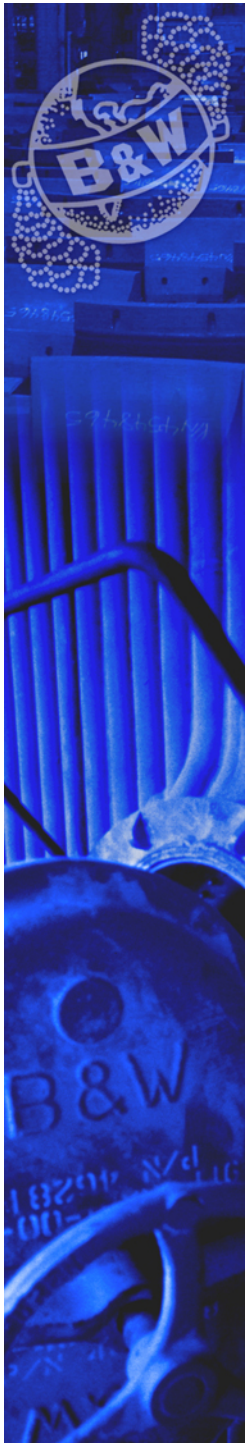


CFD and Combustion Modeling – Powerful Tools for Boiler Design

Babcock & Wilcox
a McDermott company

Rick Wessel, Alan Sayre, Kris Jorgensen

Computational Analysis Group

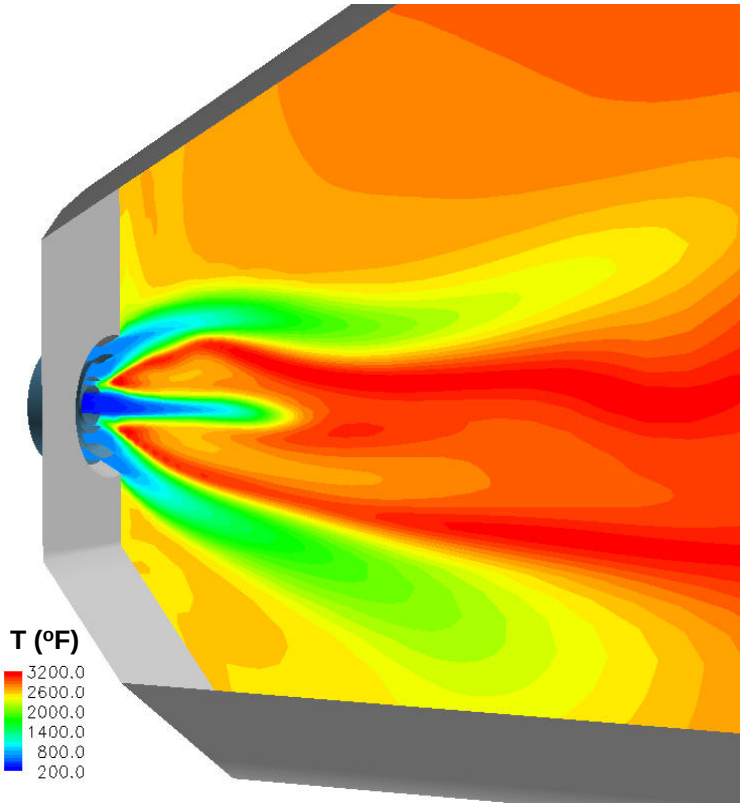
February 13, 2004

Overview

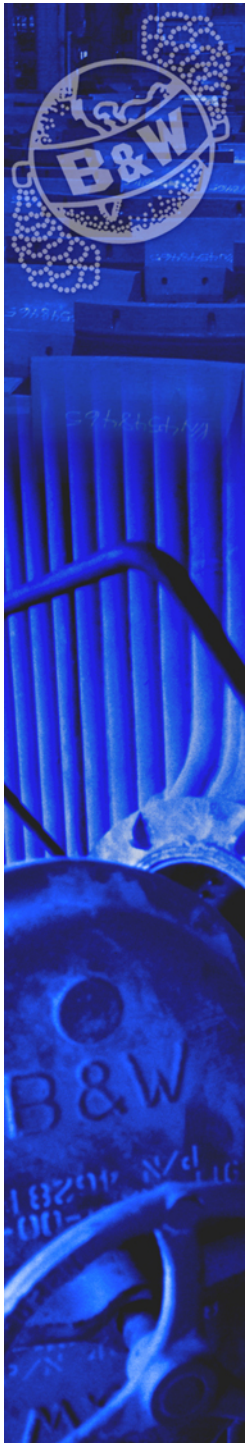
- Background
- Modeling Process
- Boiler Design Applications
- Summary

Why B&W Uses Modeling

- Predict performance of non-traditional combustion systems, outside of the envelope of B&W test data
- Understand interaction between complex physical processes
- Reduce design cycle time and cost for screening new concepts and optimizing designs prior to testing
- Add value and understanding to experimental results



Gas Temperature
Combustion & Emissions Development Facility
Alliance, OH



B&W's Combustion Model, COMO℠

- Proprietary CFD and combustion code
- Engineering group dedicated to model development and applications for B&W products in Barberton, Ohio, USA
- B&W history of CFD model development since 1975
- Maintained and improved on a continuous basis
- Scope of technology:

Processes

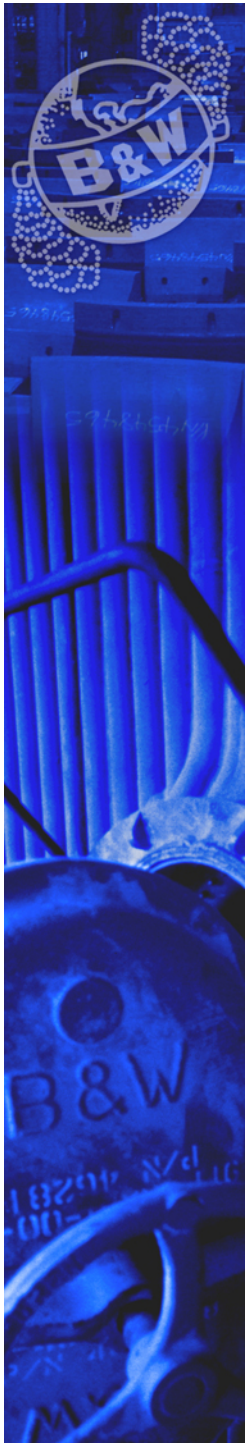
- Flow
- Heat transfer
- Combustion
- Pollutants
- Deposition
- Erosion

Fuels

- Coal
- Oil
- Gas
- Wood
- Refuse
- Black liquor

Products

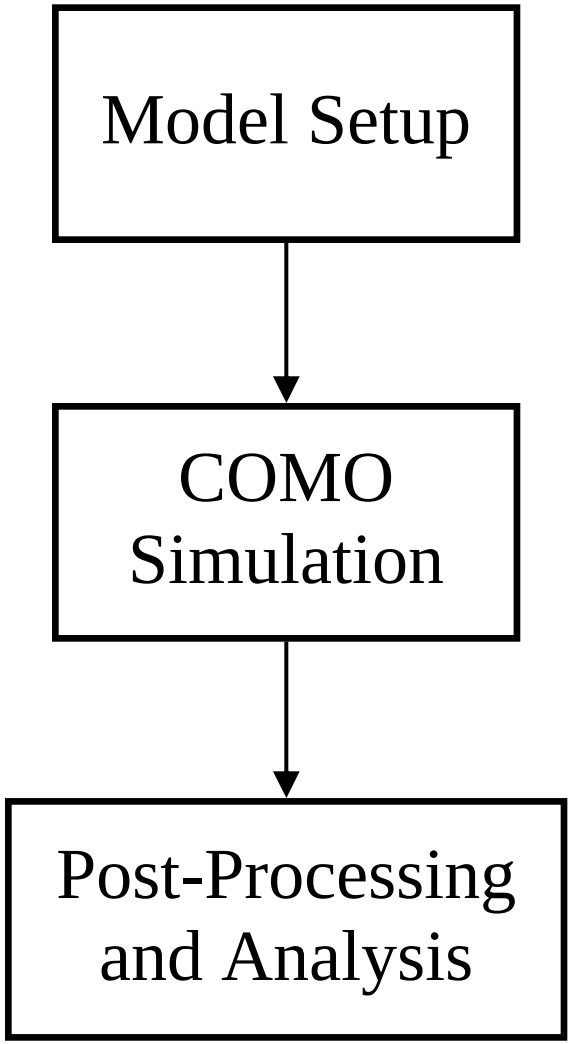
- Windboxes
- Burners
- Cyclones
- Boilers
- Gasifiers
- SCR Systems



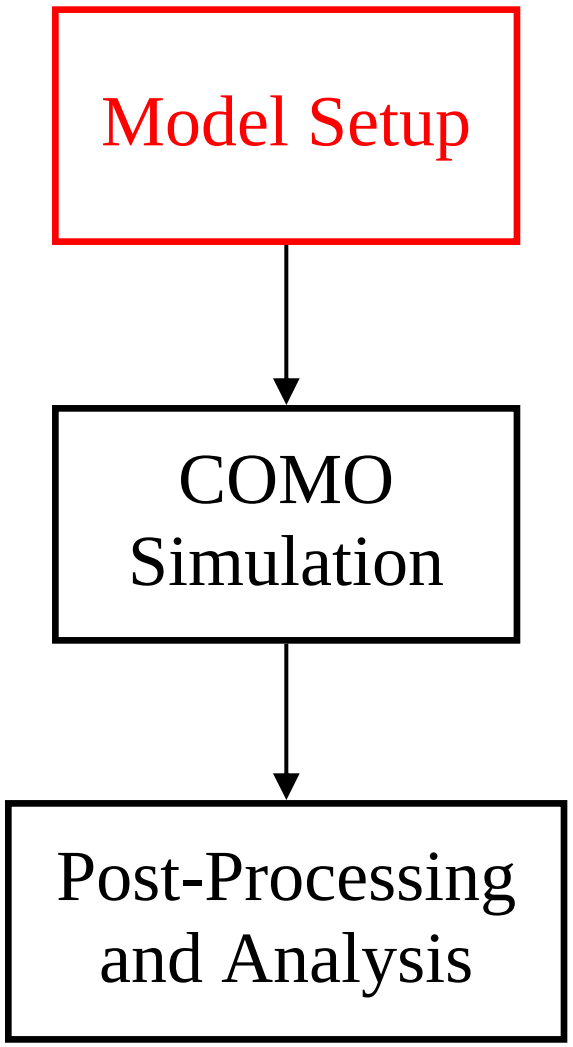
Modeling Capabilities

	windboxes	burners	cyclones	boilers	gasifiers	SCR
Unstructured Mesh	x	x	x	x	x	x
Mesh Refinement	x	x	x	x	x	x
Parallel Processing				x	x	
Turbulent Flow / Mixing	x	x	x	x	x	x
Energy & Radiation		x	x	x	x	
Heterogeneous Reactions (coal, oil, wood, black liquor)		x	x	x	x	
Particles		x	x	x	x	x
Deposit Surface Reactions			x	x	x	
Gas Phase Kinetics (volatiles, CO, NO_x, etc.)		x	x	x	x	
Tube Banks				x		

