REINHOLD ENVIRONMENTAL Ltd.

# 2013 NOx-Combustion Round Table & Expo Presentations

February 18 & 19, 2013, in Salt Lake City, UT / Hosted by PacifiCorp

# SCR Catalyst Regeneration

## Reinhold February 18, 2013
## NOx-Combustion Conference

**Presenters:**
Michael F. Mattes - COO @ CoaLogix
Kathy Payette – Sr. Consulting Engineer @ First Energy

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# Agenda

- **SCR Catalyst Regeneration**
  - SCR Basics
  - Anatomy of SCR Catalyst
  - Common Terms
  - How Regeneration Works
  - Candidates for Regeneration
  - What to Expect from Regeneration
  - How Different Catalyst Respond to Regeneration

- **First Energy**
  - SCR Management Drivers, Goals and Challenges
  - Regeneration Experience and Expectations
  - Routine SCR Practices

- **Recent Advancements in Regeneration**

# SCR Basics

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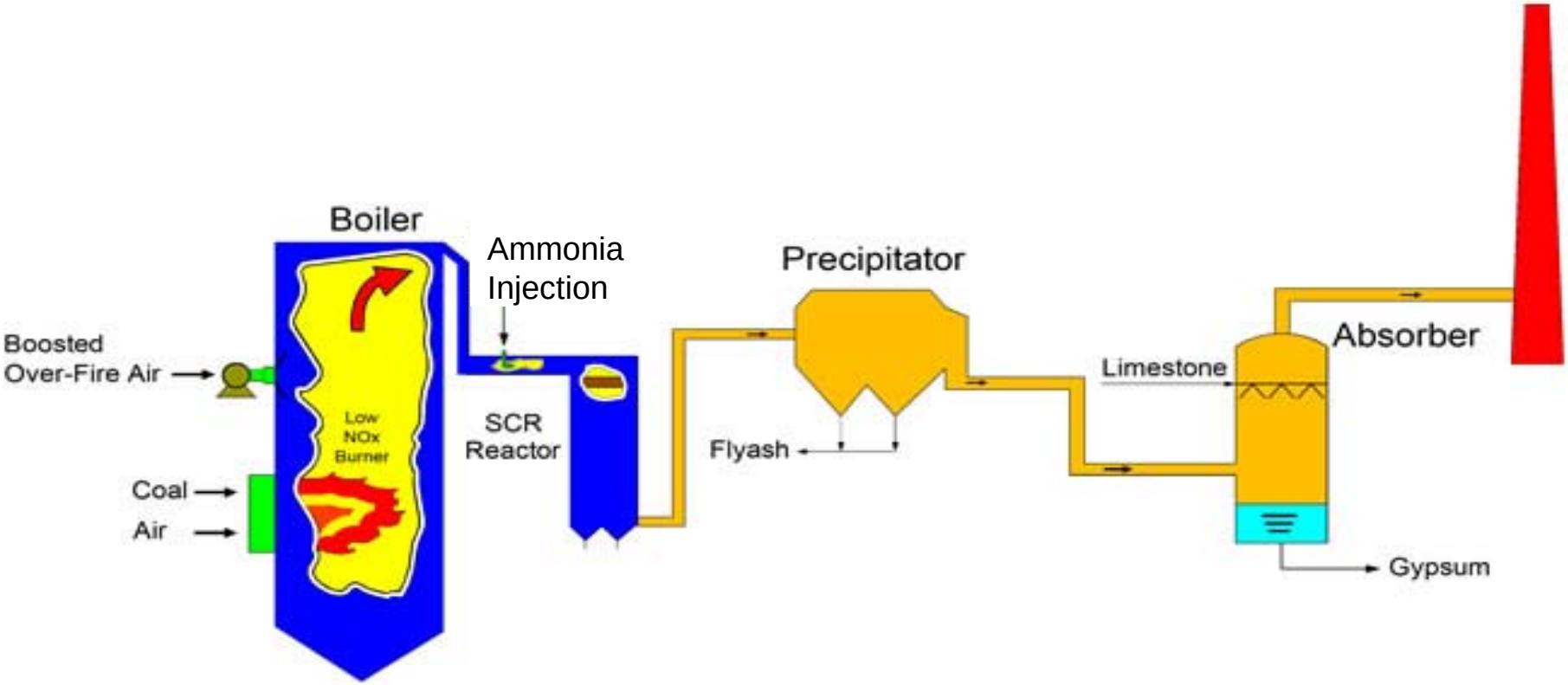
# SCR Overview




