CFD-Based Combustion Modifications in China Achieve Significant NOx Reductions in Utility PC Boilers

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Clearwater Coal Conference

Clearwater, FL June 5 – 9, 2011

Drivers for NOx Reduction in China

- ➔ **Increasing Industrialization**
- ➔ **Increasing Use of Fossil Fuels**
  - Transportation
  - Power Production
  - Industrial Processes
- ➔ **Air Quality Concerns**
- ➔ **Significant Pressure on Power Plant Operators to reduce emissions, particularly NOx**

Project Team

- *LP Amina* – Project Lead
  - Environmental Engineering Company
  - Focus in U.S., Europe, and Asia
  - Power Generation and Chemicals Industries
- *SAVvy Engineering, LLC* – Combustion Mod. Design
  - Combustion Consulting for Power Generation
  - Focus on NOx Emission Compliance
  - Located in Ohio
- *REI* – Combustion Analysis (CFD)
  - R&D Consulting in Combustion and Environmental Solutions
  - Advanced Analysis Tools and Expertise
  - Located in Utah

Overview of Projects

➔ Yixing-Union Cogen

- Yixing City, Yangtse River Basin
- One of fastest growing regions in China
- Goals
  - » Target NOx emissions of 300 mg / Nm^3
  - » Maintain / Improve Unit efficiency
  - » Limit capital investment (avoid SCR)
- Strategy - Burner and OFA mods

➔ Fengtai Power Station

- 2 x 600 MW T-fired Units with MPS type mills
- Goal: Improved classifier performance

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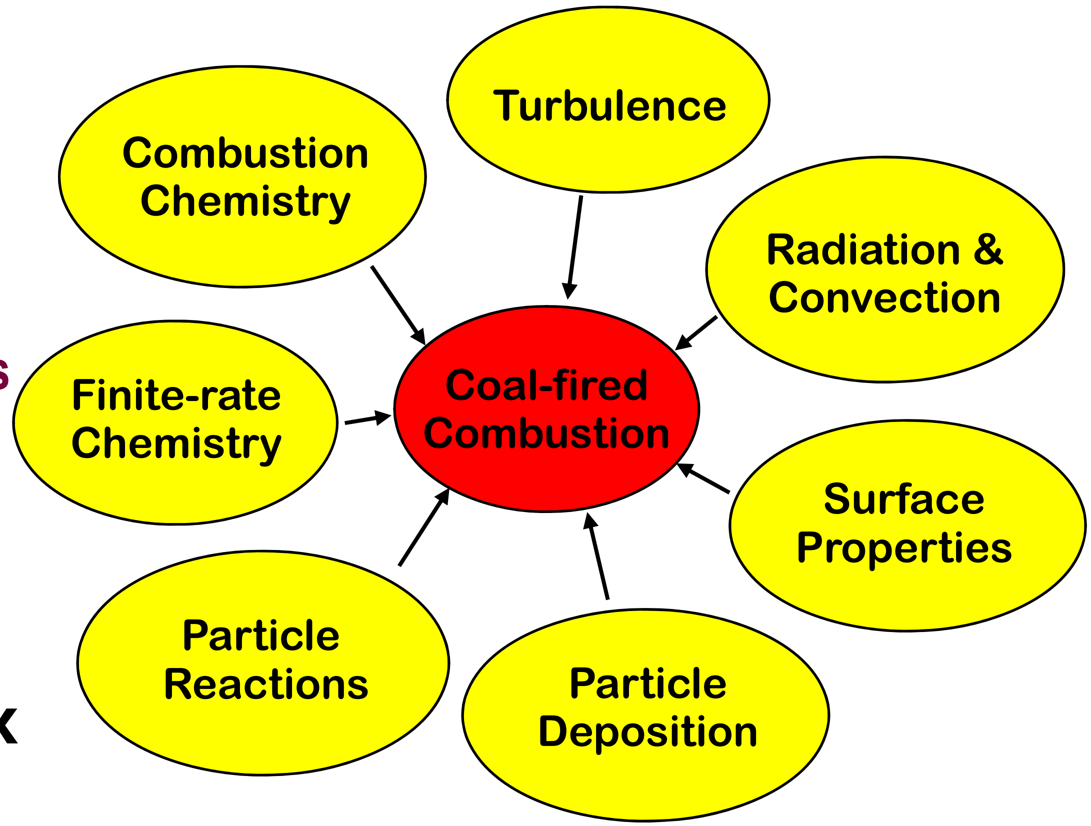
CFD Model
GLACIER

- ➔ **Accuracy Depends on**
  - Input accuracy
  - Numerics
  - Representation of physics & chemistry
- ➔ **GLACIER applied to over 200 utility boilers**
- ➔ **Particular focus on NOx emissions and impacts of Low NOx equipment**



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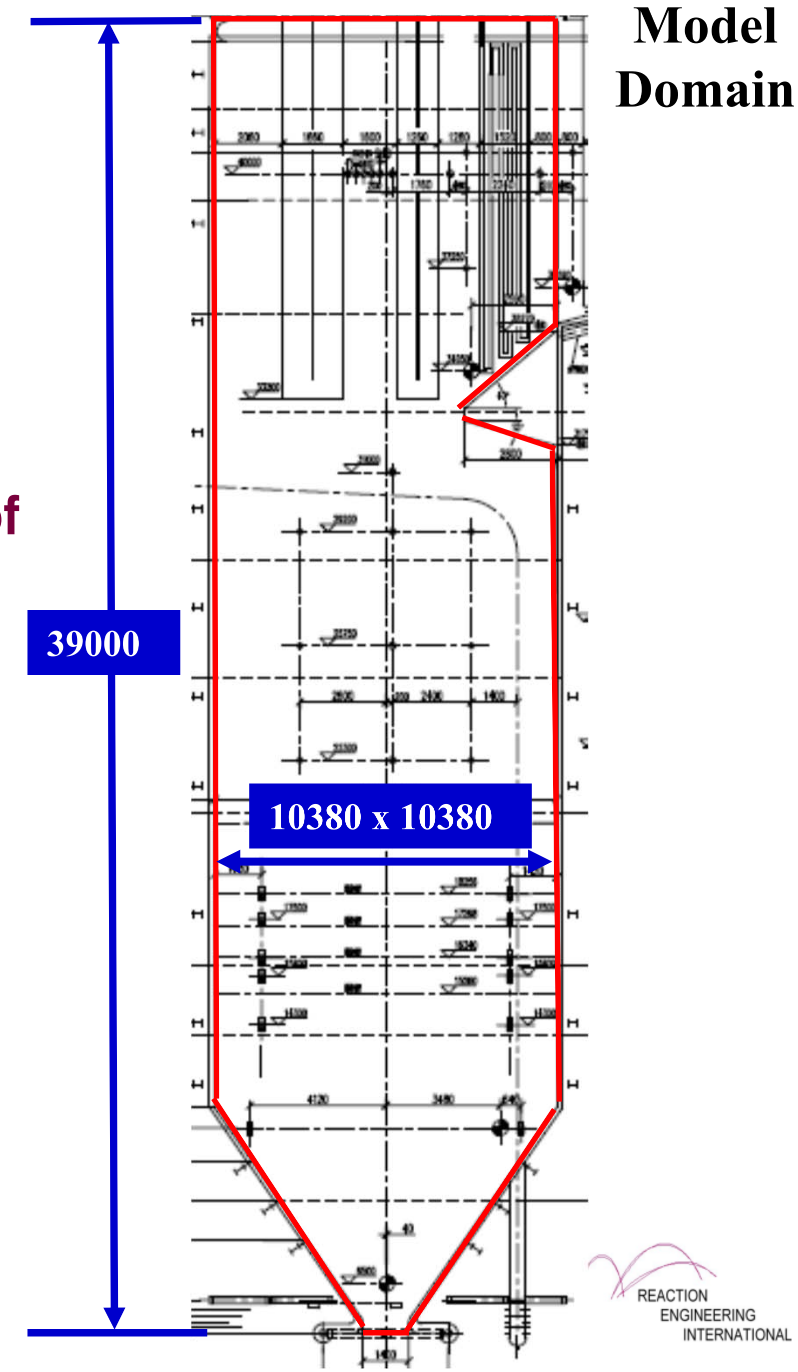
Yixing Units 8 and 9

Baseline Operation

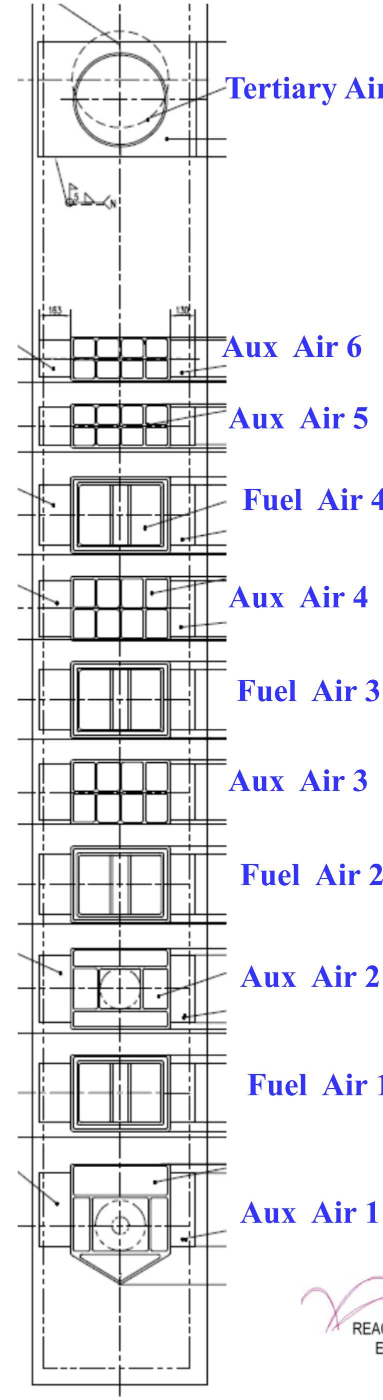
- **CE Tangentially Fired, Indirect**
  - **Four Fuel Nozzle Elevations**
  - **Heat Input: 1392 MBtu/hr**
  - **Tertiary air with Coal Fines at top of Burner Column**
- **Square Cross-section with uniform firing angles**
- **30% ash, Low Volatile Coal**
- **No Existing OFA or Off-set Secondary Air**
- **NOx Emissions: ~ 450-500 mg / Nm^3**



Baseline Operation

Yixing 8

	Baseline
Firing Rate (MBtu/hr)	1,392
Total Coal Flow Rate (lb/hr)	151,711
Combustion Air Flow Rate (lb/hr)	1,255,438
Furnace SR	1.18
Excess O_2 (wet)	3.04%
Primary Air Flow Rate (lb/hr)	242,737
Coal Flow Rate through Primary air (lb/hr)	138,057
Primary Air Temperature (^oF)	320
Tertiary Air Flow Rate (lb/hr)	131,000
Coal Flow Rate through Tertiary (lb/hr)	13,654
Tertiary Air Temperature (^oF)	160
Secondary Air Flow Rate (lb/hr)	881,701
Secondary Air Temperature (^oF)	532
Lower Furnace SR	1.18
SOFA Flow Rate (lb/hr)	0
SOFA Temperature (^oF)	532



