

Reinhold Environmental Ltd.



2010 NO_x-Combustion Round Table & Expo Presentation

February 8 & 9, 2010

Chattanooga, TN

All presentations posted on this website are copyrighted by Reinhold Environmental, Ltd (RE). Any unauthorized downloading, attempts to modify or to incorporate into other presentations, link to other websites, or obtain copies for any other uses than the training of attendees to RE's Conferences is expressly prohibited, unless approved in writing by RE or the original presenter. RE does not assume any liability for the accuracy or contents of any materials contained in this library which were presented and/or created by persons who were not employees of RE.

Catalyst Management Strategy Improvements

February 8, 2010

Chao P. Lin
(614) 716-1274



**2010 NO_x-Combustion/
PCUG Conference**

- AEP SCR Overview
- Catalyst Management Goals
- Catalyst life
 - Catalyst deactivation
 - Catalyst deactivation countermeasures
 - Negative impact by catalyst issues
 - Influenced by NOx reduction performance
 - Impacted by SCR reactor design
- Catalyst SO₃ Generation
- Catalyst Supply Blanket Contract
- Catalyst Regeneration
- Catalyst Mercury Oxidation

- AEP operates 14 SCR units ranging from 600 MW to 1,300 MW
- AEP provides engineering and catalyst management services to all AEP SCR units and ten 215 MW SCR units owned by OVEC&IKEC affiliated to AEP
- AEP SCR's have been operating during ozone season only until January 1, 2009 when year round operation began
- All the 14 SCR units have SCR reactor bypass except for 4 SCR units of which SCR's were installed after 2004.
- AEP has been using plate type catalyst for high dust SCR's and honeycomb type catalyst for low dust SCR except for partial layer installations of honeycomb type catalyst and corrugated type catalyst on fourth catalyst layer last year for operational experience

- Extend catalyst life
 - Catalyst life is defined as time period of catalyst exposure to flue gas after installation and until replacement
- Maximize SCR NO_x reduction performance potential
 - SCR NO_x reduction performance has direct influence on catalyst life
- Minimize negative impact on unit operation by NH₃ slip and SO₃ generation
 - Air heater fouling/plugging
 - Acid dew point increase and visible H₂SO₄ plume in stack
- Least costs

- Plugging
 - Micro scale (<0.1 micron) - plug catalyst pores
 - Macro scale - plug catalyst channels
- Masking
 - Coating is either deposited or produced on the surface of catalyst
 - Shield the active sites from contact by reactants
- Poisoning
 - Chemical combination of species with vanadium to form stable compounds
 - Arsenic, phosphorus
 - Alkali and alkaline earth compounds - Potassium, Sodium, Calcium
- Thermal Sintering

Plugging

- Flue gas velocity distribution
 - Ash accumulation/plugging occurs in the areas of low flue gas velocity
- Catalyst cleaning
 - Use steam/air sootblowers or sonic horns to minimize ash deposit within catalyst channels
- Catalyst selection
 - Select proper type catalyst with adequate pitch dimension to minimize potential for catalyst channel pluggage
- Moisture avoidance
 - Hardened ash by moisture condensation is difficult to be removed by ash cleaning devices
 - For SCR equipped with reactor bypass, use bypass system to protect catalyst from moisture condensation and water intrusion during unit start-up, shut down, economizer tube leak, and outage

Plugging

- Moisture avoidance
 - For SCR not equipped with reactor bypass, proper operational practices should be implemented to minimize catalyst deactivation caused by moisture
 - Flue gas temperature ramp rate during start-up and shut down should be as high as possible (within the limitation of boiler temperature ramp rate) to minimize the time that the catalyst is exposed to the temperature below moisture and sulfuric acid dew points
 - Sootblowers or sonic horns should be operated prior to shut down to minimize fly ash deposit on catalyst surface
 - Provide heat or use desiccants to keep catalyst in dry environment during outage

Masking

- Some catalyst masking occurs when fly ash adhere to the surface of catalyst. Chemical compounds (CaO , Na_2O , K_2O) in ash can react with gaseous SO_2/SO_3 to form binding layer on catalyst surface.
 - Catalyst deactivation countermeasures for catalyst plugging are applicable to catalyst masking
- Operate SCR above catalyst minimum continuous operating temperature (MCOT)
 - For SCR of which the flue gas temperature at SCR inlet is not able to be maintained above MCOT at low load, follow the guidance provided by catalyst supplier regarding duration and frequency of operating SCR with flue gas temperature less than MCOT but above minimum ammonia injection temperature (MAIT)

