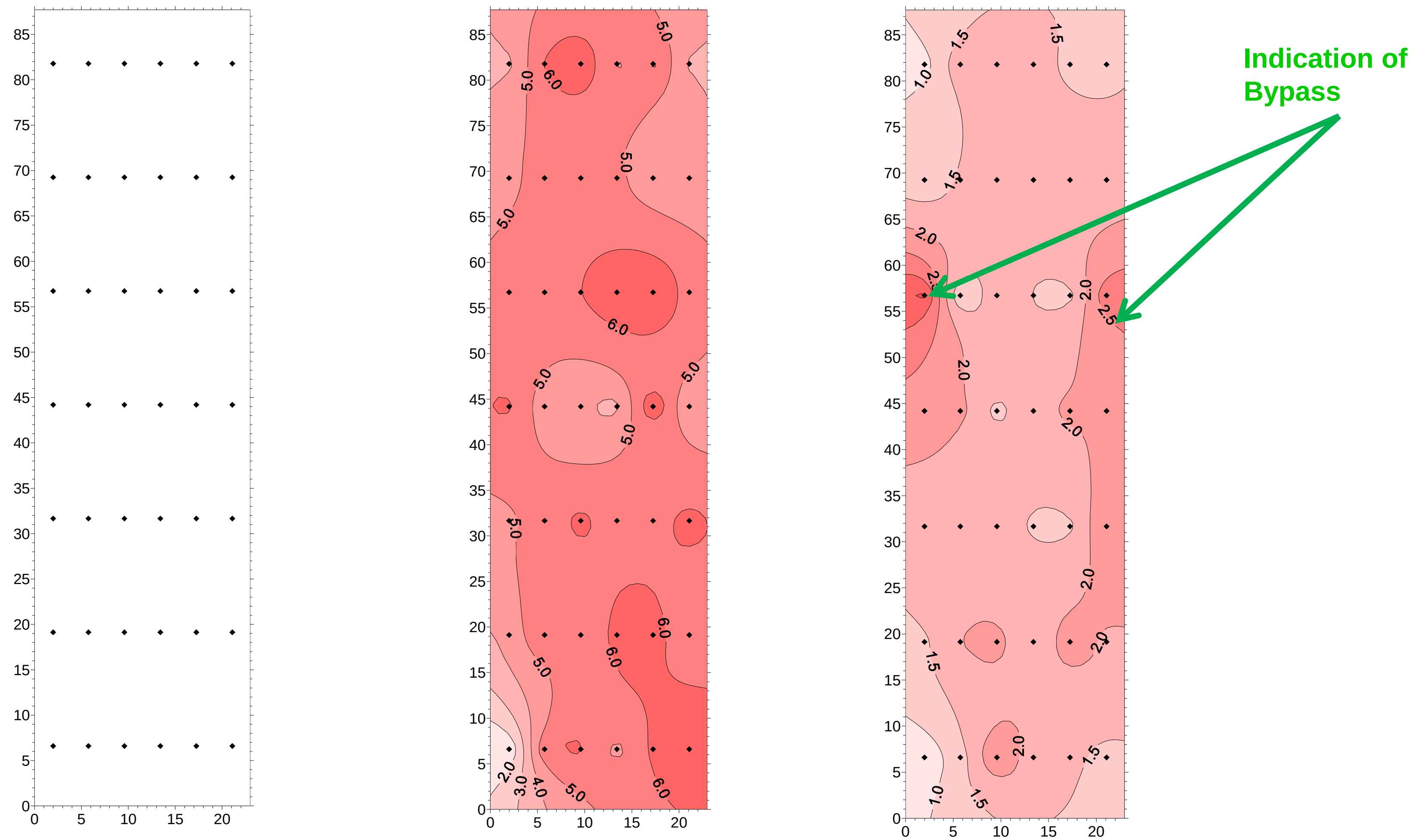
** Guseppe,M et. Al. Side Reactions in the Selective Catalytic Reduction of NO_x with Various NO_2 fractions, Ind. Eng. Chem. Res. 2002,41,4008-4015*

Flue Gas Bypass

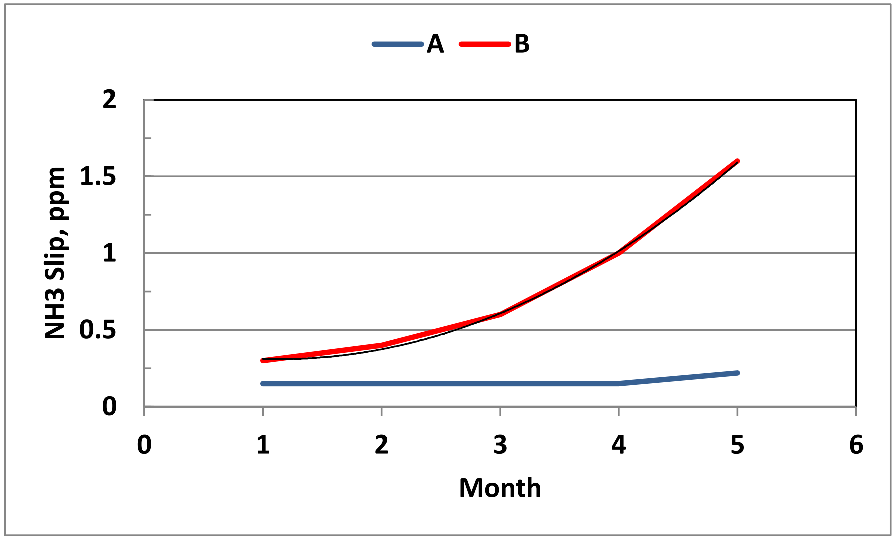
- **With Lower NO_x and NH_3 Limits Bypass Becomes an Important Issue**
- **Can be Detected with Probes at the SCR Catalyst Exit, Difficult to Quantify**
- **A Stack Test Series can Help Quantify the Amount of Bypass**

