SCR Flow Modeling

• Basic Introduction

• Case Studies
  – Scherer 3 & 4 (Physical Model, design phase)
  – Miller 3 (CFD, to address maintenance concerns)
Why is Flow Distribution Important to SCRs?

• Performance
  – Gas velocity uniformity
  – Uniform NH3-to-NOx ratio
  – Thermal mixing
  – Ash capture / build-up

• Operating costs
  – Pressure drop
  – Erosion
  – Corrosion
Fluid Dynamic Design Methods

- Physical Flow Modeling
  - Lab representation of geometry
  - Typical scale 1:8 to 1:16
  - “Cold flow” modeling
  - Visualize flow with smoke
  - Simulate ash deposition
  - Measure flow properties:
    - velocity, pressure, tracer gas
Typical 1/12 scale physical model

- Turning vanes
- AIG w/static mixers
- Economizer bypass
- Economizer outlet
- LPA screen
- Vanes
- Rectifier
- Catalyst layers
- Air heater
- Dampers
Fluid Dynamic Design Methods

• Computational Fluid Dynamics (CFD)
  – Numerical simulation of flow
  – Utilize high speed computers and sophisticated software
  – Calculate flow properties
    • Velocity & Pressure
    • Temperature
    • Ammonia
    • Particle streamlines
SCR Performance Goals

• Uniform velocity
• Uniform temperature
• Uniform NH3-to-NOx ratio
• Avoid ash build up, LPA carryover
• Minimize DP
SCR Velocity Distribution

- Velocity profile
  - At AIG
  - At SCR inlet
  - At AH inlet

- Directionality
  - At SCR inlet
SCR Thermal Mixing

- Economizer gas bypass used to boost SCR inlet gas temperature under low load operation
- Extract hot gas at econ inlet
- Inject into cooler econ outlet stream
- Sounds simple enough, but there are many options and competing design elements

Without mixer, $\Delta T = \pm 83 \, ^\circ F$

With mixer, $\Delta T = \pm 15 \, ^\circ F$
SCR Ammonia Injection

- Tracer gas in physical model
- Species tracking in CFD
Ash Deposition

- Duct floors
- Turning vanes
- Catalyst
Ash Deposition – Model Testing

- Drop out
- Re-entrainment
Model Accuracy

- Data for detailed correlation between models and actual plant operations is unfortunately limited
  - Detailed traverses at catalyst often not performed
  - Data in ductwork sometimes available
  - Tend to go by industry experience on whether catalyst performance goals are met
- In cases where CFD and physical models are both used, predictions are often within engineering tolerances (~10-20%), but not always
- Further analysis is needed and in progress
Points to Remember

• Gas flow patterns have significant impact on the performance of SCRs
• Analysis and design tools include physical and CFD flow modeling
• Models are used to optimize the design of flow control devices to achieve fluid dynamic goals
  – Ductwork, turning vanes, baffles
  – Mixers, injection systems
  – LPA mitigation baffles, screens, and hoppers
2 Case Studies

• Scherer 3 & 4 Physical model
• Plant Miller CFD models
Case 1 Scherer Units 3 & 4 SCR Modeling

• New SCRs on existing Units
Project Overview

• Objective
  – Develop design of flow devices to optimize SCR performance

• Methods
  – Modeling for flow device design and NH3 mixing verification

• Domain
  – Start at Economizer
  – End at Air Heater Inlet

• Flow conditions
  – Peak, Full, Minimum and Bypass Mode
Modeling Goals

• Flow uniformity
  – Velocity downstream of AIG:
    80% of pts within 10% (Target) or 15% (Min) of avg, 100% of pts within 15% of avg
  – Velocity upstream of LPA Screen:
    100% of pts within 15% of avg
  – Velocity at reactor inlet:
    90% of pts within 10% (Target) or 15% (Min) of avg
    100% of pts within 15% (Target) or 20% (Min) of avg
  – Velocity at Air Heater:
    100% of pts within 25%(Target) or 35% (Minimum) of avg
  – NH3 Distribution at reactor inlet:
    <3% RMS (Target), <5% (Minimum)

• Minimize pressure drop
• Avoid ash accumulation
## Model Results Overview
### Peak Load