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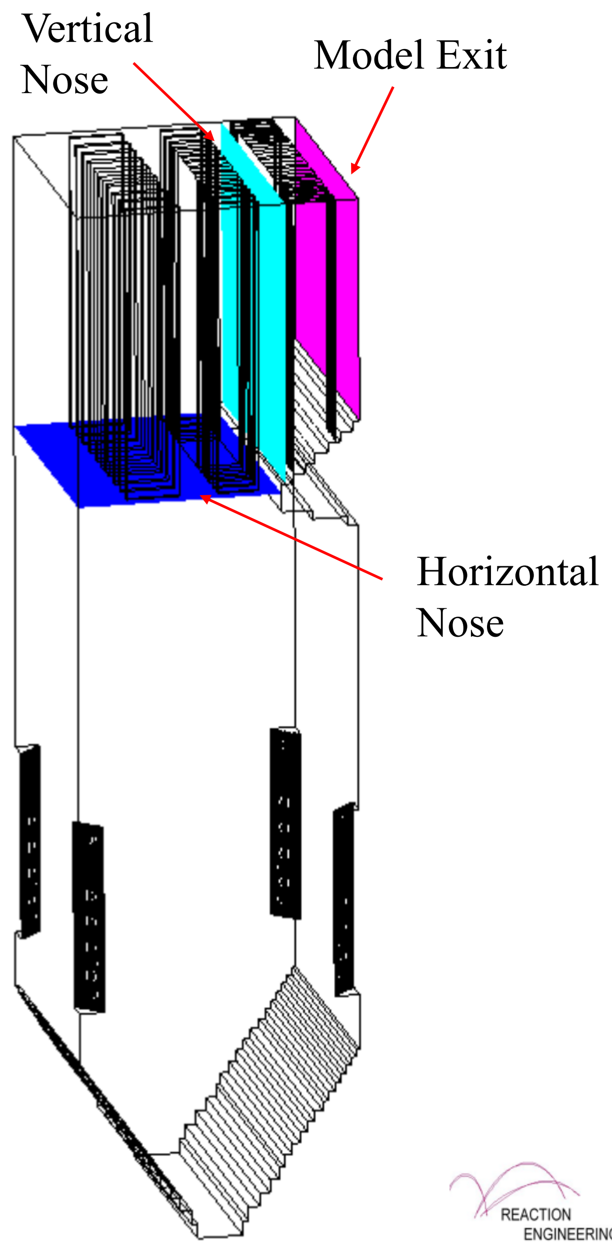
Model Predictions

Baseline

	Baseline
Horizontal Nose	
Gas Temperature (°C)	1148
CO Concentration (ppm, wet)	28
O_2 Concentration (%, wet)	3.1
NO_x Concentration (ppm, wet)	238
Vertical Nose	
Gas Temperature (°C)	963
CO Concentration (ppm, wet)	1
O_2 Concentration (%, wet)	3.1
NO_x Concentration (ppm, wet)	238
Model Exit	
Gas Temperature (°C)	842
O_2 Concentration (%, wet)	3.1
NO_x Concentration (ppm, wet)	238
NO_x Emission ($lbNO_2$/MBtu)	0.36
NO_x Emission ($mgNO_2/Nm^3$)	447
NO_x Reduction	N/A
Unburned Carbon in fly ash	0.6%



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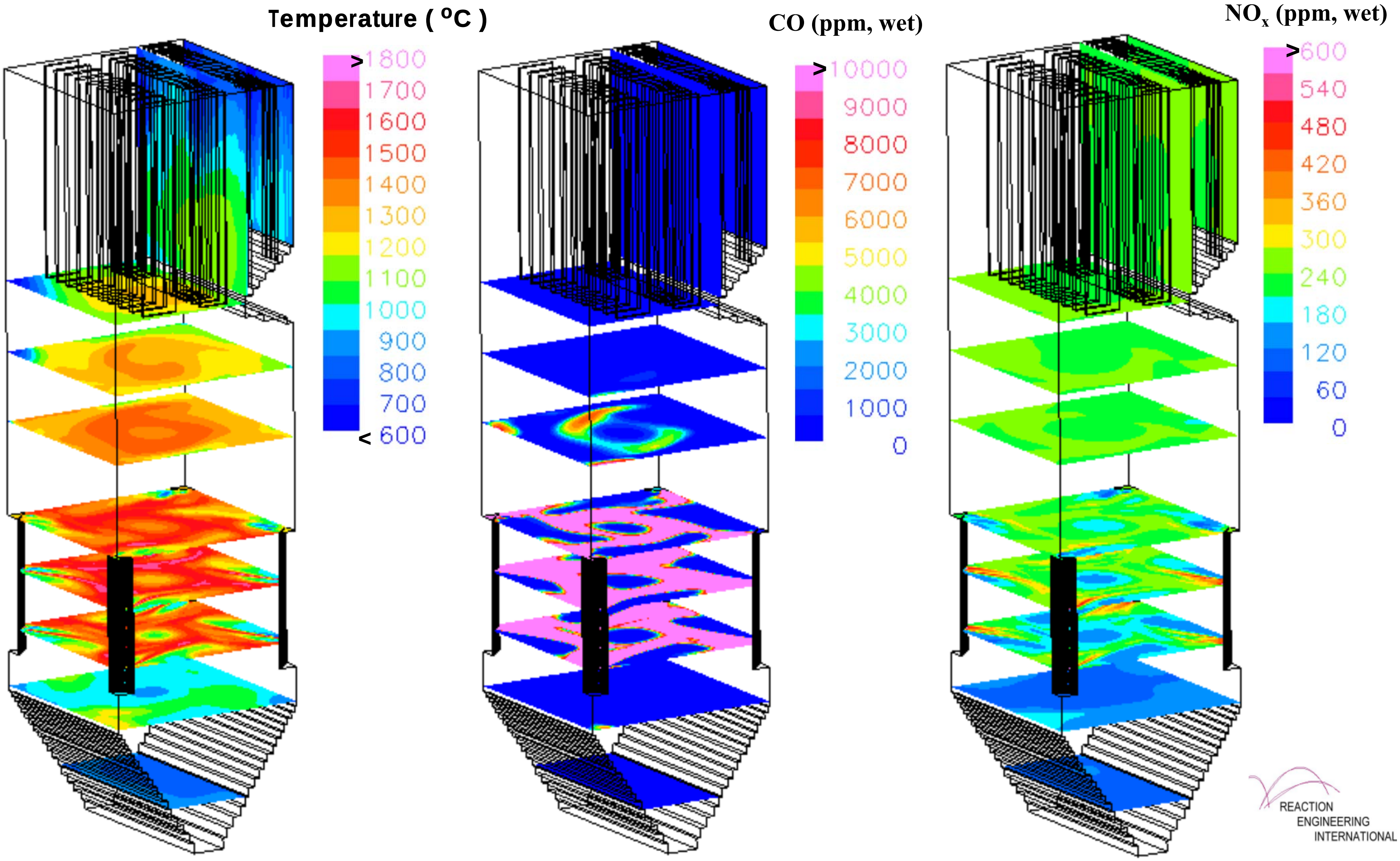
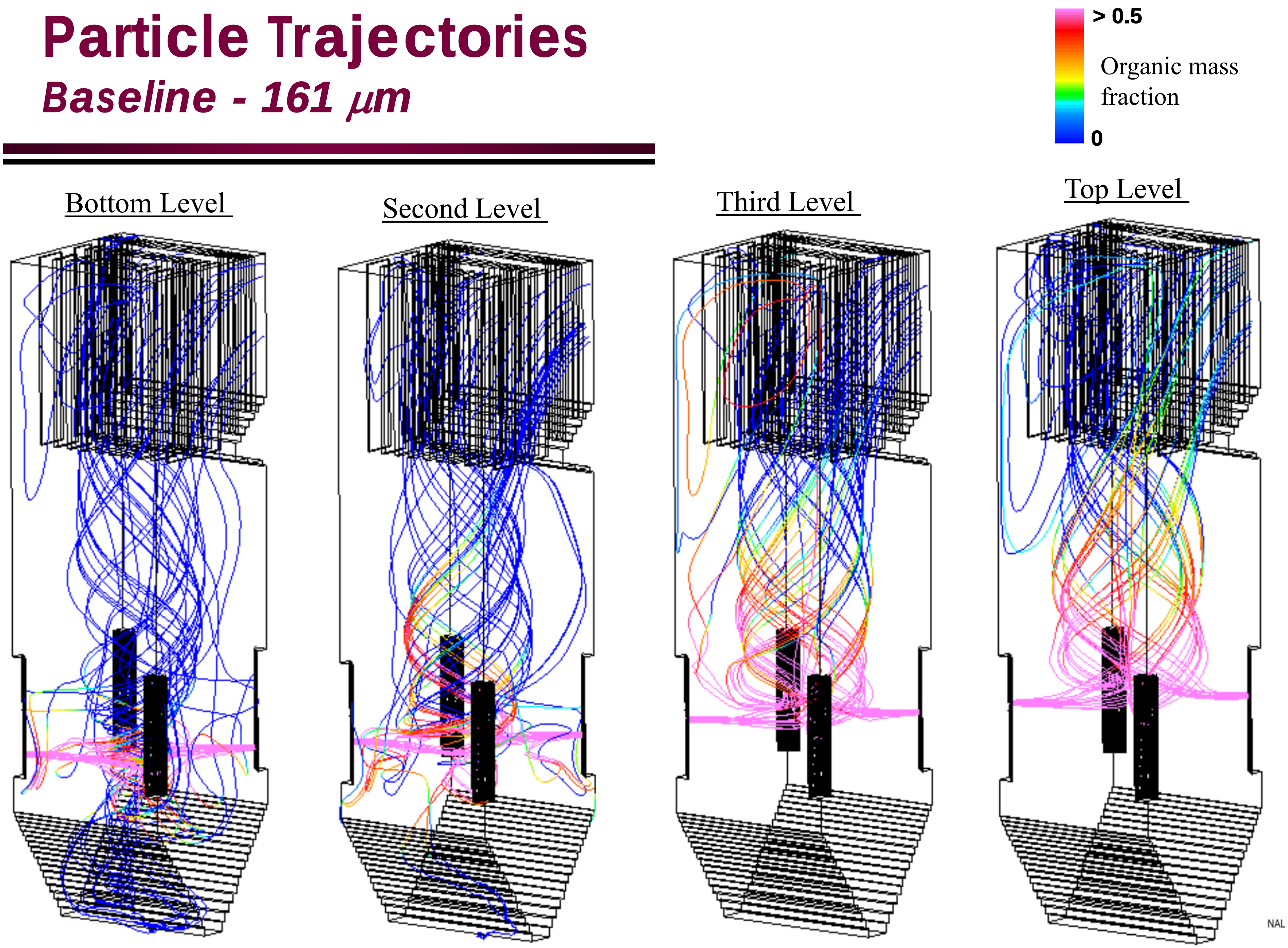
Model Results
Baseline



