

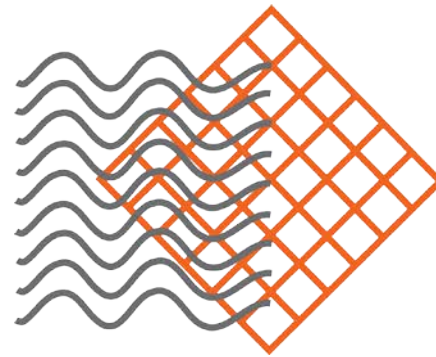
REINHOLD ENVIRONMENTAL Ltd.



**2019 REINHOLD Round Table
Presentation**

June 24 & 25, 2019, in Birmingham, Alabama / Hosted by Southern Company

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CORMETECH
RELIABILITY. DELIVERED.

Managing SCR Catalyst from Beginning to End of Life Options

June 25, 2019

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Agenda

Original Fill and Replacement

SCR Catalyst Management

Regeneration

Catalyst Selection / Optimization

Reactor Maintenance / Pluggage Mitigation

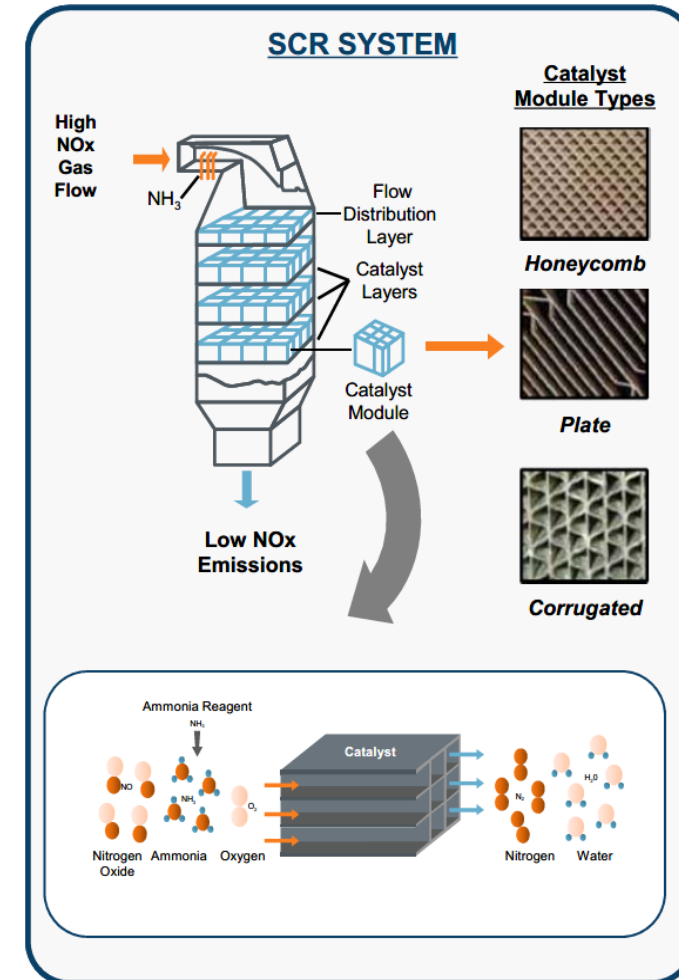
End of Life / Cormetech ReUse™



Original Fill and Replacement

The Beginning of SCR Operation

- Coal Units Operating with High Capacity Factors
- Primary Concern is When to Replace Catalyst
- Catalyst is Regulatory / Environmental so Budgets Approved



Understand Performance Requirements



NOx Removal

Rate based or tonnage based?

Stack based, plant based, fleet based?

Ammonia Slip

Toxic Release Inventory [TRI]

APH plugging

Dust collection resistivity

Ash sale criteria

SO₂ Oxidation

Plume/Opacity

Dust collection

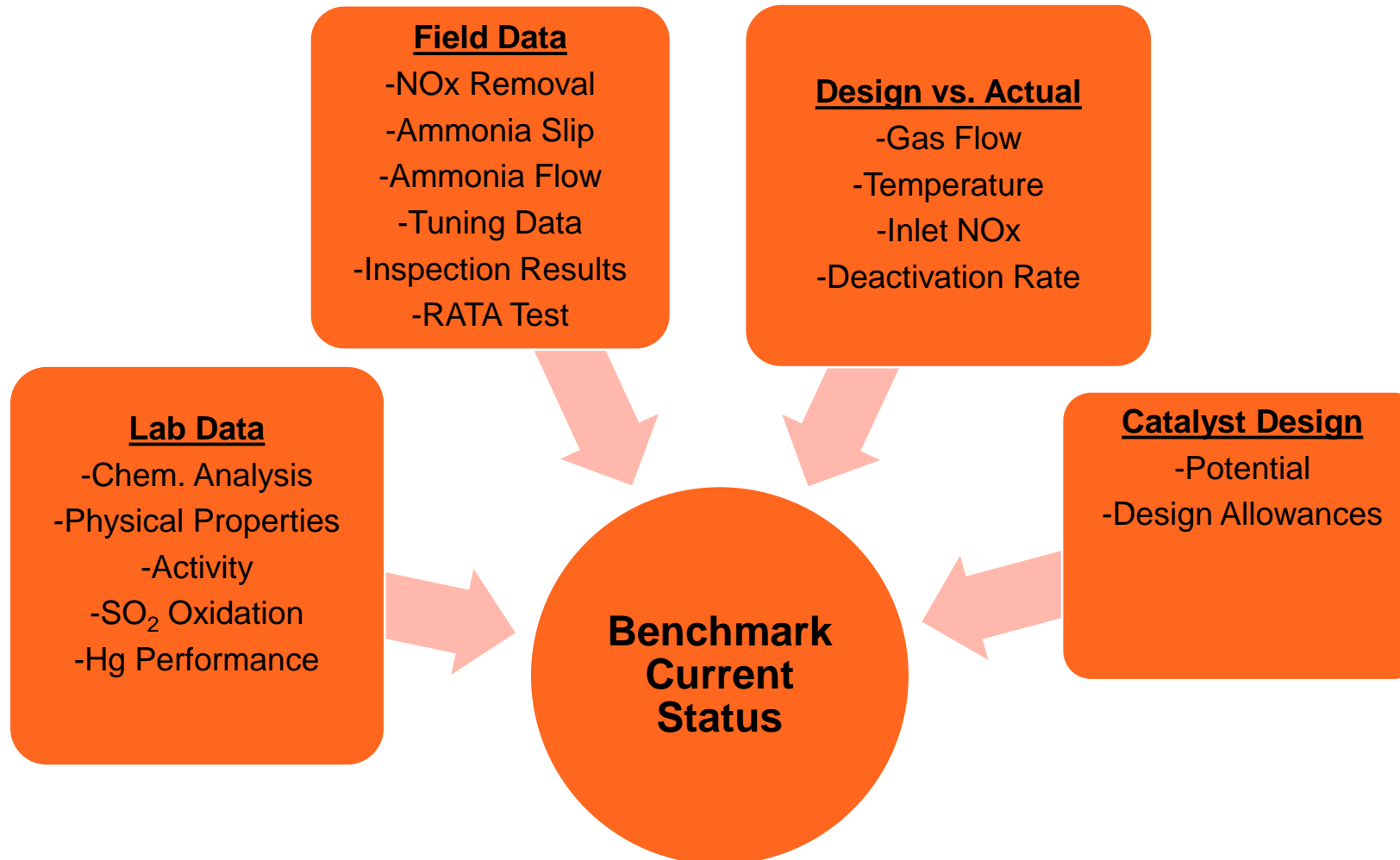
Cost of mitigation

Corrosion

Hg Oxidation

May or may not drive design

Evaluated Current Performance



New Catalyst Replacement



What catalyst was originally installed?



Johnson Matthey
Catalysts

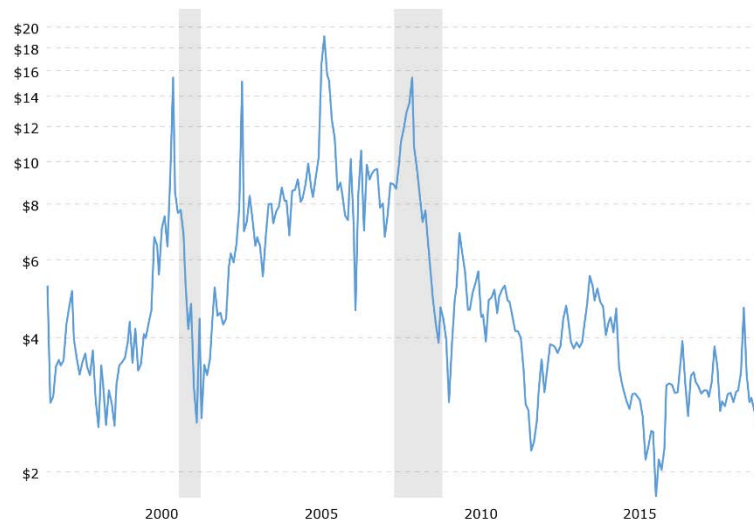
- When was an addition needed?
- When did it need to be replaced?
- Purchased from OEM
- Guaranteed Removal Efficiency



SCR Catalyst Management

Must We Change Catalyst?

