Worldwide Pollution Control Association

WPCA/LG&E and KU

Coal-fired APC Environmental Seminar

May 23-24, 2017

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Fabric Filter Flow Modeling for Optimization of Performance and O&M

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WPCA LG&E and KU Seminar
May 23-24, 2017

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Agenda

- **Introduction**
- Performance Goals for Fabric Filters
- Flow Modeling Methods
  - Computational Fluid Dynamics
  - Physical Modeling
- Case Study
- Conclusions
- Questions

Introduction

Why are flow characteristics important to APC equipment?

- Performance
  - Flow/Temperature uniformity
  - Sorbent injection
  - Ash capture / avoid build-up
- Operating costs
  - Pressure drop
  - Sorbent usage / cost
- Maintenance issues
  - Erosion
  - Pluggage
  - Vibration

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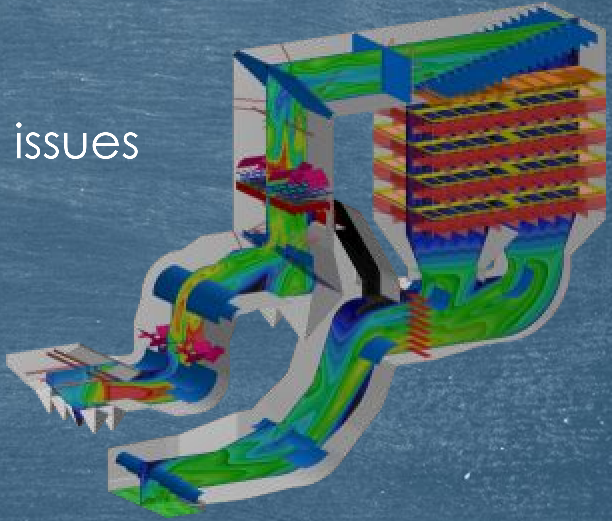
Introduction

Flow Modeling Applications

- ➢ Design of new equipment
- ➢ Retrofits of existing equipment
- ➢ Solving operational or maintenance issues



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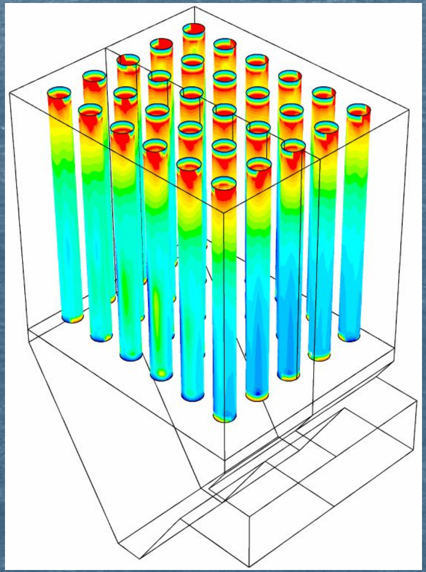
Fabric Filter Performance Goals

- ➢ Flow distribution
- ➢ Flow balance
- ➢ Pressure loss
- ➢ Temperature distribution
- ➢ Sorbent distribution and residence time
- ➢ Particle deposition



Performance targets usually based on ICAC F-7 standards or industry/vendor standards

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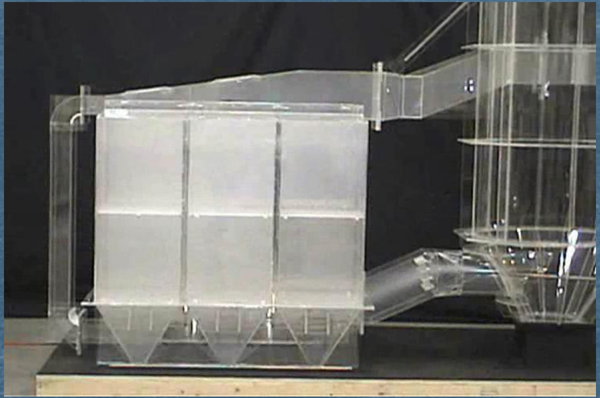
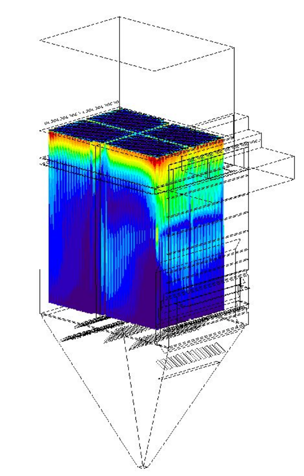
Fabric Filter Velocity Distribution

- Uniform velocity at inlet flange
  - Typical target ranges from 7.5% RMS (ICAC F-7) to 20% RMS
- Avoid high velocities impinging bags





