Flow Modeling and Pollution Control System Design

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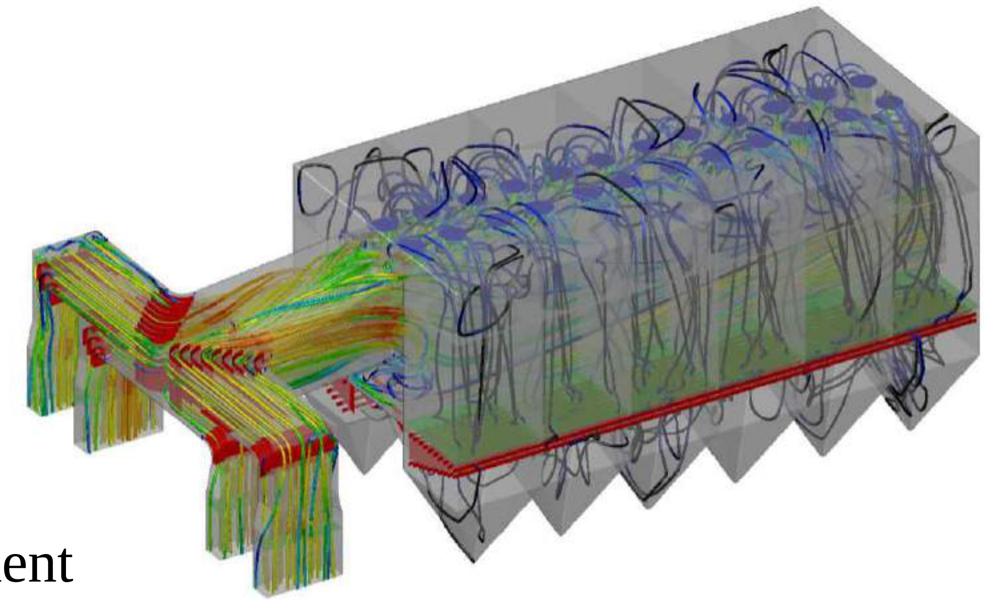
Outline

- Introduction
- Flow Analysis Techniques
- Application to Air Pollution Control Equipment
- Sorbent Injection Modeling
- Conclusions

Introduction

- Why is Fluid Flow Important to Industrial Equipment?
  - Performance
    - Flow uniformity
    - Sorbent injection
    - Ash capture / build-up
  - Operating costs
    - Pressure drop
    - Erosion
    - Corrosion
    - Sorbent Usage



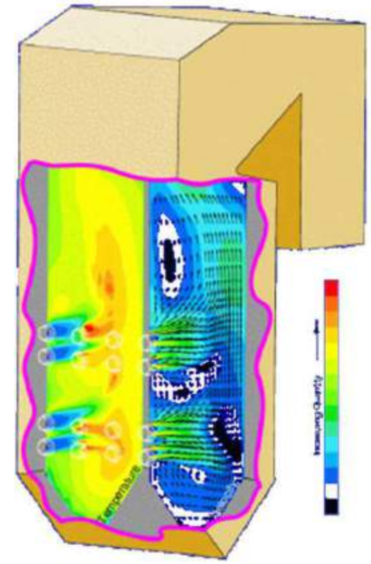
- Applications
  - Design of new equipment
  - Retrofit of existing equipment
  - Solving operational or maintenance issues

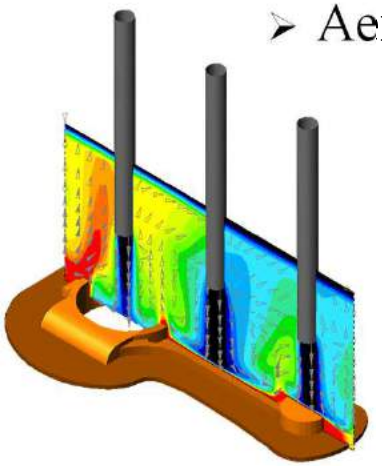
Airflow Sciences Corporation

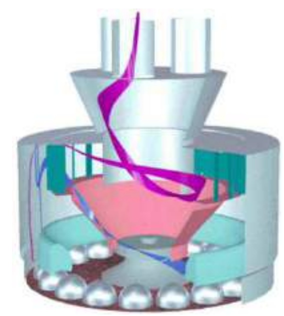
Providing engineering services to industry since 1975

Specialize in developing cost-effective solutions to problems involving

- Fluid flow
- Heat transfer
- Particulate transport
- Chemical reaction
- Aerodynamics







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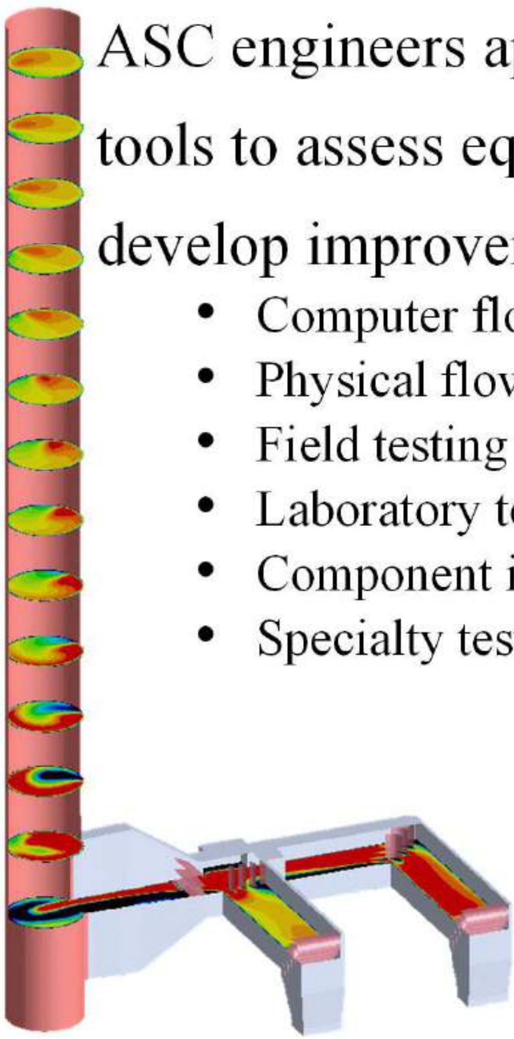
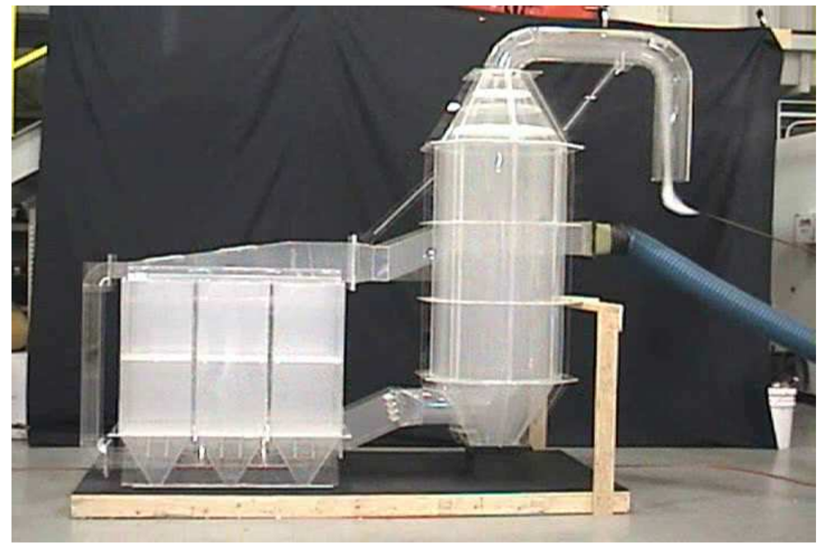
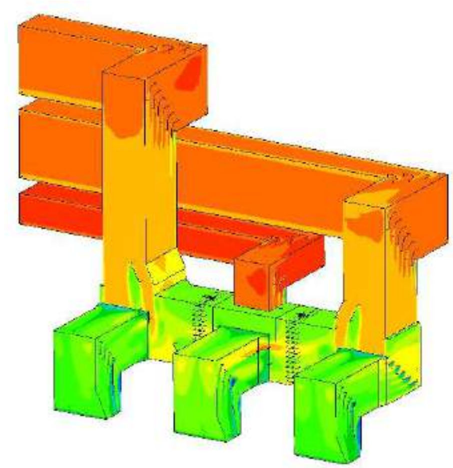


ASC engineers apply a variety of tools to assess equipment and develop improvements

- Computer flow modeling
- Physical flow modeling
- Field testing
- Laboratory testing
- Component inspection
- Specialty test equipment





