

Worldwide Pollution Control Association

WPCA/FirstEnergy Biomass Seminar

Akron, Ohio
December 3, 2009

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Gas Flow – How to Improve It to Enhance ESP, Boiler, FGD, SCR, SNCR Performance

WPCA Seminar – FirstEnergy
December 3, 2009

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?

Performance

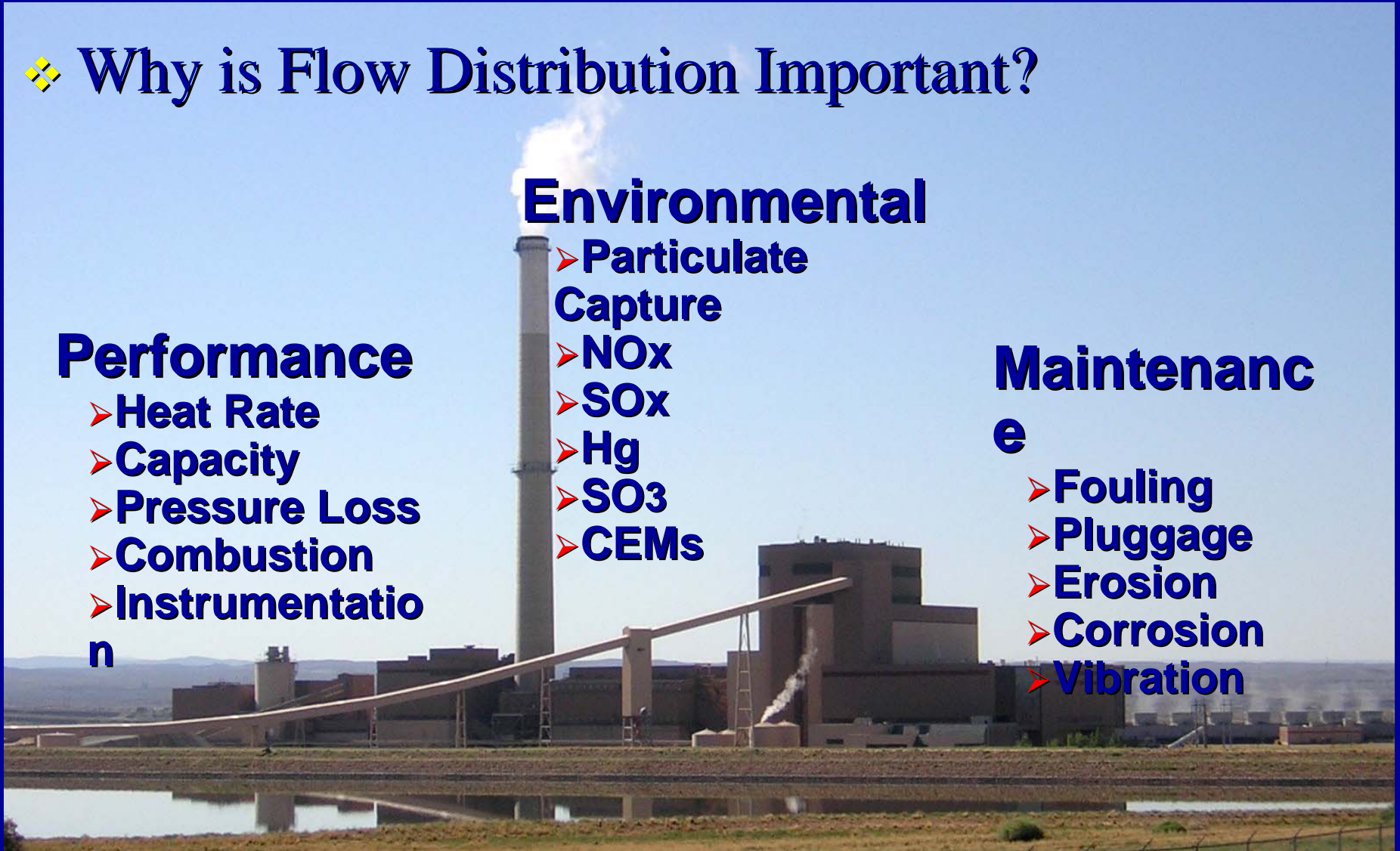
- Heat Rate
- Capacity
- Pressure Loss
- Combustion
- Instrumentation

Environmental

- Particulate Capture
- NOx
- SOx
- Hg
- SO₃
- CEMs

Maintenance

- Fouling
- Pluggage
- Erosion
- Corrosion
- Vibration



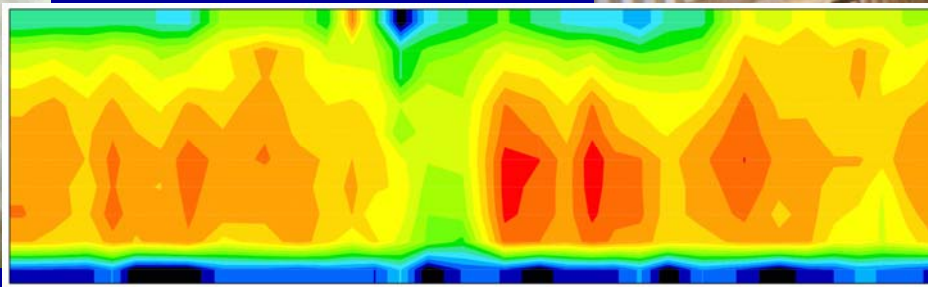
Outline

- ❖ 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

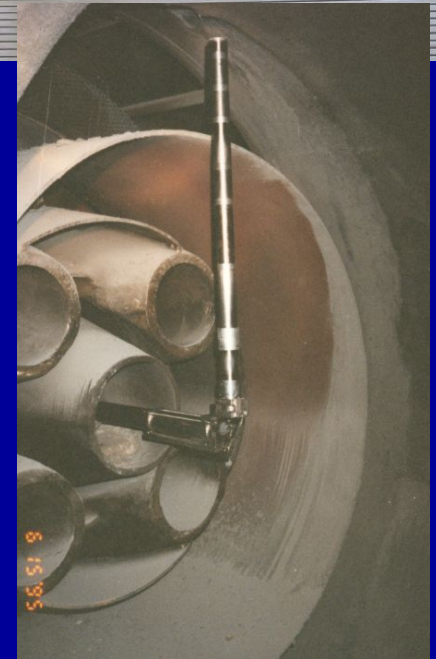


Field Testing

- ❖ Velocity
- ❖ Temperature
- ❖ Pressure
- ❖ Particulate
- ❖ Chemical species

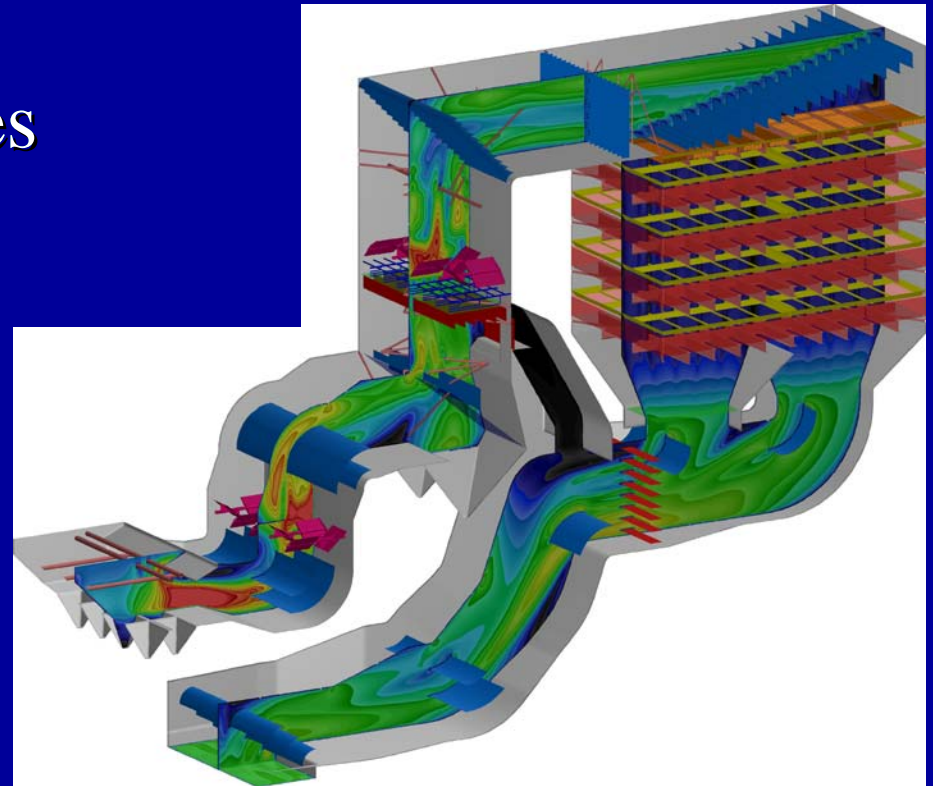


Field Testing



Computational Fluid Dynamics (CFD)

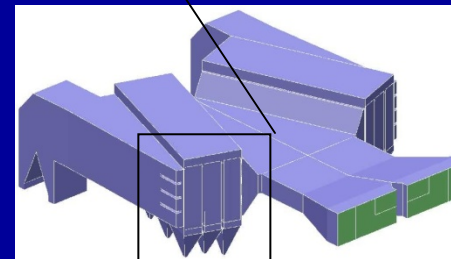
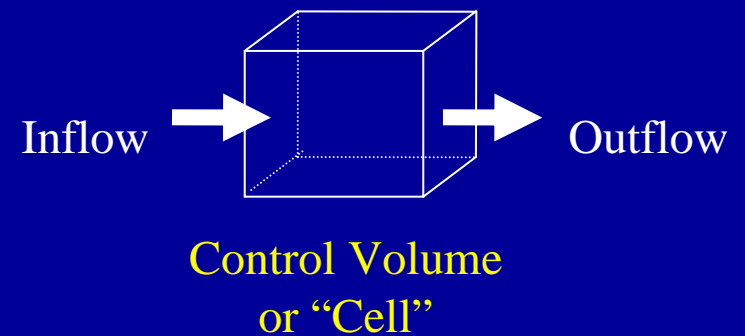
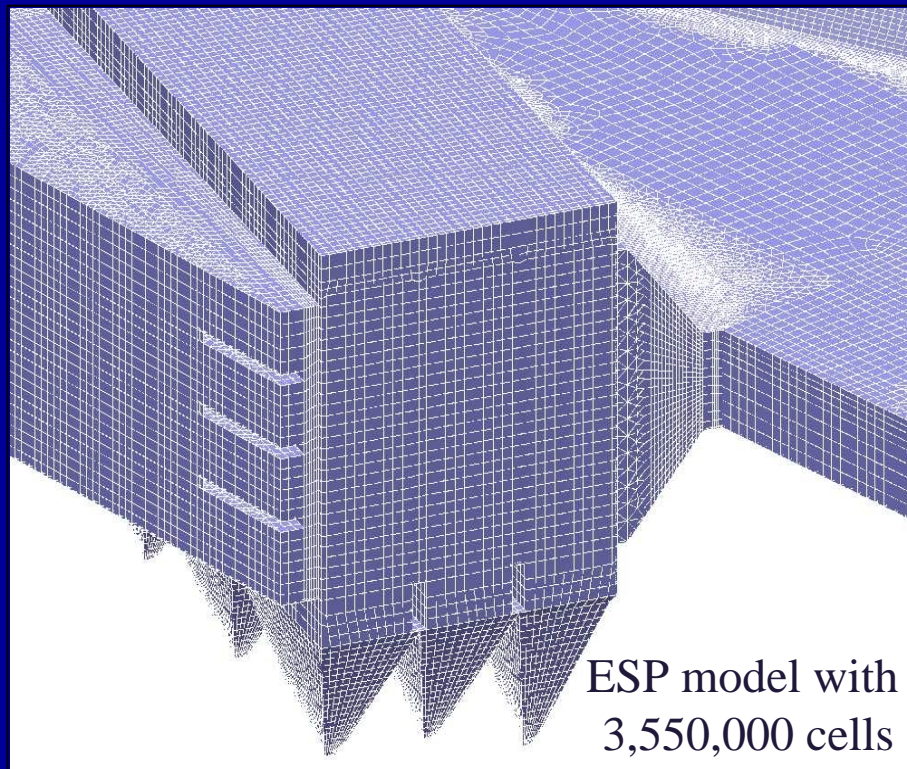
- ❖ Numerical simulation of flow
- ❖ Utilize high speed computers and sophisticated software
- ❖ Calculate flow properties
 - Velocity
 - Pressure
 - Temperature
 - Ammonia
 - Particle streamlines



