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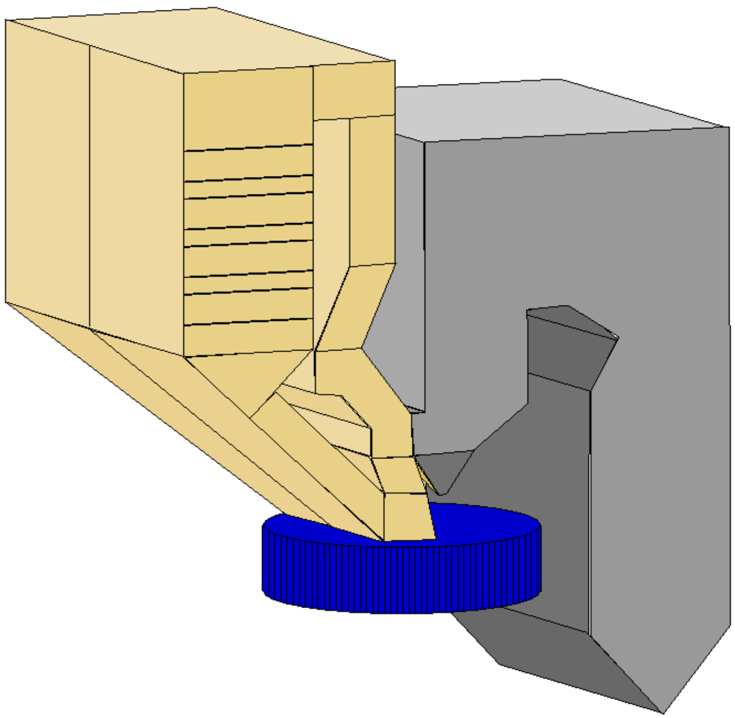
SCR Flow Modeling

- 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



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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

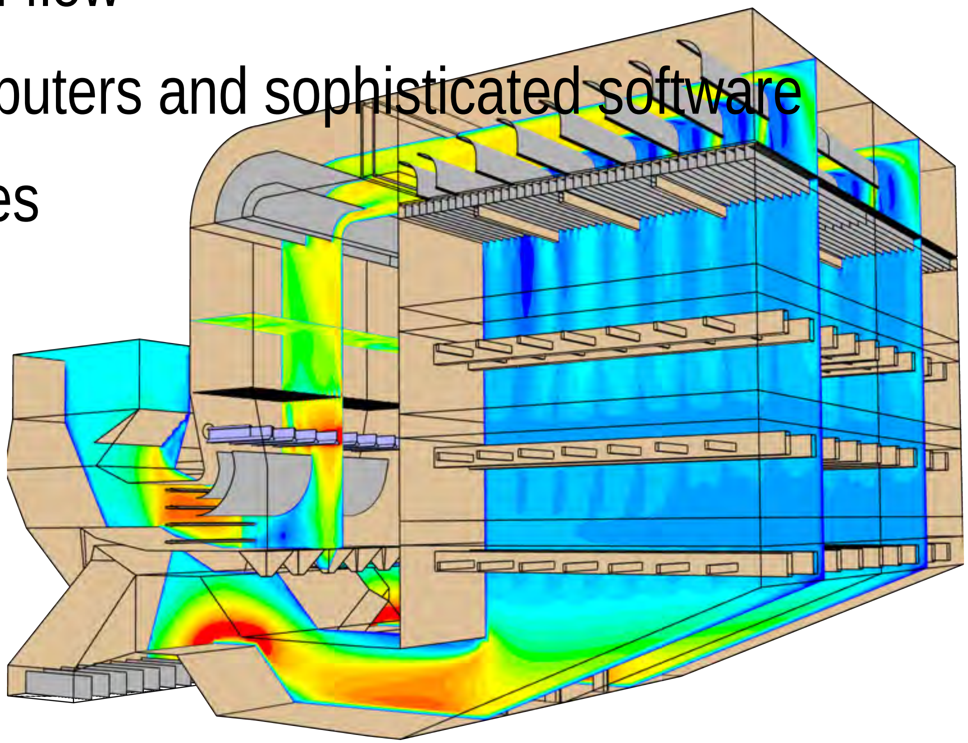
Typical 1/12 scale physical model

- 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



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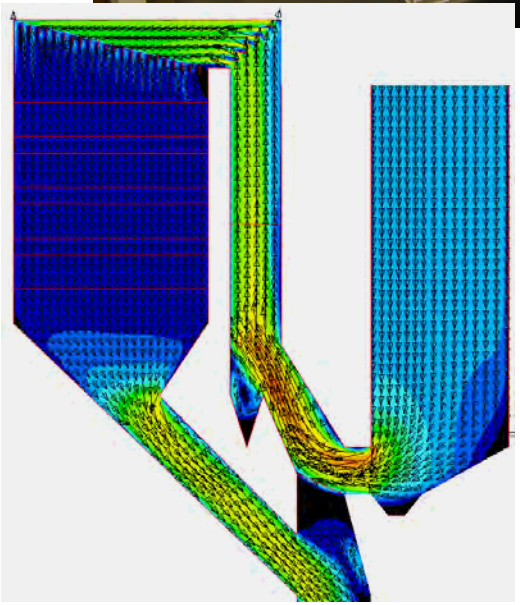
SCR Performance Goals

- Uniform velocity
- Uniform temperature
- Uniform NH_3-to-NO_x ratio
- Avoid ash build up, LPA carryover
- Minimize DP

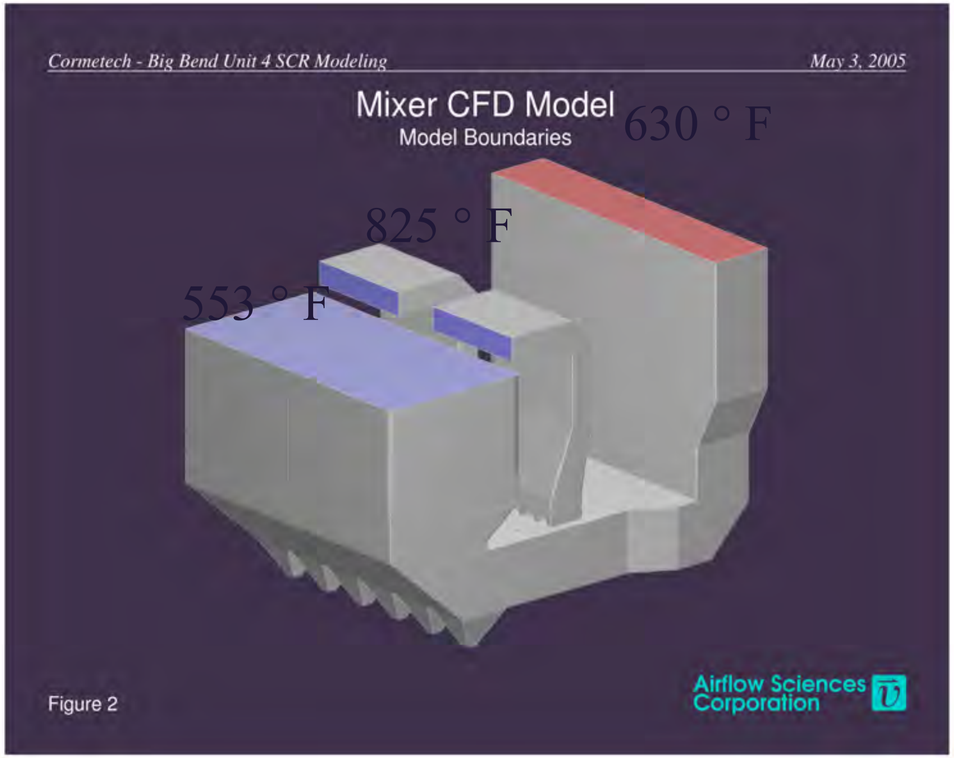


SCR Velocity Distribution

- 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, $\Delta T = \pm 83$ °F

With mixer, $\Delta T = \pm 15$ °F

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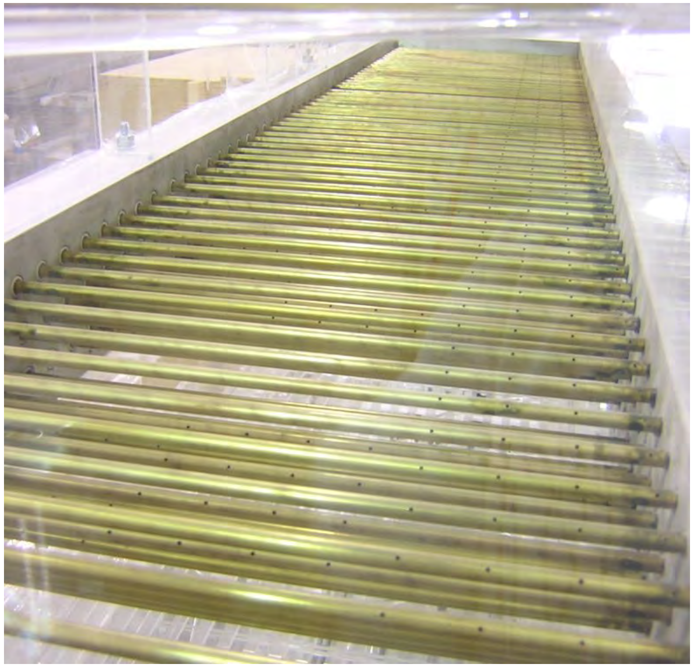
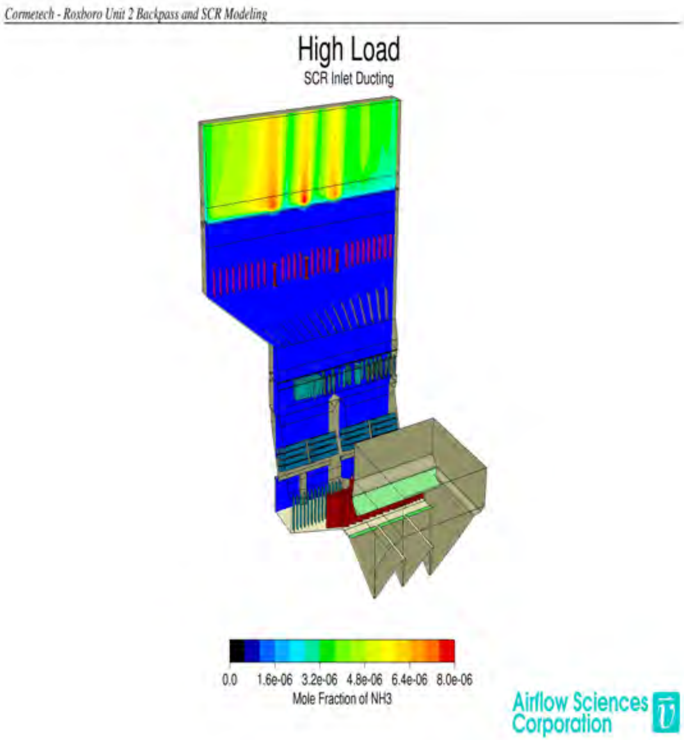
SCR Ammonia Injection

