Reinhold Environmental Ltd.

2009 NOx-Combustion Round Table & Expo Presentation

February 9 & 10, 2009, Cleveland, OH

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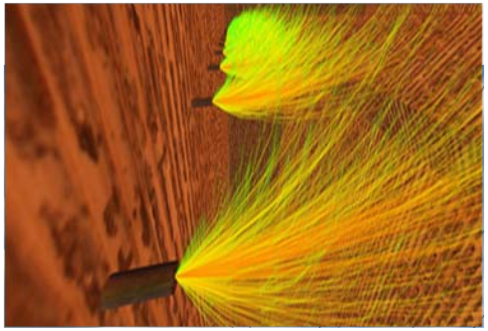
Technologies to enable clean efficient energy™





Targeted-In-Furnace Injection for Slag Control (TIFI)

J.M.Filipski

February 10, 2009

FUEL CHEM® Applications

- Coal
  - Fuel Chem Programs address slag-forming constituents in a wide range of coals throughout the world
- Oil
  - High Sulfur Oil
  - High slagging oil (Mexico)
- Other Fuels
  - Biomass
  - Pulp and Paper Black Liquor Boilers
  - Municipal Solid Waste (TCI™ Technology)

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FUEL CHEM® Program

- Slag – the iron, sodium and other minerals in coal that do not burn
- Above the ash fusion temperature these minerals melt and adhere to steam pipes and boiler walls
- More economical coals can have higher slagging properties
- Traditional removal methods
  - During Operations:
    - Air / water cannons
    - Thermal shocking
  - Shotguns
  - During Outages (6-10 days):
    - Dynamite
    - Mechanical Removal with Scrapers / Chisels / Etc.

Example of a clinker fall

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FUEL CHEM® Program Benefits

❑ Efficiency

- Recovery of Derated MW
- Heat Rate Improvement for Steam Production
- Reduced Fan Power Requirements
- Reduced Sootblowing
- Reduced Operating O_2 Level
- Reduced CO in Furnace and at the Stack
- Increased Fuel Flexibility

❑ Availability and Reliability

- Reduced Forced Outage Time
- Reduced Derates
- Increased Capacity and Boiler Availability
- Reduced Outage Cleaning Times
- Reduced Exit Gas Temperatures

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Additional FUEL CHEM® Benefits

❑ Environmental

- CO_2 Reduction
- SO_3 Reduction
- Opacity Improvement
- Promotes Mercury Capture
- Reduced Large Particle (LPA) Ash

❑ Safety

- Reduced Maintenance Operations

❑ Maintenance

- Reduced Corrosion in Economizer, Air Heater, Ductwork, and Stack
- Reduced Clinker Grinder Maintenance
- Tube Life Extension
  - Reduced Sootblowing
  - Reduced Slag Damage
- Reduced Cleaning Expenses
  - Less Explosives
  - Lower Water Consumption

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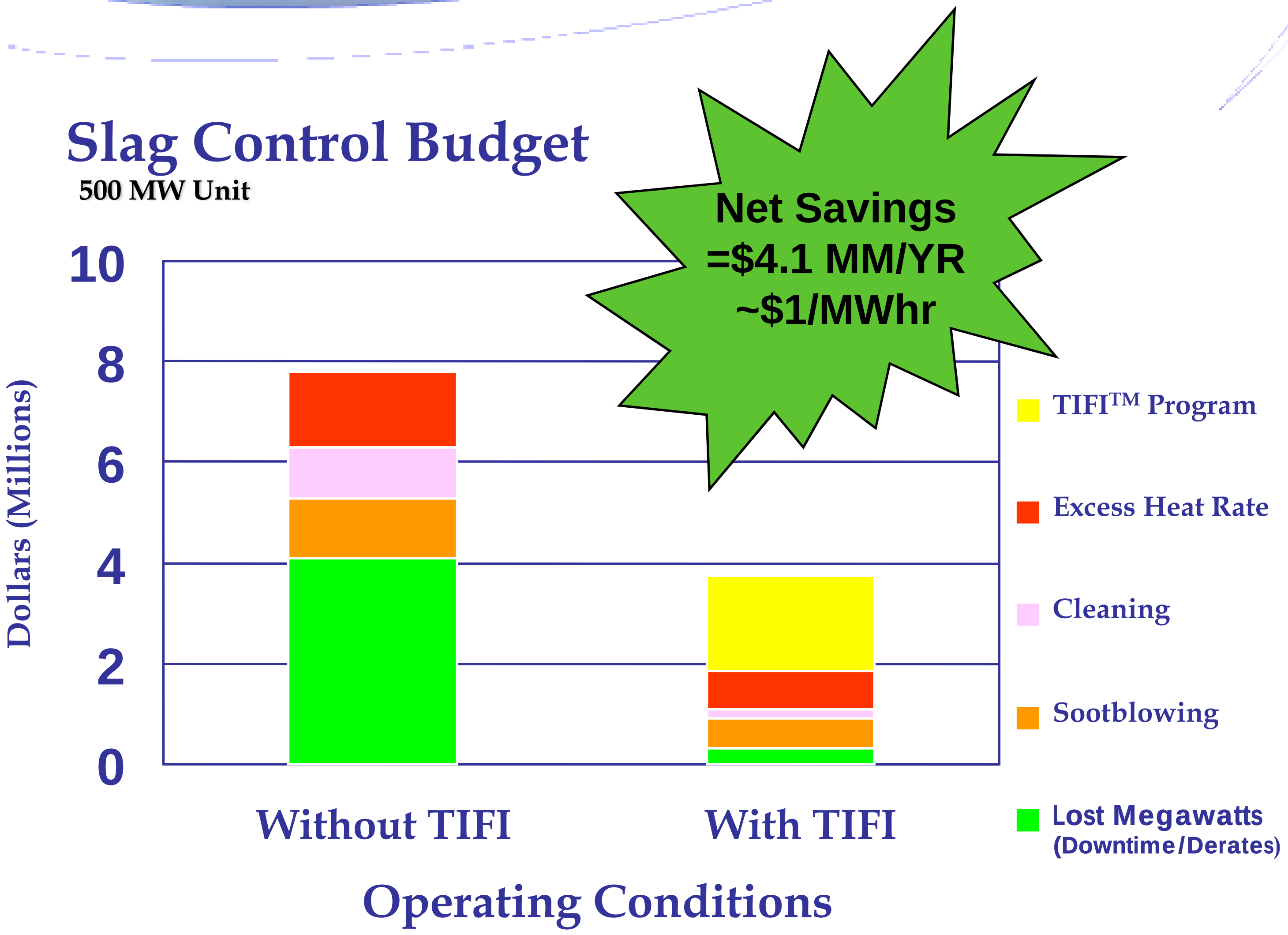
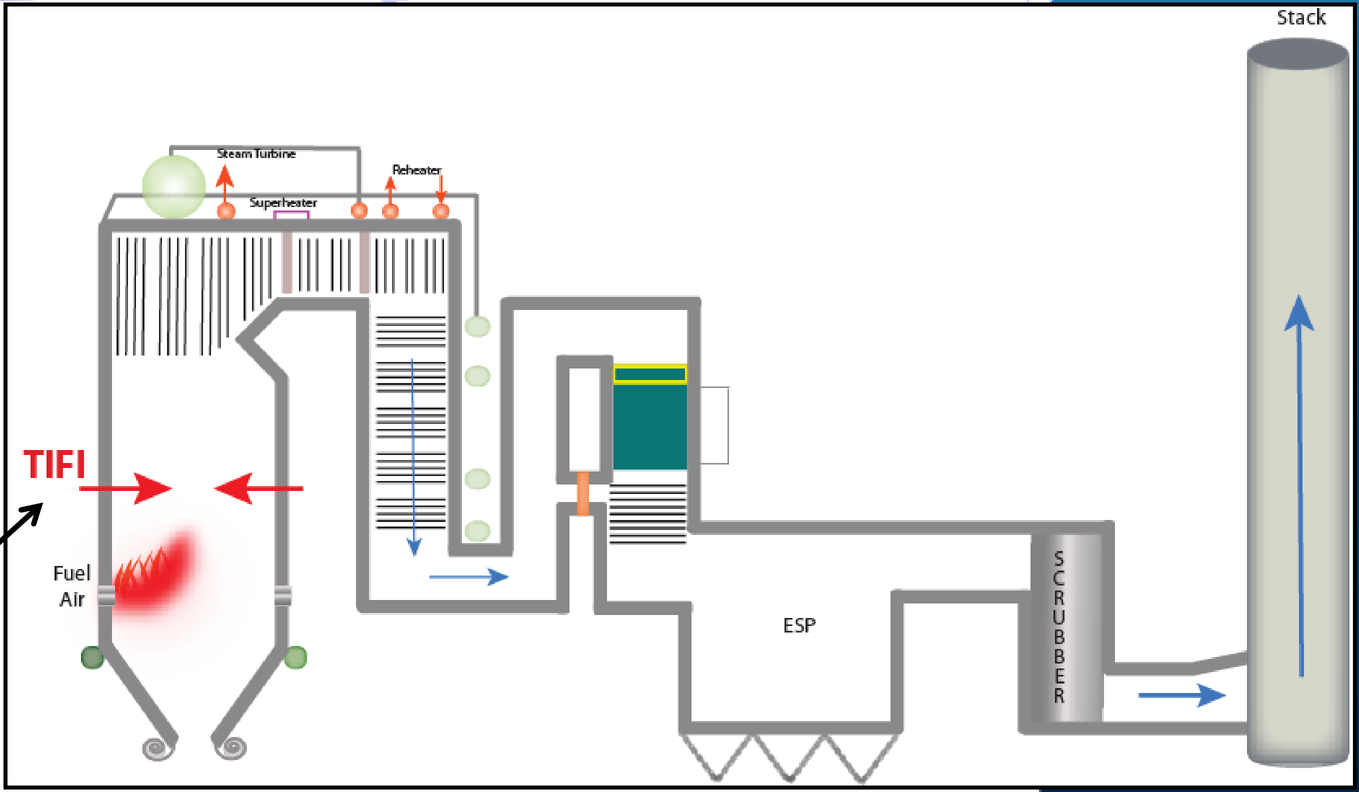
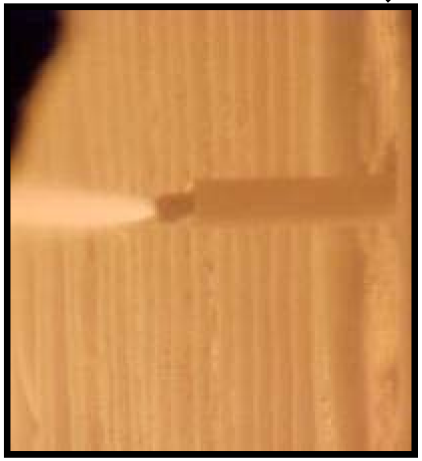
Cost Reduction with TIFI™



FUEL CHEM® TIFI Overview

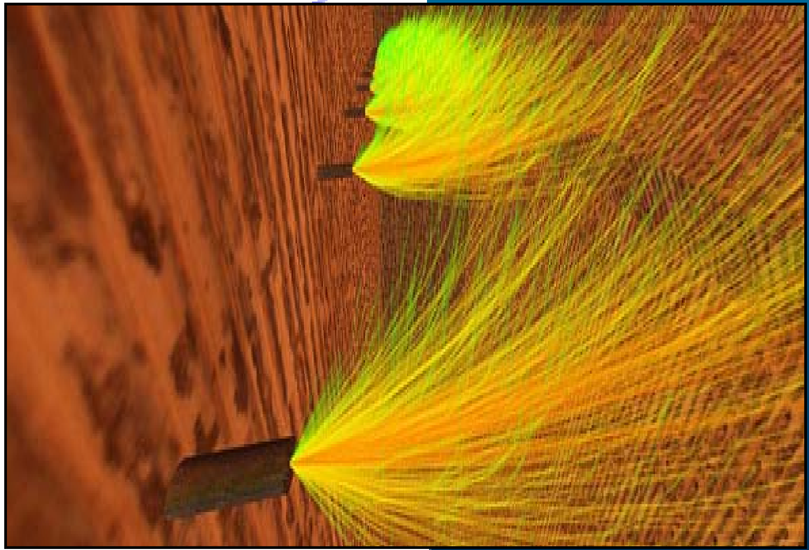


TIFI nozzle injecting Magnesium Hydroxide



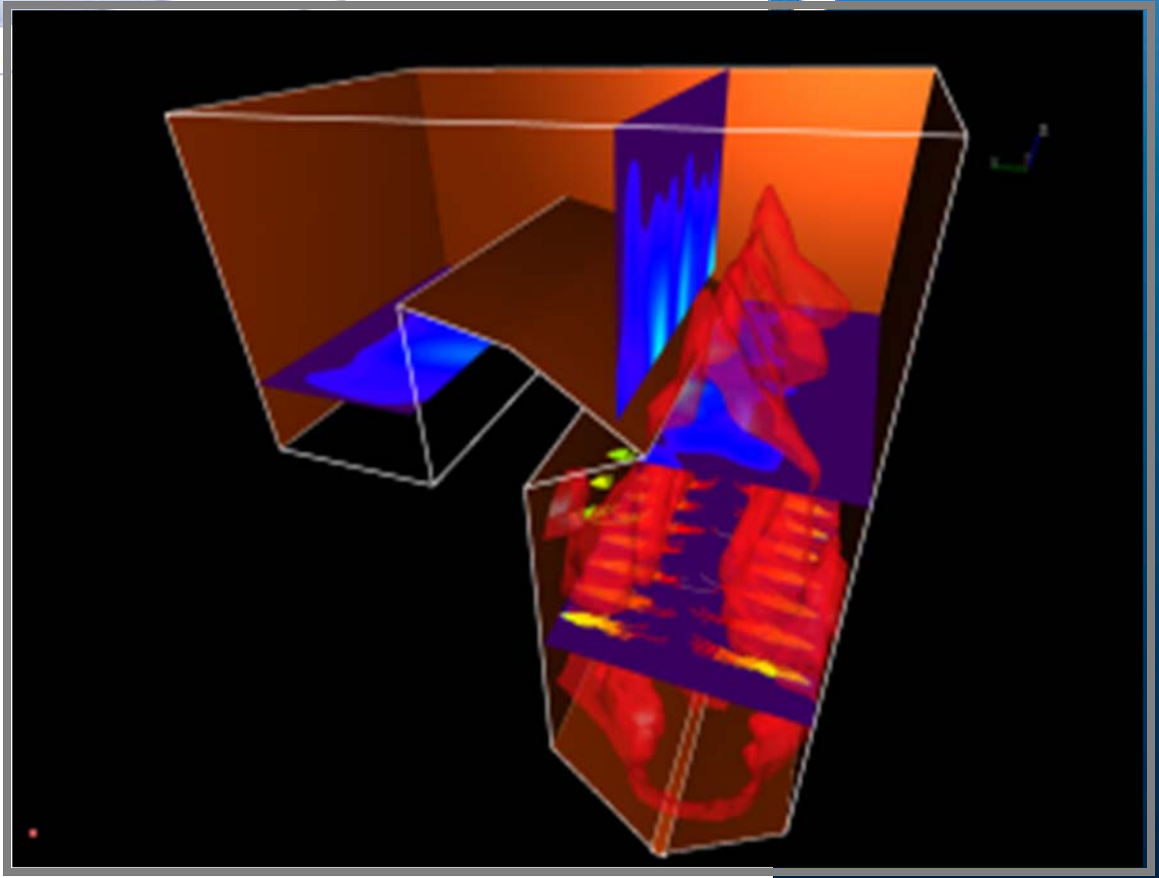
TIFI™ Targeted In-Furnace Injection™ Program

- Patented process for the injection of chemicals using Computational Fluid Dynamic (CFD) modeling as the primary design method
- Critical Criteria
  - Furnace gas flows and temperatures
  - Chemical distribution, particle size and feed rate