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



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

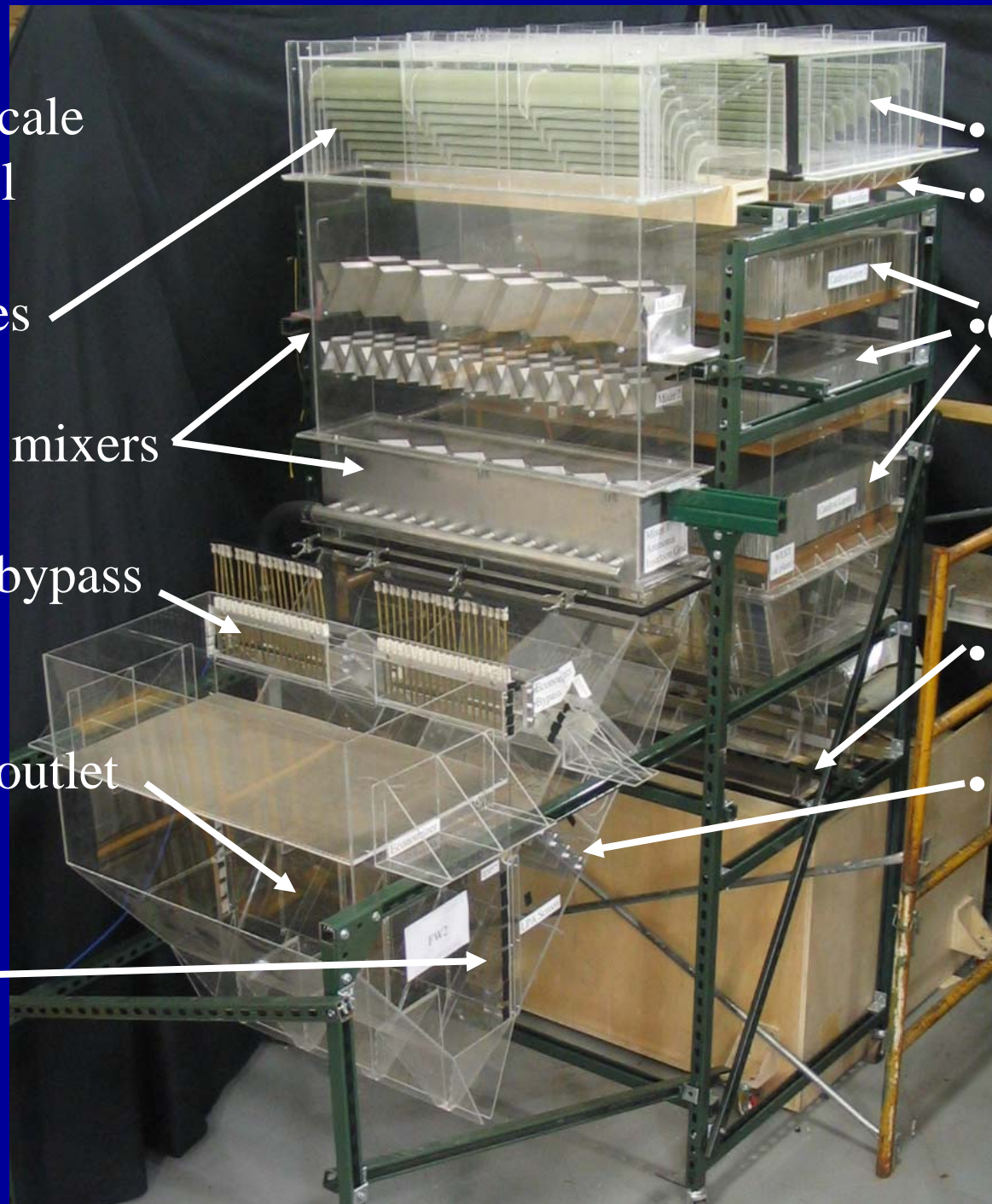
• Vanes

• Rectifier

• Catalyst layers

• Air heater

• Dampers



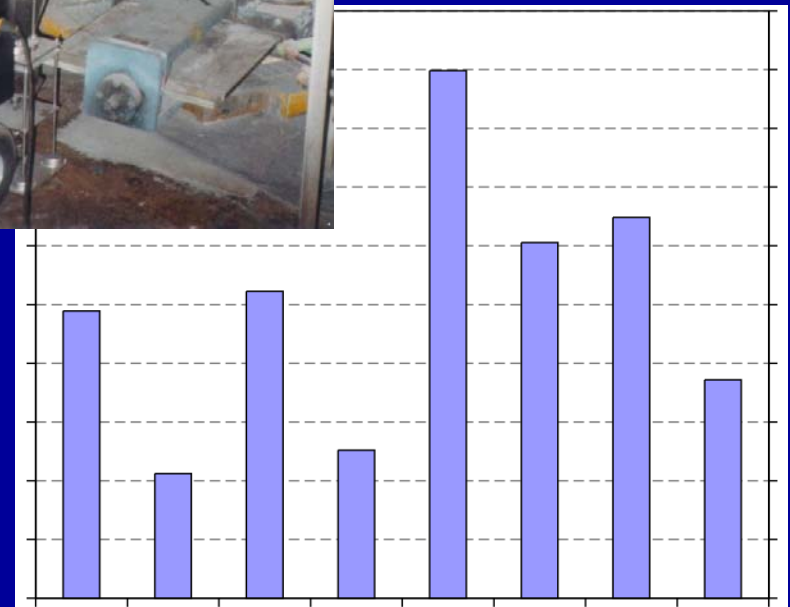
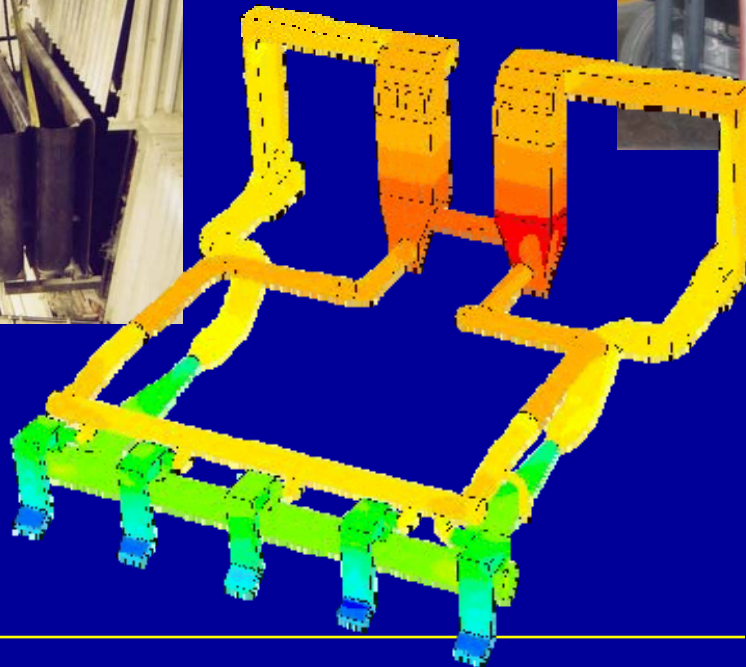
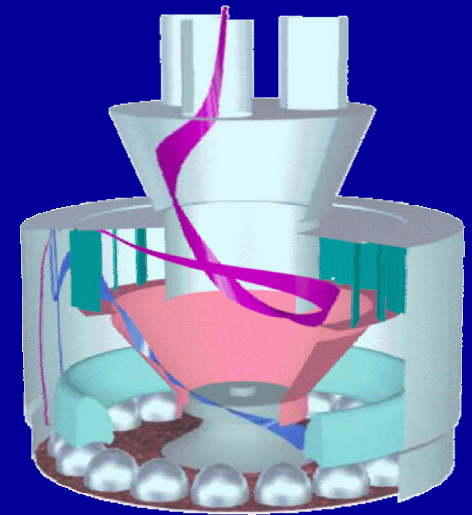
Outline

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



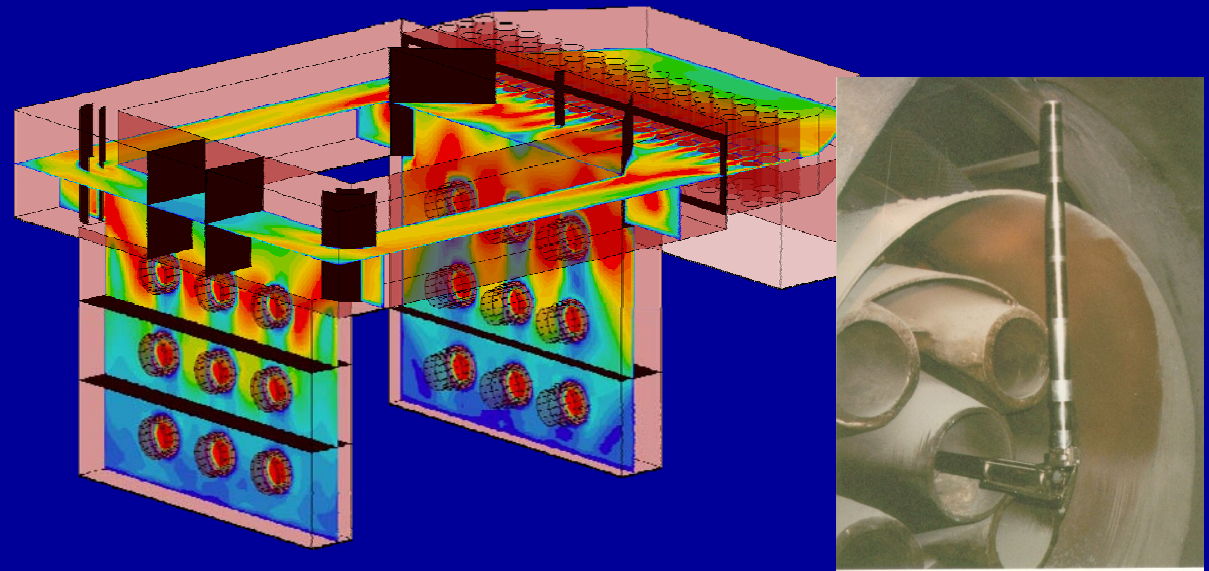
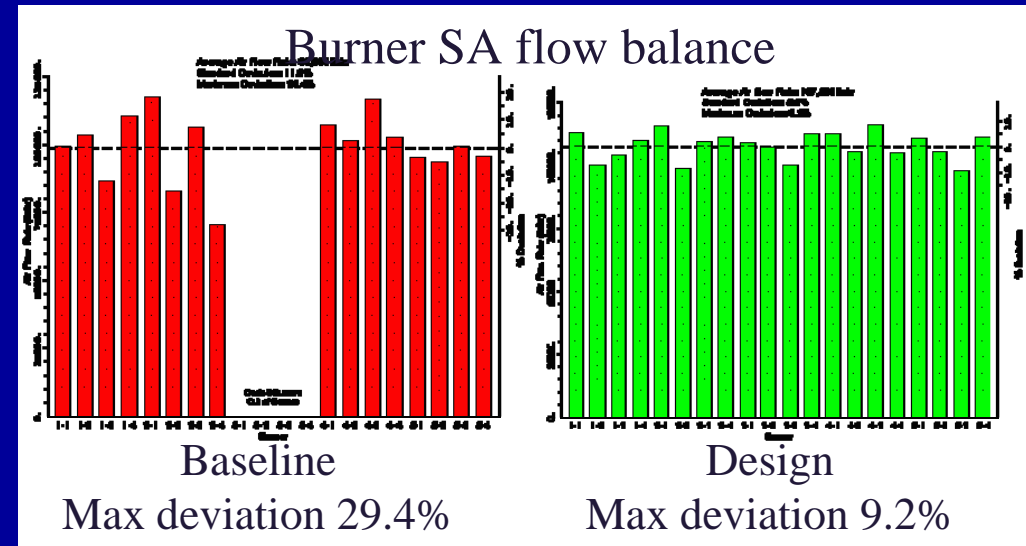
Primary Air / Coal Flow Balancing

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



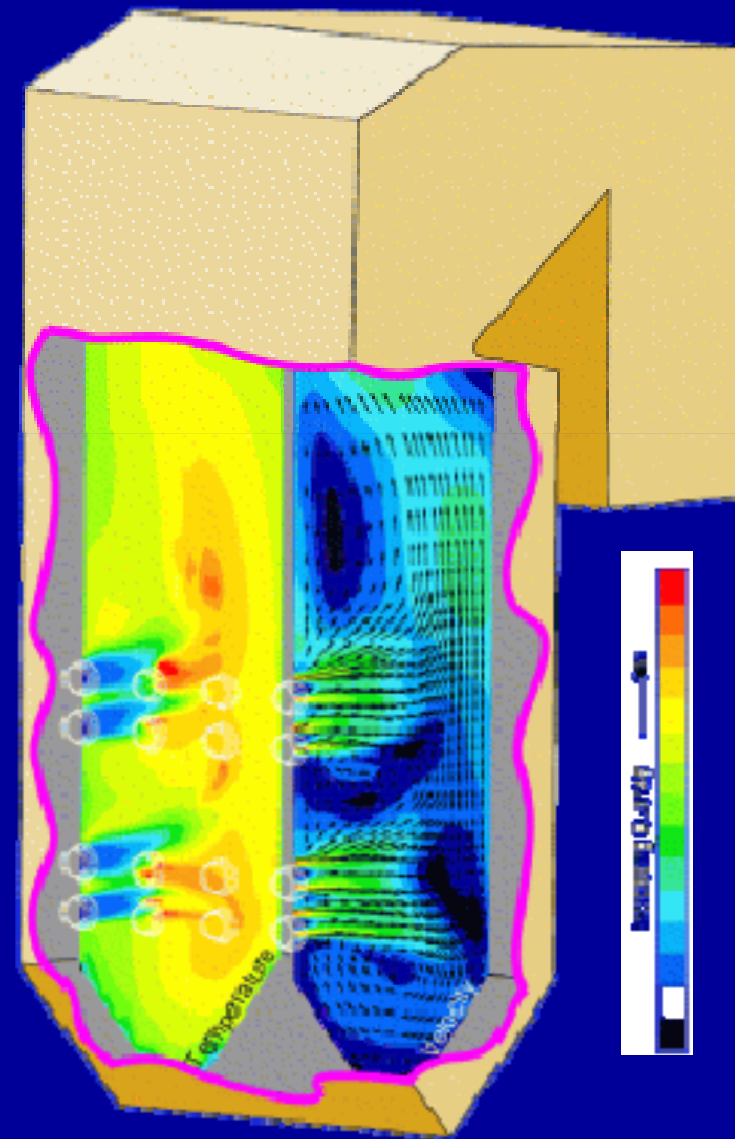
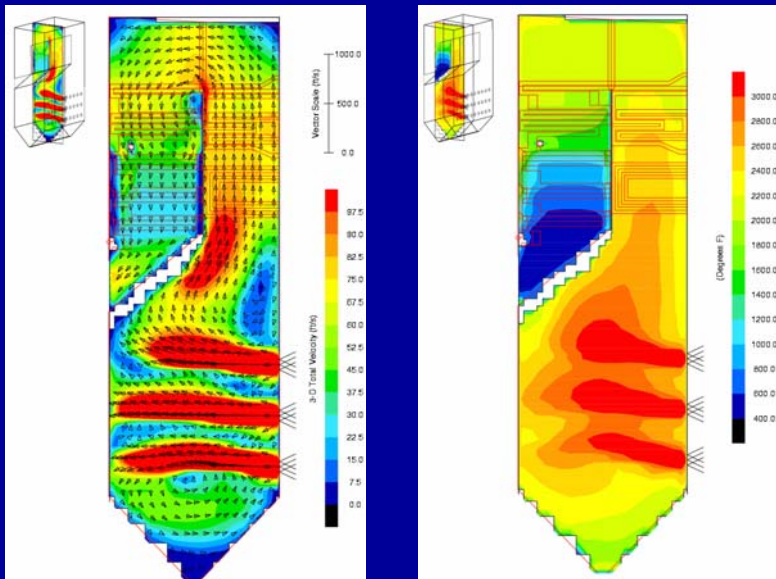
Windbox Flow Balancing

