Worldwide Pollution Control Association

IL Regional Technical Seminar

September 13-15,2011

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Optimizing Gas and Particulate Flows to Minimize NO_x, Hg, and SO_3

WPCA Illinois Technical Seminar
September 13, 2011

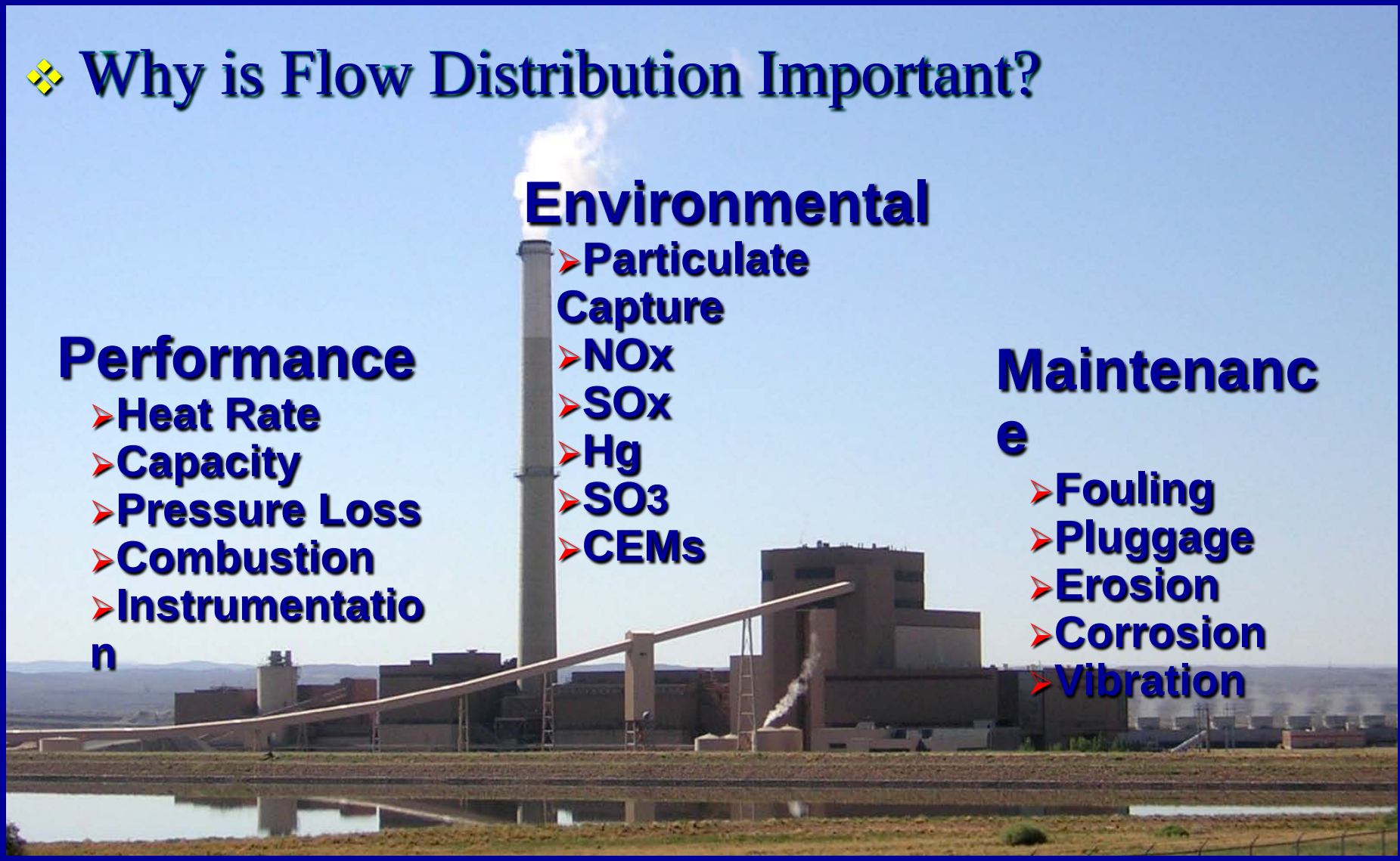
Airflow Sciences Corporation
www.airflowsciences.com

Outline

- Introduction
- Flow Distribution Analysis Techniques
- Application to Boilers
- Application to Air Pollution Control Equipment
- Other Applications
- Conclusions
- Questions

Introduction

- Why is Flow Distribution Important?

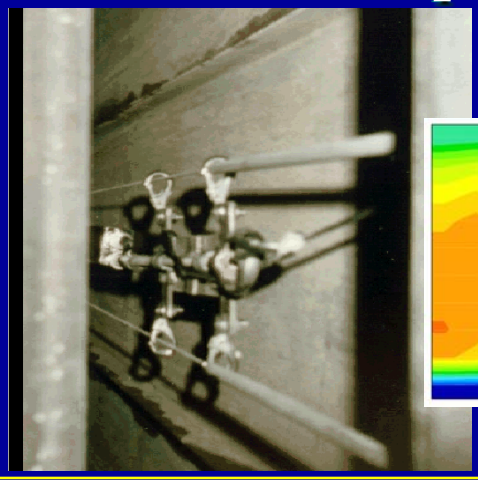


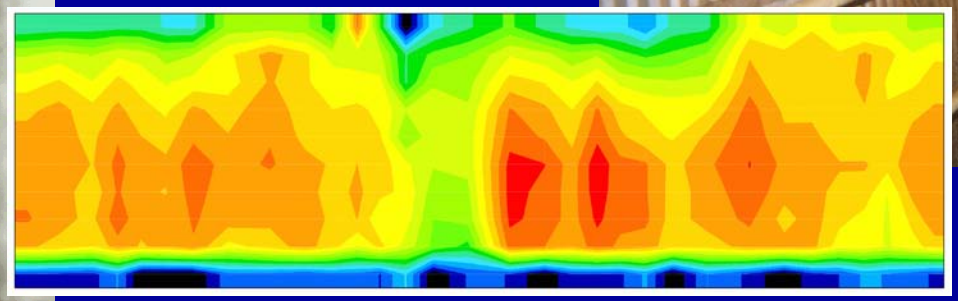
Outline

- Introduction
- Flow Distribution Analysis Techniques
  - Field Testing
  - Computational Fluid Dynamics (CFD)
  - Physical Flow Modeling
- Application to Boilers
- Application to APC Equipment
- Other Applications
- Conclusions
- Questions

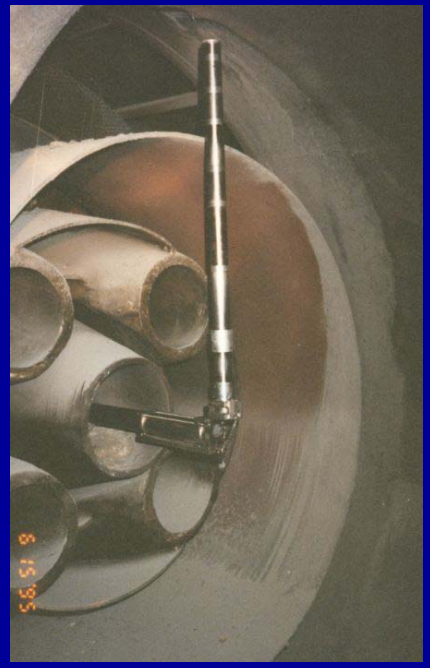
Field Testing

- Velocity
- Temperature
- Pressure
- Particulate
- Chemical species
- Video inspection



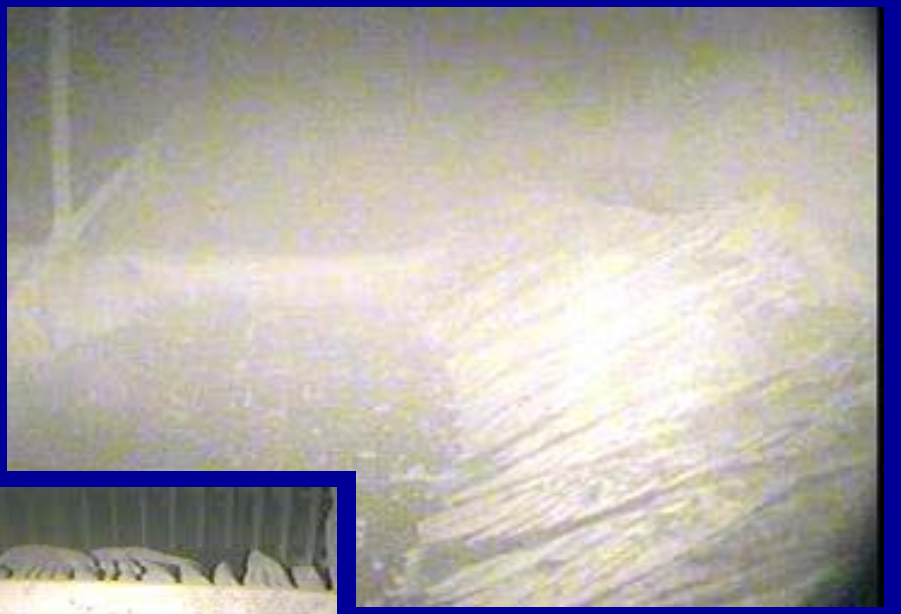


Field Testing



Field Testing

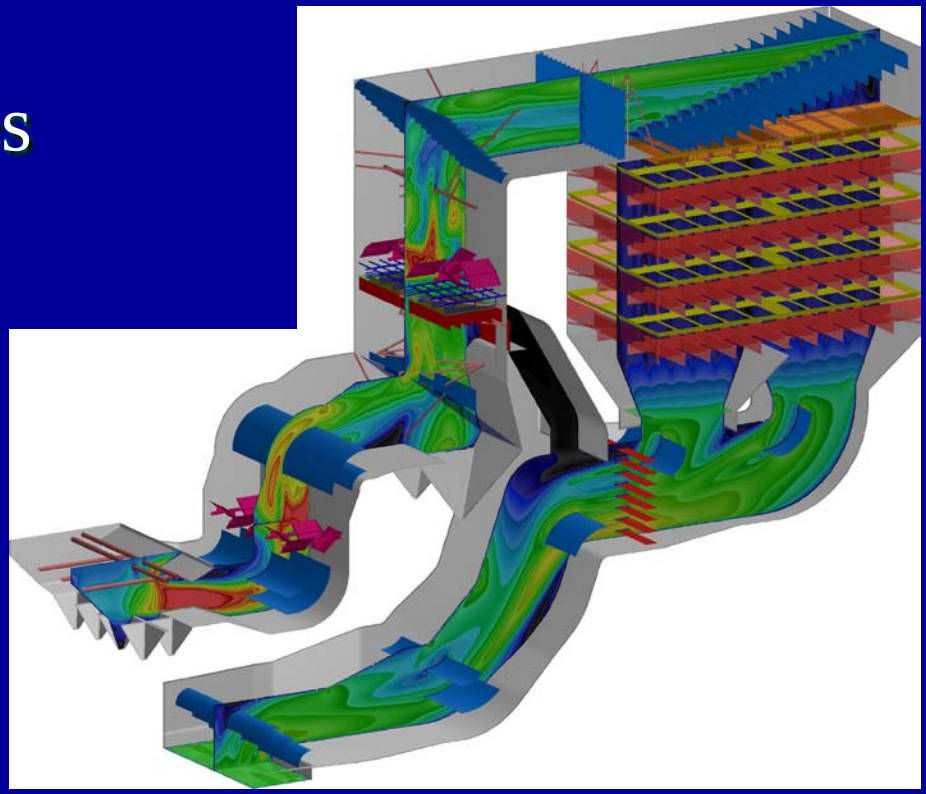
Video probe in SCR reactor



Video probe in pulverizer throat

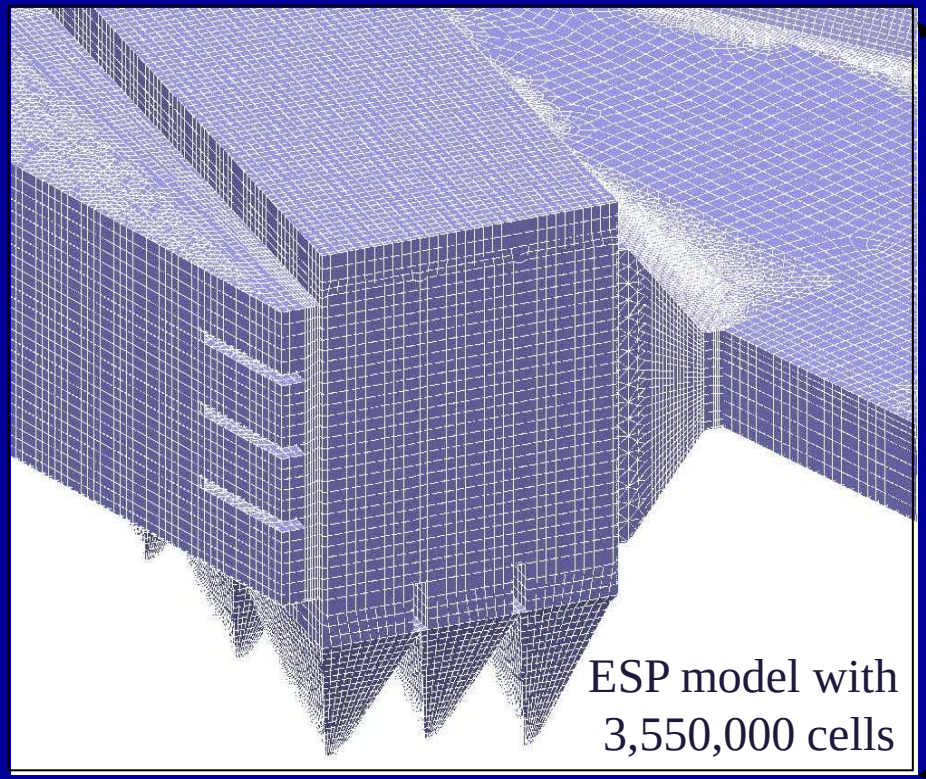
Computational Fluid Dynamics (CFD)