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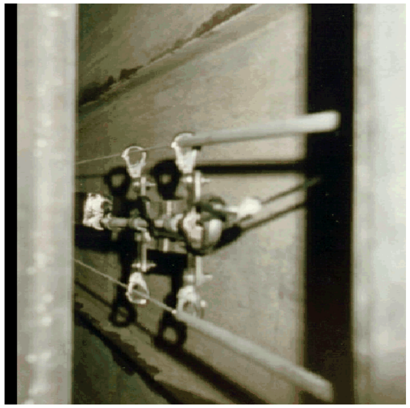
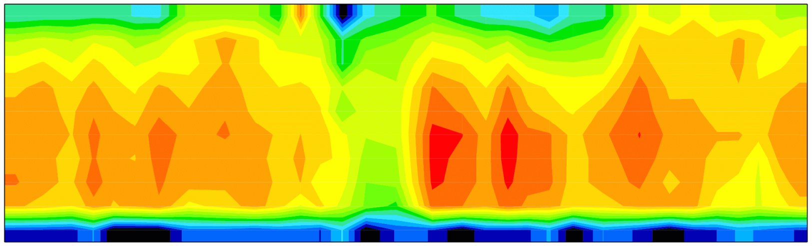
- Introduction
- Flow Analysis Techniques
  - Field Testing
  - Computational Fluid Dynamics (CFD)
  - Physical Flow Modeling
- Application to Air Pollution Control Equipment
- Sorbent Injection Modelling
- Conclusions

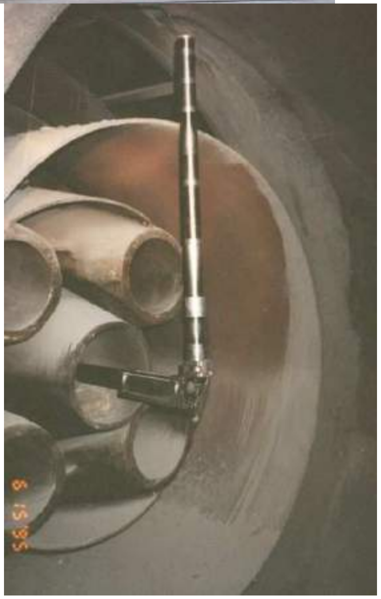
Field Testing

- Velocity
- Temperature
- Pressure
- Particulate
- Chemical Species



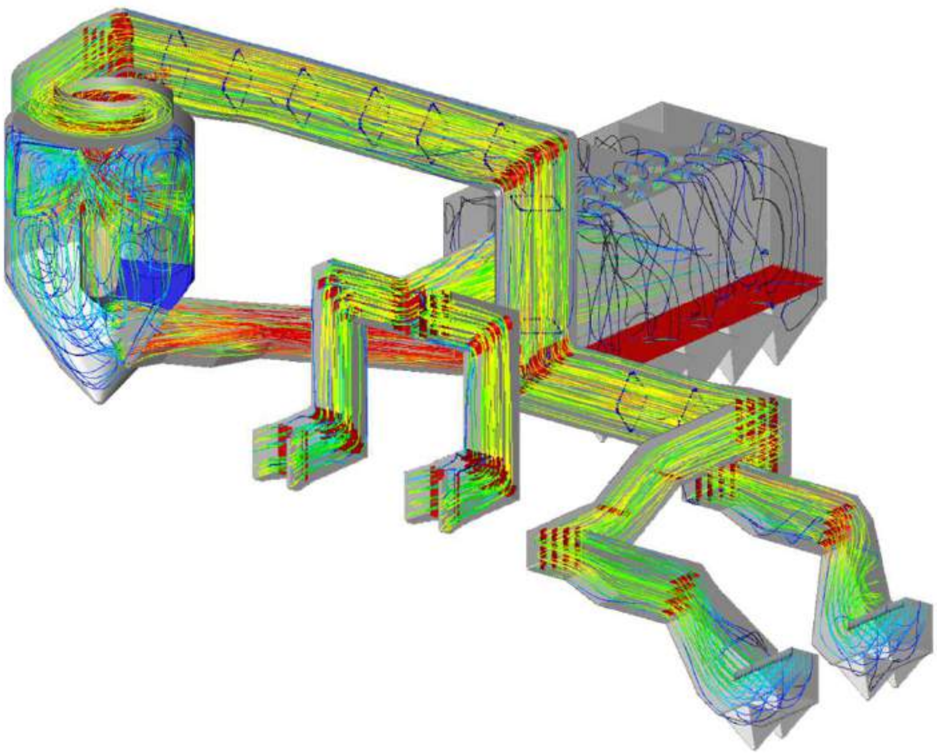


Field Testing



Computational Fluid Dynamics (CFD)

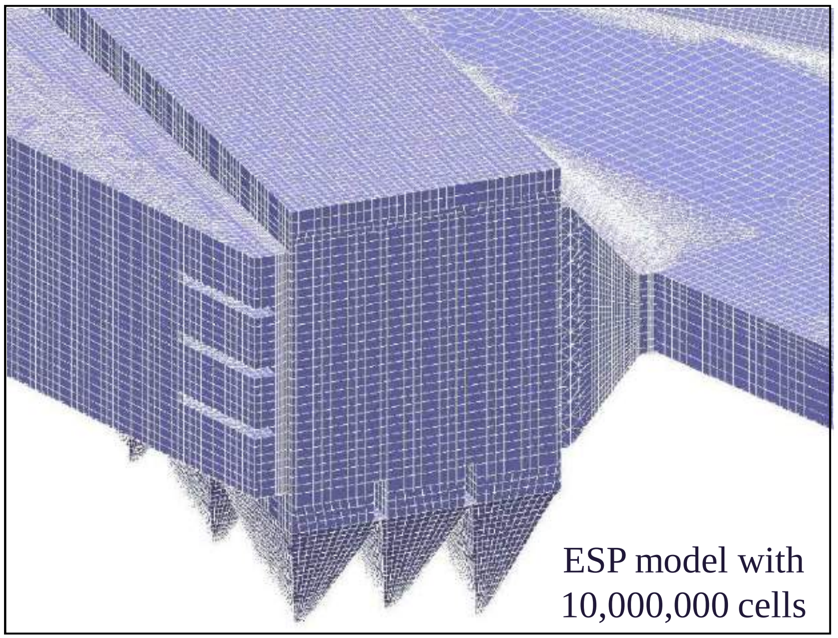
- ❖ Numerical simulation of flow
- ❖ Utilize high speed computers and sophisticated software
- ❖ Calculate flow properties
  - Velocity
  - Pressure
  - Temperature
  - Species
  - Particle streamlines

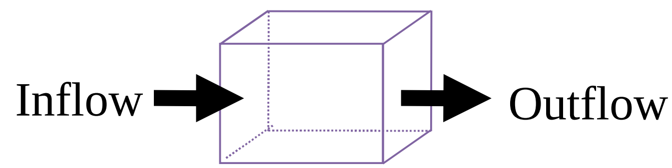


Computational Fluid Dynamics (CFD)

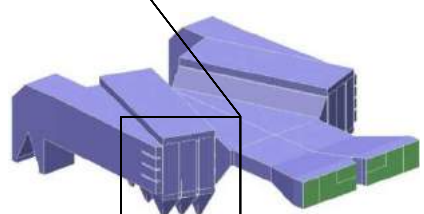
❖ Control Volume Approach

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

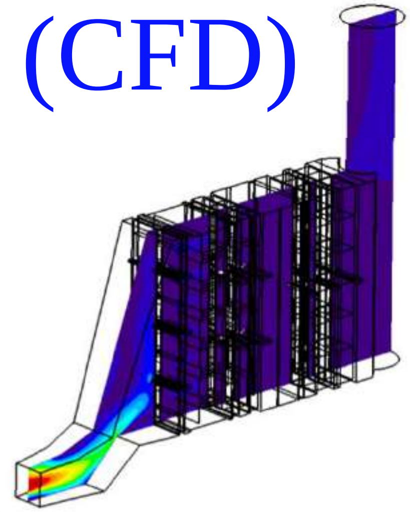




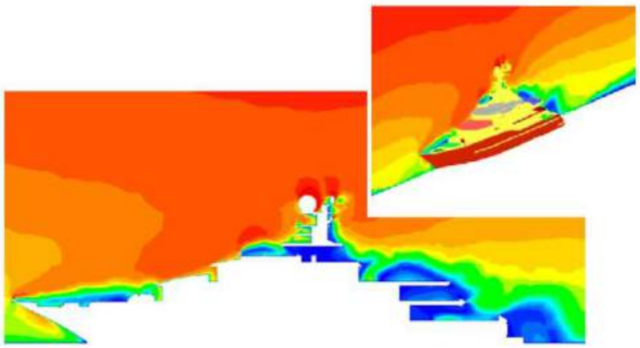
Control Volume
or “Cell”

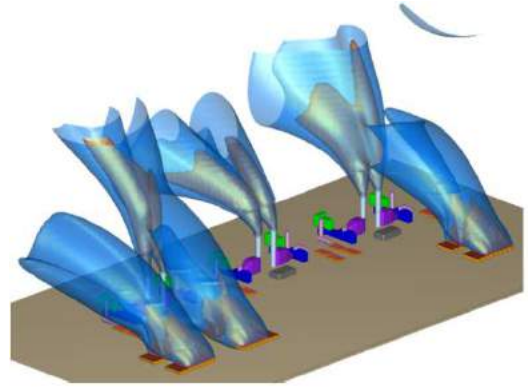


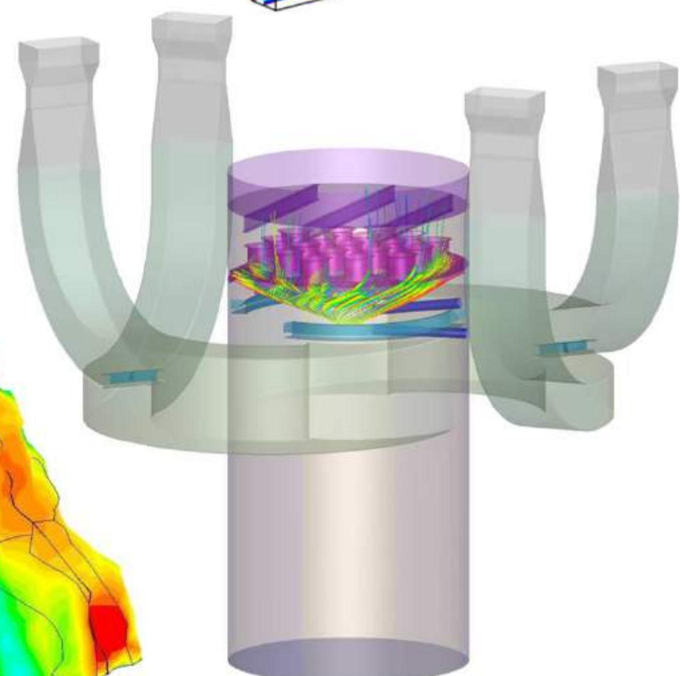
Computational Fluid Dynamics (CFD)

