



October, 2018

*Philippine Coal Plant 2020: Moving Towards H.E.L.E. (High Efficiency Low Emission) The Transformative Technology*

## **ESP FLUE GAS CONDITIONING AND BOILER SLAGGING CONTROL**



# FUEL TECH – COMPANY INFORMATION

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- \$60 - \$80 MM Annual Revenue
  - 20+ Years in Operation
- Publicly Traded on the NASDAQ (FTEK)
- Offices
  - Warrenville, IL – Project Management, Financial, and Corporate Office
  - Durham, NC – SCR Project Management, Process and Modeling
  - Westlake, OH – Particulate and FGC System Support
  - Beijing and Milan
- 150+ Employees Worldwide
- Financial Strength and Bonding Capabilities

# GLOBAL PRESENCE

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★ OFFICE LOCATIONS

● COUNTRIES WHERE FUEL TECH DOES BUSINESS:

USA, Belgium, Canada, Chile, China, Columbia, Czech Republic, Denmark, Dominican Republic, Ecuador, France, Germany, India, Italy, Jamaica, Mexico, Poland, Portugal, Puerto Rico, Romania, South Korea, Spain, Taiwan, Turkey, United Kingdom, Venezuela, South Africa

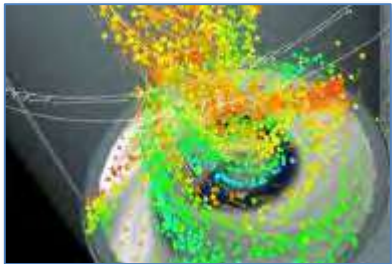
# BUSINESS SEGMENTS

## Air Pollution Control (APC)

- NO<sub>x</sub> and Particulate Control solutions to meet current and upcoming regulatory mandates
- Over 900 systems installed worldwide
- Capital project sale, typically fixed price and often turn-key
- Performance-guarantee all work

## FUEL CHEM<sup>®</sup>

- TIFI<sup>®</sup> Targeted In-Furnace Injection<sup>™</sup> technology
- Boiler efficiency, slag and corrosion reduction, SO<sub>3</sub> abatement
- Focus is on clean, efficient energy and fuel flexibility





# Electronic Precipitator (ESP) Performance Enhancement Flue Gas Conditioning Technologies (FGC)



# ESP UPGRADE DRIVERS

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Utilities require ESP modifications for many reasons

## **More stringent emission regulation**

- Reduce outlet particulate emissions /opacity
- Load restrictions / MW recovery

## **Increase ESP performance**

- Change of operation or coals

## **Improve reliability**

- Replace worn / outdated equipment
- Extend run time between forced outages

# ESP PERFORMANCE UPGRADE OPTIONS

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## I. Mechanical Upgrade - Increasing Collection Area

- Add new fields in direction of flue gas flow
- Increase the height of collecting plates

## II. Electrical Upgrade - Enhancing ESP Corona Power

- Add Rigid Discharge Electrode (RDE)
- Install Switch Mode Power Supply (SMPS) Units

## III. Flue Gas Conditioning – Reducing Fly Ash Resistivity

- SO<sub>3</sub> Flue Gas Conditioning
- NH<sub>3</sub> Flue Gas Conditioning
- Dual (SO<sub>3</sub>&NH<sub>3</sub>) Flue Gas Conditioning

# SO<sub>3</sub> FGC EXPERIENCE TO DATE

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## What Is SO<sub>3</sub> Flue Gas Conditioning?

SO<sub>3</sub> Flue Gas Conditioning (FGC) is the controlled injection of small quantities of sulfur trioxide into the flue gas stream, reducing the resistivity of the fly ash and permitting its collection in existing ESPs.

- Since 1972, there have been over seven hundred (700) FGC systems installed on a worldwide basis, representing approximately three hundred thousand (300,000) MWs of coal fired power generation
- SO<sub>3</sub> FGC has been applied to electrostatic precipitators as small as eighty (80) SCA (16 m<sup>2</sup>/m<sup>3</sup>/sec) and as large as eight hundred (800) SCA (157 m<sup>2</sup>/m<sup>3</sup>/sec)

# MAJOR UTILITY END USERS FGC SYSTEMS

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- Duke Power
- TVA
- Southern Company
- AEP
- Detroit Edison
- Ameren
- PacifiCorp
- Ontario Power
- Hong Kong Electric
- China Light and Power
- China Shenhua Power
- Eskom
- Enel
- Electrabel



# FLY ASH RESISTIVITY



The efficiency associated with the removal of particles by an Electrostatic Precipitator is given by the Deutsch-Anderson equation



$$n = 1 - \frac{1}{e \left( \omega * \frac{A}{Q} \right)}$$

Where:  $\eta$  = collection efficiency of the precipitator  
 $e$  = base of natural logarithm = 2.718  
 $w$  = migration velocity, cm/s (ft/sec)  
 $A$  = the effective collecting plate area of the precipitator, m<sup>2</sup> (ft<sup>2</sup>)  
 $Q$  = gas flow through the precipitator, m<sup>3</sup>/s (ft<sup>3</sup>/sec)

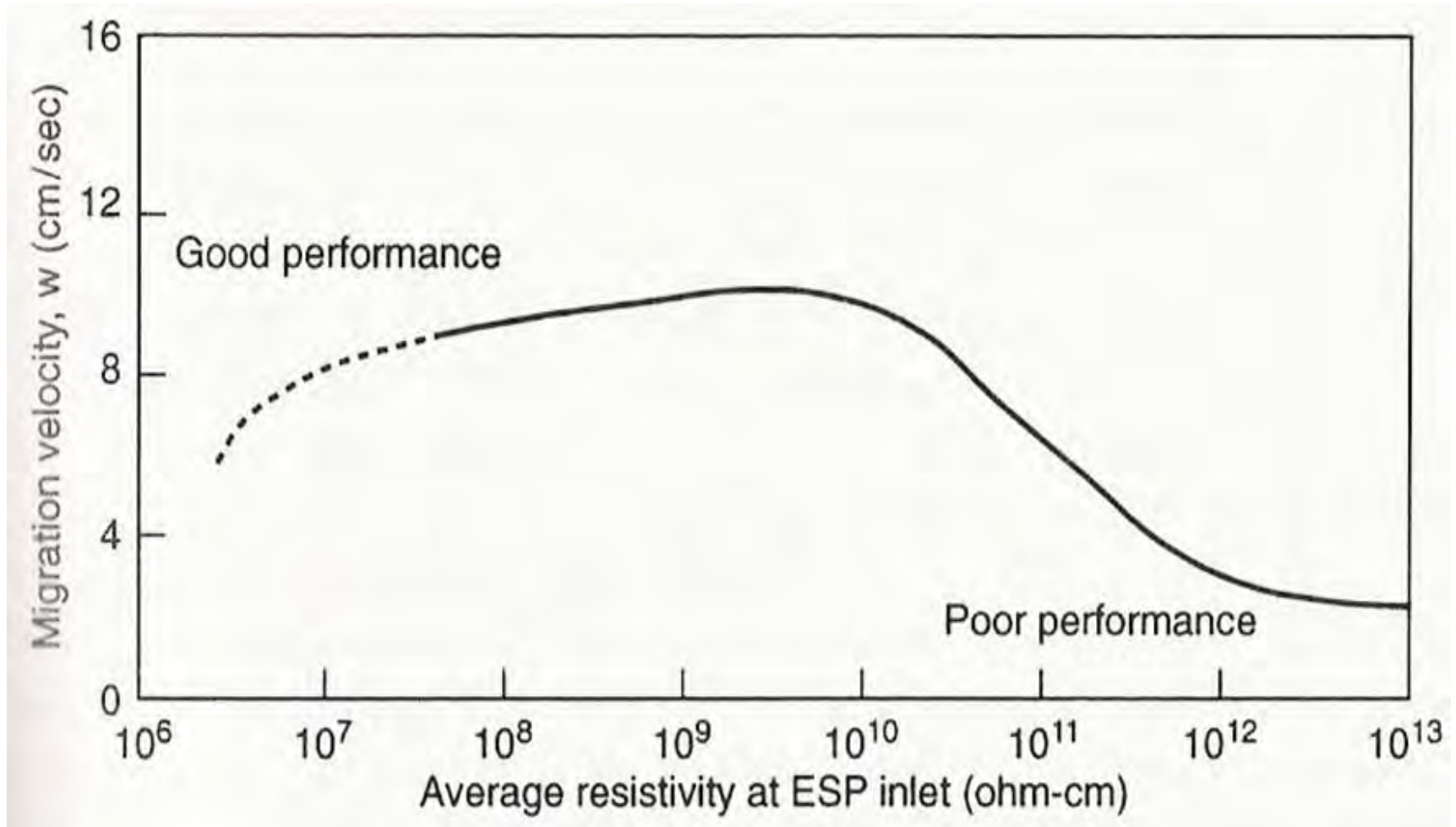
Source: Deutsch 1922; Anderson 1924.

