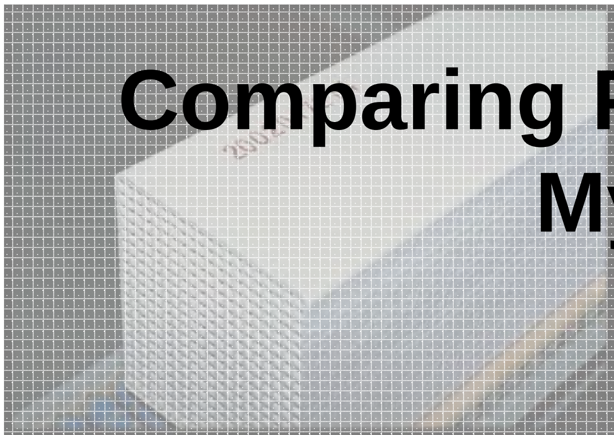
REINHOLD ENVIRONMENTAL Ltd.

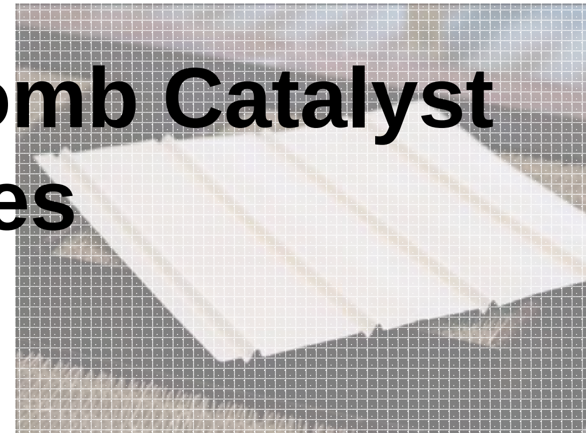
2014 NOx-Combustion Round Table & Expo Presentations

February 10 & 11, 2014, in Charlotte, NC / Hosted by Duke Energy

Reinhold Environmental
2014 NOx-Combustion Round Table
February 11, 2014

Comparing Plate & Honeycomb Catalyst Myths and Realities





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Believe It or Not?

My Catalyst Avoids Deactivation!

Increased Wall Thickness
Increases Conversion Rate!

Plate Catalyst Does Not Plug!

My Catalyst Will Not Erode!

There is No Need to Specify
a Substrate Material or Wall Thickness!

That Catalyst Will Cause a Fire!

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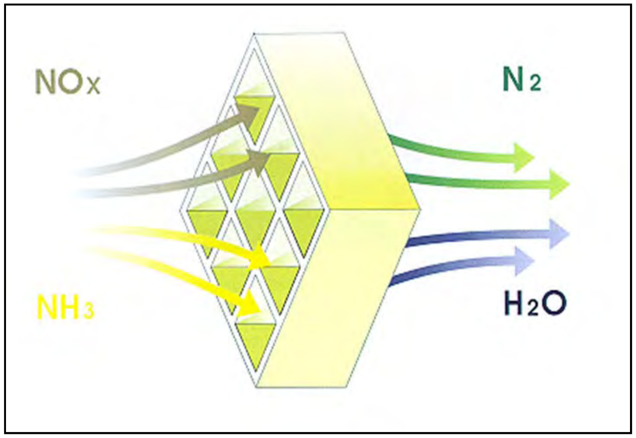
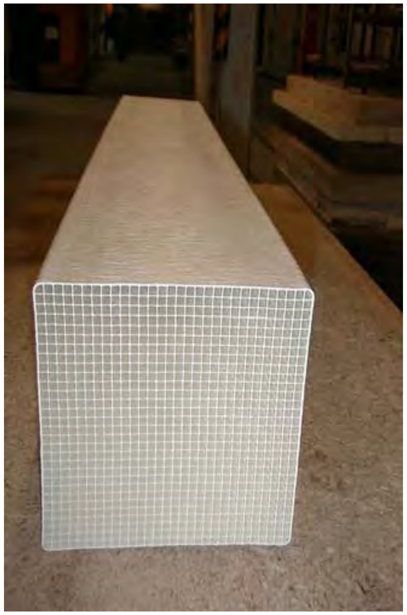
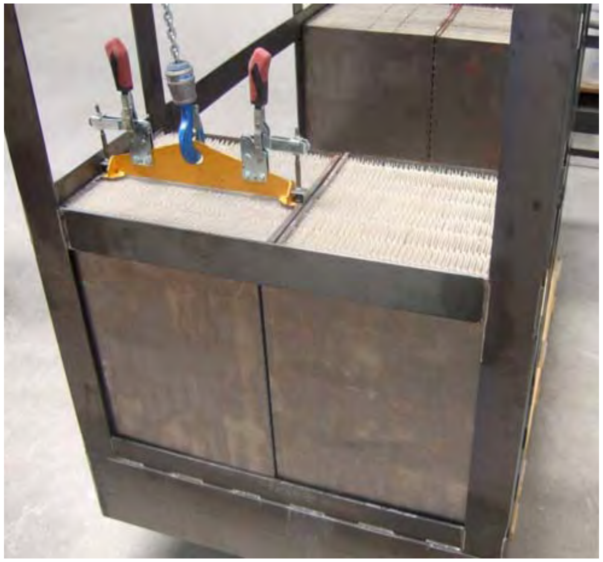
Presentation Topics



- Comparison of Physical Properties
- Comparison of Chemical Properties
- Catalyst Selection
  - Catalyst Management Comparison
- Conclusions





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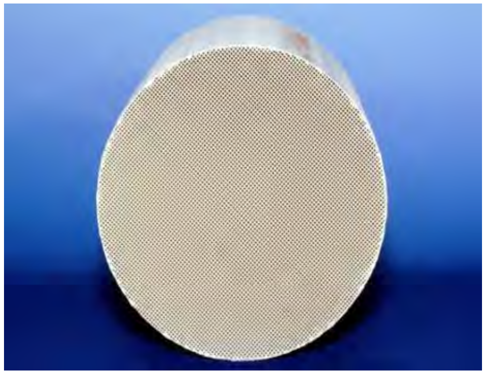
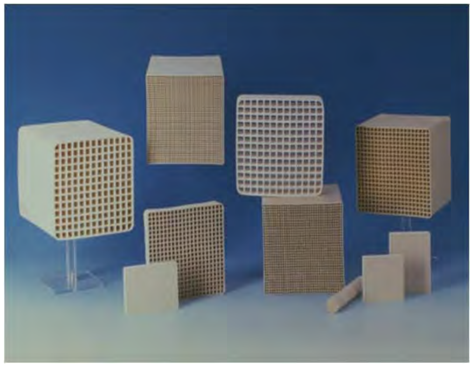
CERAM Products

- **Catalytic Honeycombs**
  - SCR (NOx emission control)
    - Stationary Sources
    - Mobile Sources
  - Oxidation (HC, VOC)
  - Dioxin / Furan
  - Mercury
- **Catalytic Plate**
  - SCR (NOx and Hg)
- **Non-Catalytic Honeycombs**
  - Heat Storage Media (RTOs)
  - Casting Filters





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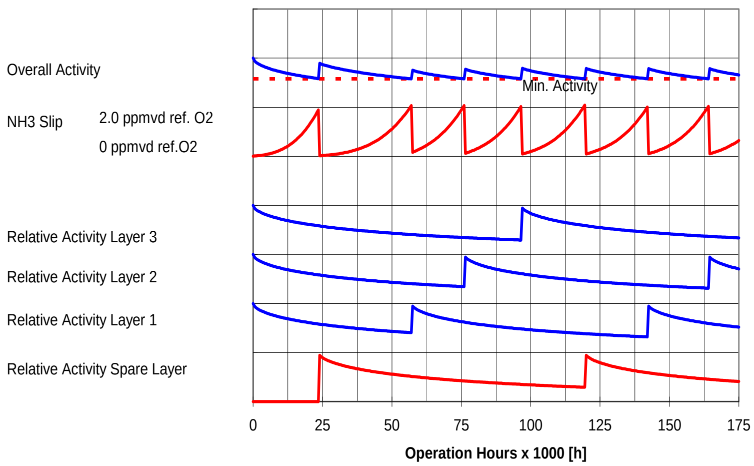
CATLife® Services

- Coordinated Catalyst Supply for >60 Units Considering More Than 30,000 MW in North America
- Providing SCR System and Catalyst Management for >40 Coal Fired Units in North America
- Comprehensive Direct Services
  - Catalyst Design
  - Flow Modeling Administration
  - Delivery Coordination
  - Training and Startup
  - Ammonia Injection Grid Tuning
  - Reactor Inspections
  - Catalyst Testing and Evaluation
  - SCR Operations (DCS) Assessments,Troubleshooting, and Reporting
  - Catalyst Management and SCR Operations Planning Using Proprietary Manage CATLife® Model



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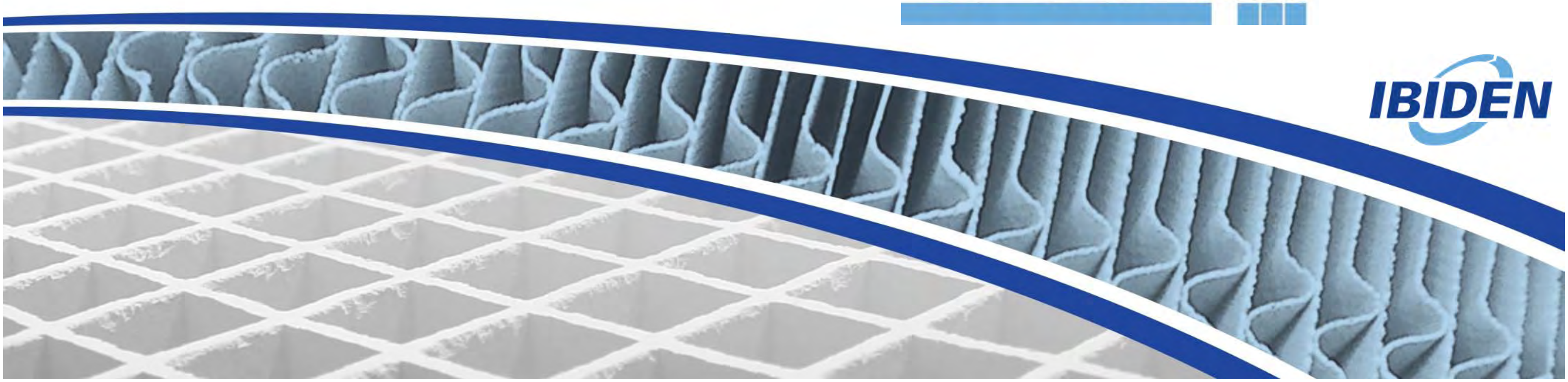
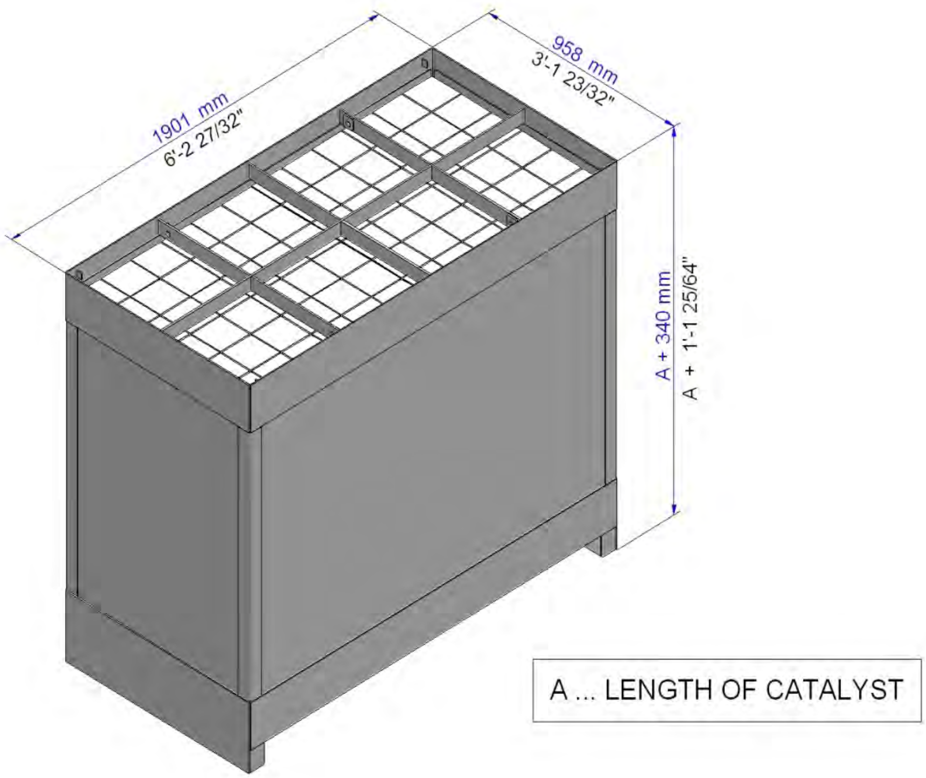
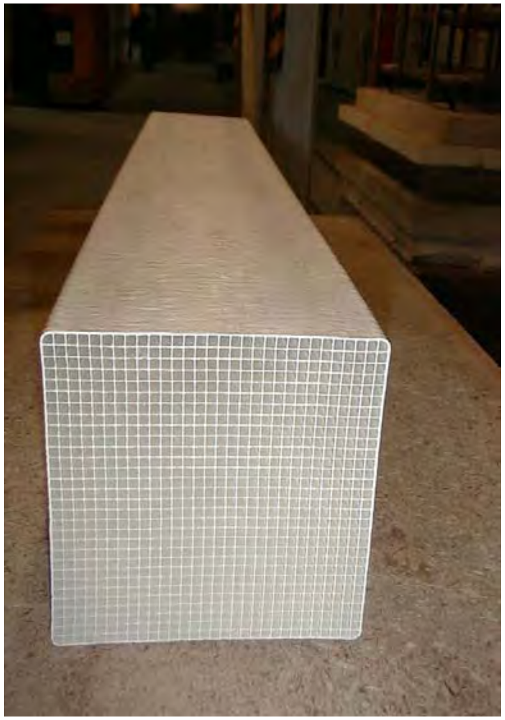
CERAM Catalyst Production Plant

