REINHOLD ENVIRONMENTAL Ltd.

2016 NOx-Combustion-CCR Round Table Presentation

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Plugging & Cleaning Catalyst
Keep It Clean!

Mark Ehrnschwender (m.ehrnschwender@steagscrtech.com)
February 2nd, 2016

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Regulations are moving down

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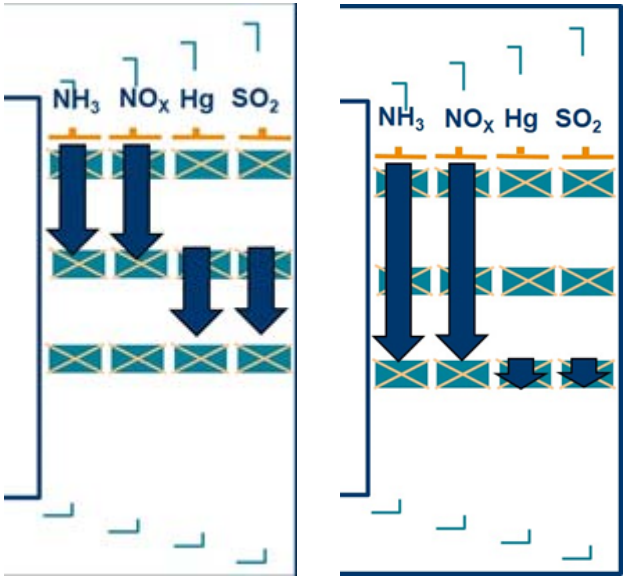
CASPR is requiring more removal of NO_X during Ozone Season. This will be anywhere from 6 to 40% additional removal from the original design of the reactor.

- **This will require:**
  - **High reactor potential before the Ozone Season Operation to maintain the higher NO_X removal.**
  - **Maintaining a cleaner reactor such that the potential is available.**
- **Using the Reactor for Mercury Oxidation requires a clean reactor to maintain a high potential.**
  - **Ammonia will suppress the oxidation.**
  - **Mercury will occur in the lower levels of the reactor.**



Beginning Ending

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The SCR reactor
What's Important for a clean reactor?

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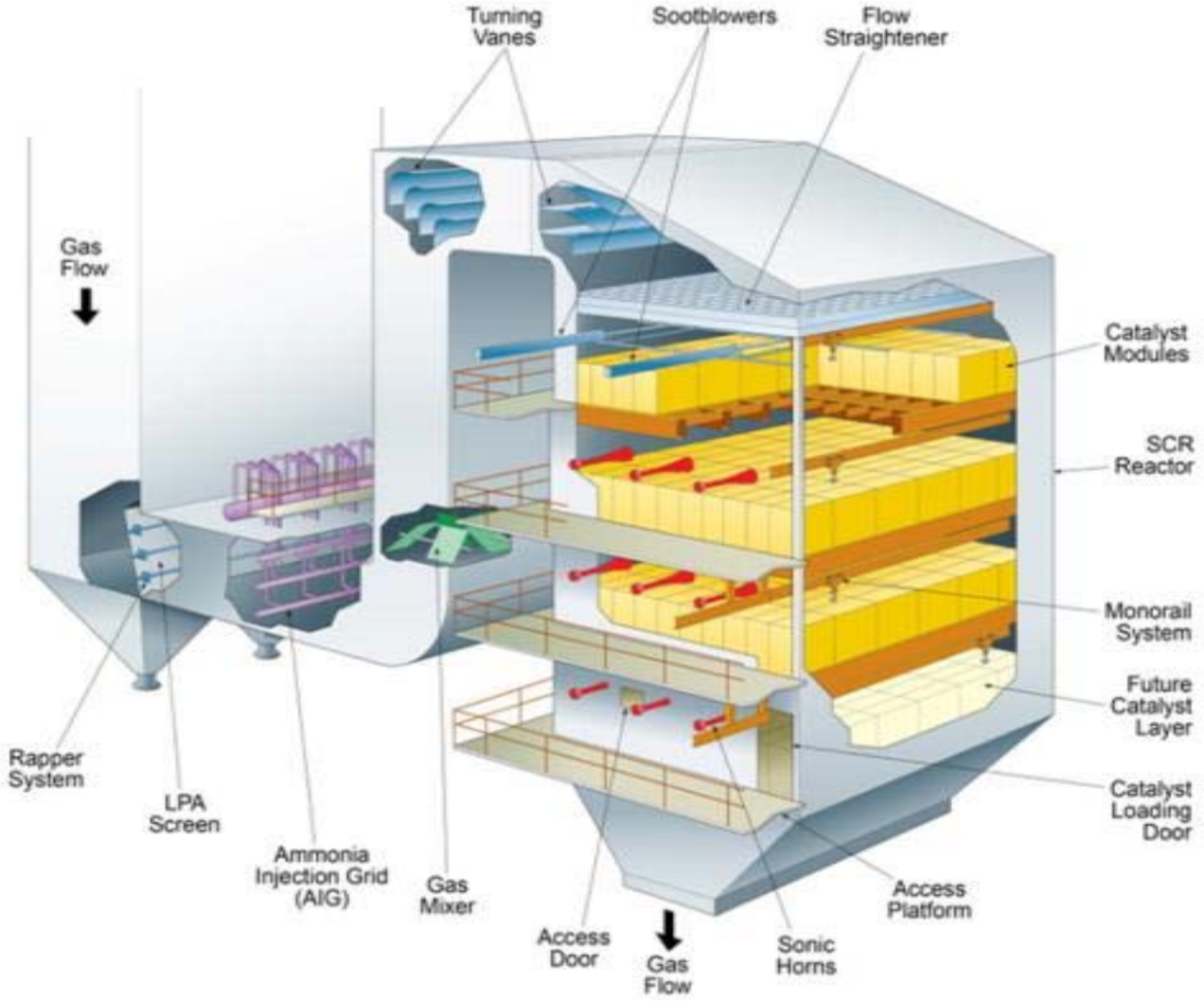

