REINHOLD ENVIRONMENTAL Ltd.

2016 NOx-Combustion-CCR Round Table Presentation

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

Diagnostic Tools for Gas Turbine CO and SCR Systems

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Reinhold 2016 NO_x-Combustion Round Table

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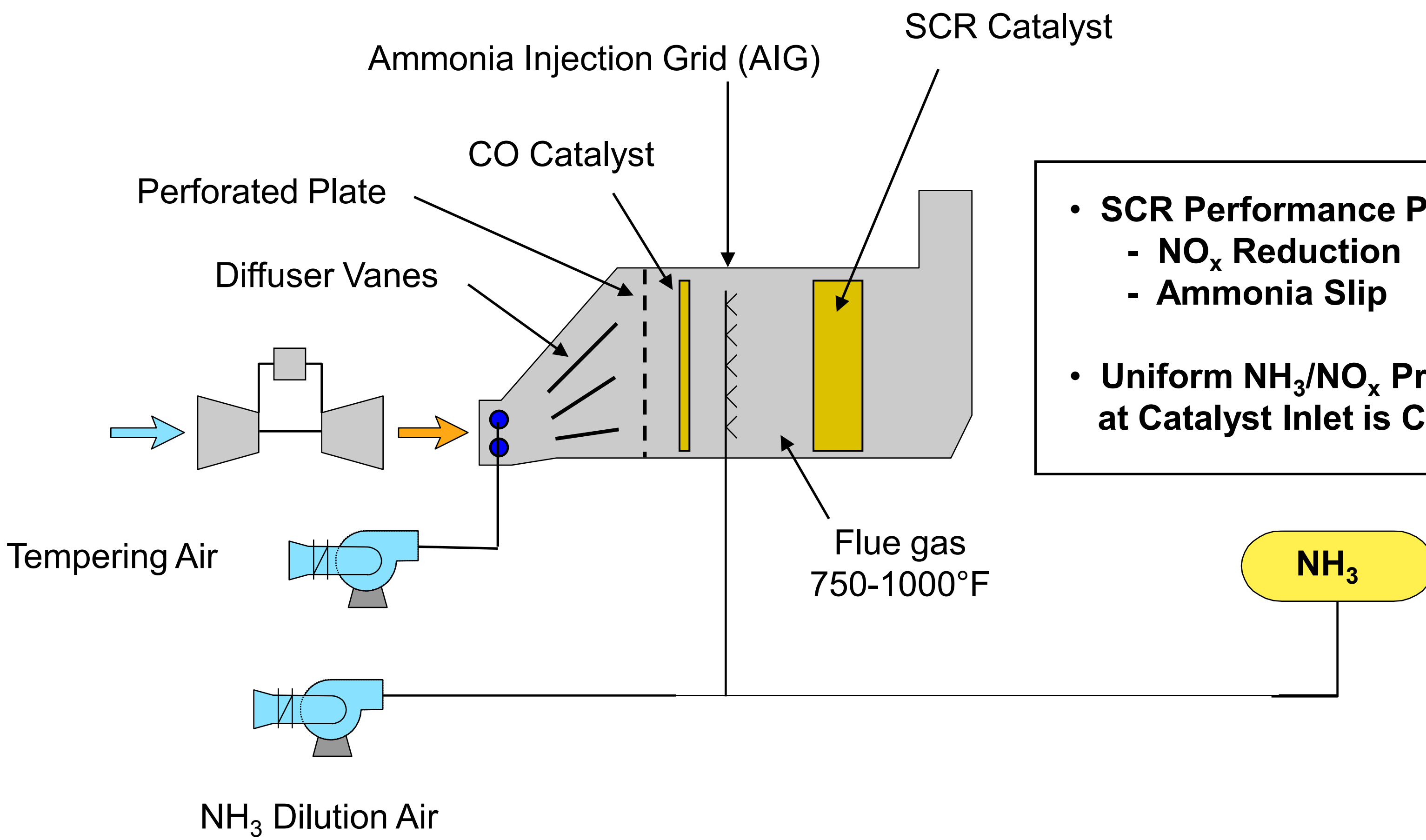
FERCo

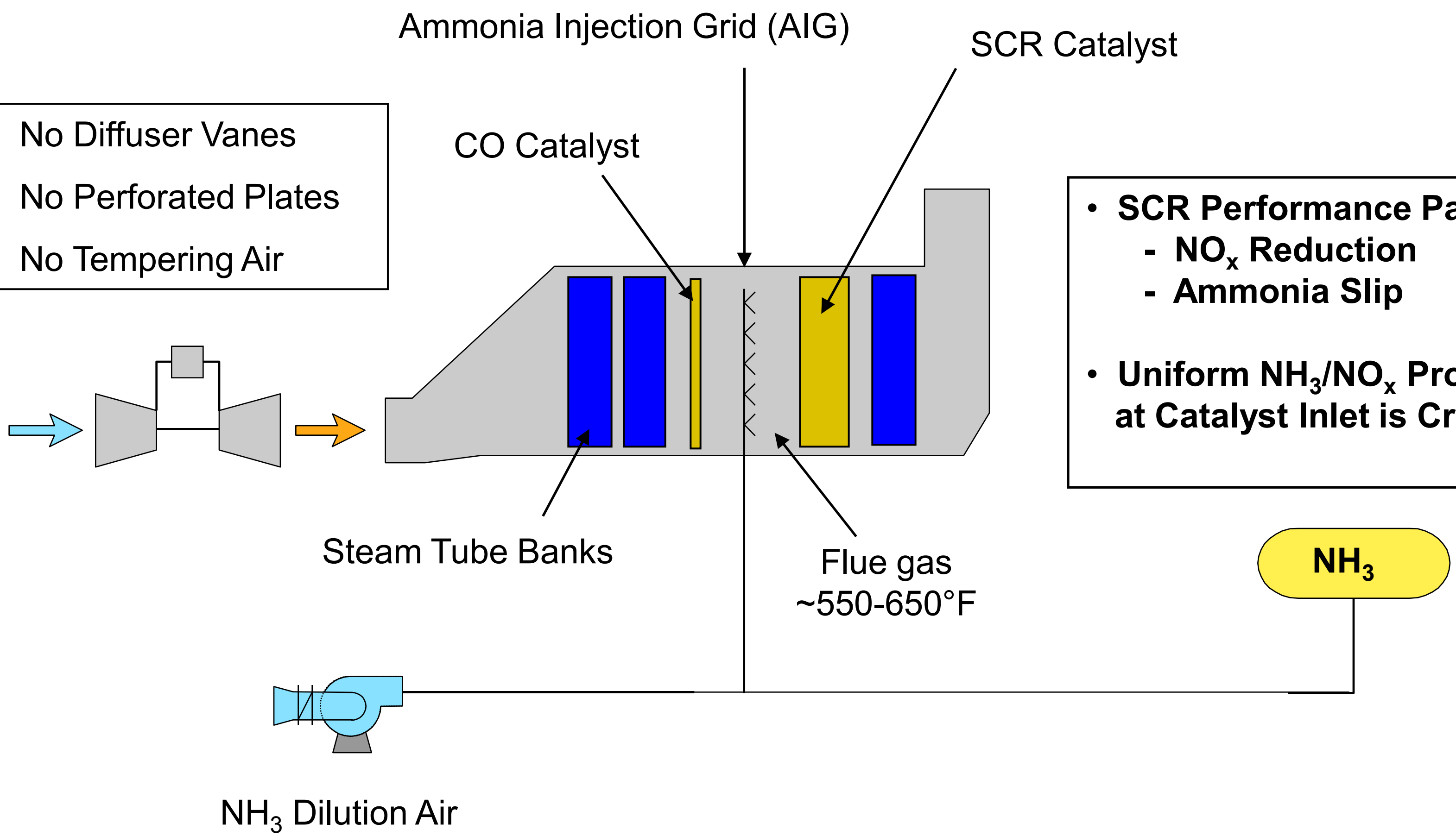
Simple Cycle Gas Turbine SCR



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

Cogeneration Gas Turbine SCR

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



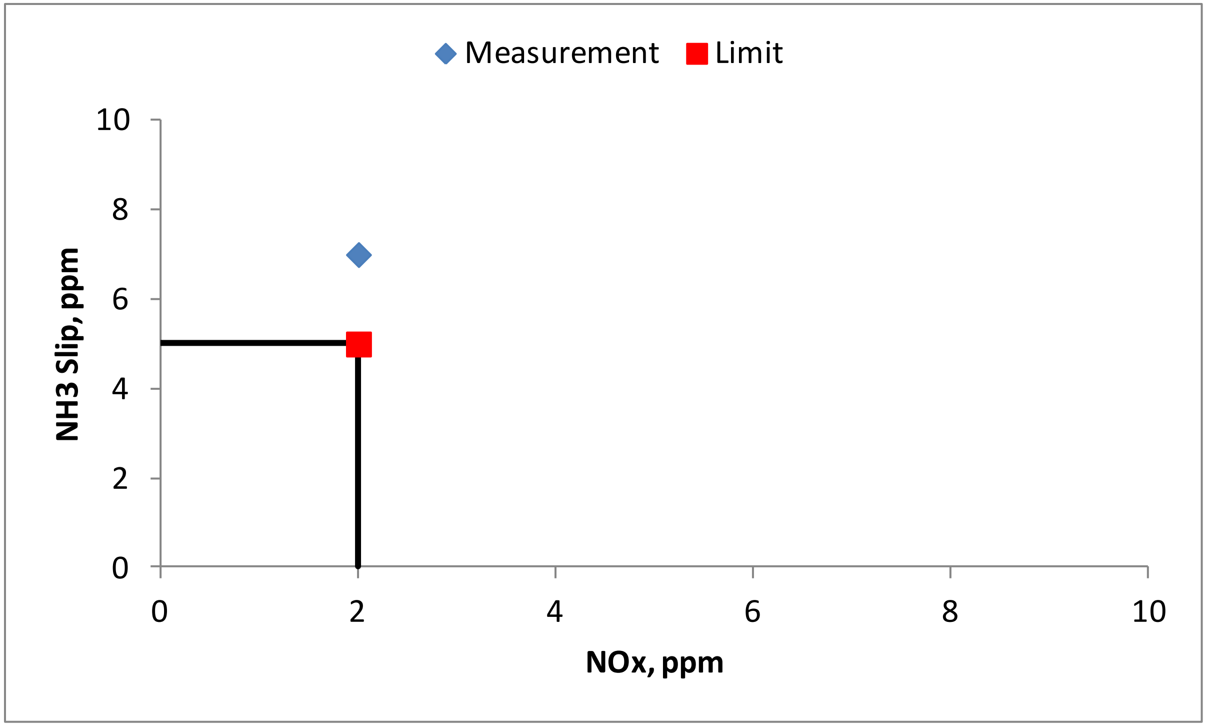
- **SCR Performance Parameters:**
  - **NO_x Reduction**
  - **Ammonia Slip**
- **Uniform NH_3/NO_x Profile at Catalyst Inlet is Critical!**

Optimizing Gas Turbine SCR Performance

Topics

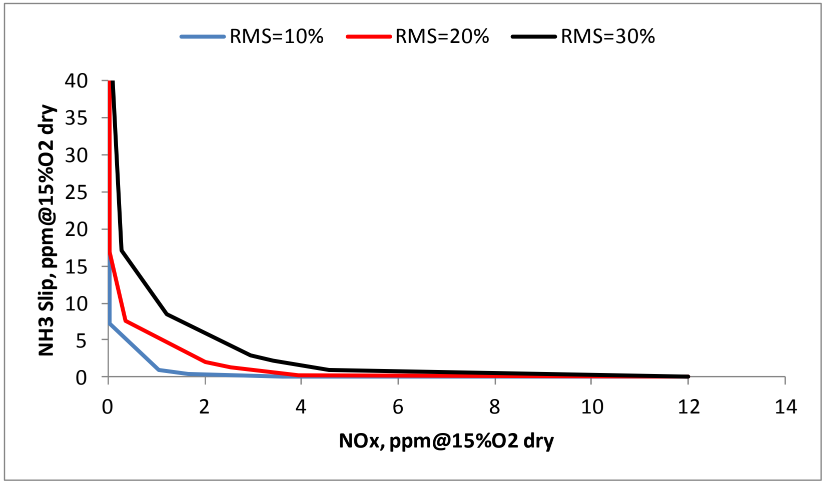
- Troubleshooting - How to Distinguish NH_3 Maldistribution from Bypass
- AIG Tuning - Catalyst Inlet NH_3/NO_x Distribution
- Identifying Flue Gas Bypass
- Catalyst Management/Measuring Catalyst Activity

What Can Lead to Non-Compliance: NH_3/NO_x Maldistribution, Bypass?