Comparison of Physical Properties



Standard Honeycomb Catalyst Module





- Elements Packed into Steel Frame
- Typically 72 Elements/Module (6x12)
- Standardized Cross Section
- Variable Lengths
- No Sublayer – Continuous Extruded Length

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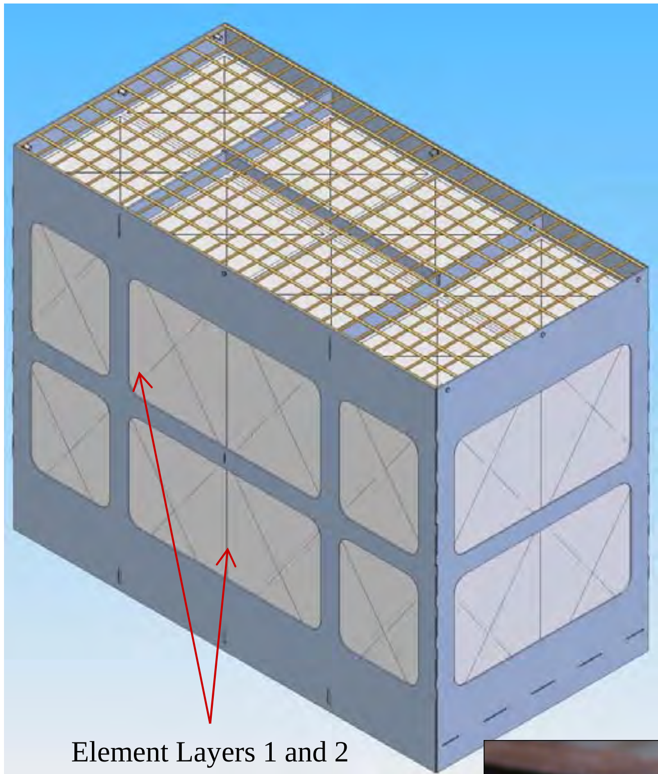
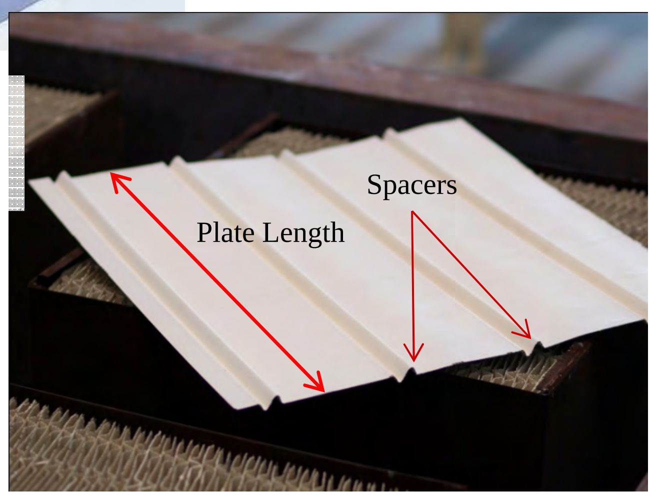
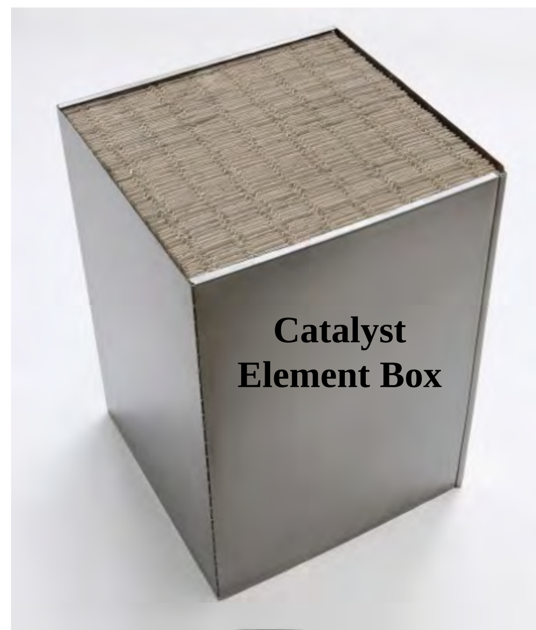
Standard Plate Catalyst Module

- Catalyst Element Boxes Arranged in Steel Frames
- ~80 Plates/Element Box
- 1 to 2 Levels of 8 Element Boxes
- Standardized Cross Section
- Variable Set Lengths for Sub Layers (i.e. 500 mm, 550 mm, 625 mm, etc.)
- Gap Exists Between Sub Layers



Steel Frame (Module)





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Internal Structure

Plate Type Structure

- Flexible Plates With Notches/Spacers to Maintain Pitch
- Large Rectangular Openings
- High Void Fraction (>85%)
- Pitch: ~5 to 7 mm (for high dust coal fired applications)

Honeycomb Structure

- Rigid Structure
- Square Openings Results in Increased Specific Surface Area
- Void Fraction >75%
- Pitch: 7 to 10+ mm (for high dust coal-fired applications)

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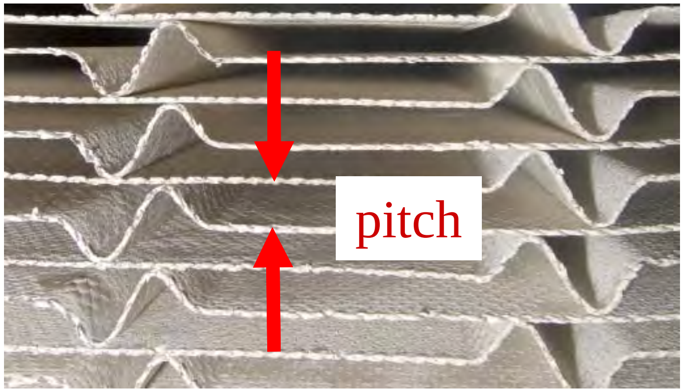
Defining Pitch



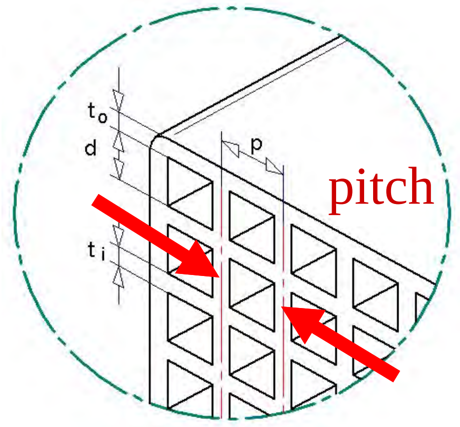


Plate Pitch (p)

$$p = (b_d - 2) / p_\#$$

b_d = block depth – perpendicular to plates

$p_\#$ = number of plates

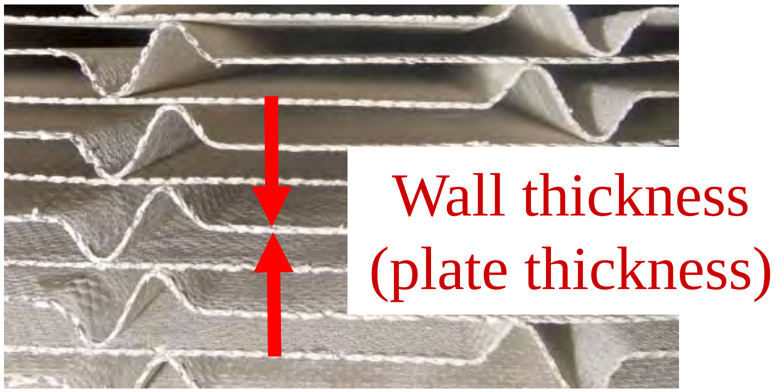
Honeycomb Pitch (p)

$$p = d + t_i$$

d = cell opening

t_i = inner wall thickness

Wall Thickness Important for Mechanical Durability & Regeneration Options



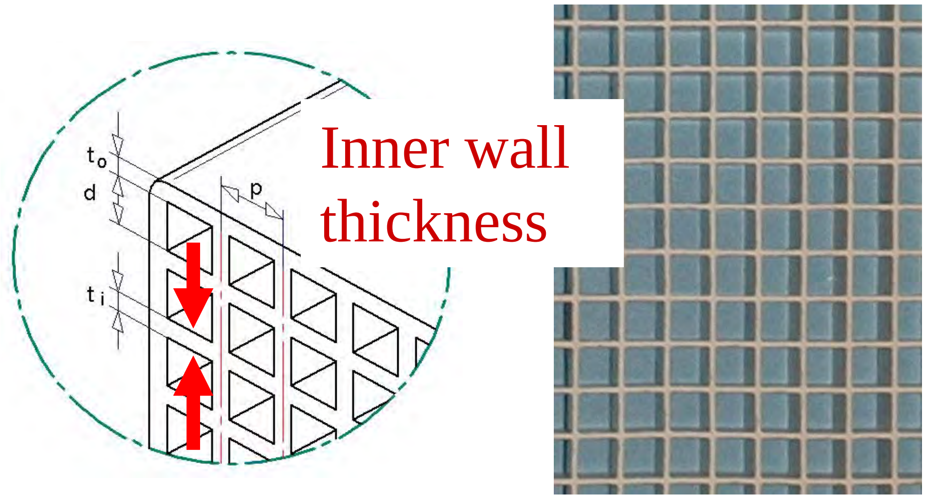


Plate Catalyst Wall Thickness Recommendations	
	>80,000 to 100,000 Mechanical Life and Multiple Regenerations
Pitch	**Plate/Wall Thickness**
mm	mm
5.6 – 7.0	>0.7 mm (steel substrate type and length also critical for mechanical life)

Honeycomb Catalyst Wall Thickness Recommendations			
		>80,000 to 100,000 Mechanical Life and Multiple Regenerations	
Pitch	**Cells**	**Inner Wall**	**Outer Wall**
mm	x by x	mm	mm
6.7	22	0.8	1.3
7.1	21	0.8	1.4
7.4	20	0.8	1.4
8.2	18	0.9	1.7

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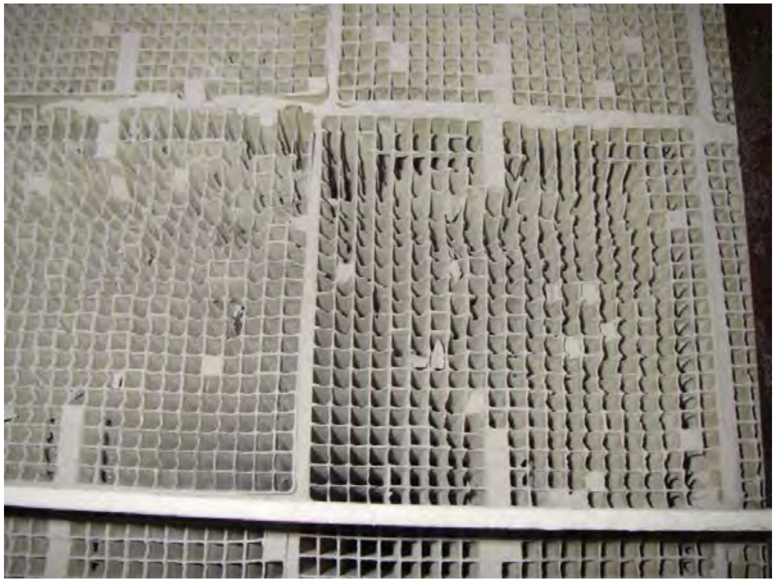
Erosion Can Affect Either Catalyst Type

- Plate Erosion
  - Catalyst Active Material Eroded from Leading Edge
  - Exposed Stainless Steel Can Corrode and Increase SO_2 to SO_3 Conversion
- Honeycomb Erosion
  - Catalyst Walls Eroded at the Leading Edge
  - Affects Localized Flow and Erosion Increases Over Time
  - Extensive Erosion Can Result in Collapse of Honeycomb Structure



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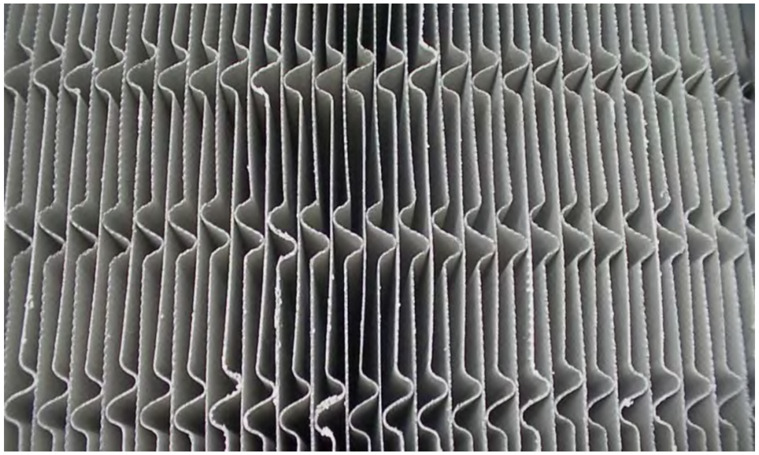
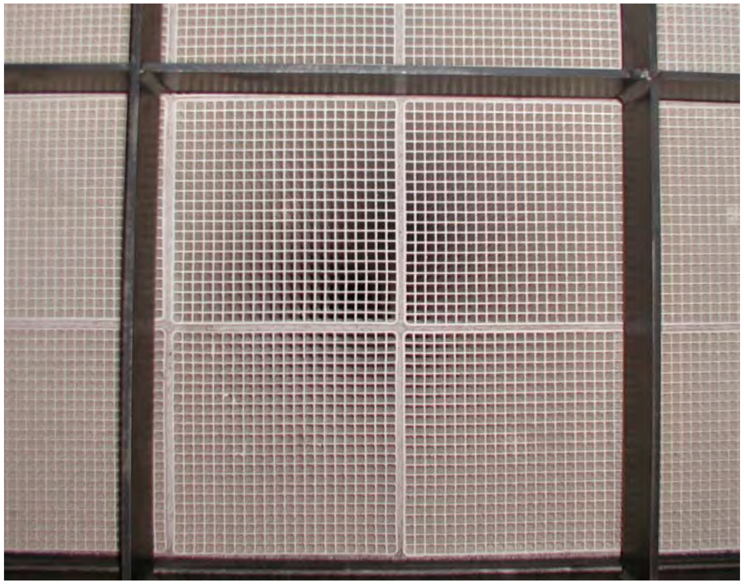
Minimizing Erosion