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



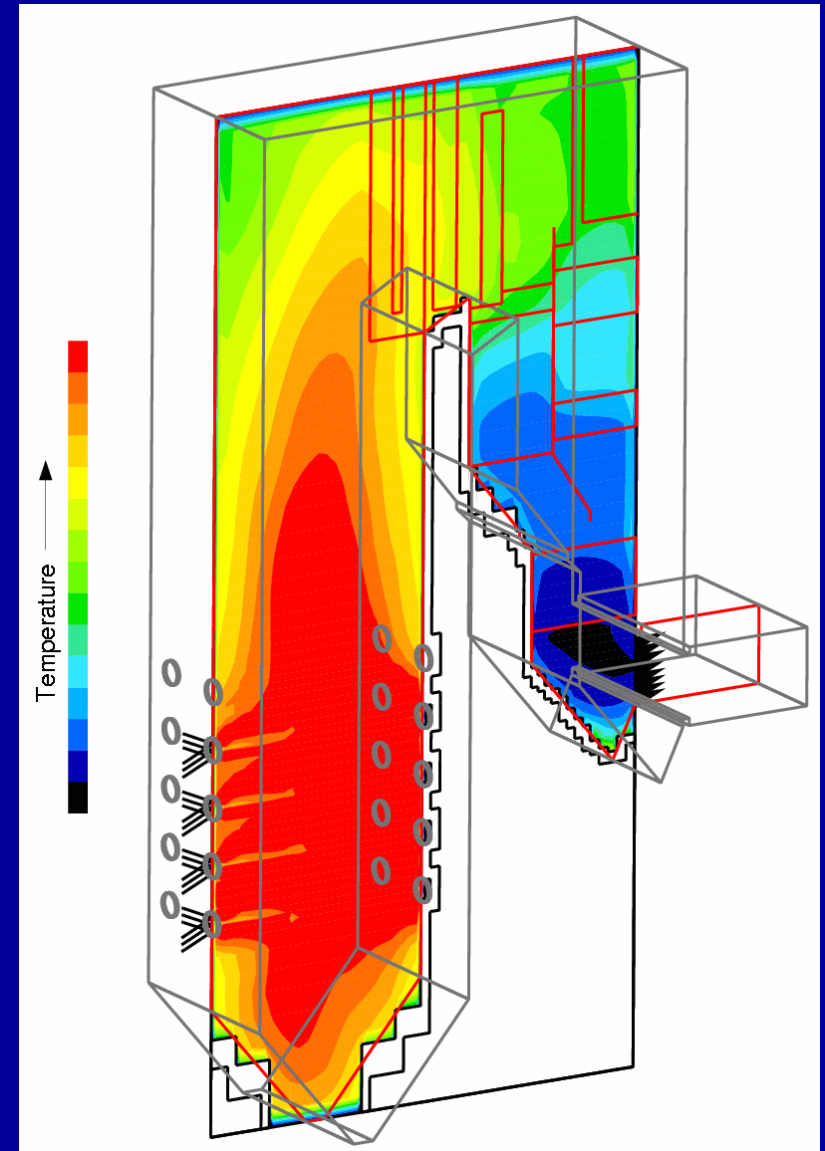
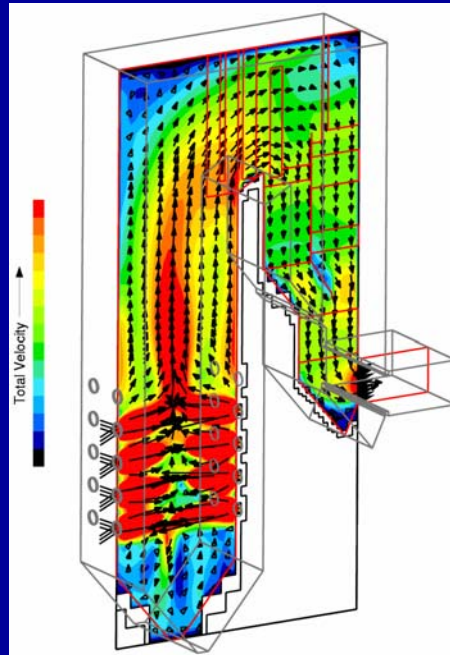
Furnace Combustion Optimization

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



SNCR

- ❖ Performance is influenced by
 - Temperature distribution
 - Velocity patterns
- ❖ Testing and modeling used to optimize performance



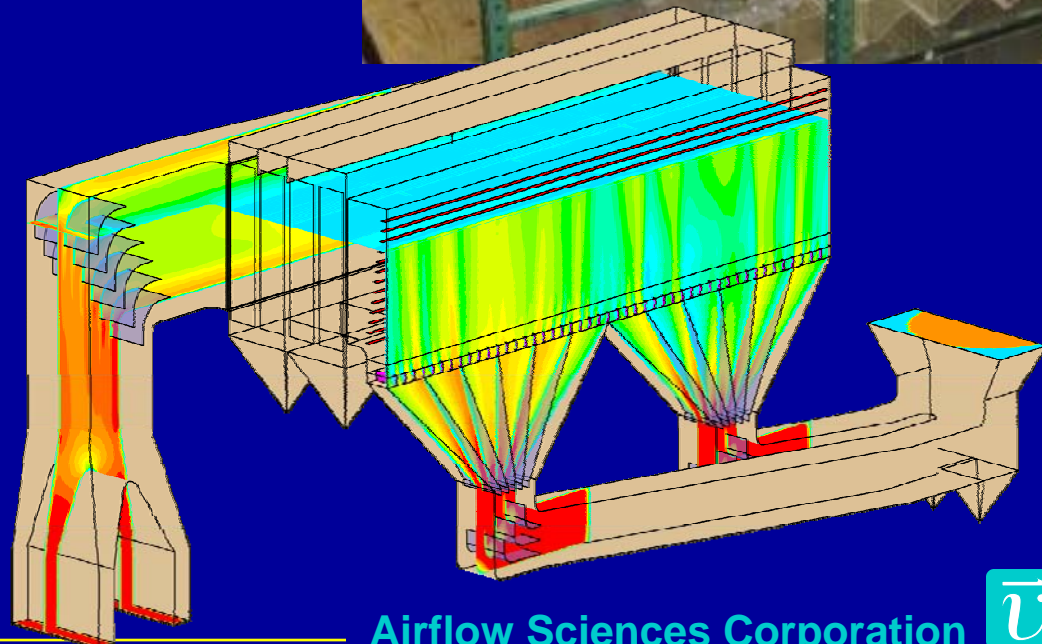
Outline

- ❖ Introduction
- ❖ Flow Distribution Analysis Techniques
- ❖ Application to Boilers
- ❖ Application to APC Equipment
 - ESP
 - FF
 - Mercury / SO₃
 - SCR
 - FGD
- ❖ Other Applications
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ESP Flow Optimization

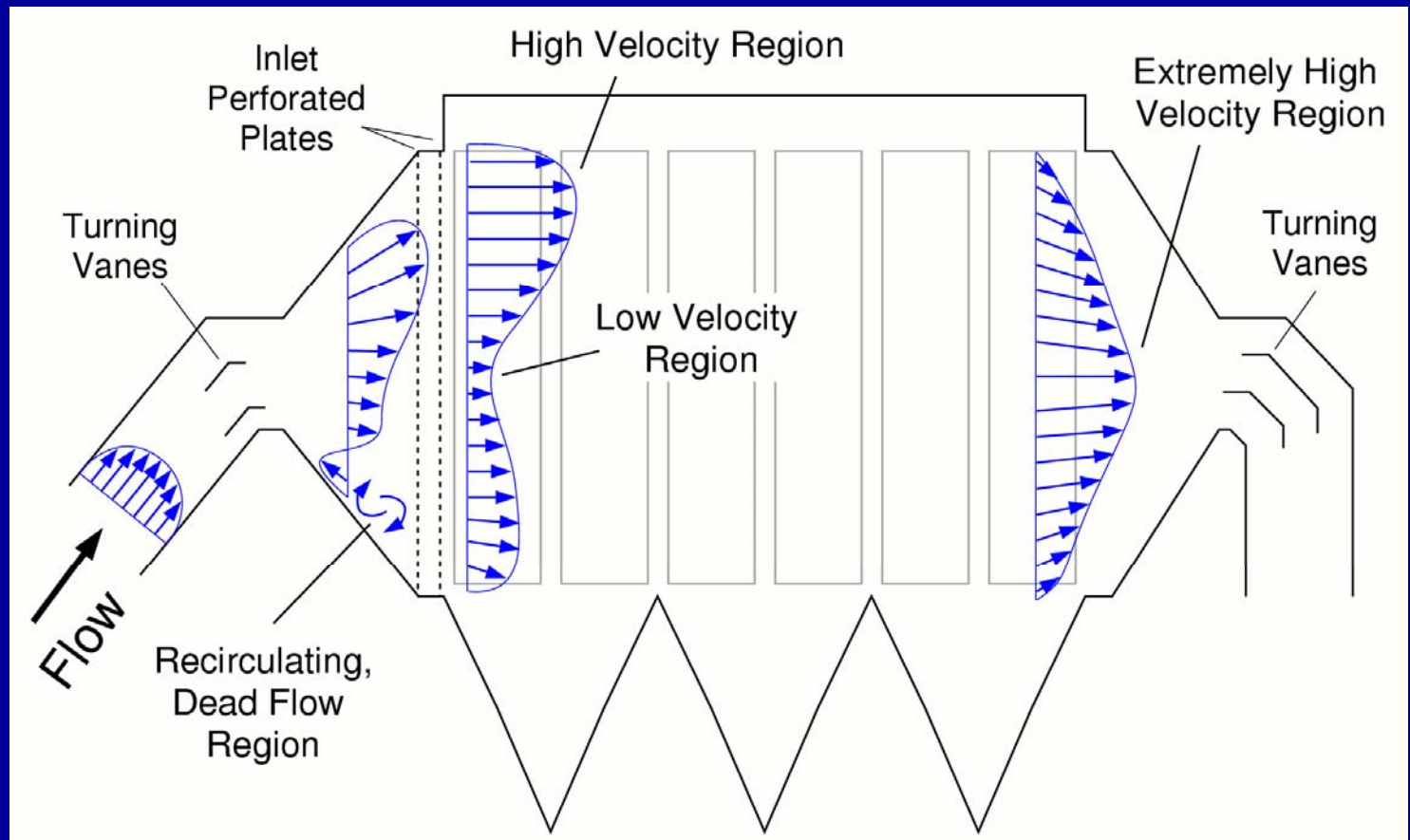
- ❖ Flow distribution
- ❖ Flow balance between cells
- ❖ Pressure loss
- ❖ Thermal mixing
- ❖ Gas conditioning
- ❖ Ash deposition



ESP Velocity Distribution

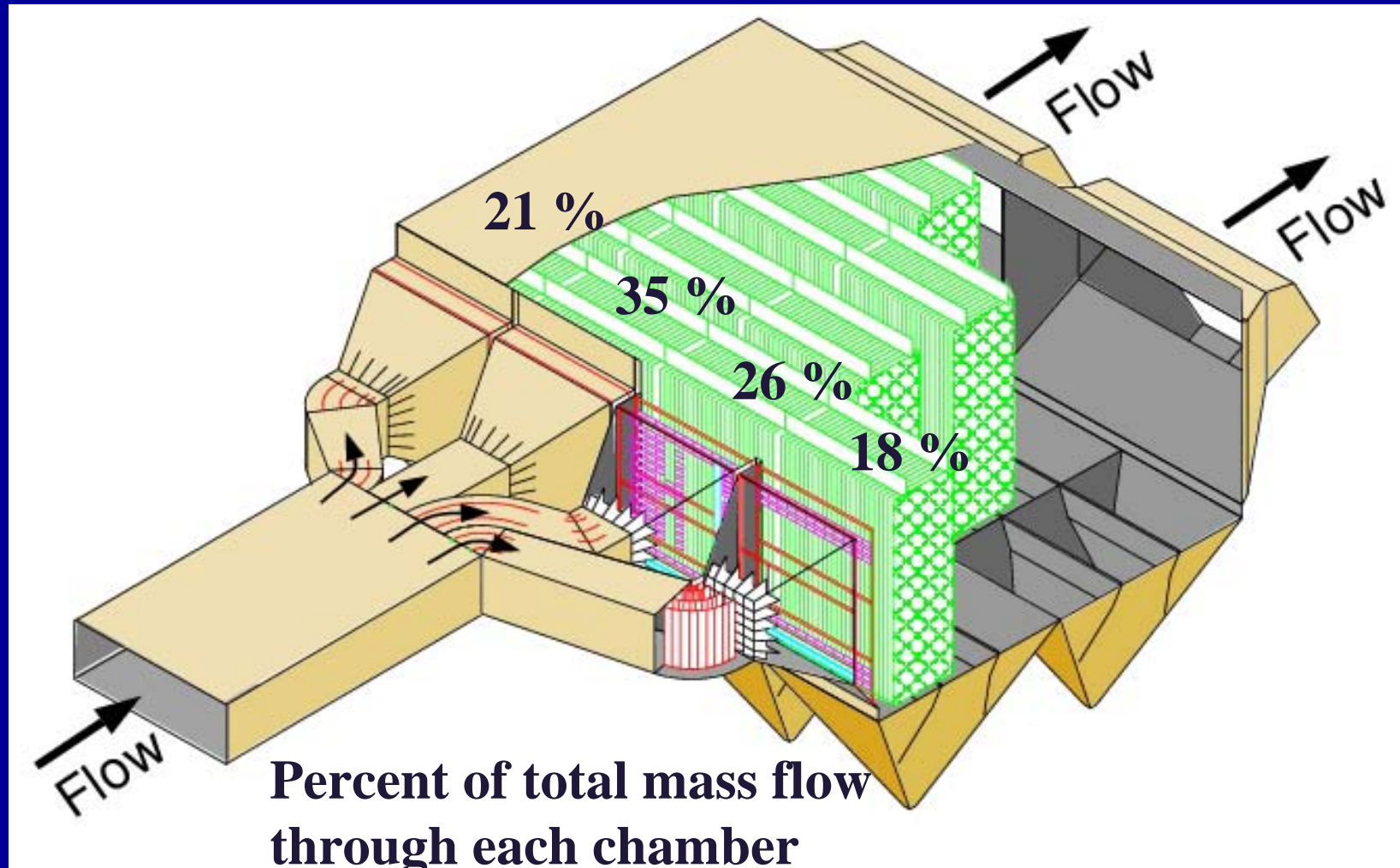
- ❖ Uniform velocity within collection region
- ❖ Industry standards