( $\omega$    $\rightarrow$   $n$  )

( $A$    $\rightarrow$   $n$  )

( $Q$    $\rightarrow$   $n$  )

# MIGRATION VELOCITY VS. RESISTIVITY

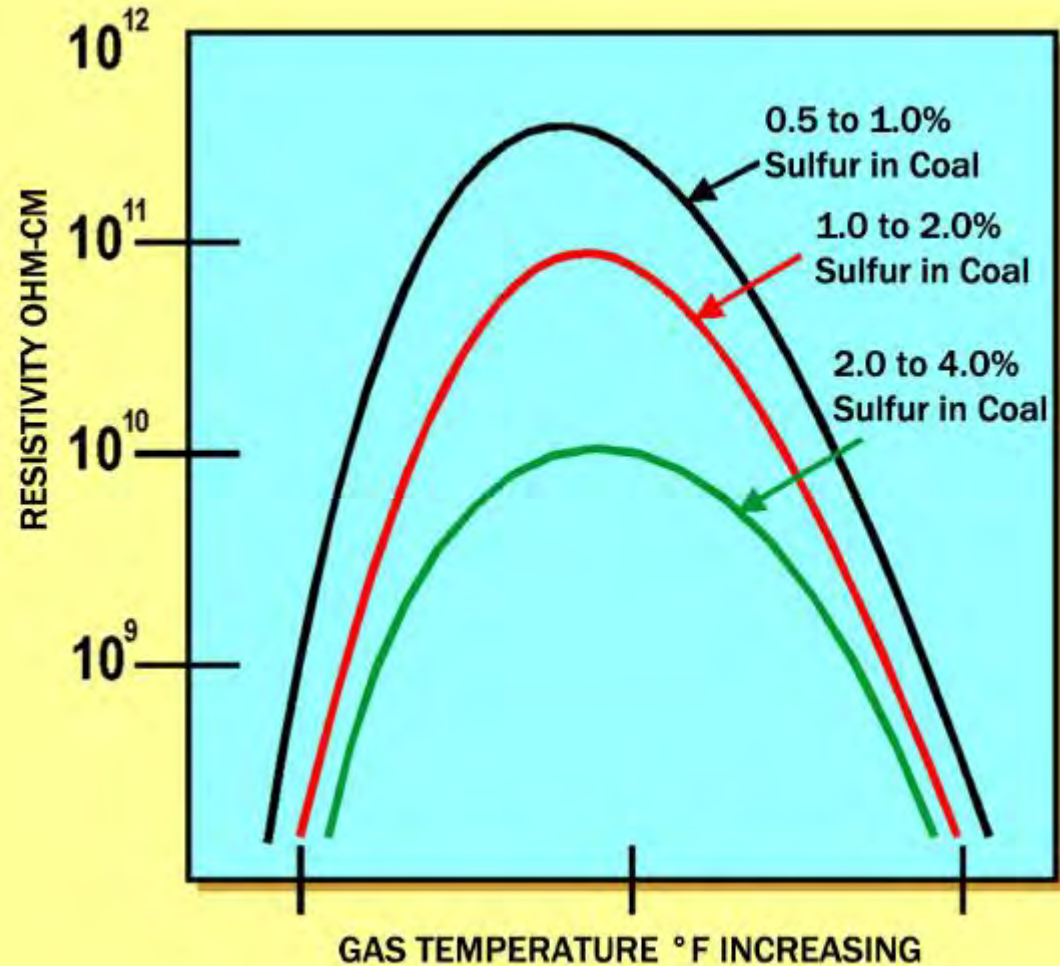


# FLY ASH RESISTIVITY VS. FLUE GAS TEMPERATURE

POOR  
PERFORMANCE

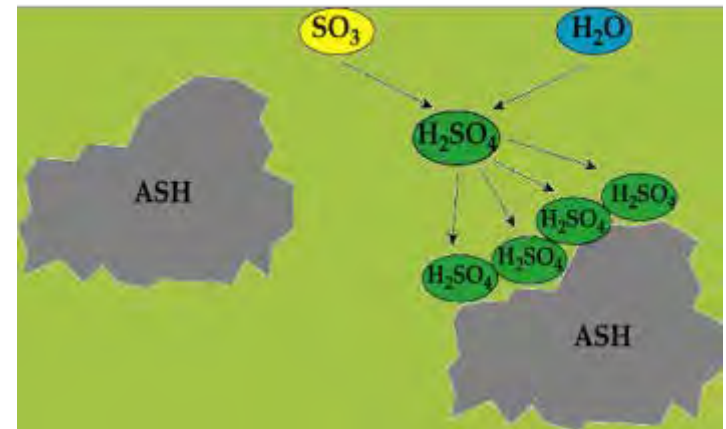
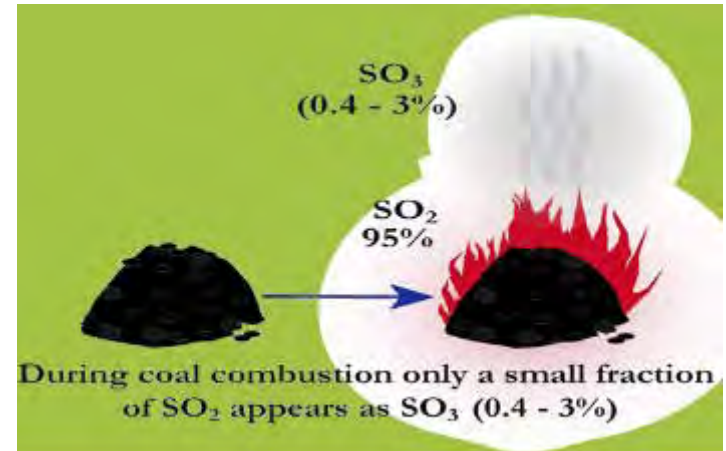
MARGINAL  
PERFORMANCE

GOOD  
PERFORMANCE



# FLY ASH RESISTIVITY VS. SULFUR CONTENT IN COAL

- Sulfur is oxidized in the boiler and as a result produces  $\text{SO}_2$  and  $\text{SO}_3$  in the flue gas.  $\text{SO}_3$  and  $\text{H}_2\text{O}$  combine in  $\text{H}_2\text{SO}_4$  and  $\text{H}_2\text{O}$  are adsorbed on the surface of the fly ash particles at flue gas temps below  $204^\circ\text{C}$  ( $400^\circ\text{F}$ ).
- $\text{SO}_3$  is normally injected into the flue gas (after the air heater) in order to decrease resistivity.
- High  $\text{SiO}_2$  and  $\text{Al}_2\text{O}_3$  (levels greater than 85%) produce an acidic acid ash which impacts the effectiveness of  $\text{SO}_3$  conditioning.