- Utilize Catalyst with Adequate Wall Thickness
- Minimize Catalyst Pluggage/High Velocity Zones
- Ensure Proper Flow Distribution and Gas Entry Angles
- Size the Reactor for the Appropriate Catalyst Face Velocity
  (5.0 to 5.5 m/s for PRB;
  4.5 to 5.5 m/s Generally)





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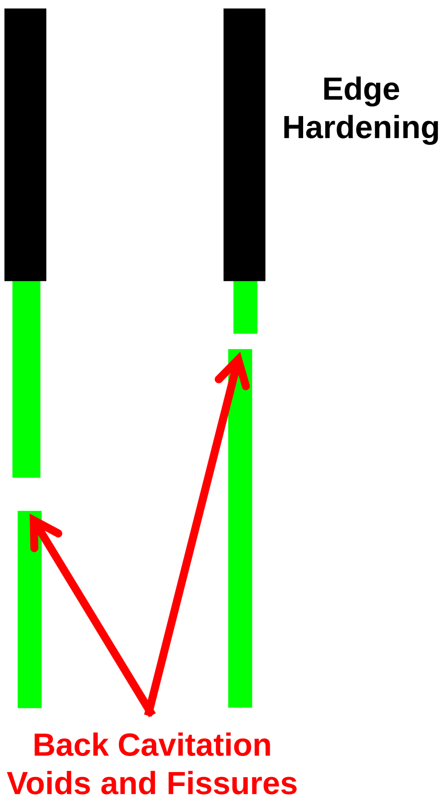
Catalyst Wall Erosion

- Thin Wall Catalyst Will Have Earlier Incidence of Mechanical Failure
- Mechanical Failure Will Lead to Increasing Pluggage Rates and Increasing Pressure Drop
- Edge Hardening Does Not Increase Catalyst Mechanical Life



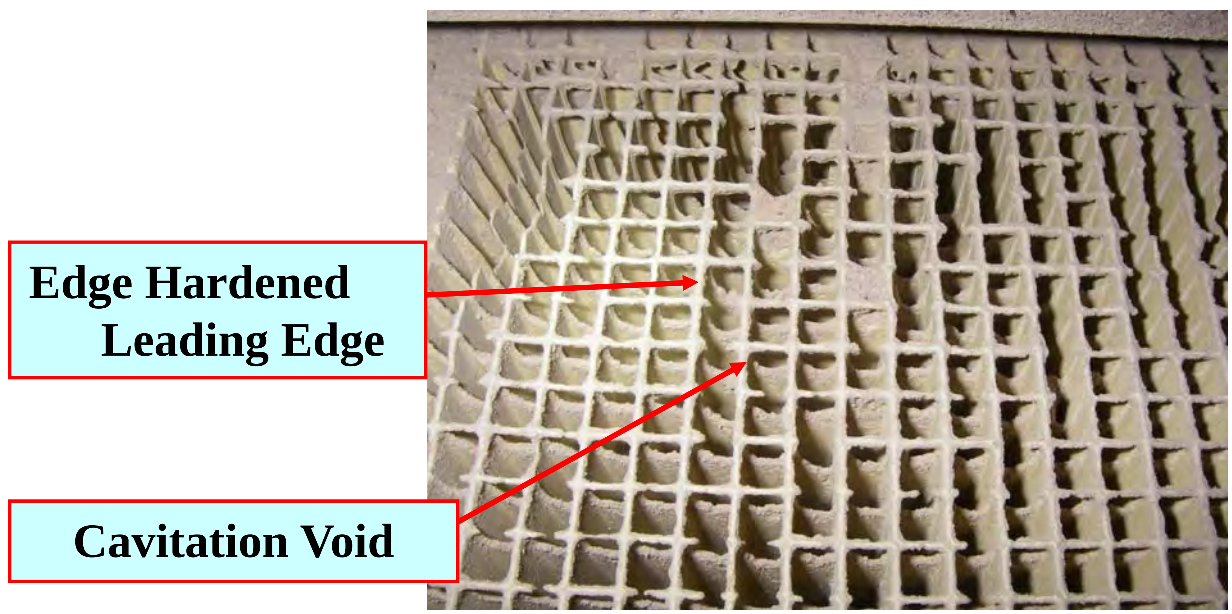


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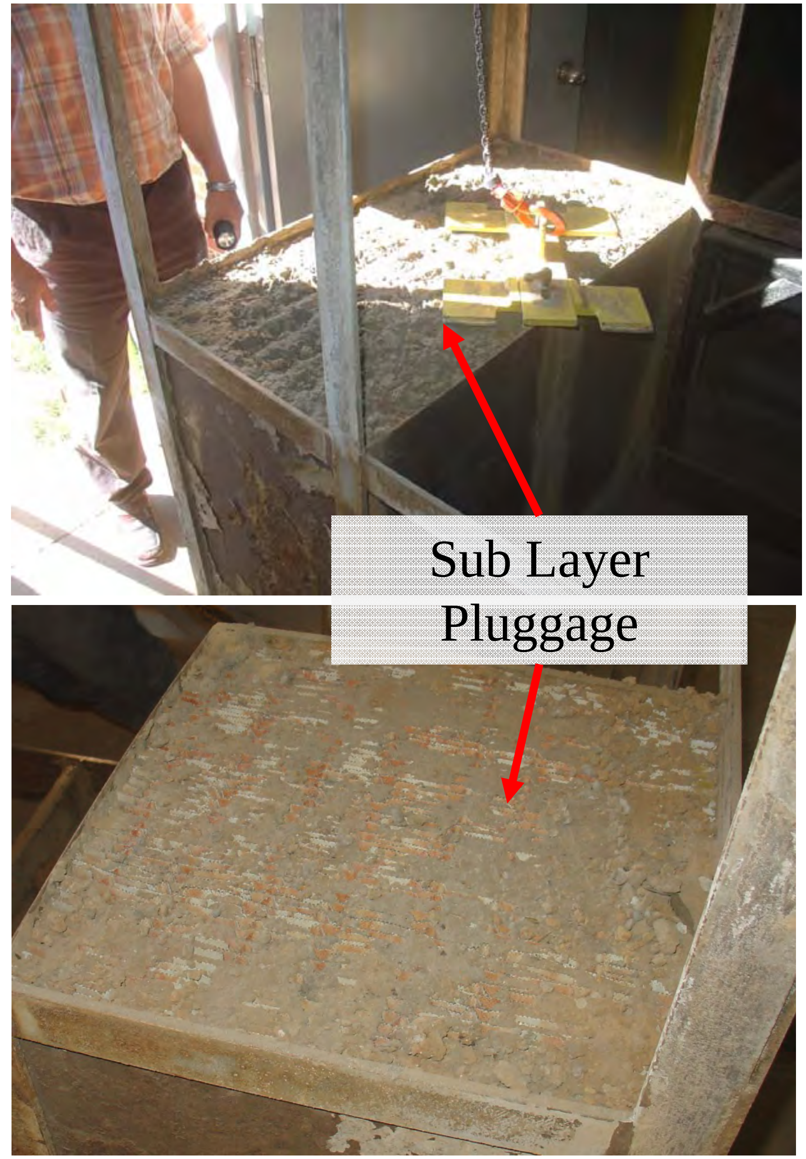
Plate Catalyst Mechanical Concerns

- Plate Catalyst Pluggage Accumulates Between Sub Layers
- Catalyst Lengths >700 mm and/or Wall Thickness <0.7 mm
  - Discouraged for Concerns of Pluggage and Material Stability
- Increased Plate Length and/or Reduced Wall Thickness Increases Risk of…
  - Pluggage Due to Dissipation of Cleaning Energy (Sootblower or Acoustic) Between Sub Layers
  - Pluggage Due to Plates Bowing and Touching
  - Catalyst Delaminating From Stainless Steel Substrate Due to Plate Vibration
- Plate Substrate Material Influences Opportunity for Regeneration



Photos taken of plate catalyst with top sub layer removed during dry cleaning in advance of regeneration.

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Ferritic (Type 400) Stainless Steel Substrate Has Deficient Mechanical Strength for Regeneration

Corrosion Loss From Plate Trailing Edge

Brittle Material Breaks Out With Thumb Pressure

Hand Torn Pieces from Element Pulled Up on Right

- Historically Plate Catalyst Used Type 300 (Austenitic) Stainless Steel
  - Excellent Mechanical Life Including Multiple Regenerations
- If Unspecified, Suppliers Will Utilize Type 400 (Ferritic) Stainless Steel to Minimize Cost (~+10% of Total Cost to Use Type 300)
- Type 400 Stainless Steel is Subject to Corrosion Each Time the Flue Gas Goes Through the Acid Dew Point

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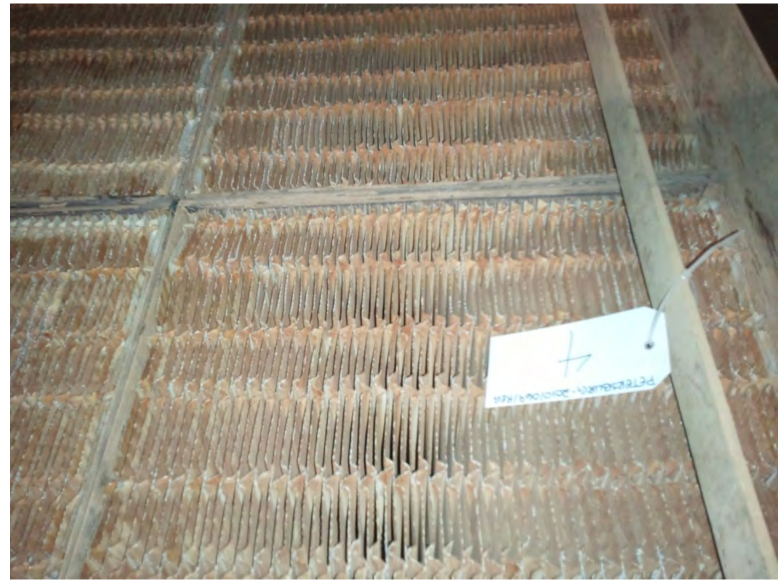
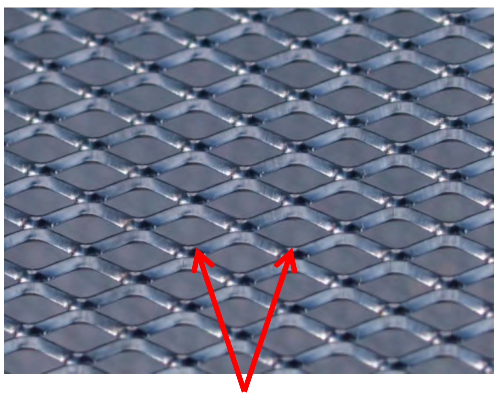
Photos taken of plate catalyst delivered for regeneration to one of the predominant suppliers of this service.

Ferritic (Type 400) Stainless Steel Substrate Has Deficient Mechanical Strength for Regeneration

Catalyst With Type 400 SS Substrate Rips by Hand Along 30° Axis Following SS Substrate Mesh Diamond Pattern

Plate Catalyst With <u>Type 400</u> SS Mesh Substrate Material With Visible Corrosion Increasing Aged Catalyst SO_2 to SO_3 Conversion Rate (Test A to Test B Consideration)





Acid Condensation Accumulates in Troughs on SS Mesh

- During Startup/Shutdown Flue Gas Goes Through Acid Dew Point
- Acid Accumulates and Weakens Stainless Steel Mesh Embrittling the Catalyst
- Difficult/Costly to Regenerate – Expect Very High Attrition Rates
- Additionally Corrosion of Type 400 Stainless Steel Leads to Increasing Oxidation Rate With Time
  - Increases of 50 to 200% Have Been Observed
- All Plate Suppliers Can Fabricate Catalyst With Either Steel Type

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Photos taken of plate catalyst delivered for regeneration to one of the predominant suppliers of this service.

Is Thin Wall Catalyst Worth It?