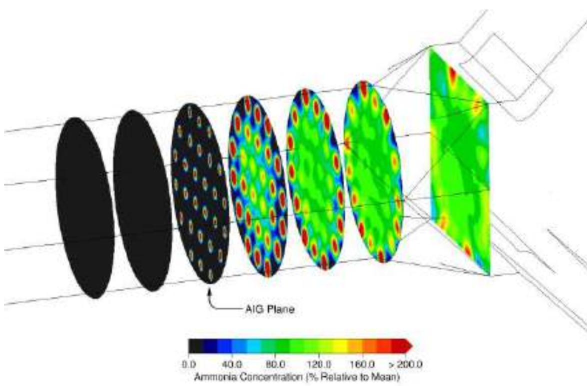


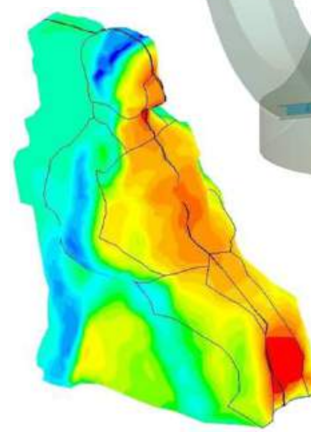
- Many applications:











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
  - Dust/Particles

Physical Flow Modeling

Typical 1:12 scale physical model

SDAs

Air Heater Outlet

PJFF Compartments

Turning vanes

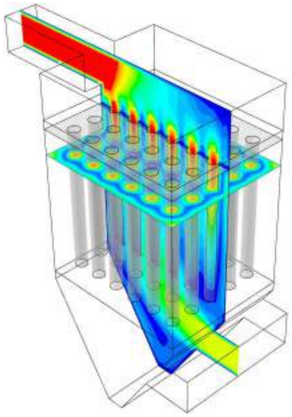
ID Fan Inlet

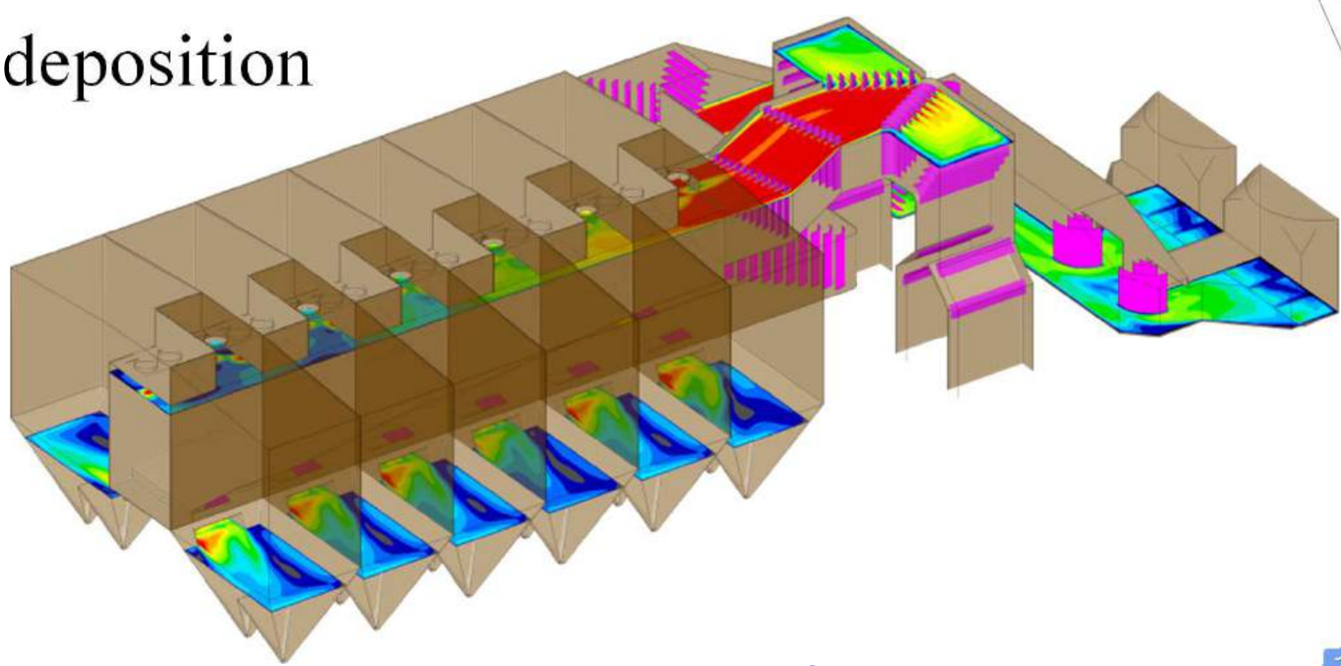
Outline

- Introduction
- Flow Analysis Techniques
- Application to Air Pollution Control Equipment
  - Fabric Filter
  - ESP
  - SCR
  - Sorbent Injection
- Sorbent Injection Modelling Process
- Conclusions

Fabric Filter Flow Modeling

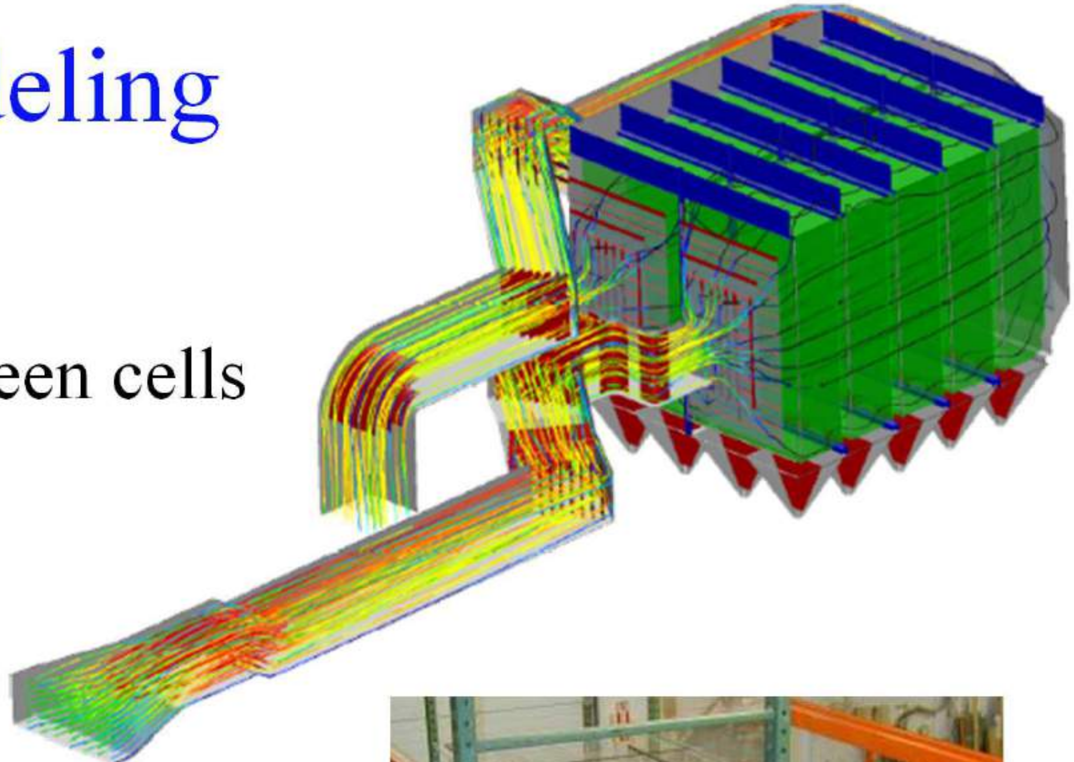
- Uniform velocity distribution and equal balance between compartments
- Pressure loss
- Avoid bag erosion
- Ash deposition





