Computational Fluid Dynamics (CFD) for Combustion and Emission Control System Design and Optimization

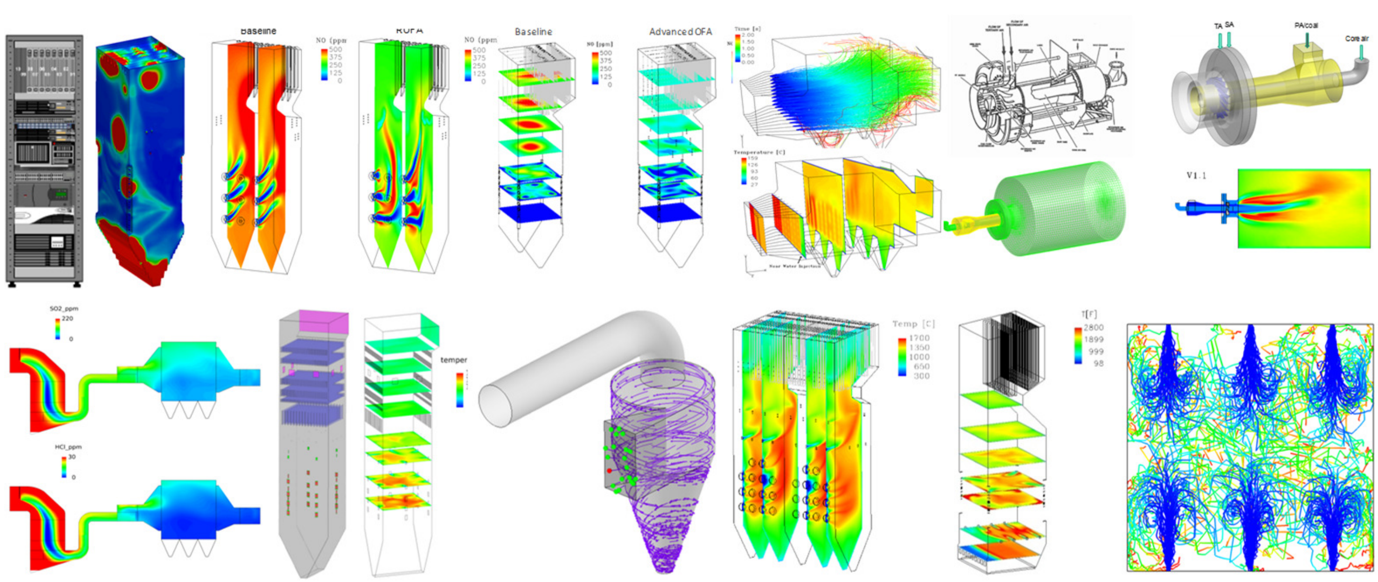
REACTION ANALYTIC SOLUTIONS CORP.

Company Overview

Located in Naperville, Illinois, a western suburb of Chicago, Reaction Analytic Solutions Corporation (RAS) is a newly established corporation that provides analytic consulting services for power generation industry and industrial facilities.

The RAS experts have Ph.D. in Chemical Engineering, and have **20 years of experience** in combustion and air pollution control business, and have designed over **50 industrialized emission control systems worldwide**, including LNB, OFA, SNCR, sorbent injection, ACI, SCR, fuel switch studies, etc. The other expertise includes power plant performance, gasification, clean coal technologies, etc.

RAS uses Computational Fluid Dynamic (CFD) simulation as a major analytical tool to evaluate, analyze, design and optimize furnace combustion and air pollution control technologies. Its 18 years CFD experience covers a full spectrum of boilers from burner design, to furnace combustion, to backend flue gas duct design and proprietary chemistry modeling. Our experts have experience with **over 90 furnace combustion models**.