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SCR Reactor Pluggage

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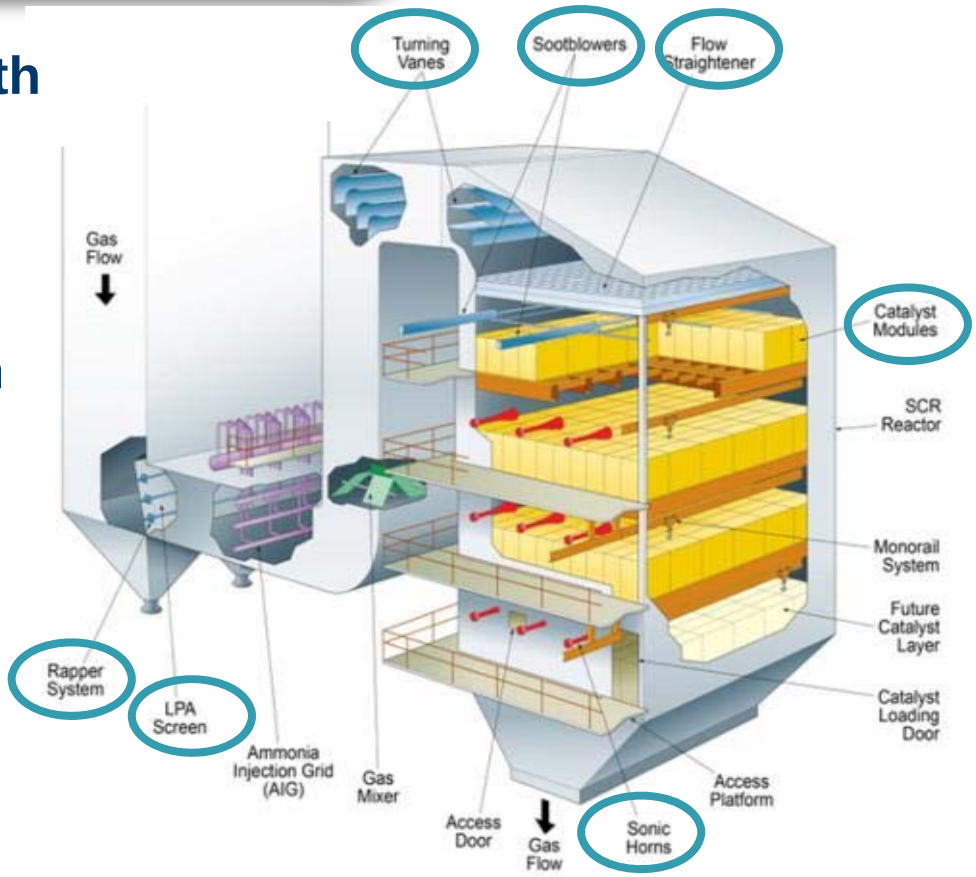
What are the key components with respect to pluggage?

