REINHOLD ENVIRONMENTAL Ltd.

2015 NOx-Combustion Round Table & Expo Presentations

February 23 & 24, 2015, in Richmond, VA / Hosted by Dominion

Keeping the SCR Reactor Clean in the new MATS World!

February 24, 2015

Mike O'Connor (Duke Energy) and
Mark Ehrnschwender (STEAG)

Keeping the SCR Reactor Clean in the new MATS World!

Agenda

- Regulatory Compliance
- The New SCR Reactor
- SCR Management requirements in “The New World”
- SCR Reactor Cleanliness
- Conclusions

Presentation Abstract

The upcoming MATS requirements include the oxidation of Mercury and regulation of other acid gases, the catalyst performance and cleanliness become more important than ever for meeting the environmental mandates. This presentation will discuss the reactor, reactor cleanliness, undesirable chemical reactions and maintaining the NO_X compliance (the primary function of the SCR reactor) from both the utility / vendor perspective. Some strategies to maintain performance of the SCR reactor will be discussed.

Environmental Compliance

- **There are a number of Environmental regulations that will effect unit operation.**
  - **CSAPR (Cross-State Air Pollution Rule)**
    - The rule is intended for compliance at the state level. Trading NOx ton credits across State Lines becomes restricted beginning in year three (2017).
  - **Mercury and Air Toxics Standard (MATS) regulations.**
    - Regulates the following Emissions
      - Acid Gas – HCl, Fluoride, etc.
      - Mercury
      - Particulate
      - SO_2

Environmental Compliance

- **There are a number of Environmental regulations that will effect unit operation.**
  - **CSAPR (Cross-State Air Pollution Rule)**
    - Compliance started on 1/1/15 and includes state level emission caps for NOx and SO_2.
    - NOx Tons caps include:
      - Year Round cap
      - Ozone Season (May through September) cap
    - Duke has to look at 4 different strategies:
      - For Florida, only ozone season will apply. Crystal River 4 and 5 operating permit cap limit. Rolling yearly average for NOx tons is still in use.
      - For North Carolina, the NC CAP (Clean Air Plan) is still in use; but the CSAPR caps will likely be more restrictive. There is a DEC limit and DEP limit on NOx tons.

Environmental Compliance

- **Environmental regulations (continued)**
  - **CSAPR (Cross-State Air Pollution Rule)**
    - For Indiana
      - Current cap allocation does not project to be overly cumbersome however; could change based on generation profile.
      - Operation will be dictated by Cap prices (Market based system) and other applicable Environmental Regulations.
    - For Ohio and Kentucky
      - Current cap allocation does not project to be overly cumbersome however; could change based on generation profile.
      - Operation will be dictated by Cap prices (Market based system) and other applicable Environmental Regulations.
      - May voluntarily lower NOx rates in ozone season per local EPA request to aid Hamilton County (Cincinnati).

Potential Train Wreck
SCR Compliance Strategy

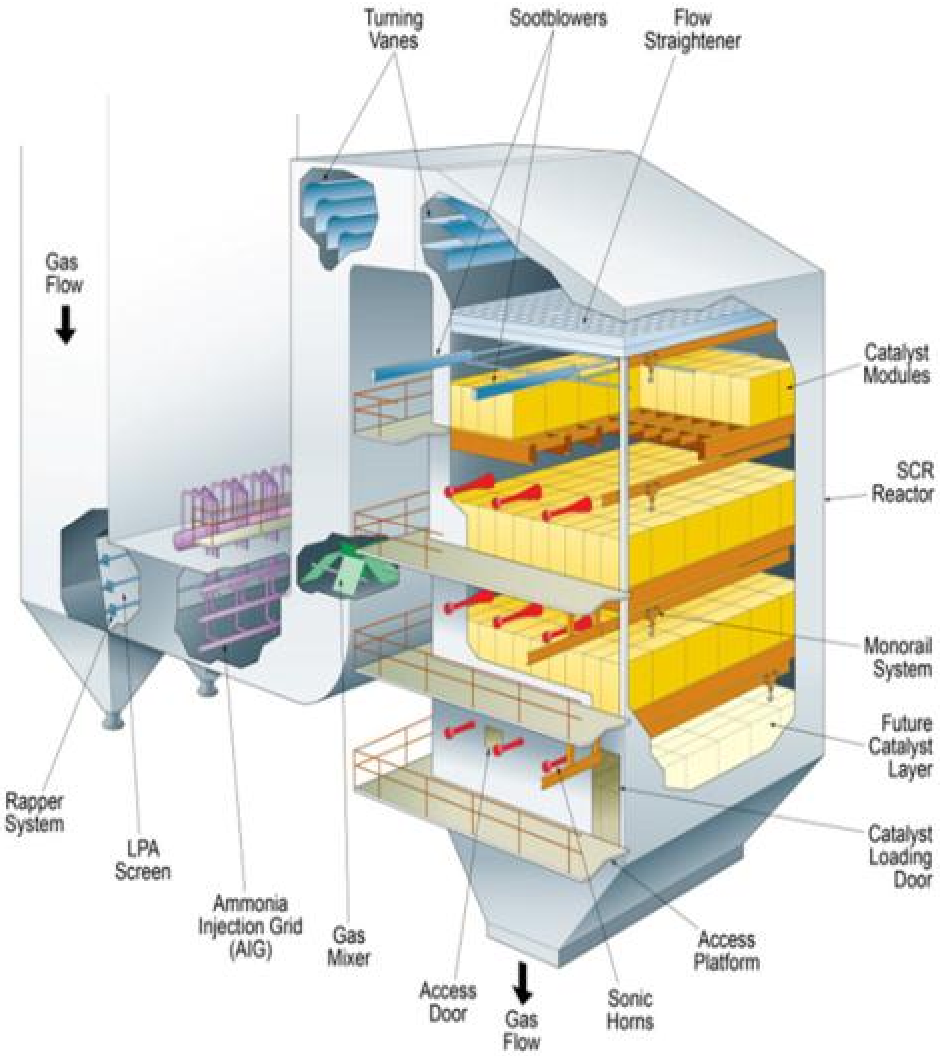
- **Meeting NOx Reduction targets**
- **Cap and Trade (Market Based System) with CSAPR.**