- ICAC
- % RMS deviation



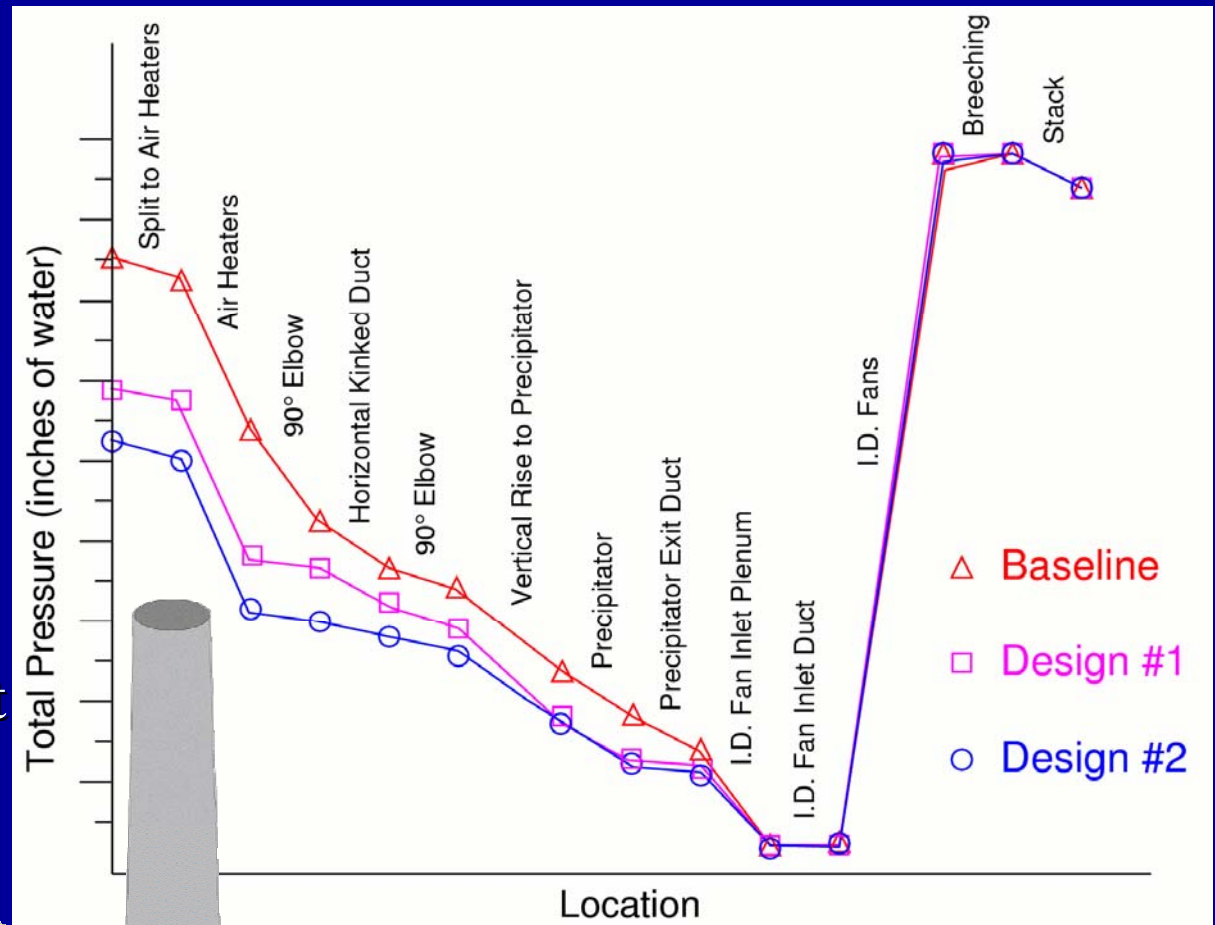
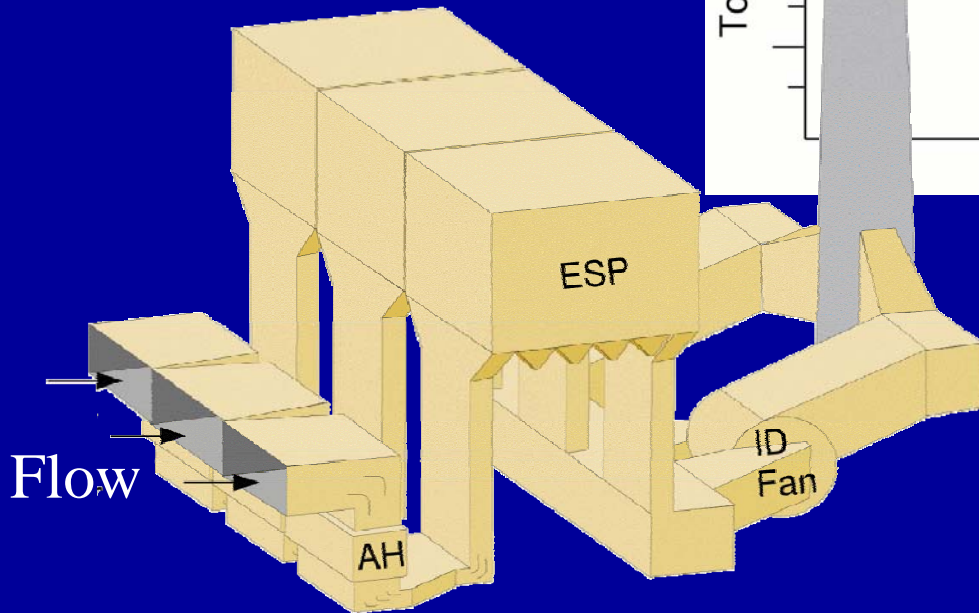
Gas Flow Balance

- ❖ Industry standard +/- 10% deviation



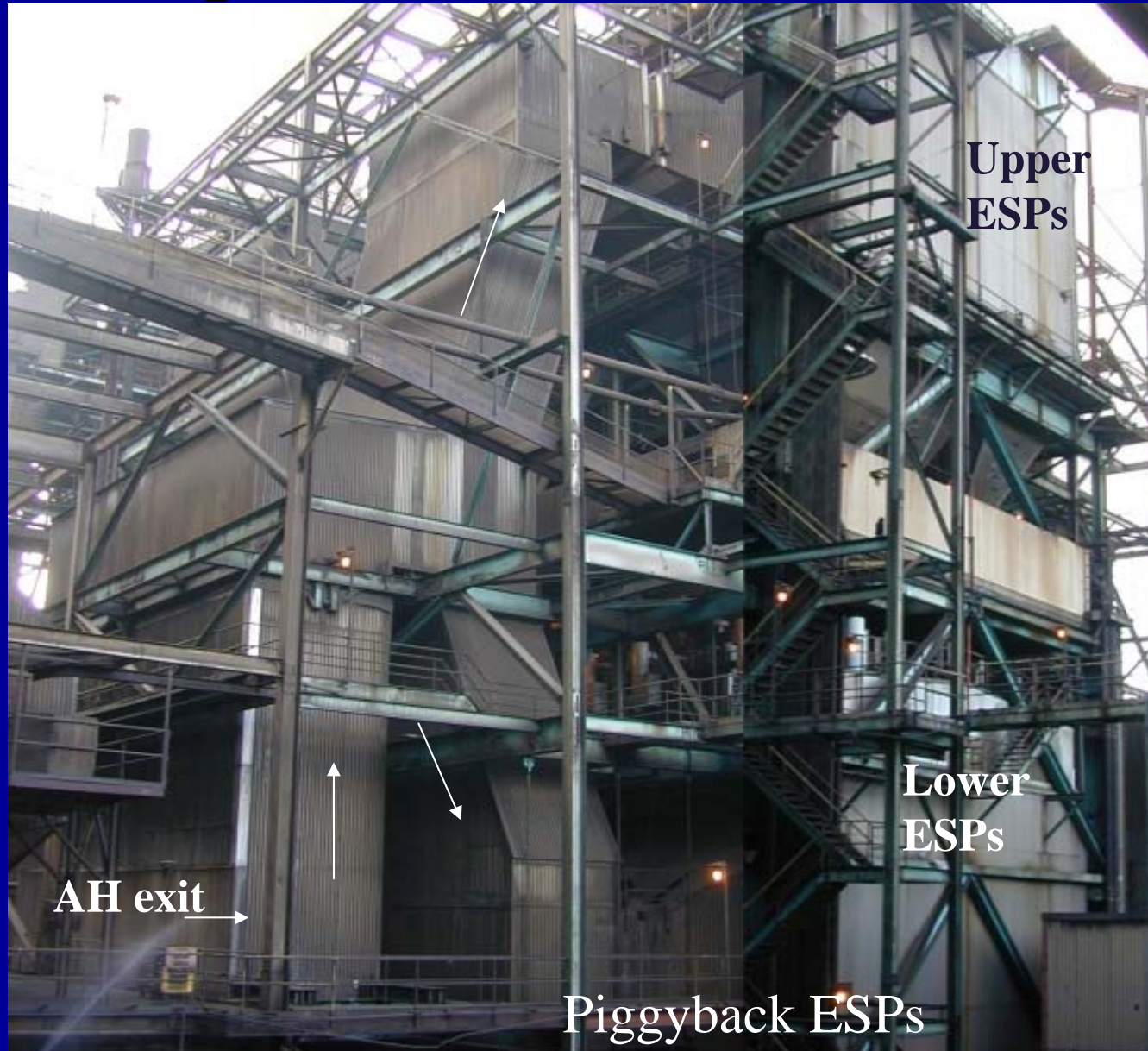
Pressure Drop

- ❖ General goal:
 - Minimize DP
- ❖ Methods
 - Vanes
 - Duct contouring
 - Area management

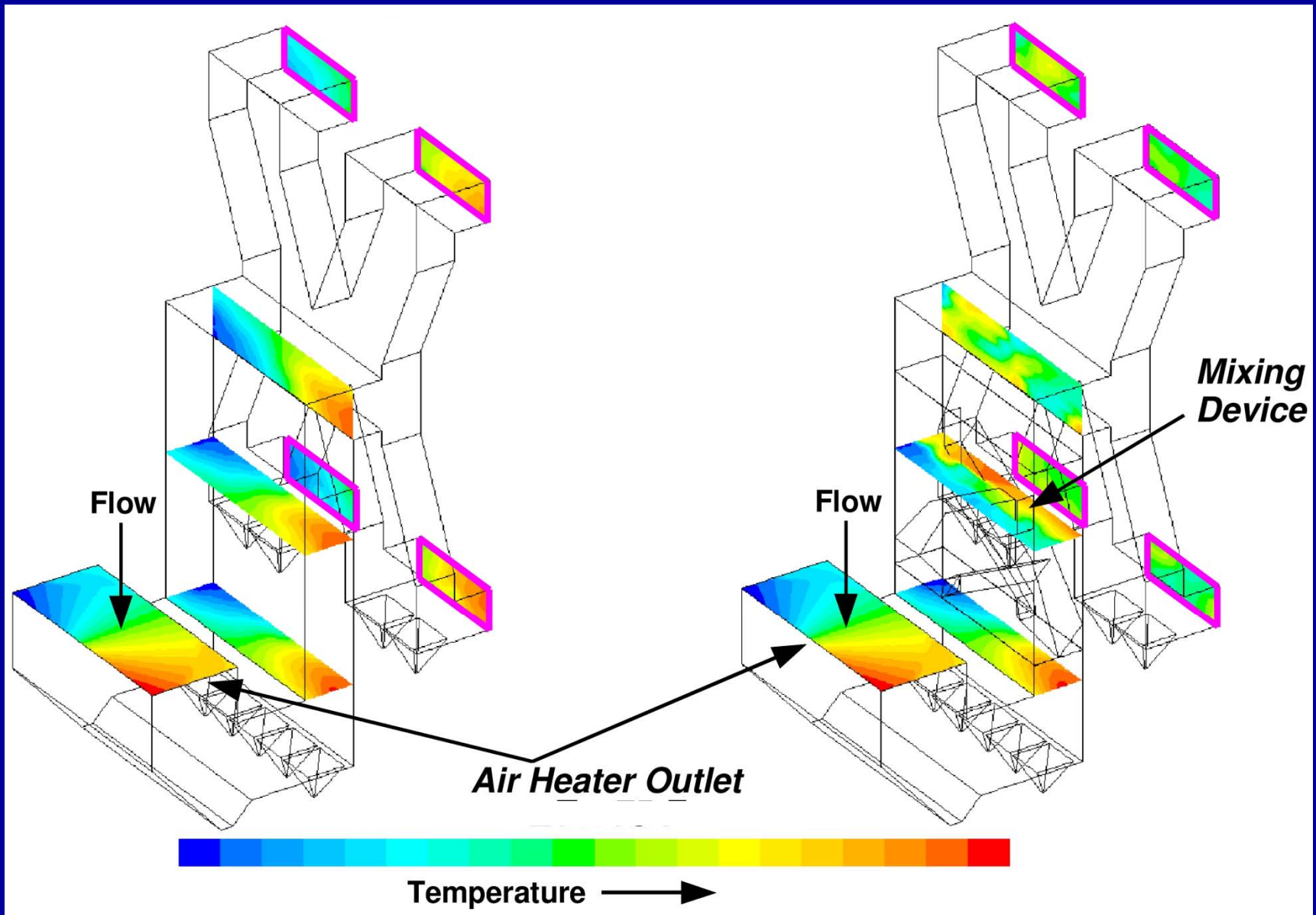


Ductwork redesign saves
2.1 inches H₂O over baseline

ESP Temperature Stratification

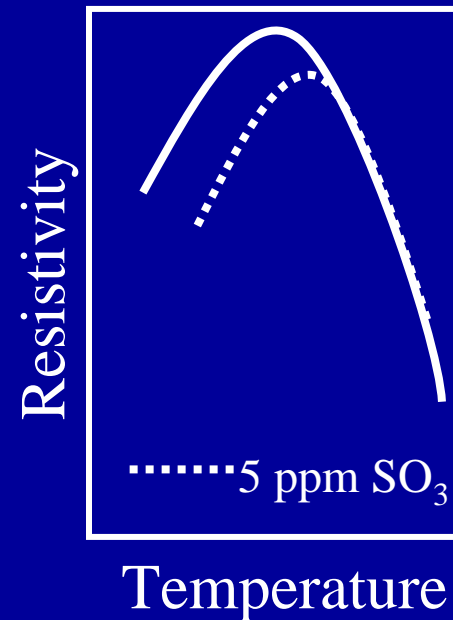


ESP Temperature Stratification

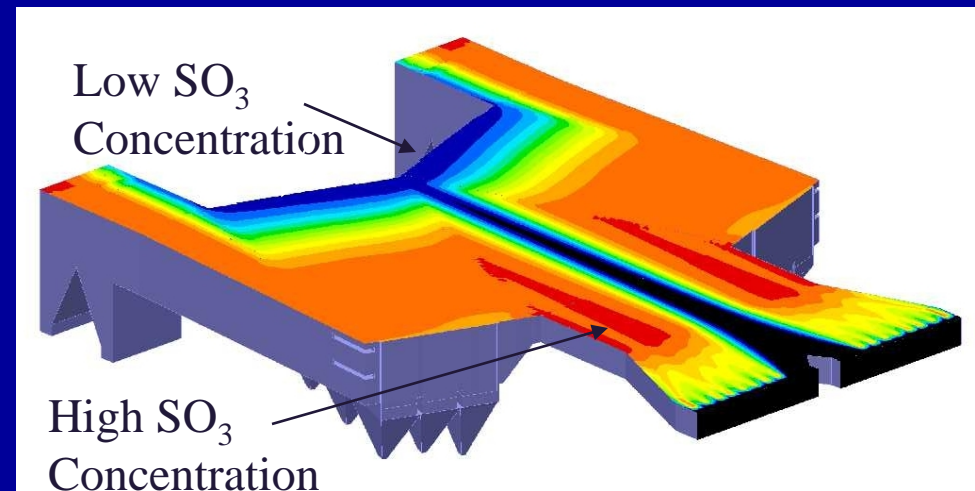


ESP Gas Conditioning

- ❖ Modify ash resistivity
 - SO_3 , ammonia, others
- ❖ Alter gas density, viscosity
 - Reduce ESP inlet temperature
 - Humidification