Particle Trajectories

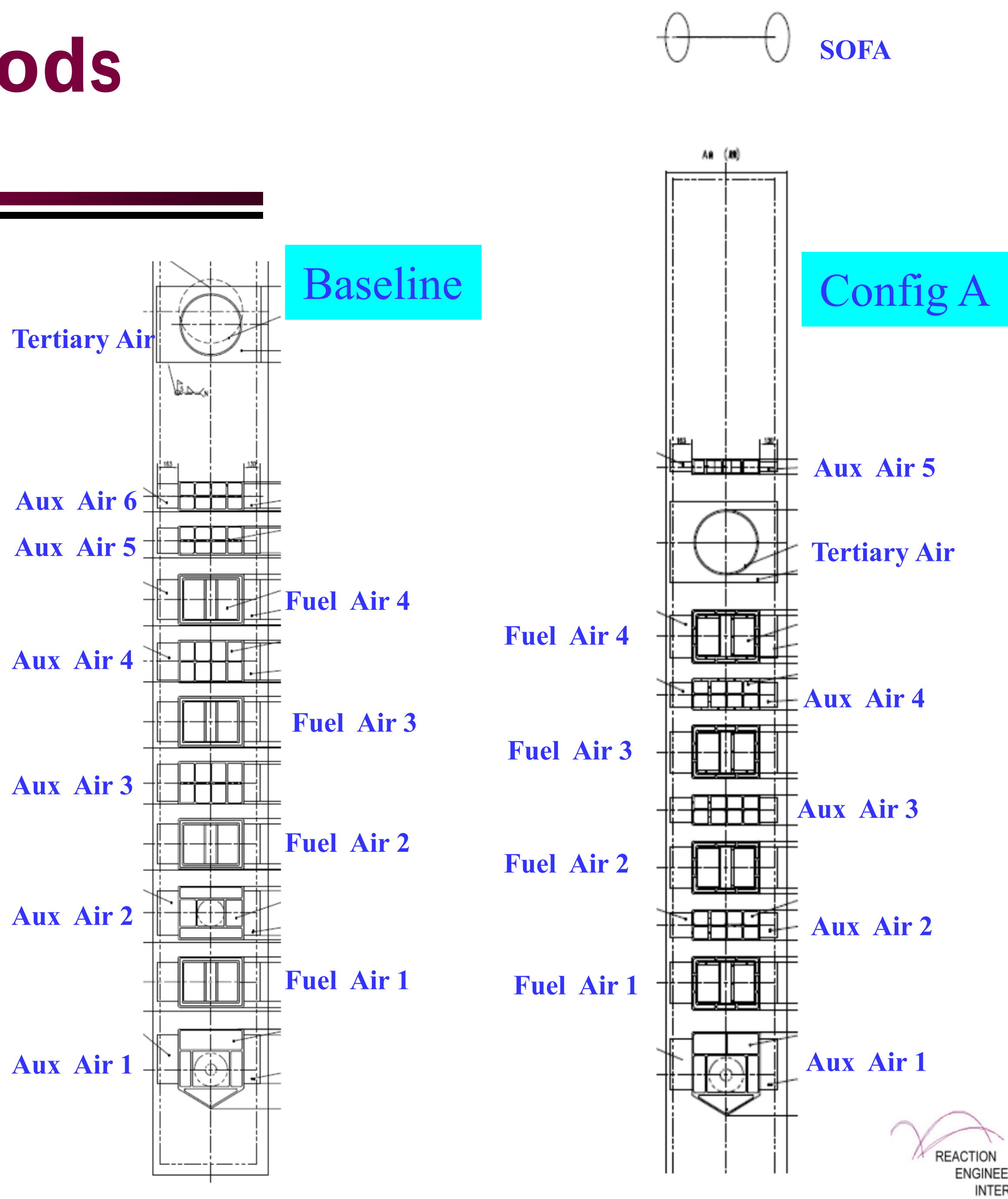
Baseline - 161 μm



Combustion Mods

Configuration A

- **Reduced size of auxiliary air ports**
- **Added offset to auxiliary air ports**
- **Shifted top three coal nozzles down**
- **Relocated TA ports just above top coal nozzles**
- **Added eight SOFA ports**



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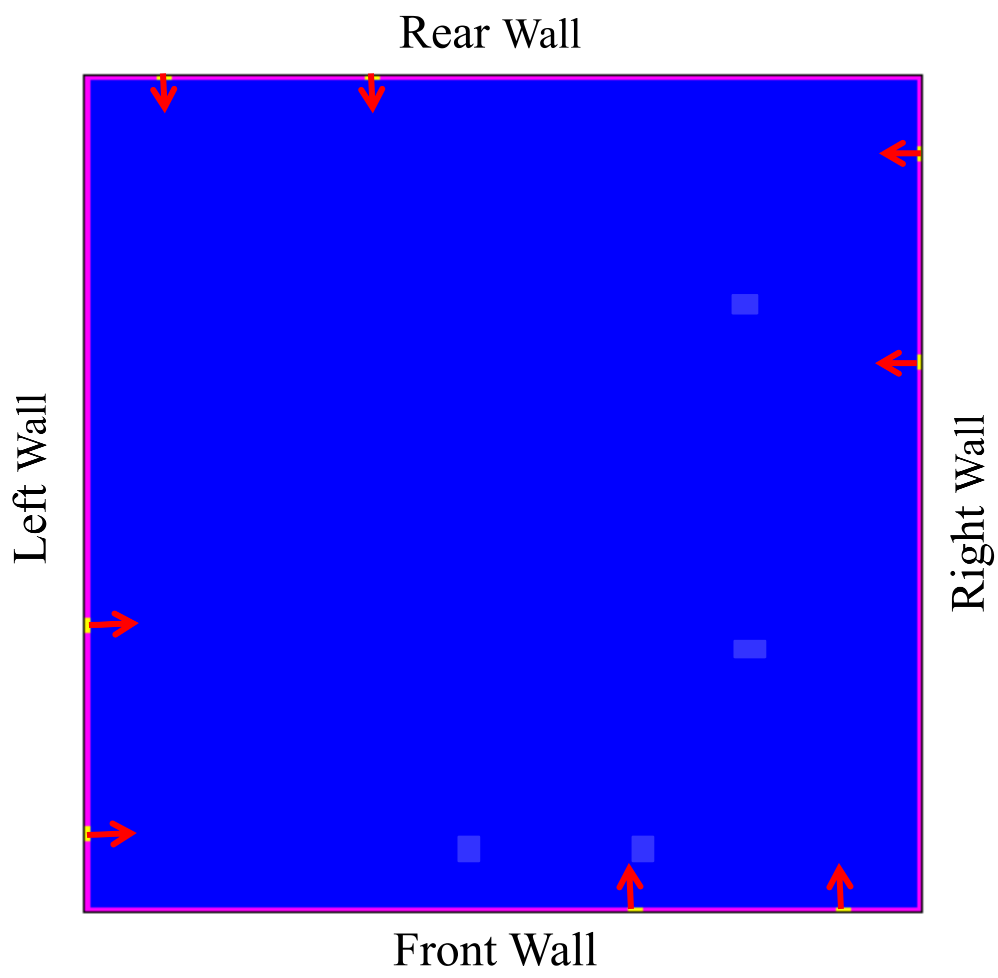
SOFA Arrangement

Configuration A



- SOFA orientation co-current with fireball
- Approximately nine burner elevations above top coal nozzle
- Ports sized for jet velocity of 200 fps at lower furnace SR=0.95

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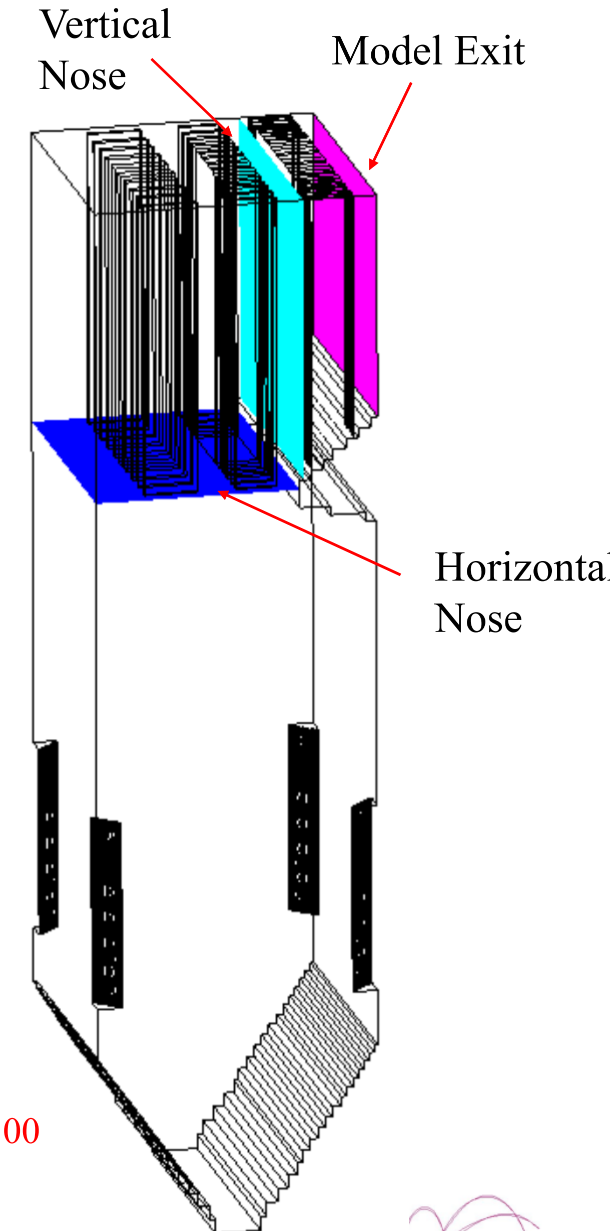
Model Predictions

Configuration A

	Baseline	Config A
Horizontal Nose		
Gas Temperature (^oC)	1148	1161
CO Concentration (ppm, wet)	28	118
O_2 Concentration (%, wet)	3.1	3.2
NO_x Concentration (ppm, wet)	238	169
Vertical Nose		
Gas Temperature (^oC)	963	926
CO Concentration (ppm, wet)	1	1
O_2 Concentration (%, wet)	3.1	3.2
NO_x Concentration (ppm, wet)	238	170
Model Exit		
Gas Temperature (^oC)	842	819
O_2 Concentration (%, wet)	3.1	3.2
NO_x Concentration (ppm, wet)	238	170
NO_x Emission ($lbNO_2$/MBtu)	0.36	0.26
NO_x Emission ($mgNO_2/Nm^3$)	447	321
NO_x Reduction	N/A	29%
Unburned Carbon in fly ash	0.6%	1.5%