Example A

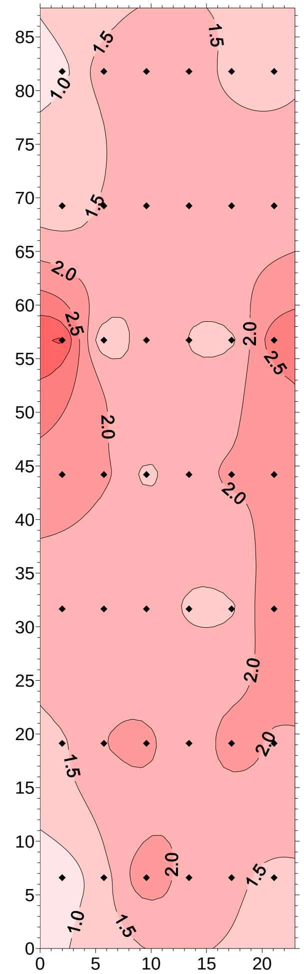
Early 2018 **Unit A** **Unit B**



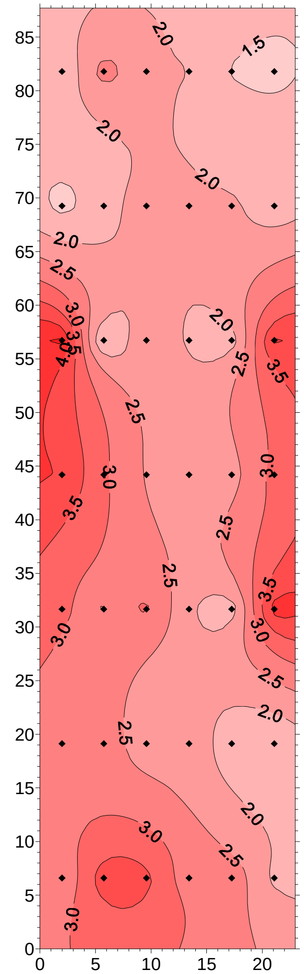
Example A



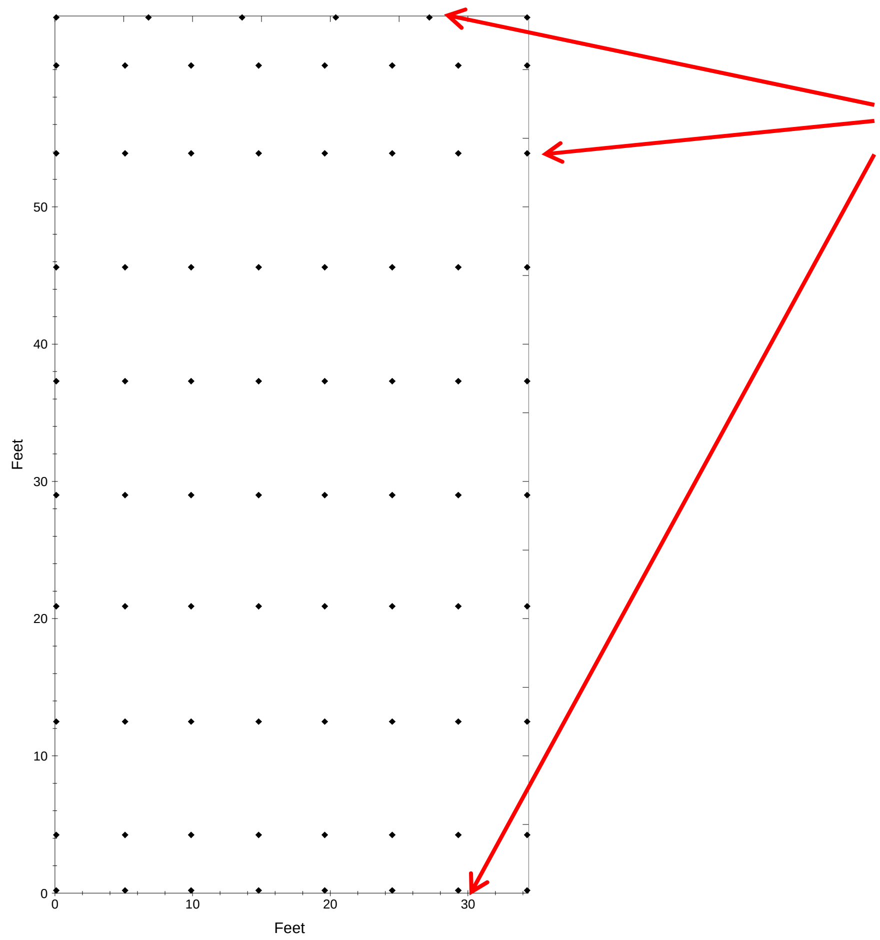
Early 2018 Unit B



Late 2018 Unit B



Example B

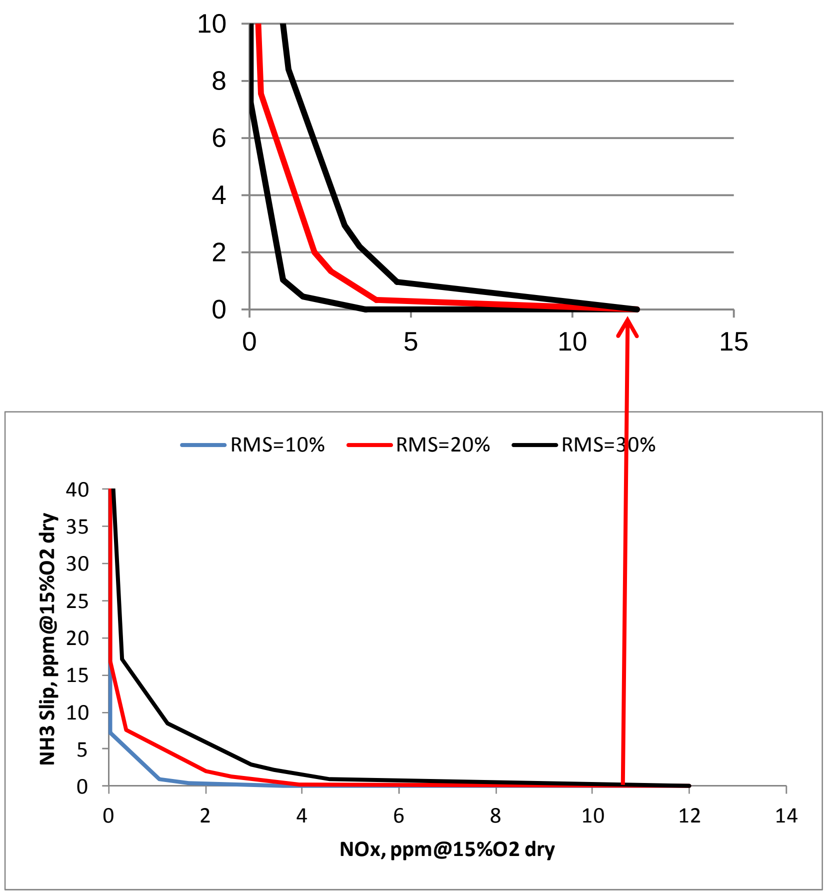


- **Probes Can be Located Near the Walls to Detect Bypass as well as Across the Catalyst for Tuning**
- **Wall, Roof, Floor Probes not used for Tuning**