- Catalyst Modules
- LPA Screen
- Turning Vanes, Reactor Design
- Flow Straightener (Rectifier)
- Ash Cleaning Mechanisms
  - Sootblowers
  - Sonic Horns
  - Ash Sweepers



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Catalyst Types

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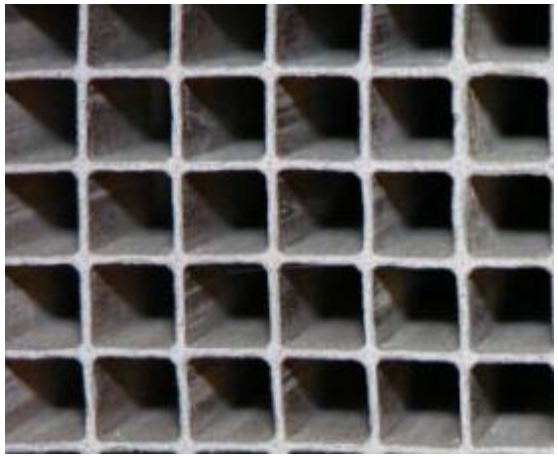
Extruded Honeycomb
Ceram, Cormetech, Johnson Matthey



Corrugated Honeycomb
Haldor Topsoe

Wire Mesh Supported Plate
Ceram, Hitachi, Johnson Matthey

Corrugated Plate
Hitachi Zosen

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Catalyst Selection Importance

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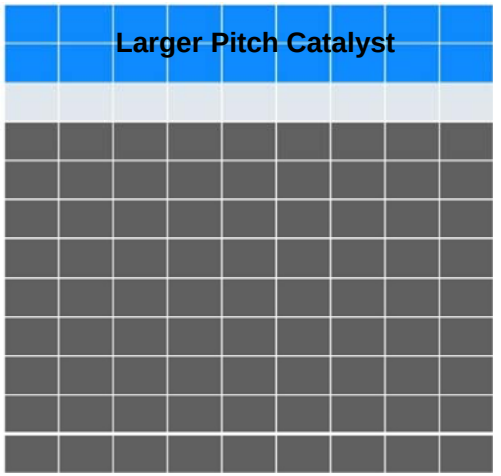
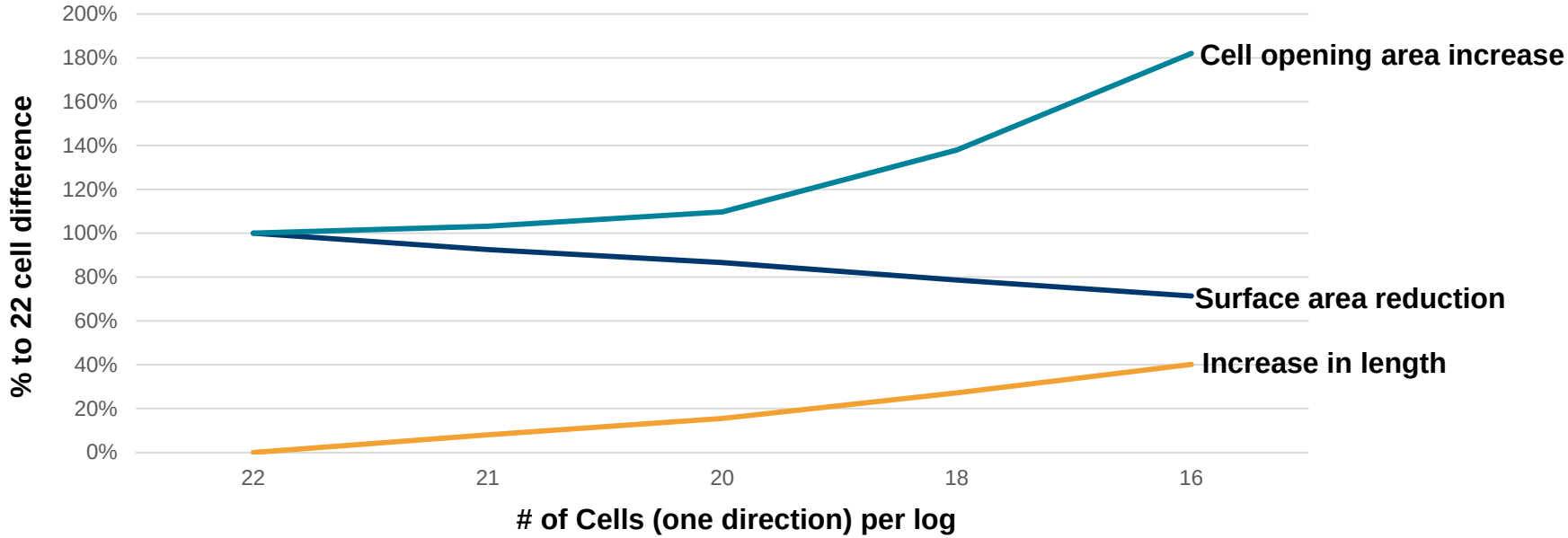
- **The General's on Catalyst Selection**
  - **The catalyst pitch**
    - Larger Pitch is better for pluggage
    - Requires longer length to maintain Potential
    - Using larger pitch catalyst for a couple rows in heavier ash area's