Target is 300



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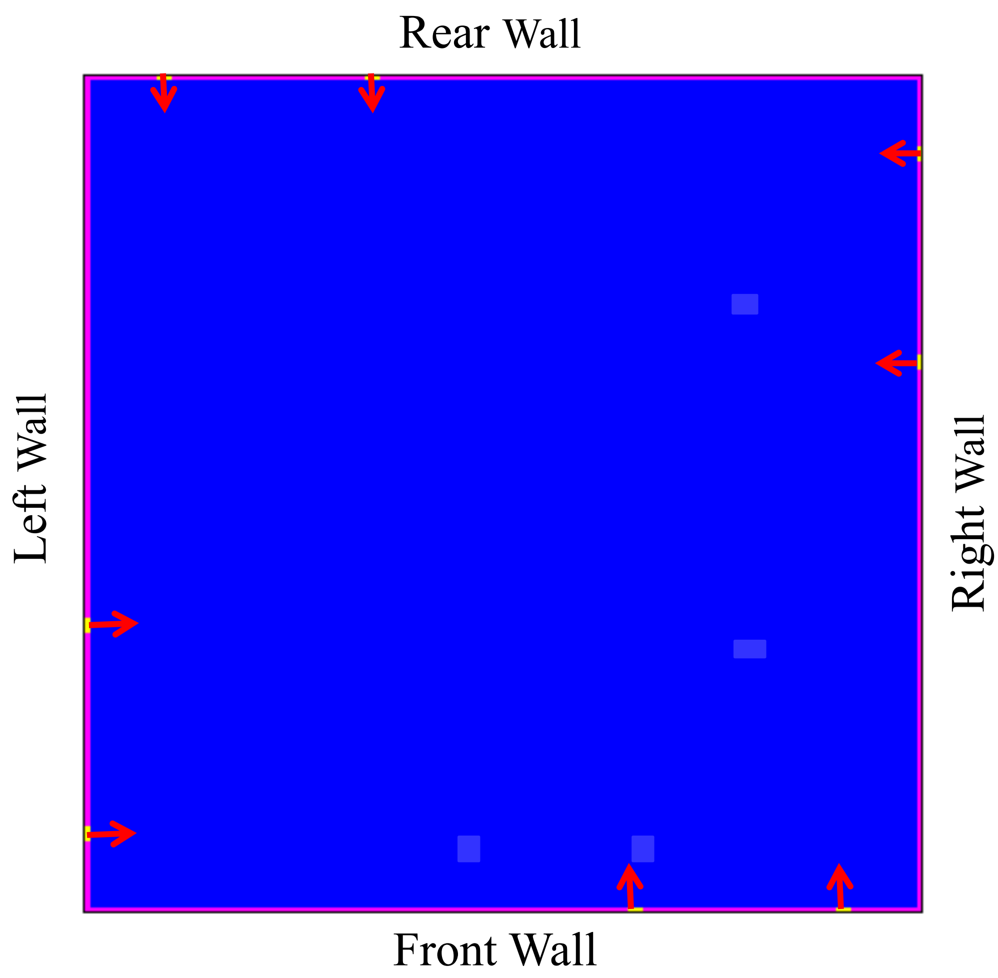
SOFA Arrangement

Configuration B



- SOFA ports 26% larger than in Configuration A
- Same SOFA Elevation as Configuration A
- Ports sized for jet velocity of 180 fps at lower furnace SR=0.90
- No changes to burner zone compared to configuration A

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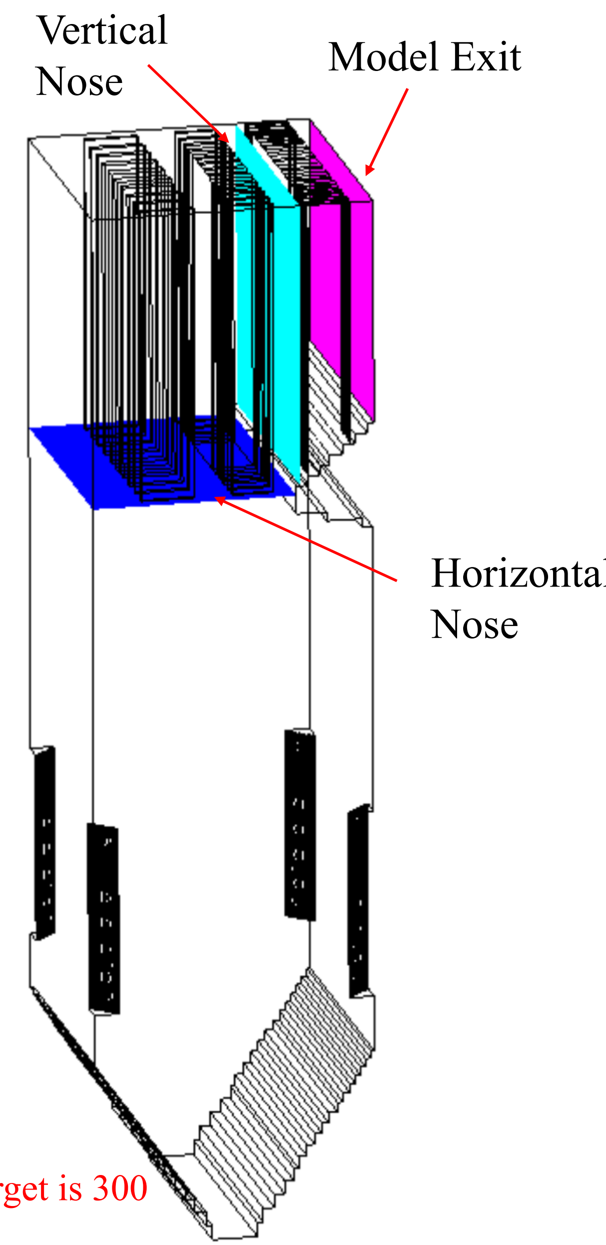
Model Predictions

Configuration B

	Baseline	Config A	Config B
Horizontal Nose			
Gas Temperature (^oC)	1148	1161	1162
CO Concentration (ppm, wet)	28	118	2658
O_2 Concentration (%, wet)	3.1	3.2	3.4
NO_x Concentration (ppm, wet)	238	169	150
Vertical Nose			
Gas Temperature (^oC)	963	926	927
CO Concentration (ppm, wet)	1	1	113
O_2 Concentration (%, wet)	3.1	3.2	3.2
NO_x Concentration (ppm, wet)	238	170	150
Model Exit			
Gas Temperature (^oC)	842	819	821
O_2 Concentration (%, wet)	3.1	3.2	3.2
NO_x Concentration (ppm, wet)	238	170	150
NO_x Emission ($lbNO_2/MBtu$)	0.36	0.26	0.23
NO_x Emission ($mgNO_2/Nm^3$)	447	321	283
NO_x Reduction	N/A	29%	37%
Unburned Carbon in fly ash	0.6%	1.5%	1.4%



Target is 300

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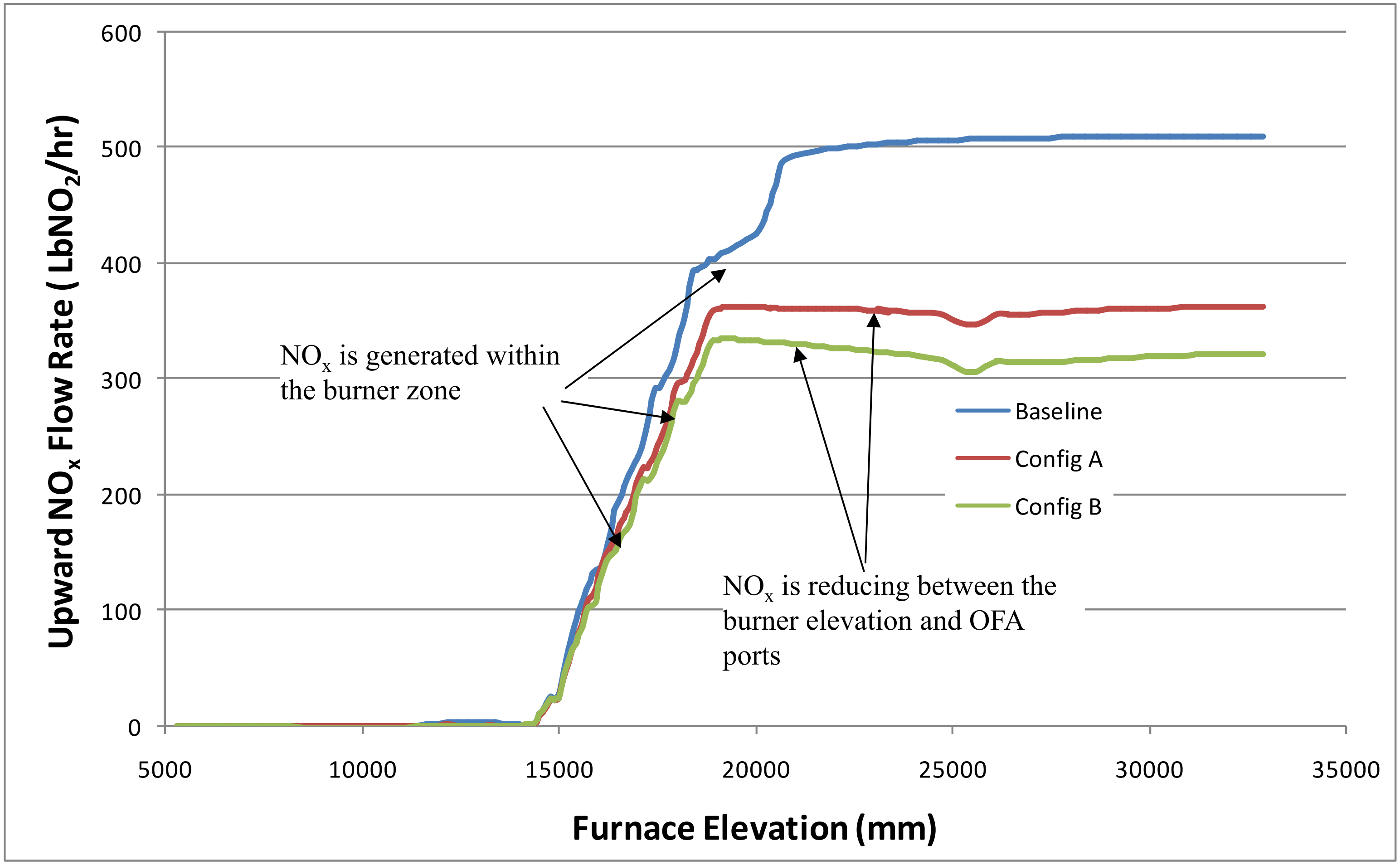
NO_x Flow Rate



Performance Test Results

YiXing Unit #8	Baseline Test (BMCR 480 t/h)	Post Modification Test 1	Post Modification Test 2
Date	2009-4-10	2009-5-24	2009-5-25
Load (BMCR 480 t/h) (%)	94% (450 t/h)	94%	94%
NOx (ppm) A / B	279 / 264	164 / 153	195 / 196
Nox (mg/m^3) @ 6% O_2	502 / 491	263 / 262	334 / 335
O2 (%) (economizer outlet) A / B	3.9 / 4.5	1.9 / 3.1	3.0 / 3.0
CO (ppm) (economizer outlet) A / B	4 / 3	3 / 5	5 / 6
UBC	2.1	2.6 / 2.3	1.71 / 1.77
Boiler Efficiency (LHV)	91.65	92.27	92.64