Poisoning

- Fuel selection
 - Bituminous coal - high in As and SiO_2
 - Sub bituminous coal - high in CaO and Na_2O
 - Lignite - high in sulfur
 - Bio mass - high in CaO, K_2O , and P_2O_5
- Fuel switch or fuel blending to reduce poisoning chemicals contained in fuel
 - For As poisoning, switch high As/CaO content coal to low As/CaO content coal or blend high As/CaO content coal with PRB coal
- Fuel additive
 - Limestone addition for As control
- Alkali metals in fly ash can be mobilized to reactive site by exposure to water
 - Countermeasures for ash plugging are applicable

Consequences of LPA plugging catalyst

- Abnormal ash accumulation in SCR reactor
- Increased pressure drop across SCR reactor
- Negative impact on NO_x removal performance caused by reducing available catalyst surface area for DeNO_x reaction and non-uniform gas flow distribution on all catalyst layers
- Catalyst erosion caused by high flue gas velocity in the remaining open areas of catalyst layer
- Ash weight could cause issue of catalyst layer support structural integrity
- Require frequent catalyst cleaning and associated cost and outage time

Countermeasures

- Installed LPA mitigation systems
 - LPA drop-out hoppers at economizer outlet
 - LPA screens in rectifier of SCR reactors

Catalyst Life - Negative Impact by Catalyst Issues - Large Particle Ash (LPA)

