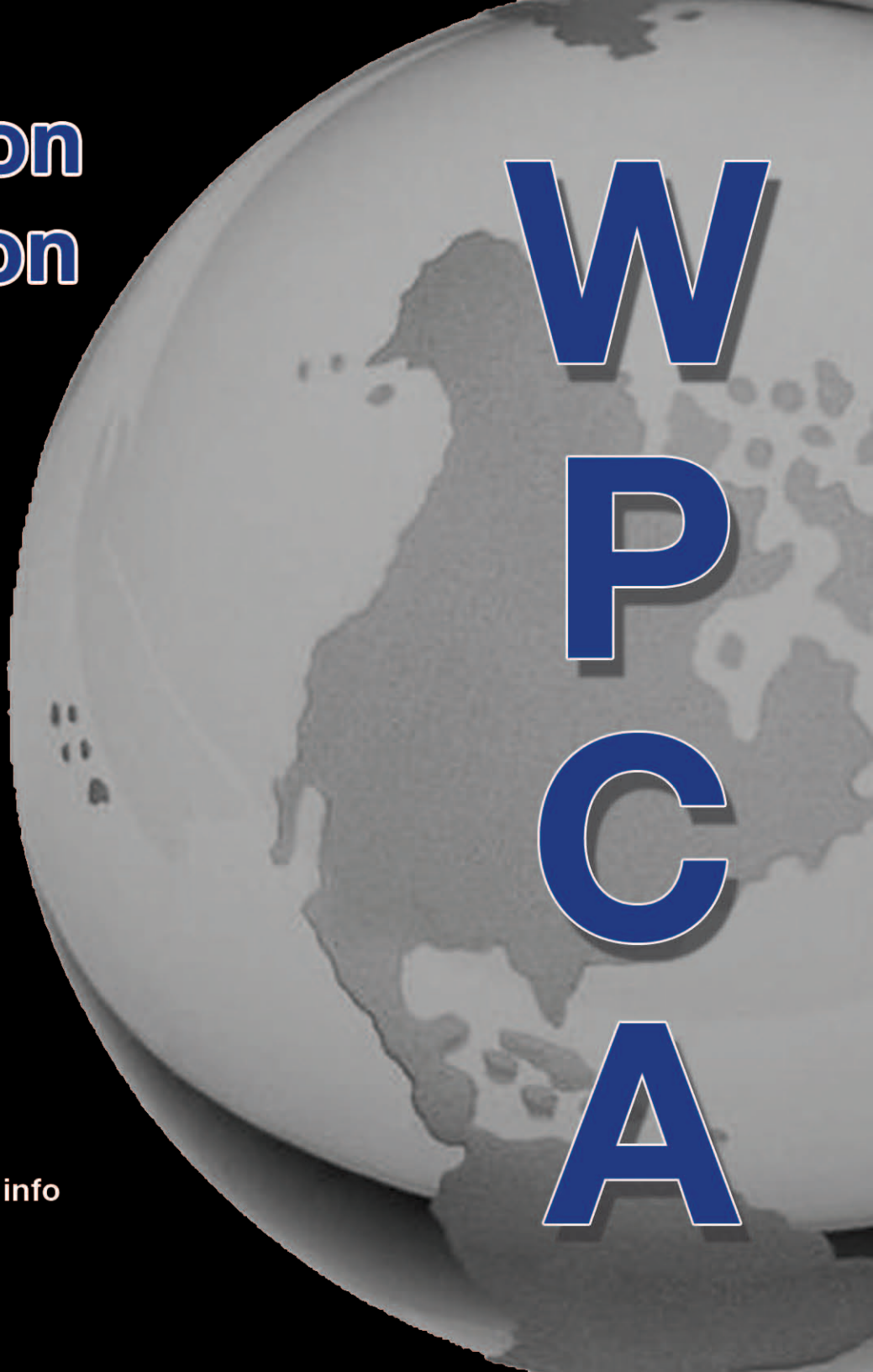
Worldwide Pollution Control Association



Particulate Control O&M Training

APC/PCUG Conference
July 12-16, 2009
The Woodlands, TX

WPCA

Visit our website at www.wpca.info

ESP O&M: Flow Related Issues

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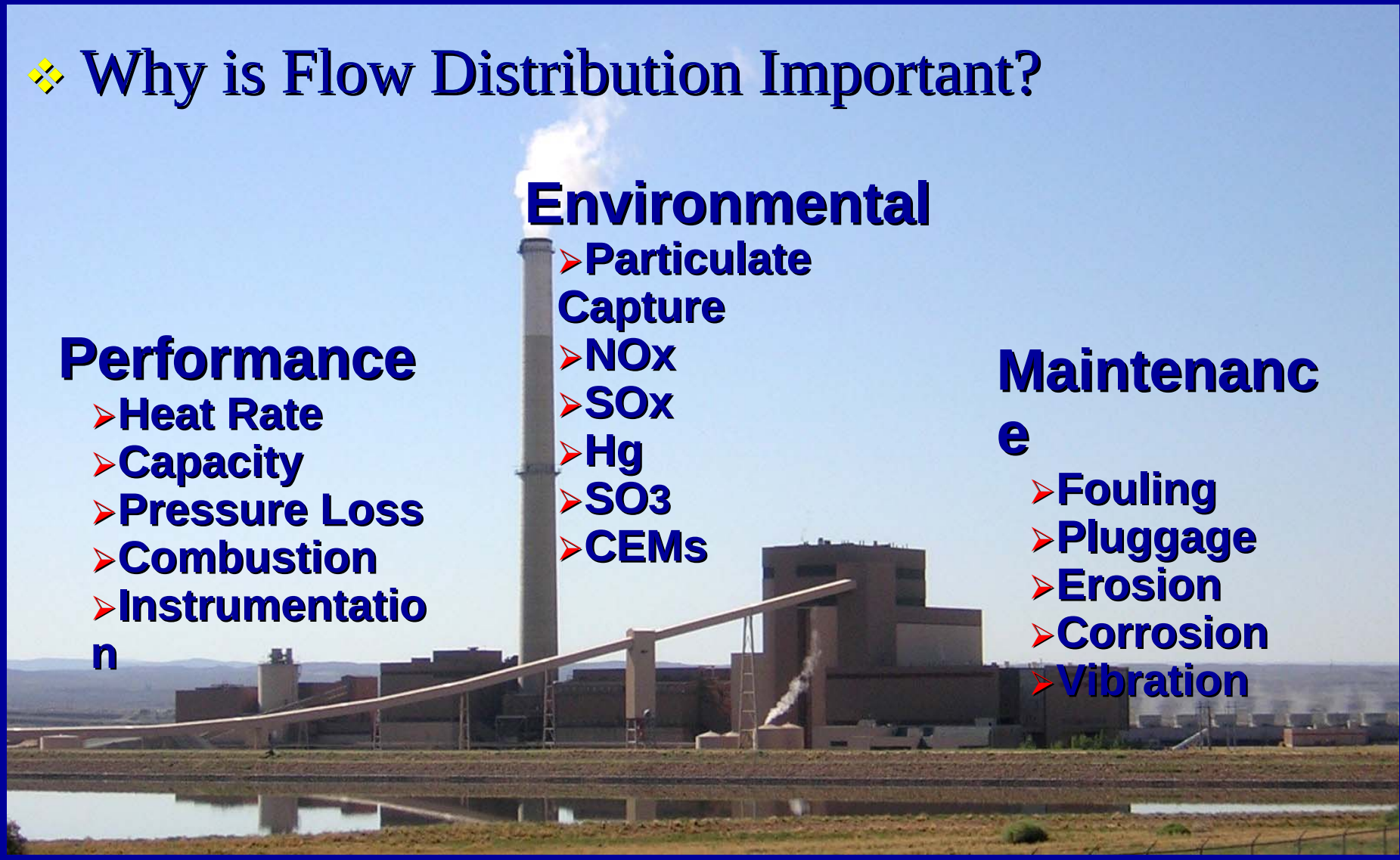
WPCA Training Seminar
July 12, 2009

Outline

- Introduction
- ESP Fluid Flow Basics
- Assessing Flow Characteristics
- ESP Flow Modeling
- Other Power Industry Flows
- Questions

Introduction

- Why is Flow Distribution Important?