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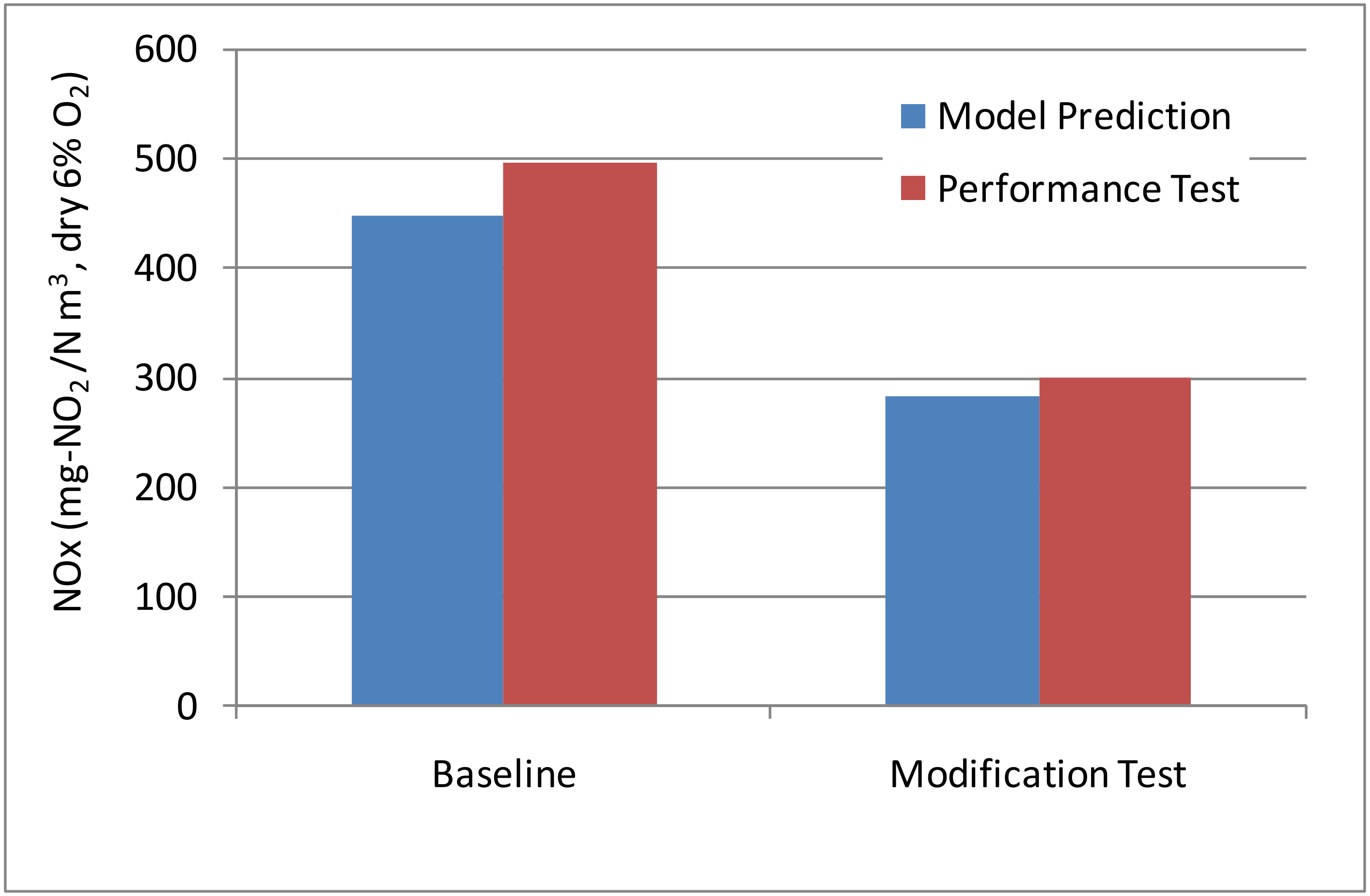
Performance Testing

NOx Emissions



Model Predictions of NOx emissions were in close agreement with pre and post modifications

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Summary
Yixing Combustion Mods.

- ➔ Significant efforts are underway in China to reduce emissions from power plants
- ➔ Smaller, older units need cost effective strategies for achieving emissions reduction targets
- ➔ Using a CFD-based design strategy, LP Amina successfully met NOx performance goals at Yixing-Union Cogen plant in Units 8 and 9 using burners mods and SOFA
- ➔ Efforts are now underway for similar mods in Units 5, 6, and 7

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Classifier Mods

CFD Evaluation

- **Initial modeling application with ball tube pulverizer**
- **Results suggested that existing design concept was less than optimal**
  - **Design Objectives**
    - » Take advantage of natural congregation of coarse particles against pulverizer roof
    - » Reduce coarse particle re-entrainment into primary air
    - » Keep fine particles in primary air flow streamlines
    - » Reduce overall pressure drop

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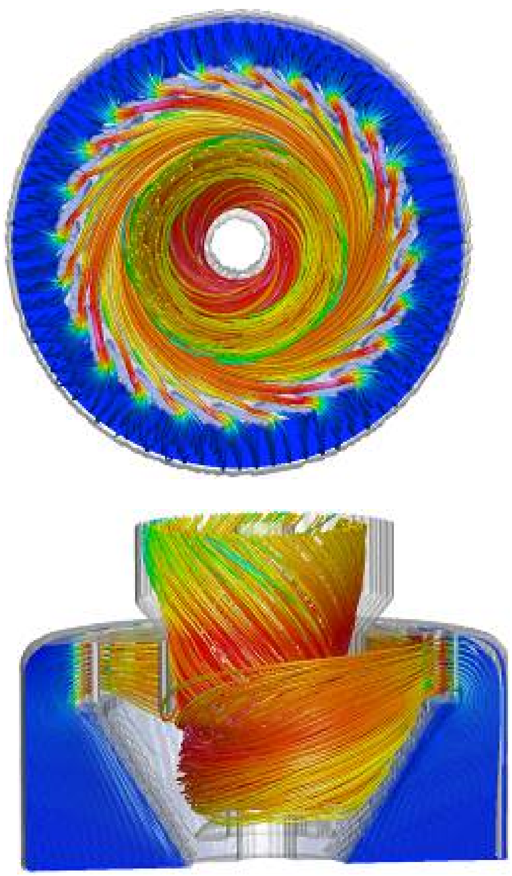
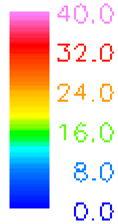
Velocity Streamlines

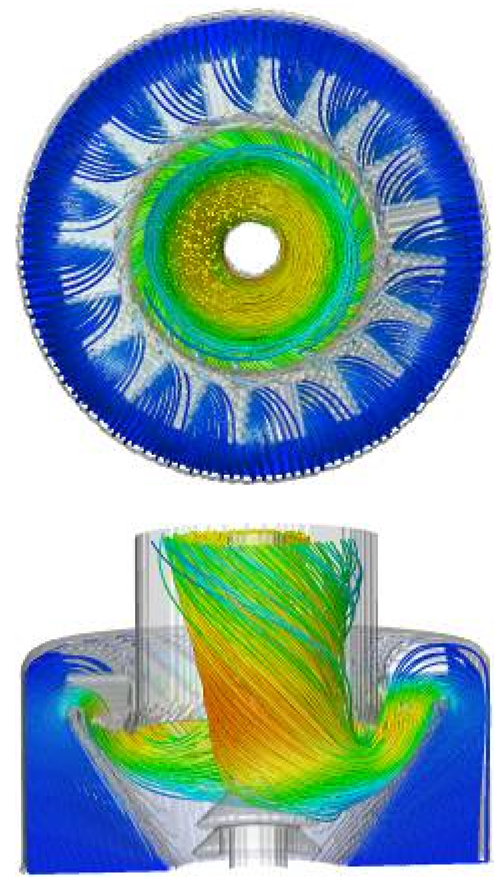
Plan View

Velocity Magnitude (m/s)





Plan View



Sectional Views

Half of Classifier

Baseline

S-Type

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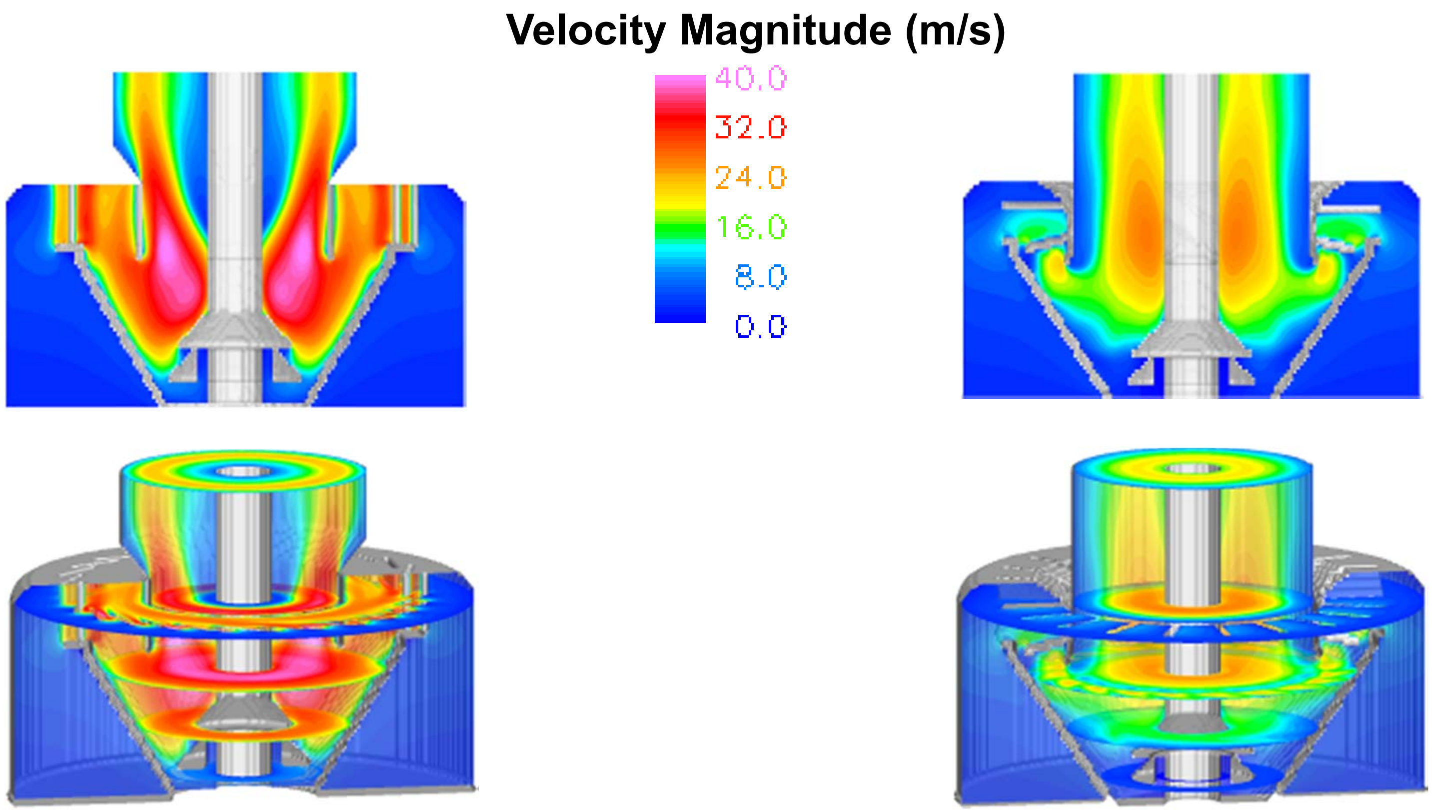
Velocity Magnitude