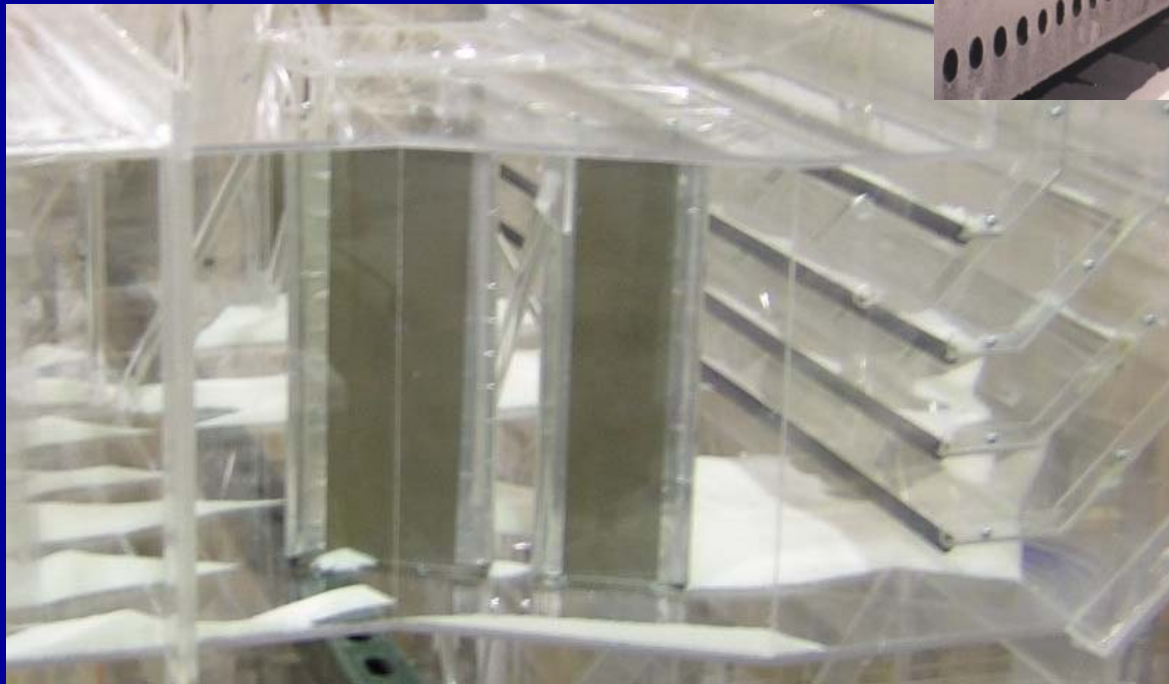


Humidification gone awry



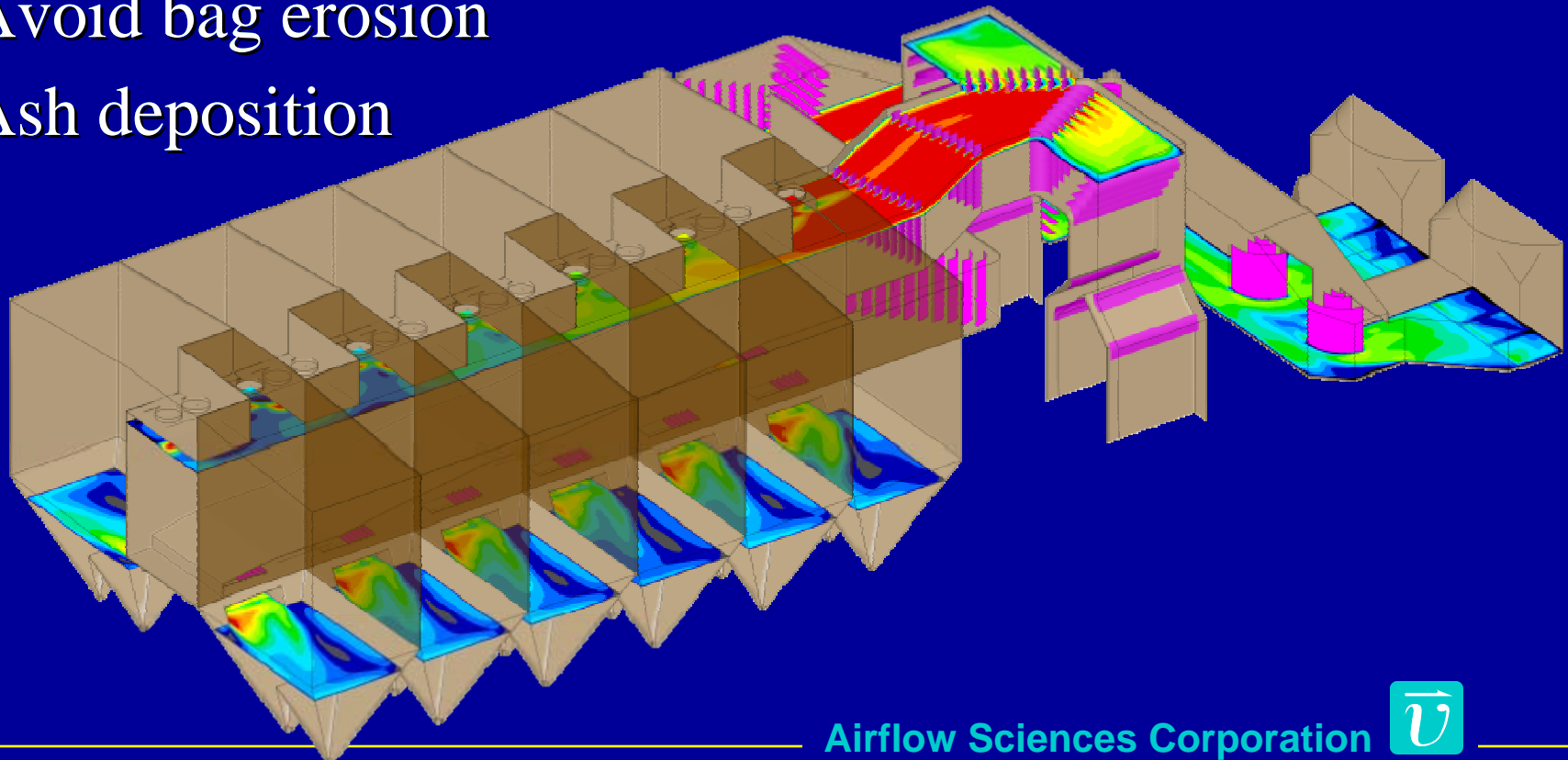
Ash Deposition

- ❖ Drop out
- ❖ Re-entrainment



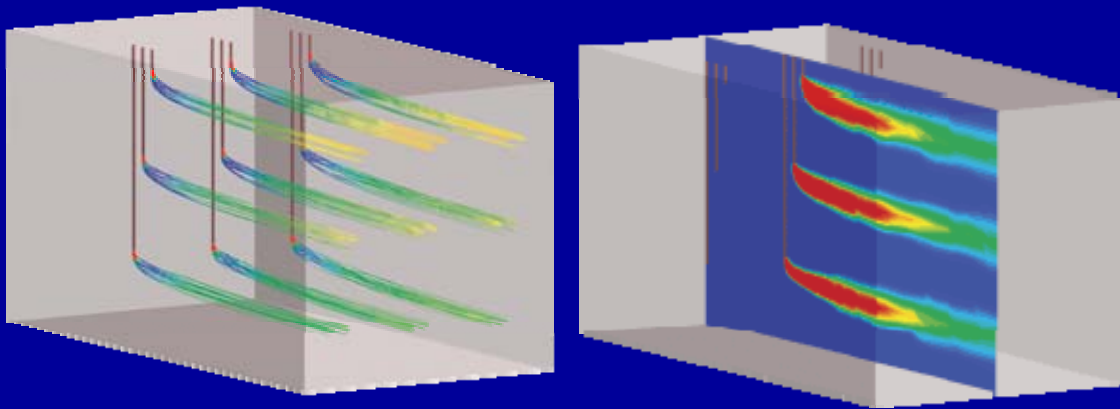
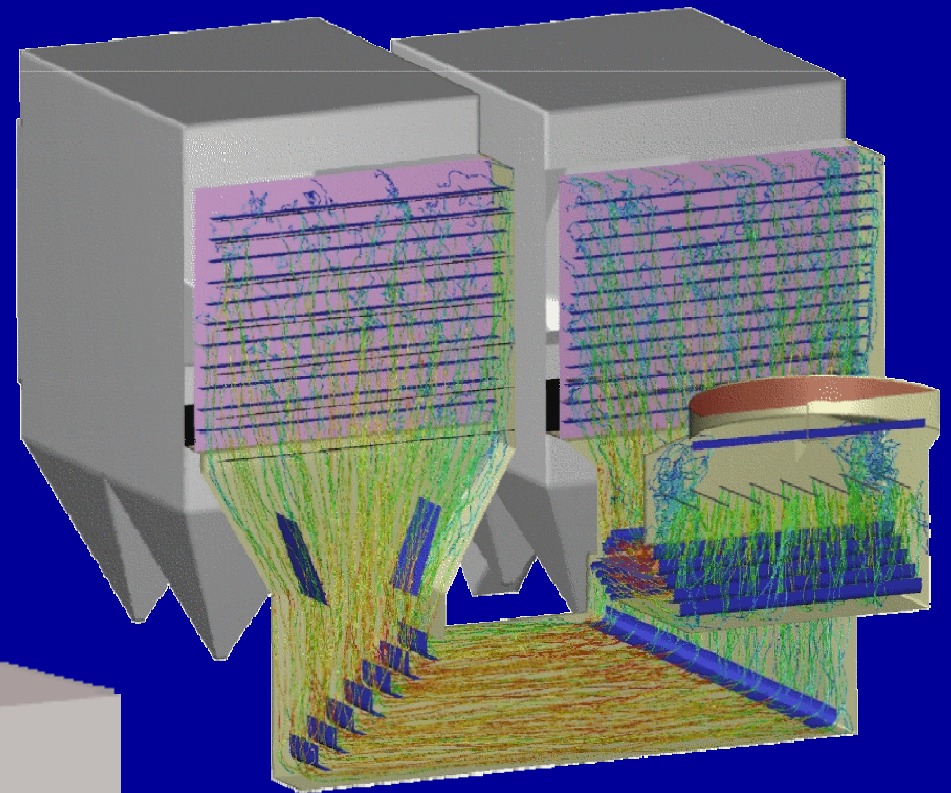
Fabric Filter Flow Modeling

- ❖ Uniform velocity distribution and equal balance between compartments
- ❖ Pressure loss
- ❖ Avoid bag erosion
- ❖ Ash deposition



Mercury / SO₃ Reduction

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



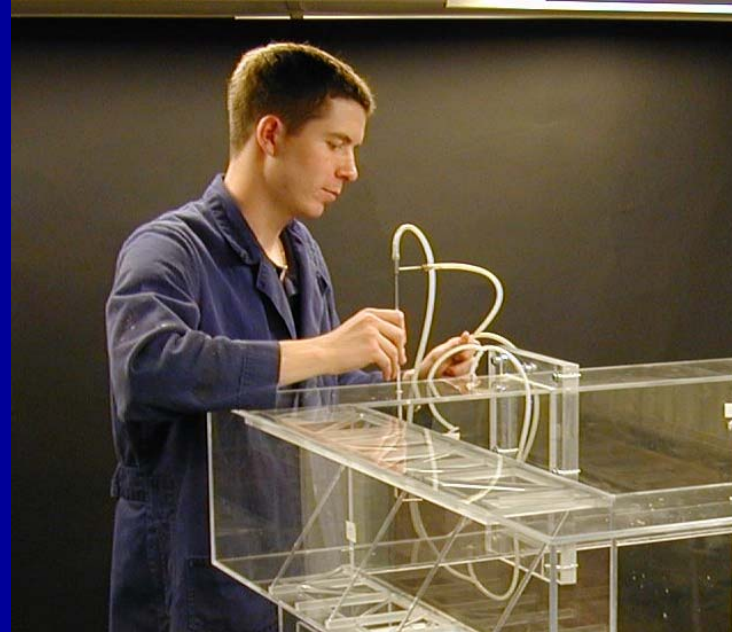
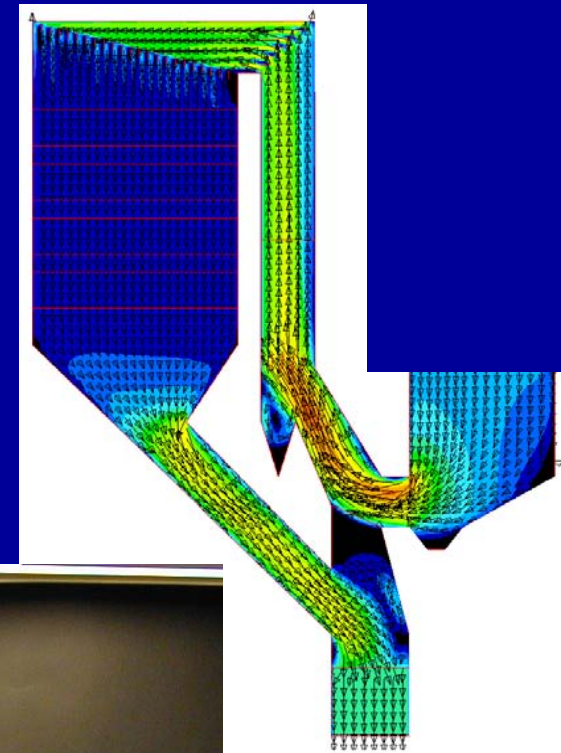
SCR Flow Optimization