- Tracer gas in physical model
- Species tracking in CFD





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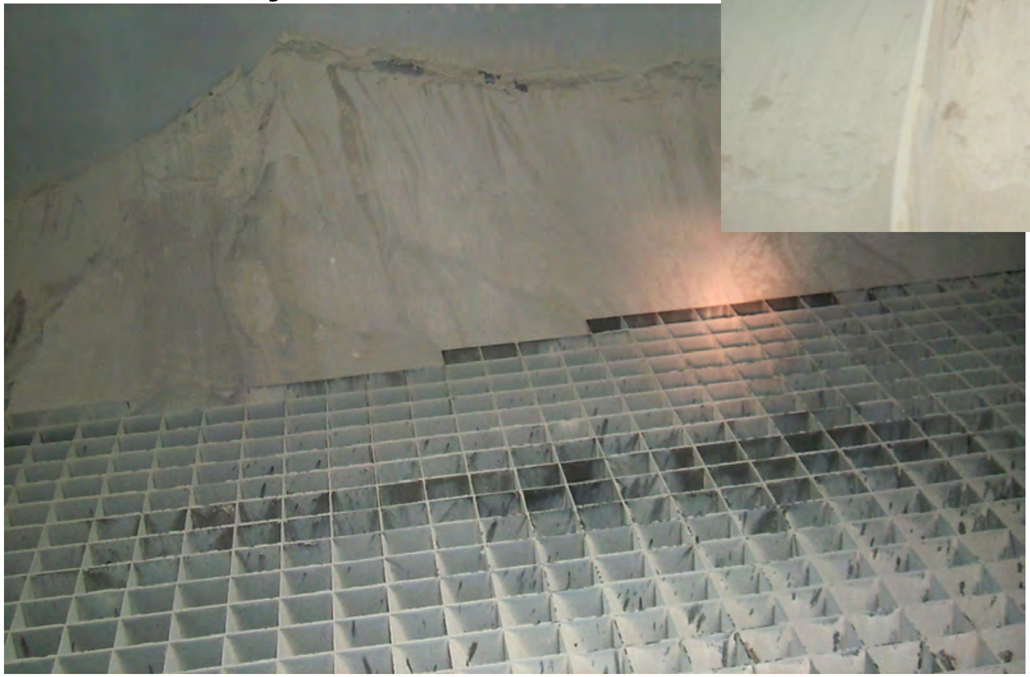
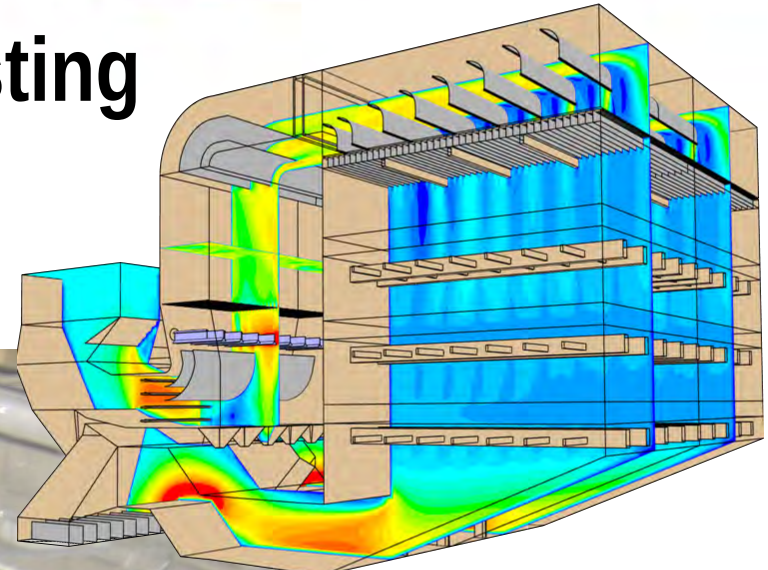
Ash Deposition

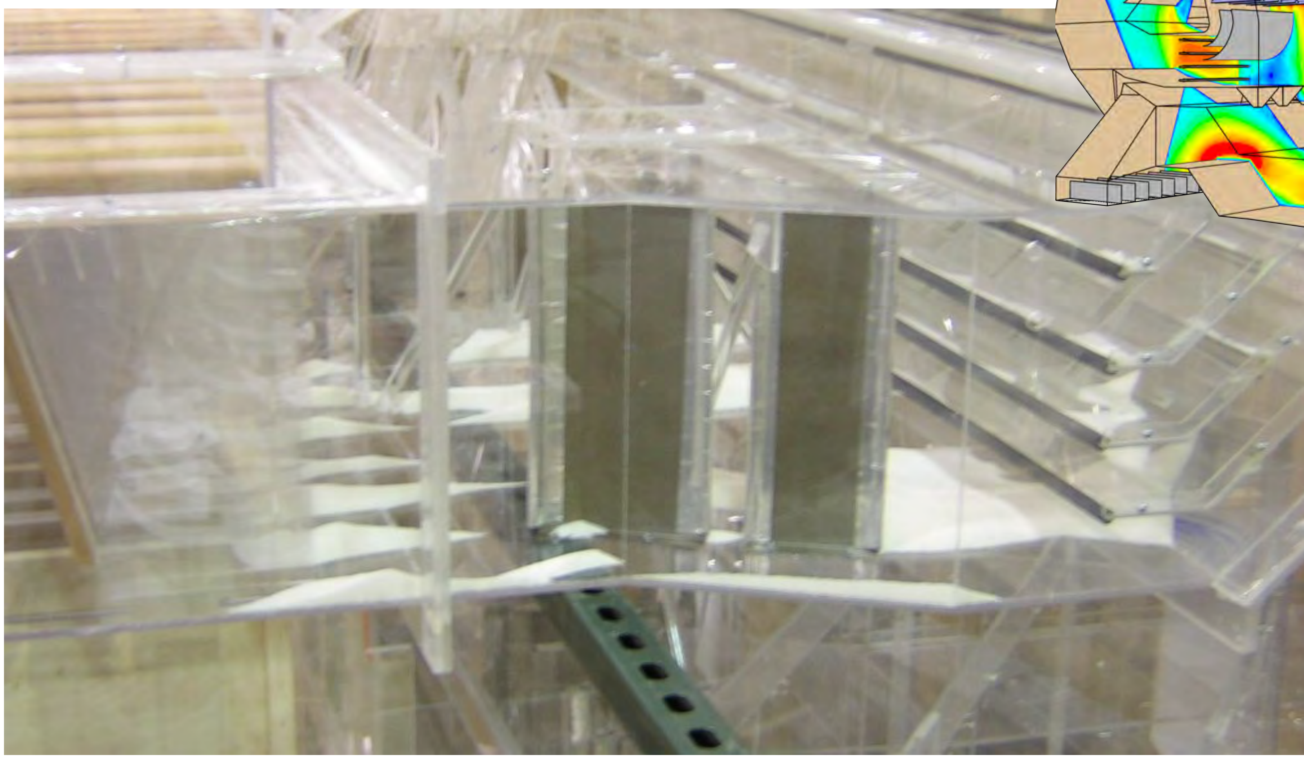
- Duct floors
- Turning vanes
- Catalyst



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

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Project Overview

- Objective
  - Develop design of flow devices to optimize SCR performance
- Methods
  - Modeling for flow device design and NH_3 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
  - NH_3 Distribution at reactor inlet:
    <3% RMS (Target), <5% (Minimum)
- Minimize pressure drop
- Avoid ash accumulation

Model Results Overview
Peak Load

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

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

Ash Testing

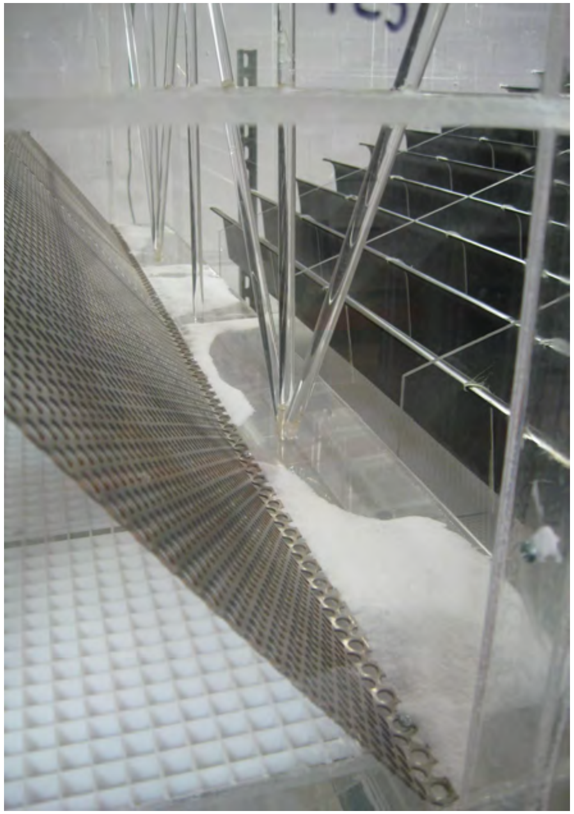
- Purpose
  - Determine areas where ash will drop out at reduced loads
  - Examine if ash is properly re-entrained when higher load is restored
- Assumptions
  - Model dust behaves similarly to ash
    - » Utilize wind tunnel data to compare model dust to actual ash
    - » Run model at correct velocity 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