Baseline **S-Type**

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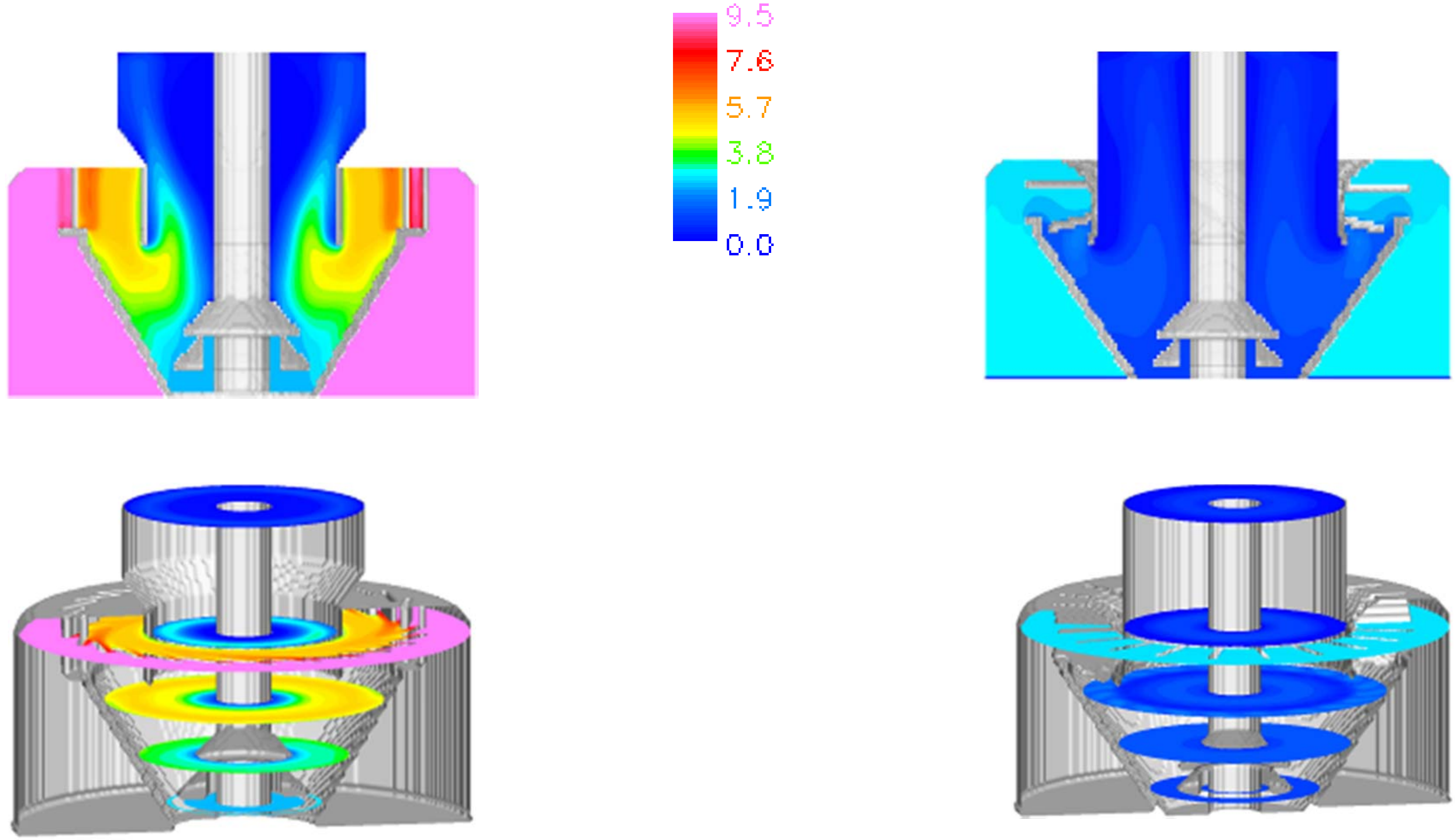
Pressure

Static Pressure (inH_2O)



Baseline **S-Type**

Over 6” wc reduced pressure drop compared to Baseline

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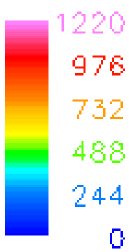
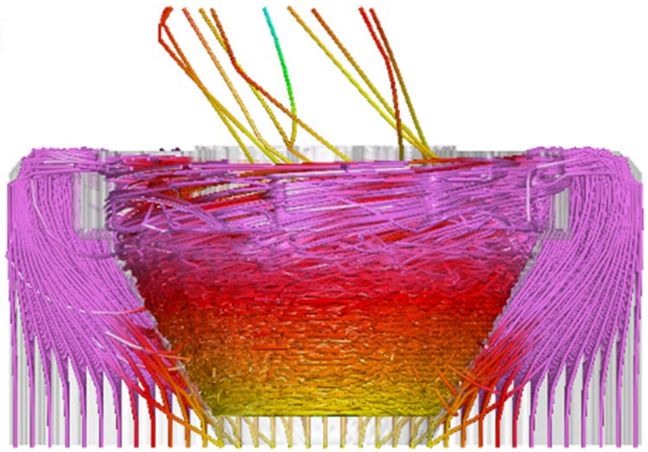
Particle Trajectories

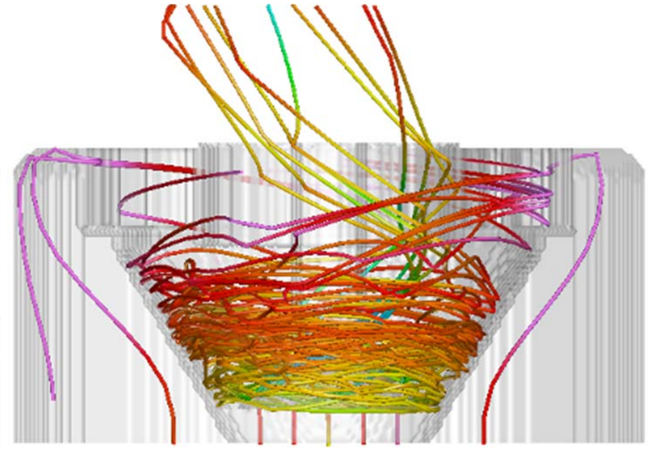
Distance from center of coal pipe (mm)



View of Particles Classified & Exiting

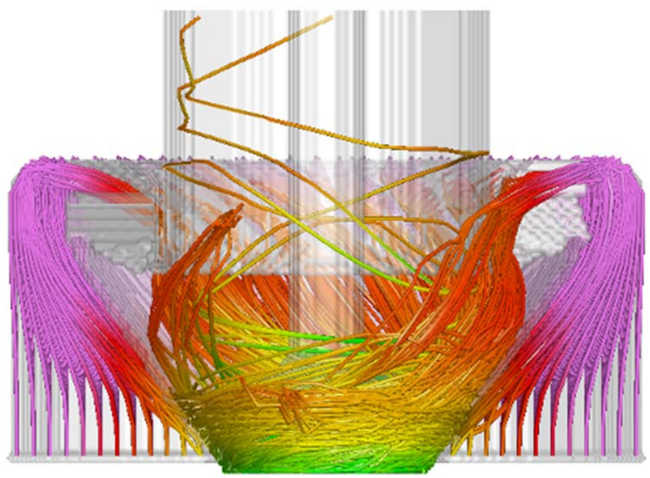


View of Particles Exiting Classifier

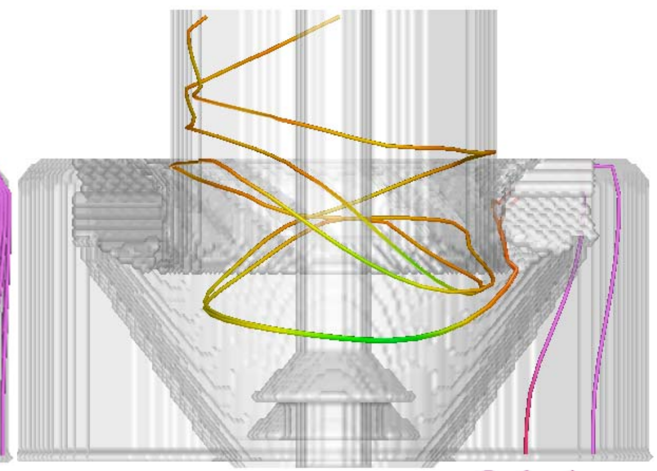


Baseline (*425 μm Particles*)

View of Particles Classified & Exiting



View of Particles Exiting Classifier



S-Classifier (*330 μm Particles*)