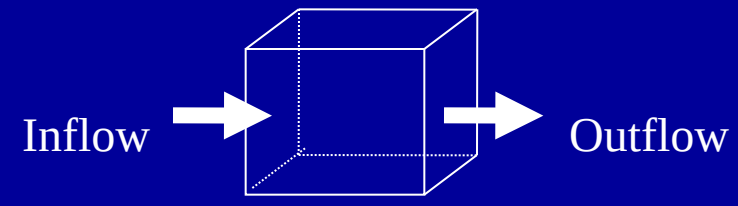
- Numerical simulation of flow
- Utilize high speed computers and sophisticated software
- Calculate flow properties
  - Velocity
  - Pressure
  - Temperature
  - Ammonia
  - Particle streamlines



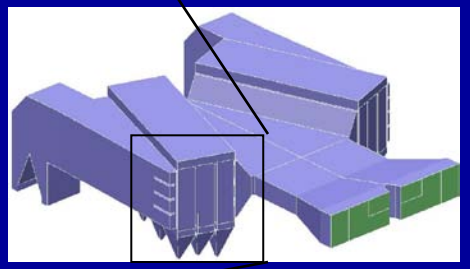
Computational Fluid Dynamics (CFD)

- Control Volume Approach
  - Divide the flow domain into distinct control volumes
  - Solve the Navier-Stokes equations (Conservation of Mass, Momentum, Energy) in each control volume





Control Volume or
"Cell"

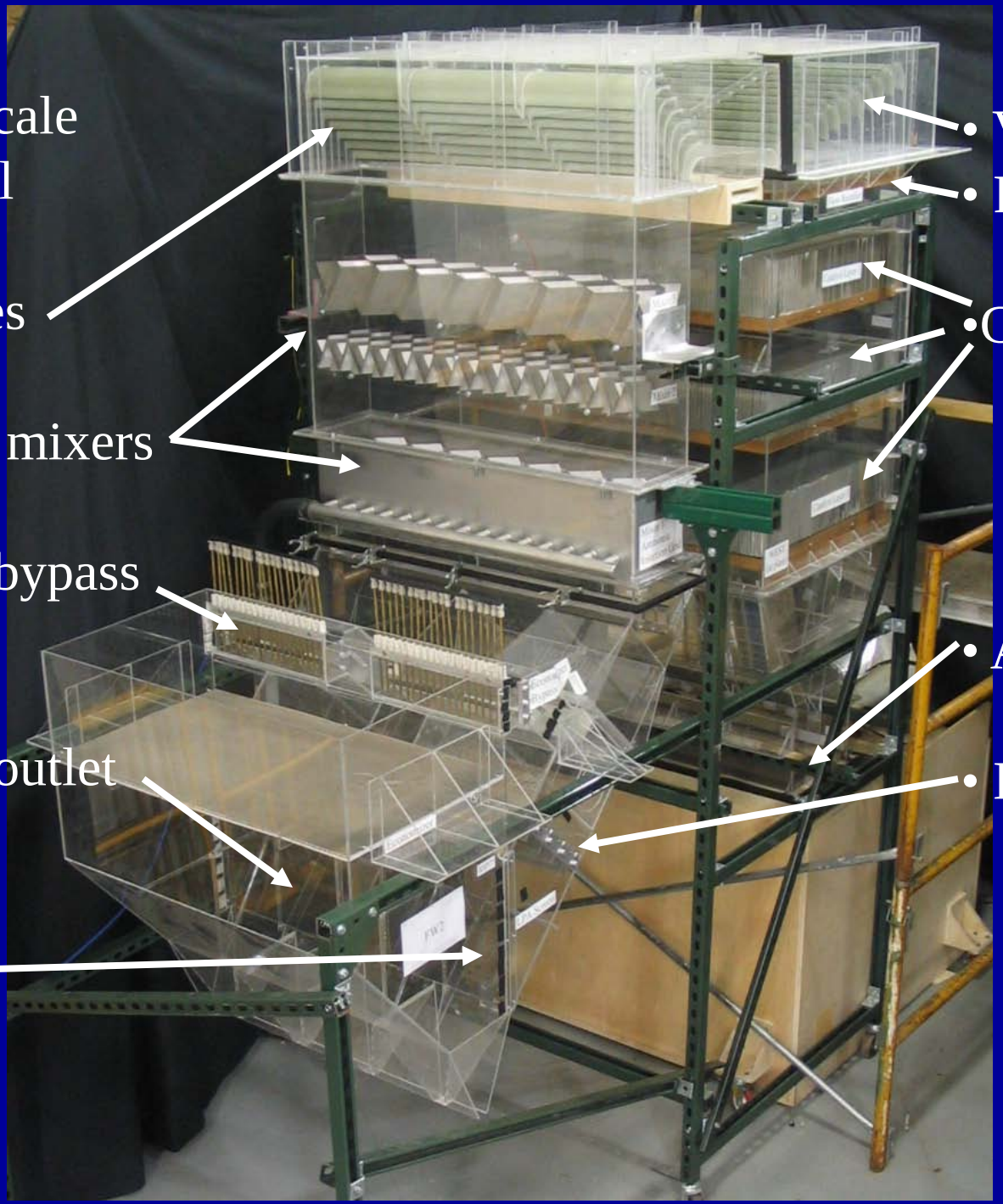


Physical Flow Modeling

- 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



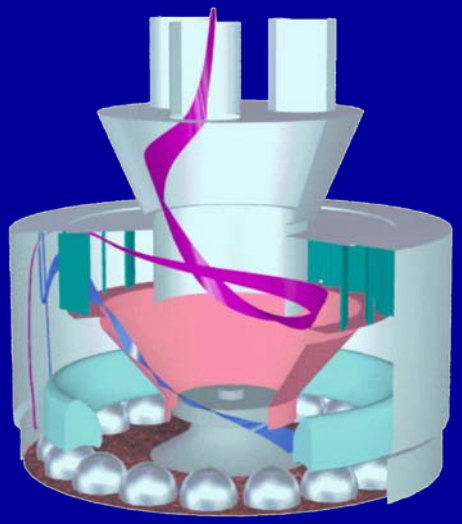
- Vanes
- Rectifier
- Catalyst layers
- Air heater
- Dampers

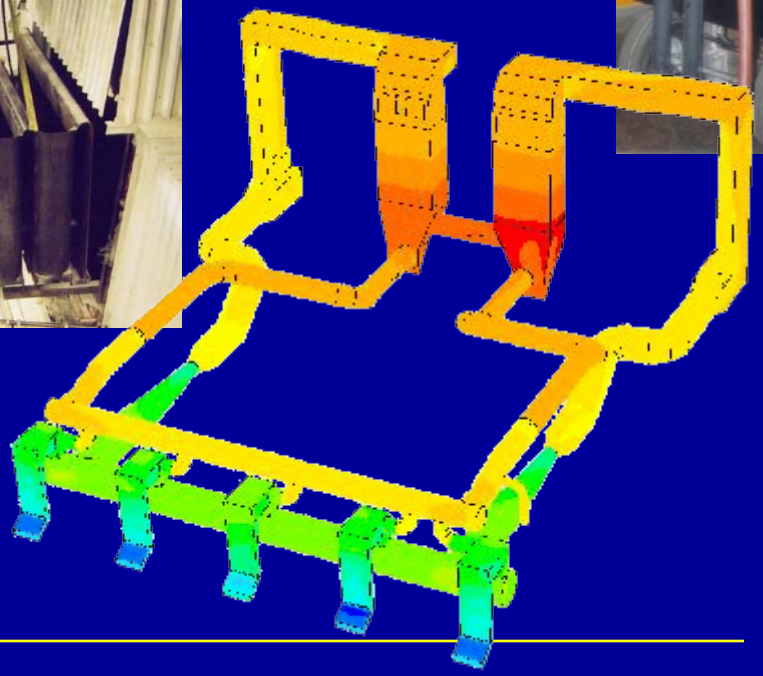
Outline

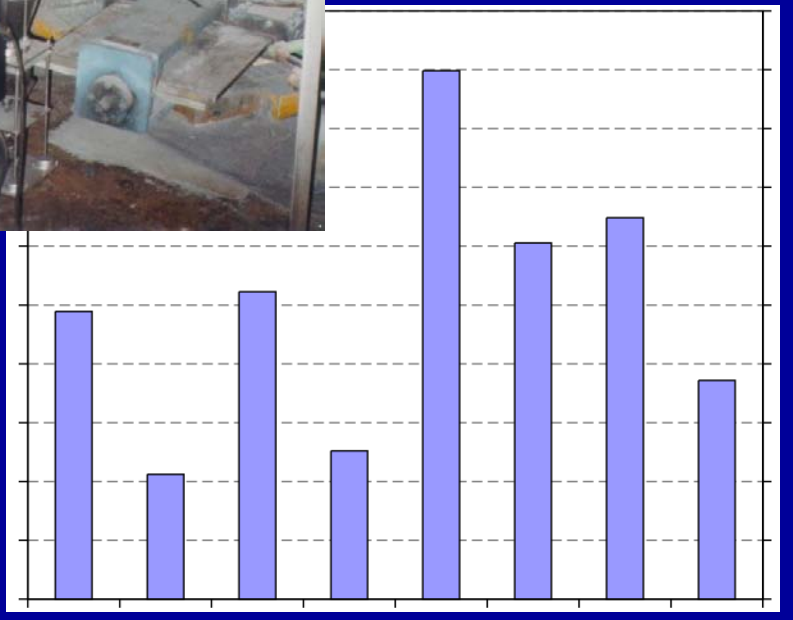
- Introduction
- Flow Distribution Analysis Techniques
- Application to Boilers
  - Primary / Secondary Air Systems
  - Furnace
- Application to APC Equipment
- Other Applications
- Conclusions
- Questions

Primary Air / Coal Flow Balancing

- Optimize combustion
  - Balance PA flows
  - Equal coal flow per burner
  - Adequate fineness
- Modeling and testing