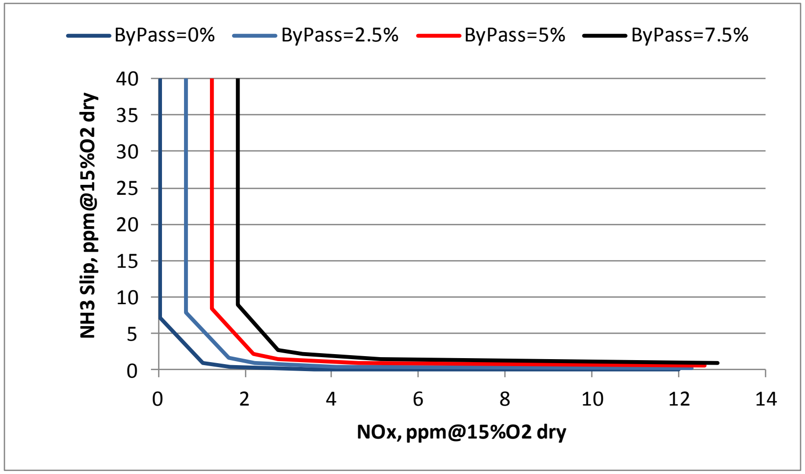


Stack NH_3 vs. NO_x

NH_3/NO_x RMS Effects



Bypass Effects



A simple stack test can distinguish

- NH_3 Maldistribution
- Flue Gas Bypass

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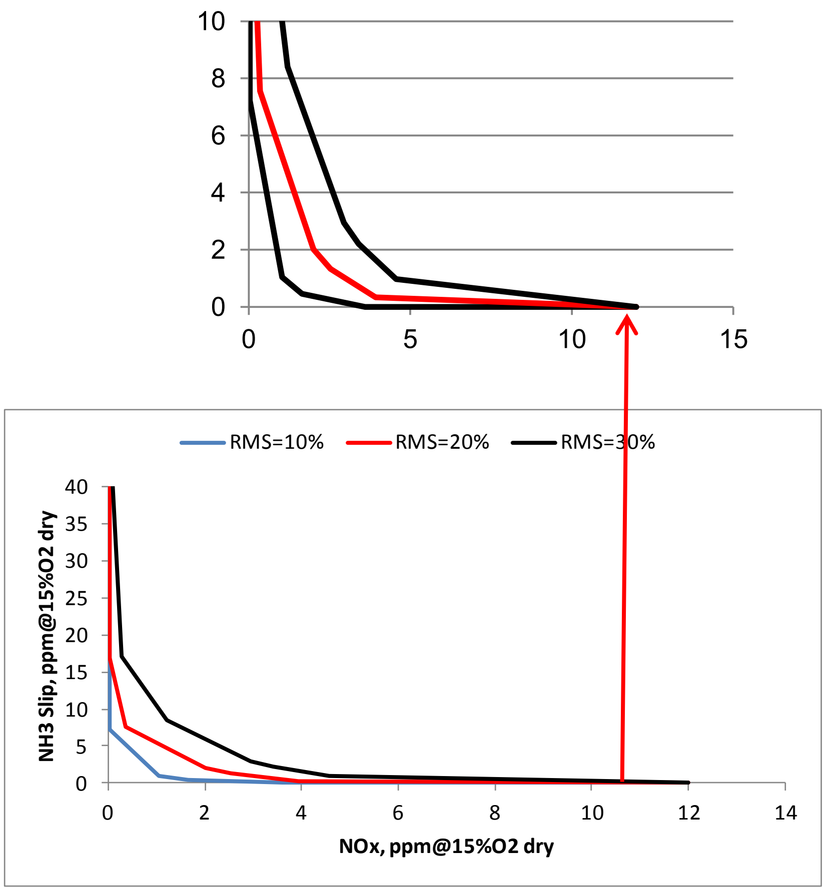
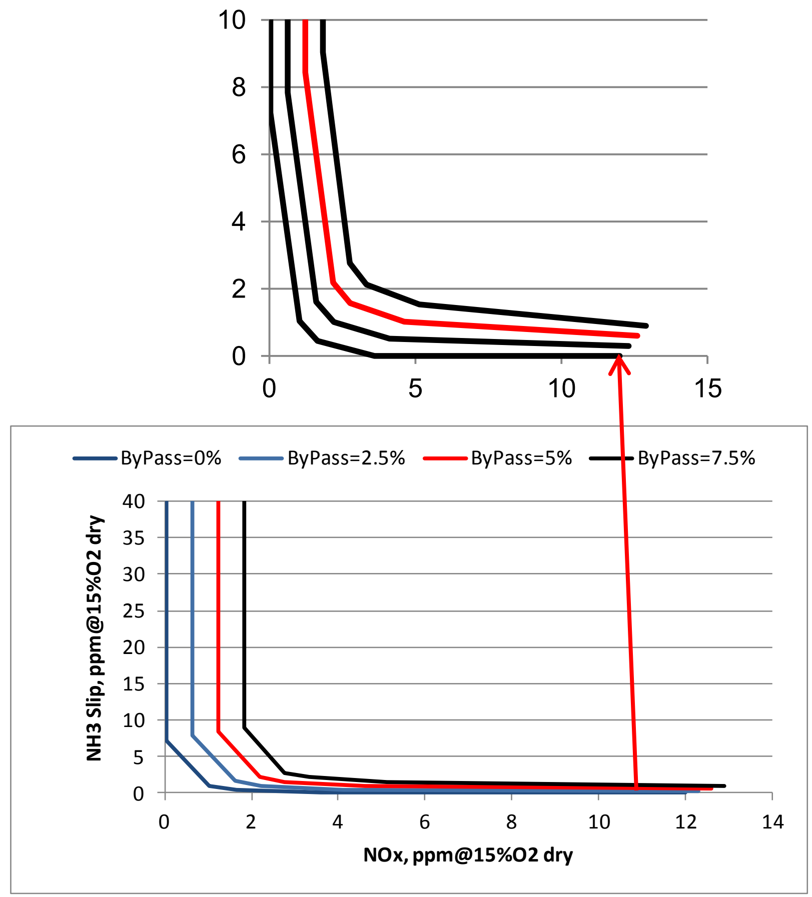
Stack NH_3 vs. NO_x

NH_3/NO_x RMS Effects



Bypass Effects



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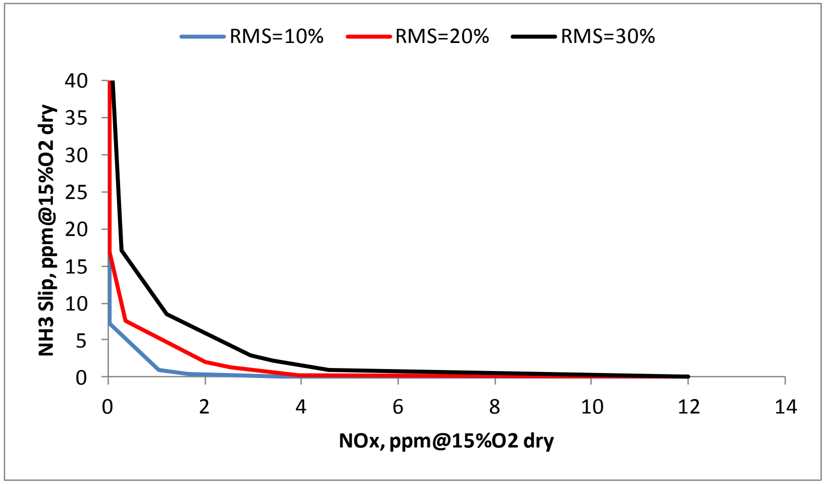
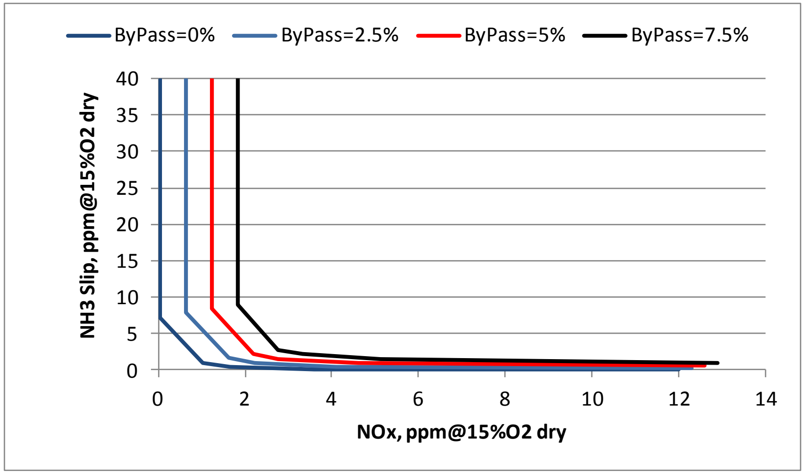
Stack NH_3 vs. NO_x

NH_3/NO_x RMS Effects



Bypass Effects

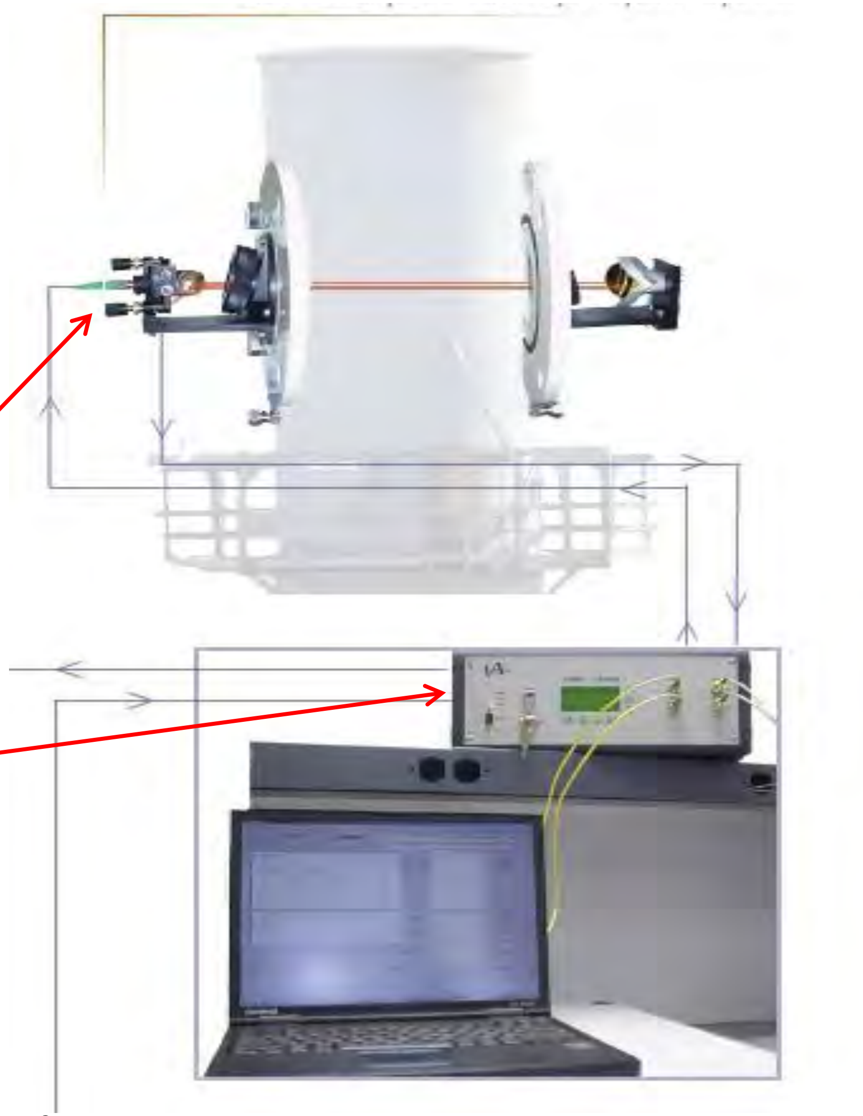


How to best generate this data?

- Wet Chemical NH_3 measurements?
- Continuous NH_3 measurements?

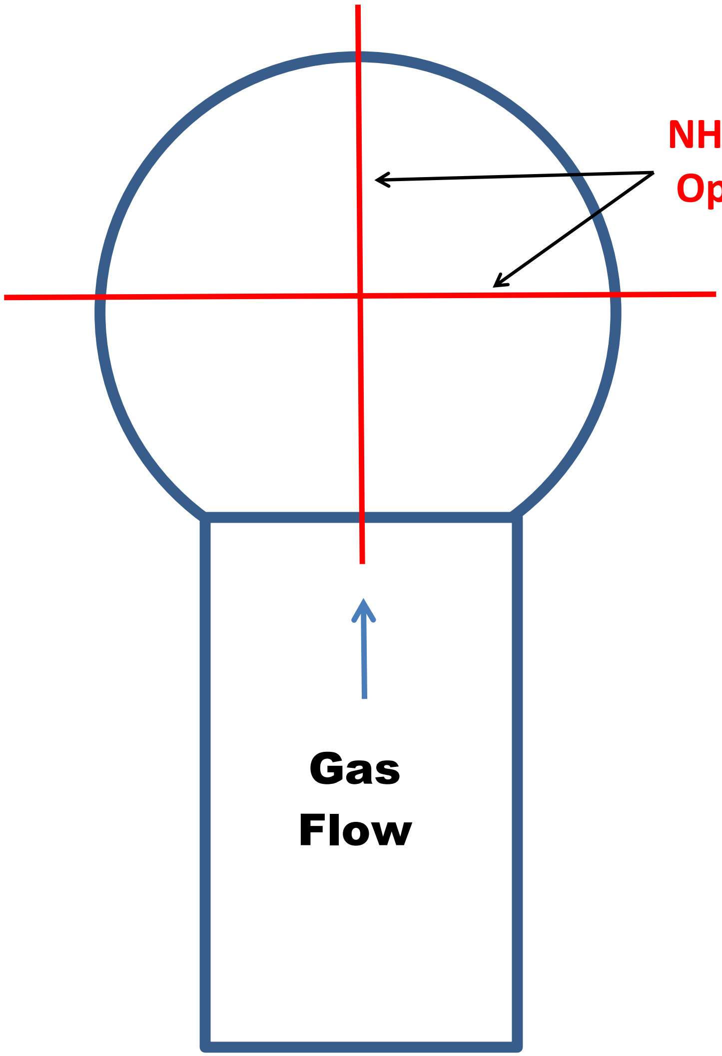
TDL Instrumentation

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



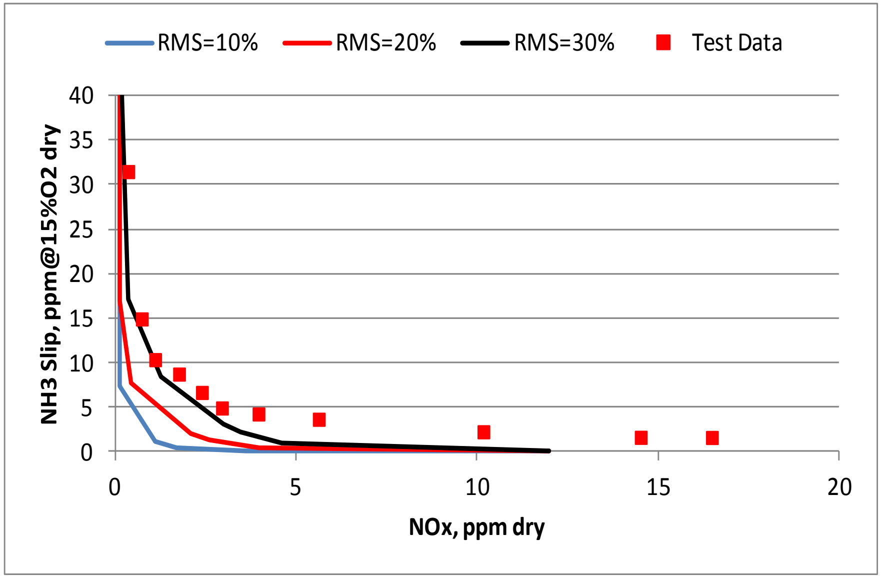
- **Unisearch NH_3 TDL**
  - Dual Path
  - Two Channel
  - Fiber Optic Coupled