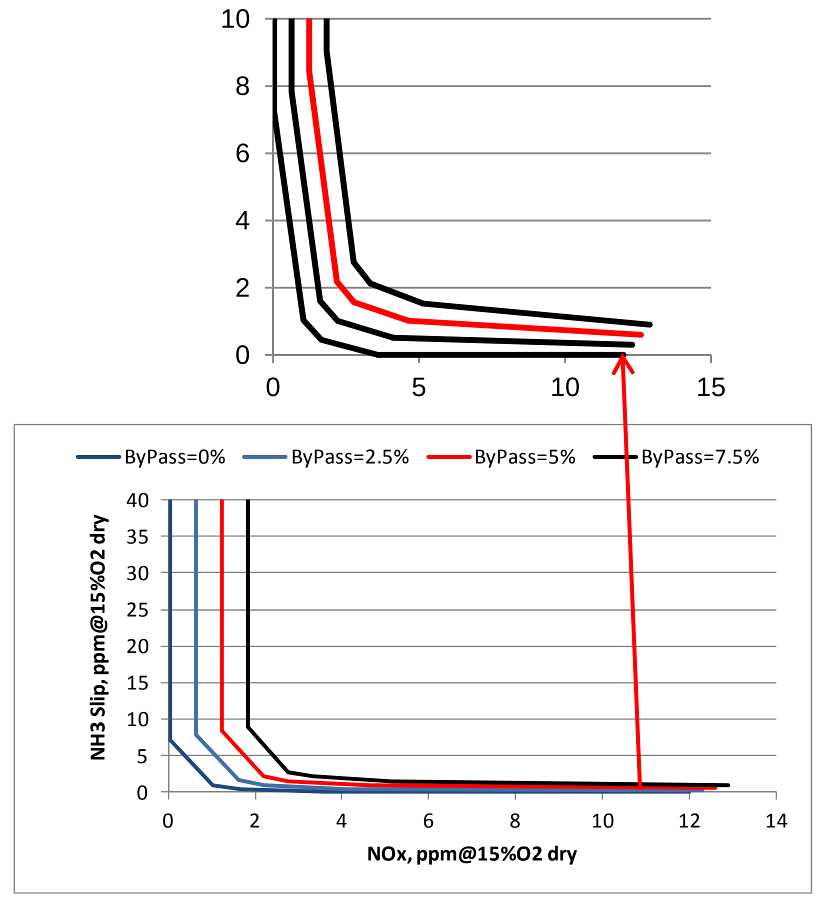
A Simple Stack Test Can Distinguish:

NH_3 Maldistribution vs Flue Gas Bypass

NH_3/NO_x RMS Effects



Bypass Effects



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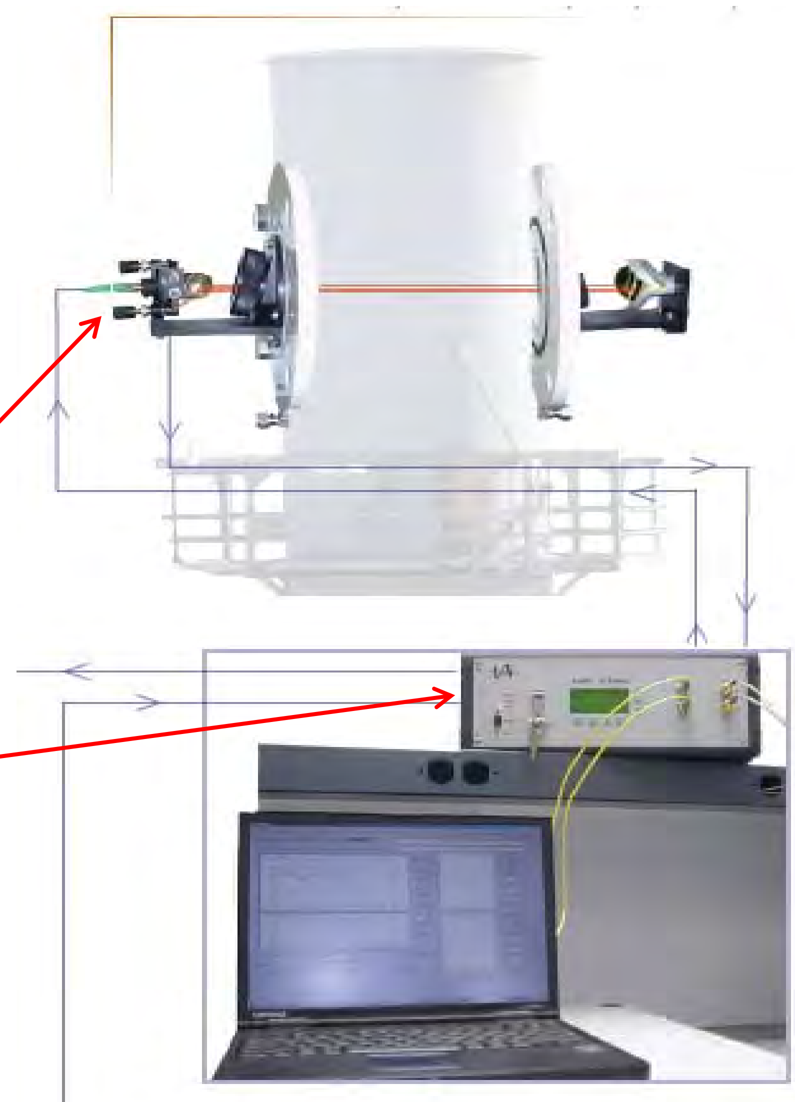
TDL Instrumentation

- **Testing Facilitated Using a Continuous TDL NH_3 Analyzer**
- **Data Set Can be Generated in Less than a Day**
- **Data Available in Real Time**



- **Unisearch NH_3 TDL**
  - **Dual Path**
  - **Two Channel**
  - **Fiber Optic Coupled**

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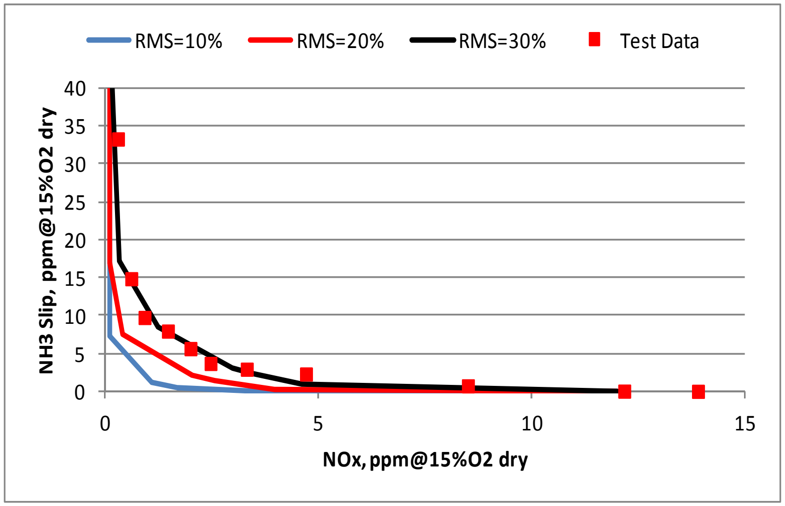
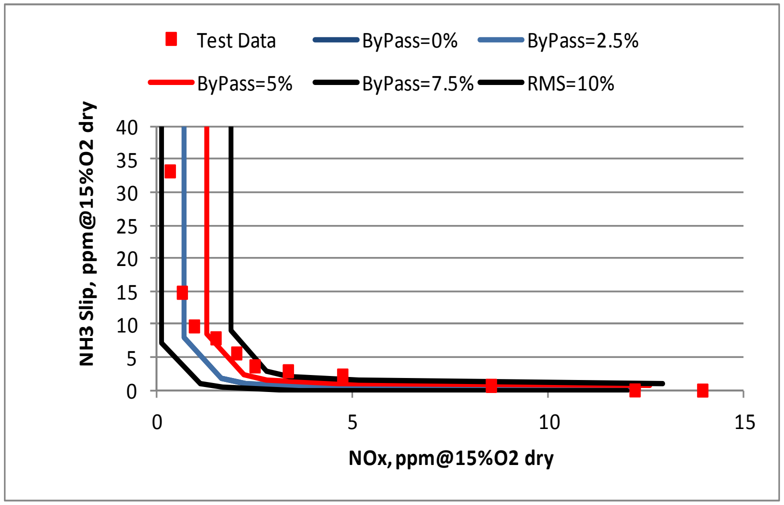
TDL NH_3 Measurements on a Large Combined Cycle