Computational Fluid Dynamics Modeling

Benefits of CFD Modeling

- Reduces costs—CFD modeling allows designers to predict results before installation, avoiding costly errors
- Saves time—CFD modeling eliminates time consuming on-site trial and error situations and unnecessary costs
- Provides detailed insights—CFD modeling gives insight into furnace operation that cannot be obtained through testing/measurement
- Identifies furnace operational problems and solutions
- Enables pre-installation testing of fuels, equipment, and accessories

Our Experience

RAS's PhD level experts have modeled over **90 models** on a wide variety of boiler configurations and fuel types including:

Boiler systems

- Circulating fluidized bed (CFB)
- Tangential-fired
- Wall-fired
- Cyclone
- Stoker/grate fired
- Kilns
- Various burner types

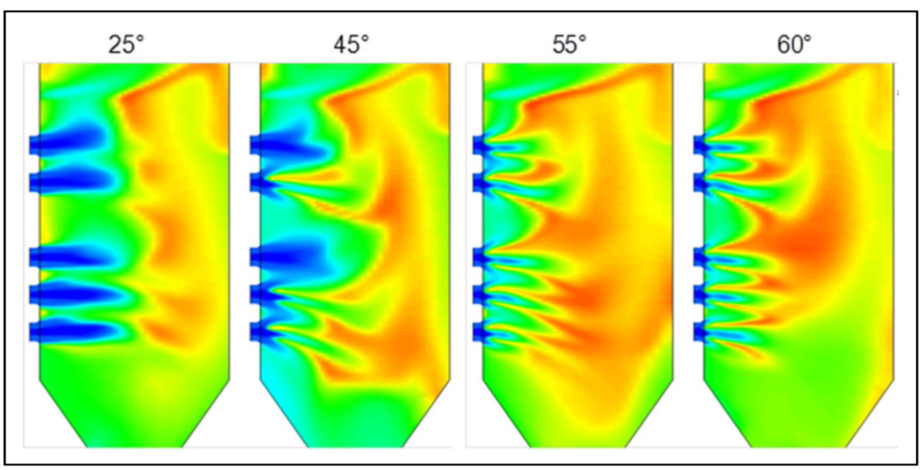
Fuel Types

- Variety of coals
- Biomass
- Biomass co-fired with coal
- Waste products
- Oil
- Natural Gas
- Waste and landfill gases

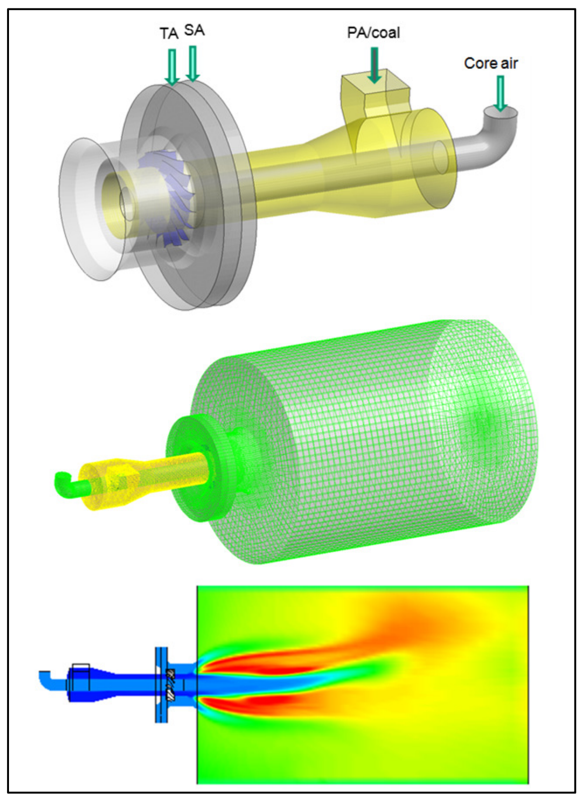
Burner Design and Tuning

Optimize Burner Design for Flame Stability

Burner design and setting are the keys to flame stability in the boiler. We routinely use CFD to perform parametric analysis to optimize burner design, to retrofit modification solutions, and to set the burner settings for specific boilers.



