

Reinhold Environmental Ltd.




2009 NOx-Combustion Round
Table & Expo Presentation

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Assessing Deactivation Trends for Catalyst Design and Management Planning



Presenter
John Cochran
CERAM Environmental, Inc.
(913) 239-9896



Coauthor
Dr Greg Holscher
CERAM Environmental, Inc.
(913) 239-9896

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ENVIRONMENTAL, INC.

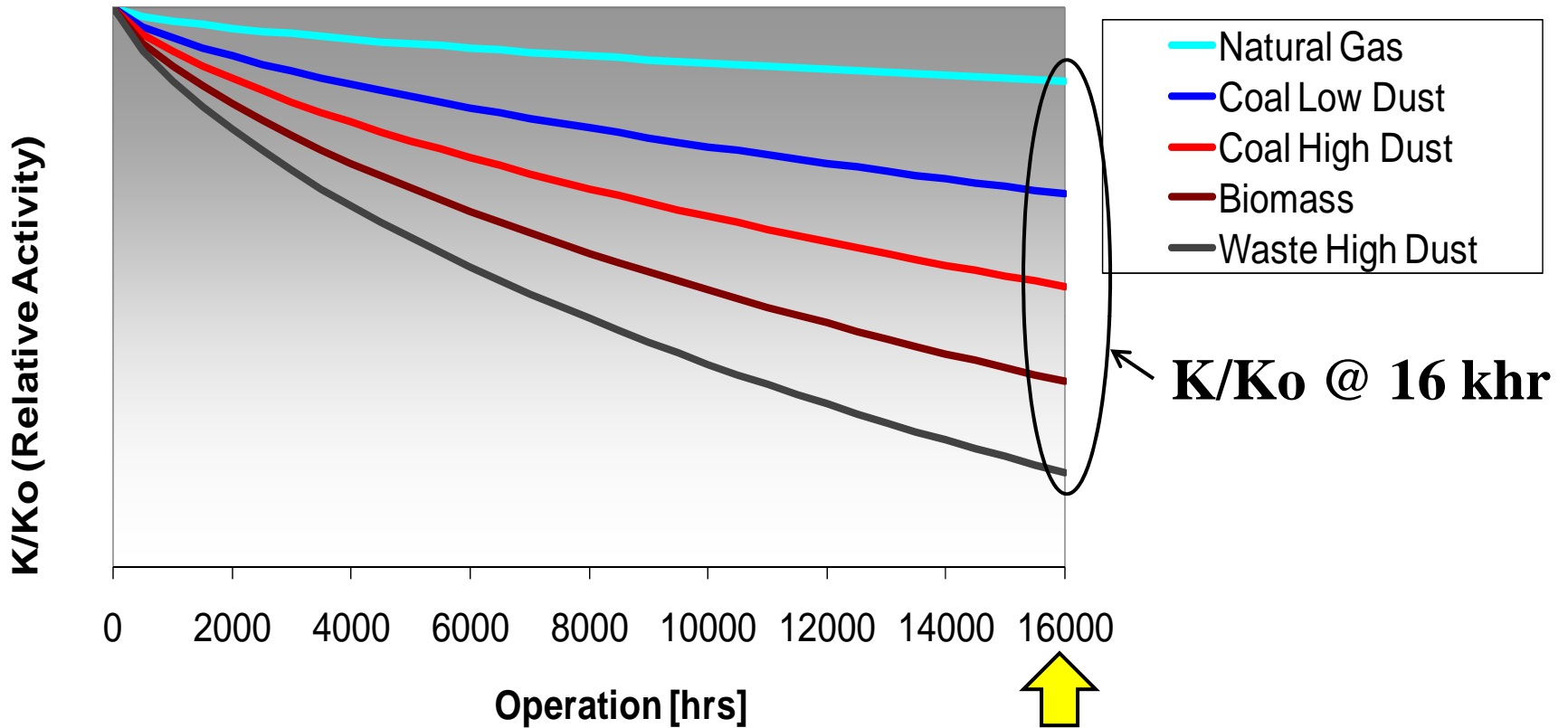
CERAM Environmental Inc.

- U.S. Based Subsidiary of CERAM Founded in 2000
- Providing Catalyst Supply Contract Coordination
 - Catalyst Design, Flow Modeling, Delivery Coordination, Training, Startup Services, Guarantee Administration
- Providing Comprehensive Catalyst Management Services for >30 Coal Based SCRs in the US
 - AIG Tunings
 - Reactor Inspections
 - Catalyst Testing
 - SCR System DCS Data Reporting, Assessments, and Troubleshooting
 - Regeneration and Rejuvenation Services Procurement
 - Catalyst Management and SCR Operations Planning



Catalyst Deactivates With Exposure to Flue Gas

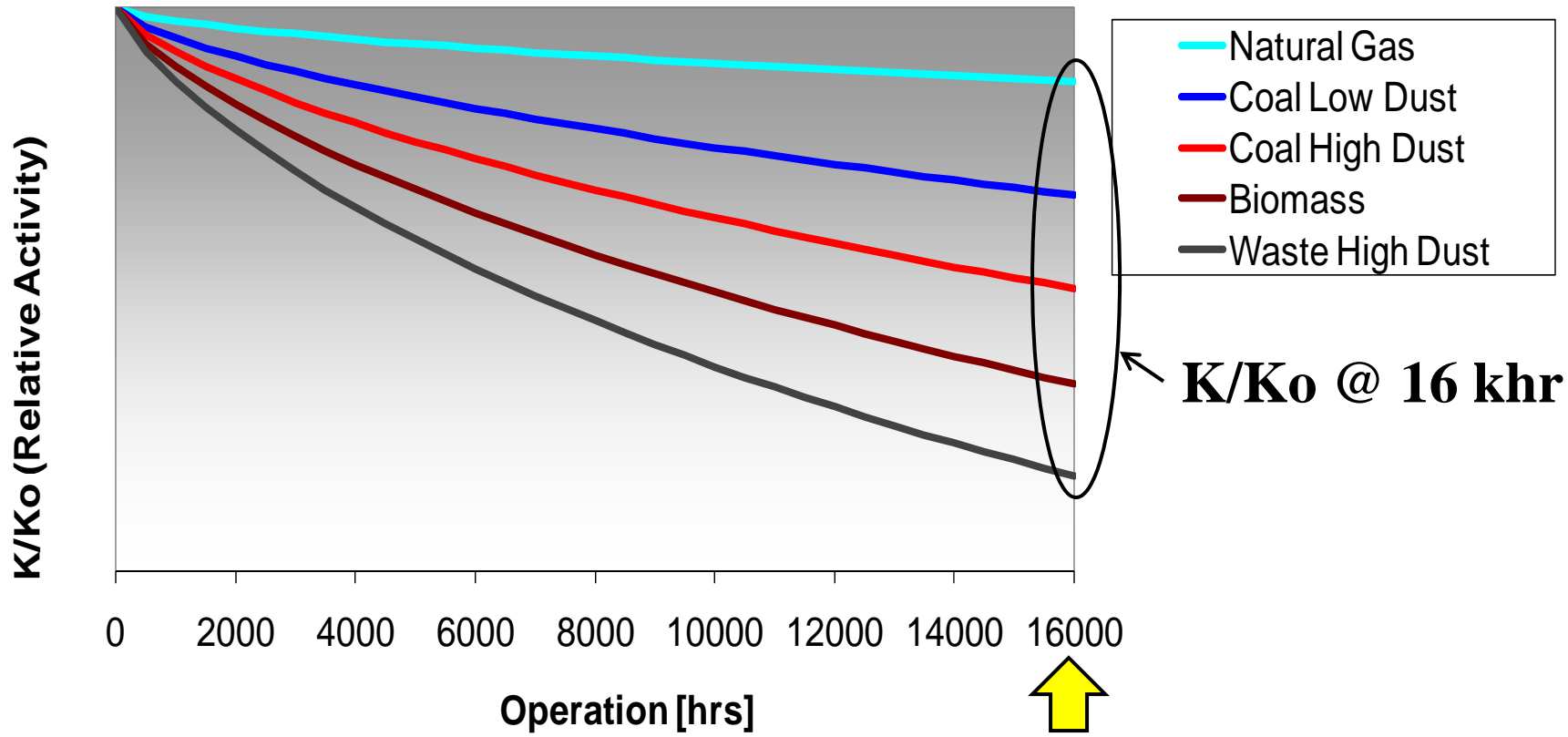
K_0 (Original Catalyst Activity)



- Definition: $K/K_0 = \text{Activity at Time of Test (K)} / \text{Original Catalyst Activity (K}_0)$
- K/K_0 @ 16khr Can Range From 0.2 to >0.9 Dependent on Fuel Quality and Operating Circumstances

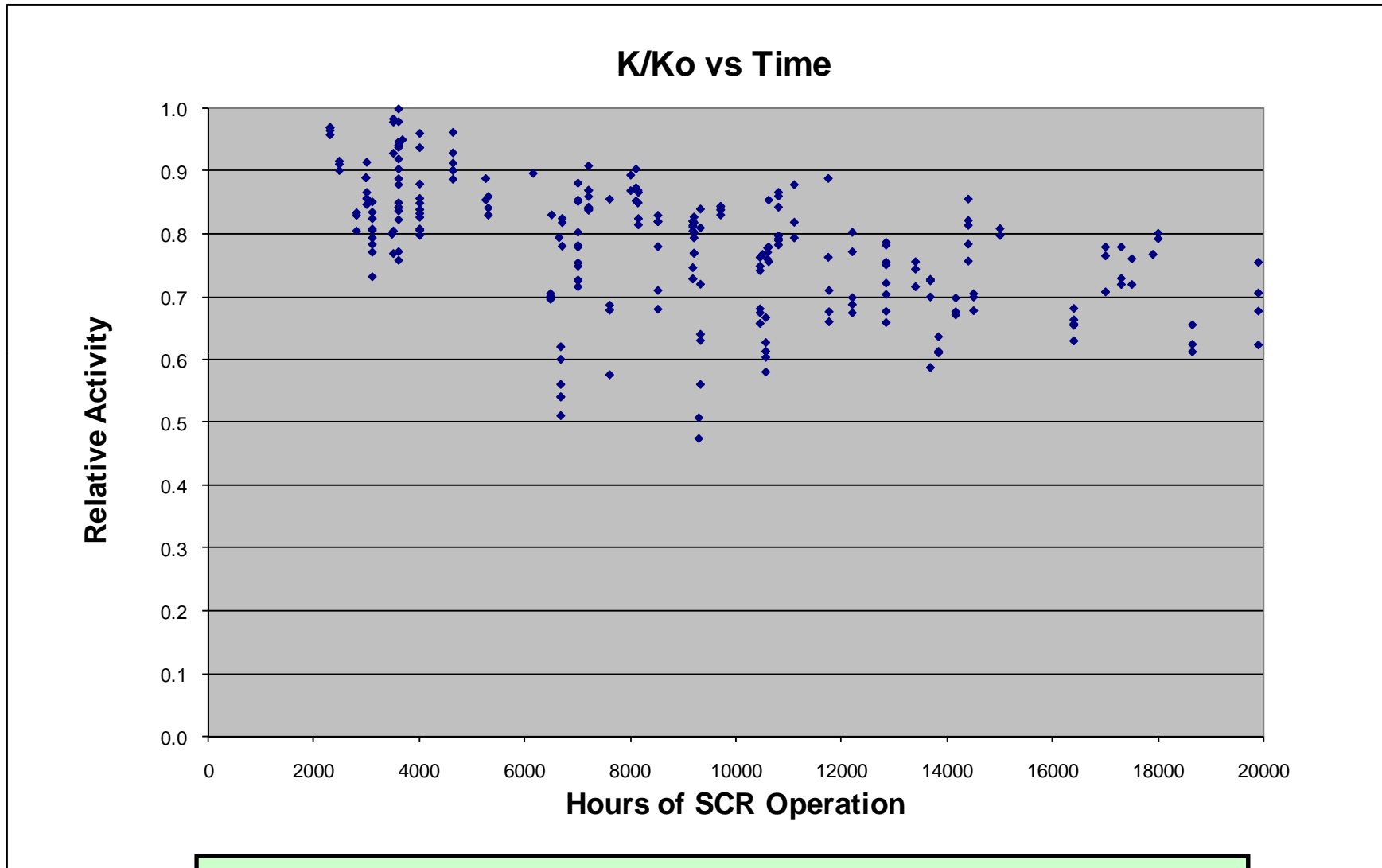
Catalyst Deactivates With Exposure to Flue Gas

K_0 (Original Catalyst Activity)



Catalyst Design (at hour=0) Must Anticipate Deactivation to End of Guarantee Period to Size Catalyst Properly

