In Situ Device for Real-Time Catalyst Deactivation Measurements*

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2006 DOE Environmental Controls Conference
Pittsburgh, PA
May 16-18, 2006

*** Patent Pending**

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Project Overview

Demonstrate the viability of an in situ approach of monitoring catalyst activity in coal-fired SCR reactors

- **Design and install a prototype in situ system at a host utility site**
- **Conduct test program to characterize deactivation rate for individual catalyst layers over two ozone operating seasons**
- **Utilize host unit operator's annual O&M catalyst sampling/analysis activities to validate the in situ deactivation measurements**

Project funding

- **U.S. Department of Energy (NETL)**
- **Electric Power Research Institute**
- **Southern Company**

Catalyst Activity and Reactor Potential

Catalyst Activity (K)

- **Measure of how active the catalyst material is for reducing NO_x**

Reactor Potential (RP)

- **Measure of the overall potential of the reactor to reduce NO_x**
- **$RP = K/A_{V,FS}$**

  $= \frac{K}{A_{Vd}}(1-B)$

  $A_{V,FS}$ = full scale area velocity (blockage)

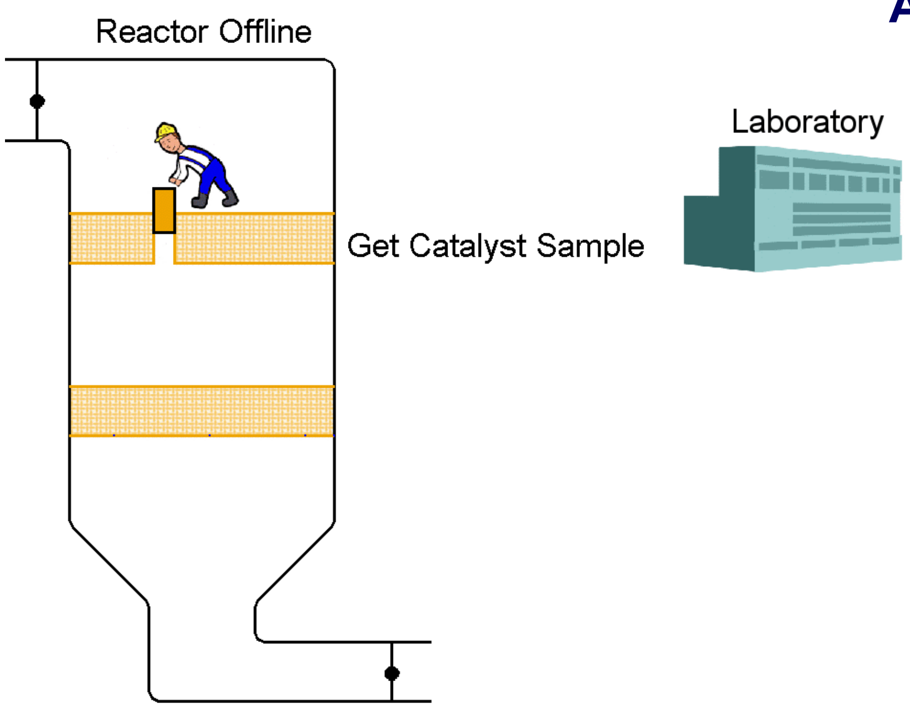
  B = catalyst blockage

  A_{Vd} = design area velocity (zero blockage)

- **Inherently accounts for both catalyst deactivation (K/K_0) as well as catalyst layer blockage, thereby providing a true assessment of the condition of the SCR reactor**
- **RP is the quantity utilized by catalyst management software programs such as EPRI's CatReact product in the evaluation of various catalyst management strategies**