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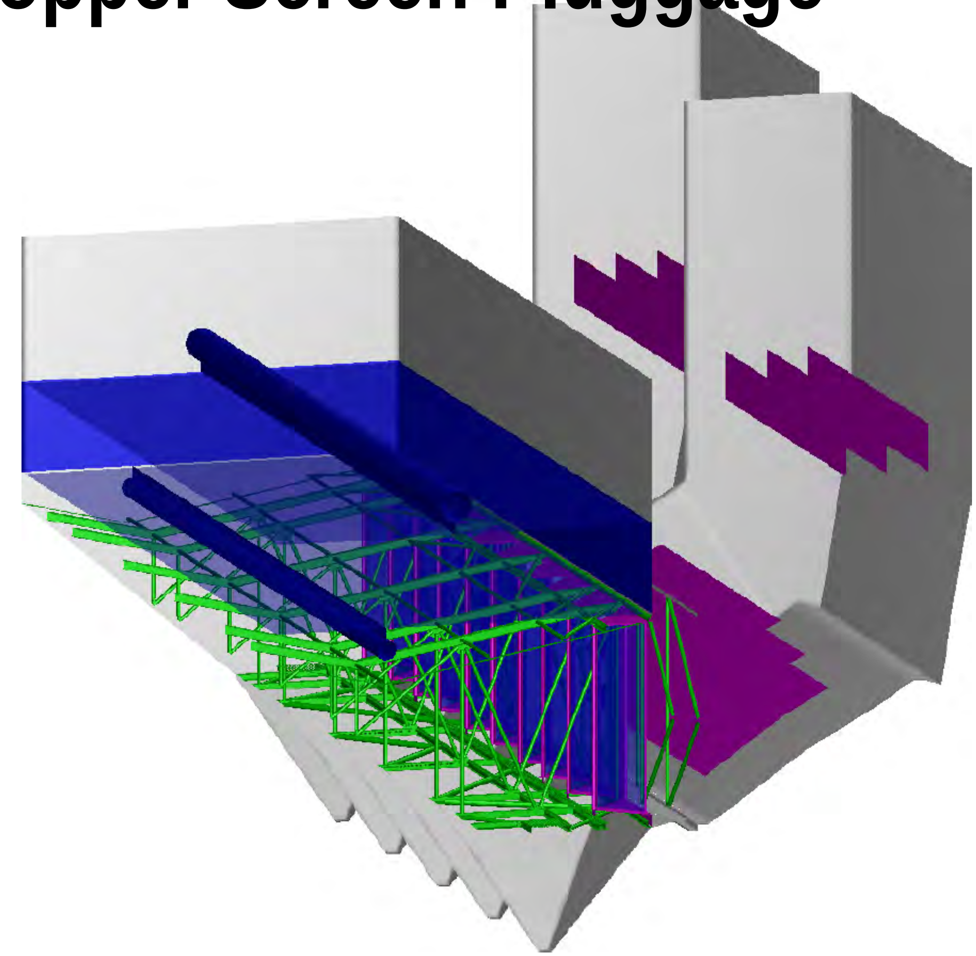
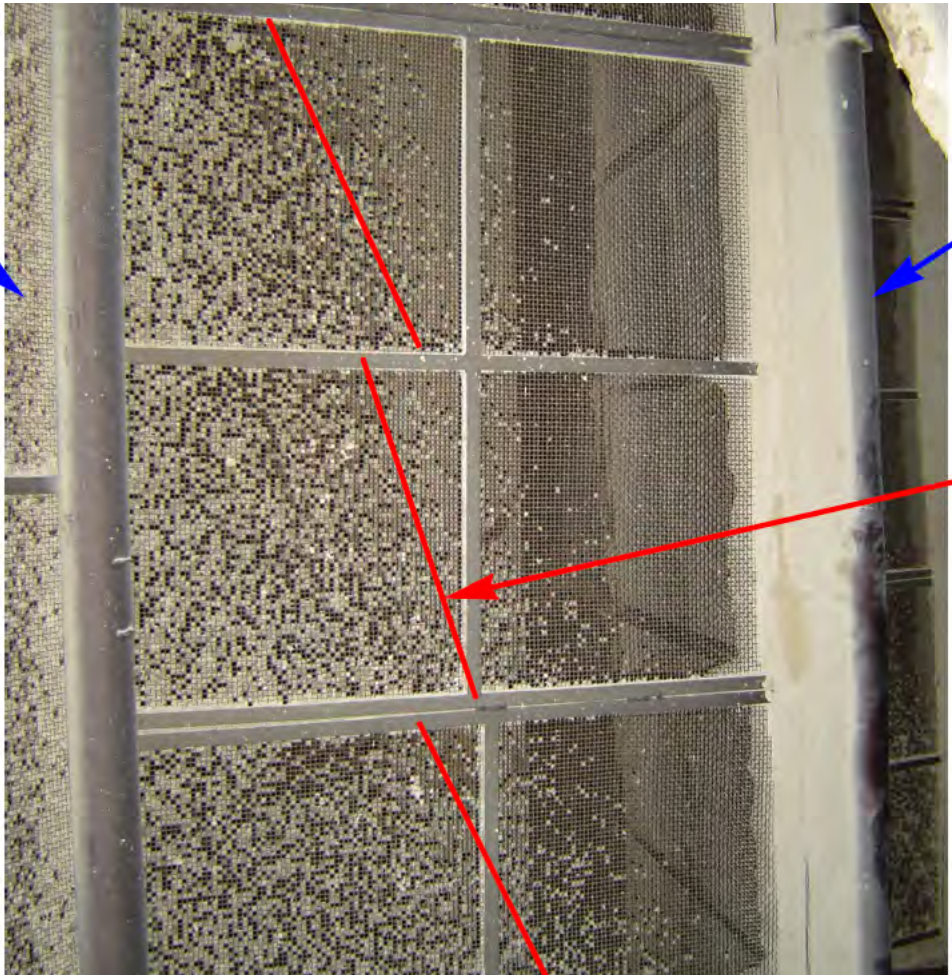
Case 2: Miller Econ Hopper Screen Pluggage

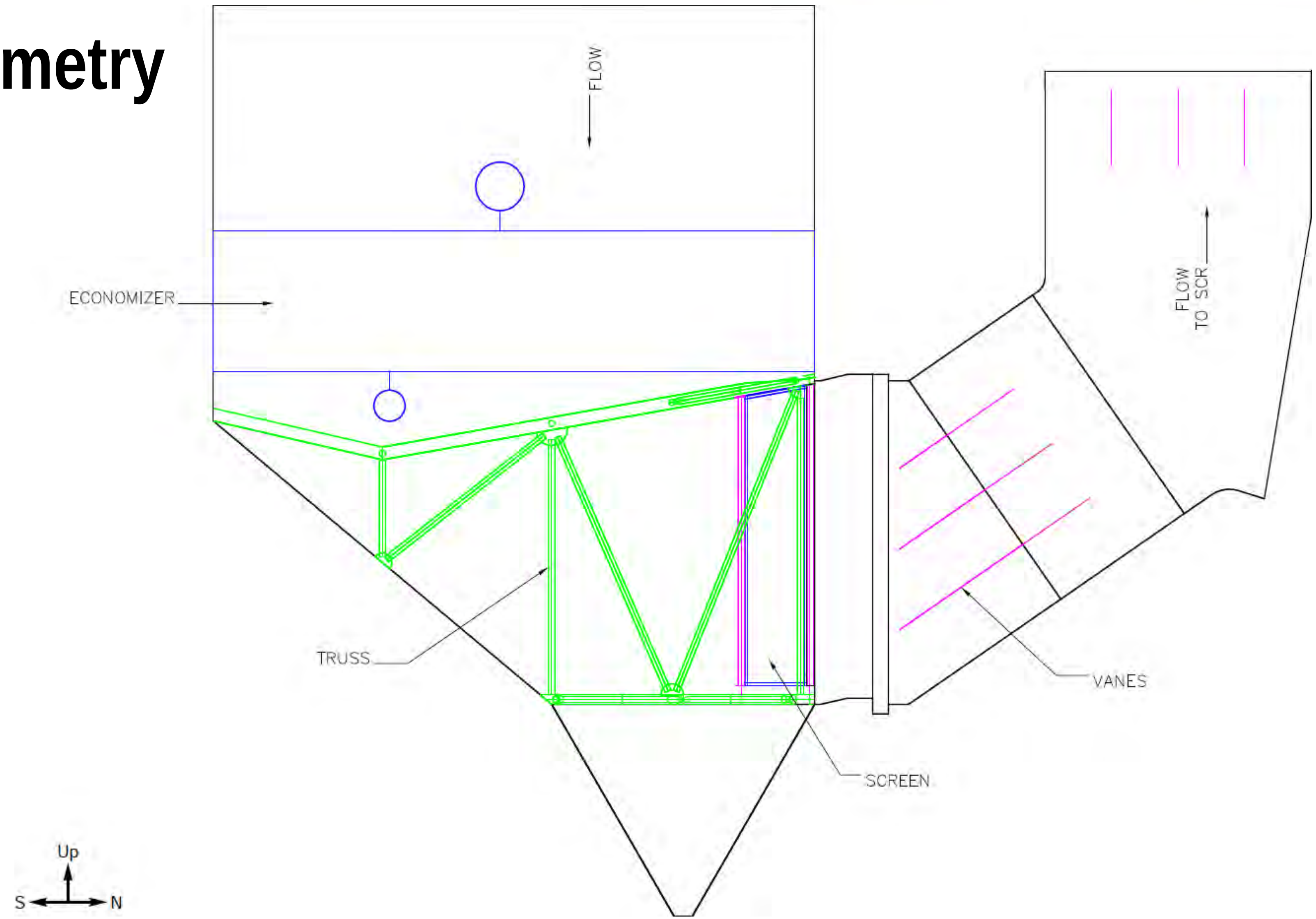


What's the Problem?

- Pleated Screen
- DP slowly increases as the unit runs
- Why? LPA screen becomes plugged