TIFI™ Injector on boiler wall

Computational Fluid Dynamics Modeling

- **Chemical injector sprays (yellow)**
- **Chemical concentration contours (purple and blue)**
- **Temperature isocontours set to the coal ash fusion temperatures to predict potential slagging areas**



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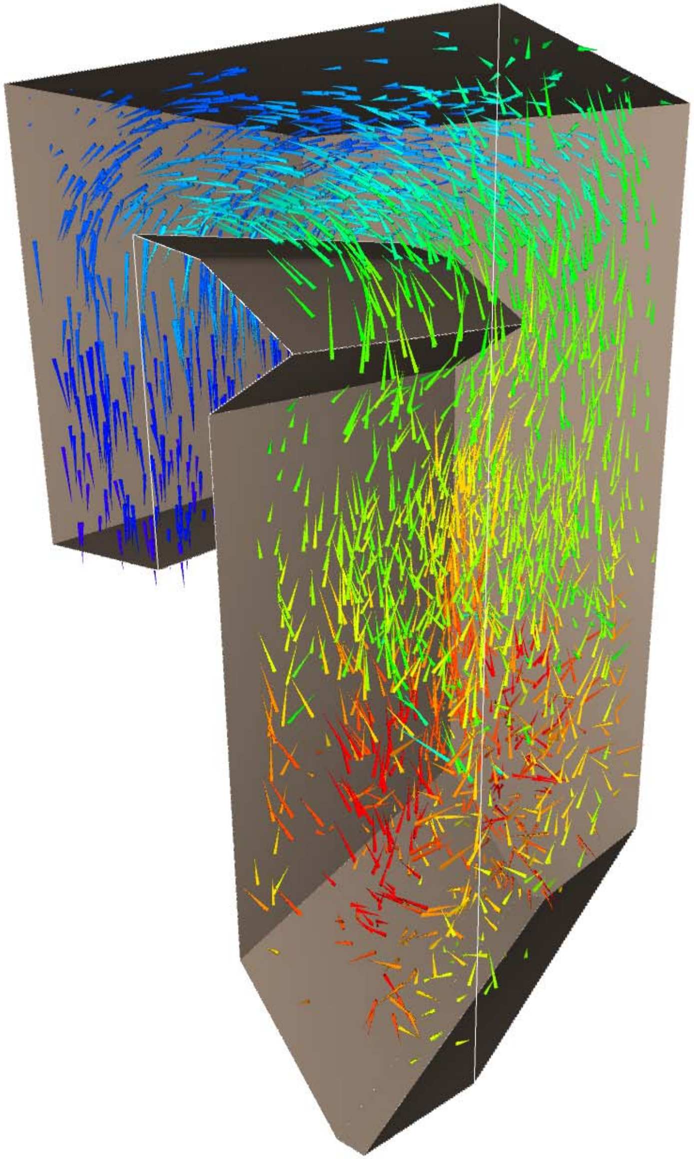
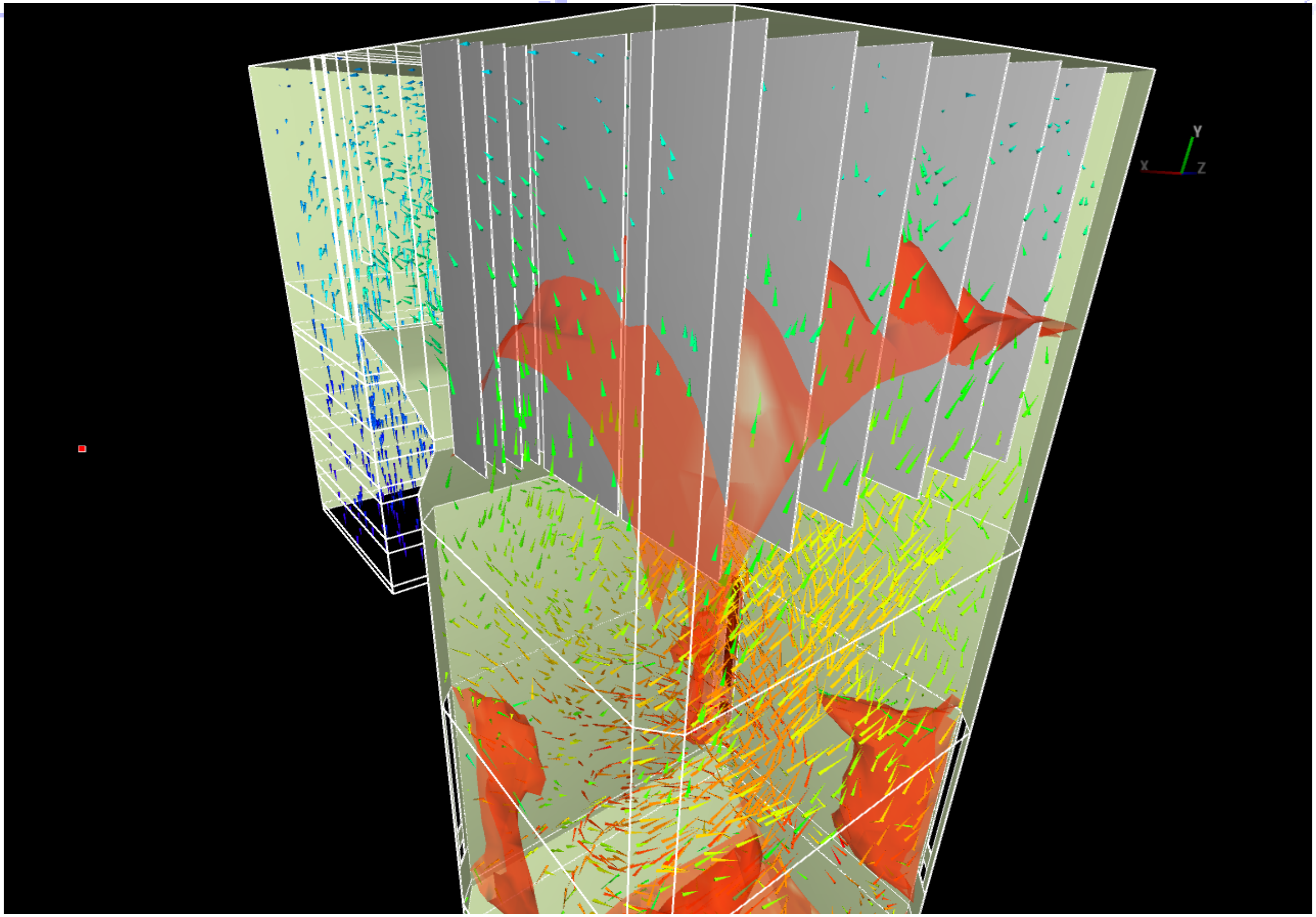
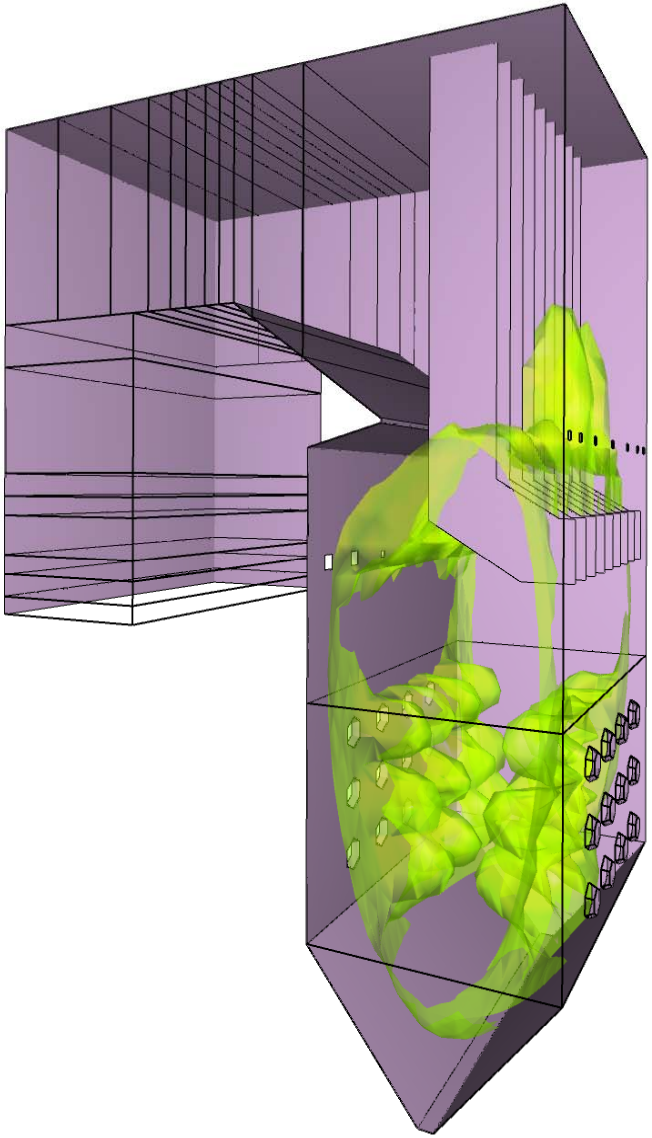
Flue Gas Flow Vectors



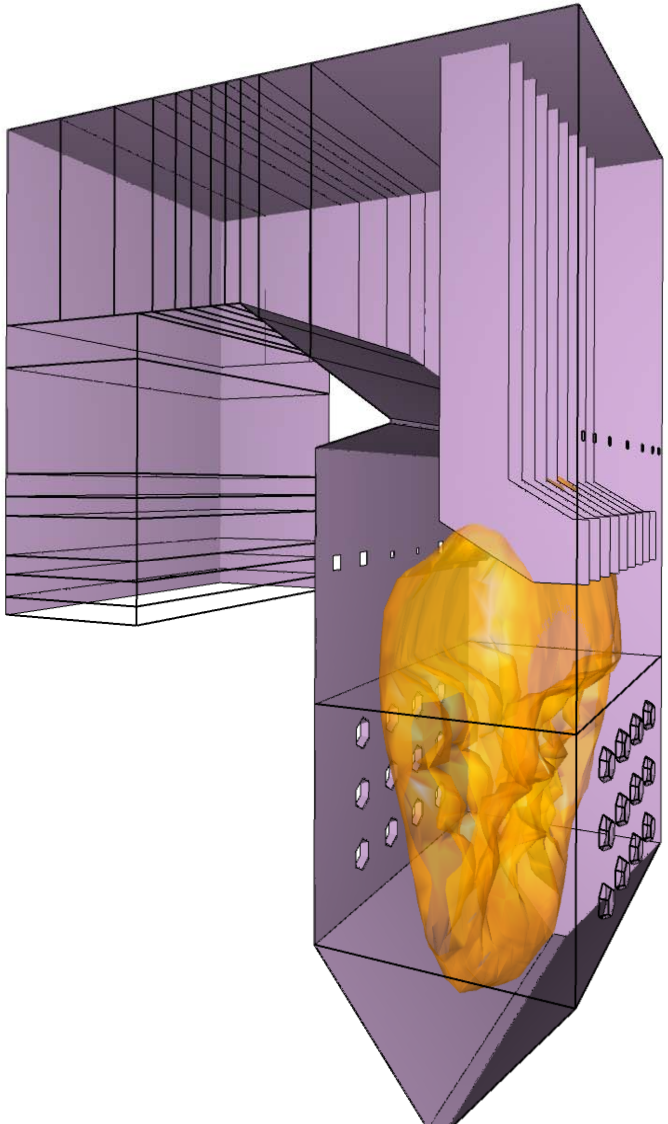
CFD Visualizations of Temperature Surfaces



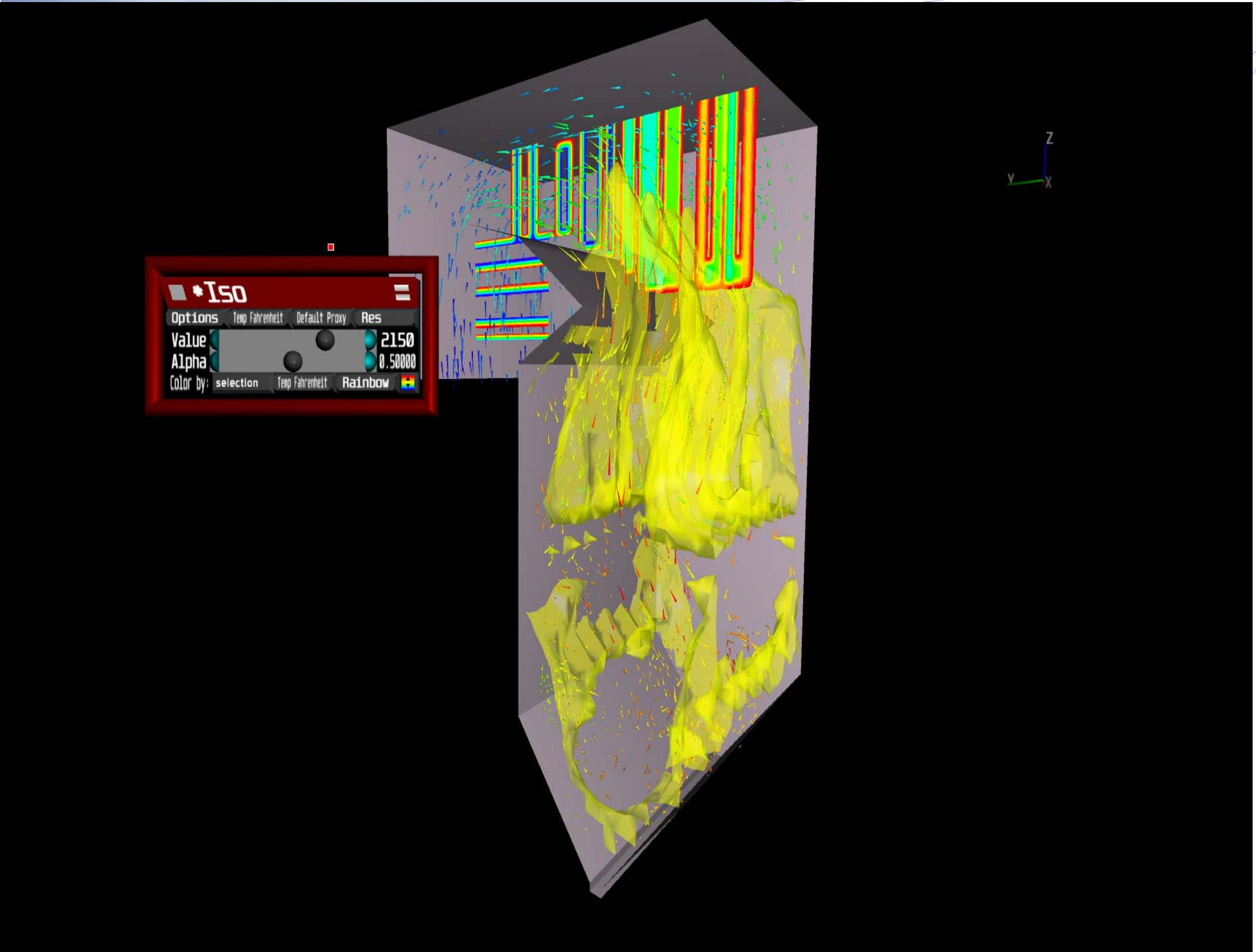
Potential Slagging Areas (Reducing)