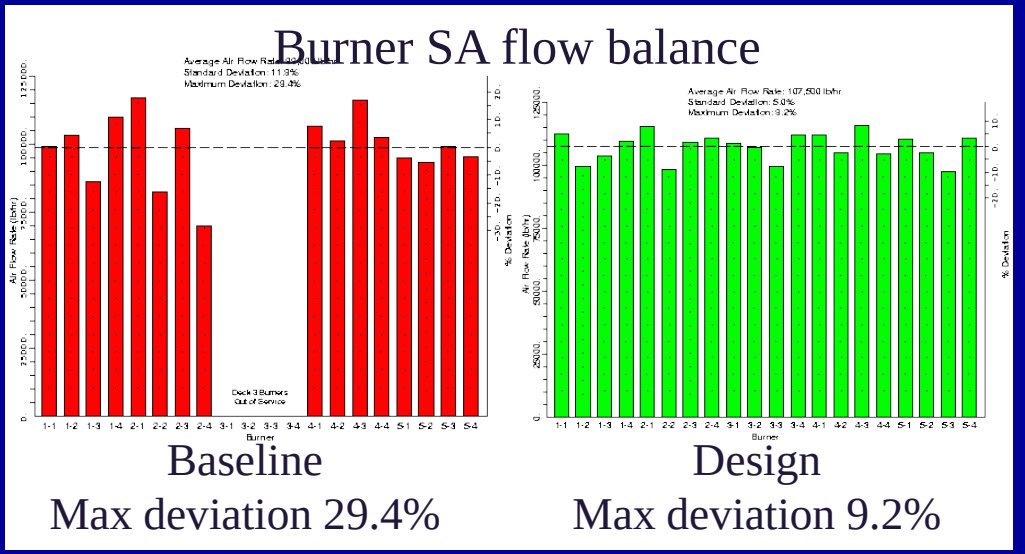


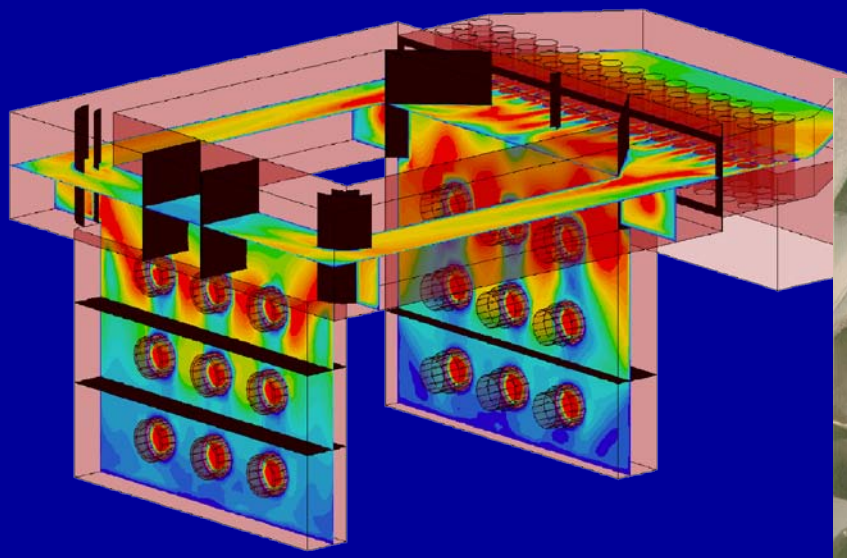


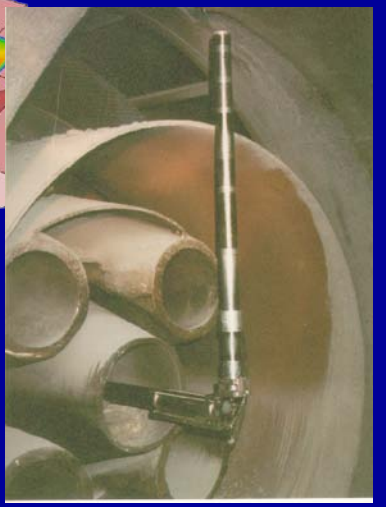


Windbox Flow Balancing

- Optimize combustion
  - Balance secondary air
  - Control flow entering burner (ram air effect)
- Modeling and testing

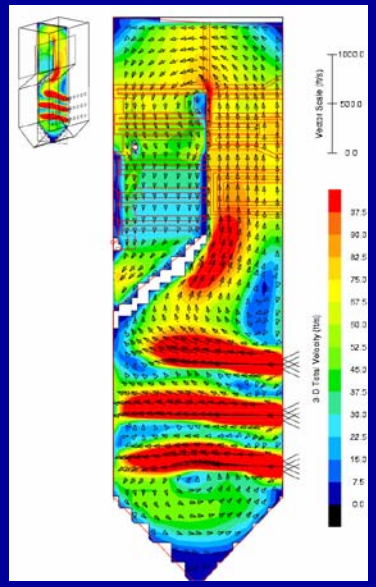


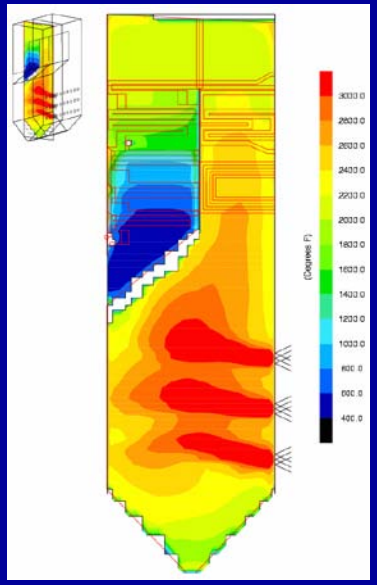


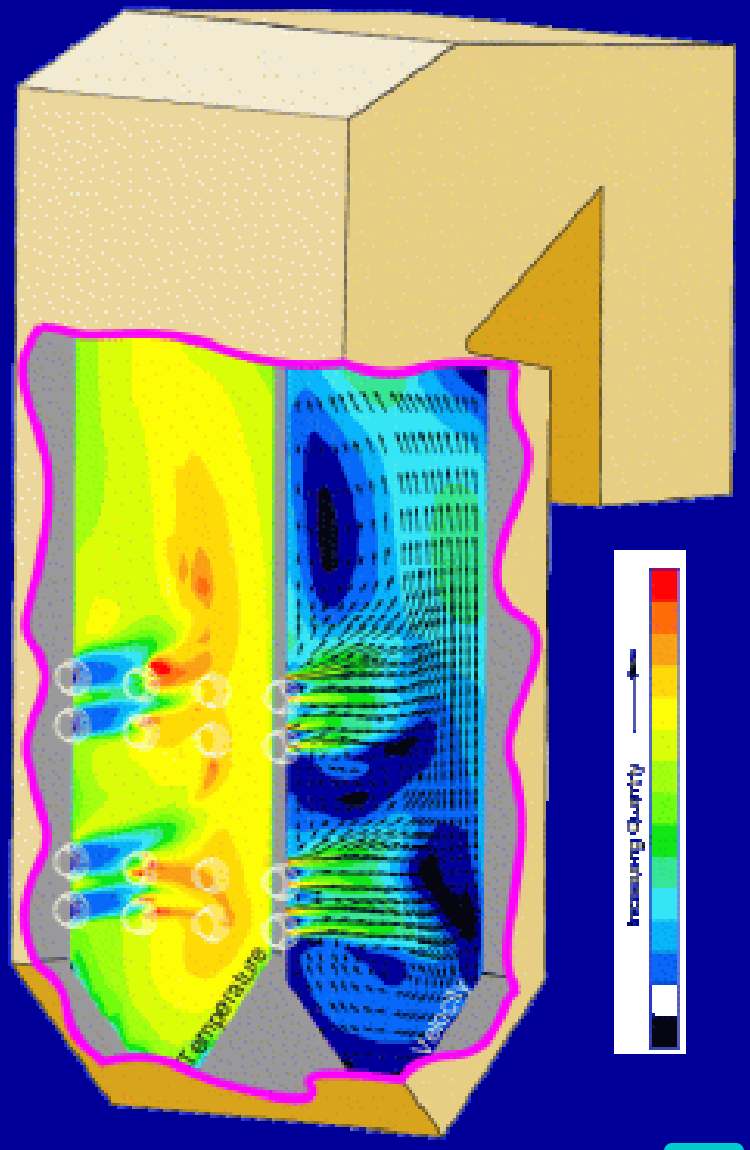


Furnace Combustion Optimization

- Typical goals
  - Reduce NOx
  - Minimize LOI
  - Improve heat transfer
  - Avoid corrosion
  - Decrease slagging







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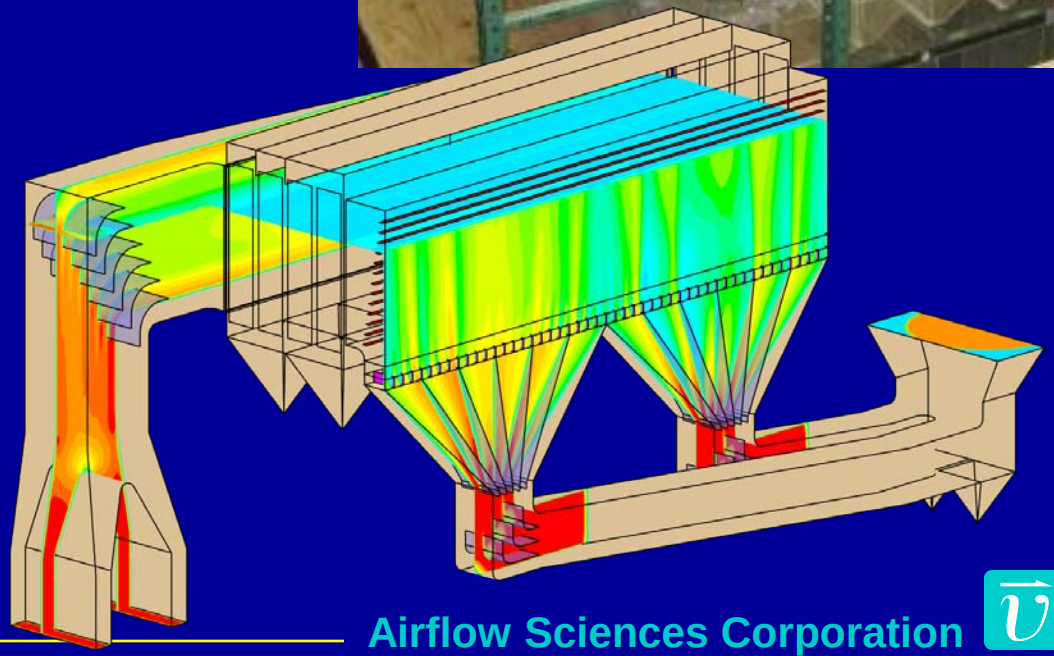
- Introduction
- Flow Distribution Analysis Techniques
- Application to Boilers
- Application to APC Equipment
  - ESP
  - FF
  - Mercury / SO_3
  - SCR
  - FGD
- Other Applications
- Conclusions
- Questions

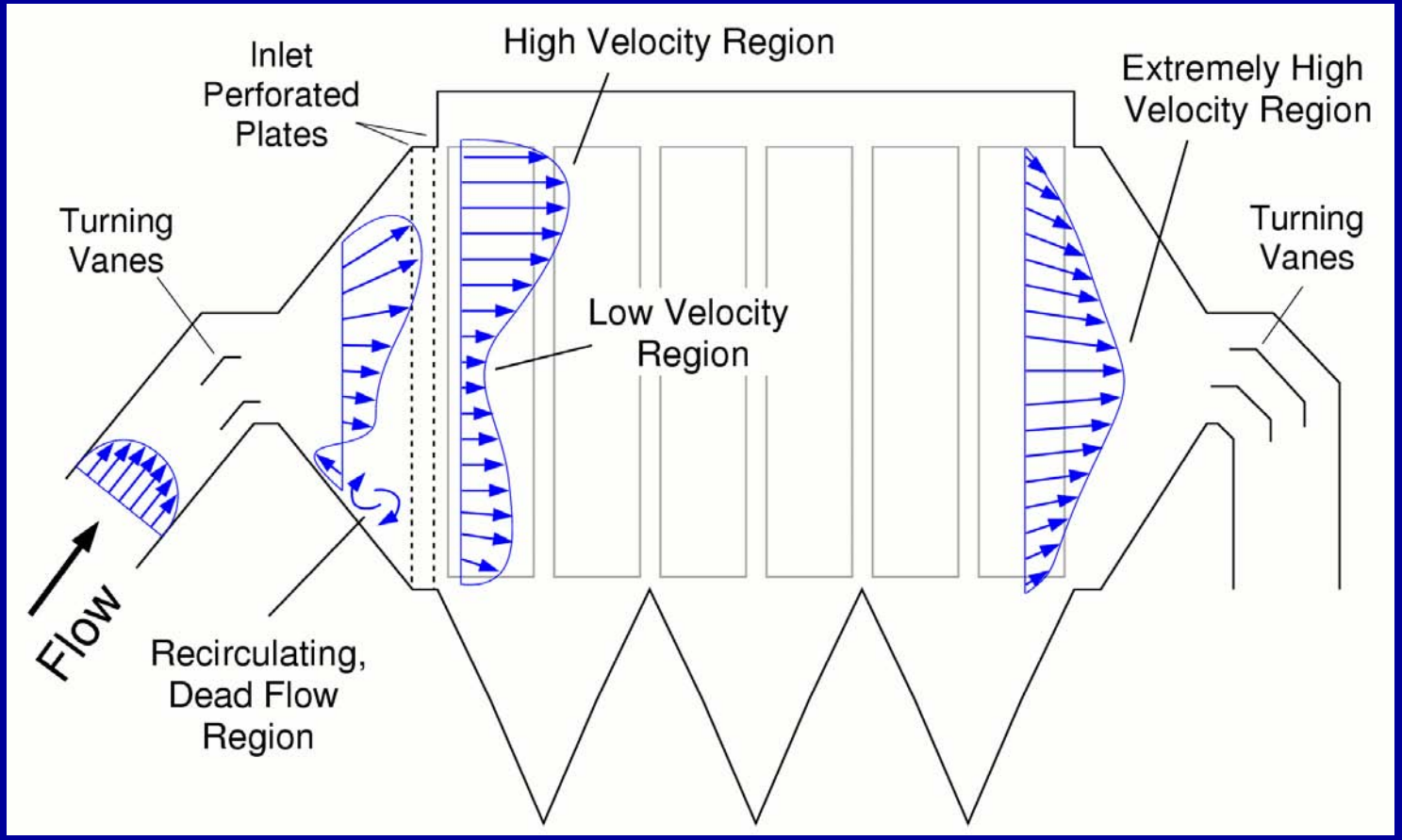
ESP Flow Optimization

- Flow distribution
- Flow balance between cells
- Pressure loss
- Thermal mixing
- Gas conditioning
- Ash deposition