Modeling Process

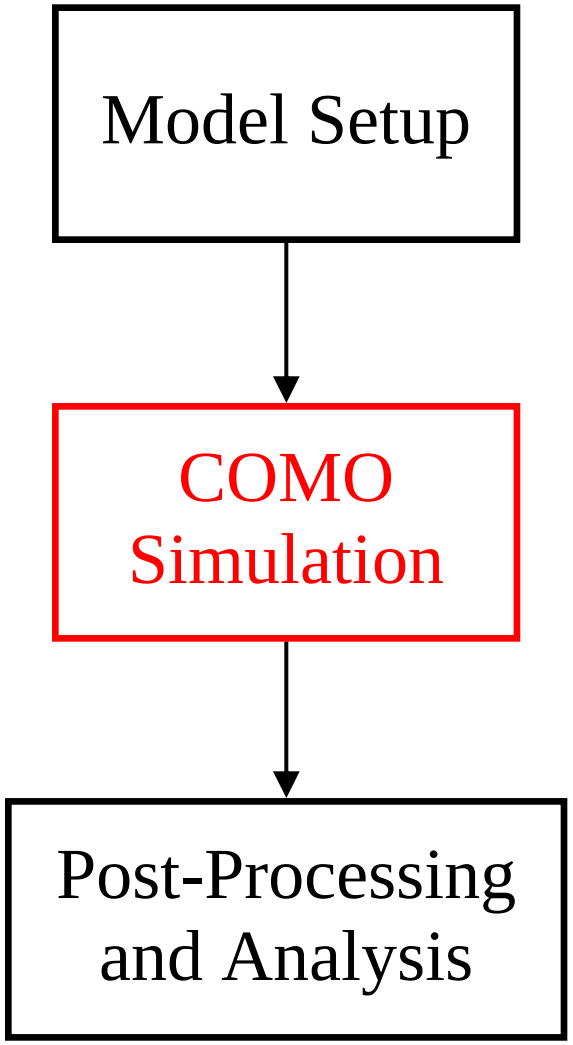


Modeling Process: Model Setup



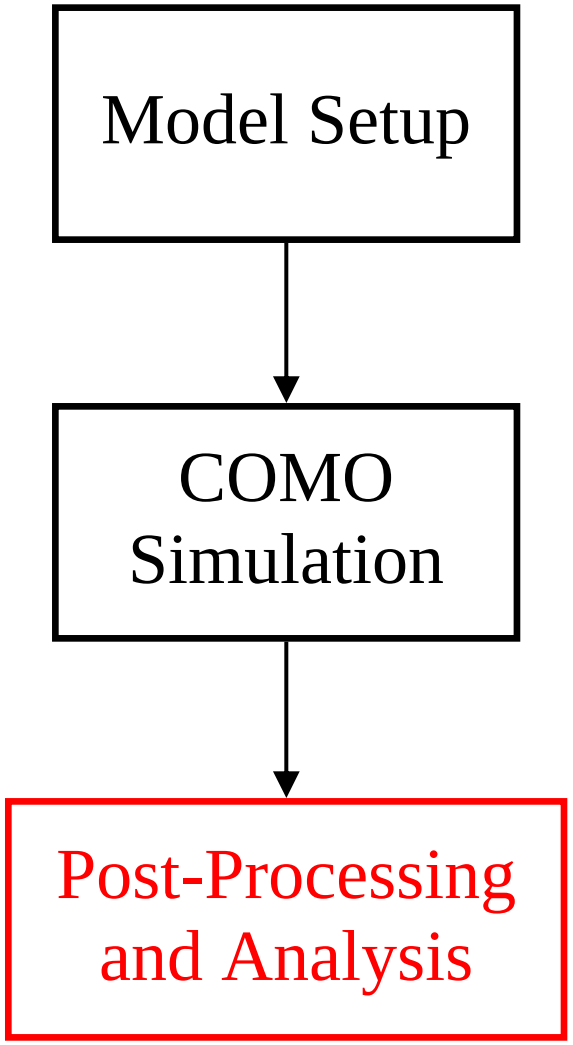
- Describe geometry, create mesh
- Apply boundary / inlet conditions
- Augment with empirical information (e.g., reaction mechanism, rate parameters, thermodynamic properties)
- Process simplified by internally-developed pre-processors (e.g., boundary mapping)

Modeling Process: COMO



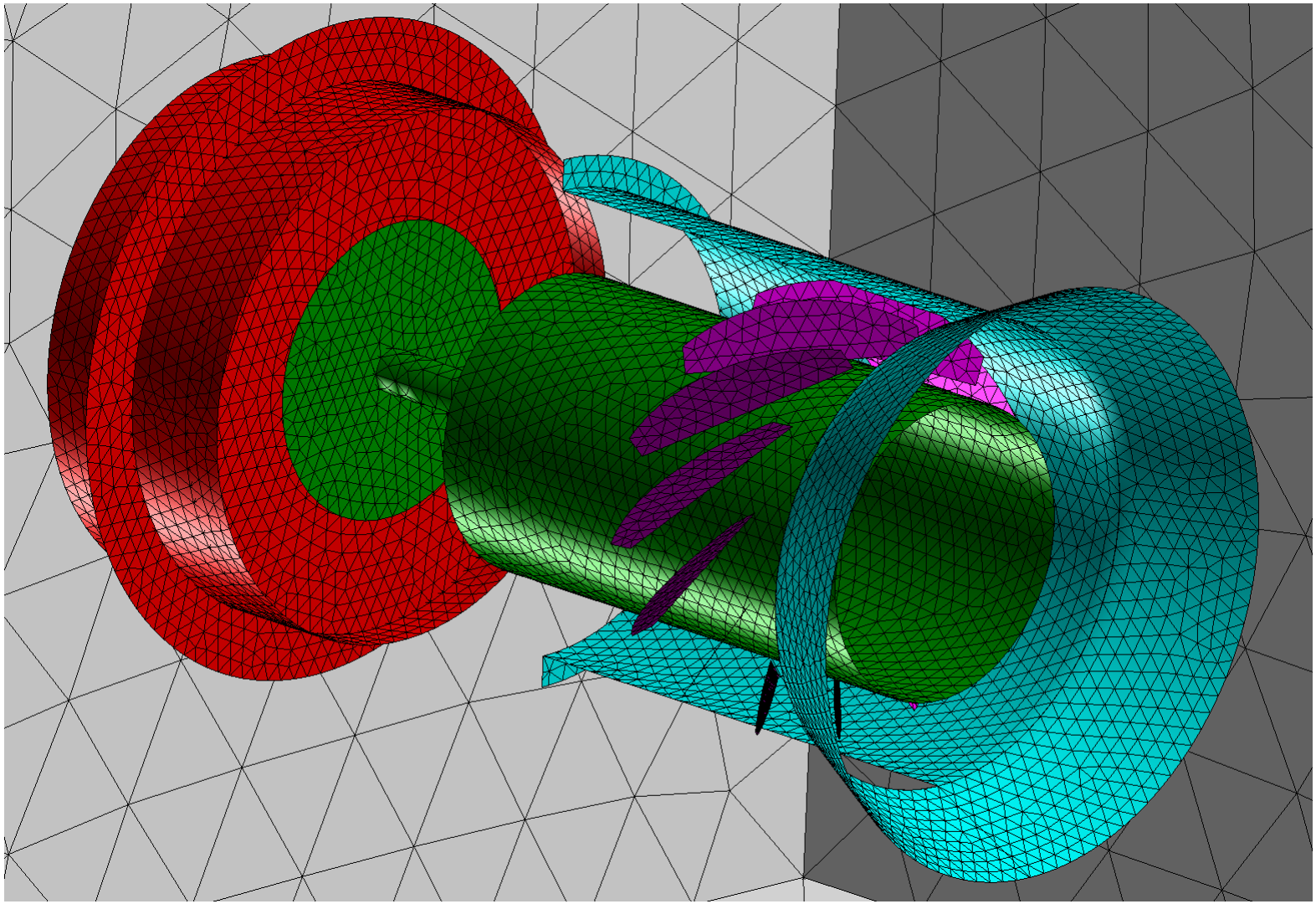
- Multiple node Linux cluster
- Monitor equation residuals and solution convergence
- Refine mesh (grid embedding and mesh adaption)
- Typical run times: 3-5 days