And NOW….

- **Mercury Oxidation**
- **Acid Gas Control / Particulate.**

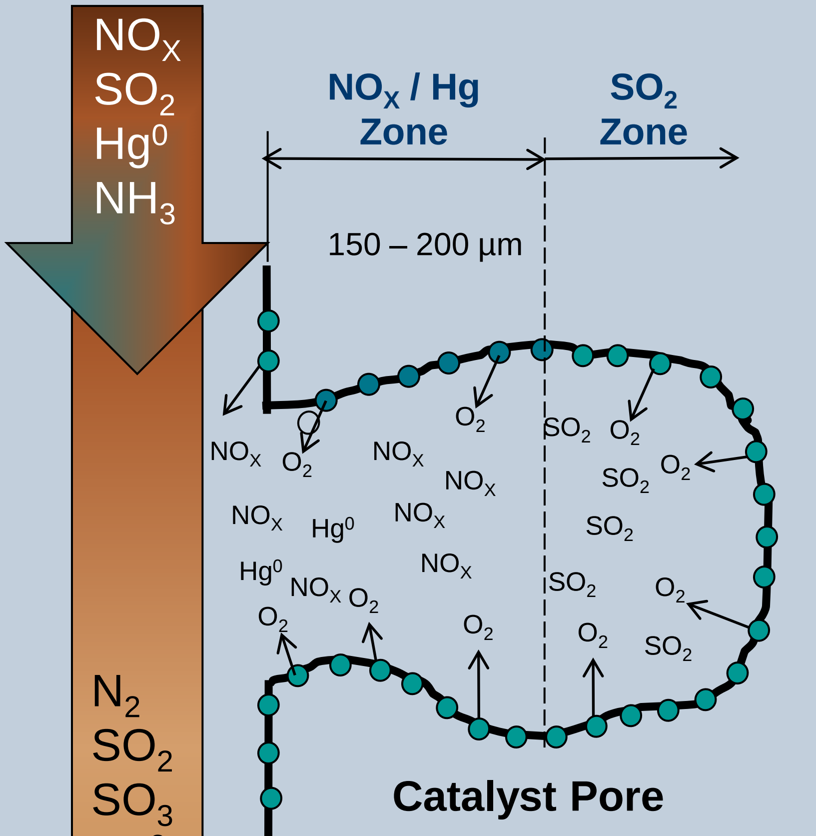
The SCR Rector
What are the Requirements!

- Good Flow distribution
- Ammonia to NOx Balance.
- Dust Loading distribution.
- Correct Catalyst Channel velocity across load range.
- Enough catalyst Potential for NOx & Mercury Oxidation.



The SCR Oxidation Reaction

- **The Vanadium Pentoxide (V_2O_5) releases oxygen (O_2)**
- **The fluegas stream contains the following constituents; Nitrous Oxide (NO or NO_2), Sulfur Dioxide (SO_2) and Mercury (Hg) which compete for the oxygen**
- **The preference for the oxygen is Nitrogen over both Sulfur Dioxide & Mercury;**
- **The presence of Ammonia (for the NOx reaction) inhibits the Mercury & SO_2 / SO_3 conversion reaction**