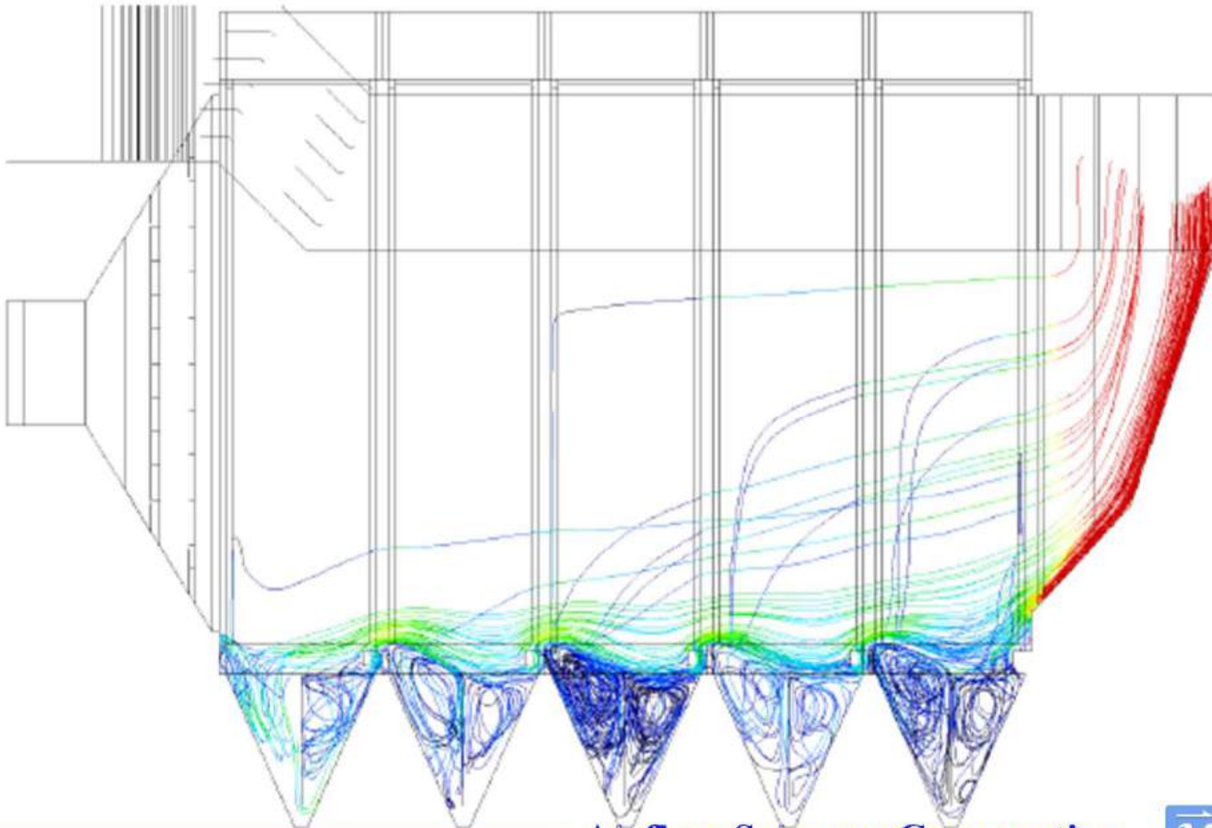
ESP Flow Modeling

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



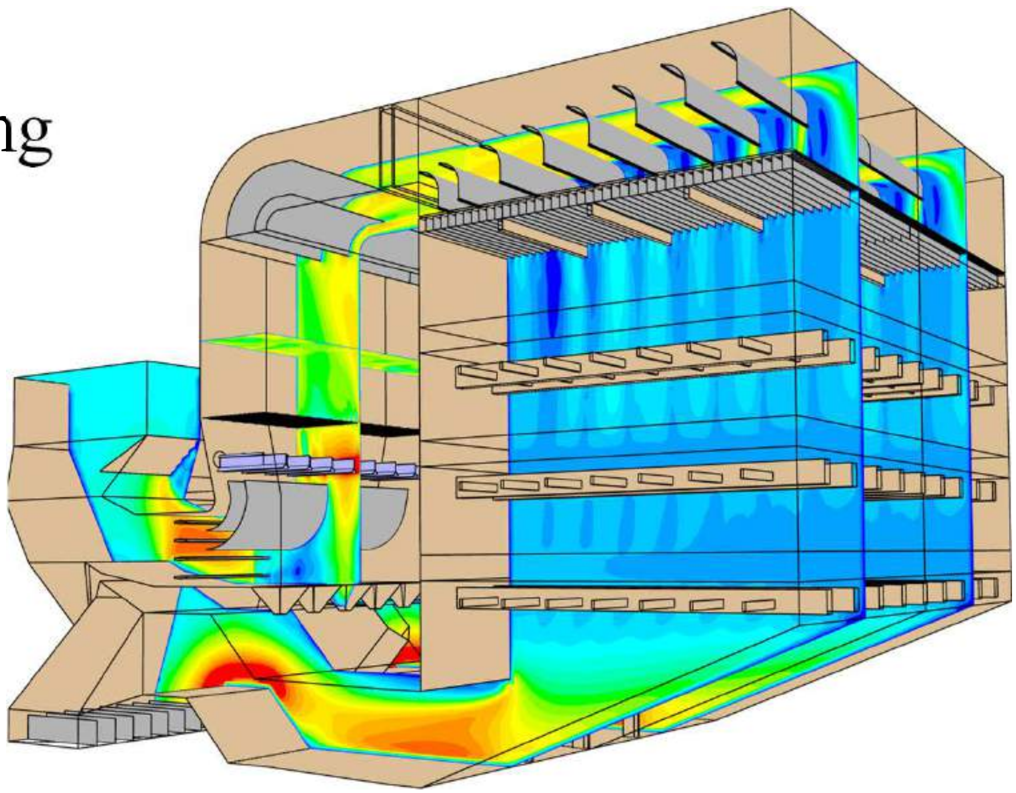
ESP Flow Modeling

- Hopper sweepage
- Very light particles (sorbent), re-entrained in the flow during the rapping process



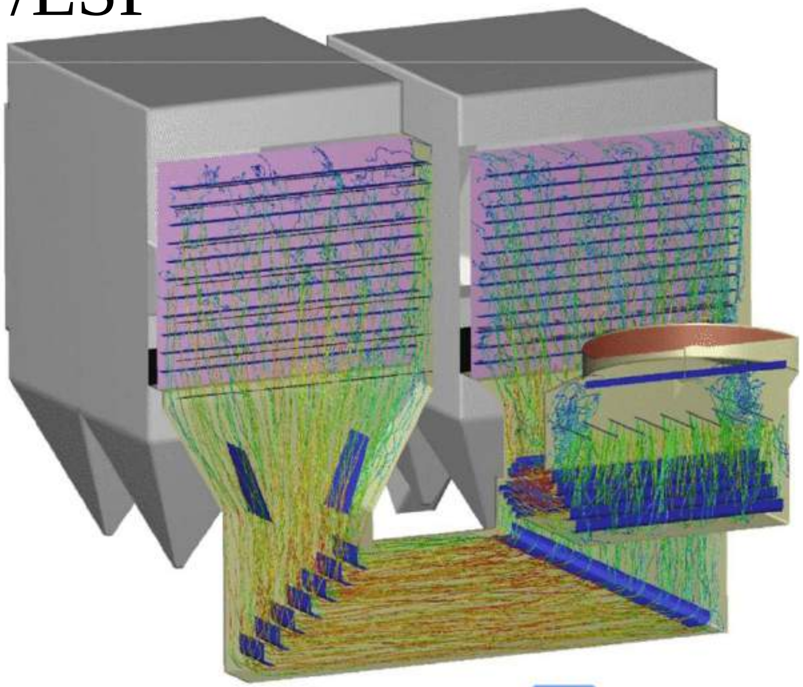
SCR Flow Modeling

- Uniform velocity distribution
- Thermal mixing
- NOx profile and mixing
- Ammonia injection
- Pressure loss
- LPA capture
- Ash deposition



Mercury / SO_3 Reduction

- Injection upstream of FF or ESP
  - Activated carbon
  - Lime, Trona, SBC, etc.
- Maximize uniformity at AH/FF/ESP
- Maximize residence time
- Uniform injection