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

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

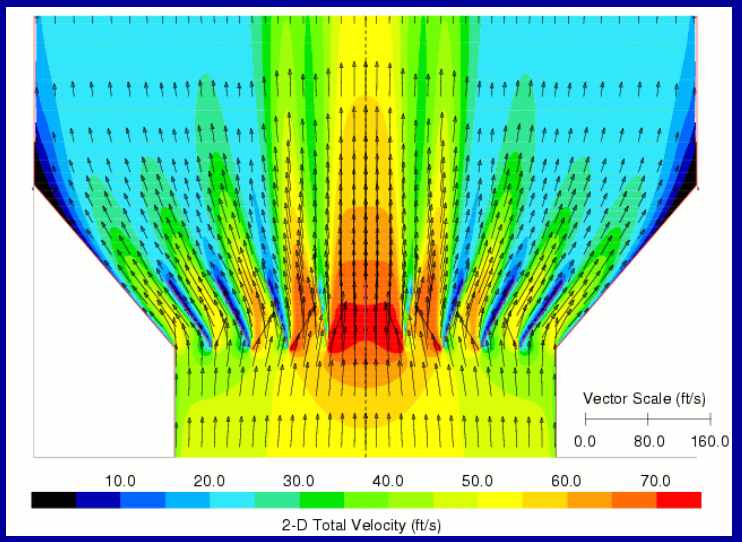
Maintenance
- Fouling
- Pluggage
- Erosion
- Corrosion
- Vibration

Outline

- Introduction
- ESP Fluid Flow Basics
  - Gas Velocity Distribution
    - Ductwork
    - Collection Region
  - Gas Flow Balance
  - Pressure Drop
  - Gas Temperature
  - Injection Systems
- Assessing Flow Characteristics
- ESP Flow Modeling
- Other Power Industry Flows
- Questions

Gas Velocity Distribution – Ductwork

- Ductwork Design Criteria
  - Maintain minimum velocity requirements to avoid particle dropout
  - Provide good flow characteristics to ESP
- Considerations
  - Horizontal surfaces
  - Cross sectional area
  - Bends
  - Structure

