Reinhold Environmental Ltd.

2009 NOx-Combustion Round Table & Expo Presentation

February 9 & 10, 2009, Cleveland, OH

Workshop XXIII: SCR Catalyst Management Strategies in a Changing Environment

2009 Reinhold NOx- Combustion Round Table Conference

February 10,2009

Workshop Panel

- **Ed Campobeneddetto, Babcock & Wilcox**
  - **Construction of the SCR and Box Design**

- **Greg Coleman, CoaLogix**
  - **Ammonia Control and AIG Tuning**

- **Joseph Skipper, CoaLogix**
  - **Mechanical Considerations**

Workshop Panel

- **Mike Cooper**
    - **Catalyst Deactivation Modeling**
- **Peter Struckmann, E.On Engineering**
    - **Catalyst Testing**

Ed Campobenedetto **Babcock & Wilcox**

CONSTRUCTION OF SCR AND BOX DESIGN

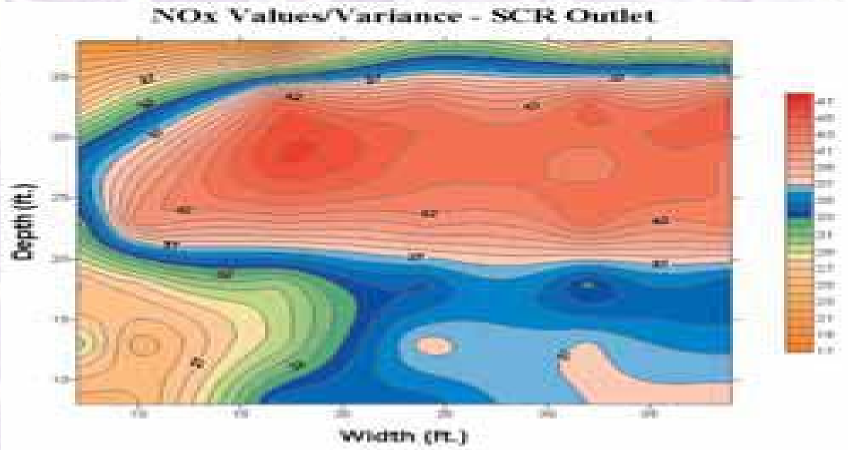
Greg Coleman

AMMONIA CONTROL

Ammonia Tuning

- SCR effectiveness is contingent on uniformity of velocity and NH_3/ NOx distribution at the catalyst surface

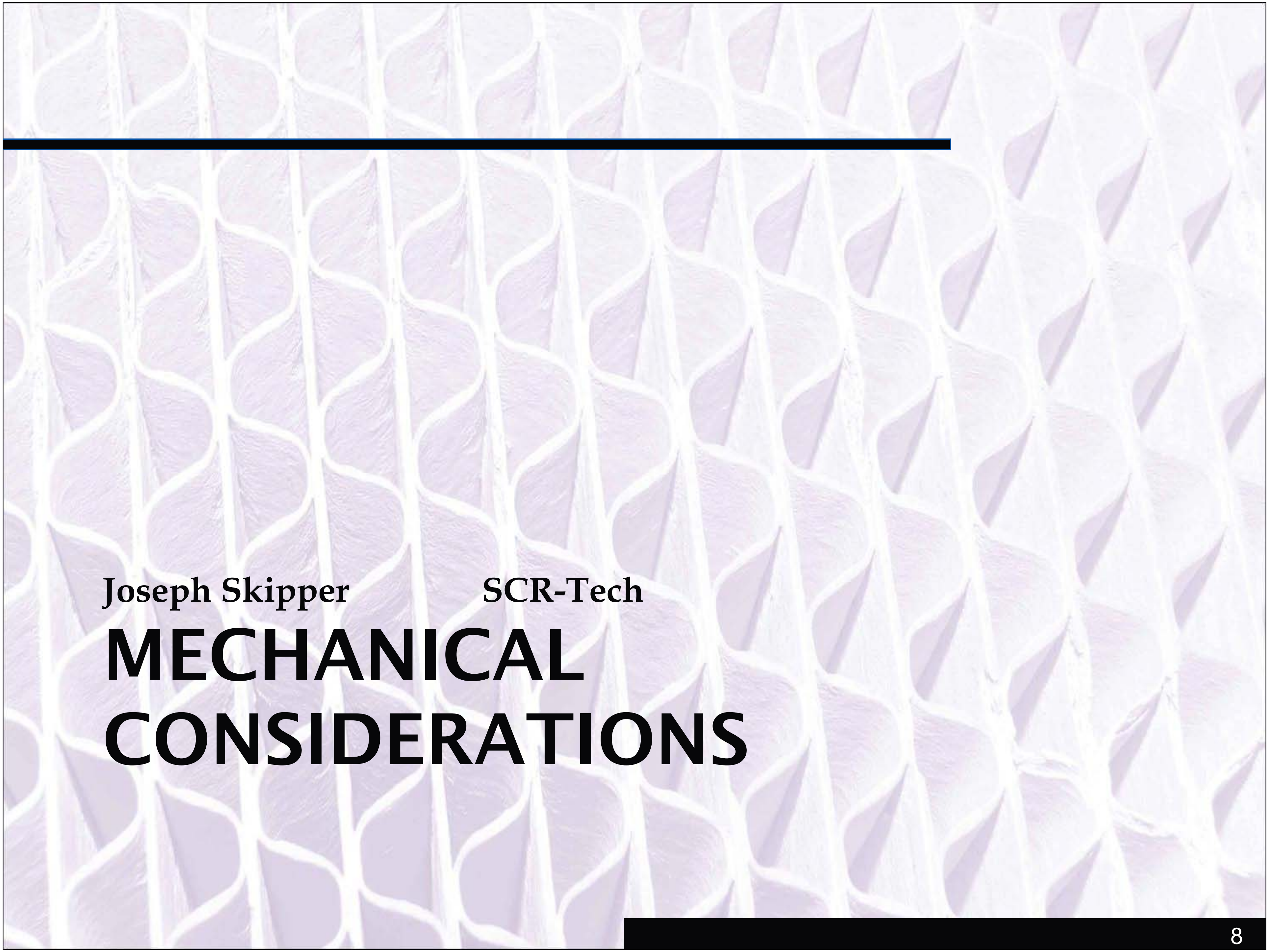
- Startup Tuning and periodic checks are necessary in high efficiency SCRs to eliminate excessive NH_3 slip