NH_3-TDL Lines of Site

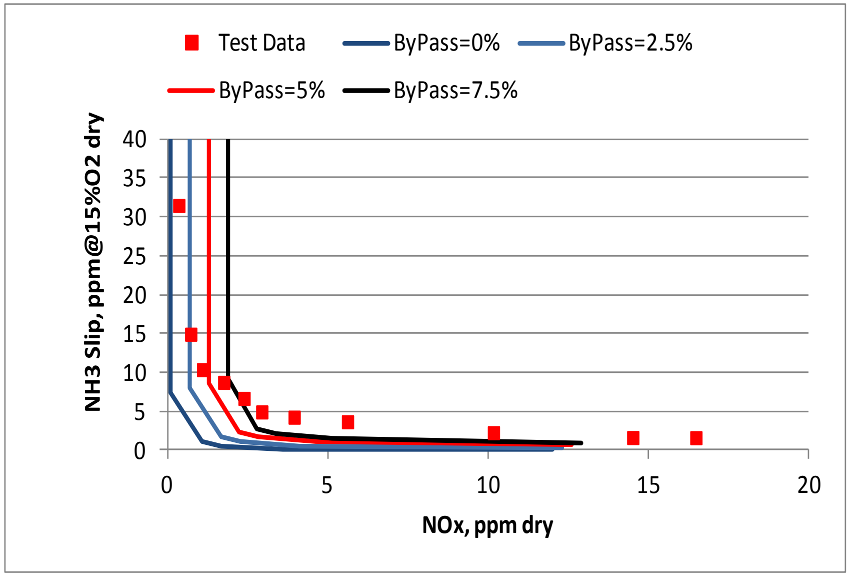


TDL NH_3 Measurements on a Large Combined Cycle

NH_3/NO_x RMS Effects



Bypass Effects



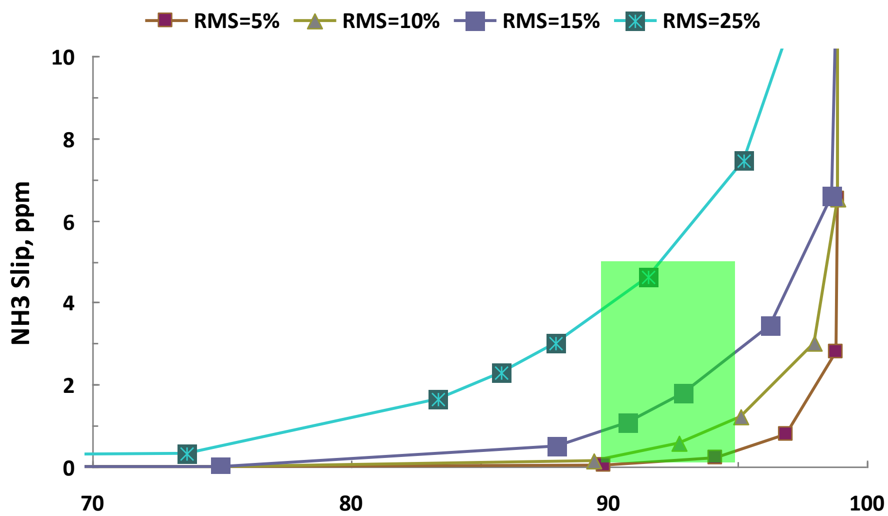
AIG Tuning

Gas Turbine SCR AIG Tuning

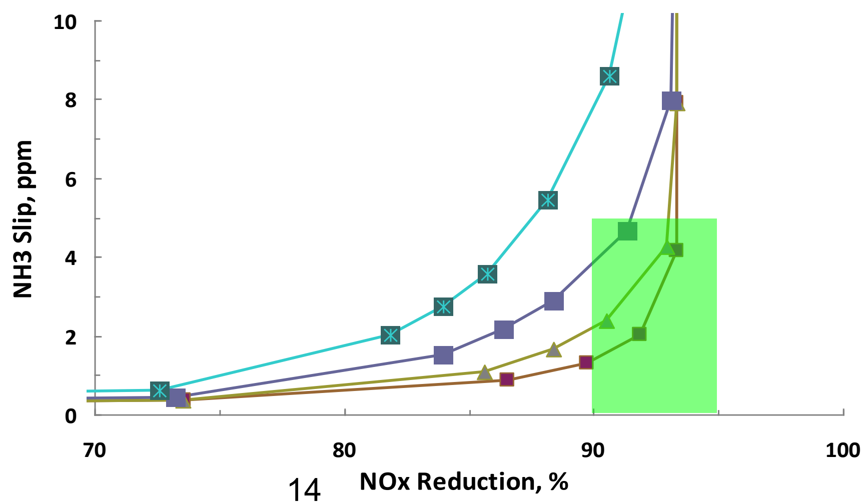
- Tuning is Facilitated by Installing a Permanent Sample Grid at the Catalyst Exit:
  - Not feasible to manually traverse a large combined cycle system for AIG tuning
  - Typically need 36 to 60 probes depending on AIG design
- With Permanent Probes Tuning can Typically be done in One Day
- The NO_x Profiles at the Exit of the Catalyst can also Help Identify Bypass

NH_3/NO_x Distribution and AIG Tuning

New Catalyst

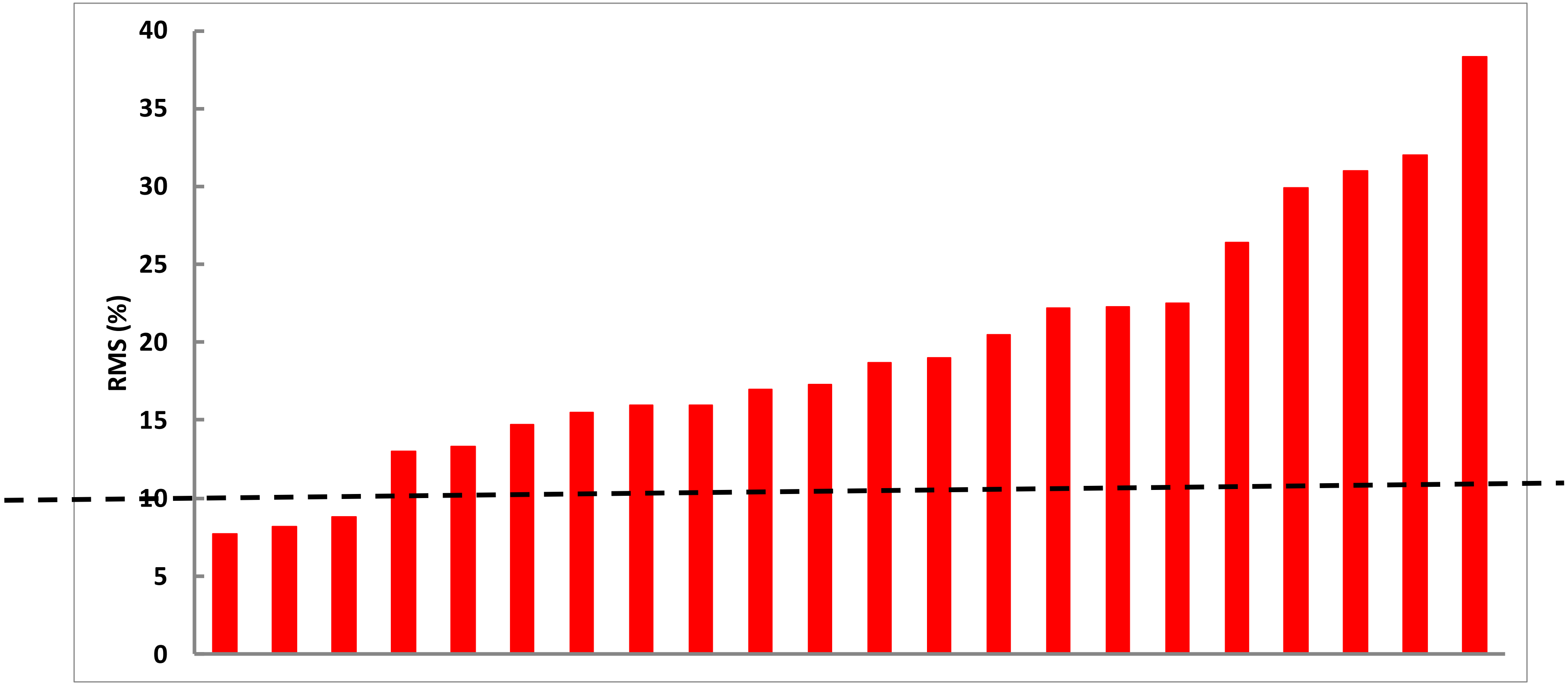


Catalyst Near End-of-Life



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

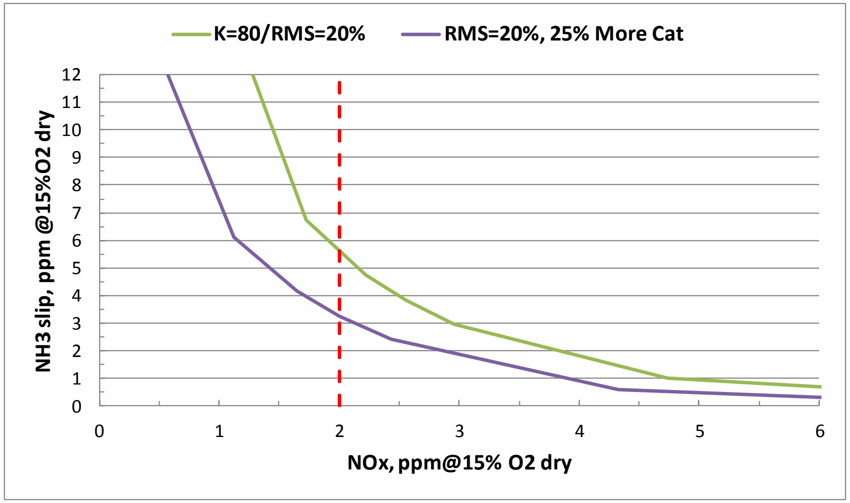
Most of the GT AIGs we encounter are not tuned very well!



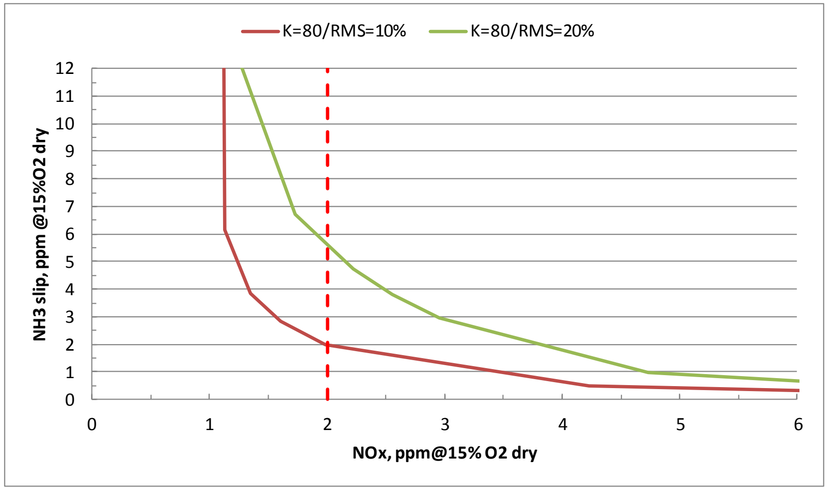
How Important is the NH_3/NO_x Distribution?

