NOx: Troubleshooting and Optimization of Combined Cycle SCR Systems

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FERCo

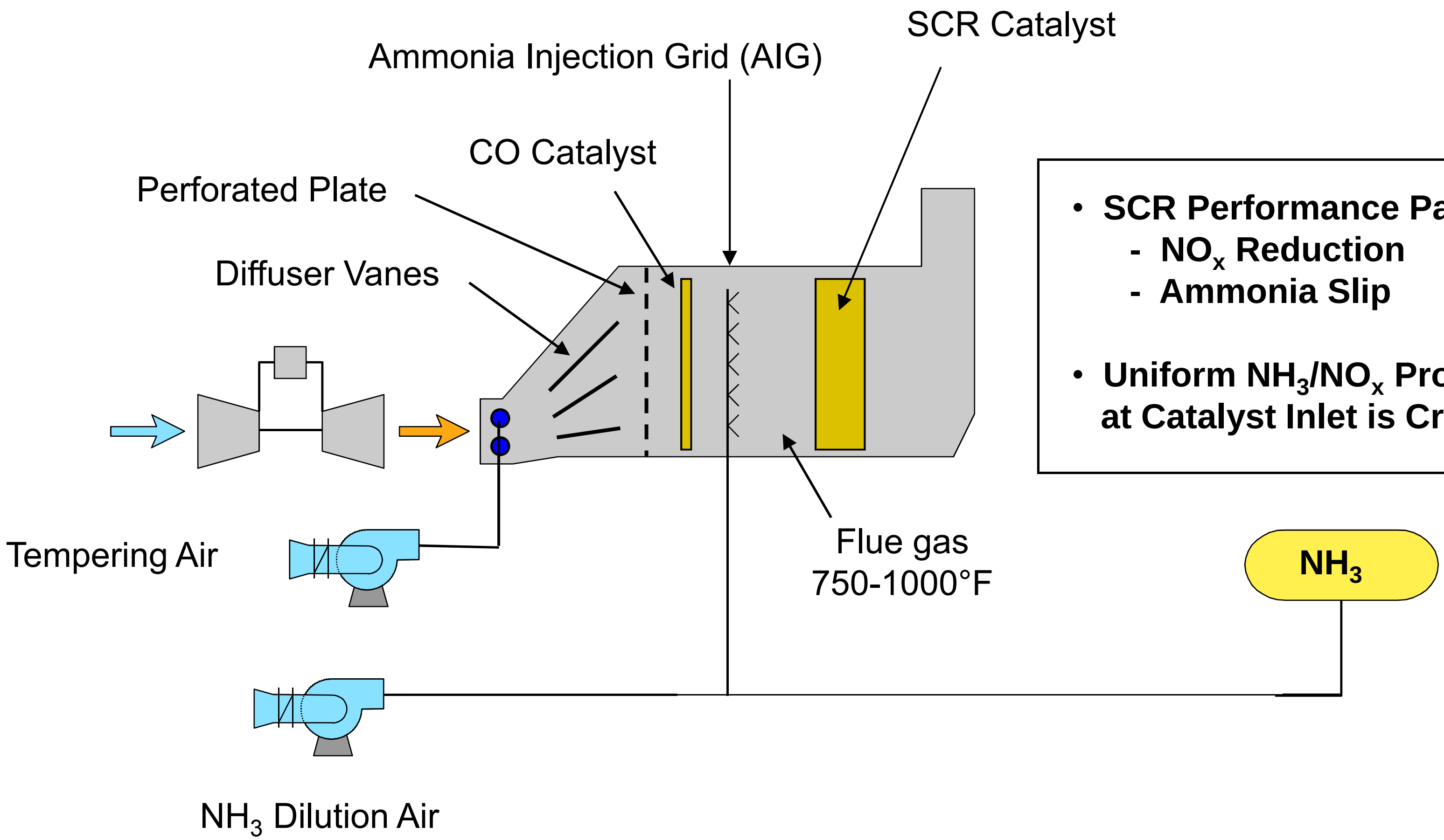
MP306

Optimizing Gas Turbine SCR Performance

Topics

- **Troubleshooting - How to Distinguish NH_3 Maldistribution from Bypass**
- **AIG Tuning - Catalyst Inlet NH_3/NO_x Distribution**
- **Identifying Flue Gas Bypass**
- **Catalyst Management/Measuring Catalyst Activity**

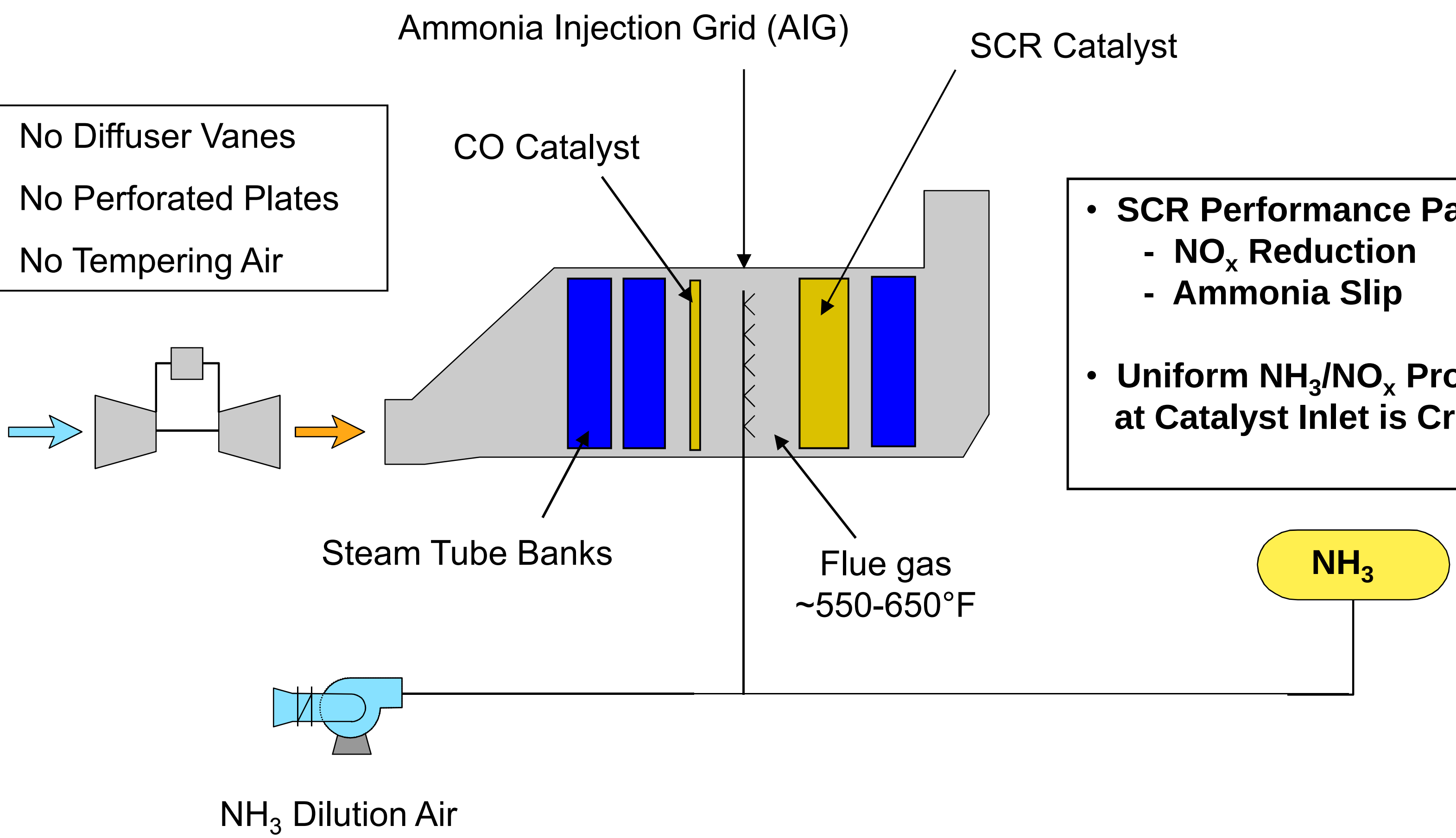
Simple Cycle Gas Turbine SCR



- **SCR Performance Parameters:**
  - **NO_x Reduction**
  - **Ammonia Slip**
- **Uniform NH_3/NO_x Profile at Catalyst Inlet is Critical!**

Combined Cycle Gas Turbine SCR

- No Diffuser Vanes
- No Perforated Plates
- No Tempering Air



- **SCR Performance Parameters:**
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  - **Ammonia Slip**
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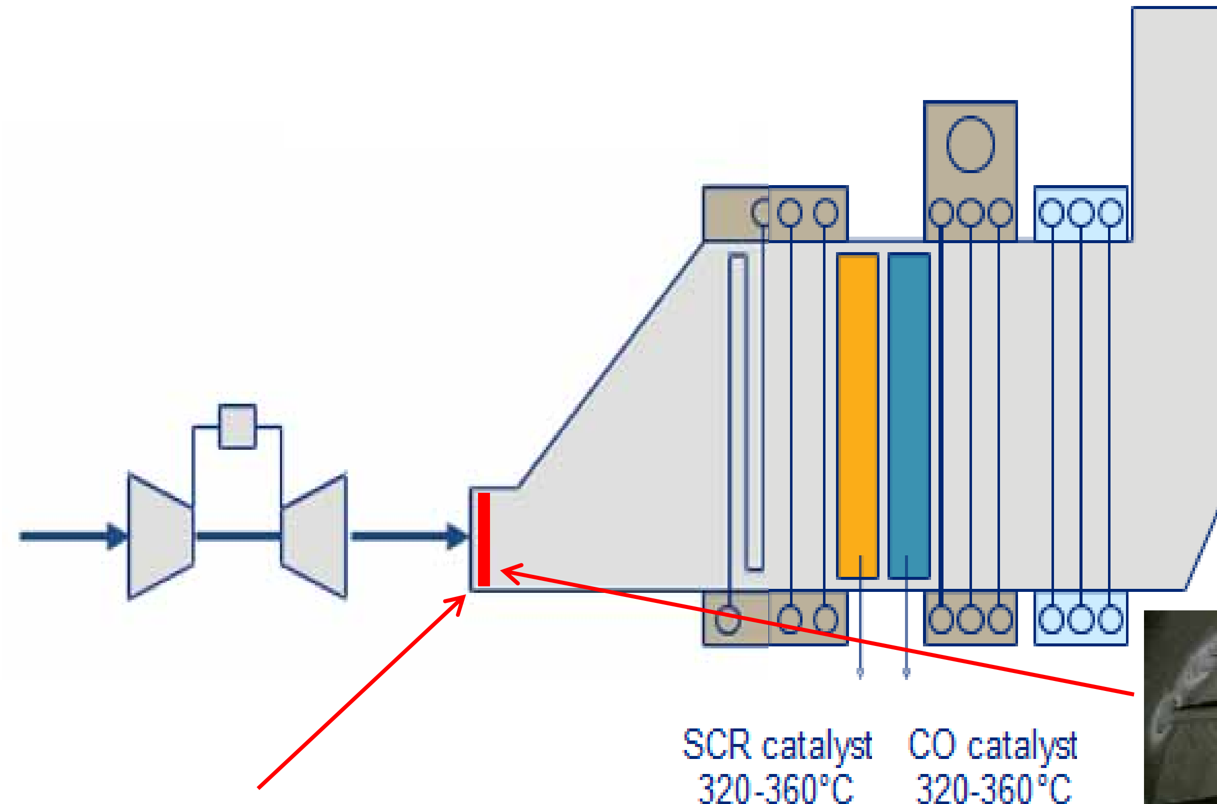
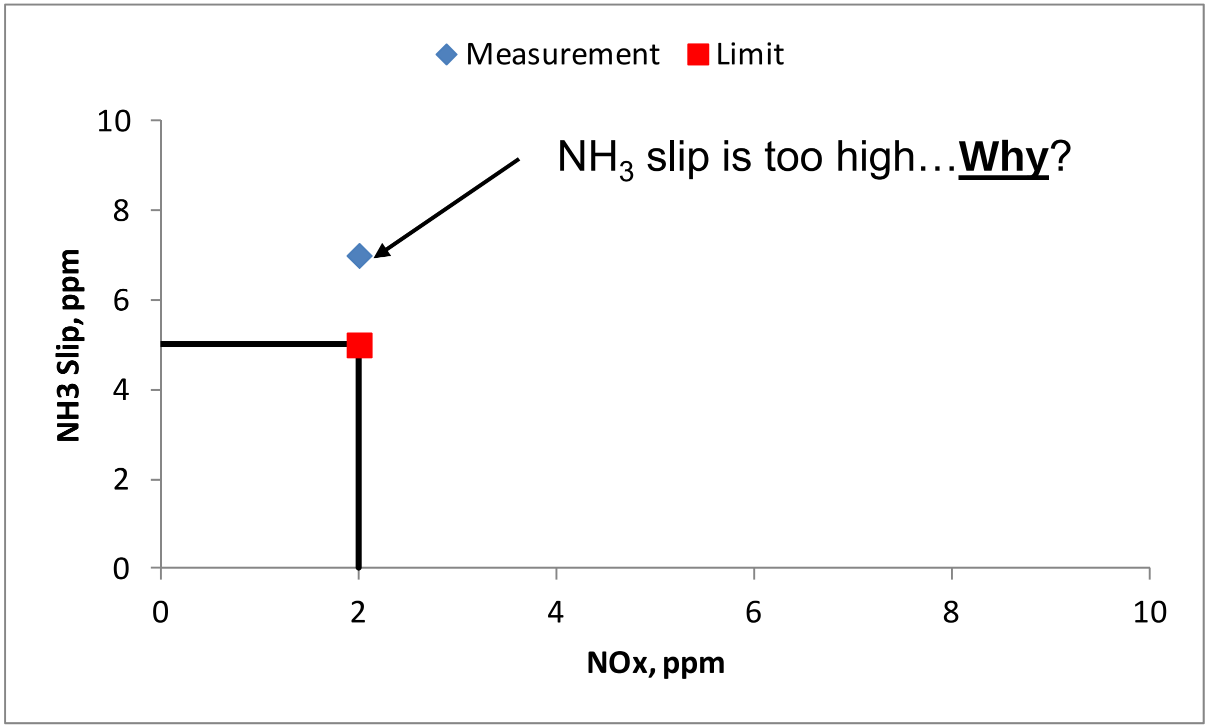
Direct Injection/Dual Function Catalyst



Direct Injection of Ammonium Hydroxide

Troubleshooting



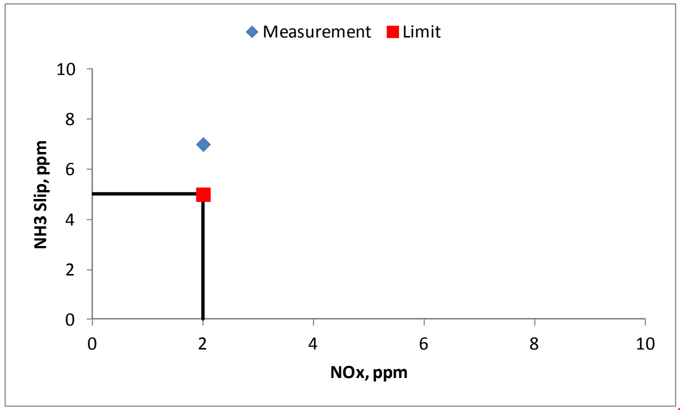
Why?