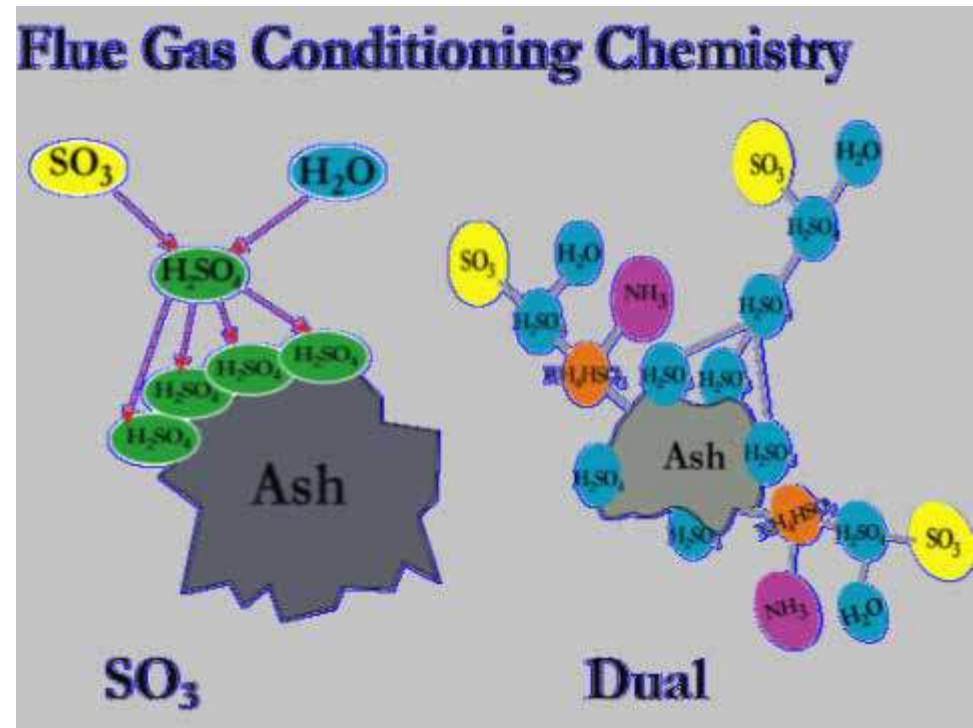
# DUAL FLUE GAS CONDITIONING (DFGC)

## Why add $\text{NH}_3$ to the Flue Gas?

Improved utilization of  $\text{SO}_3$ , forming ammonium bisulfate; more effective resistivity control.

## When is $\text{NH}_3$ Injection the Correct Choice?

- Acidic Fly Ash Chemistry (i.e. High Levels of Silica & Alumina > 85%)
- High Levels of Unburned Coal (Carbon) in the Fly Ash
- Agglomeration of Fine Particulate
- Control of Rapping Re-Entrainment Losses
- Excessive Flue Gas Velocities

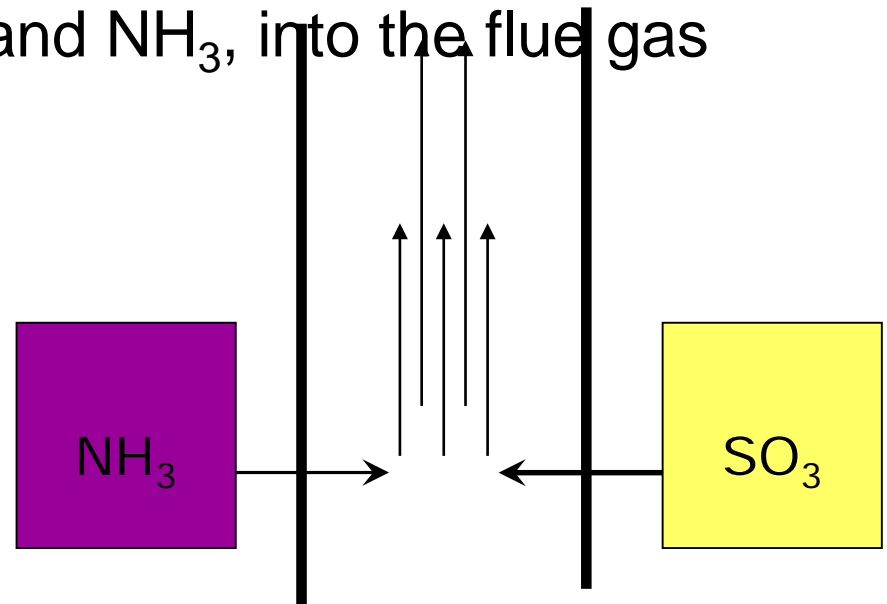


# DFGC - KEY DESIGN PARAMETERS

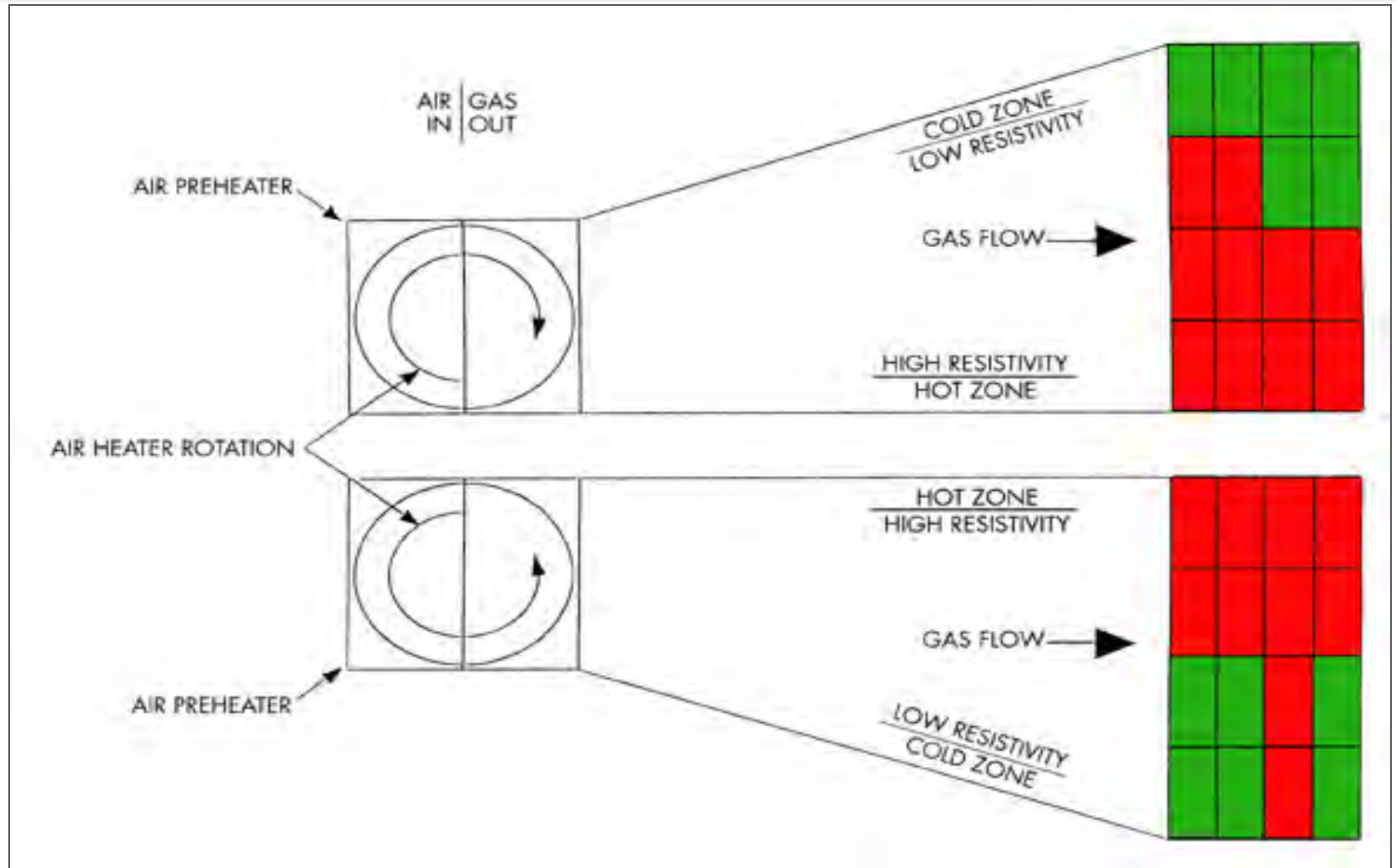
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A dual flue gas conditioning (DFGC) system simultaneously and independently injects two conditioning agents,  $\text{SO}_3$  and  $\text{NH}_3$ , into the flue gas

- Coal and Ash Analysis
- NEP Modeling
  - Injection Dosage Curve
  - Performance Guarantee
- CFD Modeling (Operational)
- Customized Equipment Engineering and Delivery