- 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

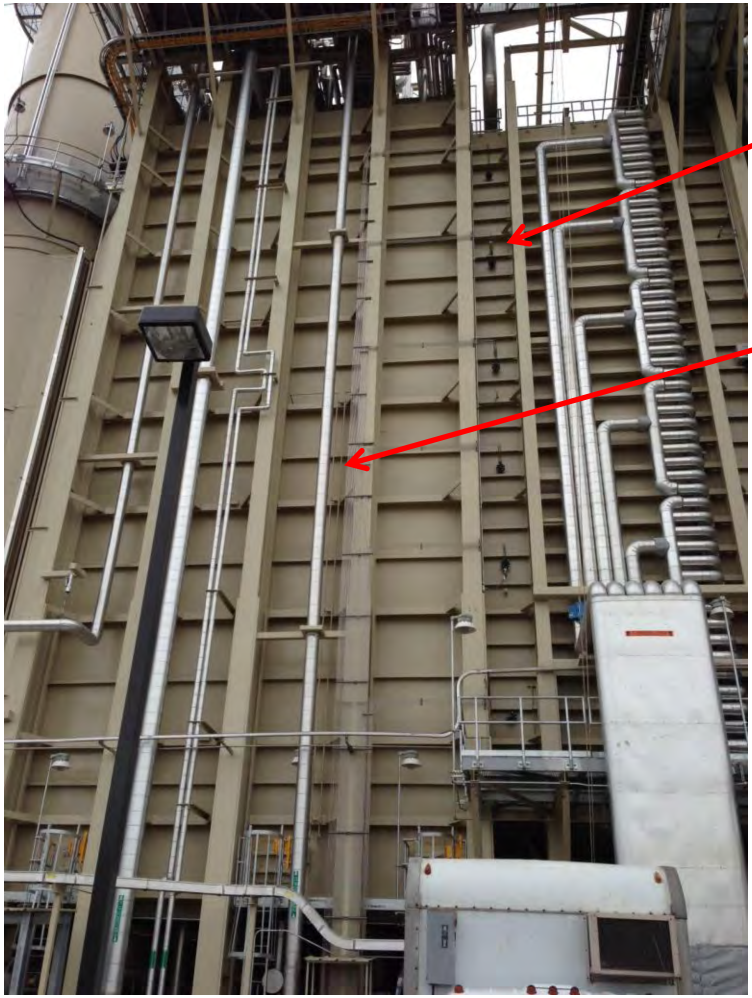


Tune AIG To RMS=10%



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

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

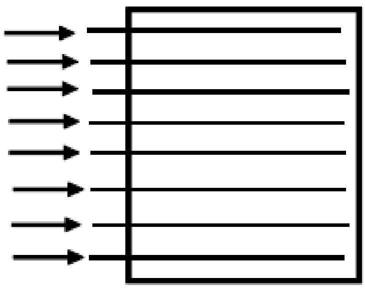
FERCo's Multipoint Instrumentation

- Samples 48 points in 15 minutes
- NO_x and O_2

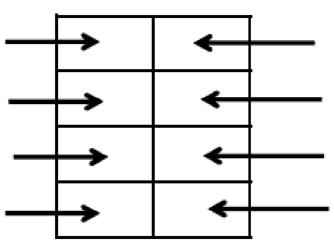
AIG Design Affects Tuning

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

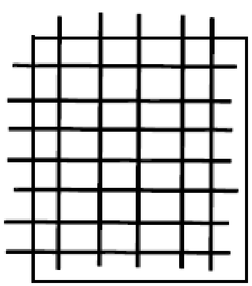
- **1-D: Commonly used design**



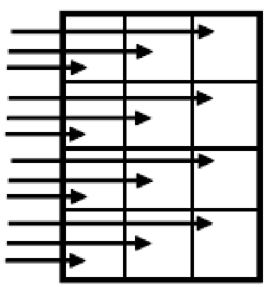
- **Multi Zone: Better**



Two Horizontal Zones

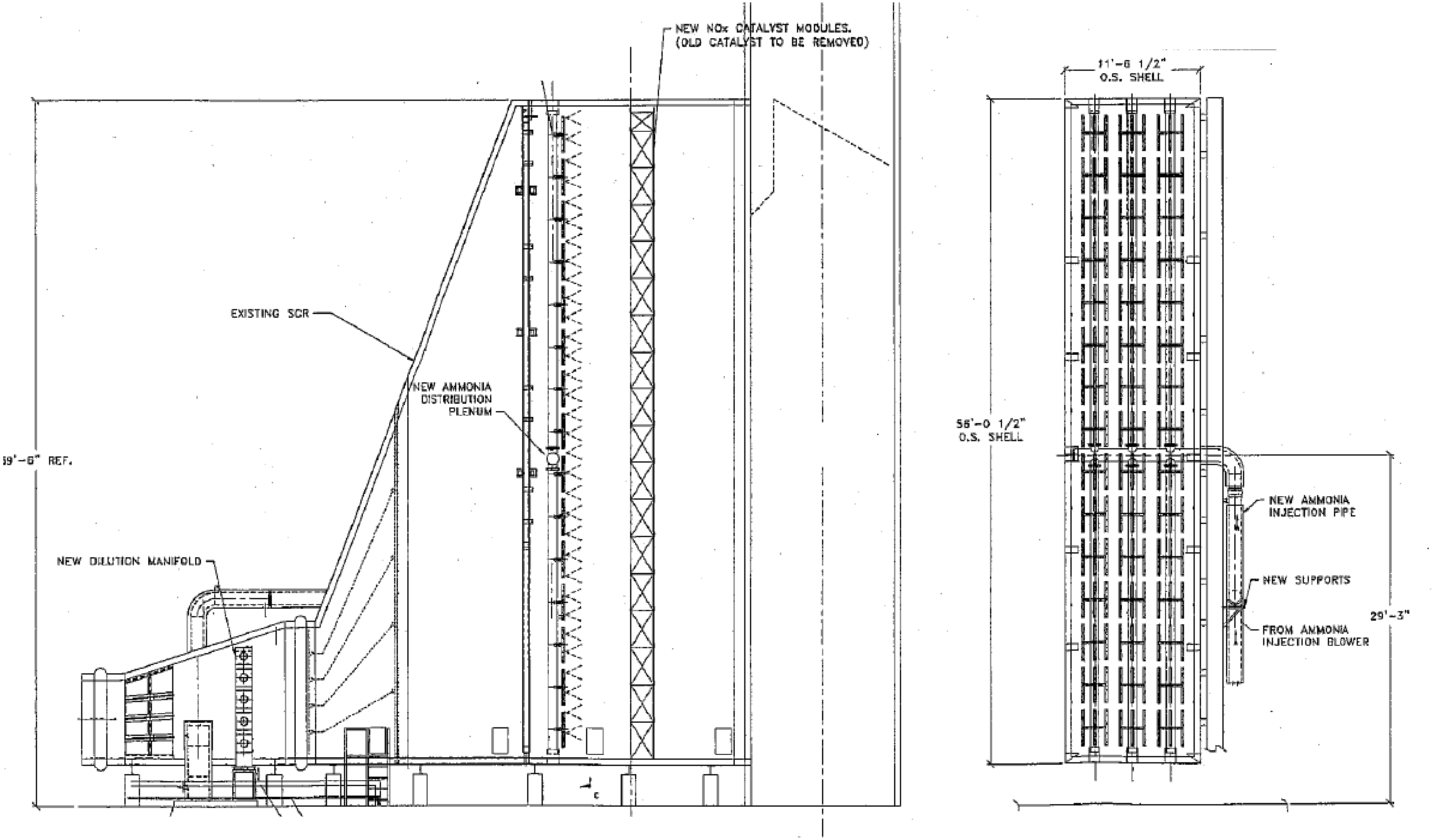


Horizontal and Vertical Lances

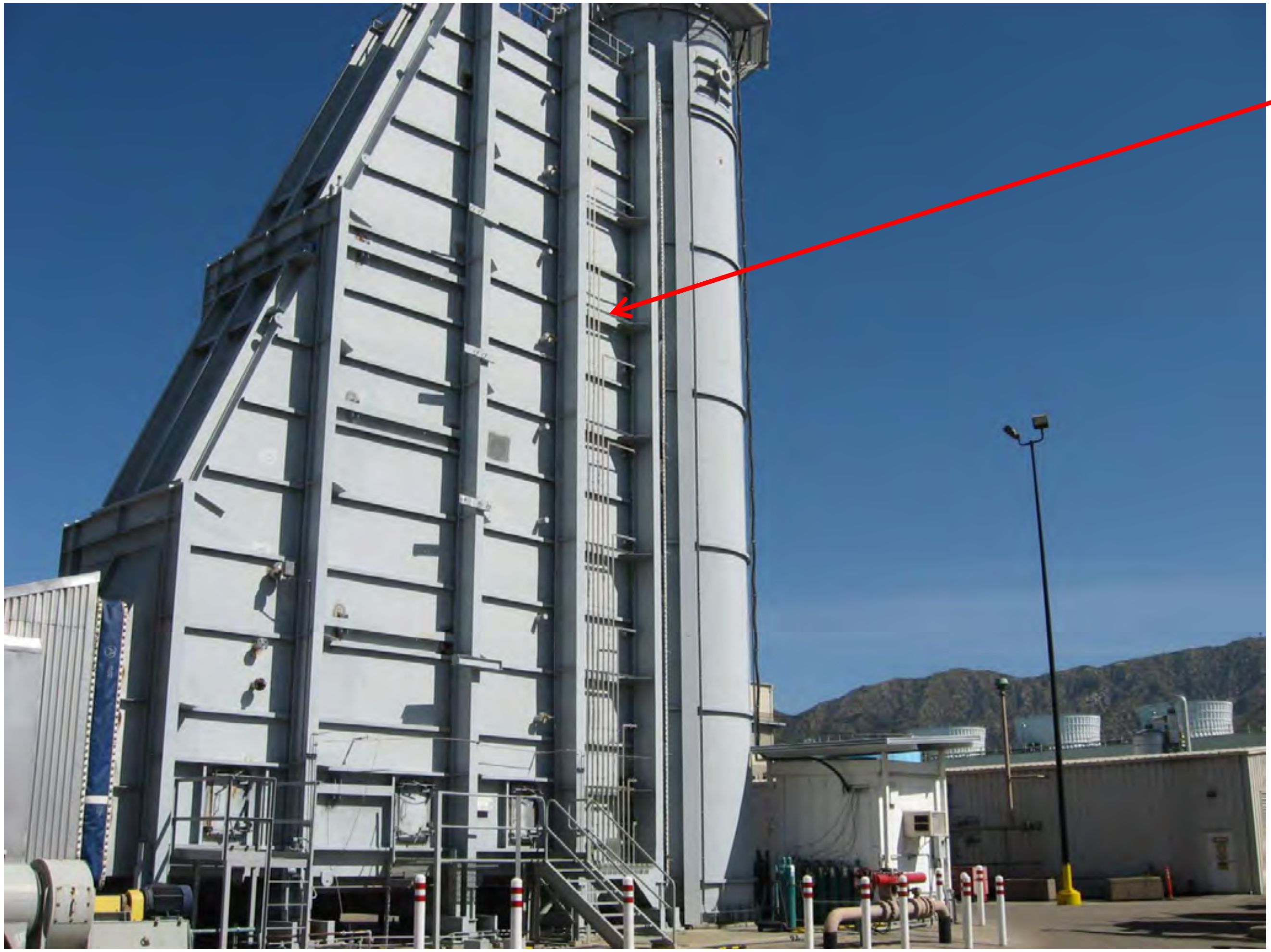


Three Horizontal Zones

AIG With No Adjustability

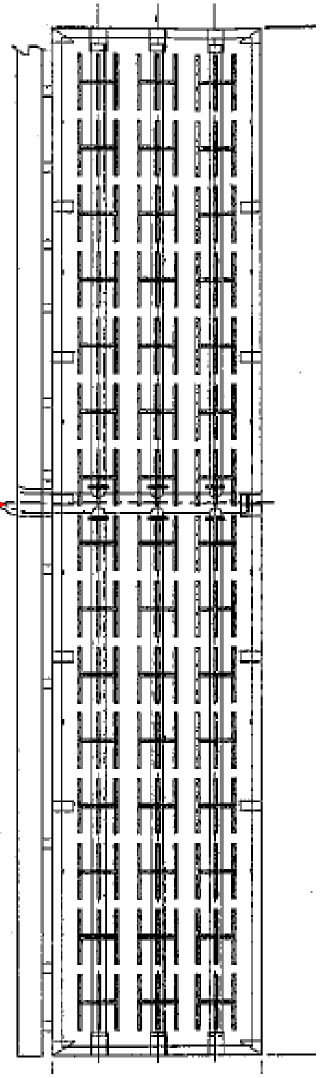


AIG: No Adjustability



Permanent Probe Grid for Tuning. Difficult to Tune Without !

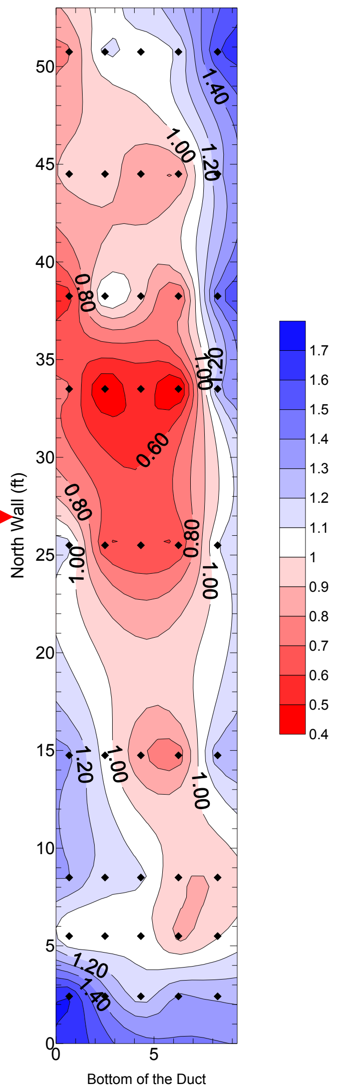
Normalized NH_3/NO_x Profiles – As Found



NH_3 Header

NH_3 Header

<u>Orig. AIG RMS = 35%</u>



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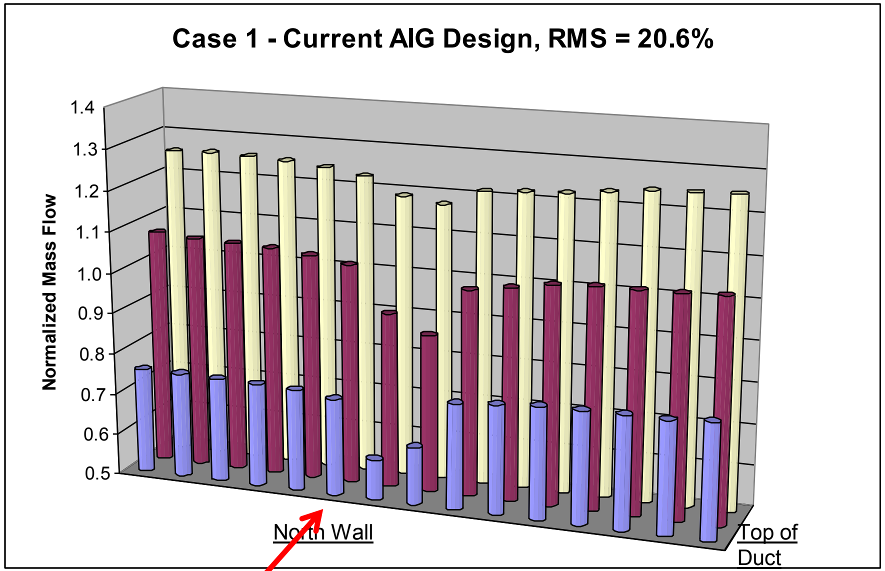
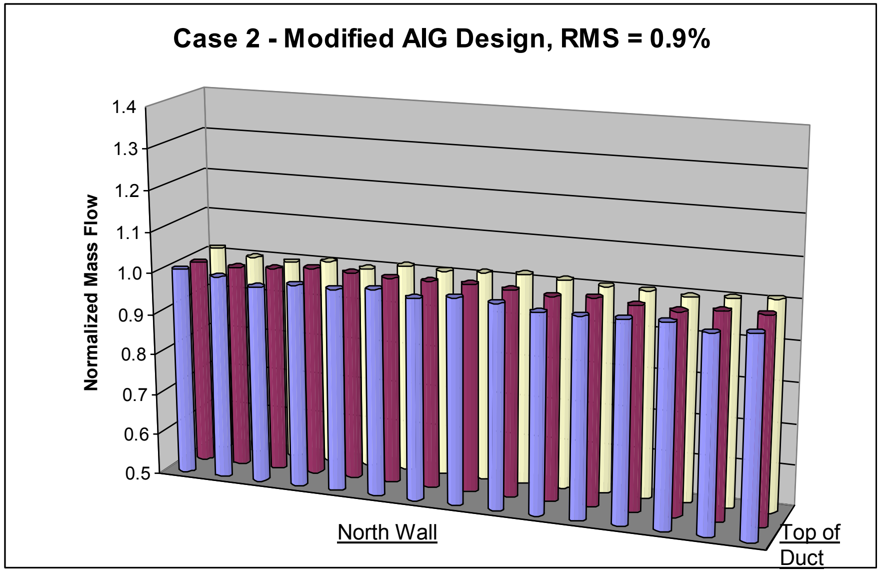
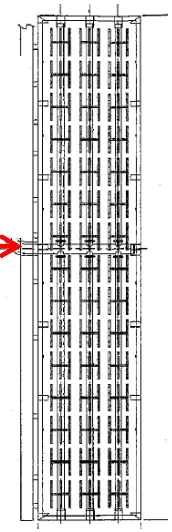
CFD RESULTS