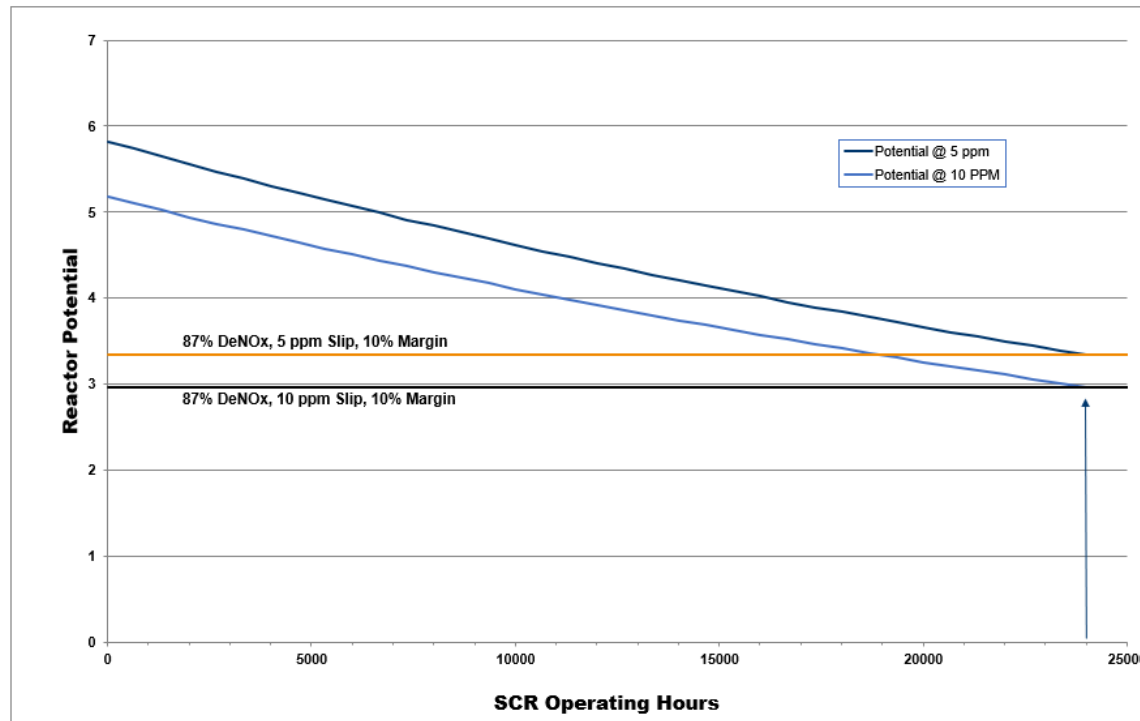
- Coal Plant Capacity Factors Decreased
- Coal Plant Budgets Reduced
- Natural Gas Became Cost Competitive
- Cost of Catalyst Replacement
- Outages are getting delayed



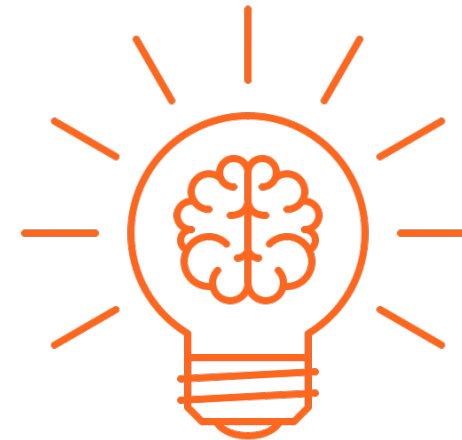
MATT GROENING

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Industry Gets Smarter



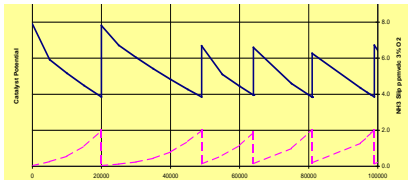
- Proper SCR inspections
- Catalyst testing
- SCR management and forecasting
- Deactivation causes
- Determination of consequences



SCR Catalyst Life-Cycle Management



Cycle primarily driven by catalyst deactivation



Monitoring & Addition/
Replacement
Management

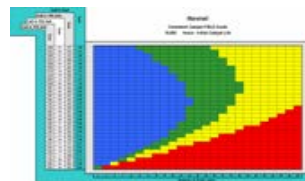
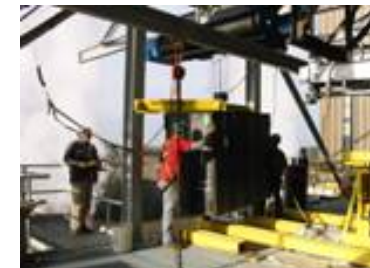
Design & Manufacture
or
Regenerate

Disposal
or Recycle



Operation & Maintenance

Installation & Commissioning

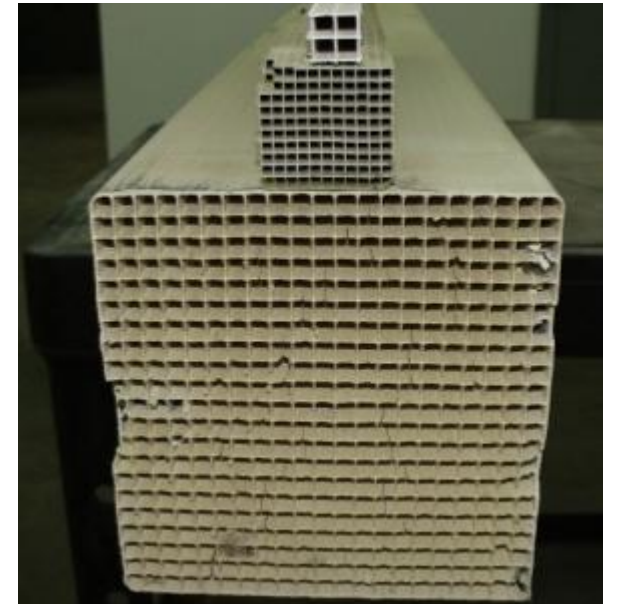


On-line cleaning,
In-situ Ice Blasting,
coal & ash monitoring,
and other deactivation
mitigation steps



Catalyst Testing Types

- **Micro-Bench Testing** – very small portion of catalyst sample, typically 2 x 2 cells or 1 – 2 plate pieces
 - Size ~15 x 15 mm (0.6 x 0.6”), no longer than 100 mm (4”)
 - Standard conditions rather than actual plant conditions, $\alpha = 1.2$
- **Semi-Bench Testing** – small portion of catalyst sample, typically 6 x 6 cells or 4 plate pieces
 - Size ~30 x 30 (1.2 x 1.2”), ~ 400 mm (16” long)
 - Standard conditions rather than actual plant conditions, $\alpha = 1.2$
- **Bench Testing** – full size catalyst sample, typically 1 log or 18 – 30 plates
 - Size – 150 x 150mm (6 x 6”) – full actual log or plate length
 - Actual unit operating conditions, $\alpha = 1$



X-Ray Fluorescence Testing (XRF)

- Surface:
 - The catalyst is being cut into the 1.5 inch diameter sized piece.
 - Test only looks at the ceramic surface of the catalyst.
- Bulk:
 - A larger piece of catalyst is crushed into “catalyst powder”.
 - 1.00g of catalyst powder and 10 g of flux make up a 1.5 inch diameter sized piece (so called “bead”).



Primary Deactivation Mechanisms



- Calcium & Phosphorous
 - Pore plugging due to calcium oxide in ash
- Arsenic
 - Coal selection
- Alkaline metals
 - Understanding sources of alkaline metals, including additives
- Catalyst Channel Plugging
 - Ash is in a very dilute phase, so can plug
 - Reactor design
 - Maintenance
 - Catalyst selection