Modeling Process: Analysis

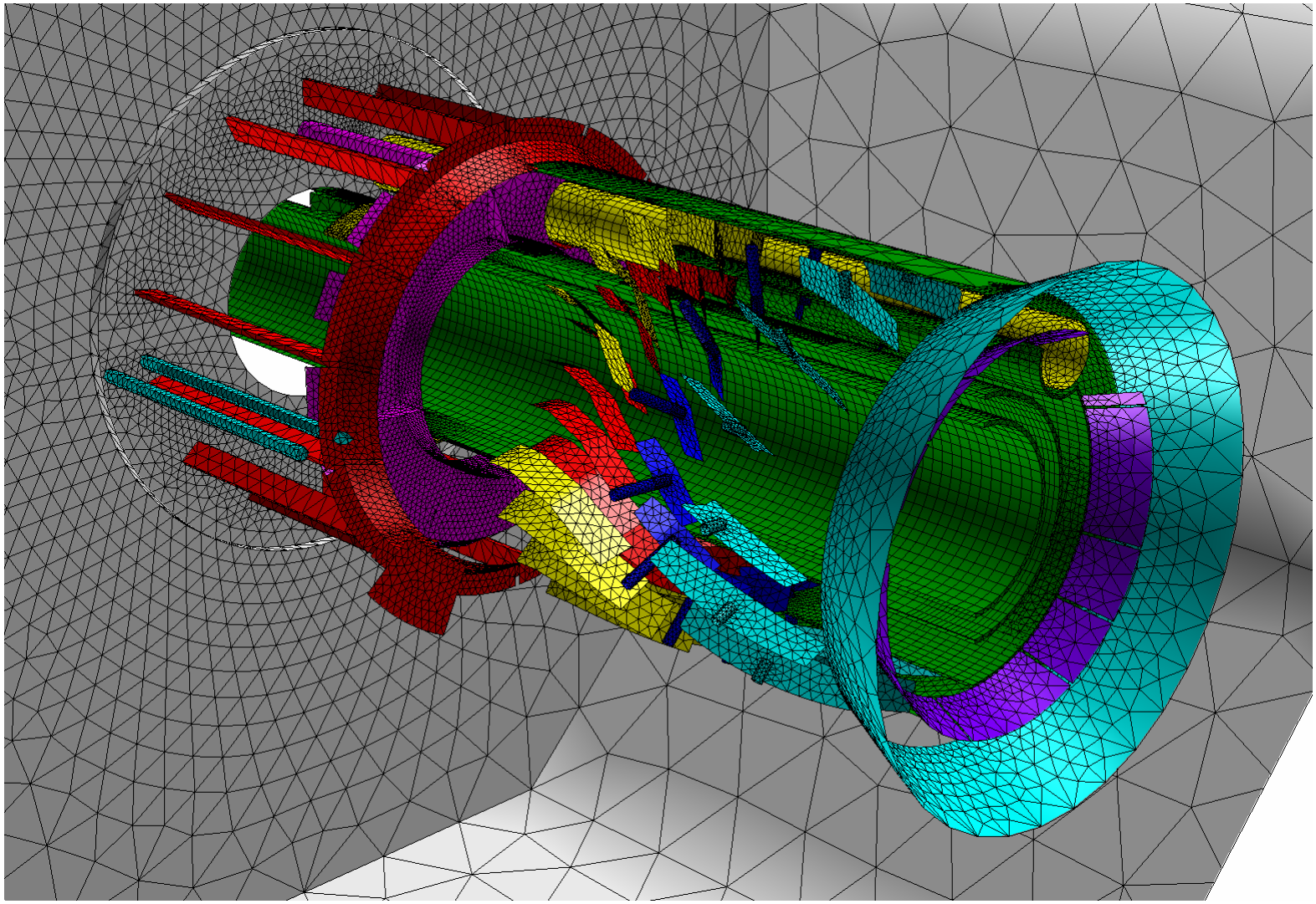


- Integrated quantities evaluated
  - Gas velocity, temperature, and species (emissions)
  - Boundary heat transfer
  - Unburned carbon in fly ash
  - Tabular and two-dimensional graphs
- 3D quantities evaluated
  - Gas velocity, temperature, and species distributions
  - Boundary temperature and heat flux
  - Particle trajectories (temperature, carbon conversion)
  - Static and animated computer graphics
- Results compared with performance criteria

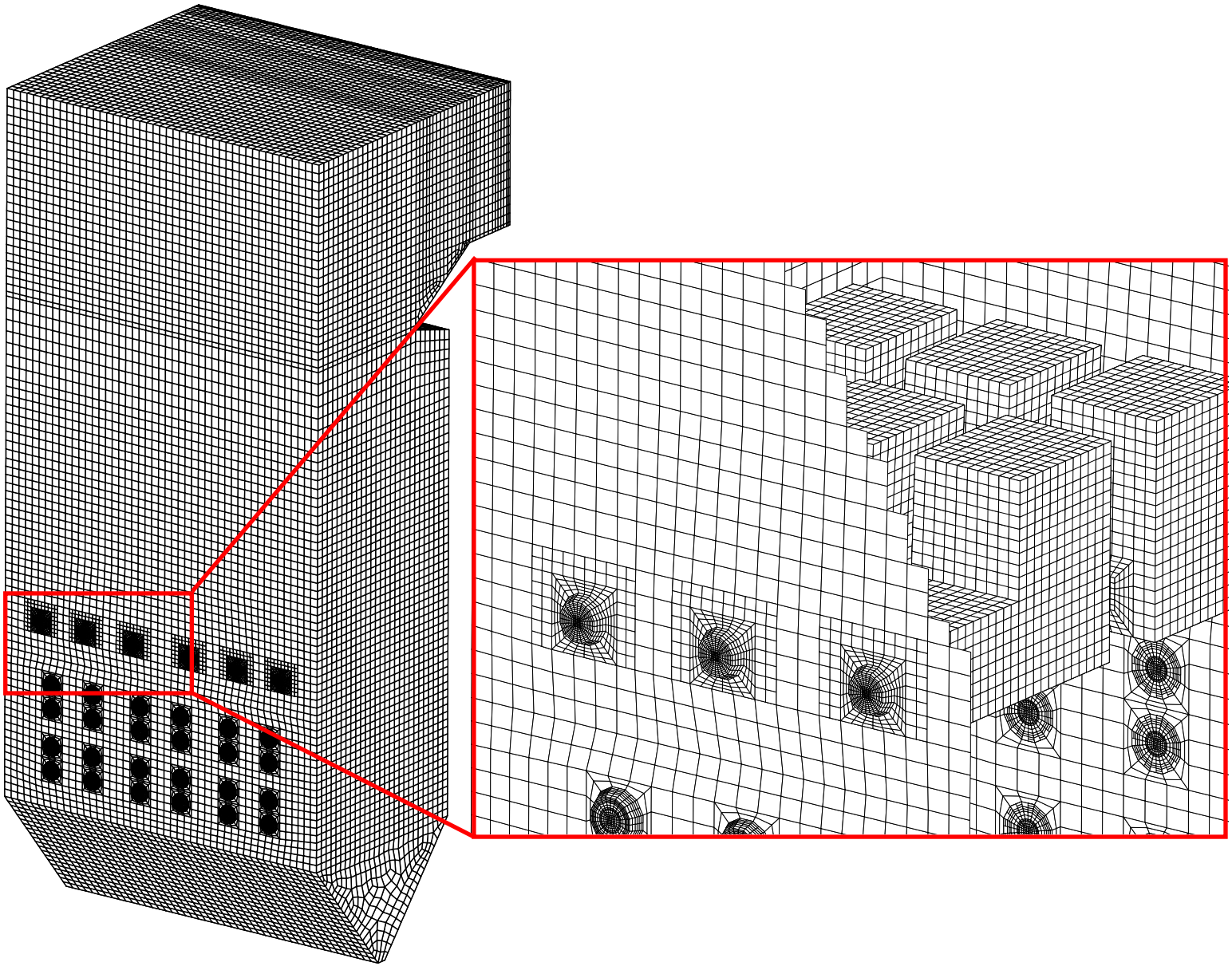
Model Setup: Example Mesh - Dual-Zone NO_x Port



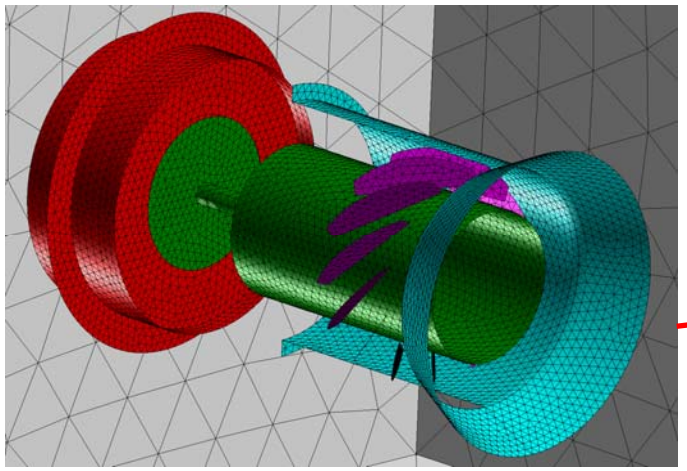
Model Setup: Example Mesh - DRB-4Z™ Burner

