February 5, 2014

KCP&L LaCygne Unit 1 - CFD Modeling for SCR Optimization

EUEC Conference 2014 – Reid Thomas

AGENDA

- KCPL Problem Statement
  - Flue gas flow maldistribution and excessive flyash pluggage in LaCygne 1 SCR
- Computational fluid dynamics (CFD) & Physical Flow Modeling
  - GSG™ Graduated Straightening Grid Technology
  - Uniform-Vertical-Non Recirculating Flow
- Implementation and Installation
- Summary of Operational & Maintenance Results
- SCR and Modeling Lessons Learned

LA CYGNE UNIT 1

- KCPL LaCygne Unit 1
  - Unit 1 is a 815 MWg cyclone fired boiler
  - PRB Blend Coal
- 2 SCR reactors added to unit in 2007
- Continuous ash build up in the reactor due to poor flow
- Finacial impacts of ash build up:
  - Replacement of 8 catalyst layers in 5 years
  - Forced outages for ash removal
  - Derate due to catalyst dp

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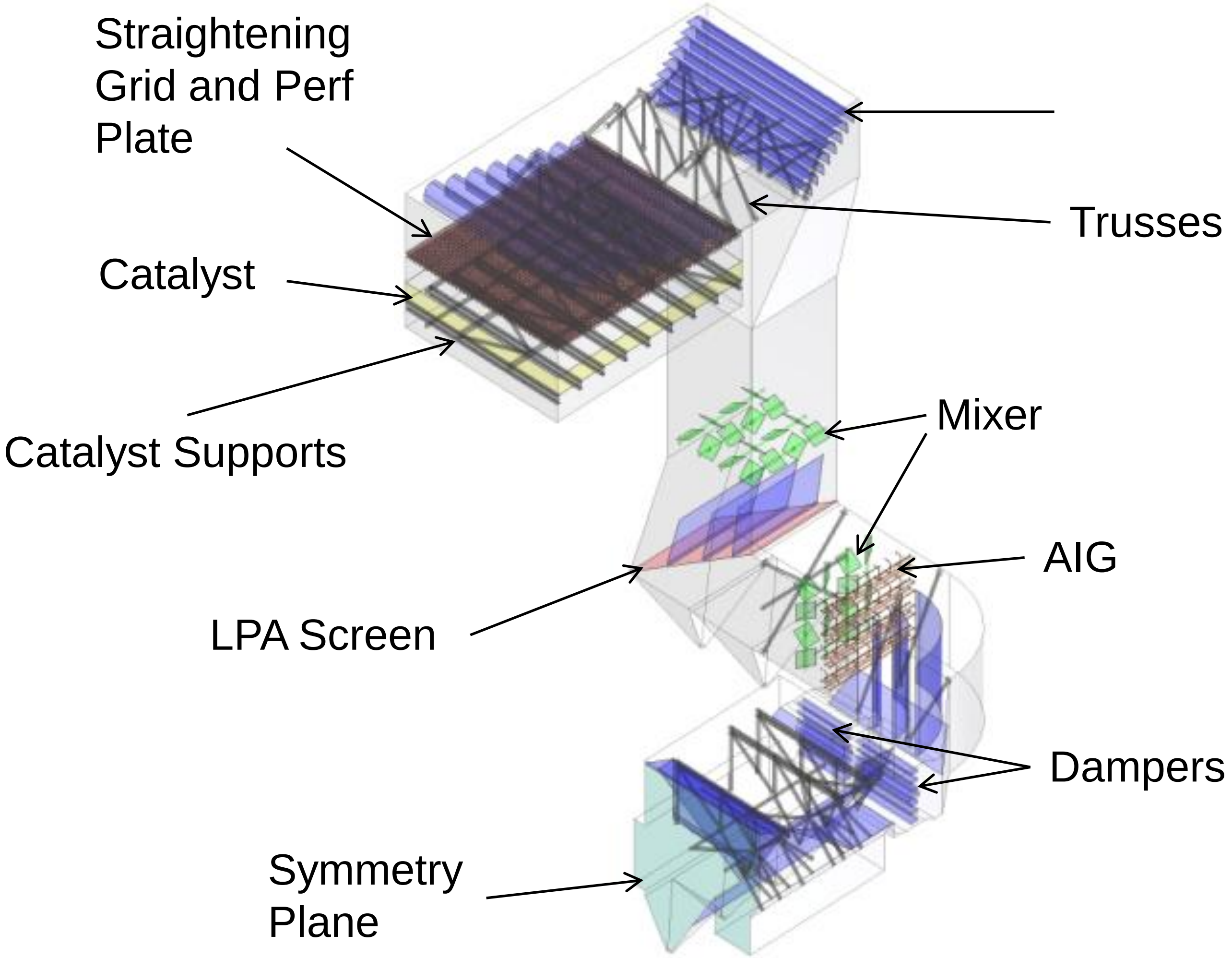
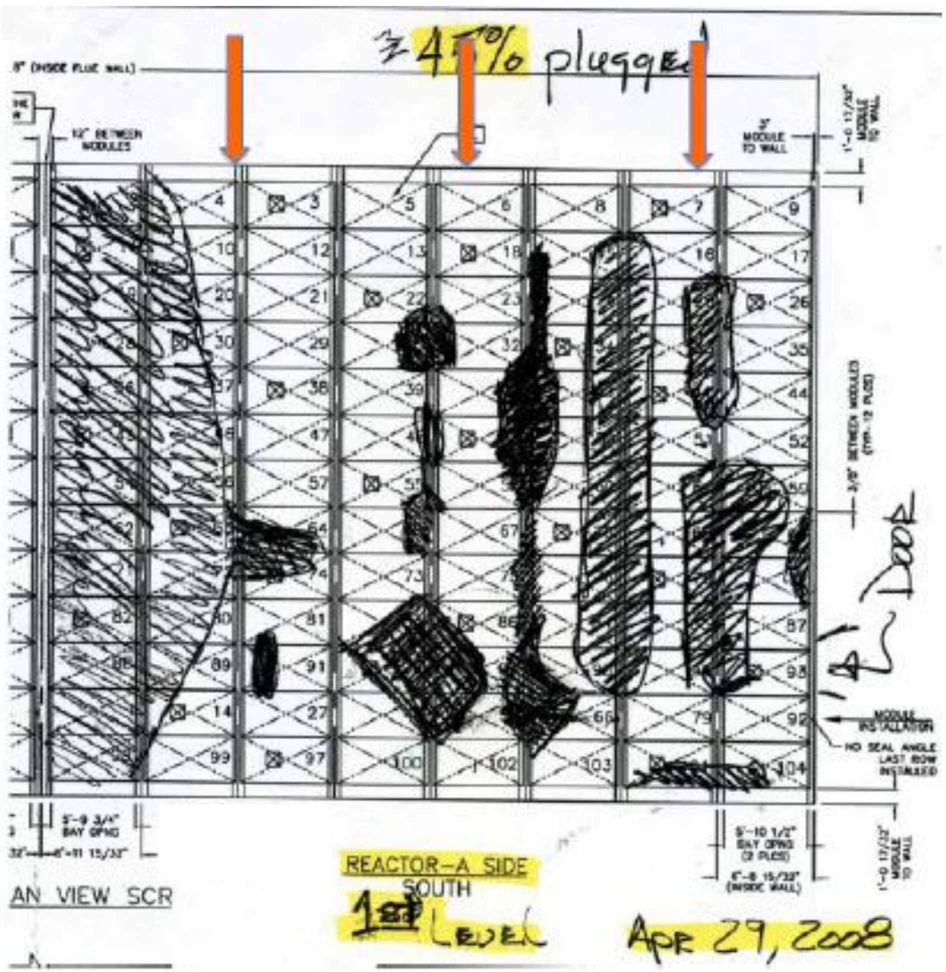
PROBLEM STATEMENT & BASELINE FLOW MODEL GEOMETRY