SCR is Critical to the Environmental System's Performance

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# SCR Reactions

**Positive Reactions:**

**$No_x$ Reduction** $NO + NH_3 + 1/4\ O_2 \rightarrow N_2 + 3/2\ H_2O$

**Hg Oxidation** $Hg + 2\ HCl + 1/2\ O_2 \rightarrow HgCl_2 + H_2O$

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# SCR Reactions

**Negative Reactions:**

| | |
|---|---|
| $SO_2$ Oxidation | $SO_2 + 1/2O_2 \rightarrow SO_3$ |
| Mercury Reduction | $HgCl_2 + NH_3 + 1/4\ O_2 \rightarrow Hg + 2\ HCl + 1/2\ N_2 + 1/2\ H_2O$<br>$HgCl_2 + SO_2 + H_2O \rightarrow Hg + 2\ HCl + SO_3$ |
| Ammonia Salts Formation | $2NH_3 + SO3 + H_2O \rightarrow (NH_4)_2\ SO_4$<br>$NH_3 + SO3 + H_2O \rightarrow NH_4\ HSO_4$ |

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# SCR Achieves More

- **SCR Impacts:**
  - NOx Reduction
  - $SO_2$ conversion
  - Mercury oxidation
  - ESP performance


- **Multi Pollutant Reduction Reactor (MPRR)**

# Anatomy of SCR Catalyst

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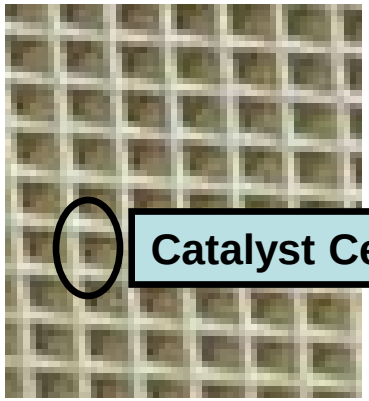
# Reaction Zones



Honeycomb Element

Catalyst Cell

**Diffusion Controlled**
DeNOx and Hg Region
0 to ~0.2 mm

**Kinetically Controlled**
$SO_2$ Oxidation Region
~0.2 - 1.0 mm.
"Low $NH_3$"

Edge Hardening

Catalyst Pore

Flue Gas Residence Time ~ 0.15 seconds per Layer

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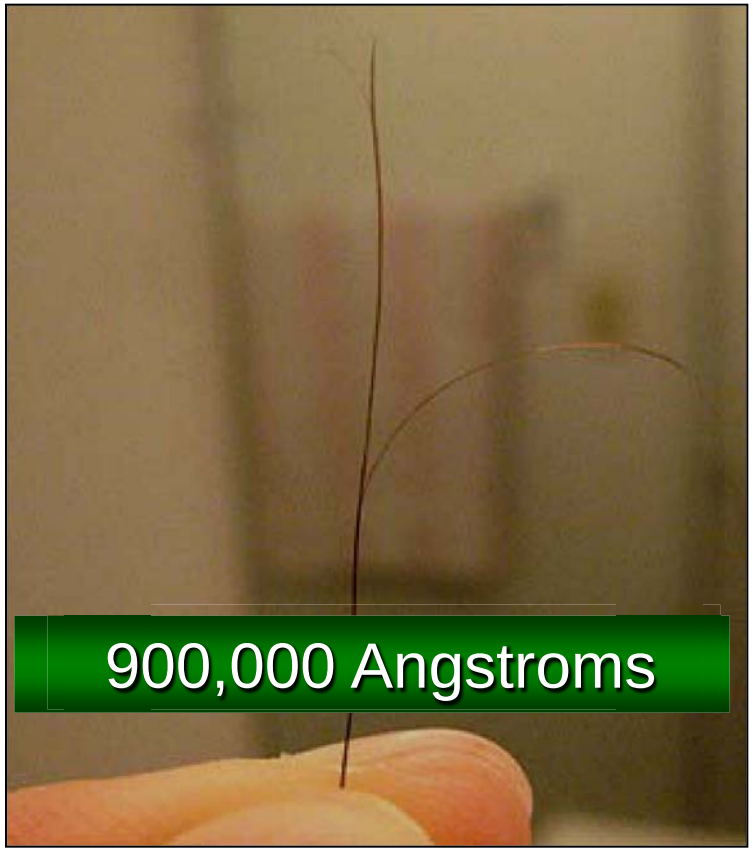
# Pore Size - Angstroms