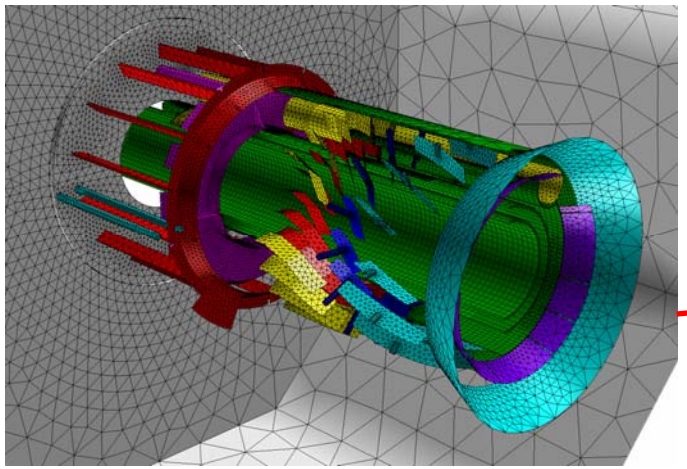


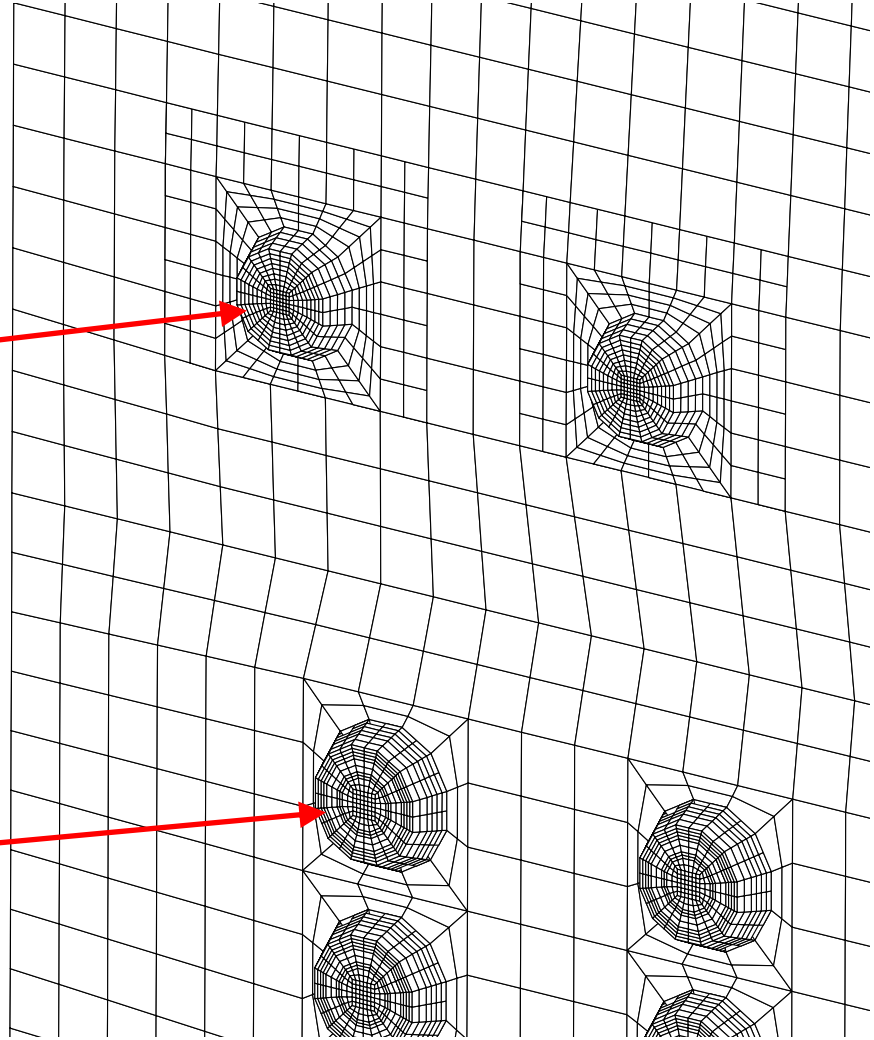
Model Setup: Example Mesh - Boiler with Refinement



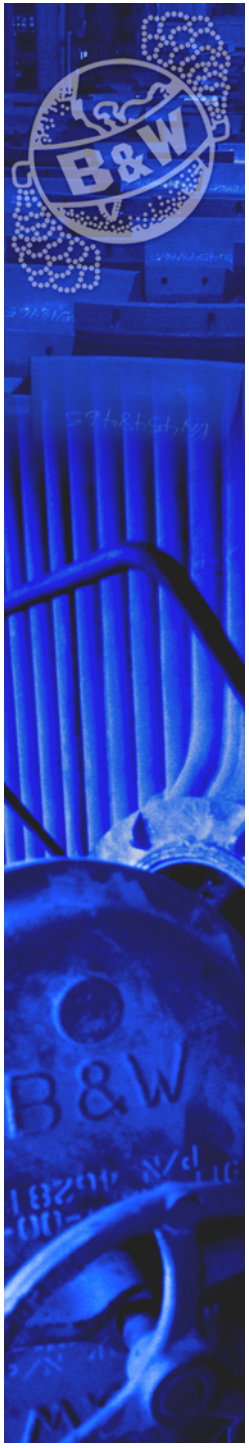
Model Setup: Solution Mapping







Component flow solution mapped to furnace inlets

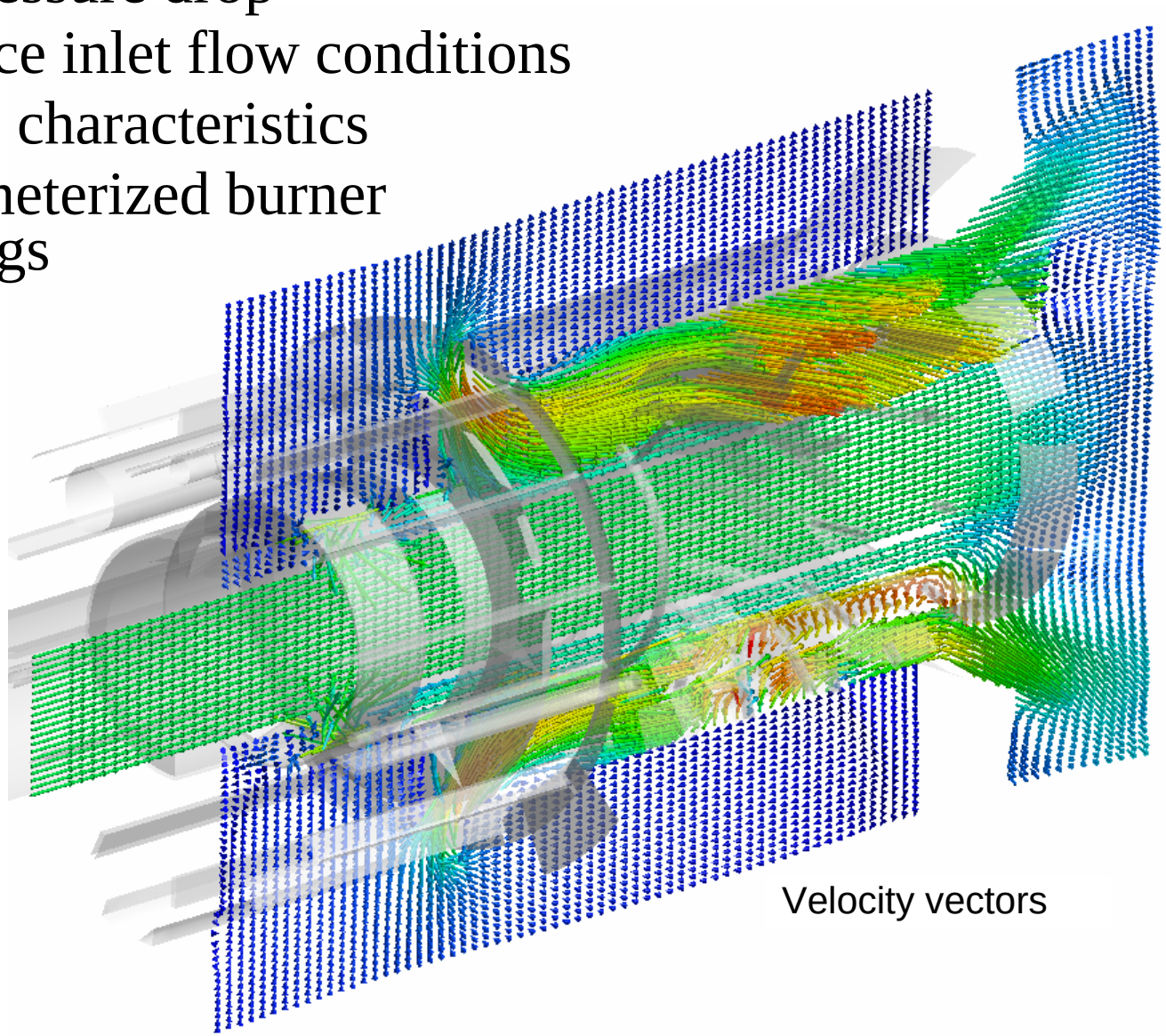


B&W Modeling Applications:

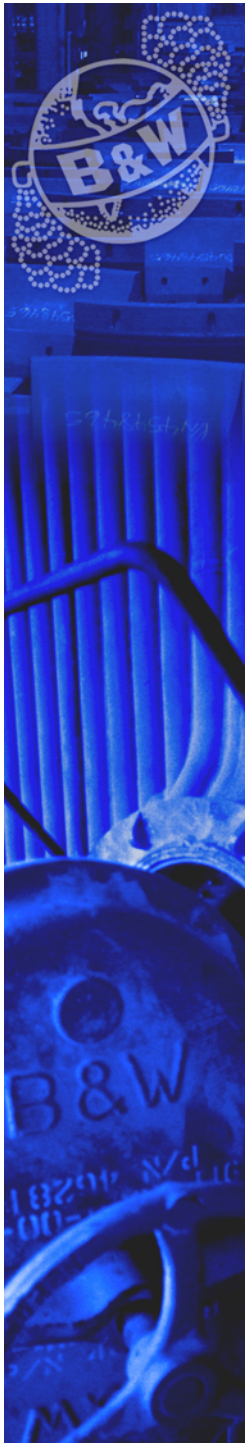
- Combustion Examples
  - DRB-4Z™ Burner
  - 680 MW Utility Boiler
  - Kraft recovery boiler
- Other applications
  - Windbox flow
  - Selective catalytic reduction (SCR)
  - Popcorn ash removal

DRB-4Z™ Burner

- air pressure drop
- furnace inlet flow conditions
- flame characteristics
- parameterized burner settings



