REINHOLD ENVIRONMENTAL Ltd.

2013 NOx-Combustion Round Table & Expo Presentations

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Tools for Optimizing Gas Turbine SCR Performance

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Reinhold 2013 NOx-Combustion Round Table

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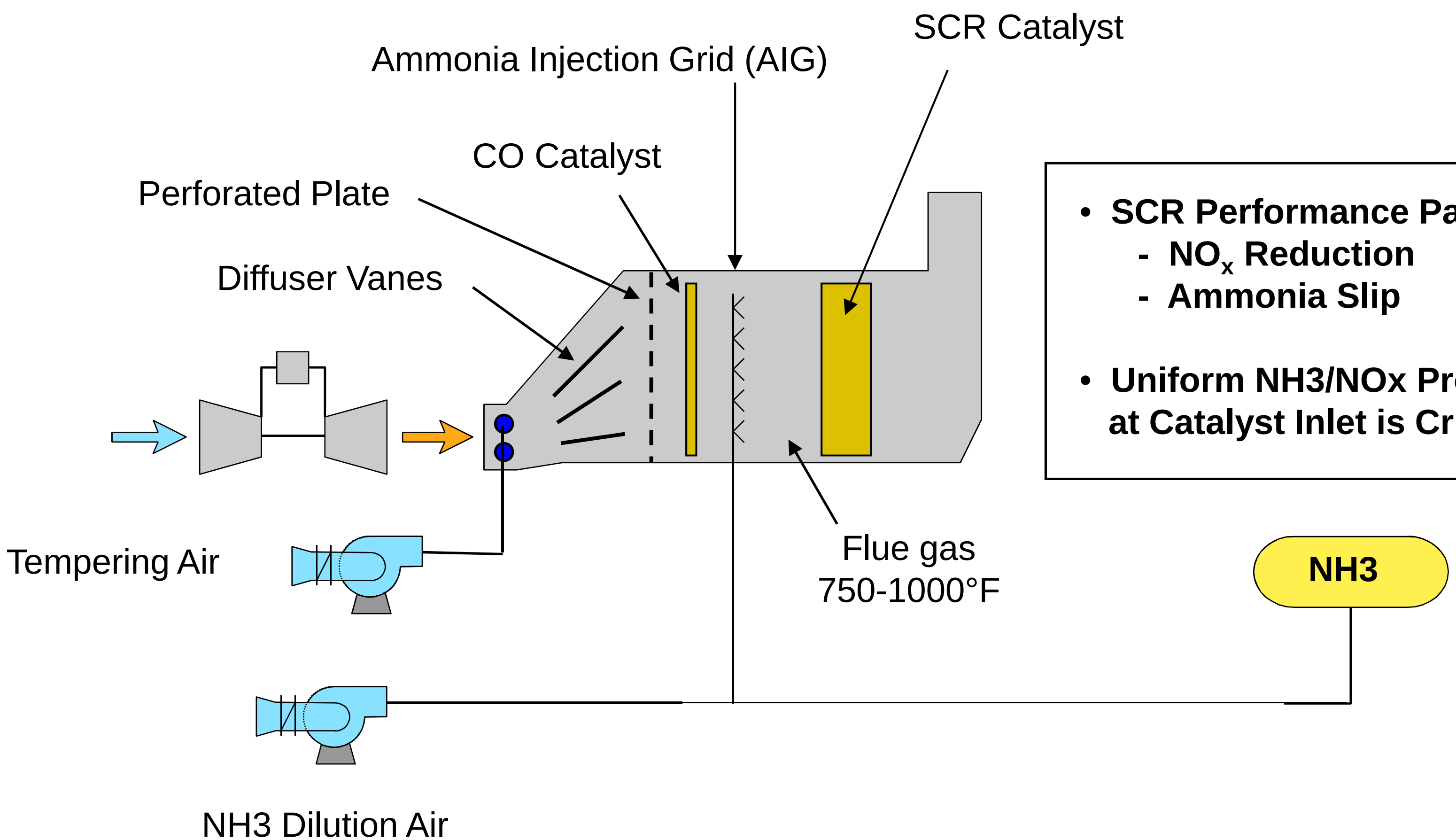
Salt Lake City, Utah

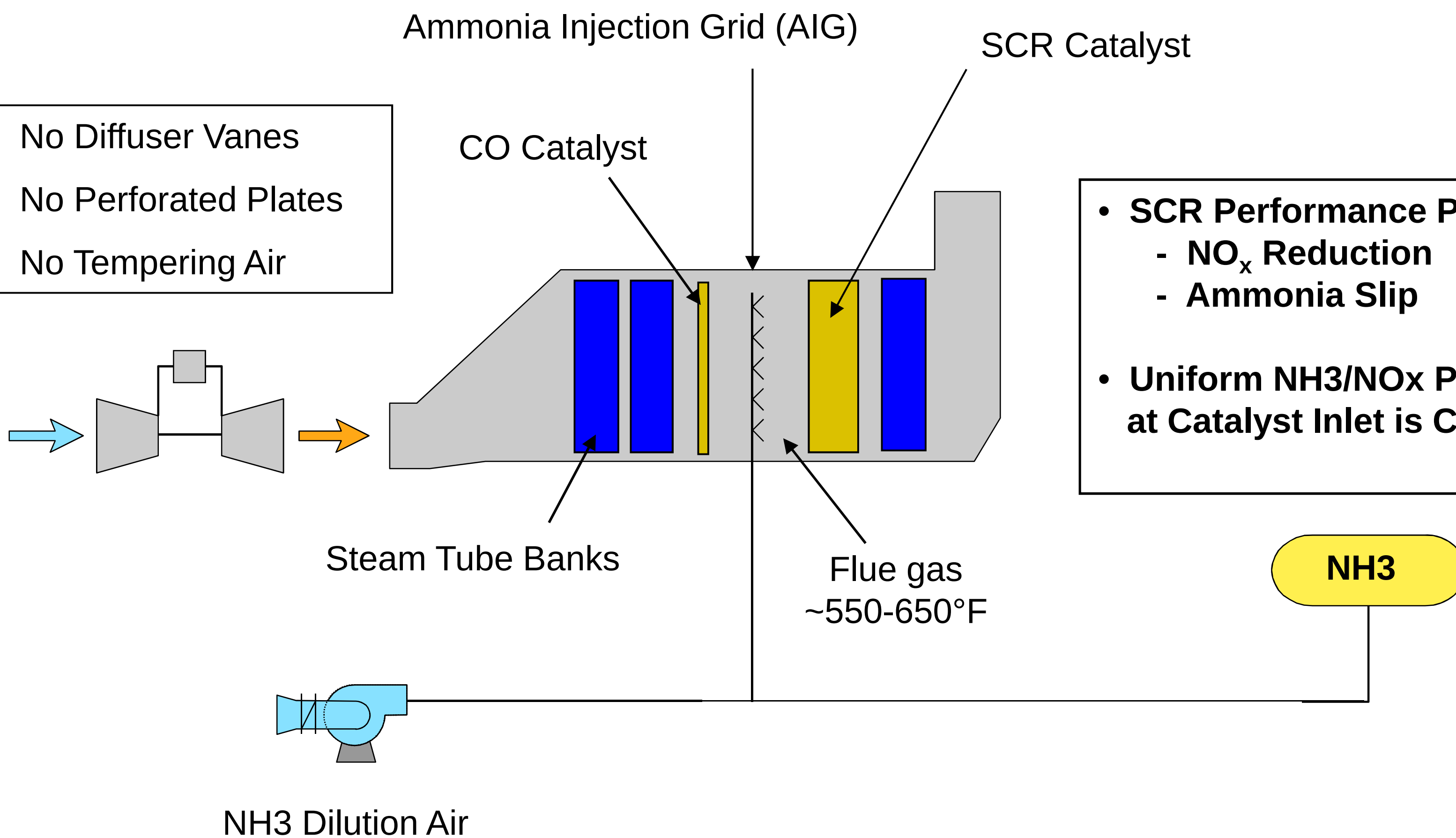
Simple Cycle Gas Turbine SCR



- **SCR Performance Parameters:**
  - **NO_x Reduction**
  - **Ammonia Slip**
- **Uniform NH3/NOx Profile at Catalyst Inlet is Critical!**

Cogeneration Gas Turbine SCR

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



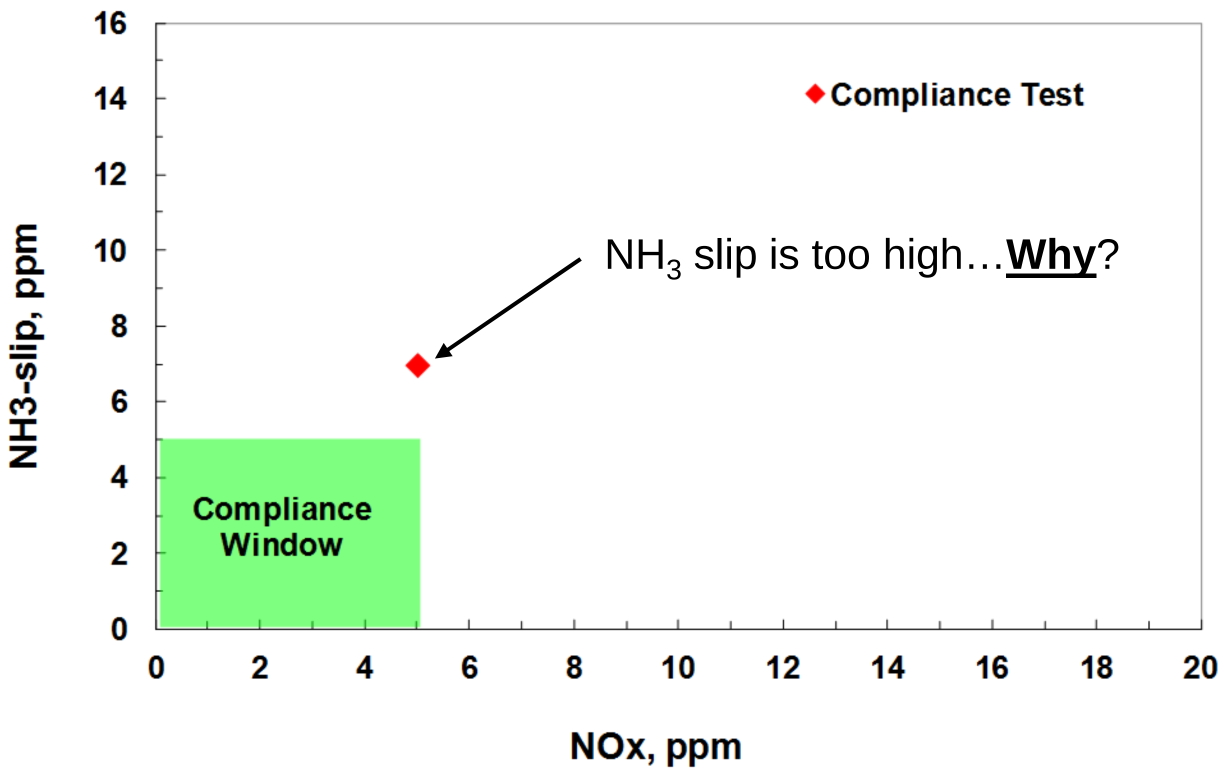
- **SCR Performance Parameters:**
  - **NO_x Reduction**
  - **Ammonia Slip**
- **Uniform NH3/NOx Profile at Catalyst Inlet is Critical!**

Optimizing Gas Turbine SCR Performance

Topics

- **Troubleshooting**
- **Catalyst Inlet NH_3/NO_x Distribution and AIG Tuning**
- **Identifying Flue Gas Bypass (e.g., Leaky Catalyst Seals)**
- **Measuring Catalyst Velocity Distribution**
- **SCR Impact on CEMs Relative Accuracy**
- **Catalyst Management/Measuring Catalyst Activity**

Troubleshooting



NH_3 slip is too high…**Why**?

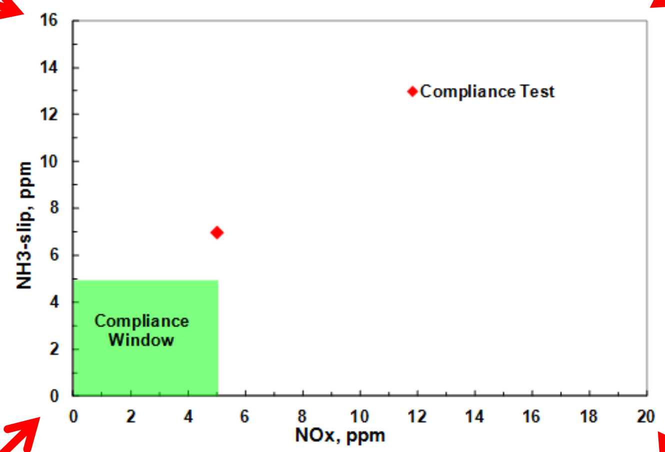
Why?