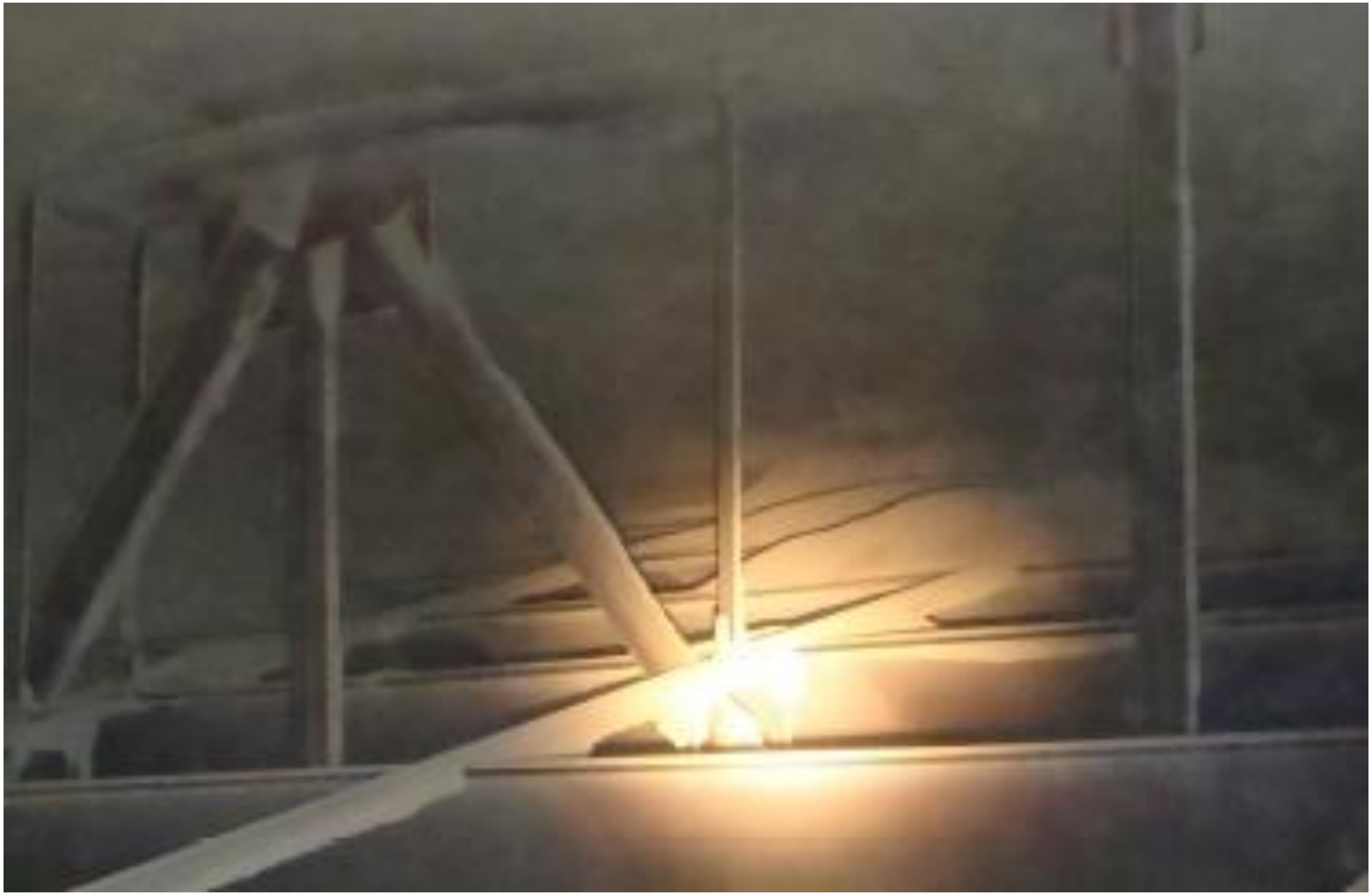


EXCESS FLYASH PLUGGAGE – LAYER 1 ASH DEPOSIT "MAP"