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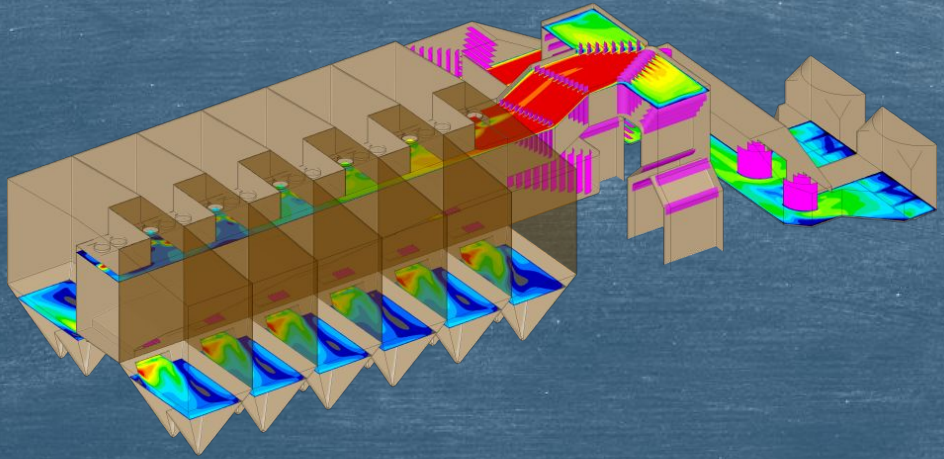
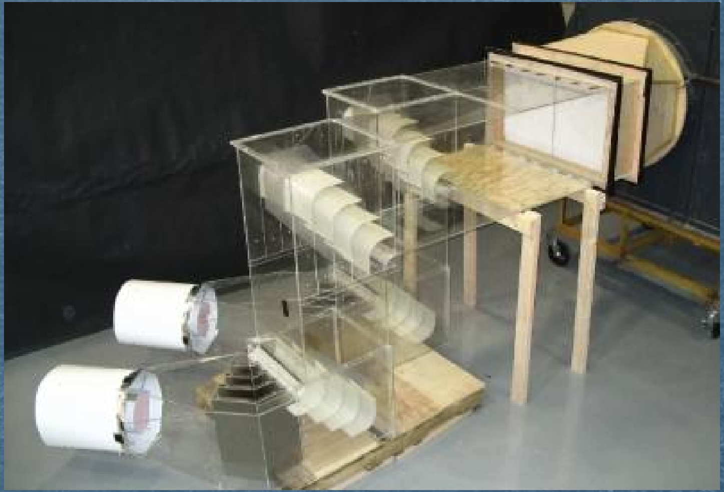
Fabric Filter Flow Balance

- Equal flow balance between compartments
  - ICAC F-7 goal is to be within +/-10% of theoretical flow split; some vendors/client target 5% deviation
- Equal flyash balance to compartments



Pressure Drop

- General Goal: Minimize dP
- Methods
  - Vanes
  - Duct design/contouring
  - Area management



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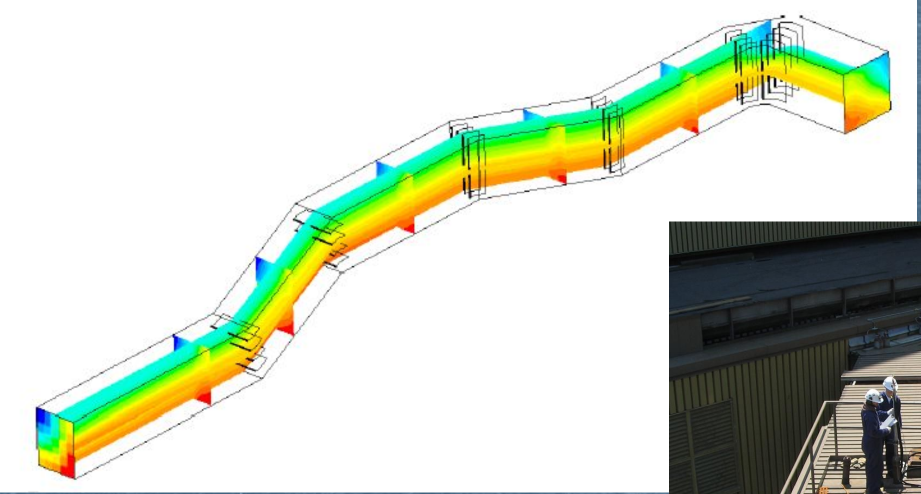
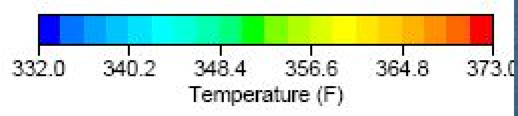
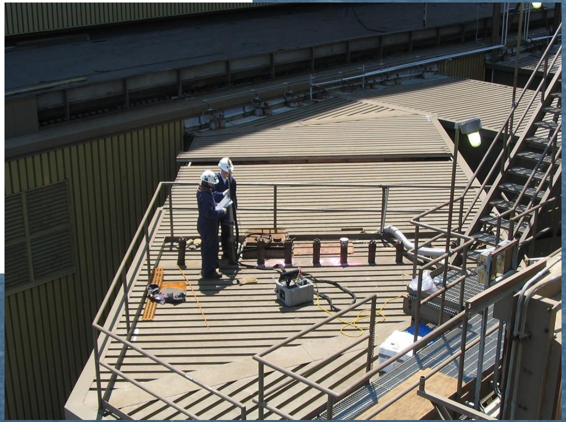
Fabric Filter Temperature Stratification