- ❖ Velocity distribution
- ❖ Thermal mixing
- ❖ NO_x profile / mixing
- ❖ Ammonia injection
- ❖ Pressure loss
- ❖ Large particle ash (LPA) or “popcorn ash” capture
- ❖ Ash deposition



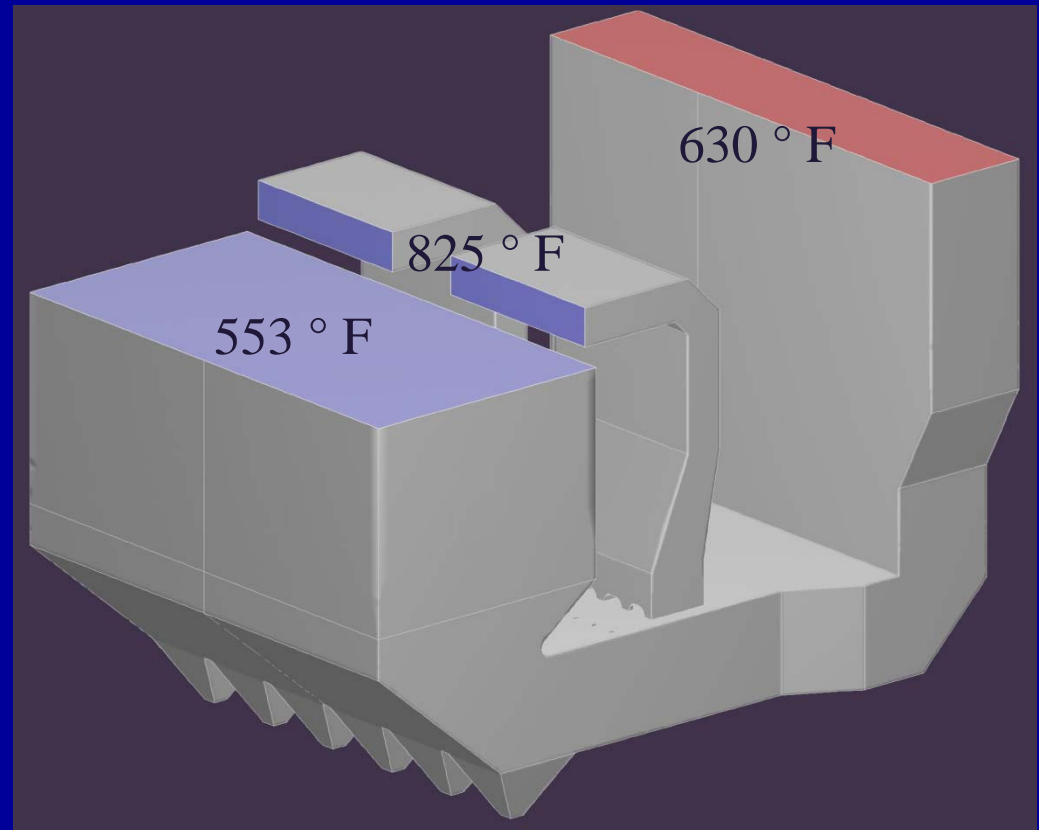
SCR Velocity Distribution

- ❖ 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

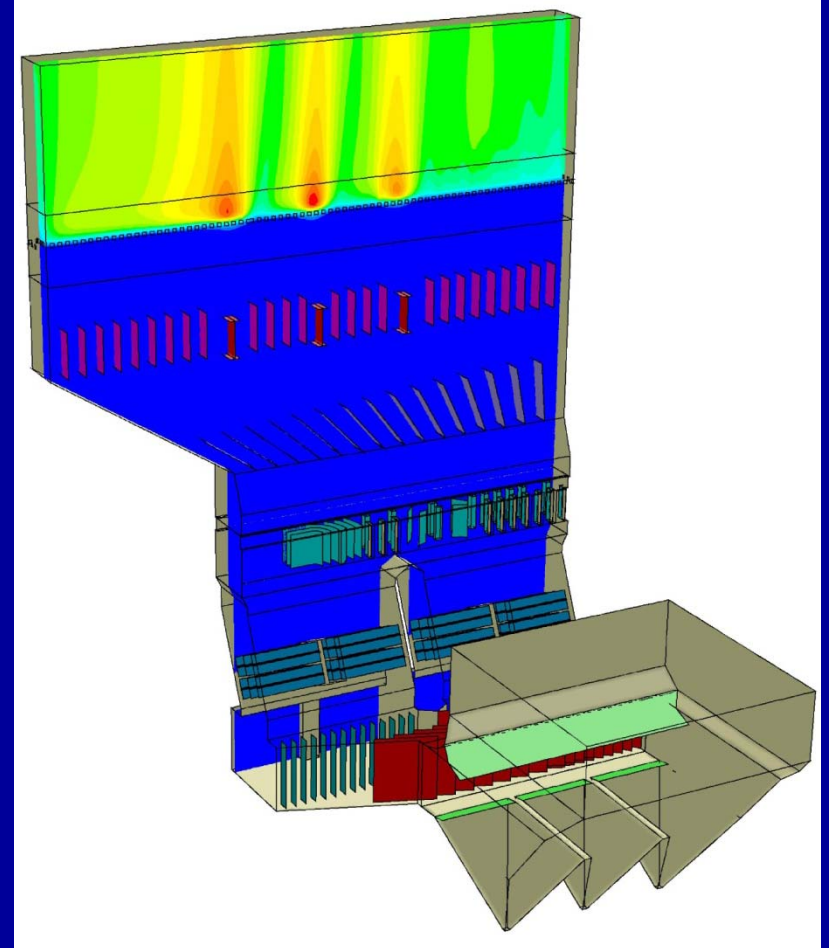


Without mixer, $\Delta T = \pm 83 \text{ }^\circ\text{F}$

With mixer, $\Delta T = \pm 15 \text{ }^\circ\text{F}$

SCR Ammonia Injection

- ❖ Desire uniform NH_3 -to- NO_x ratio at catalyst
- ❖ Tracer gas used to represent flows in physical model
- ❖ Track gas species in CFD



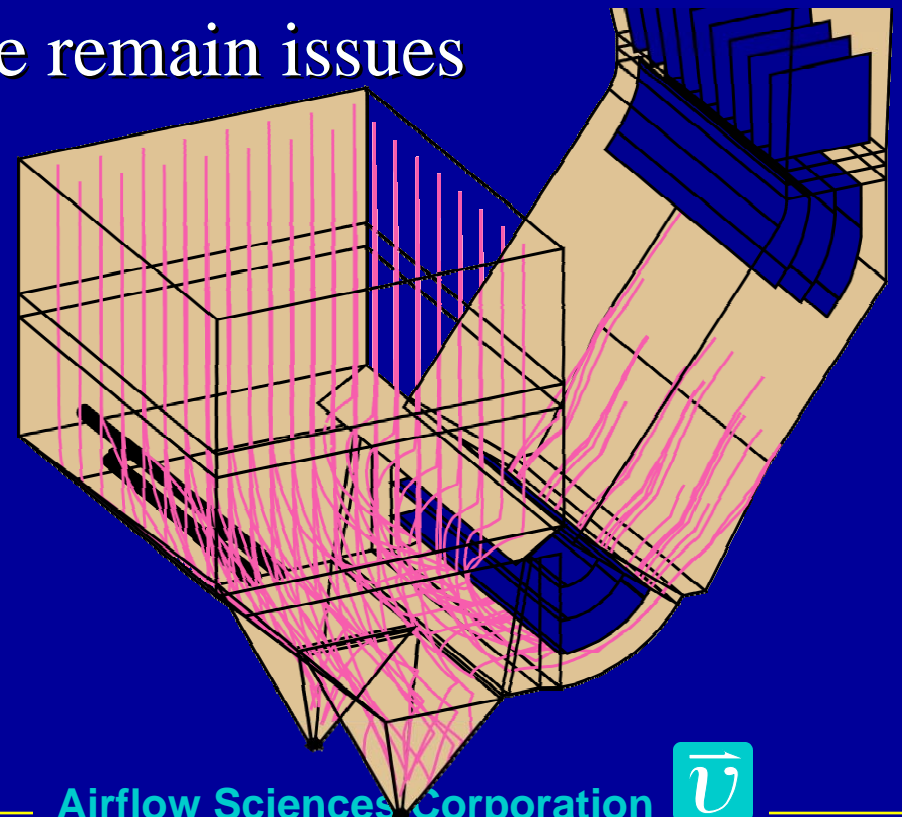
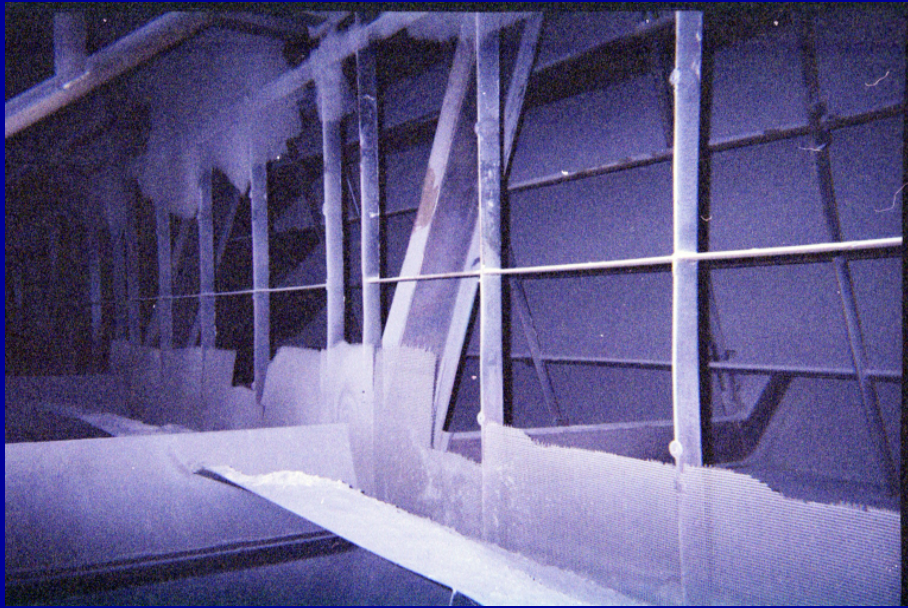
SCR Large Particle Ash Capture