Operational Tradeoffs

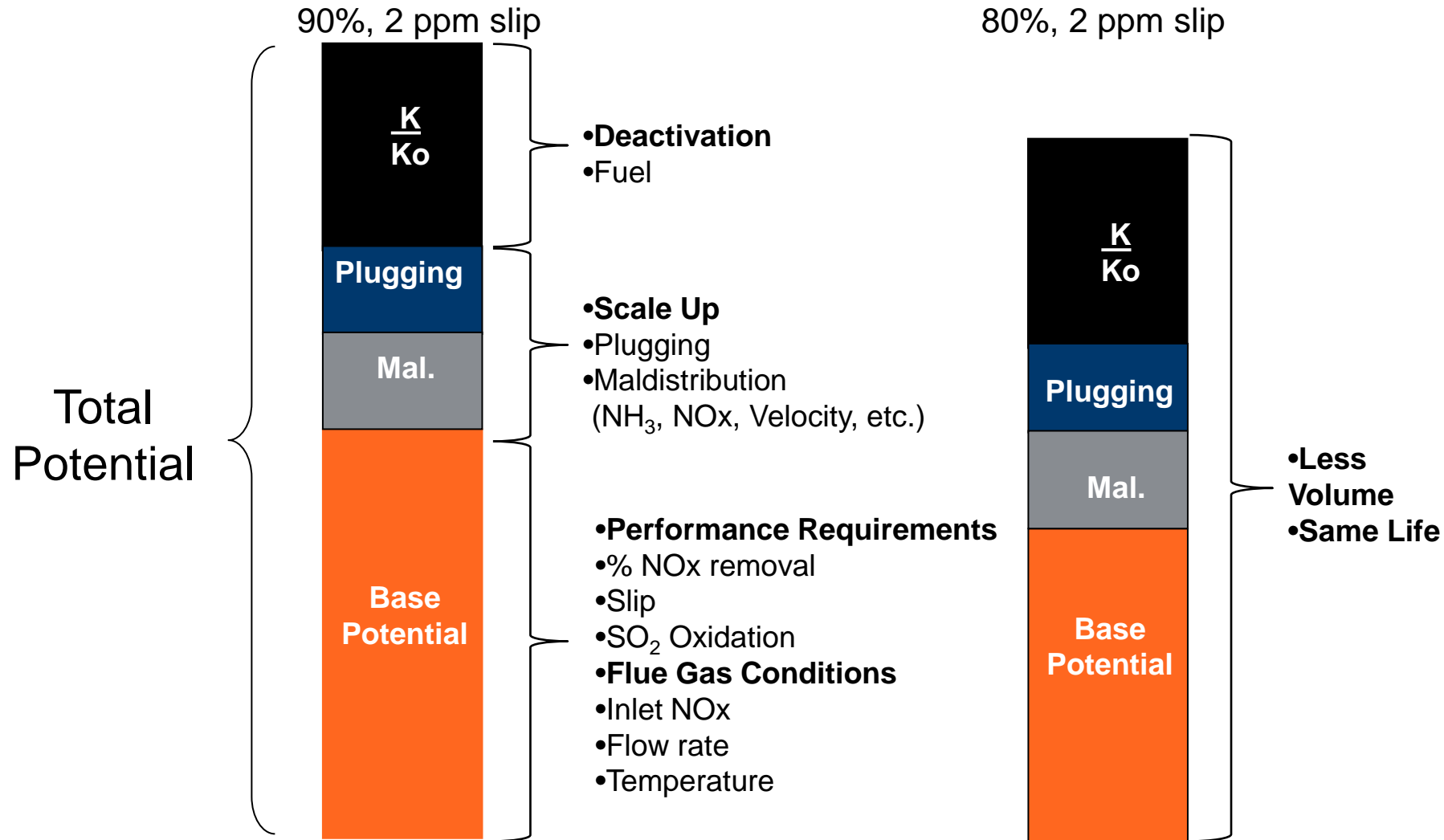


Trade-Off	Life
Higher Ammonia Slip Allowed	Increases
Reduced DeNOx	Increases
Reduced Slip Allowed	Decreases
Increased DeNOx	Decreases
Plugging/Maldistribution	Decreases
Lower Rate of Deactivation	Increases
Higher Rate of Deactivation	Decreases

Thresholds may change:

- Scale Up
- Plugging
- K/AV
 - Vary the Slip Requirement
 - Vary the NOx Removal
 - Vary the Inlet NOx
 - Vary the Flow/Load

Know Where You Are

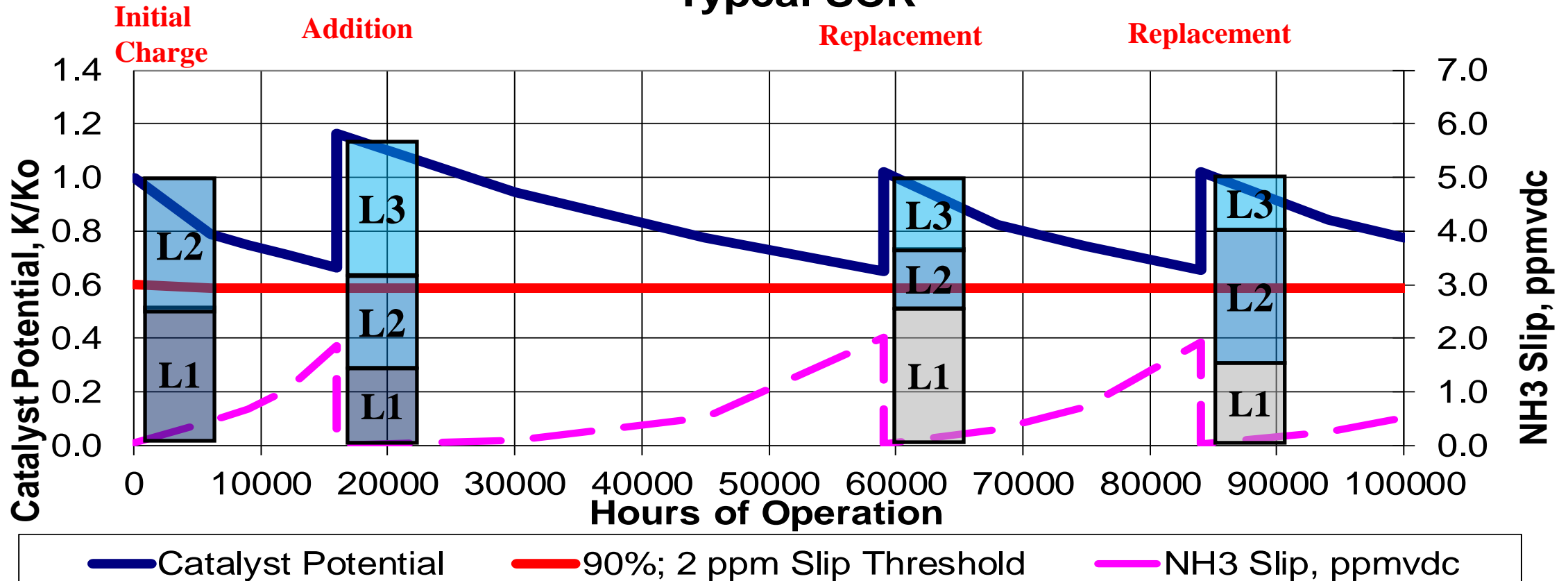


Impact on Catalyst Management



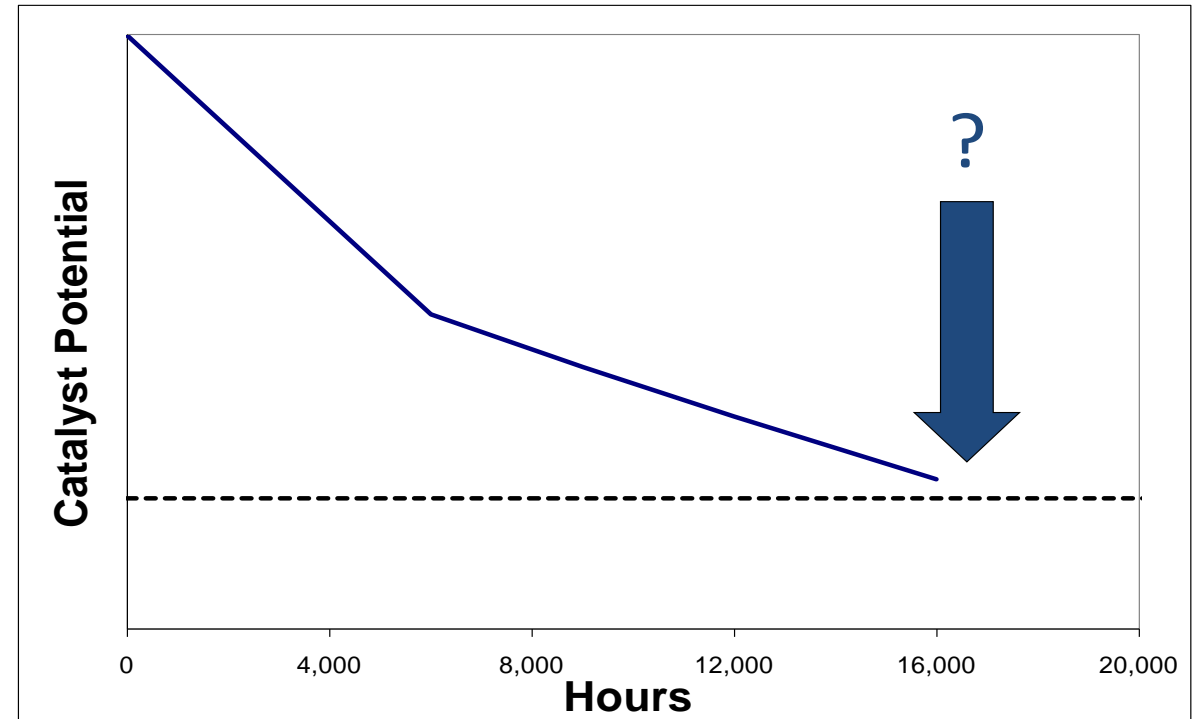
Significant catalyst potential added initially and over time to account for deactivation