NH_3/NO_x RMS Effects



Bypass Effects

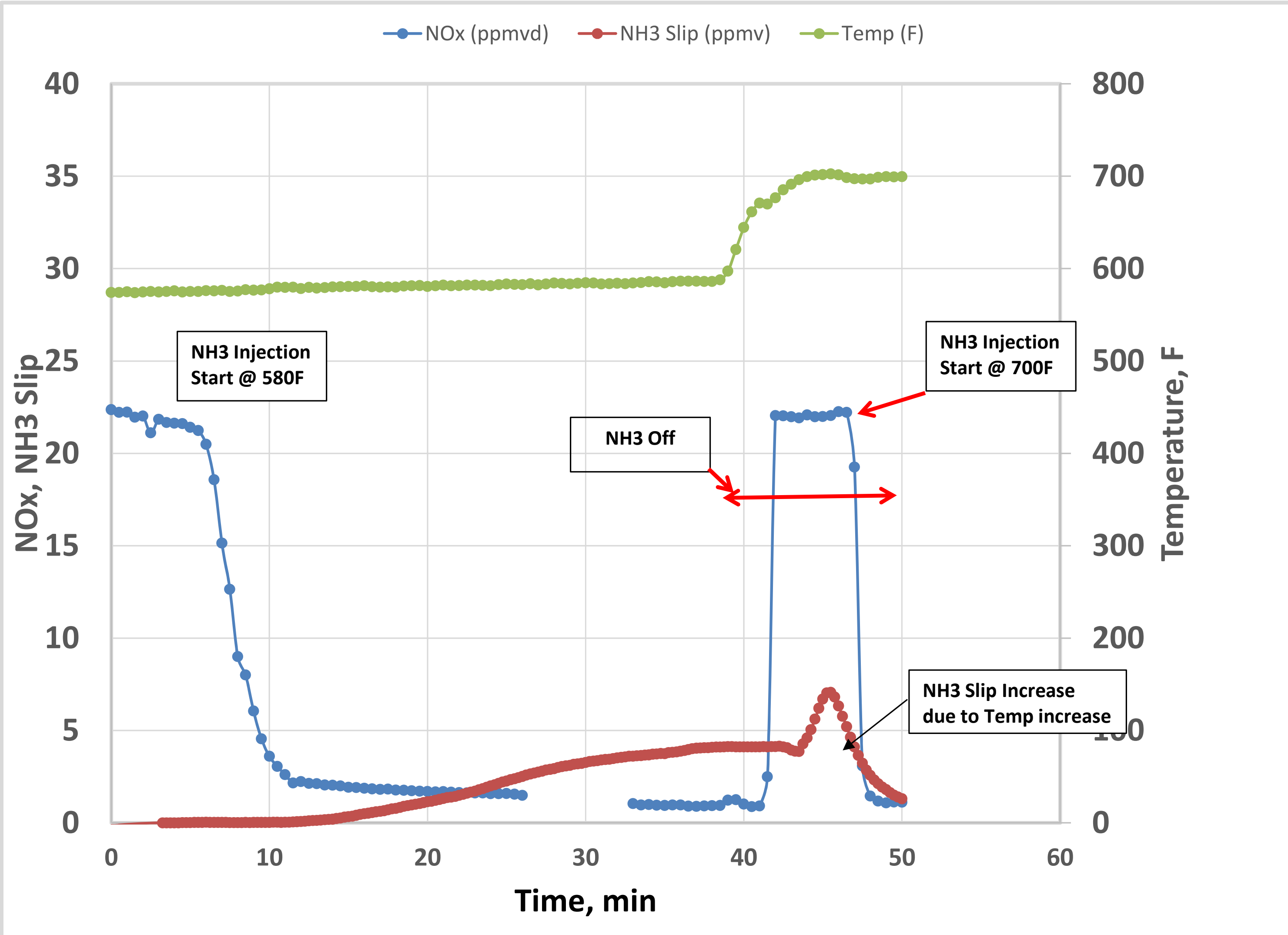


SCR Operating Temperatures

- **Seeing More and More Combined Cycle SCR/CO Catalyst Systems Operating in a Temperature Range of 570-630°F**

  Affects catalyst response time (control issues)

SCR Catalyst Response Times



What is Dual Function Catalyst?

- **New Catalyst Introduced by Catalyst Suppliers**
  - **Reduces both NO_x and CO in one catalyst bed**
  - **Basically SCR catalyst that incorporates precious metals**
  - **Suppliers:**
    - **Umicore**
    - **Cormetech**
    - **Johnson-Matthey(?)**

- **Typical Performance**

Inlet				Performance	
T F	NOx ppm	CO ppm	NH3/NOx	dNOx %	dCO %
700	70	0	1	96	-
700	70	500	1	93	99.4

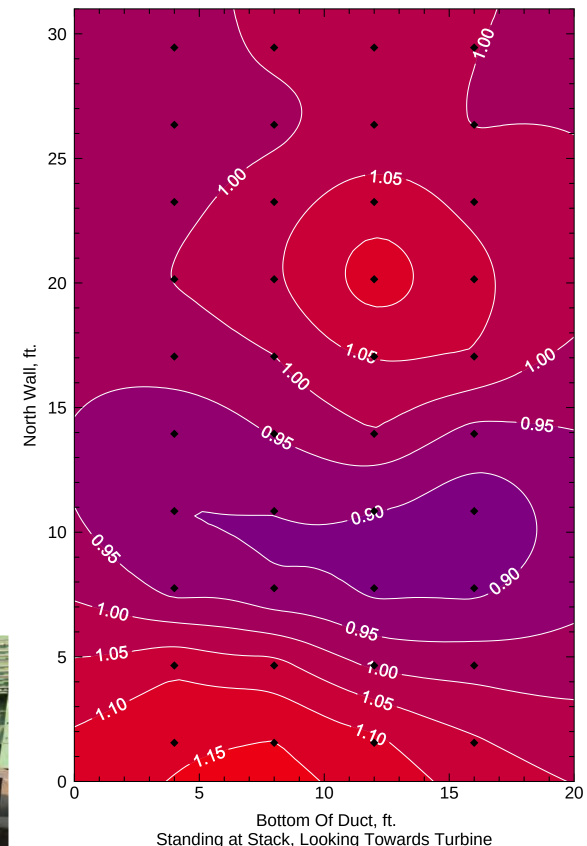
Recent Retrofit: REU (2- 45 MW GT Combined Cycles: 2 ppm NO_x/5 ppm NH_3 Slip)