- AIGs should have tuning flexibility even when static mixers are utilized

Ammonia Tuning

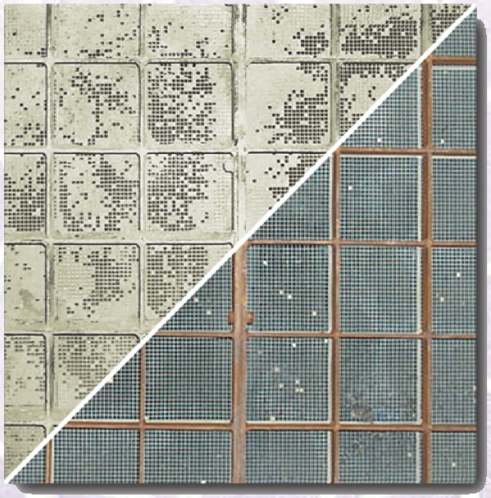
- Ammonia slip during load transitions is a costly problem
- Ammonia monitoring provides invaluable data for catalyst management
- Decreasing SO_3 upstream of the SCR has many benefits

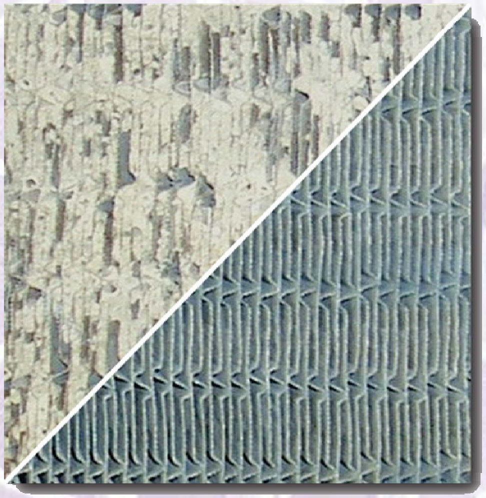


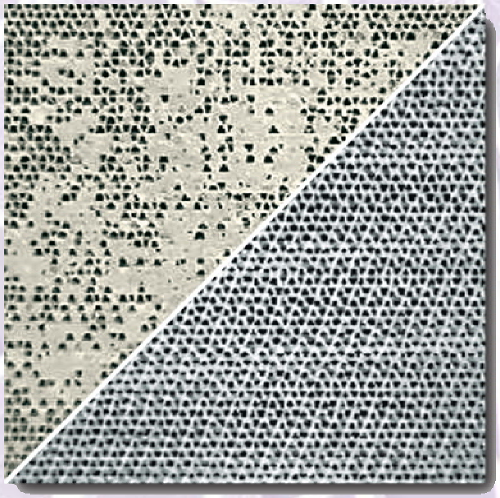
Joseph Skipper **SCR-Tech**

MECHANICAL CONSIDERATIONS

Catalyst Type



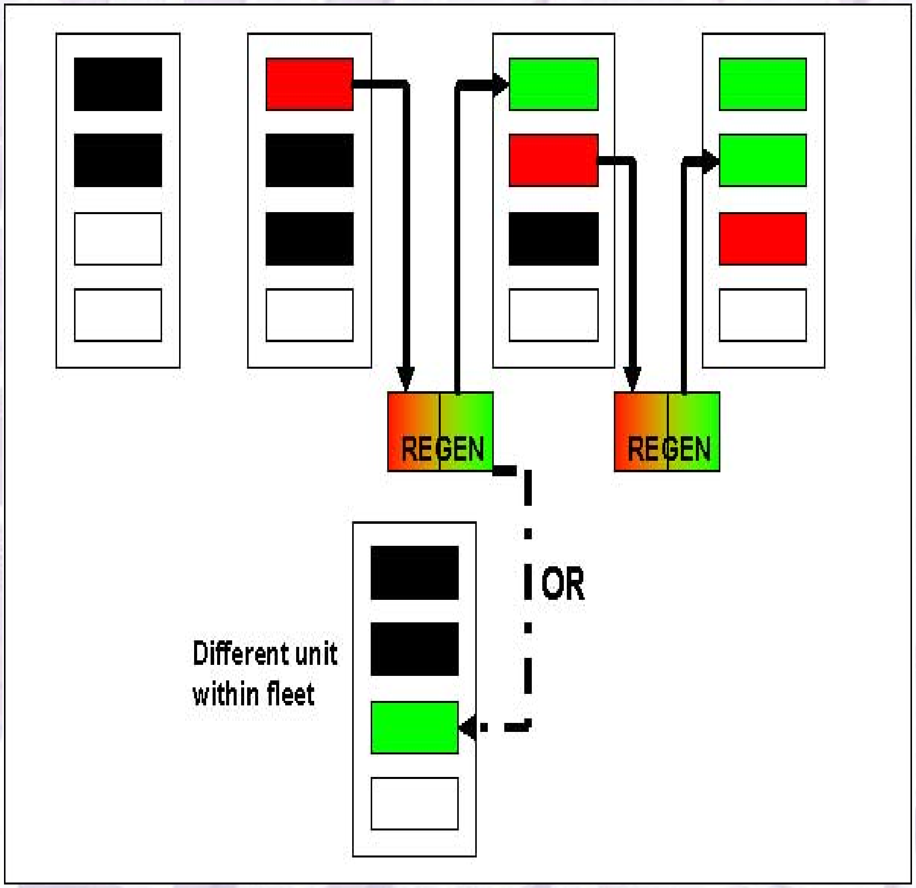


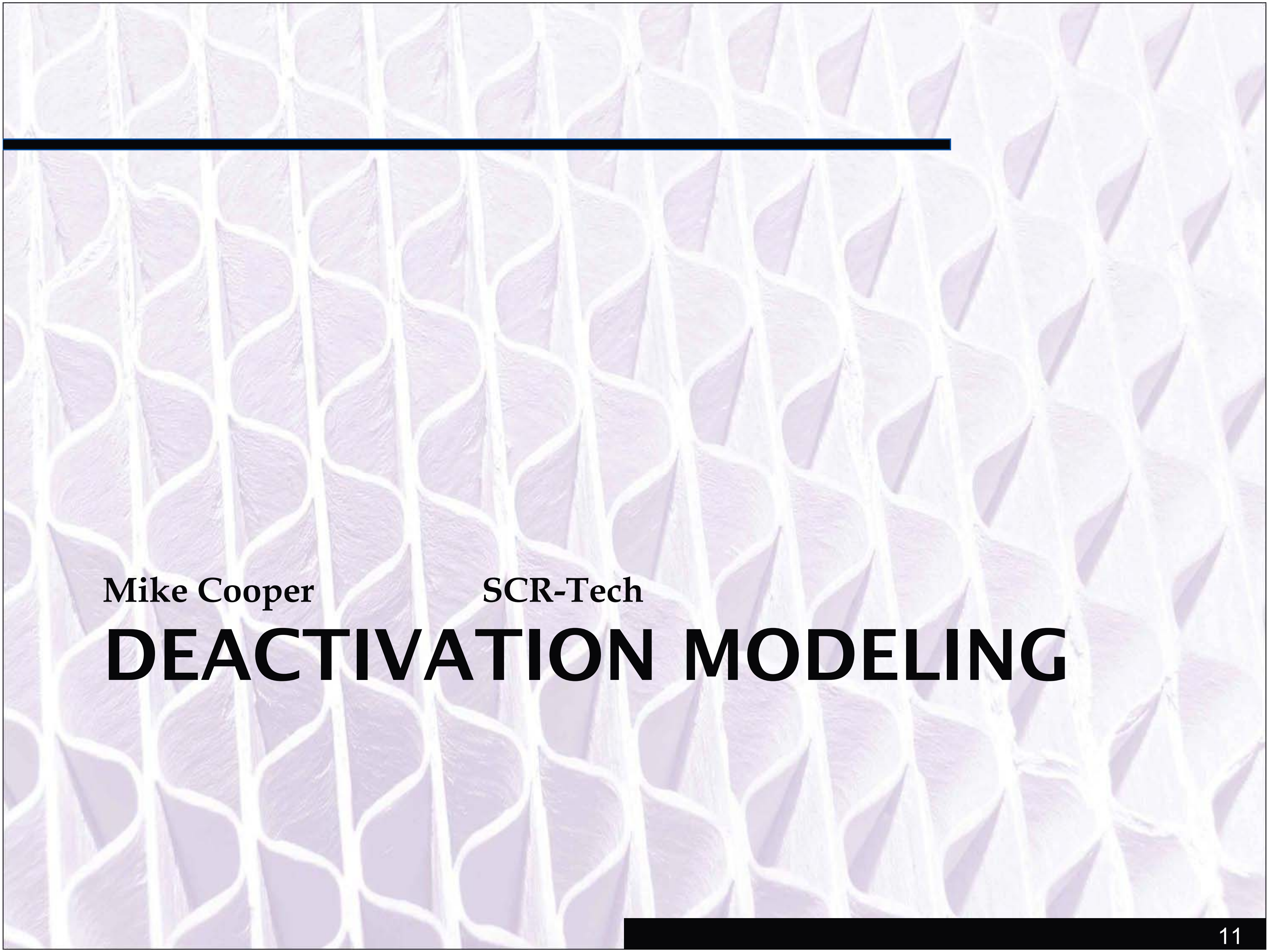


- No type is a bad type
- Catalyst type must meet demands of the reactor environment
- Physical Considerations
    - Pitch
    - Length
    - Pluggage Resistance
    - Erosion Resistance vs Strength
- Chemical Considerations
    - DeNOx Potential
    - SO_2 conversion
- Hybrid SCR
    - Pluggage resistance (Plate on top layer)
    - High surface area (Honeycomb or Corrugated in lower layers)

Catalyst Type

- Filling order
    - Top to bottom vs. bottom to top
- Rotation within system
    - Unit to Unit
    - Plant to Plant
- Number of regenerations possible
- Coal blends
    - Current vs. Future





Mike Cooper **SCR-Tech**

DEACTIVATION MODELING

Basic Calculations: Activity and Potential

- **DeNOx activity is a measure of the rate at which a catalyst is able to use NH_3 to convert NOx to N_2 and H_2O**