LPA caused abnormal ash accumulation on top catalyst layer

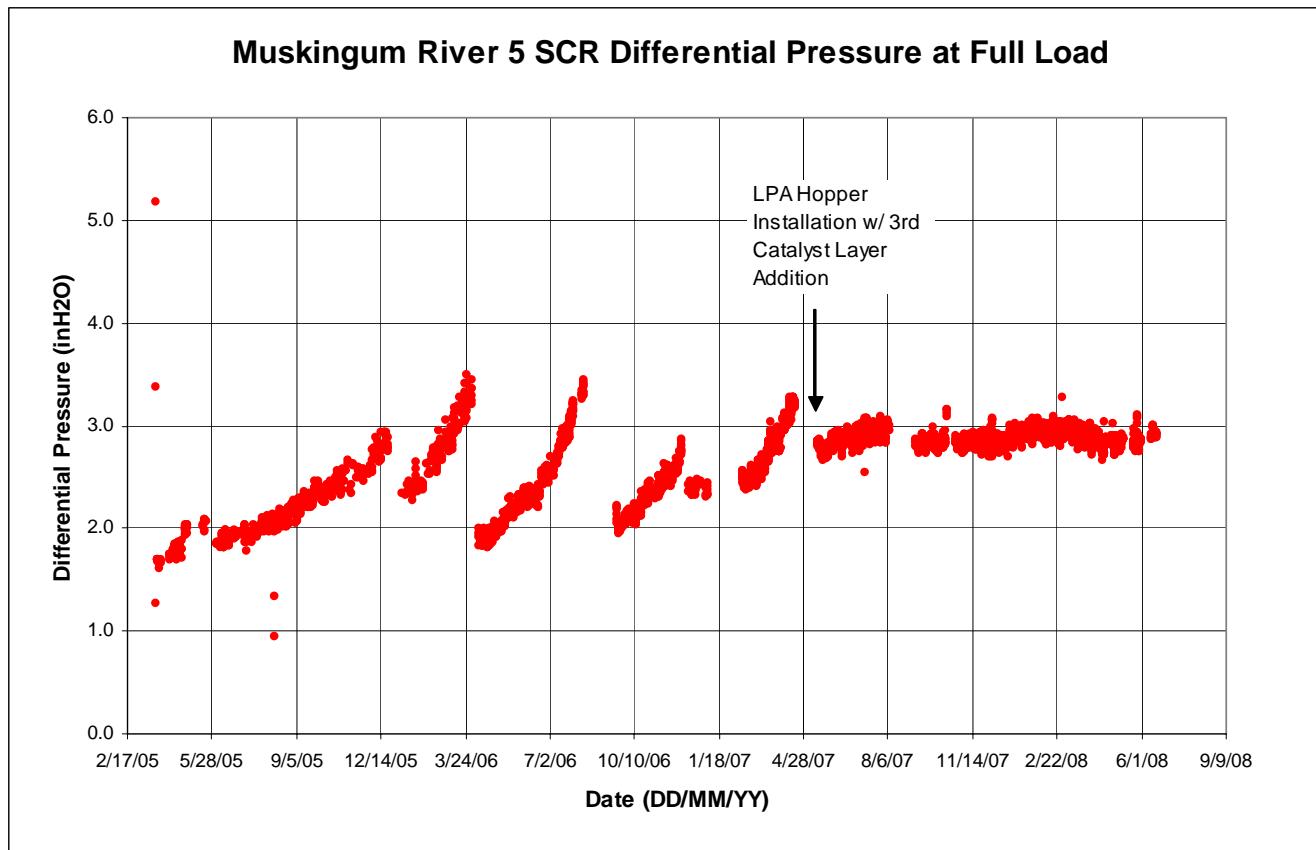


Catalyst Life - Negative Impact by Catalyst Issues - Large Particle Ash (LPA)

Top catalyst layer after LPA dropout hopper installation



Catalyst Life - Negative Impact by Catalyst Issues - Large Particle Ash (LPA)



Catalyst Life - Negative Impact by Catalyst Issues - Water Damage

- Amos Unit 3 catalyst samples collected in 2006 spring outage showed the samples were wet and catalyst material was delaminated from substrate.
- 2007 further inspection showed the water damage mostly occurred on north side of SCR
- It was caused by massive economizer tube leak based on the wet condition of catalyst plates, physical condition of economizer tubes, and historical event of economizer tube leak
- All 3 catalyst layers in north reactor, 2 catalyst layers in center reactor, and 1 catalyst layer in south reactor were replaced in spring 2008

Countermeasure

- Economizer tube banks were replaced in spring 2008
- Keep eye on economizer tube conditions, economizer tube leak event record, and condensate makeup water flow rate to prevent massive economizer tube leak

Catalyst Life - Negative Impact by Catalyst Issues - Water Damage



Catalyst Life - Negative Impact by Catalyst Issues - Catalyst Fire

- During a Amos Unit 3 late 2009 outage for catalyst replacement, it was discovered that catalyst plates in several (~5) catalyst modules in center reactor were severely burned
- The damages were localized. The damaged catalyst modules on all three catalyst layers were located in the same relative location (adjacent to SCR inlet wall)
- Based on catalyst fire experiences in Japan and Europe, It is potentially caused by unburned combustible (fuel oil or coal) carryover from incomplete combustion in the boiler
 - Swing valve of 6D fuel supply line downstream of #6 pulverizer failed to restrict coal flow to #6D burner for a period of time prior to this outage
 - Several oil lighters did not operate properly during a recent unit startup and caused bottom ash hopper fire
- Burnt catalyst samples were collected and being examined by an outside laboratory for ignition source

Countermeasures

- Properly maintain pulverizers/burners and oil lighters
- Once incomplete combustion is detected, immediately take corrective action to eliminate unburned combustible carryover
- Monitor SCR instrumentation for abnormal flue gas conditions that may occur when combustibles adhered to catalyst start oxidation
- Maintain catalyst cleaning devices operational to minimize unburned combustible deposit inside catalyst modules to reduce risk of catalyst fire
- For SCR equipped with reactor bypass and bypass dampers have not been blanked, use reactor bypass system during unit startup and shutdown to avoid or minimize unburned fuel oil carryover to SCR