Catalyst Activity (K)?

- How active the material is in reducing NOx
- f(material, geometry)

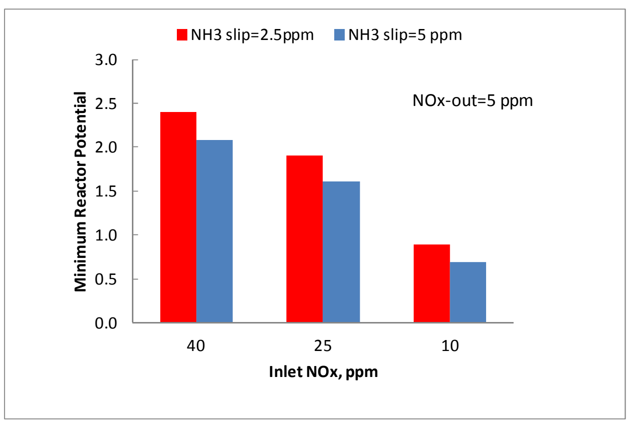
Poor NH3/NOx Distribution?

- Want NH_3/NO_x uniform across the catalyst
- Local NH_3/NO_x>1=NH_3 slip



Reactor Potential?

- Ability of the catalyst bed to reduce NO_x
- $RP= K*A_{sp}*V_{cat}/Q_{fg}$



Flue Gas Bypass?

- Any bypass by the catalyst increases stack NO_x & NH_3

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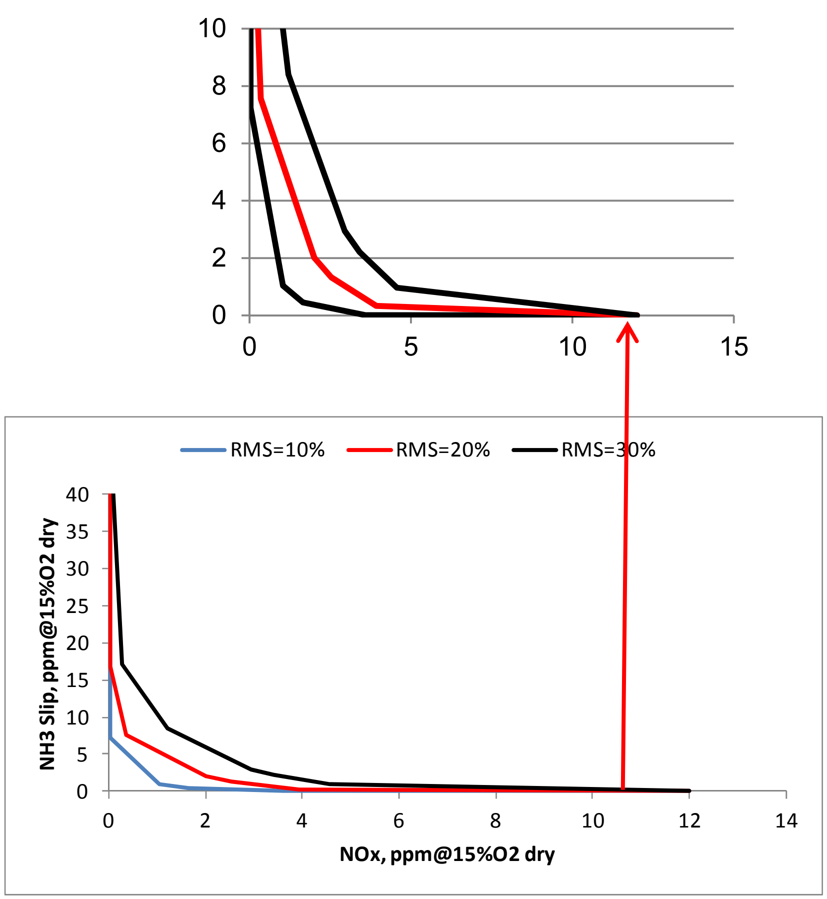
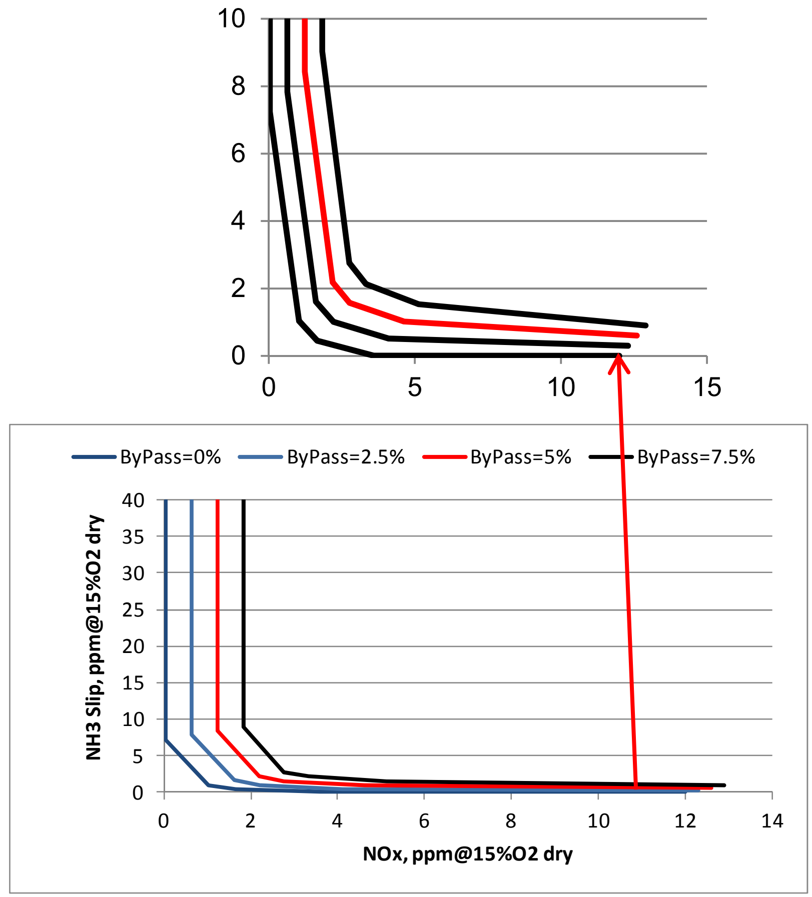
A simple stack test can distinguish
(NH_3 Maldistribution/Flue Gas Bypass)

NH_3/NO_x RMS Effects



Bypass Effects

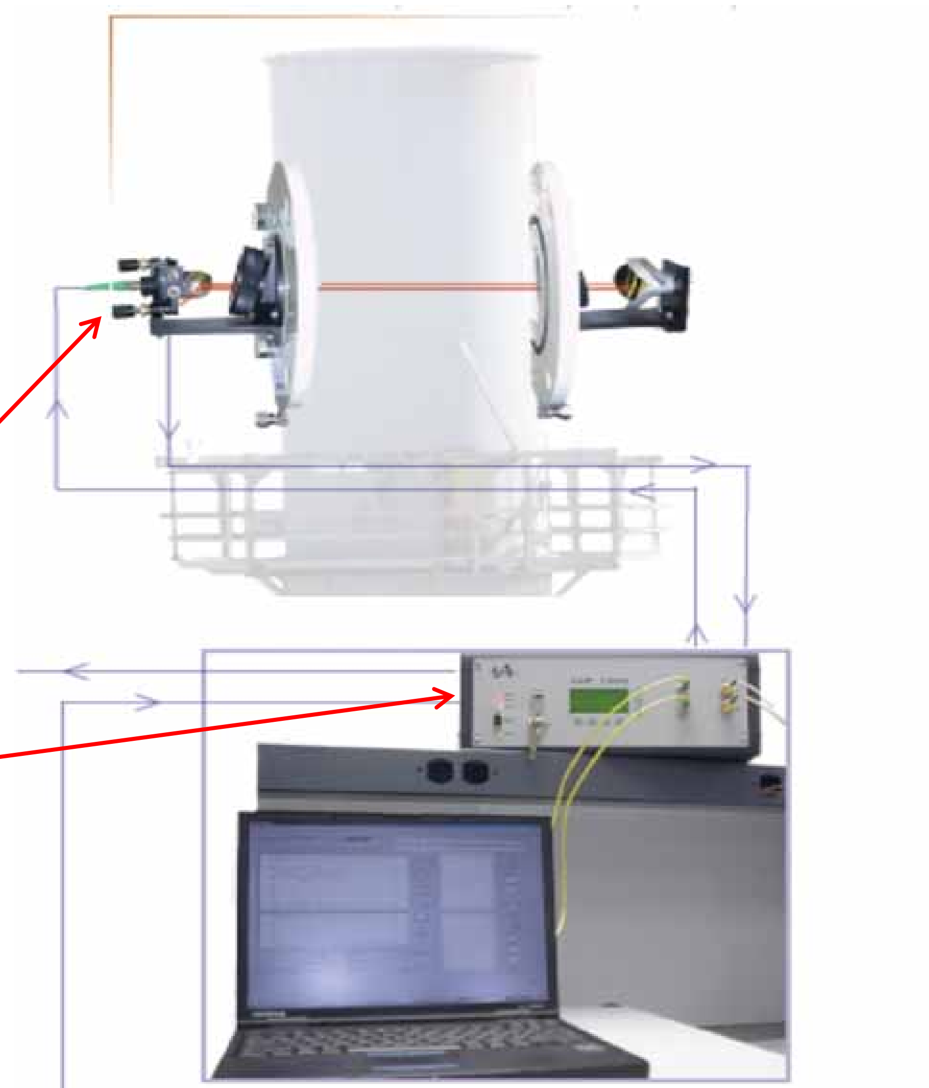


How to best generate this data?

- **Wet Chemical NH_3 measurements?**
- **Continuous NH_3 measurements?**

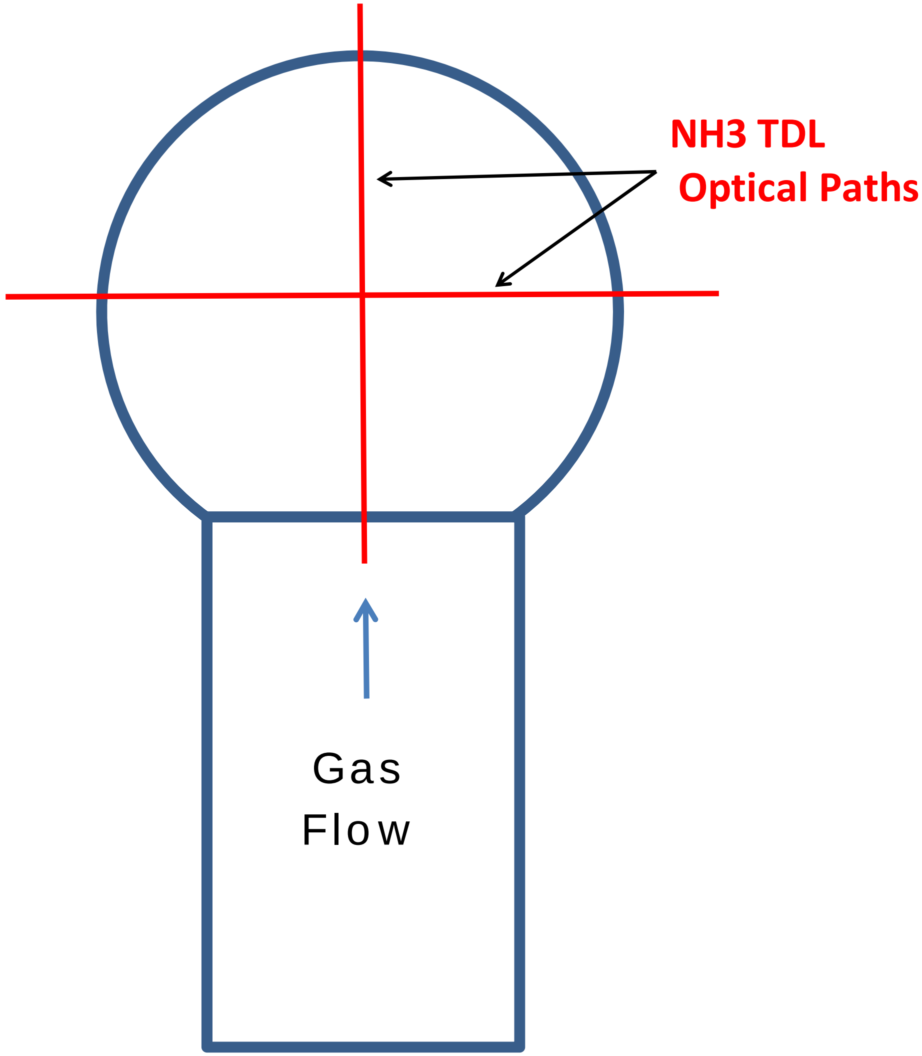
TDL Instrumentation

- **Testing facilitated using a continuous TDL NH_3 analyzer**
- **Data set can be generated in less than a day**
- **Data available in real time**