Reactor





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SCR Reactor Pluggage

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LPA Screens

- Large Particle Ash is formed in the during the combustion process.
- Has high levels of Iron Oxide
- LPA will plug the channels.
- Honeycomb and Corrugated will not be unplugged.
- “Dry Cleaning” (dis-assembling of the box) can remove the pluggage.

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The Flow Path
Turning Vanes and Reactor design

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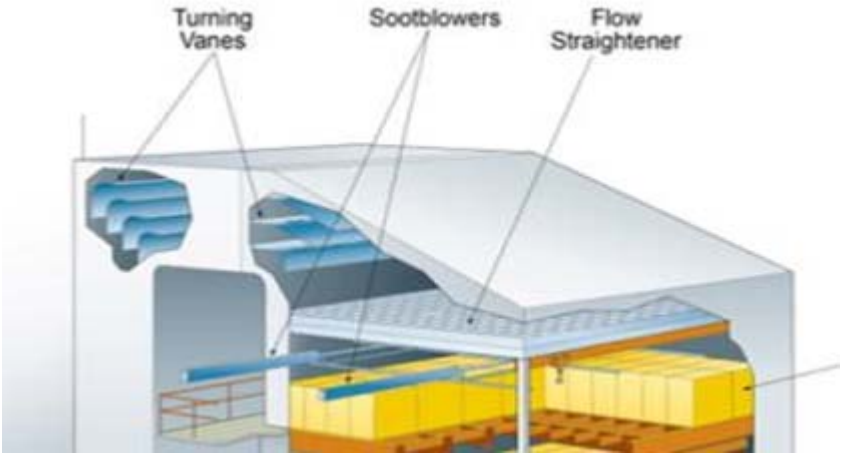
- **What is the actual ash loading for the reactor.**
- **Understand the ash loading at the inlet turning vanes.**
- **The hood angle and design is important.**
  - **Directs the flow over the entire bank of the reactor.**
  - **Need to get flow**
    - Towards the back of the reactor, and
    - At the front of the reactor.
- **Flow Straightener (Rectifier) is the**
  - **Flow straightener into the back**
  - **Depending upon design, uses some back pressure for balancing of the flow across the catalyst layer.**



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The Flow Path
Turning Vanes and Reactor design

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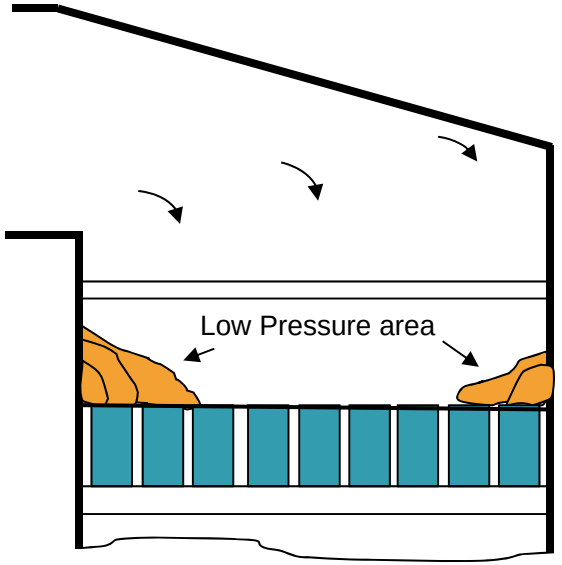
- **What are the issues**
  - **Low pressure zone by the front wall or rear walls.**
  - **Normally the most severe on the top level.**
- **Once the build-up starts, the progression of the build-up continues**
- **What is the impact of pluggage on catalyst?**



Parameter Increasing with all others steady	Activity	SO_2 / SO_3 Conversion Rate
Linear Velocity	↑	↑