Install 40 pt Probe Grid

Remove EMX Media, Replace w/Dual Function

Direct Urea Sol. Injection (6 atomizers)

NH_3/NO_x Dist (RMS = 7.2% (44MW))



Retrofit by: REU/Combustion Components Assoc/Umicore

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Redding Electric Utility

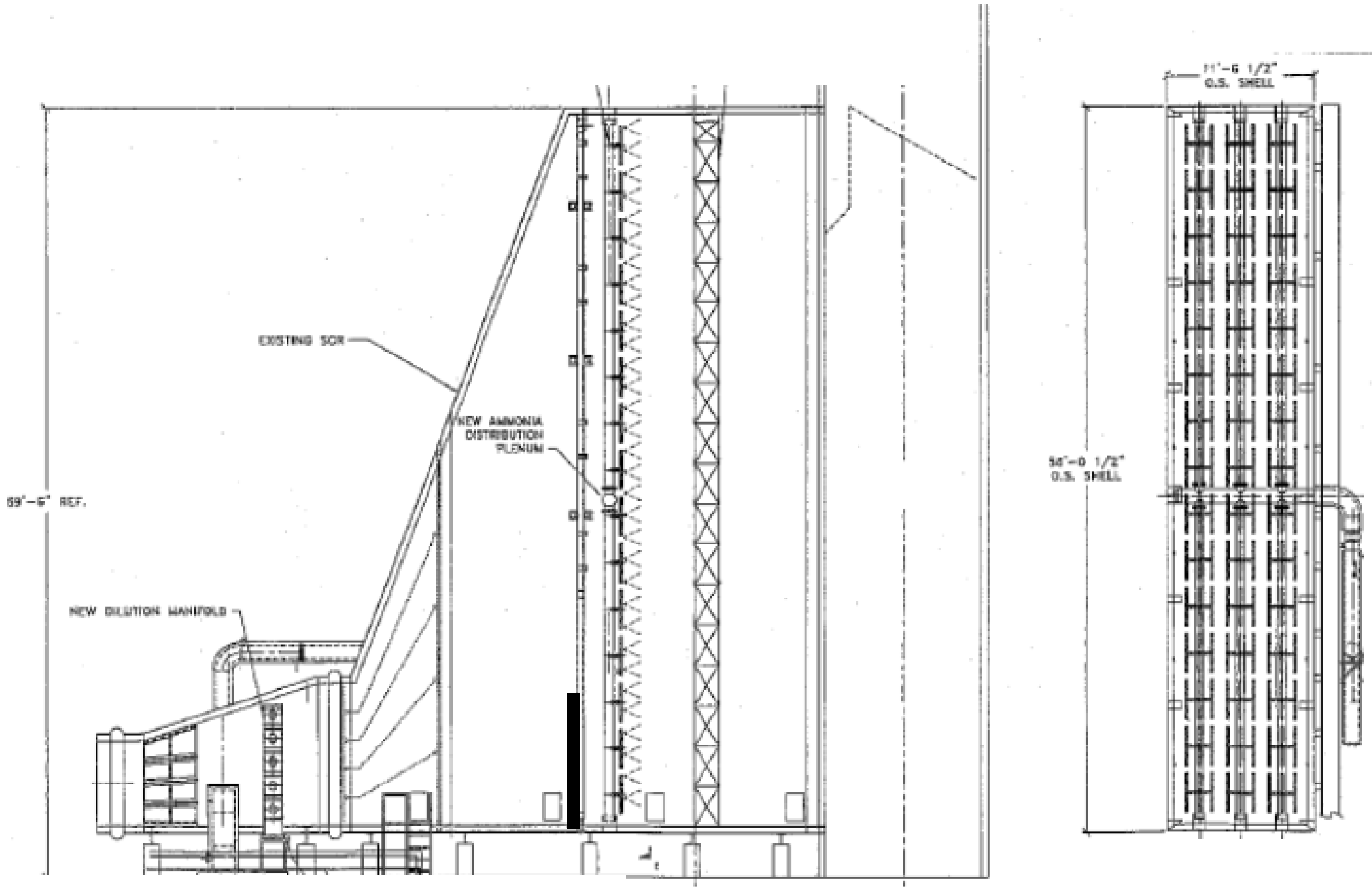
SCAQMD:Proposed Rule 1135

- **SCAQMD is phasing out Reclaim**
- **New approach is command and control**

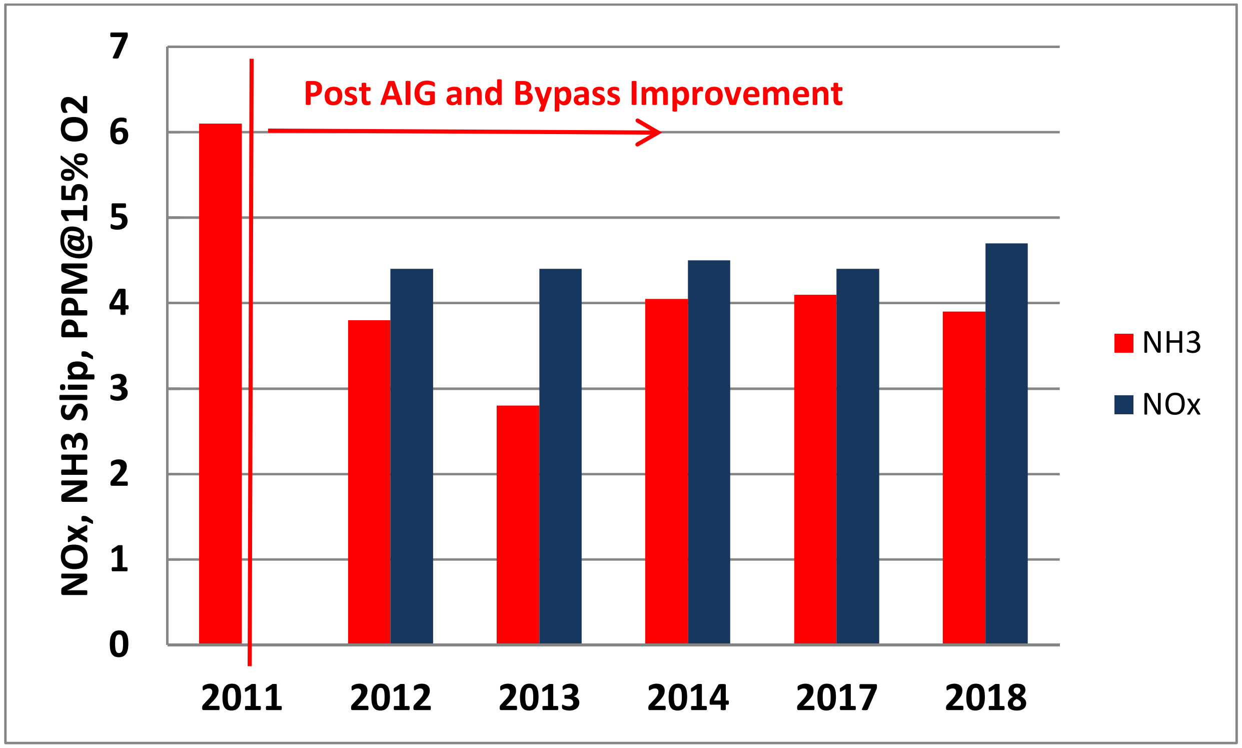
SCAQMD:Proposed Rule 1135

Equipment Type	NO_x (ppmv)	Ammonia (ppmv)	Oxygen Correction (%, dry)
Boiler	5.0	5.0	3