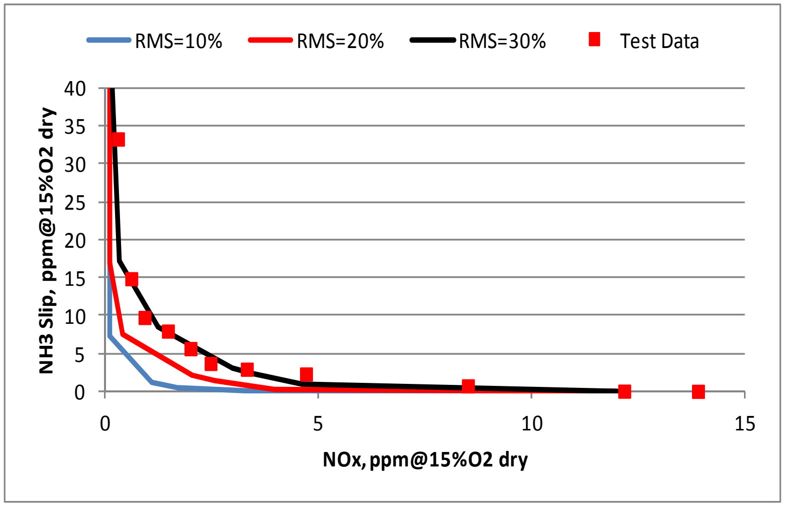
- **Unisearch NH_3 TDL**
  - **Dual Path**
  - **Two Channel**
  - **Fiber Optic Coupled**

NH_3-TDL Lines of Site

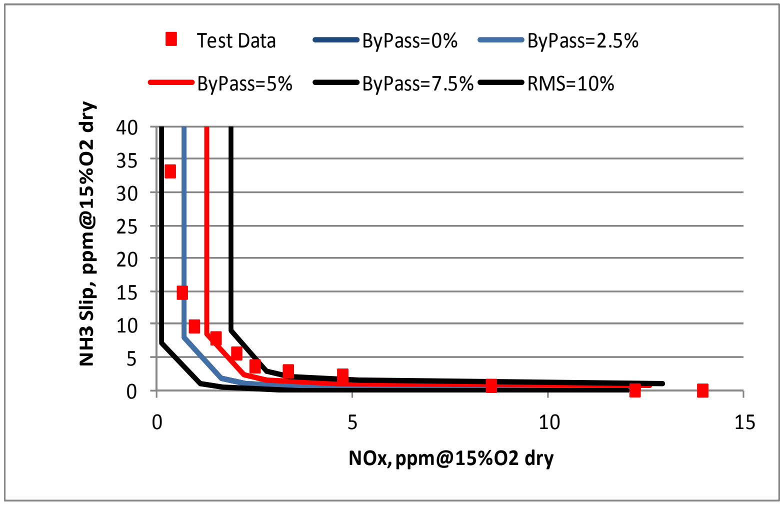


TDL NH_3 Measurements on a Large Combined Cycle

NH_3/NO_x RMS Effects



Bypass Effects



AIG Tuning

- **What is it?**
  - **Making sure that NO_x and NH_3 are matched up at every location on the catalyst**
- **How is it Done?**
  - **By making NO_x measurements at the exit of the catalyst**
  - **It is not necessary to measure both NO_x and NH_3**

Gas Turbine SCR AIG Tuning

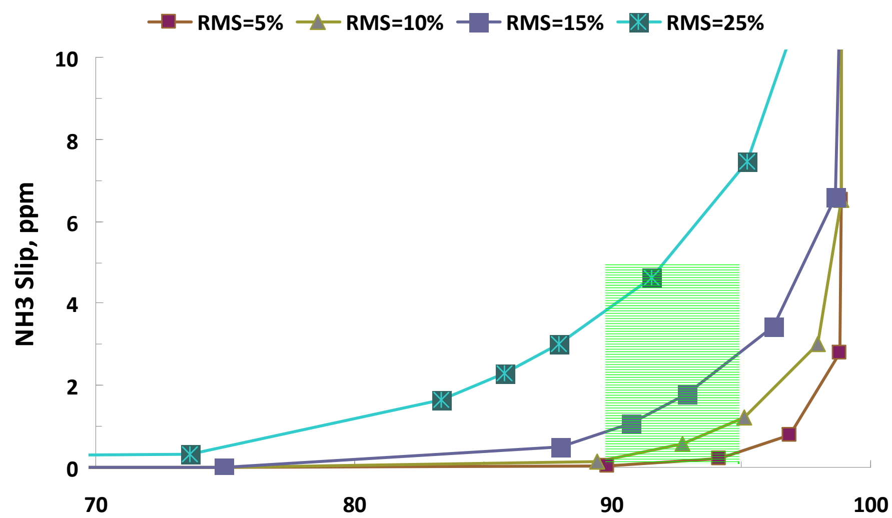
- **Tuning is Facilitated by Installing a Permanent Sample Grid at the Catalyst Exit:**
  - **Not feasible to manually traverse a large combined cycle system for AIG tuning**
  - **Typically need 36 to 60 probes depending on AIG design**

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

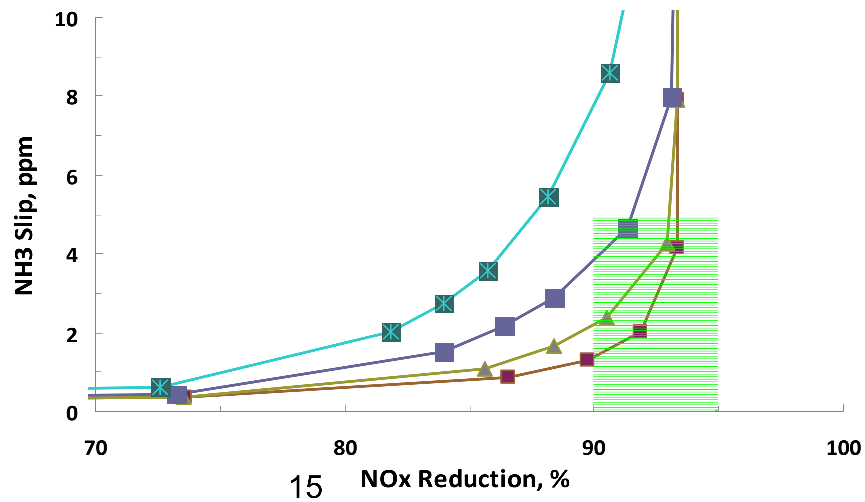
- **The NO_x Profiles at the Exit of the Catalyst can also Help Identify Bypass**

NH_3/NO_x Distribution and AIG Tuning

New Catalyst



Catalyst Near End-of-Life



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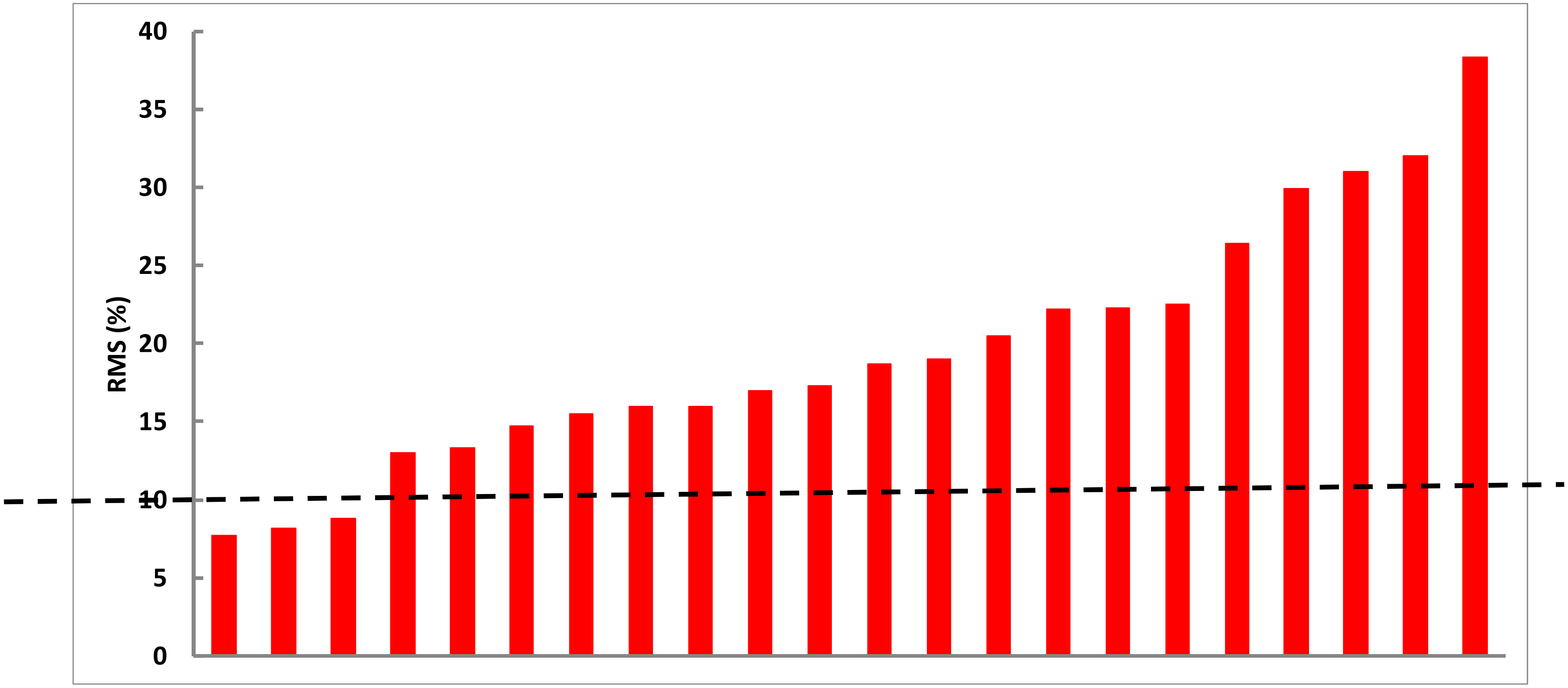
How Well is Your AIG Tuned? (As Found RMS Values)

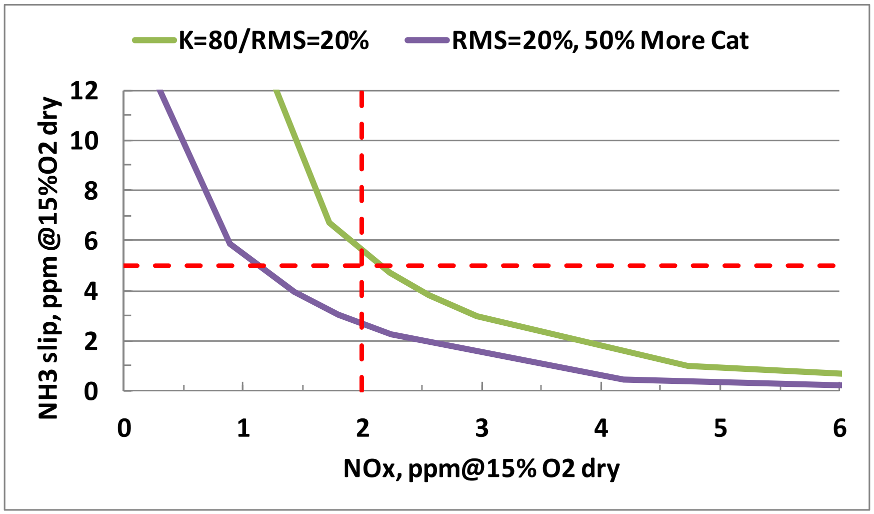
Most of the GT AIGs we encounter are not tuned very well!



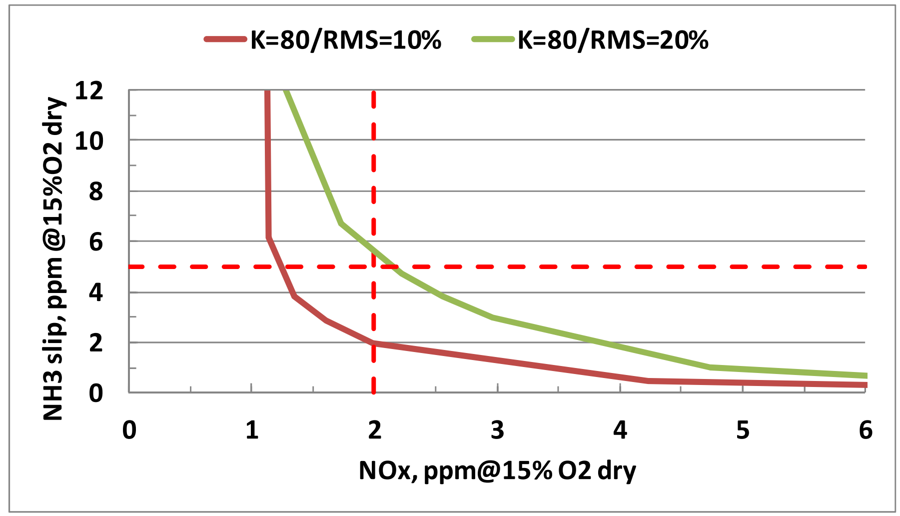
How Important is the NH_3/NO_x Distribution?