- ❖ 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



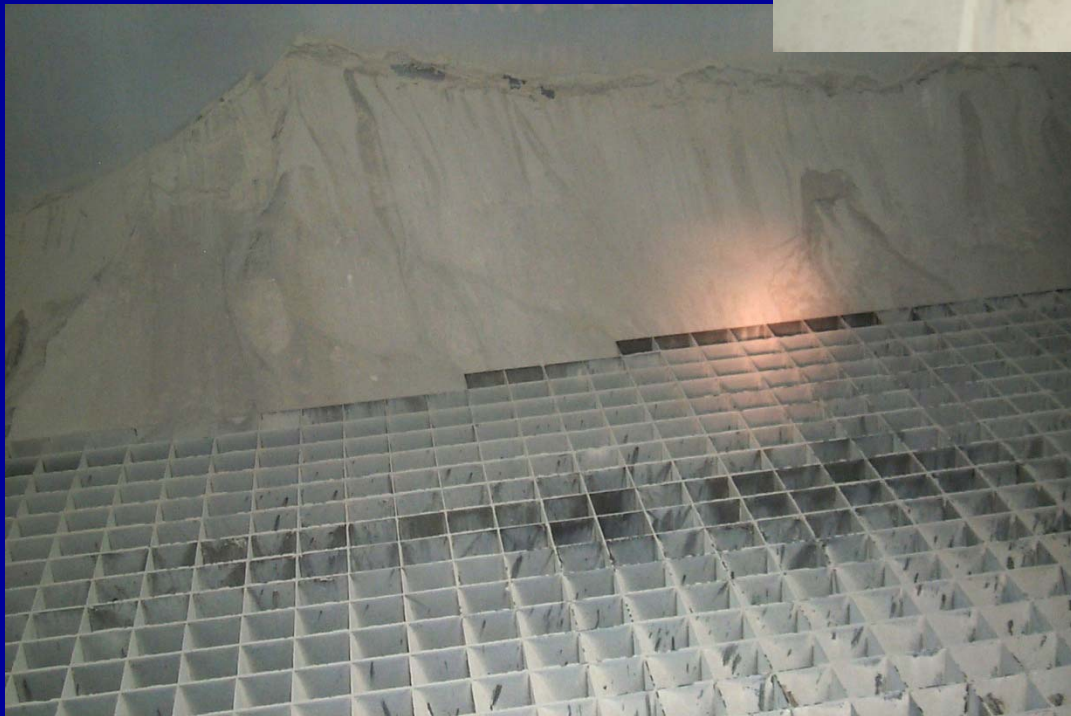
LPA System Design – Key Points

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



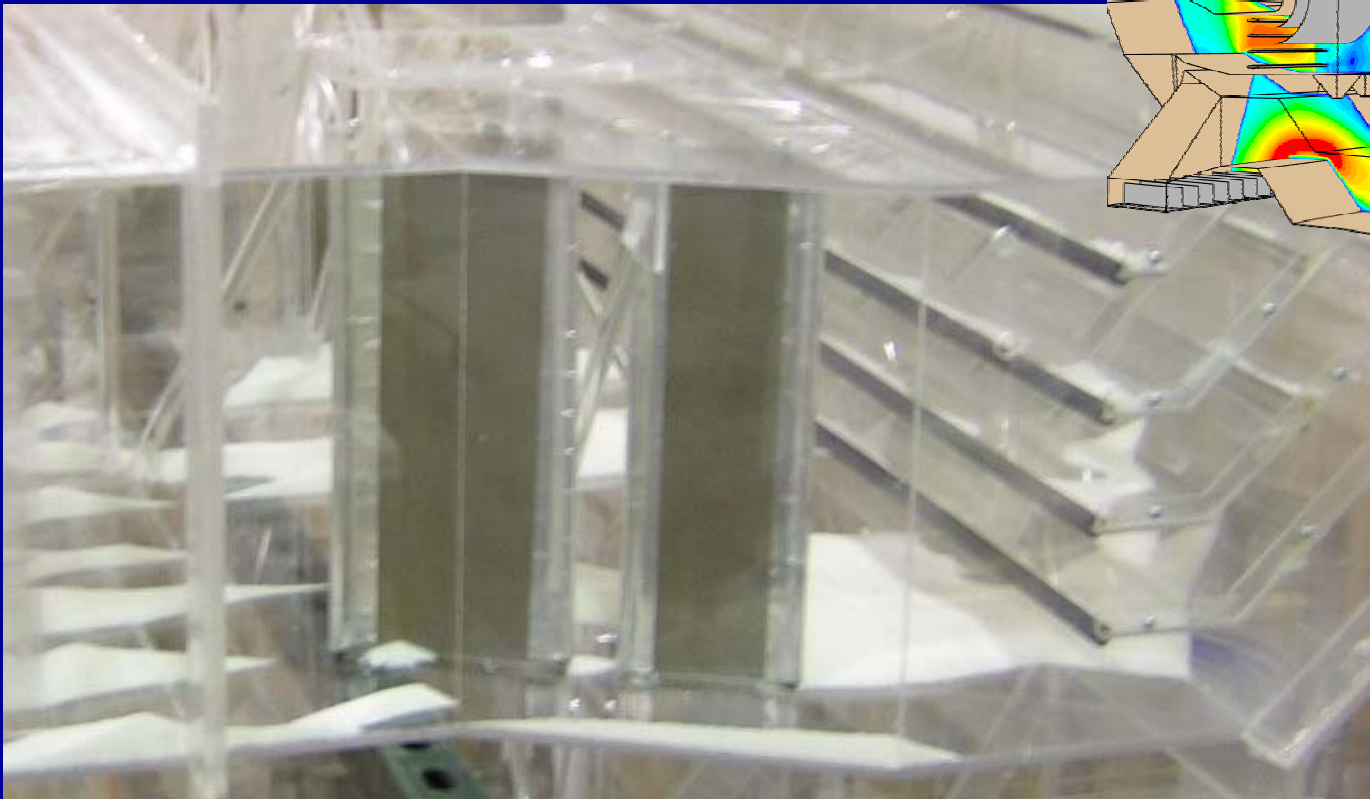
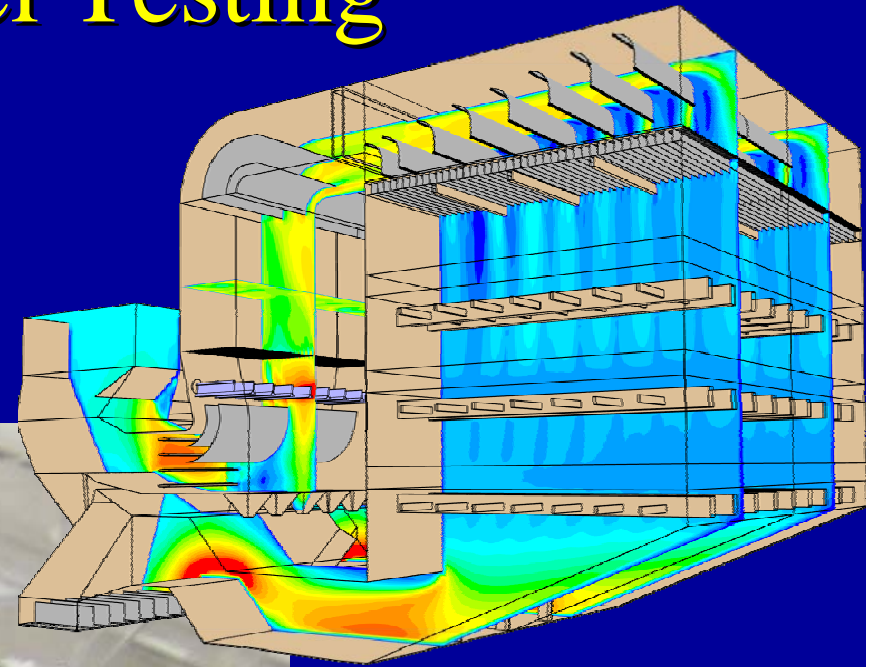
Ash Deposition

- ❖ Duct floors
- ❖ Turning vanes
- ❖ Catalyst



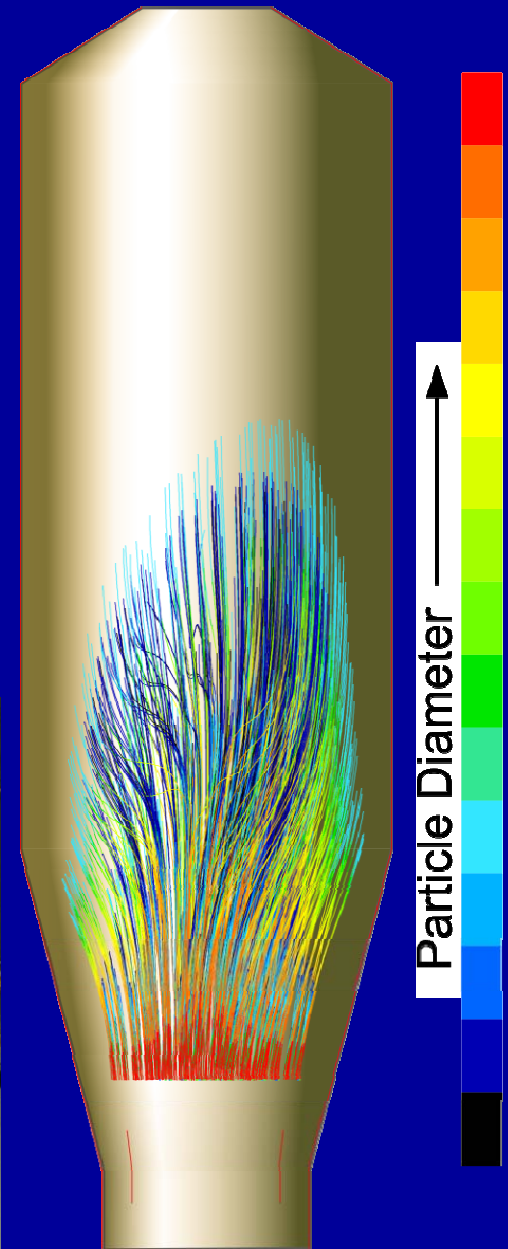
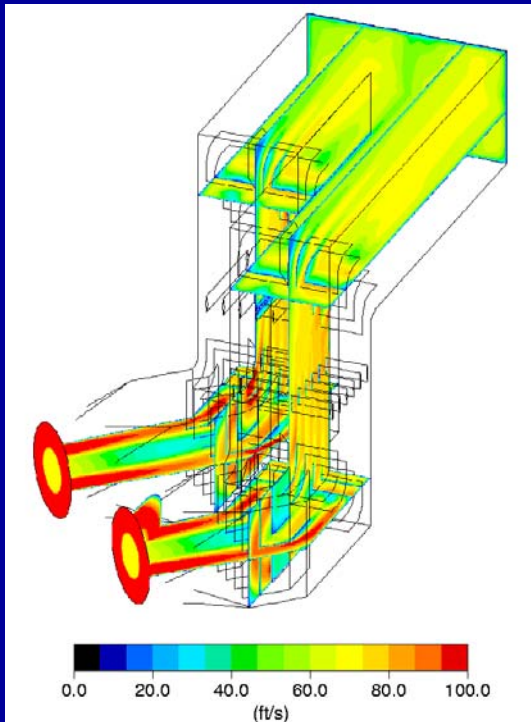
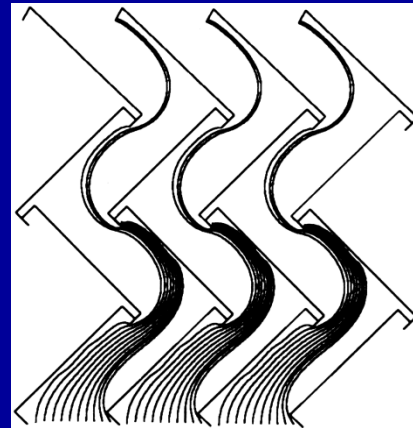
Ash Deposition – Model Testing

- ❖ Drop out
- ❖ Re-entrainment

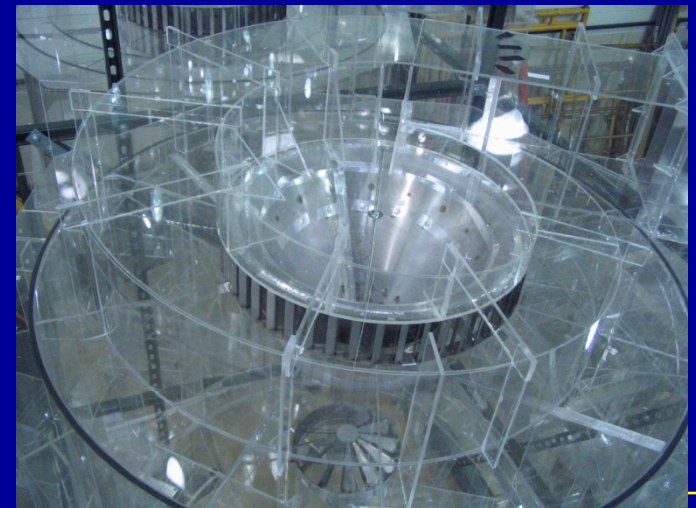


FGD Flow Modeling

- ❖ Flow distribution
- ❖ Water droplet behavior
- ❖ Pressure loss
- ❖ Ash deposition



FGD Flow Modeling



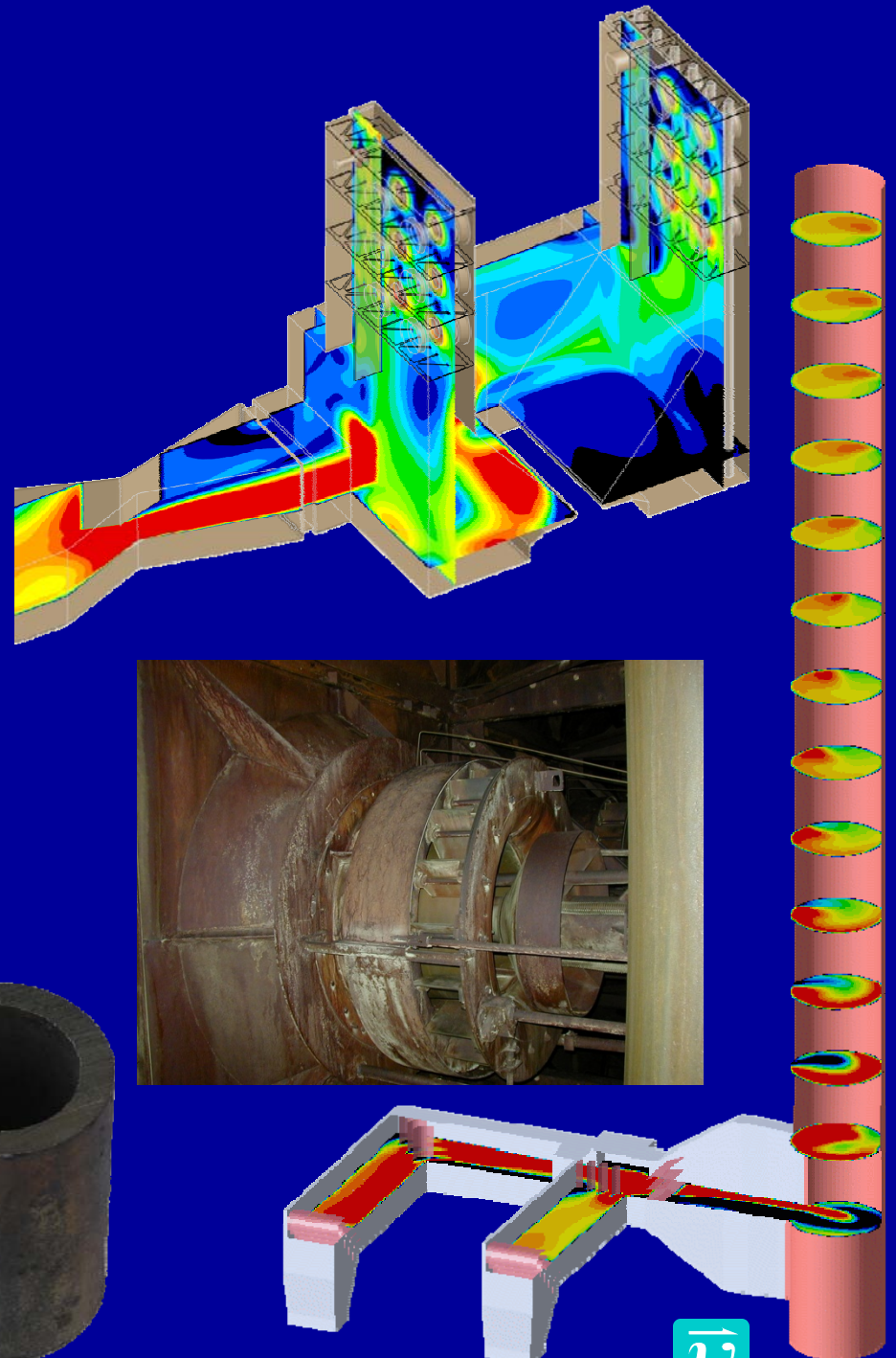
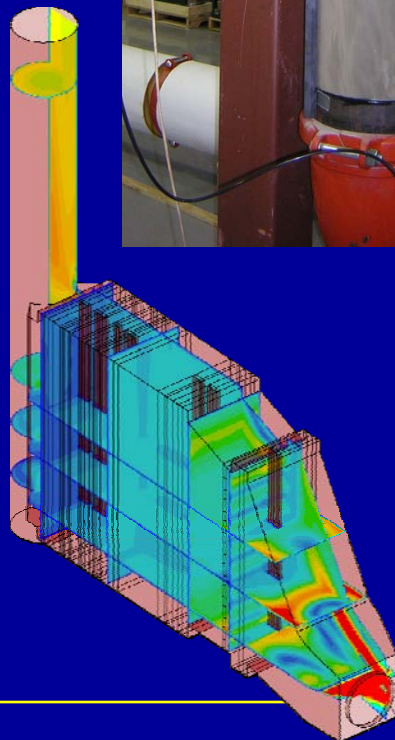
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- ❖ Flow Modeling Methods
- ❖ Application to Boilers
- ❖ Application to APC Equipment
- ❖ **Other Applications**
- ❖ Conclusions
- ❖ Questions