CFD modeling shows the change of flame shape when secondary air swirling angle increases from 25° to 60°



Model of single burner combustion

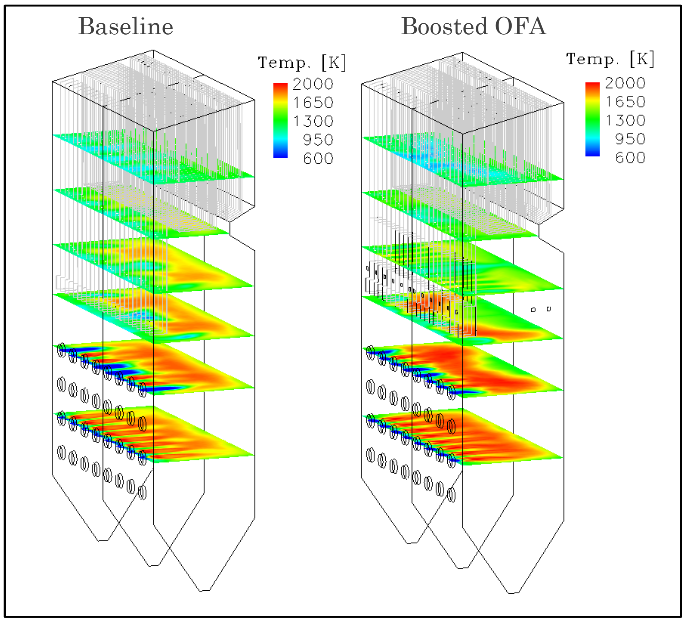
Furnace Combustion and OFA Design

Our Approach to OFA

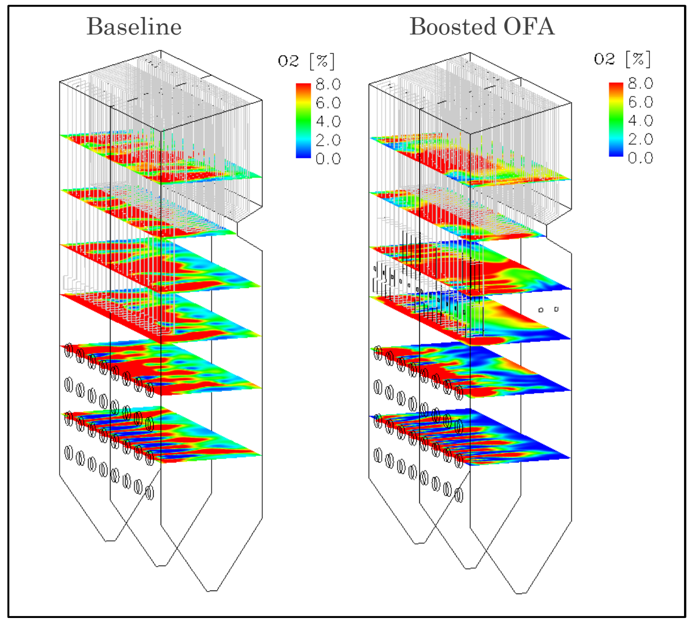
- In conjunction with burner replacement or upgrades
- Conventional OFA and/or advanced boosted or hybrid OFA depending on NOx reduction requirement
- Customized design to fit specific furnace configurations
- CFD combustion modeling to locate the OFA nozzles

Below: Models of a 600-MW wall-fired furnace combustion between baseline and Boosted OFA. The model demonstrates that while Boosted OFA reduces NOx, the furnace O_2 distribution and CO combustion are improved by Boosted OFA high momentum air jets.