- SCAQMD is pushing NO_x from 5 to 2 ppm in So. Cal.
- Assumption is that just adding more catalyst will be the solution

RMS=20% Add Catalyst



Tune AIG To RMS=10%



- Just tuning the AIG allows 2 ppm NO_x to be achieved
- Adding 50% more catalyst helps, but not as much as tuning

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

Sample probe exit ports

Sample probe lines brought down to grade

Sample Probes Attached to Catalyst Modules

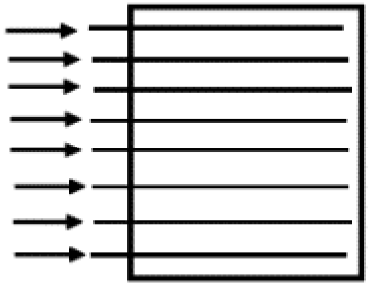
FERCo's Multipoint Instrumentation

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

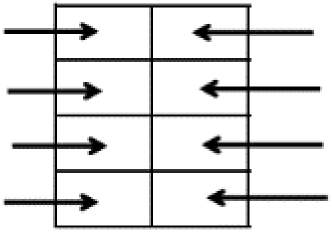
AIG Design Affects Tuning

- **No Adjustments: Some systems have no adjustment valves- Bad Idea ! ! !**

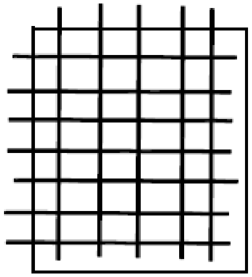
- **1-D: Commonly used design**



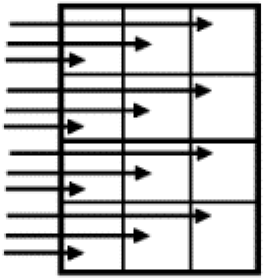
- **Multi Zone: Better**



Two Horizontal Zones

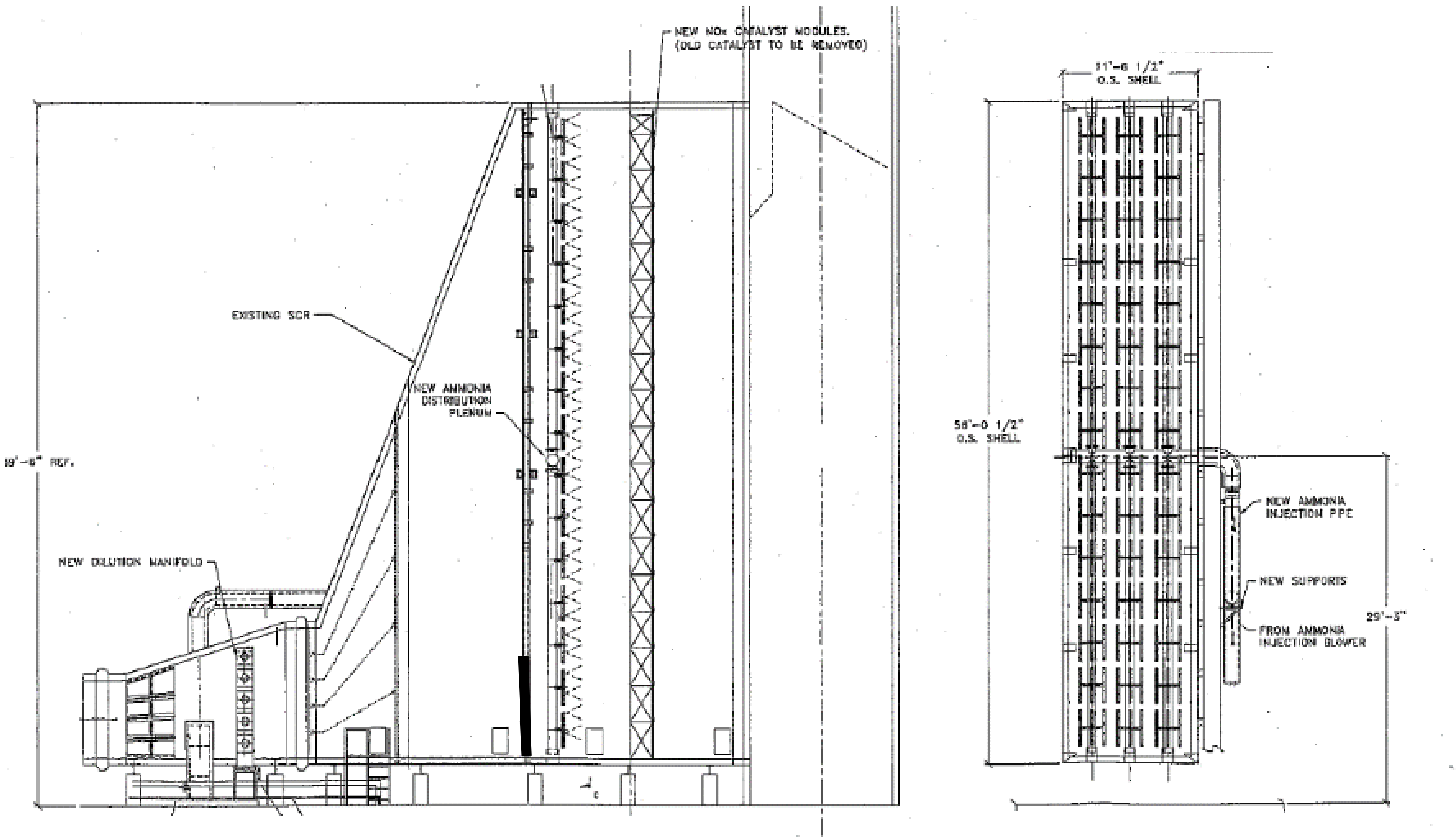


Horizontal and Vertical Lances



Three Horizontal Zones

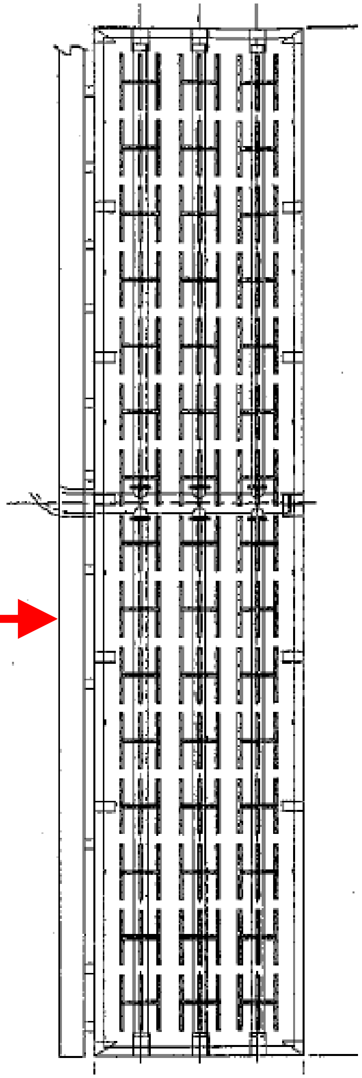
AIG With No Adjustability



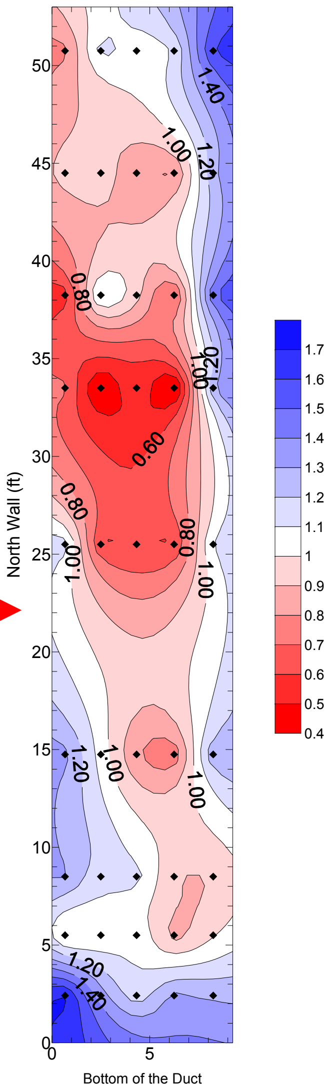
AIG: No Adjustability

Permanent Probe Grid for Tuning. Difficult to Tune Without !

Normalized NH_3/NO_x Profiles – As Found



Orig. AIG RMS = 35%



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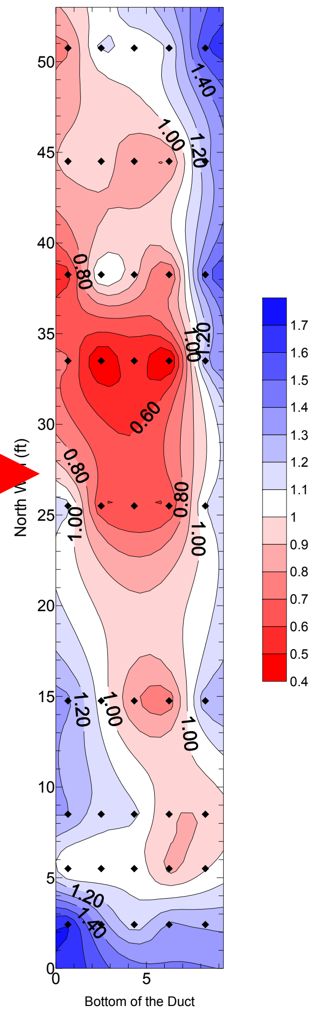
Normalized NH_3/NO_x Profiles – Before & After

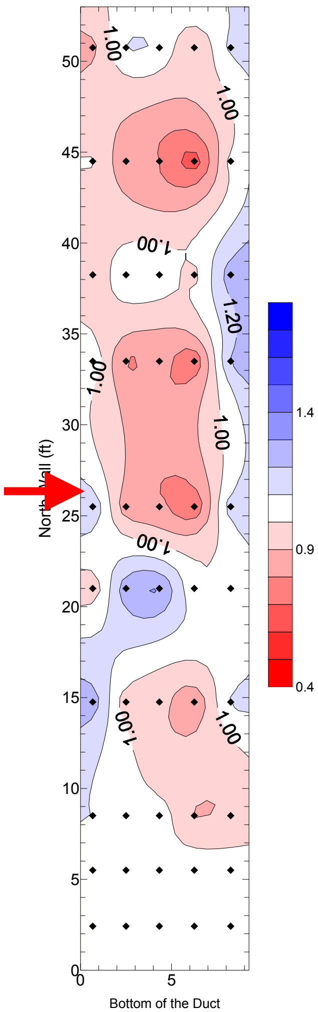
Orig. AIG RMS = 35%

NH₃ Header



All Holes Resized RMS = 16%

NH₃ Header



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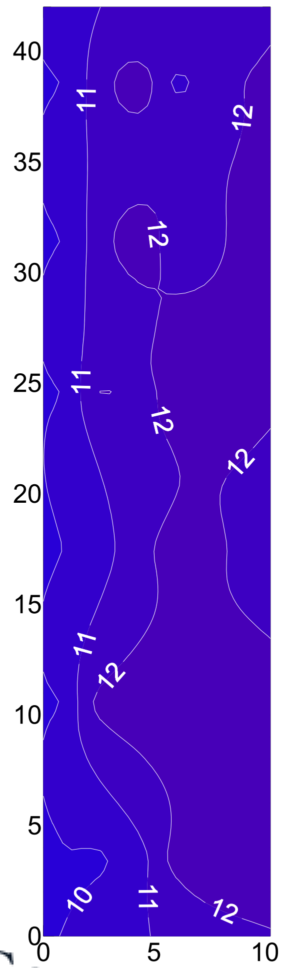
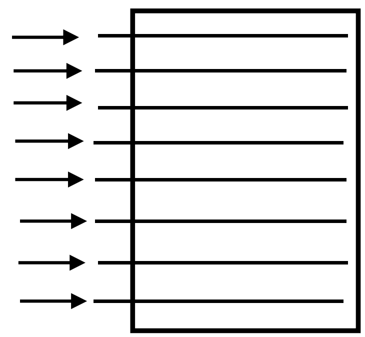
Duct Burners Impact AIG Tuning

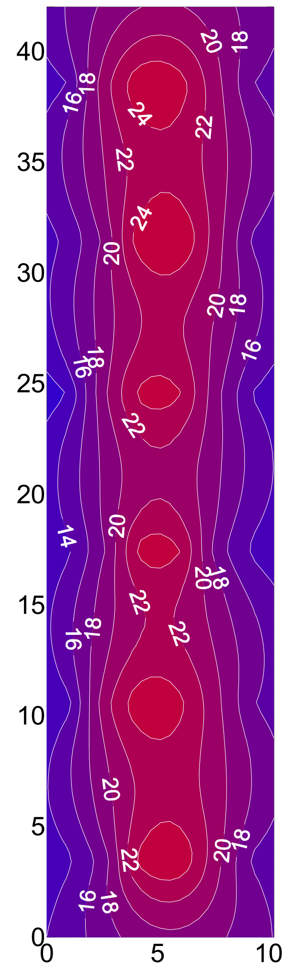
Duct Burners Off
(Inlet NO_x ppm)



AIG Difficult to Tune



Duct Burners On
(Inlet NO_x ppm)



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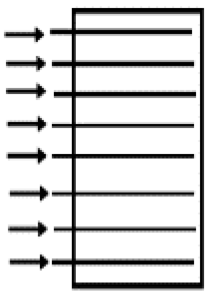
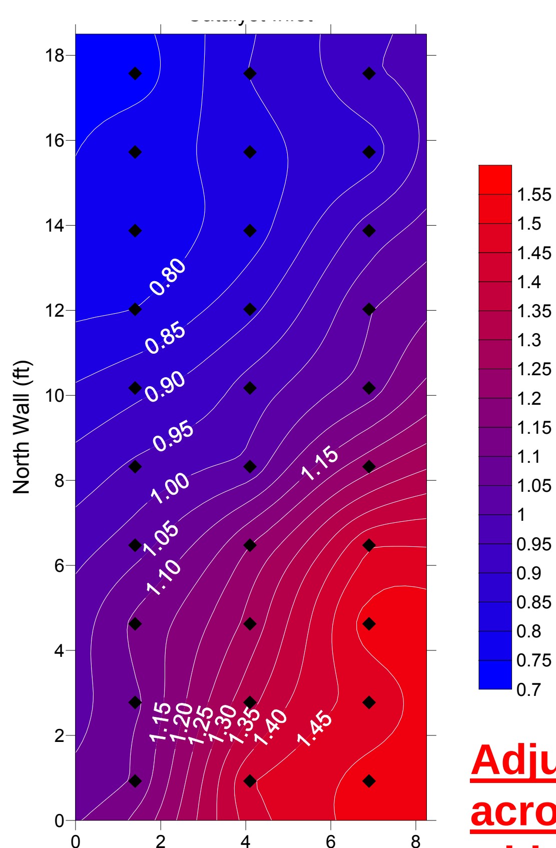
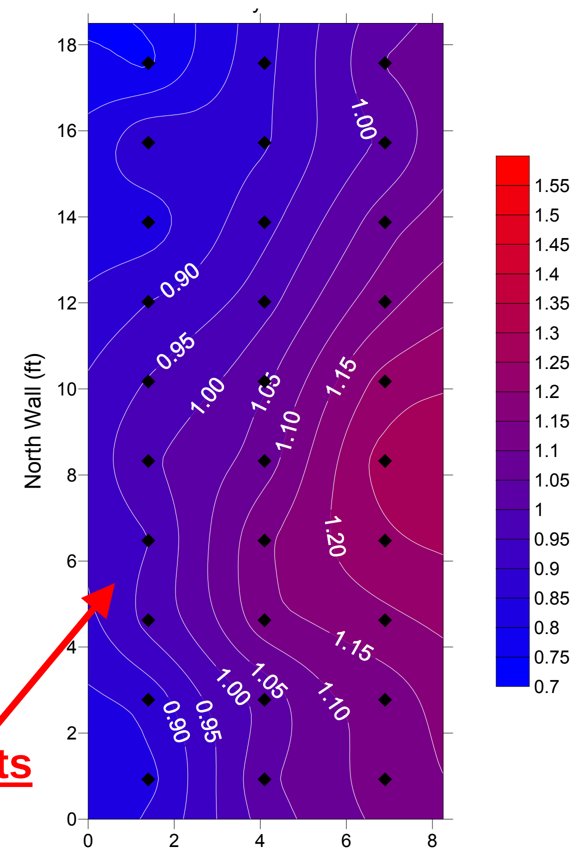
AIG Tuning, 1-D AIG Design; NH_3/NO_x