Potential will decrease

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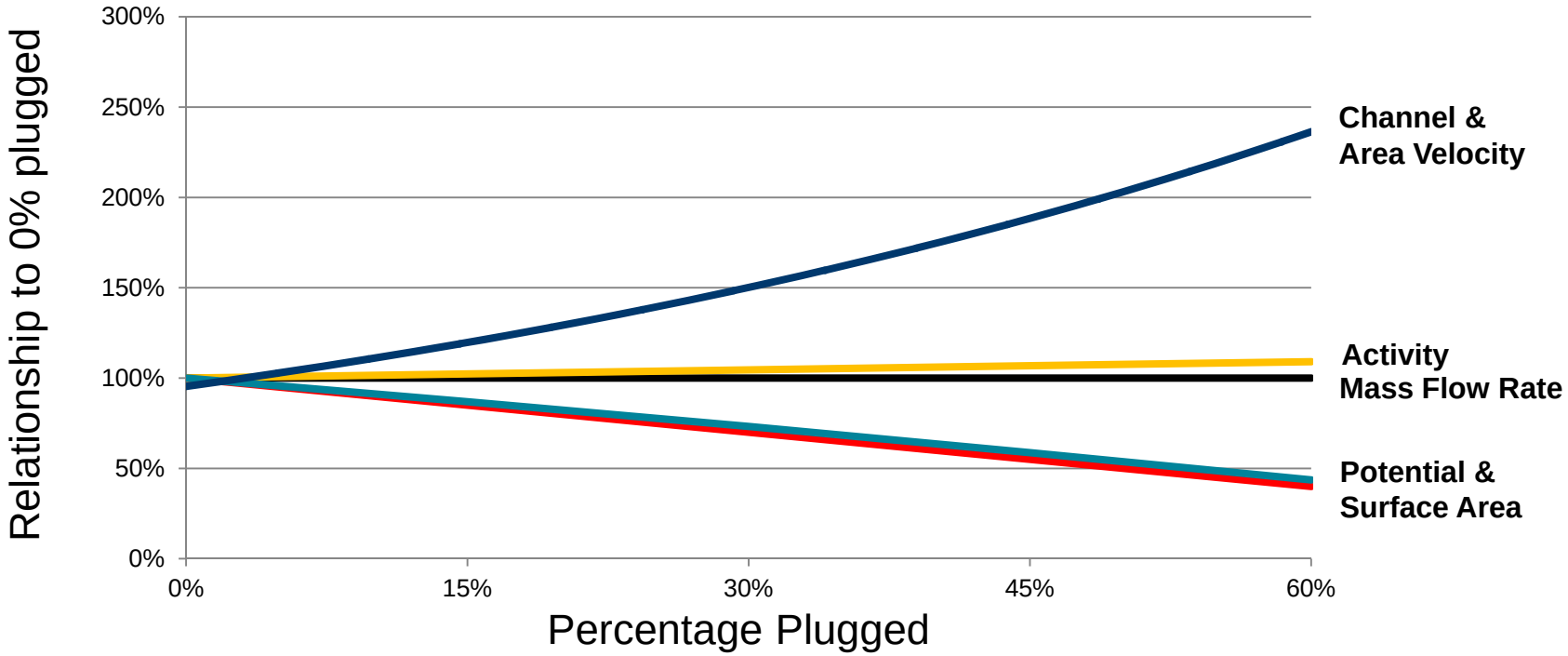
Example of Performance Degradation



- **As Pluggage Increases:**
  - **Channel Velocity increases**
  - **Potential and Surface Area decrease**
  - **Pressure Drop increases exponentially on the square**

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What can you do to minimize Pluggage?

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- **Redistribution of the accumulated ash.**
  - **Redesign of the flow path**
  - **Sootblowers**
  - **Sonic Horns**
  - **Ash Sweepers**
- **In-situ (outage) cleaning of ash during outage.**
- **Removed module cleaning**

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Redesign the flow path

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- **The is normally done with CFD Modeling and good inlet and operating information.**
  - **How is the ash density in flue prior to the SCR**
  - **What is the build-up in the SCR reactor?**
  - **What is the analysis of the flyash?**
  - **Are there any indications shown on the flue work?**
  - **Adapt the CFD model to the actual conditions.**

- **Redesign could include:**
  - **Add an LPA Screen**
  - **Modification /of adding a rectifier**
  - **Modification of turning vanes**
  - **Modification of the inlet hood.**

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Redistribution of Ash

- **Sootblowers**
  - **Stationary (Rake type) in the unit.**
    - Travel up to ~24’
  - **Very effective at distributing the ash.**
  - **Can penetrate into the unit.**
  - **Critical Issues**
    - Need to maintain the pressure of the sootblower (steam or air).
    - The distance / pressure from the catalyst to module top is critical.
    - The effectiveness of the sootblower is reduced by the catalyst screen.
    - The sootblowers do change the flow path in the unit.