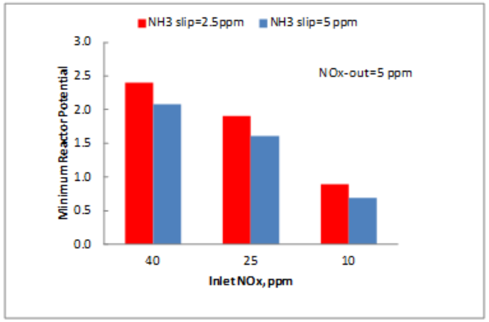
Catalyst Activity (K)?

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

Reactor Potential?

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





Poor NH3/NOx Distribution?

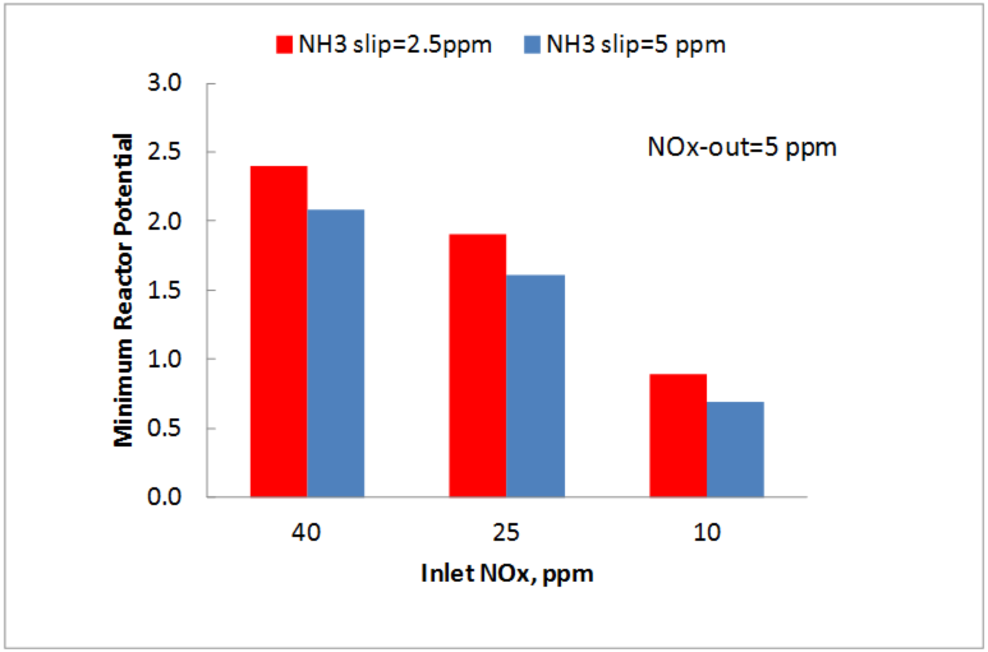
- Want NH_3/NO_x uniform across the catalyst
- Local $NH_3/NO_x>1=NH_3$ slip

Flue Gas Bypass?

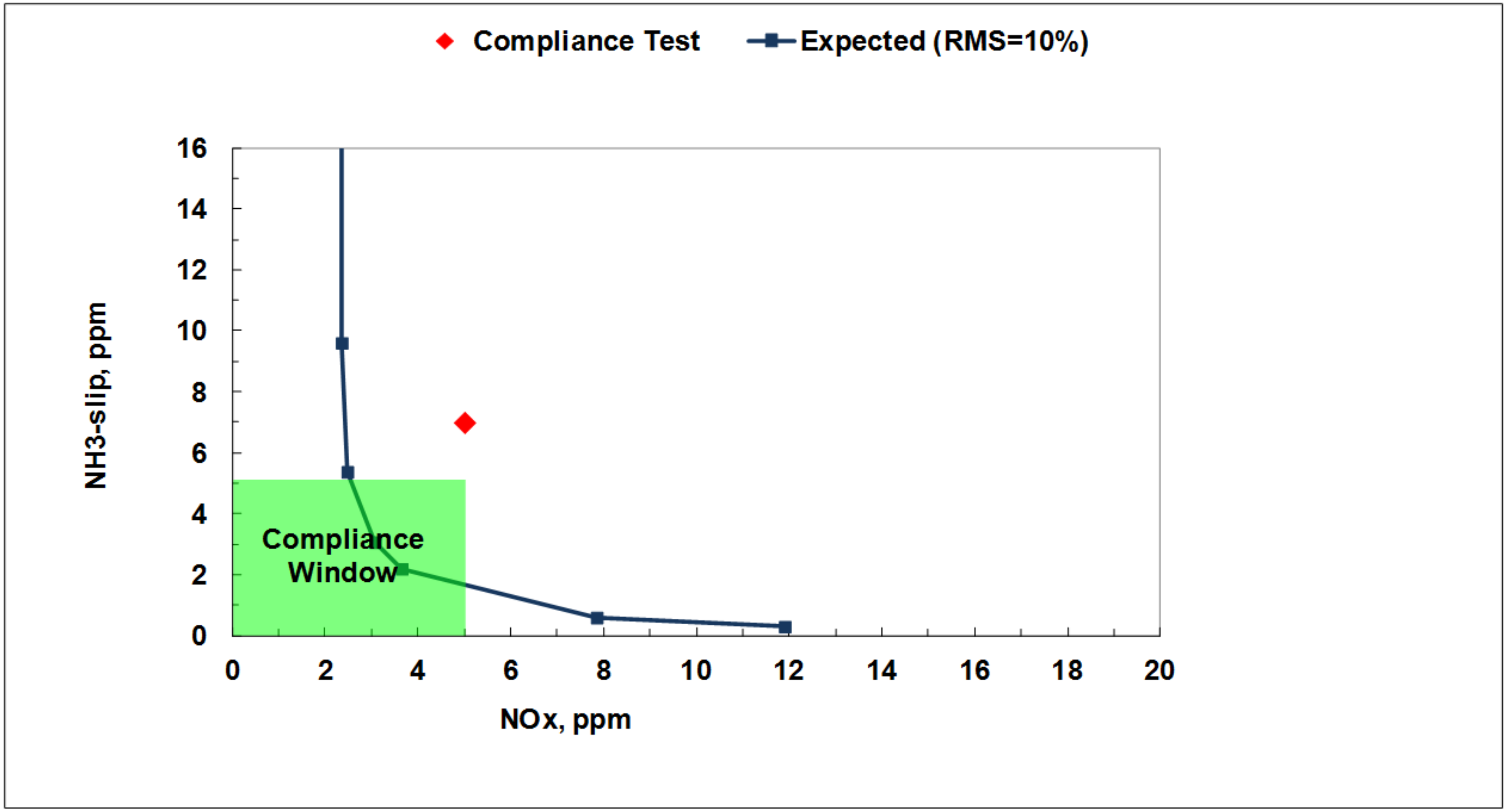
- Any bypass by the catalyst increases stack NO_x & NH_3

Reactor Potential

- Ability of the catalyst bed to reduce NO_x
- $RP= K*A_{sp}*V_{cat}/Q_{fg}$
- $RP=f(NO_xi, \Delta NO_x$,and NH_3 slip)



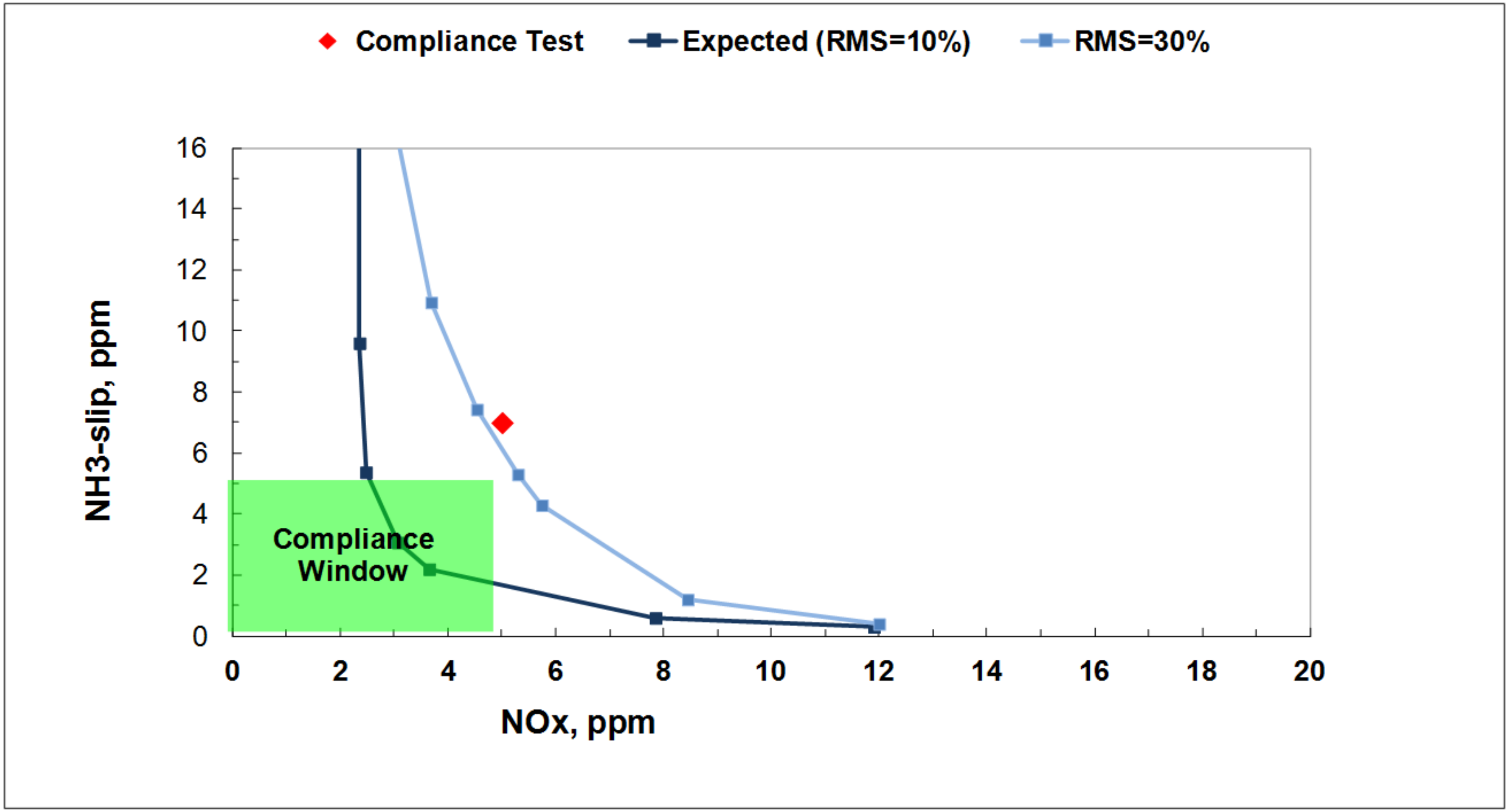
Expected Performance Based on Catalyst Properties



- Reactor Potential (RP) and is catalyst activity are typically adequate for new or young catalyst