As Found, RMS = 22%



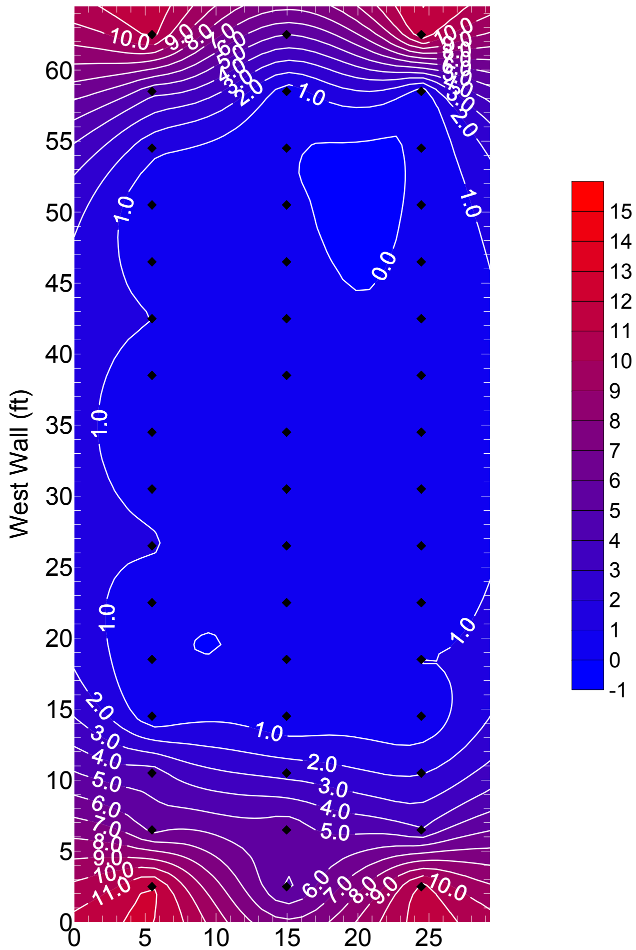
Tuned, RMS = 13%



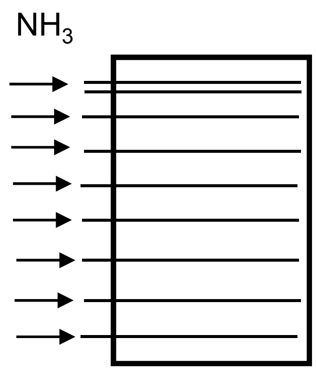
Adjustments across the width not possible

AIG Tuning, 1-D AIG Design; Outlet NO_x

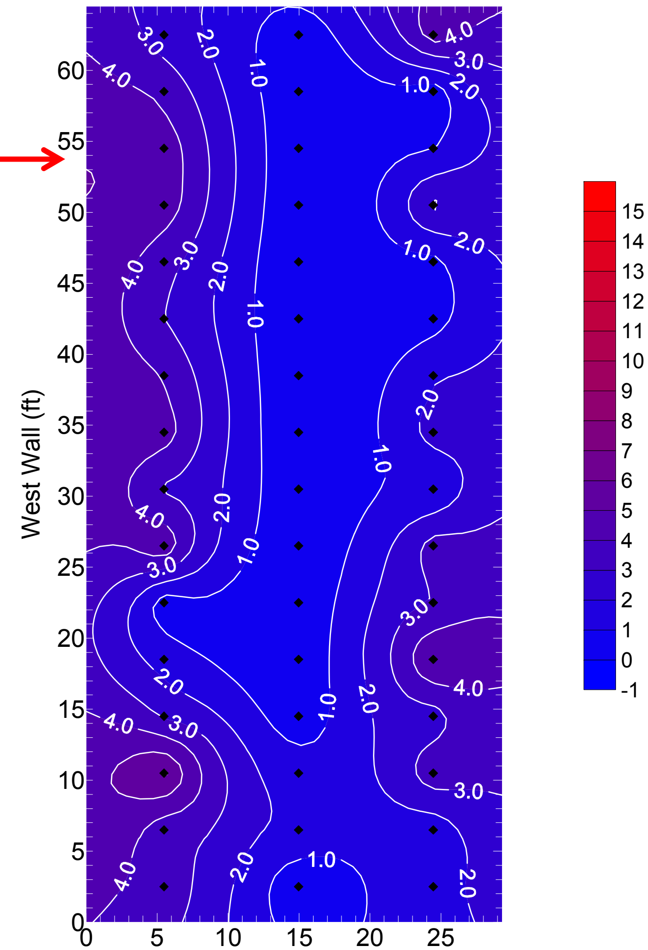
As Found



Reagent consumption reduced 5%

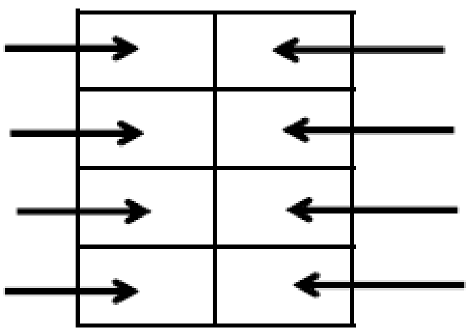


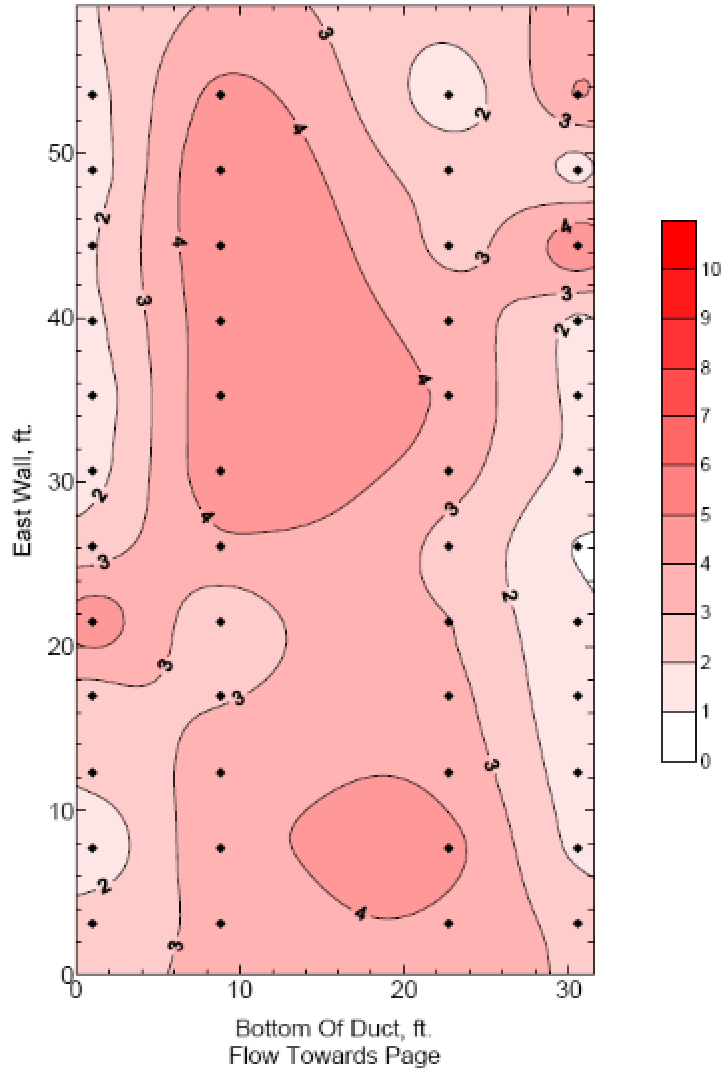
Tuned



AIG Tuning, 2-D AIG Design; Outlet NO_x

AIG Design:2-Zones Horizontally





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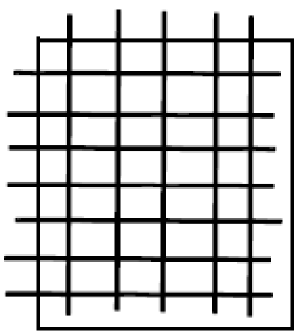
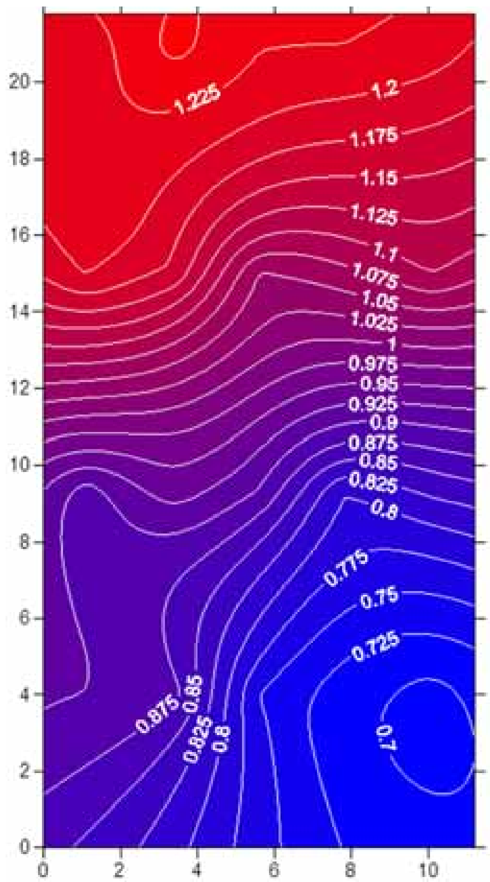
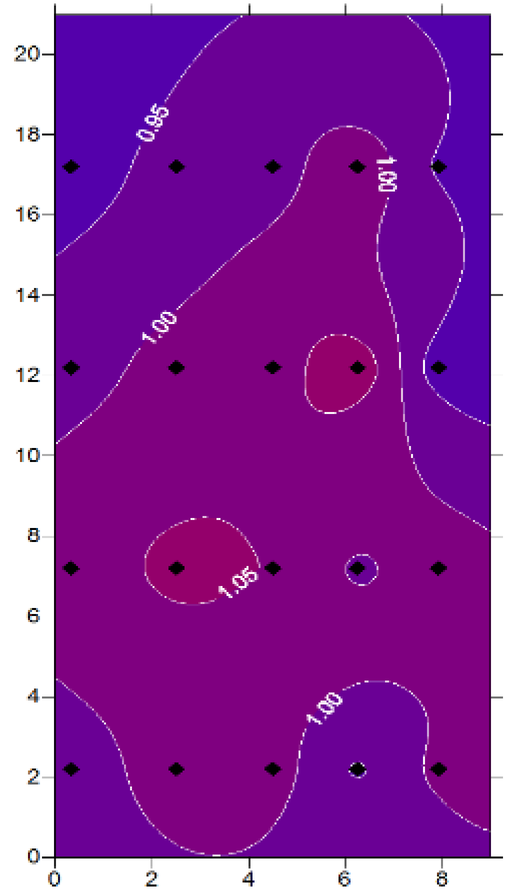
AIG Tuning, Multi Zone AIG Design; NH_3/NO_x