- After 1 year operation
- First layer 45% plugged
- Ash "rows" noted below structural supports

EXCESSIVE FLYASH PLUGGAGE – TURNING VANES



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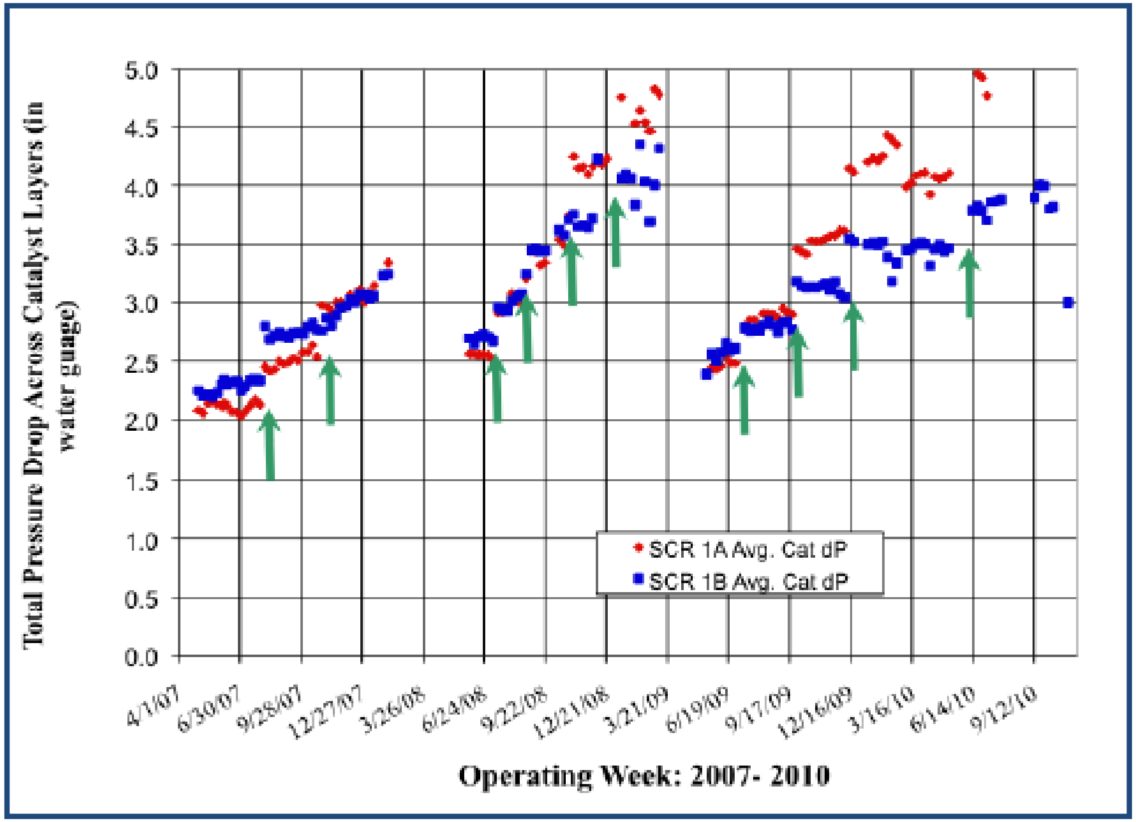
EXCESSIVE ASH PLUGGAGE – TURNING VANES



- Ash "sloughs" or falls from turning vanes after startup
- ΔP escalates following each startup
- Trend continuous from 2007 to late 2010

EXCESS FLYASH PLUGGAGE – A-SCR LAYER 2ND SEAL STRIP

FLYASH ACCUMULATION

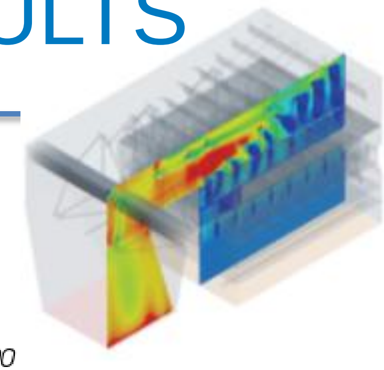
- Excessive ash removal costs
  - Catalyst cleaning was critical path during outages
- Catalyst replacement costs
- High catalyst pressure drop, fan power, and operational derates
- High NH_3 slip and increased reagent consumption