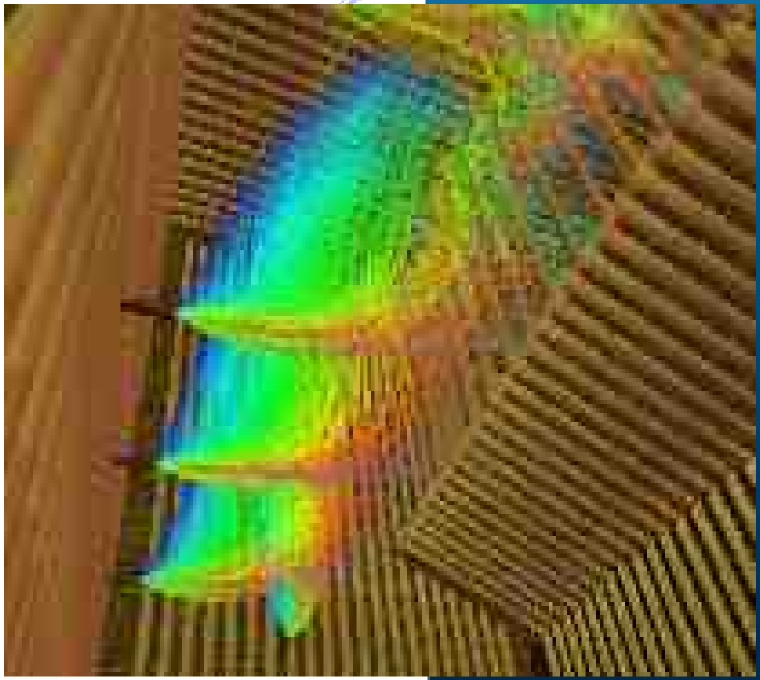
Potential Slagging Areas (Oxidizing)



Iso-surface at 2150 F



- **Understanding droplet characteristics and trajectories in the boiler environment is critical.**
- **Laser characterization studies of Fuel Chem injectors have been done to accurately predict these droplet characteristics.**



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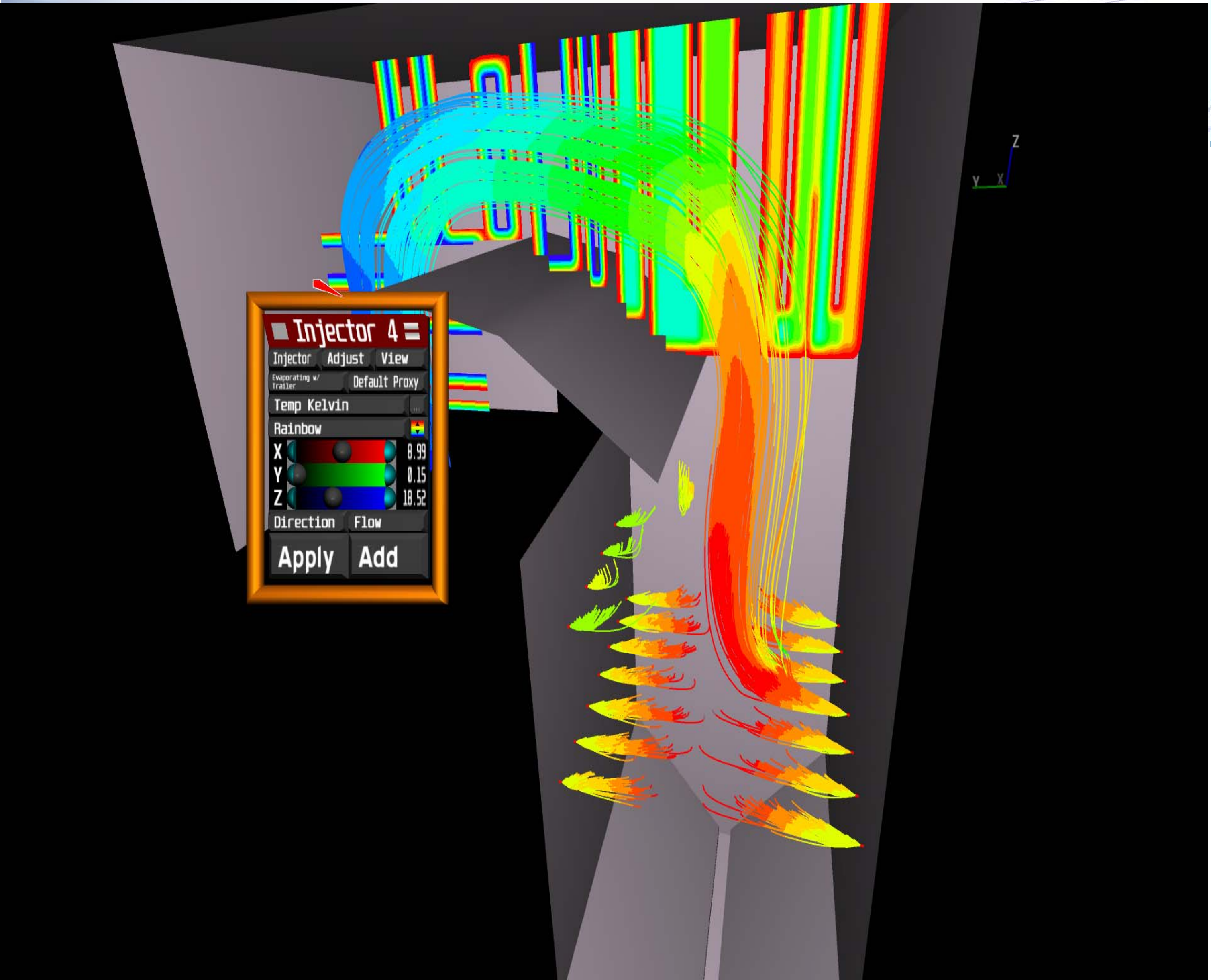
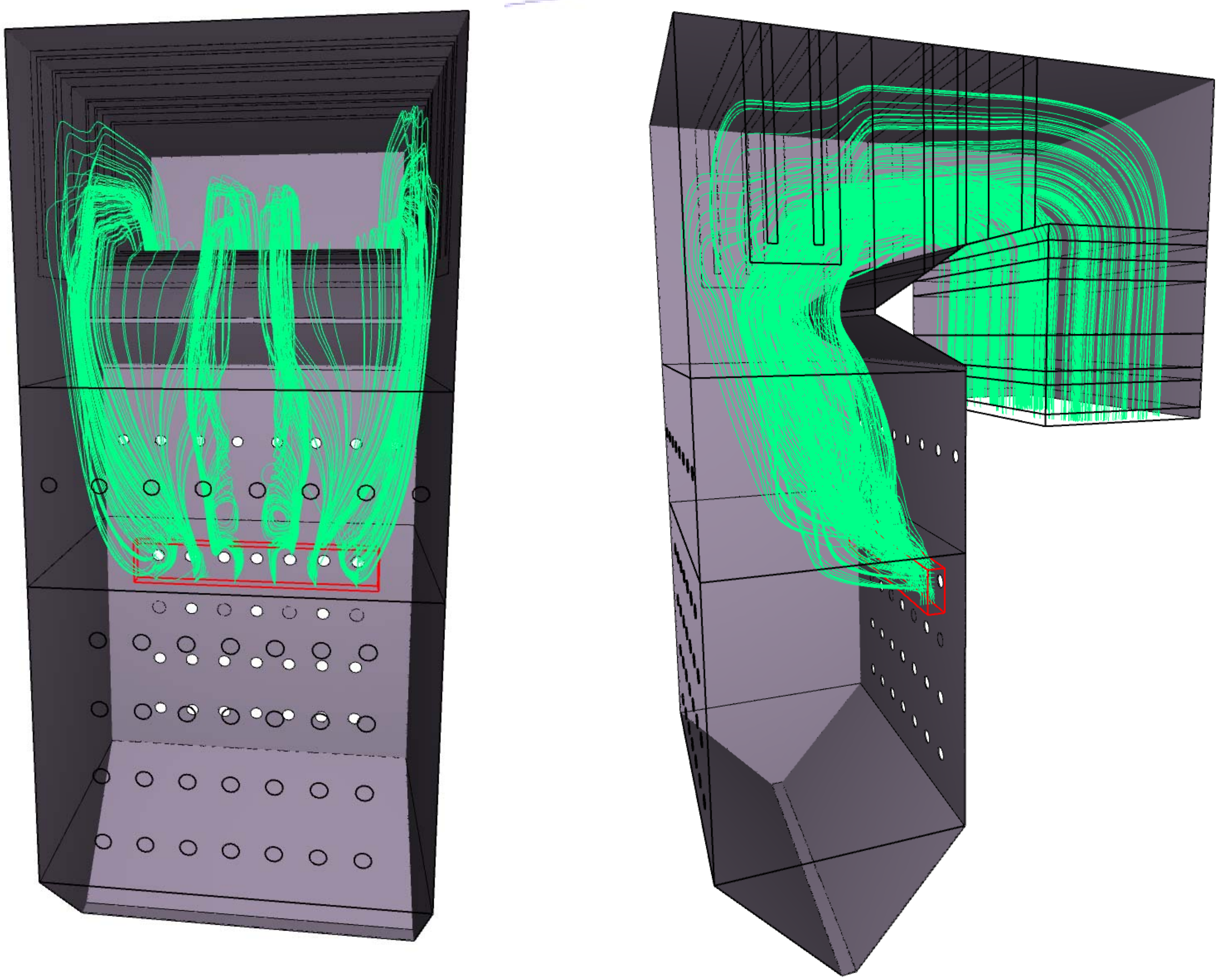
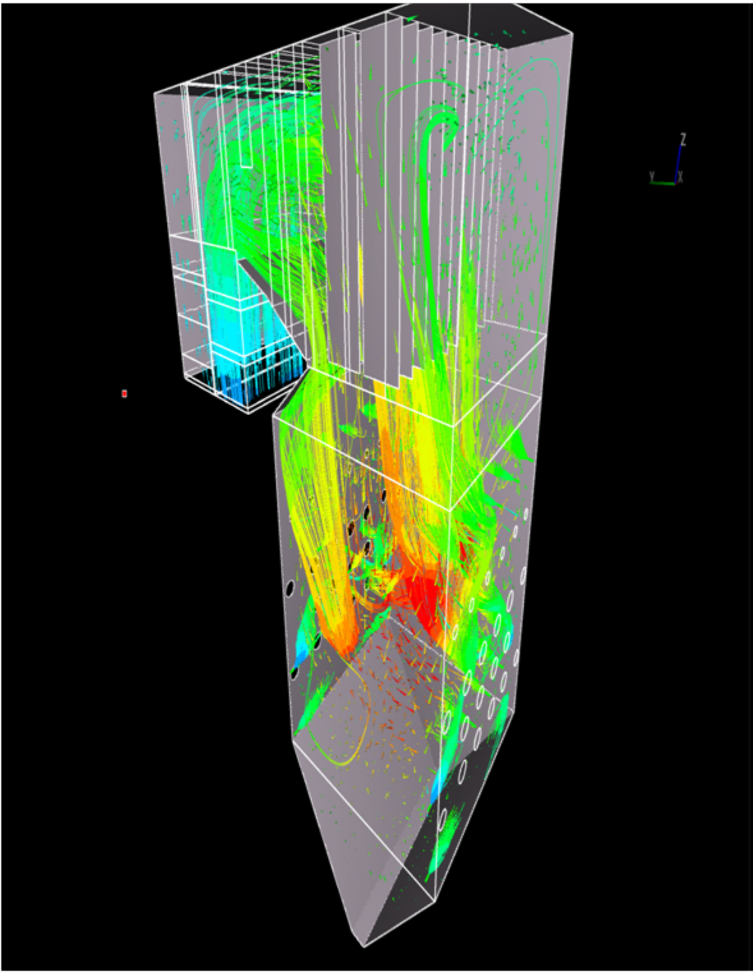
Injector Array with Streamers