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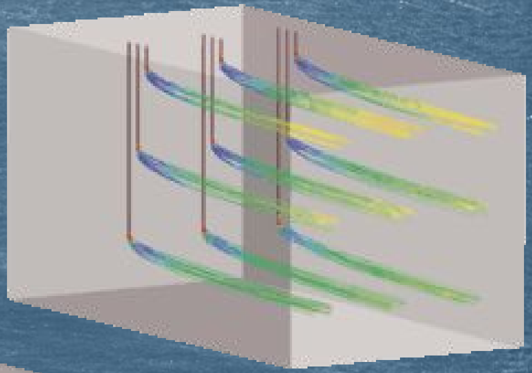
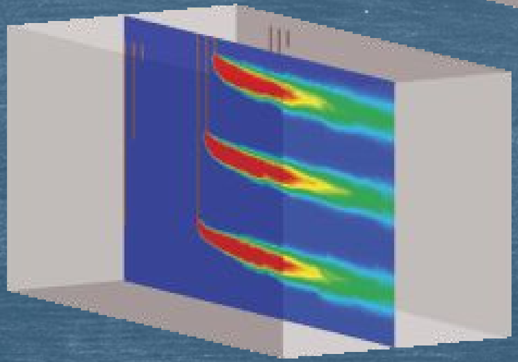
Particulate Injection

- Mercury absorption
  - Powdered activated carbon
- SO_3 mitigation
  - Lime
  - SBC
  - Trona
  - Other





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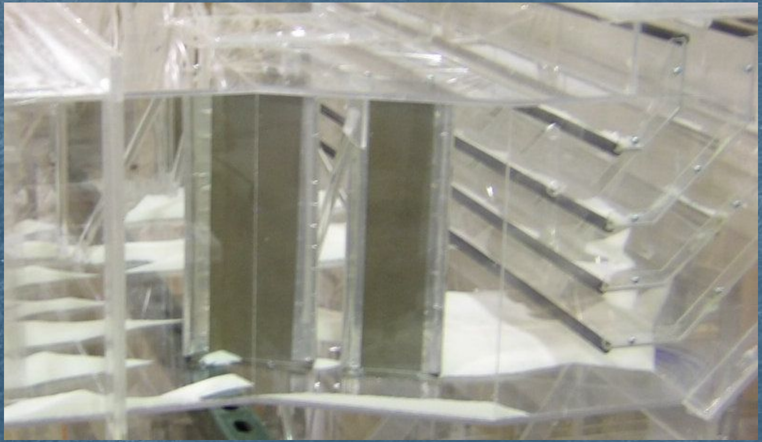
Ash Deposition

- Drop-out
- Re-entrainment



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  - **Computational Fluid Dynamics**
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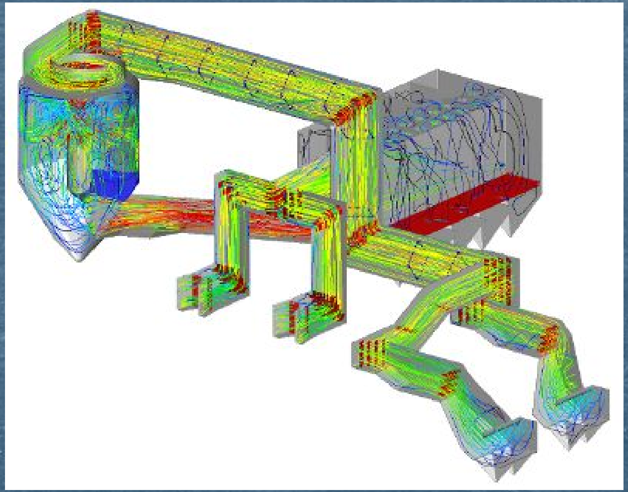
Computational Fluid Dynamics (CFD)

- Numerical simulation of flow
- Utilize high speed computers and sophisticated software
- Calculate flow properties
  - Velocity
  - Pressure
  - Temperature
  - Chemical species
  - Particle streamlines
- Azore ® software
- Ansys-Fluent ® software



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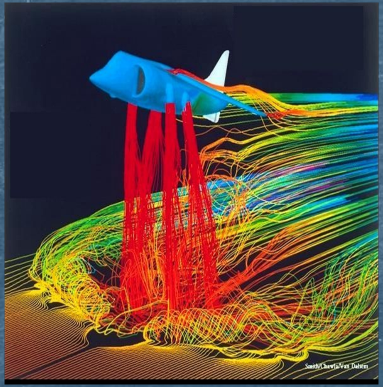
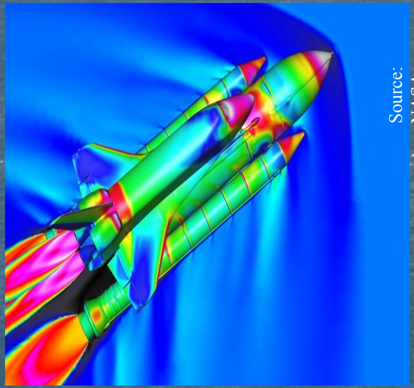
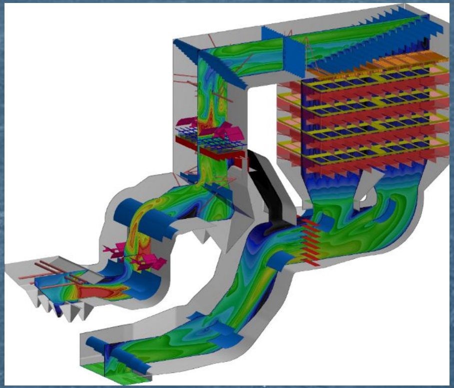
CFD History