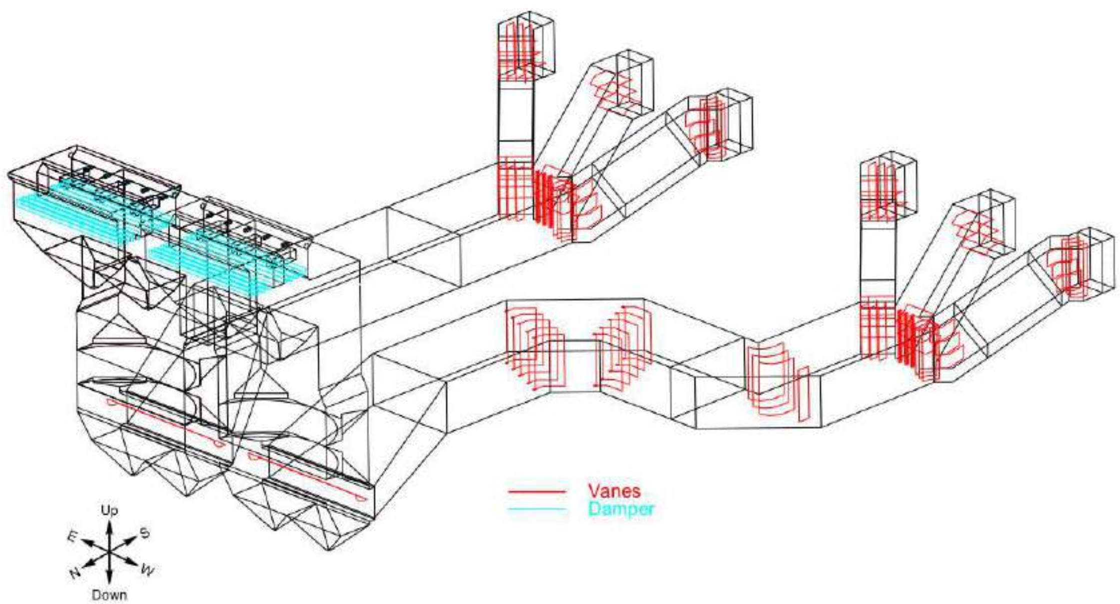
Outline

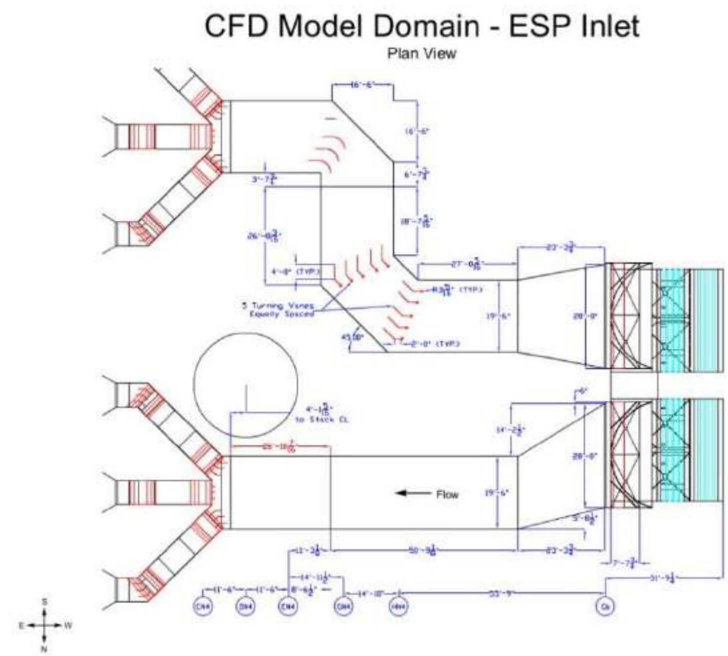
- ❖ Introduction
- ❖ Flow Analysis Techniques
- ❖ Application to Air Pollution Control Equipment
- ❖ Sorbent Injection Modeling
  - Process
  - CFD Applications
  - Physical Modeling Applications
  - Comparison
  - Future Considerations
- ❖ Conclusions

Sorbent Injection

❖ Sorbent Injection Modeling: The Process

- Review plant drawings and operating conditions
- Develop 3-D CAD model of the model domain

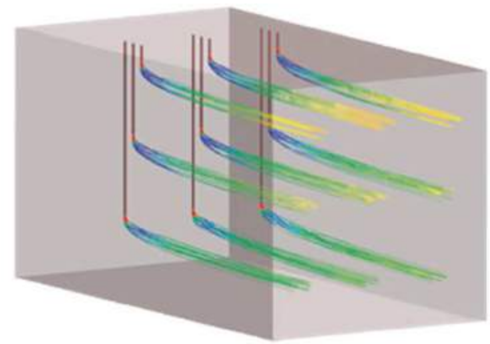




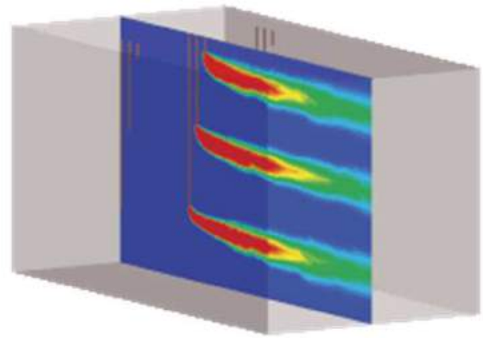
Sorbent Injection

- Several CFD techniques to analyze particulate behavior. The choice depends on factors including;
  - Particle loading
  - Particle size
  - Particle density
  - Turbulence
  - Gas velocity

Sorbent Injection



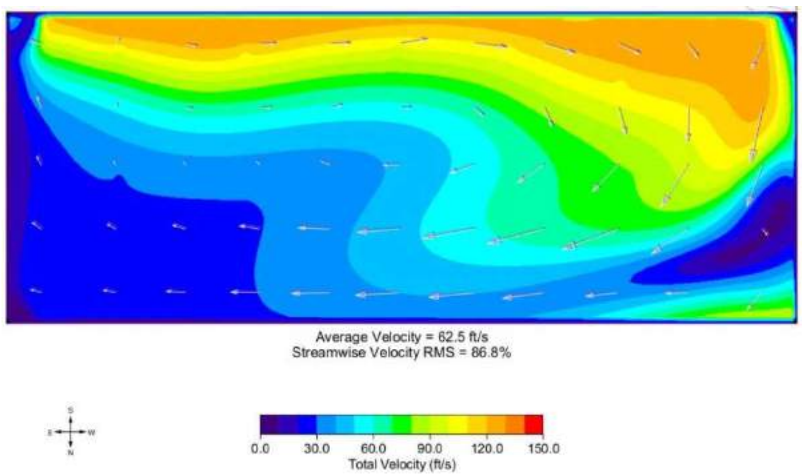
- Modeling Techniques
  - Lagrangian
    - Model particles directly
    - Forces on each particle calculated (aerodynamic drag, gravity, impacts, acceleration)
    - Commonly used for: flyash, LPA, erosion studies
  - Eulerian
    - Model particles as a gas
    - Applicable for very small particles (<50 μm)
    - Commonly used for: sorbent injection modeling
  - Fully-Coupled Two-Phase
    - Combination of Eulerian and Lagrangian, where influence of the particles on the gas stream is accounted for
    - Solved iteratively with many, many particles tracked
    - Applicable for gas streams with very high particle loading or significant particle density
    - Commonly used for: coal flow in a pulverizer or coal pipe, fluidized bed



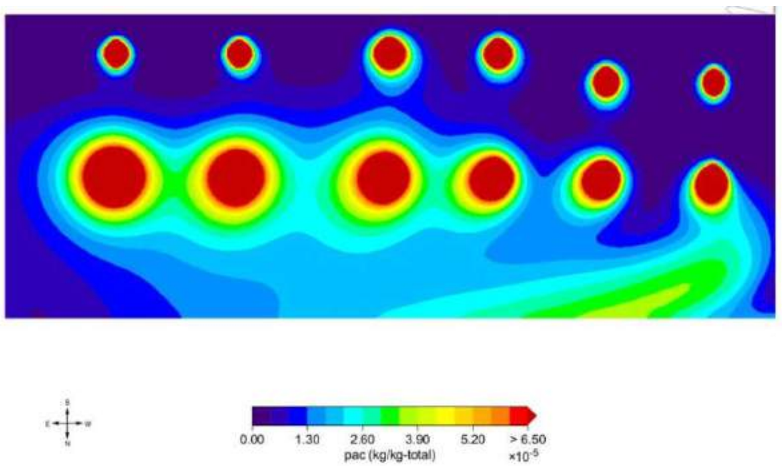
- Mesh geometry and quality is critical for each

Sorbent Injection

- Sorbent Injection Modeling: The Process
  - Discuss the design parameters and restrictions regarding the injection lances (location, number of lance, etc.)
  - Perform a baseline flow simulation with the initial injection grid geometry



Gas Velocity

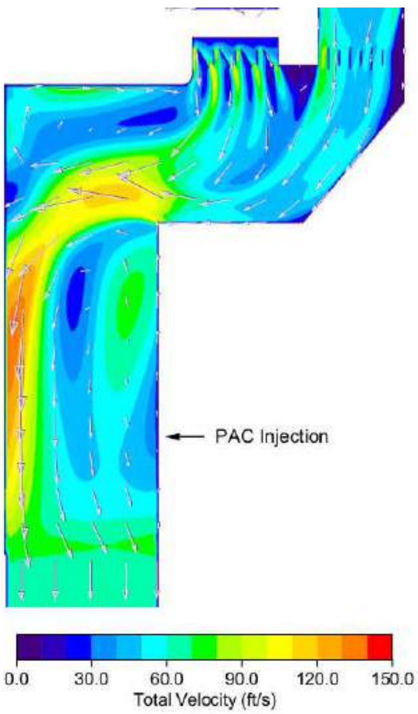


PAC Injection Concentration

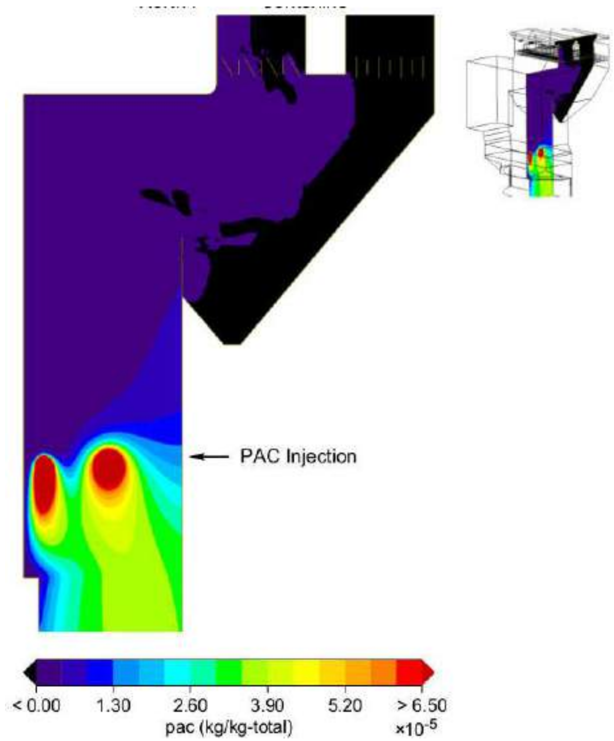
Sorbent Injection

❖ Sorbent Injection Modeling: The Process

- Issue a report with details of the flow and sorbent distribution throughout the model domain