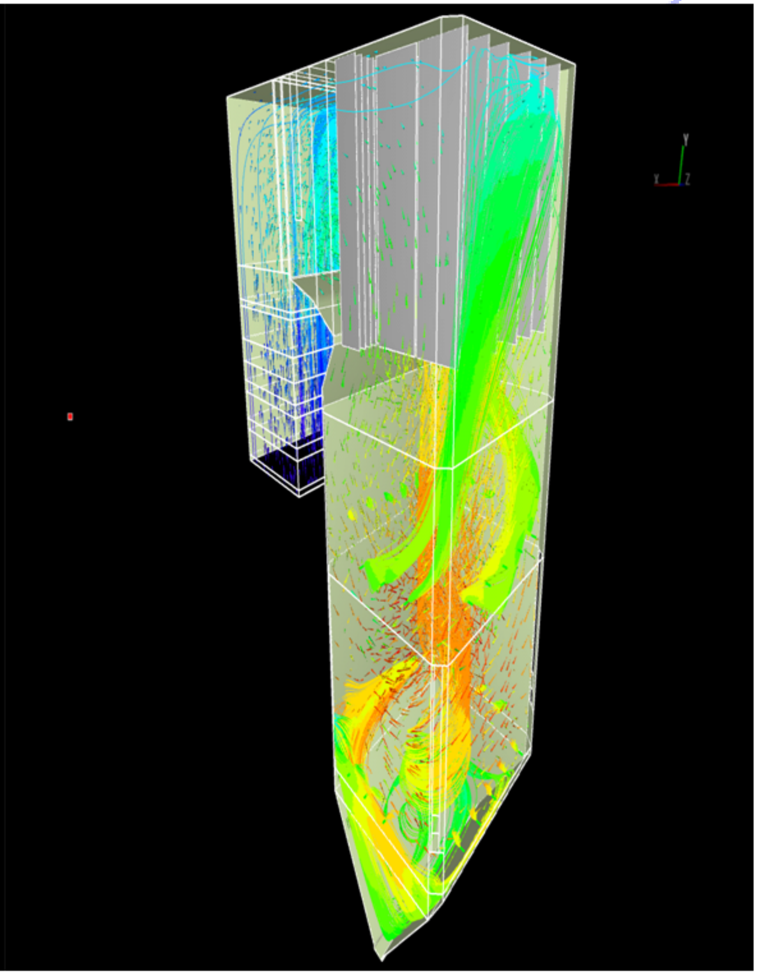


CFD Visualizations of Droplet Trajectories

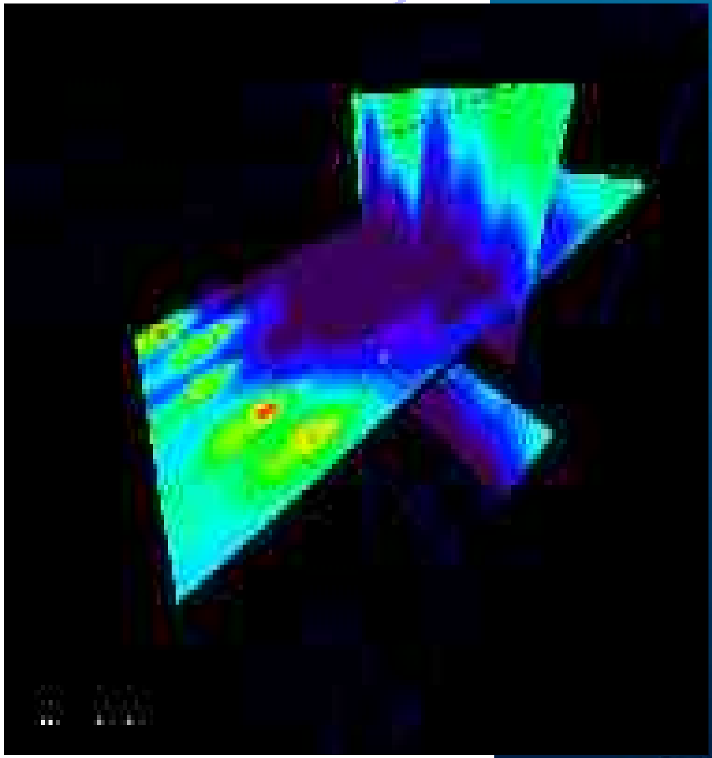


CFD Visualizations of Droplet Trajectories

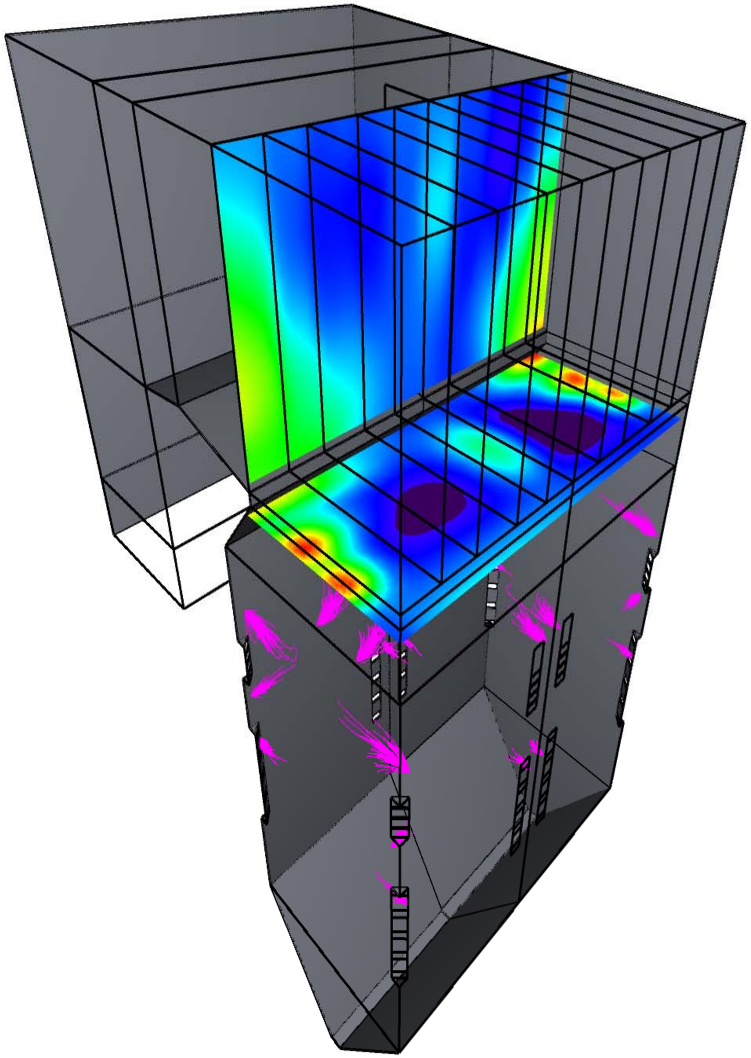




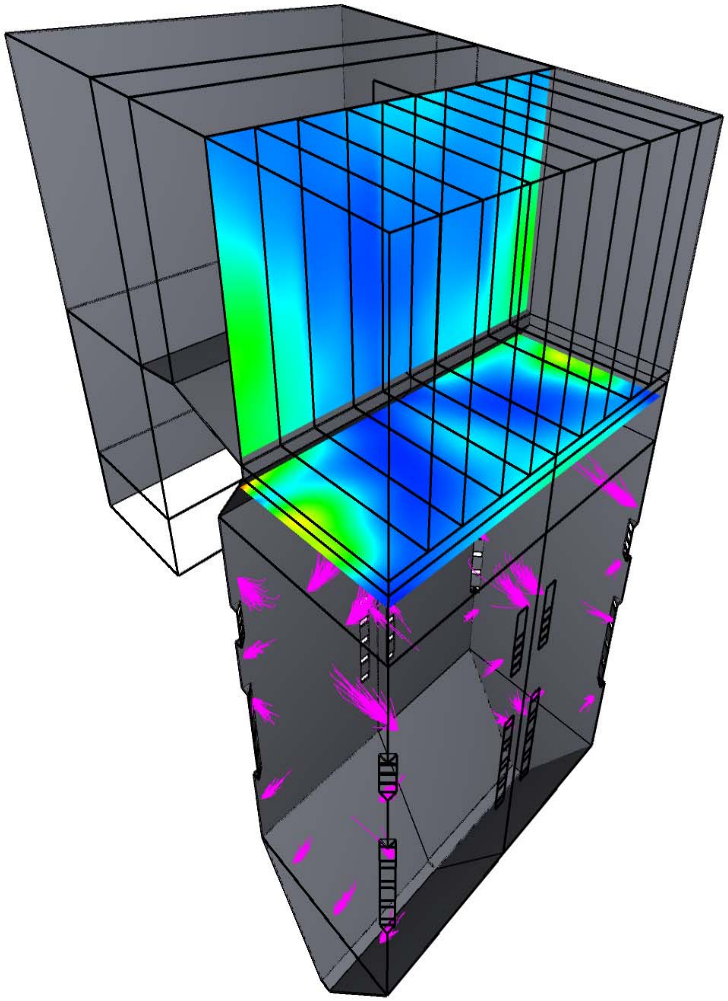
- An injector strategy can now be determined to ensure full coverage by looking at chemical concentrations across several planes.



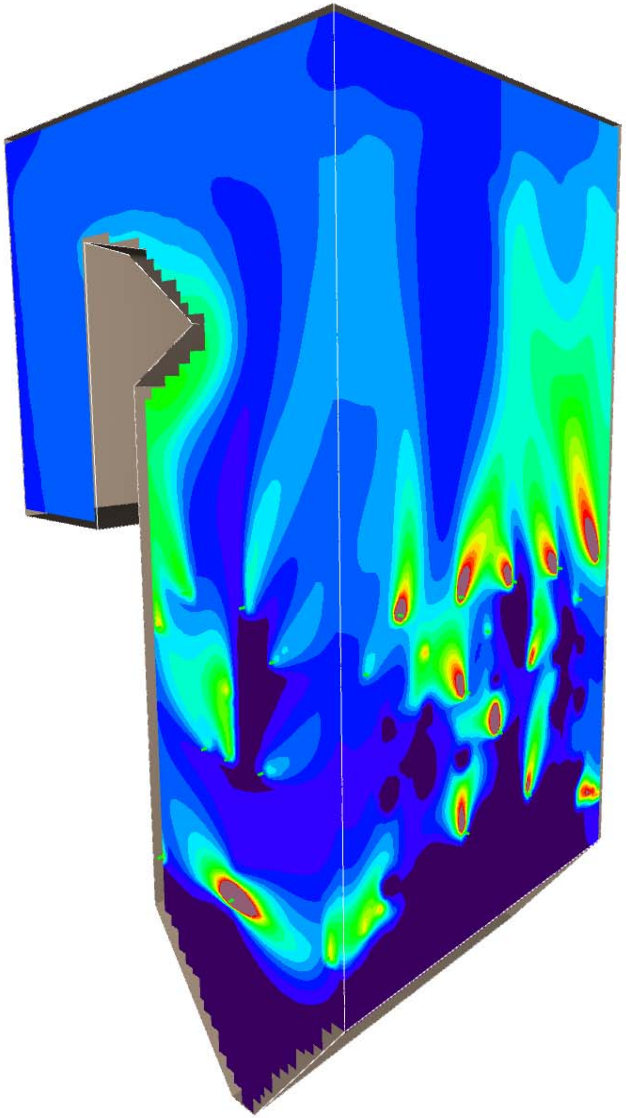
Chemical Coverage Map



Chemical Coverage Map



Front & Left Wall Coverage



MAGNESIUM CHEMISTRIES… NOT IDENTICAL

- *Chemical REACTIVITY*
  - DEAD-, HARD-, LIGHT-Burned MgO
  - Source of MgO; Brine, Mine, Seawater
  - Particle Size, Surface Area and Porosity

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Fuel Chem TIFI Process

- Mg(OH)2 Injection
  - Injector Locations
    - Lower and/or upper furnace
    - Determined by CFD model for best distribution to problem areas
- Mg(OH)2 → MgO (MP = 5000 F)
- Reacts with SO_3
- Inhibits conversion

Critical Process Parameters

- Temperature
- O2
- Soot Blowing
- Mg distribution

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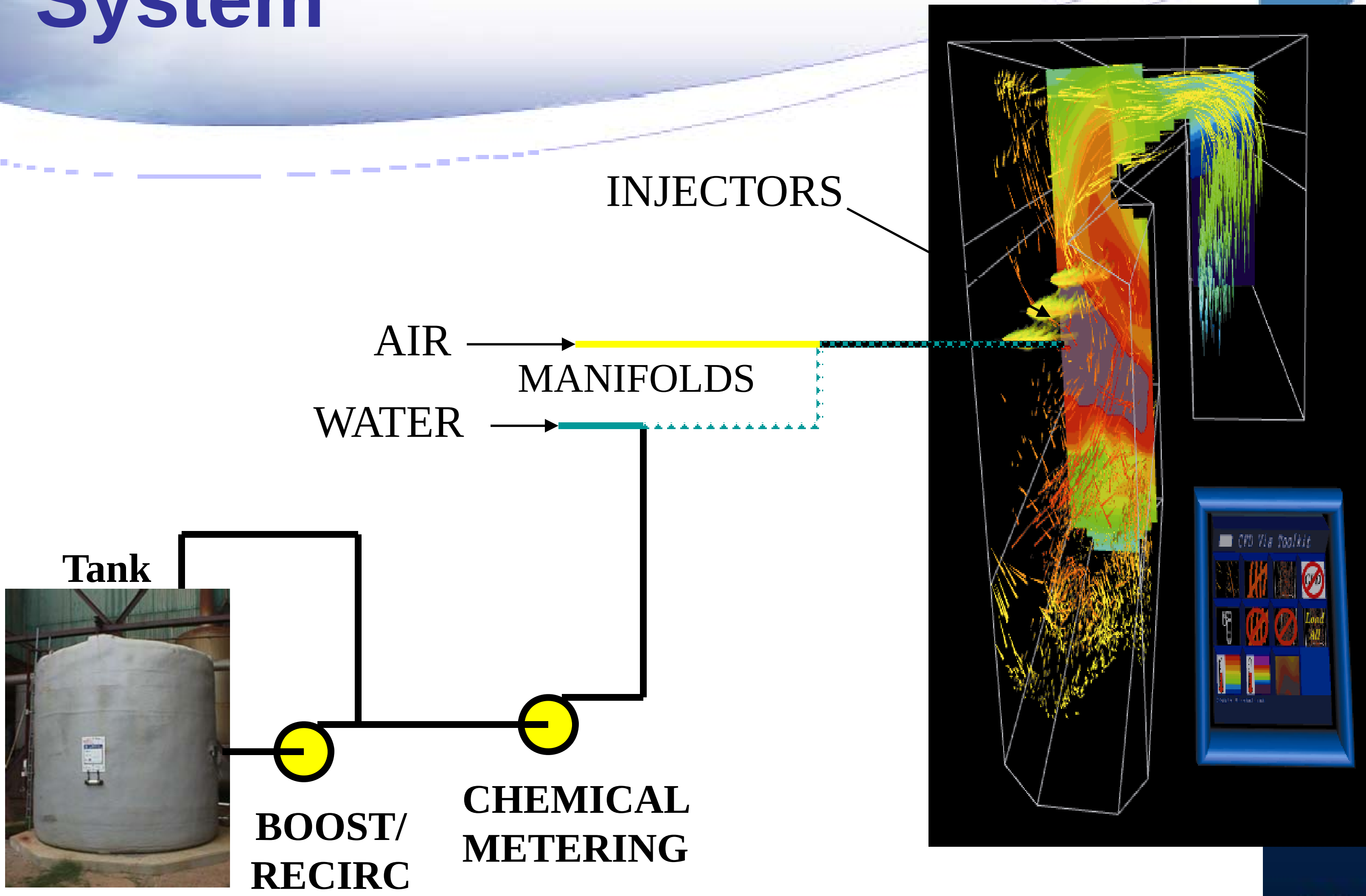
Anatomy of a Typical Injection System



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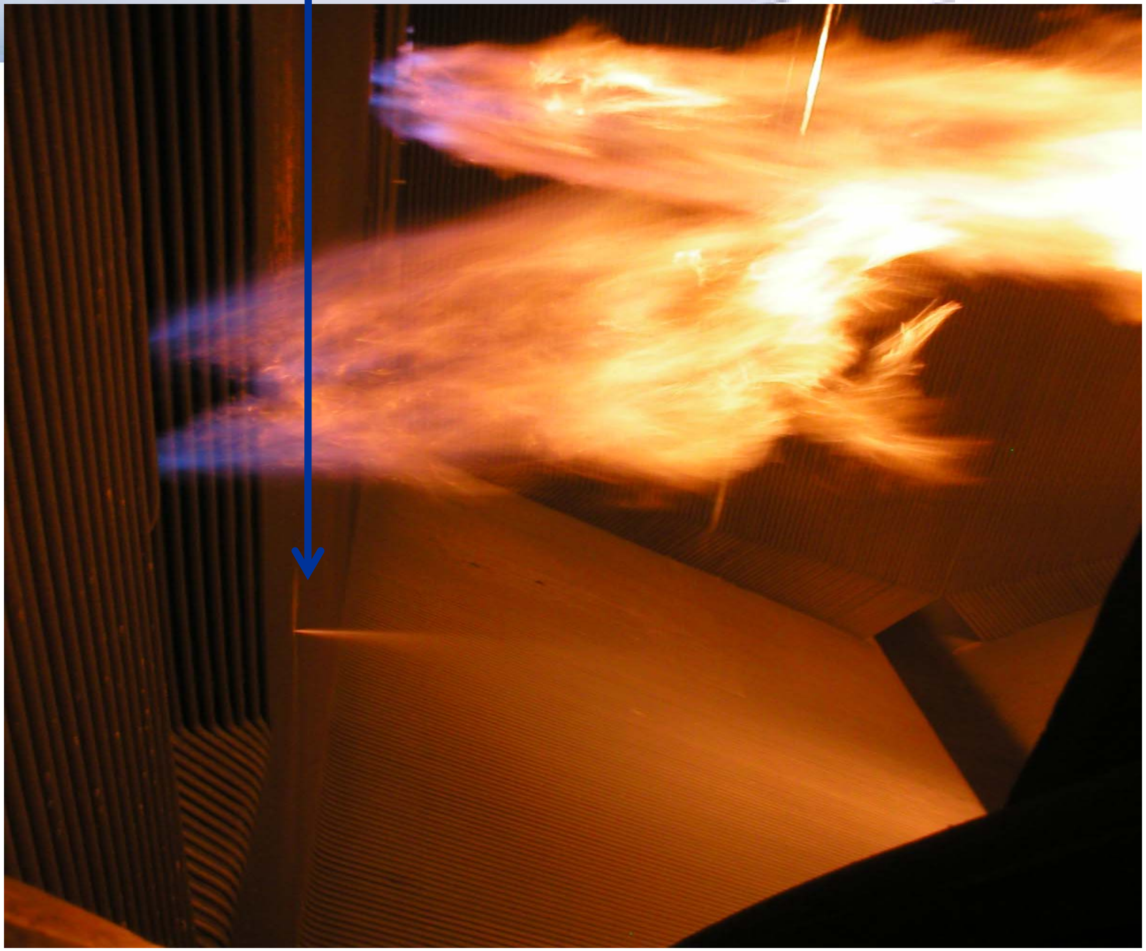
Injector Installed and Spraying



Targeted In Furnace Injectors
(TIFI)

DOOR INJECTOR

IR INJECTOR

WALL BLOWER INJECTOR

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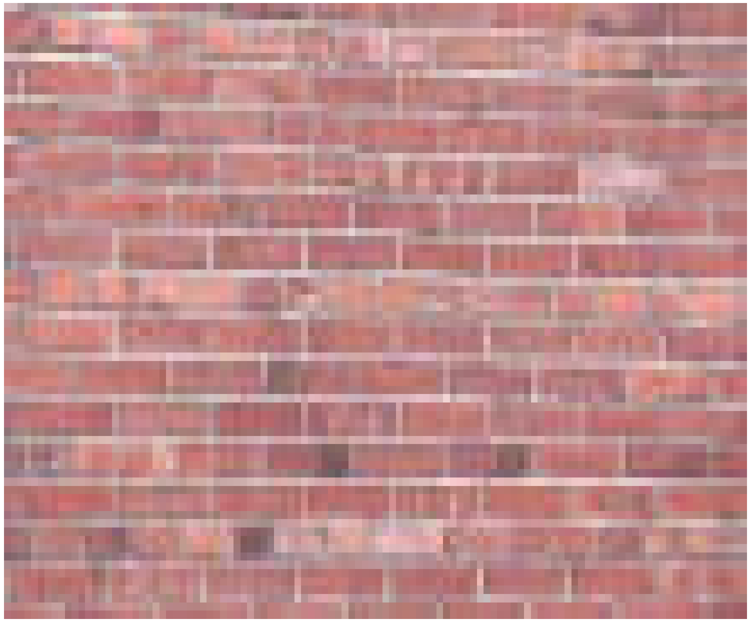
SLAGGING