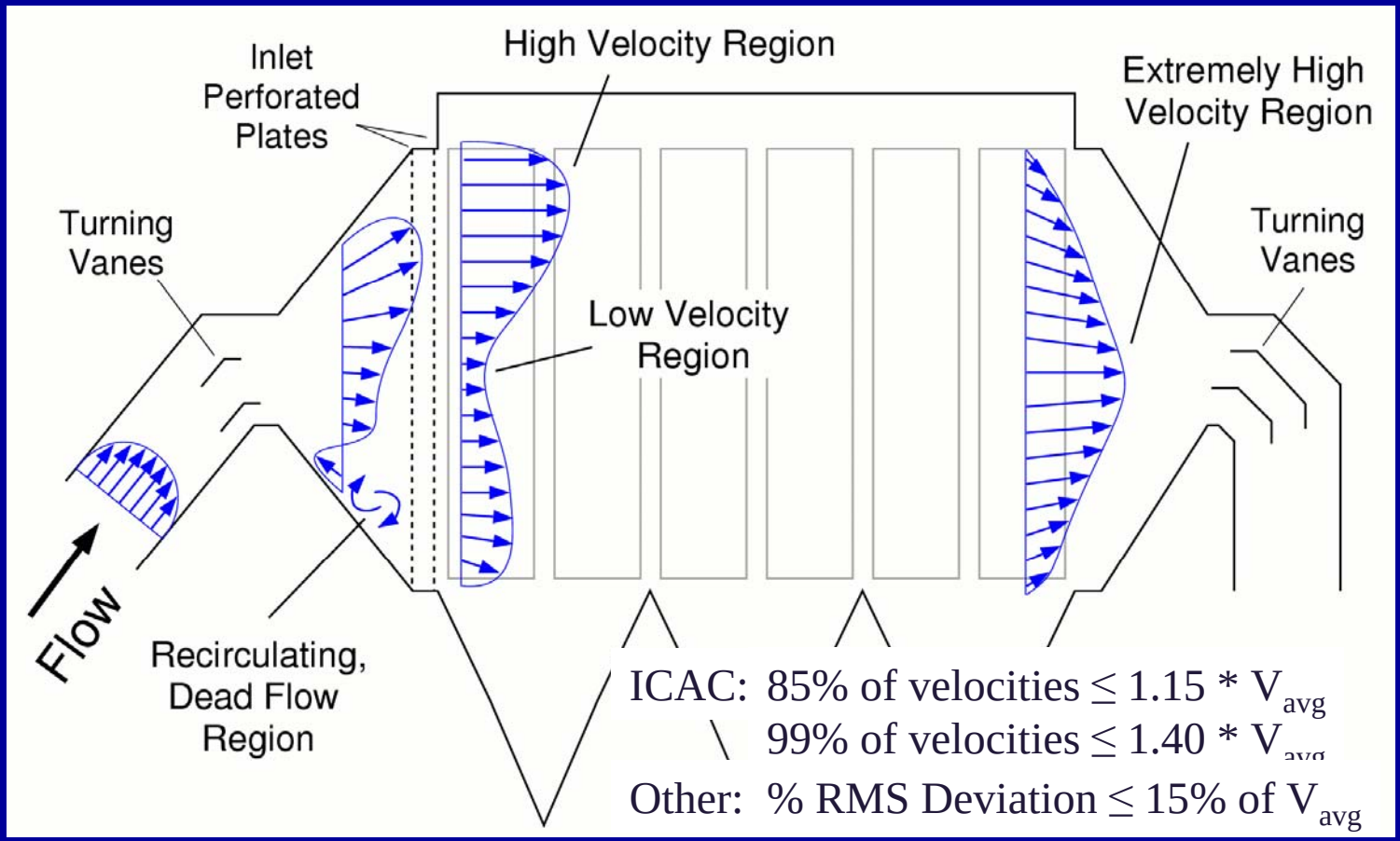


Ash Deposition

- Duct floors
- Turning vanes

Gas Velocity Distribution – ESP

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



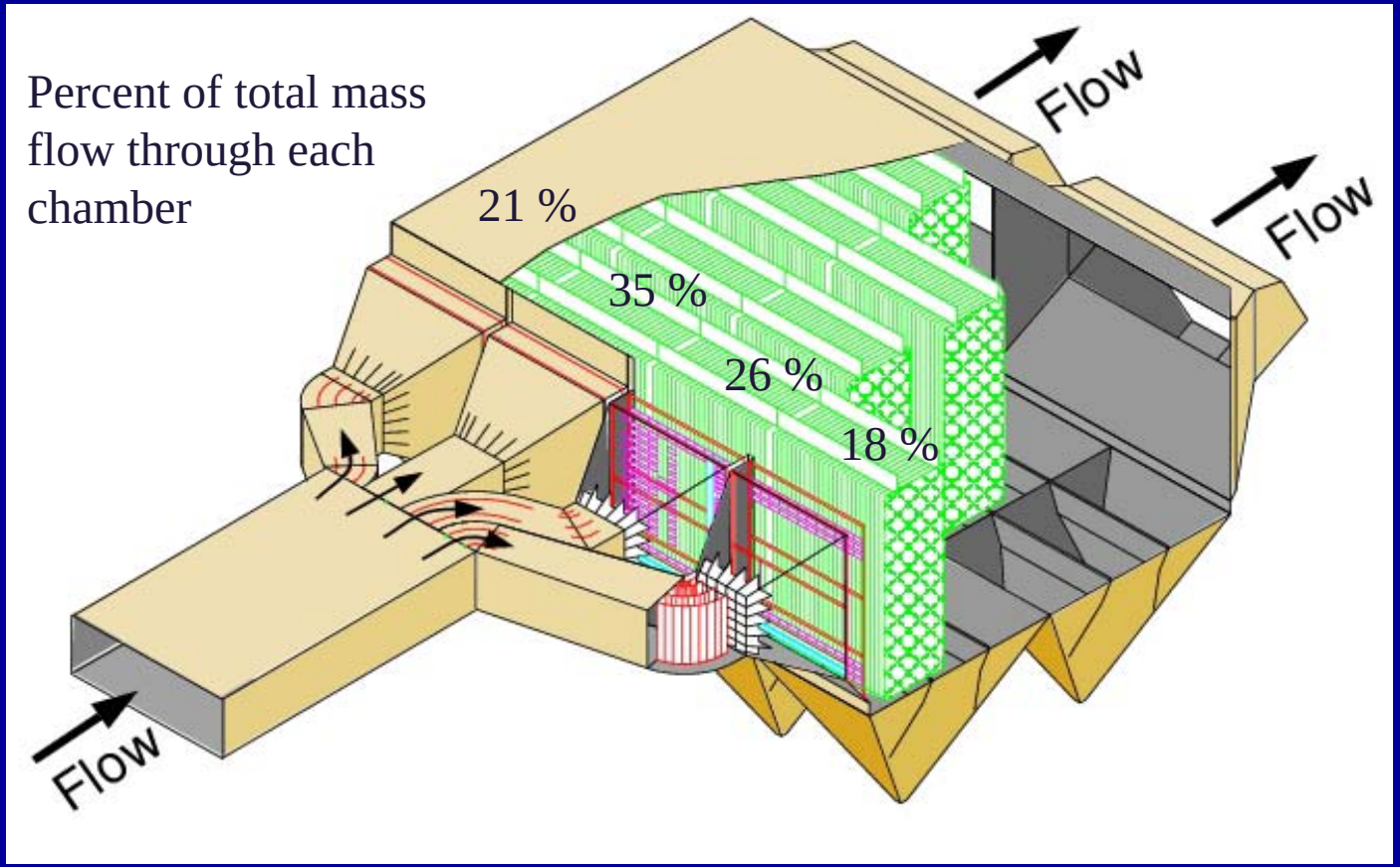
Gas Velocity Distribution – Collection Region

- Flow Control Methods
  - Vanes, baffles
  - Flow straighteners
  - Perforated plates

Gas Flow Balance

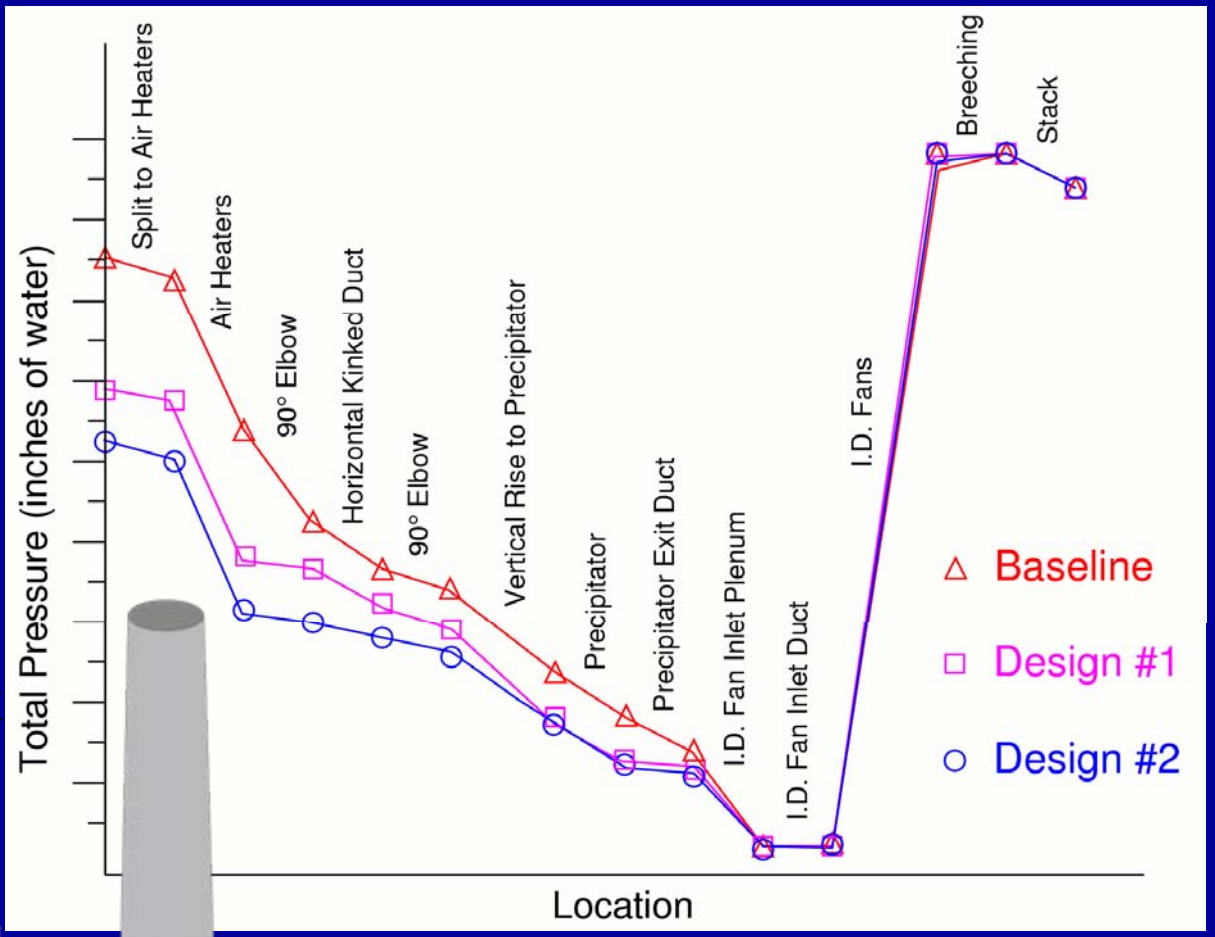
- Industry Standards
- Control Methods

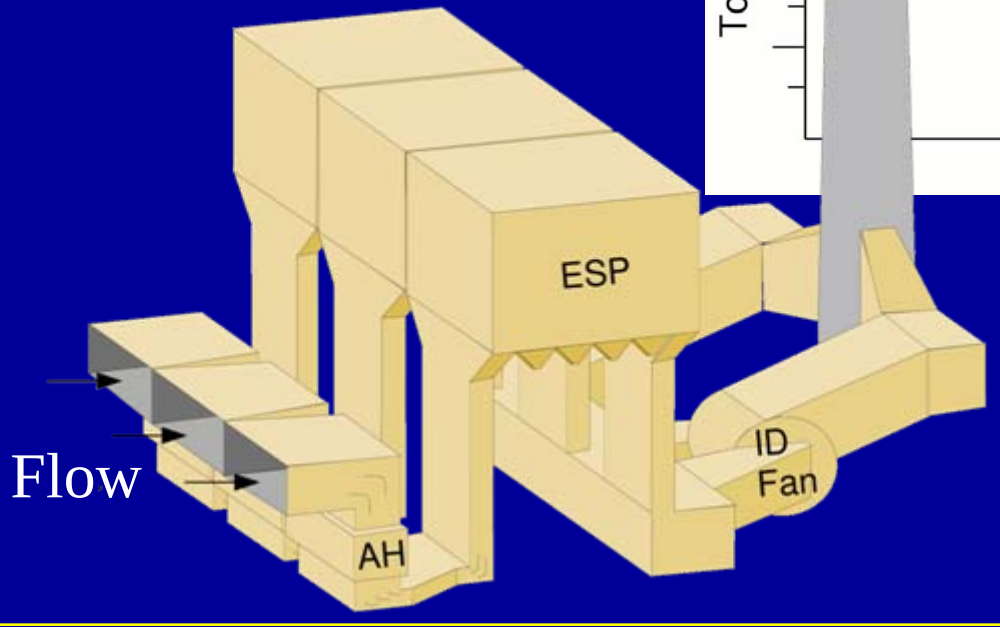
ICAC: Flow within each chamber to be within ±10% of its theoretical share