Catalyst Management Plan 2 Initial Plus 1 Spare Layer Typical SCR



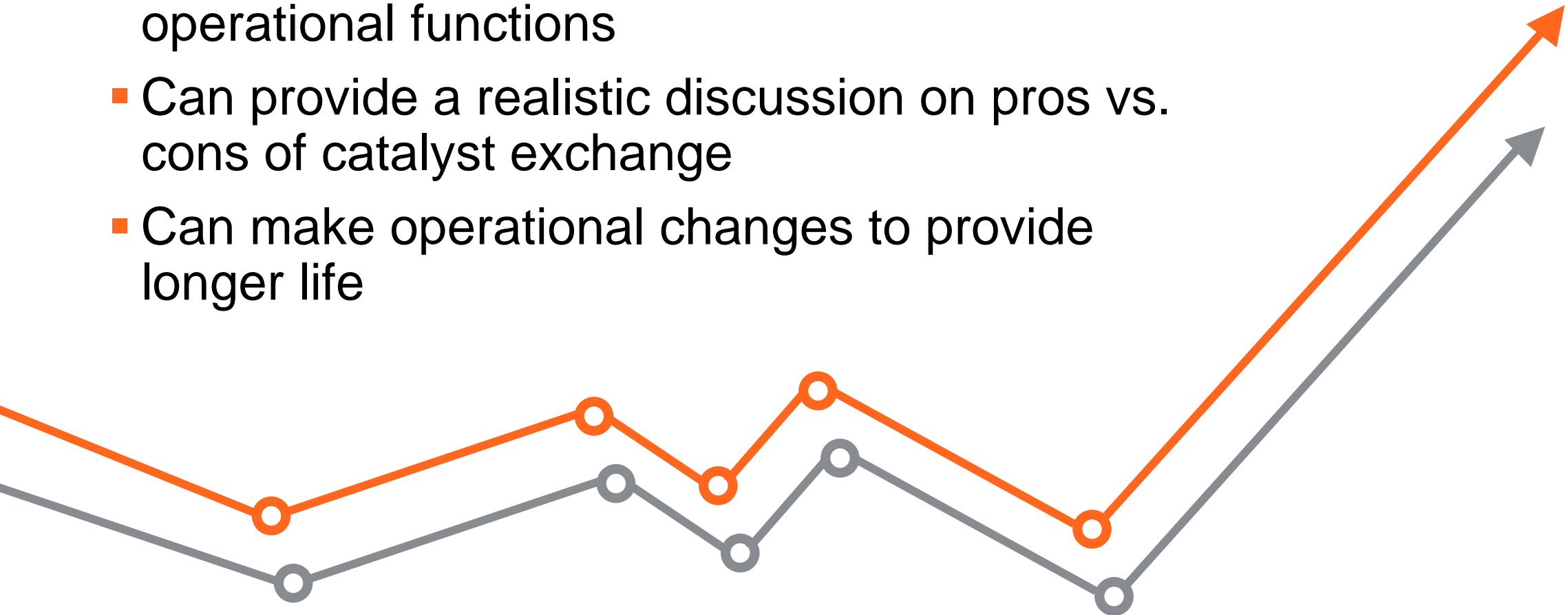
Take Action

- Catalyst as a system has a functional life
 - Typically designed for 16k – 32k hours (2 – 4 years) at a time
- Installed in layers for flexibility
- Actions are necessary to maintain performance
 - Add a layer, replace a layer, or regenerate



Benefits of Catalyst Management

- Can delay catalyst action based on known operational functions
- Can provide a realistic discussion on pros vs. cons of catalyst exchange
- Can make operational changes to provide longer life



Take Action



Layer Addition

- Greater net increase in potential and life
- Greater pressure drop and SO₂ Oxidation

Layer Replacement

- Less net increase in potential and life
- Variable pressure drop, variable SO₂ oxidation change

Regeneration

- Applicable to addition or replacement
- Or regenerate your own, existing layer(s)
- Lower cost and selection

Regeneration

Regeneration

- Reverses the catalyst deactivation mechanisms
 - Remove plugging and poisons
 - Replenish active sites
- Can normally match the original catalyst's performance
- Some plate catalyst can present regeneration issues
 - SO_3 ppm increase (% SO_2 Conversion) is most common issue due to corrosion of mesh
- Regeneration can also change the original catalyst formulation to better meet current plant operating conditions
- If catalyst is no longer regenerable, recycling may be an option to avoid landfill disposal.



Reliable and cost effective way to achieve compliance



Regeneration of Catalyst

- Proven technology for over 20 years
- In United States since mid 2000's
- Over 40,000 modules of catalyst regenerated
- Most Utilities have used Regeneration with Great Success

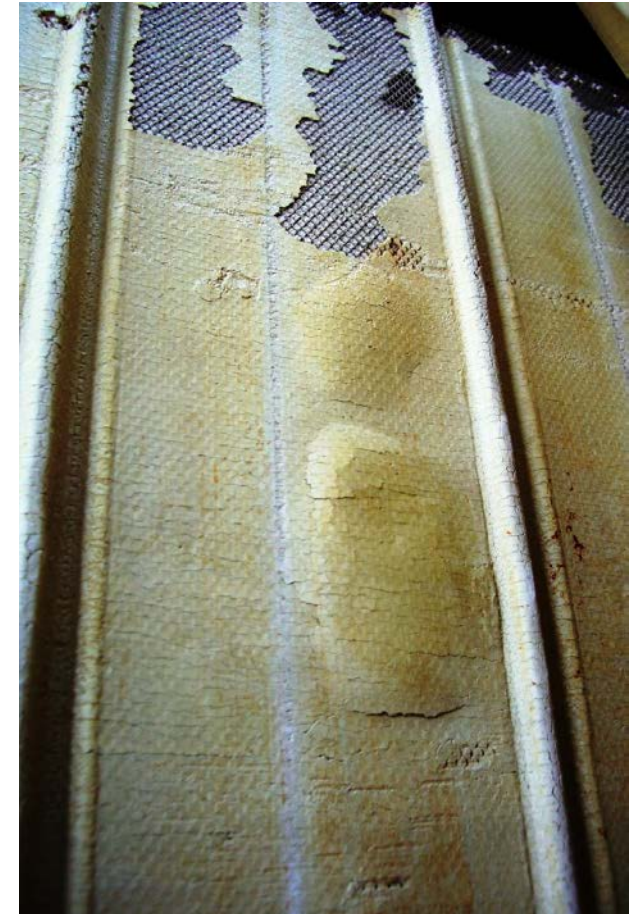
Can Your Catalyst be Regenerated



- Catalyst Must be in Physically Good Condition – limited erosion of catalyst or catalyst material off the mesh plates
- Must meet minimum catalyst thickness and bulk density
- Plate Mesh material must be of acceptable quality material and thickness



Catalyst Not Suitable for Regeneration



Catalyst Selection and Optimization

Industry Keeps Getting Smarter

Better Catalyst Selection

- Ash Loading
- Change out Frequency
- Ability to be Regenerated

Update online cleaning devices

- Better Sonic Horn Systems
- Ash Sweepers

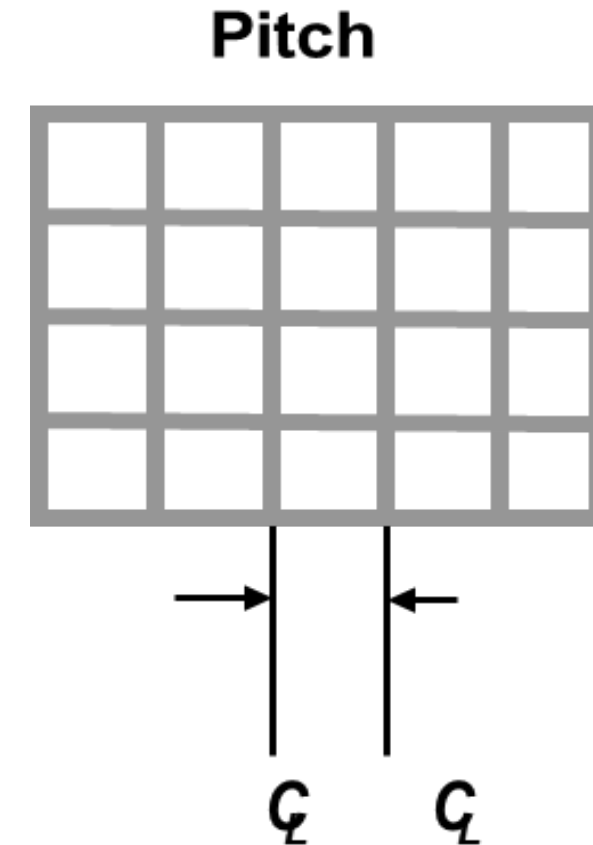
Better In-situ cleaning

- Proper Vacuuming
- Sponge Blasting
- Vibration
- Ice Blasting



Catalyst Plugging Mechanisms

- Large Particle Ash (LPA)
 - Ash diameter near size of catalyst catalyst pitch or larger (Pitch typically 5.7 – 9.5 mm)
- Collection of ash on upstream reactor surfaces and subsequent sloughing
 - “Avalanche” will plug catalyst
 - Dense phase flow
 - Units w/ higher ash loadings are more susceptible
- Poor ash flow (low velocity and/or recirculation zones, angular flow)
 - Sticky ash may start to bridge on catalyst – usually localized
 - Units w/ higher ash loadings are more susceptible



Pluggage Potential



Honeycomb



Plate



Perception: Honeycomb catalyst plugs more than plate catalyst



Fact: Pluggage resistance is based on “free opening hydraulic diameter”, not catalyst type

Pitch vs. Hydraulic Diameter

Free opening = Pitch minus wall thickness

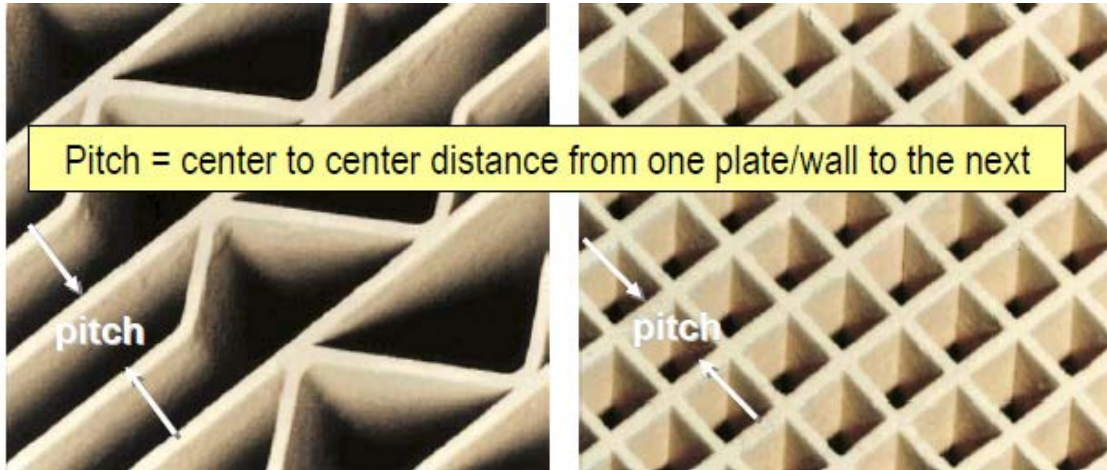
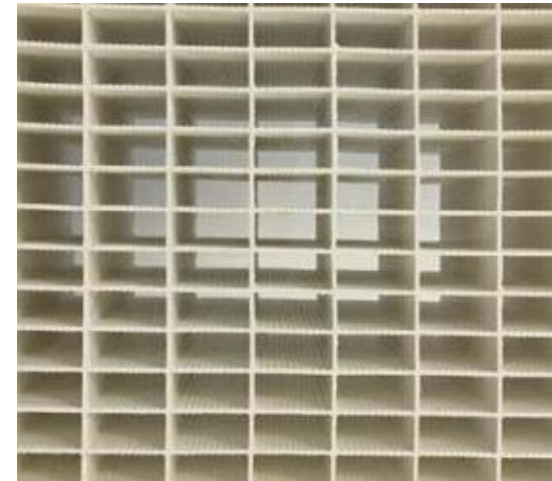