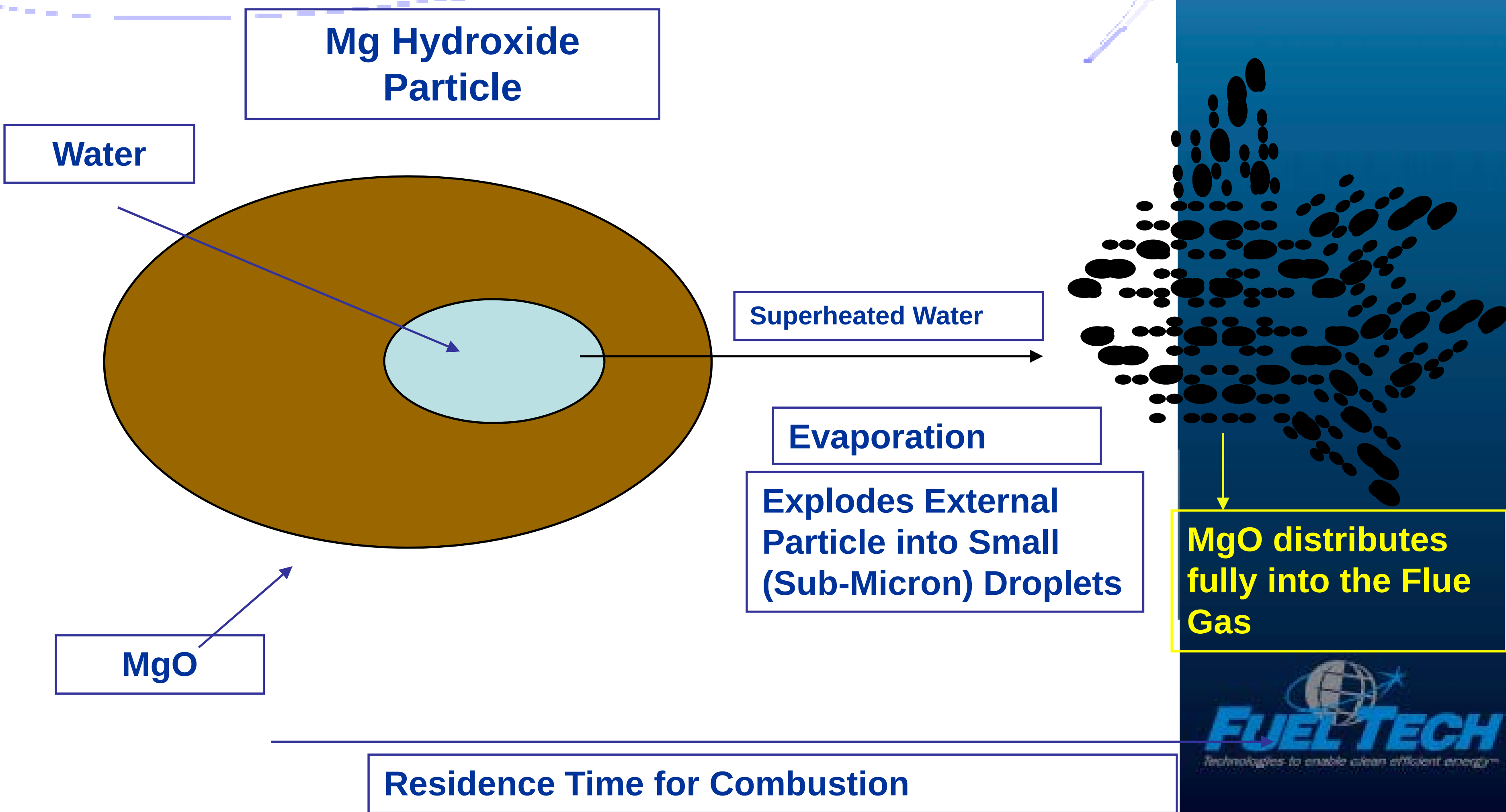
STRUCTURE

- **NEAT / TIGHT**

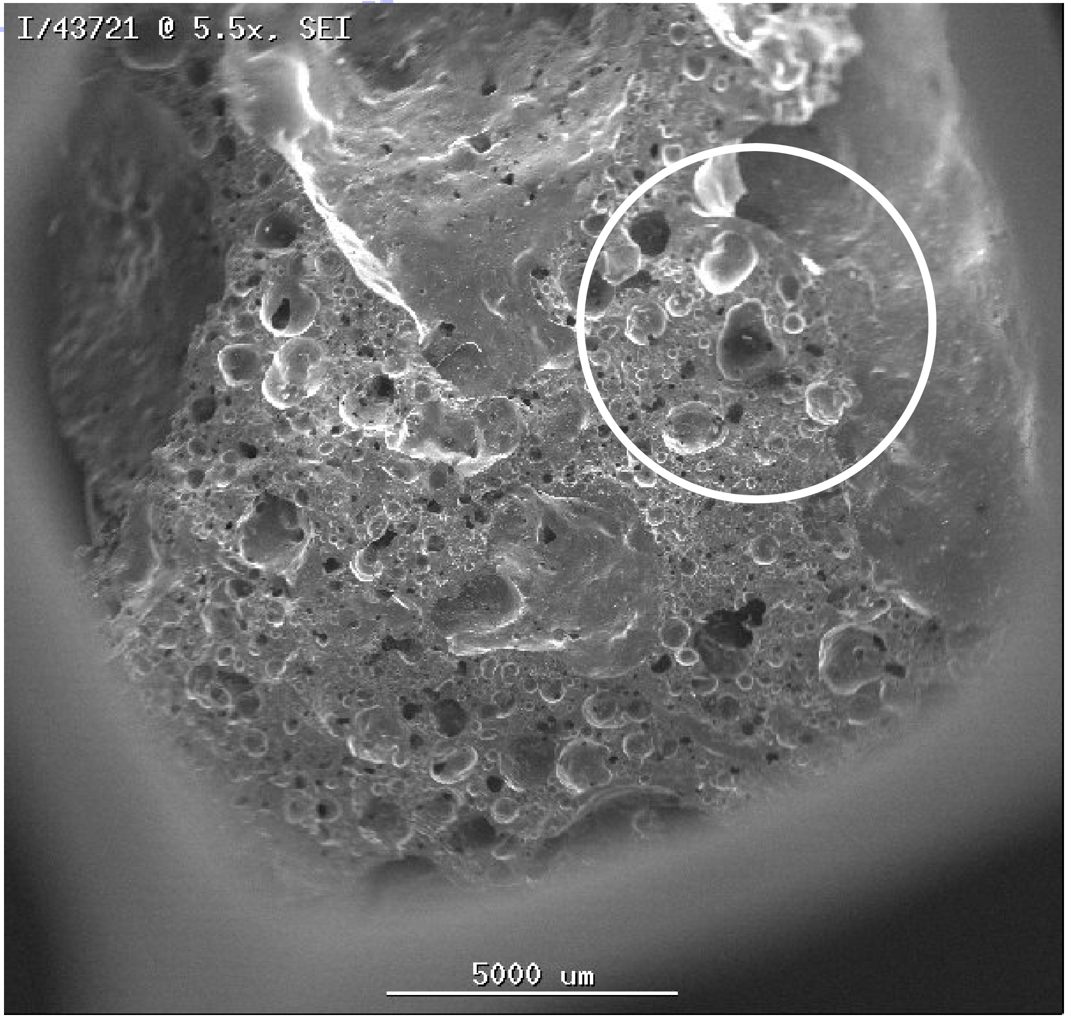
$Mg(OH)_2$:
CRYSTAL MOD
DESTROYS PACK



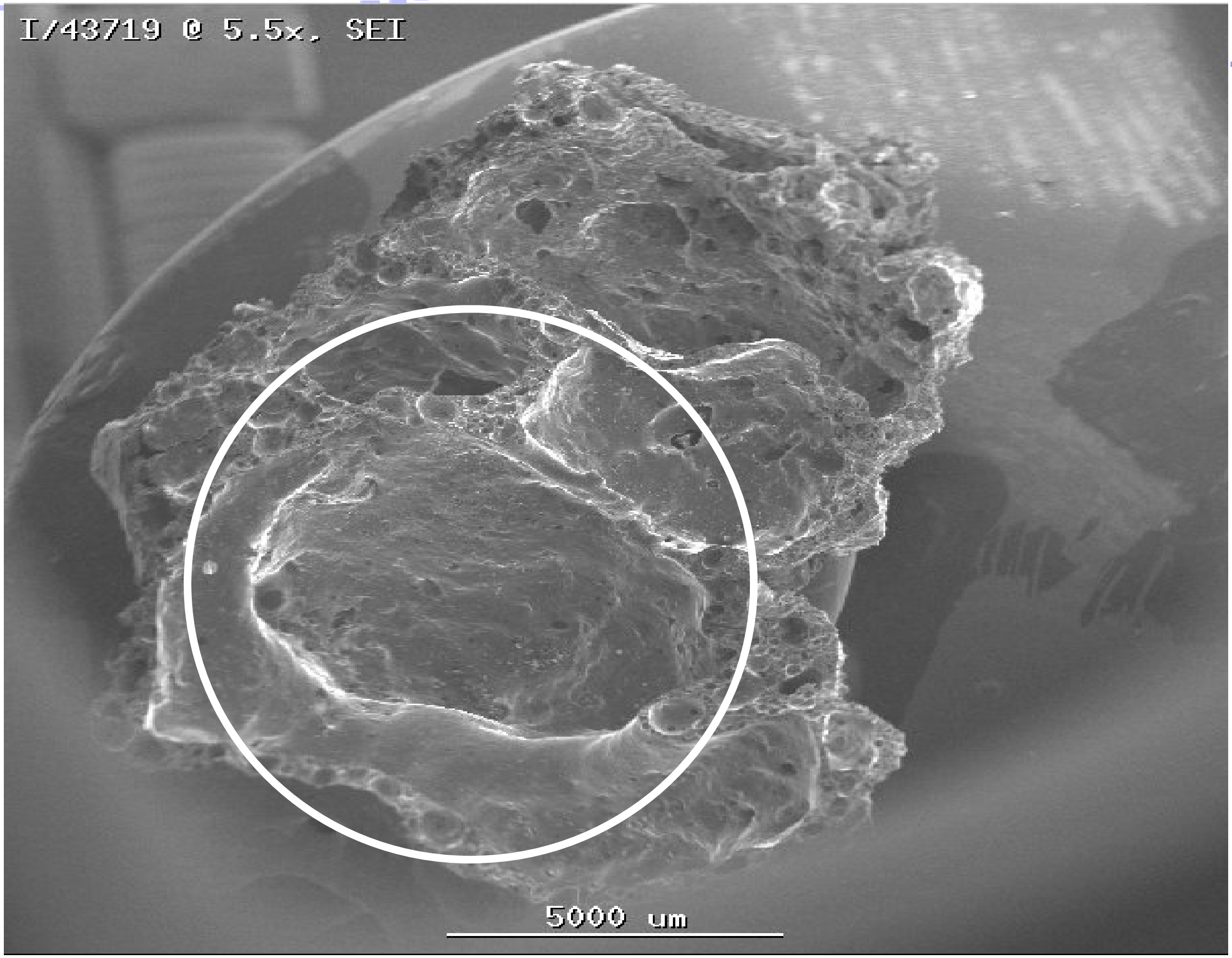
To Change The Deposit Morphology, The Mg Must Get INTO The Deposit



UNTREATED BASELINE SLAG WESTERN COAL FIRED (SEM 5.5x)

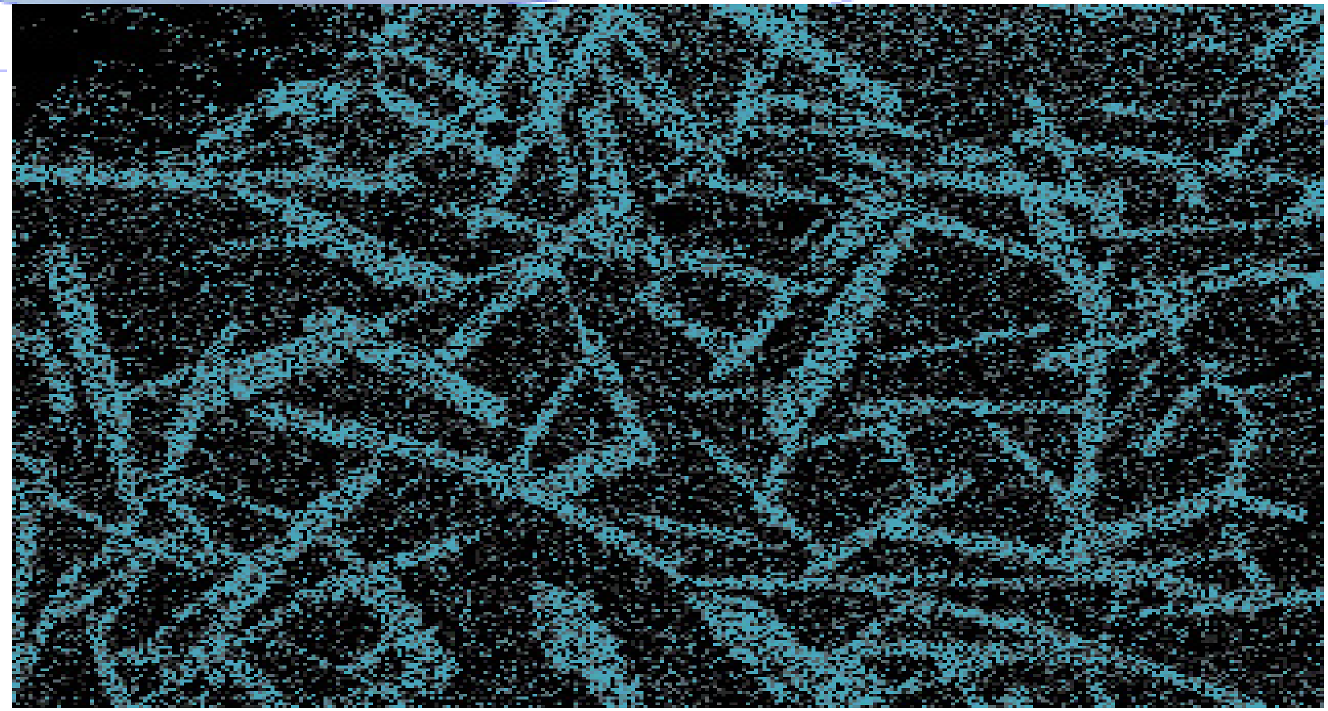


TIFI TREATED SLAG WESTERN COAL FIRED (SEM 5.5x)