- Cheaper Material to Produce With 15-35% Less Raw Material
  - Thin Wall With 0.5 to 0.6 mm vs 0.8 to 0.9 mm
  - Increases Margin of Catalyst Supplier
- Reduced Initial Pressure Drop, but Will it Last?
  - Internal Fissures/Cracks More Prevalent
  - Internal Fissures Increase Pluggage Risk w/Time
- Increased Surface Area = +3 to 4%
  - However if Mechanical Life < Chemical Life Then Advantage is Not Realized
- No Advantage Related to SO_2 to SO_3 Conversion Rate
  - Custom Formulations (At Least by CERAM)
- Becomes "One Way" Catalyst: Difficult and Expensive to Regenerate or Clean
- Similar Mechanical Life Consideration for Plate With Thin Wall (<0.7 mm) Construction

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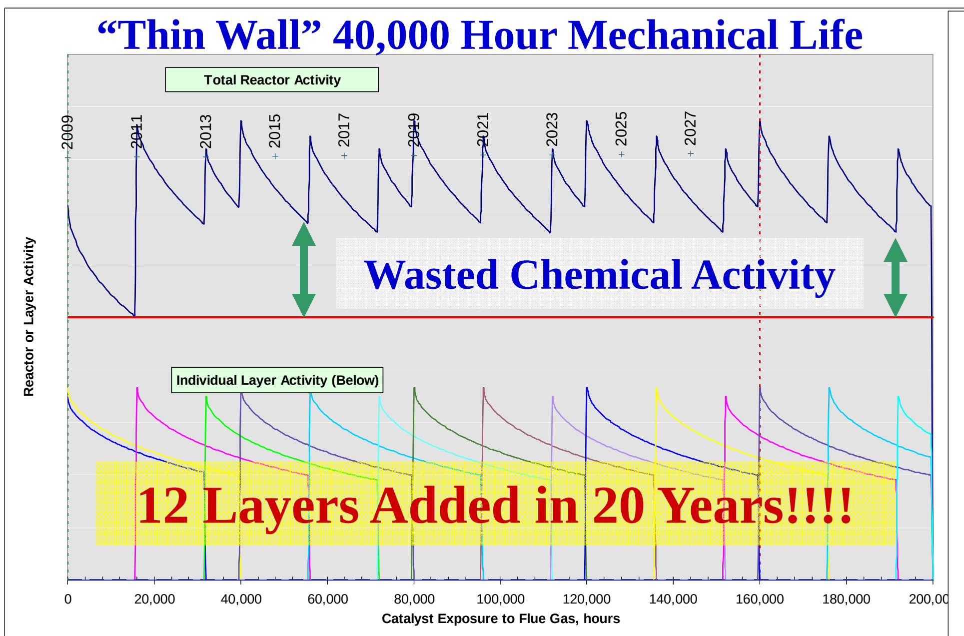
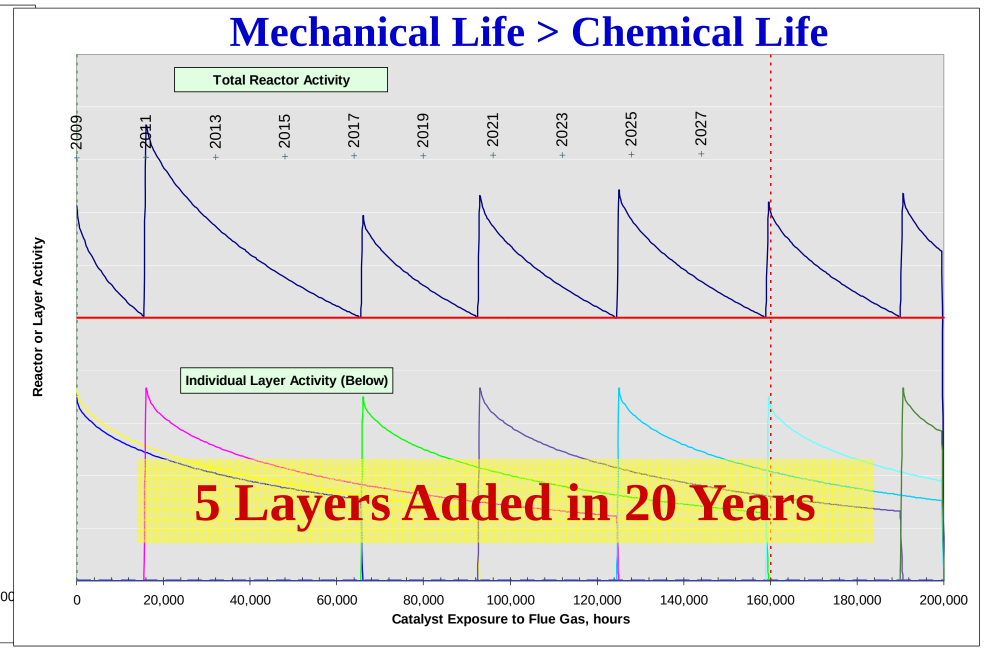
Is Thin Wall Catalyst Worth It?

- Thin Wall Expected Mechanical Life = 40,000 to 50,000 Hours
- Increased Number of Outages Needed to Replace Mechanically Deficient Catalyst
- Significantly Increases Catalyst Life Cycle Cost
- Comparison Below Illustrates Difference Between Thin Wall
  - 2+1 Reactor
  - Case 1 – Catalyst With 40,000 hour Mechanical Life
  - Case 2 – Catalyst With Mechanical Life Exceeding Chemical Life





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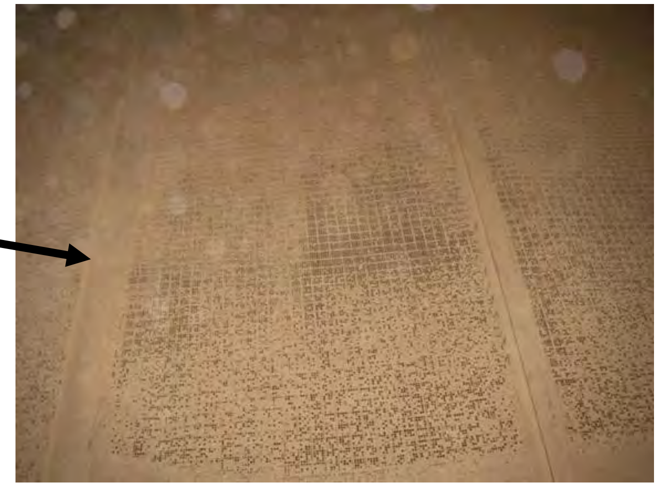
LPA Collection Extremely Important to Avoid Pluggage of Plate or Honeycomb Catalyst

LPA Screen Pluggage



Catalyst (Honeycomb or Plate) Can Be Susceptible to Fire Damage

Fused Plate Catalyst
After Fire Found In
Downstream Ductwork

Bottom of Plate Catalyst
After Fire Damage

Top of Honeycomb Catalyst
After Fire Damage

- Plate Catalyst Supports Combustion (Stainless Steel Substrate)
- Molten Plate Can Propagate Fire Downstream (Air Heater, etc.)
- Honeycomb Catalyst Material is Stable After a Fire (Made of Fully Oxidized Material)

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Physical Properties Summary

Module Size	Standard – Both Types	
Specific Surface Area	Higher Surface Area Per Volume for Honeycomb Considering Equivalent Pitch (i.e. 5.7 mm plate & 7.4 or 8.2 mm honeycomb)	
Erosion Risk	Affects either type	
	Plate • Catalyst Material Removed w/o Altering Structure & Affecting Flow • Bare Metal Increases SO2:SO3 Conversion	Honeycomb • Erosion Affects Structure & Alters Local Flow • Adequate Wall Thickness and Flow Vectors Key
LPA/Pluggage Risk	• LPA and General Ash Pluggage Affect Both Types • Proper Catalyst Pitch Selection and Flow Minimizes Pluggage Risk • Pluggage in Plate Catalyst Occurs Between the Sub-layers First	

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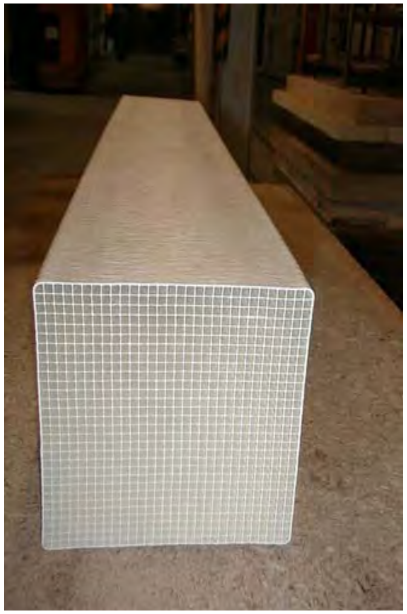
Coal High Dust SCR Catalyst Selection

- **Site Specifics Dictate Catalyst Selection**
  - NOx Removal, SO2:3 Conversion, Temperature, Required Reactor Potential, Dust Loading
- **Honeycomb Catalysts**
  - Can be Used With Dust Loadings Up To ~20 gr/dscf
  - Preferred for Gas Turbine and Engine Applications
  - Higher Surface Area per Unit Volume (+20 to 30% for High Dust)
- **Plate Catalysts**
  - Preferred for Extreme High Dust Loadings (>20 gr/dscf or 40,000 mg/Nm^3)
  - When Specified Honeycomb Catalyst Pitch is Unusually High Considering Application Requirements
  - When Replacement of Existing Plate Catalyst is Preferred by a Client
  - Higher DeNOx Activity Partially Offsets Reduced Surface Area



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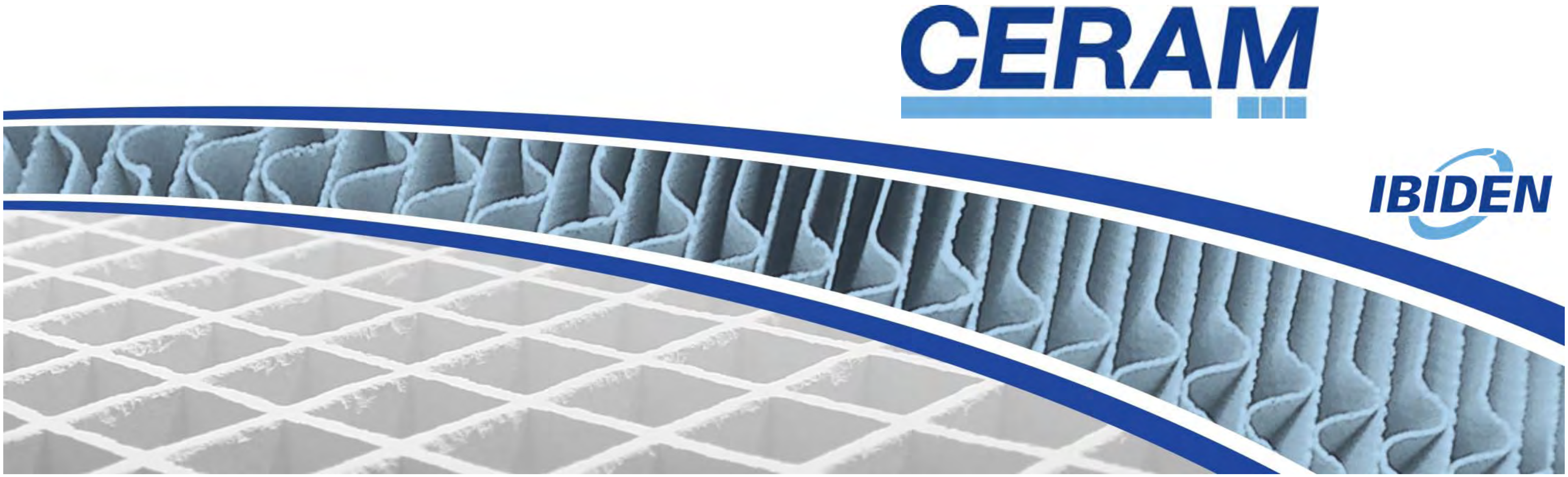
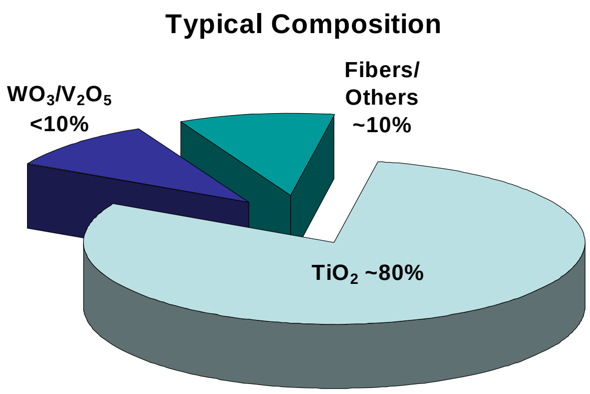
Comparison of Chemical Properties



Fresh (New) Catalyst Constituents



Catalyst Chemical Compound	Honeycomb Catalyst	Plate Catalyst
Vanadium (V_2O_5)	up to 3%	up to 3%
Titania (TiO_2)	~80%	~80%
Tungsten (WO_3)	5 to 10%	5 to 10% (1)
Molybdenum (MoO_3)	0%	5 to 10% (1)
Silica (SiO_2)	~8%	~8%

Note: (1) Plate type catalyst utilizes either tungsten or molybdenum.