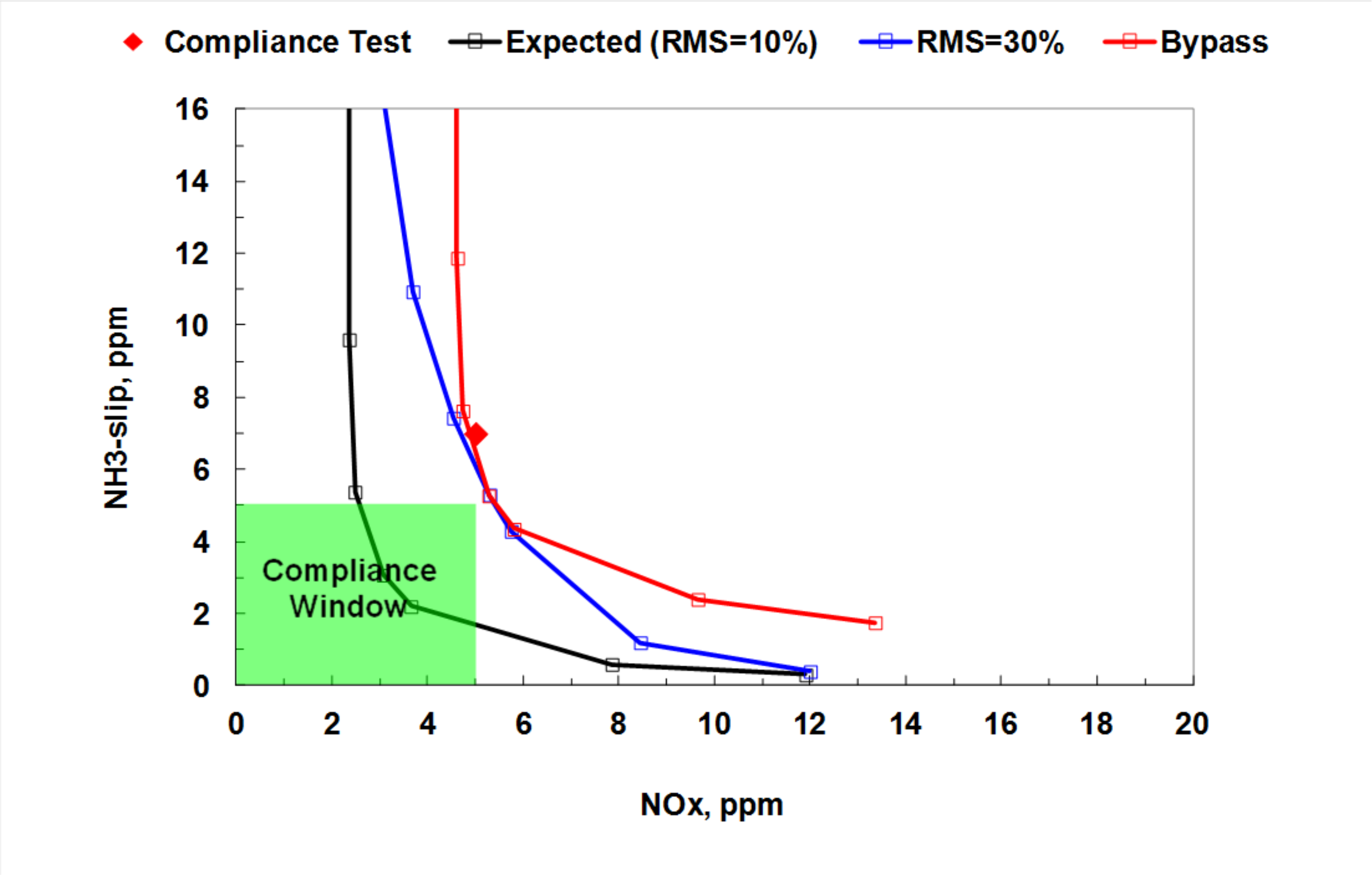
- **Exception: unexpected high temperatures**

Poor NH3/NOx Distribution?

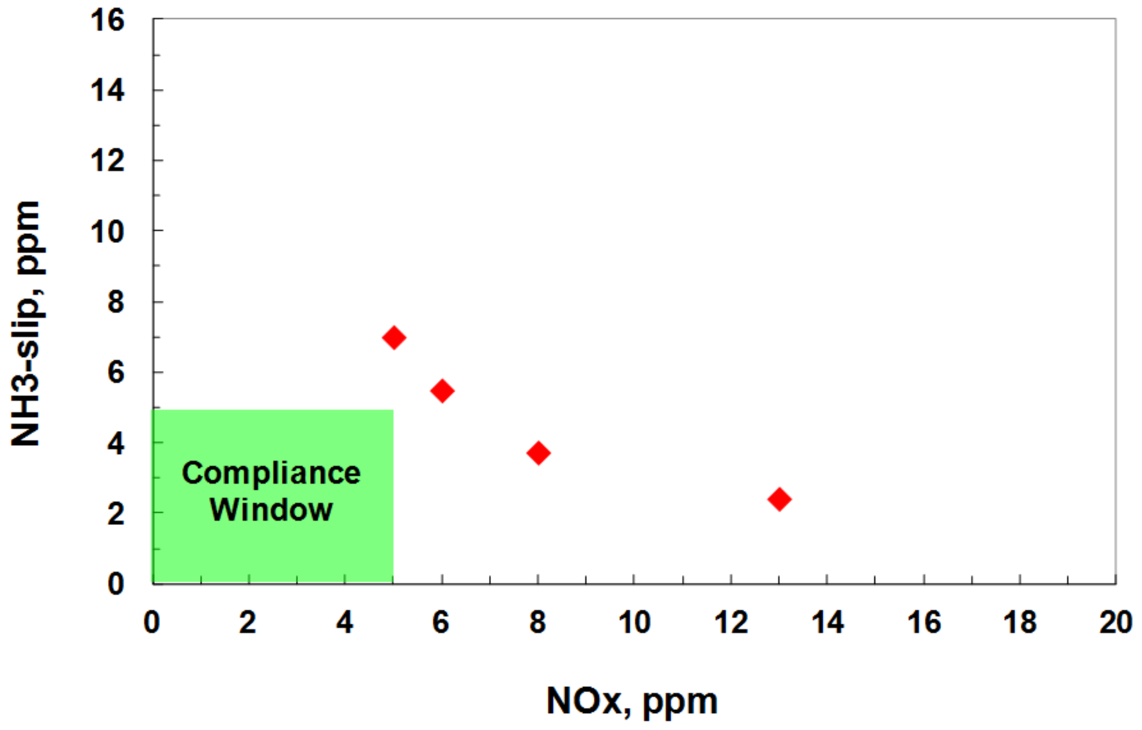


Flue Gas Bypass?

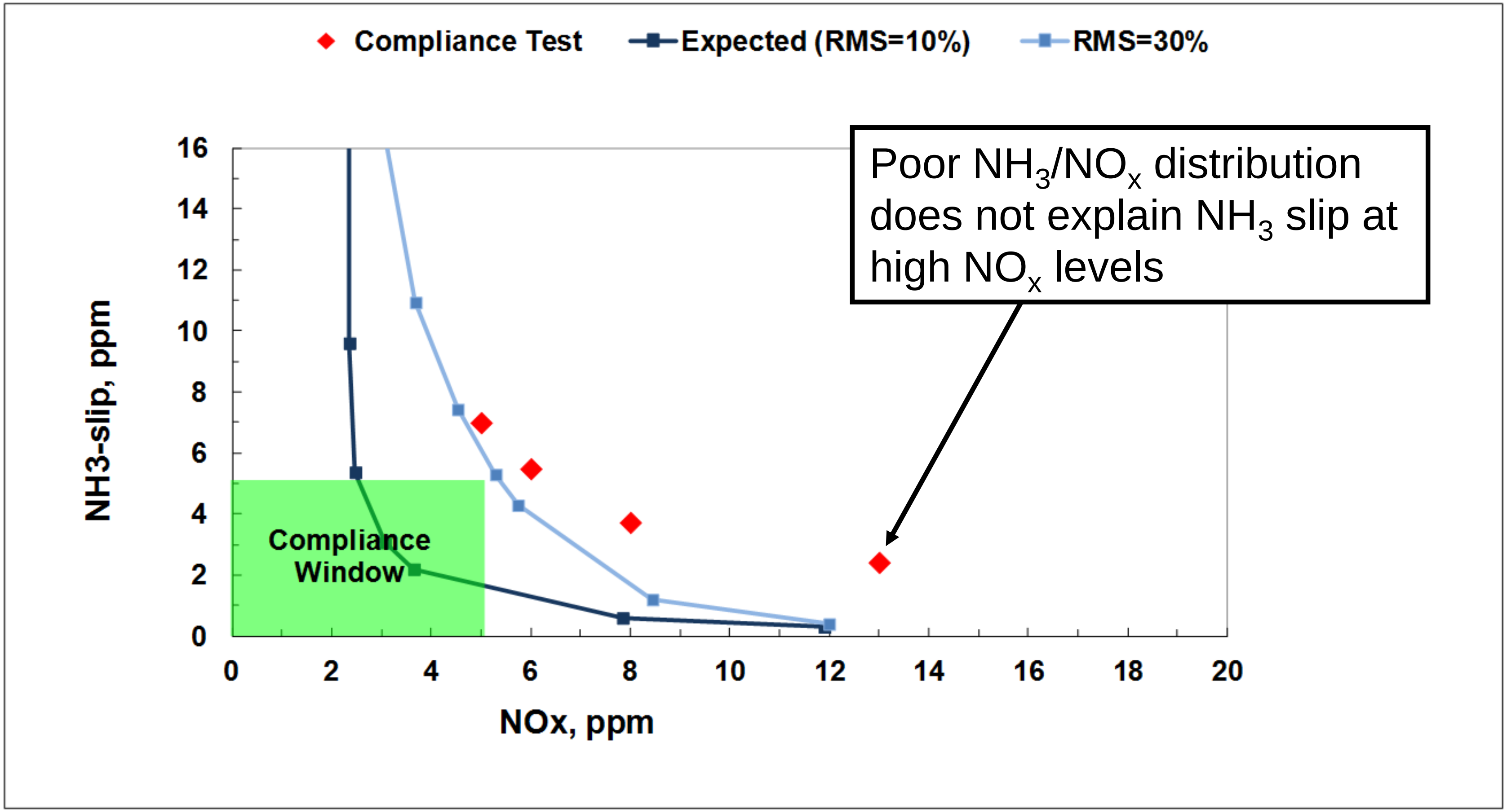
With a single test it is difficult to determine the reason for non-compliance



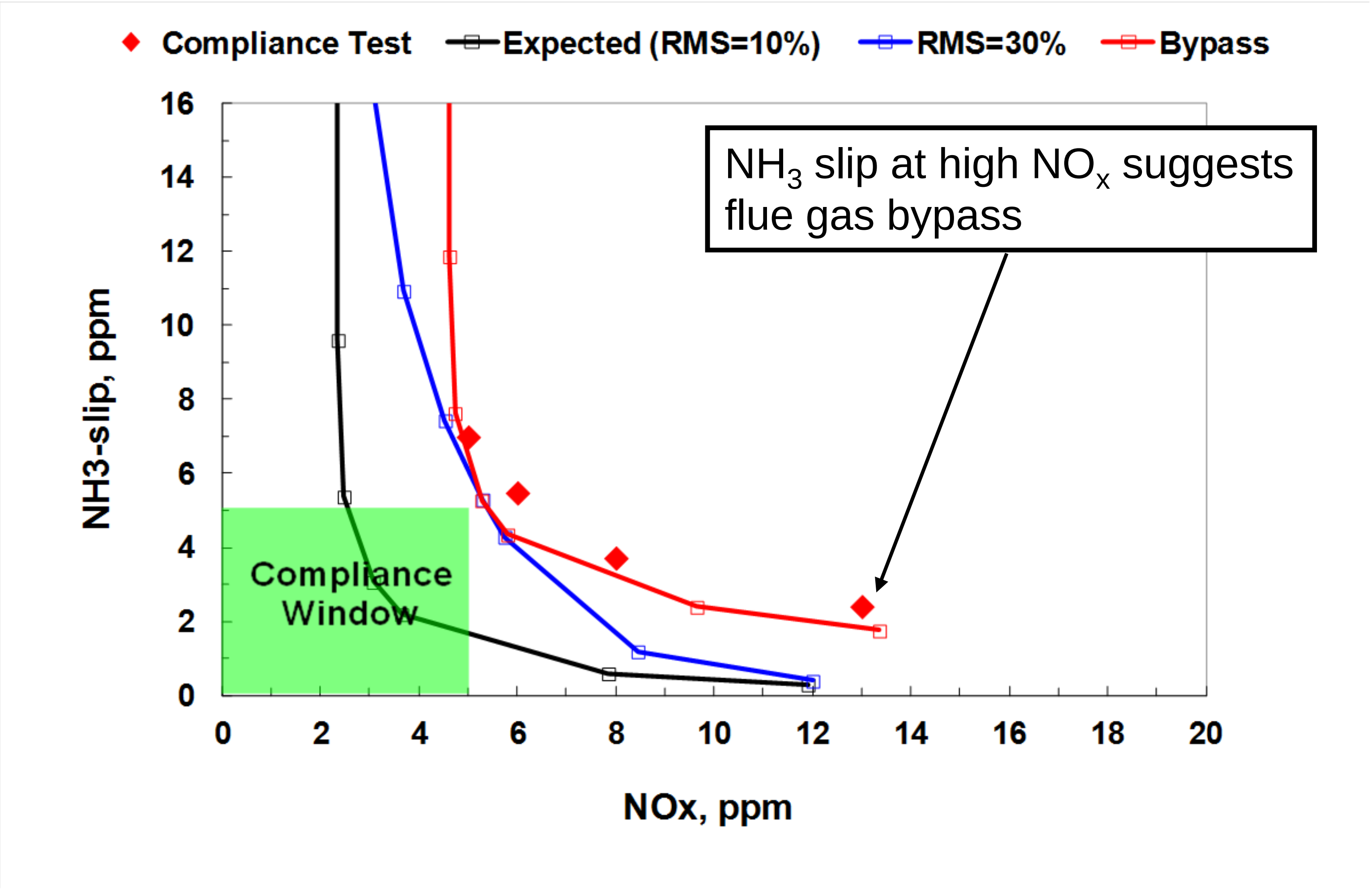
Perform Additional Tests



Poor NH3/NOx Distribution?