SLAG STRUCTURAL STRENGTH

GDMS 113x Magnification Untreated



- Aluminum Color Enhanced Blue
- AL “Fibers” Add Strength
- Acts like rebar

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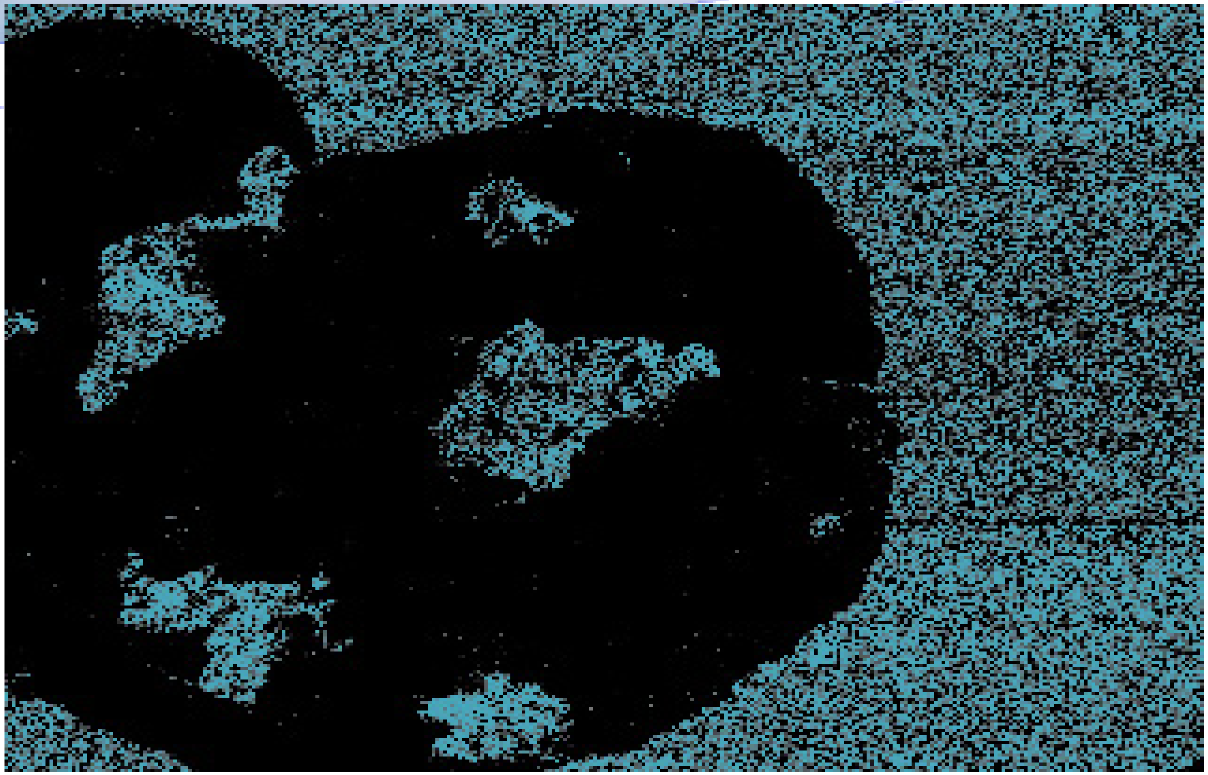
SLAG STRUCTURAL CHANGE

GDMS 113x Magnification Treated



- Aluminum Color Enhance Blue
- AL Evenly Dispersed
- TIFI Interferes With AL Fiber Formation
- Strength & Support Lower > 50%

Illinois Basin Coal

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Slag Transformation: Results of a Mid West Utility

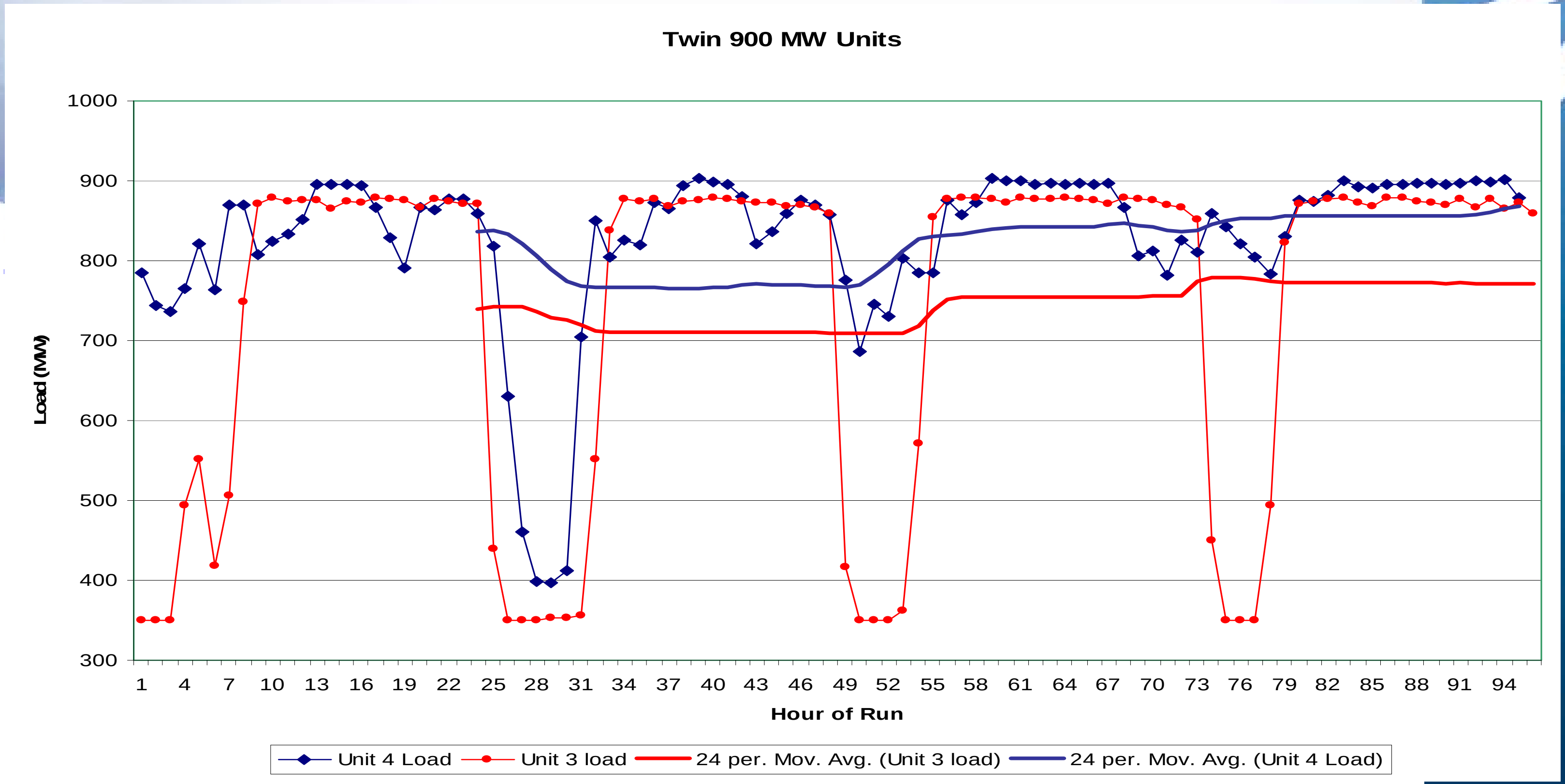
Consistency Prior to Chemical feed

Consistency After Chemical feed

Georgia Power Scherer Program Benefits

- ❑Soot blowing Reduction
- ❑Recovery of Lost Megawatts
- ❑Reduced Fireside Cleanings
- ❑Improved Heat Rate
- ❑Coal Price Premium
- ❑Reduced Tube Replacement Costs from Corrosion and Erosion

UNIT 3 vs. UNIT 4 AVG MW



- IDENTICAL 900 MW UNITS ON PRB
- NIGHTLY DERATES DUE TO SLAG
- UNIT 3 BASELINE; UNIT 4 TIFI TREATED
- UNIT 3 HAS TO CONTINUE NIGHTLY DERATES
- UNIT 4 ABLE TO AVERAGE 80 – 100 MW MORE

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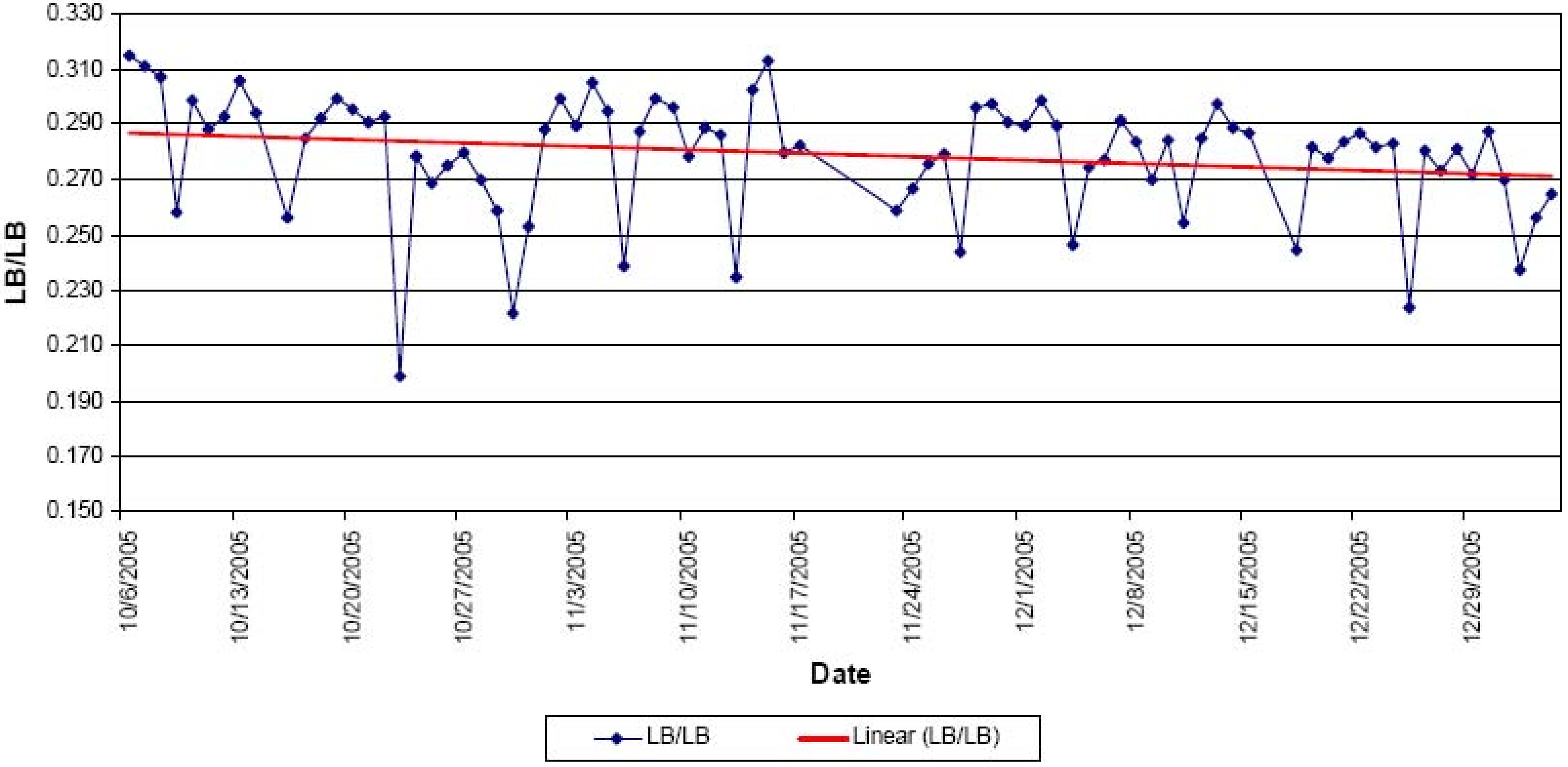
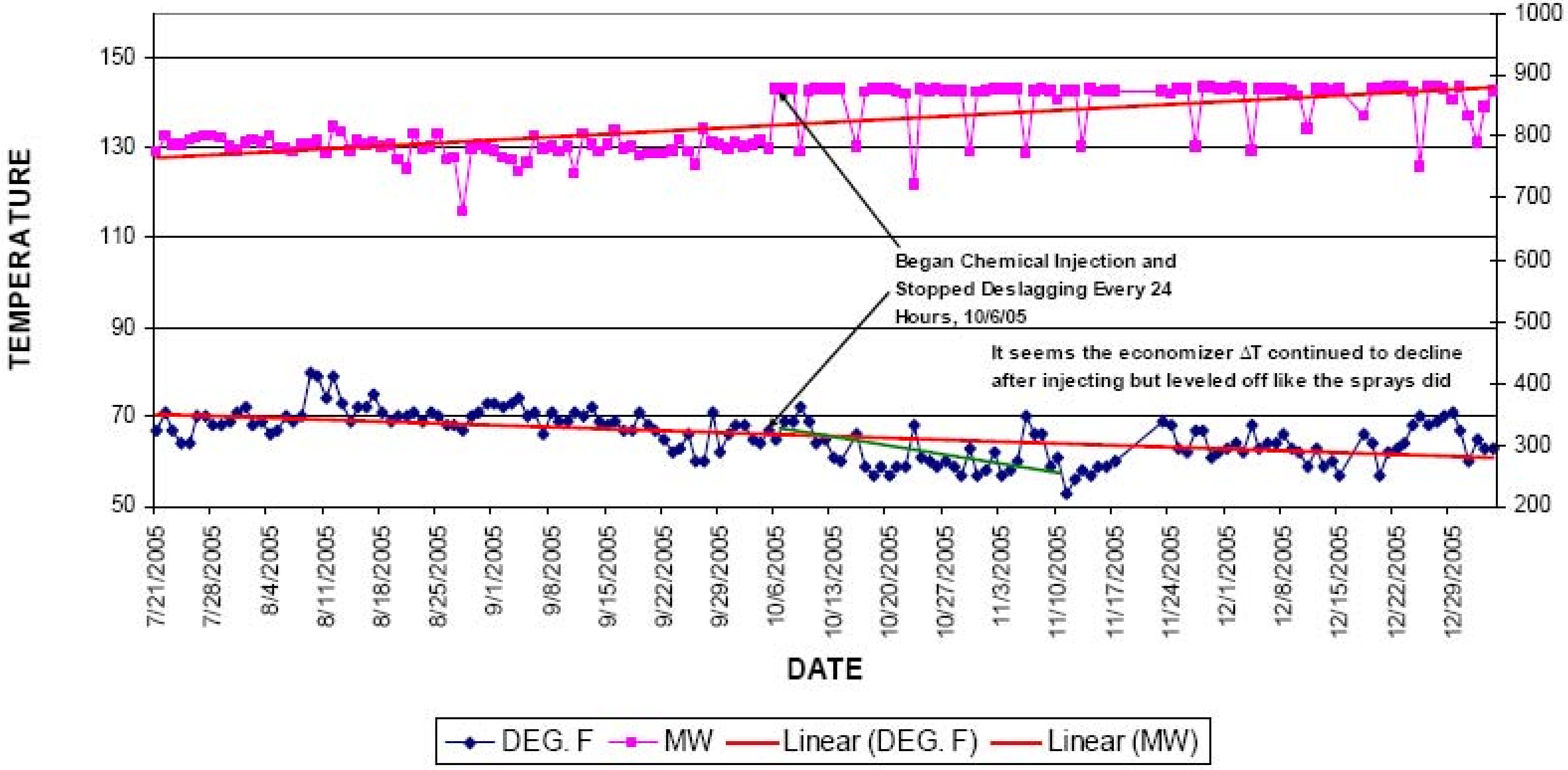
Decrease in Reheat Spray Flows



Increase in MW production



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Santee Cooper Program Benefit Highlights

- ❑Removal of SO_3 related Opacity
- ❑44.5 MW Increase
- ❑Boiler Efficiency Increase of 0.65%
- ❑120 BTU/KW-h Heat Rate Improvement while burning coals with average heat content DECREASE of 225 BTU/lb
- ❑20% TTR Reduction
- ❑50% Outage Cleaning Time Reduction
- ❑Mitigation of LPA
- ❑**Greater than 4:1 Annual Return**