COMPUTATIONAL FLUID DYNAMICS (CFD) MODELING

CFD MODELING APPROACH & GOALS

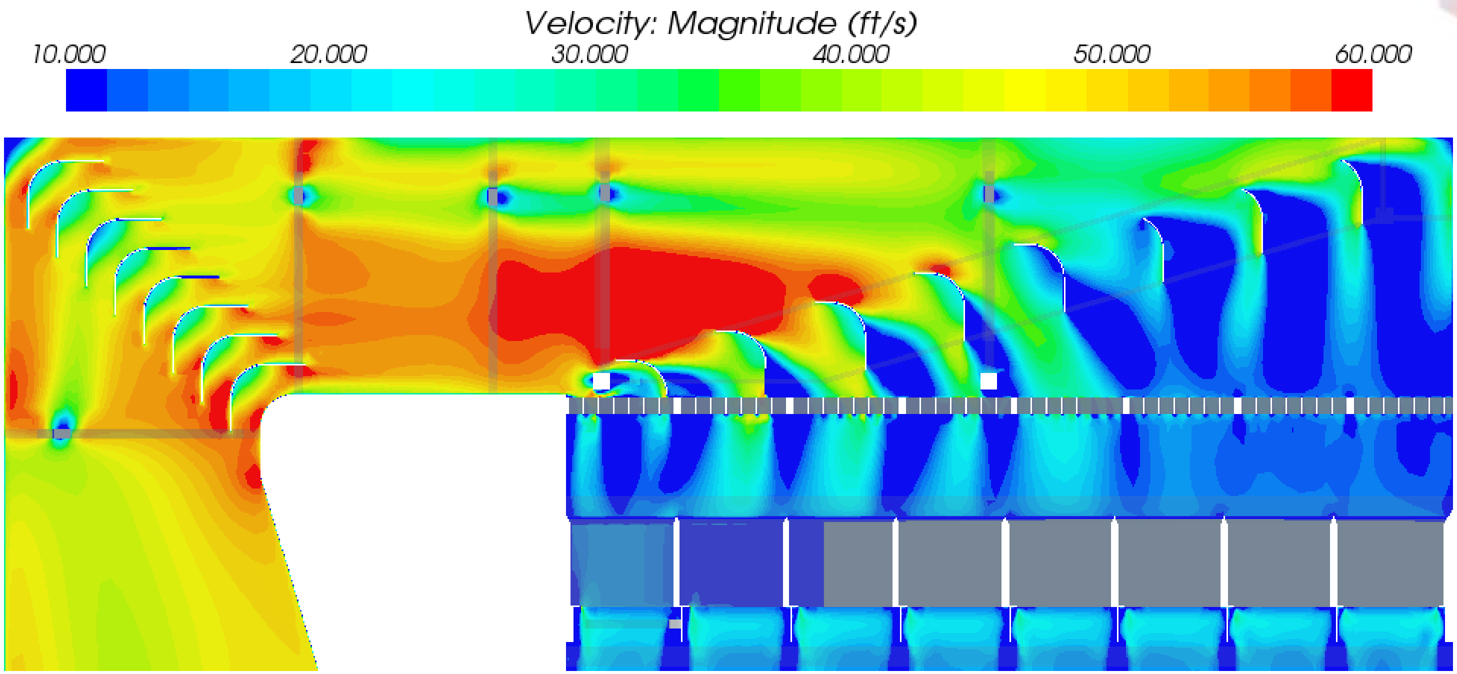
- Fuel Tech provided CFD modeling and design services for KCP&L LaCygne Unit 1
  - 2010 Initial Study to determine root cause and easy fix
  - 2012 Full Study for GSG retrofit
- Design flue gas flow distribution devices capable of improving the velocity into the catalyst reactor by 40% from the baseline
- LaCygne Unit 1 SCR system is symmetric about the boiler centerline, only one reactor (the B-side reactor) and one half of the economizer outlet duct work was modeled

CFD BASELINE VELOCITY RESULTS



STRUCTURE:
Truss & Gussets
restrict flow to back

Egg Crate STRUCTURE
disturbs flow to catalyst



High and low spots from the turning vanes are helped by the straightening grid and perforated plate but still yield a poor distribution into the 1st catalyst layer.

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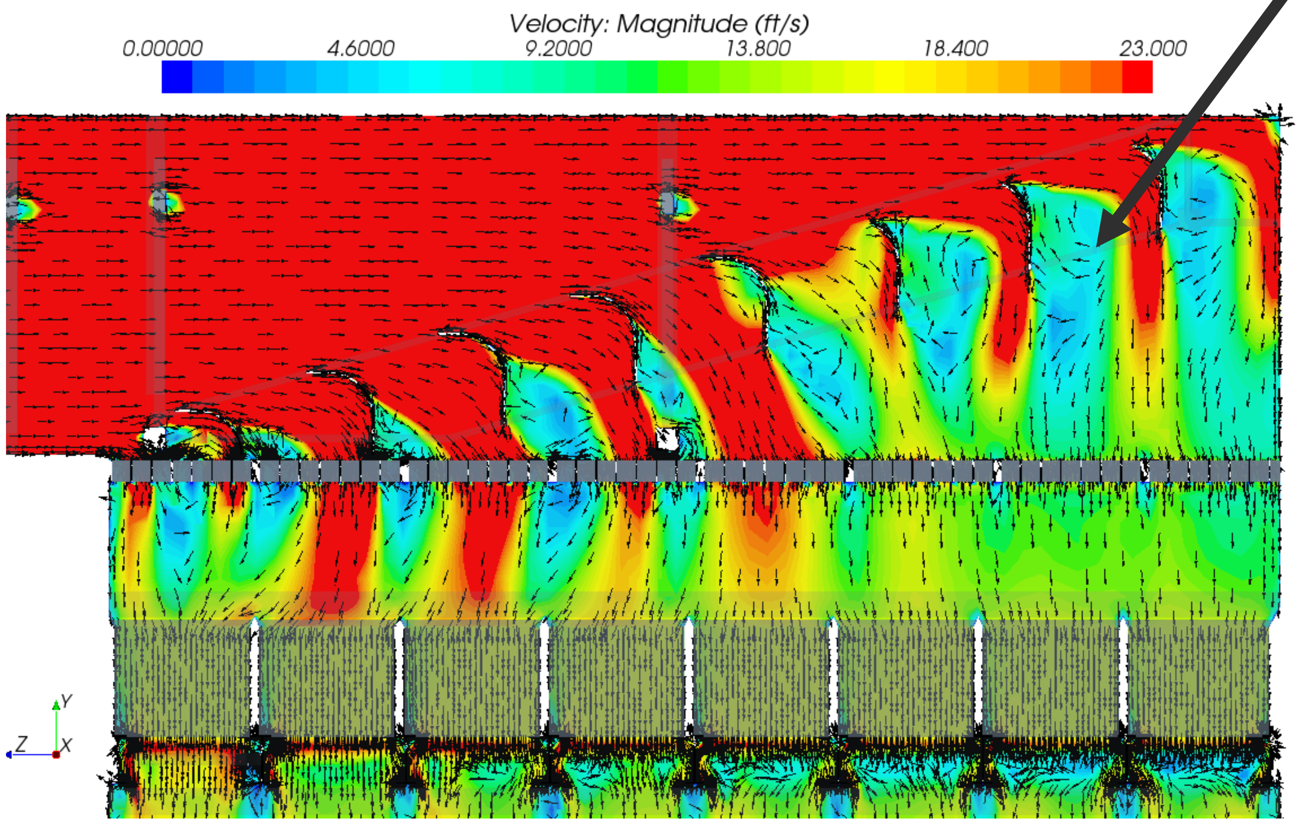
BASELINE RESULTS – VELOCITY VECTORS



TURNING VANES & RECIRC:
Turning Vanes and Perforated Plate create low flow and flow recirculation

Vectors near vanes show recirculation areas where potential ash fallout can occur.