Geometry



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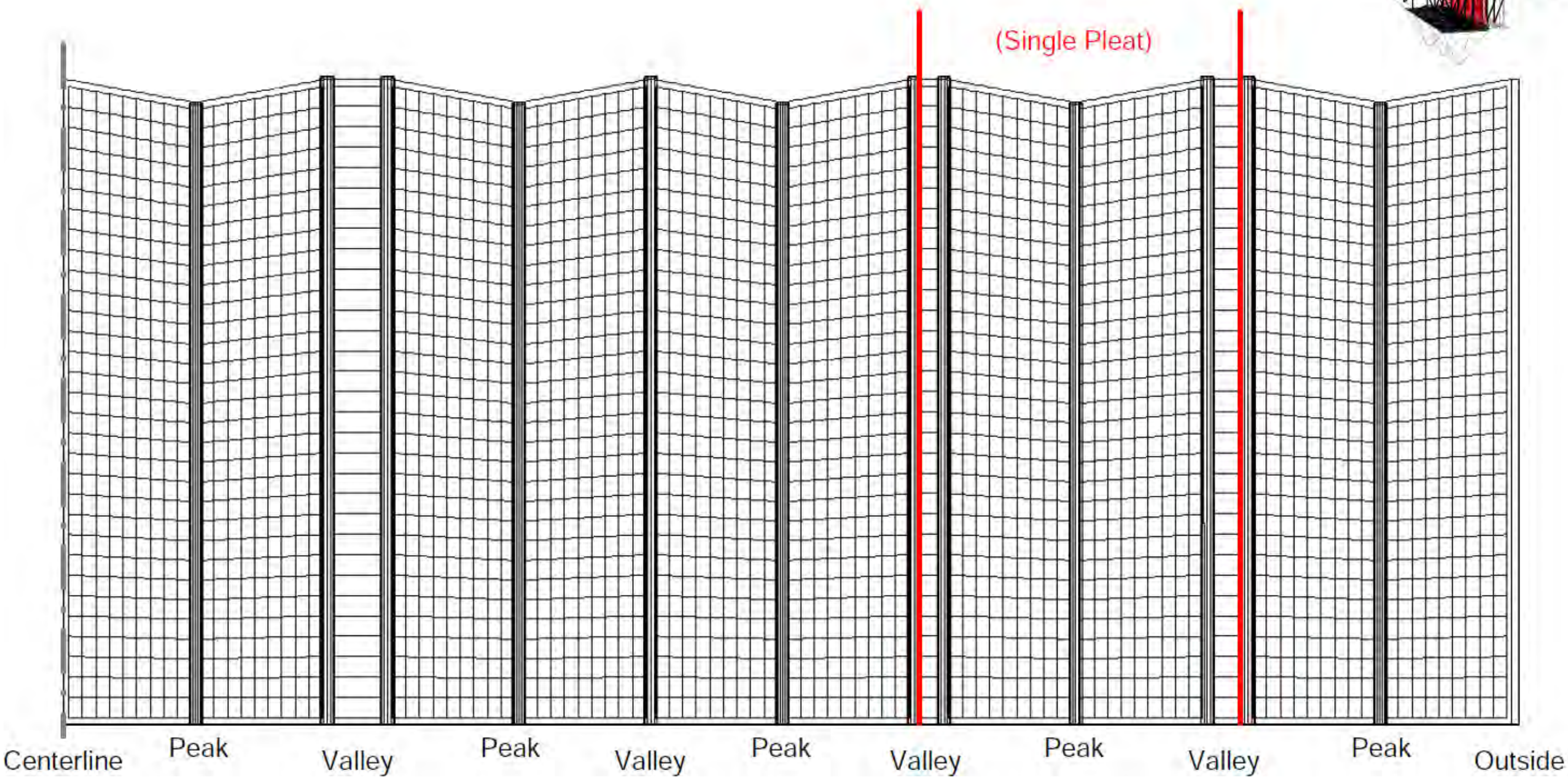
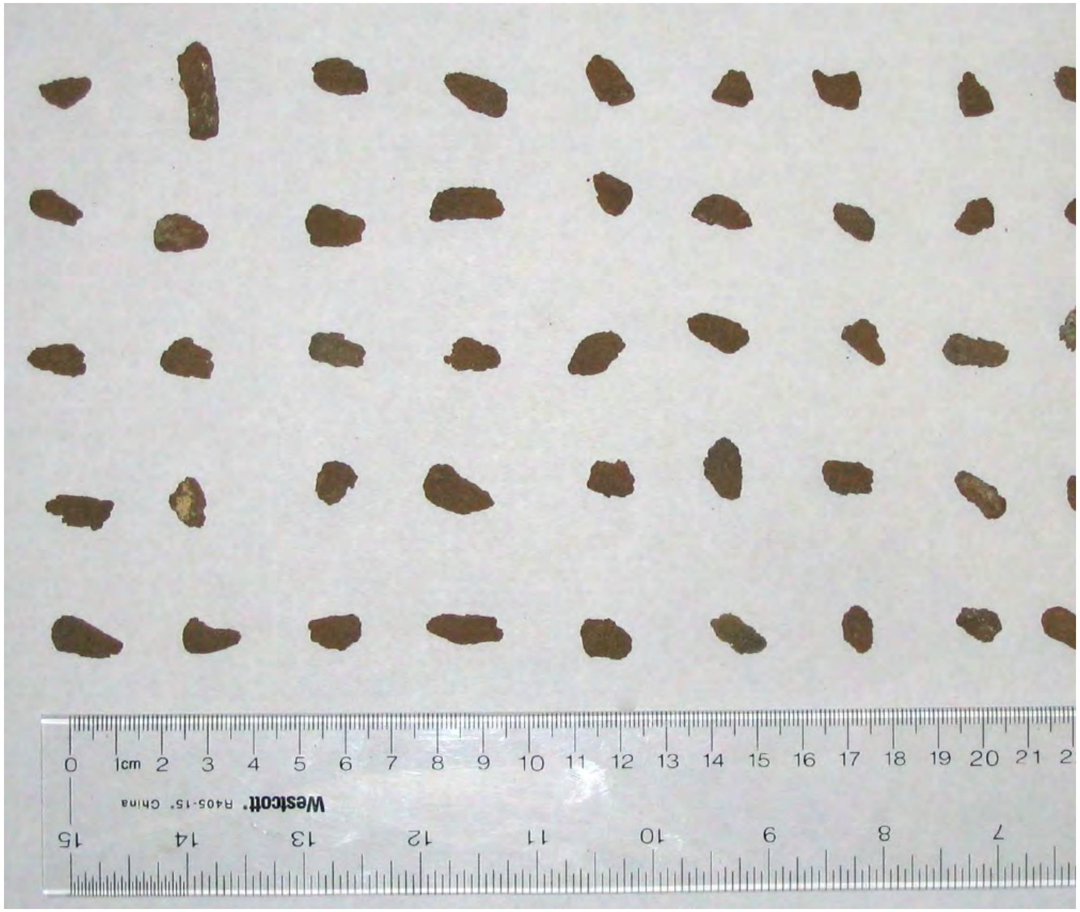
Pleated Screen Details Must Be Included



Particle Characterization

- Plugging particles measured
- Drag and rebound characteristics of LPA



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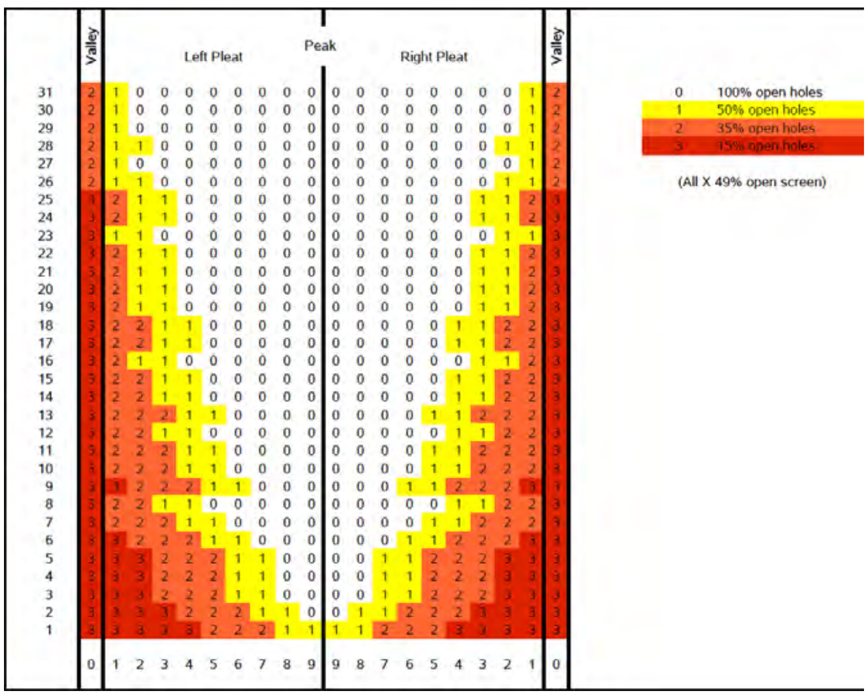
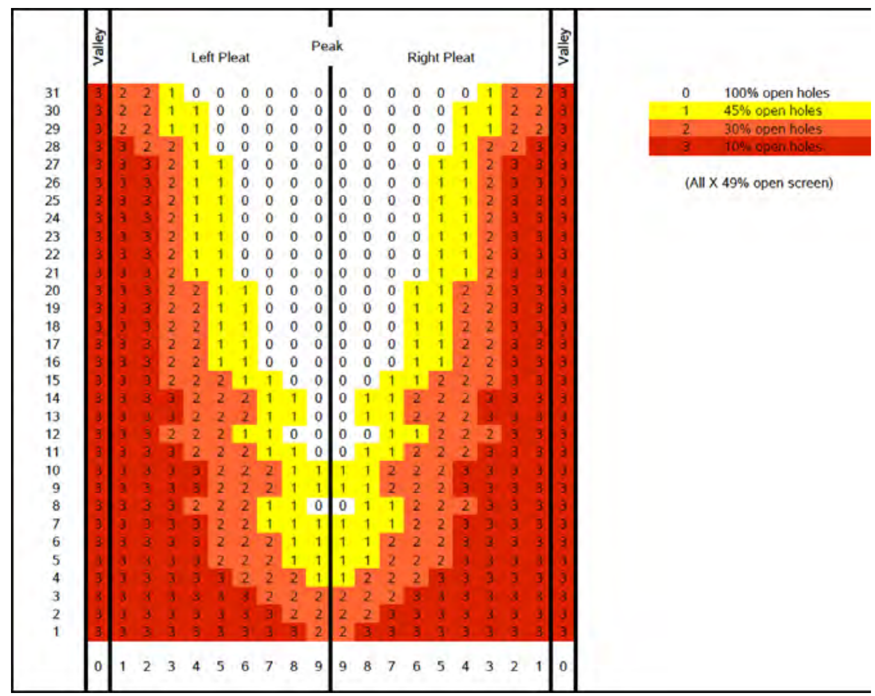
How to model changes due to buildup?

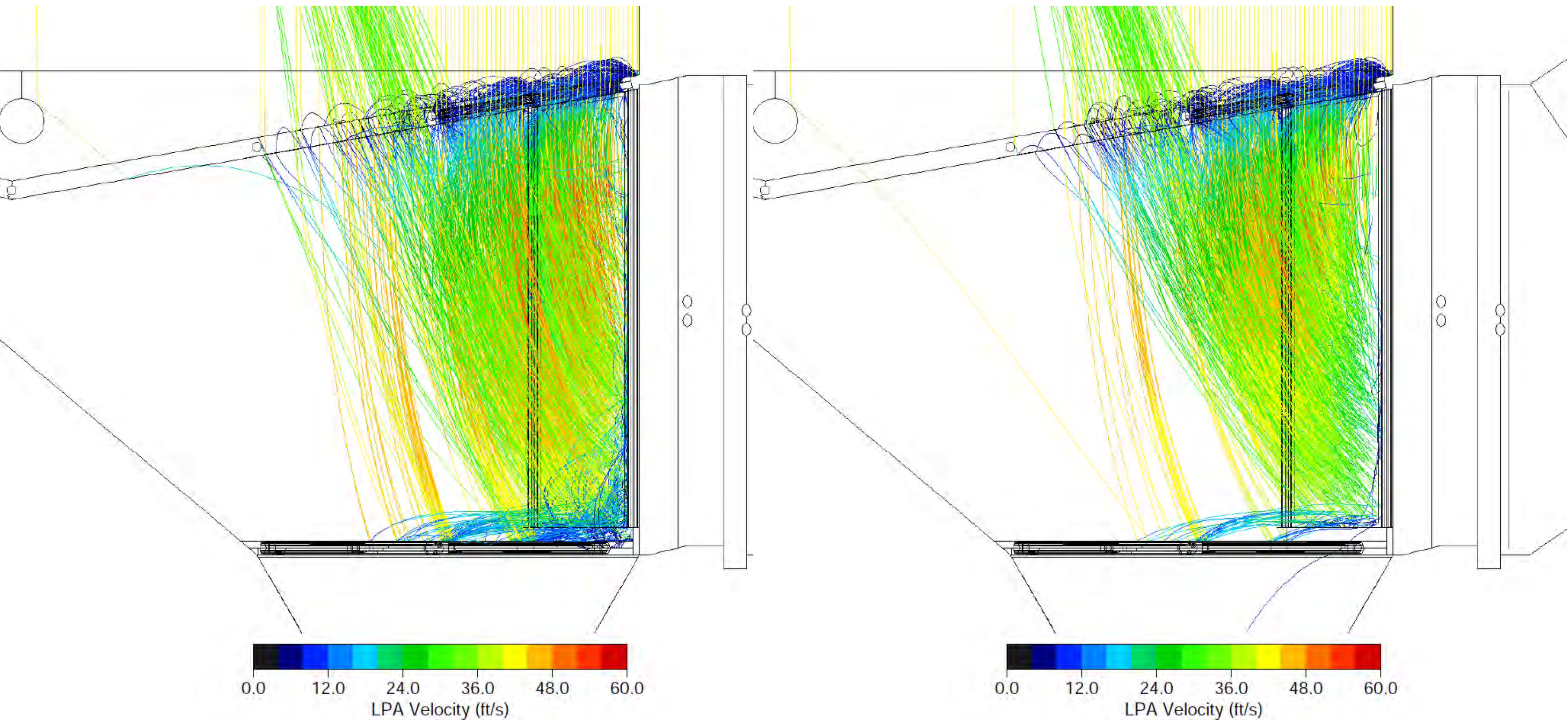
- 3 conditions modeled:
  - Clean, partially plugged, strongly plugged