Flue Gas Bypass?



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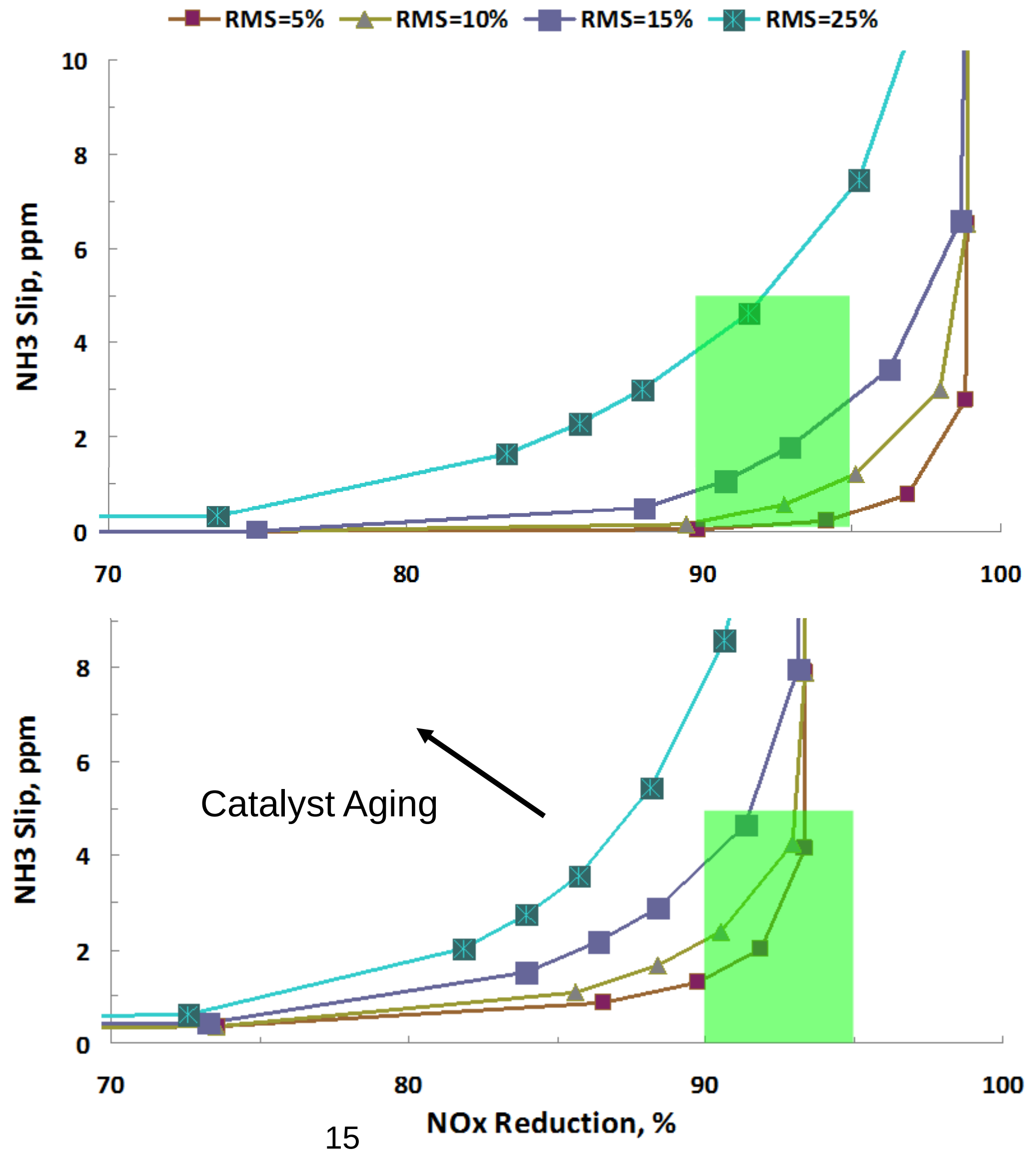
Catalyst Inlet NH_3/NO_x Distribution and AIG Tuning

NH_3/NO_x Distribution and AIG Tuning

New Catalyst

Near Catalyst End-of-Life



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Sample Probe Grid Expedites Tuning

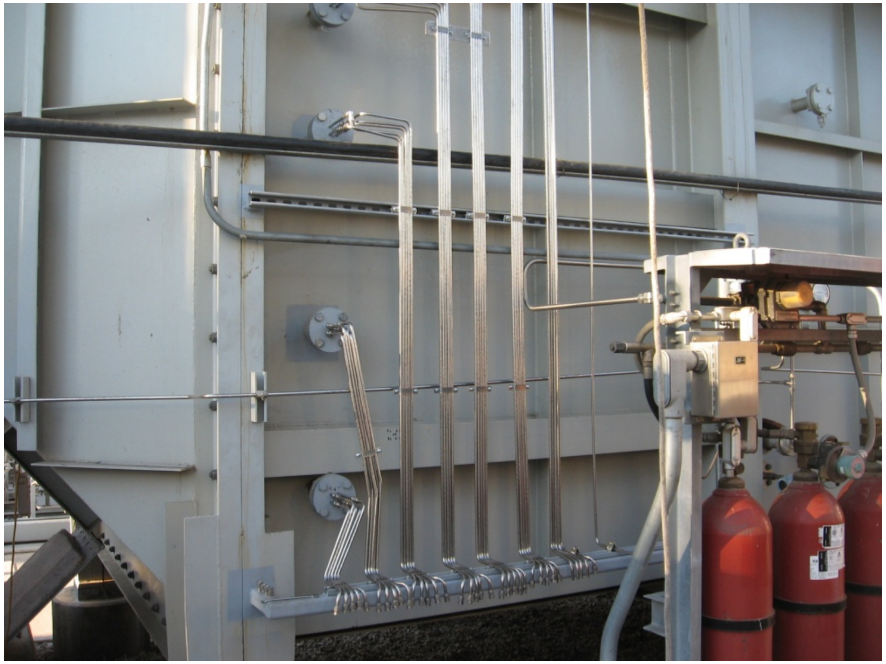
- AIG tuning is difficult without a probe grid at the catalyst exit

- The costs for installing a probe grid will be recovered in the long run:
  - No scaffolding or manlift required for testing ($, safety issues)
  - Reduced test times (no manual probe)
  - Reduced testing contractor costs
  - More data

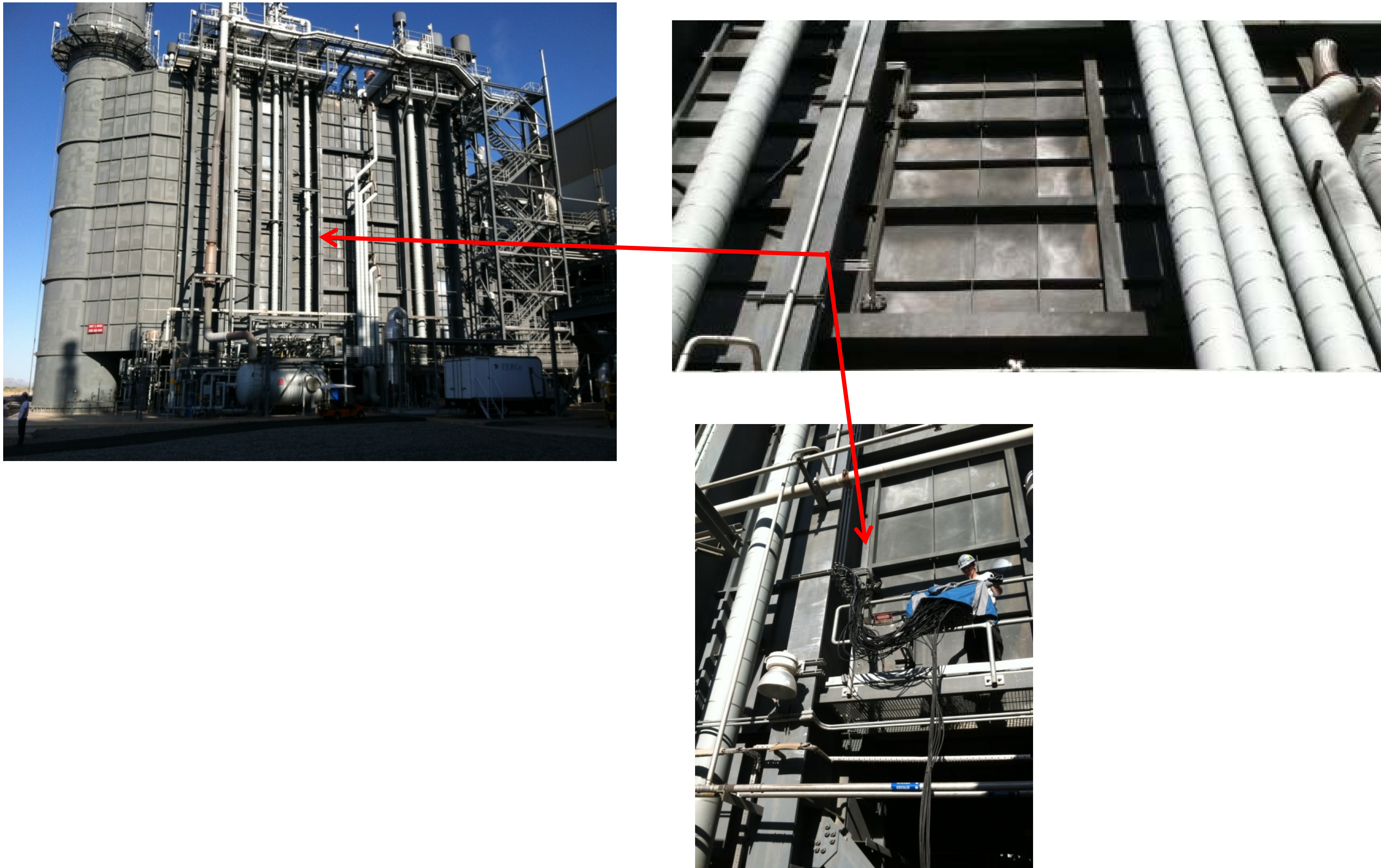
50MW simple cycle SCR
With a grid of 50 sample probes (5 x 10)

Sample Probe Grid Expedites Tuning

Sample Probe Grid Expedites Tuning



Sample Probe Grid Expedites Tuning



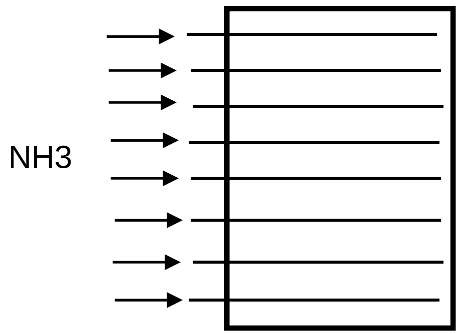
FERCo’s Multipoint Instrumentation

- Samples 48 points in 15 minutes
- NOx and O2

AIG Design Influences Tuning

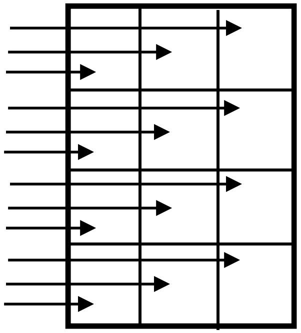
- **No Adjustments:** **Some systems have no AIG adjustment valves – *bad idea!* No flexibility to account for 1) duct velocity gradients, 2) duct NOx gradients, or 3) lance-to-lance ammonia flow gradients**

- **1-D:** **Most systems have one-dimensional adjustability**



Vertical adjustability can handle only vertical gradients

- **Multi-Zone**: **Ideal design: multiple zone adjustability**



Multiple zones allow treatment of localized gradients

AIG Tuning Procedure

<u>Basis</u> (**SCR operated with no local NH_3 slip**)

$$NH_{3_{in_i}} = (NO_{x_{in-i}} - NO_{x_{out-i}}) + NH_{3_{slip_i}}$$

$$\left(\frac{NH_3}{NO_x}\right)_i = \left(1 - \frac{NO_{x_{out_i}}}{NO_{x_{in_i}}}\right)$$