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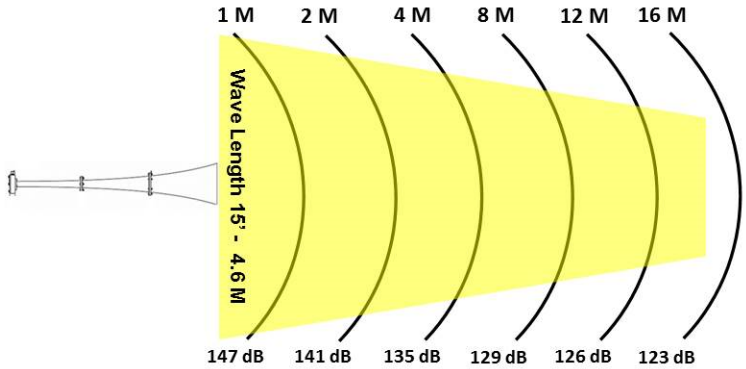
Sonic Horns



- **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**

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Ash Sweeper for Re-Entraining Ash

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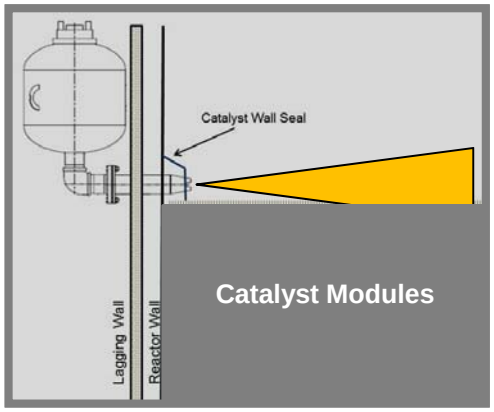
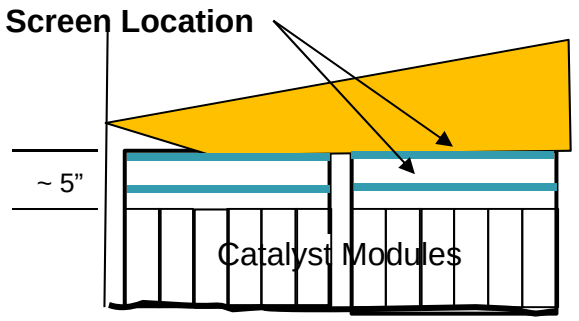


- **Added to augment Sonic Horns or Sootblowers**
- **System Effectiveness**
  - **Near the walls**
  - **Very effective at cleaning the top of the modules (module screen and above.**
  - **Less effective below the screen.**
  - **Decision of the location of the module screen (at top or on the catalyst)**



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Ash Sweeper Current Installation

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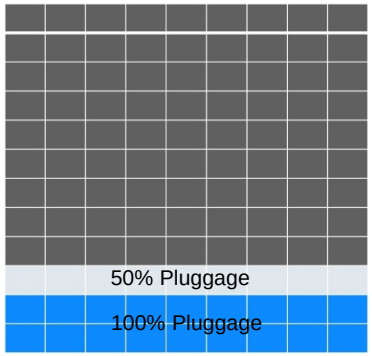
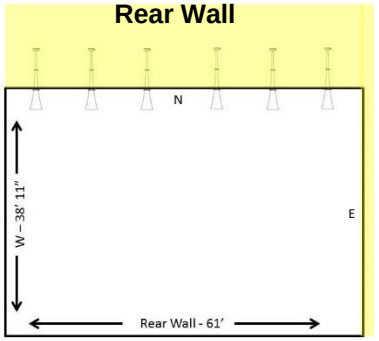
Before retrofit