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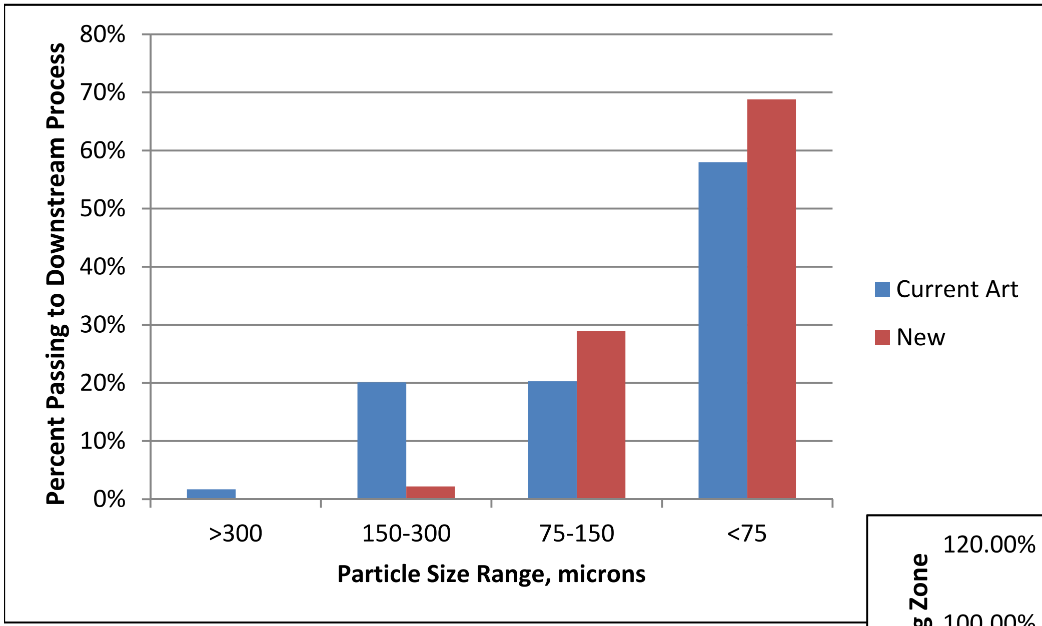
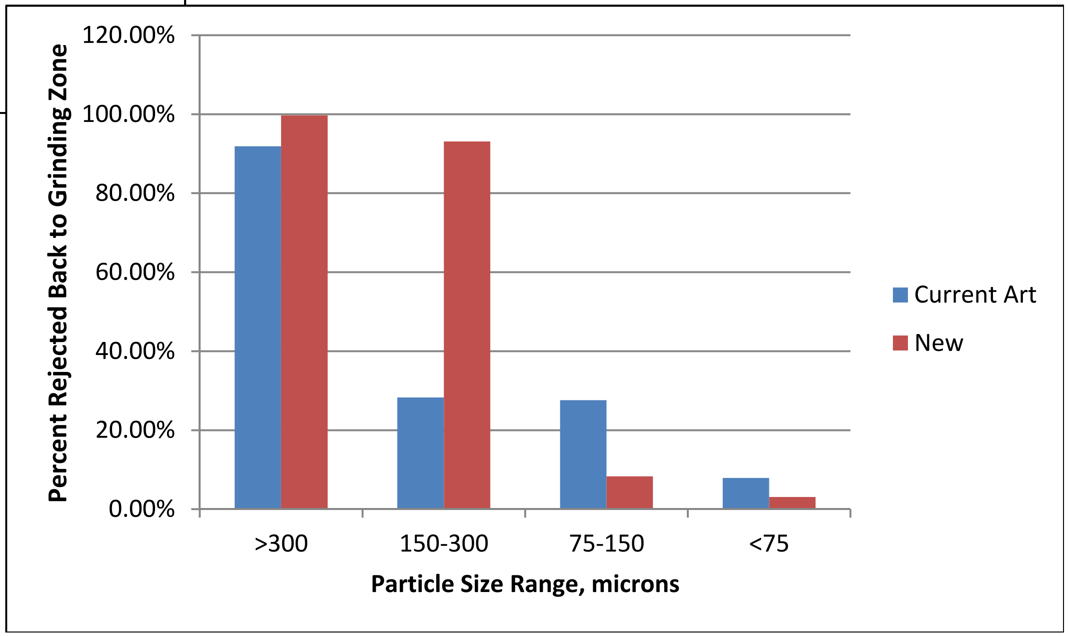
CFD Modeling Results



Note: improved true classification with significantly greater percentages of fines passing through classifier and all of the coarse particles are rejected back to the pulverizer.



CFD Modeling Summary

The S-type classifier design provides the following benefits compared to Baseline

- A finer coal size distribution at the classifier exit (elimination of particles >300 microns or 50 mesh) and more efficient classification – lower percentage of fines recirculated
- 80-90% less erosion through classifier due to lower velocities
- Approximately 6 i.w.c. of pressure drop savings. This translates into
  - Savings in fan horsepower savings
  - Increased mill throughput potentials, particularly if fan limited

Recirculation Ratios:

- Baseline = 28.5%, S-type = 36.6%

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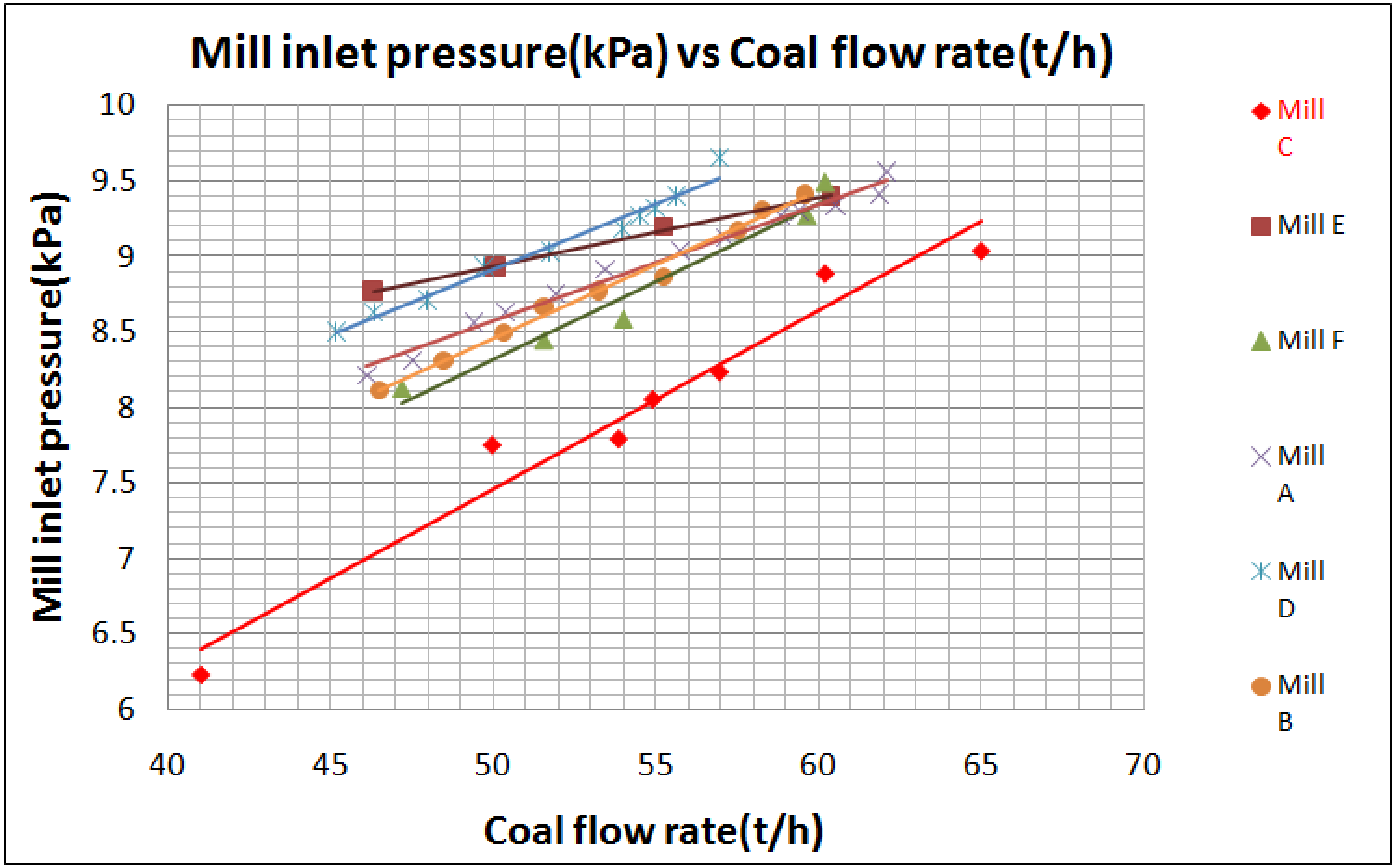
Fengtai Results

Pressure Differential



Pressure reduced by over 1 kPa (4 i.w.c.)

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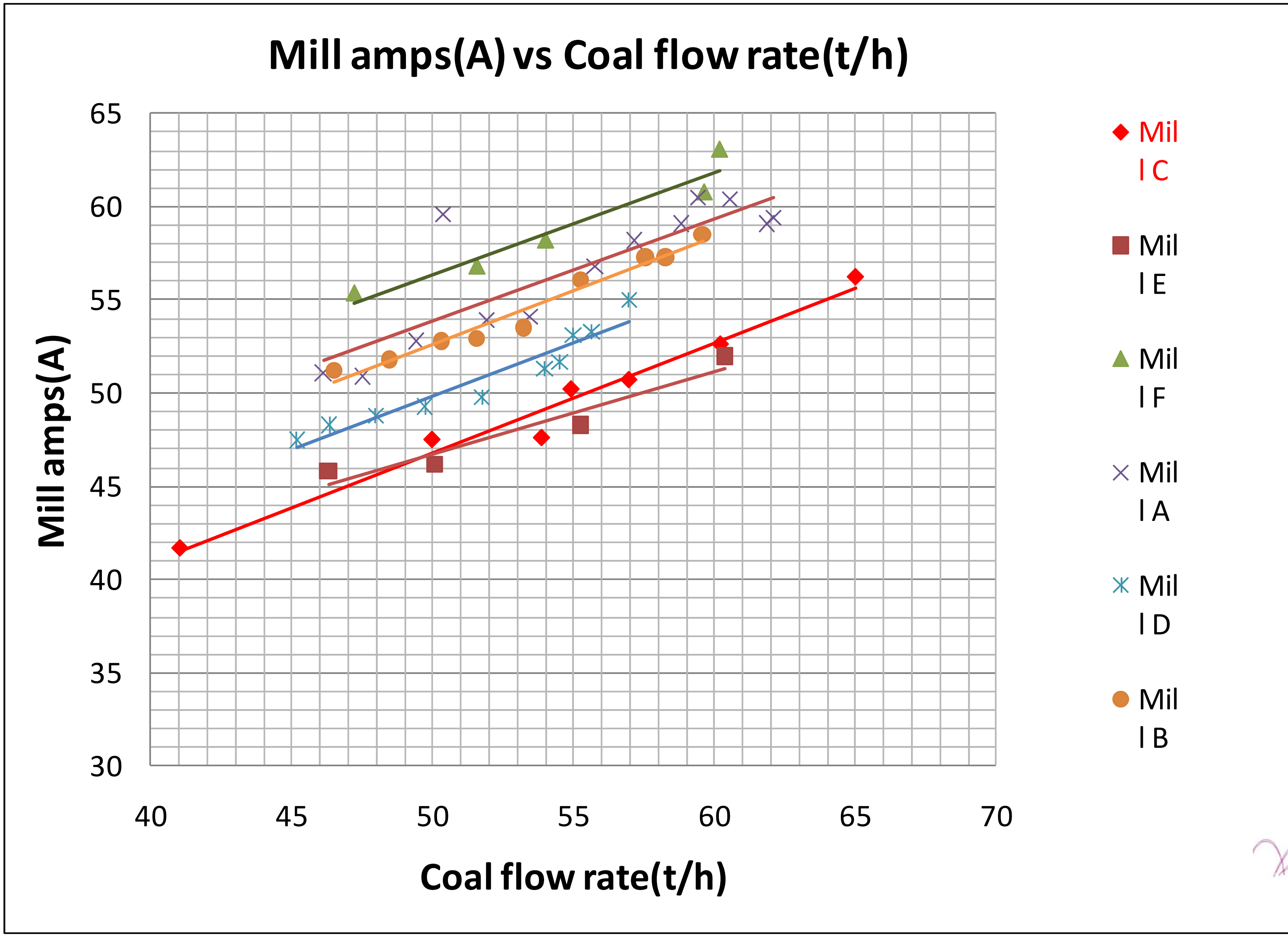
Fengtai Results