Ammonia Enters This Side



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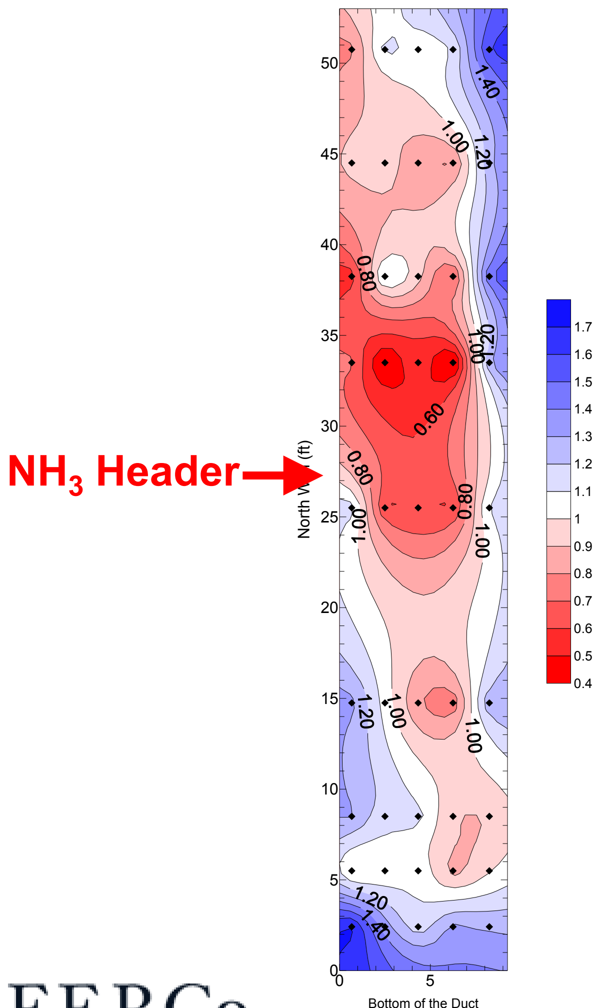
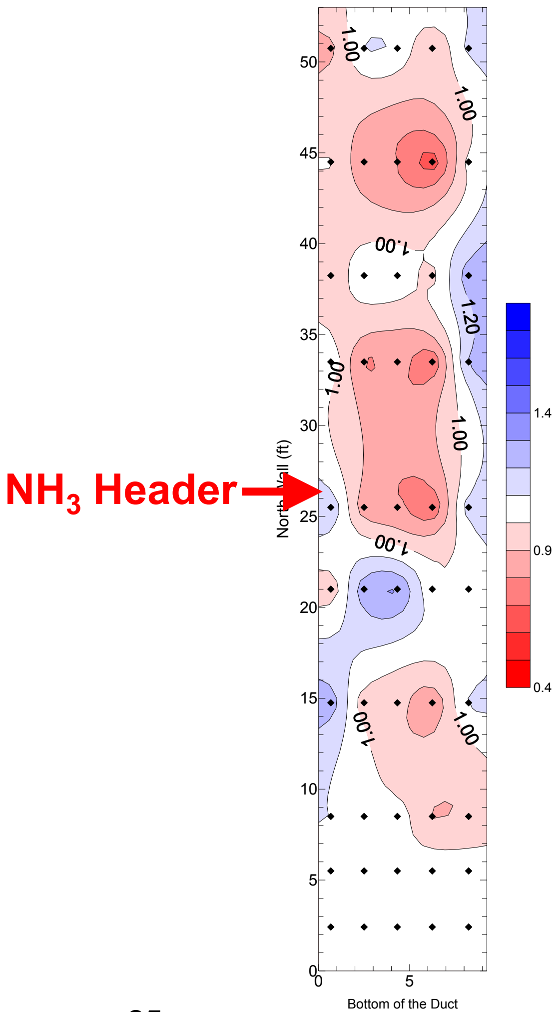
Normalized NH_3/NO_x Profiles – Before & After

Orig. AIG RMS = 35%

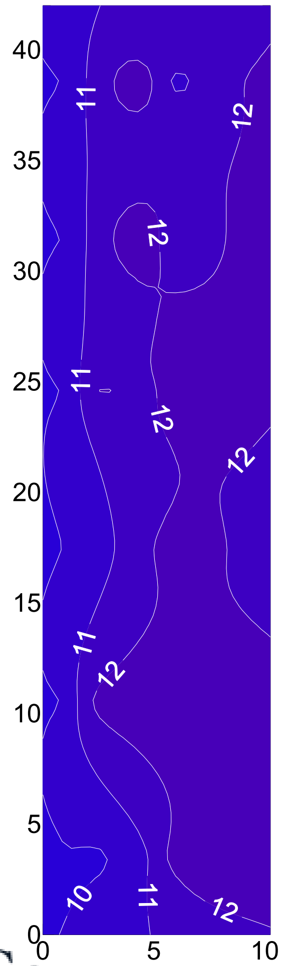


All Holes Resized RMS = 16%

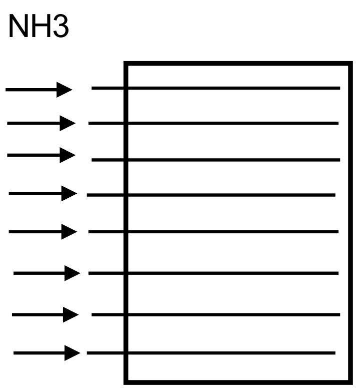


Duct Burners Impact AIG Tuning

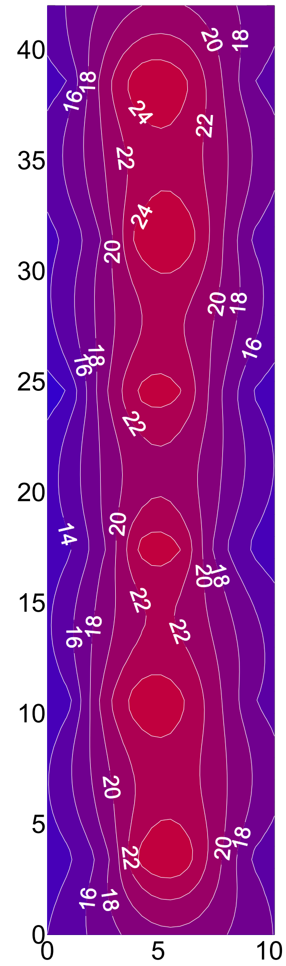
Duct Burners Off
(Inlet NO_x ppm)



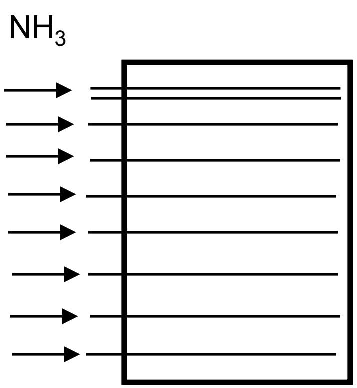
AIG Difficult to Tune



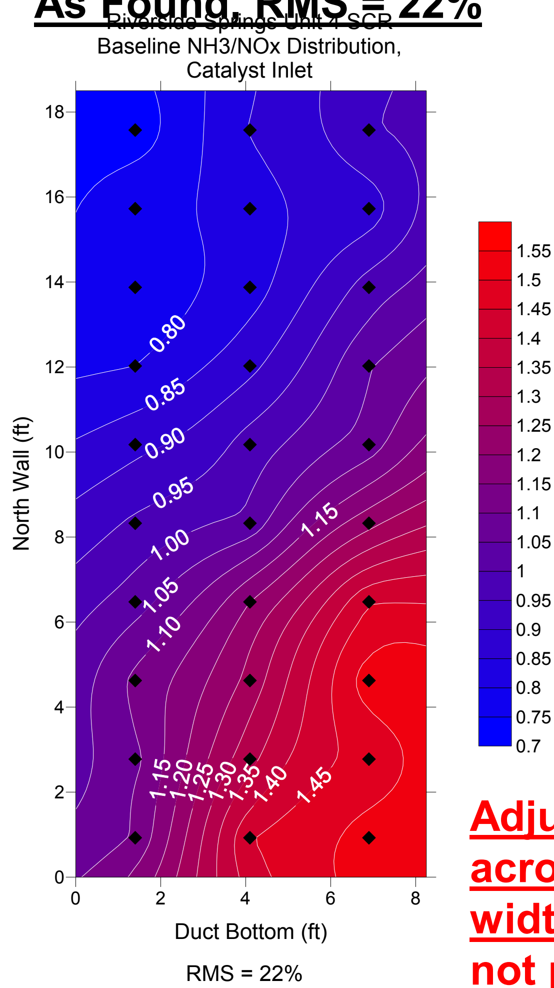
Duct Burners On
(Inlet NO_x ppm)