- Developed in the aerospace industry c. 1970 (with the advent of “high speed” computers)
- Applied to industrial equipment for 40+ years
- Underlying principle is to solve the first-principles equations governing fluid flow behavior







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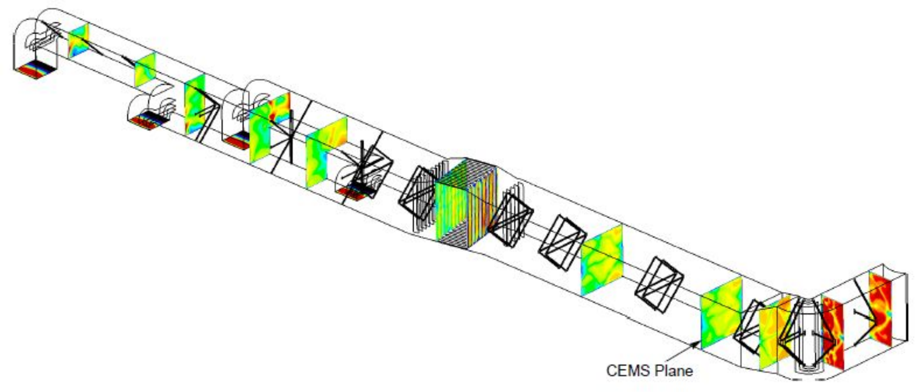
CFD Methodology

1. Set up
   - Geometry (3D CAD)
   - Computational mesh
   - Boundary conditions
2. Solve
3. Analyze
   - Contour plots
   - Flow statistics and integrations
   - Particle/species tracking



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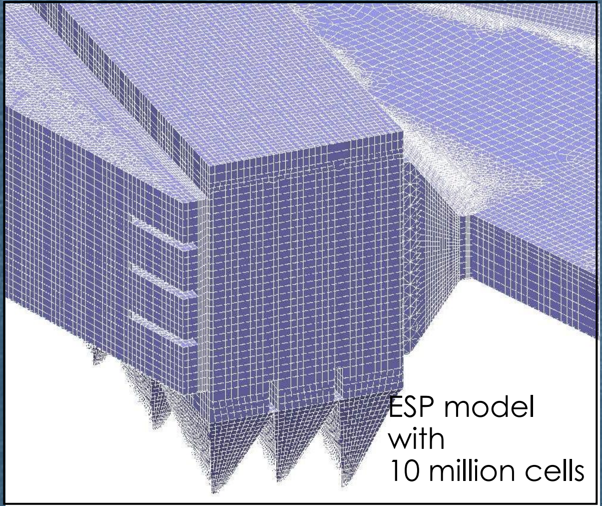
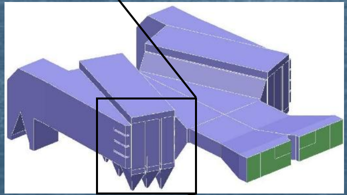
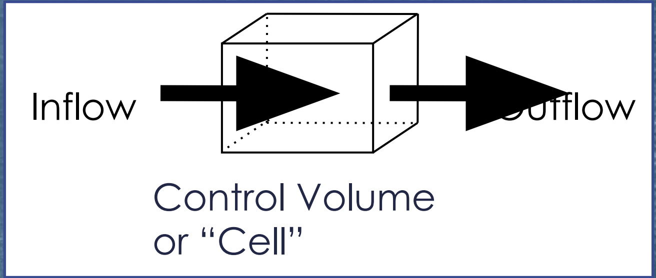
CFD Mesh