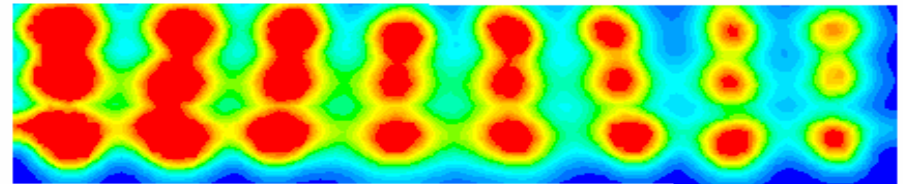
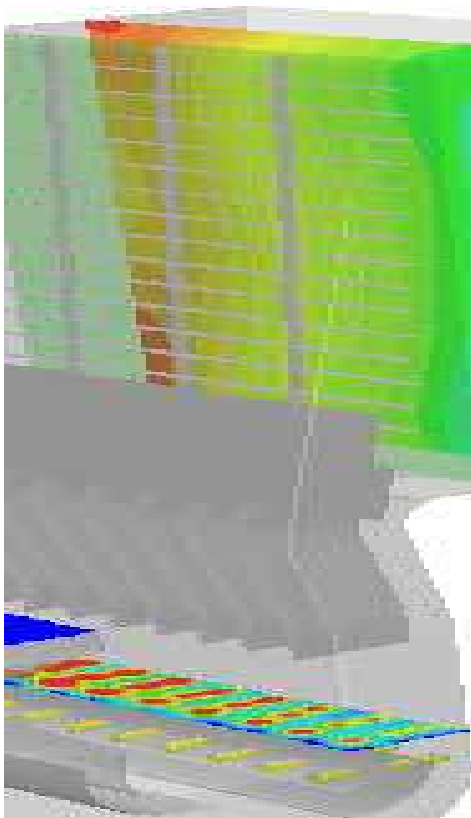
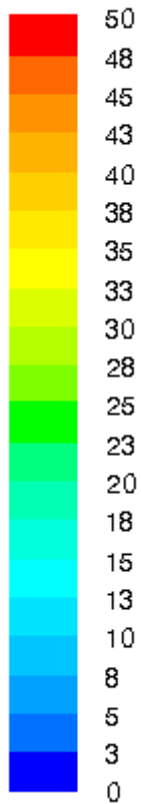