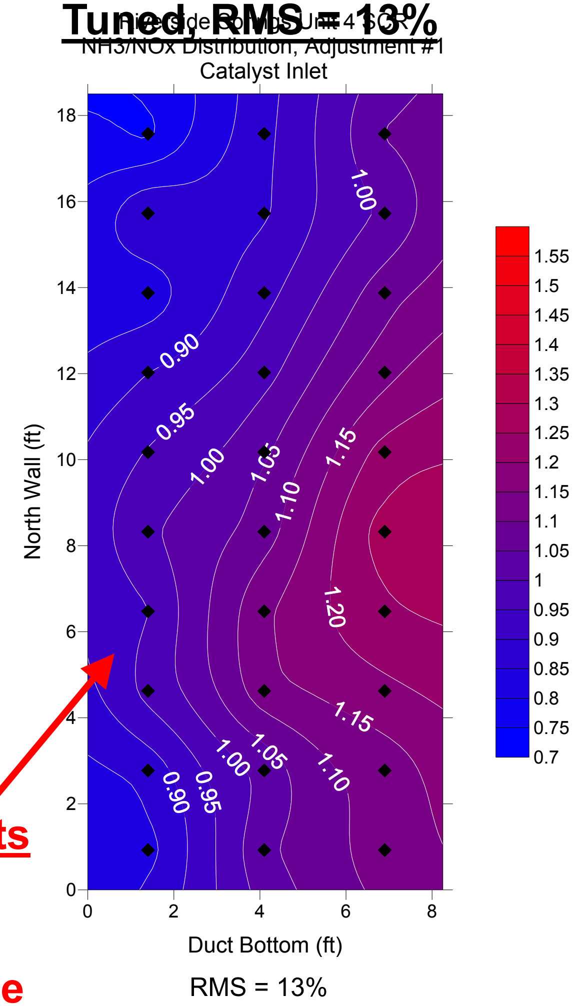
AIG Tuning, 1-D AIG Design; NH_3/NO_x



As Found, RMS = 22%



Tuned, RMS = 13%



Adjustments across the width not possible

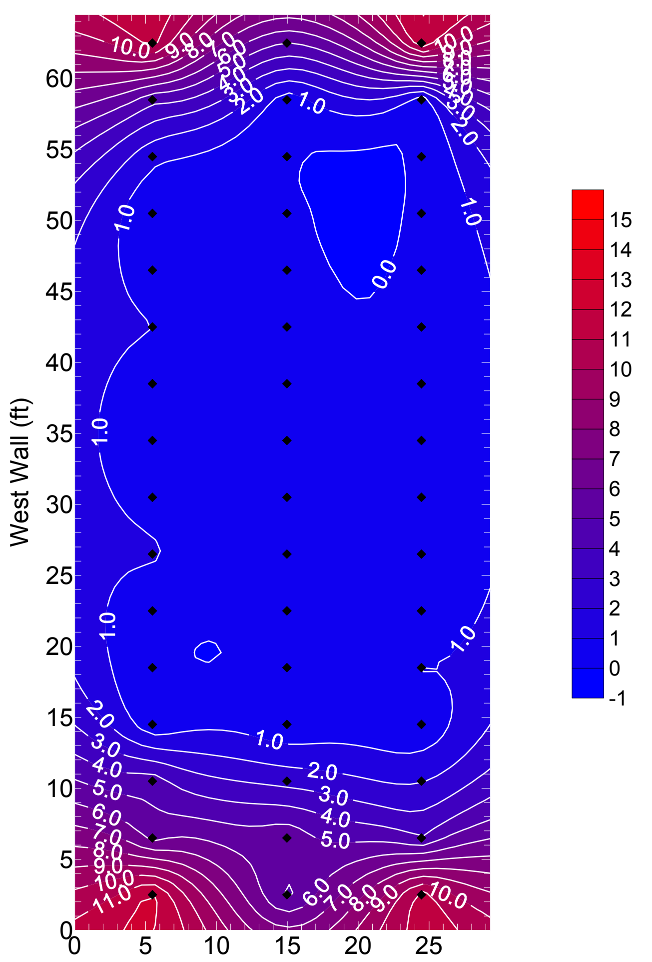
AIG Tuning, 1-D AIG Design; Outlet NO_x

Port Westward

Test 01, Full Load, 8-6-2012
Raw NOx Profile
Filename: Port Westward NOx01

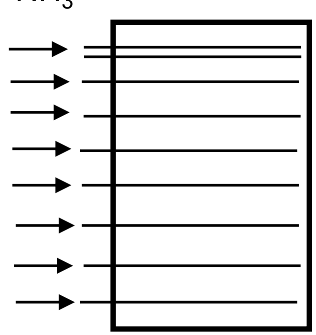
As Found

Flow into the page



RMS = 163%

Reagent consumption reduced 5%

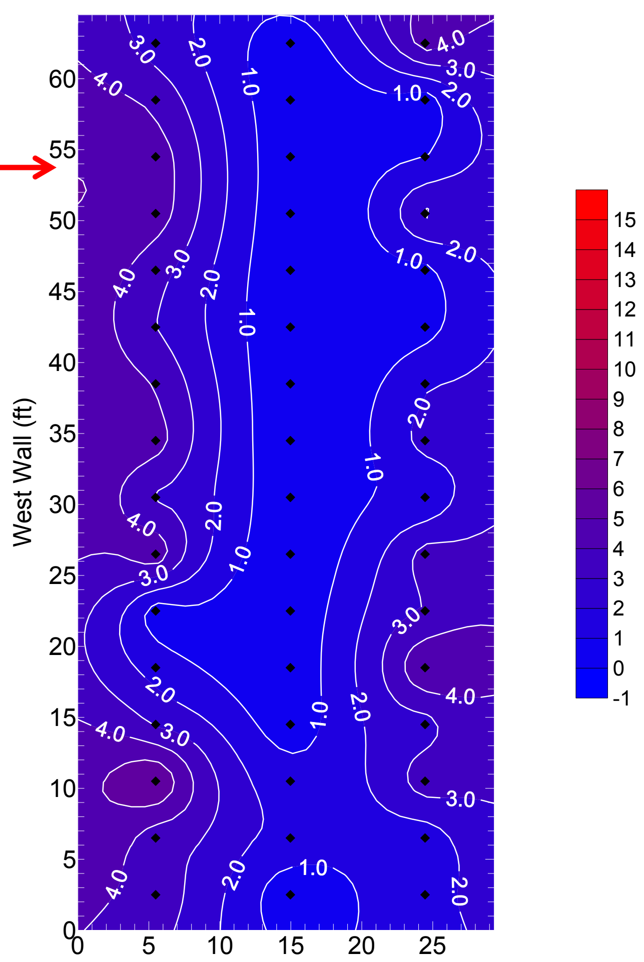


Port Westward

Test 09, Full Load, 8-8-2012
Raw NOx Profile
Filename: Port Westward NOx09

Tuned

Flow into the page



RMS = 82%

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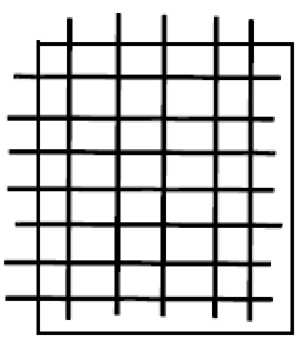
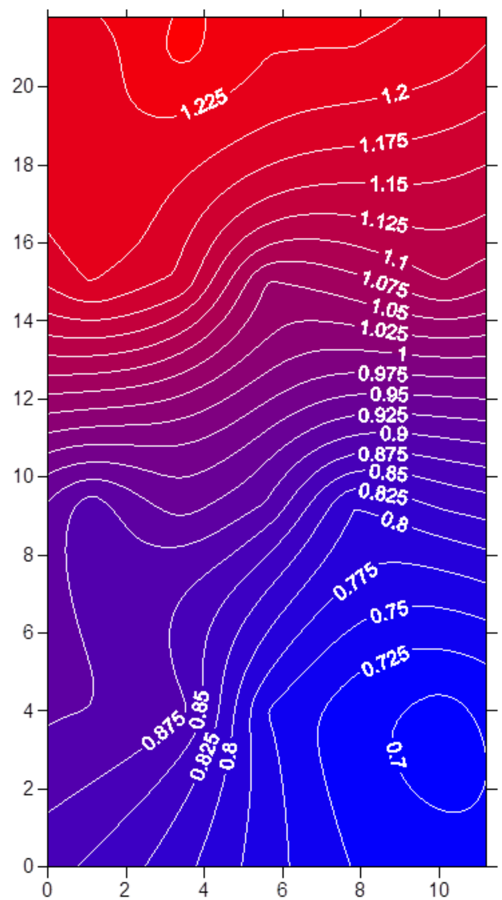
MP303

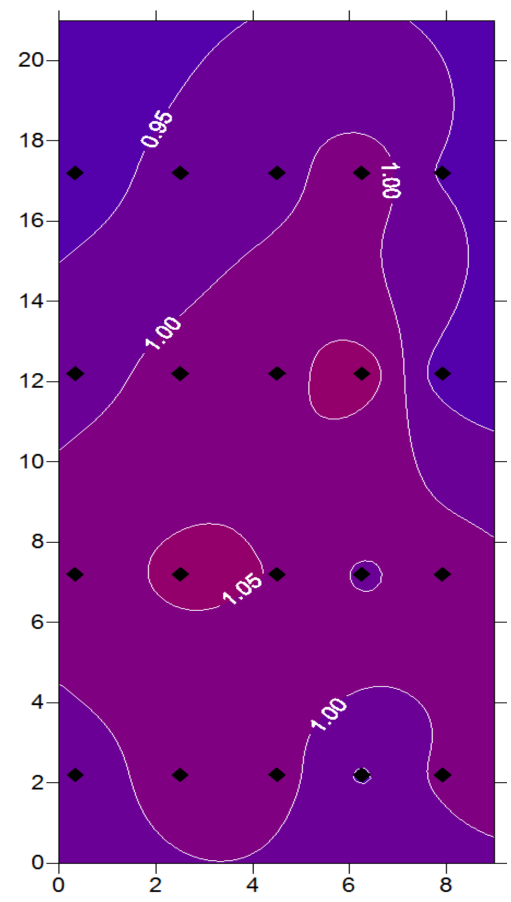
AIG Tuning, Multi Zone AIG Design; NH_3/NO_x



As Found, RMS = 19%



Tuned, RMS = 5%



Benefits of AIG Tuning

- Ability to meet NO_x and NH_3 slip requirements
- 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

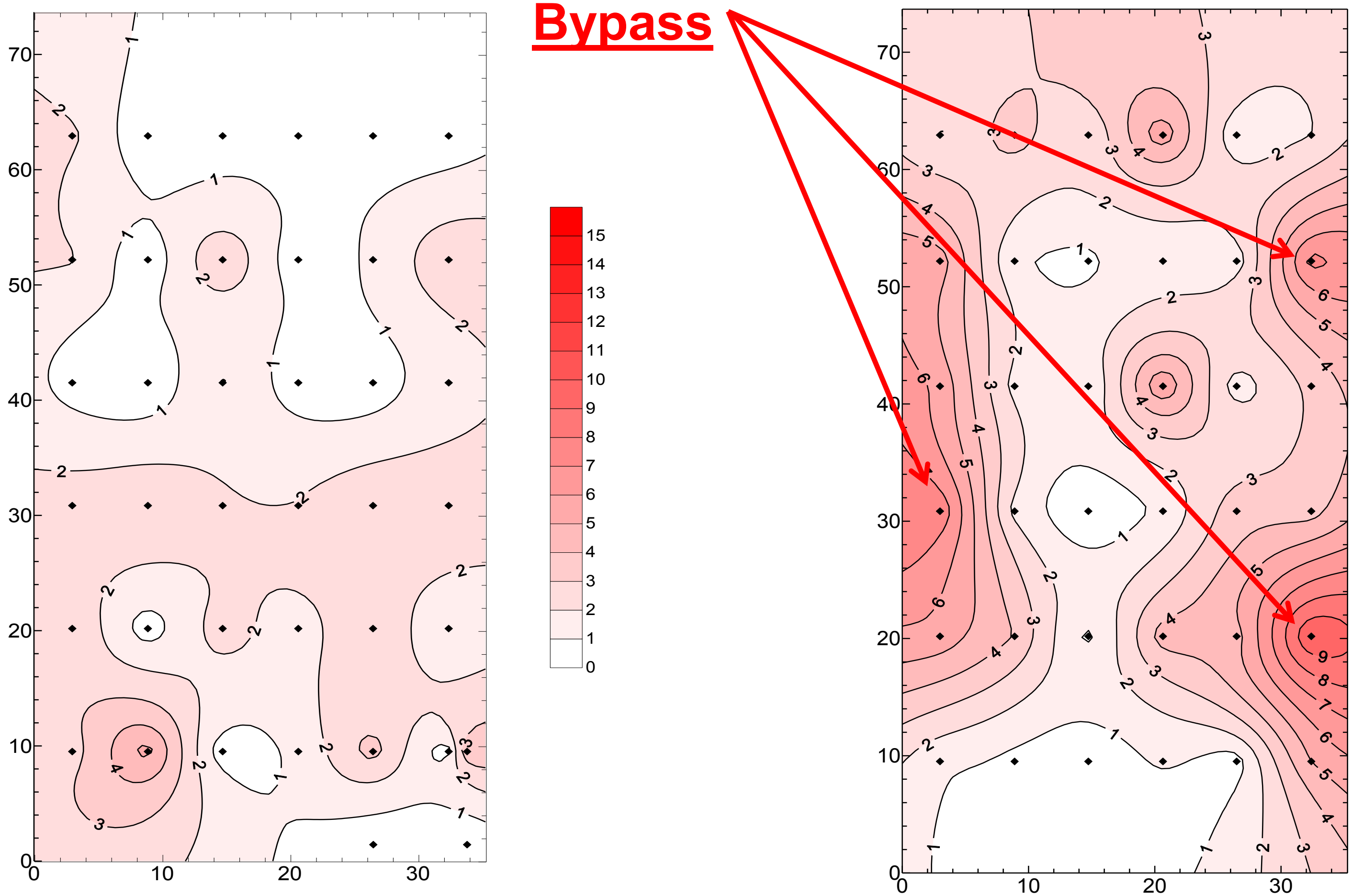
Bypass

NO_x Profiles Can Also Help Detect Bypass

Base Year

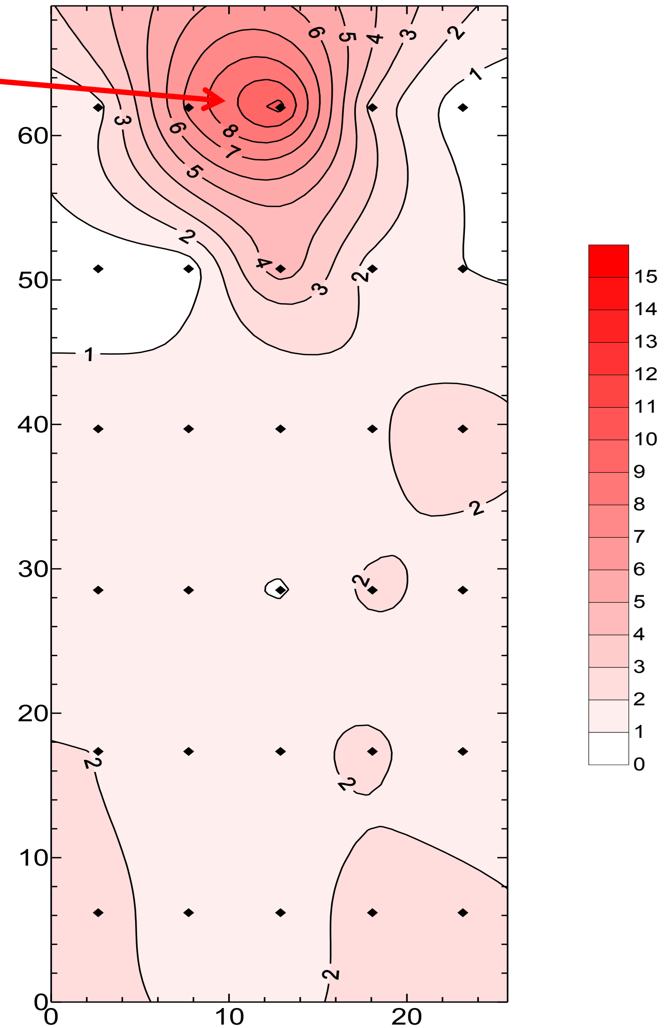
Possible Bypass

Two Years later



NO_x Profiles Can Also Help Detect Bypass

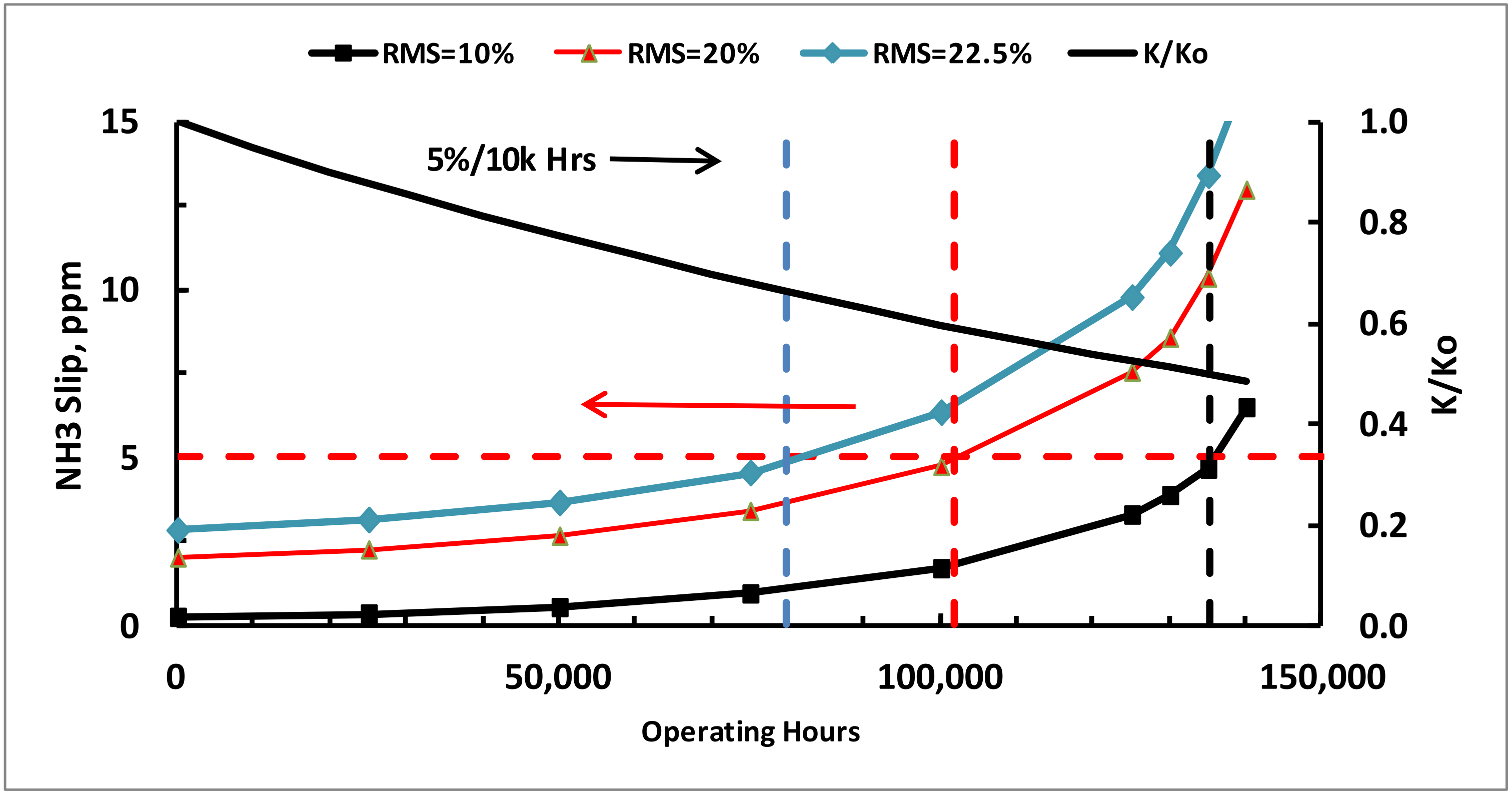
Possible Bypass



Catalyst Management

Catalyst Management

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



Catalyst Management

Catalyst management for a combined cycle SCR system entails tracking key parameters so you know when the catalyst must be changed.