$4NO + O_2 + 4NH_3 \Rightarrow 4N_2 + 6H_2O$

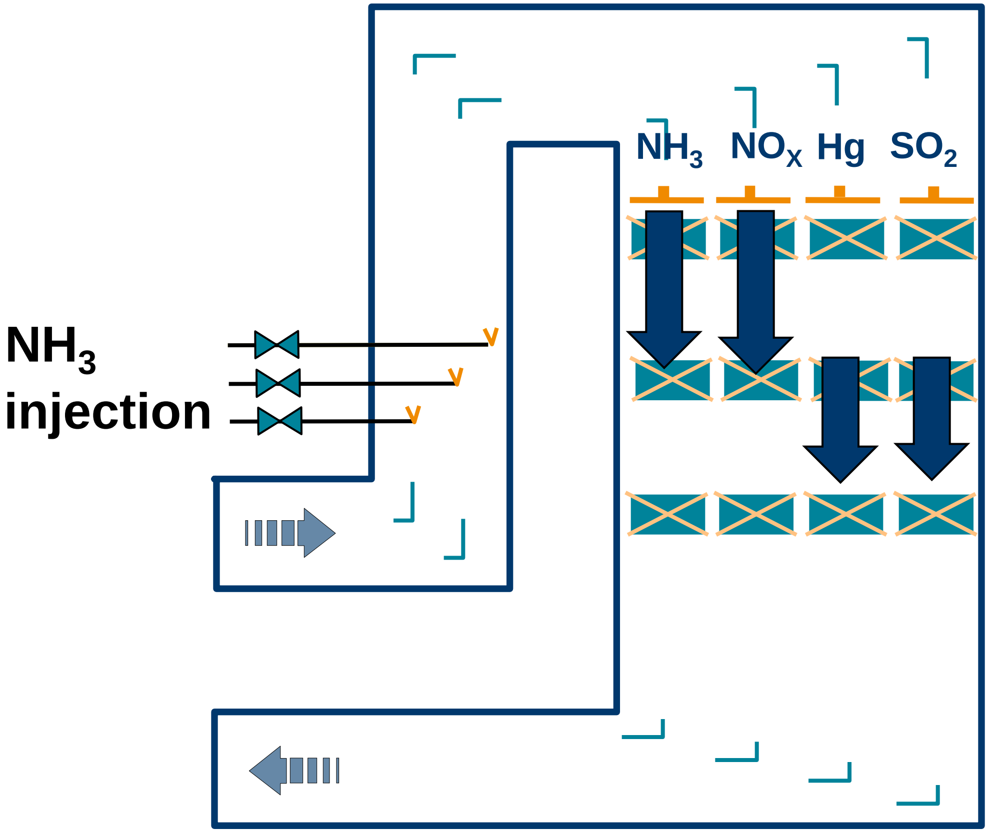
$6NO_2 + 8NH_3 \Rightarrow 7N_2 + 12H_2O$

$SO_2 + O_2 \Rightarrow SO_3$

$Hg^0 + O_2 \Rightarrow Hg^{2+}$

$NH_3 + SO_3 + H_2O \Rightarrow NH_4HSO_4$

SCR Management
What happens in the SCR?



Reactor Configuration

- Higher Activity (Potential) in the top layer.

Result

- Most of Ammonia is consumed in the SCR top layer
- Lower 2 elevations will produce oxygen for Mercury Oxidation (also SO_2 to SO_3 conversion rate)
- Having the greatest layer potential in the upper reactor layers increases the odds of better Mercury Oxidation.

High levels of Mercury Oxidation should occur with high levels of catalyst Activity!

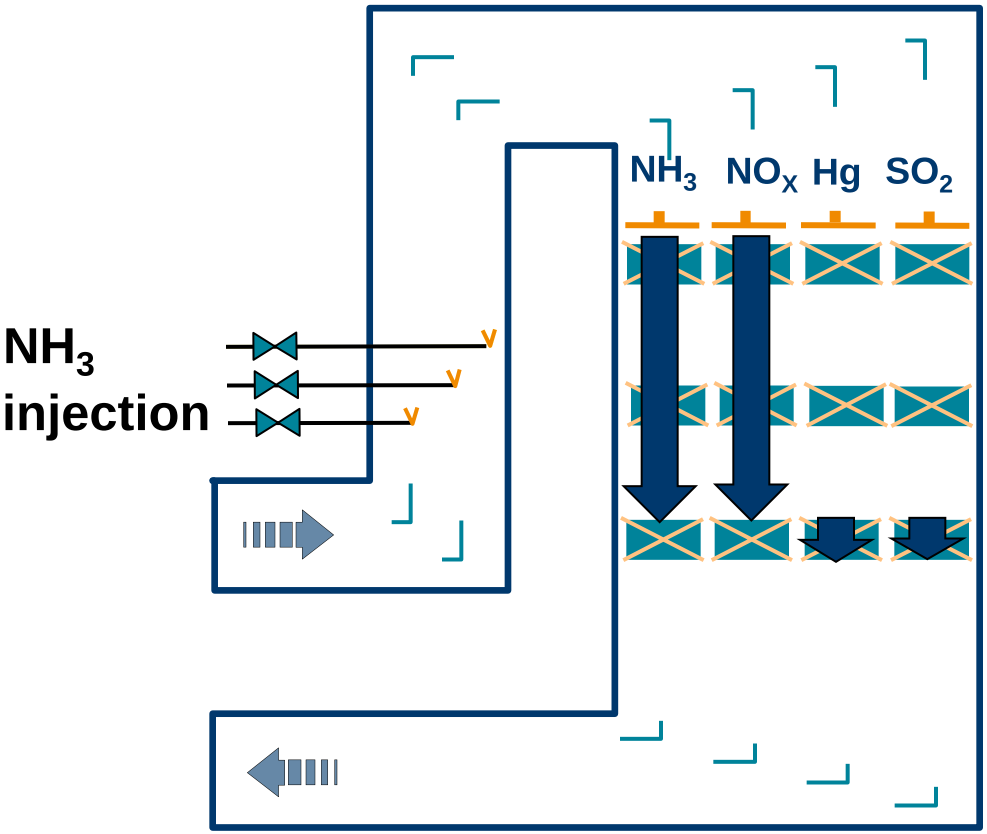
SCR Management
What happens in the SCR?

Reactor Configuration

- Lower Activity (Potential) in the top layers. This is typically a reactor which has not had layer replacements recently.

Result

- Takes longer to consume the Ammonia in the SCR .
- Lower elevations will produce oxygen for Mercury Oxidation (also SO_2 to SO_3 conversion rate)



Lower levels of Mercury Oxidation should occur with low levels of catalyst Activity!