- 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







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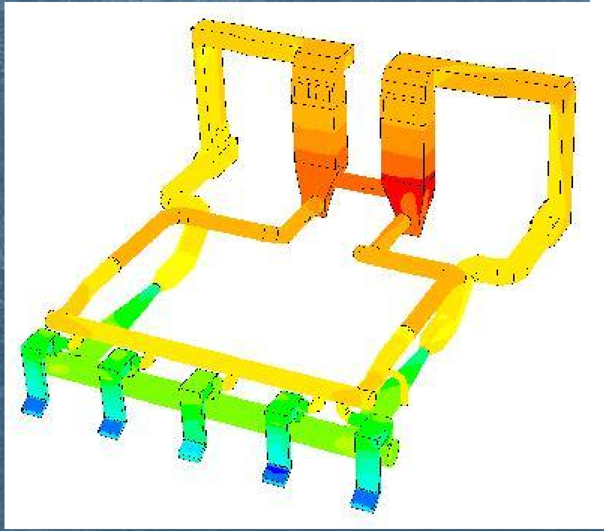
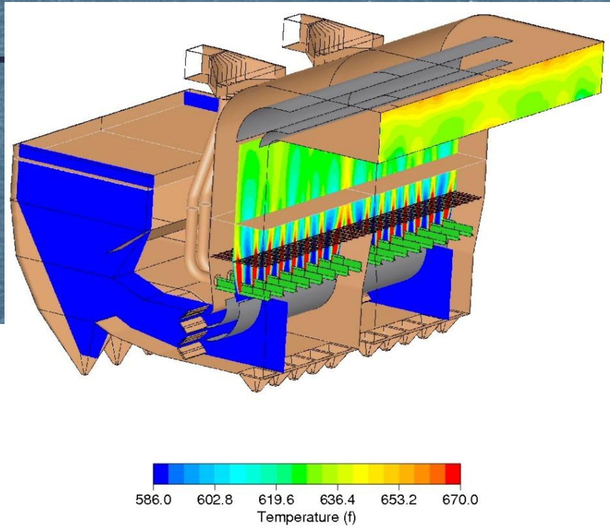
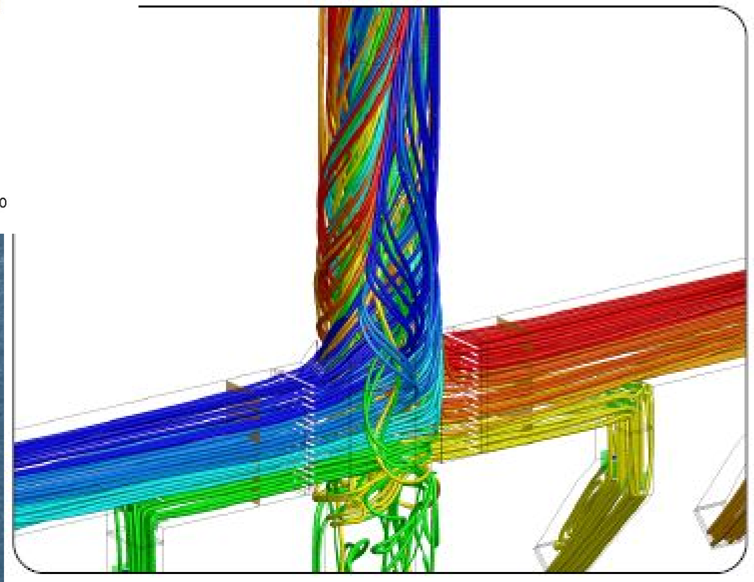
CFD Results







Physical Flow Modeling

- Laboratory representation of geometry
- Typical scale between 1:8 and 1:16
- "Cold flow" modeling
- Visualize flow with smoke
- Simulate ash drop-out/re-entrainment
- Measure flow properties
  - Velocity (Hot wire or pitot)
  - Pressure (Pitot-static probe w/ manometer)
  - Tracer gas (Gas analyzer)

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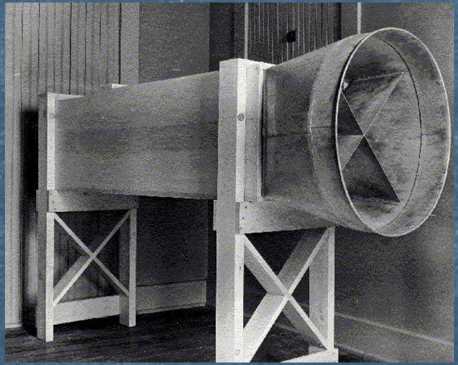
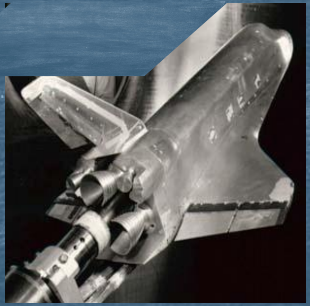
Physical Modeling History

- Utilized for fluid flow analysis for a century…or more?
- Applied to industrial equipment for decades
- Underlying principle is to reproduce fluid flow behavior in a controlled, laboratory environment





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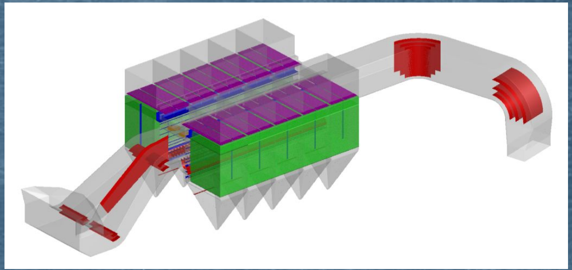
Physical Model Methodology

- Key criterion is to generate "similarity" between the scale model and the real-world object
  - Geometric similarity
    - Accurate scale representation of geometry
    - Inclusion of all influencing geometry elements
    - Selection of scale can be important
  - Fluid dynamic similarity
    - Precise Reynolds number (Re) matching is not feasible
    - General practice is to match full scale velocity but ensure that Re remains in the turbulent regime throughout the model



$$Re = \frac{\rho v D_h}{\mu}$$

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Physical Model Methodology

1. Set up
   - Fabricate(from CAD)
   - Boundary conditions
   - Similarity calculations
2. Test
3. Analyze
   - Contour plots
   - Flow statistics and integrations
   - Flow visualization
4. Optimize