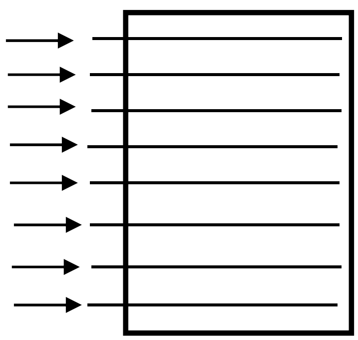
<u>Procedure</u>

1. **Turn off NH_3, obtain NO_x outlet profile**
2. **Turn NH_3 on to produce 50-70% ΔNO_x, obtain NO_x outlet profile**
3. **Use 1 and 2 to calculate local NH_3/ NO_x ratios**
4. **Make contour plot of NH_3/ NO_x distribution**
5. **Adjust AIG and repeat 2-4**

AIG Tuning, 10 MW Gas Turbine SCR

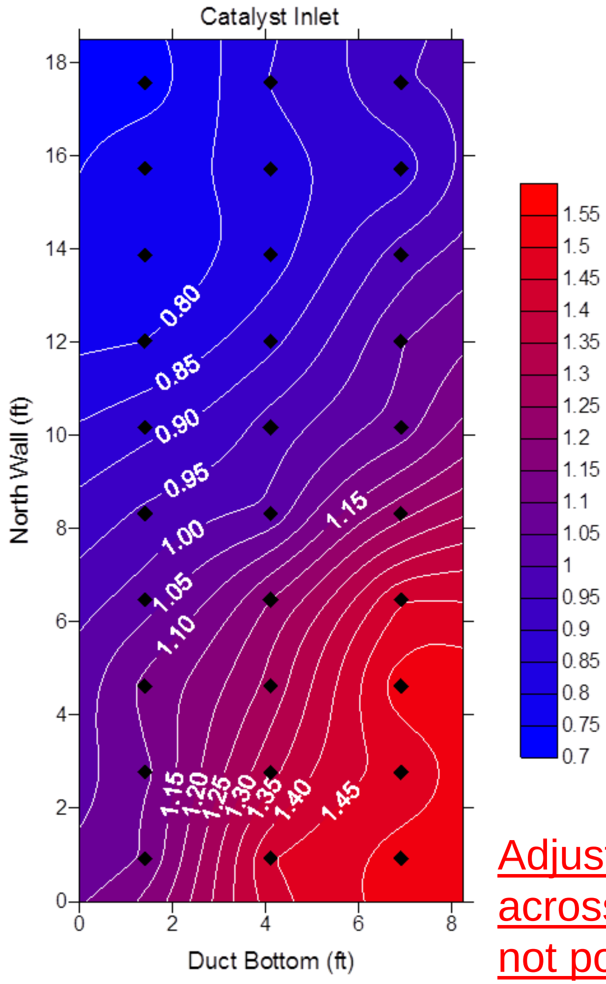
One-Dimensional, Vertical AIG

NH3



As-Found

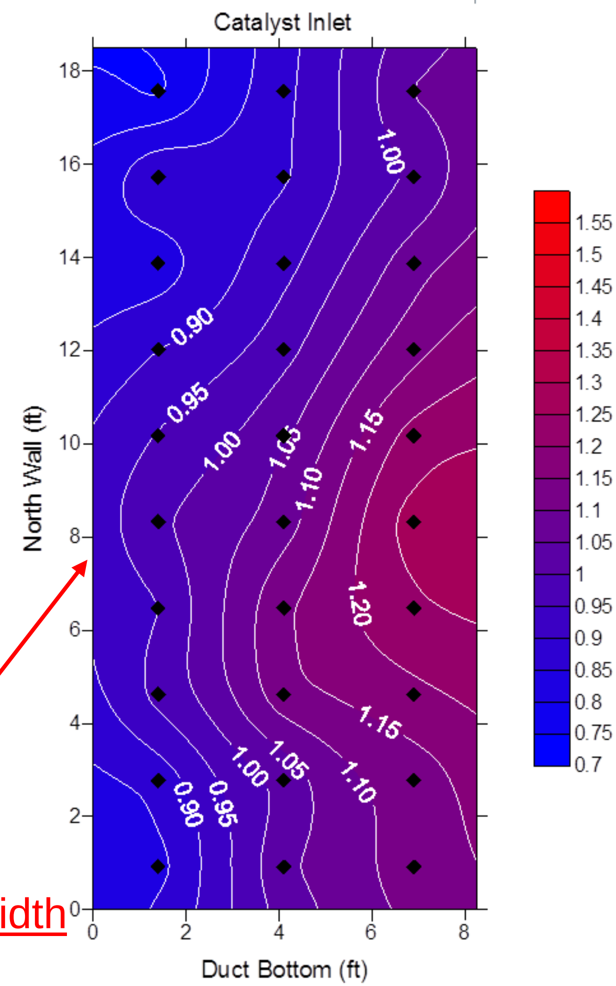
NH3/NOx Distribution



RMS = 22%

Adjusted

NH3/NOx Distribution



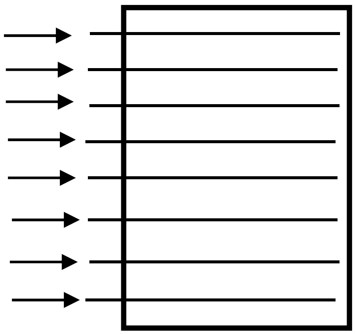
RMS = 13%

Adjustments across the width not possible

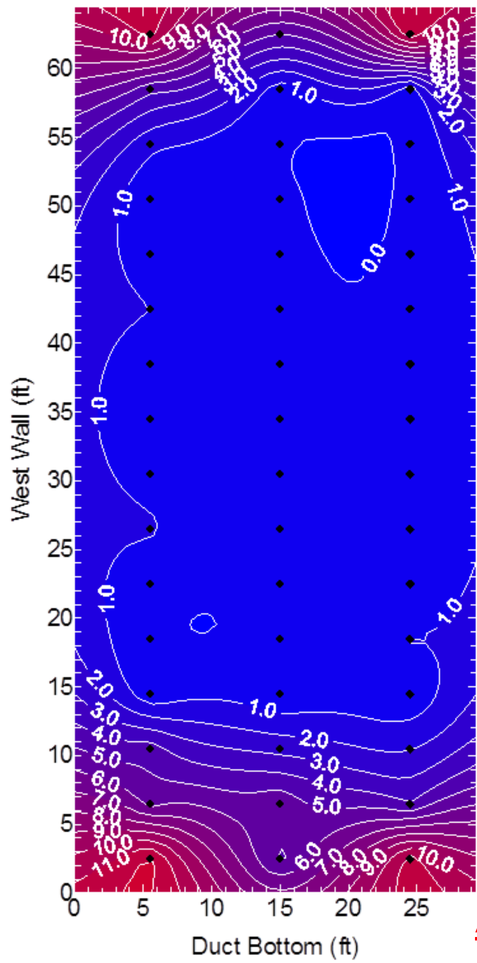
AIG Tuning, 350MW Combined Cycle SCR

One-Dimensional, Vertical AIG

NH3

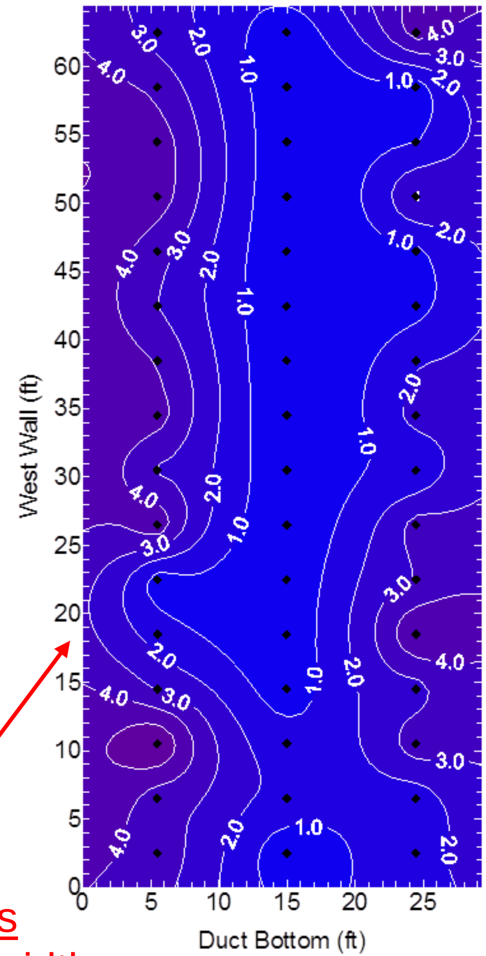


As-Found Outlet NOx (ppm)



NH_3 consumption reduced by 5%

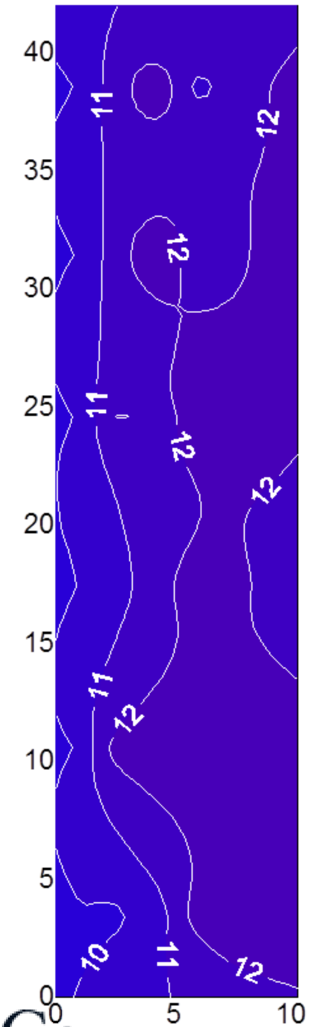
Optimized Outlet NOx (ppm)



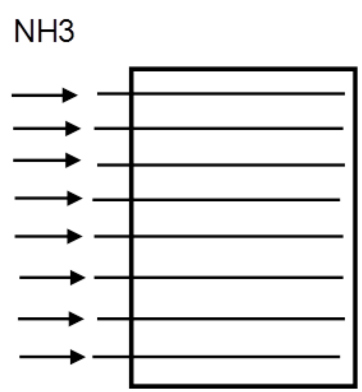
Adjustments across the width not possible

Duct Burners Impact AIG Tuning

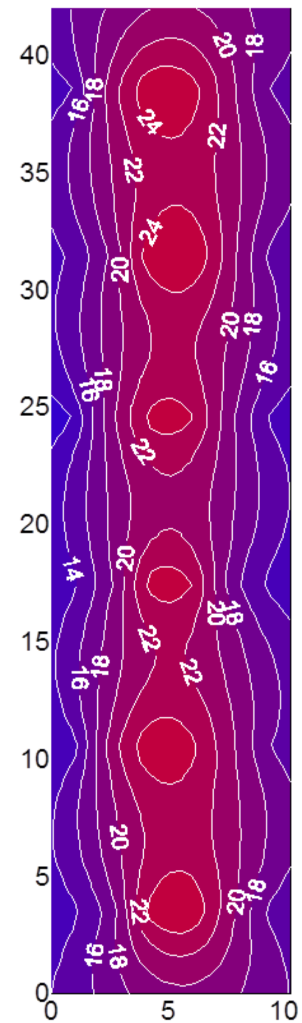
Duct Burners Off
(Inlet NO_x ppm)



AIG Tough to Tune



Duct Burners On
(Inlet NO_x ppm)