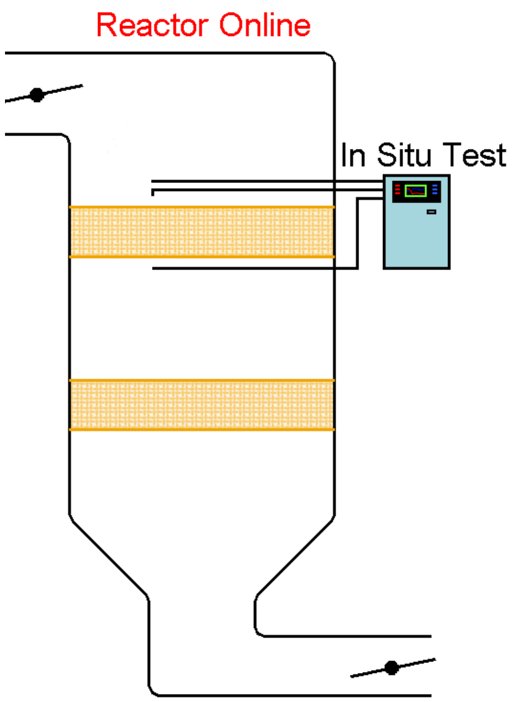
Laboratory Determination of Reactor Potential

- A catalyst sample is tested at the design A_V with $NH_3/NO_x = 1$, and then the activity determined from $K = -A_{Vd} \cdot \ln(1 - \Delta NO_x)$
- An estimate of the blockage in the full scale reactor is then used to calculate the reactor potential: $RP = \frac{K}{A_{Vd}}(1-B)$