After Retrofit



Rear Wall



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Recent Installation

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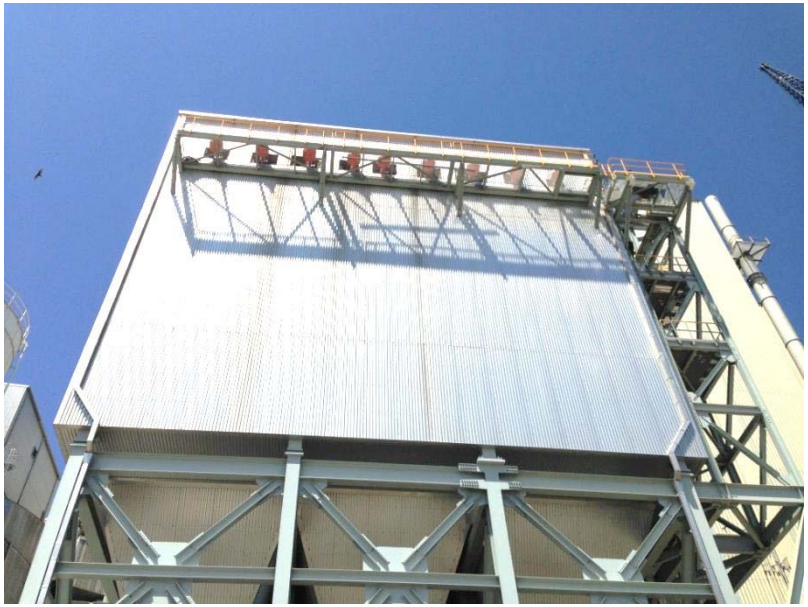

Air Cannon Location on Rear Wall

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Re-distribution Conclusions

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- All methods can be integrated together.
- Sootblowers are more aggressive and harder to control.
- The changing height of catalyst needs to be considered for both sootblowers and ash sweepers.
- Catalyst height is less of a concern for sonic horns.
- Not effective for catalyst channel pluggage. Other technics for cleaning at outages.

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Conventional Catalyst Cleaning Techniques

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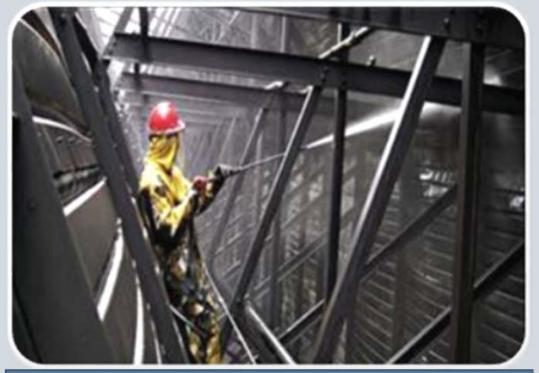

High Pressure Wash

- Remove accumulated ash on plate.

Issues

- Reacts with Sulfur trioxide and Sulfuric acid.
- Plates fly ash compounds (like iron oxide) on the catalyst surface. Potential degradation of catalyst performance.
- Remaining fly ash will harden within the catalyst channels or in-between plates.

Air Lancing

- High pressure air to remove pluggage.
- Use plant air to remove fly ash on top catalyst layer.

Issue

- Only removes top layer and pushes fly ash into middle of catalyst.
- Does not work on harder fly ash plugs

Scraping / Poking

- Mechanical applications to unplug catalyst cells.

Issues

- Physical damage catalyst making the layer.
- Pushes any ash plugs deeper into the catalyst

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It's Outage Time!
Cleaning Techniques

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Vacuuming

- Removal of large amounts of top ash accumulations only.
- Catalyst Screens need to removed during this activity.

- **Issues**
- Does not remove "deep" layer pluggage.

Mechanical Shakers

- Plate type catalyst cleaning method.
- Individual Catalyst cassette / boxes .
- Cassettes / boxes are removed from the module. Module remains in place.
- Normally only top layer needs to have the mechanical cleaning.

- **Issues**
- Significant Manual Labor

Thompson Process

- In-situ Process.
- Vibration of the main support beams of each layer
- **Issues**
- Vibration of main beams
- Movement of logs on crowns
- Loss of packing seals

- Sponge Blasting
- Sponges through the pores.
- **Issues**
- Heavily plugged pores
- Sticking to walls

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In-situ Cleaning Process

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The Process – Patent: 8,268,743

- A mechanical method to reduce SCR catalyst pluggage using a blasting steam of pressurized carrier gas and dry ice particulates (CO_2)

Why does it work?