Combined Cycle Gas Turbine and Associated Duct Burner	2.0	5.0	15
Simple Cycle Gas Turbine	2.5	5.0	15

So. Cal. LM6000

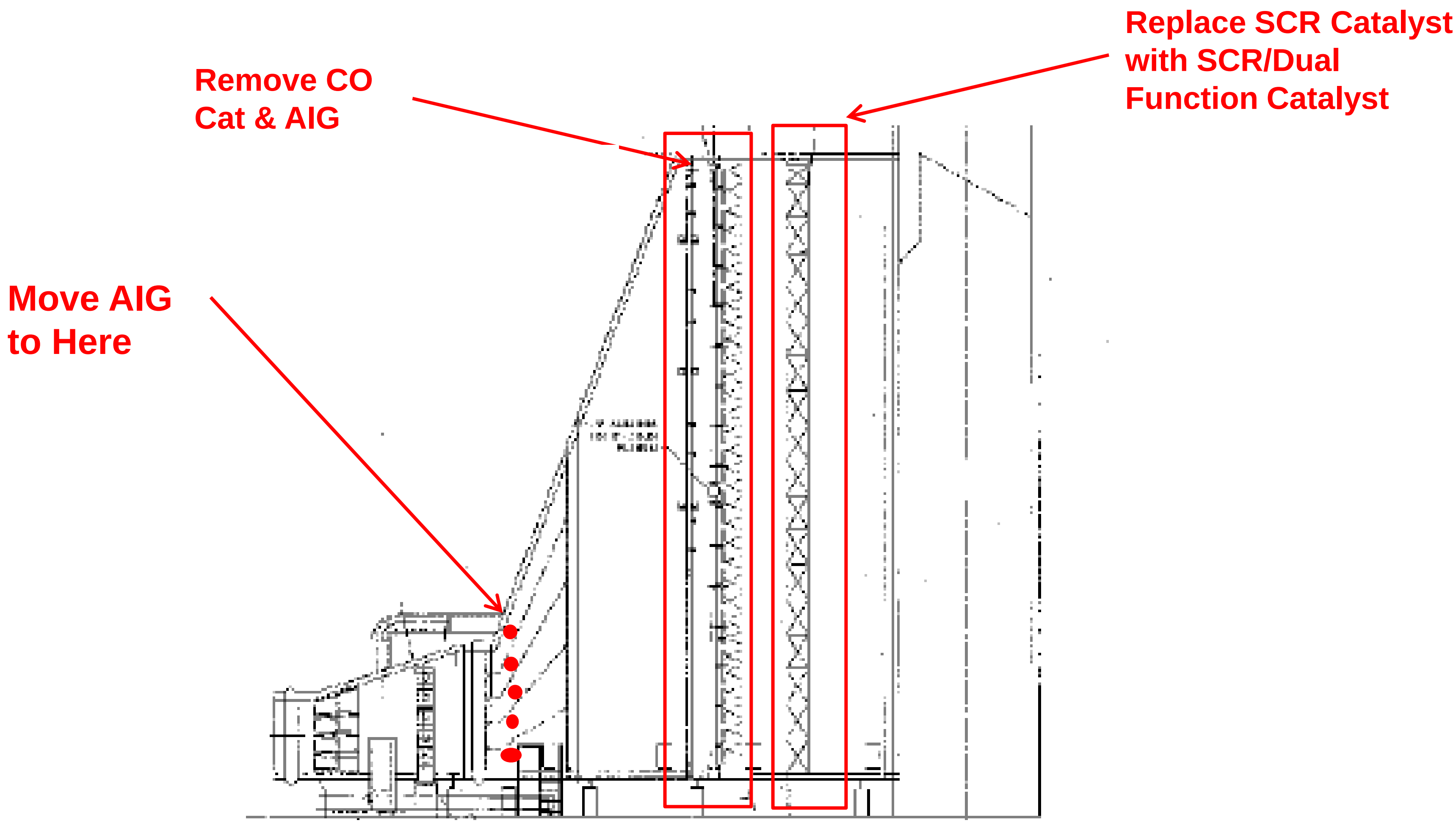


So Cal LM6000



- **Minor Improvements will Not Allow 2.5 ppm NO_x/5 ppm NH_3 Slip**

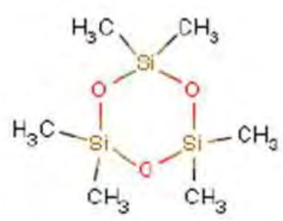
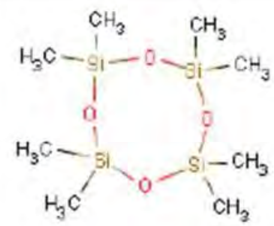
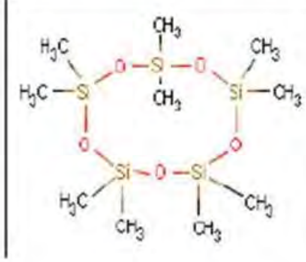
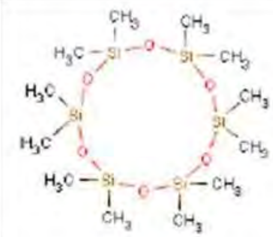
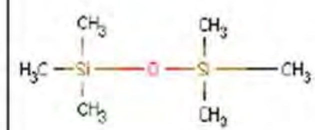
So Cal LM6000 (Recommended Modifications)



Irvine Landfill (7-3MW Caterpillar Reciprocating Engines)

Irvine Landfill (7-3MW Caterpillar Reciprocating Engines)