The Predominant Variable Constituent Modulated is Vanadium to Achieve SO_2 to SO_3 Conversion Rate Objectives

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Reactor Potential

$$P = K/A\nu$$

P = Reactor Potential

K = Catalyst Activity, Nm^3/m^2h or Nm/h

$A\nu$ = Area Velocity, Nm/h
(normal gas flow, Nm^3/h divided by total installed catalyst surface area, m^2)

The Magnitude of Reactor Potential Determines the Amount of SCR System Performance Possible (DeNOx & Ammonia Slip Control)

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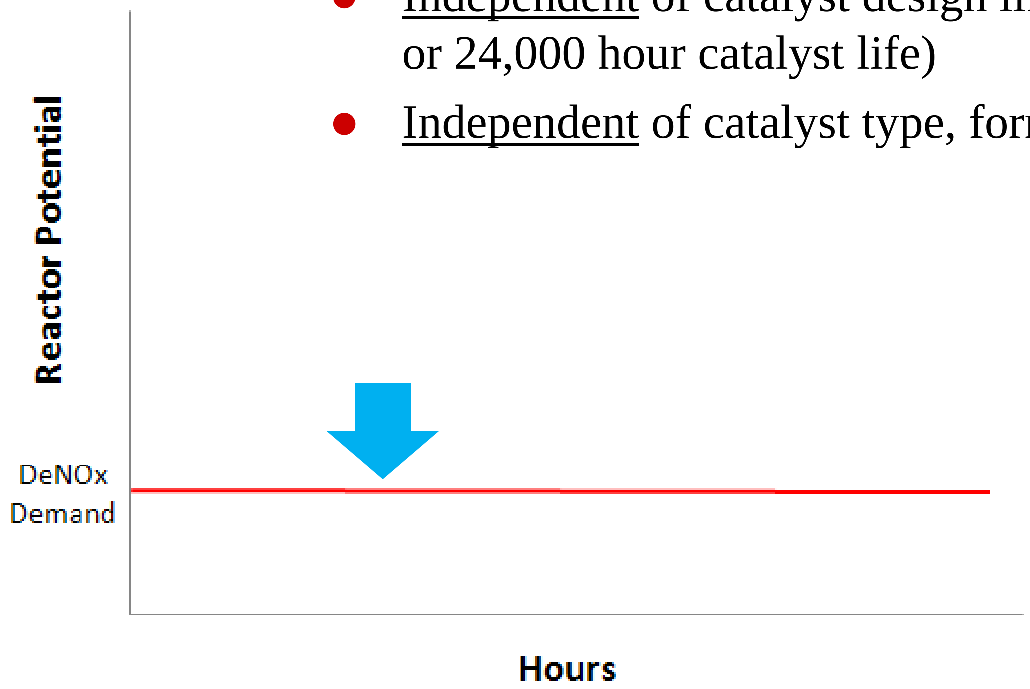
DeNOx Demand

- DeNOx Demand (P_{req}) = The reactor potential required to meet NOx removal and ammonia slip requirements
- Calculated based on NO_X removal requirements, NH_3 slip, and SCR reactor pluggage and distributions (velocity, NH_3/NOx, temperature)
- <u>Independent</u> of catalyst design life (i.e. same value for 16,000 or 24,000 hour catalyst life)
- <u>Independent</u> of catalyst type, formulation or manufacturer



$$P_{req} = K_{req} / Av$$

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Area Velocity (Av)

$$Av = Q_{fg} / A_{cat} = Q_{fg} / \left(V_{rcat} \times SSA\right)$$

Where: Q_{fg} = flue gas flow rate, Nm^3/h
A_{cat} = catalyst geometric surface area, m^2
V_{rcat} = reactive catalyst volume available, m^3
SSA = catalyst specific surface area, m^2/m^3

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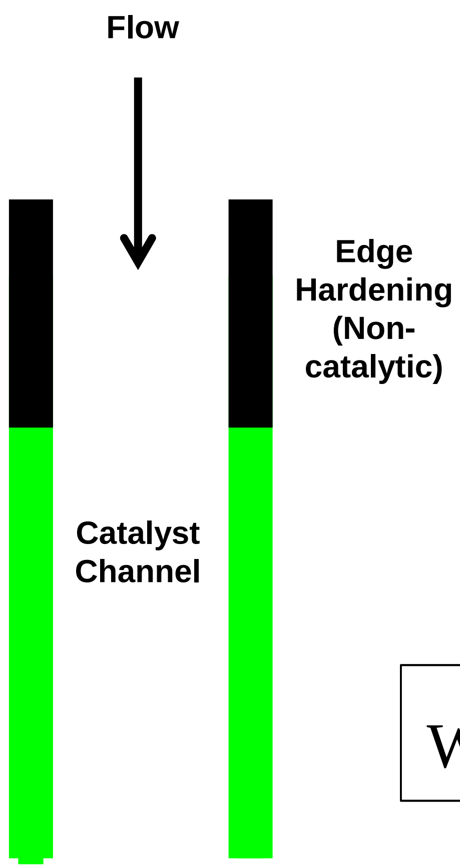
Volume Calculation
Considering Edge Hardening



$$V_{rcat} = V_{cat} \times \frac{(l_{cat} - l_{eh})}{l_{cat}}$$

Where: *Vcat* = total catalyst volume, m^3
lcat = catalyst element total length, m
leh = length of edge hardening applied to each catalyst element, m

When No Edge Hardening is Used: ***Vrcat = Vcat***

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Laboratory Testing

- CERAM Laboratory Capabilities
  - 1 Bench Reactor and 16 Semi-Bench Reactors
  - BET, Pore Volume, Pore Size Distribution
  - Compression Strength & Abrasion Resistance
  - Testing New and Aged Catalyst Samples (Honeycomb, Plate, Corrugated Fiber)
  - >1400 Tests Performed Annually

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Bench Compared to Semi-Bench Reactor Activity Testing

	Bench Test	Semi-Bench Test
Sample Size	• Full Size Element	• Cut Sample
Flue Gas Source	• Natural Gas Combustor	• Calibrated Bottle Gas
Test Conditions -Temperature -AV -Molar Ratio	• Standard or Match Design • Approx. 15 m/h • 1.0	• Standard or Match Design • Approx. 25 m/h • 1.2
Applications	• VGB or EPRI Testing • Guarantee Verification • Catalyst Management	• CERAM QA/QC Testing • Guarantee Verification • Catalyst Management
Advantages	• Catalyst Element not Destroyed • Most Widely Used Test Method	• Less Cost • Faster Turn-Around • Same Basis as CERAM QA/QC Results

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Catalyst Activity Testing

Plate	Honeycomb
• Accurate Results in ***Bench Only*** • Correct Number of Plates and Notches **Critical to Result**	• Accurate Results in Semi-bench or Bench • Full element Used for Bench • Semi-bench Length Easily Calculated • Semi-bench accuracy well developed by CERAM

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Laboratory Testing - Activity

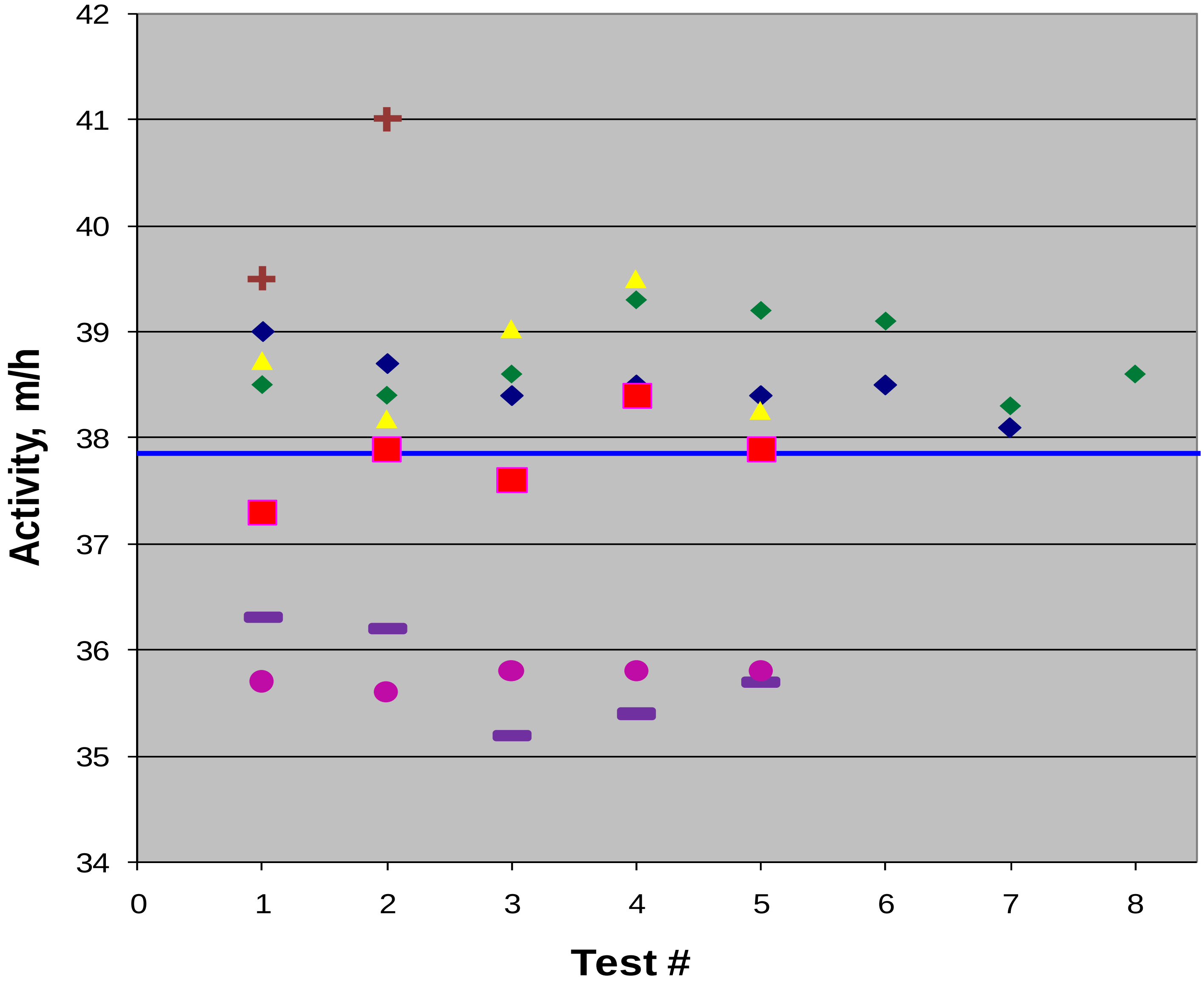
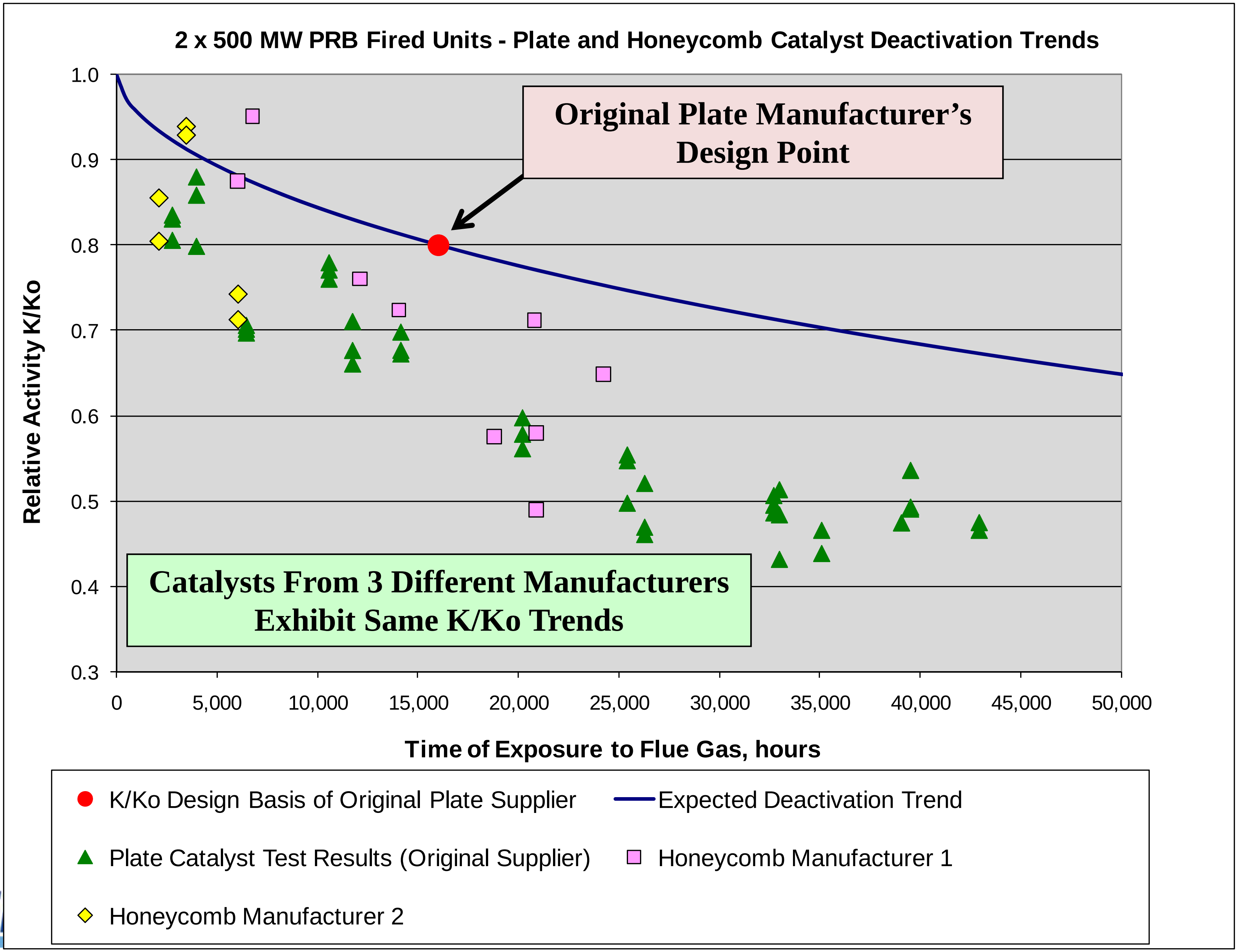
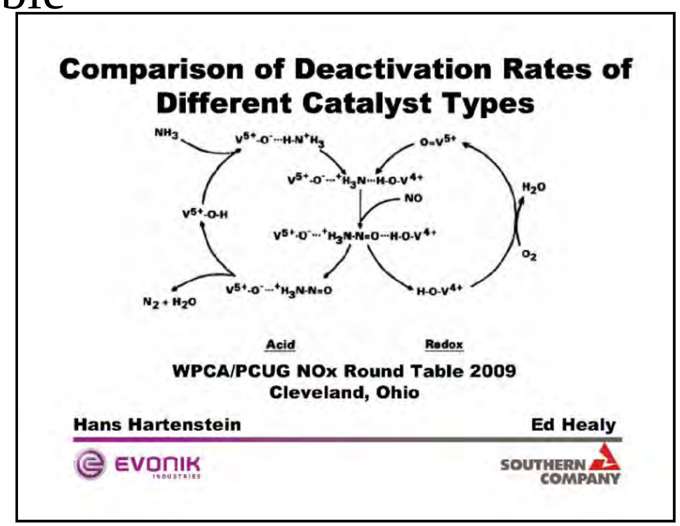