Pressure Drop

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

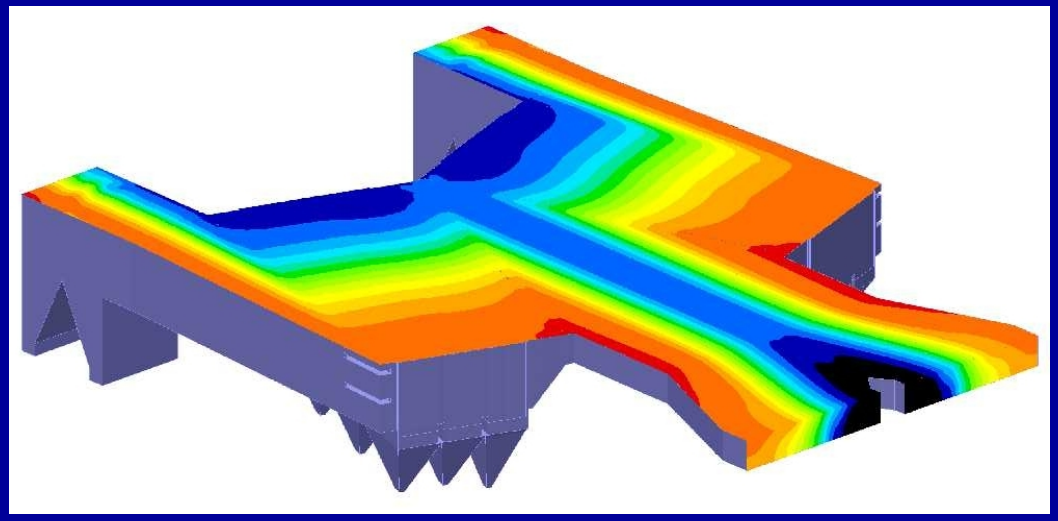


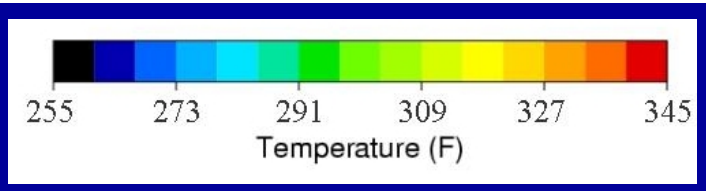


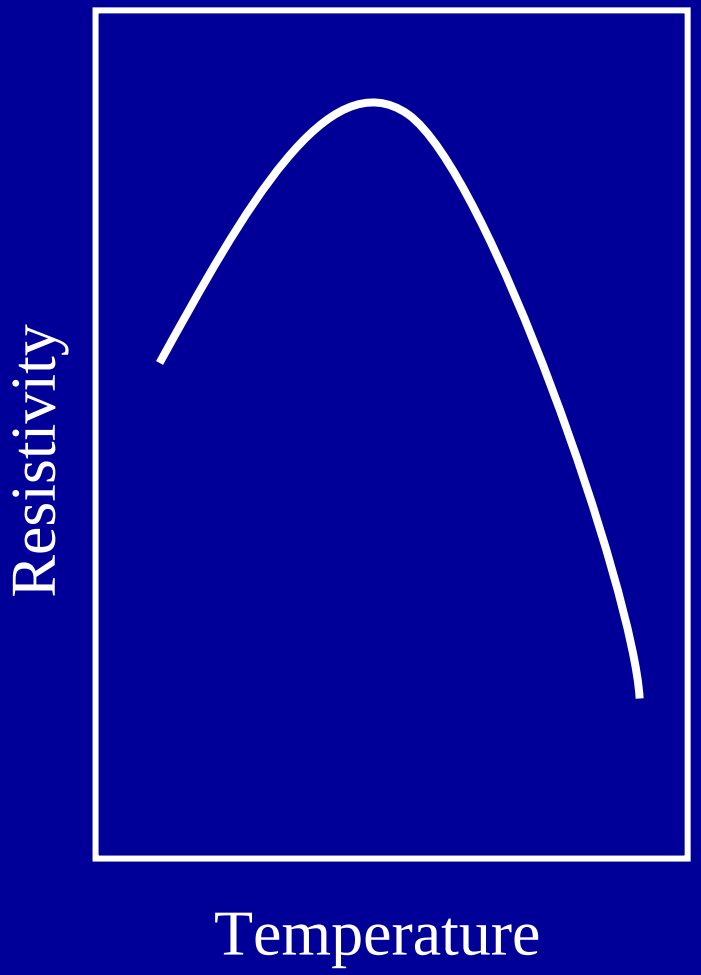
Ductwork redesign saves
2.1 inches H_2O over baseline