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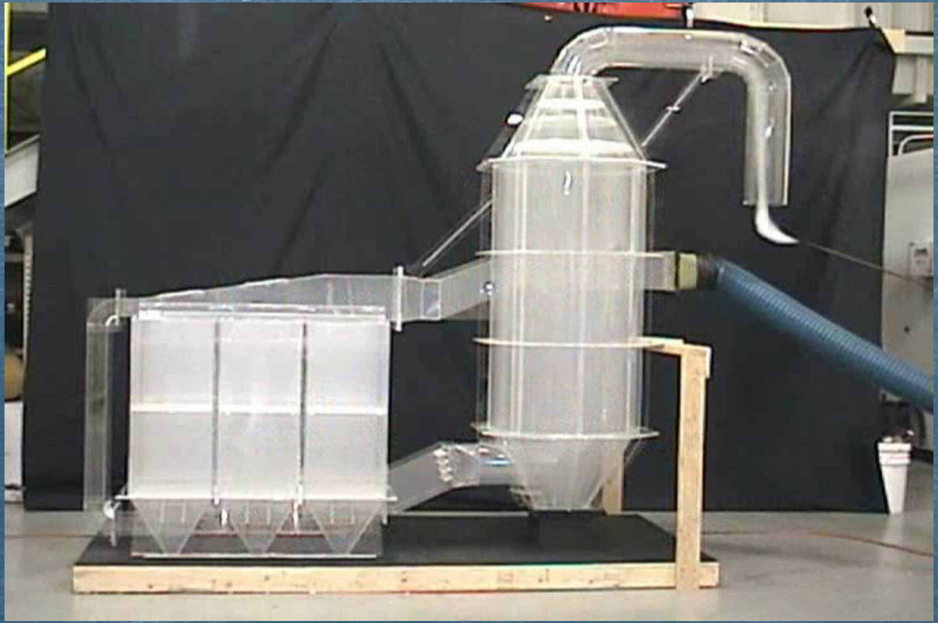
Physical Model Smoke Flow



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Flow Modeling Pros and Cons

- Physical Modeling - Pros
  - Proven technique
  - Can "touch and feel" model
  - Complex flow simulations and solutions
  - Sorbent distribution modeling using tracer gas
  - Ash drop-out and re-entrainment
  - Flow visualization
- Physical Modeling - Cons
  - Design iterations can be time consuming (no parallelization)
  - Thermal mixing difficult
  - Limited number of measurement points
  - Cannot simulate complex physics (chemical reactions, density variations)
  - Model storage can take up significant space

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Flow Modeling Pros and Cons

- CFD Modeling - Pros
  - Iterations can be done in parallel
  - Detailed representation of flow and mixing patterns
  - Data available at millions of traverse points
  - Output can be customized to maximize information
  - Can track particulate in flight
  - Model stored on computer or CD/DVD
- CFD Modeling - Cons
  - Accuracy of results relies on mesh quality and resolution
  - Particulate drop-out/re-entrainment capability is limited
  - Sorbent distribution modeling requires detailed (dense) mesh
  - Some physics and geometries are difficult to resolve in mesh

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Case Study

- Mid-sized US plant
- Two new PJFFs
- Activated Carbon Injection

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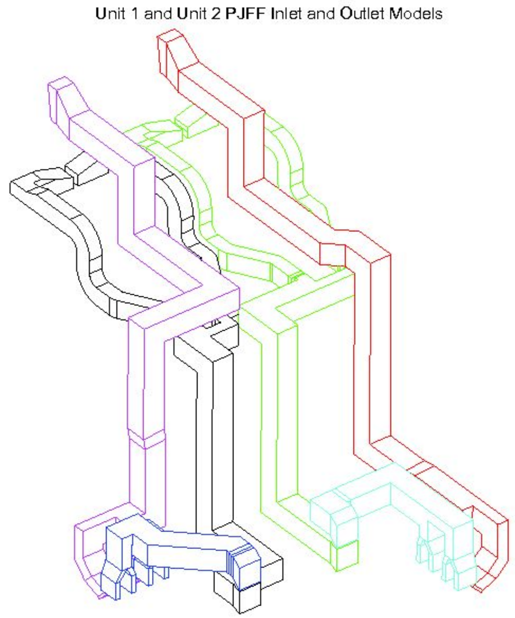
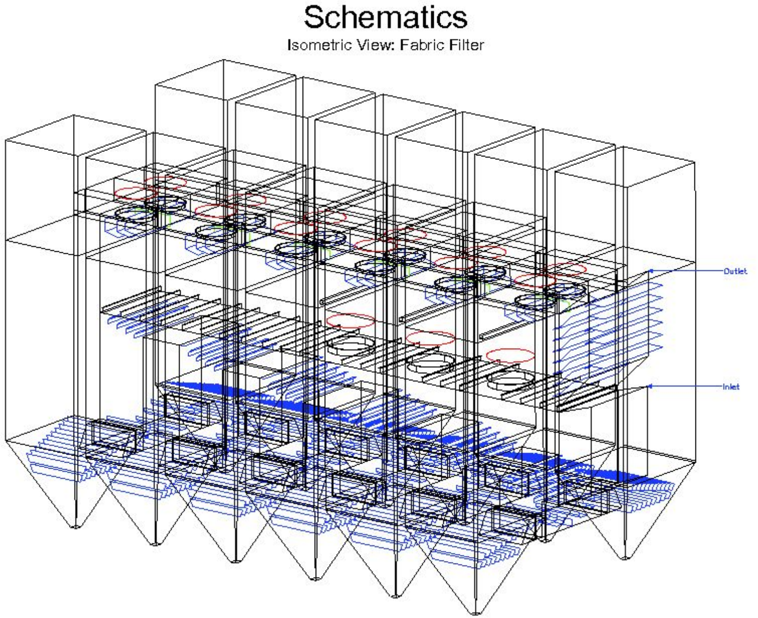
Model Geometry