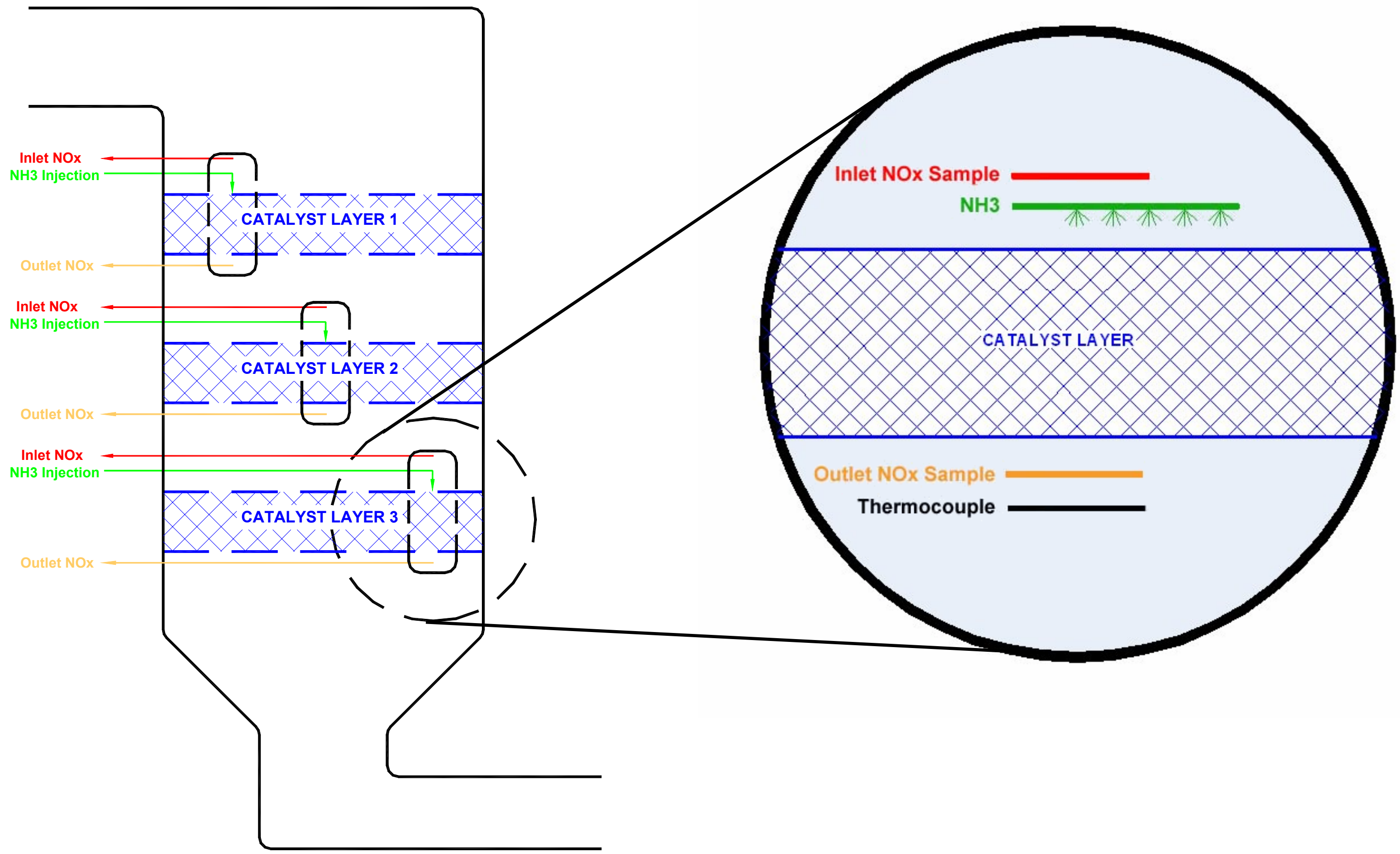


In Situ Reactor Potential

- If RP = $K/A_{V,FS}$ and K = $-A_{V,FS} \cdot \ln(1-\Delta NO_x)$, then **RP = $-\ln(1-\Delta NO_x)$**
- Thus, an in situ measurement of the maximum NO_x removal across the layer yields a direct measurement of the reactor potential



Multiple *In-Situ* Test Modules - General Approach



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Host Site Description

Demonstration host site provided by Southern Company

- **Alabama Power Company's Gorgas Unit 10**
  - **700 MW**
  - **Twin-furnace, tangentially-fired**
  - **Started operation 1972**
  - **Alabama bituminous coal**
- **SCR on-line May 2002, ozone season operation**
  - **Two reactors**
  - **3 + 1 configuration**
  - **Anhydrous NH_3**
  - **Initial load: three layers of extruded honeycomb catalyst**
  - **Fourth layer of plate catalyst added prior to 2006 ozone season**

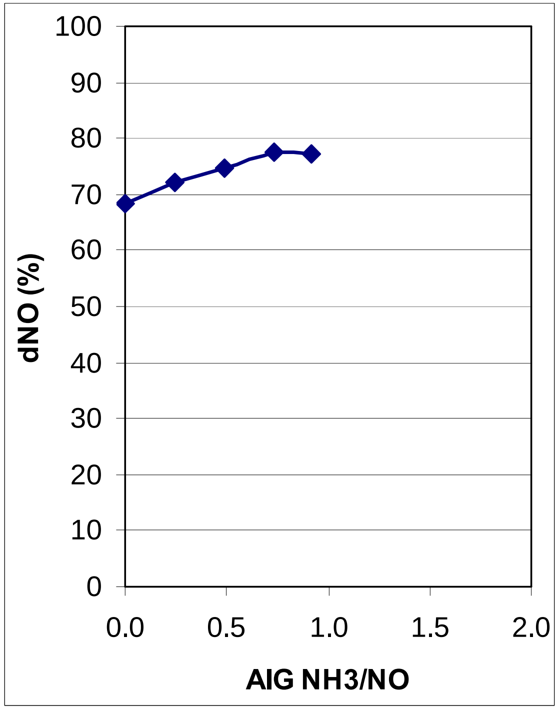
Equipment Overview

- Stationary NEMA 4 enclosure housing multi-position sampling valves
- Portable "cart" housing gas analysis instrumentation and control system