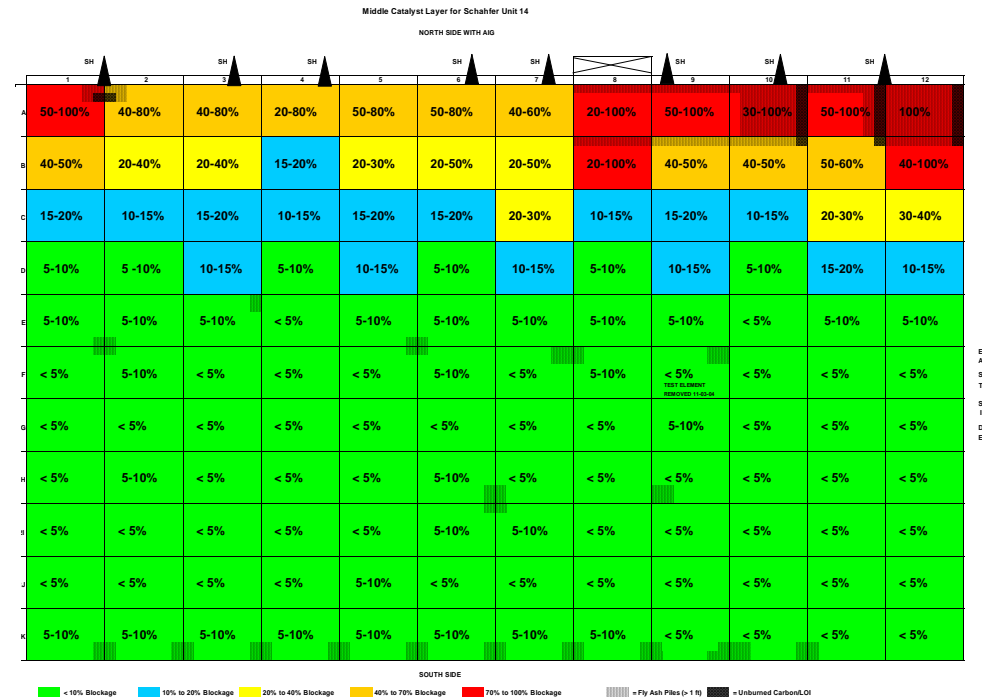
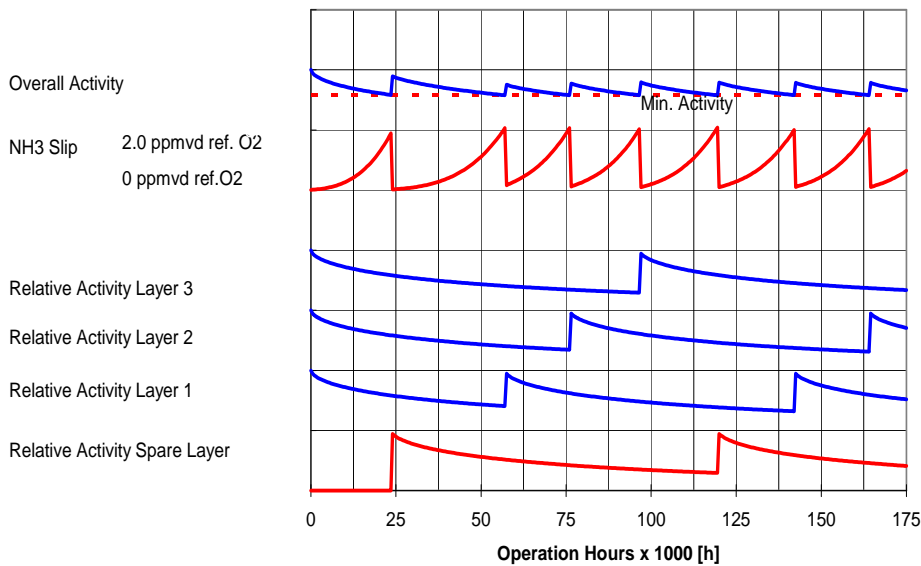
Catalyst Deactivation is Very Site and Fuel Specific



Tracking K/Ko Trends Critical to Accurately Manage Catalyst

Reasons for Catalyst Additions or Replacements

- Deactivation – Loss of chemical activity
- Plugging/Surface Accumulations – Loss of active catalyst surface area
- Erosion – Loss of catalyst material or loss of mechanical integrity
- Sintering – Thermal destruction of activity



Catalyst Testing is an Essential Element of Catalyst Management Planning

- Measurements:
 - DeNO_x Activity (K_o and K)
 - Surface Chemical Analysis
 - Bulk Chemical Analysis
 - Other – SO₂ to SO₃ Conversion Rate, Pore Volume, Specific Surface Area, Abrasion Resistance, Compression Strength
- Predominant Catalyst Test Objectives:
 - Assess Deactivation Rate and Project K/K_o Trend
 - Identify Deactivation Mechanisms
 - Evaluate Mechanical Properties
- Information Obtained Used to Assess Catalyst Capabilities and Project Future Replacements

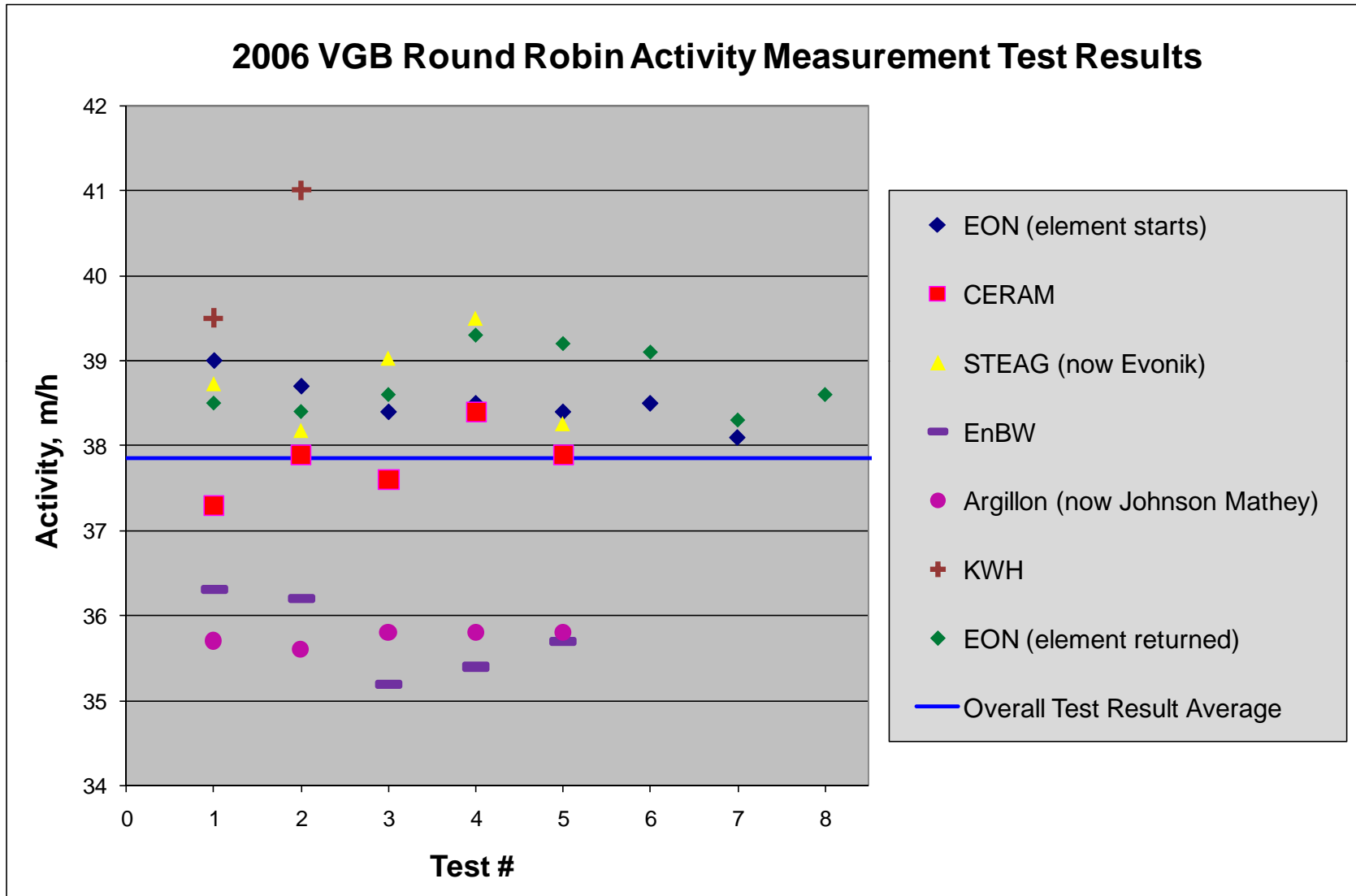


CERAM Laboratory Capabilities

- Extensive Laboratory Capabilities
 - 1 Bench Reactor and 7 Semi-Bench Reactors
 - Testing New and Aged Catalyst Samples (Honeycomb, Plate, Corrugated Fiber)
 - >1000 Tests Performed in 2008
- 2006 VGB Catalyst Activity Testing Round Robin
 - Element With Unknown Activity Circulated to 6 Laboratories
 - CERAM Result Was Closest to Average Result
 - ◆ Activity -0.1% (-0.03 m/h) From Average
 - ◆ 1.1% Standard Deviation for 5 Tests
 - Other Labs (Total of 37 Measurements in 6 Labs)
 - ◆ Activity -2.6 m/h (-7.0%) to +3.2 m/h (+8.3%) From Average
 - ◆ Average Activity Variance = 1.0 m/h

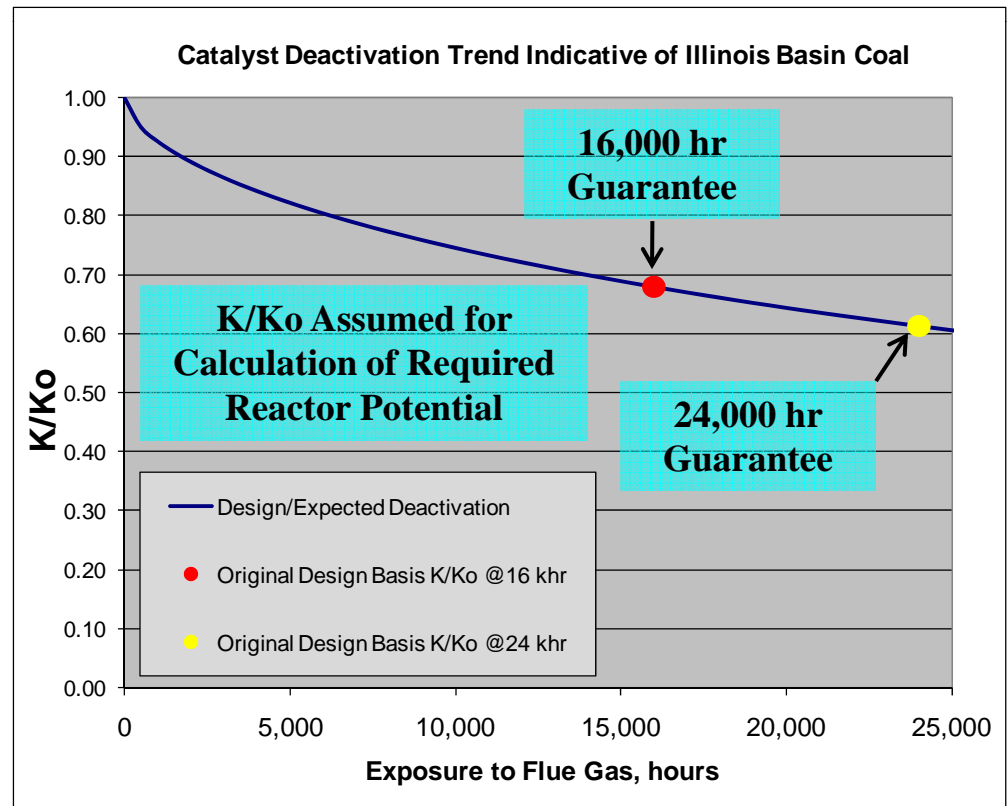


Laboratory Test Results



Original Catalyst Sizing

- Catalyst Supplier Projected a Deactivation Rate (K/Ko Expected at the End of the Specified Guaranteed Period) Based on **Experience and ...**
 - **Specified** SCR Design Type (High Dust, Low Dust, or Tail-End)
 - **Specified** Fuel Conditions (S, Ash, As, CaO, P, K, Na, etc.)
 - **Specified** Operating Conditions
- Supplier Sized Catalyst (Determined the Required Reactor Potential) Based on This K/Ko Projection and **Specified** Design Point Data....
 - NO_x In/Out and NH₃ Slip
 - Flue Gas Temperature
 - Gas Flow Rates & Constituents
 - Distributions (V, NH₃/NO_x, T)
 - Expected Catalyst Pluggage
 - Other Specified Items

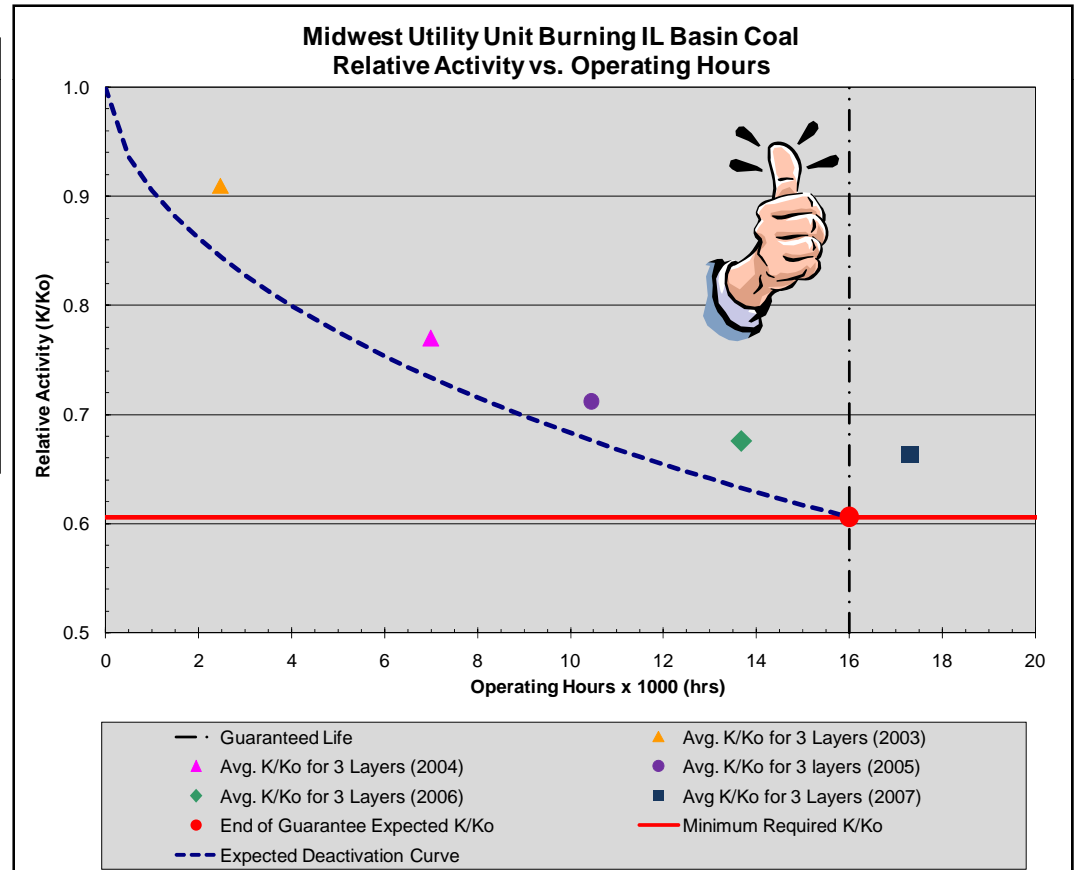


Traditional Catalyst Management

- Utility Pulls Test Elements
- Test Elements Sent to Laboratory
- Laboratory Tests Elements
- Laboratory Indicates if K/Ko is Above Original Sizing Basis
- Is This Catalyst Management Planning?