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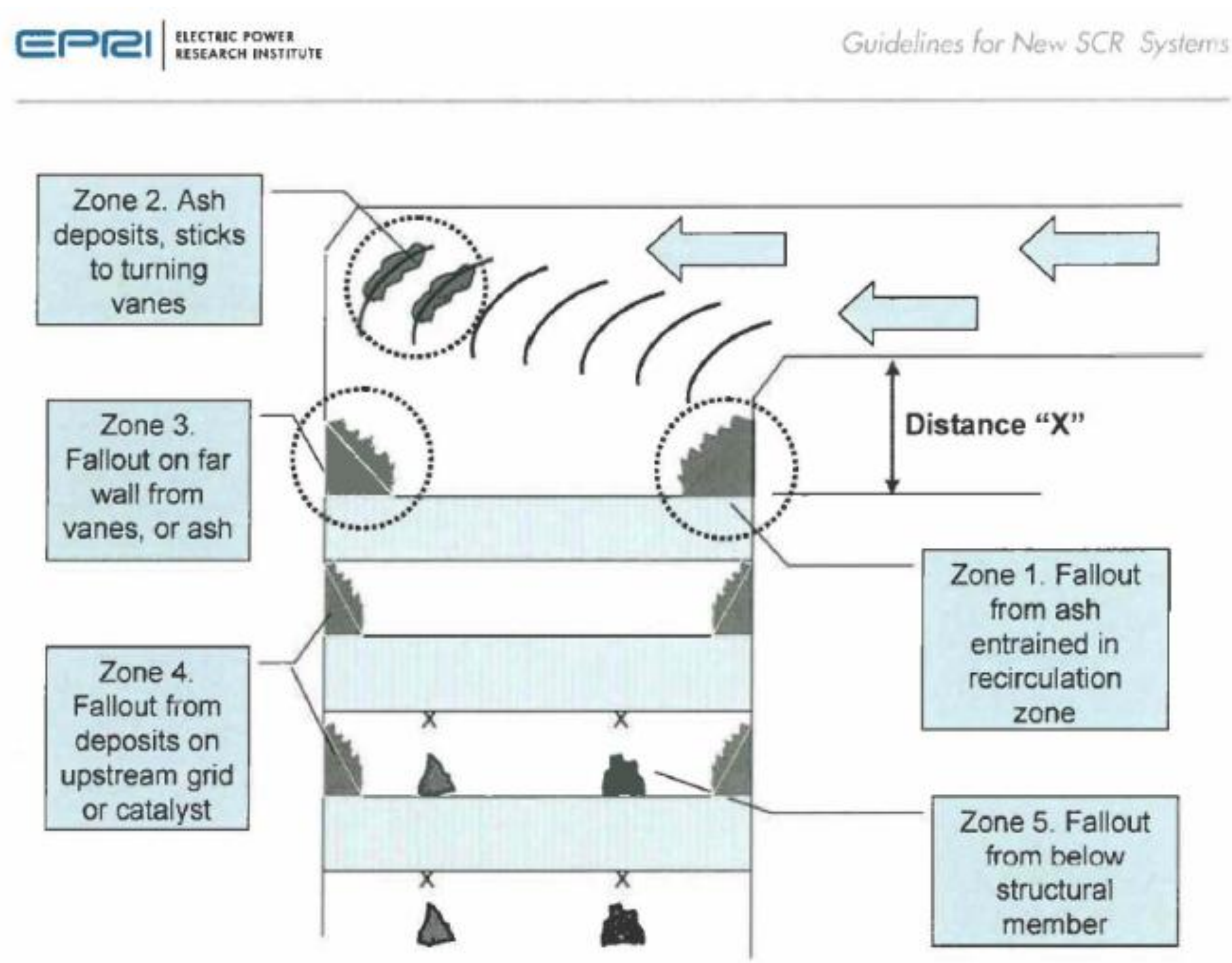
ASH BUILDUP AND FLOW RECIRCULATION