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

  - **Formally defined by the following**

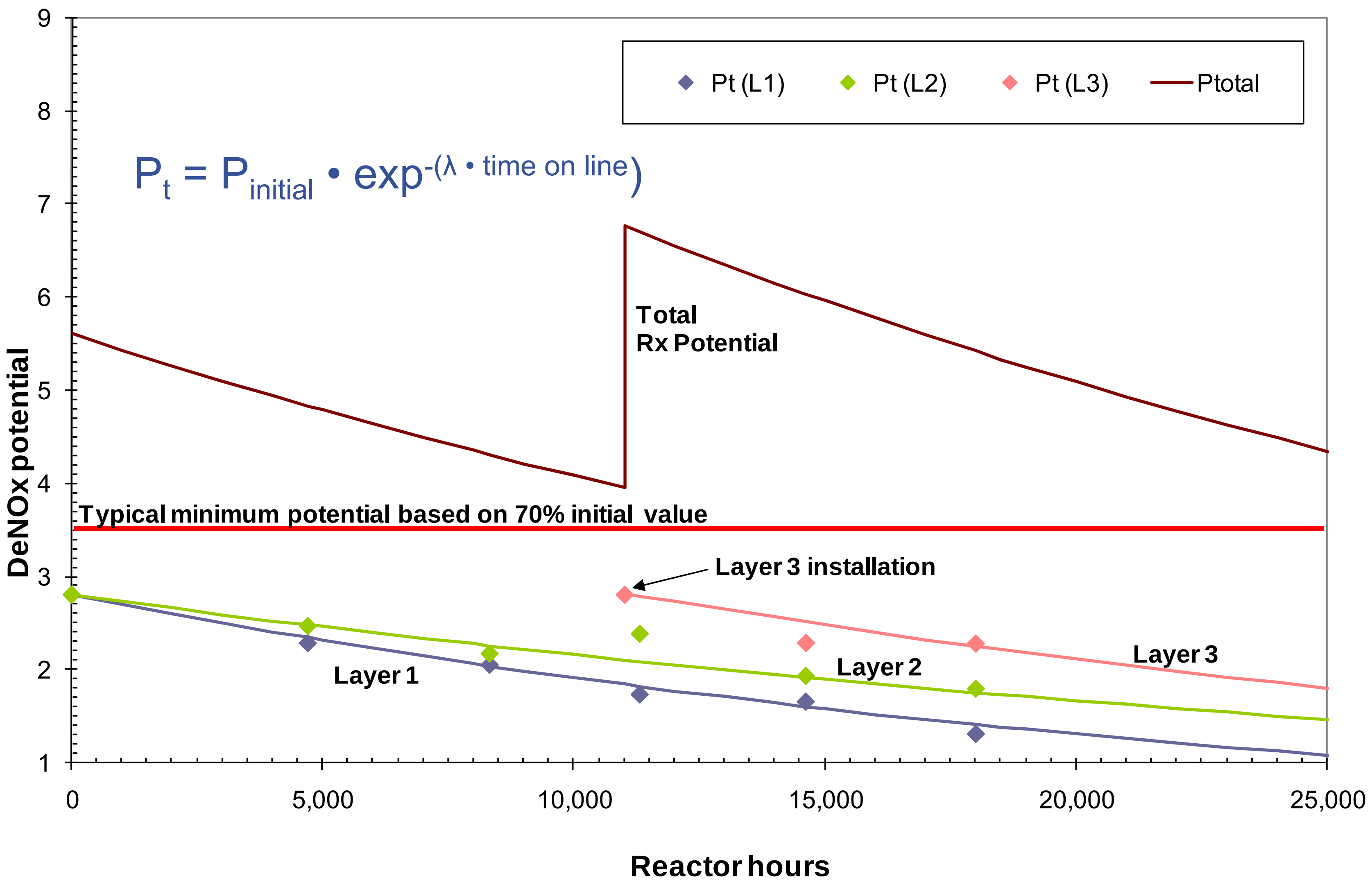
$$K = \frac{VolumetricFlow}{CatalystSurface} \bullet - \ln[1 - \frac{(NOx_{in} - NOx_{out})}{NOx_{in}}]$$

- **Potential is a direct measure of how much NOx is converted**
  - **Formally defined by**

$$Potential = \frac{K}{AV} = -\ln[1 - \frac{(NOx_{in} - NOx_{out})}{NOx_{in}}]$$

  - **Example of potential use**
    - ❖ **Inlet [NOx] = 1 Potential of layer = 2.2**
    - ❖ **Outlet [NOx] = $e^{-2.2}$ = 0.112 or 88.9% NOx reduction**

Deactivation Modeling Based on Best Fit to High Quality Bench Test Data



$$P_t = P_{initial} \bullet \exp^{-(\lambda \bullet \text{time on line})}$$

Catalyst Deactivate by Exposure to Flue Gas – Fuel Type Determines Rate

- ☐ **Bituminous**
  - High sulfur and arsenic
    - ❖ "Bundled" as pyrites – metal sulfides (FeAsS & AsS)
  - High ash content
  - Greater tendency for slag formation
    - ❖ With high ash → LPA formation issues
- ☐ **Sub-bituminous (includes PRB)**
  - High in group I alkaline metal (sodium & potassium)
    - ❖ With SO_3 and PO_4 "sticky" material that increases deposition
