Motivation for Verification and Validation

• Primary method to assess accuracy
• Builds confidence and credibility
• Use of combustion modeling is increasing
Combustion Modeling

Design
- Validate design performance
- Compare alternatives
- Gain understanding

Troubleshoot
- Investigate problem
- Identify/Validate solution

Use is wide spread
- Accepted method of engineering analysis
Verification & Validation

**Verification**: The process of determining that a model implementation accurately represents the developer’s conceptual description of the model and the solution to the model.

**Validation**: The Process of determining the degree to which a model is an accurate representation of the real world from the perspective of the intended uses of the model.

Validation Goals

Characterization and minimization of uncertainties and errors in the computational model as well as in the experimental data

Increase confidence in the quantitative predictive capability of the computational model
Validation Hierarchy – Complete System
Validation Hierarchy – Subsystem Cases

Complete System

Subsystem Cases
Validation Hierarchy – Benchmark Cases

- Complete System
- Subsystem Cases
- Benchmark Cases
Validation Hierarchy – Unit Problems

- Complete System
- Subsystem Cases
- Benchmark Cases
- Unit Problems
COMO Validation

- Identify Target System or Application
- Unit Problems
- Benchmark Cases
- Subsystem Cases
## COMO Capabilities

<table>
<thead>
<tr>
<th>Capability</th>
<th>windboxes</th>
<th>burners</th>
<th>cyclones</th>
<th>boilers</th>
<th>gasifiers</th>
<th>SCR</th>
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</thead>
<tbody>
<tr>
<td>Turbulent Flow / Mixing</td>
<td>X</td>
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<td>Energy &amp; Radiation</td>
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<tr>
<td>Heterogeneous Reactions (coal, oil, wood, black liquor)</td>
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<td>Particles</td>
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<td>Deposit Surface Reactions</td>
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<td>Gas Phase Kinetics (volatiles, CO, NO$_x$, etc.)</td>
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<td>Tube Banks</td>
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Target System – Coal Fired Boiler

- Utility Scale Boiler
- Pulverized Coal
- Modern Low NOx Burners
- Staged Combustion
Coal Fired Boiler – Unit Problems

- Gas Phase Reactions
- Radiation
- Gas Radiative Properties
- Particles
- Turbulent Mixing
- Soot
- Coal Devolatilization
- Char Oxidation
- Thermal NOx
- Fuel NOx
Coal Fired Boiler – Benchmark Cases

Diagram showing relationships between different combustion processes and properties, including:
- TNF Flame (Gas)
- BERL Flame
- Non-reacting Particles in Jet
- B&W Flat Flame Burner
- B&W Entrained Flow Reactor

Properties and processes include:
- Gas Phase Reactions
- Radiation
- Gas Radiative Properties
- Particles
- Turbulent Mixing
- Soot
- Coal Devolatilization
- Char Oxidation
- Thermal NOx
- Fuel NOx
Benchmark Case – Flat Flame Burner

- Operating temperature – 900 -1600 °C
- Residence time – 15 -150 ms
- Heating rate – 105 K/sec
Benchmark Case – Entrained Flow Reactor

- High-temperature reactor (1600°C/2900°F)
- Single or cloud particle feed
- FTIR analyzer
- Gas chromatograph
- Oxy-fuel and conventional operation modes
Benchmark Case – TNF Flame

- Non-premixed co-axial jet flame
- Jet diameter: 3.2 mm
- Reynolds number, Re = 8,500
- Fuel composition: 40% CO, 30% H₂ and 30% N₂
Coal Fired Boiler – Subsystem Cases

- U. Of Stuttgart Combustor
- IFRF PC Flame
- B&W Small Boiler Simulator
- B&W CFPF
- TNF Flame (Gas)
- BERL Flame
- Non-reacting Particles in Jet
- B&W Flat Flame Burner
- B&W Entrained Flow Reactor

- Gas Phase Reactions
- Radiation
- Gas Radiative Properties
- Particles
- Turbulent Mixing
- Soot
- Coal Devolatilization
- Char Oxidation
- Thermal NOx
- Fuel NOx
Subsystem Case – Small Boiler Simulator

- 6 million Btu/hr
- Coal, natural gas, oil
- Cyclone and wall firing modes
- Representative flue gas & tube temperatures
- Oxy-fuel combustion ready
Subsystem Case – CFPF

- 6 million Btu/hr
- Staged or unstaged
- Multiburner
Complete System – 680 MW Utility Boiler
Conclusions

• A standard validation process has been developed for COMO simulations of pulverized coal combustion models.
• Facilities have been developed at B&W that support COMO validation.
Thank You