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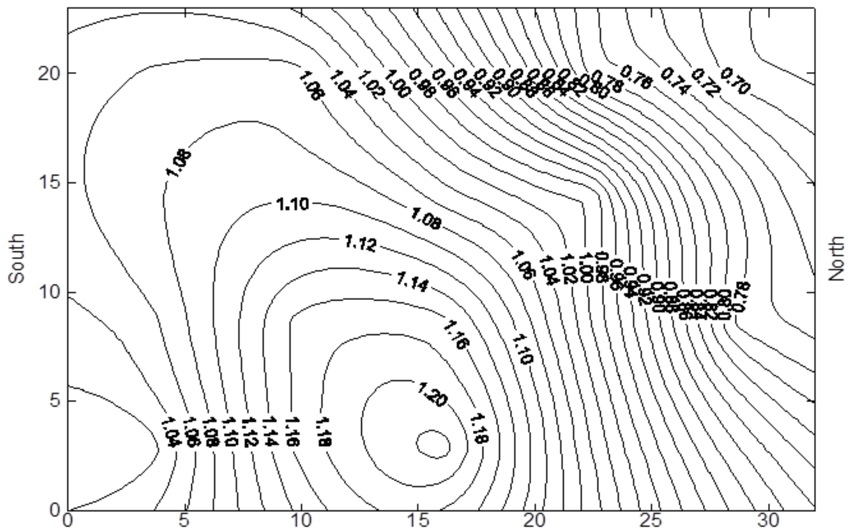
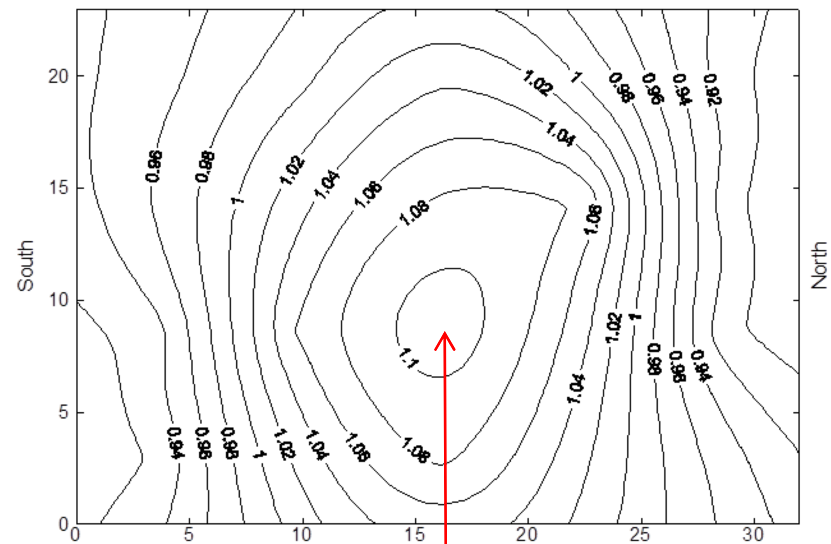
MP289

AIG Tuning, 14 MW Gas Turbine SCR

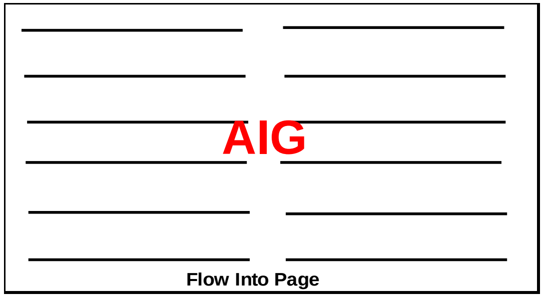
As-found (RMS = 14.7%)



Optimized (RMS = 6.5%)

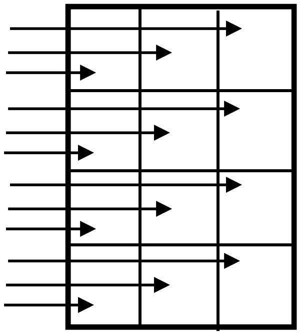


Vertical AIG,
Two Horizontal Zones



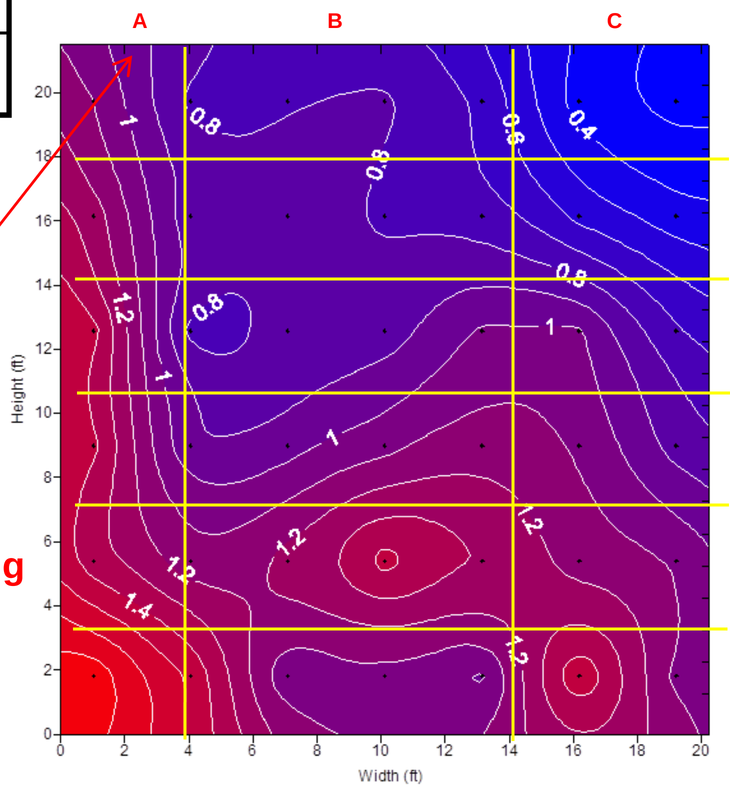
No way to adjust the center

AIG Tuning, 10 MW Gas Turbine SCR, 90° Turn



As-Found

Normalized NH_3/NO_x Distribution

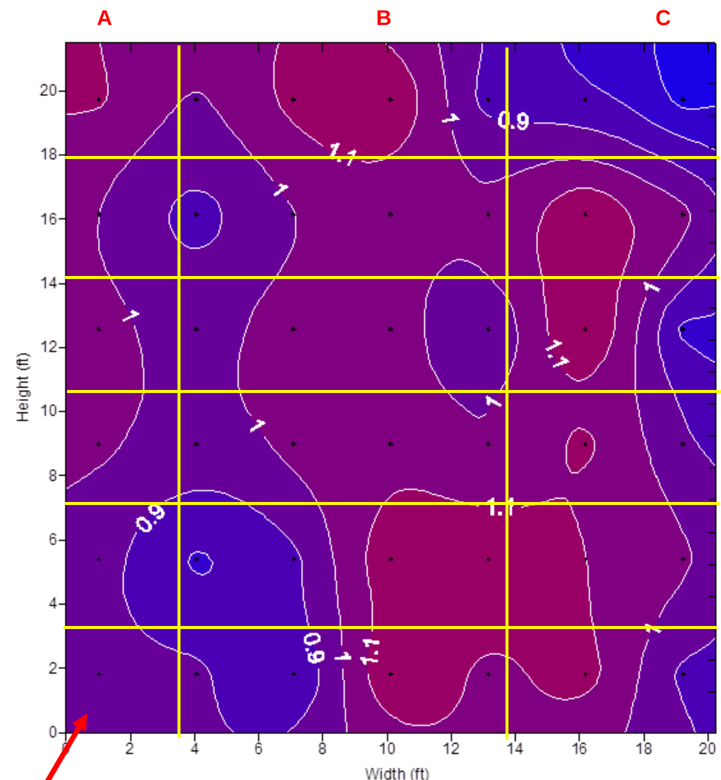


Multiple zones, skewed based on flow modeling

RMS = 32%

Tuned

Normalized NH_3/NO_x Distribution



Corners adjusted

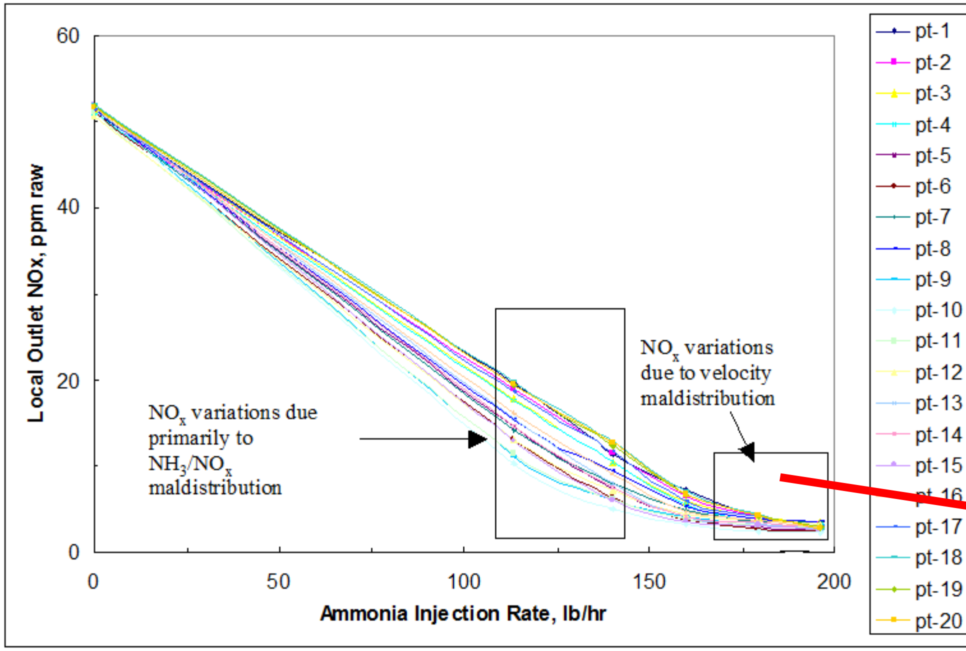
RMS = 13%

Measuring Catalyst Velocity Distribution

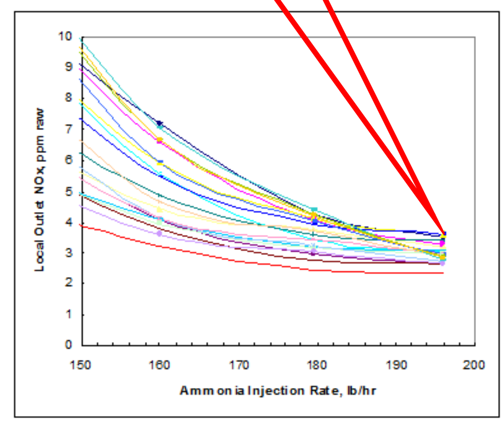
Catalyst Velocity Distribution

- **Velocity uniformity typically in the specification**
- **Velocity uniformity established during the SCR Design (Cold Flow and/or CFD)**
- **Can it be measured at full scale?**
  - Difficult; large reactors, long probes, low velocities(~15 ft/sec)
  - Pitot Probes, Thermal Anemometers
  - Pitot Probe dPs ~0.02 in H2O
  - Velocity profile re-aligns very close to the surface
- **Velocity distribution can be inferred using NOx measurements**

Local Outlet NO_x VS. NH_3 Injection Rate



$dNO_x=1-e^{-K/Av}$



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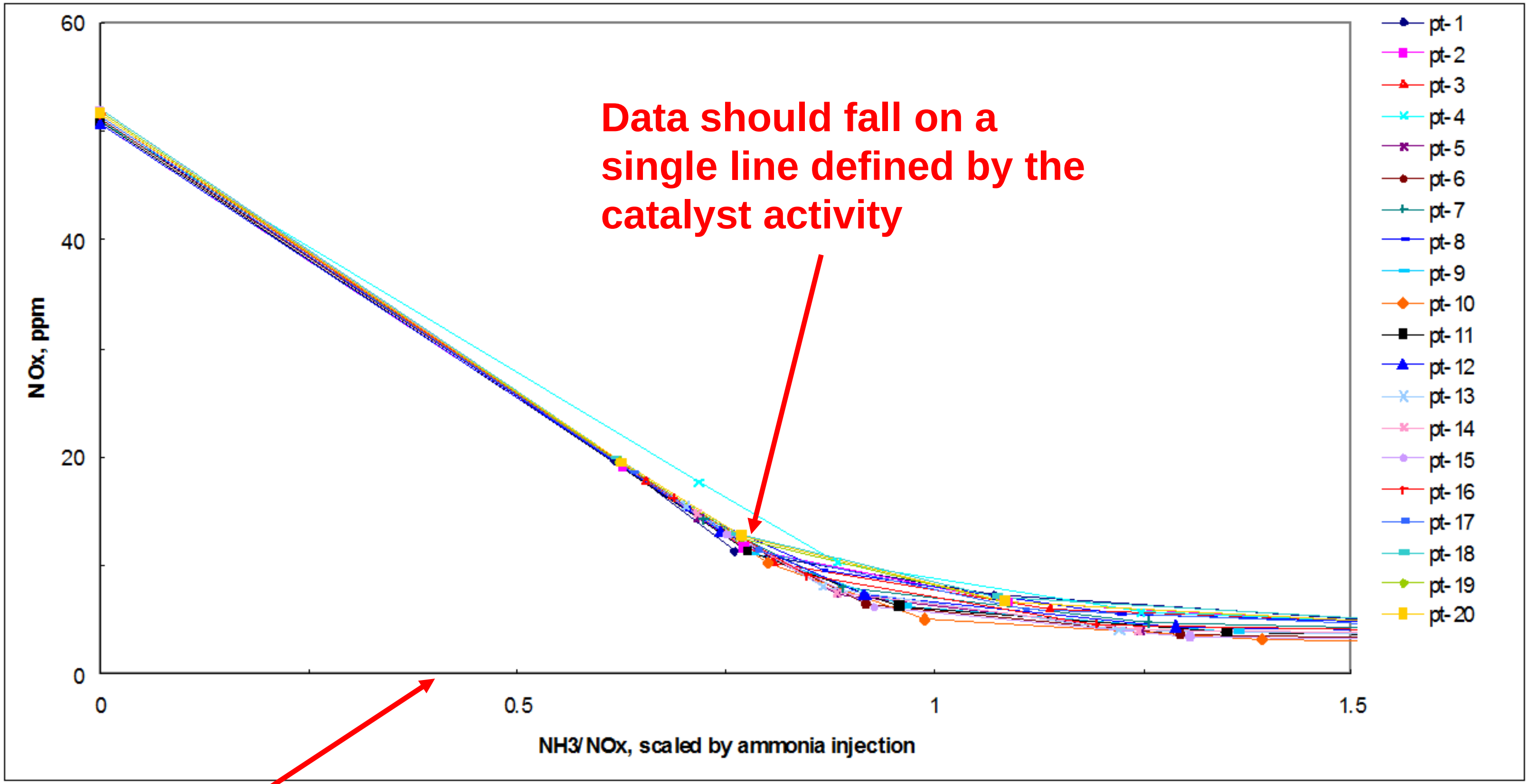
Identifying Flue Gas Bypass