# IMPORTANCE OF MODELING FLUE GAS TEMPERATURES AHEAD OF ESP

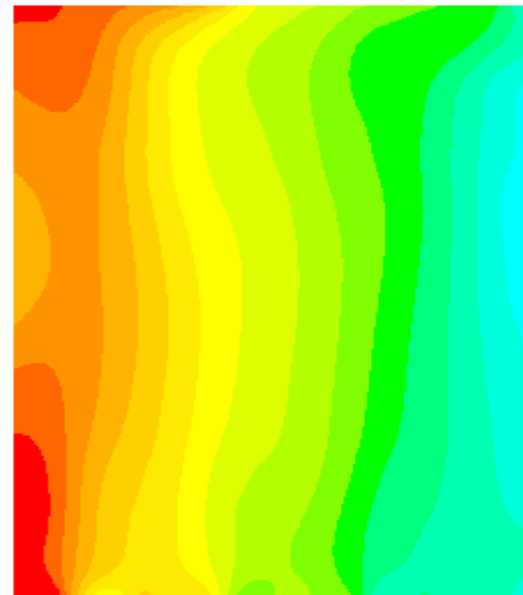


# BIASING OF SO<sub>3</sub> INJECTION PROBES

## SO<sub>3</sub> Injection Modeling

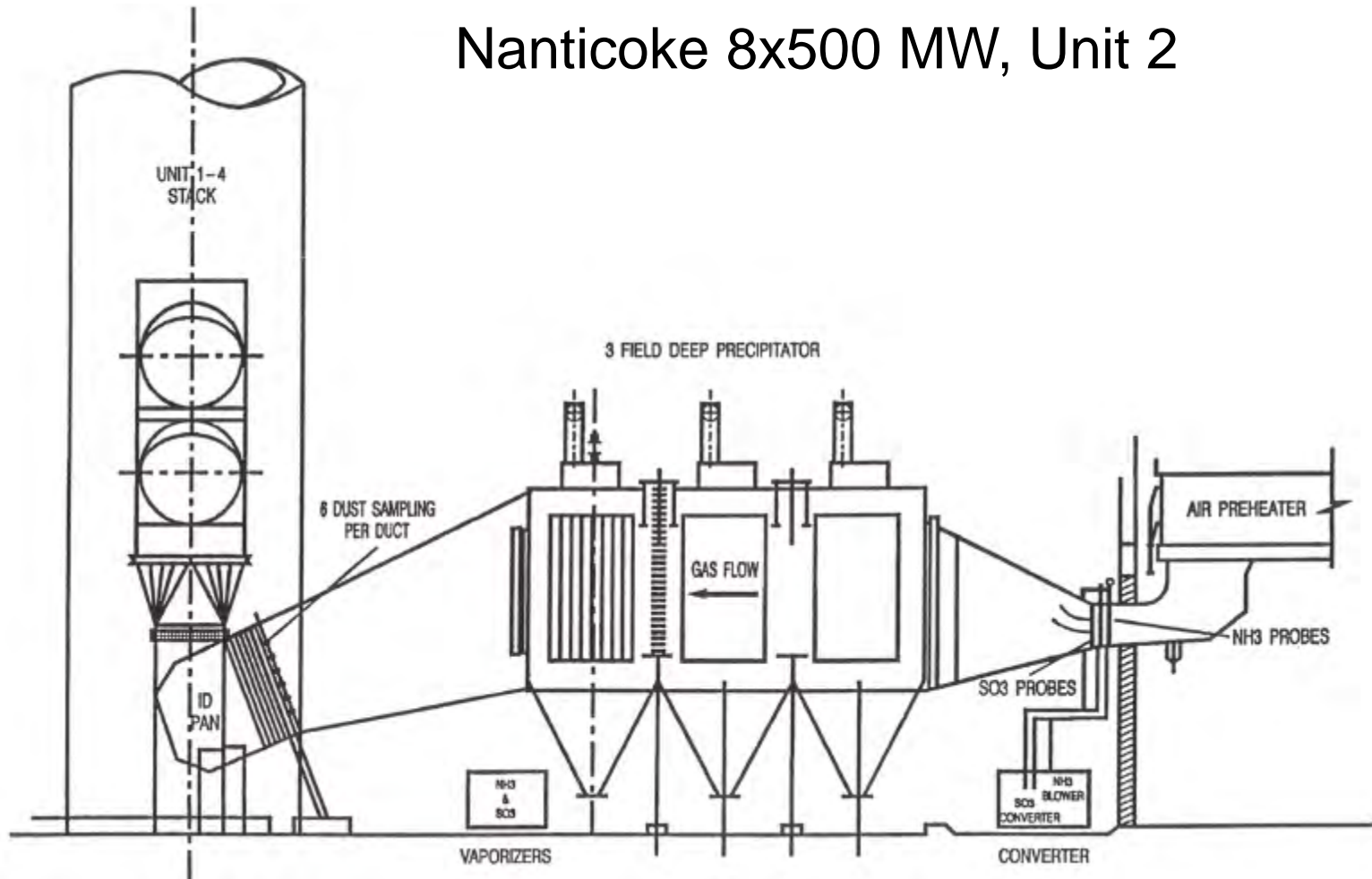


*SO<sub>3</sub> Concentration (ppm)*

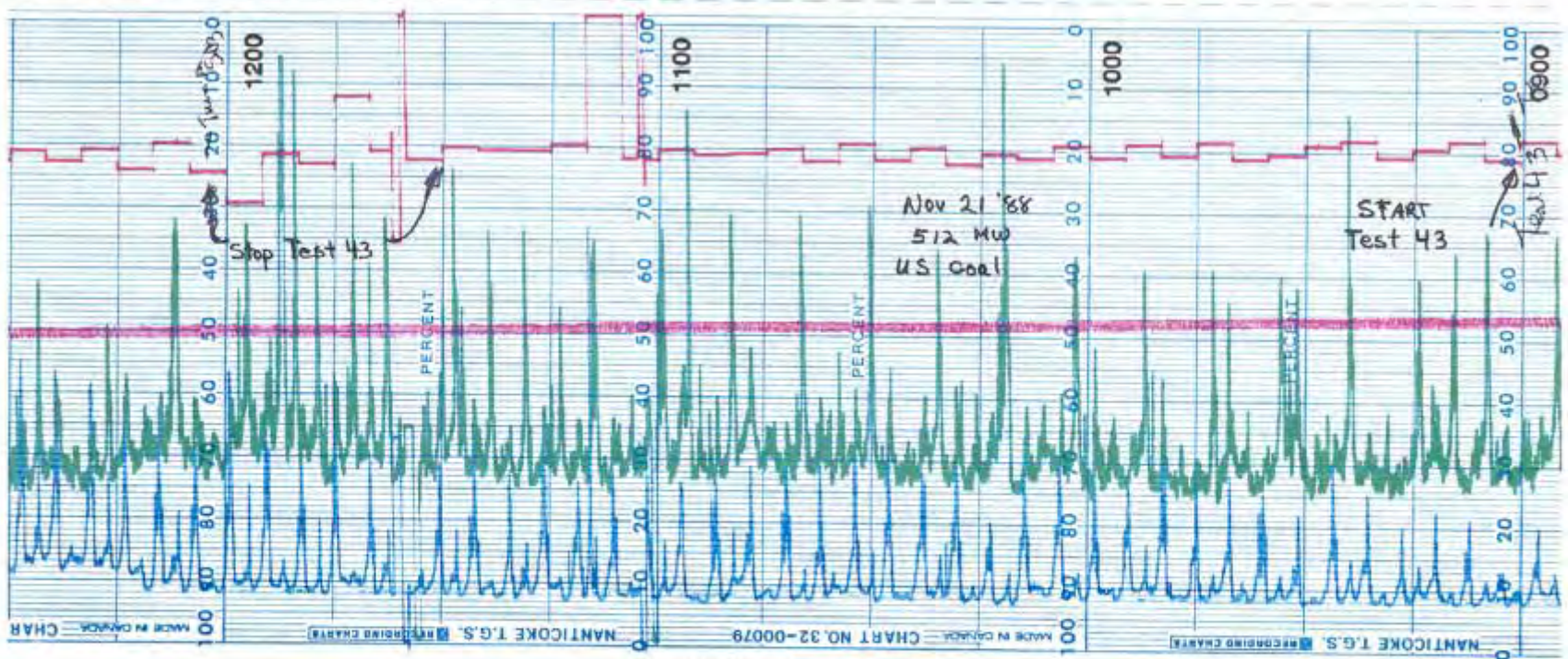


# DUAL FGC TEST SYSTEM INSTALLATION

Nanticoke 8x500 MW, Unit 2

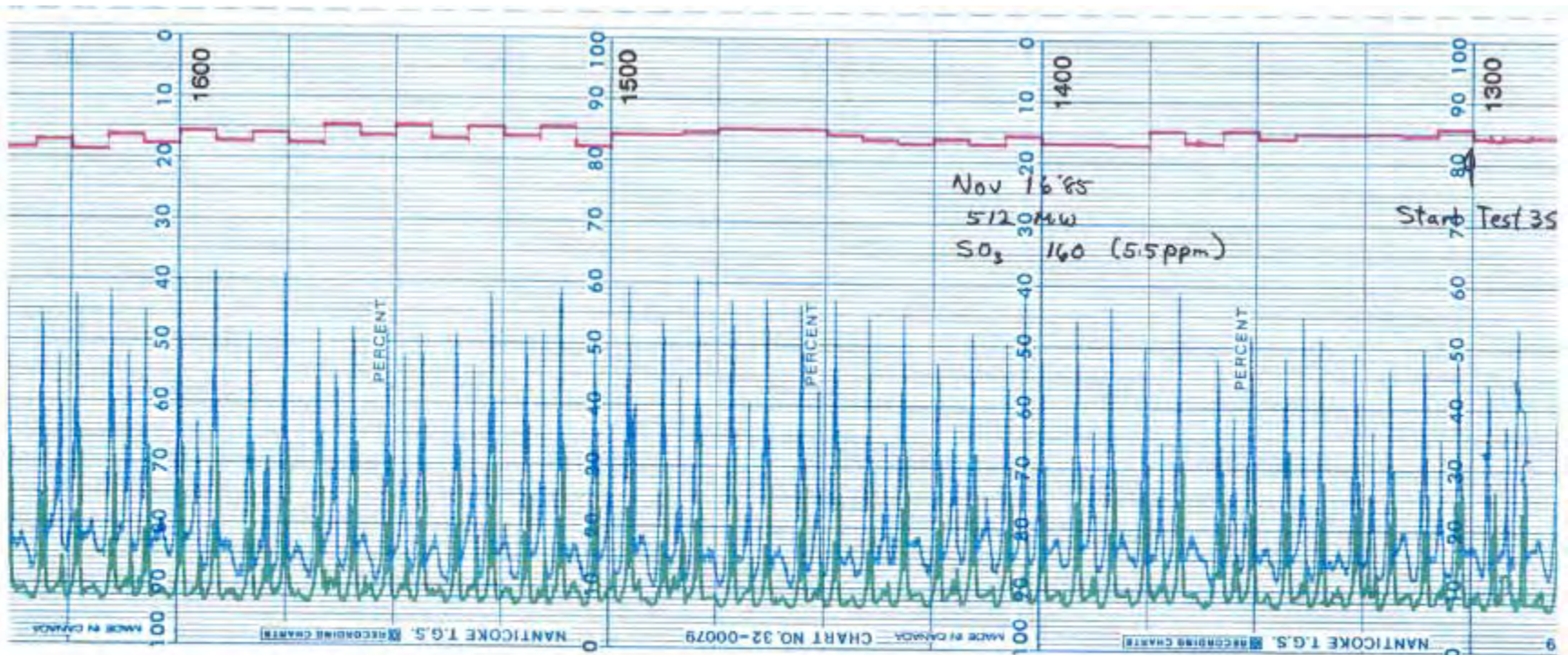


# NANTICOKE UNIT 2 OPACITY – NO FGC



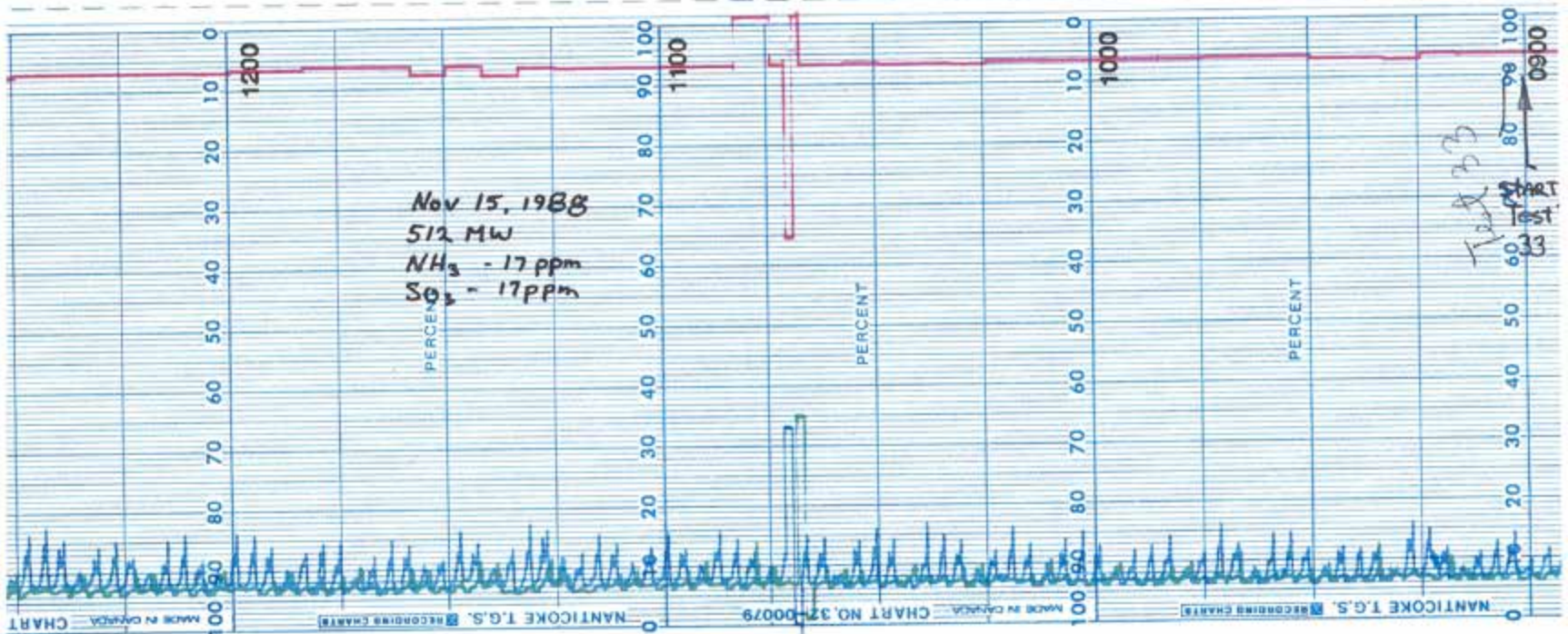
LOW SULFUR 50/50  
TEST 43  
SO3 OFF  
NH3 OFF