This Approach:

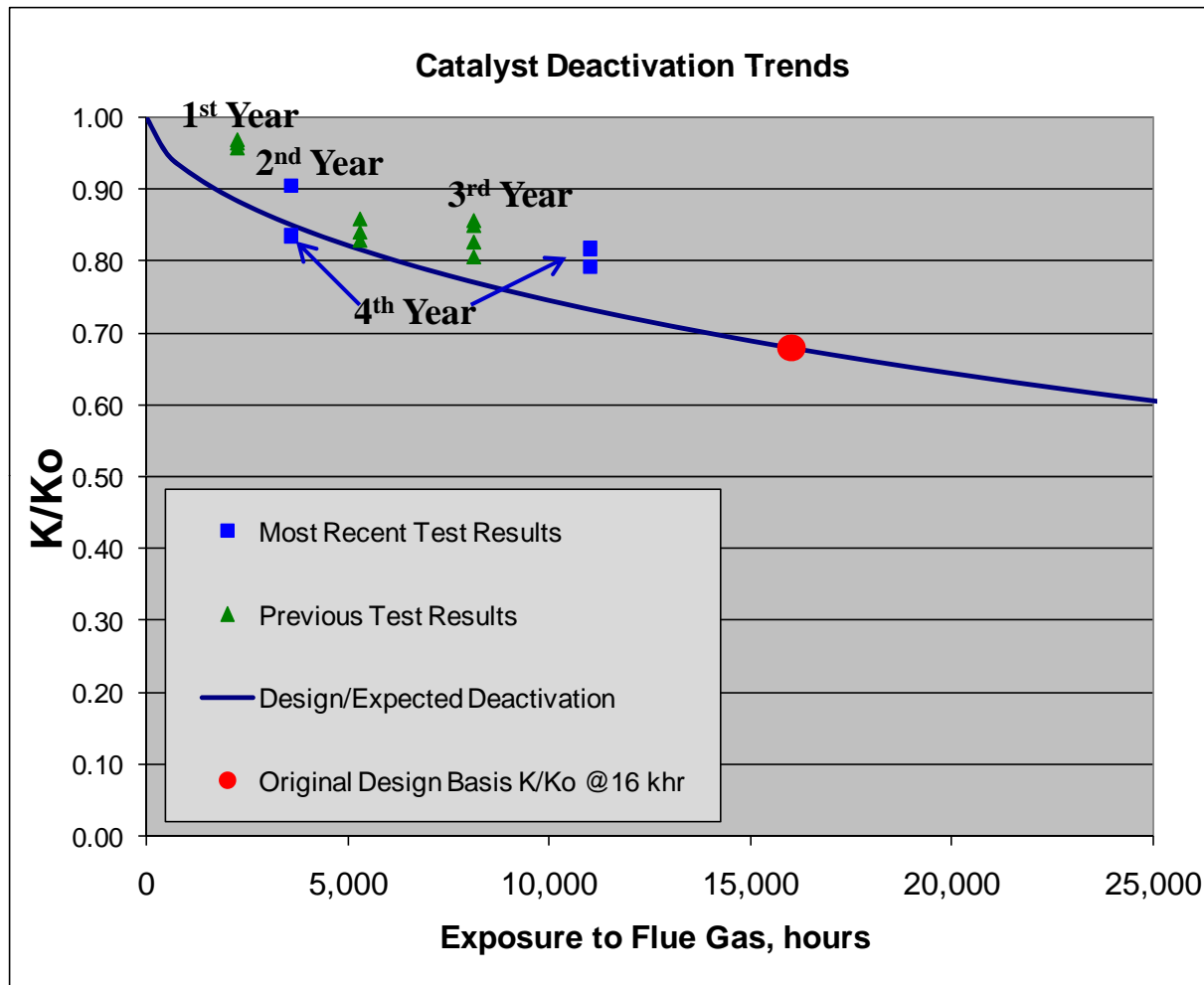
- Neglects Reactor Mechanical Condition (Pluggage)
- Neglects Different DeNO_x Operating Demands from Design/Specification Basis



K/Ko Tracking is NOT the Only Part of an Effective Catalyst Management Program!!!

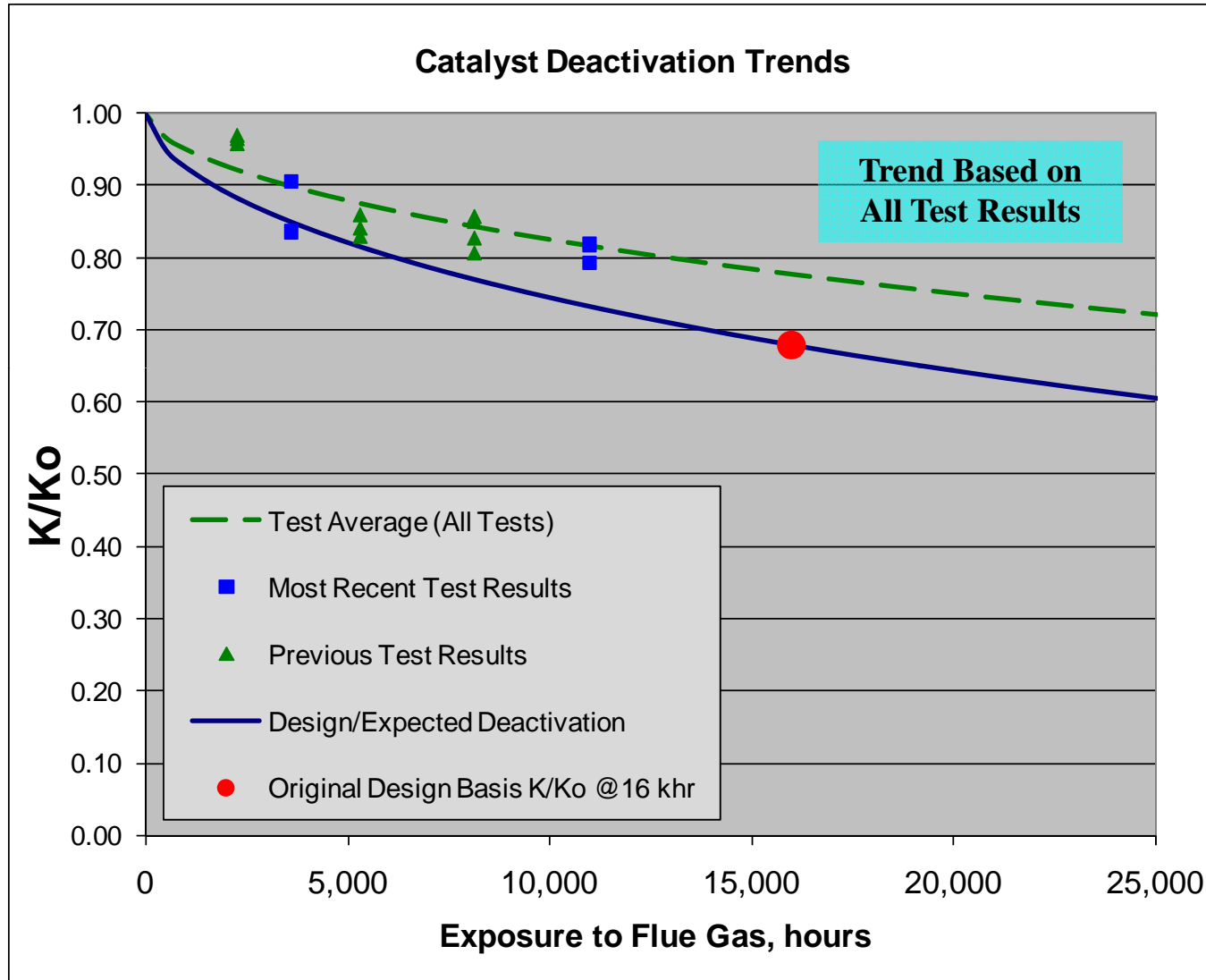
- Items Not Accounted for With K/Ko Testing Include...
 - Relative Accuracy of Activity Measurements
 - Reactor Pluggage Present
 - Original Catalyst Activity Different From Design Basis
 - Conditions Different Than Design/Specified Basis
 - ◆ Inlet NO_x
 - ◆ Outlet NO_x
 - ◆ Ammonia Slip
 - ◆ Gas Temperatures
 - ◆ Distributions
 - ◆ Flow Rates
 - ◆ Flue Gas Constituents
 - Did Catalyst Supplier Estimate the Correct Required Reactor Potential for Conditions Present?

Catalyst Activity Should be Tracked Annually

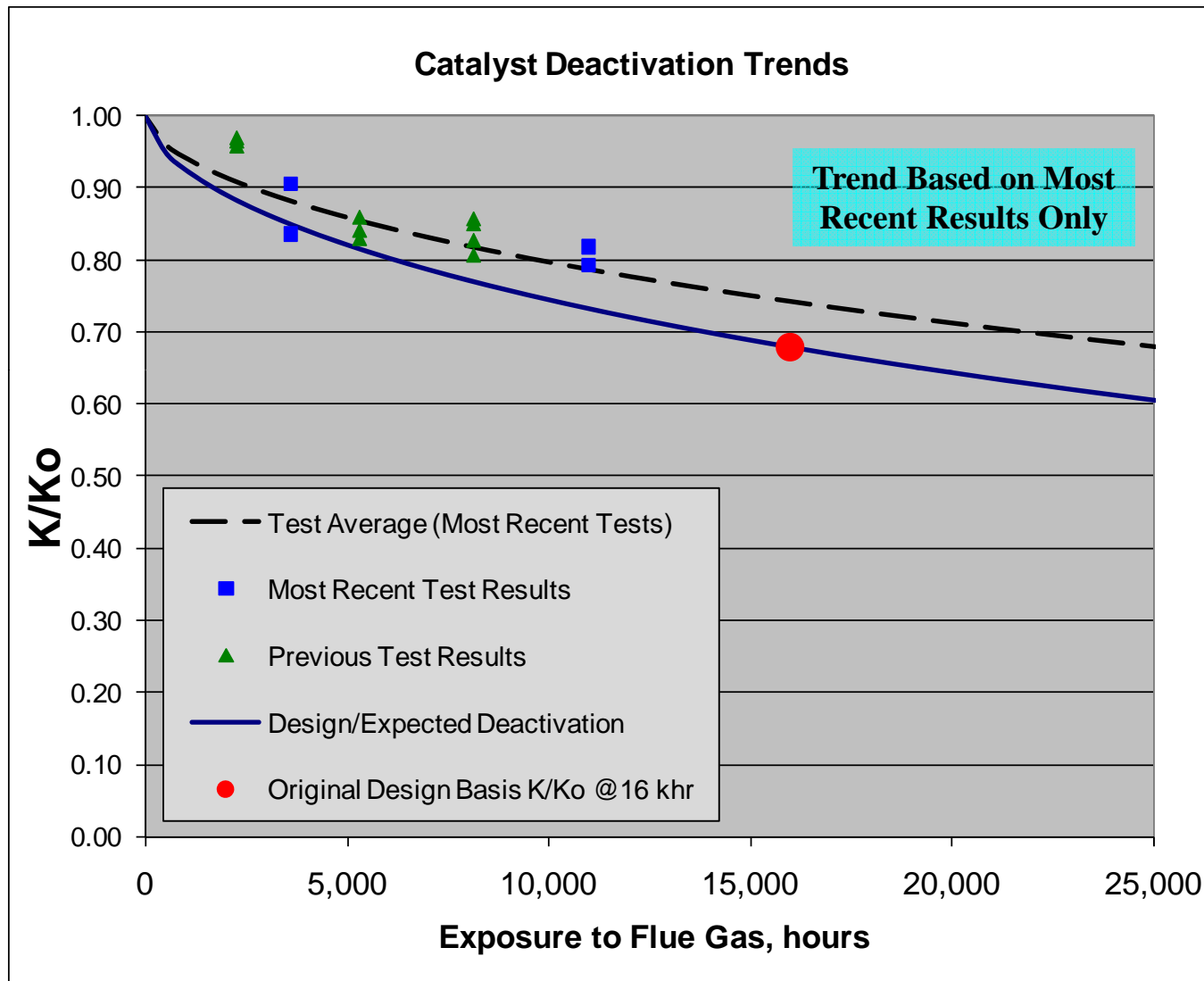


- Trend Analysis Should Consider All Results With Emphasis on Most Recent Results