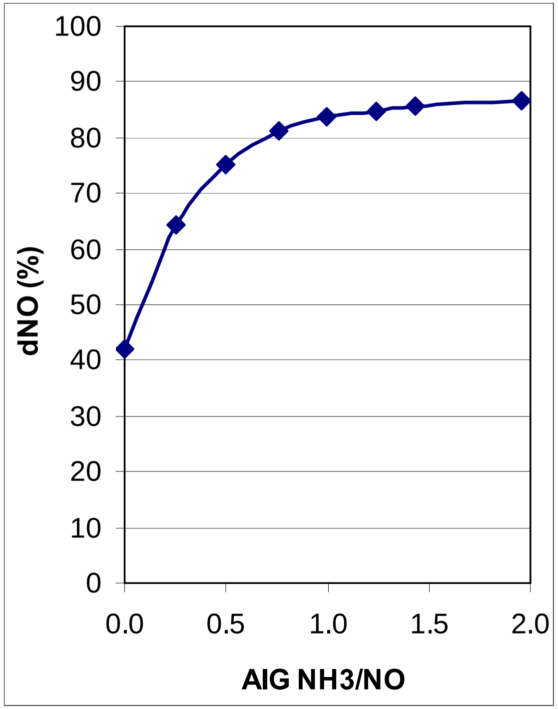
In Situ Test Protocol and Typical Test Results

- Measure NO removal across test module without NH_3 injection
- Add NH_3 via test module AIG to point of maximum NO removal
- Calculate reactor potential from RP = -ln(1- ΔNO)