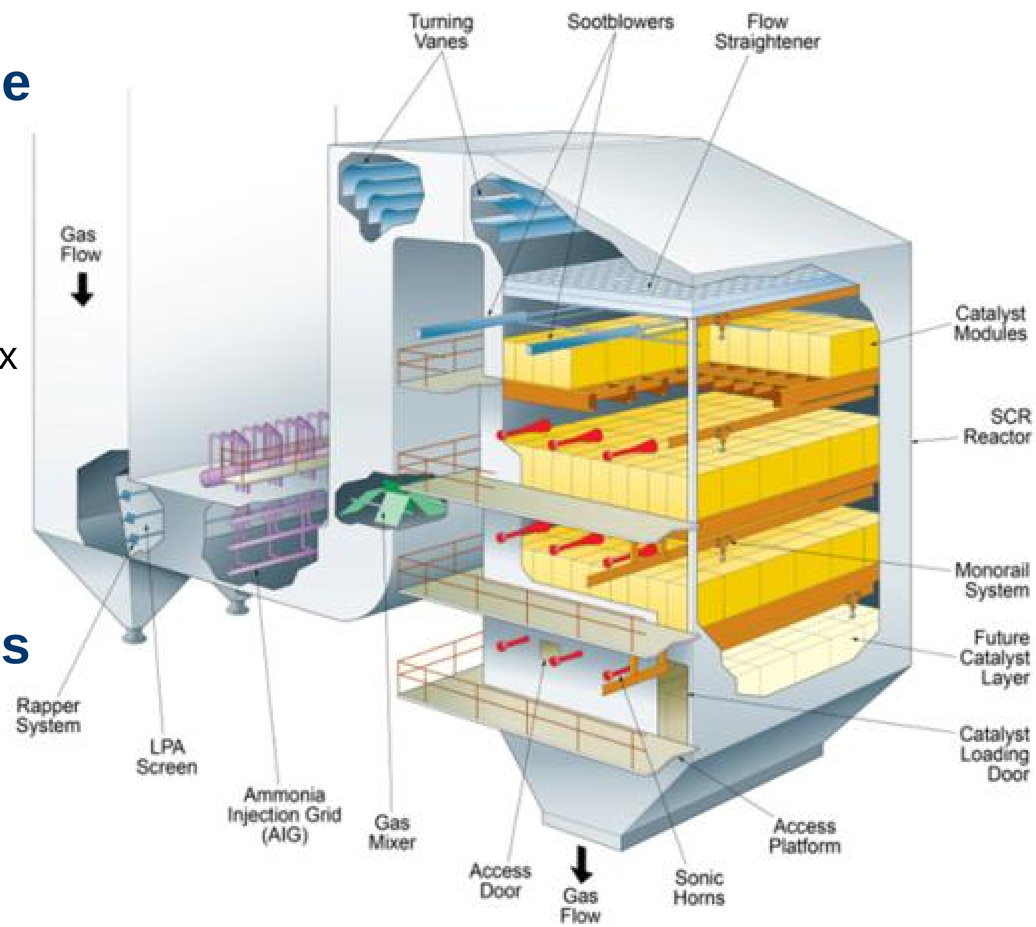
The Every Changing World!

It is critically important to realize that variations of each catalyst testing parameter have a distinct influence on the result.