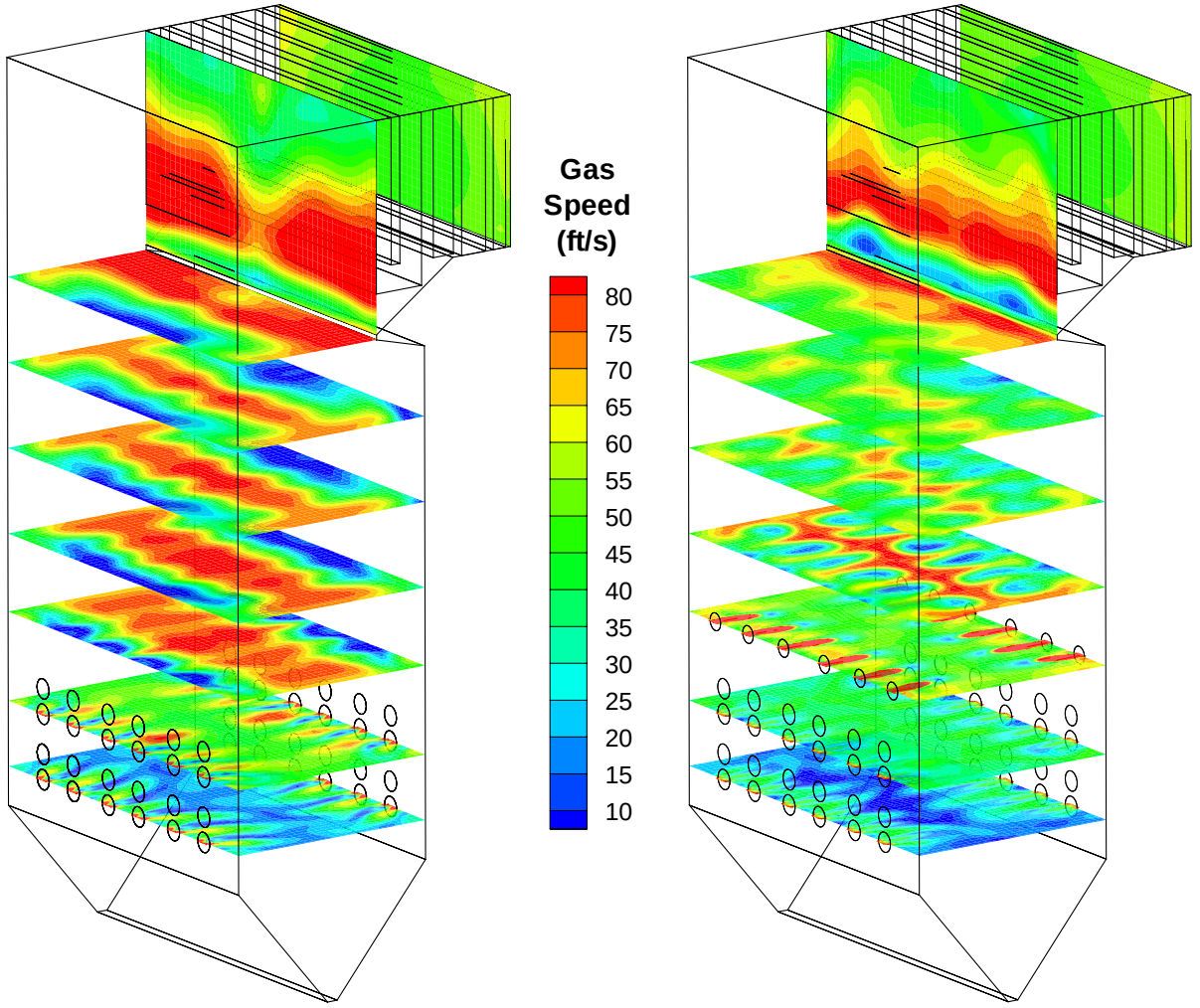
Velocity vectors



680 MW Utility Boiler – Pulverized Coal

- Baseline
  - 48 third-party burners (single secondary air zone)
  - NO_x ports NOT installed
- Retrofit (NO_x reduction)
  - 48 DRB-4Z burners
  - 12 dual-zone NO_x ports