| Pore Classification | | Pore Size | |
|---|---|---|---|
| | | Angstroms | Microns |
| Micro | Smallest | 30 | 0.003 |
| Meso | Medium | 500 | 0.05 |
| Macro | Largest | 1,000 | 0.1 |
| $NO_x$ Molecule | | 8 | 0.0008 |

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# Catalytic Surface Area


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# Common SCR Terms

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# Common Terms – Catalyst Processing

| Term | Definition |
|---|---|
| Dry Mechanical Cleaning | Utilizes compressed air and vacuum to removed loose fly ash. |
| Rejuvenation | Wet process to primarily remove “physical “ pluggage.<br>No addition of active ingredient(s). |

# Temperature Zones

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Meeting the World Energy Challenge.

Drying

Regeneration

Final Heat Treatment

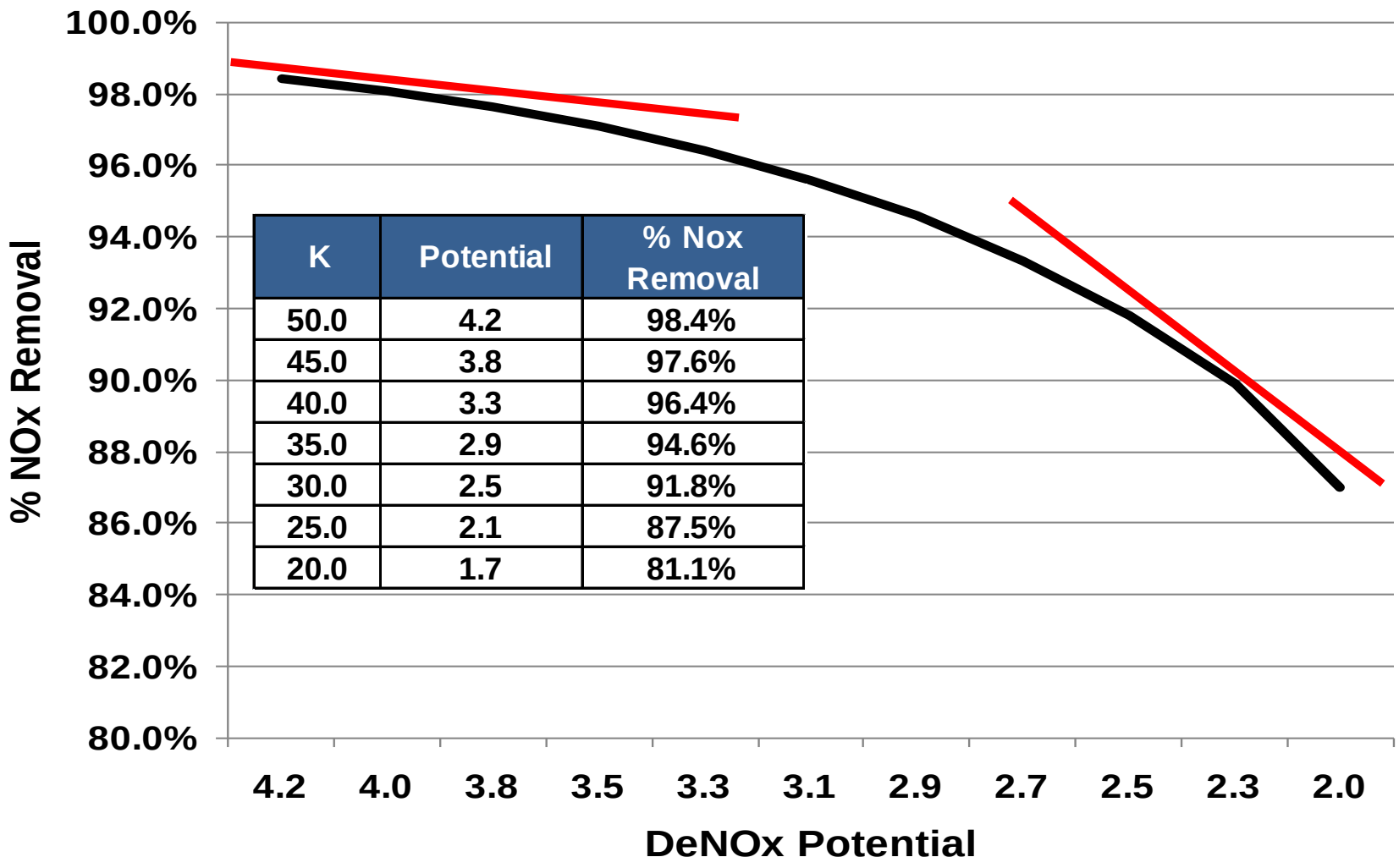
Avoid OEM Calcination Temperatures

Temperatures Zones are Time Sensitive

# Common Terms – Catalyst Performance

| Term | Symbol | Units | Origin | Definition |
|---|---|---|---|---|
| Flue Gas Flow | FGF | Nm3/hr | Set by Design | Design Flue Gas Flow |
| Visible Catalyst Surface Area | VCSA | m2 | Set by Design | Visible Catalyst Surface Area<br>Varies by catalyst type, pitch and length. |

# Potential Vs % NOx Removal




| K | Potential | % Nox Removal |
|---|---|---|
| 50.0 | 4.2 | 98.4% |
| 45.0 | 3.8 | 97.6% |
| 40.0 | 3.3 | 96.4% |
| 35.0 | 2.9 | 94.6% |
| 30.0 | 2.5 | 91.8% |
| 25.0 | 2.1 | 87.5% |
| 20.0 | 1.7 | 81.1% |

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# How Regeneration Works?

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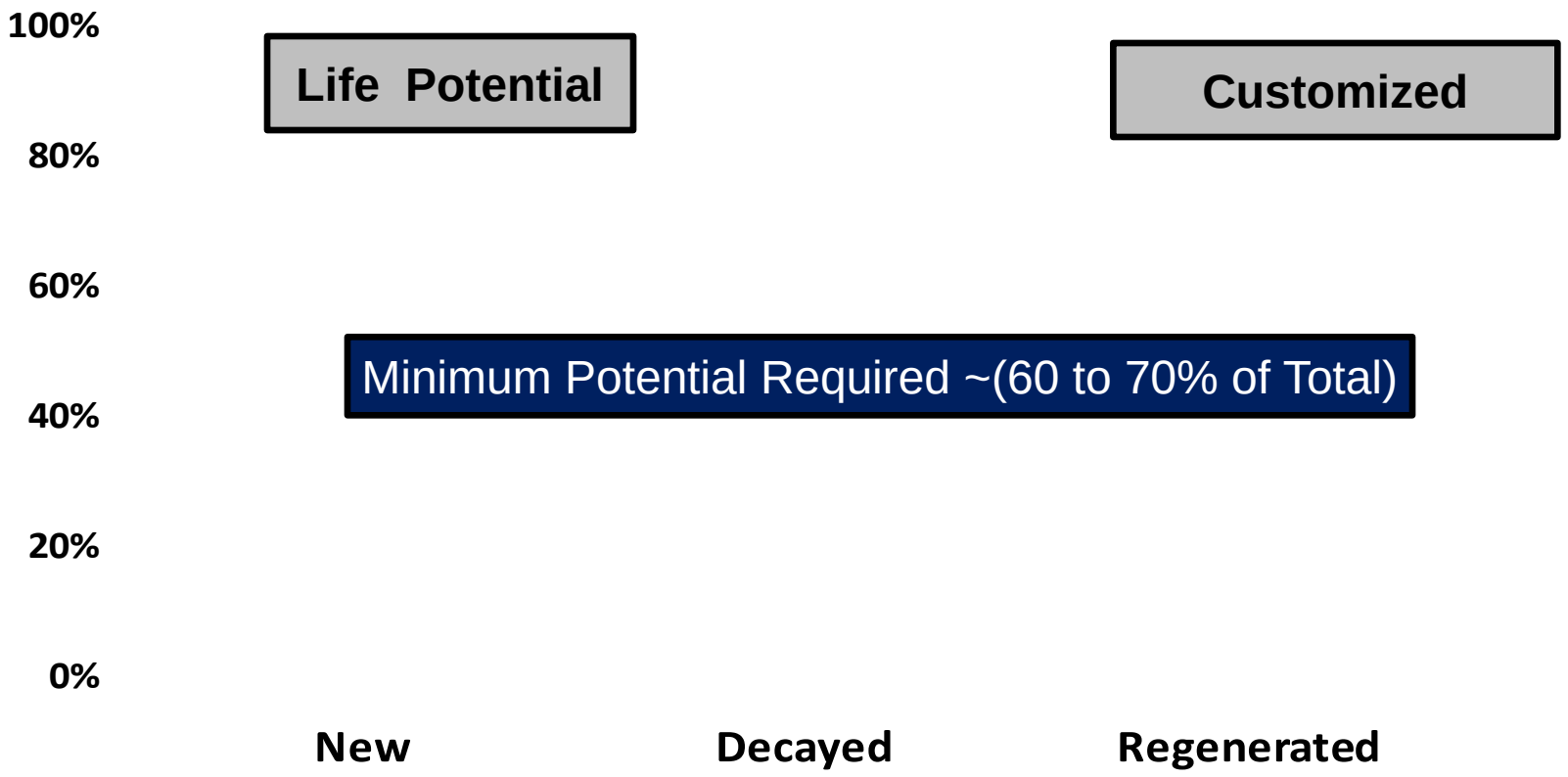
# How Regeneration Works?