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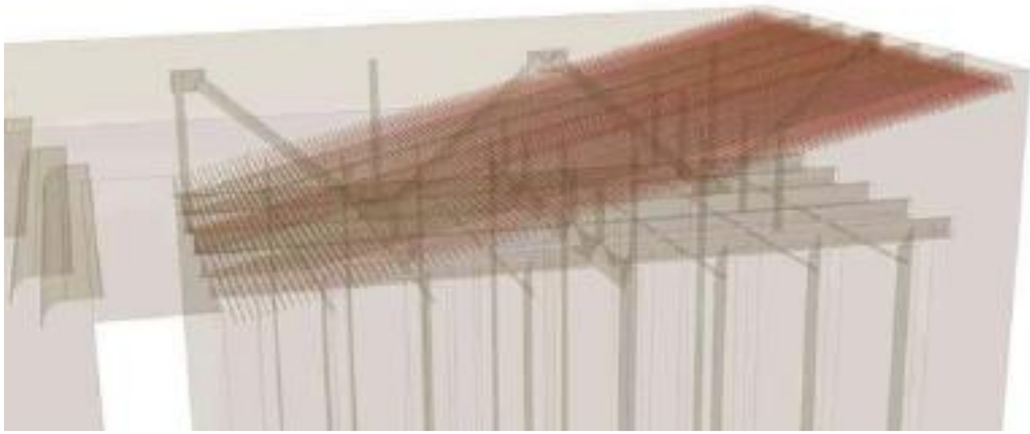
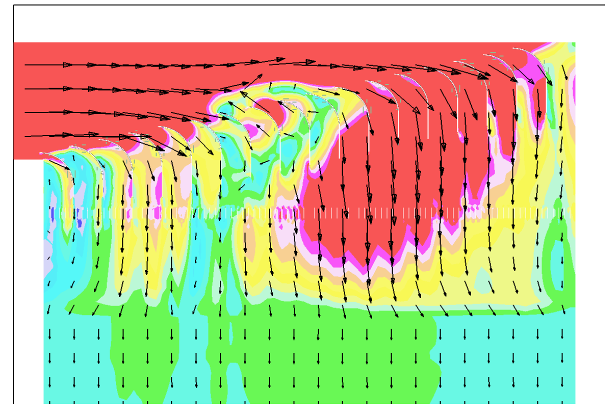
CFD AND EXPERIMENTAL MODELING

- Multiple CFD runs to reach optimized solution
- 1:12th Scale Experimental model tests of optimized solution:
  - Velocity profiles at catalyst
  - Pressure drop
  - Ash fallout
- GSG optimization
- Converged results of CFD and experimental model

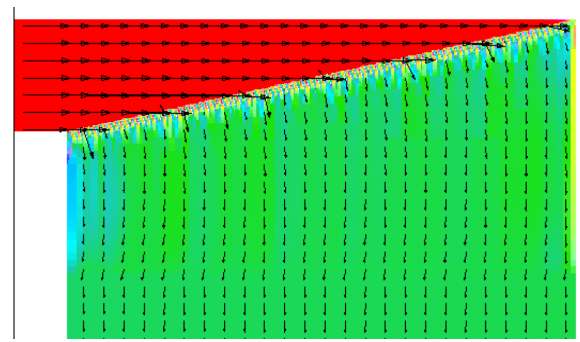
GSG™ GRADUATED STRAIGHTENING GRID FLUID DYNAMICS - PATENTED



- Dramatically Improves Flue Gas Velocity Distribution without Increasing Cost, Complexity or Compromise on Performance
- Minimizes Angle at which Ash Particles Enter Catalyst, Near Perfectly Vertical Flow into Catalyst
- Innovative Design Allows for
  - Higher Flue Gas Velocity, Improved Operating and Financial Performance via Longer Catalyst Life and Reduce Downtime
  - Reduction in Time Required to Tune Ammonia Injection Grid
  - Higher Flue Gas Velocity Translates into Smaller Cross-section and , Lower Capital