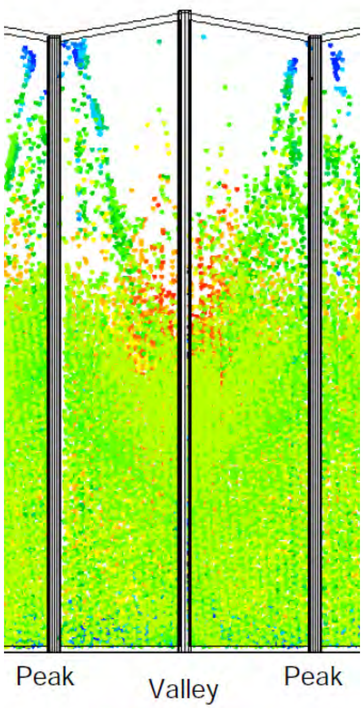
5mm Particles Striking the Screen

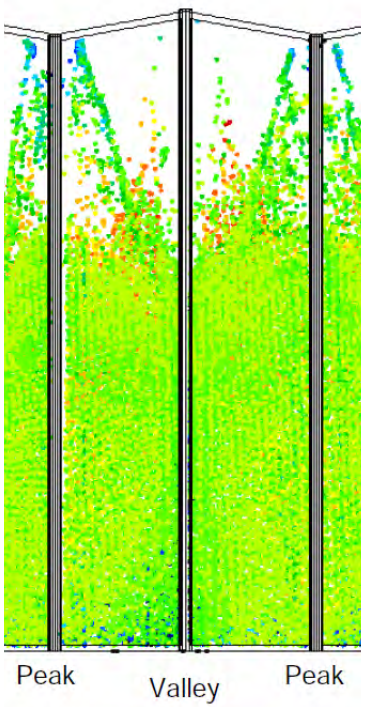
- Clean on right, strongly plugged on left

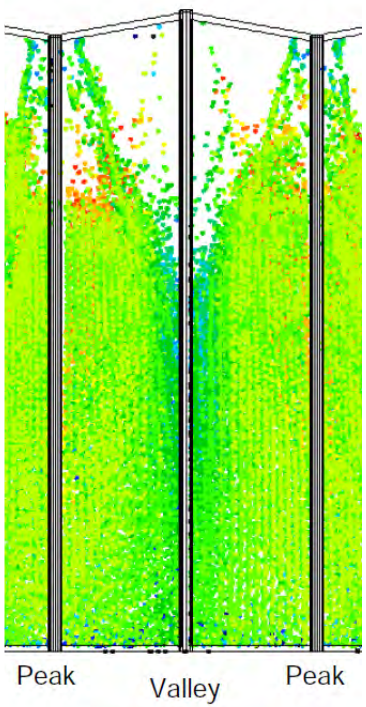


Some Shift in Pluggage Pattern over Time

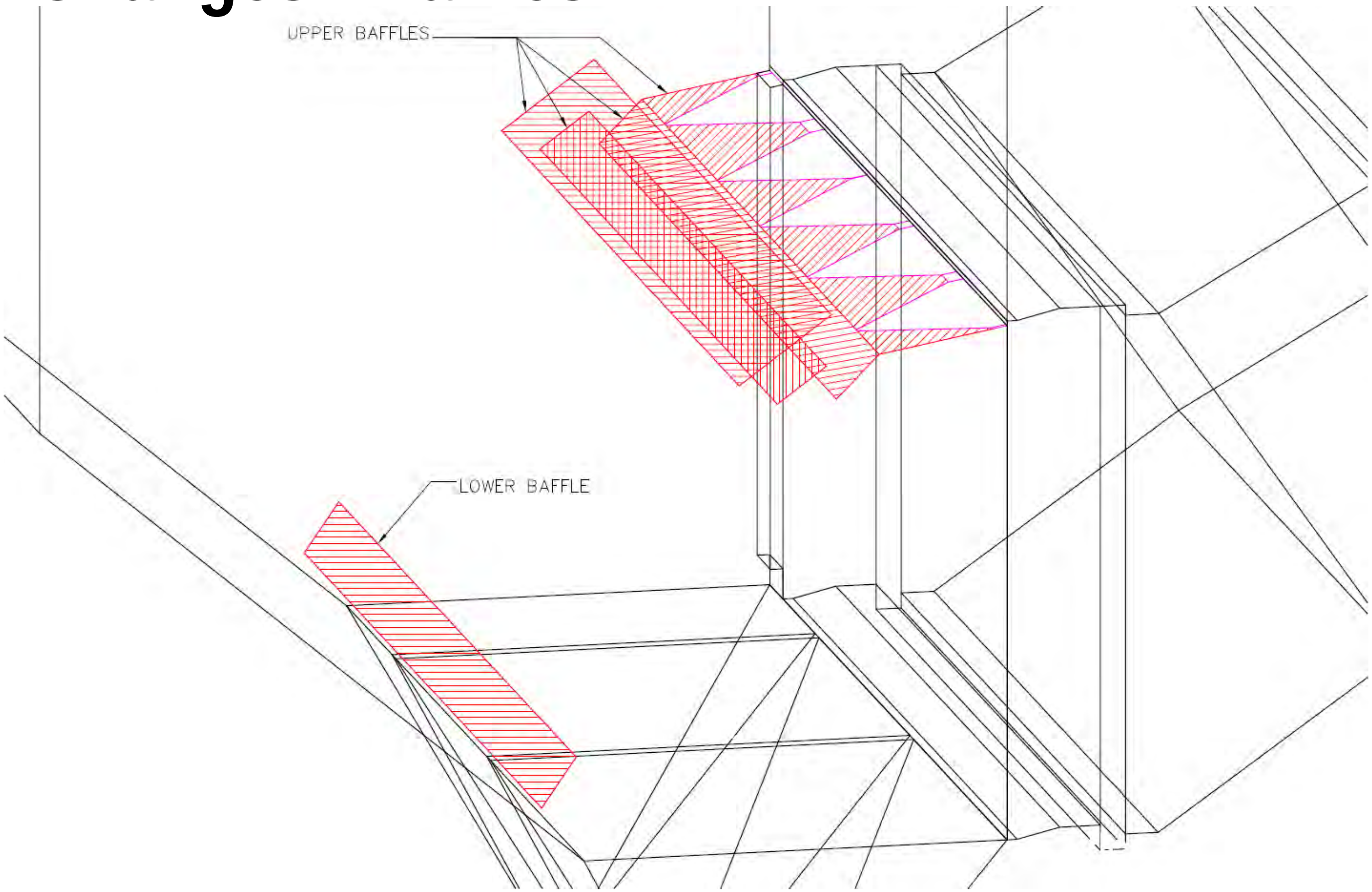
- Clean Partial Plugged Strongly Plugged