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# Physical Decay

- Thermal Sintering
  - Excessive temperature > 900 $^{o}$ F
  - Leads to loss in catalytic surface area
  - Not common in coal fired units

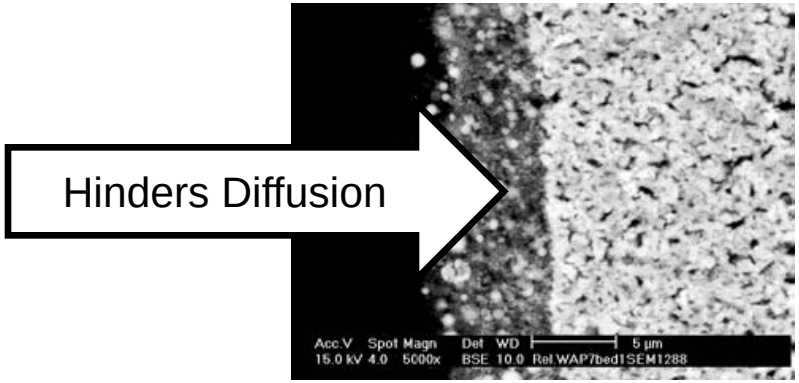
- Mechanical Erosion
  - < 30% pluggage - Minor
  - > 30% to 50% pluggage - Significant
  - >50%  pluggage –  Very Severe

Irreversible

# Physical Decay

- Catalyst Plugging
  - Fly ash near inlet wall
  - LPA /  “popcorn ash”
  - Easily detected
  - Often primary decay mechanism

- Pore Mouth Blinding
  - Sodium silicate
  - *Gypsum*
  - *Calcium carbonate*
  - *Fine particulate*