As Found, RMS = 19%

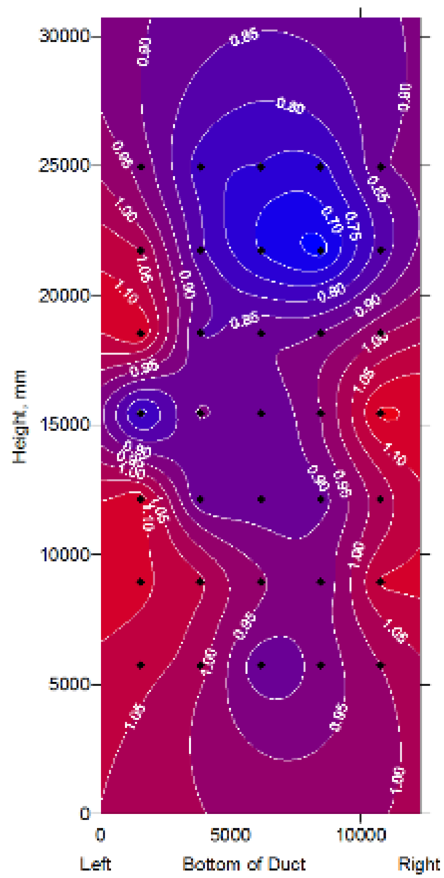


Tuned, RMS = 5%

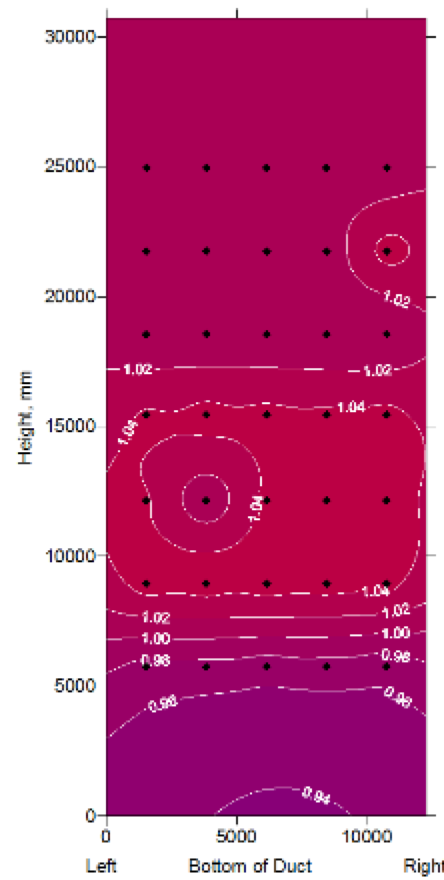


Direct Injection of Aqueous Ammonia@ Turbine exhaust

As Found, RMS = 14%



Tuned, RMS = 3%



Benefits of AIG Tuning

- **Reduce NH_3 slip at required outlet NO_x**

- **Reduced Reagent Consumption**

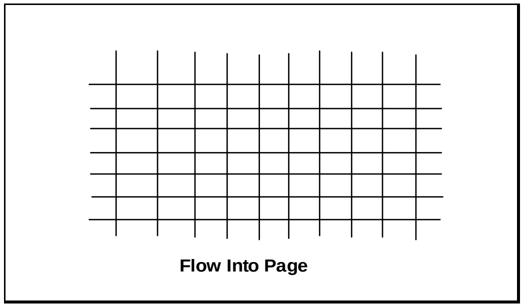
GT Load MW	As Found lb/hr	Tuned lb/hr	Reagent Reduction %
244	669	633	5
174	410	355	13
29	42	35	17

- **Reduced Required GT Water Injection**

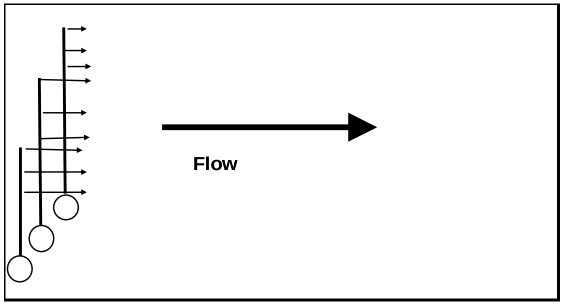
GT Water Inj GPM	Inlet NO_x ppm	NH_3 Slip ppm
30	20	3
26	26	3.5

Coal SCR: AIG Design Influences Tuning

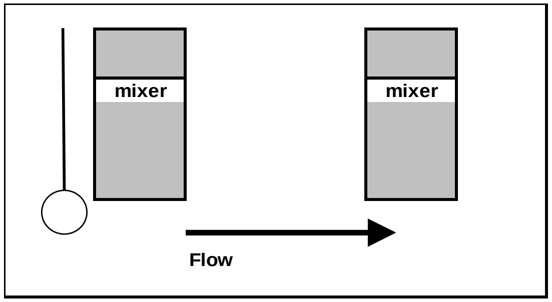
Cross Grids



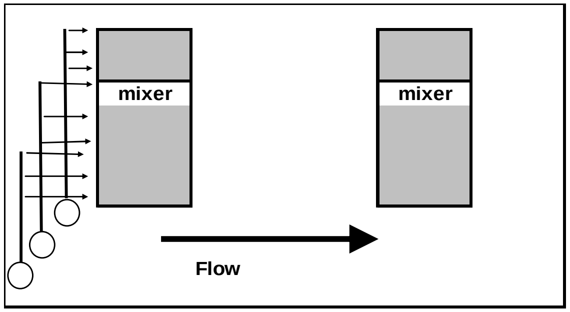
Multi-Zones



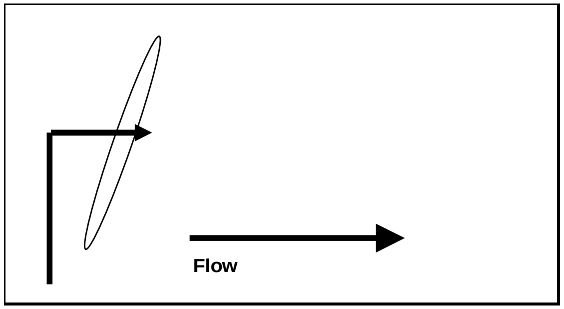
Mixer with 1-D Adj.



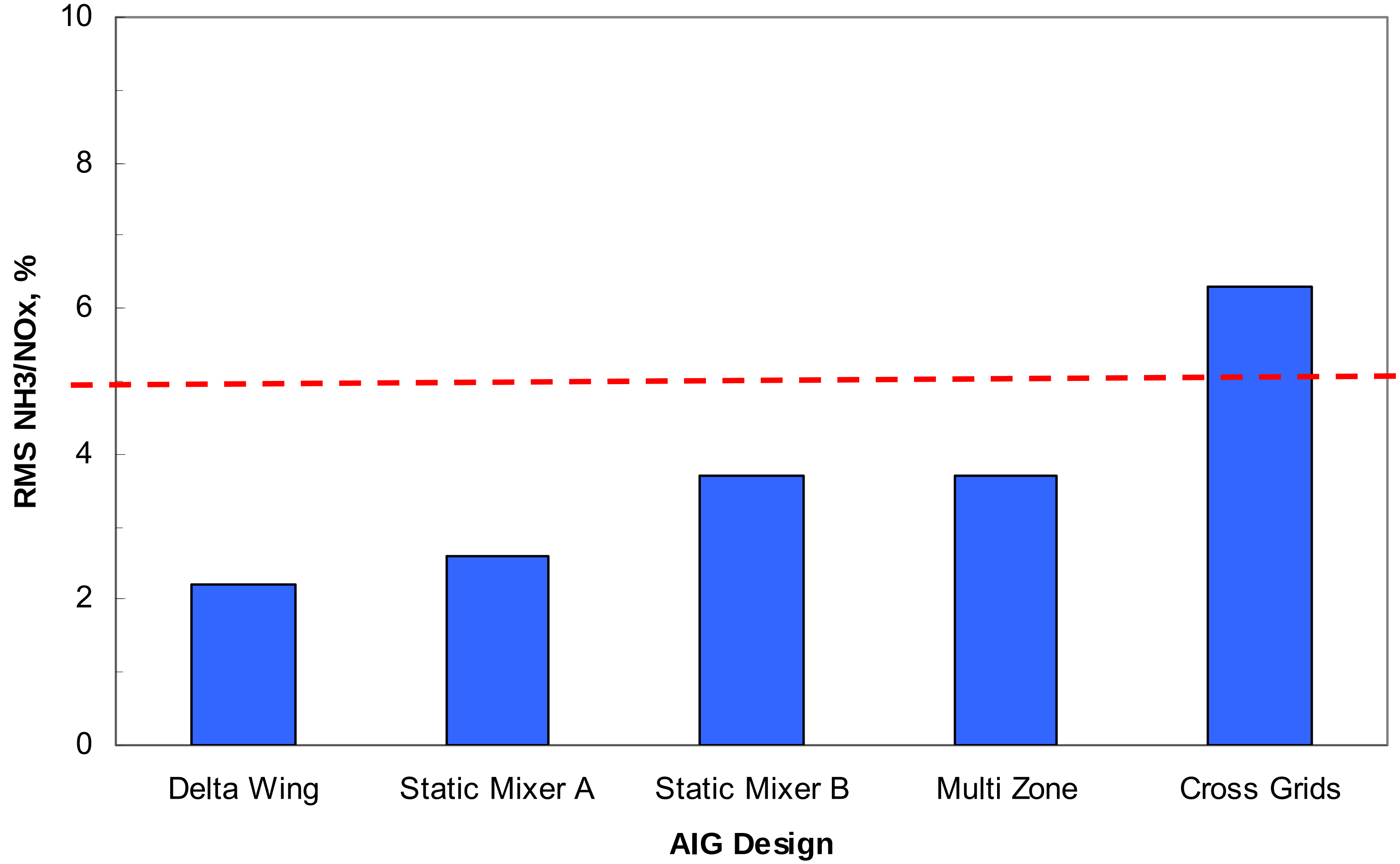
Mixer with Multi Zone Grid



Delta Wings

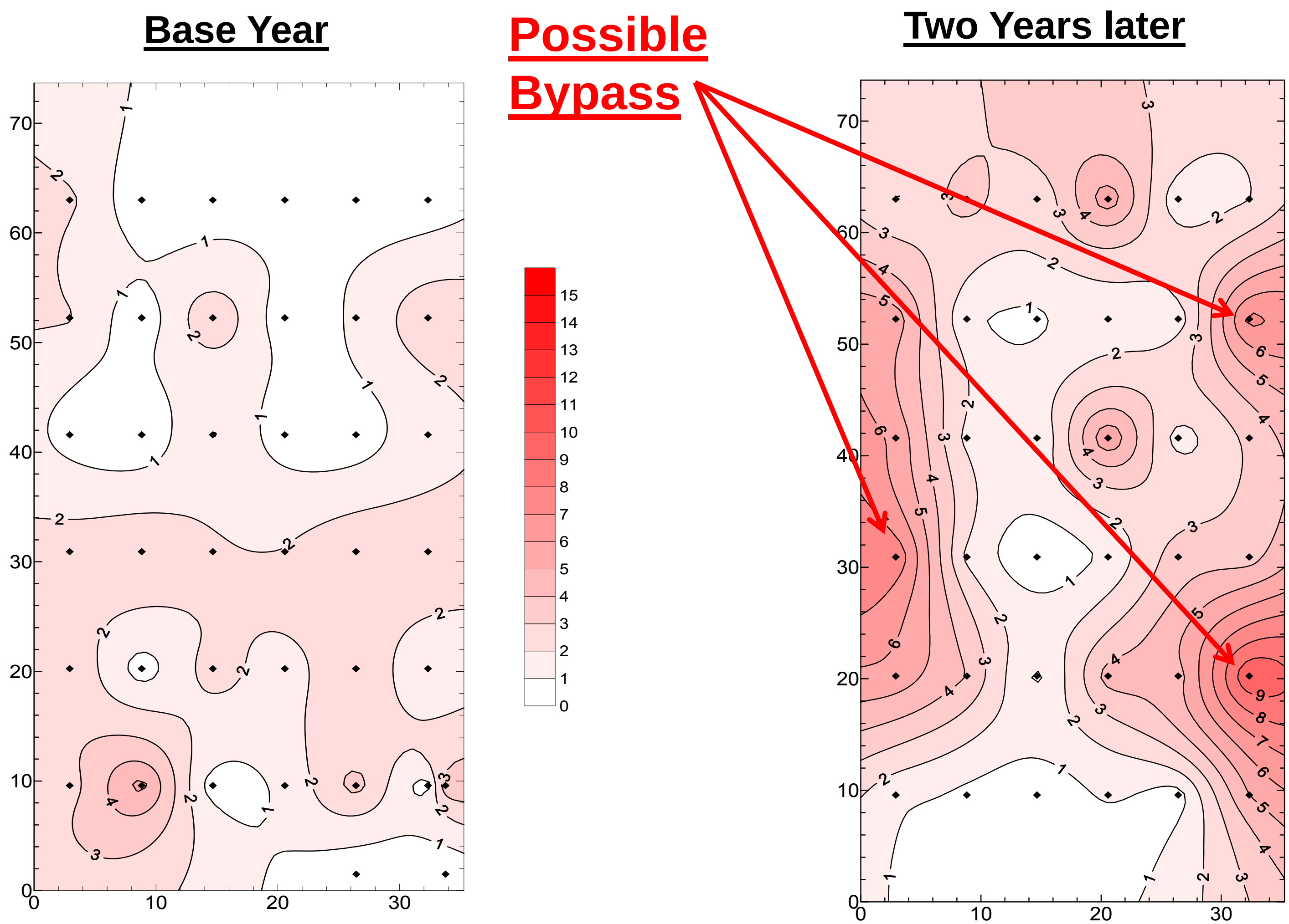


Coal:AIG Design Effects



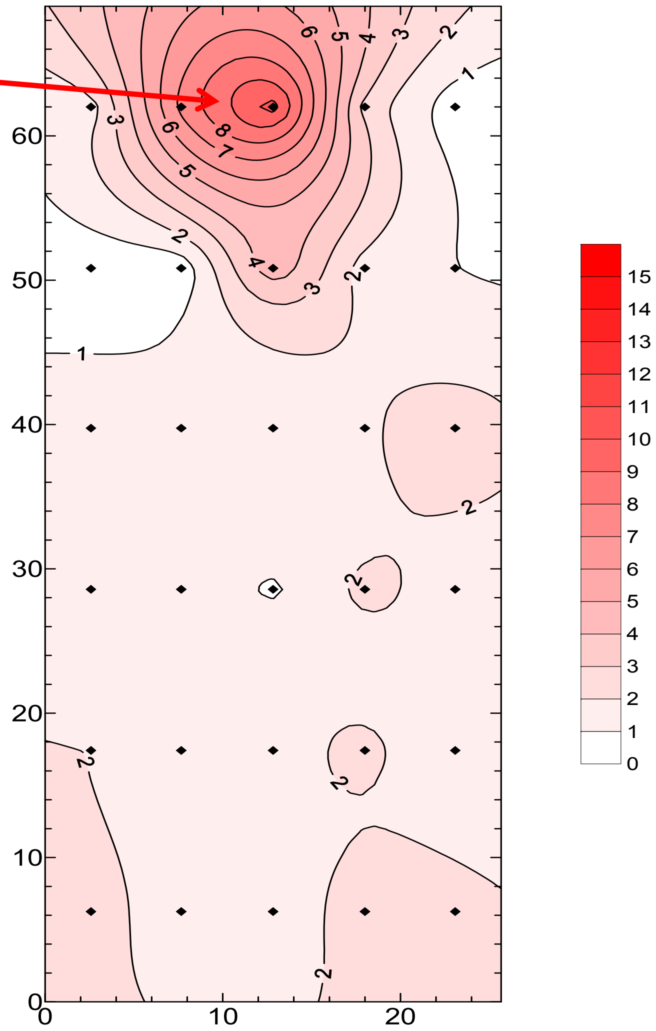
Bypass

NO_x Profiles Can Also Help Detect Bypass



NO_x Profiles Can Also Help Detect Bypass

Possible Bypass



Catalyst Management

Catalyst Management

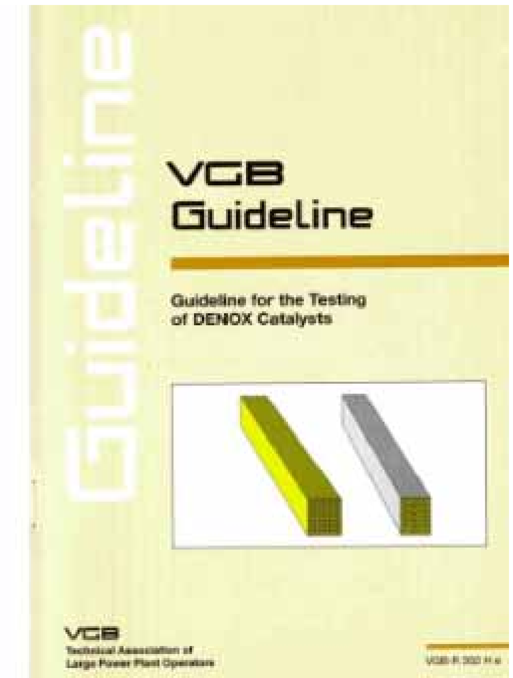
- Tracking catalyst activity and NH_3/NO_x distribution
- Ensure continued environmental compliance
- Plan for catalyst replacements