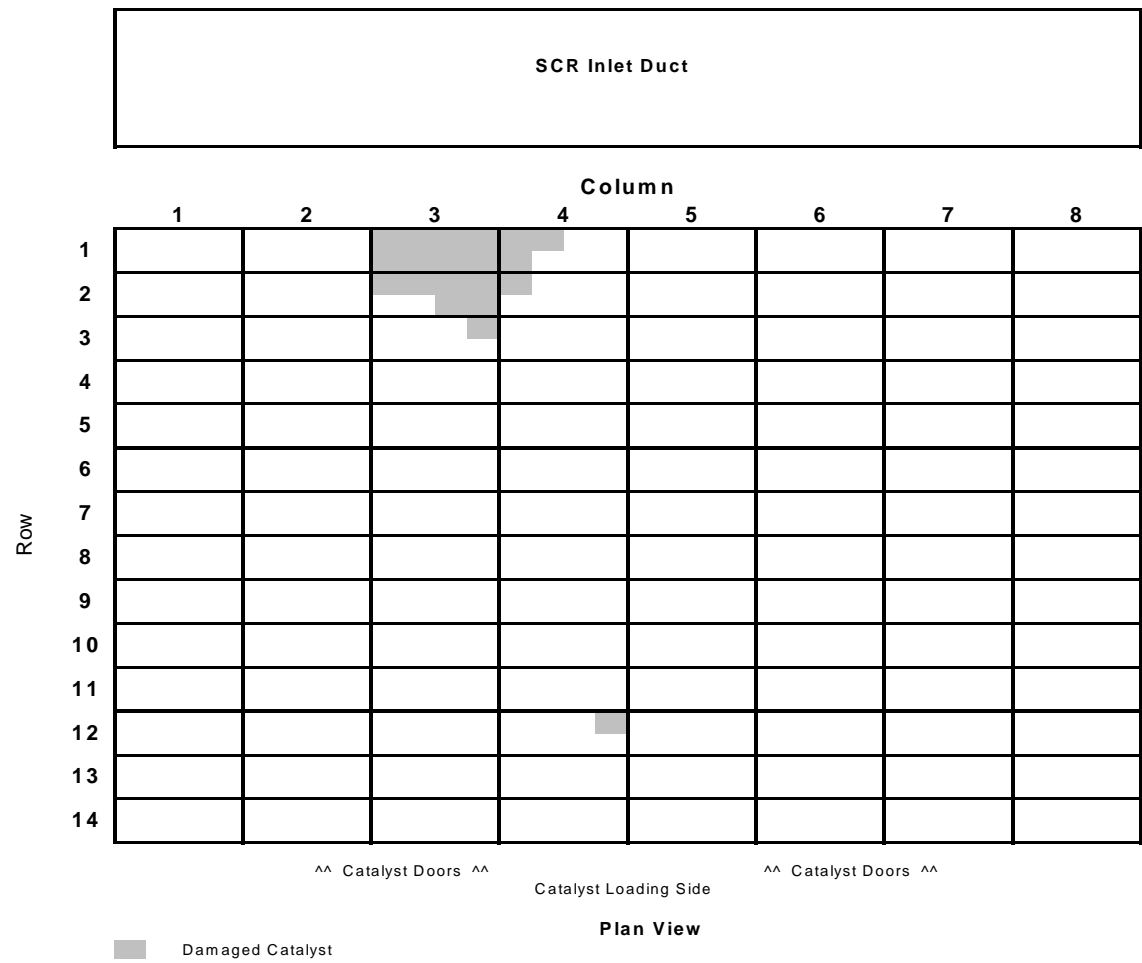
Catalyst Life - Negative Impact by Catalyst Issues - Catalyst Fire



Catalyst Life - Negative Impact by Catalyst Issues - Catalyst Fire



Catalyst Life - Negative Impact by Catalyst Issues - Catalyst Fire

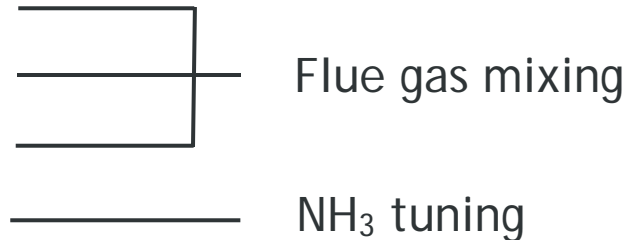


Catalyst Life - Influenced by NOx Reduction Performance

NOx reduction performance of SCR is defined as achievable NOx reduction capability without exceeding defined NH3 slip with given DeNOx potential in SCR reactors

SCR NOx reduction performance depends on the following factors

- Total DeNOx activity (potential) of catalyst in SCR reactors
- Flue gas flow distribution entering SCR reactors
 - NOx concentration
 - Velocity distribution
 - Temperature distribution
 - NH3/NOx molar ratio