Reversible

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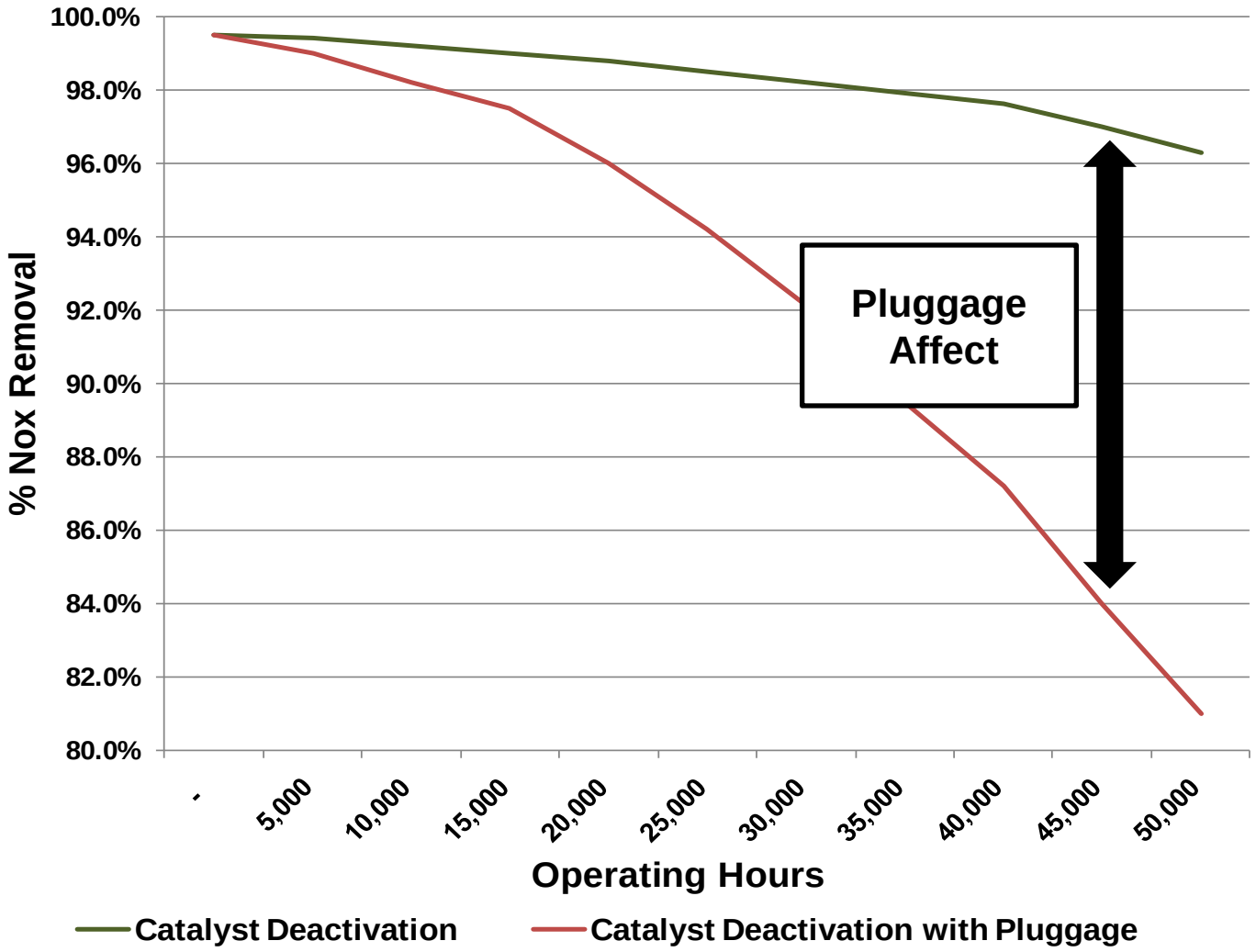
# Pluggage Impact