Gas Temperature

- Average temperature
- Temperature stratification
- Inleakage

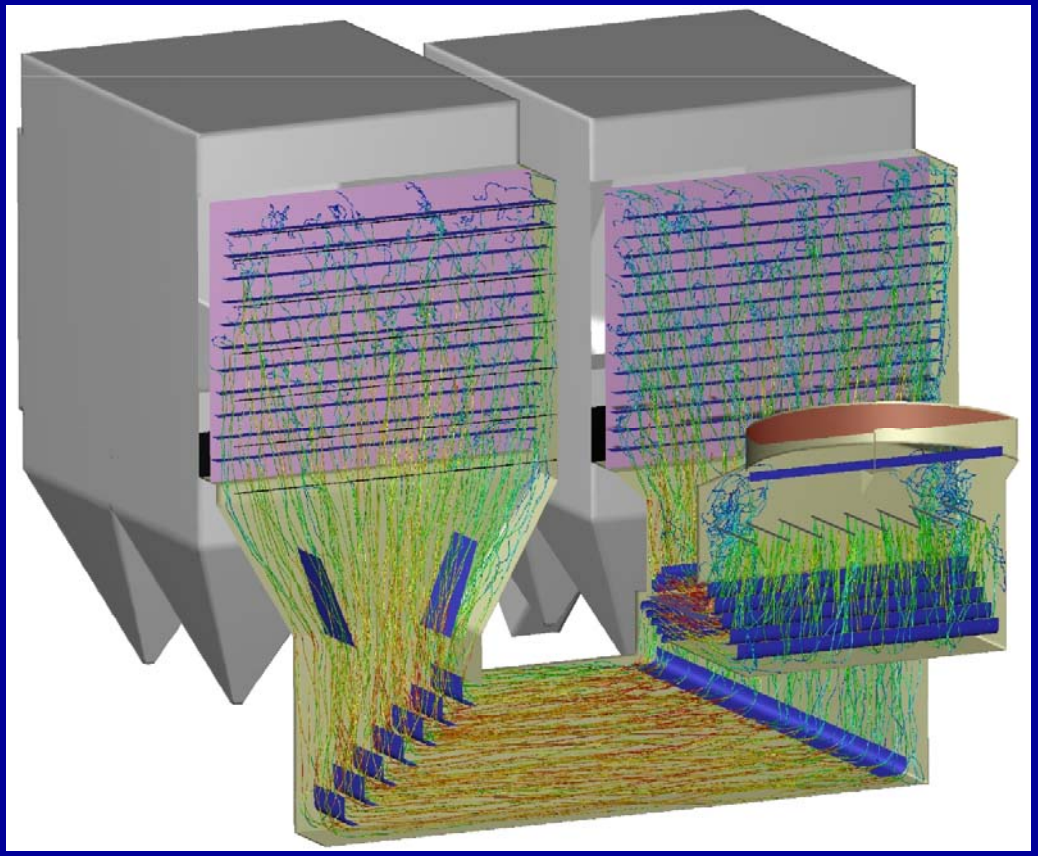


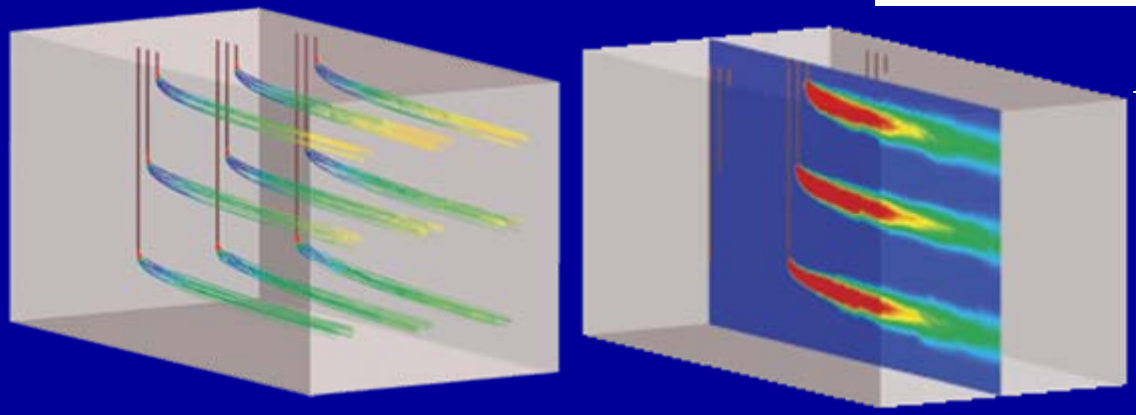




Injection Systems

- Gaseous injection
  - SO_3, NH_3, others
- Particulate injection
  - Activated carbon
  - Trona, SBS, lime, etc.

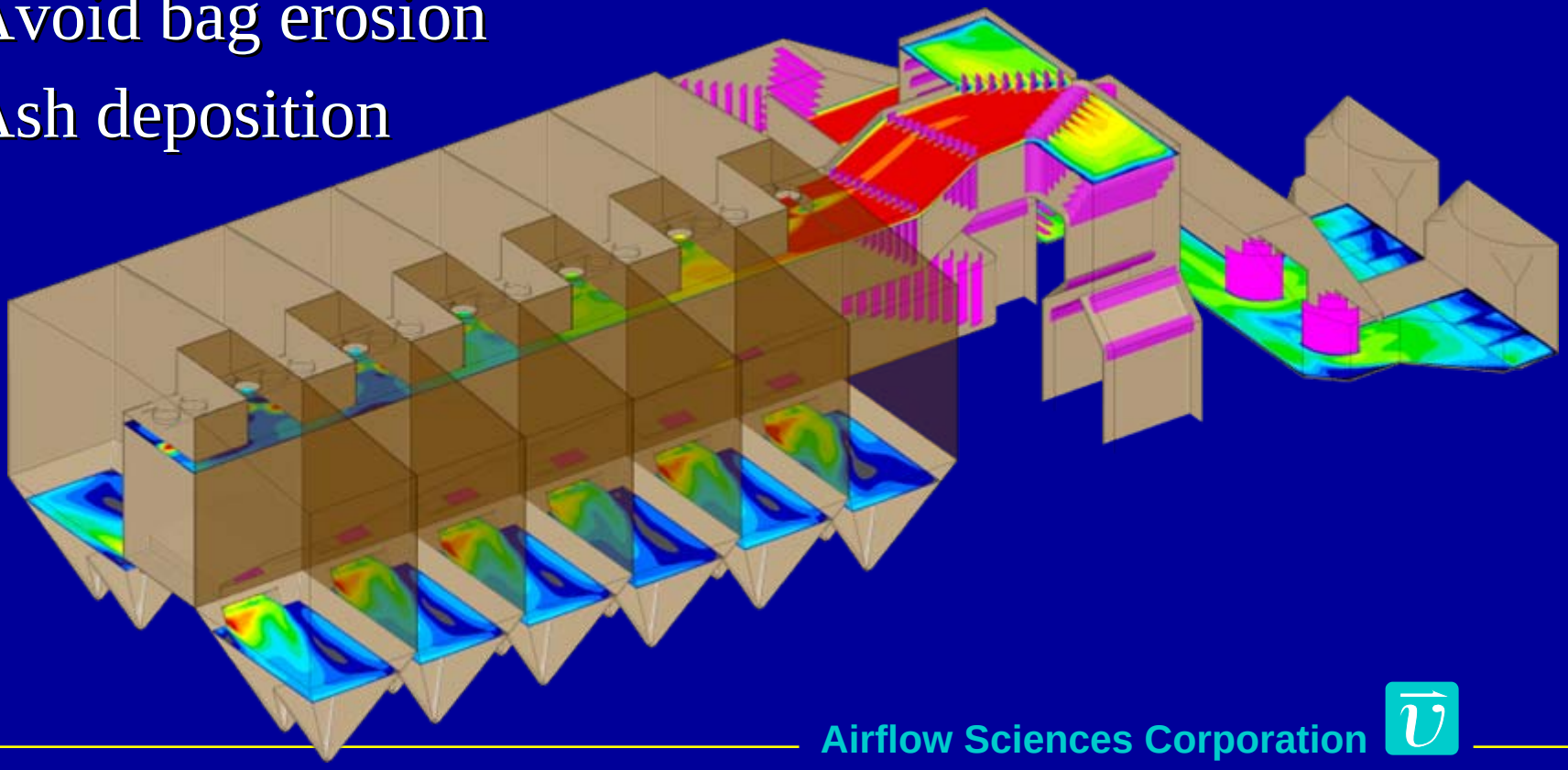




Activated Carbon Injection – Particle Tracking

Fabric Filters

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

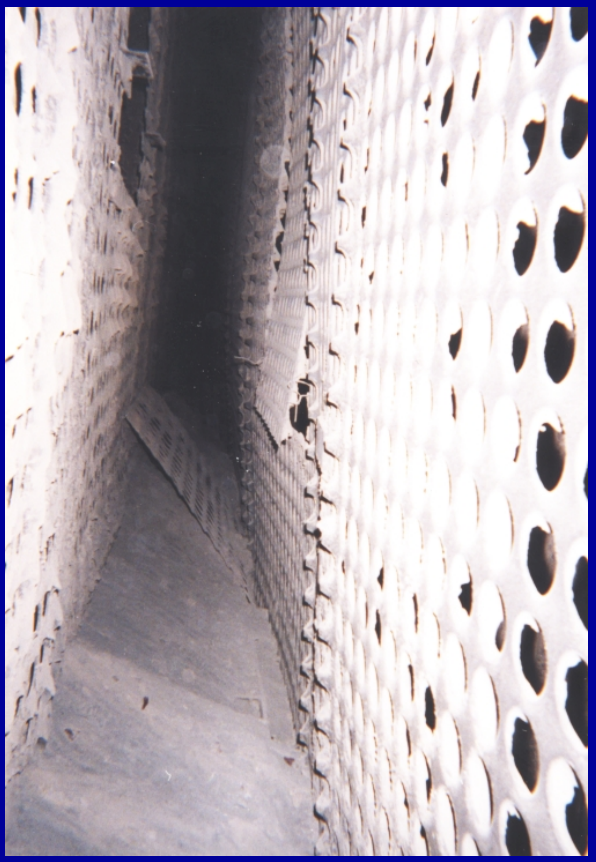


Outline

- Introduction
- ESP Fluid Flow Basics
- Assessing Flow Characteristics
  - Inspections
  - Field Testing
    - Ductwork
    - Collection Region
- ESP Flow Modeling
- Other Power Industry Flows
- Questions