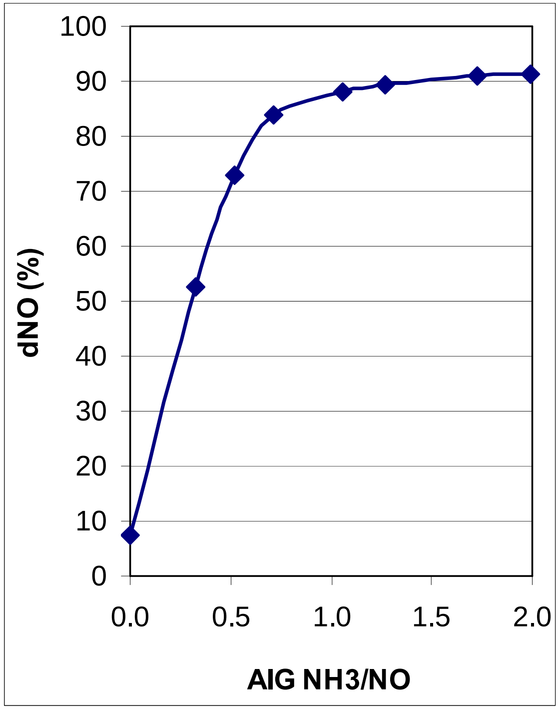
Catalyst Layer 1



Catalyst Layer 2



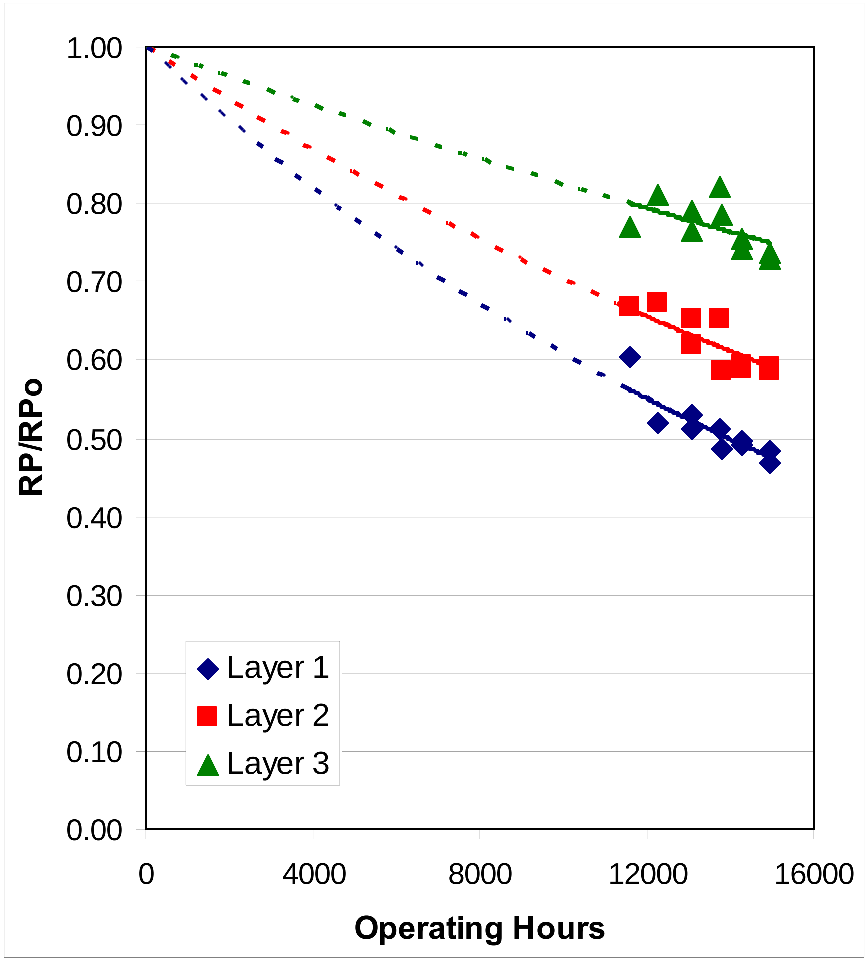
Catalyst Layer 3



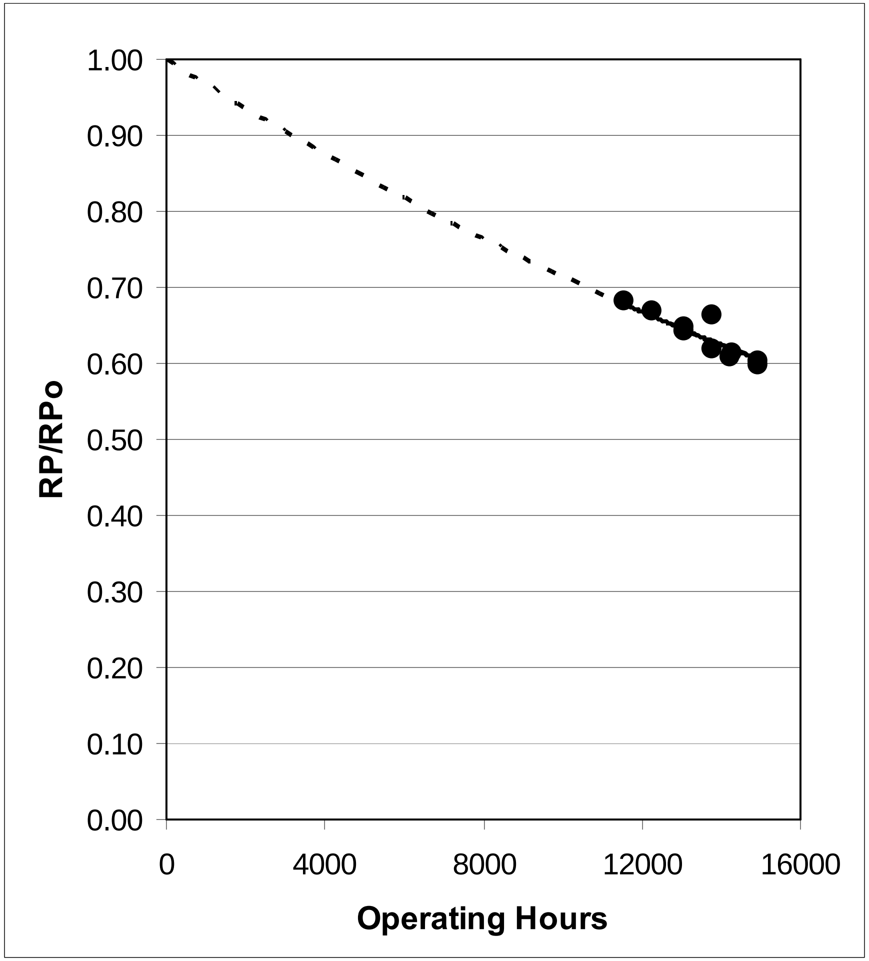
- dNO maximum = 77.3%
- dNO maximum = 86.6%
- dNO maximum = 91.3%