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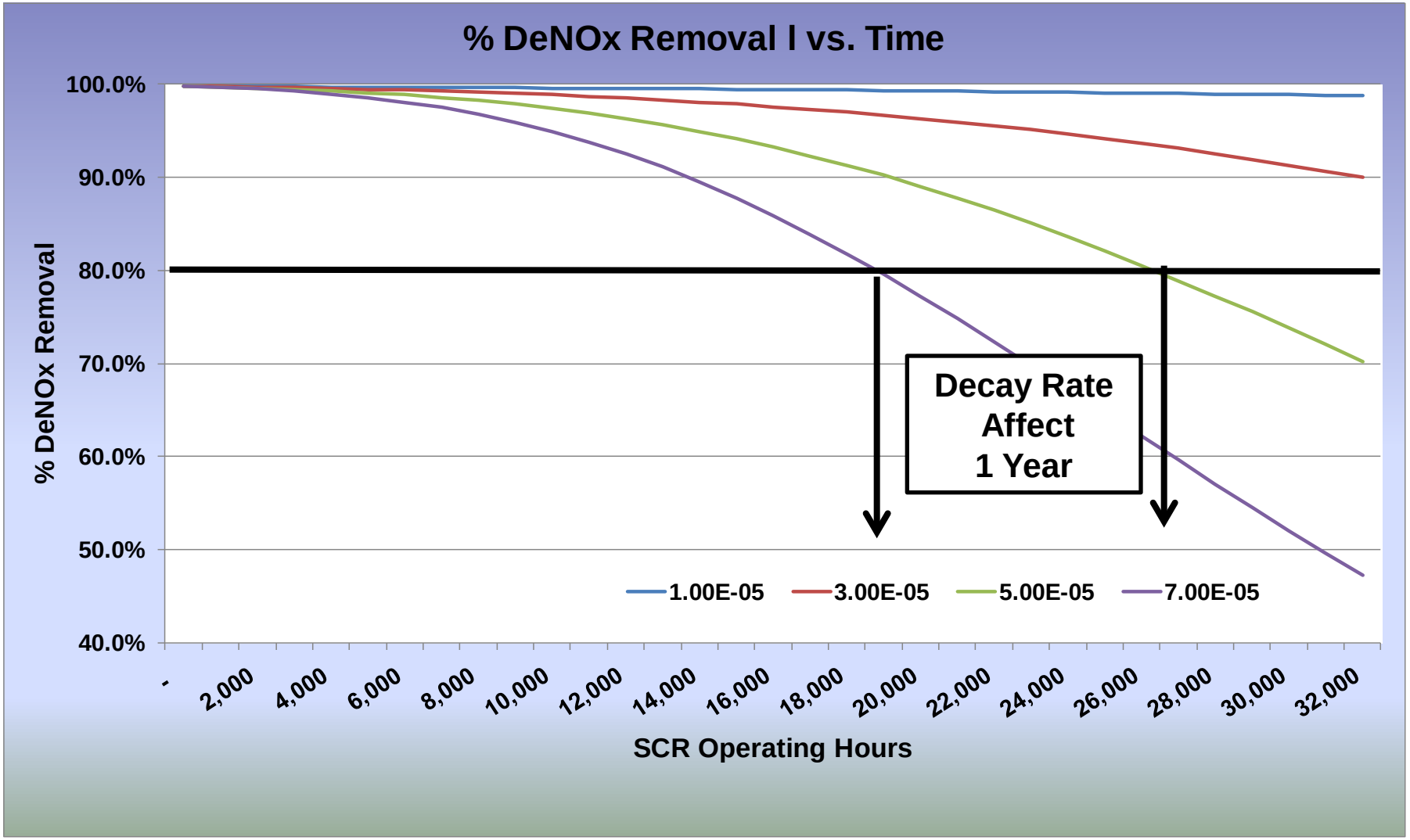
# Catalyst Poisons

- Sodium (Na)
- Potassium (K)
- Phosphorous (P)
- Arsenic (As)


Reversible

# Decay Rate Impact (Lambda –λ)

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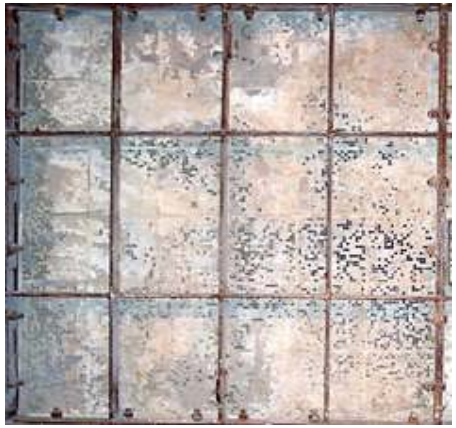
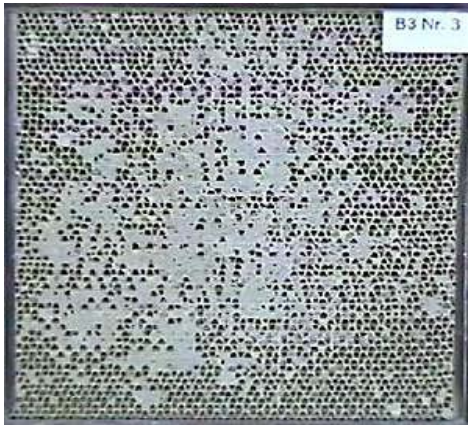
# Regeneration Candidates