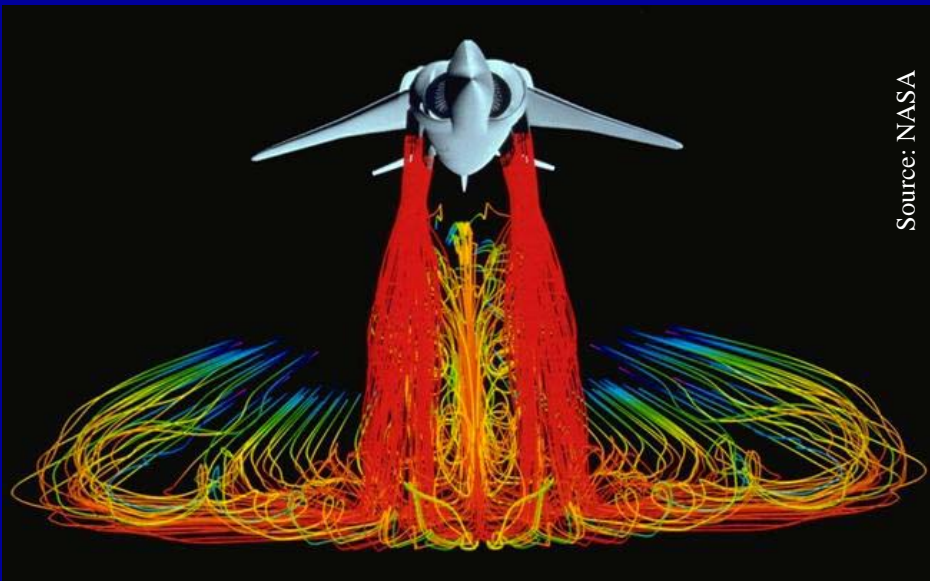
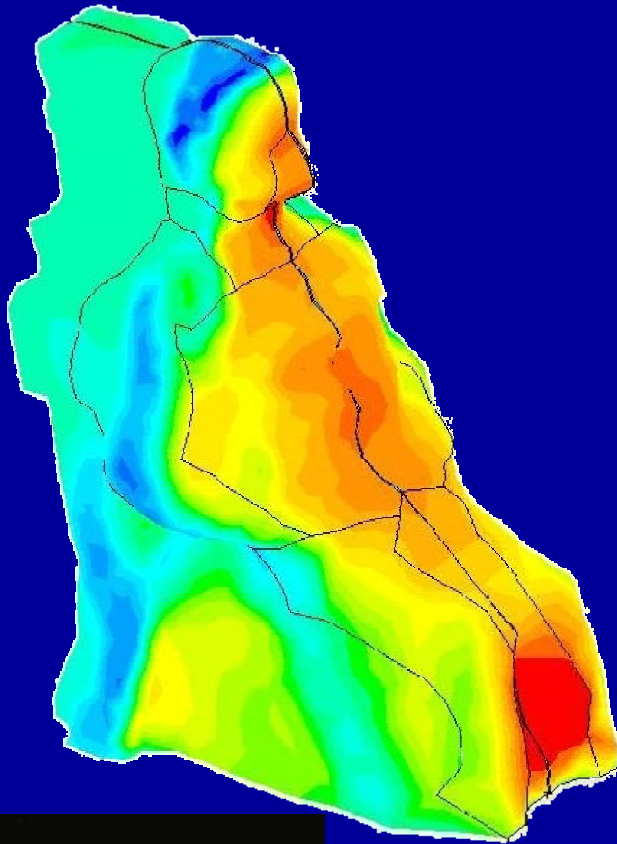
Power Industry

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



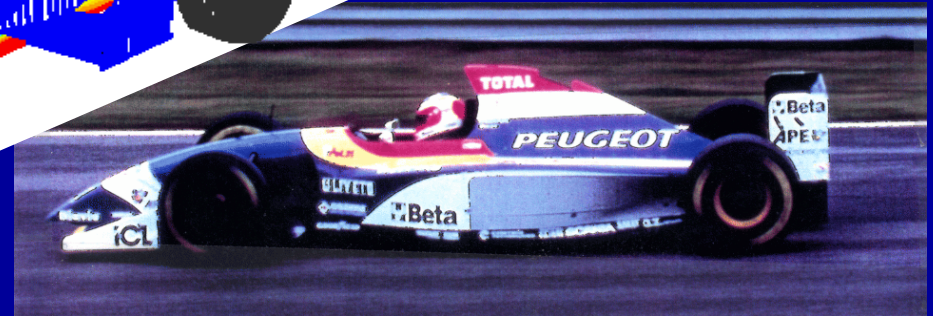
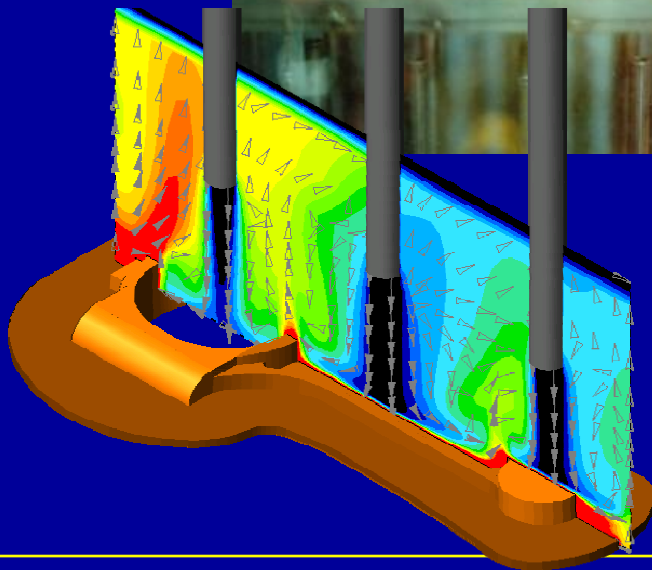
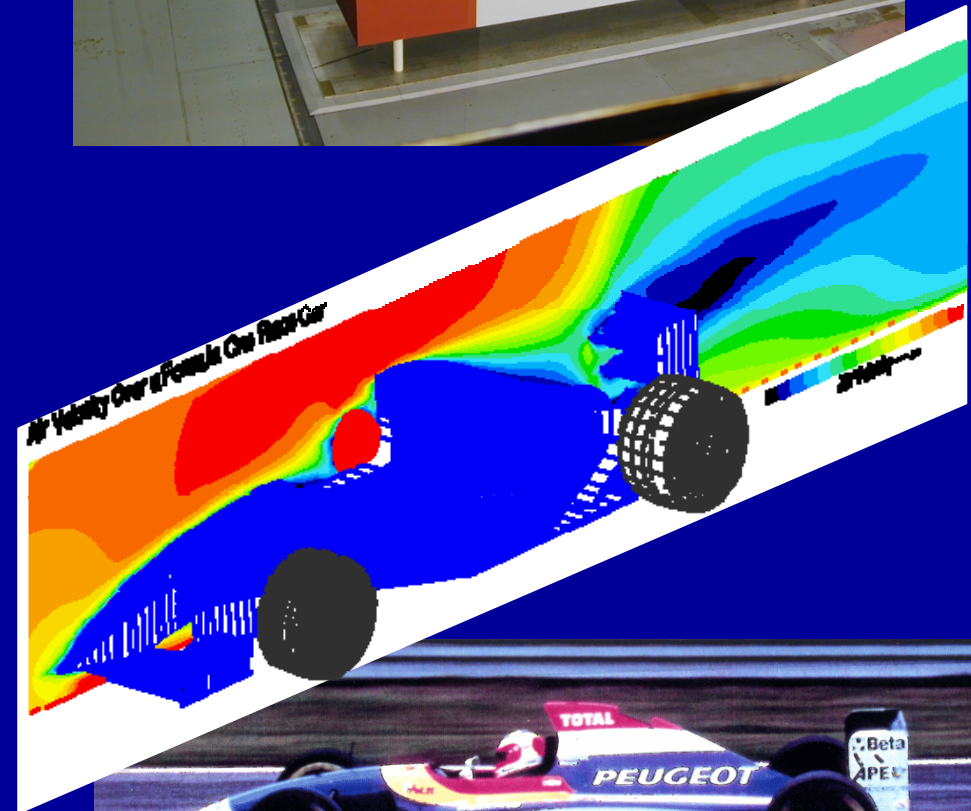
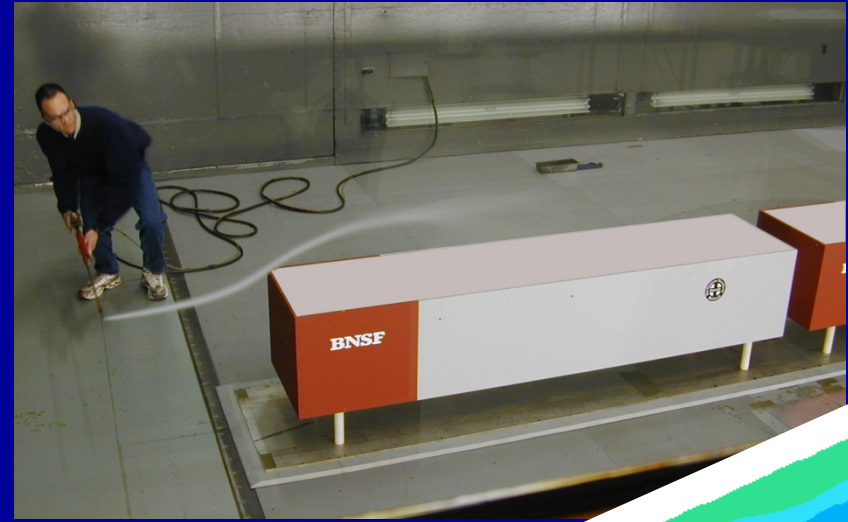
Aerospace

- ❖ Spacecraft
- ❖ Aircraft
- ❖ Missiles
- ❖ Engines



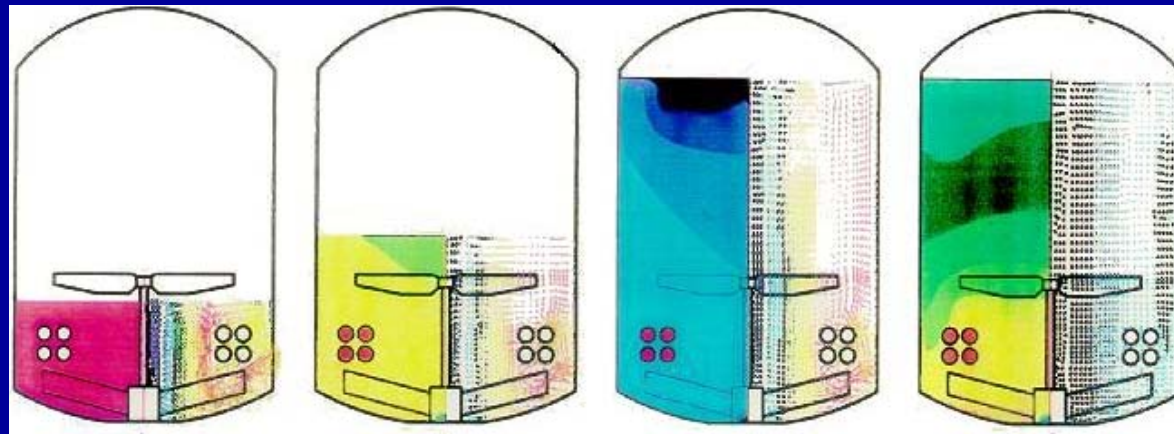
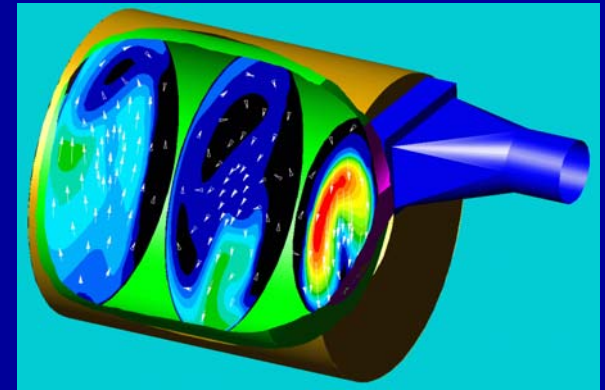
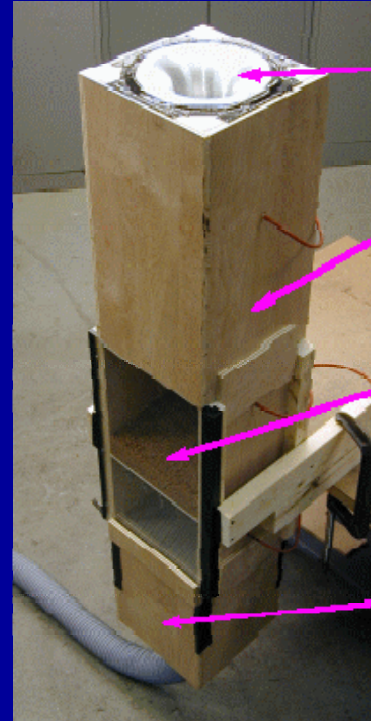
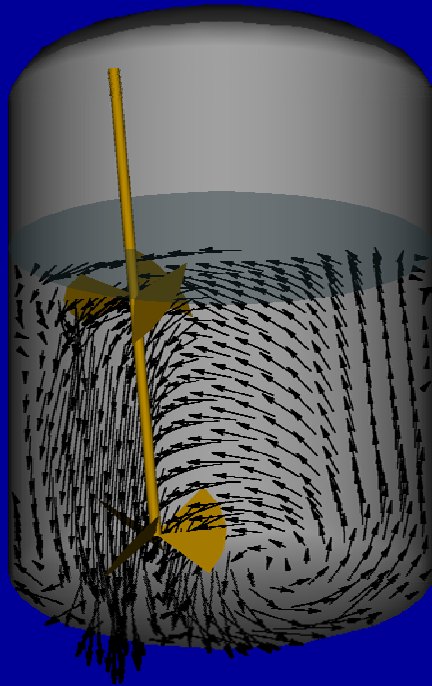
Vehicle Design

- ❖ 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?