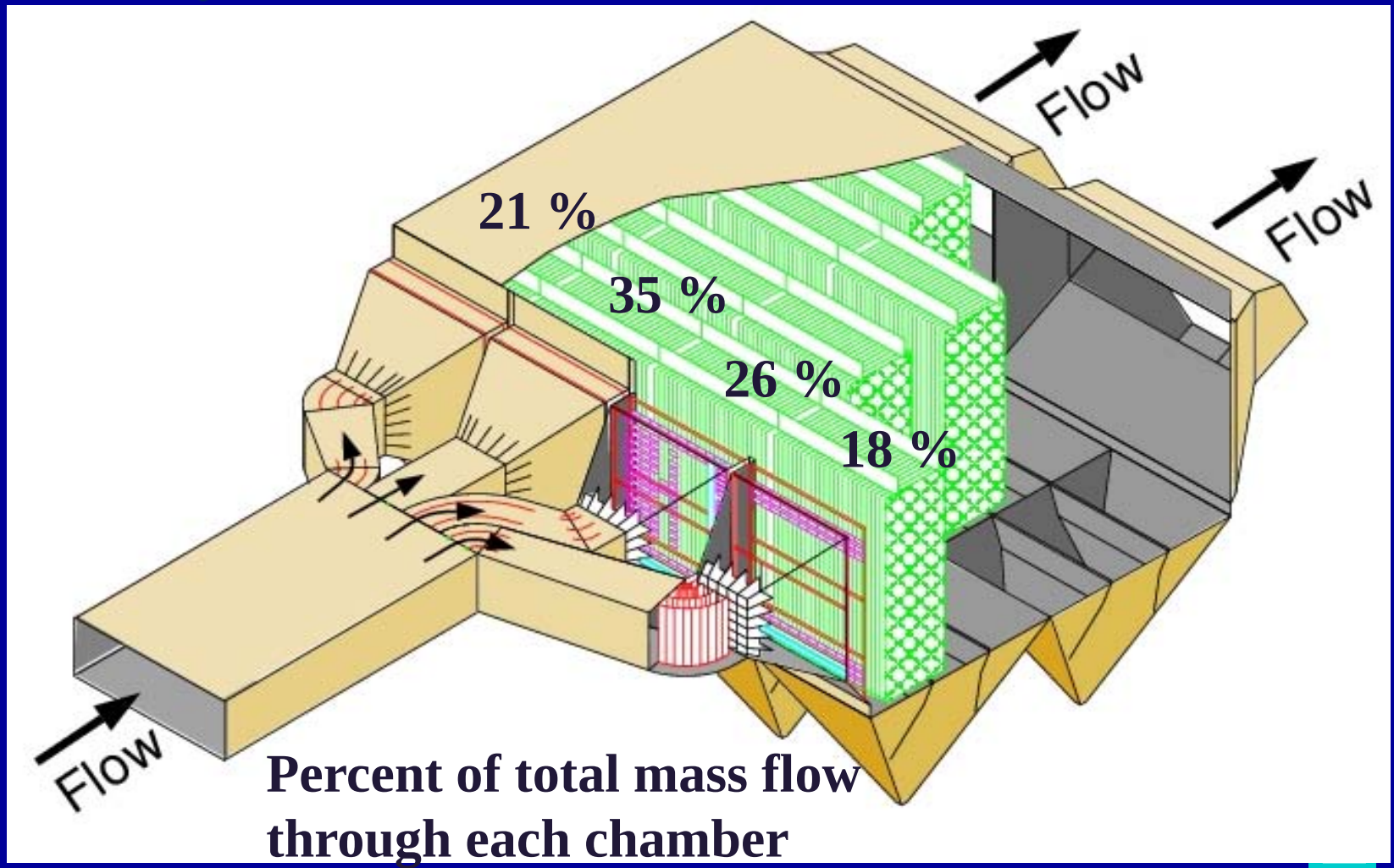
ESP Velocity Distribution

- Uniform velocity within collection region
- Industry standards
  - ICAC
  - % RMS deviation