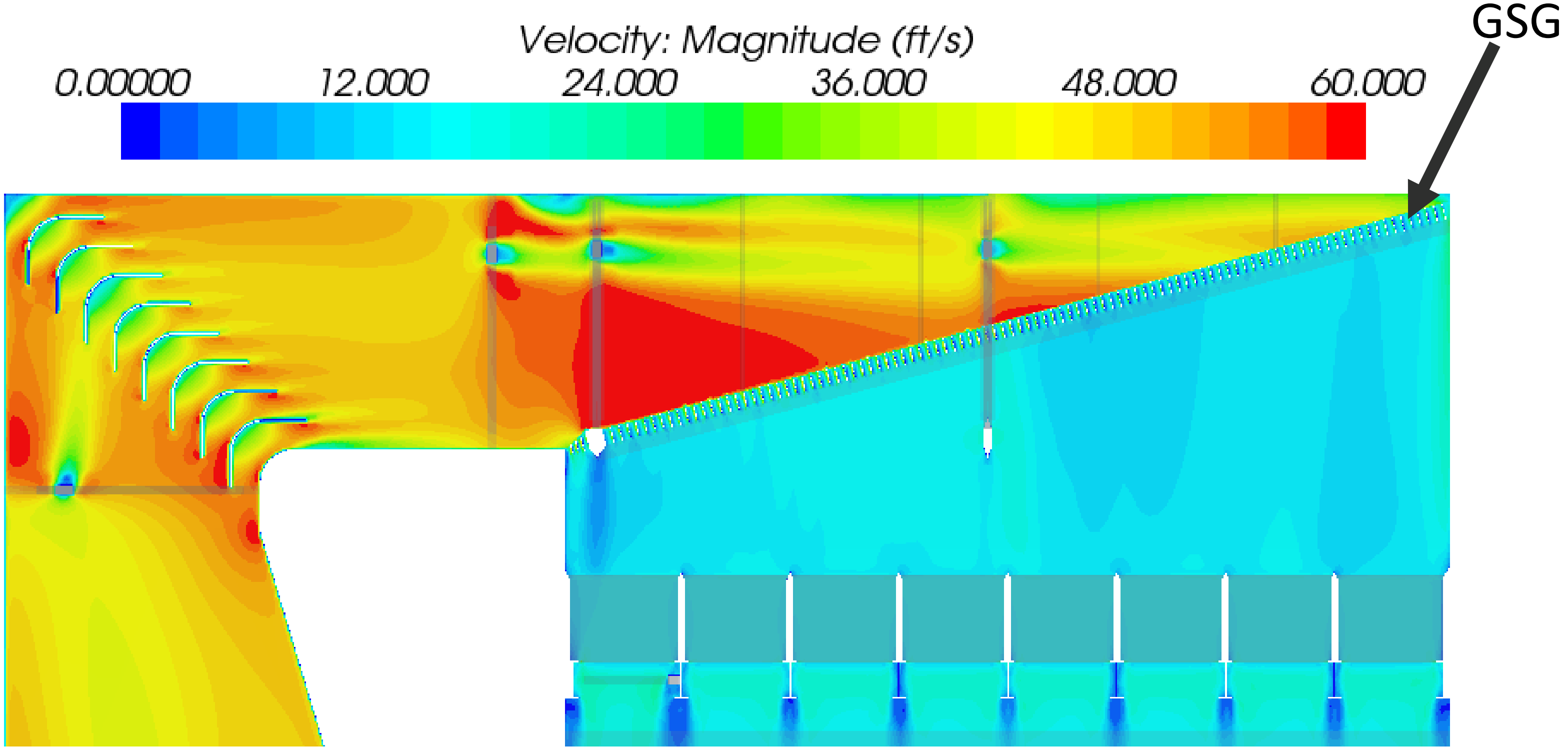
Typical Arrangement



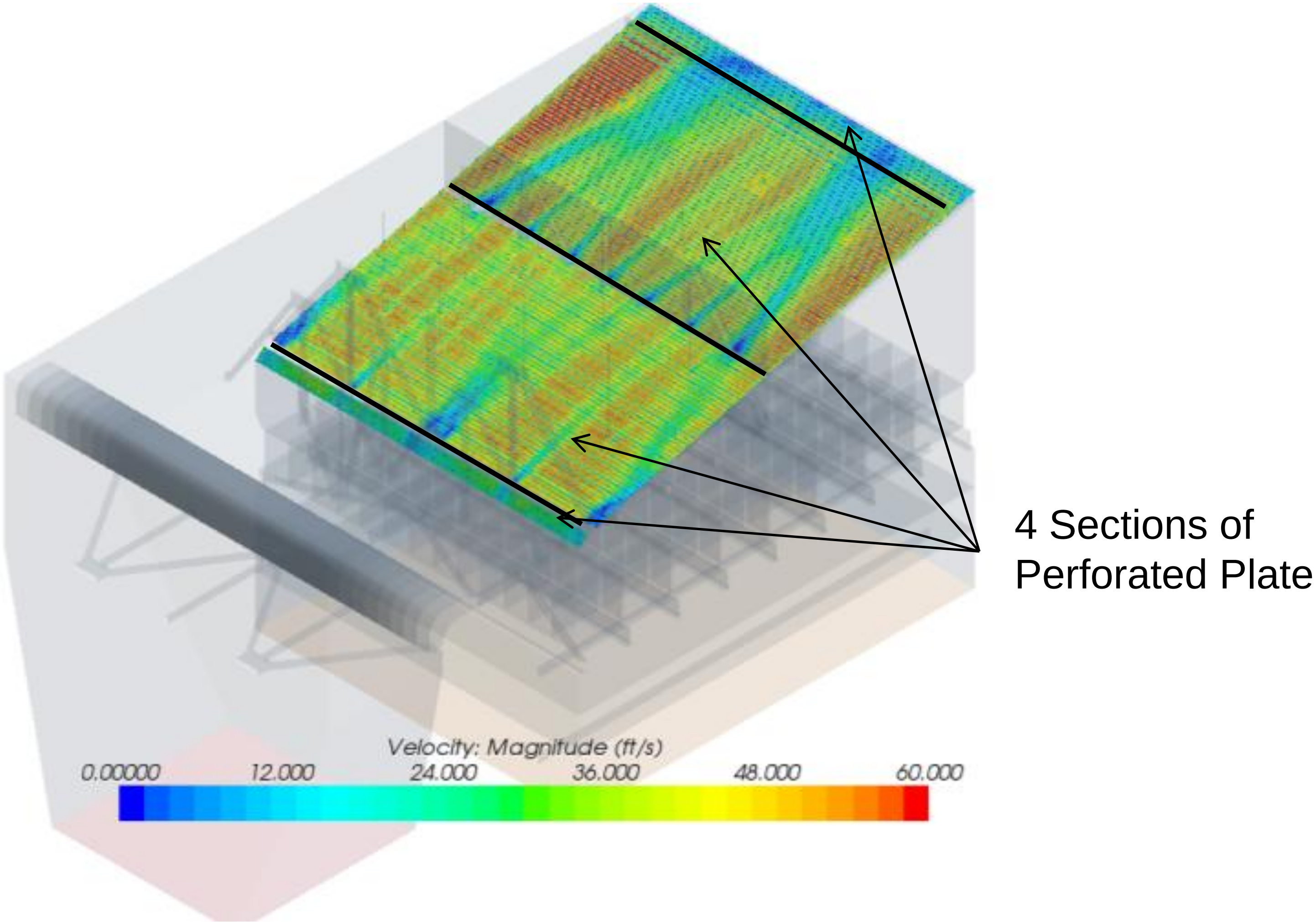
GSG Arrangement

CFD FLOW MODELING AND GSG BENEFITS

- GSG with variable perforated plate eliminates turning vane and recirculation zone
- Structural egg crate members removed