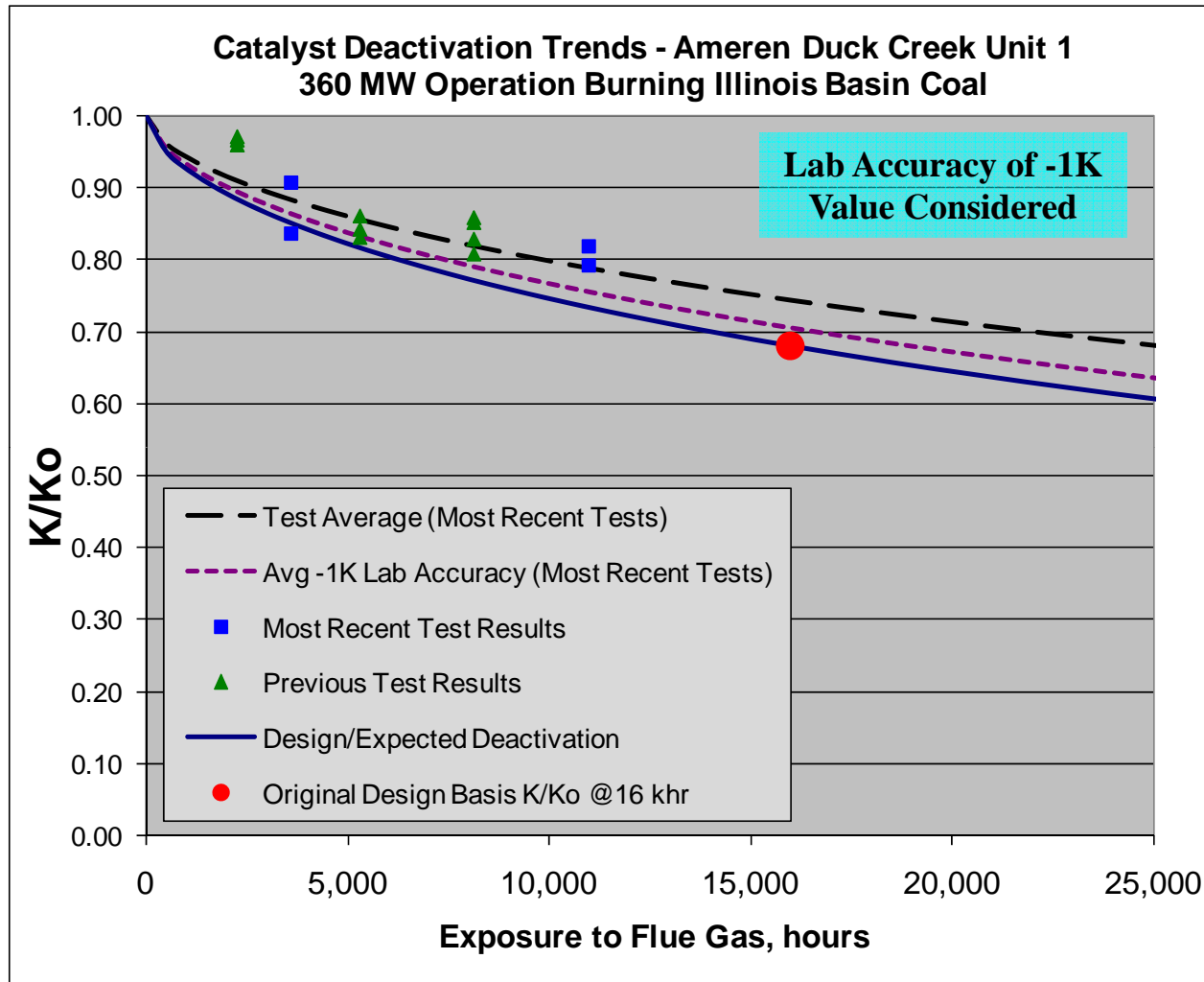
Aging Model Applied to Results to Determine Long Term Trends



Most Recent Results May Indicate Most Representative Trend

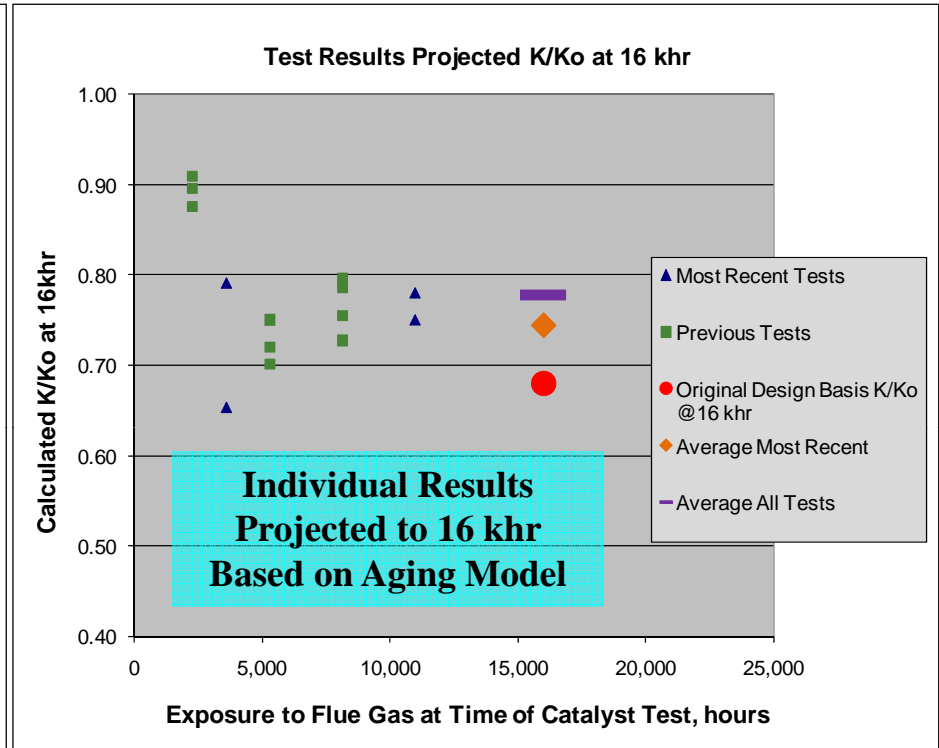
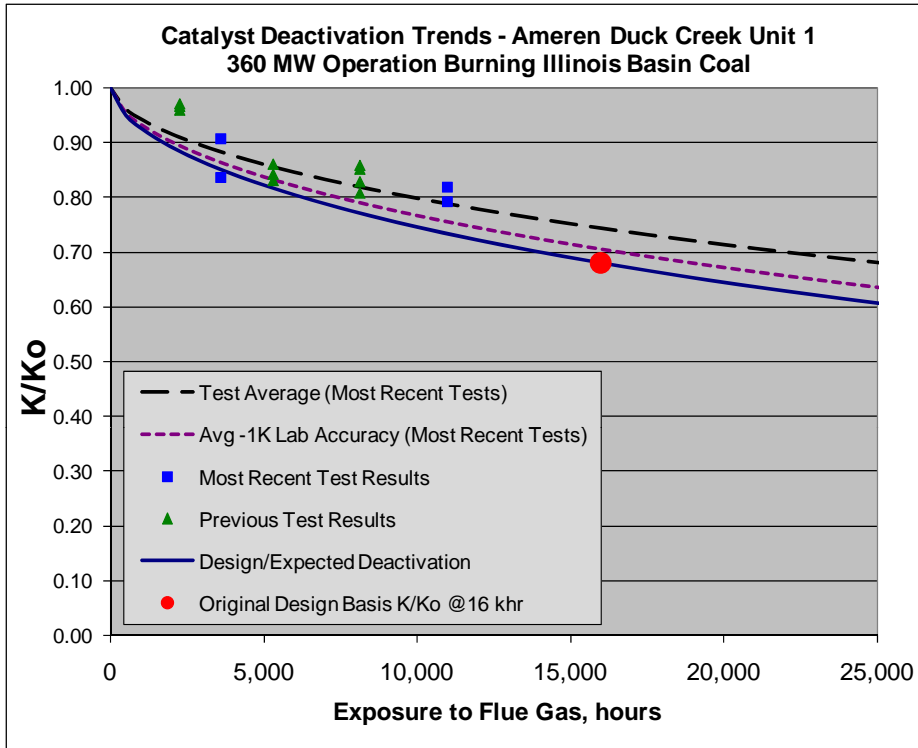


Things Going According to Plan



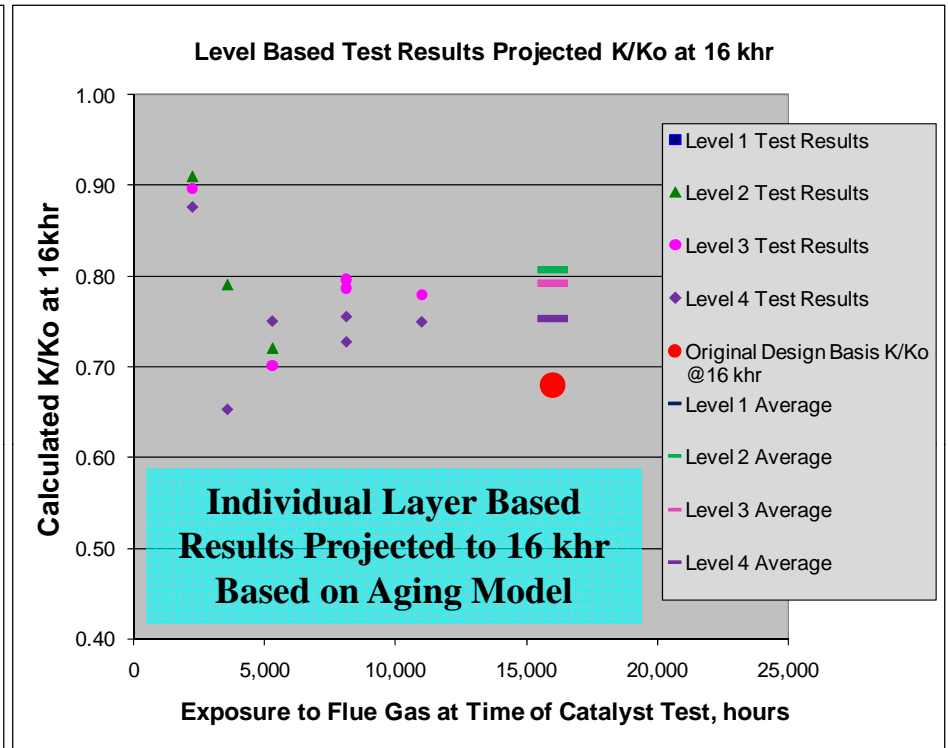
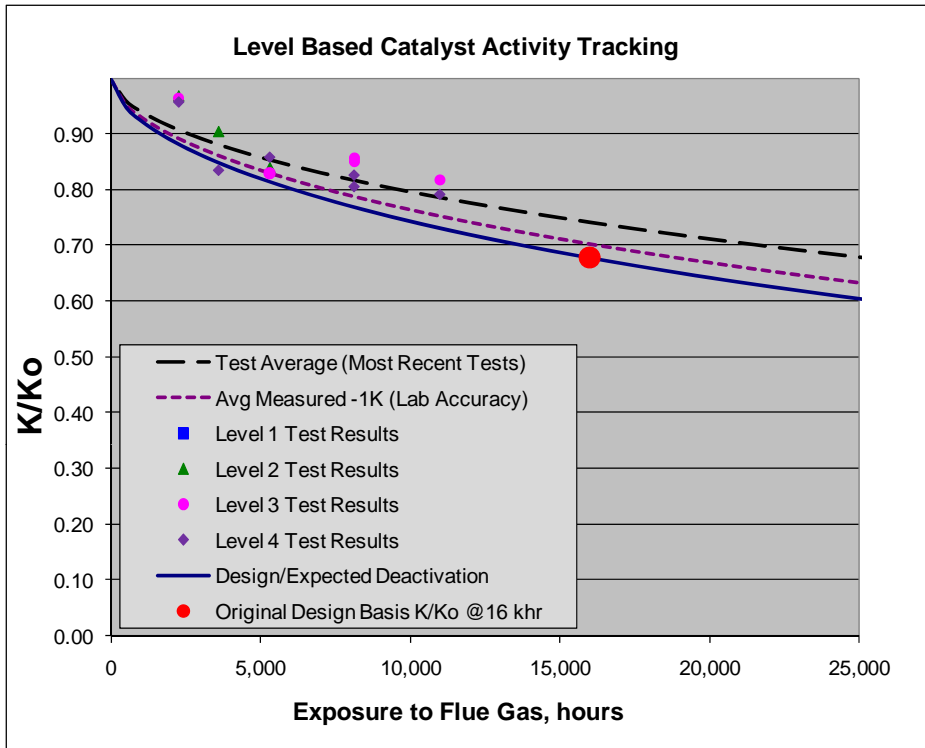
- The Lab Accuracy (± 1 K) Should Also Be Considered in the Trending Analysis

Is The Trend Changing With Time?