These Parameters are:

1. **Catalyst Activity (K, m/hr)**
2. **Reactor Potential (RP, dimensionless)**

Catalyst Activity

- Catalyst Activity determines how well a catalyst is performing regarding NO_x reduction.
- Typical poisons in a combined cycle SCR include sodium and phosphorous.
  - Na: GT water injection, water for aqueous NH3 production, ambient sources (ocean air).
  - P: GT lube oil

Reactor Potential

- **Although catalyst activity is important, the key parameter for determining SCR performance is the reactor potential RP.**
- **RP is essentially the activity multiplied by the total catalyst surface area per unit of exhaust gas.**

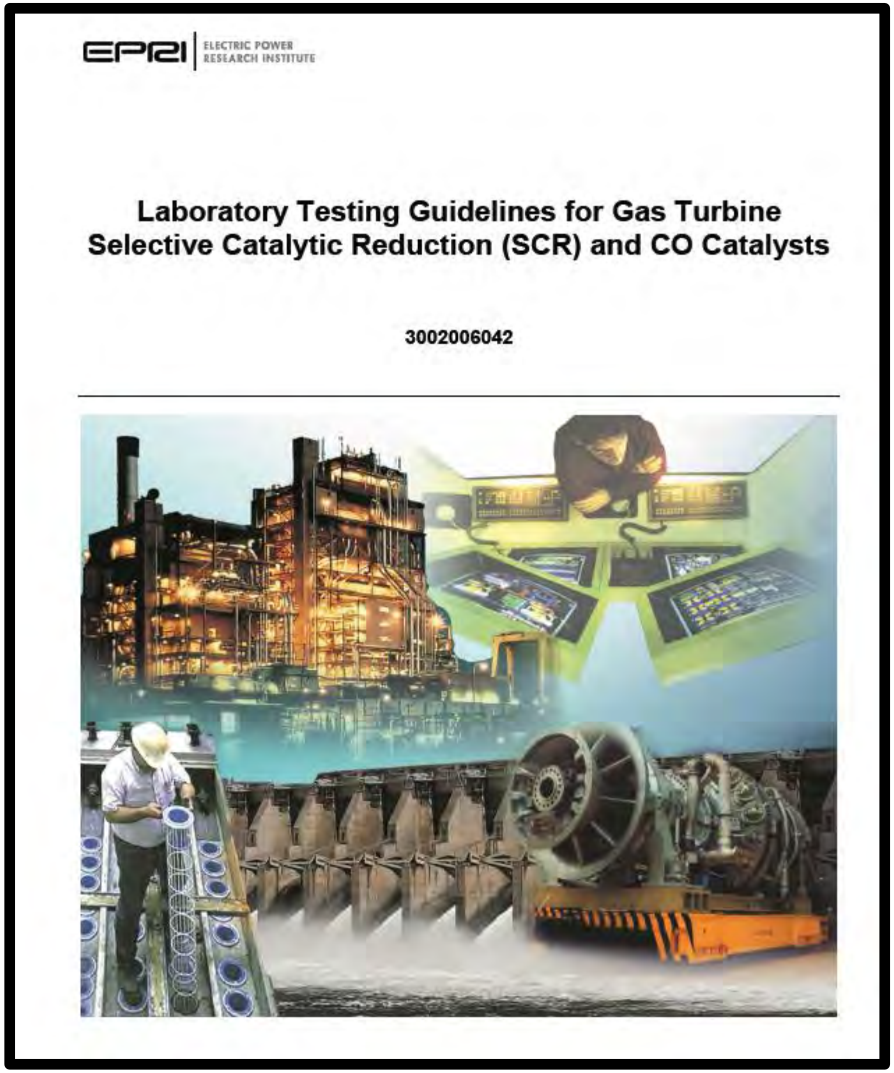
$$RP = \frac{(K)(A_{surface})}{Q} = \frac{K}{A_v}$$

- **RP is important because it reflects the effects of both catalyst activity and area velocity.**

Catalyst Activity

- **Laboratory activity measurements historically has been a key step in catalyst management**
- **Until recently there were no standard testing guidelines for GT SCR or CO catalyst. This led to variations among laboratories.**
- **EPRI recently released a Guideline for testing Gas Turbine SCR and CO catalyst**
- **Available at the EPRI Website (Report 3002006042)**

EPRI GT SCR/CO Testing Guidelines



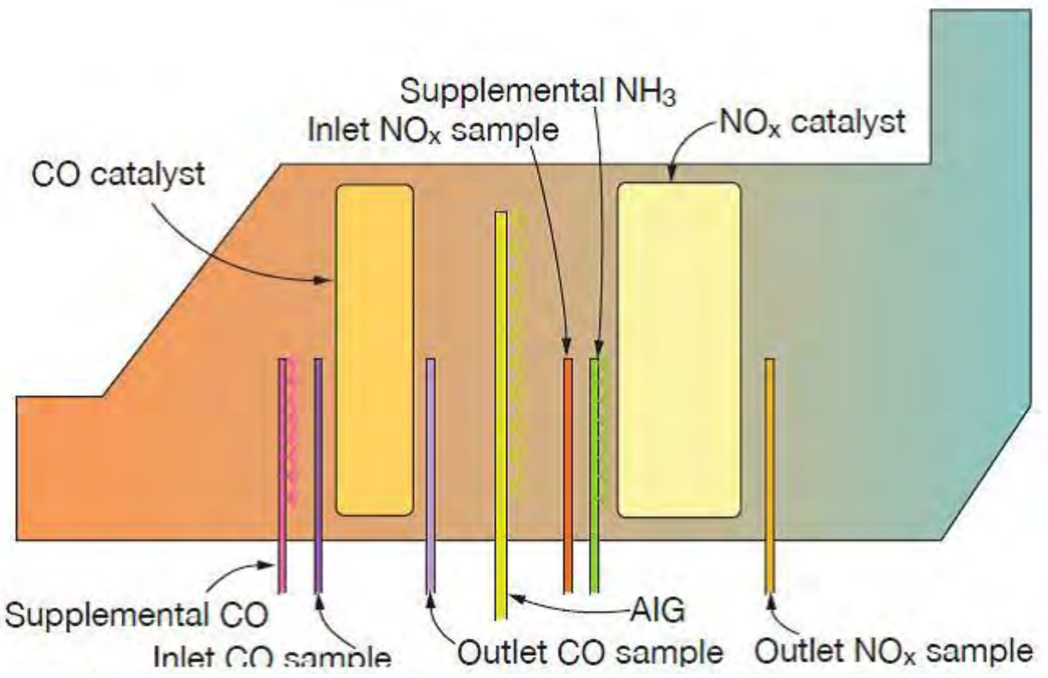
- Developed by an industry consortium
- SCR Catalyst: Outlines Standardized Test Methods
  - Activity, K
  - ΔNOx @ NH_3 slip limit
- CO Catalyst
- Chemical and Physical Analysis

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**

CatalysTraK® System Components

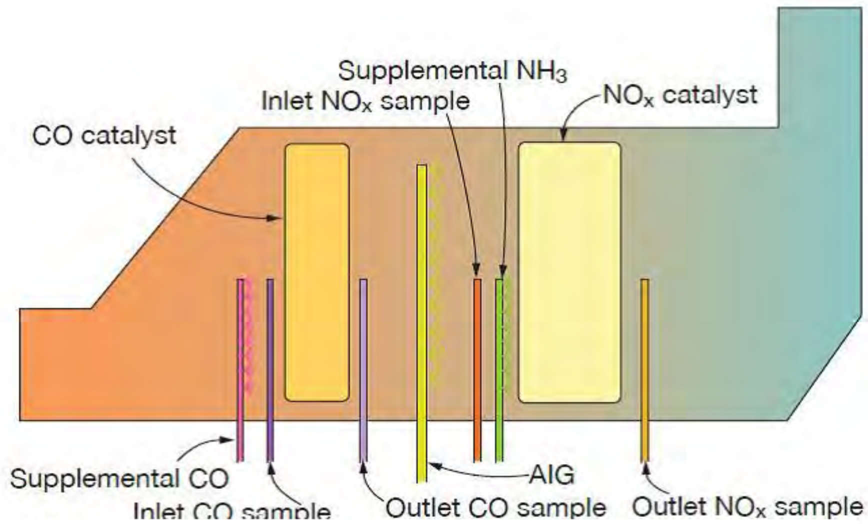
Similar to the lab approach for SCR catalyst, NO_x reduction is measured across a small cross section (test section) of the catalyst bed. A small supplemental ammonia injection grid (AIG) is permanently mounted upstream of the test section.



CatalysTraK® System Components

Additionally, an inlet gas sampling probe is installed directly upstream of the AIG, and an outlet gas sampling probe is installed immediately downstream of the catalyst bed at the test section. The supplemental AIG is used to increase the NH_3/NO_x level and provide excess ammonia across the catalyst test section.

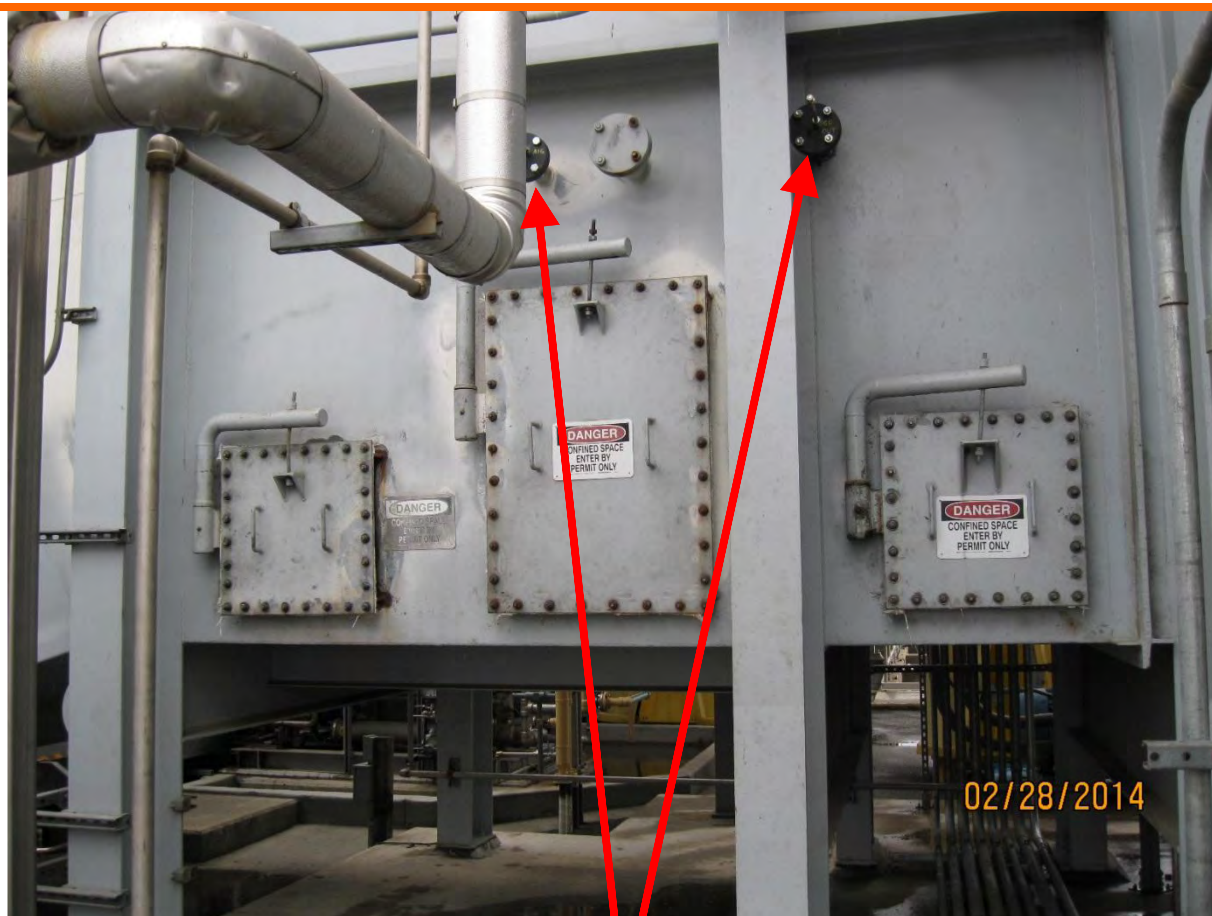
The RP calculation then is based on the maximum NO_x reduction measured across this catalyst test section.