Measuring Catalyst Activity

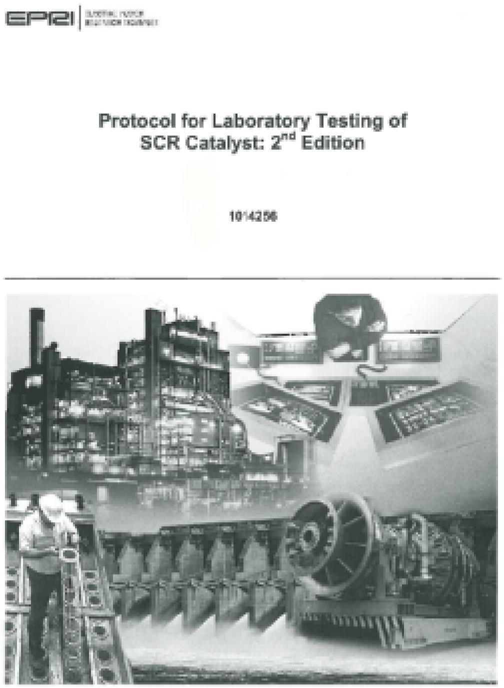
- **There are Laboratory Protocols for testing SCR catalyst**
  - **Coal**
  - **Natural Gas (Gas Turbine Systems)**

Measuring Catalyst Activity: Coal

VGB Guidelines



EPRI Protocol

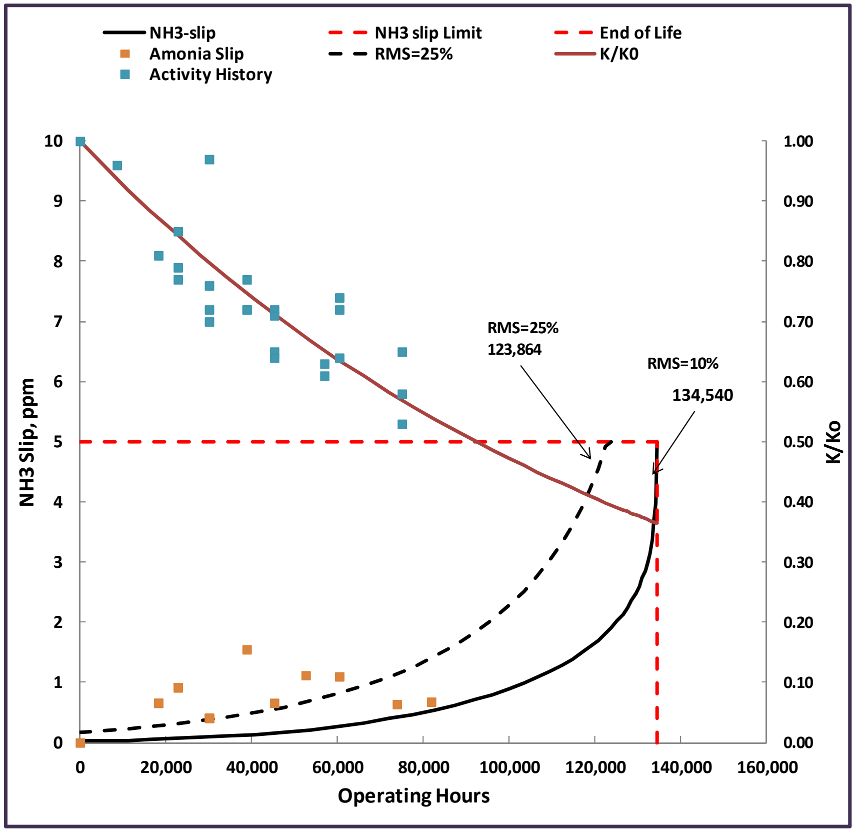


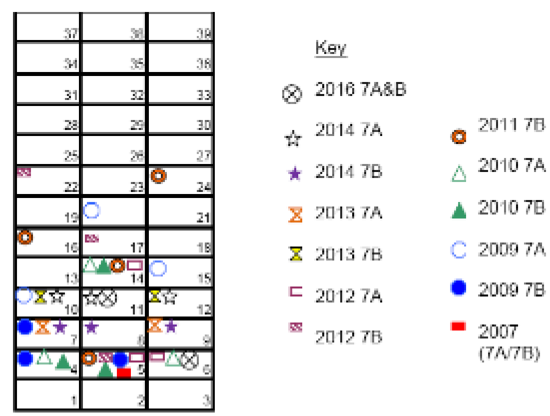
Measuring Catalyst Activity: GT SCR/CO

- **Until recently there were no standard testing guidelines for GT SCR or CO catalyst. This led to variations among laboratories.**
- **Last year EPRI issued a guideline for testing GT SCR & CO Catalyst**
- **Available at the EPRI Website (Report 3002006042)**

Catalyst Management

- **Tracking catalyst activity and NH_3/NO_x distribution**
- **Insure continued environmental compliance**
- **Plan for catalyst replacements**





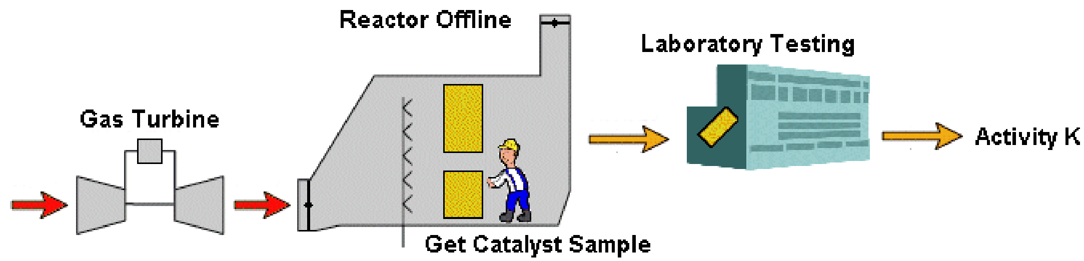
Measure RP Insitu

- **While sending samples to a lab for activity measurements historically has been a key step in catalyst management, it is no longer necessary.**
- **Today an owner operator can take control of catalyst management with the CatalysTraK®, a system that measures catalyst activity and RP in-situ.**
- **Insitu tests are performed at actual full scale operating conditions**
- **Tests can be conducted at any time, no outage required**
  - **Performed during an annual compliance test**
  - **At any time there may be an issue with catalyst performance**
- **Applicable to both NO_x and CO catalyst**

In Situ Catalyst Activity Measurement*

Traditional Lab Measuremet

- Typically one per year



$K_{Lab} = -A_{Vdesign} \ln(1-\Delta NO_x)_{Lab}$

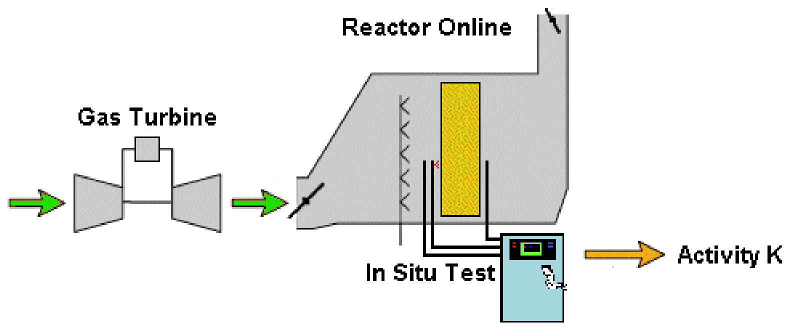
@NH3/NOx=1.2

FERCo's CatalysTrak®*

- *in situ* measurement
- No outage required

$K_{In\text{-}situ} = -A_{Vactual} \ln(1-\Delta NO_x)_{full\ scale}$

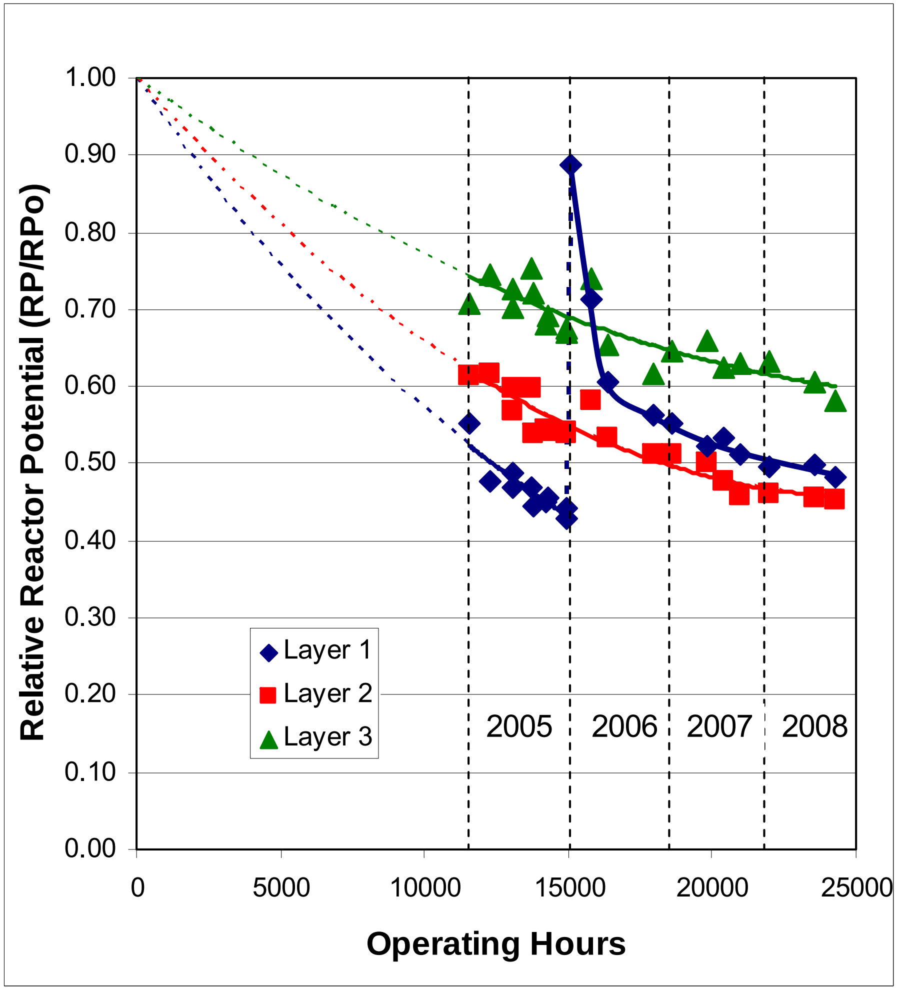
@NH3/NOx>1 locally



*** Patented Process**

In Situ CatalysTrak™ Measurements: Individual Layers

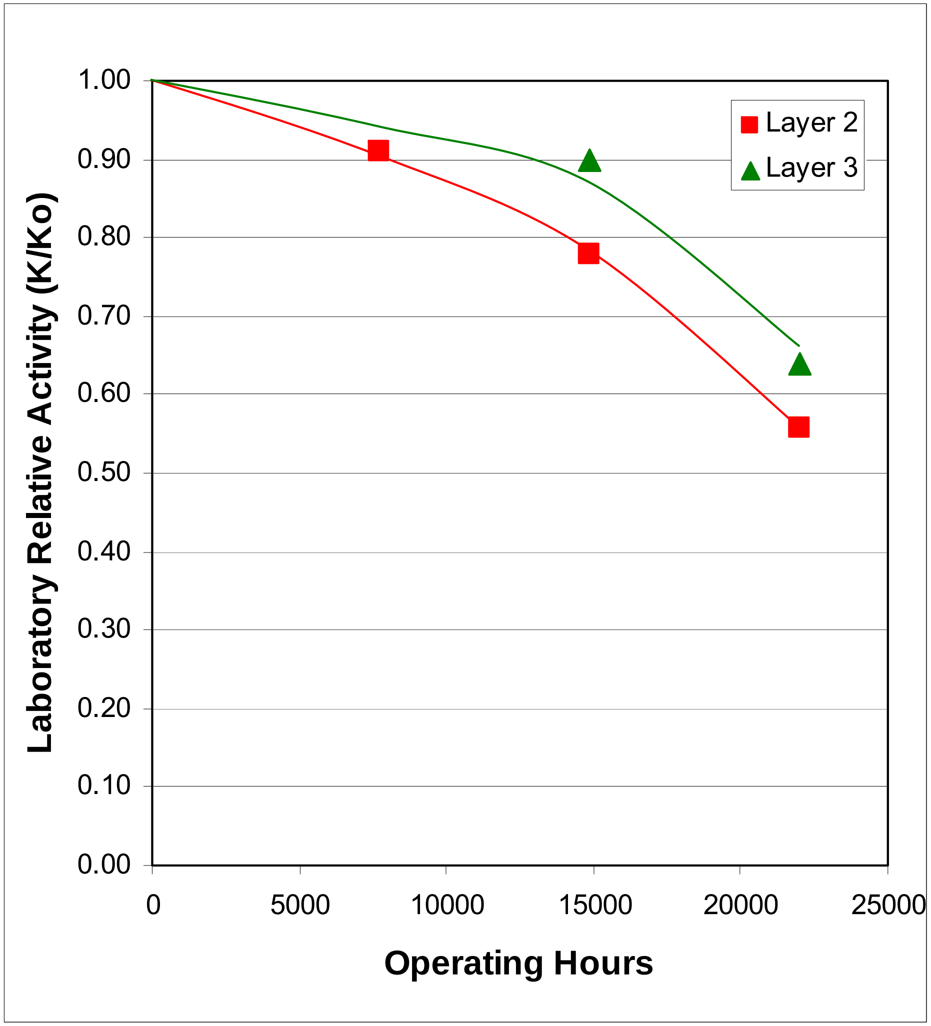
CatalysTraK® was originally developed for coal-fired SCR's. These systems are characterized by multiple catalyst layers.