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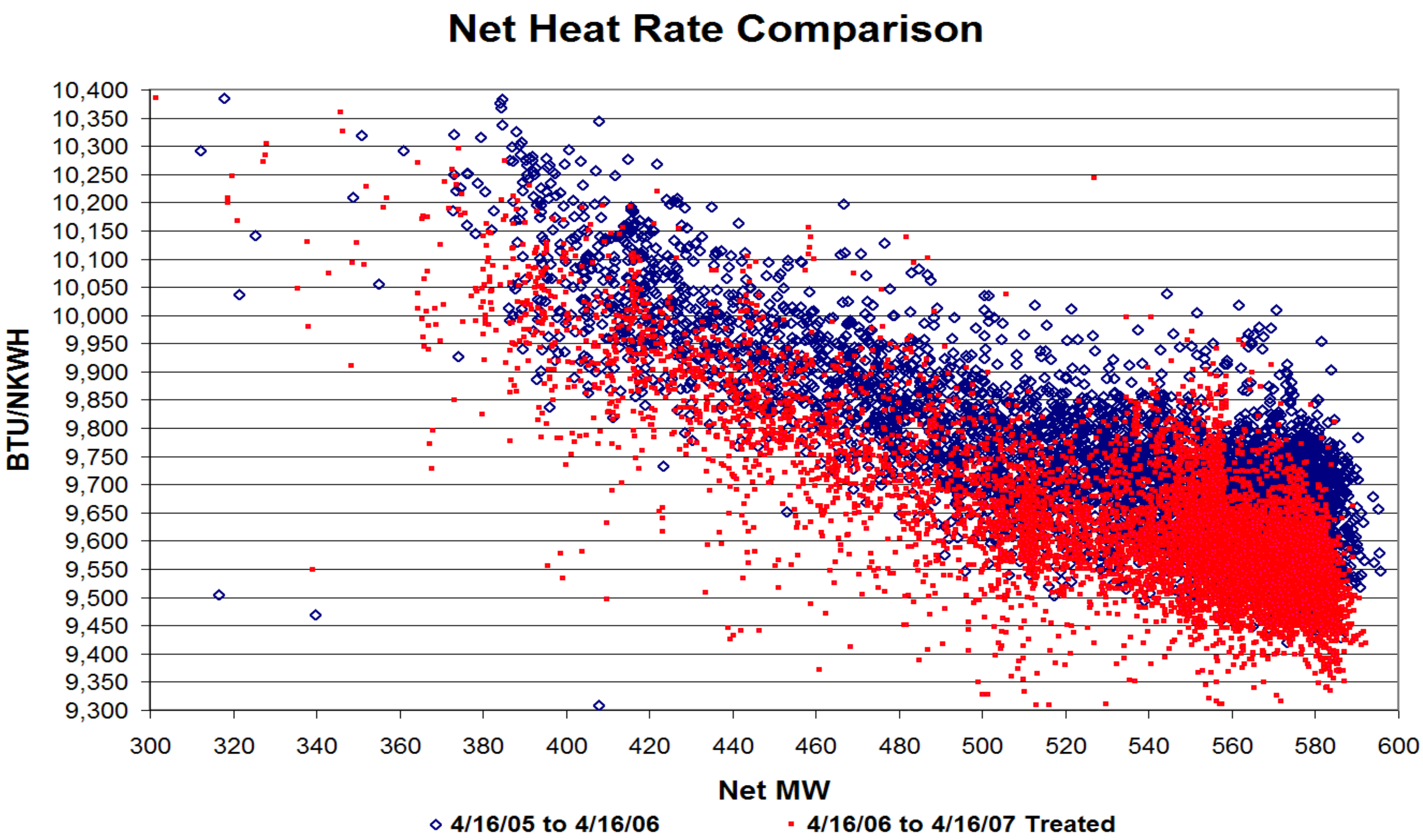
Heat Rate Improvement



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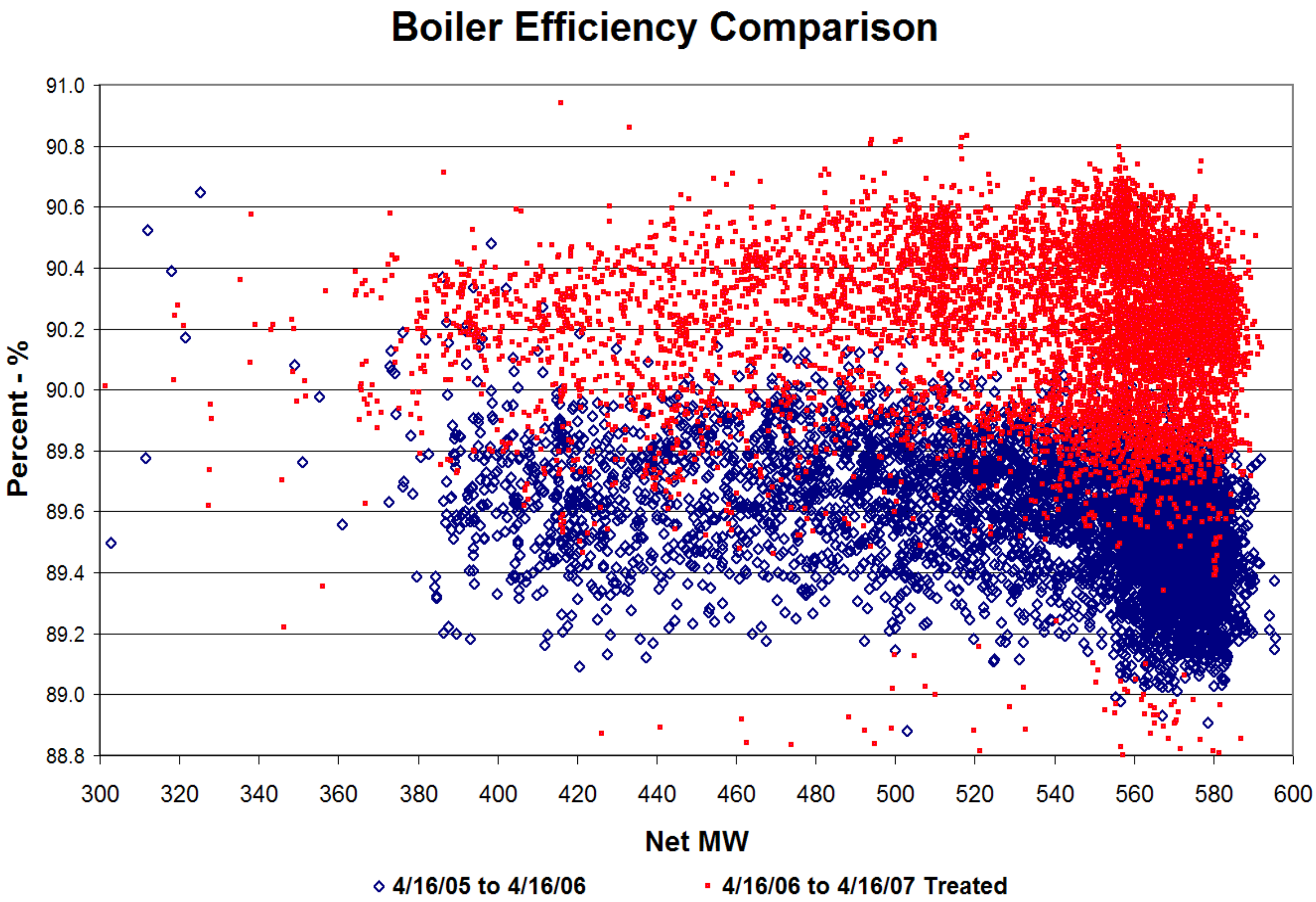
Boiler Efficiency Improvement



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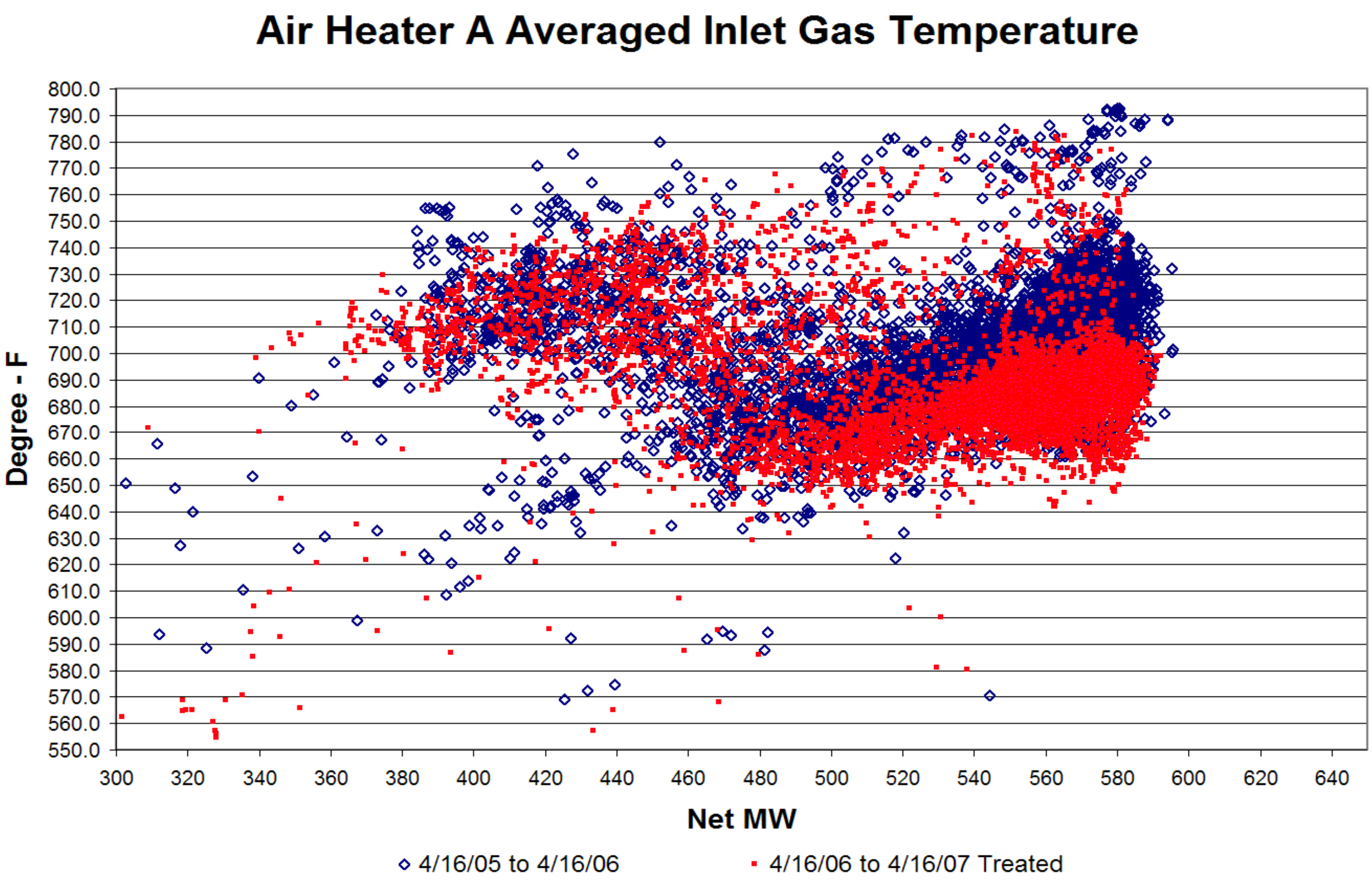
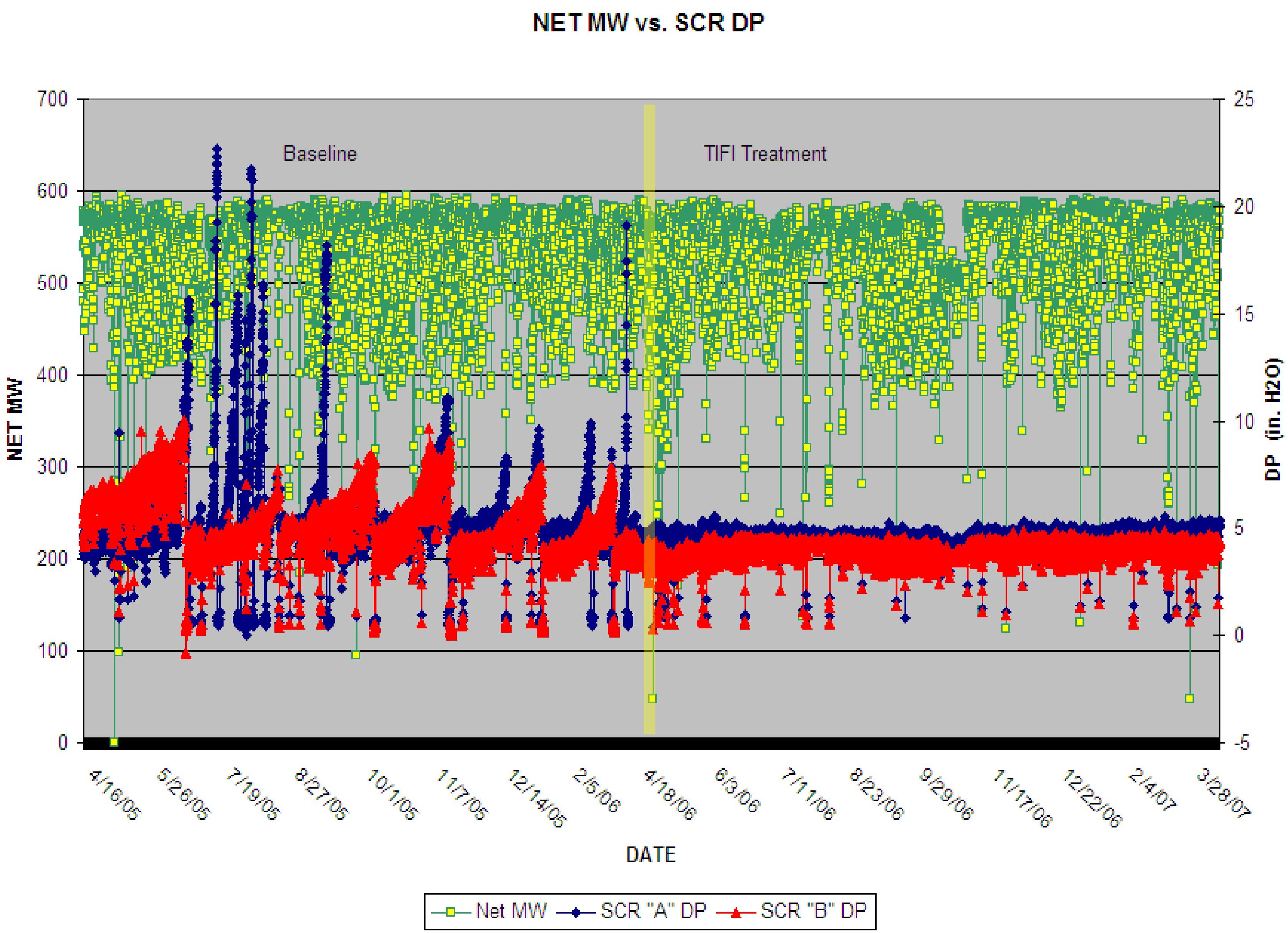
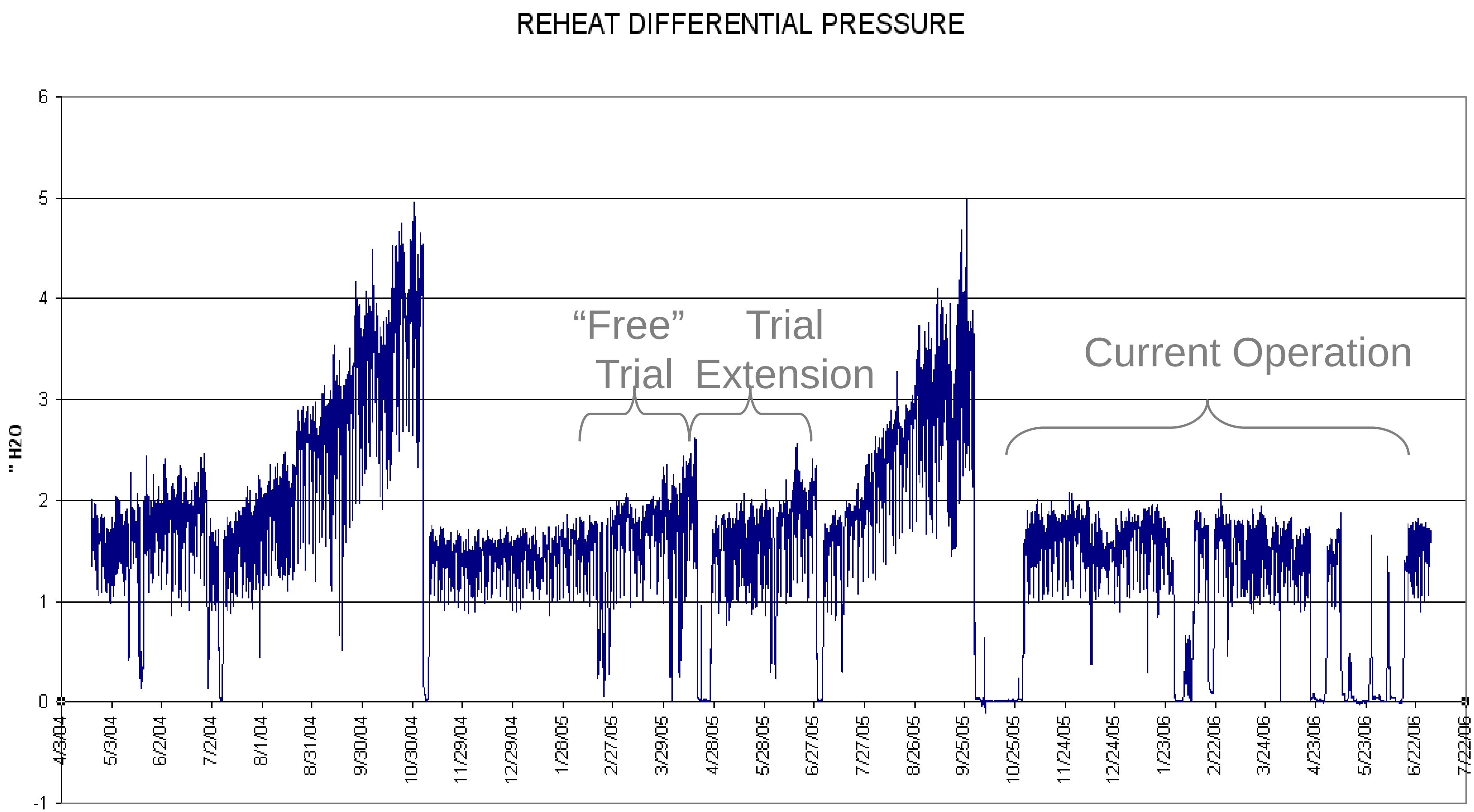
Air Heater Inlet Temps