Inspections

- Ash Patterns
- Geometry Influence on Fluid Dynamics
- Irregularities

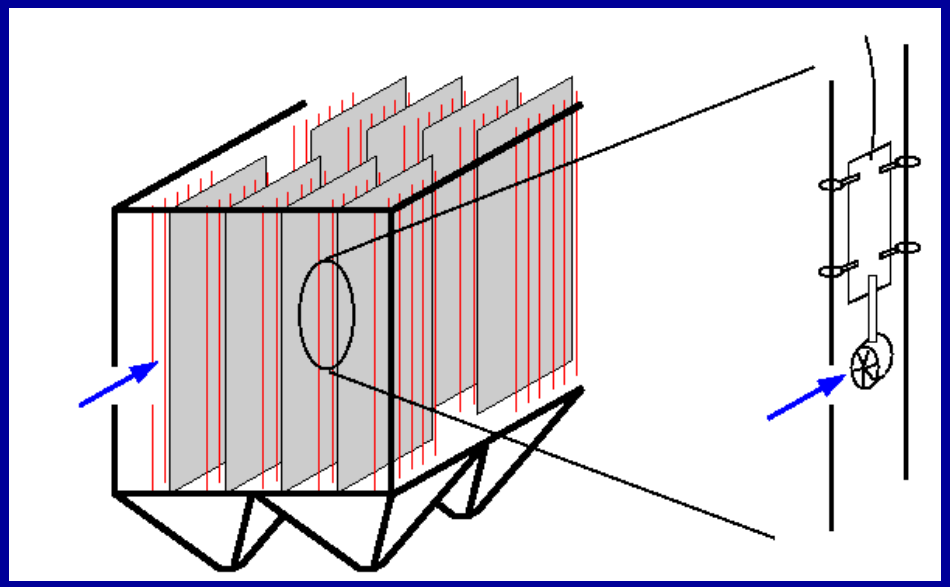


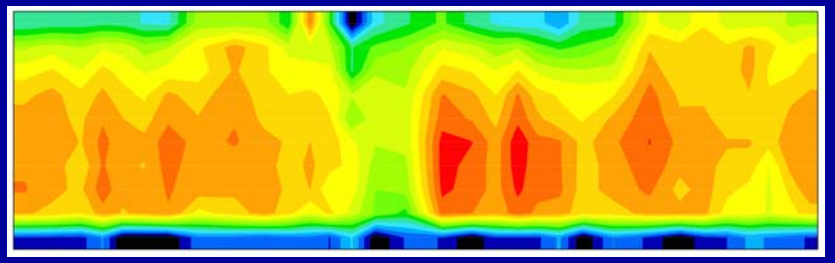
Field Testing – Ductwork

- Velocity
- Temperature
- Pressure
- Particulate
- Chemical Species

Field Testing – Collection Region

- Velocity Distribution
  - Cold flow conditions
  - Vane anemometer
    - Accuracy 1% in 3-10 ft/sec range
    - Lightweight, portable
    - Sensitive to flow angularity, turbulence, dust





Outline

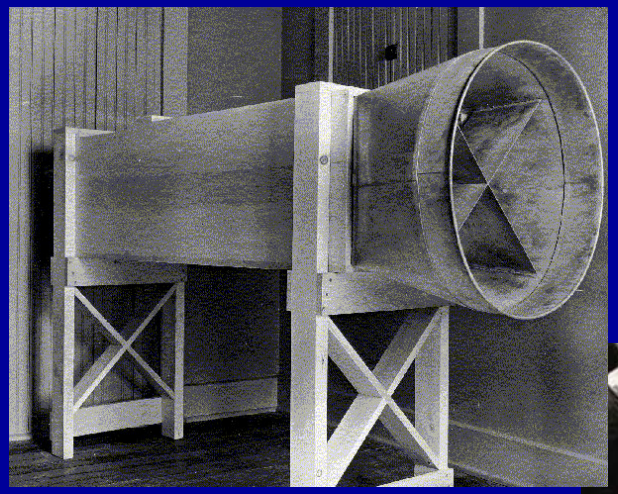
- Introduction
- ESP Fluid Flow Basics
- Assessing Flow Characteristics
- ESP Flow Modeling
  - Physical Models
  - Computational Fluid Dynamics (CFD) Models
- Other Power Industry Flows
- Questions

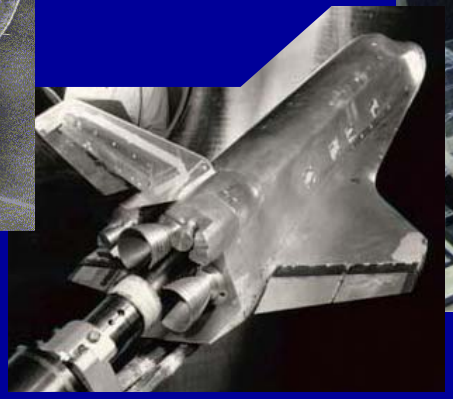
ESP Modeling – Physical Models

- Background
- Theory
- Simulation Parameters (how the model is set up)
- Results Analysis (what you get from the model)

Physical Models – Background

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





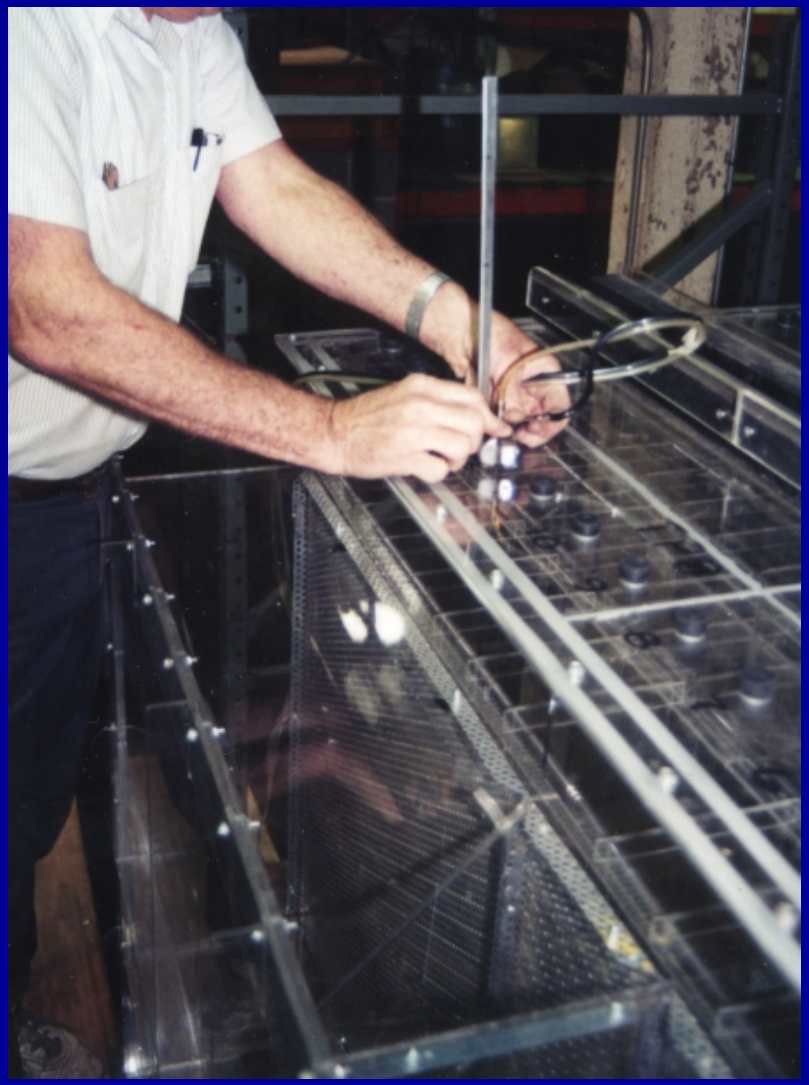
Physical Models – Theory

- Key criteria 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 (typically those >4”)
    - 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 range throughout the model

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

Physical Models – Simulation Parameters

- ESP geometry
  - 1/8th to 1/16th scale representation
  - Include features >4-6” in size
- Flow conditions
  - Scaled air flow rate (ambient temperature)
  - Reproduce velocity profile at model inlet
  - Simulated chemical injection
  - Simulated particle tracking