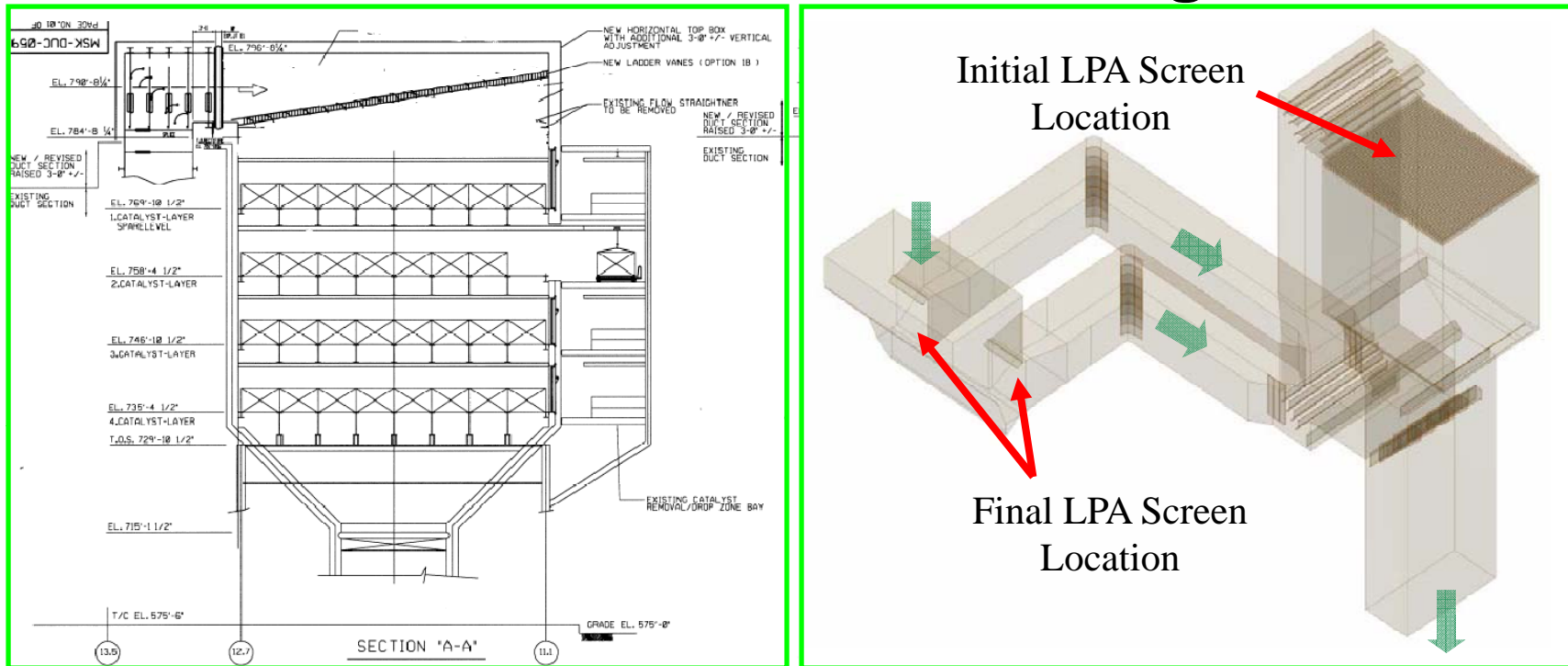
- Use Aging Models to Project K/Ko Result to 16,000 Hours
- K/Ko at 16 khr Projection Provides a Common Basis to Assess Deactivation Trends

Which Reactor Level is the Weak Link?



- Deactivation Rates Can Vary From Level to Level in the Reactor
- Information Useful to Determine Which Level Has Lowest Activity When Time to Change Out Catalyst

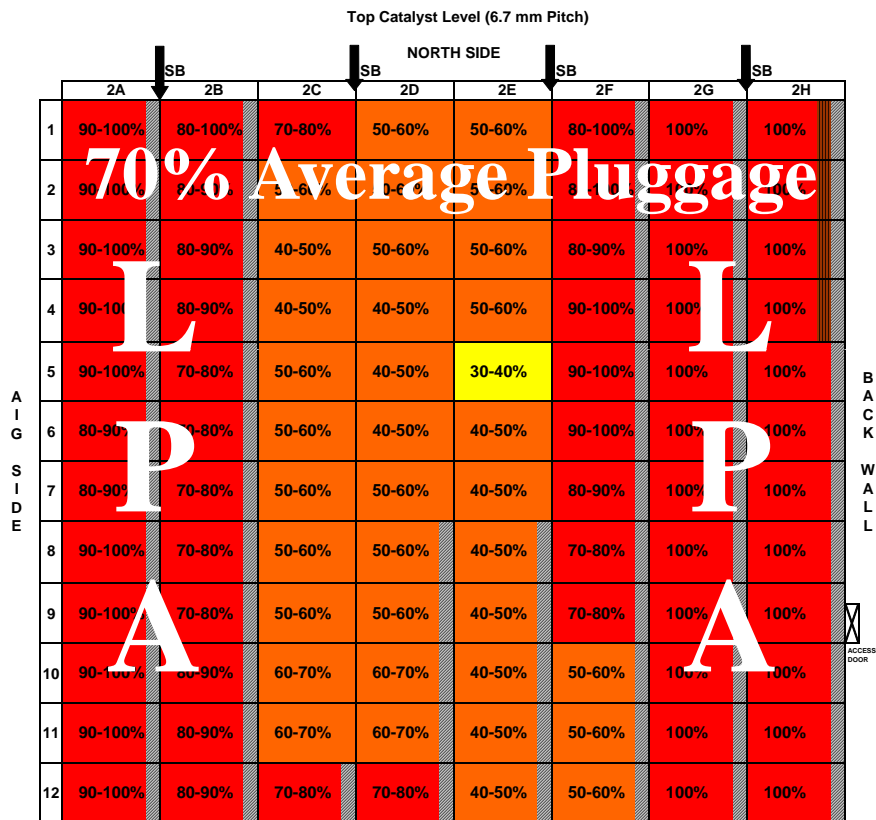
Duck Creek Reactor Arrangement



- Initially No LPA Screen Installed
 - LPA Observed and Caused OEM to Install Screen
- First LPA Screen Installed by OEM Above Flow Rectifier
 - LPA Deposited on Back Side of Reactor
- Final LPA Screen Located at Economizer Outlet
 - High Velocity at LPA Screen (75 to 90 fps) and Failures Passed Further LPA Resulting in Pluggage on AIG Side of Reactor

Duck Creek Top Layer Pluggage Map

After 2005 6.7 mm/1mm Wall



- Initial Operation Without Screen – LPA on AIG Side of Reactor
- LPA Screen Added Above Catalyst – LPA Deposited on Far Side of Reactor

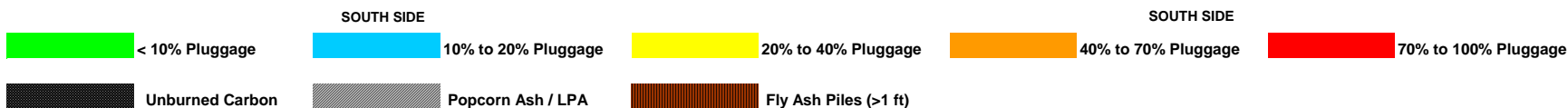
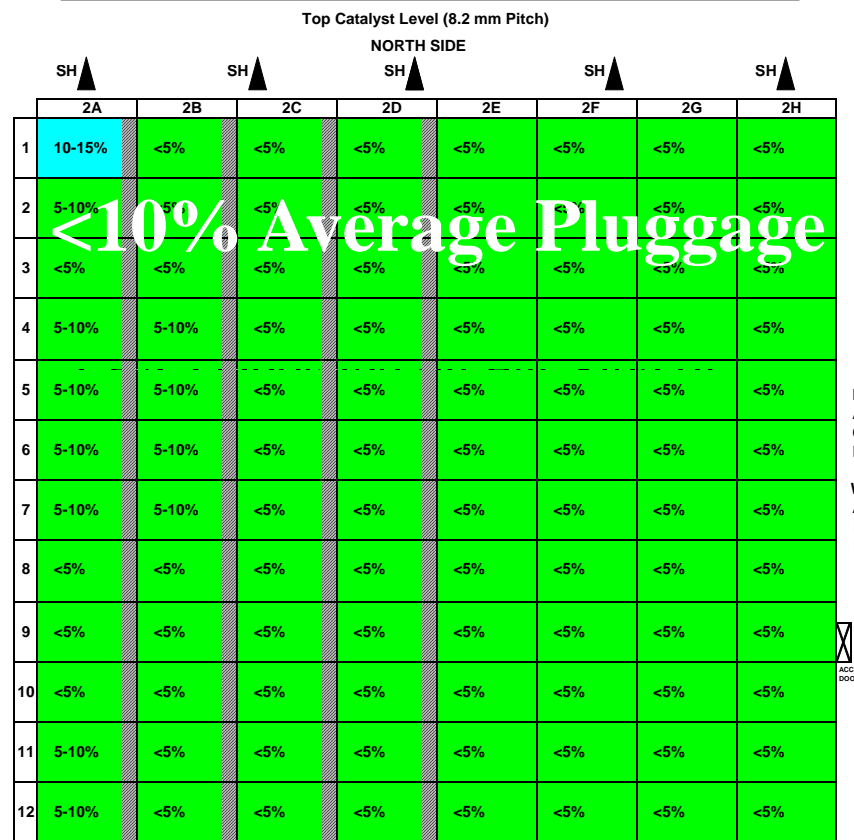
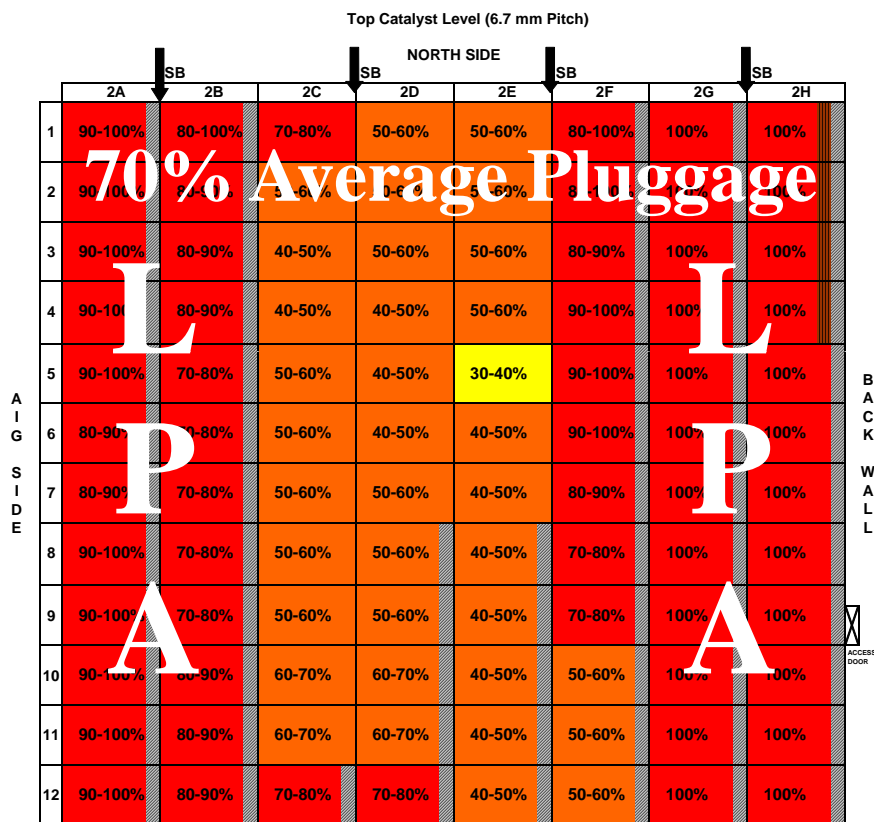
After 2 Ozone Seasons of 40 to 70% Pluggage No Significant Erosion Noted With 6.7 mm Catalyst