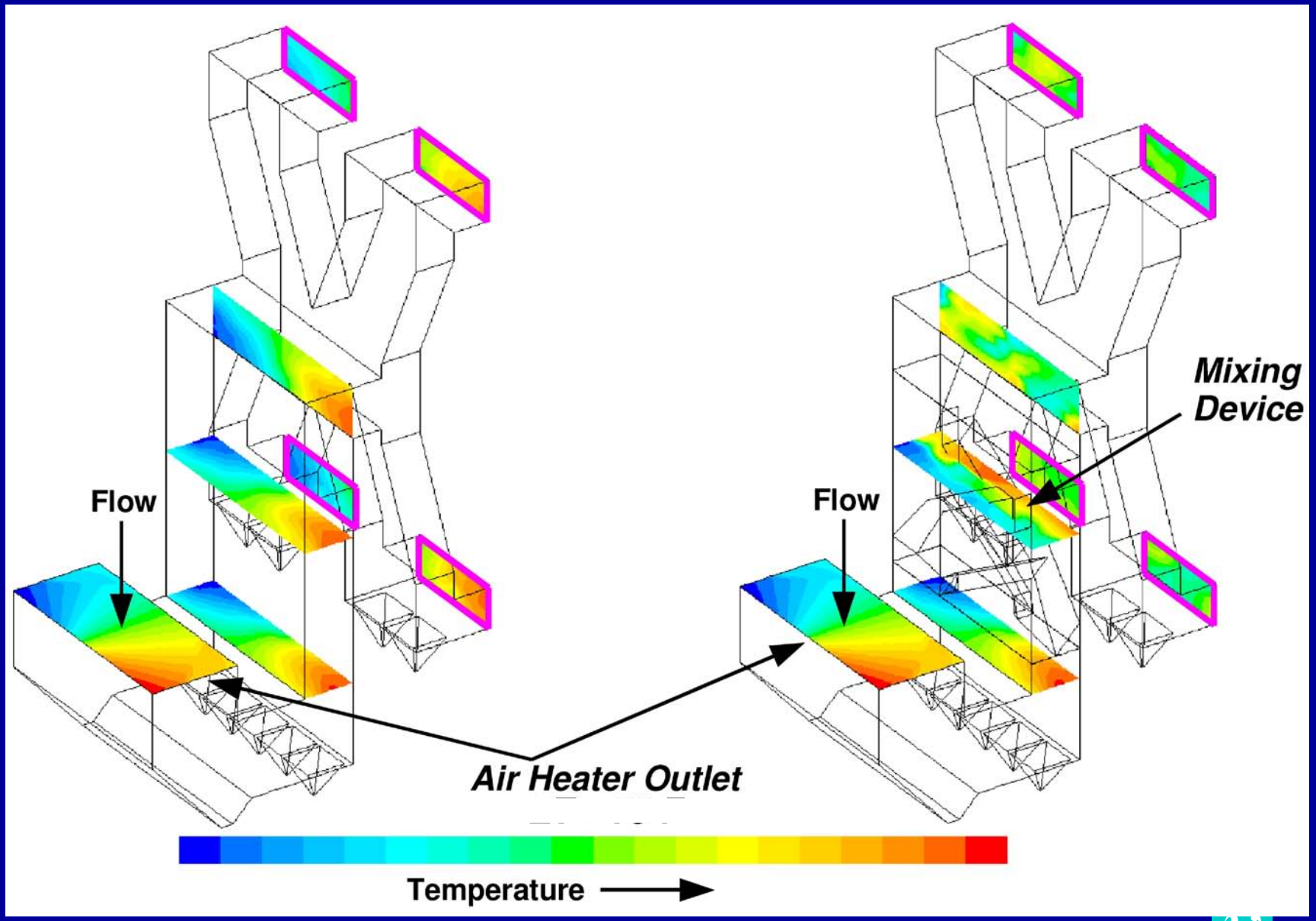
Gas Flow Balance

- Industry standard +/- 10% deviation



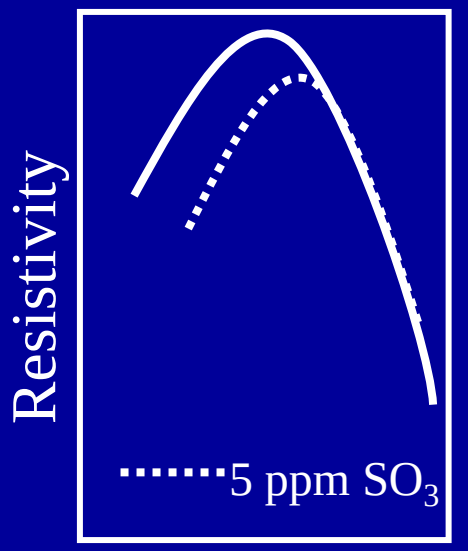
ESP Temperature Stratification

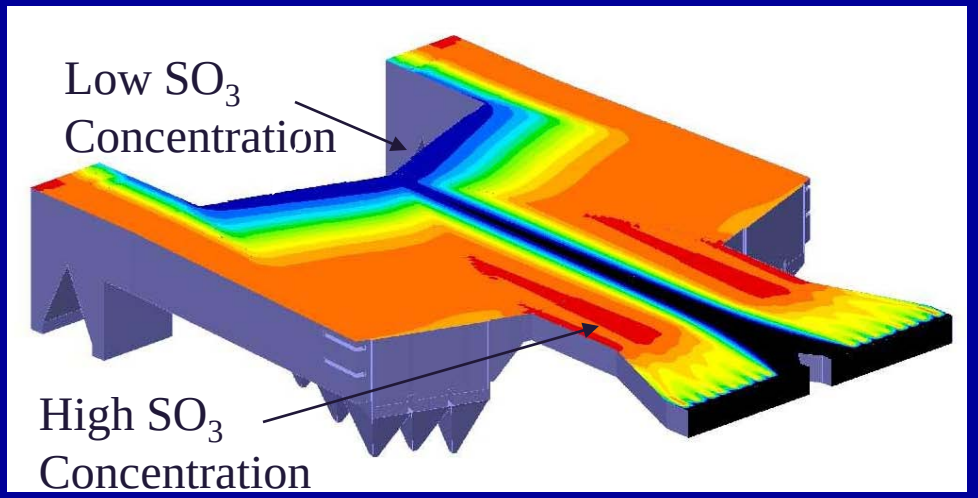
ESP Temperature Stratification

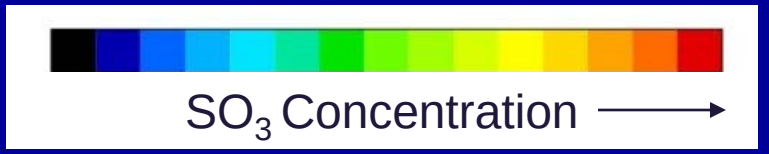


ESP Gas Conditioning

- Modify ash resistivity
  - SO_3
  - Ammonia
  - Others

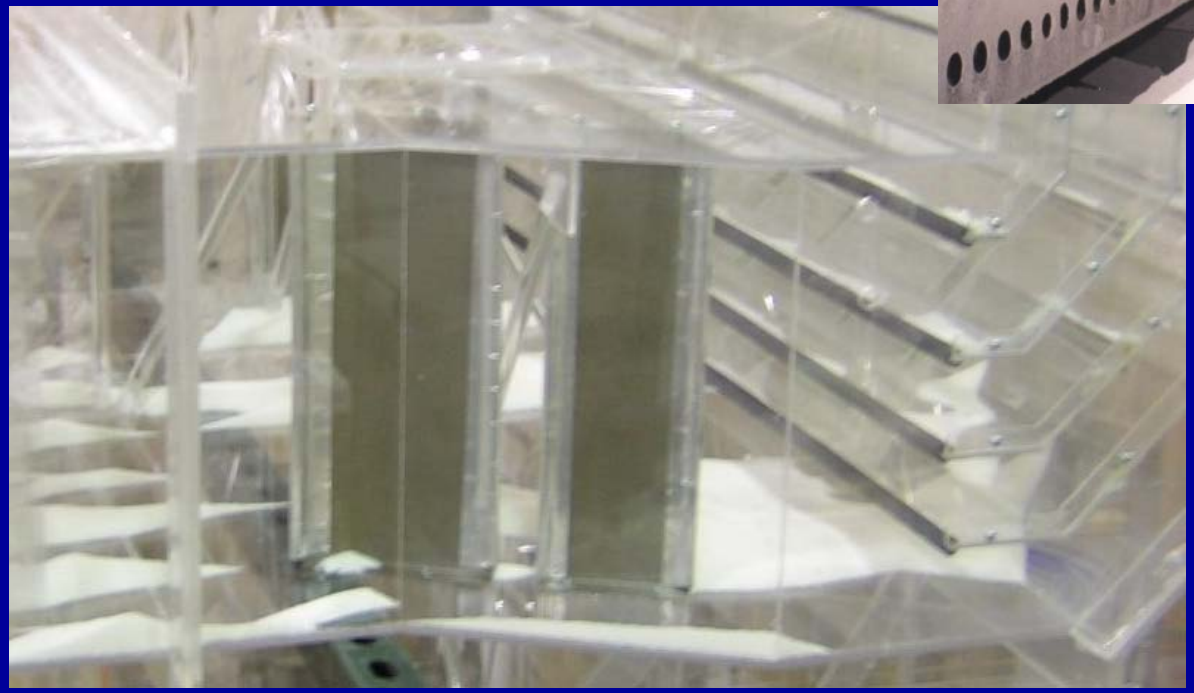






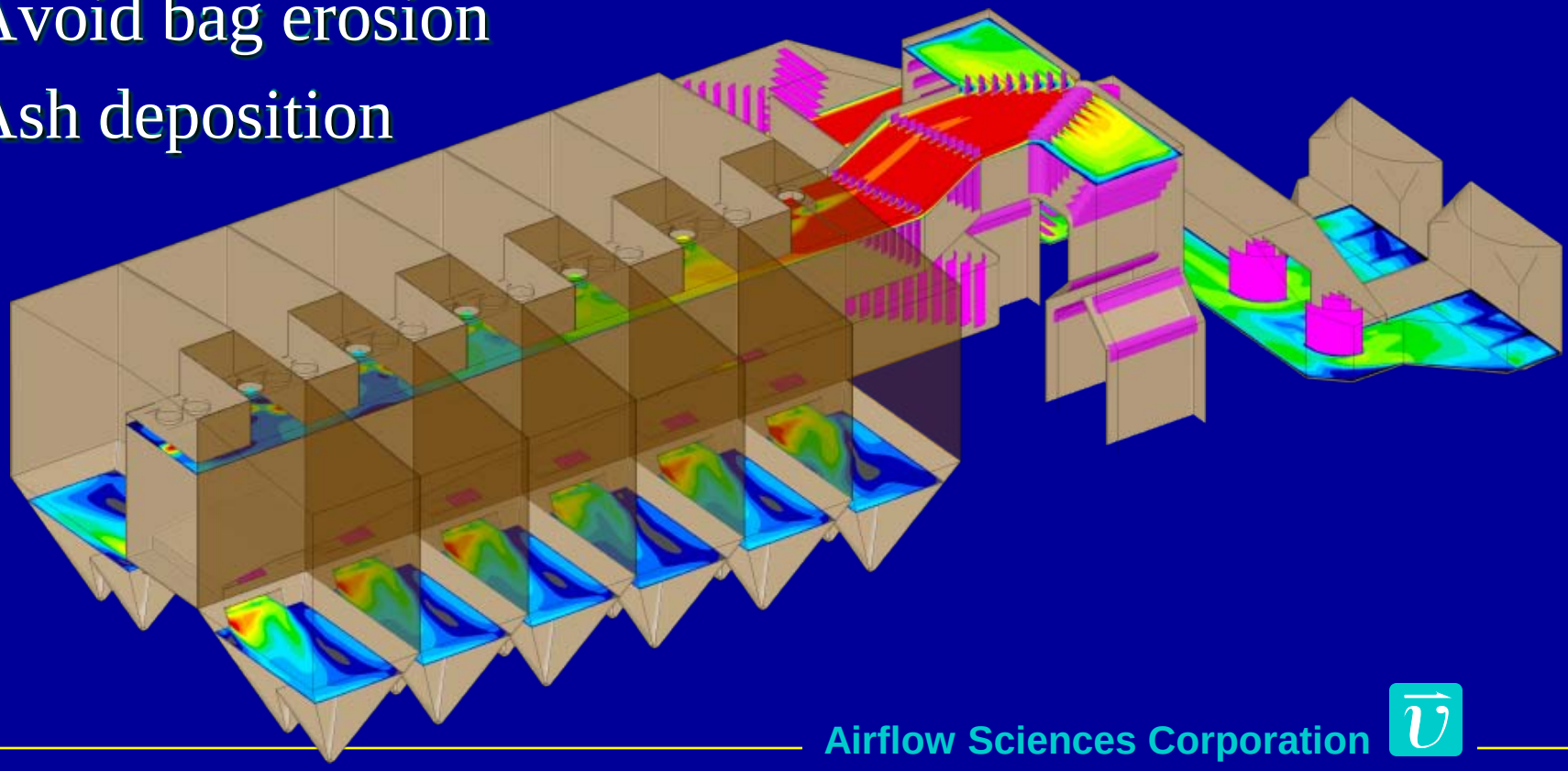
Ash Deposition

- Drop out
- Re-entrainment



Fabric Filter Flow Modeling

- Uniform velocity distribution and equal balance between compartments
- Compartments out-of-service
- Avoid bag erosion
- Ash deposition

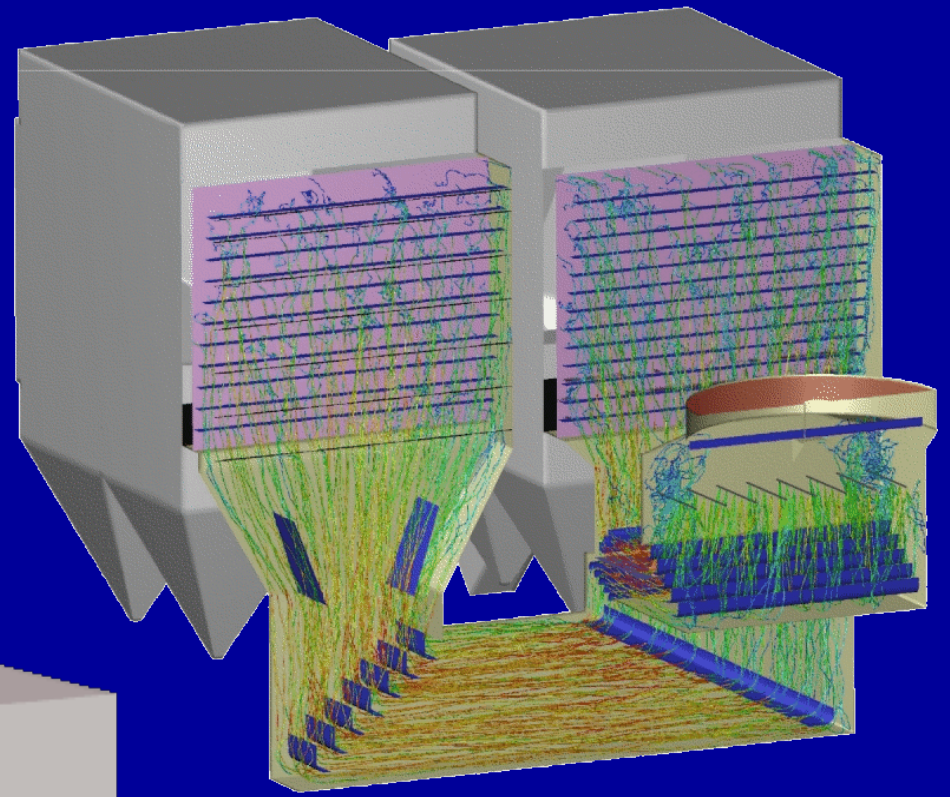


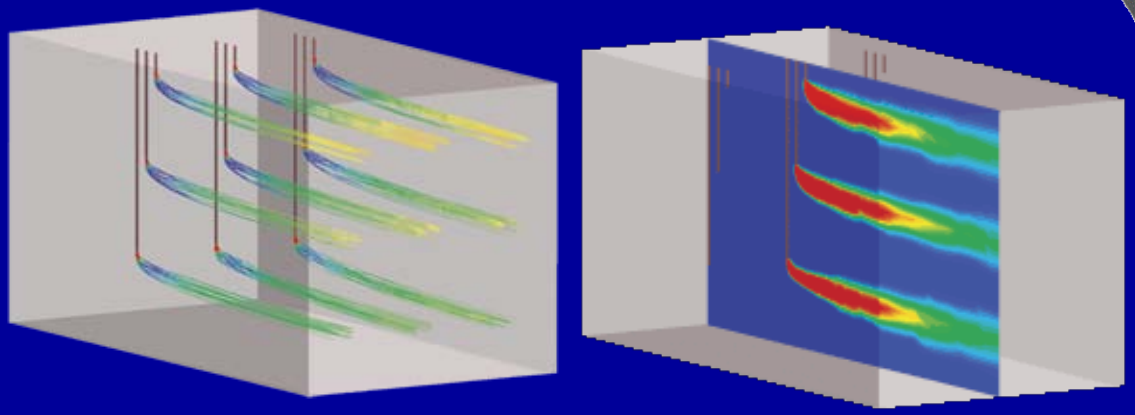
Fabric Filter Flow Modeling

FF with SDA

Mercury / SO3 Reduction

- Injection upstream of baghouse or ESP
  - Activated carbon
  - Lime, Trona, SBS, etc.
- Uniform sorbent distribution
- Maximize residence time



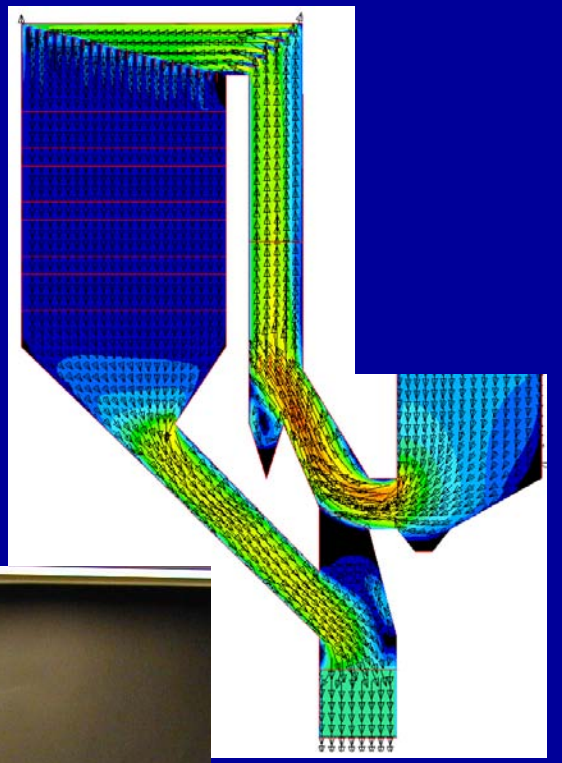


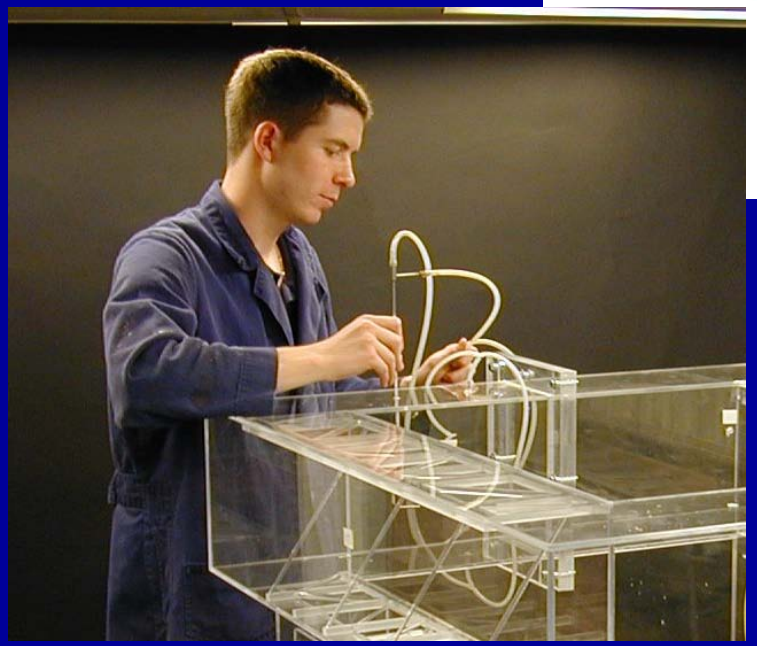
SCR Flow Optimization

- Velocity distribution
- Thermal mixing
- NOx profile / mixing
- Ammonia injection
- Pressure loss
- Large particle ash (LPA) or "popcorn ash" capture
- Ash deposition