Plate and Honeycomb Deactivation Trends - PRB Units



Catalyst Deactivation

- Supplier Claims of "Poison Resistant" Catalysts are NOT Supported by Industry Experience
- Vanadia–Titania Type Catalysts Deactivate **<u>Independent</u>** of….
  - Catalyst Type and Geometry
  - Catalyst Composition
- 25+ Years of Experience With Testing Catalyst From All Suppliers Confirms Conclusion
  - Experience Confirmed by Major Utilities and IPPs: Southern Company, AEP, Steag, E.ON
  - Reference Also Paper Presented by the Southern Company and Evonik (now Steag) at the 2009 Reinhold Round Table
- Deactivation Resistance <u>ONLY</u> Comes From Providing Adequate Reactor Potential



<u>Web Address for Paper:</u>
<u>http://www.reinholdenvironmental.com/public/47bc6d6a7e8f479388a20d66579738f8/Hans%20Hartenstein%20presentation%20Deactivation%202009.pdf</u>

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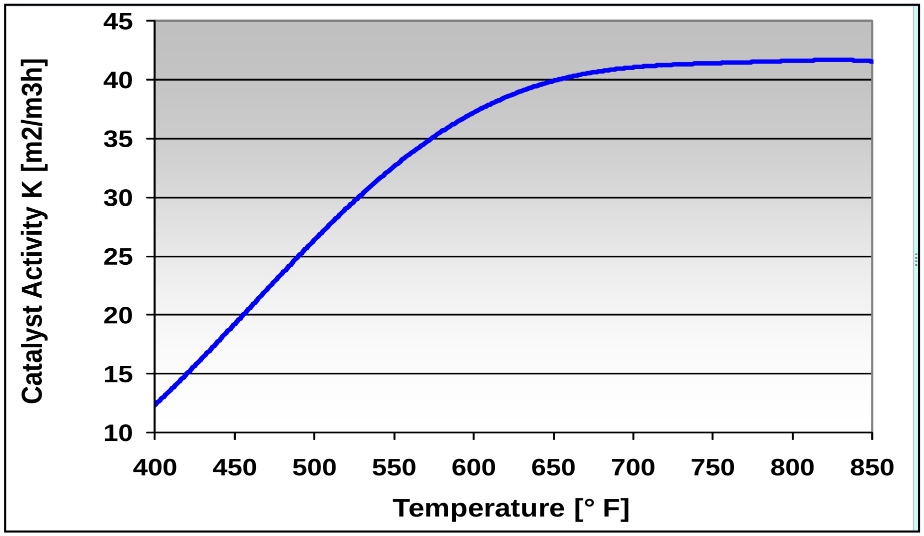
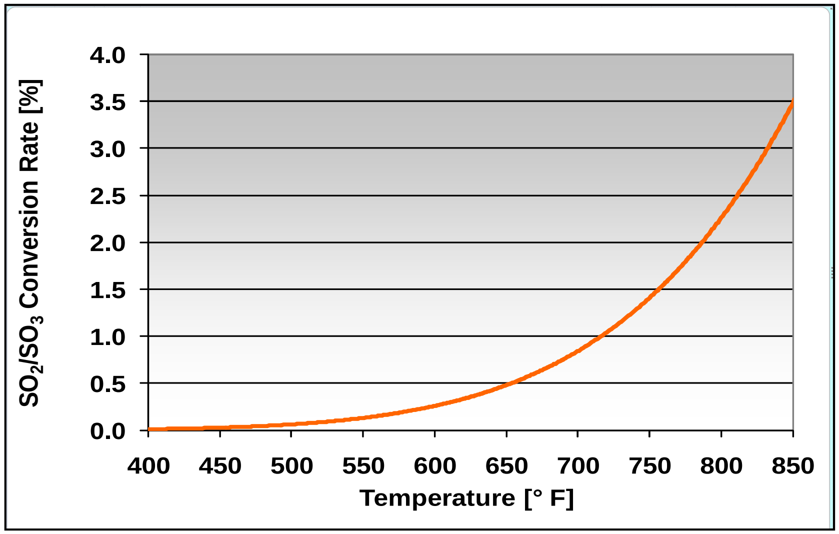
Catalyst Activity vs SO_2/SO_3 Conversion Rate





Note: Curves Presented are for a Fixed Catalyst Chemical Composition. Curves Shift Precipitously Based on Different Compositions

Activity and SO_2/SO_3 Conversion Rate are a Function of….

- Catalyst Composition (Vanadium)
- Temperature (Exponential Effect on SO_2 to SO_3 Conversion)
- Catalyst Geometry (Open Area and Wall Thickness)
- Gas Composition (SO_2, O_2, Ash Characteristics)

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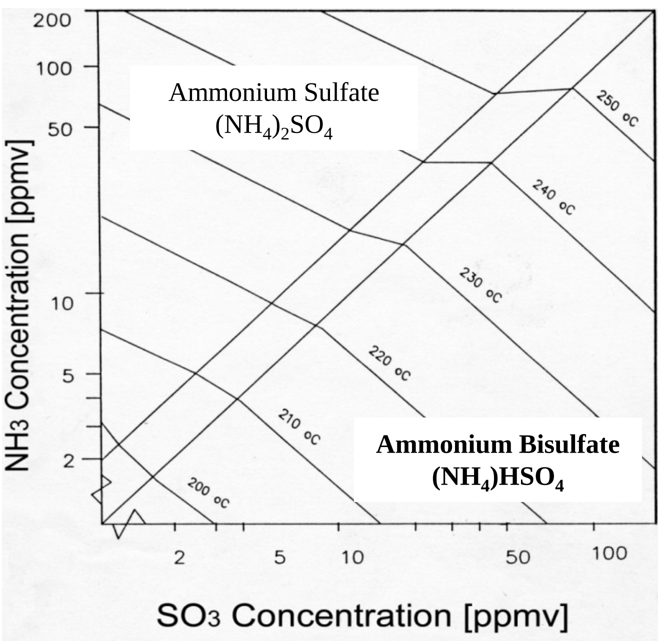
Catalyst Temperature Operating Range

- Minimum Temperature is Independent of Catalyst Type and Formulation
  - Dependent on Ammonium Bi-Sulfate (ABS) Formation Temperature
  - Function of Gas SO_3 and SO_2 Content
  - Lowest Temperature for ~Zero Sulfur Flue Gas (e.g., Natural Gas)
  - Reversible Process – ABS Releases With Time at Higher Temperatures
    - Trace Buildup Can Be Problematic for Routine Cycling
- Maximum Temperature is Dependent on Catalyst Type and Formulation
  - Catalyst Sinters (Micro Pores Closing) Above Maximum
  - Irreversible Process



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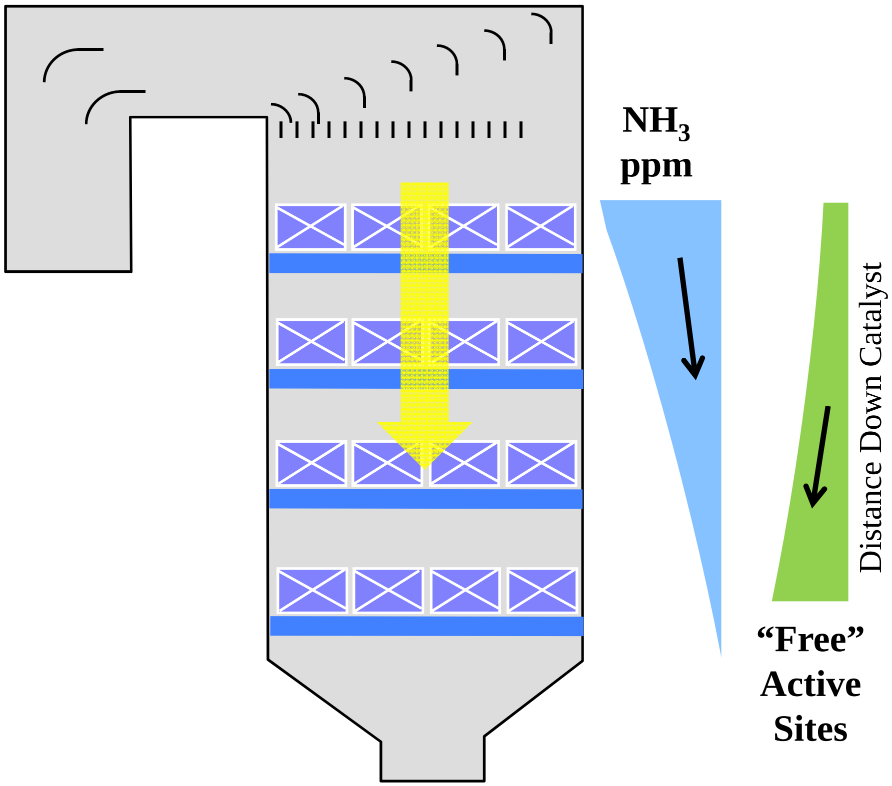
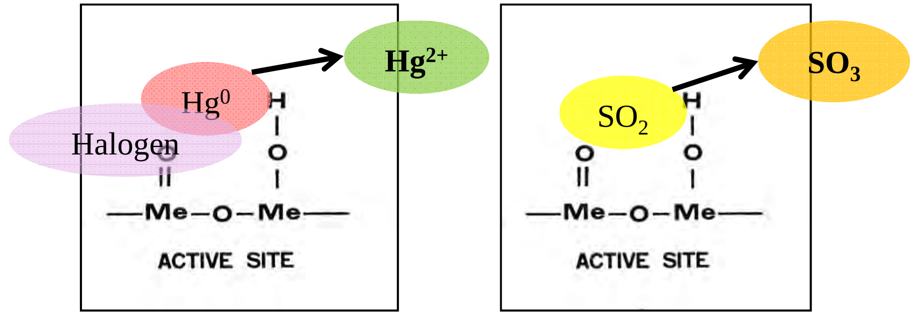
Oxidation Rates Increase in Lower Layers
Plate and Honeycomb Catalyst



- Ammonia Concentration Decreases as Flue Gas Flows Down Through Catalyst Layers
  - Surplus or "Free" Active Sites Increase Down Through Reactor
- Surplus Active Sites (Reactor Potential) Result in Increasing Rate of…
  - SO_2 to SO_3 Oxidation
  - Mercury Oxidation
  - Dependent on Catalyst Aging



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Catalyst Selection &
Catalyst Management Planning

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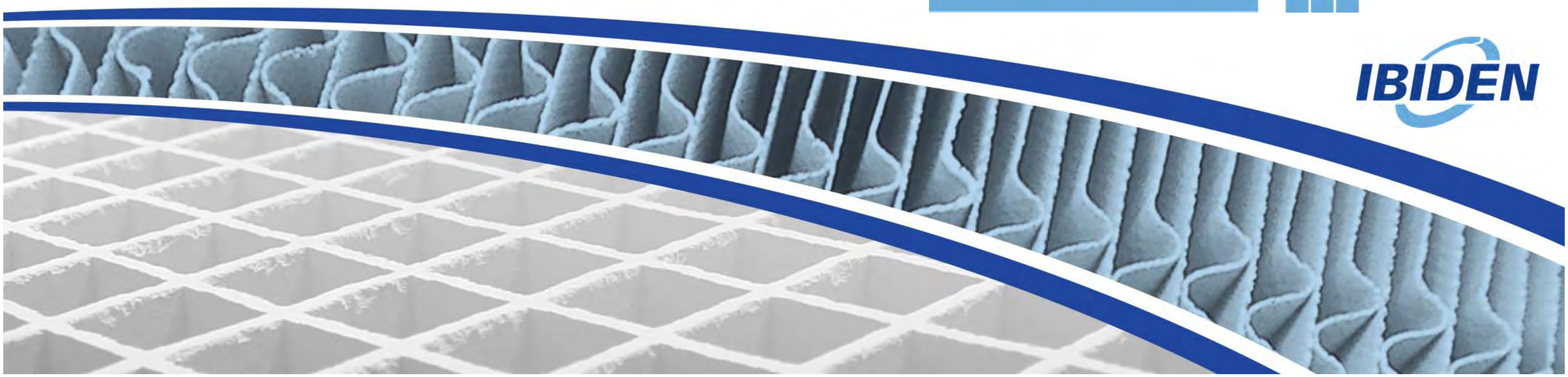


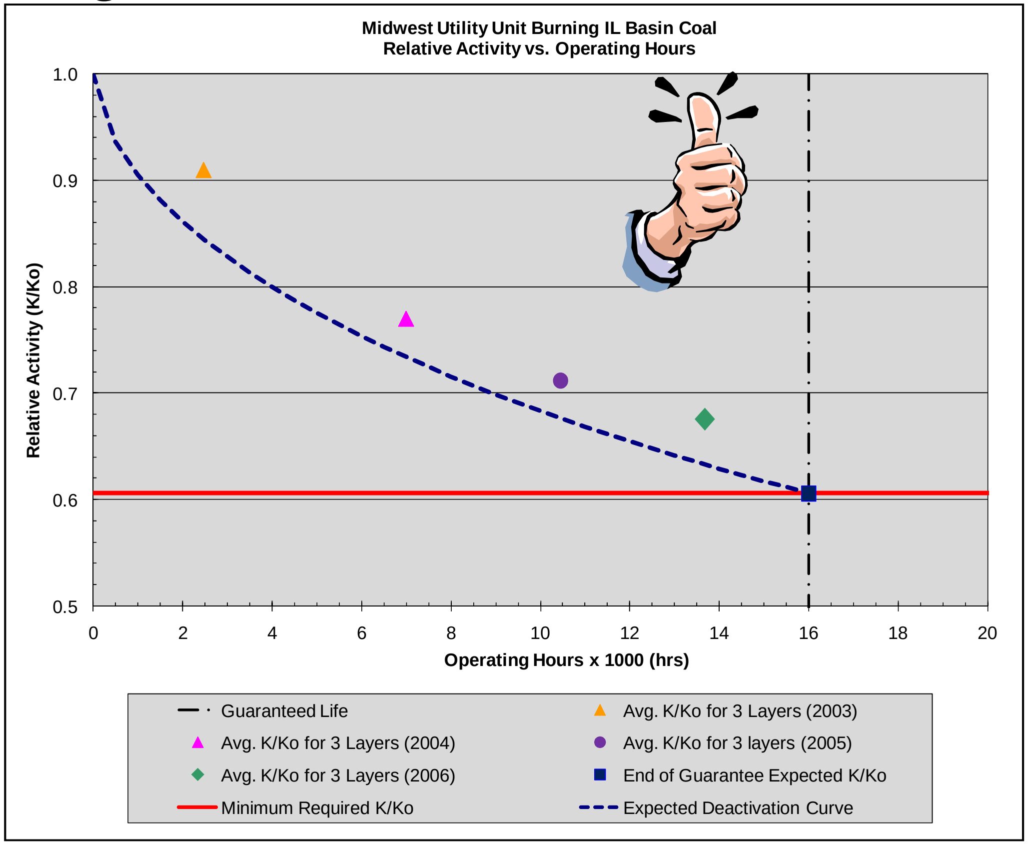
Traditional Catalyst Management

- Test Elements Removed From Reactor and Sent to Laboratory
- Laboratory Tests Determine if K/Ko is Above Original Sizing Basis Ke/Ko
- However, What Has Changed Since Original Design?
  - Boiler Operations (T, NOx, O_2, etc.), Fuels, Pluggage, DeNOx Objectives….
- Is This Catalyst Management Planning?