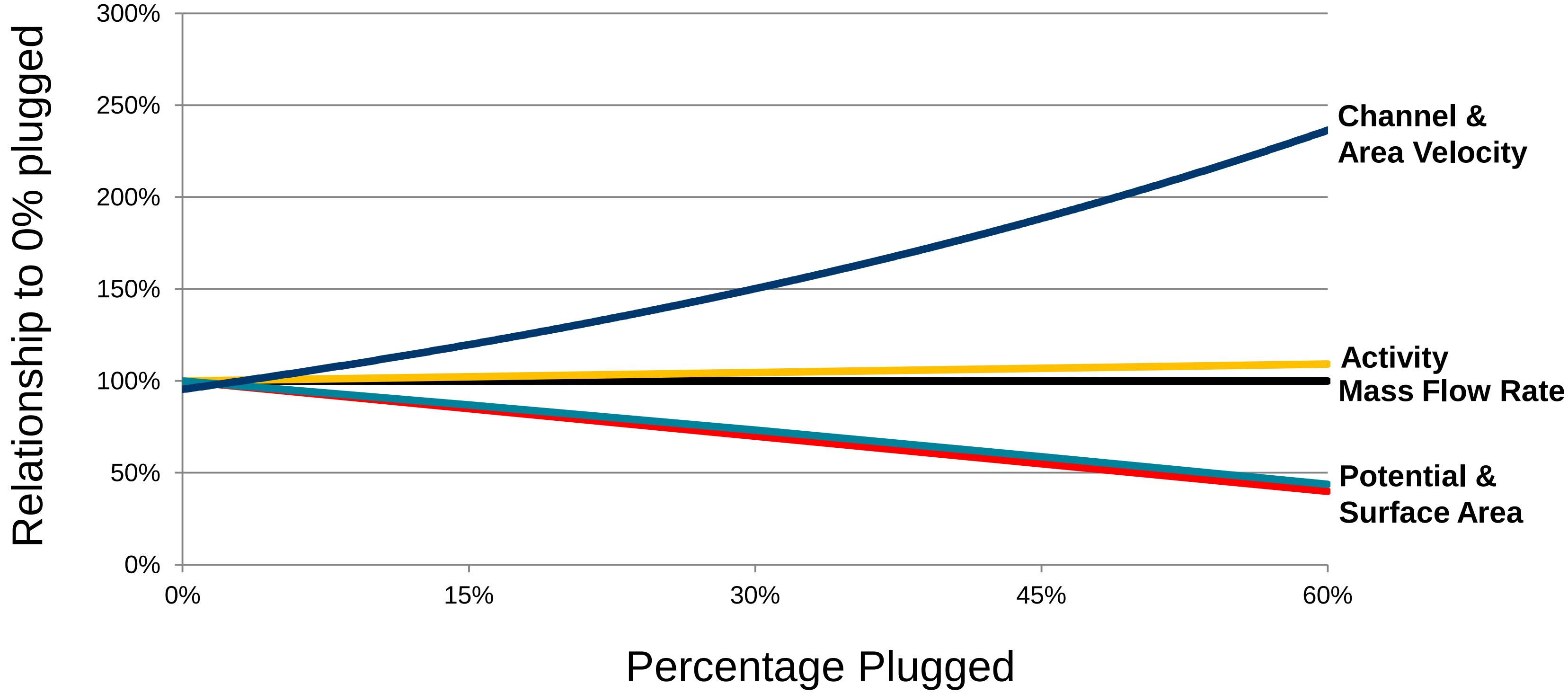
Parameter Increasing with all others steady	Activity	SO_2 / SO_3 Conversion Rate	Mercury
Nitrous Oxide (NO)	↑	↑	Neutral
Sulfur Dioxide (SO_2)	↑	↓	↓
Sulfur Trioxide (SO_3)	↑	↓	↓
Moisture (H_2O)	↓	↓	↓
Oxygen (O_2)	↑	↑	↑
Temperature	Lower temp ↑ ↓ Elevated temp	↑	↓
Vanadium	↑	↑	↑
Linear Velocity	↑	↓	↓

As the SCR Reactor Plugs

- **NO_X to Ammonia imbalance occurs.**
  - Slight increase in Ammonia consumption to maintain NOx reduction as non-catalytic versus catalystic reaction to maintain NOx reduction.
  - Higher Slip potential
  - Lower SO_2/SO_3 conversion rate
  - Lower Mercury Oxidation
- **Reactor Flow distribution is changed.**
  - Higher catalyst channel velocity – higher localized Activity
  - Lower reactor Potential.
  - Greater catalyst erosion potential
  - Higher ΔP.



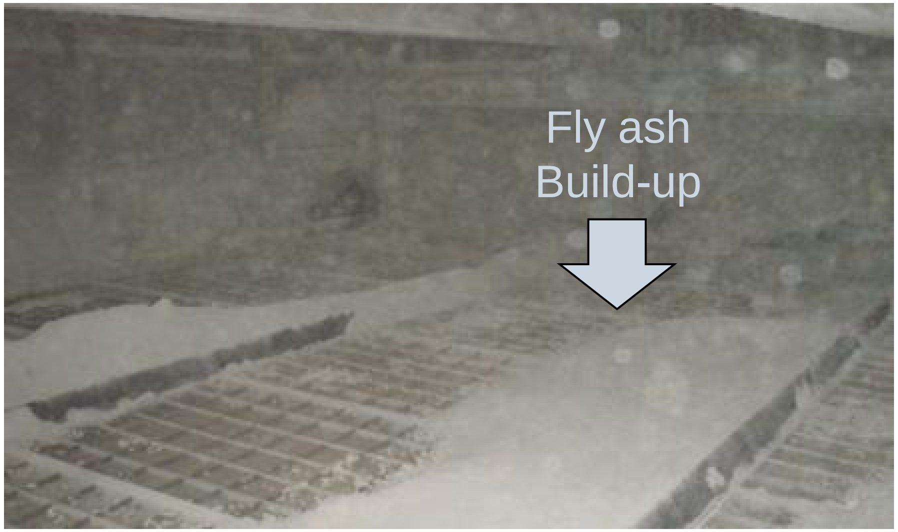
Example of Performance Degradation



As Pluggage increases:

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

Keeping the SCR Reactor Clean



- **Removing the Fly ash build-up in the reactor will become more important to meet the MATS implementation.**
- **There are a series of both on-line and outages in "Keeping the SCR Reactor Clean."**

Keeping the SCR Reactor CleanChanging the Catalyst

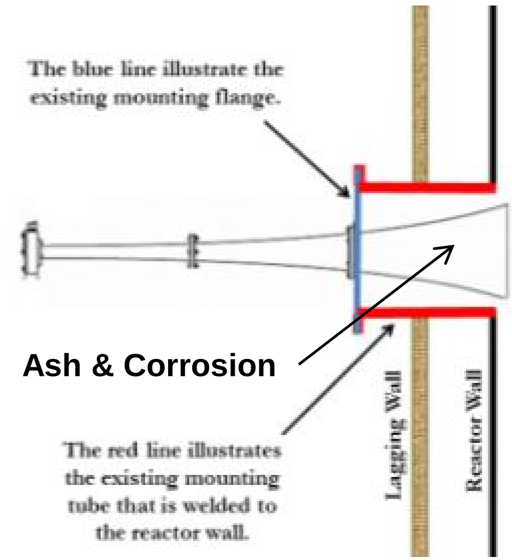
Make the catalyst opening larger

	Honeycomb	Plate
Original		
• Cells / Plates	22/21	82
• Cell Opening	6.3 /6.5	5.6
Redesigned		
• Cells / Plates	18	66
• Cell Opening /	7.4	6.3
• Catalyst surface Area reduction	22%	18%
• Area velocity increase	27%	23%

Keeping the SCR Reactor On-line System

Miami Fort Station.