CatalysTraK® Supplemental Injection Grid

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

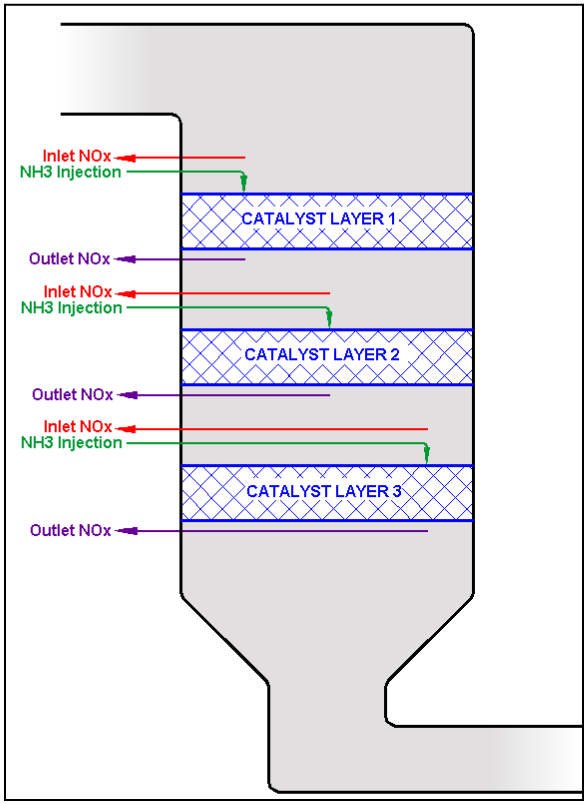
CatalysTraK® Access Ports on a Small Combined Cycle

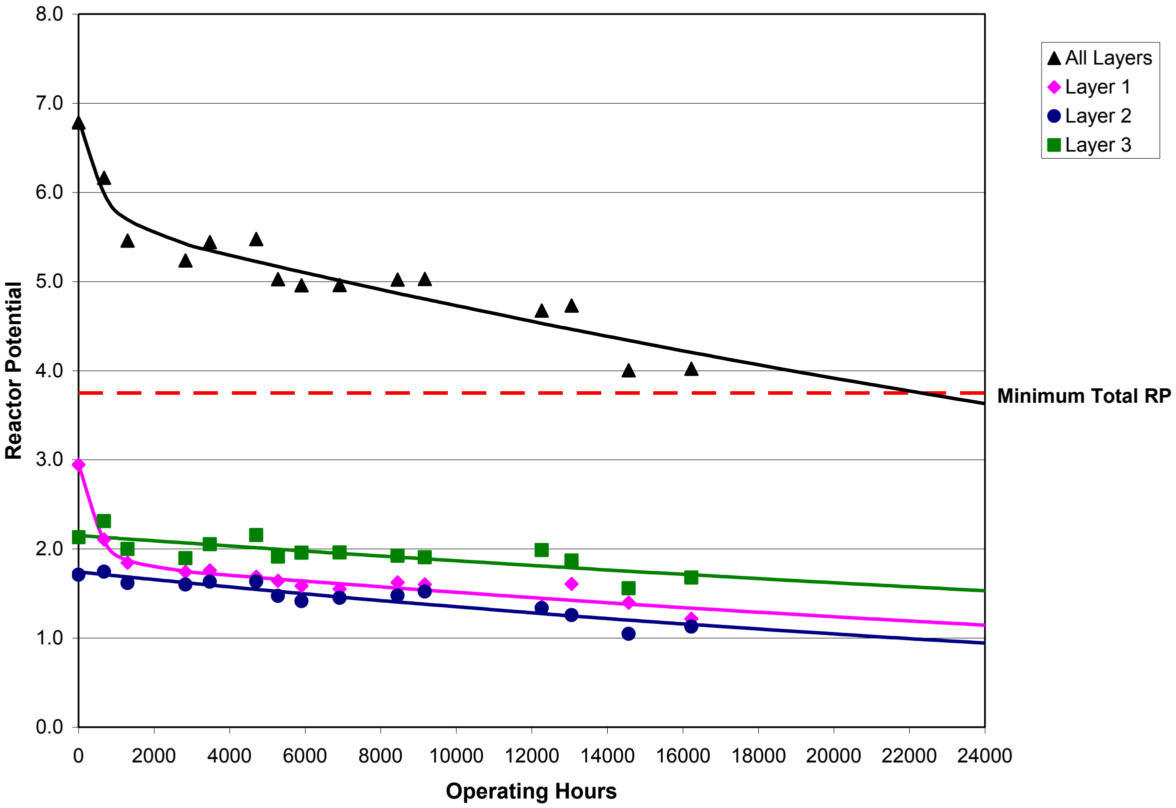


CO Measurement Access Ports

CatalysTraK® History

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





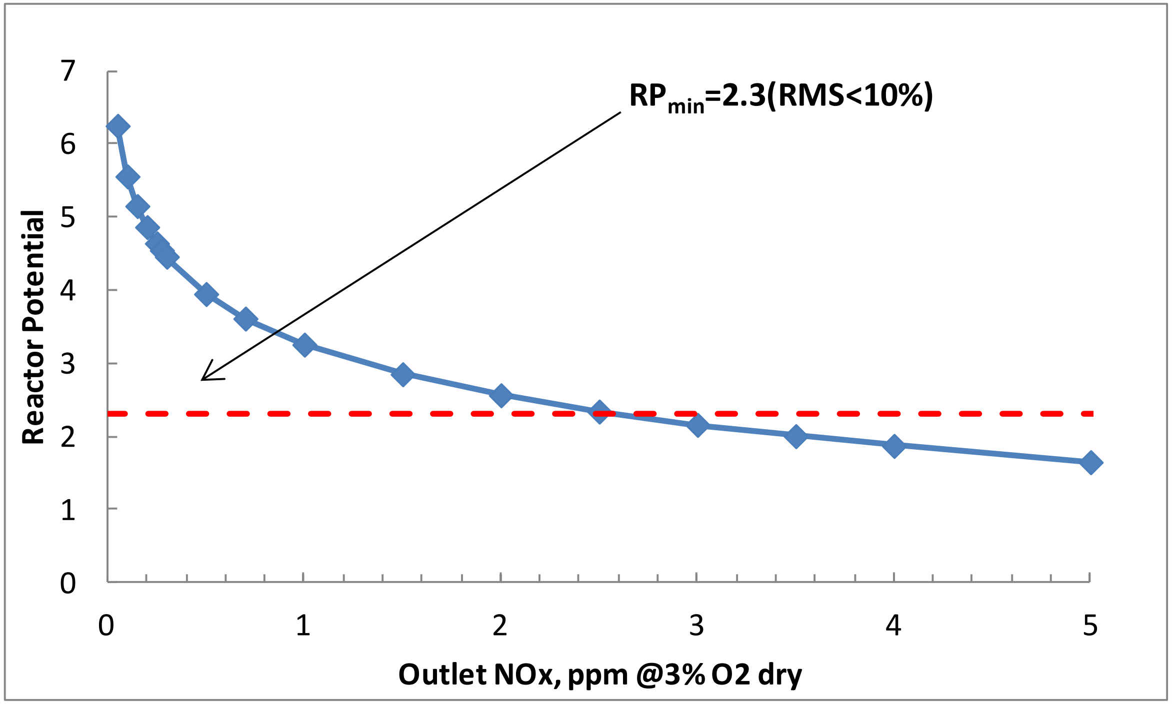
CatalysTraK® Application to Turbines

One issue related to the application of CatalysTraK® to a GT SCR is that these systems have a single layer of catalyst and it contains all of the reactors RP.

Thus when the catalyst is relatively new, the measured NO_x reduction across a layer of GT catalyst can be greater than 99%. This can make it difficult to accurately determine the reactor potential RP.

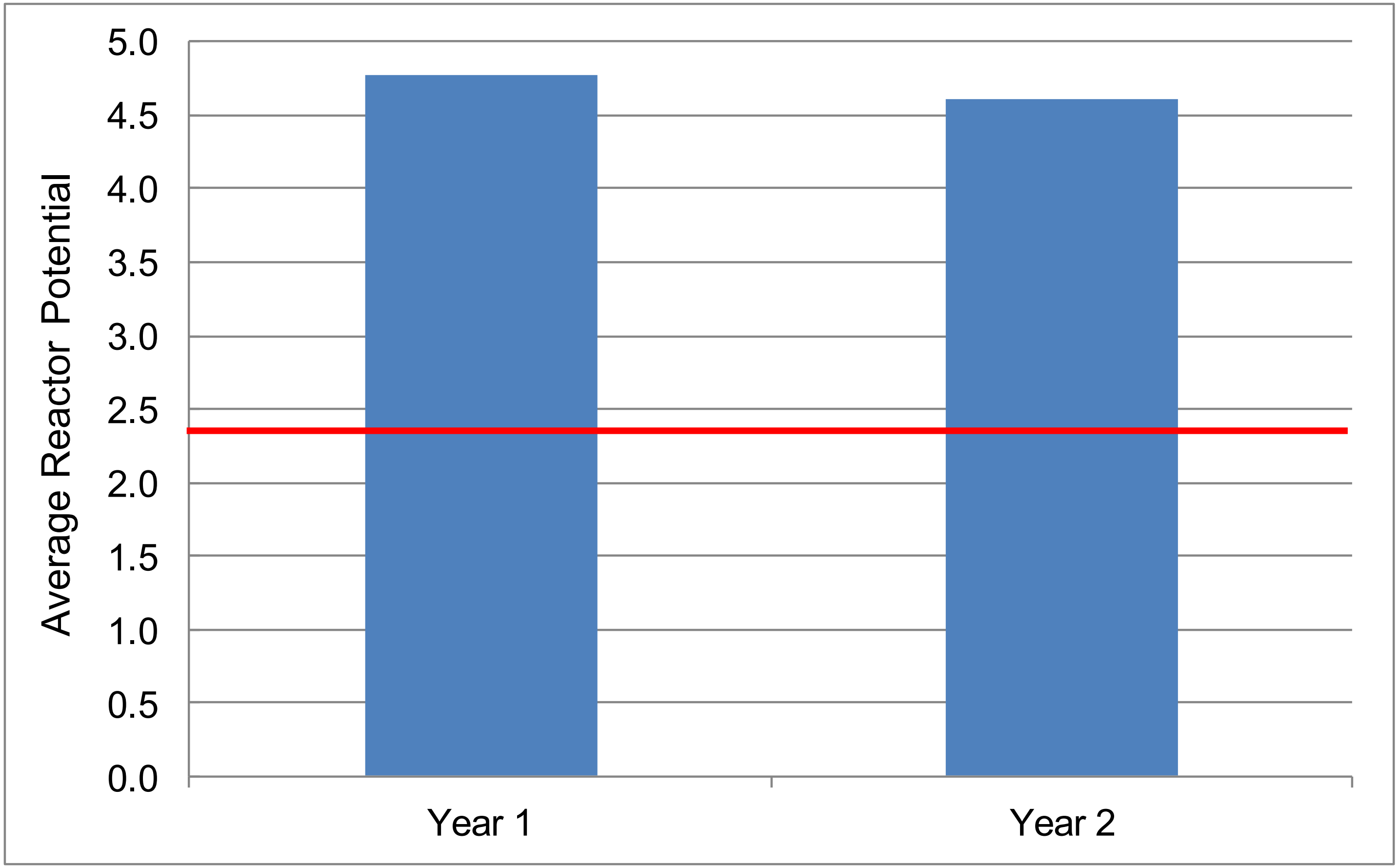
CatalysTraK® Application to Turbines

The bottom line: Early in a catalyst's life, the CatalysTraK® measurement may have a higher degree of uncertainty associated with RP, but at that point in the catalyst's lifecycle it is not critical that the RP be precise. ***This is also an issue in laboratory testing of new GT SCR catalyst!***



CatalysTraK® Reactor Potential Results

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



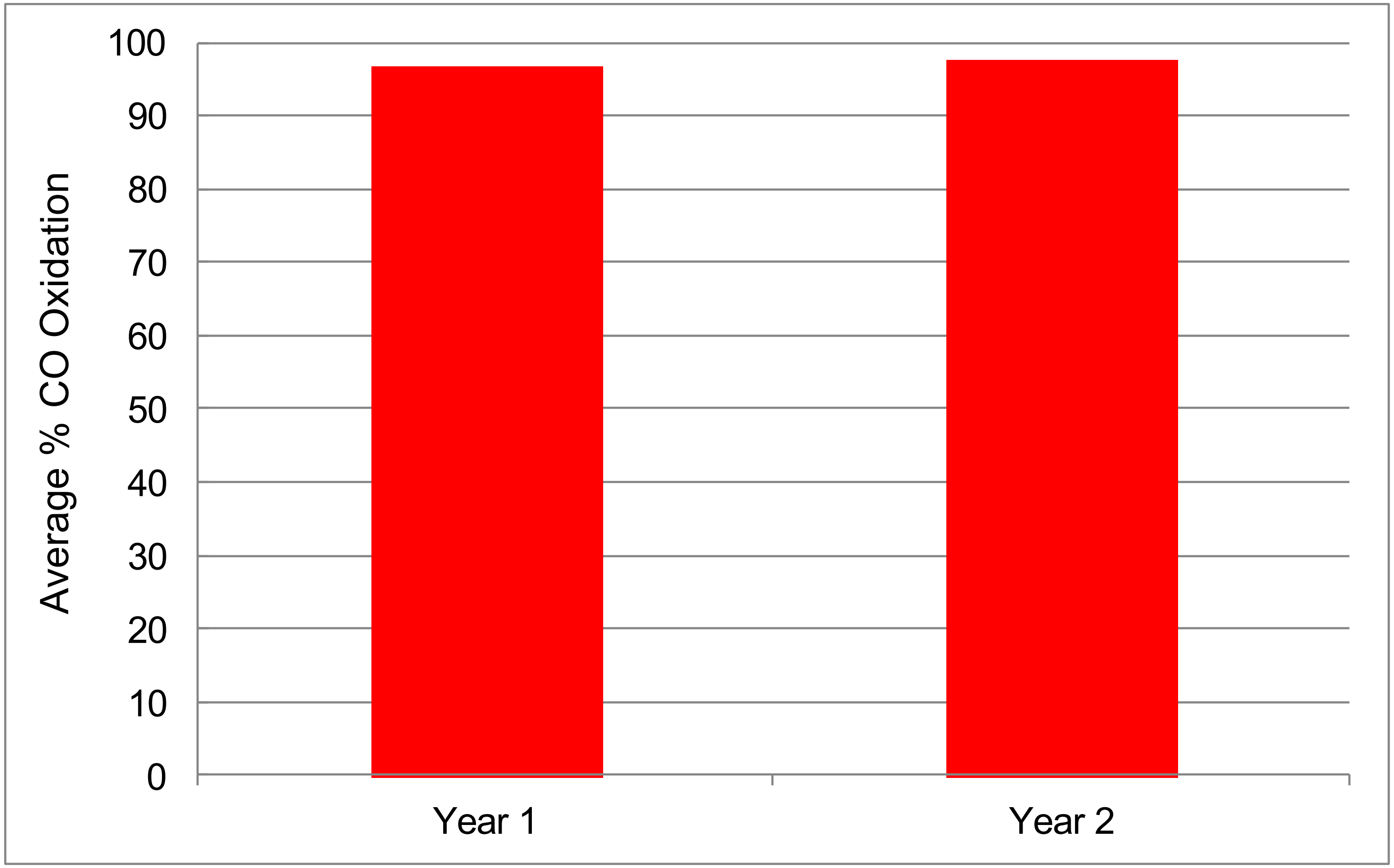
CO Catalyst Testing

As with SCR catalyst, CO catalyst performance also degrades over time. Historically core samples are drilled out or pulled from test panels and tested in a lab. The test 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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