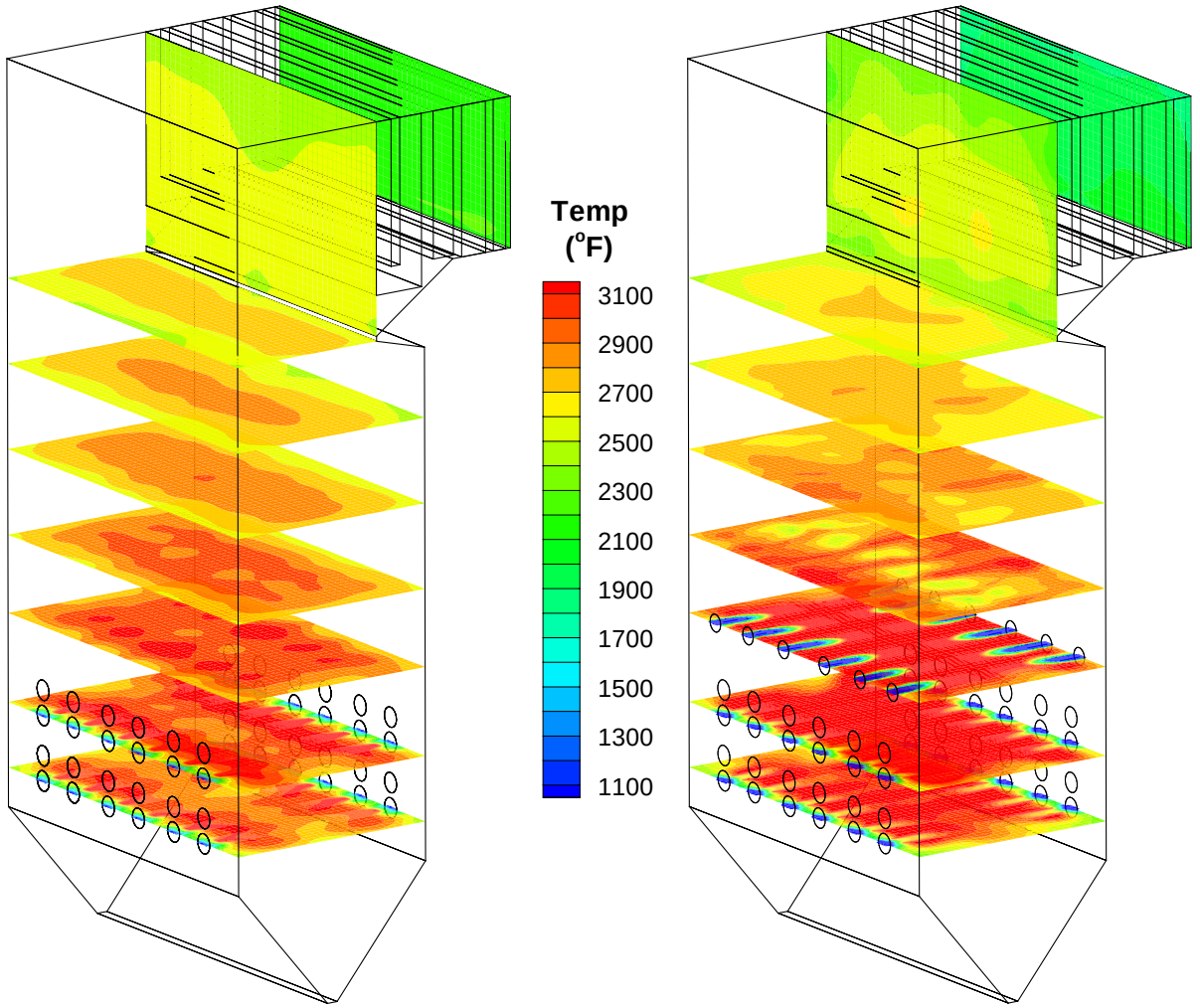
Gas Speed Comparison



Original **Retrofit**

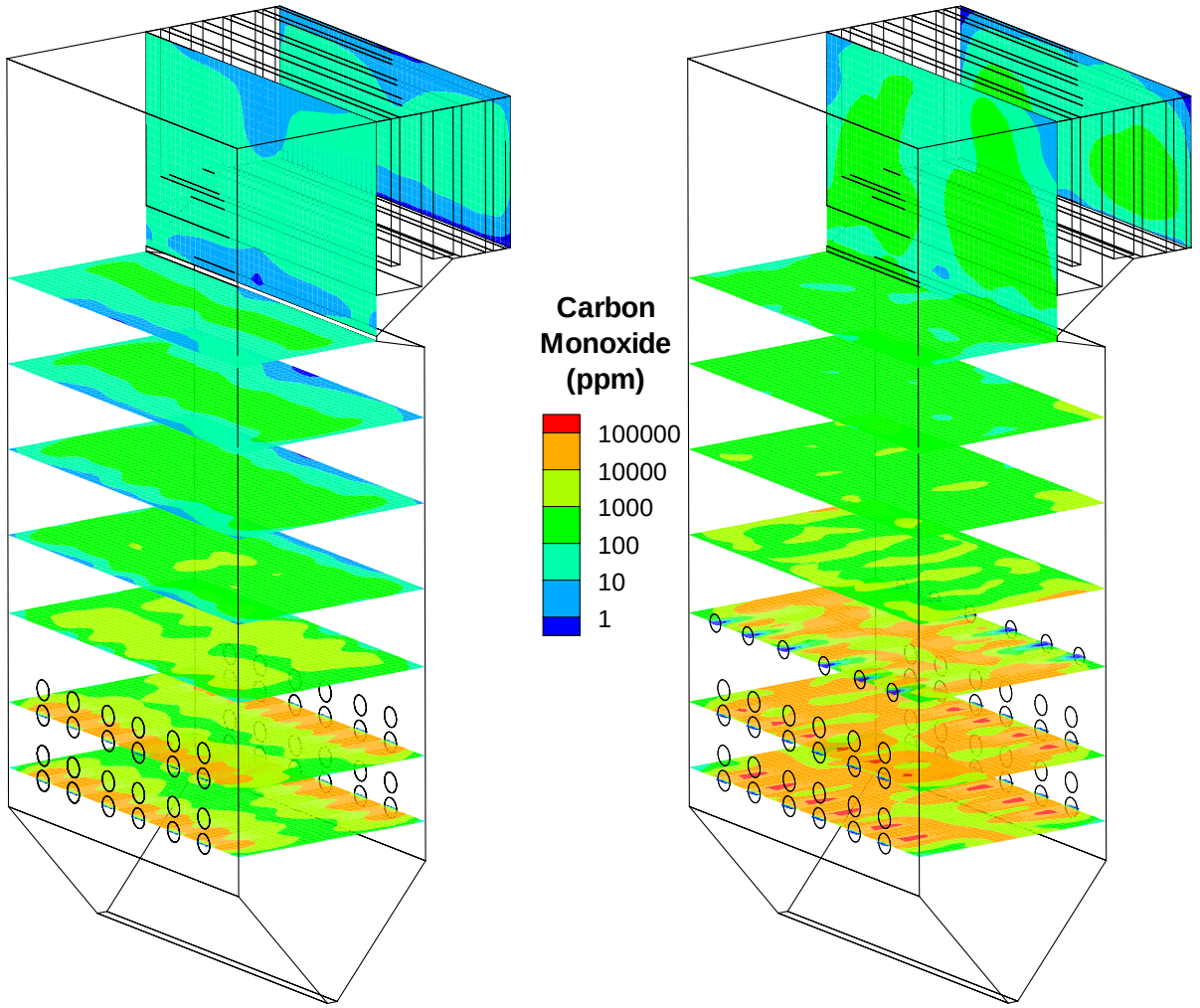
680 MW Coal-Fired Boiler

Temperature Comparison



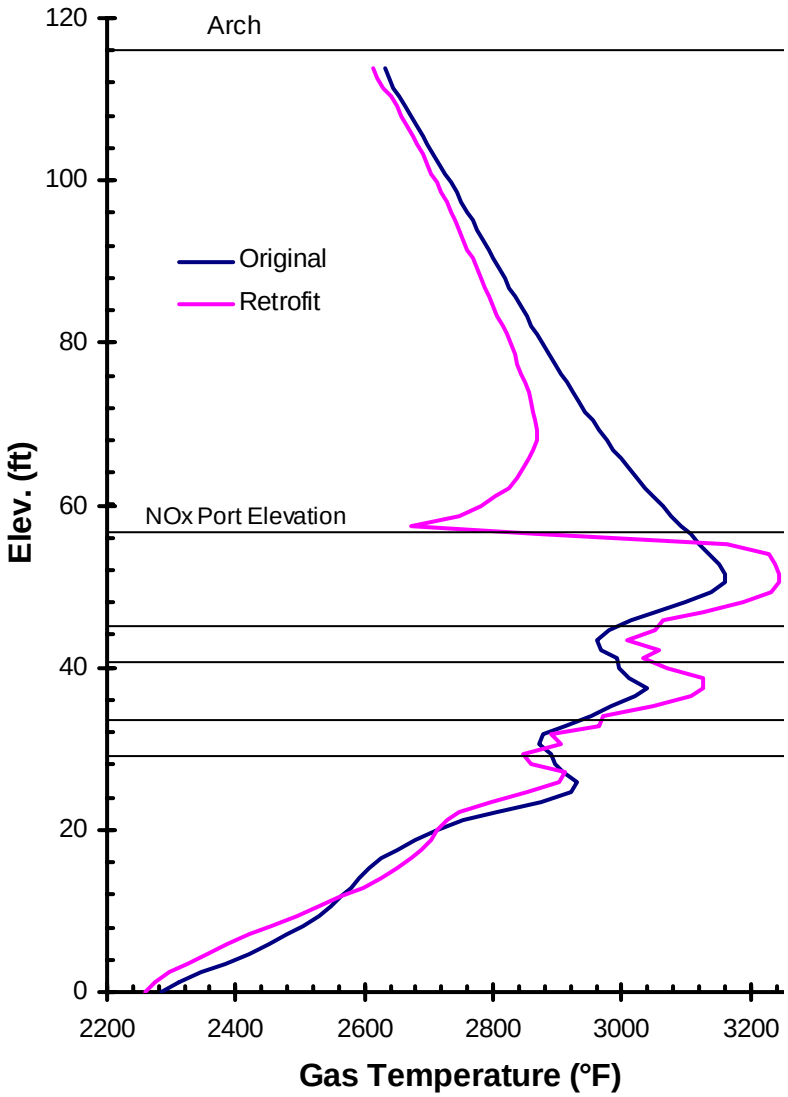
680 MW Coal-Fired Boiler

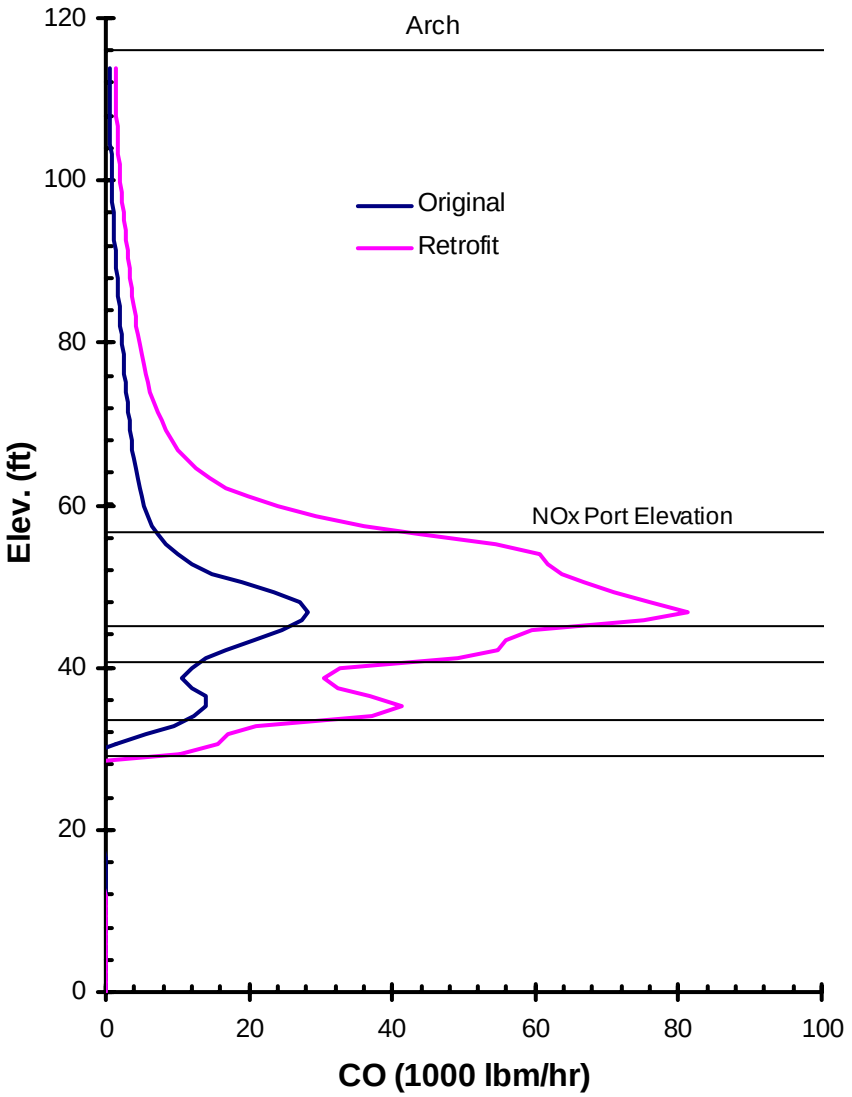
Carbon Monoxide Comparison



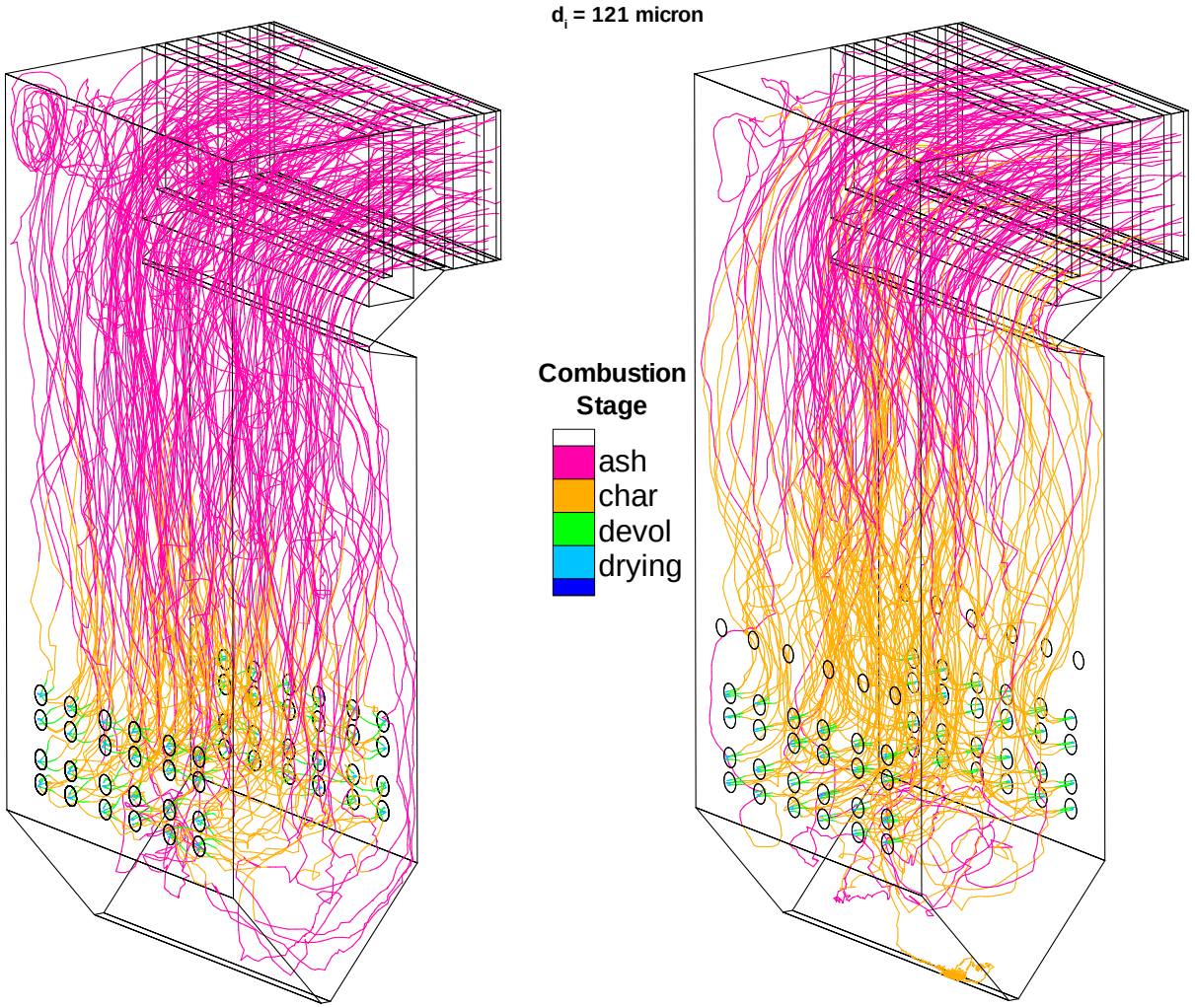
680 MW Coal-Fired Boiler

Temperature and CO Profiles

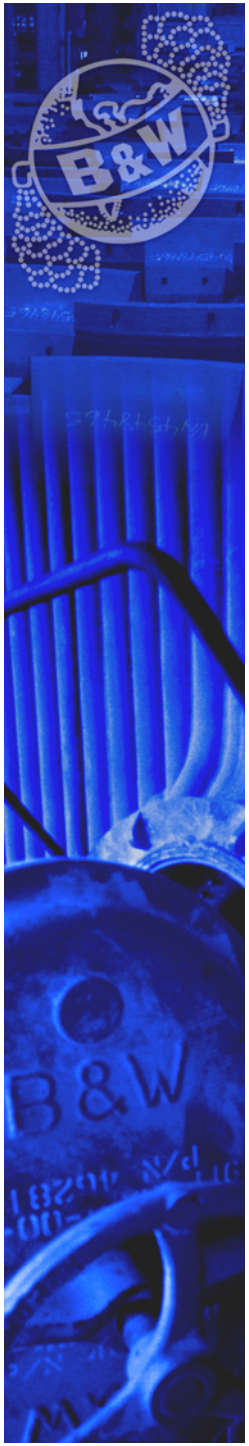




Particle Trajectories Comparison



680 MW Coal-Fired Boiler

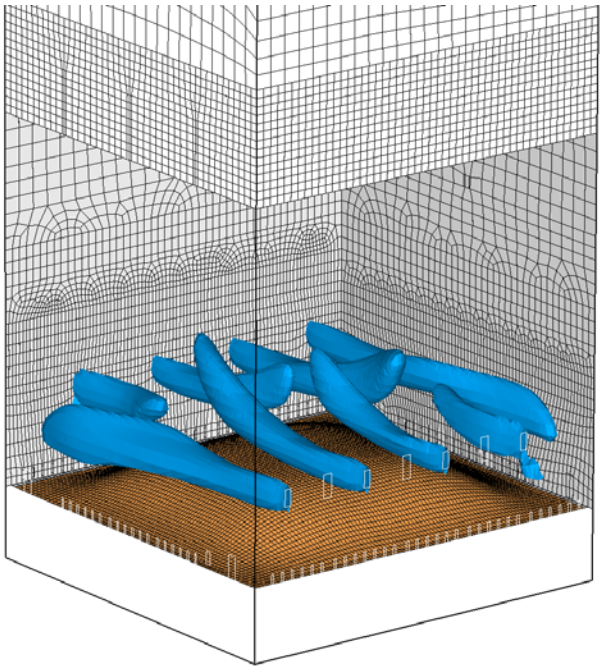


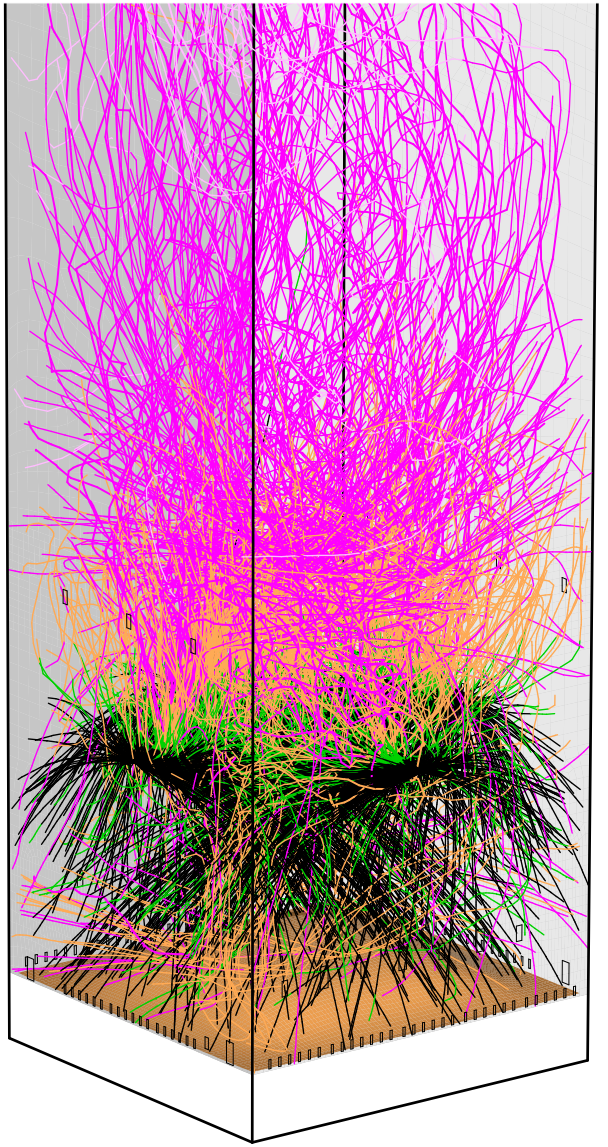
COMO Example Application Summary

- Modeling provides details of flow and combustion throughout boiler, not just exit values