- Original Sonic Horn Design
  - Standard 75 Hz acoustic cleaner flush mounted
- Issue
  - Corrosion and Ash build-up
  - Broken horns

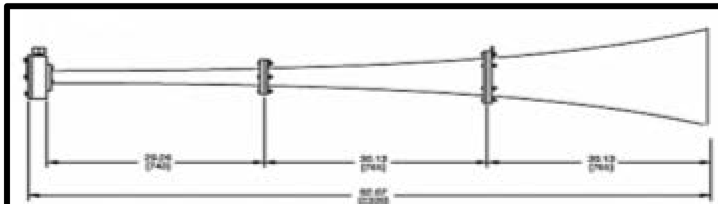


Original Design

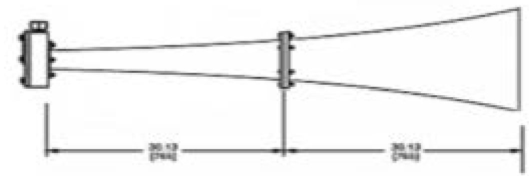
Keeping the SCR Reactor On-line System

Upgrading / Retrofit design

- Shortening of the Horn.
- Reduction in size of the wall mounting unit.
- Up-grade of the Sound Generator.



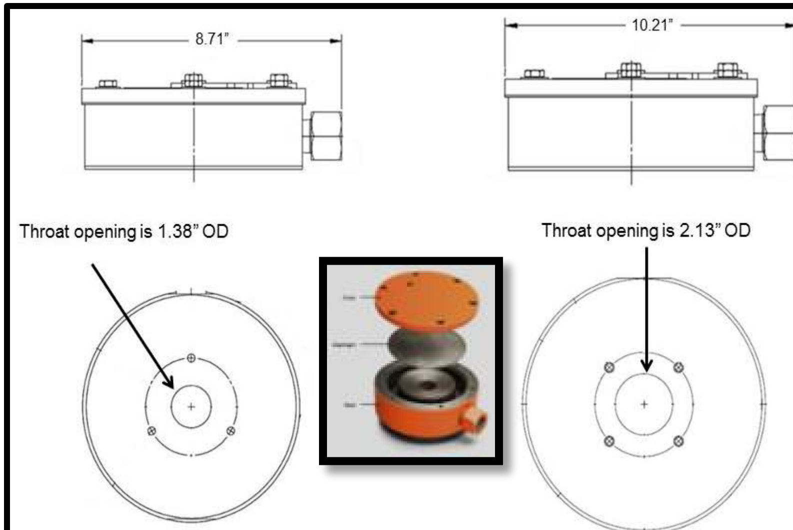
Original Standard design



Retrofit Design

Before

After



Std. Sound Generator

UpgradedSound Generator

Reactor
On-line System

Major dust loading beyond sonic horn Capabilities

- **Computational Modeling (CFD).**
- **Ash Sweeping systems.**

Ash Sweeper

- **Reservoir of compressed air discharges as an eruption into a storage or process vessel to promote flow and prevent material buildup.**
- **Introduced ~1975, accepted across industry, around the world.**
- **Common in power plants on coal bunkers and chutes.**
- **Available as individual units *(one outlet per tank)***
- **Or as multi-port system (*one tank serves several outlets).***

Multi-Port Unit

Individual Unit

Ash Sweeper


Before


After


Ash Sweeper/Acoustic Cleaner Installation

It's Outage Time!
Cleaning Techniques

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.

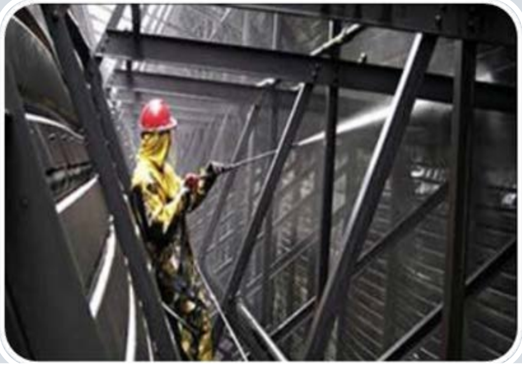
- **Issues**
- Significant Manual Labor

Thompson Process

- In-situ Process.
- Vibration of the main support beams of each layer
- Individual module high pressure air / vacuum hood.