Flue Gas Bypass

- **Improper perimeter seals**
- **Improper seals between catalyst modules**
- **Difficult to diagnose just looking at overall performance**
- **A likely region of bypass is the roof**

Flue Gas Bypass

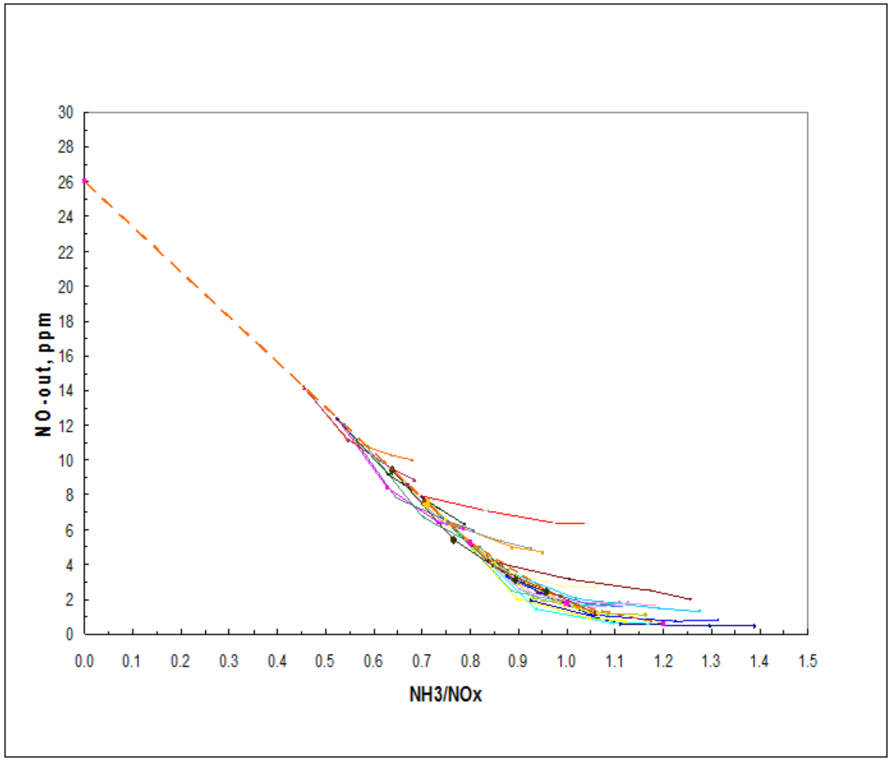


Data should fall on a single line defined by the catalyst activity

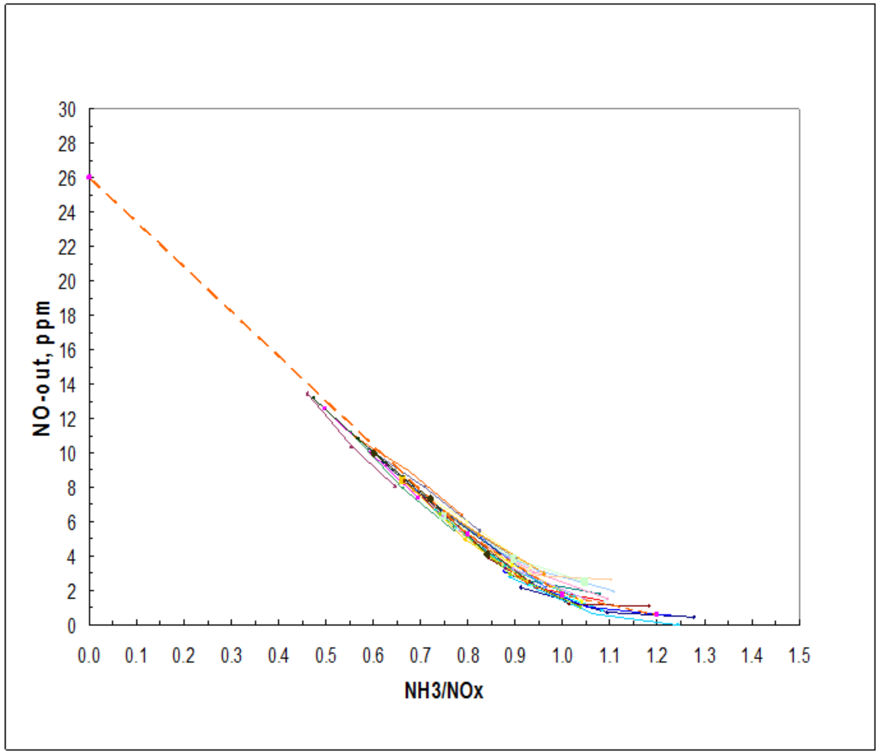
Plot Local NH3/NOx rather than ammonia injection rate

Flue Gas Bypass, 50 MW Gas Turbine SCR

As-Found



Repaired



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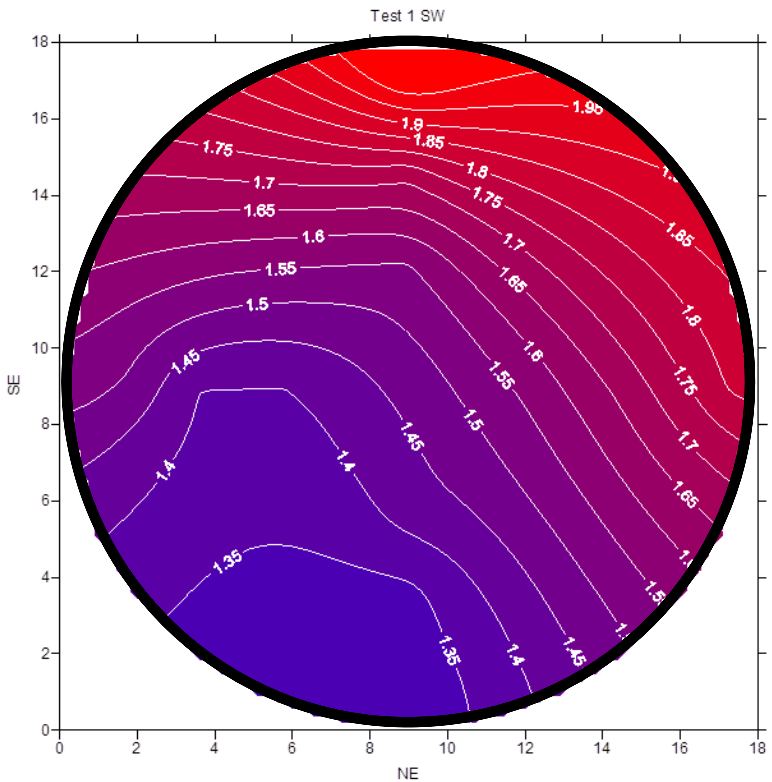
SCR Impact on CEMs Relative Accuracy

CEMs Relative Accuracy

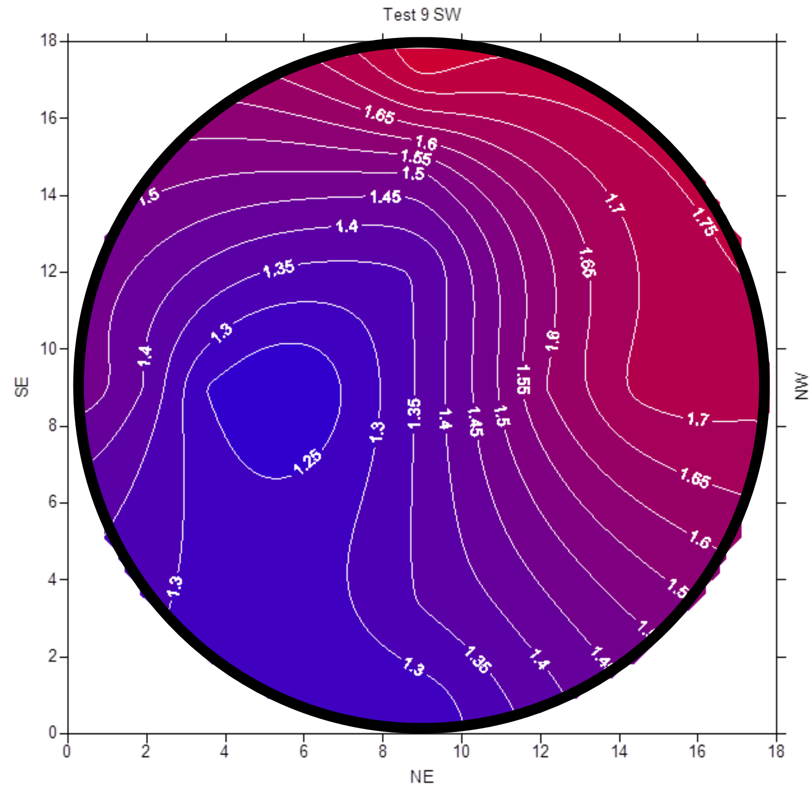
- NH_3/NO_x gradients at the catalyst inlet create NO_x gradients at the exit of the catalyst
- Close proximity of the stack CEMs to the catalyst exit on a gas turbine simple cycle SCR system may result in a stratified NO_x profile at the CEMs
- It may be necessary to tune the AIG specifically to pass the Relative Accuracy Test

Relative Accuracy Example

As Found (RA=-25%)



Tuned (RA=-6.6%)