    - ❖ Surface poison by blocking surface Bronsted acid sites
  - High in group II alkaline earth (calcium & magnesium)
    - ❖ Up to 30% Ca and 10% Mg in PRB
    - ❖ Form reflective CaO & MgO silicates → pore blinding
    - ❖ CaO reacts with CO_2 to produce "plaster" like channel plugging
    - ❖ Combines with SO_3 to form $CaSO_4$ which plugs pores

Catalyst Deactivation Rates and Arsenic Poisoning

- As_2O_3 (As^{III}) is a condensable gas
  - Fills micro-pores then meso-pores
    - Macro-pore > 500Å
    - Meso-pore = 20 – 500Å (NO kinetic diameter ~11.5Å)
    - Micro-pore = 7 - 20Å Most surface area is here!
  - Rate depends on Partial Pressure : Saturation Vapor Pressure ratio or P/P_0
- Condensed As^{III} further oxidizes to insoluble As^{V}
  - Rapid early loss of surface – loss of DeNOx activity
- Are some catalyst more arsenic resistant?
  - Less surface in micro-pore range → As_2O_3 condensation rate equilibration occurs at higher P/P_0
    - As resistance possible through control of pore size distribution
  - Test and analysis data show high DeNOx activity at > 3,000ppm As for some catalyst