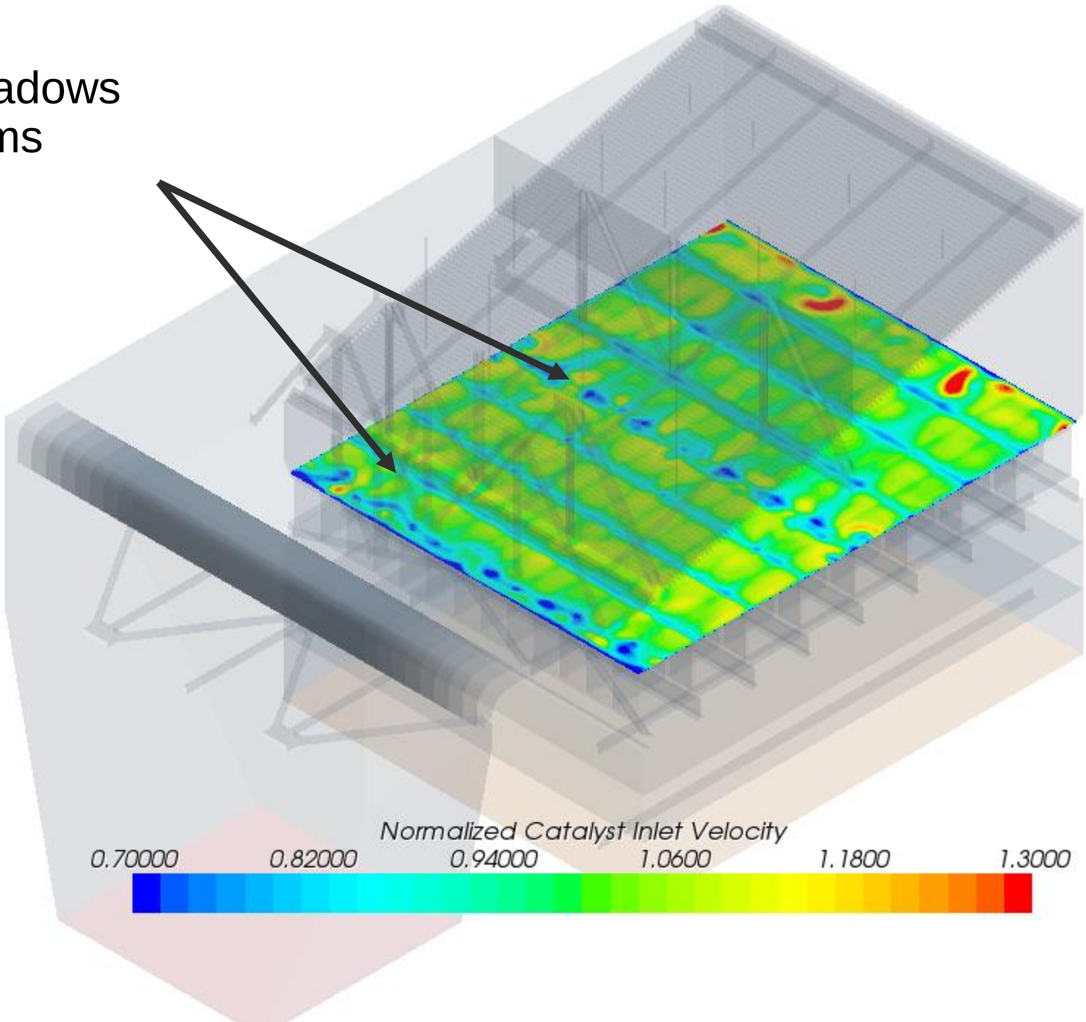


CFD OPTIMIZED RESULTS (GSG) - VELOCITY



OPTIMIZED RUN RESULTS (REACTOR) - VELOCITY

Smaller shadows below beams



Catalyst Inlet Velocity – 9.5% RMS

CFD FLOW MODELING BENEFITS & RESULTS

	Baseline	GSG	Desired
Flow +/- 15%	58%	91%	100%
Flow +/- 30%	94%	99%	Not Used
RMS	17.5%	9.5%	Not Used

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CONSTRUCTION & IMPLEMENTATION

DEMOLITION OF EGG CRATE STRAIGHTENER AND SUPPORTS

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GSG PANEL INSTALLATION

GSG PANEL INSTALLATION

OPERATING RESULTS

SIGNIFICANT REDUCTION OF ASH BUILDUP AFTER 4 MONTHS

Before – Structure sloughs and recirculation causing excessive buildup

After – Modified beam internal structures and "tent" shaped catalyst seals

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RESULTS AT 4 MONTHS

LAYER 2 – 2ND SEAL STRIP

LAYER 2 DIVISION WALL

2013 FALL OUTAGE

- Recent fall outage showed ash build up along the shared wall:
    - During vacuuming a hard crusted layer of ash was found attached to the catalyst
    - During the previous outage in January the SCR dampers failed to close allowing cold moist ambient air to reach the catalyst
    - The flyash absorbed the moisture and solidified on the honeycomb layers
    - Once the unit restarted, ash built up on the crusted solid layer causing the complete blockage near the shared wall
    - Patented cleaning method using dry ice was used to remove the hard ash layer.

GSG BENEFITS FOR LACYGNE UNIT 1 OPERATION

- Improved flue gas flow distribution and reduced fly ash accumulation resulting in:
  - Reduced catalyst replacement costs. The next catalyst layer replacement budgeted after 2019, resulting in one layer being replaced after 7 years of operation
  - Reduced fly ash vacuum removal costs/reduced complexity of outages
  - Reduced catalyst pressure drop and fan power costs eliminating de-rate of Unit
  - Reduced ammonia slip and ammonia reagent costs. The lower ammonia slip also reduces FGD foaming that can damage ID Fan
- $5MM in realized operating & maintenance cost savings

KEY SCR DESIGN REQUIREMENTS AND LESSONS LEARNED

- Uniform, vertical, non-recirculating flow into catalyst
- Flue Gas flow design criteria – 15% from Mean vs. RMS or Cv
- CFD and Physical Modeling – Complimentary design activities. Matching results validate each model.
- Flow Modeler needs to have SCR experience & PRB coal experience
- Flow model resolution – 5MM to 10MM cells SCR Hood to Layer 1
- Equipment modeled – 6” in physical / all flow disturbances in CFD

LESSONS LEARNED - CONTINUED

- Minimal structure inside SCR reactor and flue gas ductwork – flow disturbances
- Minimize horizontal surfaces – PRB ash accumulates on any surface
- Catalyst pitch – minimum 8.2 mm Honeycomb or 5.7 mm plate
- Outage layup – keep SCR hot or use heaters to prevent condensation
- Sonic horn failures – Moisture and PM
- LPA screen failures – Erosion or layout
- Outage ash cleaning method – vacuum to catalyst face
- Inspections and Monitoring – catalyst management program

CONTACTS AND QUESTIONS

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