# NANTICOKE UNIT 2 OPACITY – SO<sub>3</sub> INJECTION



LOW SULFUR 50/50  
TEST 35  
SO<sub>3</sub> 5.5 ppm  
NH<sub>3</sub> OFF

# NANTICOKE UNIT 2 OPACITY – DUAL INJECTION



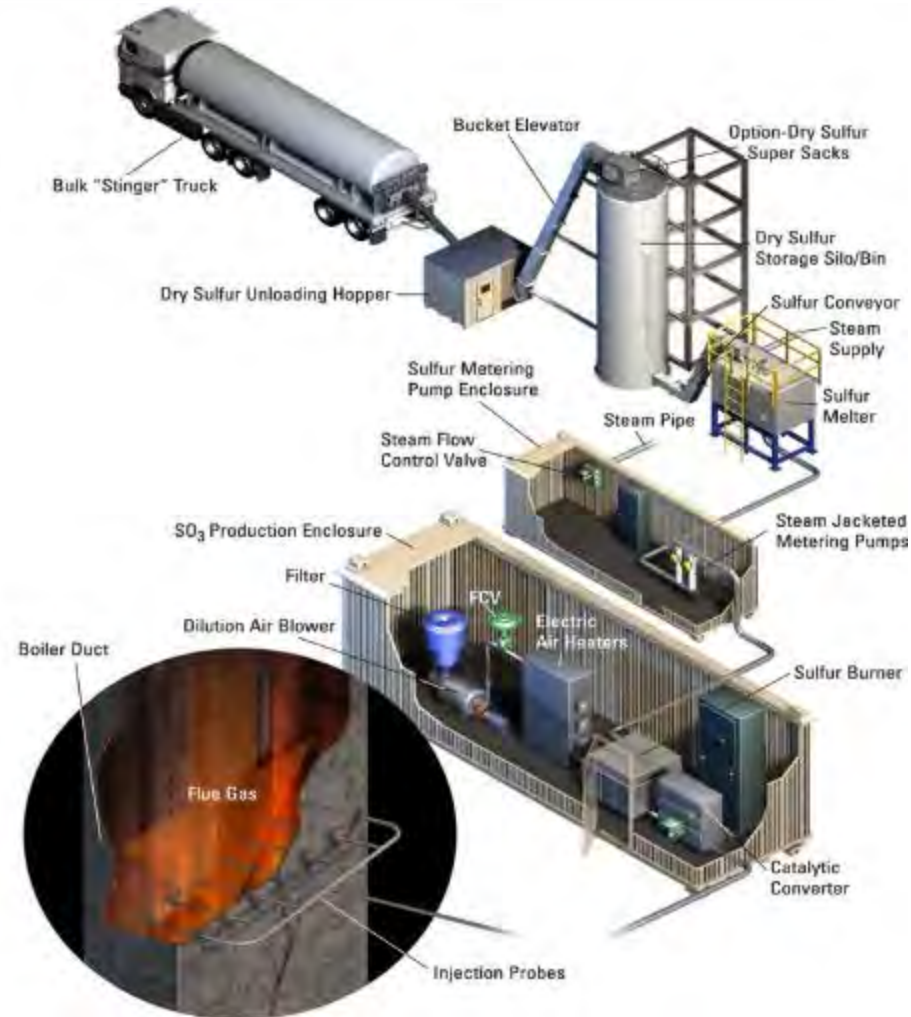
LOW SULFUR 50/50  
TEST 33  
SO<sub>3</sub> 17 ppm  
NH<sub>3</sub> 17 ppm

# STACK EMISSIONS (LOW SULFUR COAL WITH DUAL FGC)

	Test No.	14-1	14-2	15-1
SO <sub>3</sub>	Injected (ppmV)	17	17	17
SO <sub>3</sub>	Exiting Stack (ppmV)	1.8	2.0	1.5
NH <sub>3</sub>	Injected (ppmV)	17	17	17
NH <sub>3</sub>	Exiting Stack (ppmV)	0.13	0.04	0.16

# MOLTEN SULFUR ON DEMAND (MSD) SO<sub>3</sub> FGC EQUIPMENT

- Best suited for a wide range of applications.
- More expensive feedstock option than molten sulfur.
- Proven, reliable technology offered exclusively from Fuel Tech, Inc.



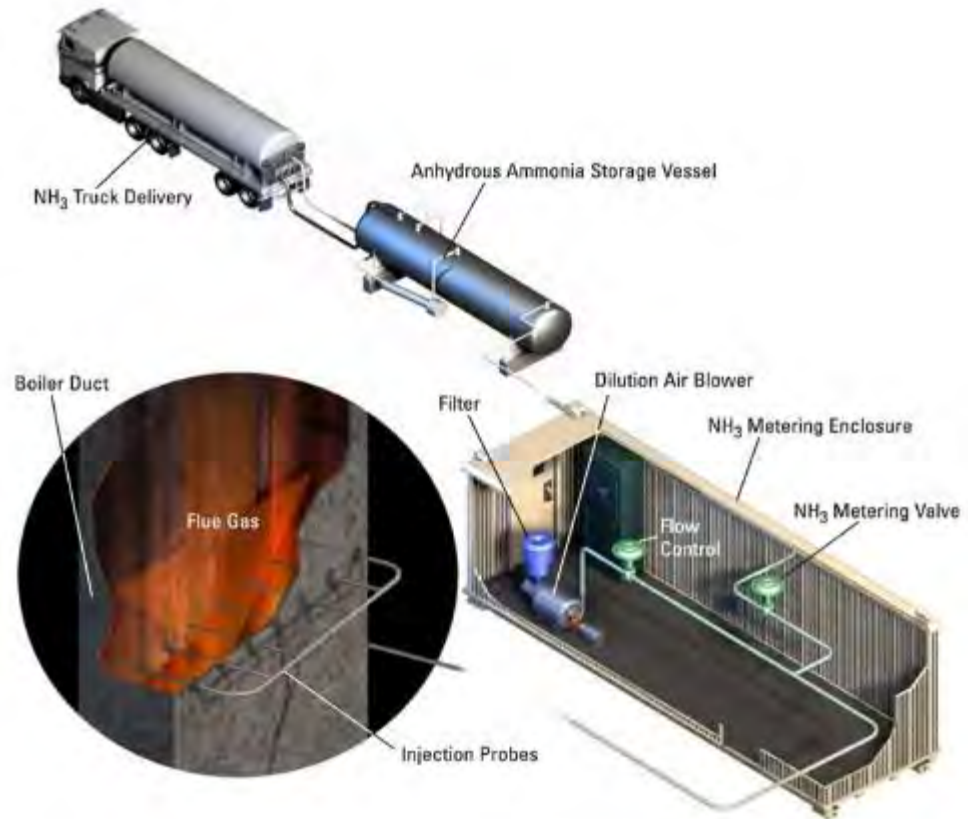
# SO3 FGC SYSTEM – 700 MW UNIT

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# ANHYDROUS AMMONIA BASED FGC EQUIPMENT

- Anhydrous  $\text{NH}_3$  feedstock requires least energy input
- Anhydrous system utilizes uninsulated carbon steel piping for transport to the injection probes for lowest cost installation
- 2,000 gallon tank is under the threshold for Risk Management Plans and intensive safety requirements



# ANHYDROUS AMMONIA STORAGE TANK & DILUTION SKID - 2X500MW UNIT

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# SO3 FGC PROGRAM CASE STUDY