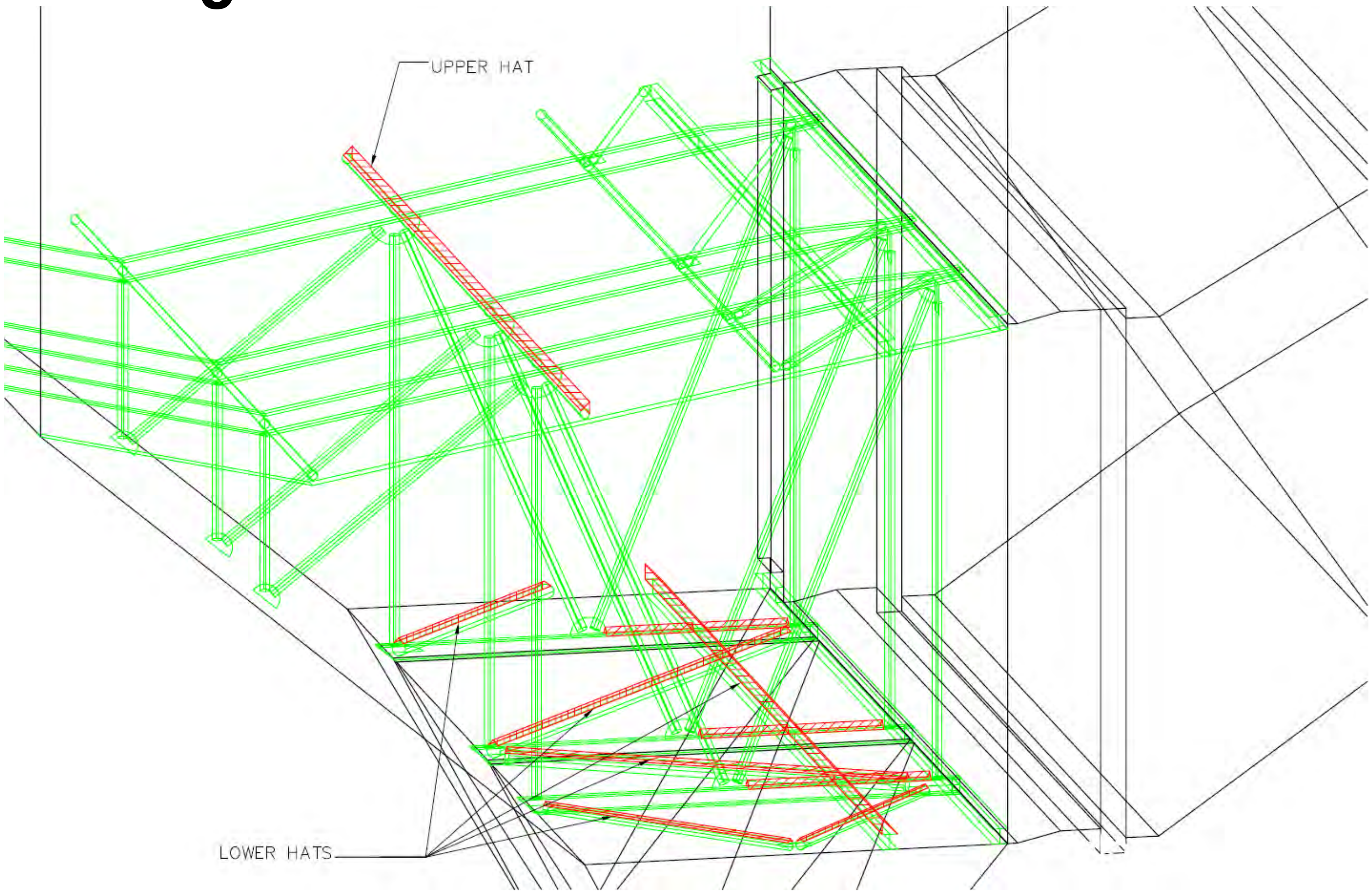




Design Changes - Baffles

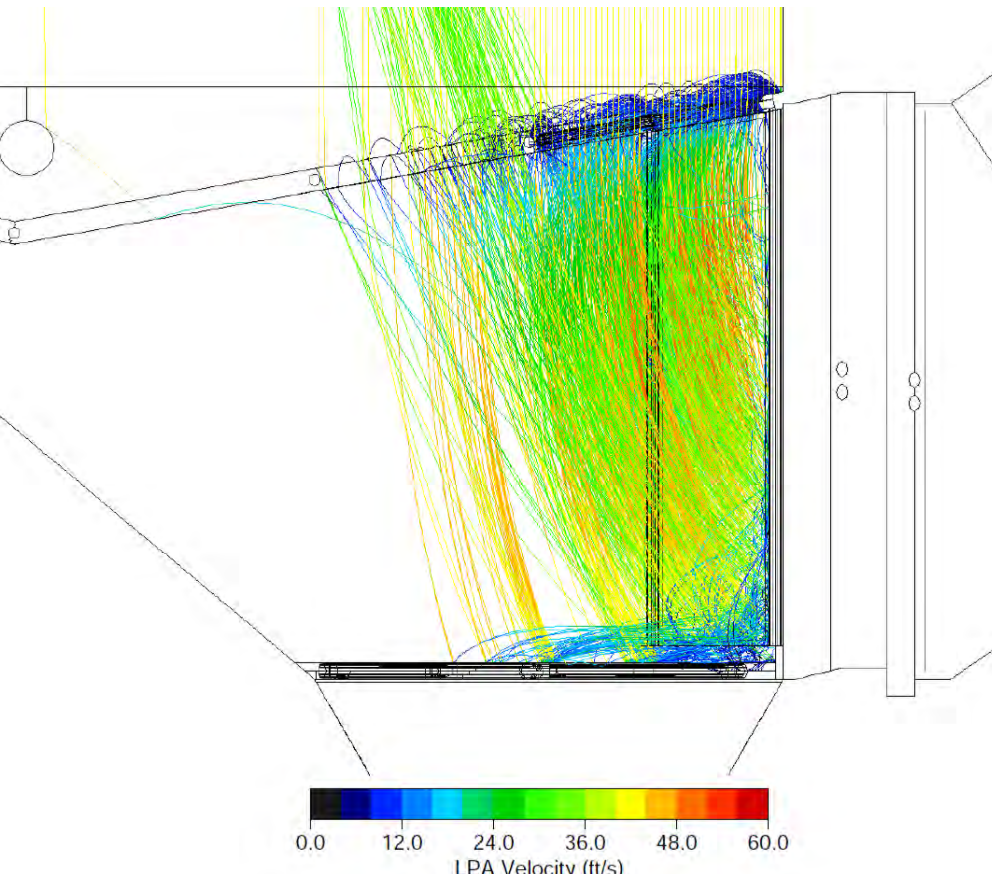


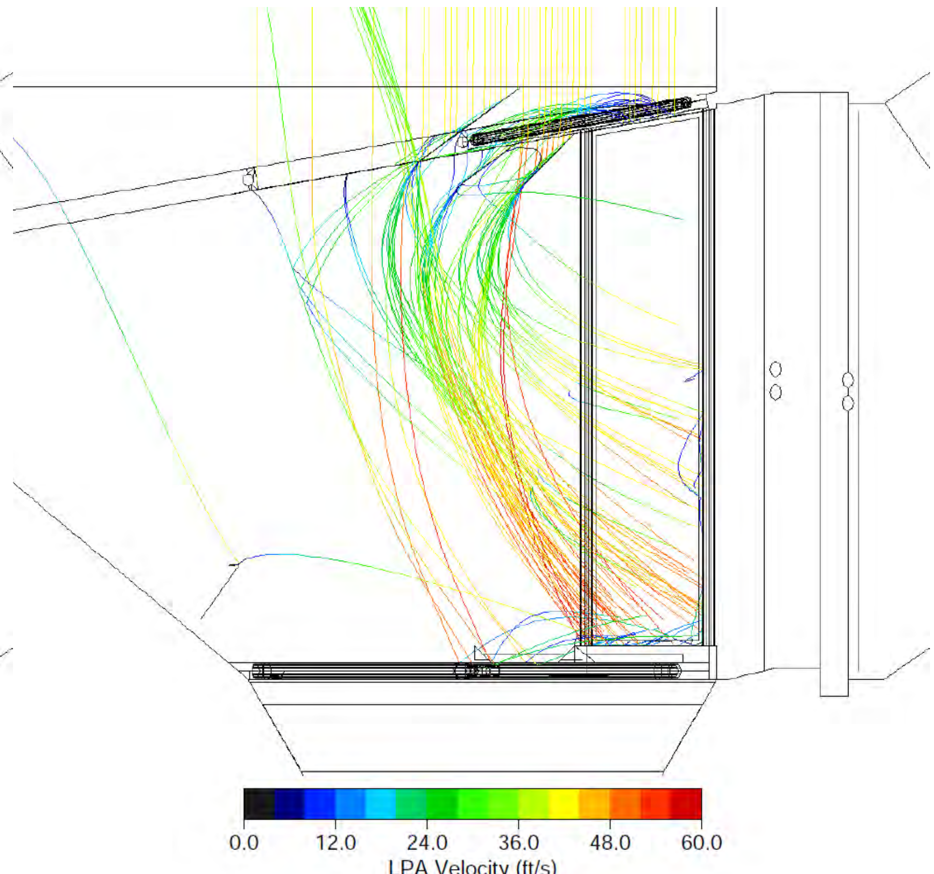
Design Changes – "Hats"