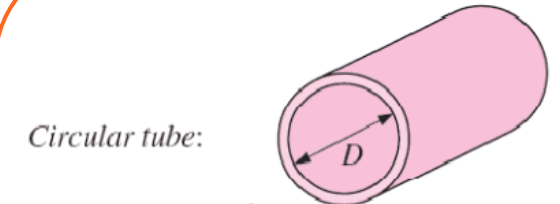
Plate-Type Structure

Honeycomb Structure

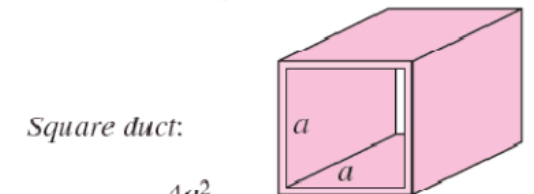


CORMETECH
Dust Buster[®]

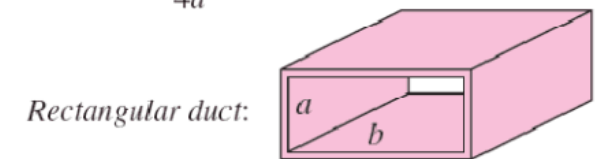
Catalyst Hydraulic Diameter



$$D_h = \frac{4(\pi D^2/4)}{\pi D} = D$$



$$D_h = \frac{4a^2}{4a} = a$$



$$D_h = \frac{4ab}{2(a+b)} = \frac{2ab}{a+b}$$

Dust Buster™ Catalyst Innovation



Innovative catalyst for difficult coal-fired applications

- Very high ash loading (e.g. > 40 g/Nm³ of flue gas)
- And/or sub-optimal reactor design:
 - Ash collection zones in reactor
 - Poor ash distribution in reactor
- Localized use or entire layer
- 1350mm continuous layers
 - Avoids plugging between sub-layers
- 100% Catalytic Material
- Low SO₂ to SO₃ Conversion
- Optimal for Regeneration and ReUse™

CORMETECH
Dust Buster®



Catalyst Physical Dimensions

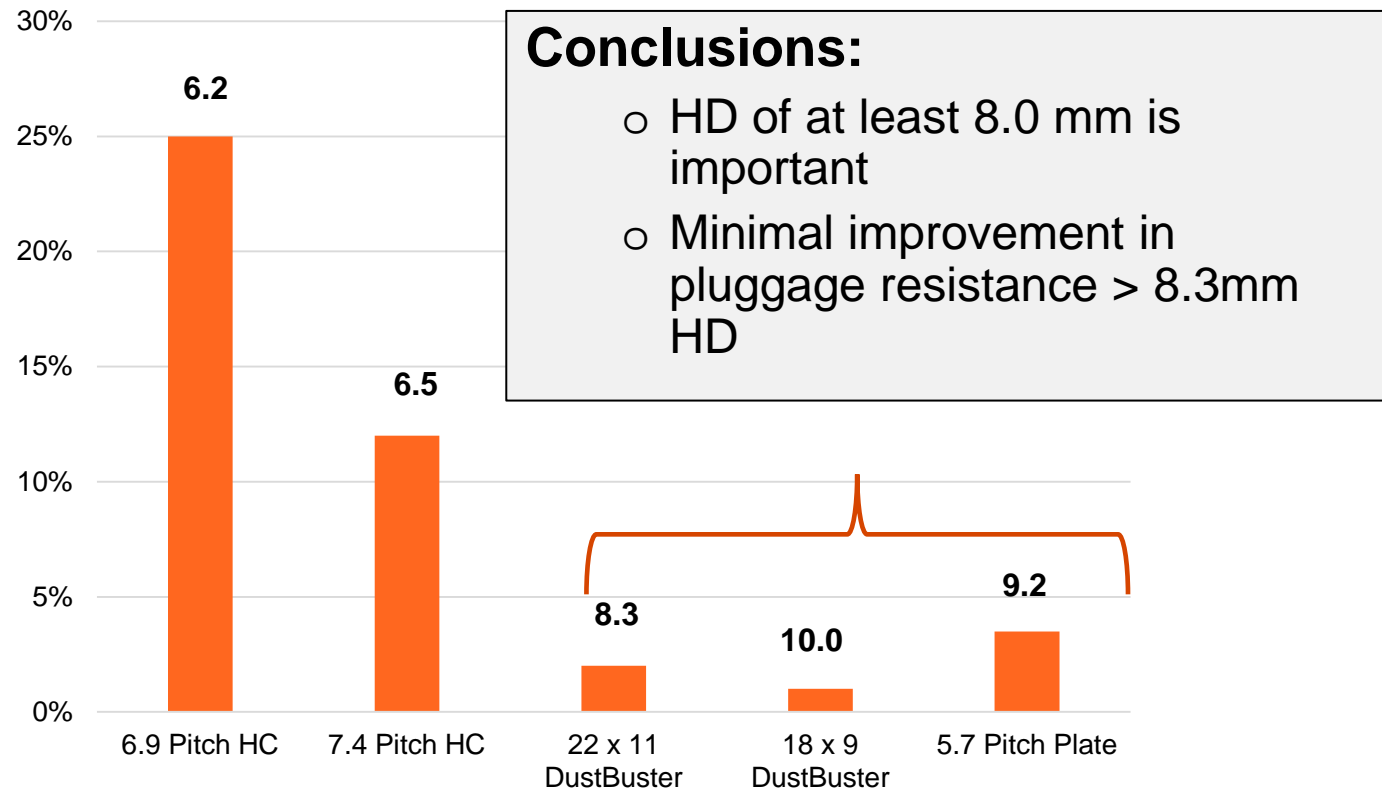


Catalyst Type	Product	Pitch A (mm)	Pitch B (mm)	Wall Thickness (mm)	Free Opening A (mm)	Free Opening B (mm)	Free Opening Hydraulic Diameter (mm)	Geometric Surface Area (m ² /m ³)	Ratio of Free Opening Hydraulic Diameter	Ratio Geometric Surface Area
Plate	5.7 mm Pitch	5.7	62.0	0.7	5.0	61.3	9.2	350	Base	Base
DUST BUSTER	18 x 9 Cell	8.2	16.4	0.8	7.4	15.6	10.0	331	1.1	1.0
DUST BUSTER	22 x 11 Cell	6.9	13.8	0.8	6.1	13.0	8.3	411	0.9	1.2

Hydraulic Diameter Testing Results



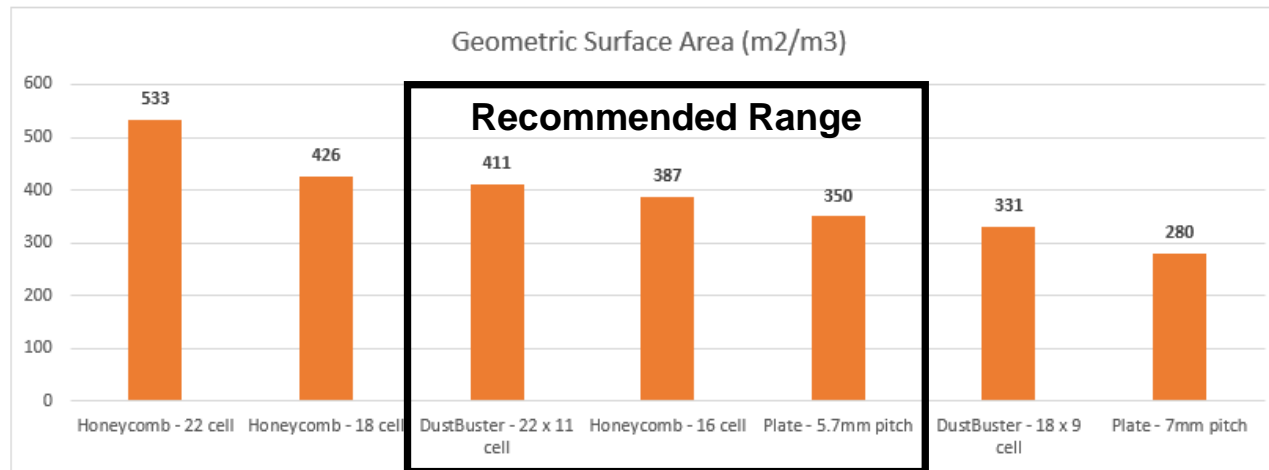
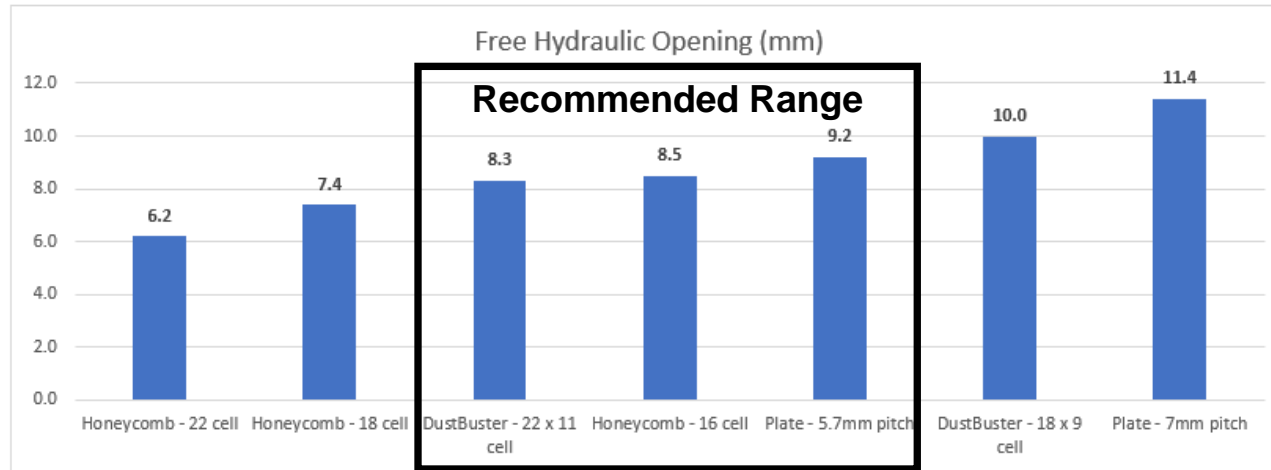
Pluggage Percentage versus Free Hydraulic Diameter (mm)