Reduction of Popcorn Ash Fouling



MidSize Unit



WFEC Hugo Station Program Highlights

- ❑2.5% Capacity Factor Increase
- ❑FEGT Drop from 2600 to 2500 F
- ❑Excess O_2 Drop from 3.0 to 2.5
- ❑$500K Annual in NOx Credits
- ❑Coal Purchase Flexibility
- ❑80% Outage Cleaning Time Reduction
- ❑**3:1 Average Annual Return**

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Minimize Outage Cleaning Time Requirement & Intensity

With FUEL CHEM:
12-18 hours of off-line moderate charge cleaning

Without FUEL CHEM:
3-5 days of off-line high explosive cleaning

Transalta Program Benefit Highlights

- ❑Cleaning outage avoidance of 10 days/unit/year
- ❑Cleaning cost avoidance ~ $100,000/day
- ❑Increased generation capacity – derate reduction
- ❑Economizer cleanliness = ~ 30 MW gain
- ❑Bottom ash maintenance improvement – grinders, no issues, no clinkers
- ❑Fuel flexibility – Spring Creek and Rawhide
- ❑**4:1 Average Annual Return**

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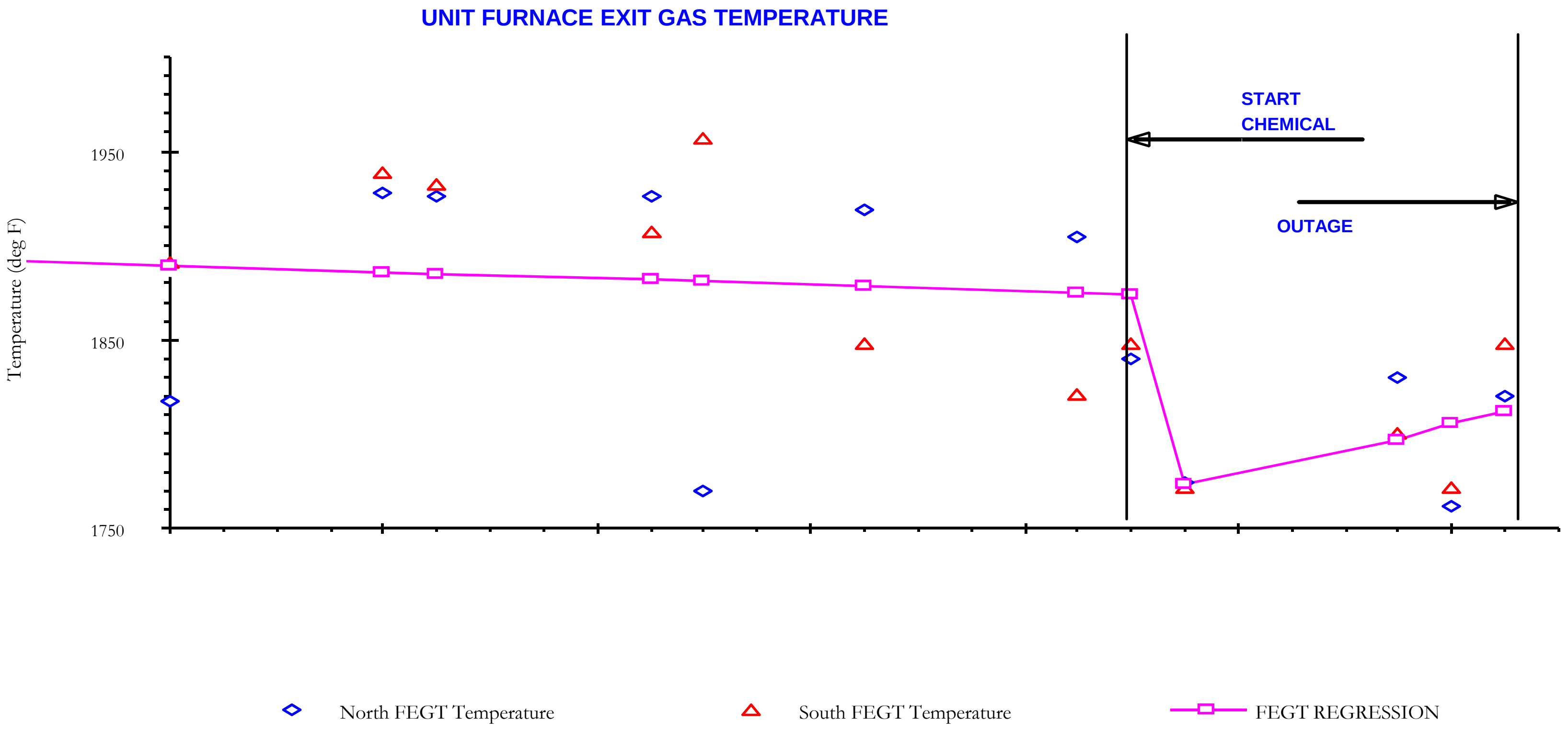
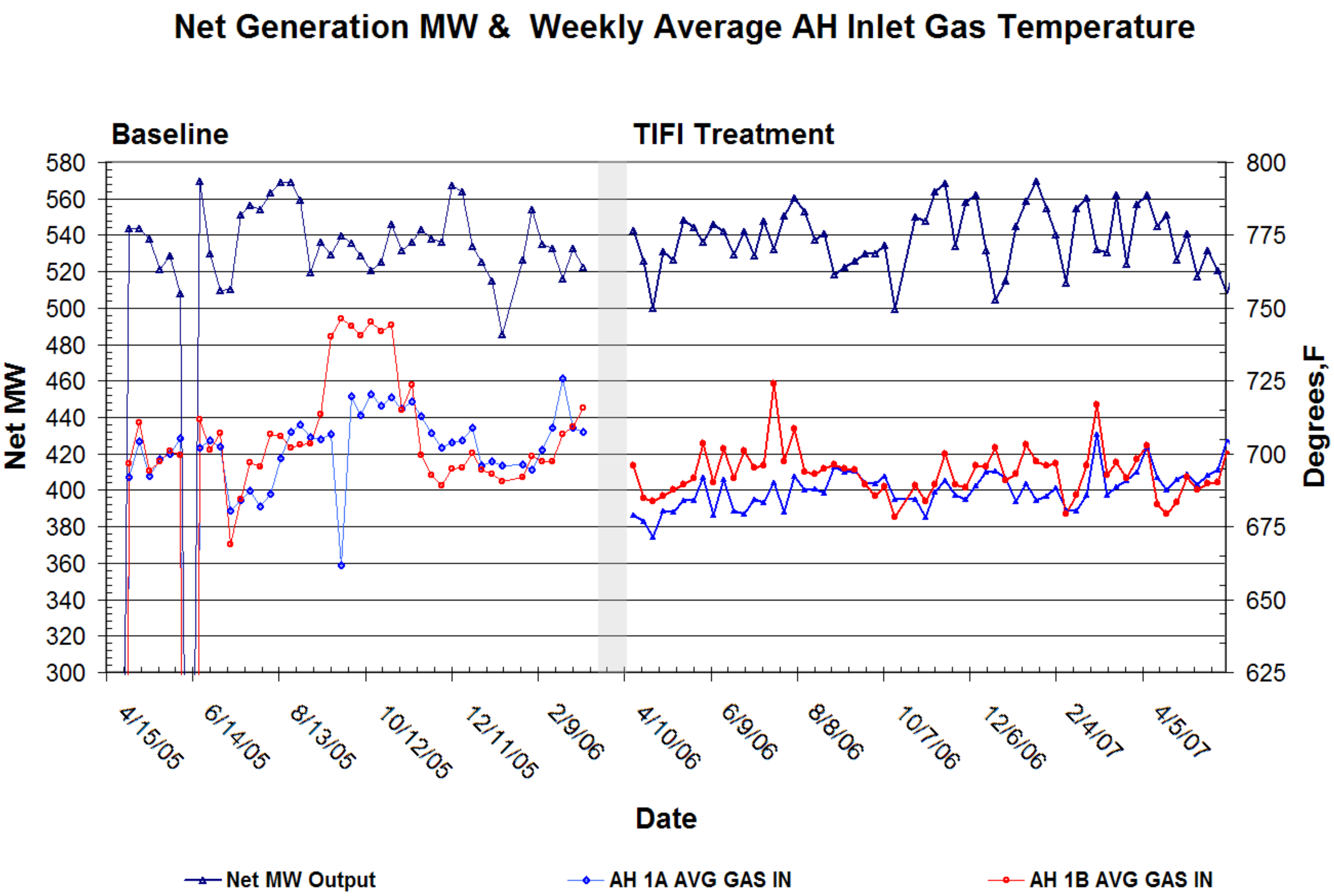
Midwestern Utility

- Started on a dirty boiler
- Prior to start, Unit was restricted due to high steam temps
- Capacity increased and visual clean up occurred.
- Ability to keep Steam Temps below 1000F



Peak Generation Increase



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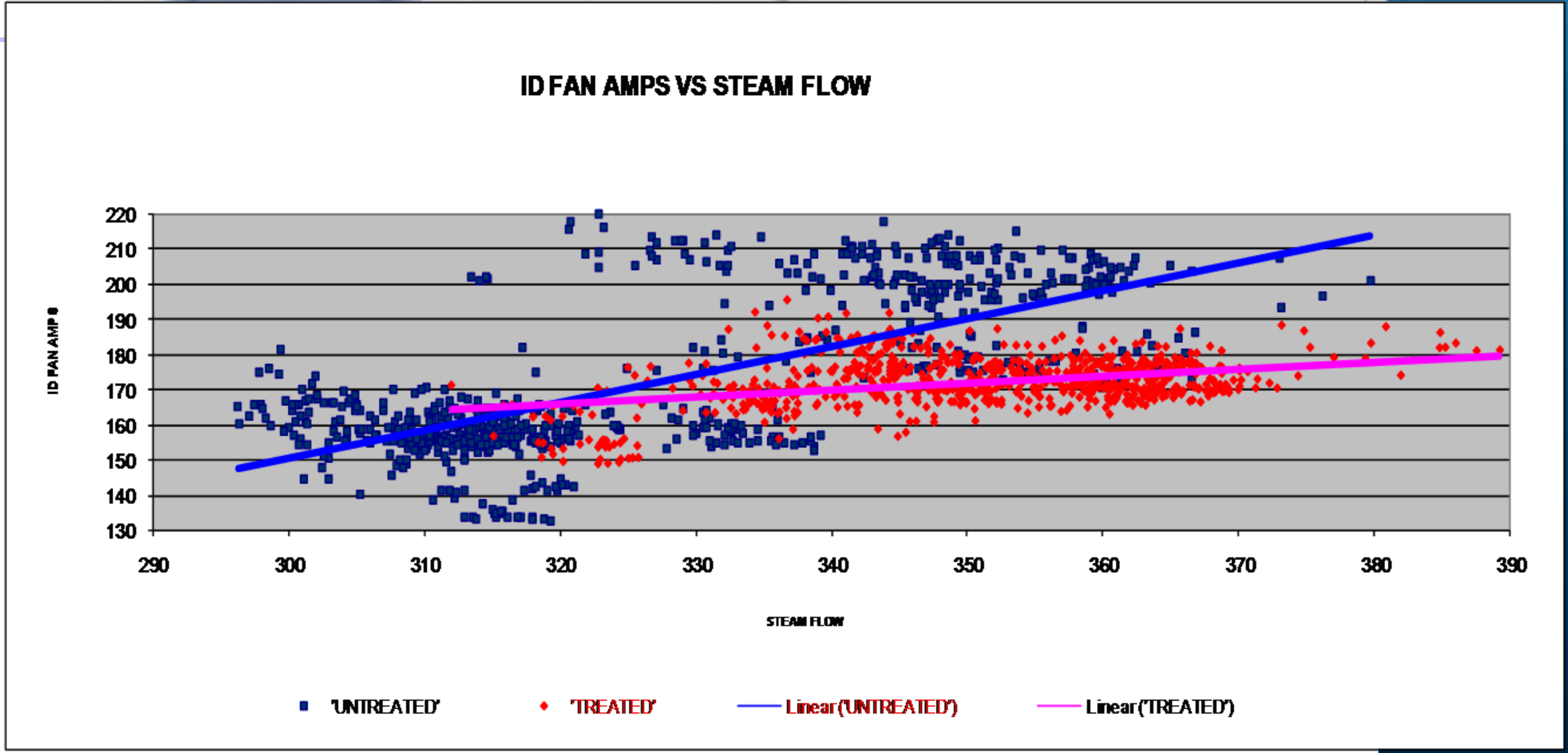
Midwestern Industrial



Midwestern Utility

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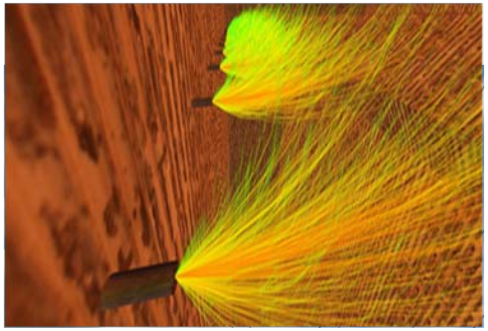

Questions