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

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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?

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

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

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

ESP model with 3,550,000 cells
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
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• 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

![Burner SA flow balance](chart)

- Baseline: Max deviation 29.4%
- Design: Max deviation 9.2%
Furnace Combustion Optimization

- Typical goals
  - Reduce NOx
  - 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
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  - FF
  - Mercury / SO3
  - SCR
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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

Percent of total mass flow through each chamber
Pressure Drop

- General goal:
  - Minimize DP

- Methods
  - Vanes
  - Duct contouring
  - Area management

Ductwork redesign saves 2.1 inches $H_2O$ over baseline
ESP Temperature Stratification
ESP Temperature Stratification

Air Heater Outlet

Flow

Mixing Device

Temperature
ESP Gas Conditioning

- Modify ash resistivity
  - SO$_3$, ammonia, others

- Alter gas density, viscosity
  - 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
- 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, $\Delta T = \pm 83^\circ F$

With mixer, $\Delta T = \pm 15^\circ F$
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 a cell, 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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Power Industry

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

- Spacecraft
- Aircraft
- Missiles
- Engines

Source: NASA
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?

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