SCR Velocity Distribution

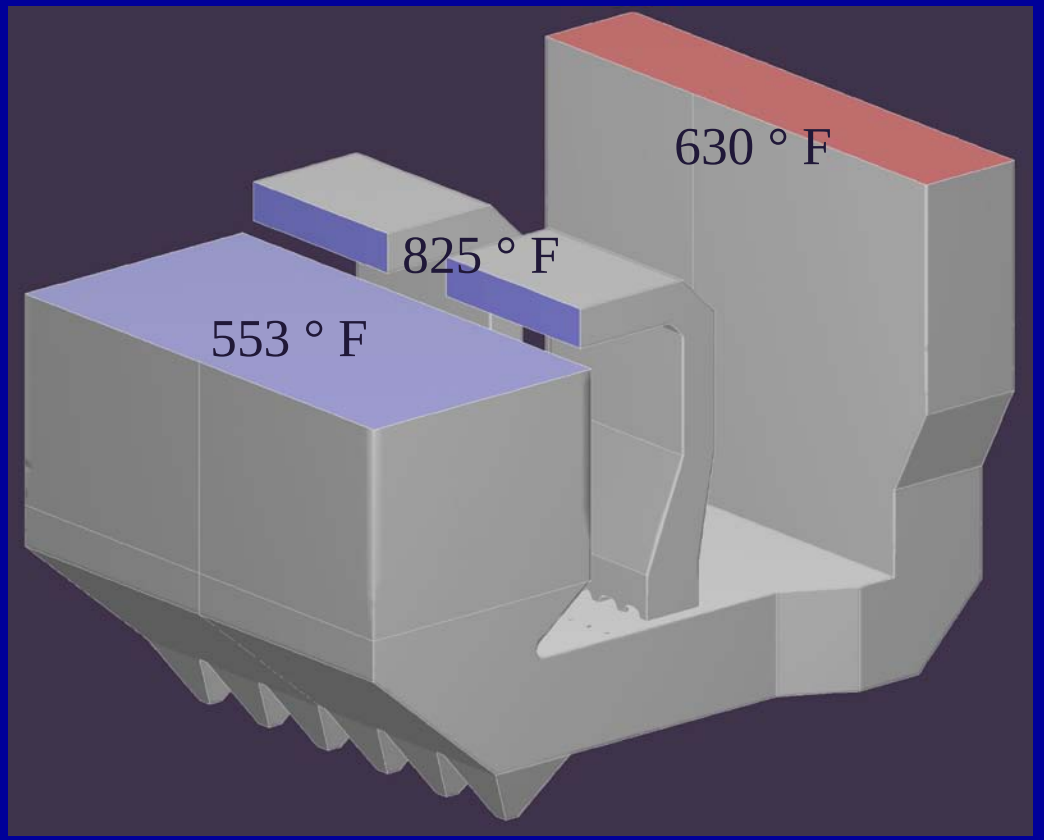
- Uniform velocity profile
  - At ammonia injection grid
  - At catalyst inlet
  - At air heater inlet
- Minimal angularity
  - At catalyst inlet





SCR Thermal Mixing

- SCR low load operation with economizer bypass
- CFD model to design mixer using full scale operating conditions
- Physical model tracer gas tests to confirm design

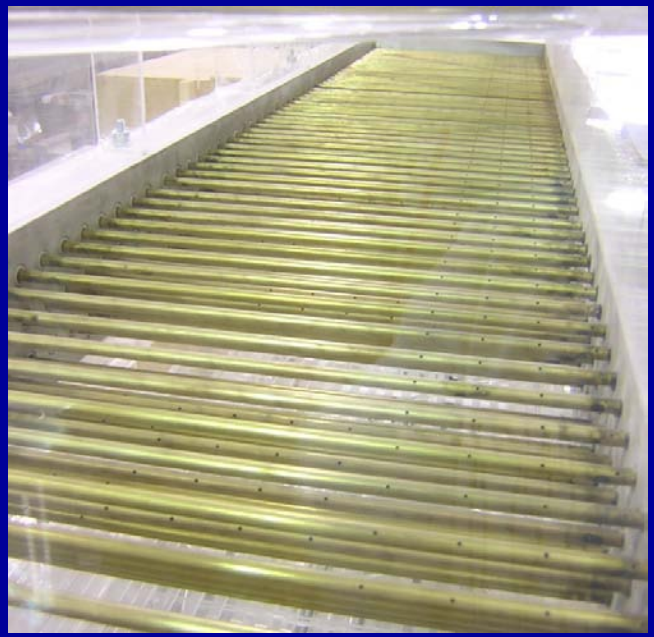


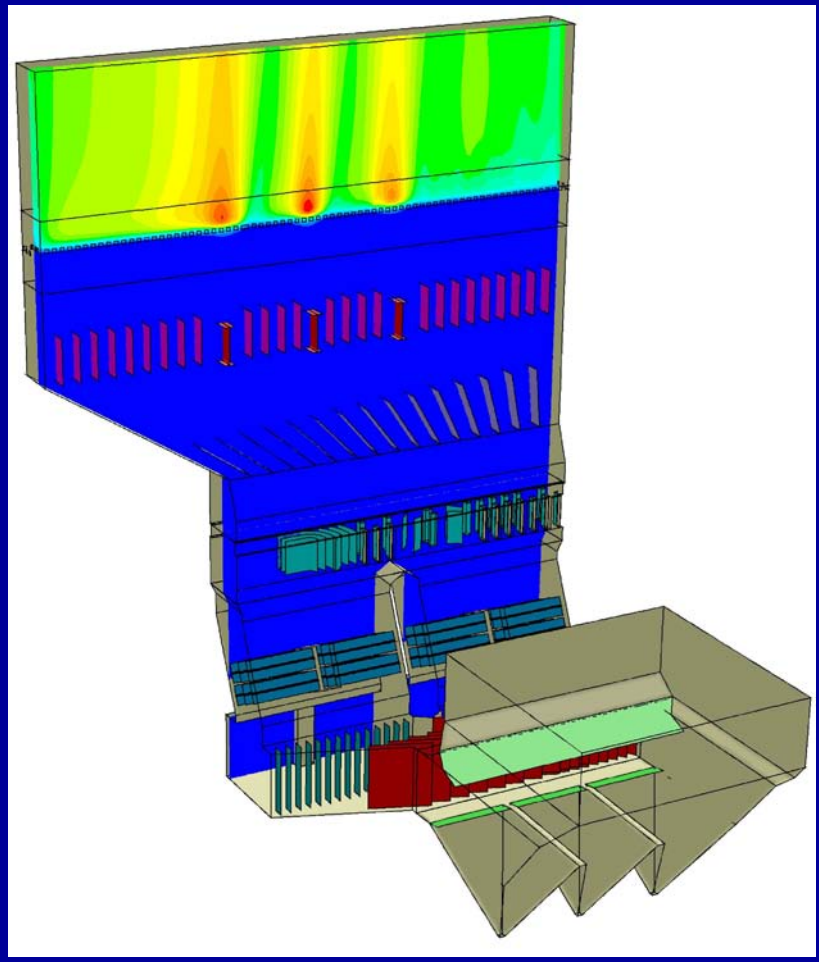
Without mixer, ΔT = ±83 °F

With mixer, ΔT = ±15 °F

SCR Ammonia Injection

- Desire uniform NH3-to-NOx ratio at catalyst
- Tracer gas used to represent flows in physical model
- Track gas species in CFD



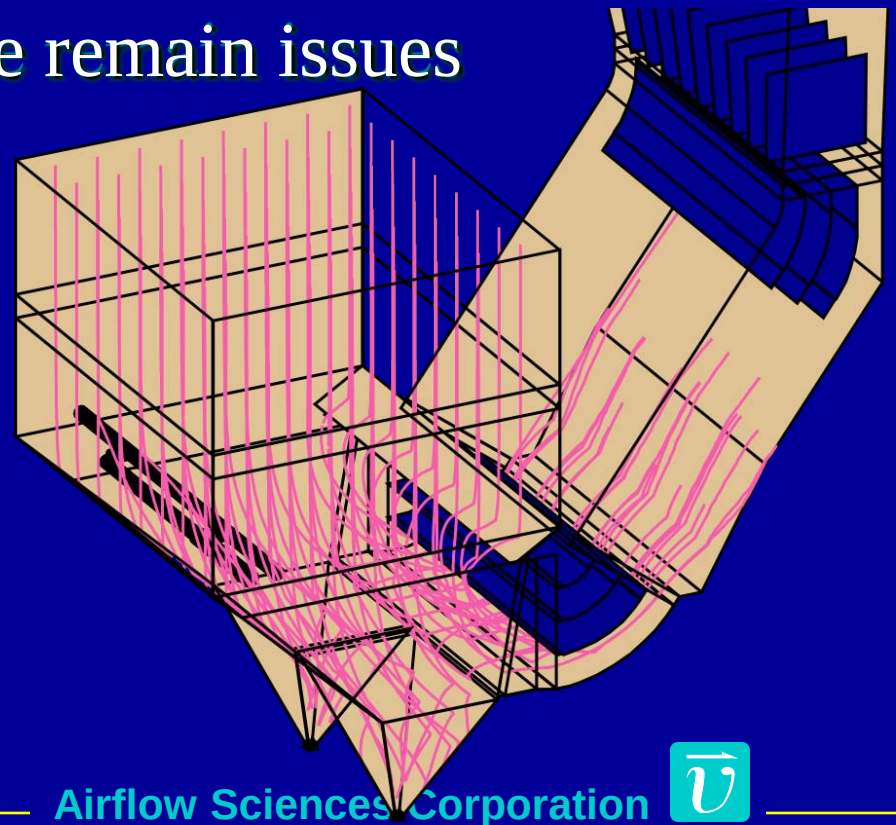


SCR Large Particle Ash Capture

- Catalyst openings for coal-fired plants are smaller than LPA particles
- Once LPA becomes “wedged” into the catalyst, fine ash builds up as well
  - Hard to clean
  - Get dunes of ash on top layer catalyst

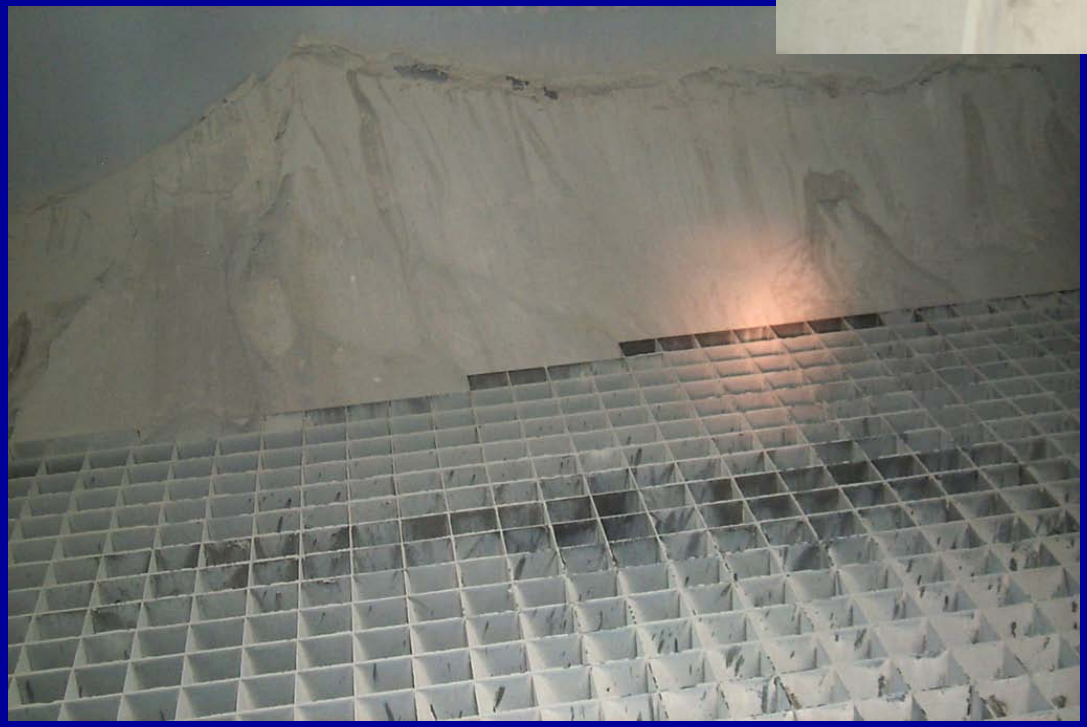
LPA System Design – Key Points

- Capture LPA in hoppers of adequate size
- LPA screens have become standard practice
- Ash deflection baffles also useful
- Screen erosion and pluggage remain issues