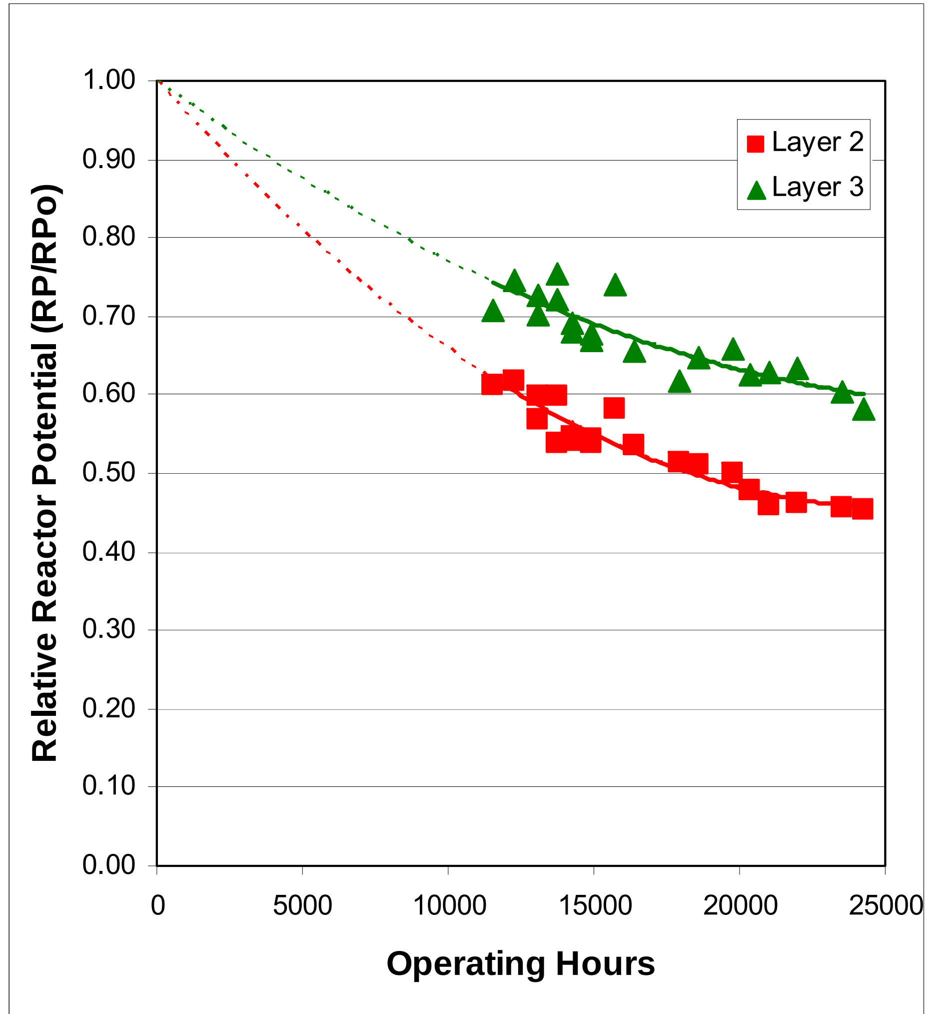
- First 4-years of operation beginning in 2005
  - 700 MW unit
  - E. bituminous coal
- SCR on-line May 2002
  - Seasonal operation
  - Two reactors
  - 3 + 1 configuration
  - Initial load: 3 layers honeycomb catalyst
  - Layer 1 replaced with plate catalyst prior to 2006 ozone season

Volume of Data: Laboratory vs. *In Situ*

Annual Laboratory Analysis



On-Demand CatalysTrak™ Measurements



FERCo

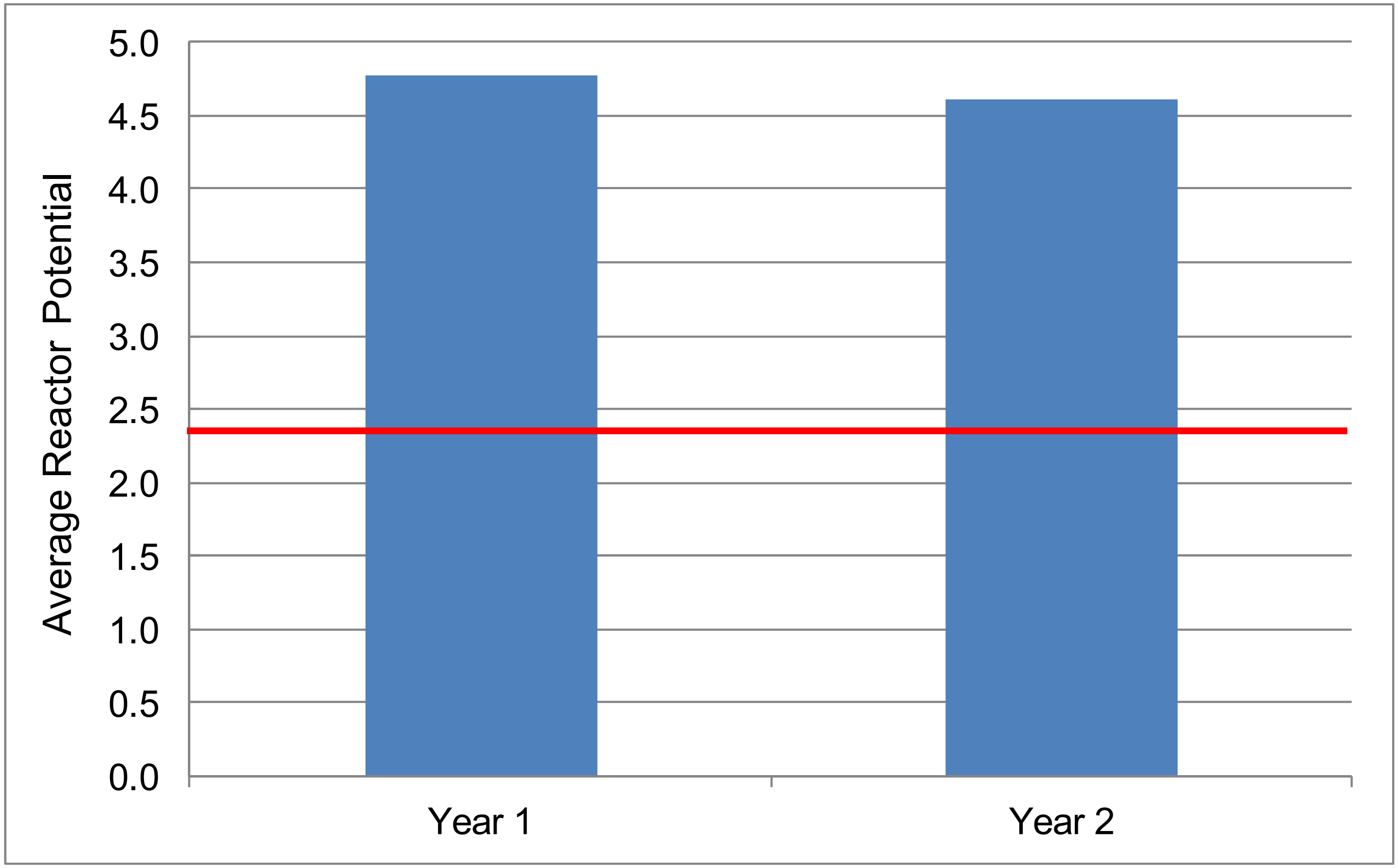
MP306

CatalysTraK® Supplemental Injection Grid

Supplemental injection grids located upstream of both CO and NO_x Catalysts.

CatalysTraK® Reactor Potential Results

CatalysTraK® tests run over two years show the RP is well above the minimum level required.



CO Catalyst Testing

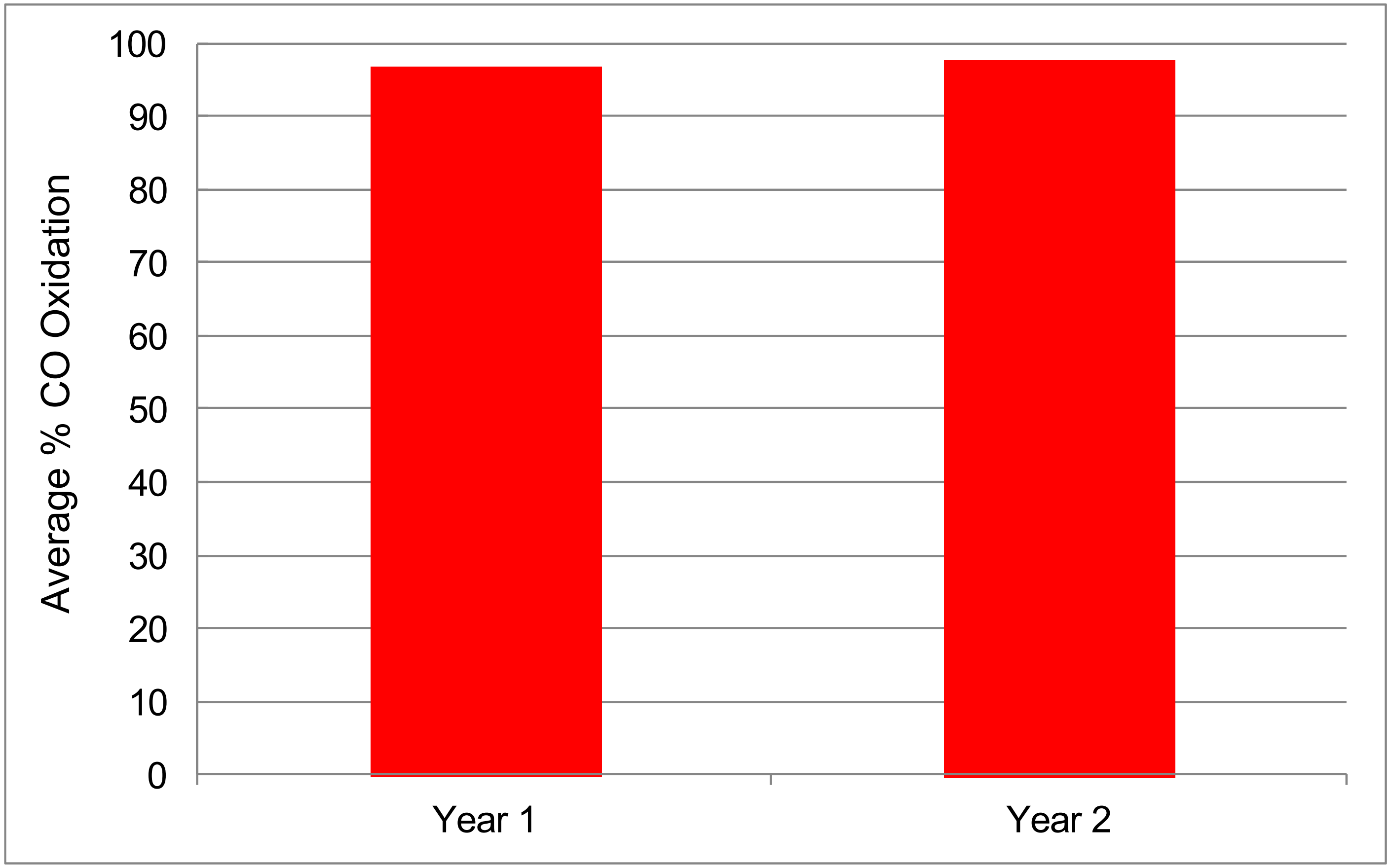
As with SCR catalyst, CO catalyst performance also degrades over time.

Laboratory CO tests involves just measuring the amount of CO oxidation that occurs across the sample, while simulating full-scale temperature and space velocity.

Why not just measure the oxidation across the actual CO catalyst bed while it is operating?

CatalysTraK® CO Catalyst Test Results

The tests run over two years show CO oxidation rates of between 96% and 98%.



Summary

- **Simple stack measurements (NH_3 vs NO_x) can distinguish Gas Bypass from NH_3/NO_x maldistribution**
  - **Facilitated by using a continuous TDL analyzer to make the NH_3 measurements**
- **AIG tuning facilitated using a permanent probe grid at the catalyst exit**
  - **With a probe grid and multipoint sampling, AIG tuning completed in one day**
- **AIG Design affects how well a unit can be tuned**
- **NO_x profiles at the SCR outlet can also help diagnose areas of Gas Bypass**

Summary (Continued)

- Historically, lab tests have been used to monitor the performance of both SCR and CO catalysts over time.
- EPRI recently released GT SCR/CO testing guidelines **(Report 3002006042)**
- Recent tests showed both SCR and CO catalysts can easily be characterized in-situ.
- The in-situ technique is simple.
- It can be done easily during the annual compliance test, does not require an outage, and provides an opportunity to obtain a more comprehensive data set.

Questions?

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