Siloxanes

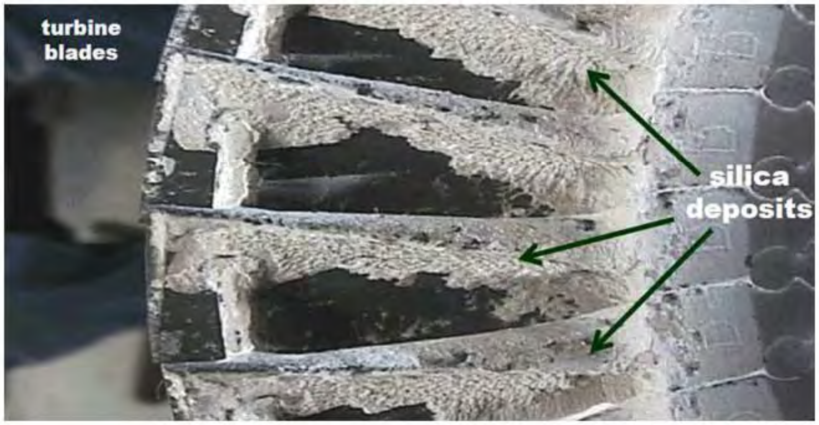
Name	Hexamethylcyclo-trisiloxane (D3)	Octamethylcyclo-tetrasiloxane (D4)	Decamethylcyclo-pentasiloxane (D5)	Dodecamethylcyclo-hexasiloxane (D6)	Hexamethyldisiloxane (HMDS)
Molecular formula	C_6-H_{18}-O_3-Si_3	C_8-H_{24}-O_4-Si_4	C_{10}-H_{30}-O_5-Si_5	C_{12}-H_{36}-O_6-Si_6	C_6-H_{18}-O-Si_2
Structural formula					

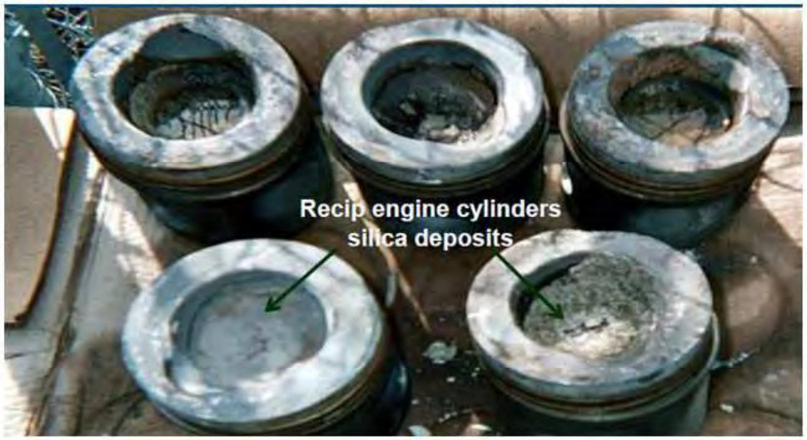
Trimethysilanol: $(CH_3)_3$Si--O—Si$(CH_3)_3$