- Emissions predictions are sensitive to large changes in boiler design and operation (e.g., staged/ unstaged / mixing)
- Results are validated with field data and boiler retrofit experience

Kraft Recovery Boiler

- Air System Design
- Liquor Distribution
- Capacity Increase
- Carryover, ISP, and Fume
- CO and NO_x
- Furnace heat flux and circulation

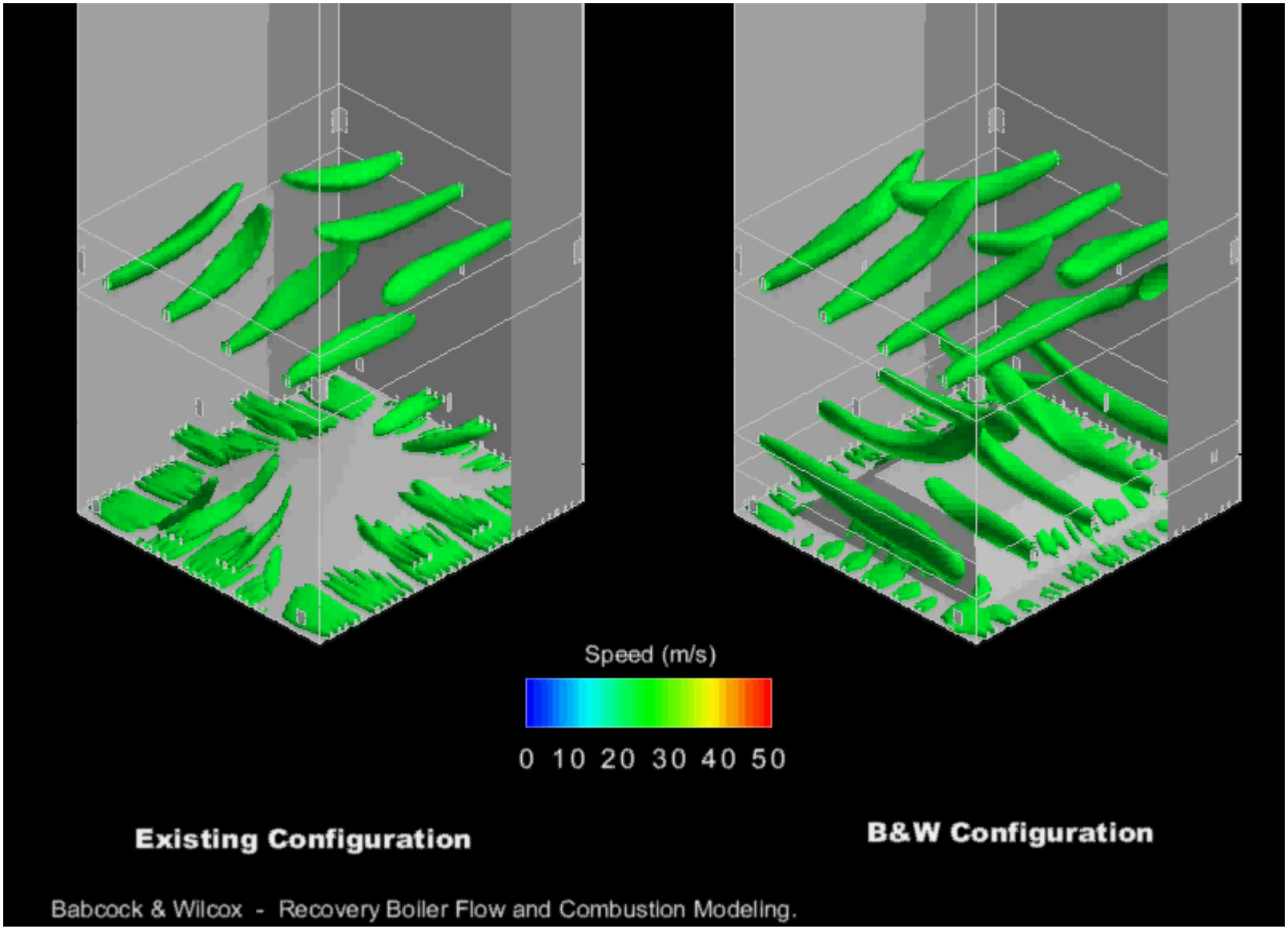




Particle Combustion Stage

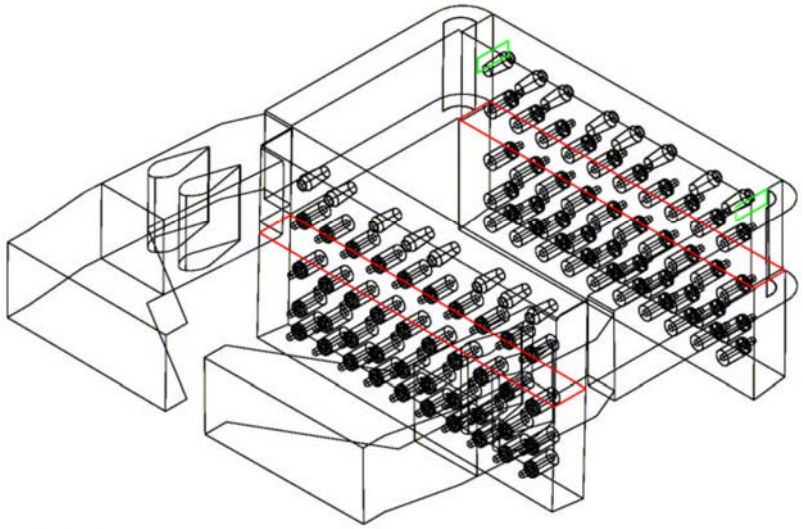
- salt
- smelt
- char
- devol
- drying

Animated Modeling Results

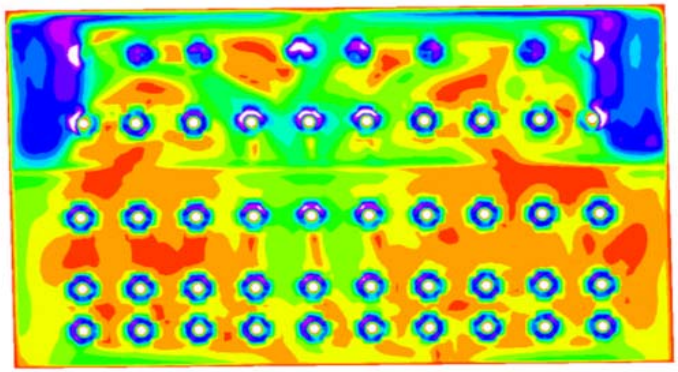


Windboxes

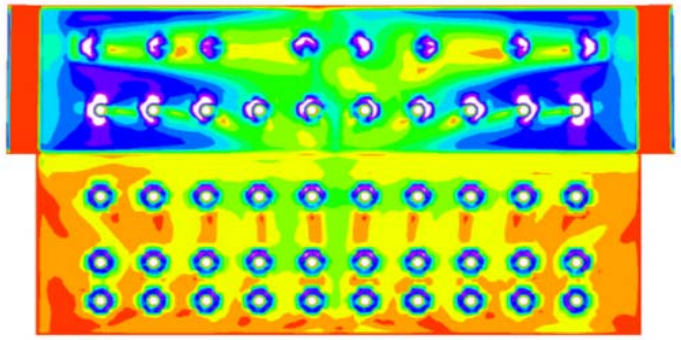
- Burner flow distribution/balancing and pressure drop