ASH DROP TEST– to simulate poor reactor design

- 50:50 fly ash/flour mixture to simulate sticky ash
- 1.25 Kg of mixture dropped per square foot of catalyst

Hydraulic Diameter vs Geometric Surface Area

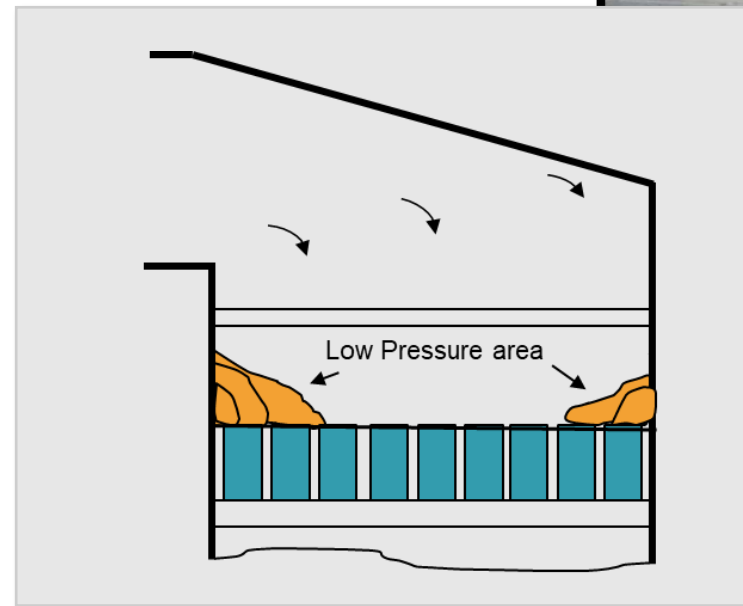


- Hydraulic Diameters greater than 8.3 performed about the same for pluggage resistance
- The larger the Geometric Surface Area the higher the catalyst potential

Reactor Maintenance and Pluggage Mitigation

Pluggage Mitigation - Clean up my Reactor

- Reactors are plugging
- Losing catalyst area
- How to mitigate the impact to the plant



Plugging Mitigation – LPA Screens

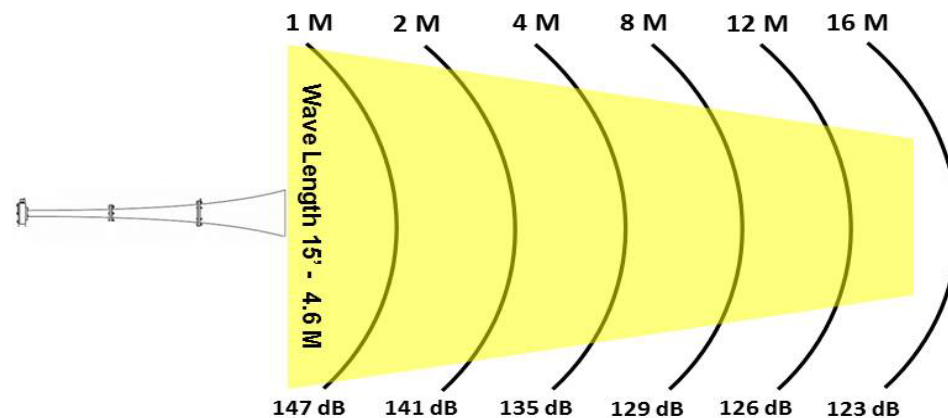
- Removes LPA upstream of catalyst
- Pleated design
 - Lower pressure drop
 - Less erosion
 - Self cleaning



Sonic Horns

The use of sonic waves for ash agitation

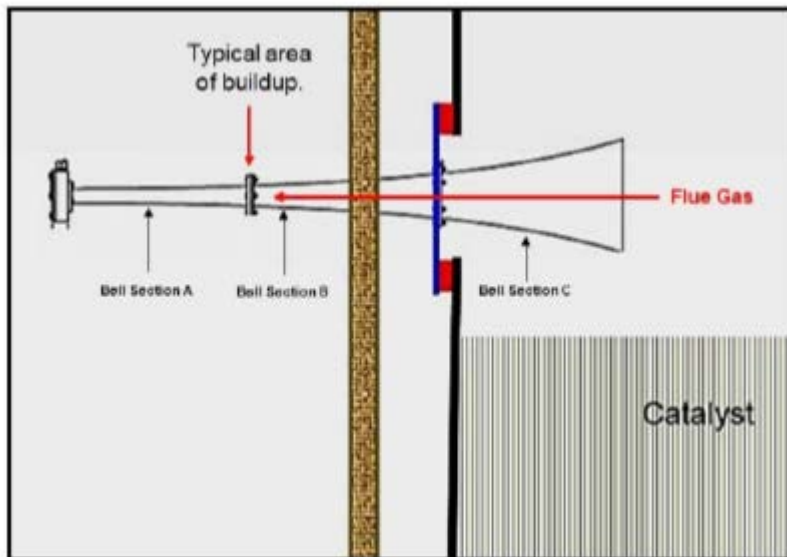
- The effect of sonic horn:
 - How does it work (up to 45')?
 - The effective area for cleaning
 - Location of the horn to the top layer



Sonic Horns - Maintenance

Bell Sections

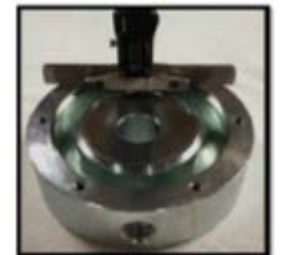
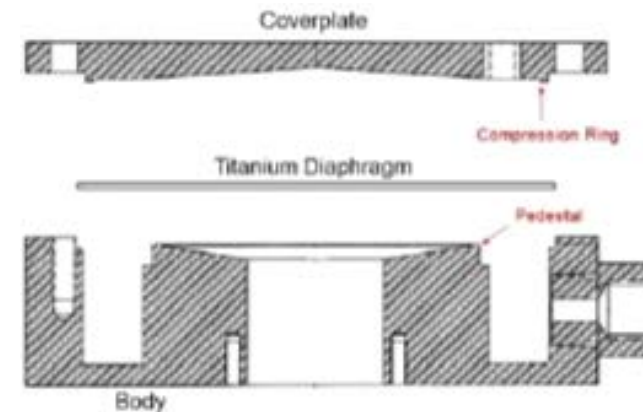
The flue gas that backs into the bell sections is dripping below the acid dew point causing a slow steady growth deposits. The deposits can be very difficult to dislodge.



↑
Plugged Bell Section A

Sound Generator

- After years of operation, check wear surfaces of sound generator by using depth micrometer
- Wear surfaces = compressing ring on cover plate and the pedestal on the body



Body/Pedestal

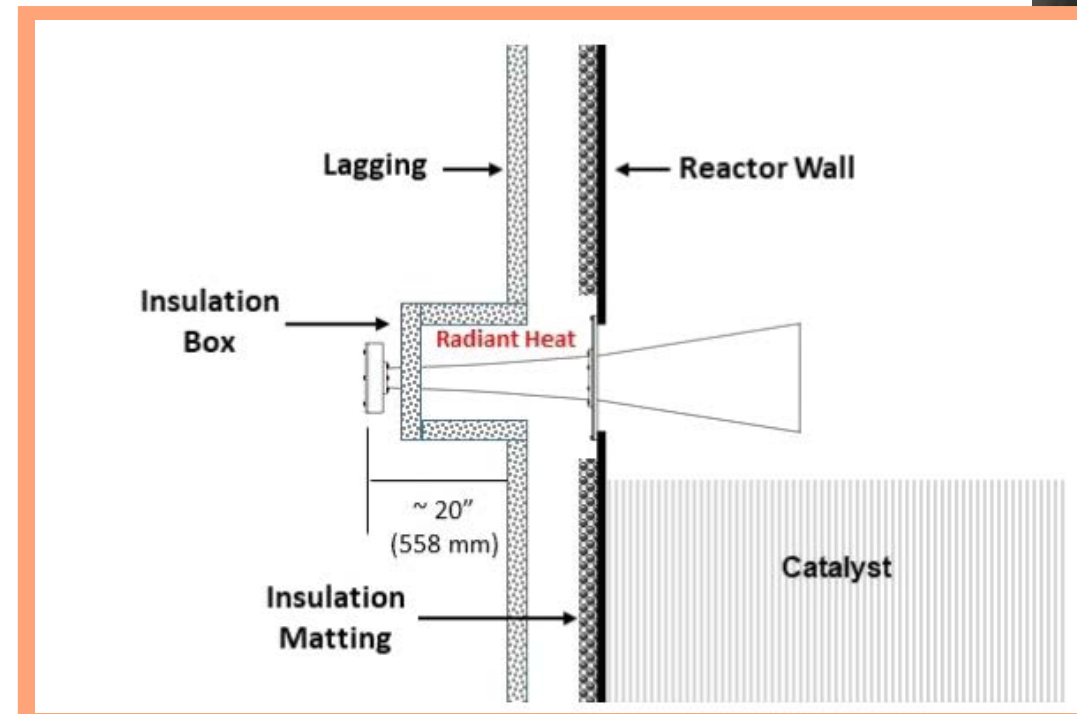


Cover plate

- Micrometer depth used to check tolerances of surfaces
- Sound generator should be rebuilt/replaced if wear surfaces are out of tolerance