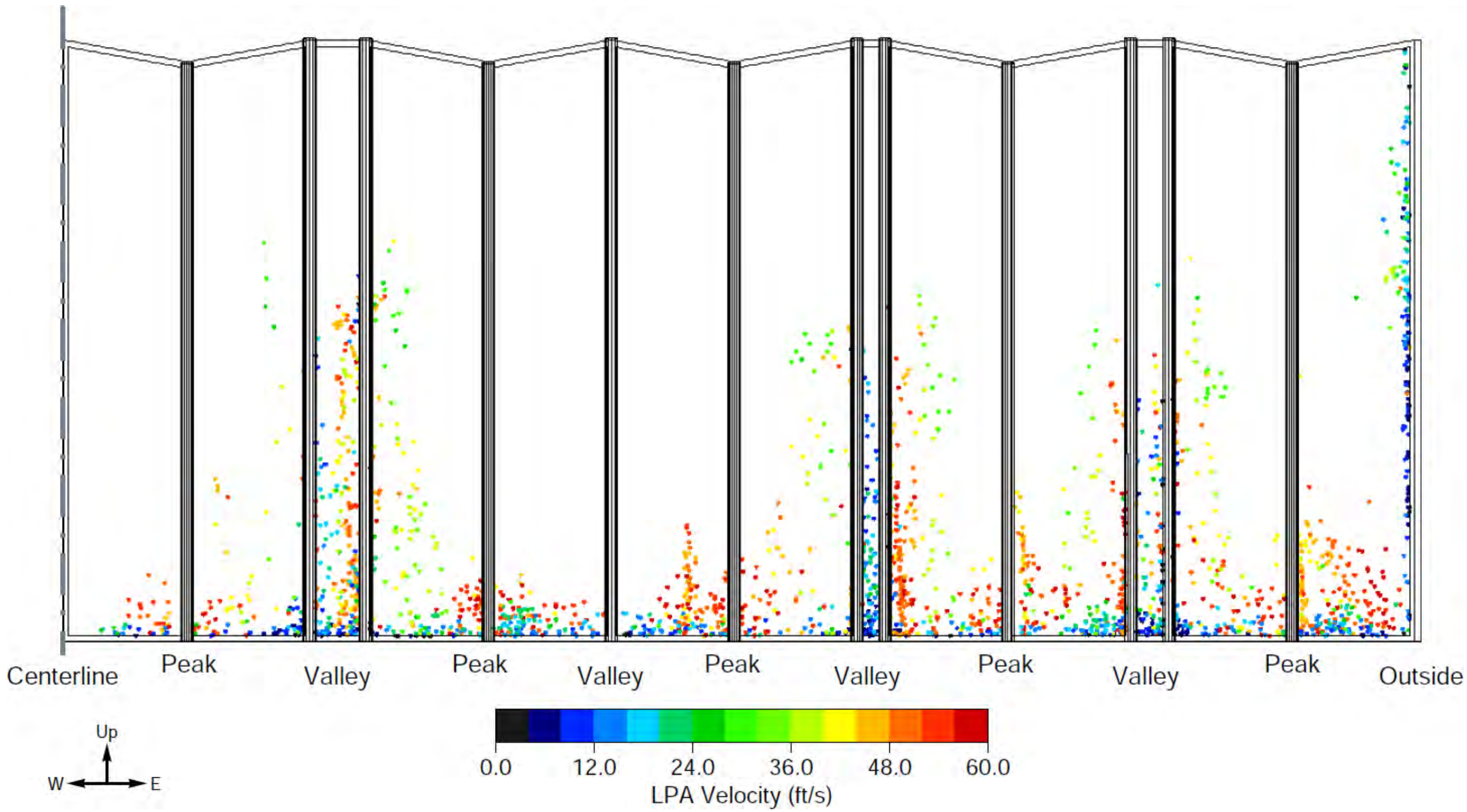
Drastically Reduced Impacts

- Baseline on left, final design on right





Drastically Reduced Impacts



Results

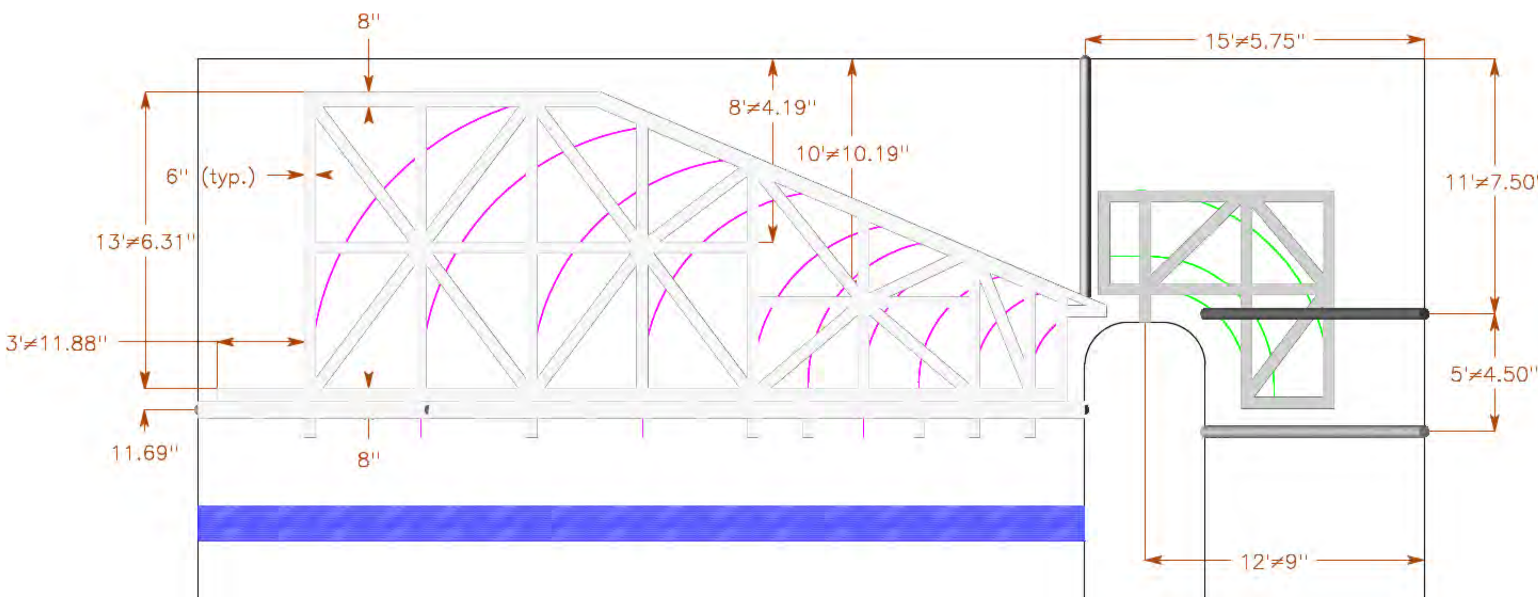
- Initial results, through June 2008, indicate that pressure drop across the screen versus time is staying reasonably stable
- Ian Mylenbush will present recent outage observations

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



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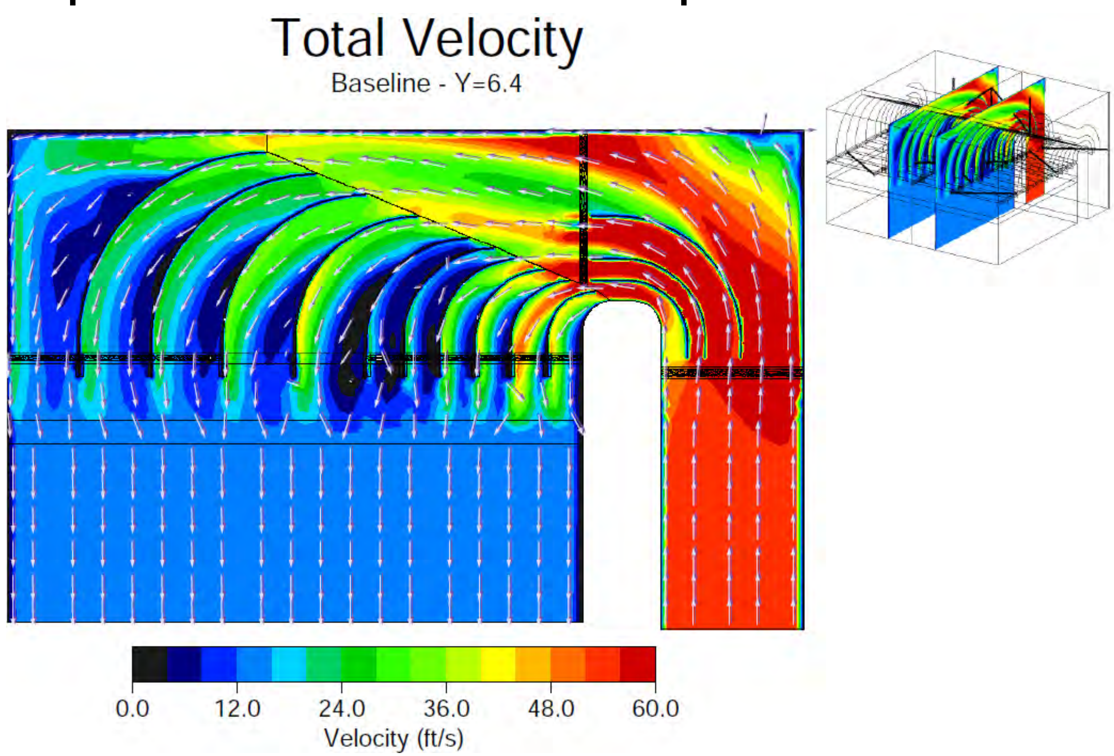
Buildup

Buildup

Baseline CFD results

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

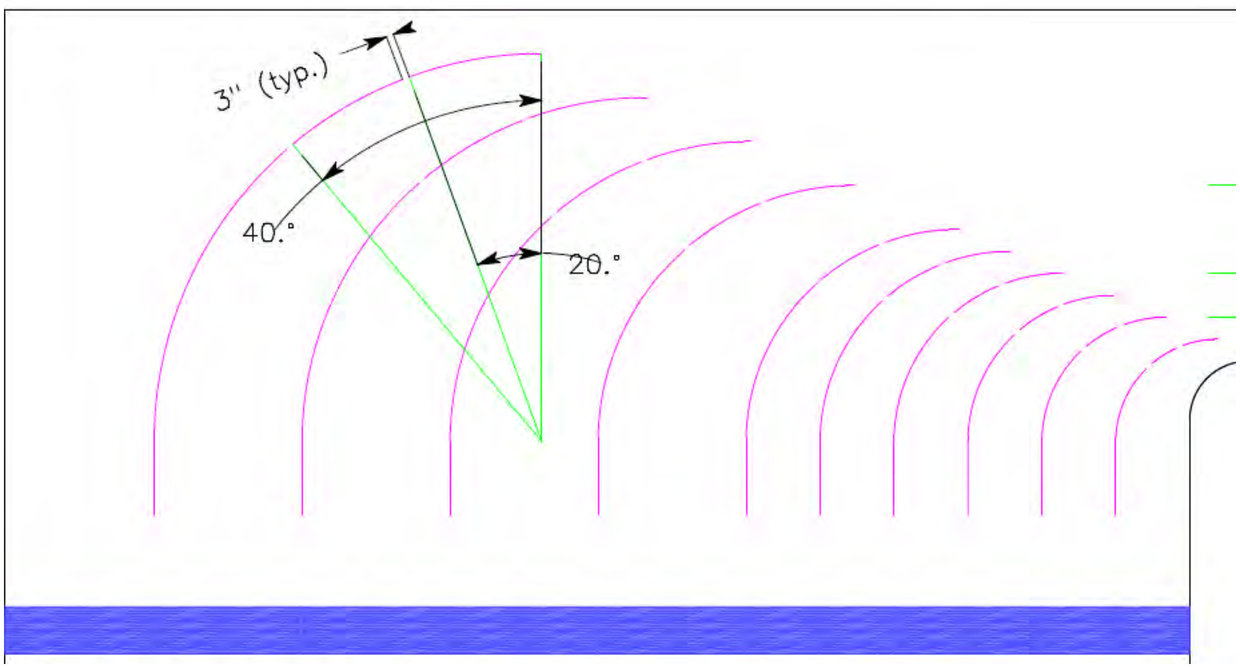


Options?