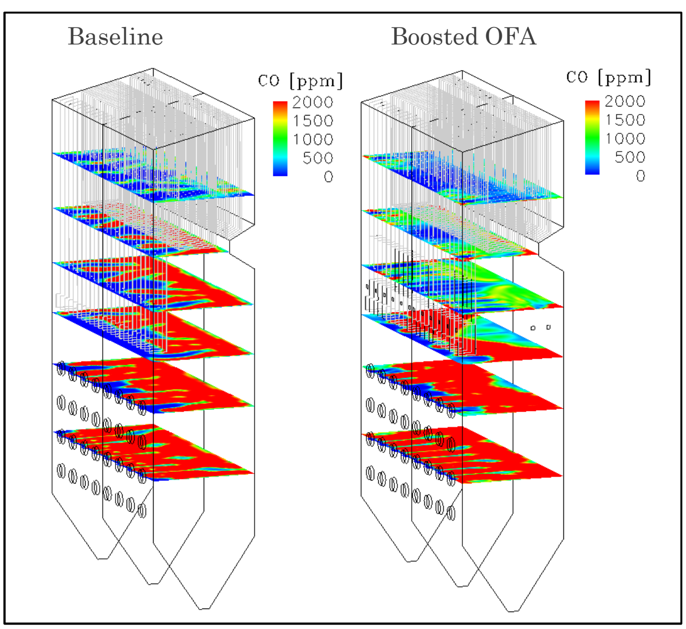
Temperature Distribution



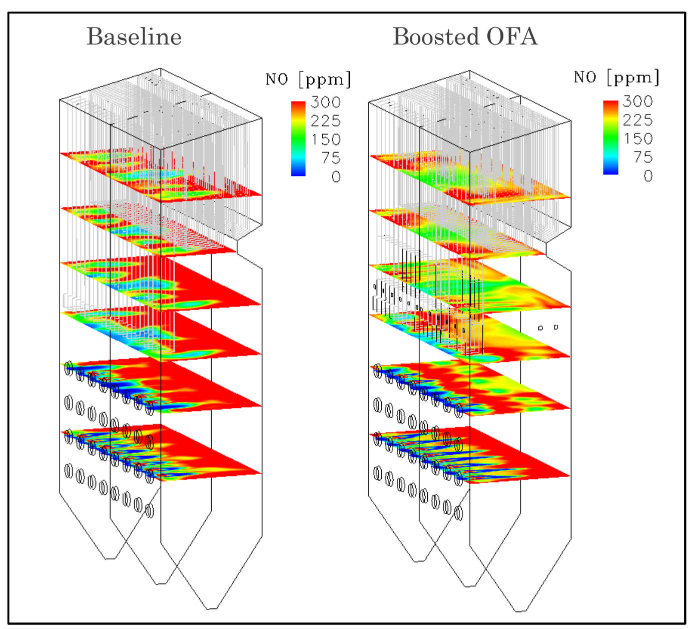
O_2 Distribution



CO Distribution



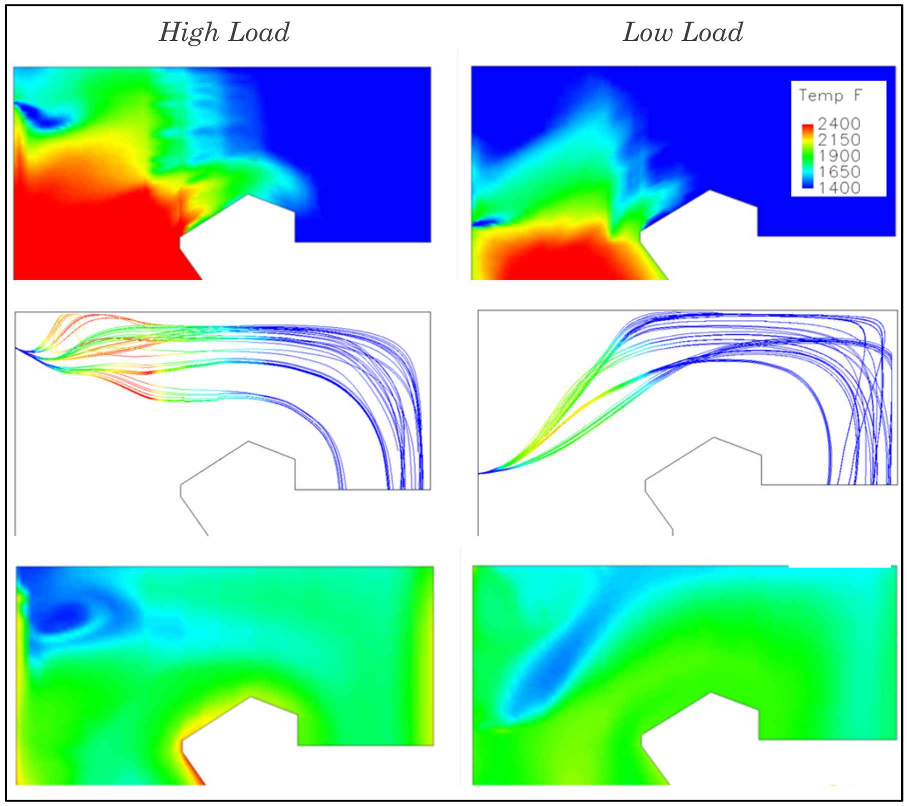
NOx Distribution



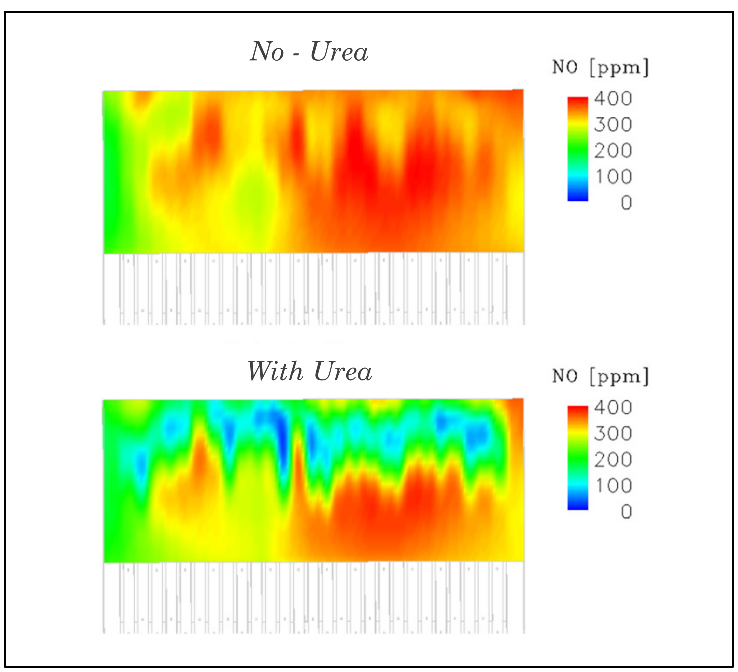
SNCR Design and Optimization

Our Approach to SNCR

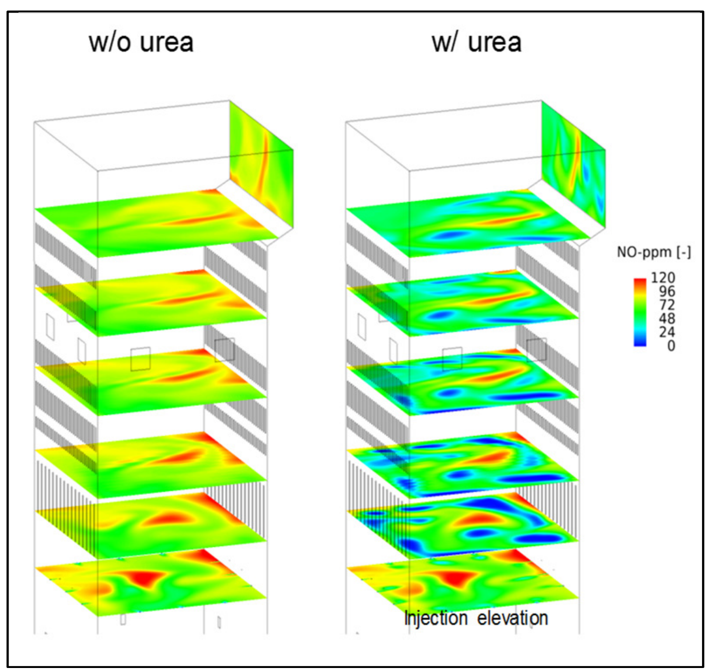
- Temperature measurement is the most important design basis
- CFD of SNCR chemistry to locate nozzles
- Nozzles engineered with different angles
- Multiple elevations for load change
- Adjustable urea concentration
- Individual lance urea flow control
- High chemical utilization efficiency
- Low water usage to minimize efficiency loss
- Reliable system



Models of furnace temperature (upper), urea injection trajectory (middle) and NOx concentration (lower) of SNCR system, as applied to a 700 MW boiler.



Model of furnace outlet NOx concentration without urea injection (upper) and with urea injection (lower) for a 420-MWe wall-fired unit.



Model of furnace outlet NOx concentration without (left) and with urea injection (right) for a 350-MWe tower furnace burning lignite.