Sonic Horns Today

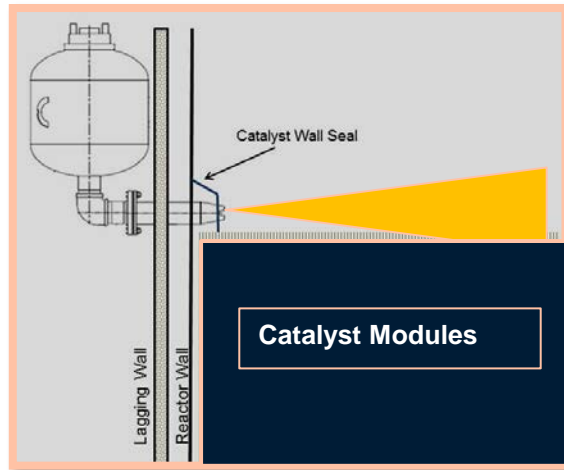
- Entire bell section is enclosed
- Radiant heat is trapped in the insulation box
- Flue gas temperature stays above dew point



Ash Sweeper for Re-Entraining Ash



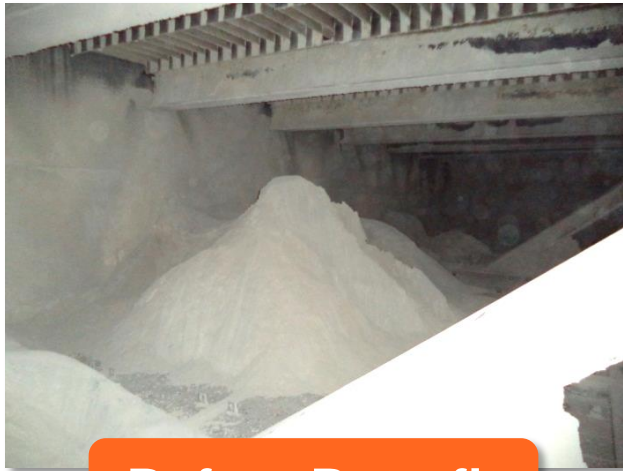
Added to augment sonic horns or soot blowers



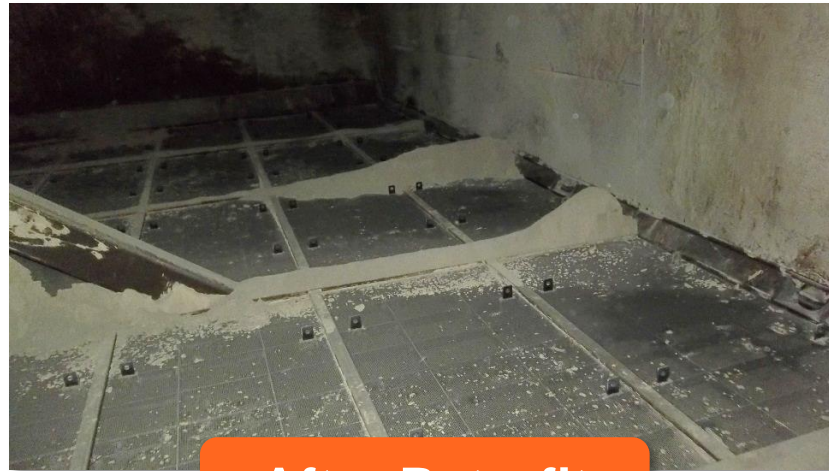
System Effectiveness:

- Near the walls
- Very effective at cleaning the top of the modules (module screen and above)
- Less effective below the screen.
- Decision of the location of the module screen (at top or on the catalyst)

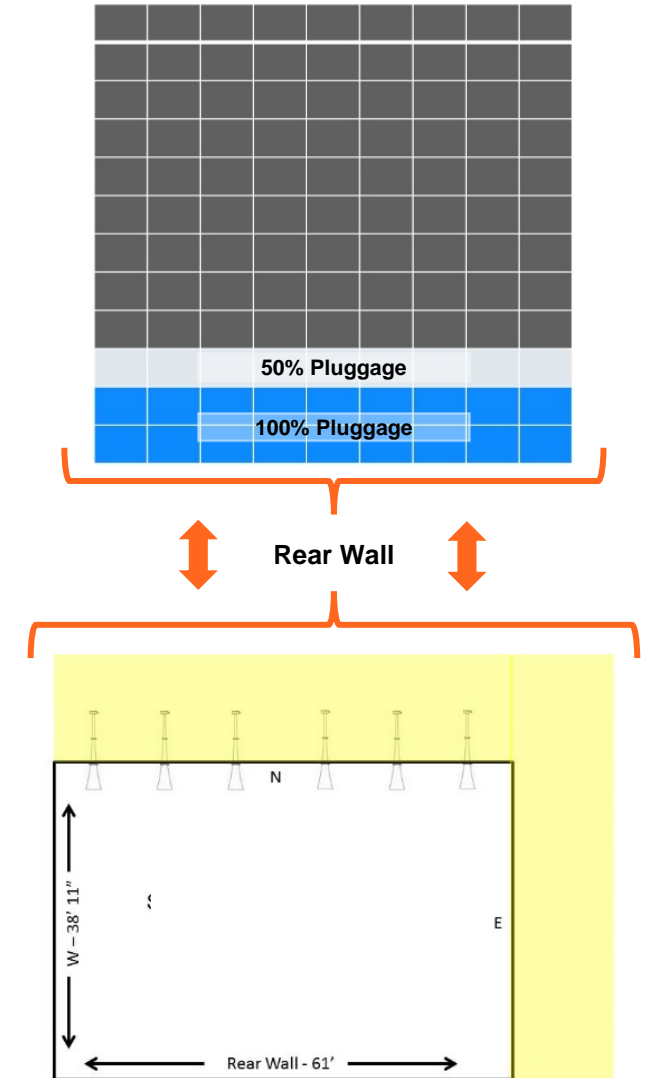
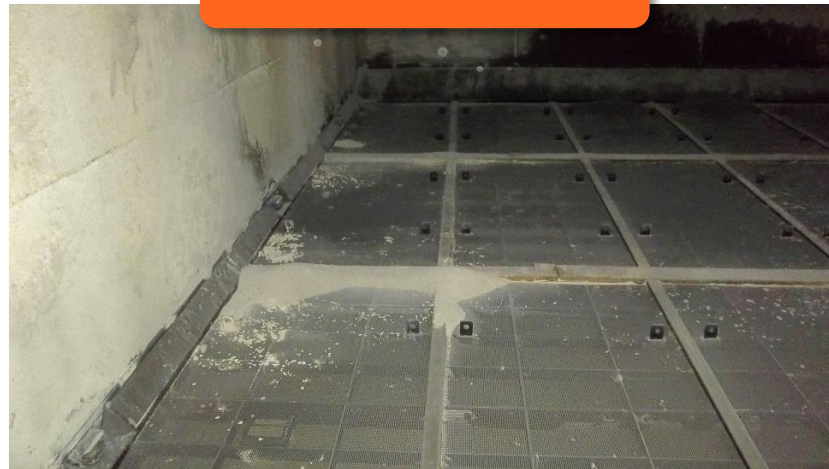
Ash Sweeper Current Installation



Before Retrofit



After Retrofit

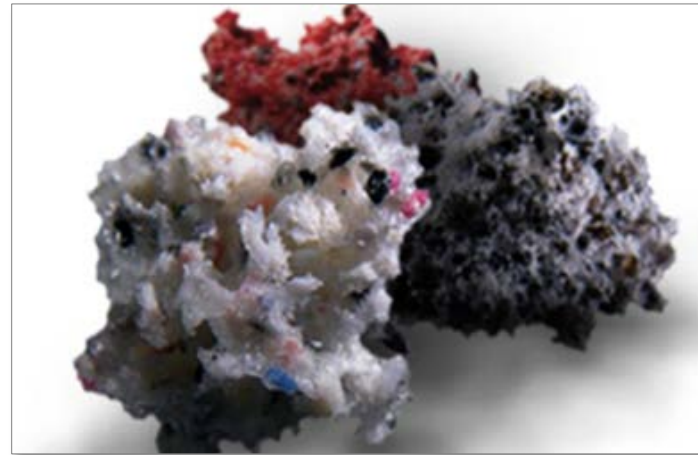


Off-Line Cleaning



Ice Blasting

- Dry Ice Pellets and Compressed Air through the channels
- Dry ice expands breaking up the catalyst pluggage



Sponge Blasting

- Sponge media and compressed air through the channels
- Material pushes through the catalyst channels



Off-Line Cleaning



Vacuuming

- Removal of large amounts of top ash accumulations
- Catalyst screens need to be removed during the process



Vibration Process

- In-Situ Process
- Vibration of the Main Support Beams of Each Layer



End of Life and Cormetech ReUse Technology

End of Life for Catalyst



At some point, catalyst has lost its useful life

- Mechanically unsuitable for regeneration
- Regeneration is not part of the strategy

Prior to now, catalyst would need to be disposed of in some place

- Could be off site landfill – potential hazardous or non hazardous
- Could be on site landfill
- Sent to Regenerator



New Environmental Concerns

- Must catalyst be disposed of as hazardous waste?
- What long term legacy issues could exist?
- As a company, are we doing the right thing?
- Are we looking at future disposal costs?