## CHINA SHENHUA ZHUNGEER POWER PLANT

### Project Overview

- Original ESP dust concentration were 25 g/Nm<sup>3</sup> for Unit 1 and 15 g/Nm<sup>3</sup> for Unit 2 at inlet, and 116 mg/Nm<sup>3</sup> for Unit 1 and 85 mg/Nm<sup>3</sup> for Unit 2 at outlet
- FGC performance requirement to improve ESP outlet concentration to less than 20 mg/Nm<sup>3</sup> for Unit 1 and 2

<b>Fuel Type</b>	ZhunDong Coal
<b>Boiler Type and Size</b>	Two 330 MW tangentially-fired pulverized coal units

### Fuel Tech Solutions / Approach

- Challenging high dust resistivity conditions prevented client ESPs with large collecting areas to meet latest environmental regulatory goal of 30 mg/Nm<sup>3</sup>
- Fuel Tech designed FGC system to enhance customer's electrostatic precipitator performance and successfully meet client requirements
- Dual SO<sub>3</sub>/NH<sub>3</sub> flue gas conditioning system
- Project completed in 2014
- With Fuel Tech's FGC solution, Unit 1 achieves 18 mg/Nm<sup>3</sup> Unit 2 achieves 17 mg/Nm<sup>3</sup> at ESP outlet

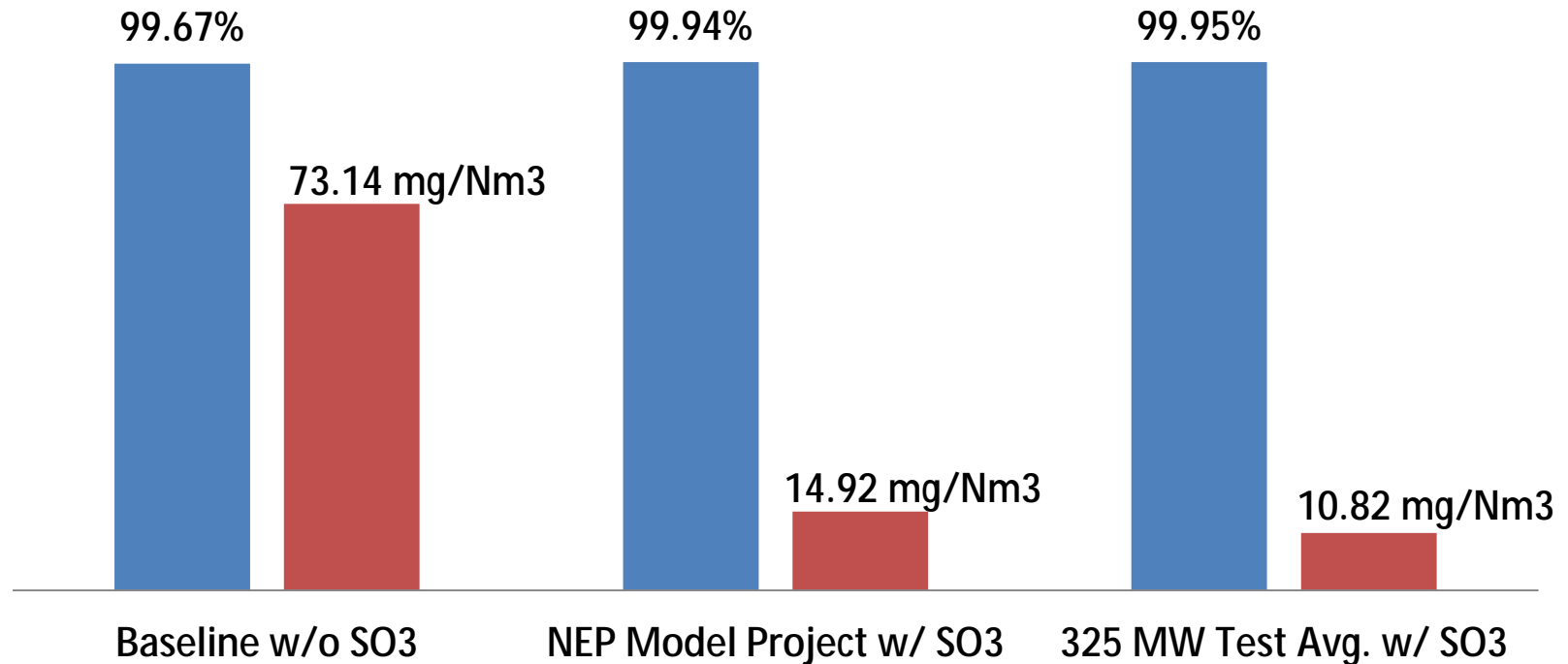


# SO3 FGC PROGRAM CASE STUDY

## CHINA SHENHUA ZHUNGEER POWER PLANT

### Zhungeer Power Plant 2x300MW, Unit 2 ESP Performance Comparison

■ Eff., %   ■ ESP Outlet Emissions, mg/Nm<sup>3</sup>



# ESP PERFORMANCE AND IMPROVEMENT STRATEGY EVALUATION – CASE HISTORY

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## Scope of Work

- ESP operational audit
- Control optimization
- ESP internal inspection
- Computational Fluid Dynamics (CFD) modeling of flue gas flow distribution
- Numerical ESP Performance (NEP) modeling of upgrade option and performance

## Achieve Result

- Optimize Automatic Voltage Controllers control parameter to maximize power input to ESPs
- Optimize rapping control to mitigate high opacity spikes
- Identify measures and mechanical modifications to increase dust collection efficiency by improving flue gas flow distribution and decrease opacity by preventing re-entrainment of fly ash

# NEP EVALUATION FOR ESP PERFORMANCE UPGRADES

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## Numerical ESP Performance (NEP) Modeling

- Analyze different cases of coals and coal blending scenarios. Determine the importance of total Fuel Flexibility at a given power station
- Predict ESP outlet PM emission levels and stack opacity
- Compare the existing ESP performance with different mechanical upgrade options and/or with the combination of SO<sub>3</sub> FGC, DFGC, and HFPS technologies in service.

**Recommend the most cost effective solution for ESP performance enhancement by incorporating the combined results from the ESP internal inspections, the operational audits, CFD modeling services and NEP modeling results.**

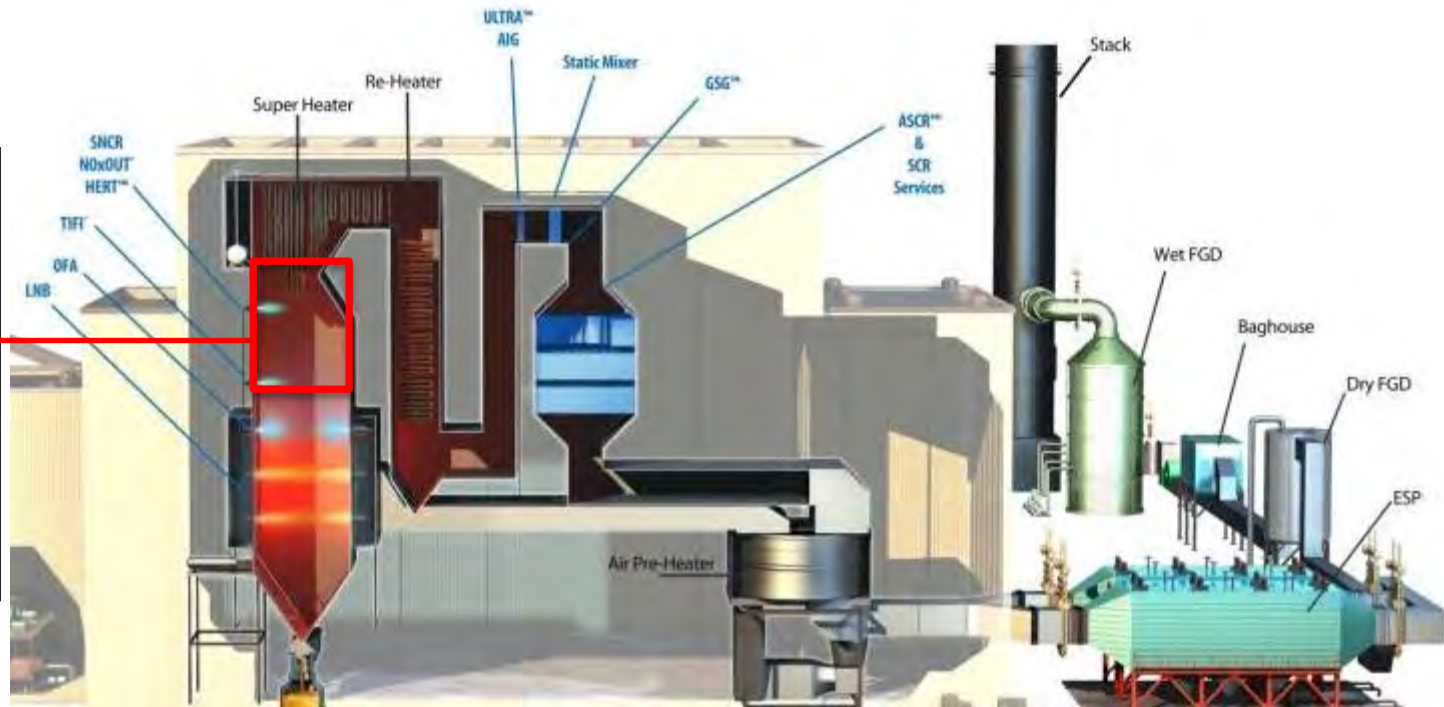
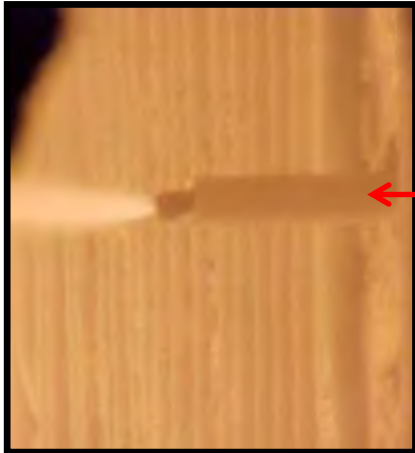