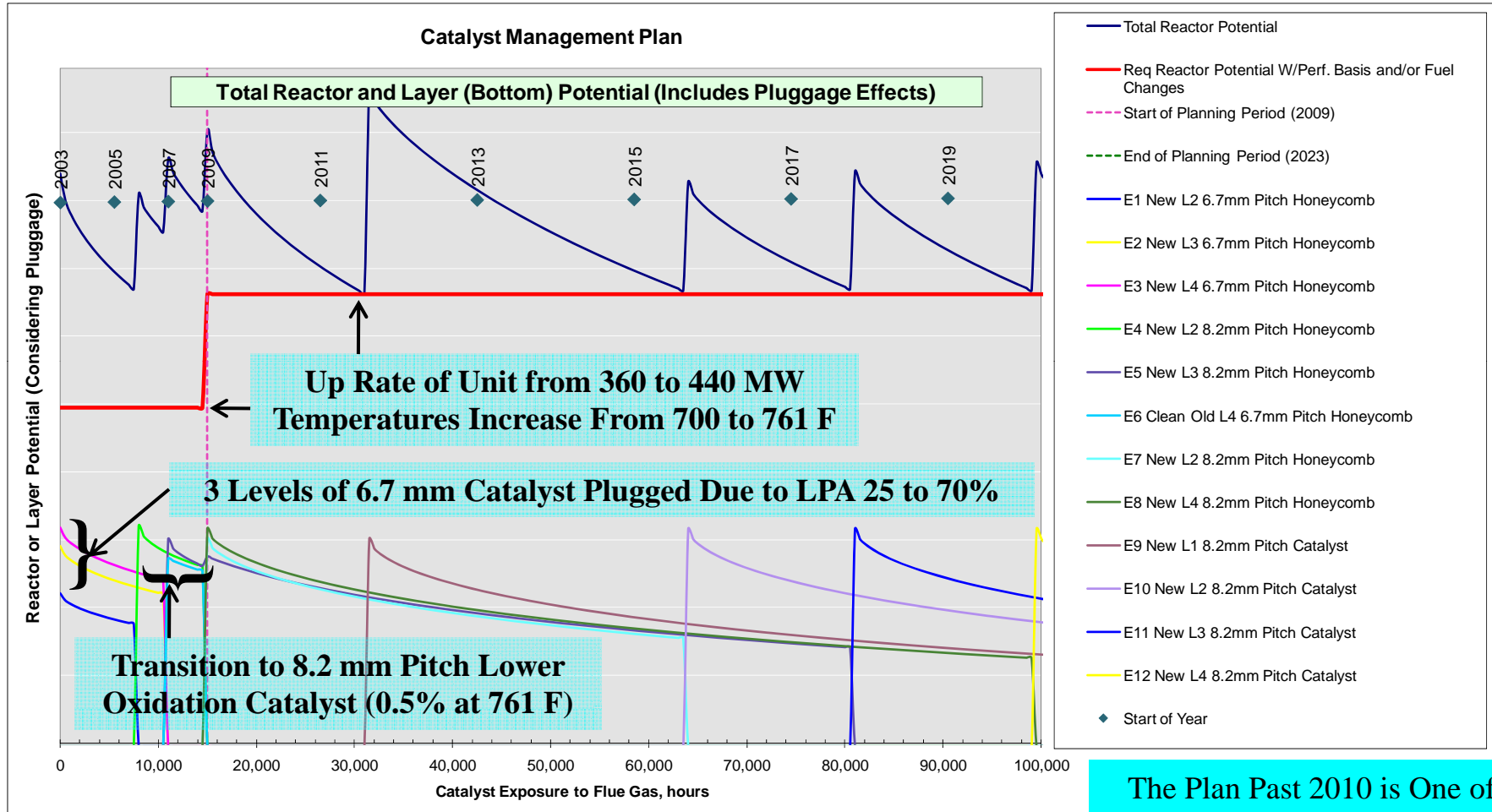
Duck Creek Top Layer Pluggage Map

After 2005 6.7 mm/1mm Wall

After 2006 8.2 mm/1mm Wall



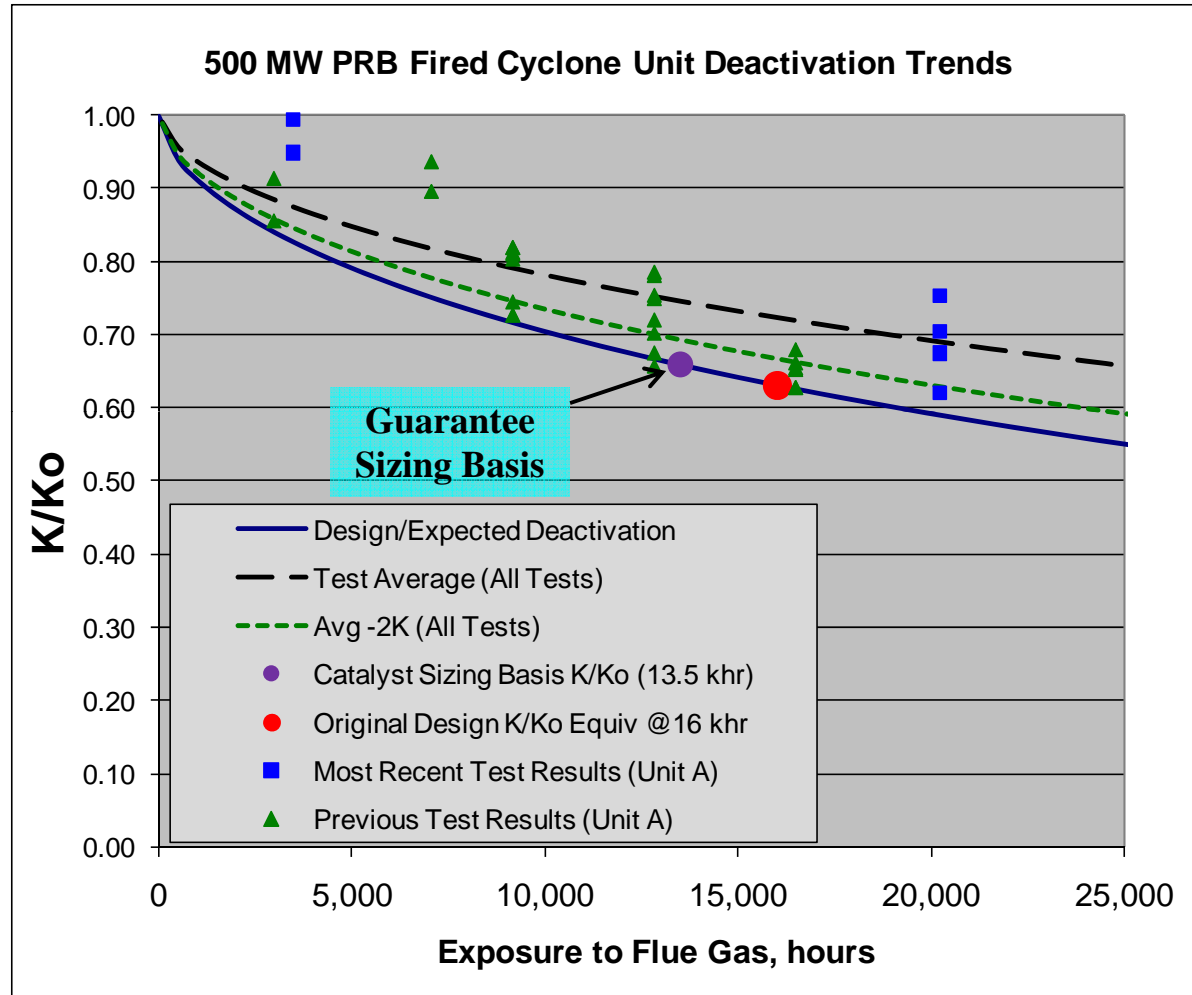
Ameren Duck Creek Unit 1 Catalyst Management Plan



- CERAM Honeycomb Catalyst
- Final Oxidation Rate for 8.2 mm Pitch/1 mm Thick Wall Catalyst <0.5% @761 F

Catalyst Deactivation Trends

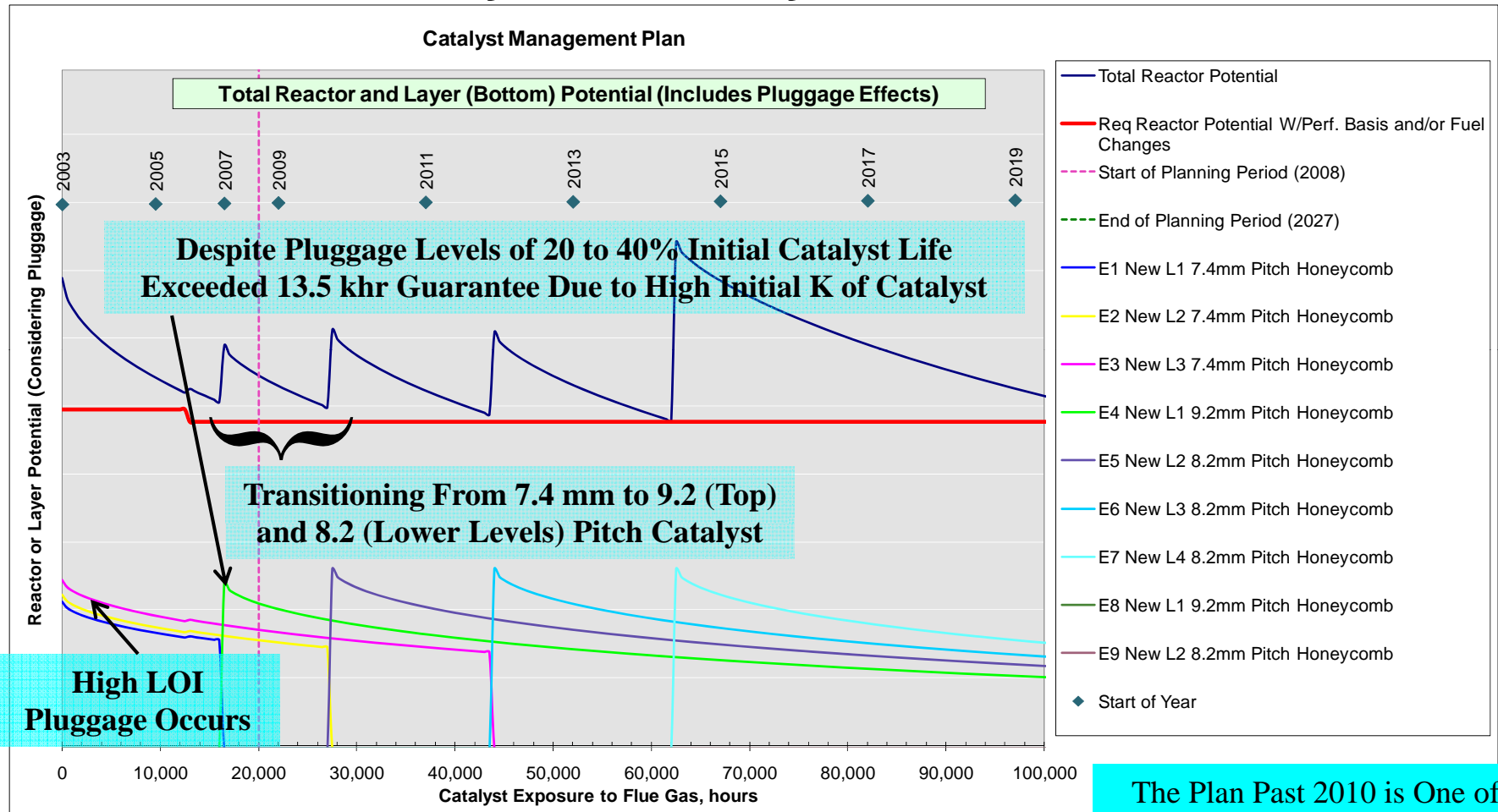
Indiana Utility 500 MW Cyclone 85% PRB Blend



- Catalyst Sized Based on $K/K_o = 0.66$ at 13,500 Hours
- Guarantee: 89% NO_x Removal and 2.0 ppm Slip for 13,500 hours

Catalyst Management Plan

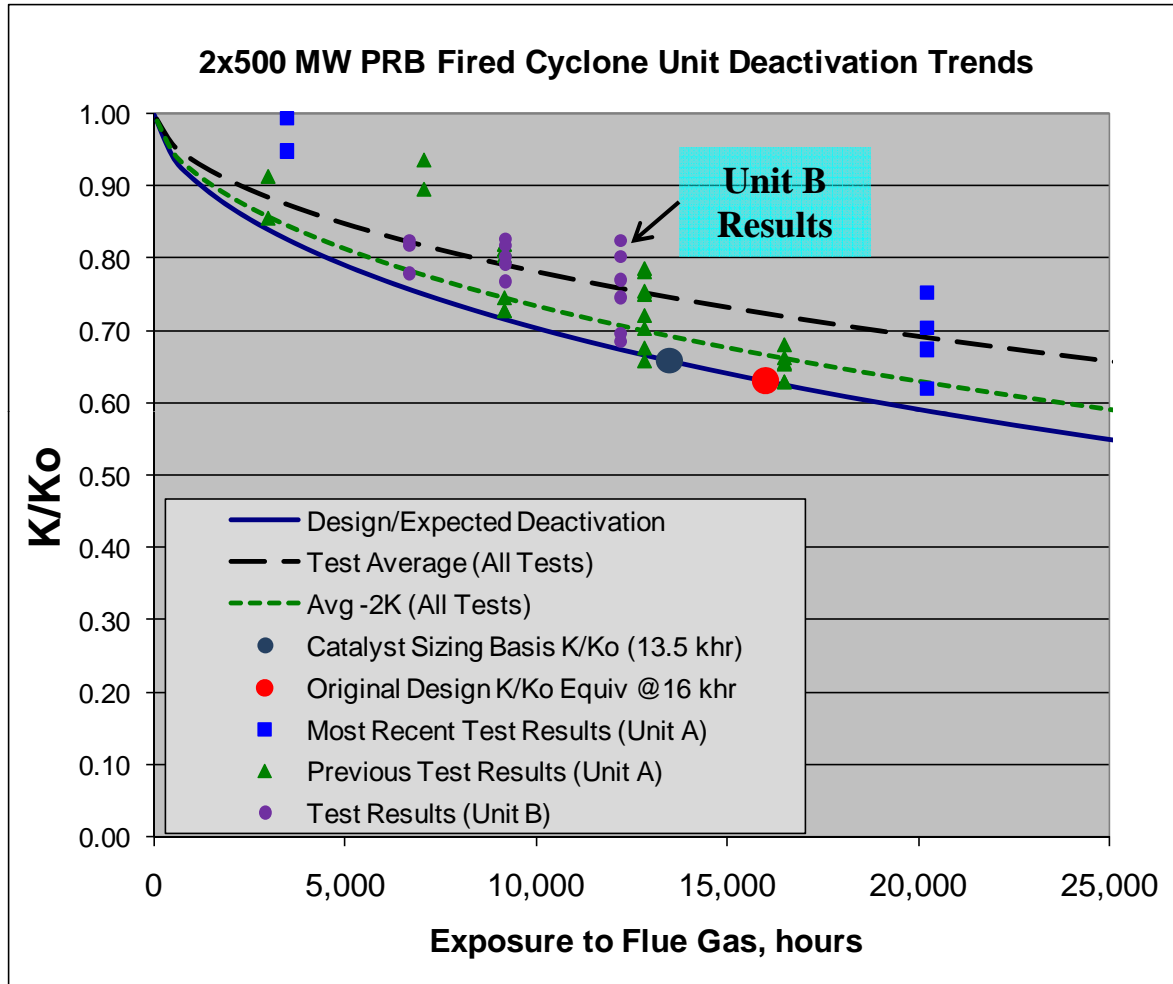
Indiana Utility 500 MW Cyclone 85% PRB Blend



- CERAM Honeycomb Catalyst
- Guarantee – 89% NO_x Removal and 2.0 ppm Slip for 13,500 hours