Mill Amps



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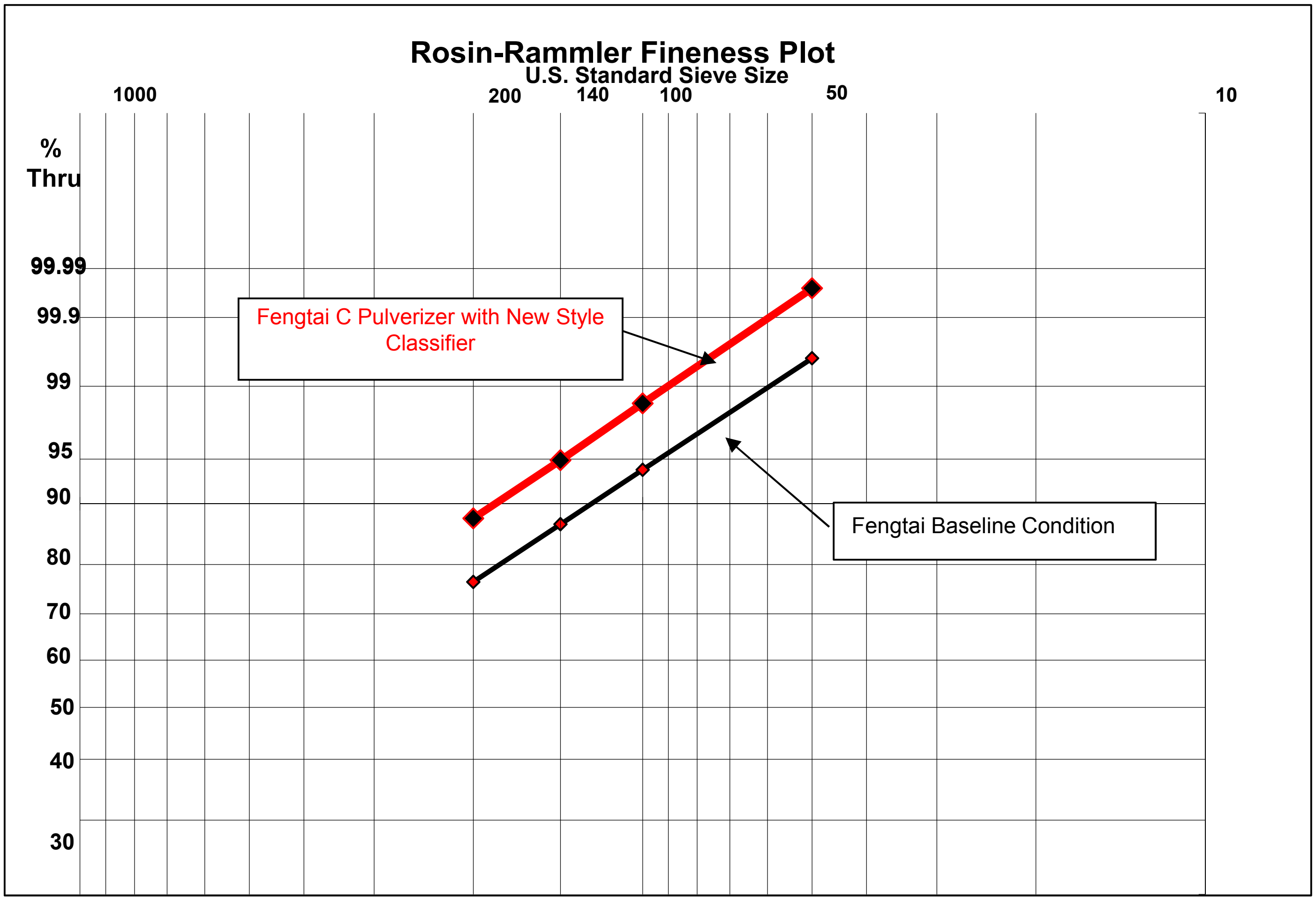
Fineness Improvements



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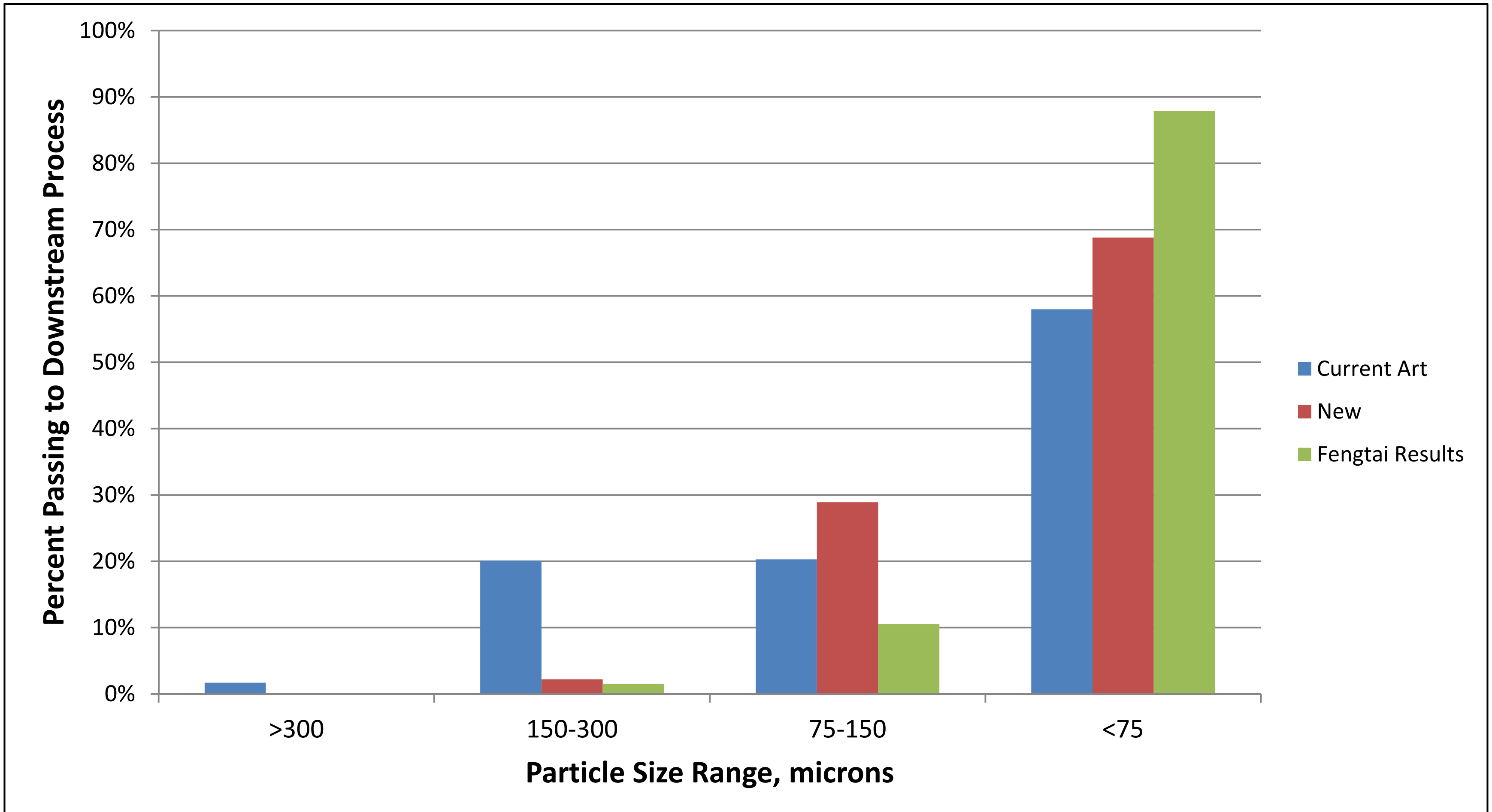
CFD vs. Field Results



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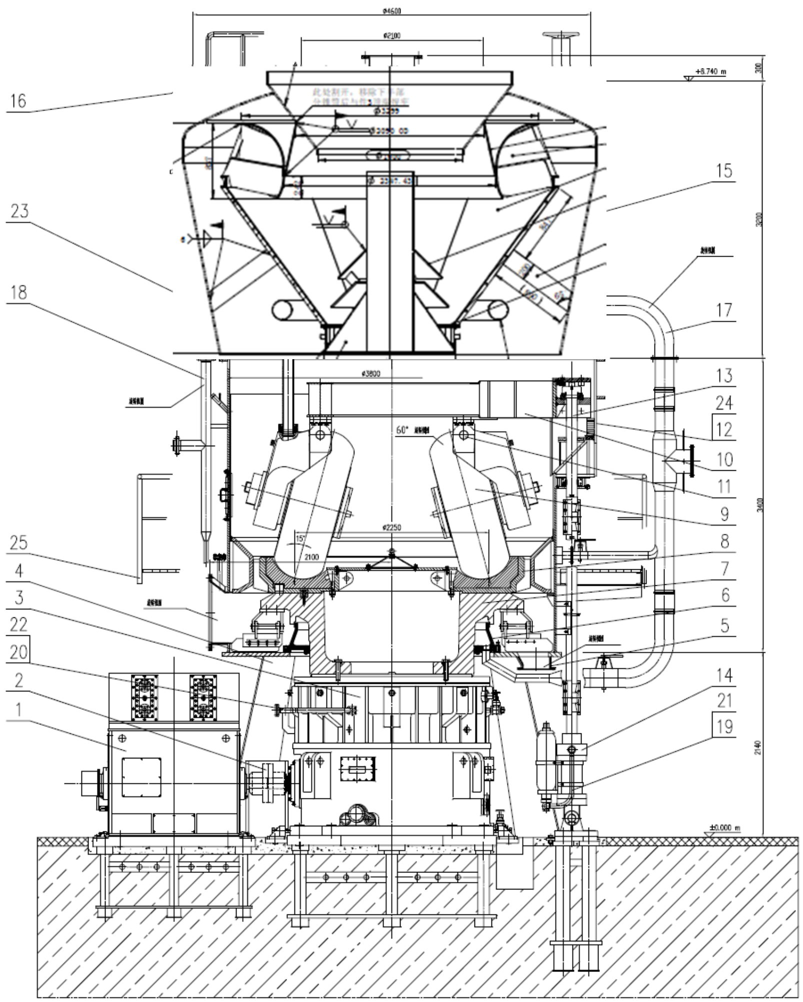
Summary

Fengtai Classifier Mods



Performance

1) Passing 200 mesh	88% (baseline 76%)
2) Retained on 50 mesh	0% (baseline 0.44%)
4) Throughput increase	8%
5) Mill amps	unchanged
6) Reduction in mill dp	> 4 i.w.c.
7) Reduction in classifier erosion	

Anticipated Benefits

1) Add'l NOx Reduction	approx. 10%
2) Unit Efficiency Improvement	improved UBC
3) Add'l unit turndown without oil	5% to 10%
4) Reduction in slagging	
5) Increase in fuel flexibility	

*** Payback period is unit specific, but is generally expected to be well below 1 year

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Thank You

CFD images in this presentation were produced with Fieldview 12.0 by Intelligent Light

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