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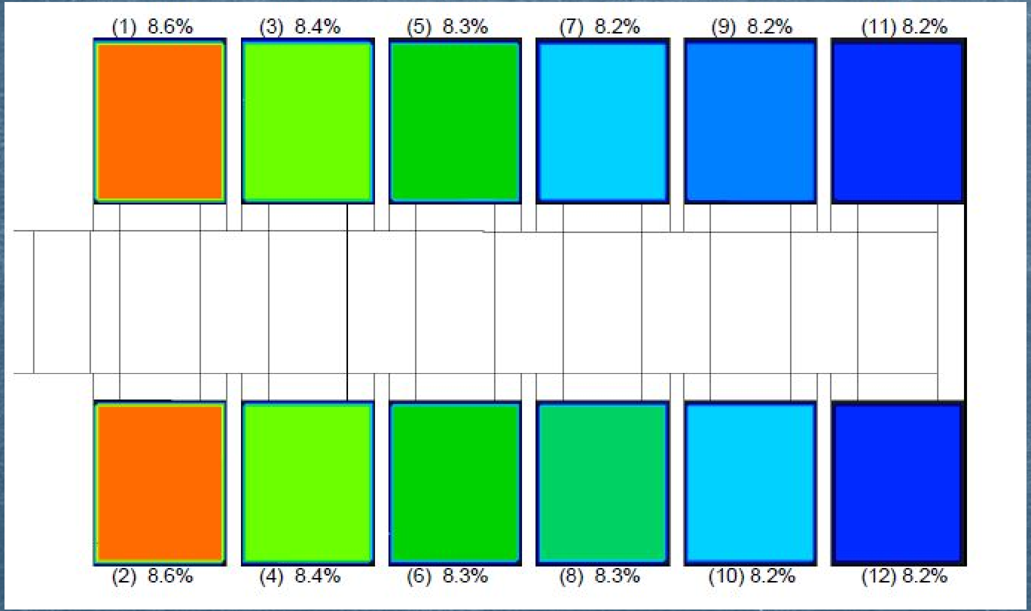
Compartment Gas Flow Split



- Goal was to achieve equal gas flow split between compartments.
- Flow split ranged between 8.2 and 8.6% vs 8.3% theoretical split.
- This implies a deviation of +/-3.2%, meeting ICAC goal of +/-10%

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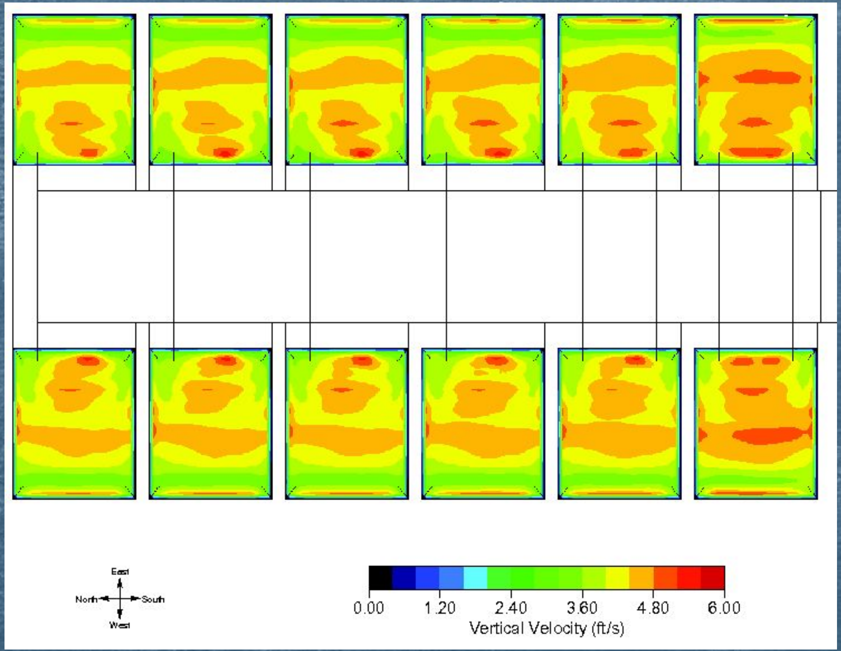
Velocity Distribution Under Bags