Physical Models – Results Analysis

- Quantitative data available at discrete measurement points
  - Velocity magnitude, directionality
  - Pressure (corrected to full scale)
  - Chemical species concentrations
- Integrated/reduced data
  - Mass balance between ESP chambers
  - Comparison to ICAC conditions or target velocity profiles
  - Correlation to test data
- Qualitative data
  - Flow directionality (smoke, tufts)
  - Particle behavior, drop-out

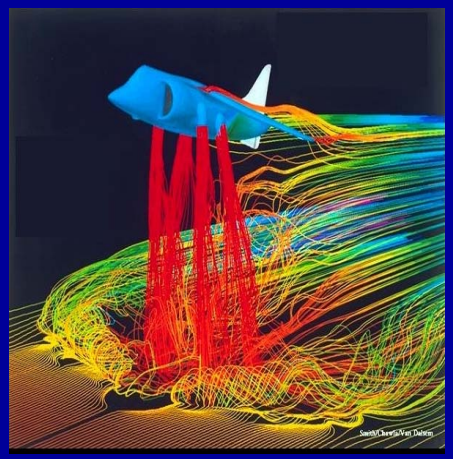
Physical Models – Flow Visualization

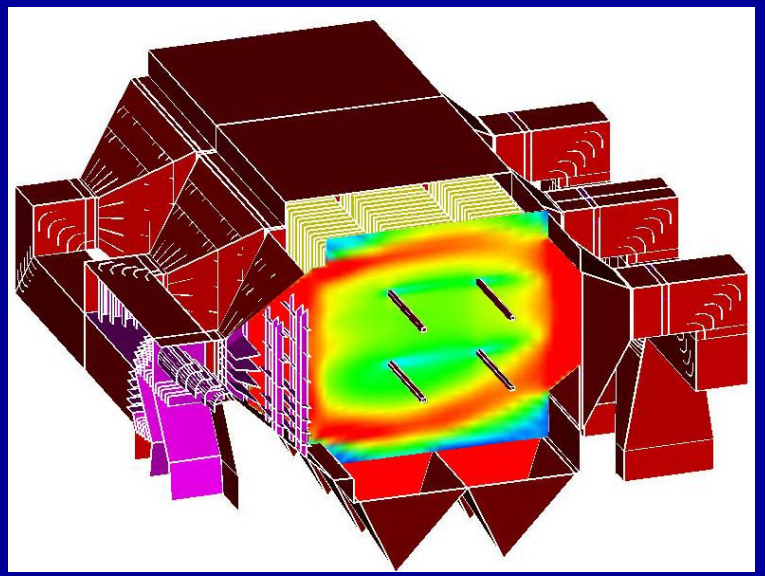
Flow Modeling – Computational Fluid Dynamics (CFD)

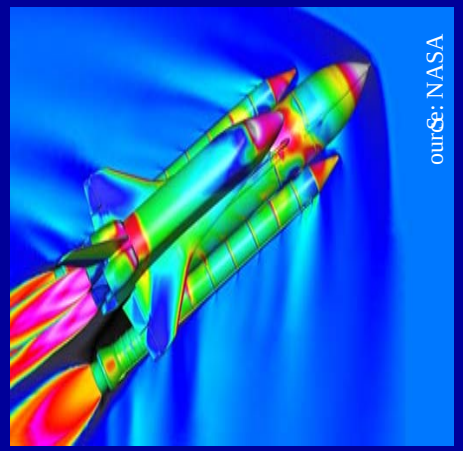
- Background
- Theory
- Simulation Parameters (how the model is set up)
- Results Analysis (what you get from the model)

CFD – Background

- Developed in the aerospace industry c.1970 (with the advent of “high speed” computers)
- Applied to ESPs for 18+ years
- Underlying principle is to solve the first-principles equations governing fluid flow behavior using a computer