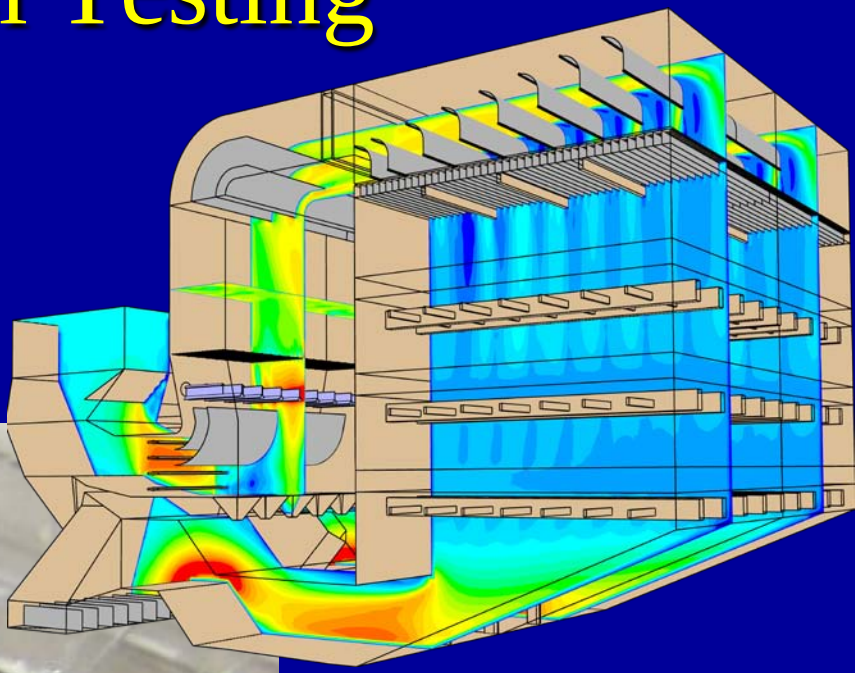
Ash Deposition

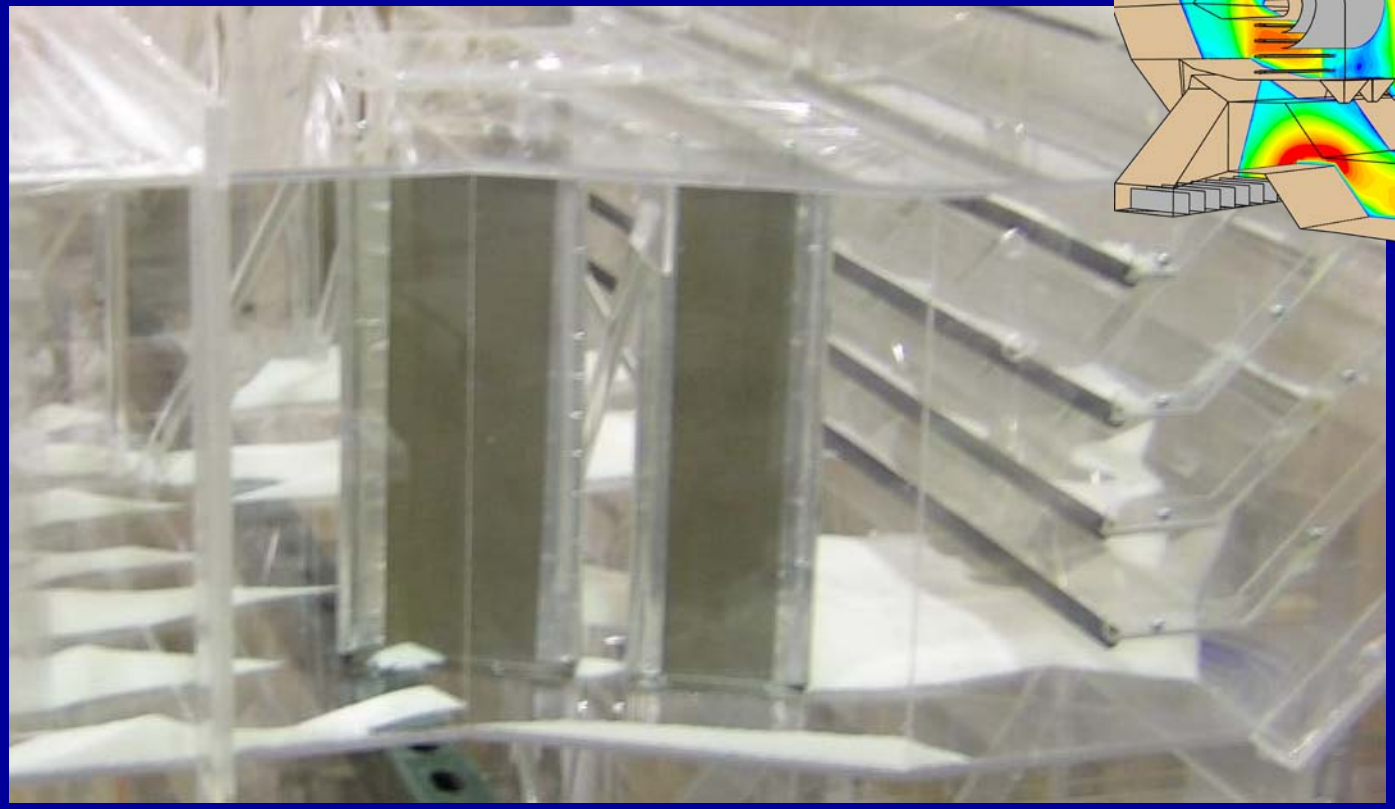
- Duct floors
- Turning vanes
- Catalyst



Ash Deposition – Model Testing

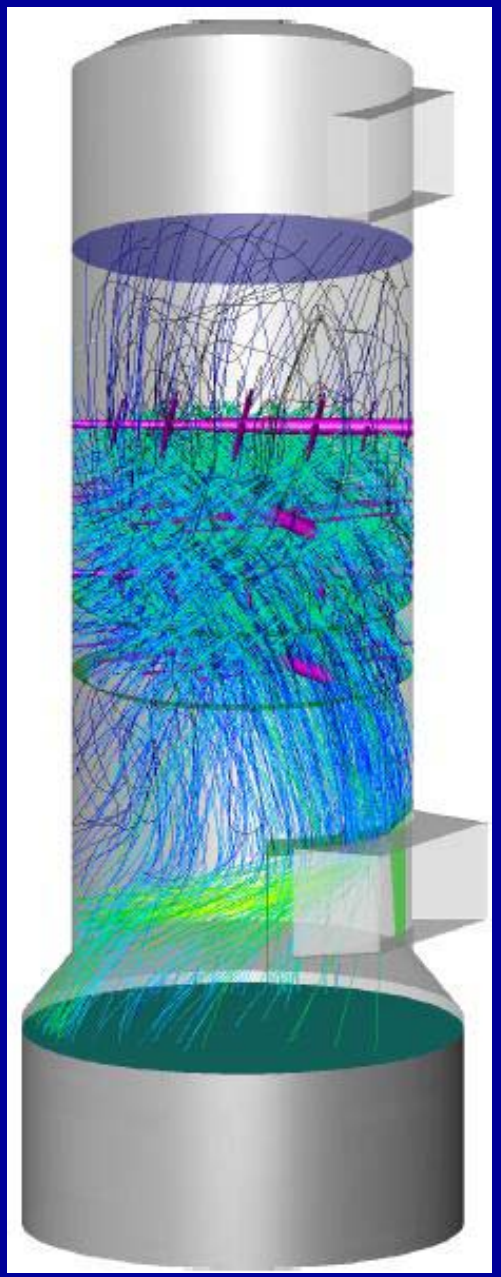
- Drop out
- Re-entrainment

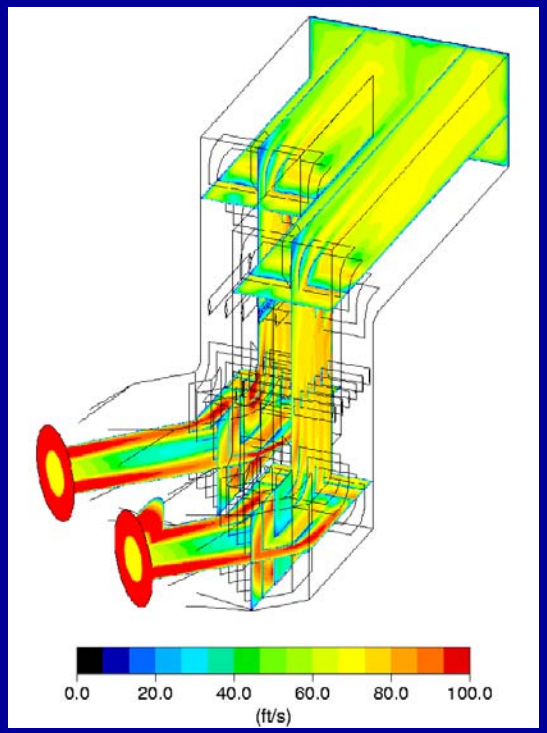




Wet FGD Flow Modeling

- Flow distribution
- Water droplet behavior
- Pressure loss
- Solids deposition





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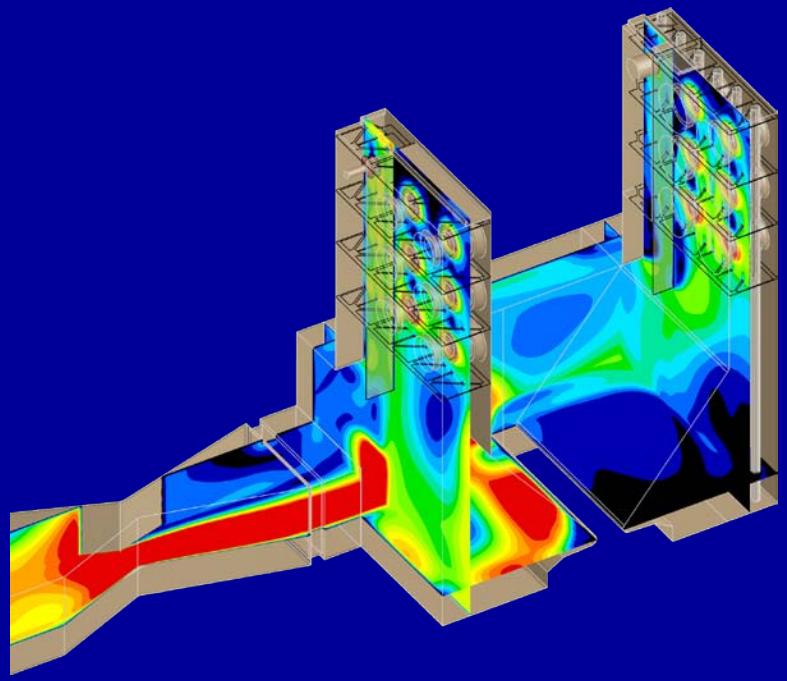
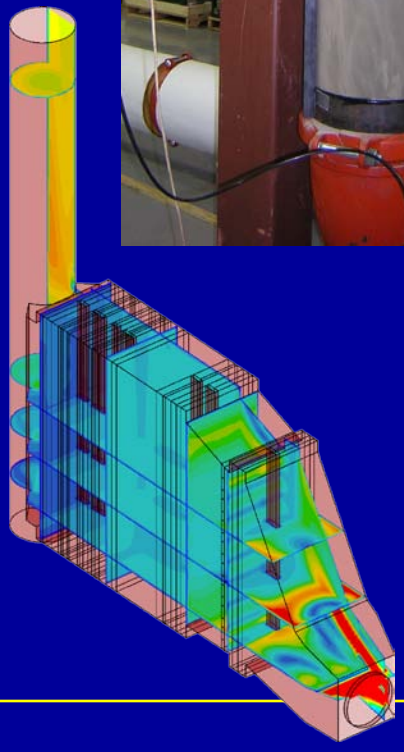
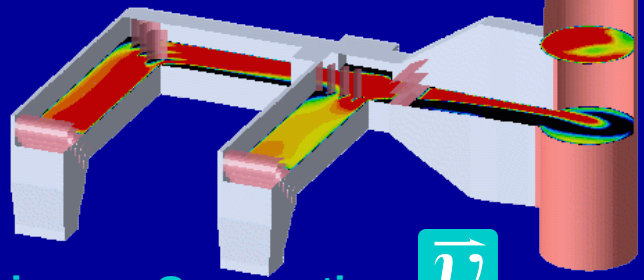
Power Industry