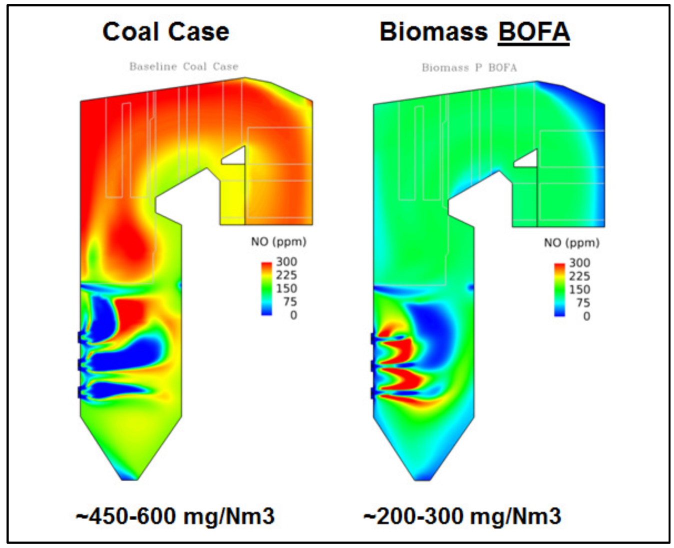
Fuel Switch Combustion Engineering

Solutions for Fuel Switch and Impacts on Boiler

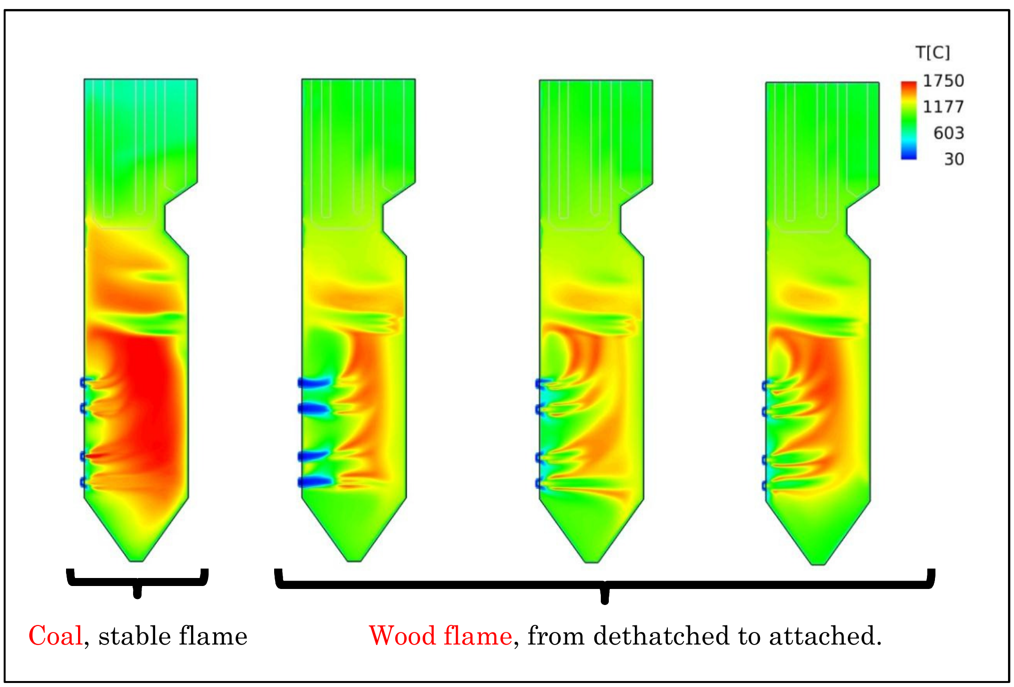
RAS offers coal-to-gas, and coal-to-biomass fuel switch studies. We have unmatched expertise and extensive experience on biomass cofiring and conversion projects.

Our capabilities include:

- Burner modification or retrofit
- Evaluate impact of fuel properties on furnace combustion, (*e.g.*, moisture content, particle size, volatile matter content, etc.)
- Control of slagging and corrosion formation
- Impact on furnace exit gas temperature and hence steam temperature and boiler efficiency
- Application of emission control technologies



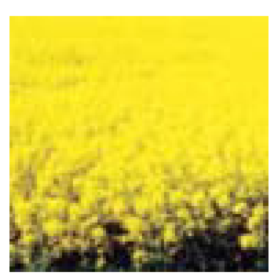
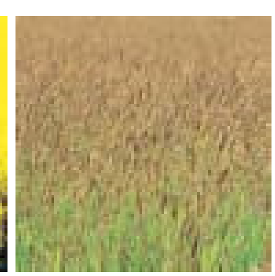
CFD modeling of coal-to-wood conversion for a 500 MW wall-fired furnace. Modeling shows predicted NOx emissions between coal and biomass with BOFA NOx reduction technology.