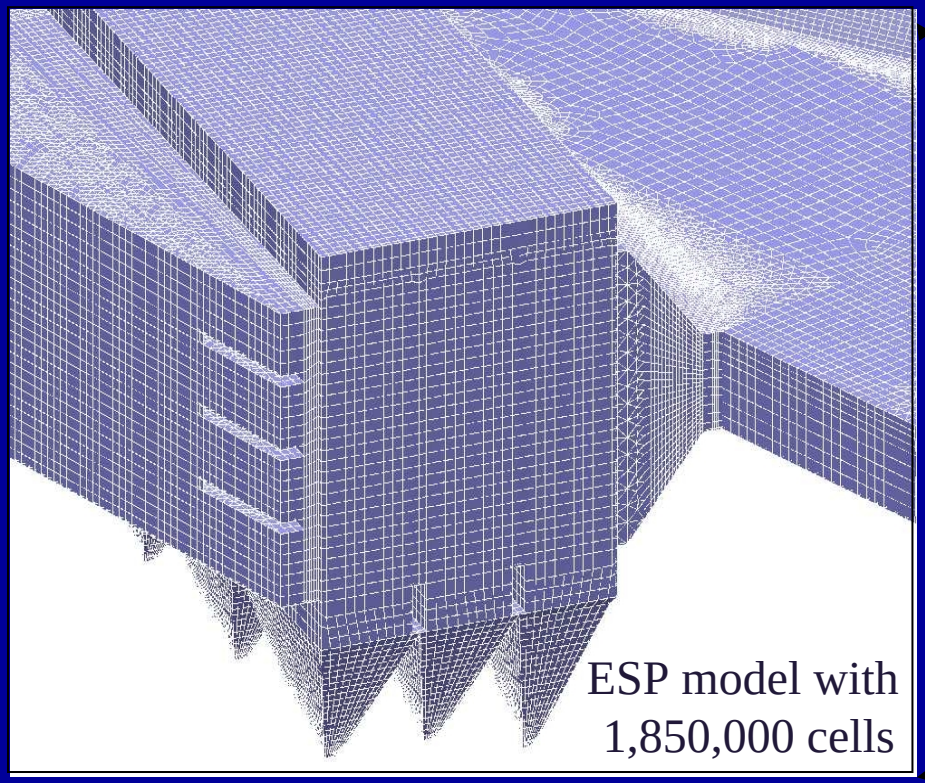


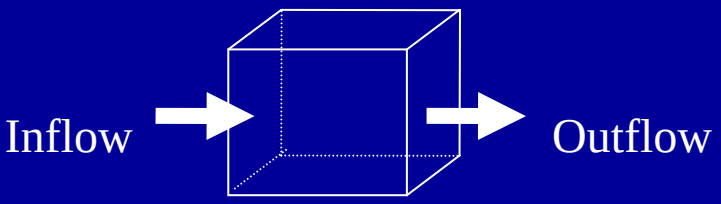




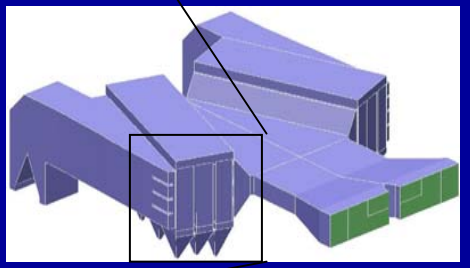
CFD – Theory

- 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



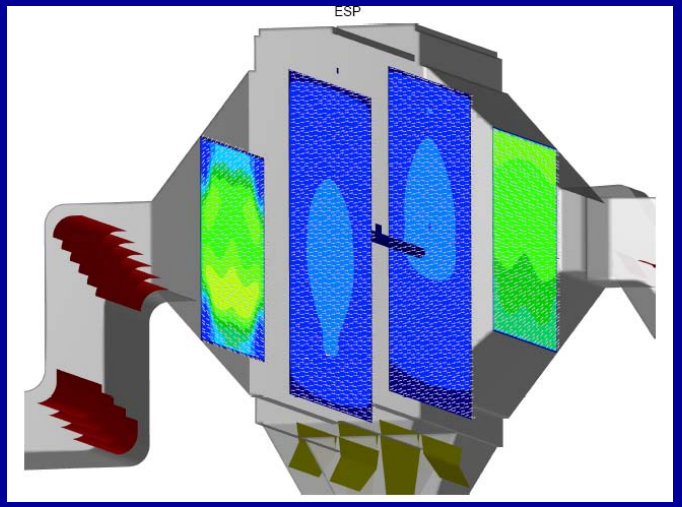


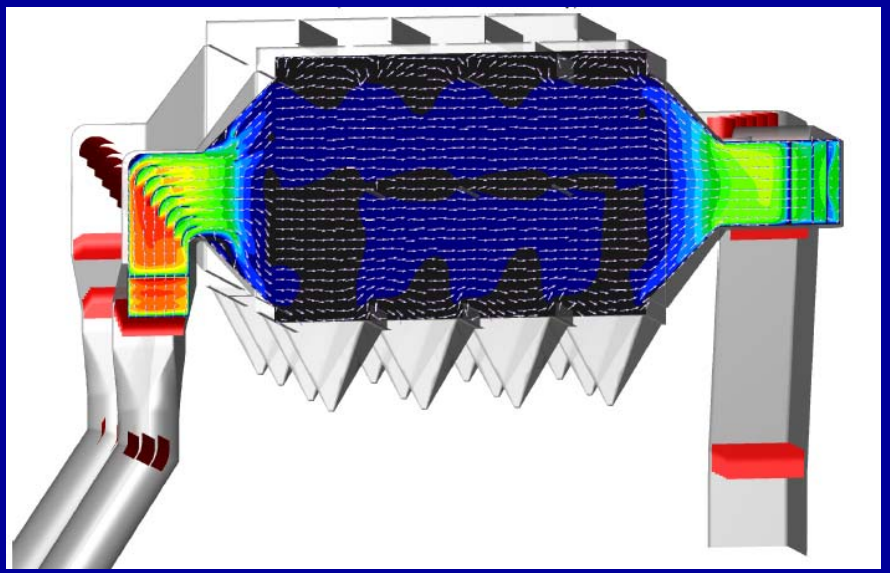
Control Volume
or “Cell”



CFD – Simulation Parameters

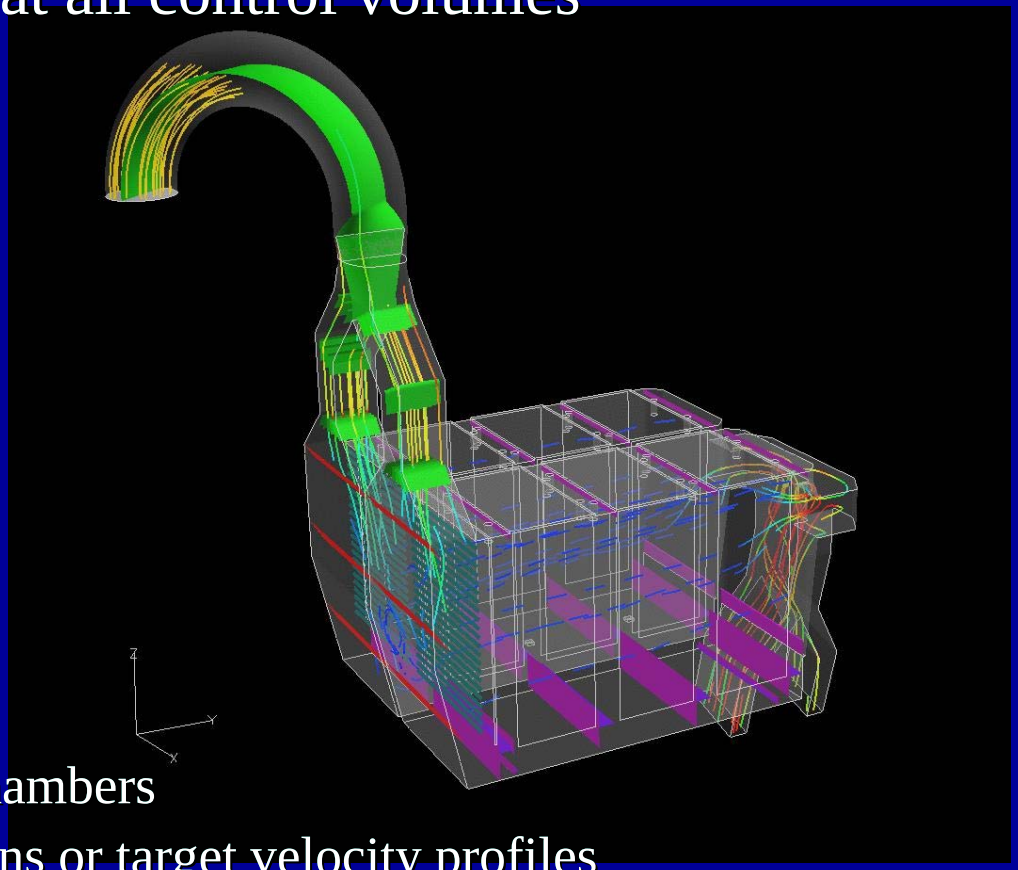
- ESP geometry
  - Full scale representation
  - Include features >4” in size, more detail if possible
- Flow conditions
  - Full scale gas flow rate
  - Reproduce velocity profile at model inlet
  - Reproduce temperature profile at model inlet
  - Simulated chemical injection
  - Simulated particle tracking





CFD – Results Analysis

- Quantitative data available at all control volumes
  - Velocity magnitude, directionality
  - Temperature
  - Pressure
  - Turbulence
  - Chemical species concentrations
  - Particle trajectories

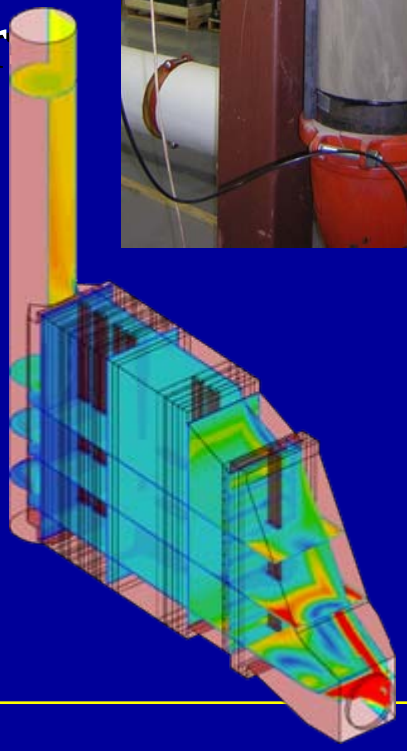


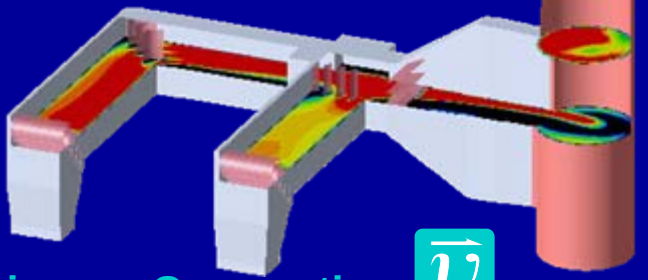
- Integrated/reduced data
  - Mass balance between ESP chambers
  - Comparison to ICAC conditions or target velocity profiles
  - Correlation to test data

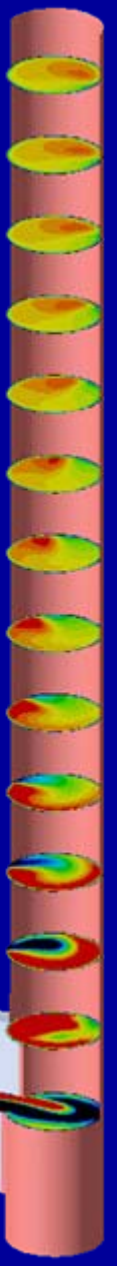
CFD – Flow Animations

Other Power Industry Flows

- Fans / Ducts
- Pulverizers
- Windboxes
- Furnaces
- Air Heater
- SCRs
- LPA
- FGD
- Stacks
- …







Questions?

If you would like an electronic copy of this presentation, please contact Rob Mudry as follows:

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