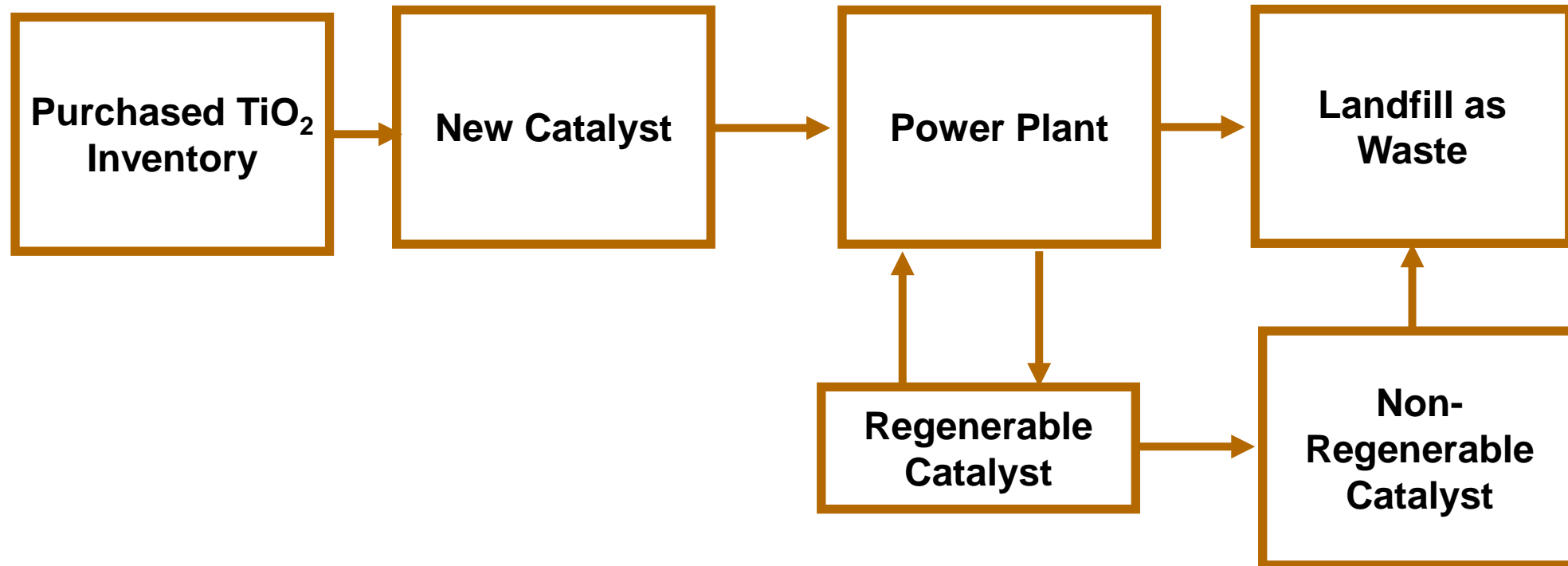


What Do These Two Have in Common?

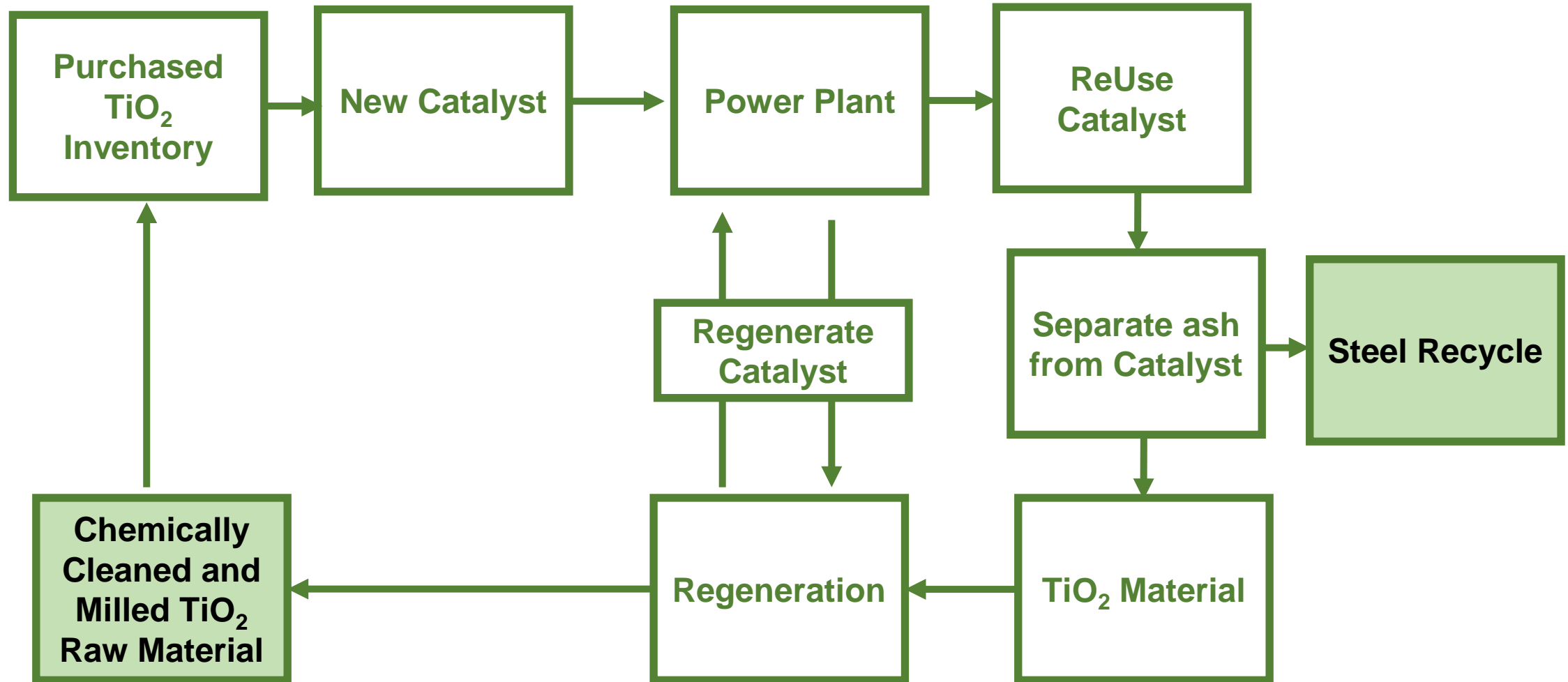


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Past: Catalyst Disposal was an Open Loop ending in Landfill



Current: Total Catalyst Management is Closed Loop Lifecycle

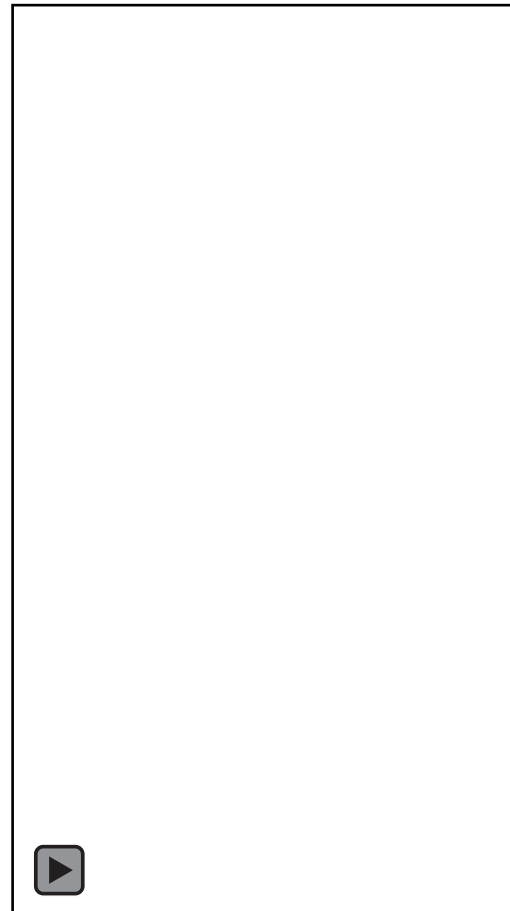


Start and End of Process

START



FINISH



Summary of Re-Use Process



End goal is to preserve & protect resources, and save money:

- Ideally all catalyst are regenerated, but there are limits (e.g. erosion or concrete like pluggage).

Re-Use Process can help do the right thing:

- 80-90 percent of honeycomb catalyst material by weight can be preserved
- NOT ALL Catalyst can be REUSED

End User Benefits:

- Reduces landfill disposal costs
- Reduces legacy environmental risks
- No additional tons of disposable material to report to EPA or local authorities
- Right thing to do



Conclusion



Industry has become smarter

SCR Management Provides Valuable Insight

Regeneration of Catalyst is a Proven Technology

Correct Catalyst Selection Ensures Long Term Success

Proper Maintenance is Critical for Efficiency Operation

Honeycomb Catalyst can be Reused not Landfilled



Thanks To:



- Paul Abernathy – CORMETECH
- Jake Shelton – Acoustic Cleaning Systems
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