Raw Gas

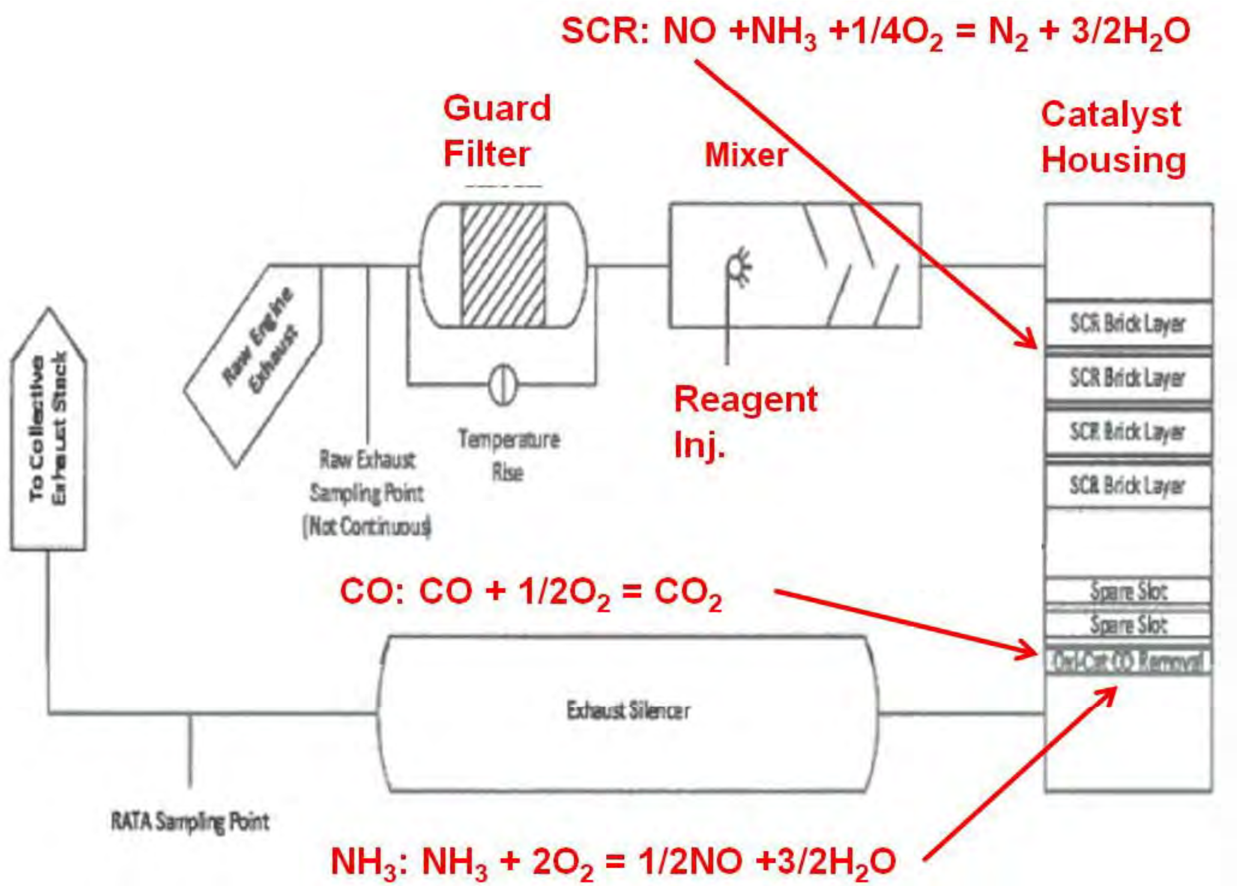
To Engine/SCR

Siloxane Impacts



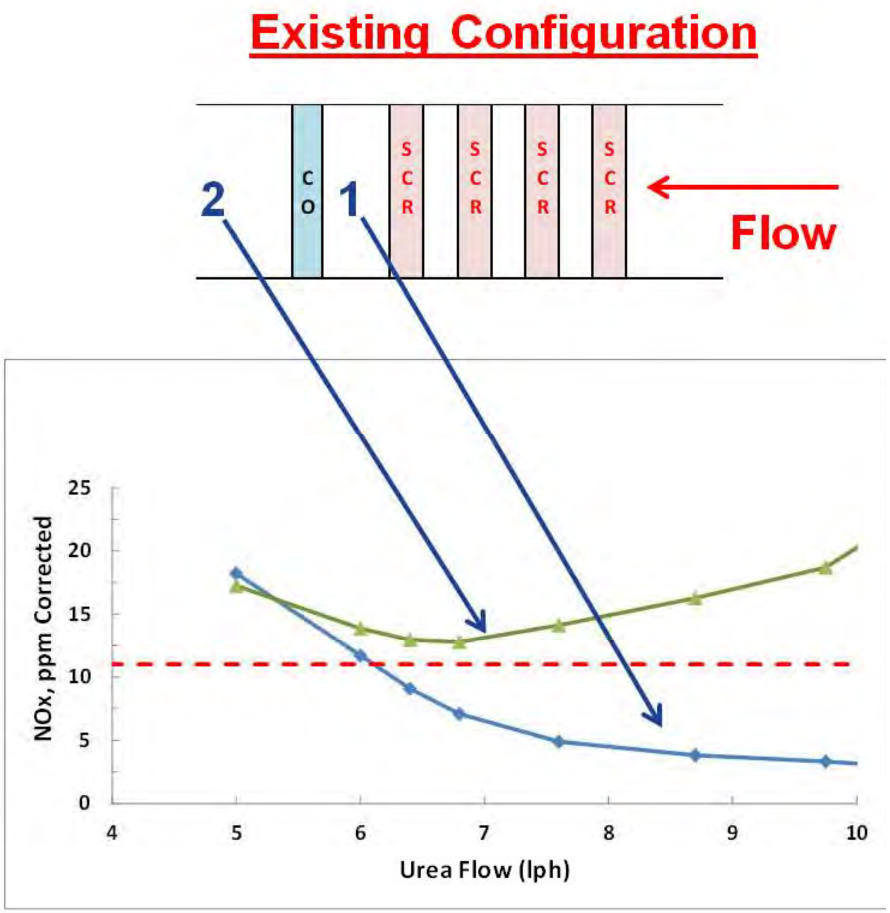


Irvine Landfill (Engine Emission Control Systems)



CO Catalyst Oxidation of NH_3

- Dual Function Catalyst : New Product to the Industry
- Reduces Both NOx and CO



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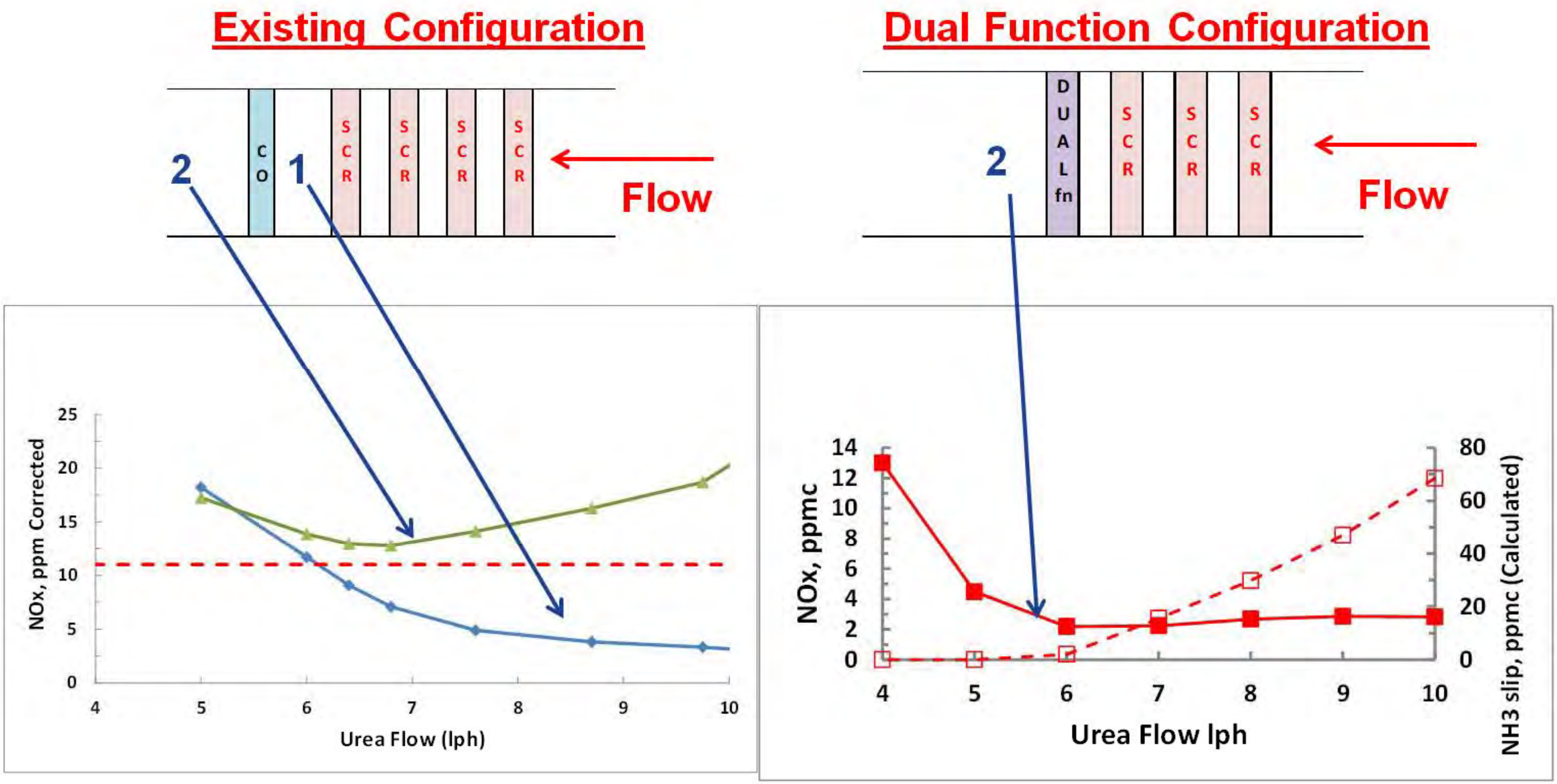
- Dual Function Catalyst : New Product to the Industry
- Reduces Both NOx and CO



Summary

- Make Sure Sufficient Catalyst Has Been Installed
- Make Sure the AIG Design is Consistent with the NO_x and NH_3 Slip Limits that Need to be Achieved
- Install a Permanent Probe Grid at the SCR Exit (facilitates tuning and assessing bypass)
- Assess NO_2 Issues at Low Loads; Dual Function Catalyst can Eliminate NO_2 Formation Across Traditional CO Catalyst

Questions?

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