- Fans
- Ducts
- Pulverizers
- Windboxes
- Furnaces
- Air Heaters
- Stacks
- Turbines
- Condensers
- HRSGs
- …

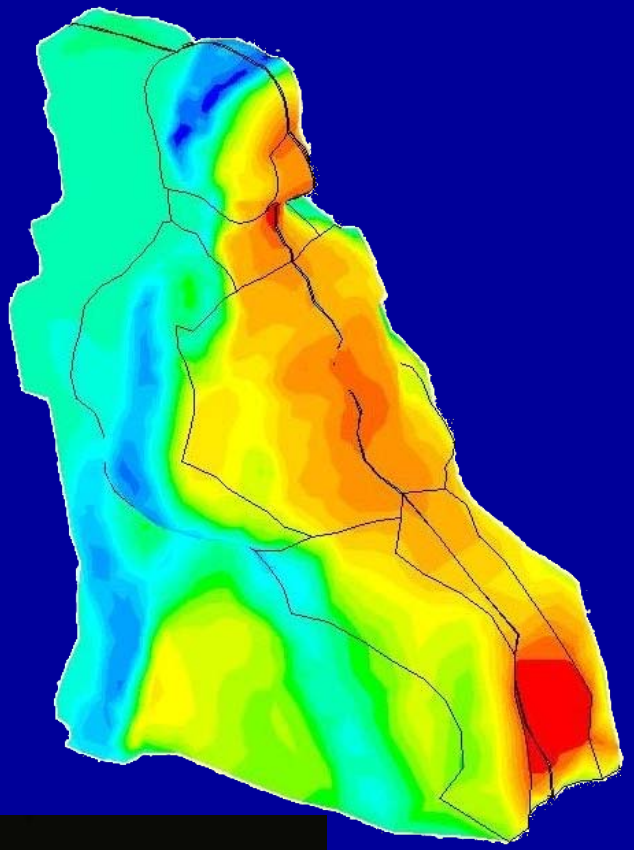






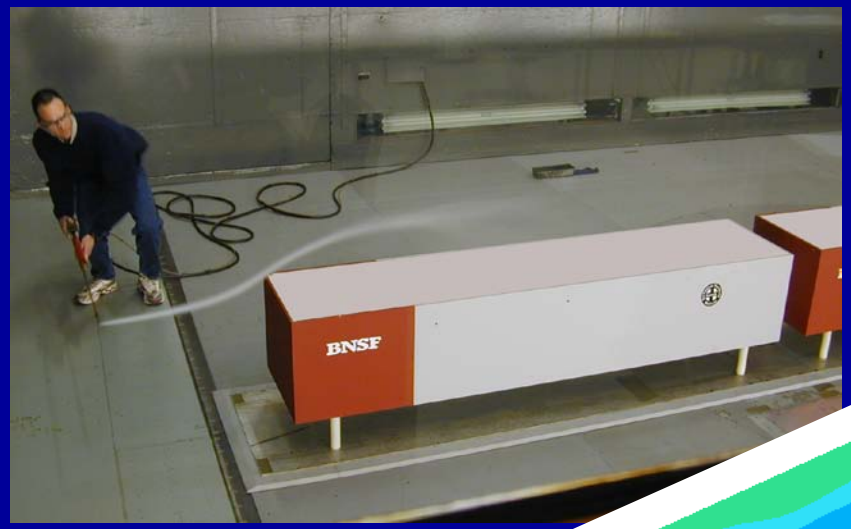
Aerospace

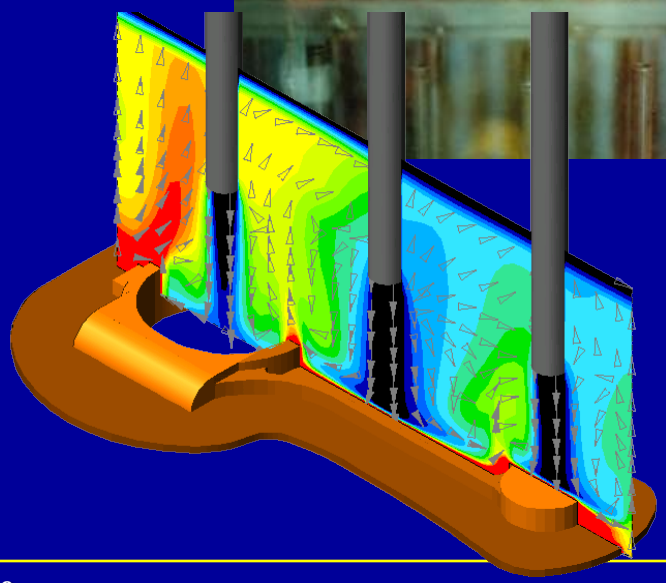
- Spacecraft
- Aircraft
- Missiles
- Engines

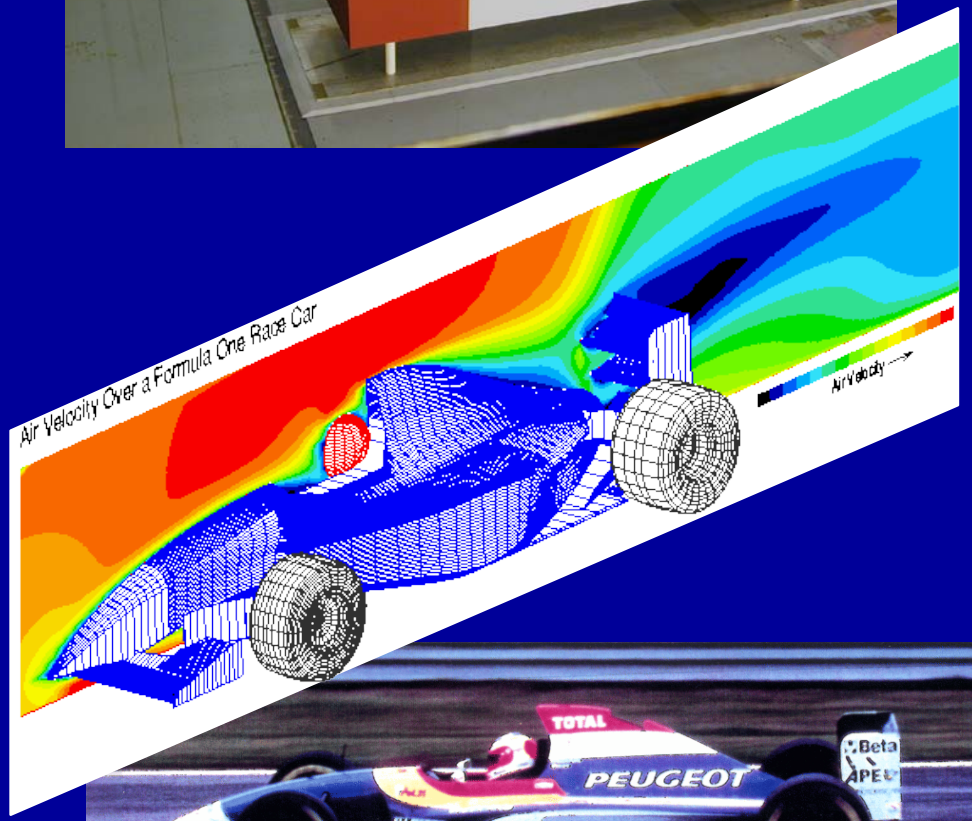


Vehicle Design

- Aerodynamics
- HVAC, cooling systems
- Engine components

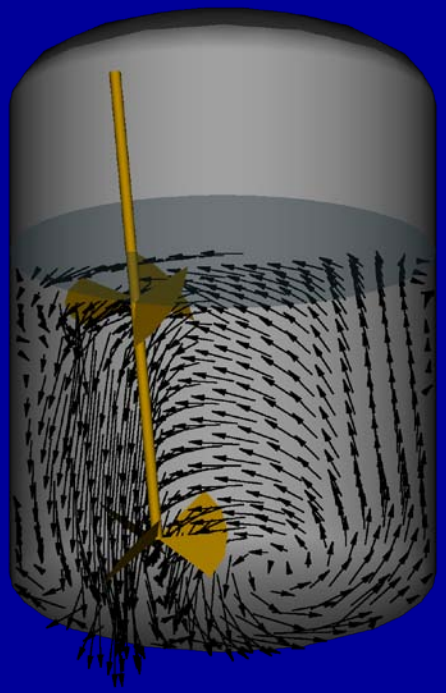


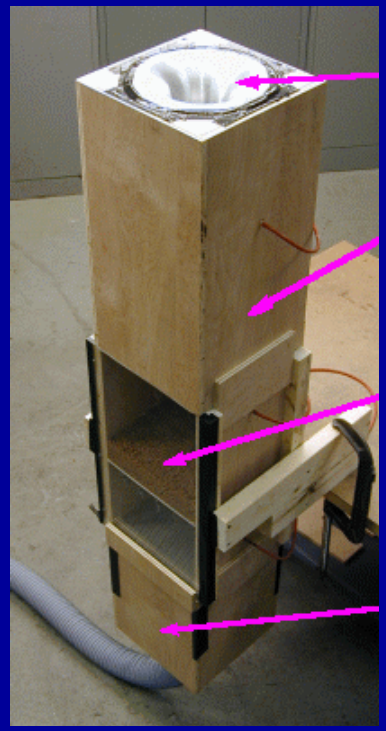


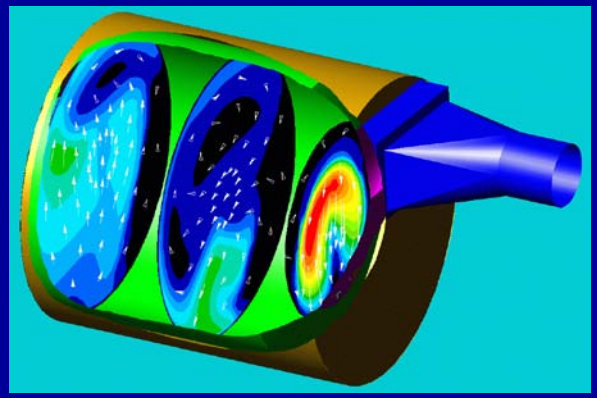


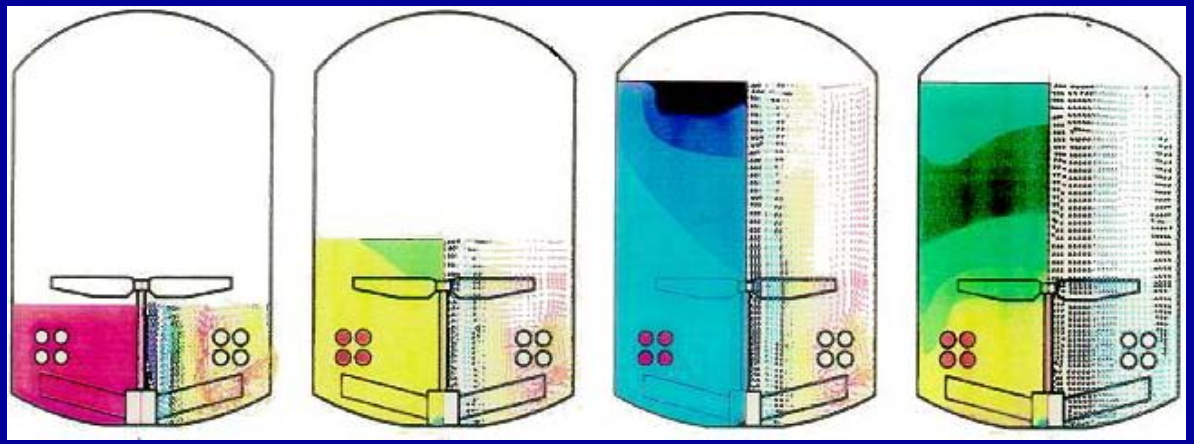
Food Processing

- Baking
- Toasting
- Roasting
- Drying
- Frying
- Chilling
- Coating
- Mixing









Conclusions

- Gas flow patterns have significant impact on the performance of power plant equipment
- Analysis and design tools include field testing and flow modeling
- CFD and physical modeling are applied to a wide range of equipment “from the fan to the stack”

Questions?