**Honeycomb**



**Plate**

**Corrugated**




## Not Regeneration Candidates

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# Regeneration Process

| | |
|---|---|
| Dry Mechanical Cleaning | Plate catalyst disassembled. Can hold > 2,000 lbs. of fly ash |
| Wet Chemical Treatment | Precise control, mild chemicals, removes remaining physical pluggage |
| Ultrasonic Treatment | Utilized as required. Allows removal of difficult contaminants with mild chemicals. |
| Pre-Drying | Removal of all cleaning compounds and impurities. Critical to catalyst performance. Especially $SO_2$ conversion. |
| Drying | Removal of free water. Amount varies by catalyst type and size. Can be > 100 gallons per module. |

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# Regeneration Process

| | |
|---|---|
| Drying | Continuation |
| Re-impregnation | Customized to meet requested performance. Primarily places chemicals in the $DeNO_x$ and Hg oxidation vs. $SO_2$ Conversion zone. |
| Final Heat Treatment | Removes bound water, properly activates the added ingredient(s) and strengthens catalyst. Temperature varies by regeneration process used. |
| Repairs | Module casings and catalyst elements or cassettes. |
| Storage | Weather controlled. . |

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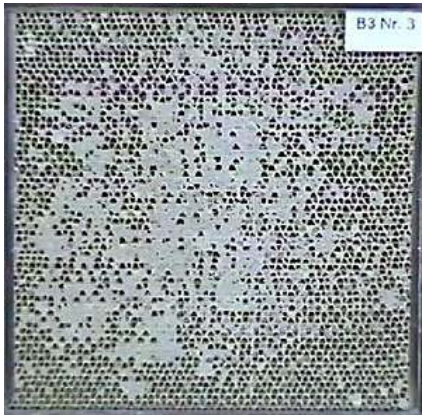
# Process Results

| | Corrugated | Honeycomb | Plate |
|---|---|---|---|
| **Before** |  |  |  |
| **After** |  |  |  |

Regeneration is Very Effective in Pluggage Removal

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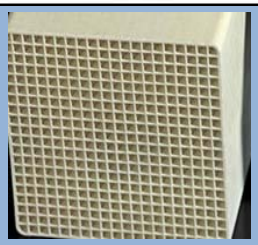
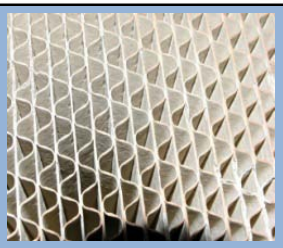
# What to Expect from Regeneration?

- Pluggage ≤ 5%
- Repair damaged modules and packing
- Replace damaged catalyst
- Performance similar to original catalyst
- Mechanical strength suitable for transportation and catalyst expected useful life
- Guarantees for % DeNOx removal, SO2 conversion and pressure drop

# Catalyst Response to Regeneration

| |  |  |  |
|---|---|---|---|
| **Item** | **Honeycomb** | **Corrugated** | **Plate** |
| **Dry Mechanical Cleaning** | **Depends on ash type, presence of LPA, time since removal from reactor.** | | **Easily cleaned** |
| **Rejuvenation "Wet Chemical Cleaning"** | **All can be processed to < 5% pluggage** | | |

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# Recent Advancements in Regeneration

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# Recent Regeneration Advancements

- **Ability to Unplug PRB Ash**
  - Improved chemistry
  - Improved mechanical systems
  - Lessons learned from improper storage
  - Lessons learned from delayed ash removal

- **Higher Contaminant Levels**
  - Longer exposure times
  - More cycled operation
  - Increased time at “minimum operating temperatures”

# Recent Regeneration Advancements

- **Re-impregnation Process**
  - More combinations of active ingredient addition
  - Advanced drying and heat treatment steps
- **Quality Control**
  - Experience gained from every project
  - More “real time” monitoring
  - Tighter tolerances
- **Mercury Oxidation**
  - “Standard” catalyst high confidence
  - “New” mercury specific catalyst to be determined
  - Key future focus

# Questions?

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