CFD modeling of coal-to-wood conversion for a 500 MW wall-fired furnace. Modeling shows significant combustion differences between fuels and burner settings





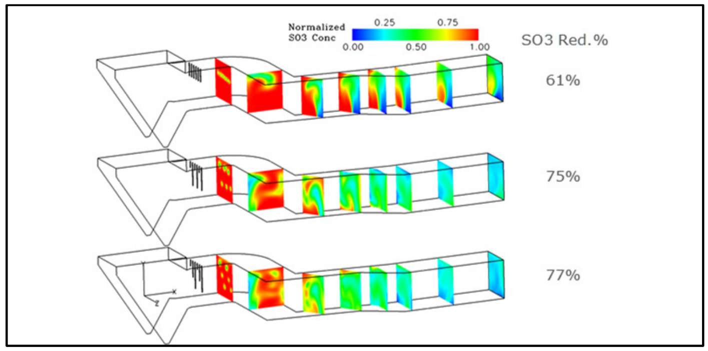



Dry Sorbent/Activated Carbon Injection

Integrated with Proprietary Kinetic Chemistry Submodels

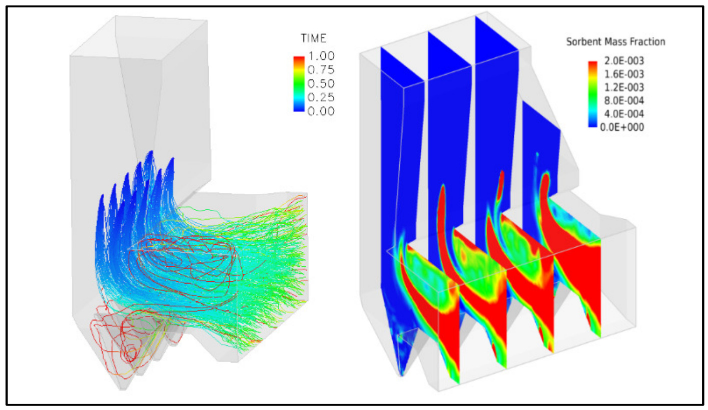
Reaction Analytic Solutions has significant modeling experience and strong capability in design and optimization of Dry Sorbent Injection (DSI) and Activated Carbon Injection (ACI) technology for pollutants removal from flue gas. In addition to Conventional CFD flow modeling, we have incorporated a number of our in-house proprietary sorbent chemistry sub-models, including:

- Hydrated lime + SO_3
- Hydrated lime + HCl/SO_2
- Trona + HCl/SO_2
- Limestone + SO_2
- Activated carbon + $Hg/HgCl_2$



CFD predictions of SO_3 concentration and reduction percentage for a DSI system on a 450-MWe unit for 3 Cases with injection lances.

The following table summarizes the advantages of chemistry-based Advanced CFD modeling versus flow-only (or non-chemistry) Conventional CFD modeling, in terms of CFD outlet and evaluation capabilities. Advanced CFD model provides "real-life" predictions, including not only the mixing and flow related output that a conventional CFD can provide, but also gas species concentration and reduction predictions. Advanced CFD model approach provides a much comprehensive and useful tool for evaluating a number of important design/operating parameters as well as sorbent properties.



CFD model to determine injection locations and number of injections to obtain the best coverage of sorbent downstream before airheater inlet

	Conventional CFD Model (Flow-only)	Advanced CFD Model (Chemistry-Based)
CFD Output		
Particle Concentration Distribution	√	√
Particle Concentration RMS	√	√
Particle Trajectory	√	√
Pollutant Species Concentration	-	√
Pollutant Reduction	-	√
Evaluation Capability		
Impact of Injection Strategy	√	√
Impact of Residence Time	-	√
Impact of Flue Gas Temperature	-	√
Impact of Inlet Species Concentration	-	√
Impact of Sorbent Type	-	√
Impact of Sorbent Size	-	√
Impact of Sorbent Porosity	-	√
Impact of Sorbent Surface Area	-	√
Impact of Sorbent Flow Rate	-	√

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