Catalyst replacement takes place when SCR NOx reduction performance is not able to achieve the minimum requirement

Improvement of flue gas flow distribution will extend catalyst life

Catalyst Life - Impact by SCR Reactor Design

- It is beneficial to design SCR reactor with spare layer for later catalyst addition after initial catalyst installation
- Comparison of reactor designs (3 + 1), (2 + 1), & (2 + 2) with (3 + 0)
 - Longer catalyst layer change-out intervals
 - For same initial SCR NO_x reduction performance
 - More catalyst volume per layer
 - Higher total SO₂/SO₃ conversion rate and pressure drop across SCR reactor with all catalyst layers filled
- A 20 year economic analysis was performed by taking into account the costs of catalyst change-out, SO₃ mitigation sorbent consumption, and heat rate penalty caused by pressure drop across catalyst layers
 - Reactor designs (3 + 1), (2 + 1), & (2 + 2) have significant economical benefit in comparison to (3 + 0)
 - Reactor design (2 + 2) is the best among reactor designs from catalyst life and economics point of view

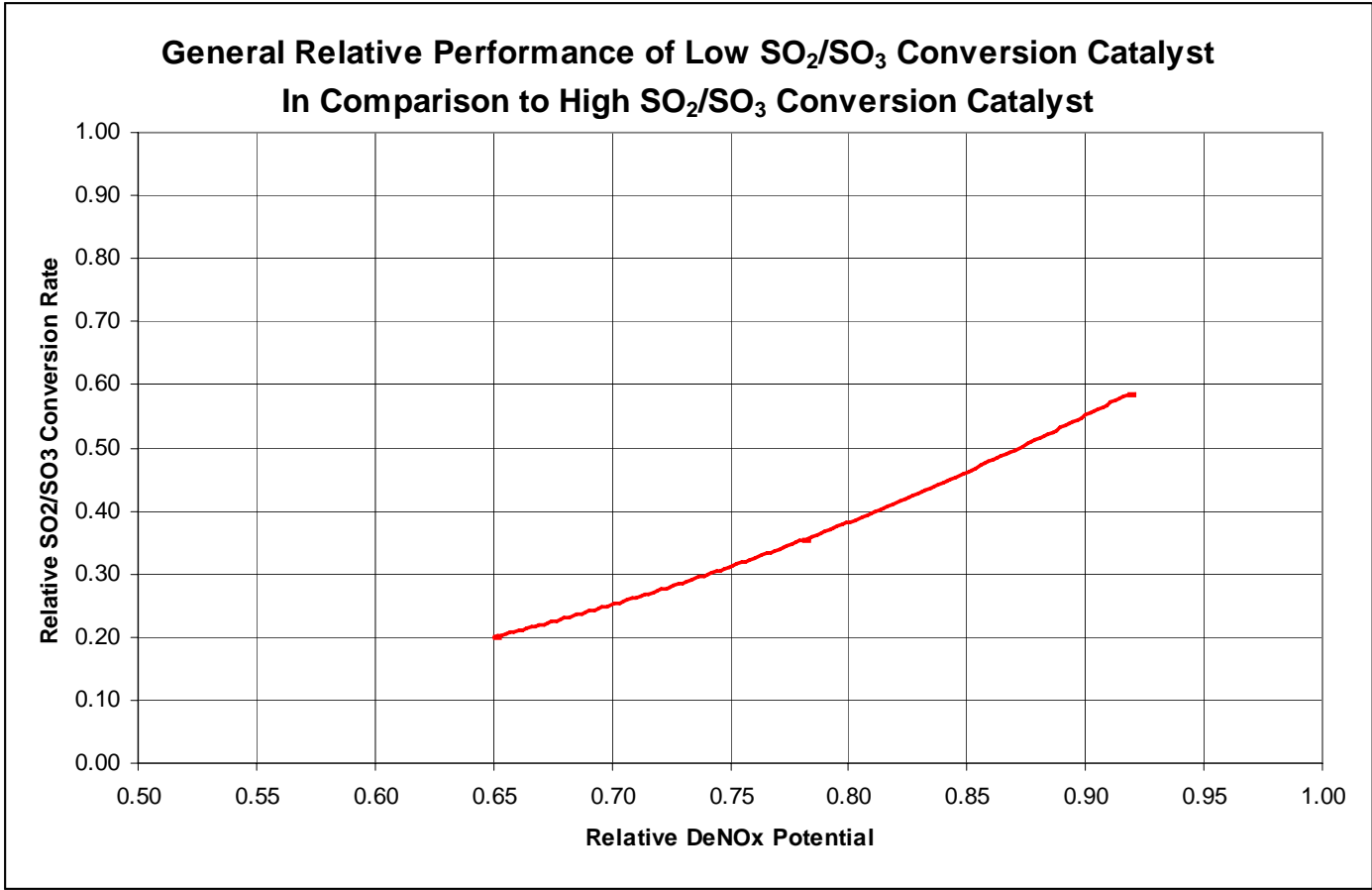
Downstream Equipment Impact

- Acid Dew Point Increase
 - Increase potential of downstream equipment and structural steel corrosion
 - Unit heat rate penalty due to air heater exit temperature increase
 - Increase potential of ABS formation and air heater fouling/pluggage
- Improve ESP performance
- Appearance of H₂SO₄ plume in stack

Solutions

- SO₃ mitigation sorbent injection
 - Effectiveness of SO₃ reduction
 - Capital and O&M costs
- Replace original high SO₂/SO₃ conversion catalyst with low SO₂/SO₃ conversion catalyst
 - DeNO_x potential and SO₂/SO₃ conversion rate performance of catalyst
- Combination

Catalyst SO₃ Generation



SO₃ Mitigation Strategy

- SCR catalyst is not the sole source of SO₃ in flue gas
- Low SO₂/SO₃ conversion catalyst selection
 - How low the SO₂/SO₃ conversion rate required
 - Balance of DeNO_x potential and SO₂/SO₃ conversion rate
 - Impact of thin wall low SO₂/SO₃ conversion catalyst on catalyst life and future catalyst regeneration
- Low SO₂/SO₃ conversion catalyst alone may not be able to solve SO₃ issues
- SO₃ mitigation sorbent injection
 - Sorbent section
 - Sorbent injection location
- SO₃ mitigation sorbent injection alone may not be cost effective for life of SCR