This Approach:

- Neglects Catalyst Mechanical Condition
- Neglects DeNOx Demand Different from Original Design Basis
- Neglects Catalyst Operating Condition

CERAM's Approach Incorporates All Considerations



Replacement Layer Selection - Case Example

- Case Example Considers:
  - 3 Layer Reactor
  - Equivalent SO2:SO3 Conversion Rate Catalyst Design Proposals
  - 2 Layers Currently Installed
  - New Layer Installed Into 3rd Layer
  - Historical & Future K/Ko @ 16 K = 0.67
  - Case Example Does Not Consider Regeneration for Simplicity

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Replacement Layer Selection - Case Example

Proposal	Catalyst Type	Reactor Potential	$/Reactor Potential (Normalized)	Pressure Drop
Base	8.2 mm Honeycomb (0.9 mm wall)	3.1	1.00	Base
Option 1	5.7 mm Plate (Type 300 substrate)	3.1	0.99	Same as Base
1) All designs provide the same SO_2:SO_3 oxidation rate 2) Values provided as an example case for analysis				

- Essentially the same replacement proposal
  - Equal Reactor Potential
  - Equal Pluggage Risk
  - Equal Deactivation & Management Plan
- Decision Factors:
  - $/Reactor Potential or Total Price
  - Utility Preference: Plate or HC
  - Fleetwide Regeneration and Rotation Potential
  - Erosion Risks, LOI, etc.

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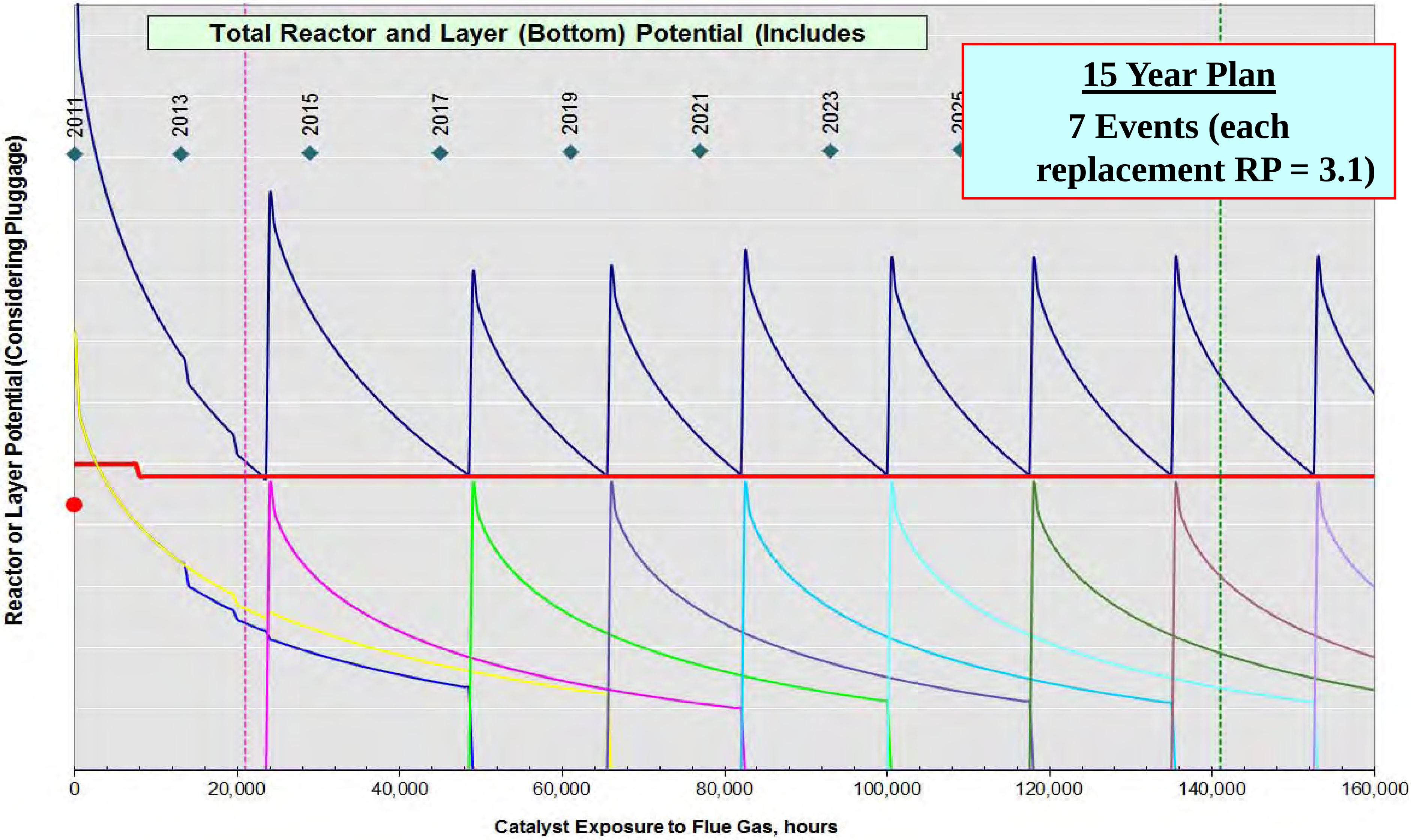
Replacement Layer Selection – Case Example
Management Plan - Base or Option 1



15 Year Plan

7 Events (each replacement RP = 3.1)

K/Ko @ 16,000 hours = 0.67

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Replacement Layer Selection - Case Example
Add Option 2 – Shorter Catalyst Length

Proposal	Catalyst Type	Reactor Potential	$/Reactor Potential (Normalized)	Pressure Drop
Base	8.2 mm Honeycomb (0.9 mm wall)	3.1	1.00	Base
Option 1	5.7 mm Plate (Type 300 substrate)	3.1	0.99	Same as Base
Option 2	**8.2 mm Honeycomb (0.9 mm wall)**	**2.5**	**0.97**	**-0.15 in.wc.**

1) All designs provide the same SO_2:SO_3 oxidation rate
2) Values provided as an example case for analysis

- Option 2 Provides Lower Reactor Potential (Shorter Length)
- Option 2 Provides the Lowest $/Reactor Potential
- ***Is $/Reactor Potential An Effective Metric in this Case?***
- *How Does Option 2 Affect the Catalyst Management Plan?*

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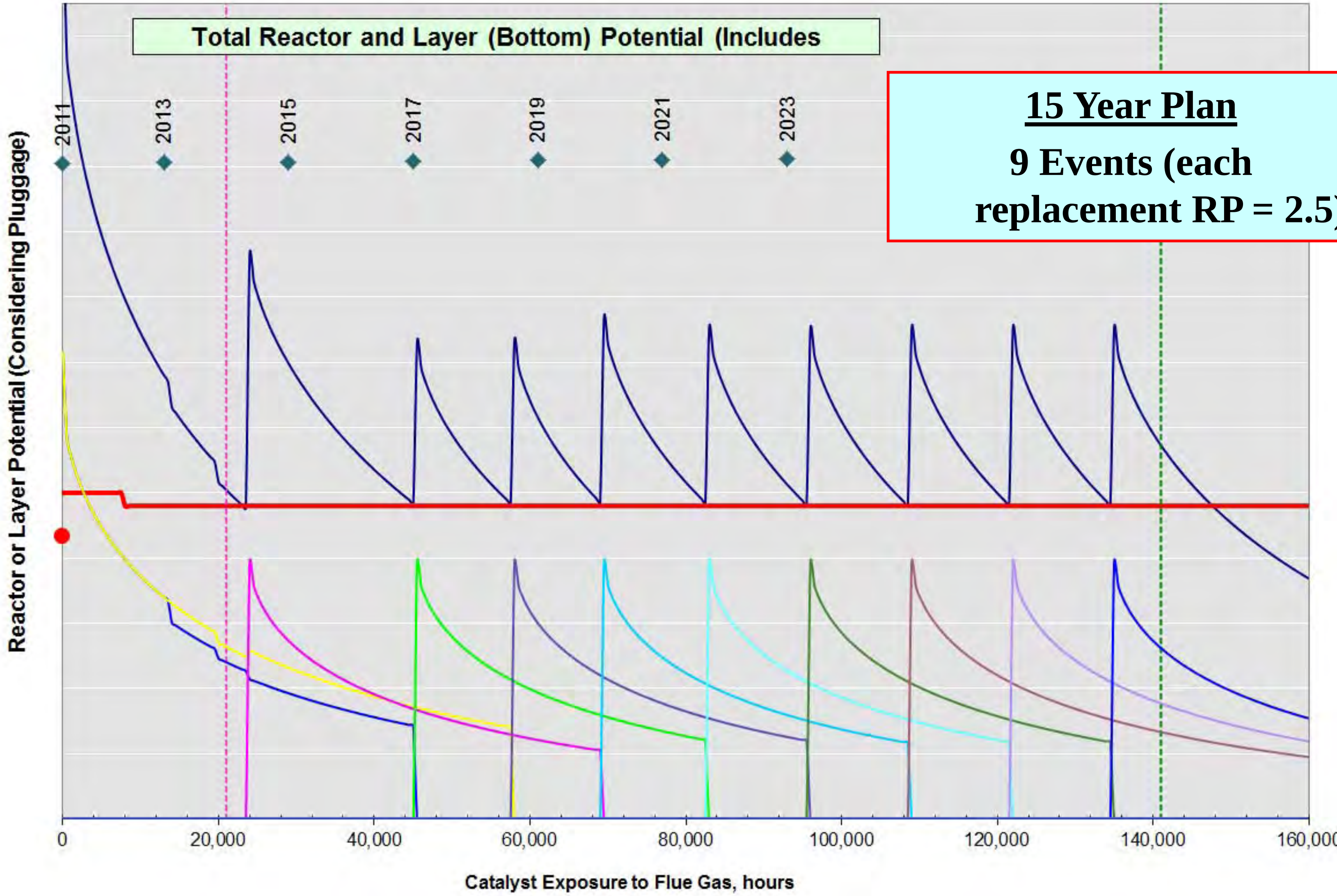
Replacement Layer Selection Case Example
Management Plan – Option 2



<u>15 Year Plan</u>

9 Events (each replacement RP = 2.5)

3% - $/RP Savings But Also 2 Additional Events

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Replacement Layer Selection - Case Example NPV Analysis

Proposal	Catalyst Type	Reactor Potential	$/Reactor Potential - Normalized	Pressure Drop	NPV (15 Year Plan) - Normalized
Base	8.2 mm Honeycomb (0.9 mm wall)	3.1	1.00	Base	**1.0**
Option 1	5.7 mm Plate (Type 300 substrate)	3.1	0.99	Same As Base	**1.0**
Option 2	8.2 mm Honeycomb (0.9 mm wall)	2.5	0.97	-0.15 in.wc.	**1.0**

- NPV Considers:
  - Catalyst Cost, In/Out Costs,
  - Fan Energy Cost
  - Ammonia Cost
  - Indirect Outage Costs Not Considered
- Essentially Equivalent NPV for All Options
- **Option 2 Requires Two Additional Outages With No NPV Benefit**
- **Additional RP=2.5 May Not Meet Next Scheduled Outage**