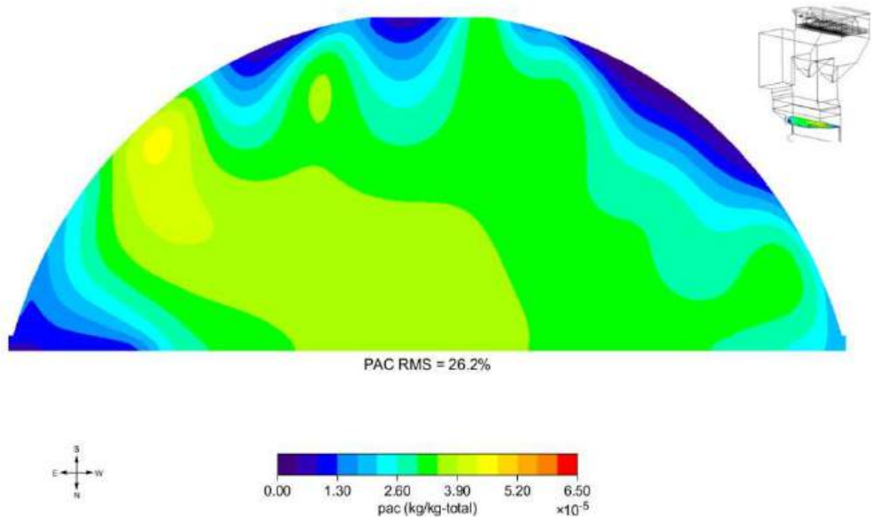
Gas Velocity



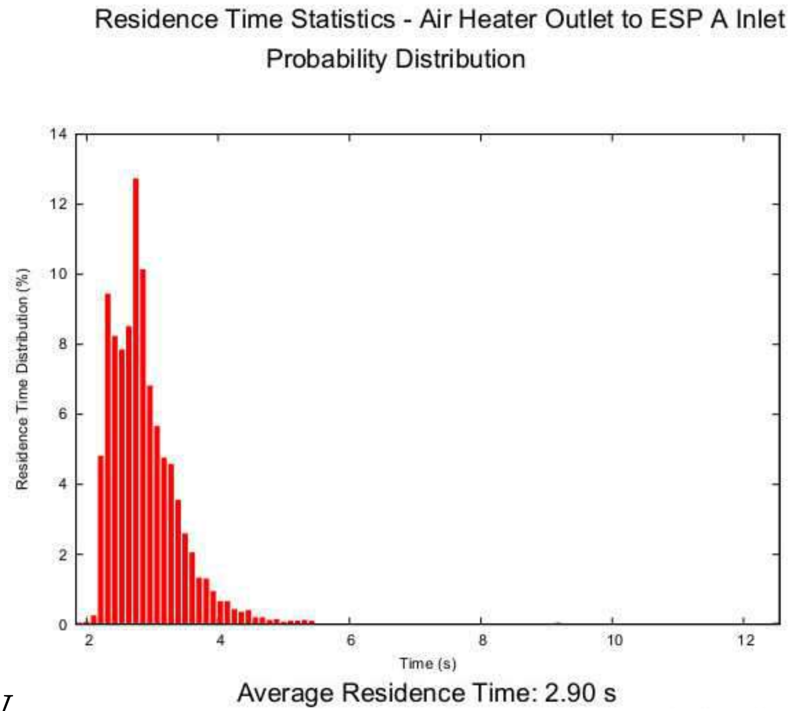
PAC Injection Concentration

Sorbent Injection

- Sorbent Injection Modeling: The Process
  - Particle residence time and sorbent uniformity at the target planes are presented

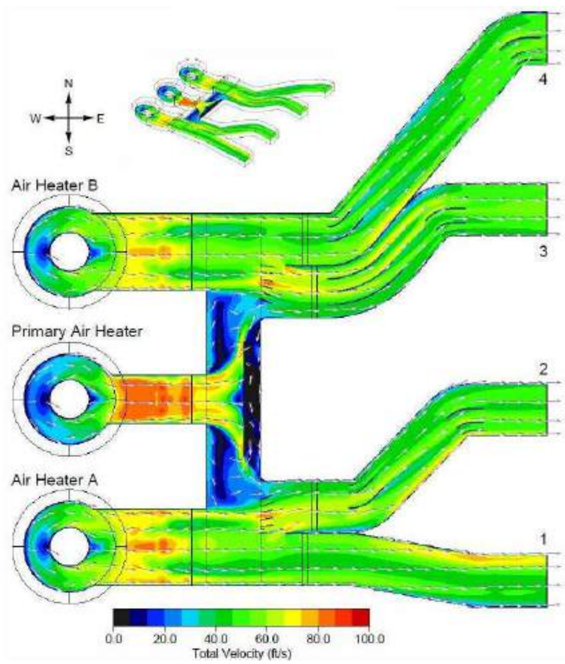


15-20% is the industry standard for uniformity

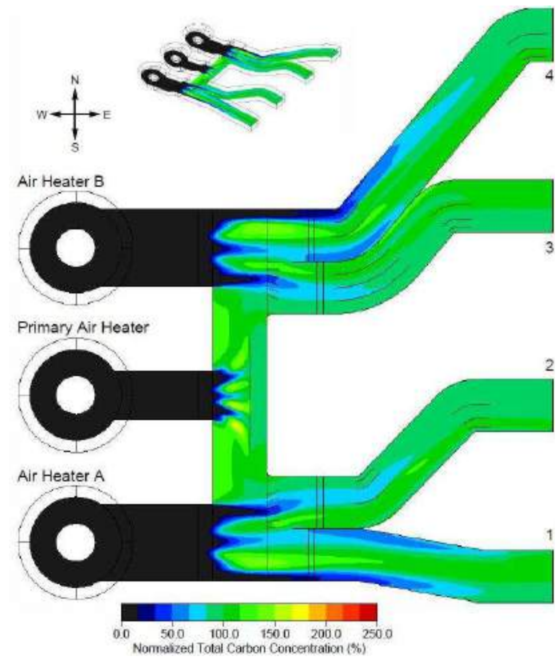


CFD Applications

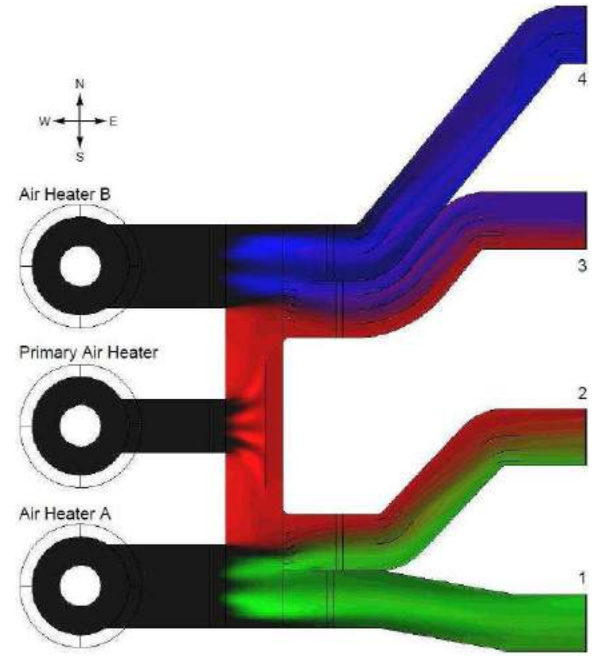
❖ Example: Carbon Injection with Multiple Air Heaters



Gas Velocity



PAC Injection Concentration



PAC Injection Balance

Physical Flow Modeling Applications

Physical Flow Modeling Applications

- Lab representation of lance geometry
- Sorbent injection modeled using tracer gas
- Gas analyzer used to measure distribution downstream

Modeling Comparison: CFD/Physical

Target	CFD	Physical
DSI Uniformity – Target Plane 1	6.9%	3.9%
DSI Uniformity – Target Plane 2	9.1%	7.5%
ACI Uniformity – Target Plane 1	11.4%	12.7%

- Example data comparison from recent projects
  - Data comparable between the two methods
  - Tracer gas testing for other applications (NOx distribution, NH_3 injection) confirms good agreement