- Perform economic analysis to determine the most effective and economical option for SO₃ mitigation

- Purpose
 - Increased world demand on SCR catalyst results in long lead time for catalyst order
 - Reserve manufacturing space for catalyst production and secure catalyst supplies for long term catalyst needs
- Advantages
 - Assure long term catalyst supplies
 - Save time and effort of developing contract for individual catalyst supply
 - Could offer more favorable catalyst price from open bid and volume discount
- Things to consider
 - Contract term - how many years?
 - Pricing structure - firm lump sum or adjustable?
 - Payment terms - refine project budget projections
 - Flexibility - catalyst supply schedule change, catalyst supply cancellation

- SCR catalyst regeneration technology has been developed in Europe for more than 10 years
- Catalyst regeneration process has been continuously improved
- Costs
 - Very attractive in comparison to new catalyst
- Performance
 - DeNO_x activity/potential is competitive to new catalyst
 - SO₂/SO₃ conversion rate results have not been consistent
 - Deactivation is similar to new catalyst in most cases
 - Impact on mercury oxidation need to be determined
- Catalyst regeneration planning / consideration
 - Accounting classification - capital or O&M
 - Salvage value of used catalyst determines the economics of catalyst regeneration
 - Maintain ownership or sale and buy-back option
 - Required turn around time
 - Used catalyst storage prior to regeneration

- A combination of mercury oxidation by SCR catalyst and oxidized mercury removal by wet FGD is one of proven technology for mercury reduction
- SCR catalyst mercury oxidation depends on many factors
 - HCl / HBr concentration in flue gas
 - Residence time / space velocity
 - Flue gas temperature
 - NH₃ concentration in flue gas
 - SO₂ concentration in flue gas
 - Catalyst aging
- Preparation for upcoming mercury emission regulation
 - Field tests on mercury oxidation capabilities of existing SCR's as well as oxidized mercury removal capabilities of wet FGD
 - Supplemental mercury reduction options
 - Cl / Br addition to fuel
 - Activated carbon injection
 - Mercury oxidation catalyst



Catalyst Management Strategy Improvements

Questions ?