- Goal was to quantify and reduce gas velocities impinging on bags

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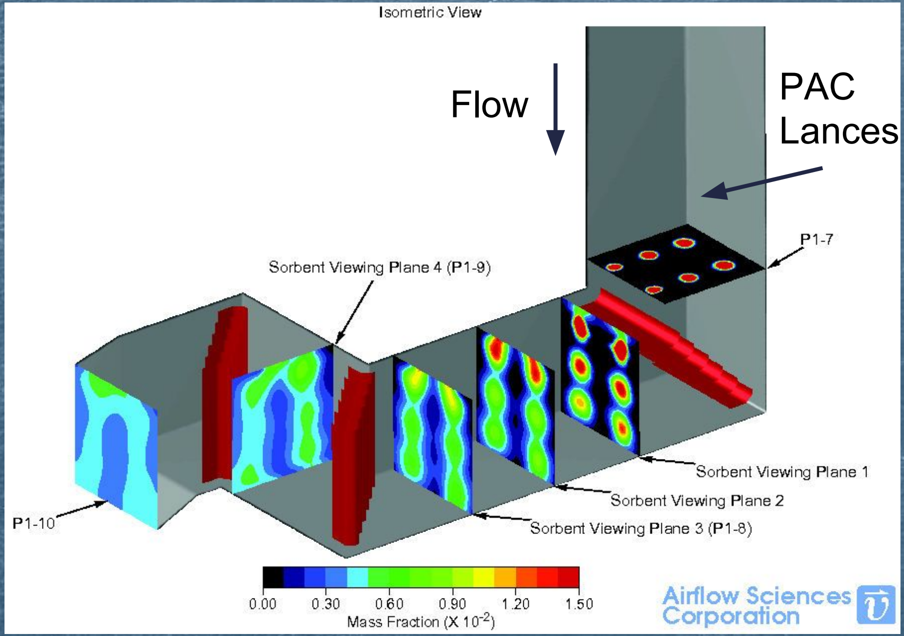
Activated Carbon Injection



- Goal was to achieve equal flow split of carbon to the compartments.

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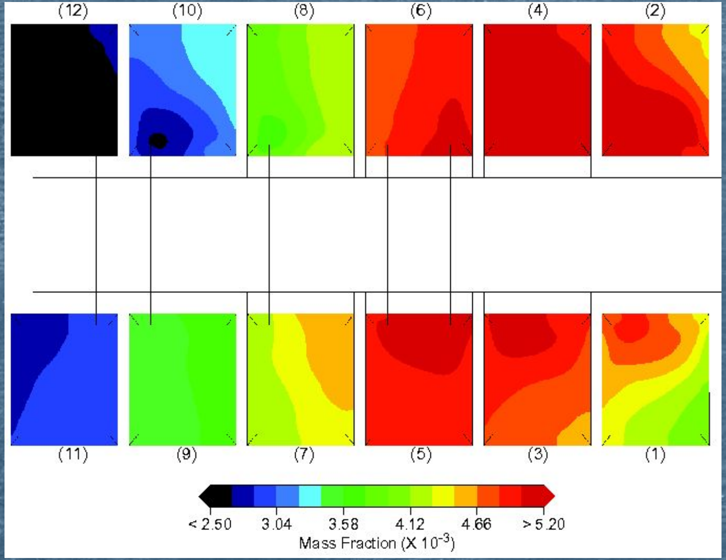
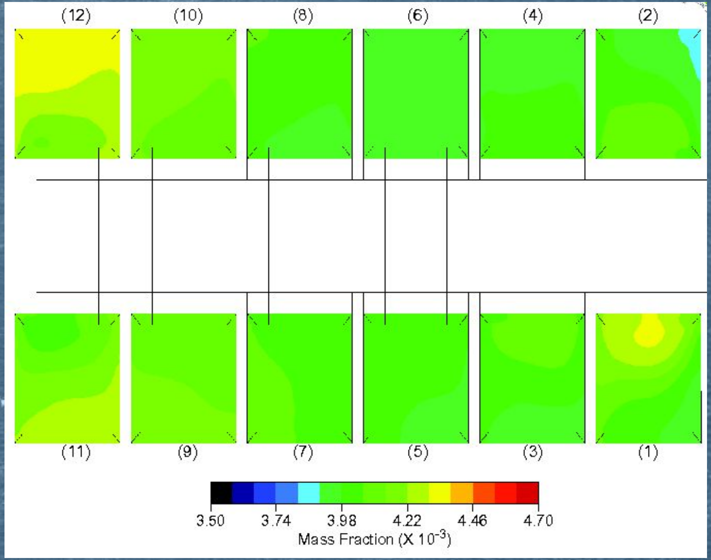
Activated Carbon Injection



Baseline Design
PAC Split = +/-44% from Average



Final Design
PAC Split = +/-8% from Average

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Conclusions

- Gas flow patterns have a significant impact on the performance of fabric filters and other pollution control equipment
- Flow models (CFD and physical) are widely employed for pollution control equipment original design and retrofit:
  - Each method has advantages and disadvantages
  - Provide accurate results to within typical engineering tolerances when used correctly
  - Leads to better performance and reduced costs

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Questions / Discussion

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