Modeling Comparison: CFD/Physical

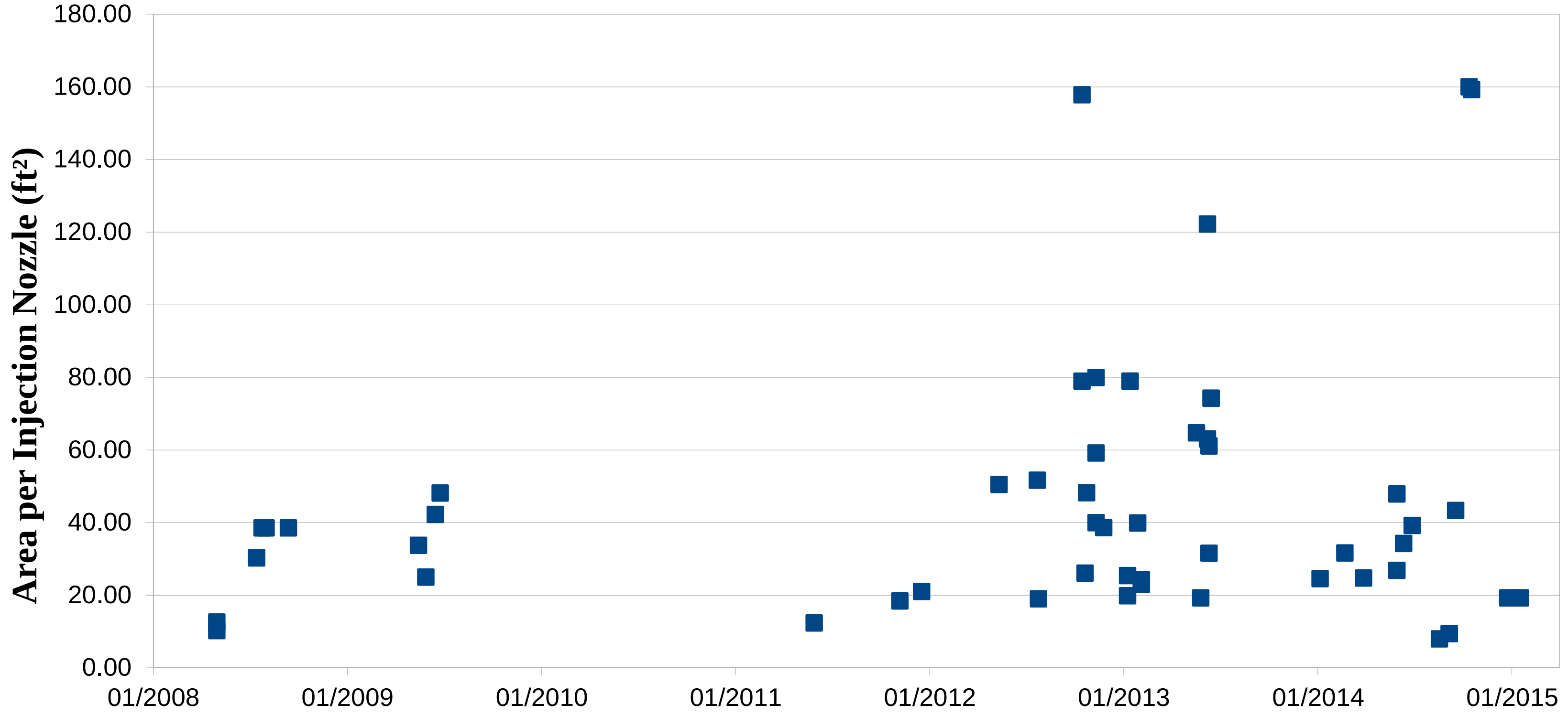
CFD	Physical
$	$$
Multiple configurations investigated simultaneously	One test at a time
Can include lance details	Lance does not scale (2" dia lance not modeled as 1/6" dia lance)
More data points	Discrete data grid for analyzing mixing
Assumptions related to meshing or algorithm	Assumptions related to scaling and similarity

Future Considerations

- Typical Parameters to Consider:
  - Do you have enough lances?
  - Residence time compared to duct size.
  - Is your lance configuration well-suited for the duct aspect ratio?
  - Can the plant fans handle dp of a static mixer?
  - Substantial internal trusswork?
  - You don’t necessarily want the most uniform velocity profile at the injection plane.

Future Considerations

❖ Do you have enough lances?

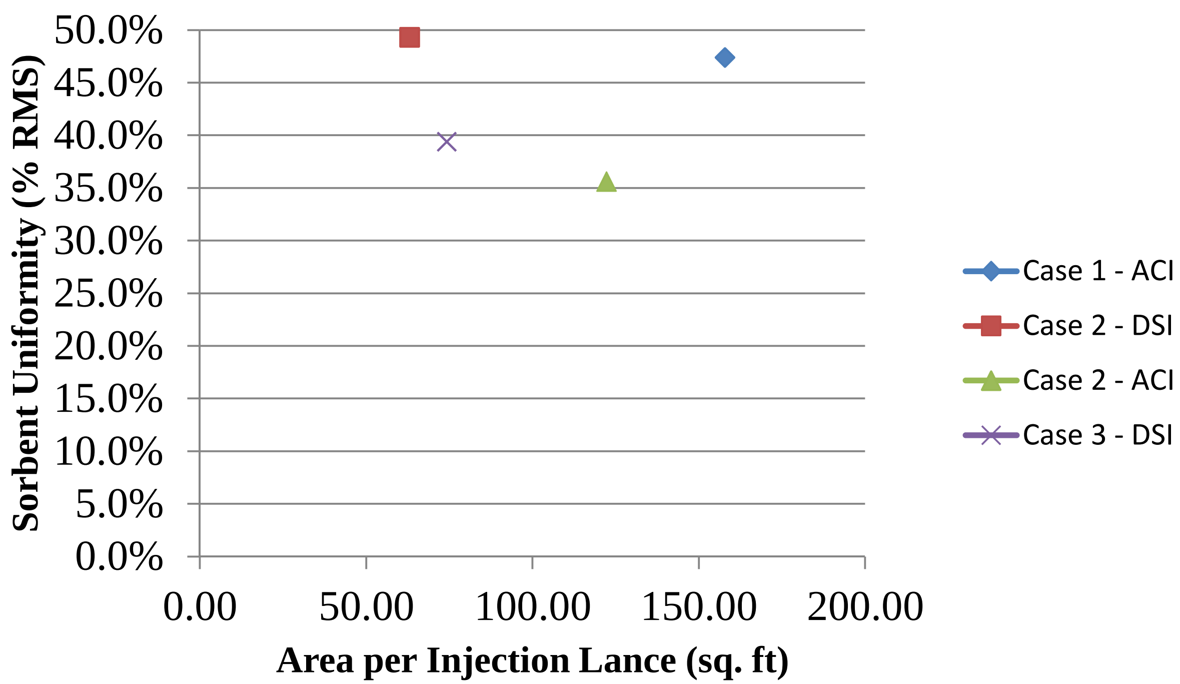


❖ 40-45 square feet per lance is a good guideline.

❖ Adding more lances after contract award is a tough pill to swallow.