- Dry ice pellets (Temperature of -78.5 °C (109.3 F) are shot out of a nozzle of compressed air expanding into the catalyst cells compresses the flyash plug
- The compressed air force pushes the smaller plug out of the channel

The results

- The CO_2 does not leave any residue for the CO_2 blasting material
- No loss of catalyst material loss or performance loss from the CO_2 blasting material
- Catalyst cleaned to less than 5% pluggage
- Will work on all catalyst types

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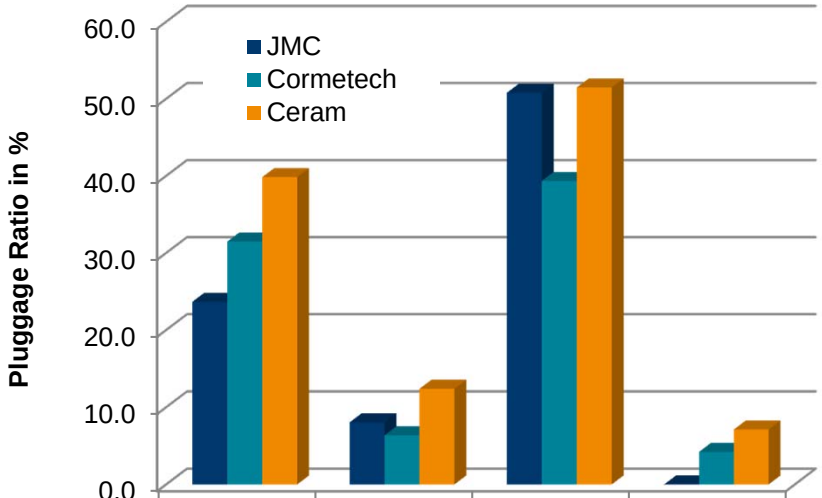
Ice Blasting Case Study

- **Plant Details:**
  - **Layer 1 – empty;**
  - **Layer 2 – JMC plates;**
  - **Layer 3 – Cormetech honeycomb;**
  - **Layer 4 – Ceram honeycomb**
- **Development of pluggage charts for each layer to track progress**
- **Removal of Catalyst Screens**
- **Vacuuming of loose fly ash from modules**
- **Tarp catalyst layer which is below the one receiving Ice Blasting treatment**
- **Vacuuming of loose fly ash from tarps**



	Reactor before	Reactor after	Module before	Module after
JMC	23.7	8.0	50.8	0.0
Cormetech	31.5	6.4	39.3	4.2
Ceram	39.8	12.4	51.5	7.1

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Removal of Module cleaning

- **Issues with removal of modules:**
  - **The modules need to be protected during the removal process!**
  - **The modules need to be wrapped / covered after removal.**
  - **Type of coal can be an issue:**
    - PRB coal ash – the modules cannot sit for extended periods of time without cleaning. Calcium in Ash
    - Bituminous coal ash – Moisture with sulfur content can deteriorate / delaminate the plate. More prevalent on thinner catalyst material plate (<0.6mm)

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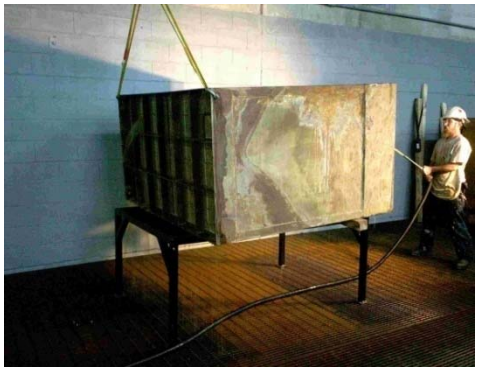
Removed Module Cleaning

- **Honeycomb Modules:**
  - **Power washing of the module:**
    - PRB Catalyst – if it dries and the plug is not removed, may not be removed.
    - Bituminous – The iron oxide is released from the ash onto the catalyst.
  - **Ice Blasting – Longer term storage before regeneration.**
  - **Sponge Blasting – Limited success for cleaning of the modules.**
- **Plate Modules:**
  - **Complete dismantling to remove the flyash.**
  - **Can remove the flyash and any LPA trapped in the module.**



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Conclusions

- **Legislation is going to require lower emissions requirements below many reactors original designs.**
- **Mercury Oxidation a further conflicting operation of the SCR Reactor.**
- **The reactor is going to need to be cleaner with all potential available in the layers.**
- **SCR reactors are going to require much cleaner reactors.**
- **The good news:**
  - **the advancement of on-line cleaning with ash sweepers has been very successful.**
  - **In-situ cleaning has advanced with our preferred preference of ice blasting.**
  - **Shop cleaning for future regenerations has advanced**

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Questions

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