Catalyst Deactivation Trends

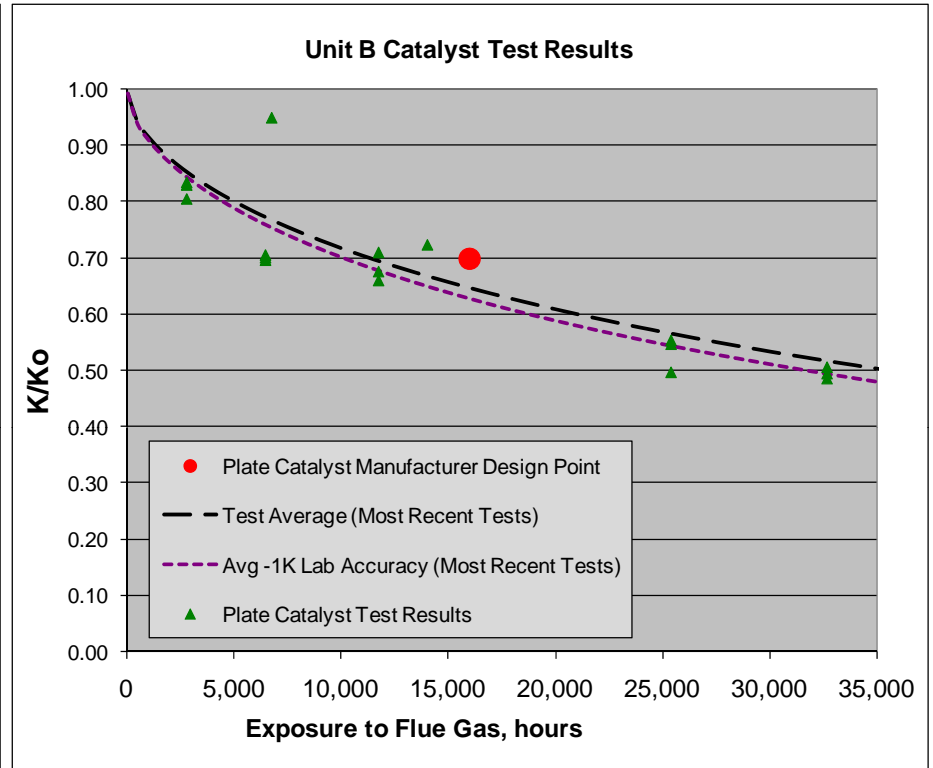
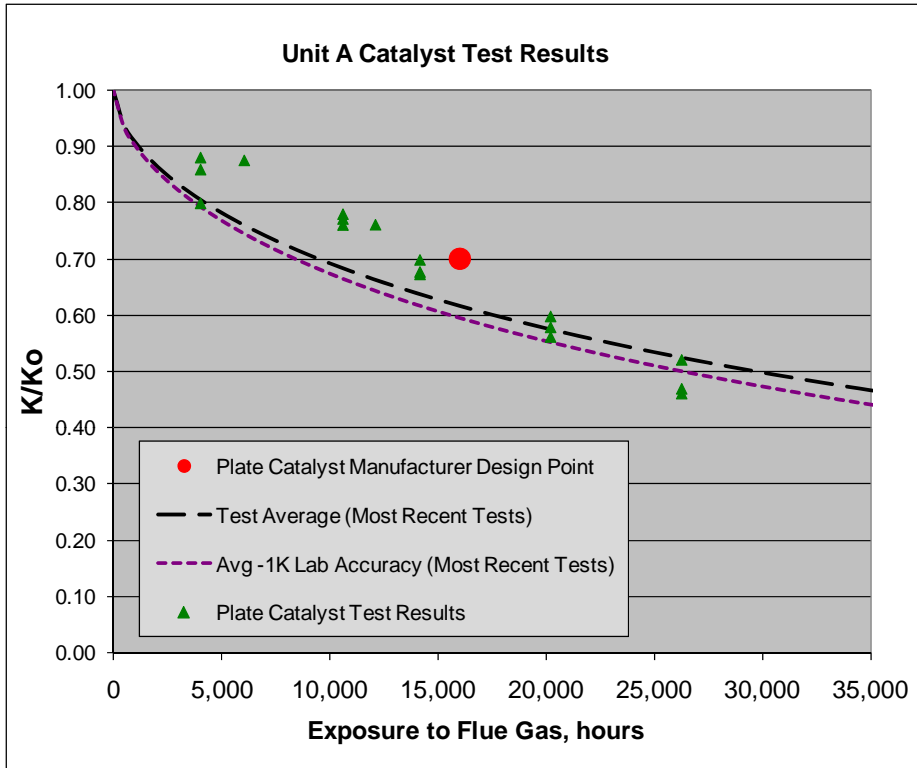
Indiana Utility 500 MW Cyclones 85% PRB Blend



K/Ko@16khr Catalyst Test Results Summary	All Tests	All Tests
	Unit A	Unit B
Reactor Average	0.725	0.706
Level 1	0.740	0.713
Level 2	0.724	0.712
Level 3	0.712	0.692
Level 4		

- Results From Sister Unit (500 MW Cyclone) Burning Predominately Same PRB Blend Exhibits Similar Deactivation Rate

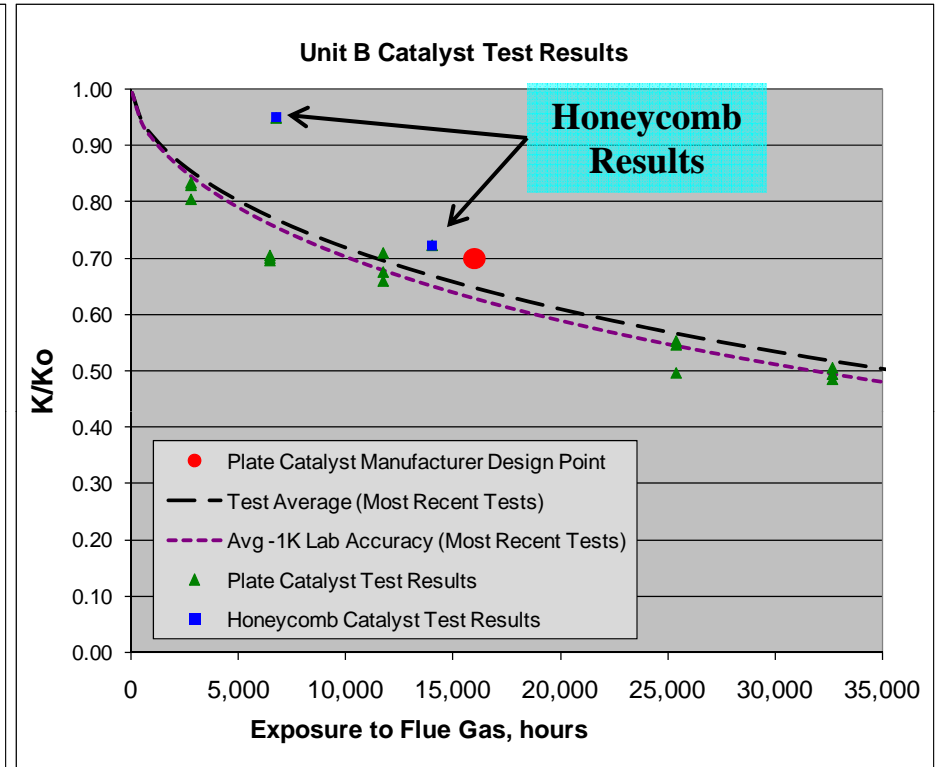
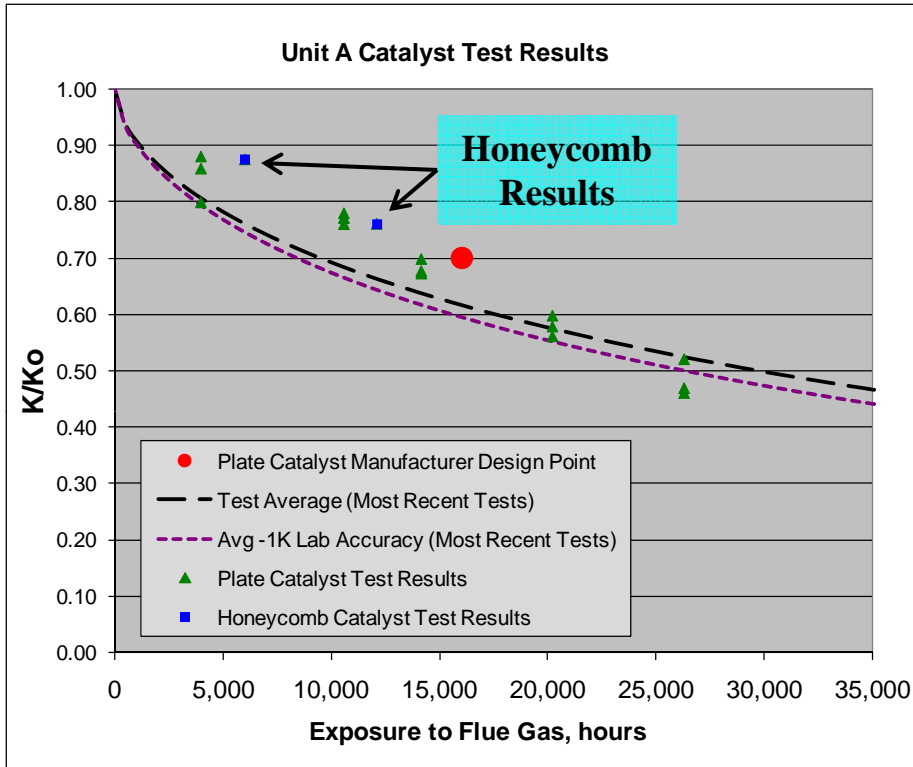
North American Station 2 x 500 MW PRB Blend (80%) Wall Fired Units



K/Ko@16khr Catalyst Test Results Summary	Most Recent	Most Recent
	Unit A	Unit B
Reactor Average	0.616	0.648
Level 1	0.559	0.629
Level 2	0.567	0.621
Level 3	0.613	0.638
Level 4	0.725	0.706

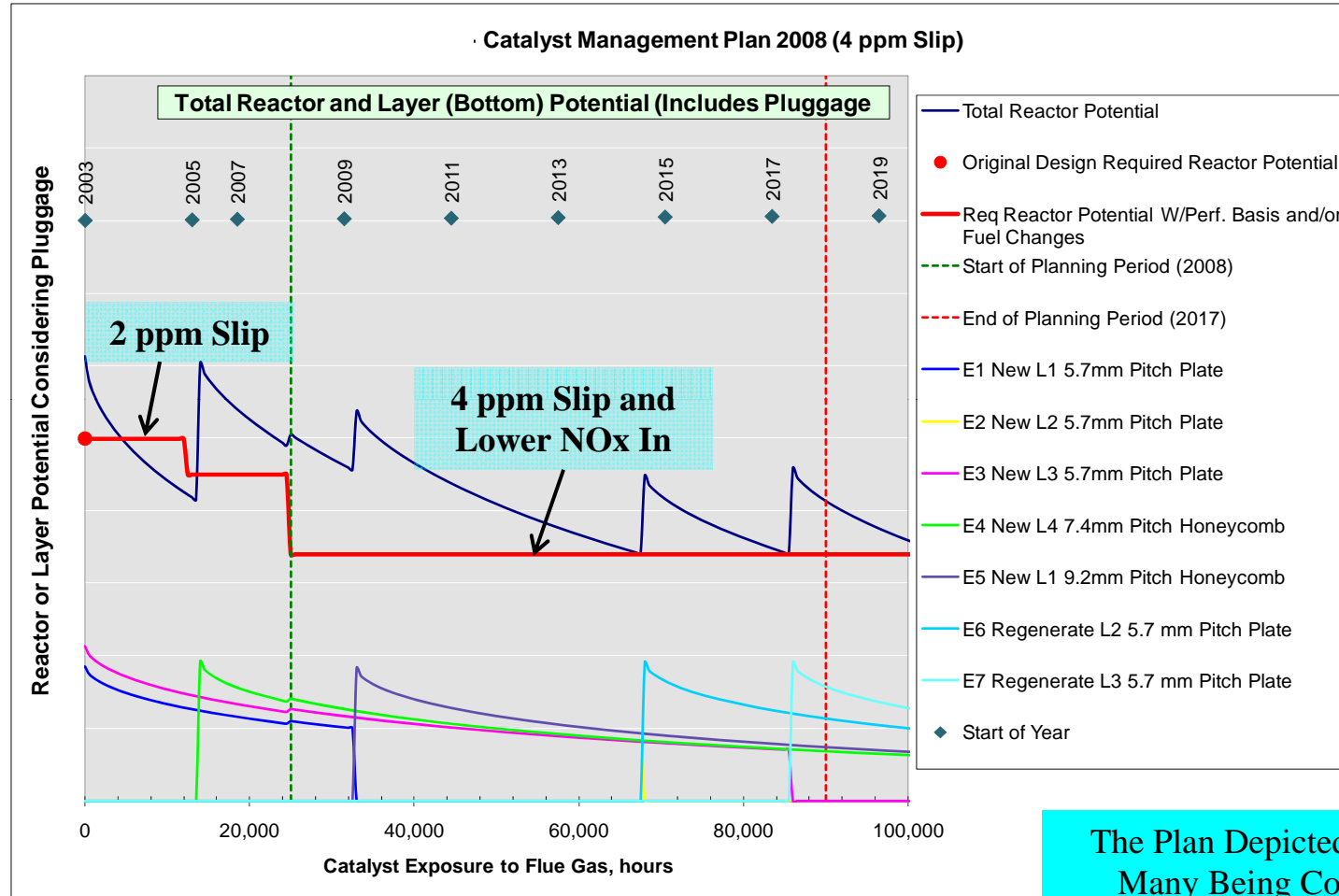
- Plate Catalyst Sized Based on K/Ko of 0.70 at 16,000 Hours