- **Issues**
- Vibration of main beams
- Movement of logs on crowns
- Loss of packing seals

Conventional Catalyst Cleaning Techniques



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

STEAG's In-situ Cleaning Process

<u>The Process – Patent: 8,268,743</u>

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

<u>Why does it work?</u>

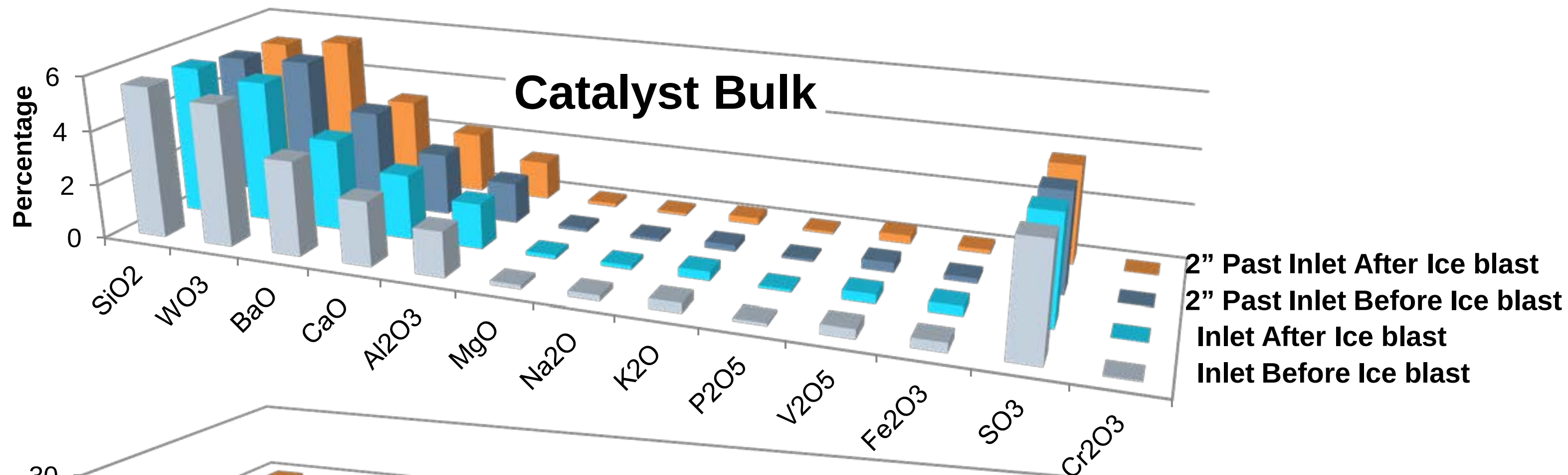
- Dry ice pellets (Temperature of -78.5 °C (109.3 F) are shot out of a nozzle of compressed air expanding into the catalyst cells compresses the flyash plug.
- The compressed air force pushes the smaller plug out of the channel.

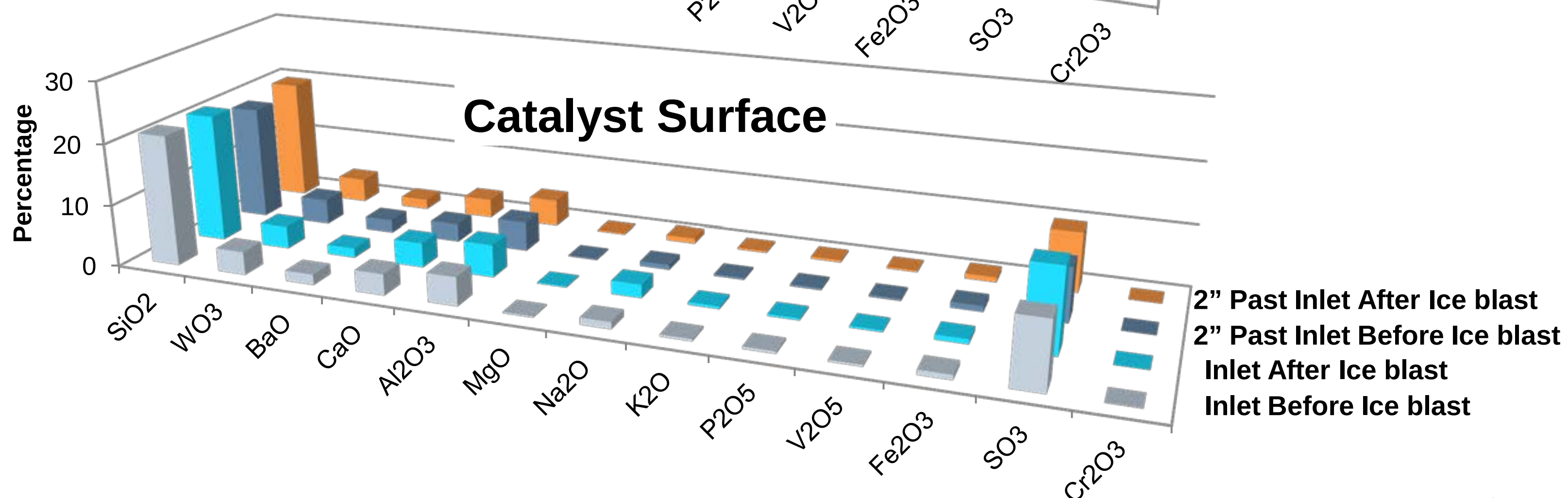
<u>The results</u>

- 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.