- 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

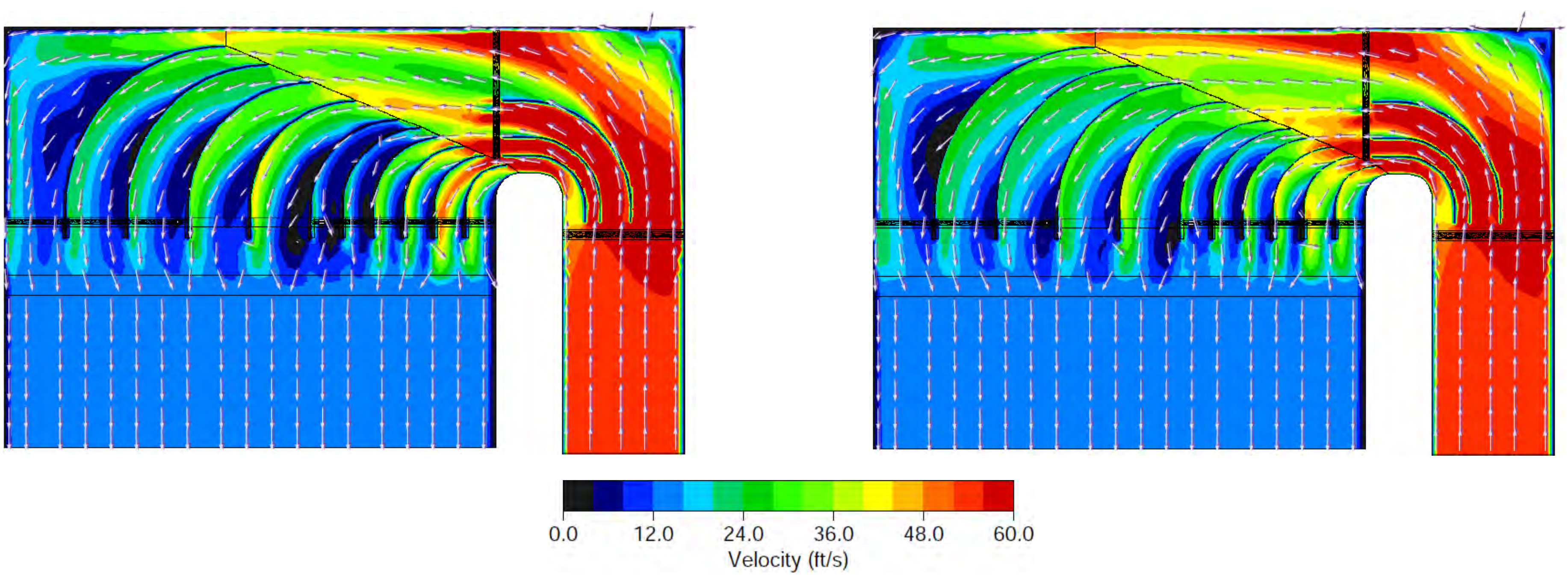
Design 1

- 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



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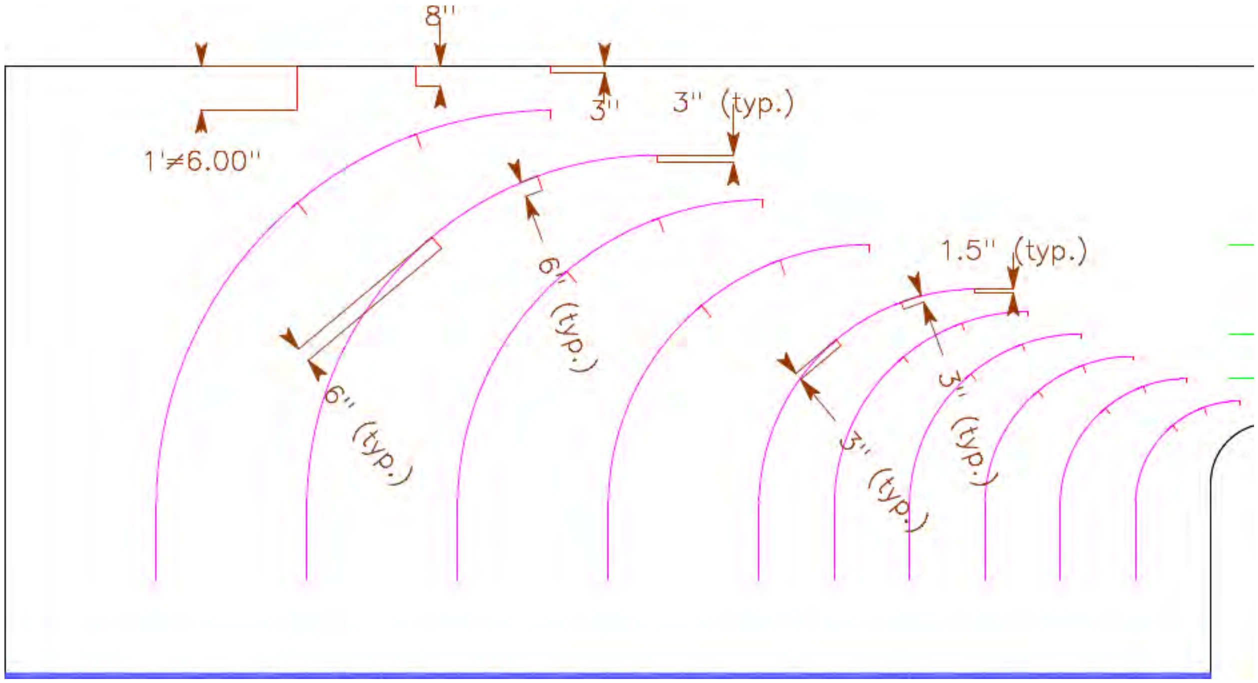
Design 2

- Angle iron on underside of vanes



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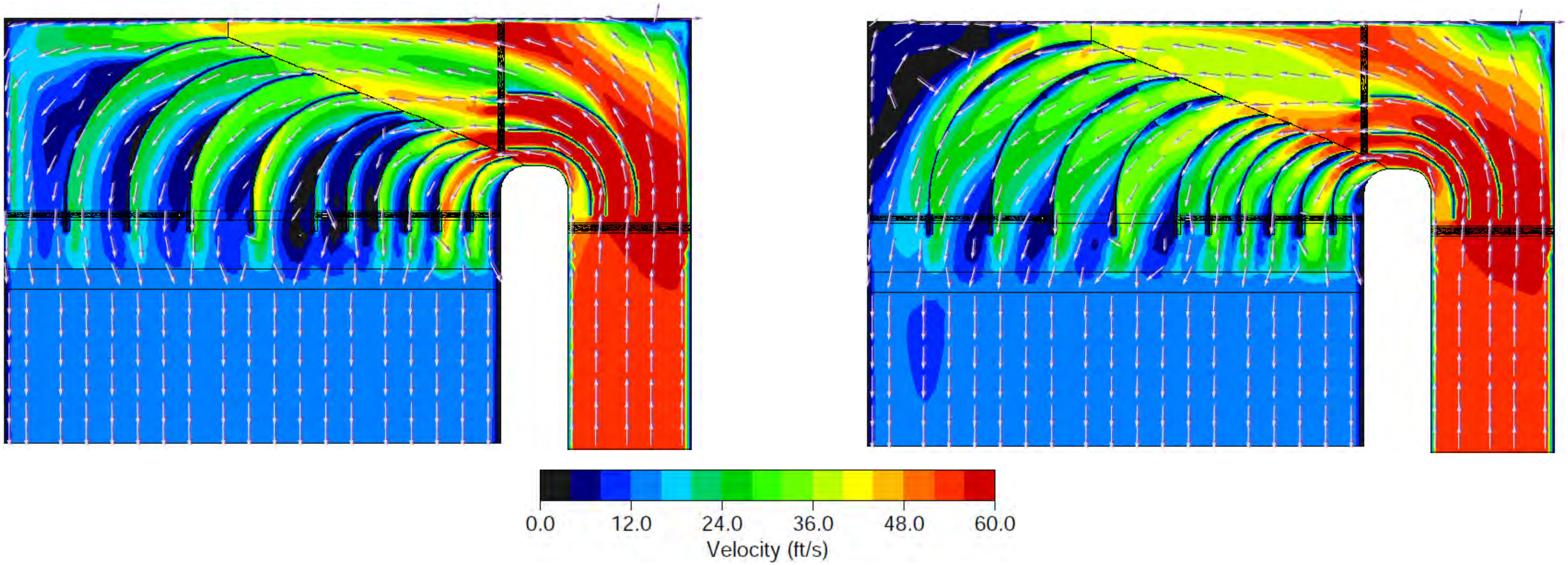
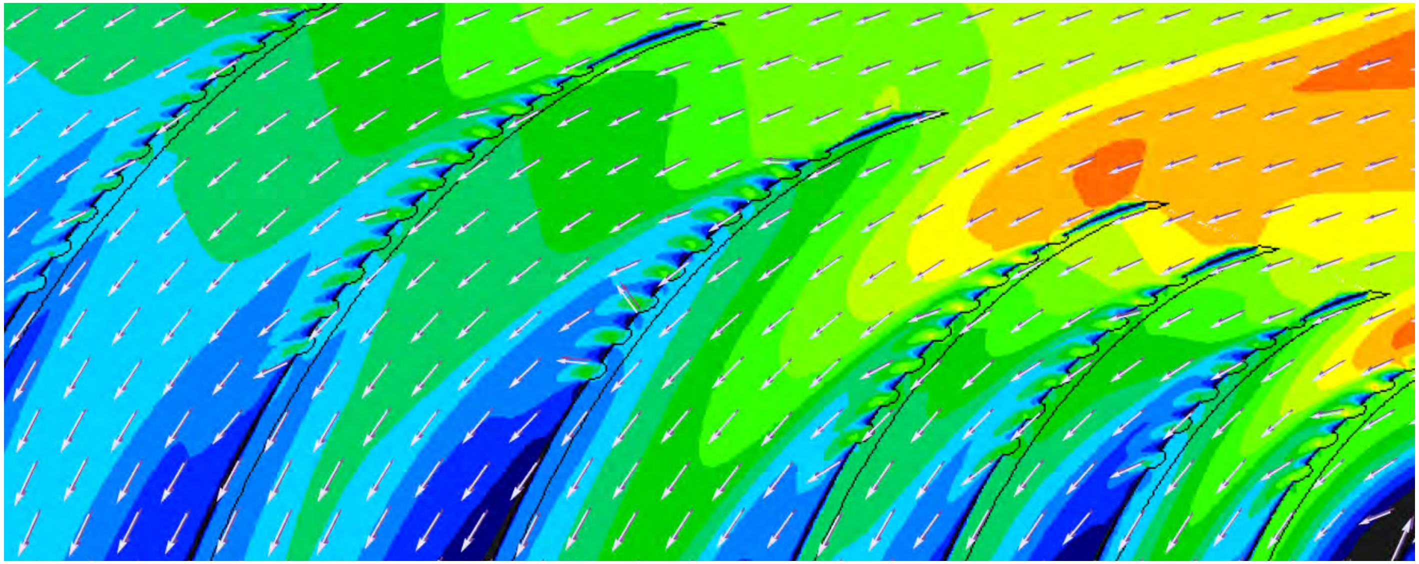
Design 2 Results

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



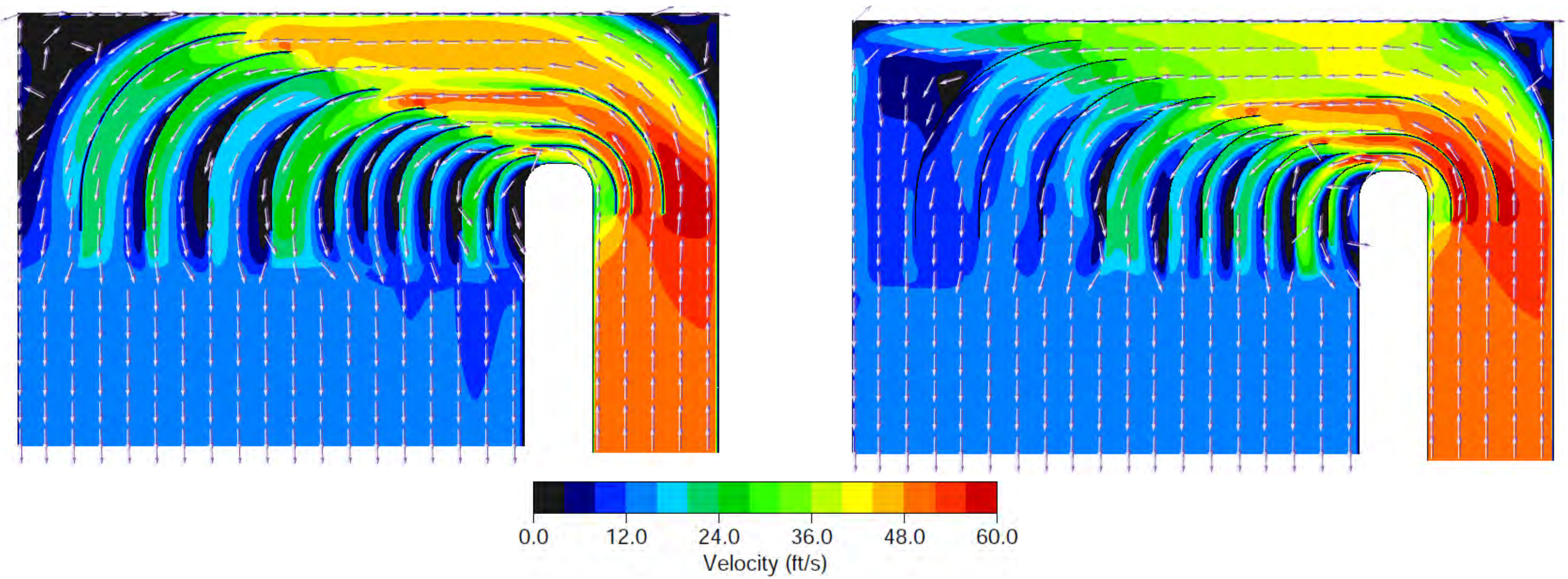
Design 3

- 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?

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