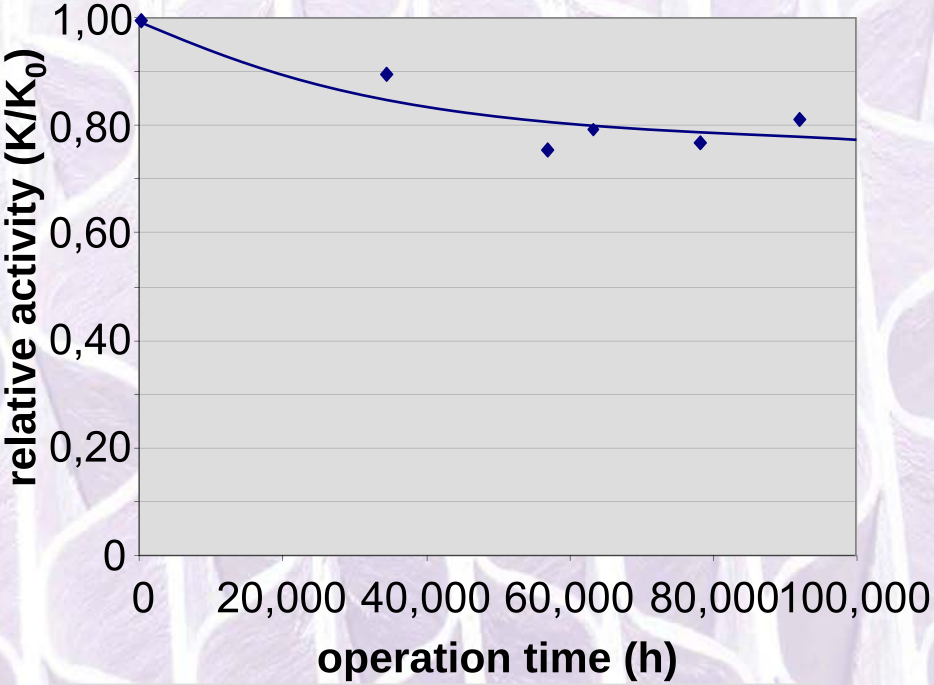
Peter Struckmann **E.ON Engineering**

CATALYST TESTING

DeNOx activity requirements for year around operation

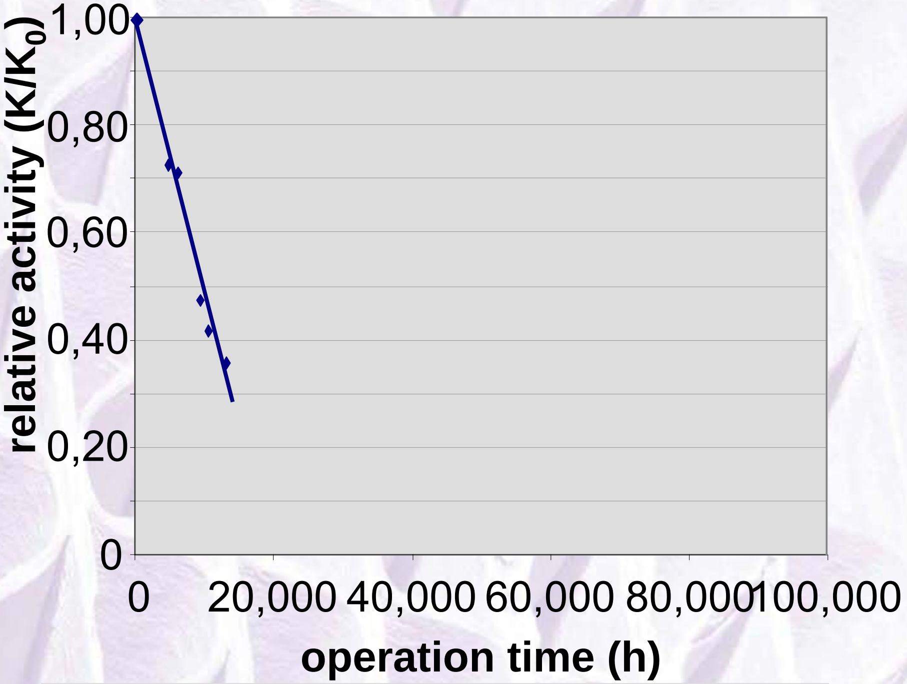
- Tracking of relative activity over time

appr. 22 % loss / 100,000 h



- **740 MW dry ash boiler**
- **tangentially fired**
- **imported coal**
- **10 % ash**
- **district heating**

appr. 70 % loss / 15,000 h



- **740 MW dry ash boiler**
- **tangentially fired**
- **local domestic coal**
- **10 % ash**
- **co-combustion of sewage sludge**