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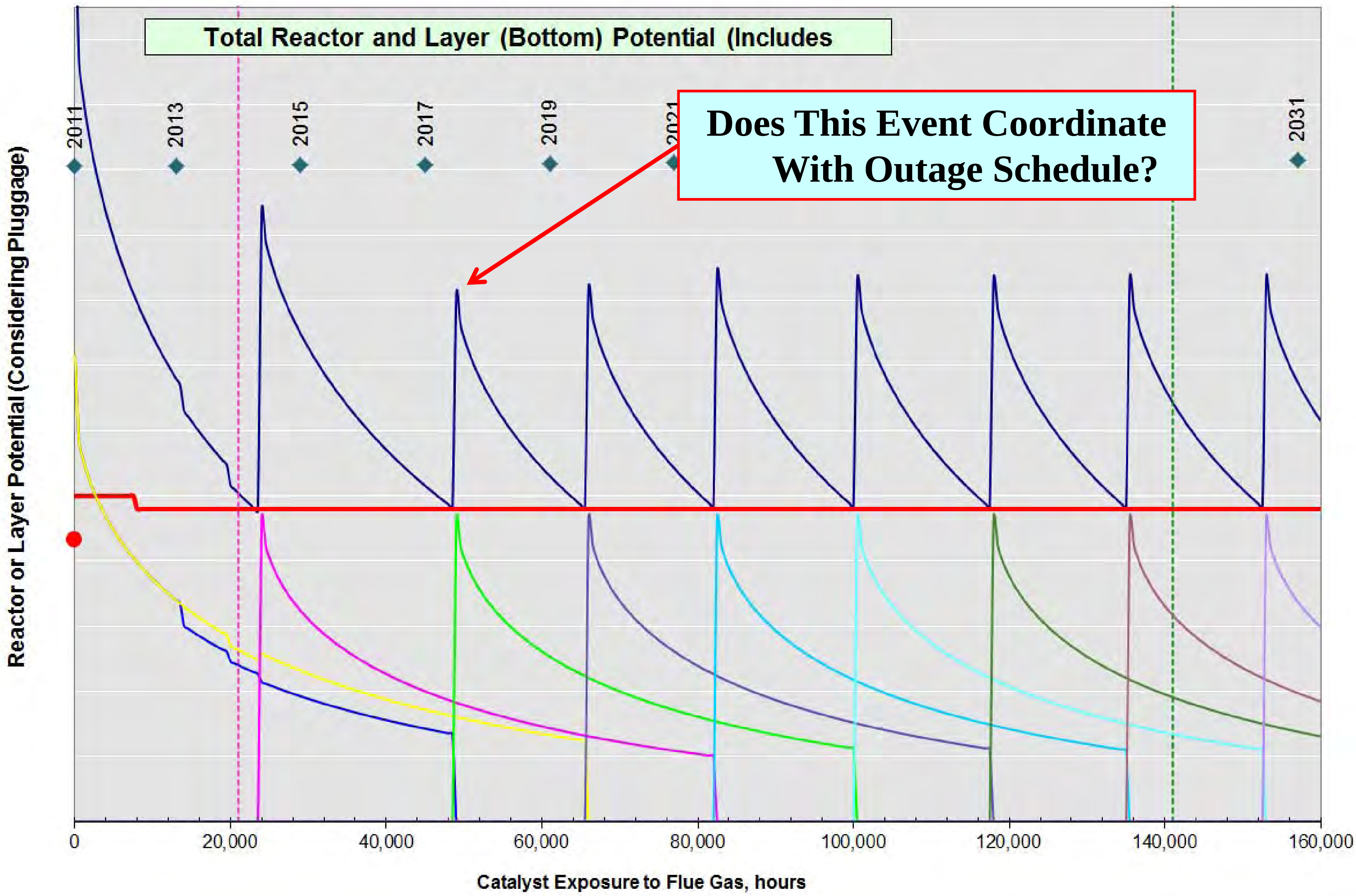
Replacement Layer Selection Case Example
Management Plan – Base or Option 1



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Replacement Layer Selection - Case Example
Add Option 3 – Smaller Pitch

Proposal	Catalyst Type	Reactor Potential	$/Reactor Potential (Normalized)	Pressure Drop
Base	8.2 mm Honeycomb (0.9 mm wall)	3.1	1.00	Base
Option 1	5.7 mm Plate (Type 300 substrate)	3.1	0.99	Base
Option 2	8.2 mm Honeycomb (0.9 mm wall)	2.5	0.97	-0.15 in.wc.
Option 3	**7.4 mm Honeycomb (0.8 mm wall)**	**3.6**	**0.83**	**+0.1 in.wc.**

1) All designs provide the same SO_2:SO_3 oxidation rate
2) Values provided as an example case for analysis

- Option 3 Provides Higher Reactor Potential (Same Length as Base)
- Pluggage Risk Assessment Critical
- 7.4 mm Pitch Honeycomb May Be Acceptable in Layers 2 & 3

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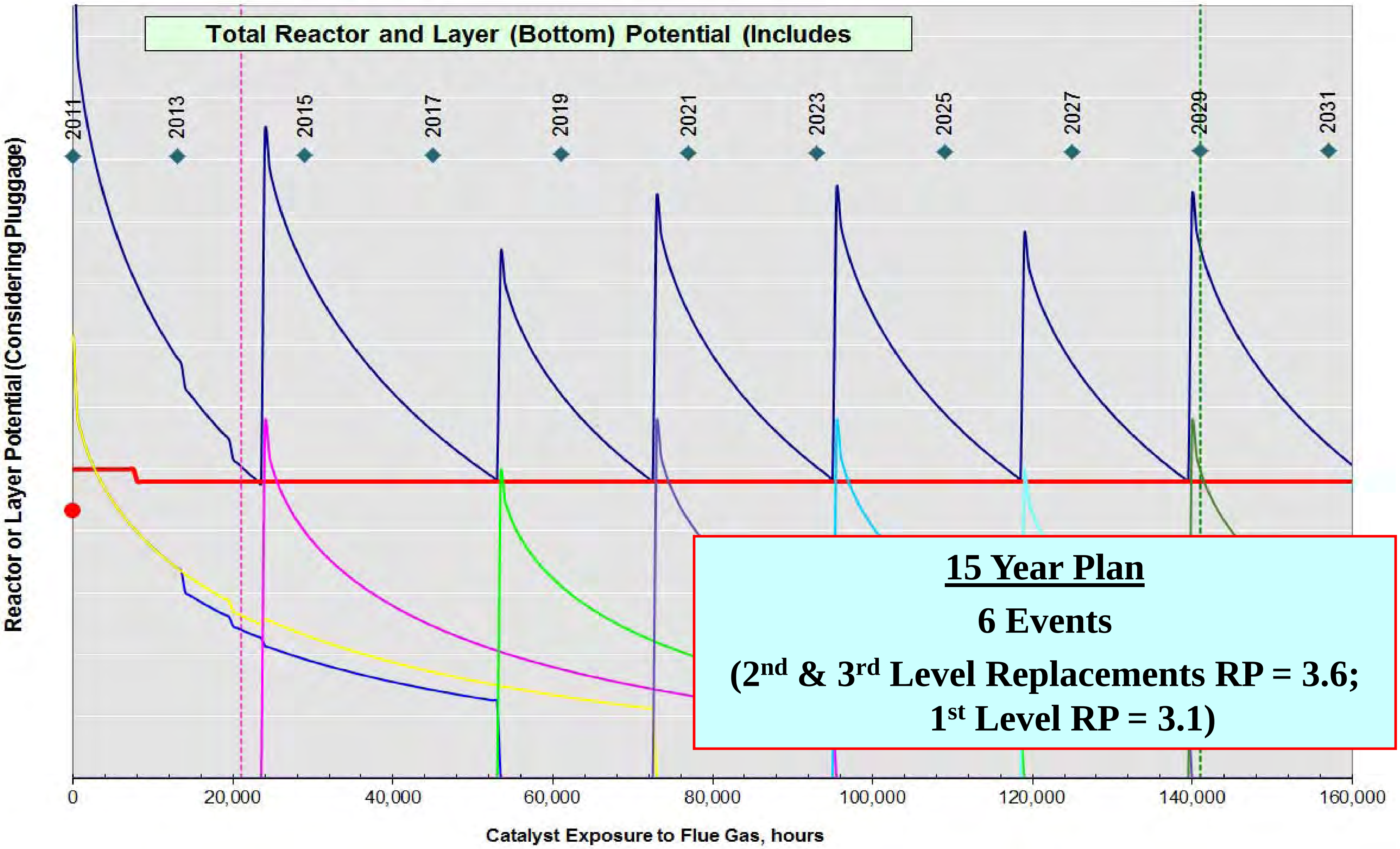
Replacement Layer Selection Case Example
Management Plan – Option 3



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Catalyst Management Summary

- Catalyst Evaluation Should Consider Many Factors
  - Physical Factors – Catalyst Type, Erosion Risk, Pluggage Risk, LOI & LPA
  - Chemical Factors – DeNOx Activity (Reactor Potential) & SO_2/SO_3 Conversion Rate
  - Catalyst Management Planning – Outage Timing & NPV
  - Pricing – Total & Per Reactor Potential
- $/Reactor Potential Can Be a Useful Tool
  - When Total Reactor Potential is Comparable
  - When SO_2/SO_3 Conversion Rate is Comparable
  - When Options are Appropriate Catalyst Type, Pitch & Mechanical Durability

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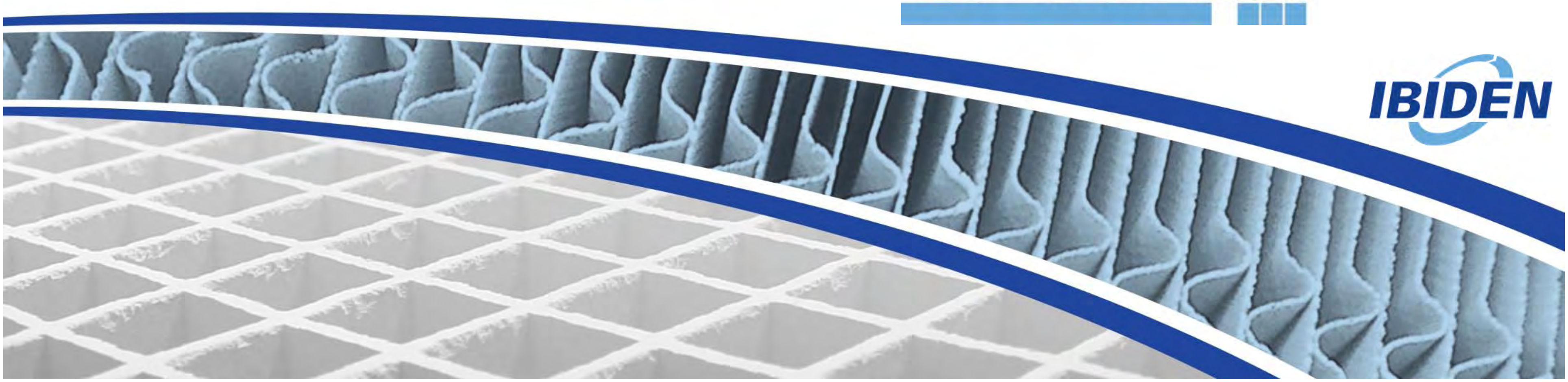
Conclusions



Conclusions

- Honeycomb and Plate Catalyst Myths and Realities…
  - Reality is Both Can Erode
    - For High Ash Loading (>20 gr/dscf) Better Selection is Plate
    - Exposed Metal Increases SO_2/SO_3 Conversion Rate
  - Reality is Both Need Sufficient Wall Thickness for Regeneration
    - Honeycomb 6.6-7.4 mm Pitch; >0.8 mm, 8.2 mm Pitch; >0.9 & Plate 5.6 mm Pitch; >0.70 mm
  - Reality is Plate Substrate Very Important (Type 300 vs. Type 400 Stainless Steel)
  - Reality is Both Can Plug Due to LPA or Ash Maldistribution
    - Pluggage Easily Visible for Honeycomb
    - Pluggage Between Sub Layers for Plate
  - Reality is Both Can Sinter (Propagate with Plate)
  - Reality is Honeycomb Has Higher Surface Area Per Volume Considering Equivalent Pitch
    - Honeycomb is Preferred for Gas/Engine Applications
  - Reality is Plate Has Higher DeNOx Activity May Offset Reduced Surface Area
    - Ensure Activity Makes Sense When Calculating Reactor Potential

Conclusions

- Honeycomb and Plate Catalyst Myths and Realities…
  - Reality is Plate Has Lower Production Cost/m^3 and Faster to Produce
  - Reality is All V_2O_5-TiO_2 Type Catalyst Deactivates the Same Based on…
    - Site Specific Fuel Quality and Burner Operating Characteristics
  - Reality is There is No “Magic” or “Superman” Catalyst
    - Demand Independent Verifying Test Results
  - Reality is Catalyst Management Planning Becomes Increasingly Complex for Either Type of Catalyst
  - Reality is That Evaluation of $/RP is a Good Metric If Comparing “Apples to “Apples”
    - Evaluation Must Also Consider Catalyst Management Planning
    - Accurate Catalyst Management Planning Considers ALL Aspects of SCR Design and Boiler Unit Operations

Thank You!

Questions?

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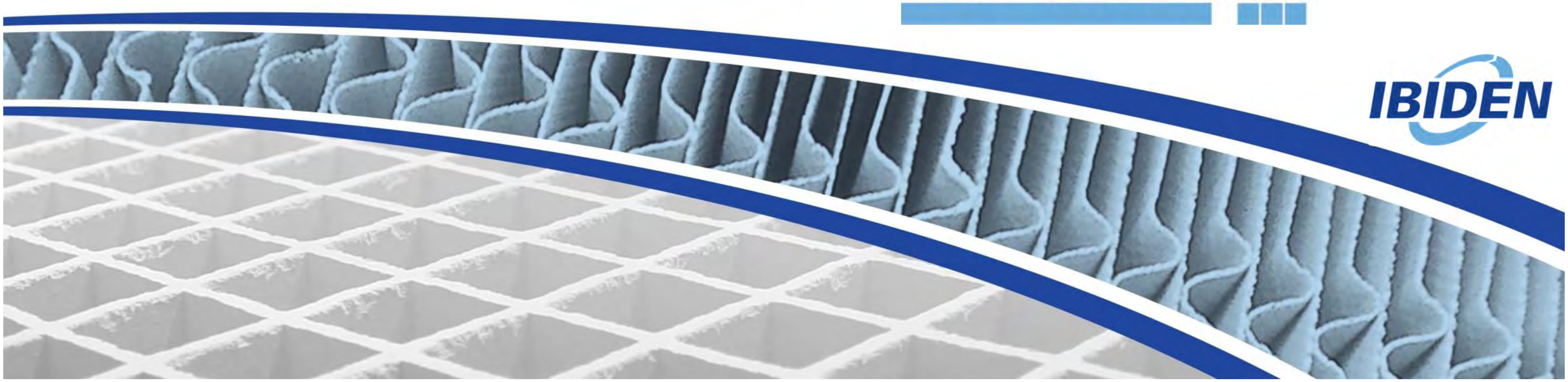

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