Validation of no performance loss

- Extensive testing has been conducted to validate any Performance Issues.
- No metal compounds are removed during the process





Duke Energy Eastbend
Ice Blasting

- **Eastbend**
  - **Capacity: 600 net megawatts**
  - **Location: Boone County, Kentucky**
  - **Commercial Date: 1981**
  - **SCR Added in 2002.**
  - **Low Dust SCR**
  - **2 Rector with 168 modules (84 per reactor).**
  - **Configuration:**
  - **Layer 1: Empty, Layer 2: plugged, Layer 3; Just replaced with regenerated catalyst**
- **The Pluggage Issue**
  - **During start-up it is believe a large quantity of high moisture flyash was carried into the SCR.**
  - **Reactor Had high ∆ P (70% to 80% plugged)**

Before Ice Blasting

After Ice Blasting

Duke Energy Eastbend
Ice Blasting - Project

- **Ice Blasting was used to remove Pluggage**
  - **Unit Remained on-line – double issolation dampers**
  - **Elevated safety procedures were utilized.**
- **The Ice Blasting Project**
  - **Two (2) layers were cleaned in each reactor.**
  - **Higher temperature equipment was worn. Max. working Temp 115 ºF / Actual 90 – 105 ºF.**
  - **There was a safety extraction team (4 man crew).**
  - **STEAG's crews wore the high temperature suits with external supplied air.**
  - **External air brought through access doors on the working elevation (air movers)**
  - **Exhaust air / CO_2 from below the layer doors (air movers).**
  - **Work completed within 3 days plus 1 day safety training and set-up.**

Before Ice Blasting

After Ice Blasting

Duke Energy Eastbend Ice Blasting - Results

- **The results were < 2% to 5% pluggage after the Ice Blasting.**

Unit # 2 SCR A 80% Plugged: Before Ice Blasting

	Unit 2	East	SCR	2A			
	A	B	C	D	E	F	G
Acess Door							
Trolley Beam							
75%-80%		42					
55%-65%		10					
35-50%		32					

Unit # 2 SCR A <2% Plugged: After Ice Blasting

	Unit 2	East	SCR	2A			
	A	B	C	D	E	F	G
Acess Door							
Trolley Beam							
< 5%		35					
< 2%		49					

Unit #2 SCR B 75% Plugged Before Ice Blasting

	Unit 2	West	SCR	2B			
	A	B	C	D	E	F	G
Acess Door							
Trolley Beam							
75%-80%		26					
55%-65%		26					
35-50%		32					

Unit #2 SCR B <2% Plugged After Ice Blasting

	Unit 2	East	SCR	2B			
	A	B	C	D	E	F	G
Acess Door							
Trolley Beam							
< 5%		24					
< 2%		60					

STEAG's In-Situ Catalyst Cleaning

- Restores Pressure Drop back to "new" catalyst levels (<5% plugged)
- Regain of the lost active surface due to pluggage.
- Normal payback in less than 8 months
- Non-evasive technology to the catalyst.
- Does not release de-activating compounds from the catalyst.
- Does not remove any activating compounds.
- Found effective on the micro plugging.

Before Ice Blasting

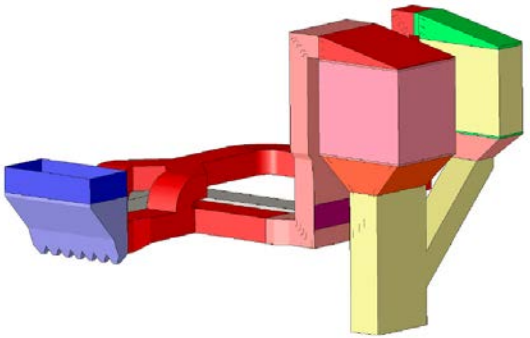
After Ice Blasting

Conclusions

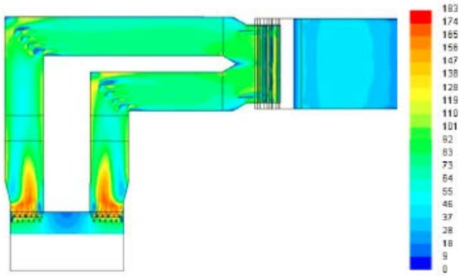
- **The MATS Rule, for most Utilities, forces the SCR Catalyst to serve the dual purpose of both reacting ammonia with NOx and oxidizing mercury.**
- **This makes <u>identifying</u> and <u>maintaining</u> the required Catalyst Potential to meet all SCR requirements paramount to an Unit's success.**
- **An often overlooked area that robs a SCR of significant catalyst Potential is flyash pluggage. Pluggage has many detrimental effects by lowering catalyst Potential and thus reduction in NOx and also the mercury oxidize potential while increasing the risk of ammonia slip and its consequences.**


Conclusions

- **Reactor redesign may be required to minimize ash formation:**
  - **Re-sizing of the catalyst is the lowest cost alternative at the time of scheduled replacement.**
  - **Potential may be lost with larger catalyst pitch and not increasing the catalyst length.**



- **Reactor re-design**
  - **CFD Modeling and reactor AIG, hood, rectifier and catalyst re-design may be warranted to get**
    - **Better flue gas distribution.**
    - **Better ash loading across the reactor**



Conclusions

- **There are on-line solutions to improve the Catalyst Cleanliness:**
  - **Proper maintenance and upgrade options of Sonic Horns and Soot blowers.**
  - **Ash Sweepers for those areas needing additional attention.**
- **It is also vital to thoroughly clean the catalyst when during the outages:**
  - **Vacuuming of the reactor is probably not enough.**
  - **Advanced cleaning methods during the outage will probably be required as MATS is implemented.**

Questions?