DeNOx activity requirements for year around operation

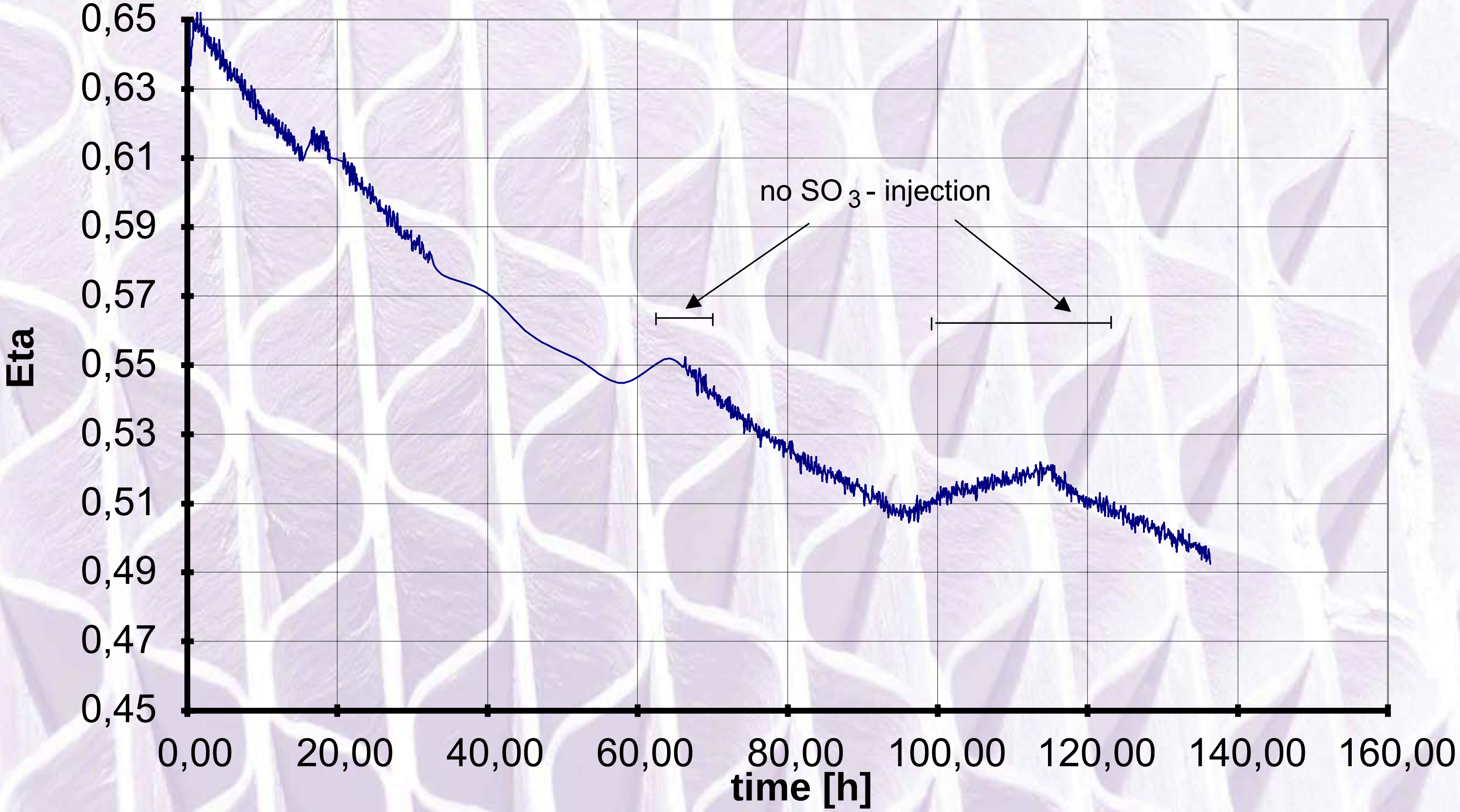
- Still annual sampling / testing
  - Communication
  - Co-operation
  - Flexibility

DeNOx activity requirements for year around operation

- ❑ A possible challenge for year around operation is the need for substantial load changes during a year while meeting the NOx reduction compliance limits.
- ❑ The plant load adjusts to power demands caused by variations in weather conditions, industrial needs, house hold consumption...
- ❑ Load changes affect the entire plant operating regime including the SCR‘s ability to operate.