600 MW Oil Fired Unit



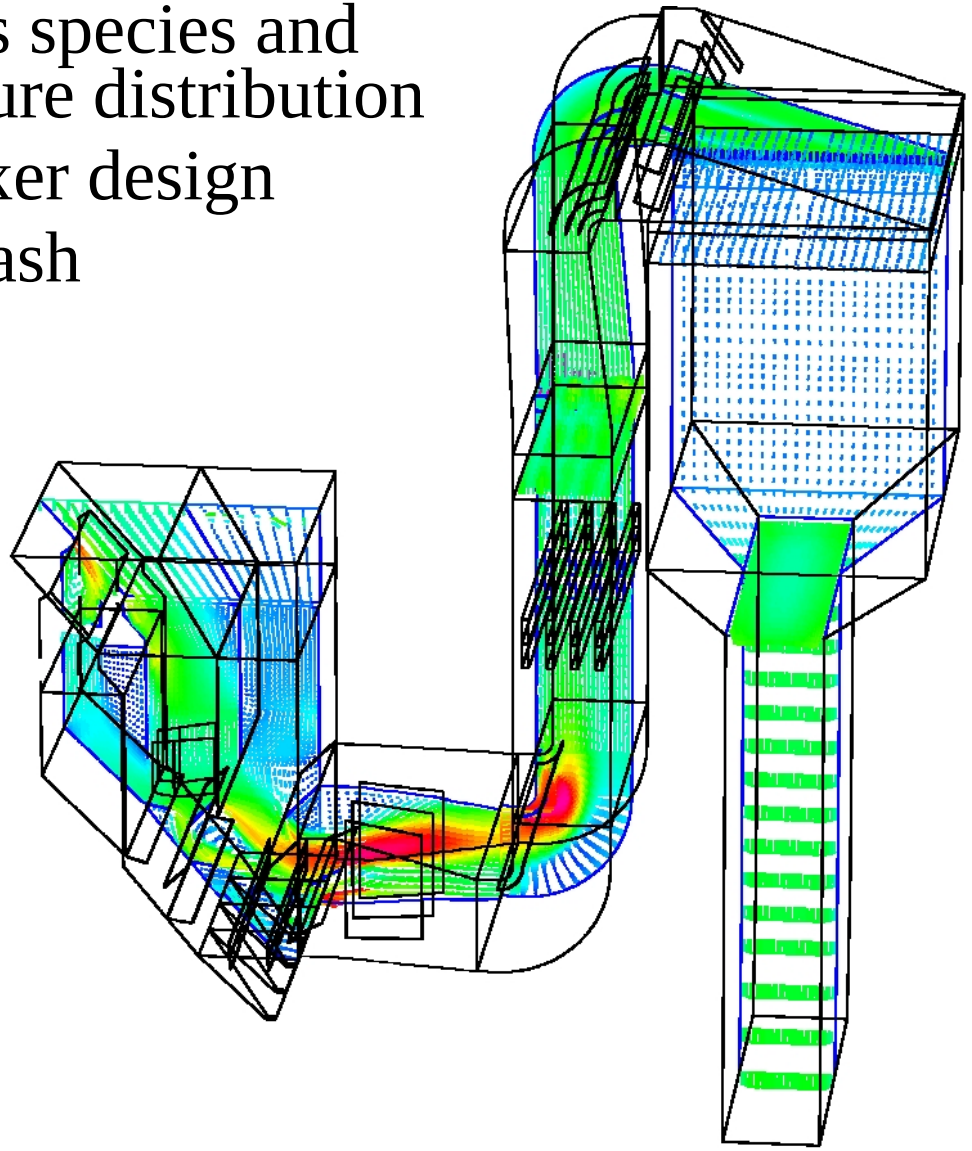
Gas Speed - Rear Wall



Gas Speed - Front Wall

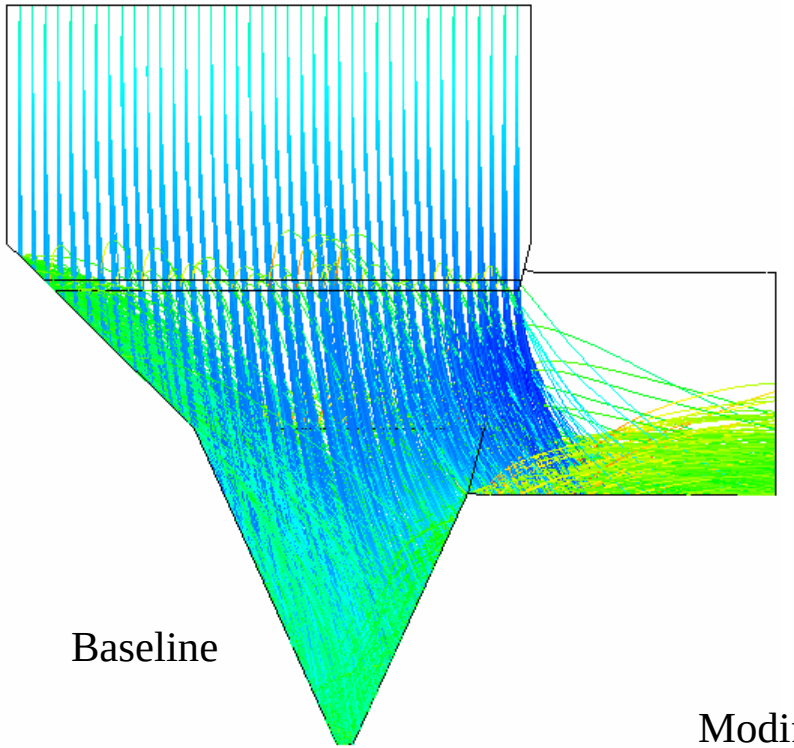
Selective Catalytic Reduction (SCR)

- Flow, gas species and temperature distribution
- static mixer design
- popcorn ash

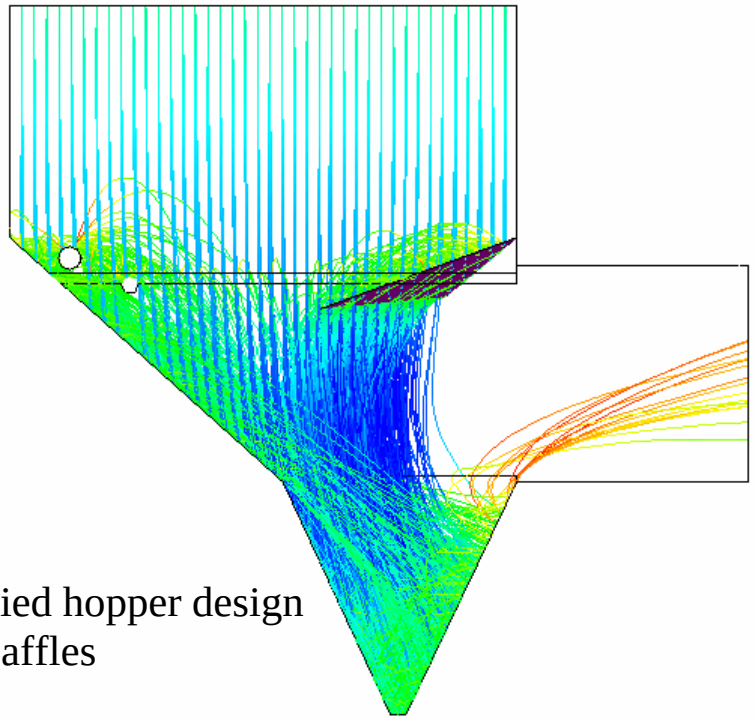


Popcorn Ash

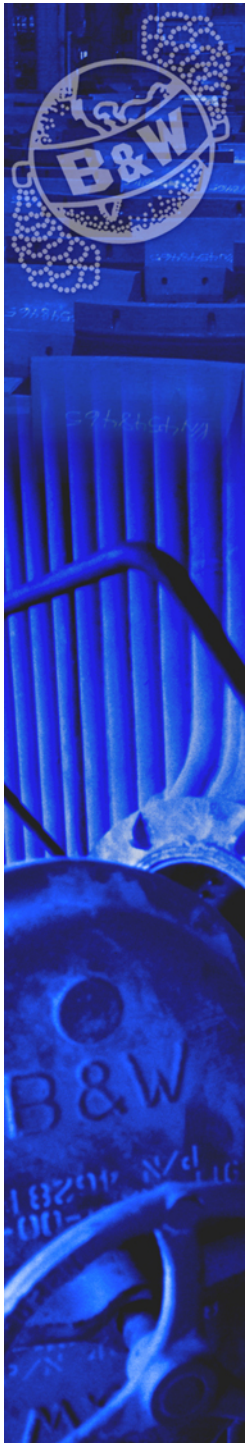
- Particle flow and capture of popcorn ash in an economizer hopper



Baseline



Modified hopper design with baffles



Summary

- B&W has been an industry leader in combustion modeling for over 25 years
- Modeling is routinely used to assist in design and analysis of combustion equipment
- Some capabilities essential for accurate results
  - Mesh refinement (improved accuracy and efficiency)
  - Accurate representation of operating conditions (inlet and boundary conditions, including mapping)
  - Combustion sub-models (heterogeneous reactions and gas phase kinetics)
- Modeling is powerful tool for non-traditional concepts (outside experience envelope)