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Target Goal</th>
<th>Model Result -Peak</th>
</tr>
</thead>
<tbody>
<tr>
<td>Velocity Downstream AIG</td>
<td>80% of pts within 10% of average</td>
<td>97.9%</td>
</tr>
<tr>
<td>Velocity Downstream AIG</td>
<td>100% of points within 15% of average</td>
<td>100%</td>
</tr>
<tr>
<td>Velocity Upstream LPA Screen</td>
<td>100% of points within 15% of average</td>
<td>54.3%</td>
</tr>
<tr>
<td></td>
<td>* goals changed during project</td>
<td></td>
</tr>
<tr>
<td>Velocity Upstream first catalyst</td>
<td>90% of points within 10% of average</td>
<td>96.3%</td>
</tr>
<tr>
<td>Velocity Upstream first catalyst</td>
<td>100% of pts within 15% of average</td>
<td>97.5%</td>
</tr>
<tr>
<td>NH3 Distribution</td>
<td>RMS &lt;3%</td>
<td>2.6% RMS</td>
</tr>
<tr>
<td>Velocity at Air Heater Inlet</td>
<td>100% of points within 25% of average</td>
<td>87.5%</td>
</tr>
<tr>
<td></td>
<td>min goal 100% of pts within 35% of avg</td>
<td>100%</td>
</tr>
<tr>
<td>Total pressure drop, economizer outlet to air heater inlet</td>
<td>Excluding catalyst pressure loss</td>
<td>3.89&quot;H2O</td>
</tr>
</tbody>
</table>
Physical Model

- **Methodology**
  - 1/12 scale model represents geometry
  - Scaled flow rates to match velocity head between model and full scale
  - Incorporates important structure (vanes, trusses)
  - Catalyst modeled as honeycomb and perforated plates

- **Measurement techniques**
  - Velocities using vane anemometer, hot wire
  - Pressures using pitot probe
  - Ammonia injection simulated with tracer gas
  - Ash drop-out and re-entrainment simulated with salt
Physical Model Results Summary

Test Plane
Ash Testing

• **Purpose**
  - Determine areas where ash will drop out at reduced loads
  - Examine if ash is properly re-entrained when higher load is restored

• **Assumptions**
  - Model dust behaves similarly to ash
    » Utilize wind tunnel data to compare model dust to actual ash
    » Run model at correct velocity ratio to provide best comparison
  - Ash is not wet, cindered/hardened, packed solid in a cavity, etc.
Ash Deposition Testing Process

- Low load velocity setting
- Dust injected at economizer and downstream of AIG
- Dust injected until a stable depth was achieved
Ash Re-Entrainment Testing Process

- Dust was deposited on horizontal surfaces to approximately 0.5-1" depth
- Flow was slowly increased to full load velocity
- Ash re-entrainment was observed and documented
Case 2: Miller Econ Hopper Screen Pluggage
What’s the Problem?

- Pleated Screen

- DP slowly increases as the unit runs

- Why? LPA screen becomes plugged
Geometry
Pleated Screen Details Must Be Included
Particle Characterization

- Plugging particles measured
- Drag and rebound characteristics of LPA
How to model changes due to buildup?

- 3 conditions modeled:
  - Clean, partially plugged, strongly plugged
5mm Particles Striking the Screen

- Clean on right, strongly plugged on left
Some Shift in Pluggage Pattern over Time

- Clean
- Partial Plugged
- Strongly Plugged
Design Changes - Baffles
Design Changes – “Hats”
Drastically Reduced Impacts

- Baseline on left, final design on right
DraSTICALLY REDUCED IMPACTS
Results

- Initial results, through June 2008, indicate that pressure drop across the screen versus time is staying reasonably stable
- Ian Mylenbush will present recent outage observations
Case 3: Plant Miller Unit 3 SCR Hood Vanes

- Hood vanes designed by original flow modeler
- Severe ash buildup found on the vanes
- Periodically, clumps of ash would avalanche down into the SCR
- How to reduce the buildup?
Hood Vane Geometry

- Big, arching vanes
Buildup
Buildup
Baseline CFD results

- Large areas of low velocity on back sides of vanes
- Ash buildup a concern under 25 fps
Options?

• Replacing vanes wholesale is deemed too expensive/intrusive
• 3 possible vane modifications stand out
• Critical that modification does 2 things:
  – Reduce ash accumulation
  – Retain flow uniformity at catalyst inlet
Design 1

- Long slots cut in vanes
  - 2 slots in each vane along entire width of the vane
Design 1 Results

- Reduced low-velocity zones between vanes
- Baseline on left, Design 1 on right
Design 2

- Angle iron on underside of vanes
Design 2 Results

- Regions of low velocity are no longer in areas where buildup can occur
- Baseline on left, Design 2 on right
Design 3

- Perforate a portion of each vane
- Very challenging to model – hole details must be included
  - 3d “slice” model employed
  - Inlet conditions differed – new baseline run
Design 3 Results

• Minor global changes, but definite local changes near holes
Which to select?

• All three seem to offer significantly reduced ash accumulation, varying level of difficulty to install
• Plant decides to perform an experiment – install all three in different areas
Questions?