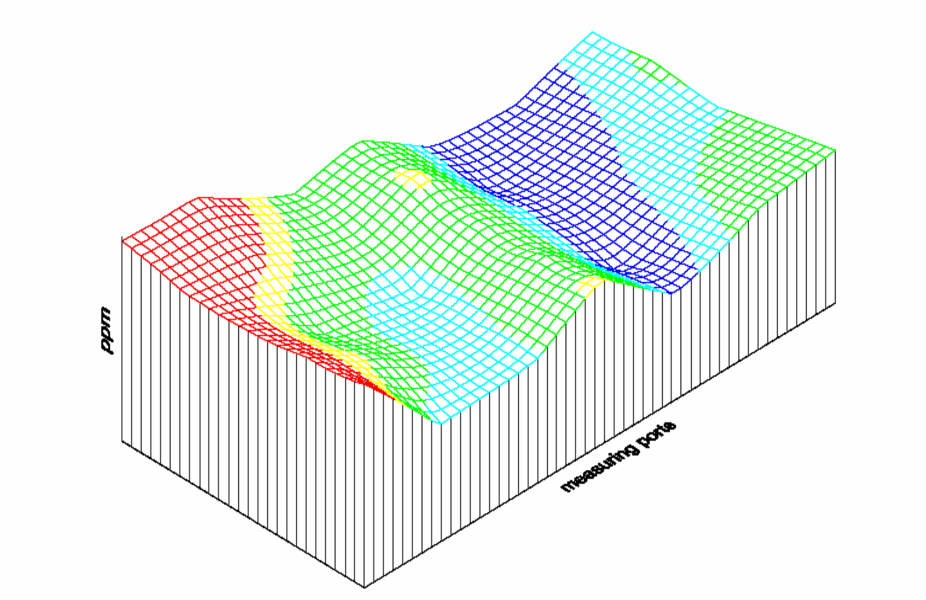
DeNOx activity requirements for year around operation

- Catalyst deactivation - ammonium sulfate pore blocking (tail end SCR, low temperature application)



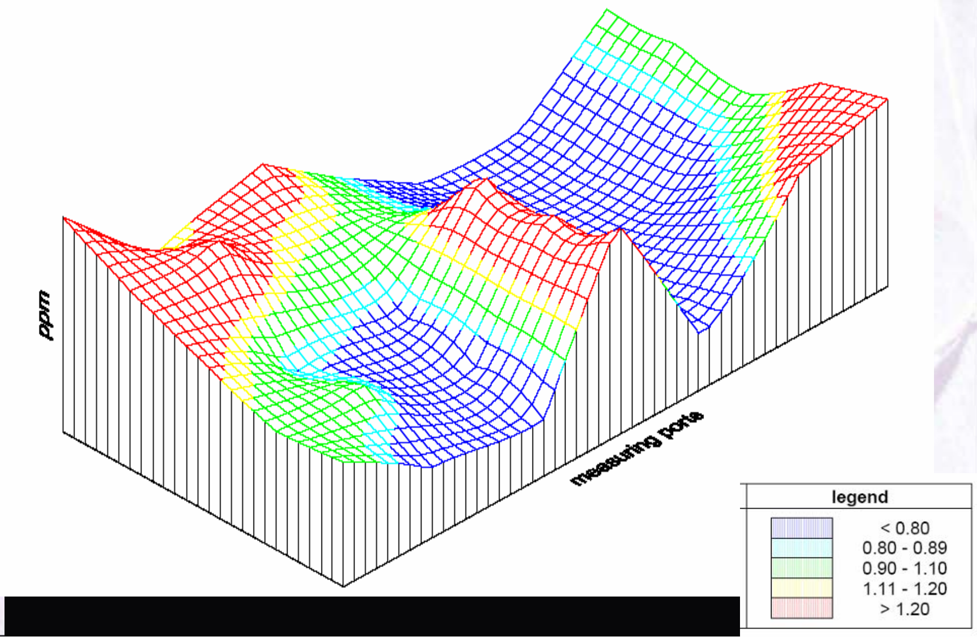
DeNOx activity requirements for year around operation

- Influence of Load Change on the NOx Outlet Distribution



AIG Tuning – After Optimization
(Full Load)
NOx outlet distribution

AIG Tuning – After Optimization
(Low Load)
NOx outlet distribution



Discussion