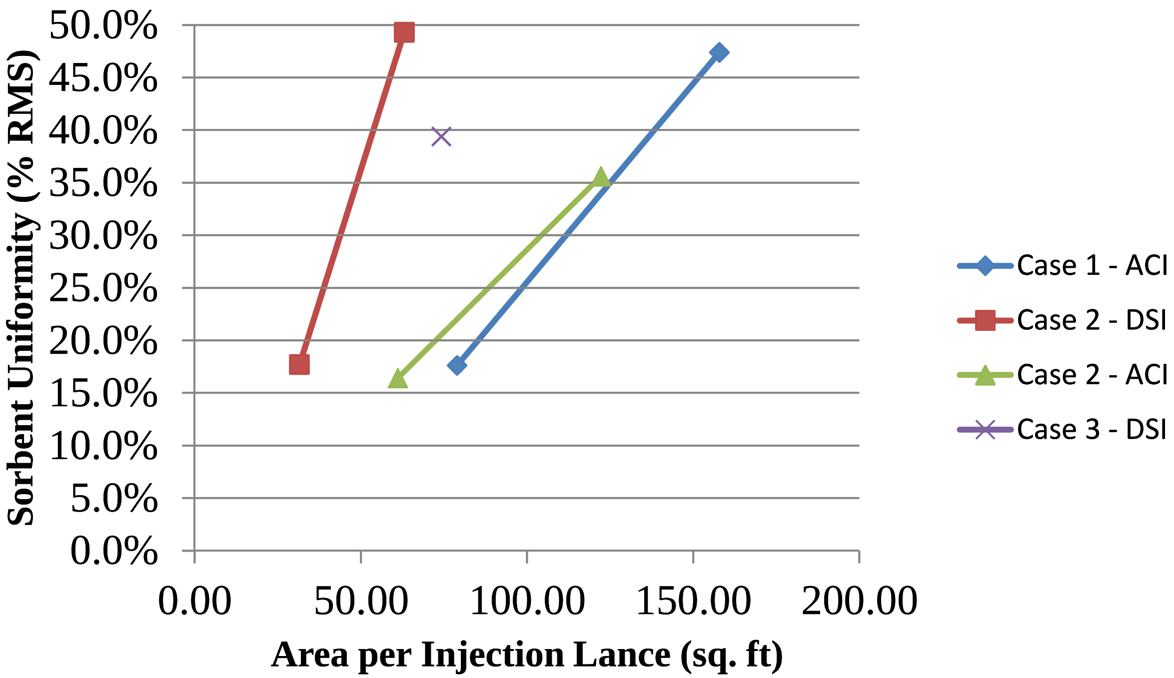
Future Considerations

❖ More Lances = Better Uniformity



Future Considerations

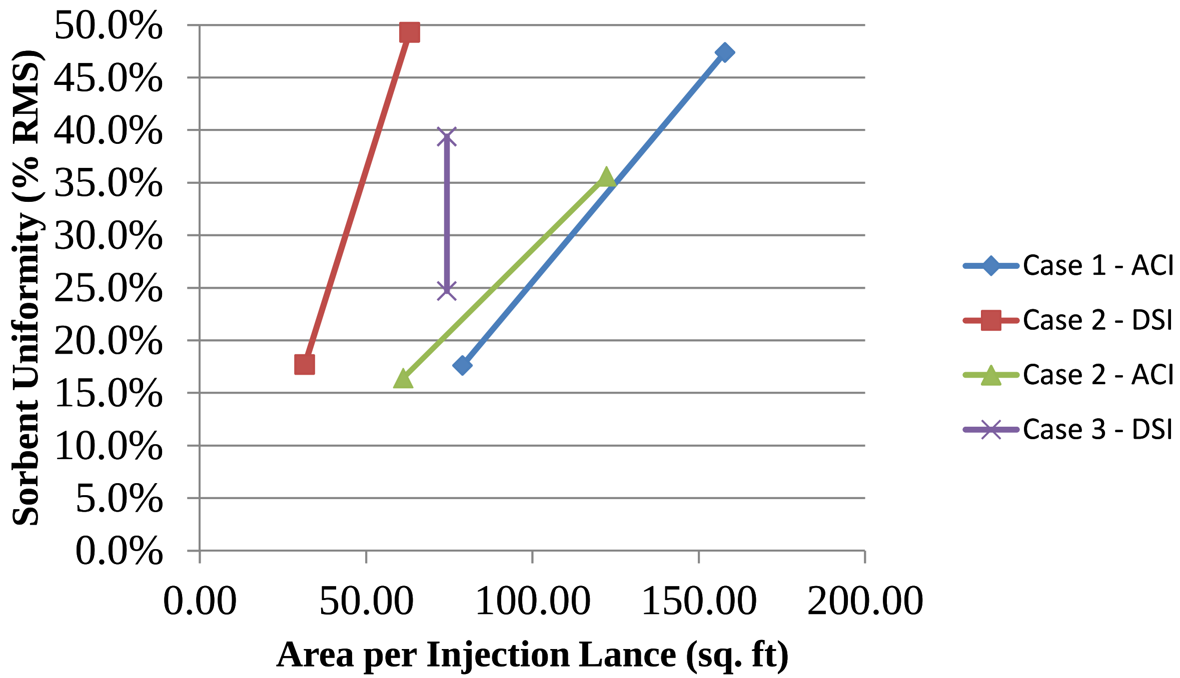
- More Lances = Better Uniformity



Cases 1 and 2, the number of lances had to be doubled to approach the uniformity goals.

Future Considerations

- More Lances = Better Uniformity

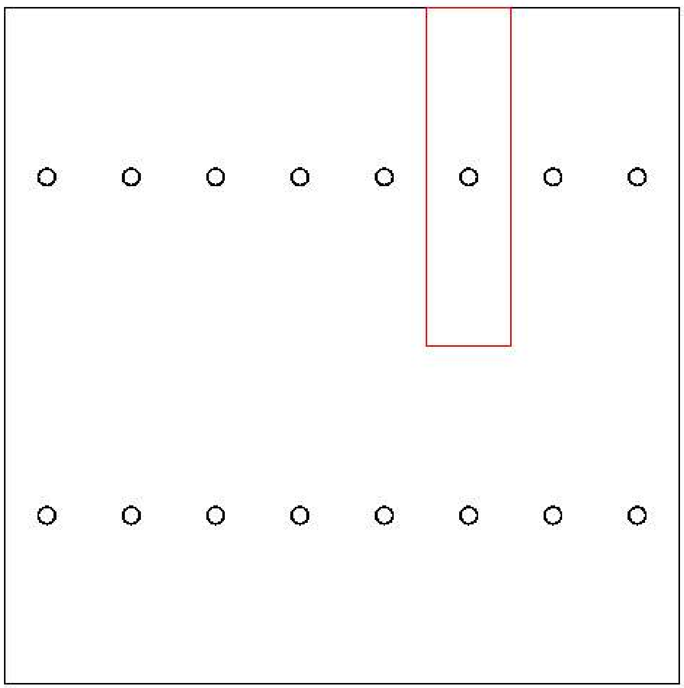


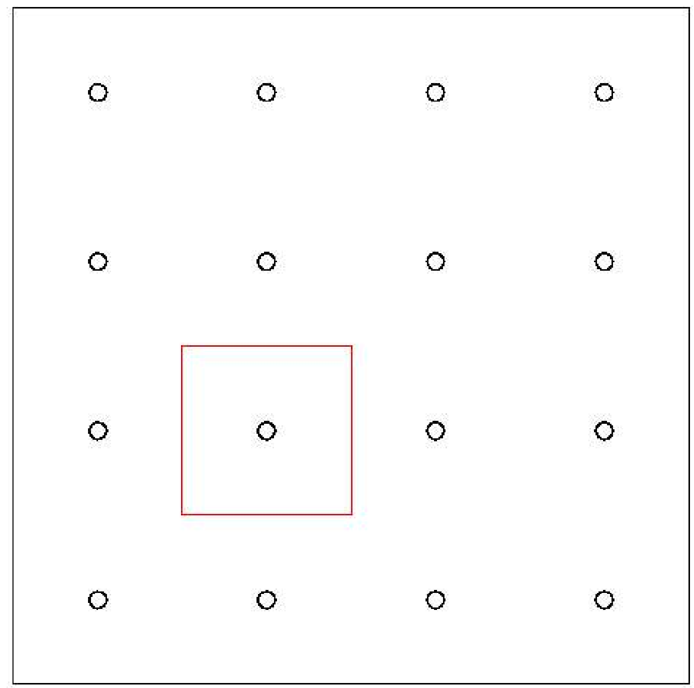
Cases 1 and 2, the number of lances had to be doubled to approach the uniformity goals.

The lance configuration was fixed for Case 3, but the addition of a low dp static mixer proved effective at significantly improving the uniformity.

Future Considerations

- Is your lance configuration well-suited for the duct aspect ratio?

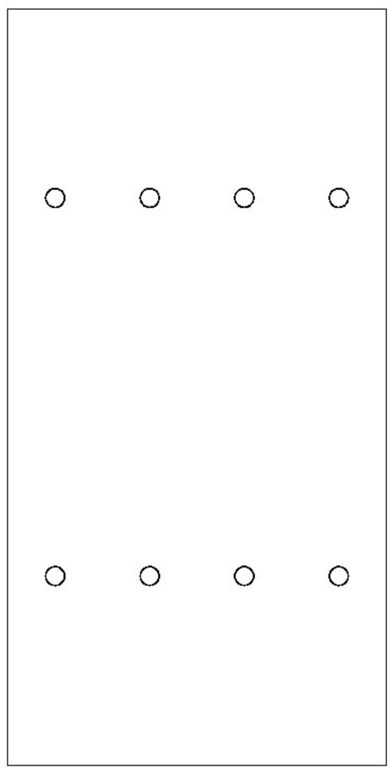


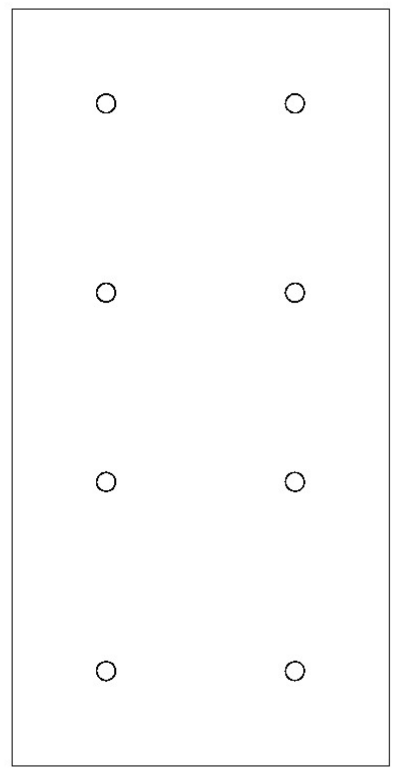


Preferred Orientation

Future Considerations

- Is your lance configuration well-suited for the duct aspect ratio?





Preferred Orientation

Future Considerations

- Mixer?
- Pressure loss limitations
- Local or global mixing?
- Truss location and design

Future Considerations

❖ Modeling vs. Real-Life

- 15%-20% RMS is the industry standard for "uniform" distribution
- RMS required may depend on what is downstream

  FF > WFGD > ESP
- How does this compare to actual system effectiveness, "Will I meet my guarantee?"
- A database of correlation data could be developed based on the many projects that have already been completed in order to give modelers, injection companies, and end users confidence regarding the system performance.

Conclusions

- Fluid dynamics and thermodynamics have significant impact on the performance of power plant equipment
- CFD/Physical modeling is used to optimize the position and arrangement of sorbent injection lances

Better uniformity → Less sorbent usage → Reduced operating cost

Questions?

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