North American Station 2 x 500 MW PRB Blend (80%) Wall Fired Units



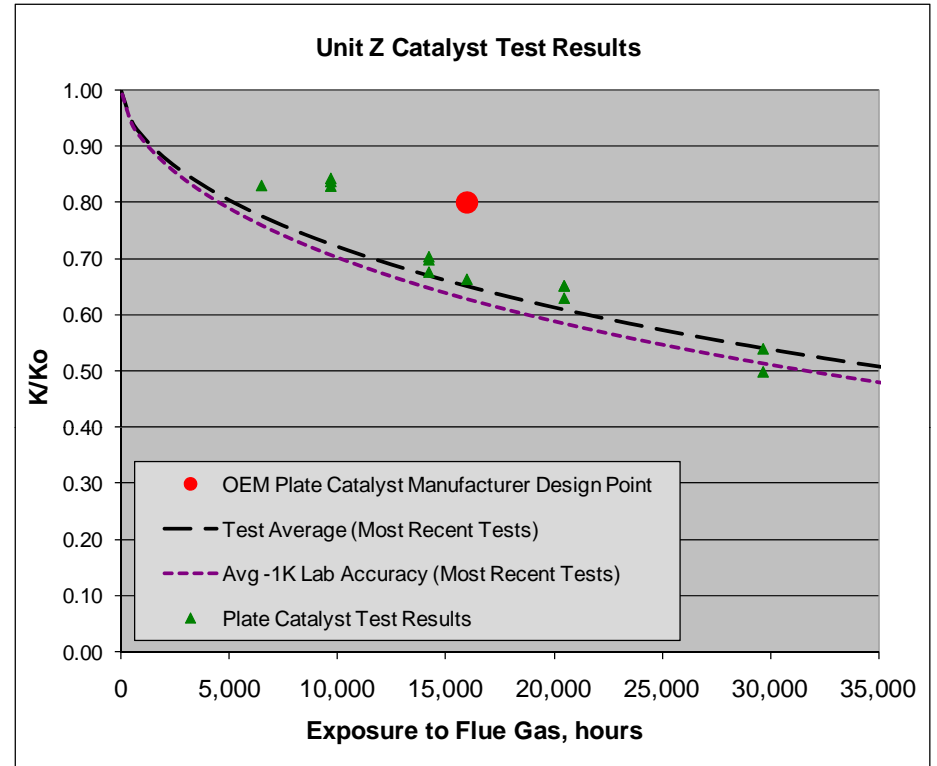
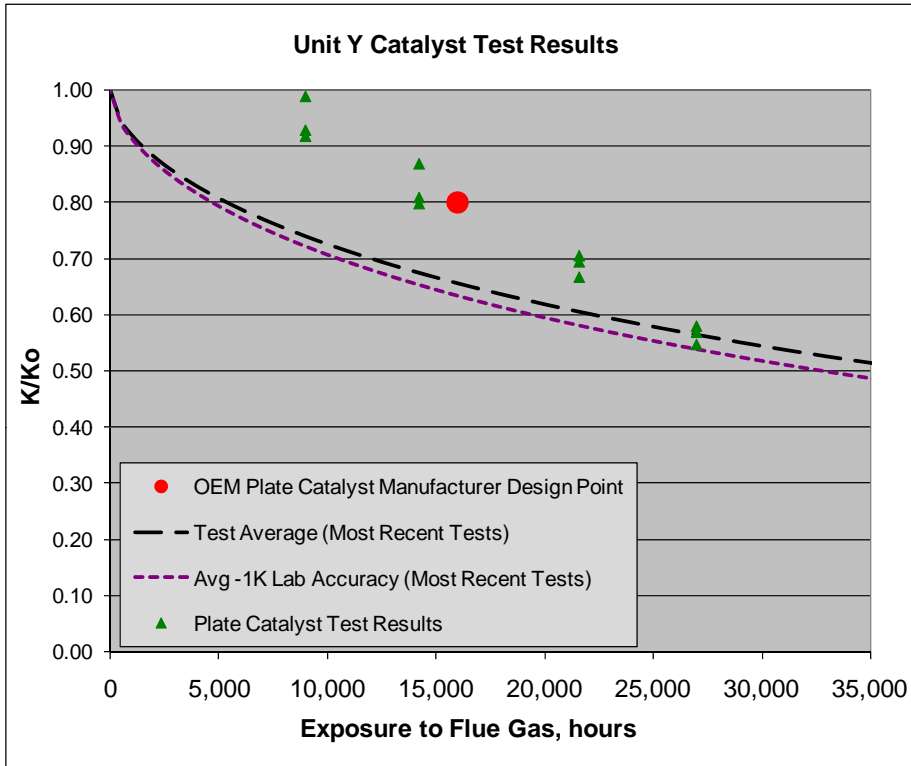
- Plate and Honeycomb Catalyst are Exhibiting Similar Deactivation Rates

North American Station 500 MW PRB Blend (80%) Wall Fired Unit



- Guarantee – 83% NOx Removal and 2.0 ppm Slip for 16,000 hours
- Plate and Honeycomb Catalyst in Reactor

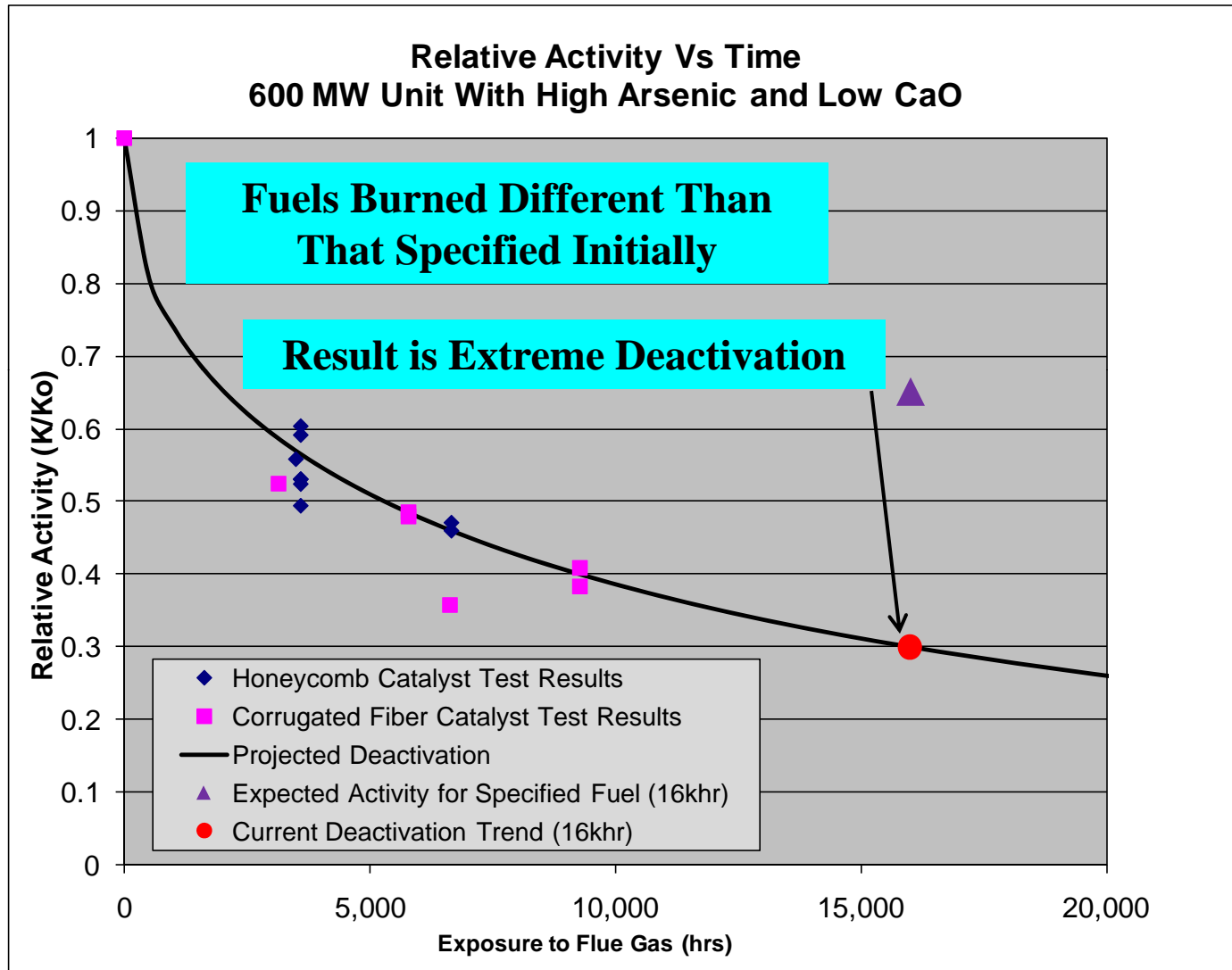
North American Station 2 x 500 MW High Sulfur Bituminous Coal



K/Ko@16khr Catalyst Test Results Summary	Most Recent	Most Recent
	Unit Y	Unit Z
Reactor Average	0.656	0.651
Level 1	0.669	0.671
Level 2	0.659	0.617
Level 3	0.640	0.651
Level 4		0.665

- Catalyst Sized Based on K/Ko of 0.80 at 16,000 Hours

Catalyst Deactivates Independent of Catalyst Type High Arsenic/Low Calcium Oxide Operating Unit



Catalyst Testing is Only One Part of Effective Catalyst Management

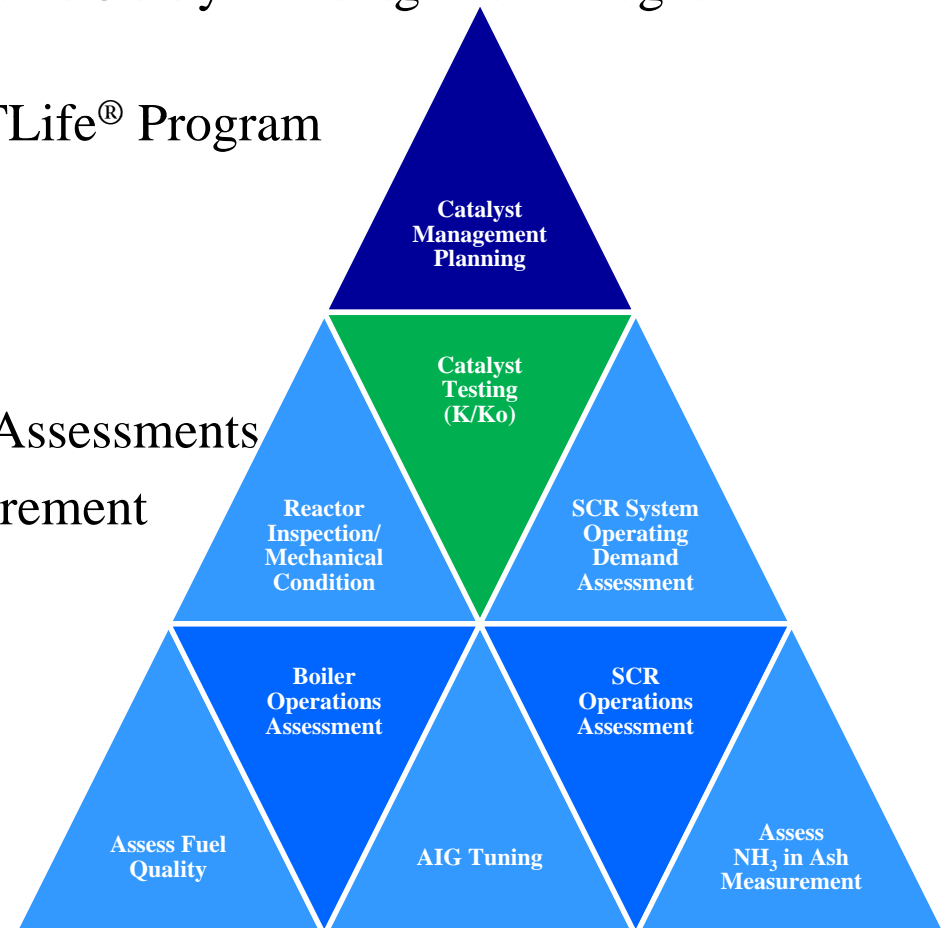
Activity	Objectives
AIG Checks and Tuning	Optimize NH ₃ /NO _x Distribution (Check/Tune Annually)
Monitor Ammonia in Fly Ash	Test Frequently and Track Ammonia Slip Trends
Operations Data Assessment	Evaluate DeNO _x Demand (NO _x , T, Flow, Delta P, etc.)
Monitor Fuels Data	Evaluate Possible Effects on Catalyst
Reactor Inspections	Assess Pluggage and Mechanical Condition
Catalyst Testing	Assess Current Activity Levels and Deactivation Trends
Catalyst Management Planning	Evaluate Near Term SCR System Performance Capabilities
	Predict Next Need for Catalyst Addition
	Evaluate Options for Catalyst Addition (New vs Regen, etc.)

AIG = Ammonia Injection Grid

Conclusions

- Careful Attention Should be Paid to Initial Catalyst Sizing to Ensure a Proper Reactor Potential and K/Ko Basis is Utilized
- Catalyst Deactivation Rates are Independent of Catalyst Type
- **New Plants:** Seek Hard K/Ko Data to Substantiate Catalyst Design
- Catalyst Testing is Not the Only Part of a Catalyst Management Program
- CERAM Performs Comprehensive Catalyst Management Services – CATLife[®] Program

- Catalyst Testing
- Reactor Inspections
- AIG Tunings
- Operating Data and Fuel Quality Assessments
- Regeneration/Rejuvenation Procurement
- Catalyst Management Planning (Manage CATLife[®] Model)
 - ◆ Considering Full Range of Options (New/Wash/Regen)



**Thanks!!!
Any Questions?**