In Situ Reactor Potential Results - 2005

Individual Layers



Overall Reactor



Blockage Estimation for Laboratory RP Calculation

End of 2005 Ozone Season

Source of Estimate	Blockage Estimate		
	Layer 1	Layer 2	Layer 3
Plant visual inspection	20%	30%	25%
Calculate from change in layer pressure drop from new (clean)	40%	24%	n/a

$$RP = \frac{K}{A_V}(1-B)$$

Question: What would B need to be to make the laboratory RP value equal to the in situ value?

	Layer 1	Layer 2	Layer 3
Calculate blockage value from in situ RP and laboratory K/A_v	41%	24%	19%

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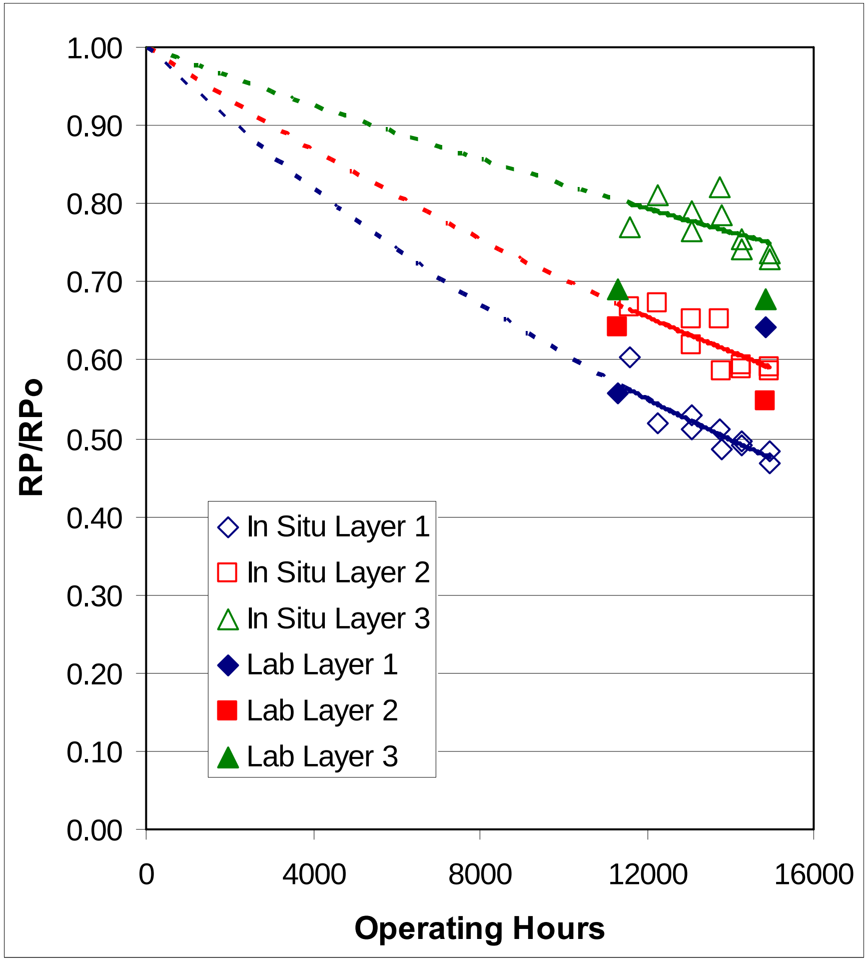
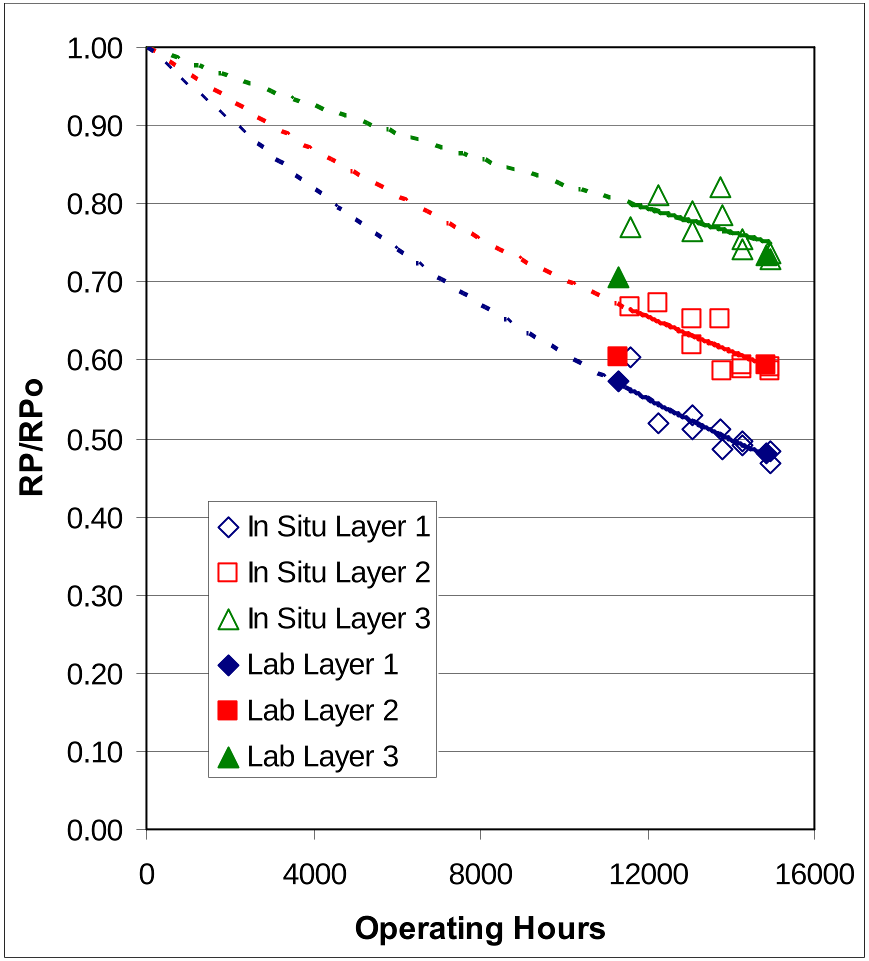
Laboratory RP/RP$_0$ for Individual Catalyst Layers