Catalyst Management

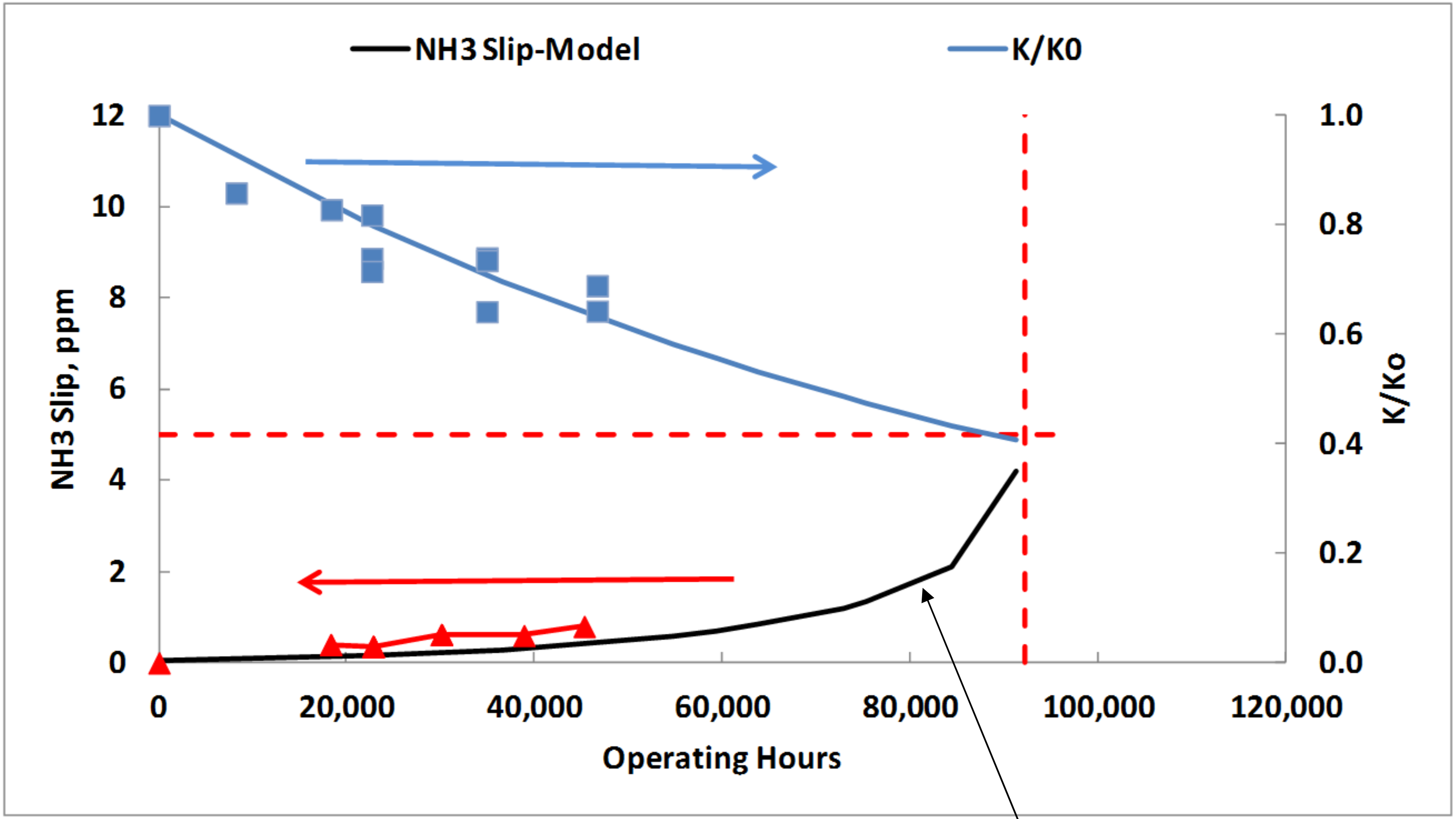
Catalyst Management

- **What is Catalyst management?**
  - Keeping track of catalyst activity to ensure continued compliance

- **How is Catalyst Management Done?**
  - Periodically determining the activity of the catalyst in the reactor
  - Laboratory analysis (if a sample can be obtained)
  - In situ analysis (later discussion topic)
  - Utilize catalyst management software for planning

- **Why is it Done?**
  - Forecast when catalyst additions or replacements are necessary
  - Provide sufficient lead time to procure catalyst (6-9 months)

Catalyst Activity Degrades With Time



Monitoring ammonia slip is also critical

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In Situ Catalyst Activity Measurements

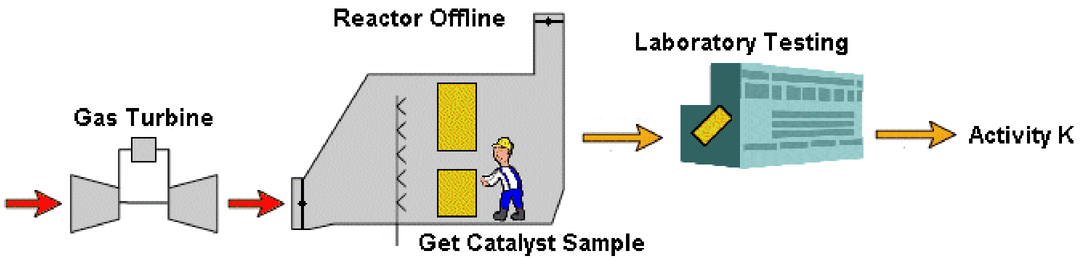
In Situ Catalyst Activity Measurement*

Traditional Lab Measuremet

- Typically one per year
- Currently no test protocol

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

@NH3/NOx=1-1.5

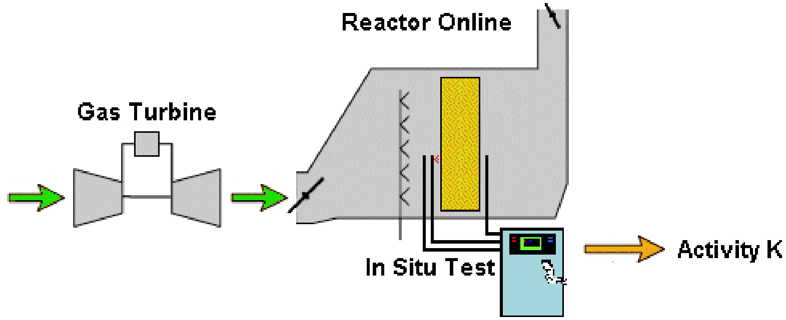


FERCo's CatalysTrak®*

- *in situ* measurement
- No outage required

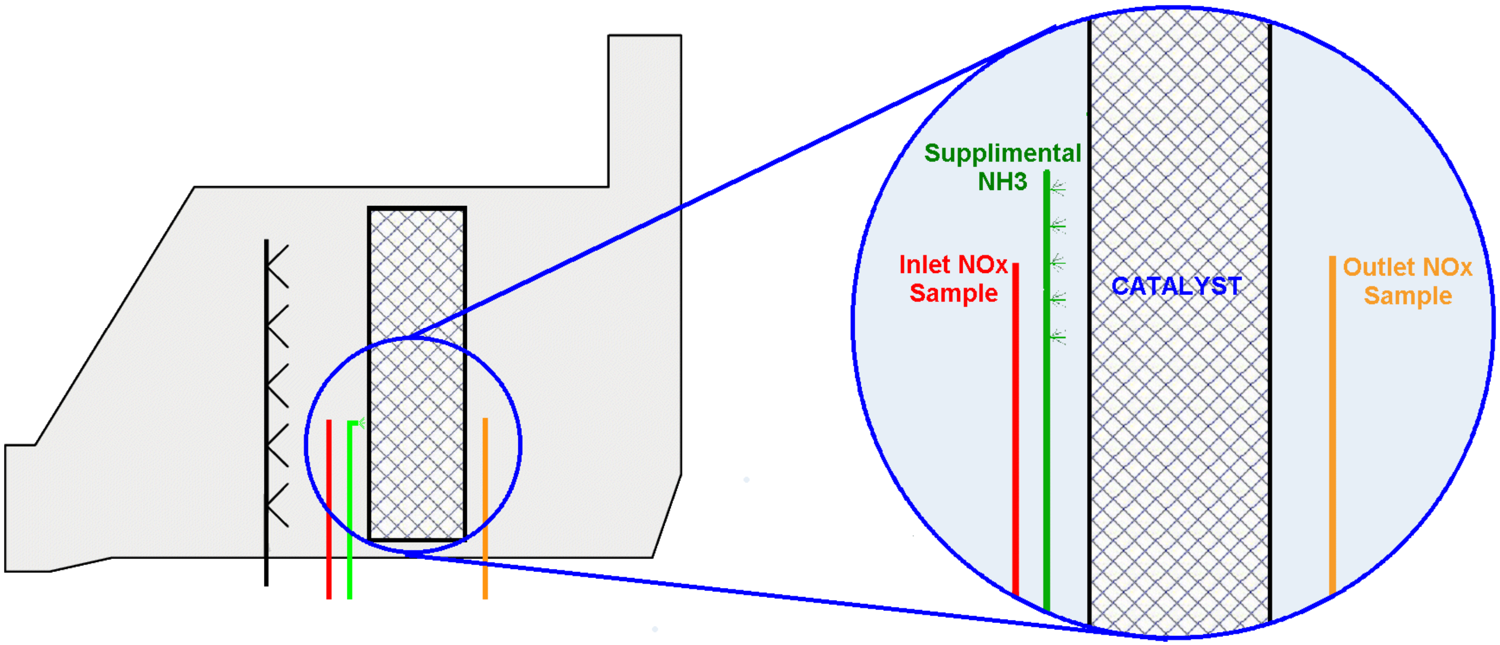
$$K_{In\text{-}situ} = -A_{Vactual} \ln(1-\Delta NO_x)_{full\ scale}$$

@NH3/NOx>1 locally

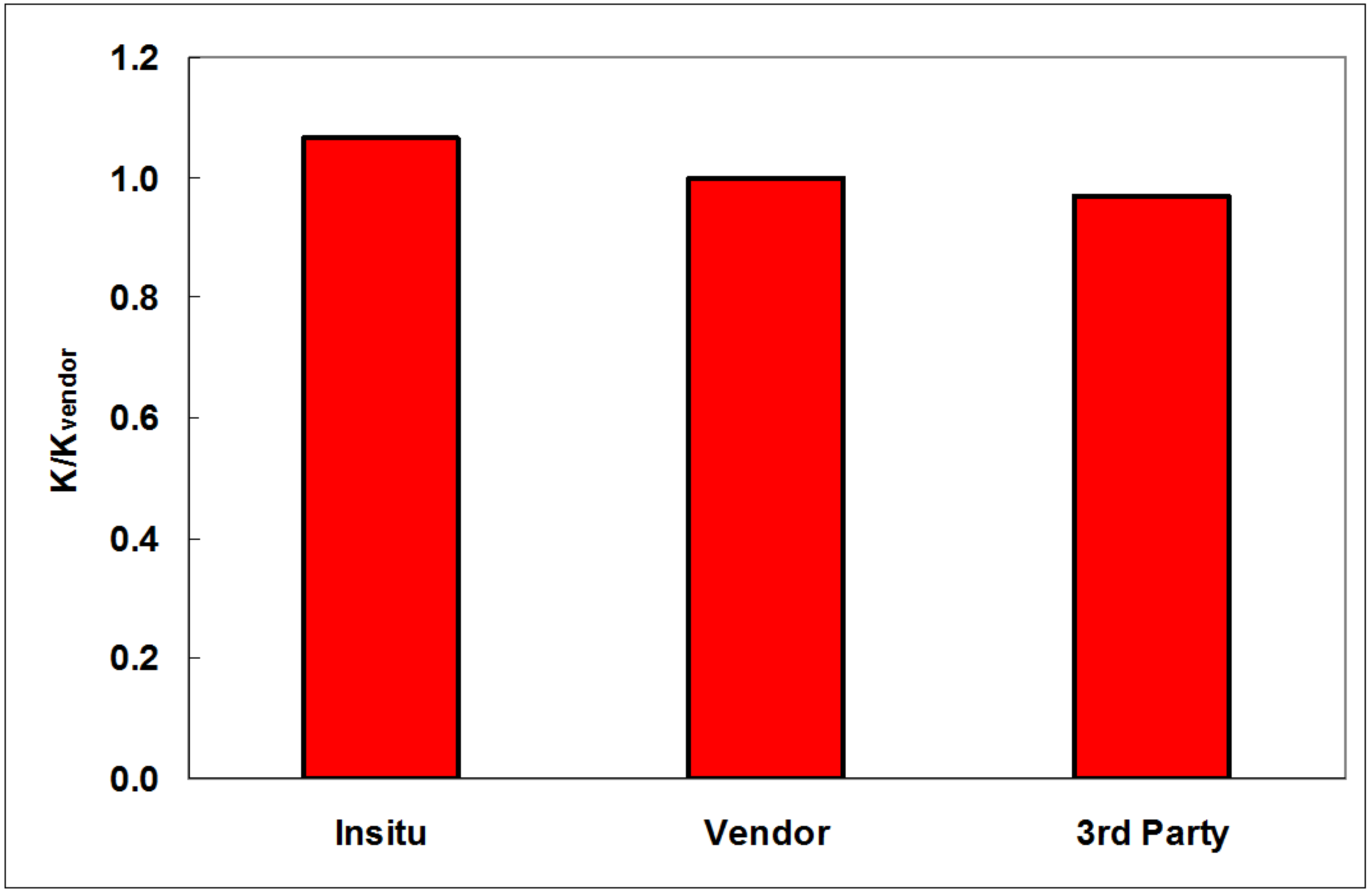


*** Patented Process**

CatalysTraK® *In Situ* Test Modules



In Situ vs Laboratory Activity Measurements



Summary

- **Troubleshooting**
  - Obtain a curve of NH3 slip vs Outlet NOx
  - Can help distinguish poor NH3 distribution vs bypass
- **AIG Tuning**
  - Important activity
  - Easy to do with a permanent probe grid installed downstream of the catalyst
- **Flue Gas Bypass and Velocity Profiles**
  - Can be determined with NO_x measurements
- **CEMs Relative Accuracy**
  - SCR tuning may impact stack NO_x distribution
- **Catalyst Management/Catalyst Activity**
  - Requires knowledge of Activity vs Time
  - CatalysTrak® allows online determination of activity


Questions?
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