Visual Blockage Estimate



Blockage Calculated from dP



Why do the In Situ and Laboratory RPs Differ?

Laboratory technique measures K at the design A_V

- Estimated blockage needed to calculate RP may be in error
- Actual flue gas flow may differ from the design flow

In Situ technique measures RP for the same piece of catalyst

- Laboratory uses a different piece for each test
- Possible variations in K across the catalyst layer

Operating Hours	K/K_0 Layer 1	K/K_0 Layer 2	K/K_0 Layer 3
11317 (end 2004)	0.71	0.75	0.79
14870 (end 2005)	0.80	0.78	0.90

In Situ tests at NH_3/NO_x ~ 1.5, laboratory tests at NH_3/NO_x = 1.0

- Increasing NO_x removal at NH_3/NO_x > 1 will yield higher RP, but the RP/RP_0 should be the same.

Comparison of Measurement Techniques

Laboratory	In Situ
Pro • Accurate K determination • Physical sample can also be analyzed for physical and chemical properties	**Pro** • Direct measurement of RP • Larger data set • Can test immediately after unit "upset"
Con • Relies on an estimate of blockage to calculate RP • Limited data set (outages only)	**Con** • Need blockage to calculate K • ΔNO_x increase at $NH_3/NO_x > 1$ may yield slightly higher absolute RP values

The in situ technique should not be thought of as a replacement for laboratory analysis of catalyst samples, but as a companion measurement

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