# Slagging and Fouling Control in the Coal Utility Industry



# TIFI<sup>®</sup> TARGETED IN-FURNACE INJECTION<sup>™</sup>

TIFI nozzle injecting reagent



# SLAG/FOULING CONTROL WITH TIFI

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- **Targeted injection towards problem areas**
  - Reagent slurry injection
  - Small quantities of chemical (sub-stoichiometric for deposit control)
- **Deposit control and SO<sub>3</sub> plume mitigation**
  - Furnace to stack
  - Minimum operating temperature (MOT) issues with SCR
- **Increased unit efficiency**
  - Increased unit availability/higher MW per ton of fuel fired
  - Lower operating costs
  - Optimized heat transfer
  - CO<sub>2</sub> reduction
- **Fuel flexibility**
  - Ability to fire opportunity fuels with lower ash fusion temperatures
  - Co-firing applications
  - Slagging and fouling control with biomass fuels
- **Safety**
  - Eliminate explosive de-slugging
  - Eliminate slag falls that can result in boiler damage/tube leak
  - Eliminate risk to personnel exposed to clinkers

# KEY TECHNOLOGIES TO CONTROL SLAGGING & FOULING

- Deposit Analysis
- Computational fluid dynamics (CFD)
- Injection technology
- Chemical technology
- Combustion expertise



# EFFICIENT CHEMICAL DELIVERY TO PROBLEM AREAS

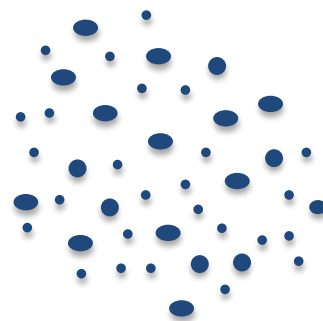
Particle calcination/disintegration

Distribution/reaction

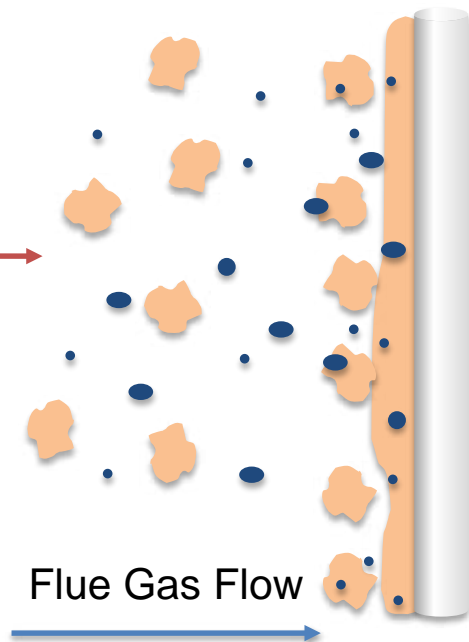


Reagent Particle  
( $d_{0.5}$  – 1.6-2.3  $\mu\text{m}$ )

Furnace Injection  
superheated  
 $\text{H}_2\text{O}$



Reagent Particles  
( $d_{0.5}$  – 0.06-0.3  $\mu\text{m}$ )  
(300-30,000 particles)

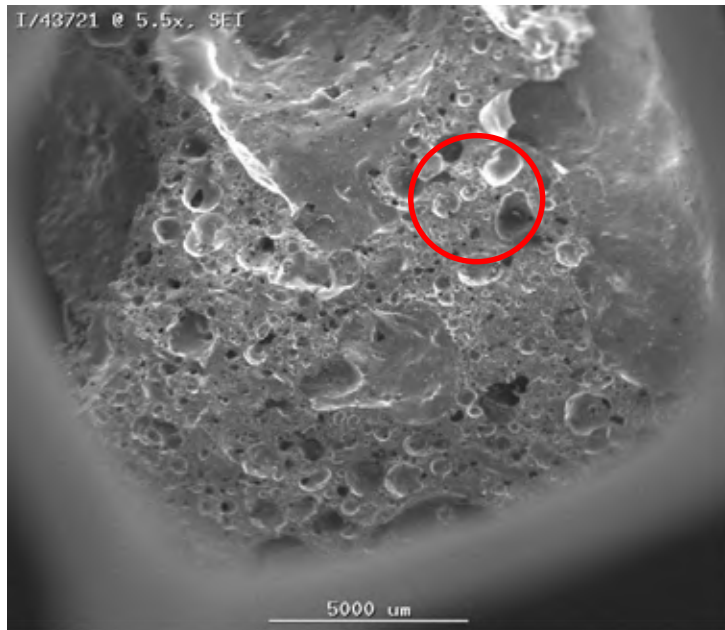


Deposits embedded  
with reagent  
particles

# IMPACT ON DEPOSIT PHYSICAL PROPERTIES

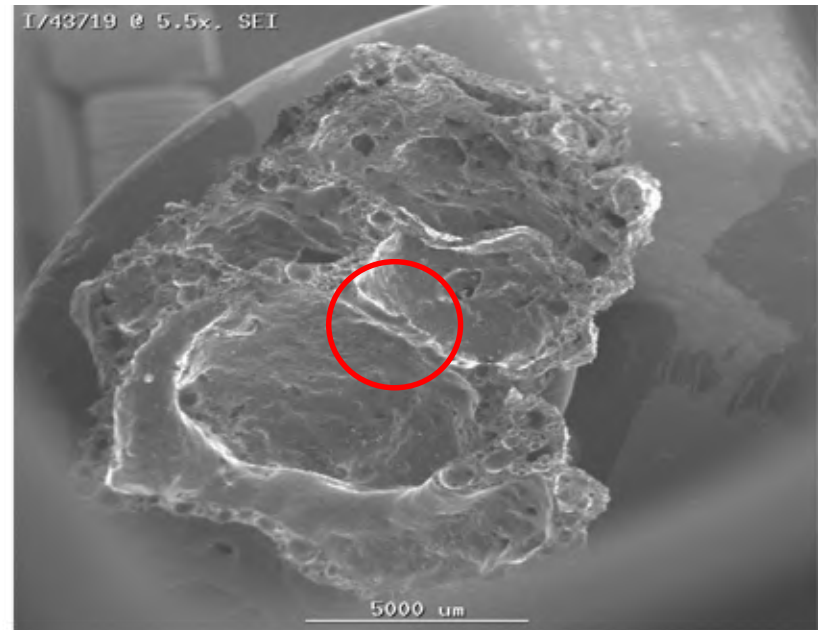
Scanning Electron Microscope (SEM) at 5.5X magnification

**NOTE: pore size comparison**



**Deposit without TIFI®**

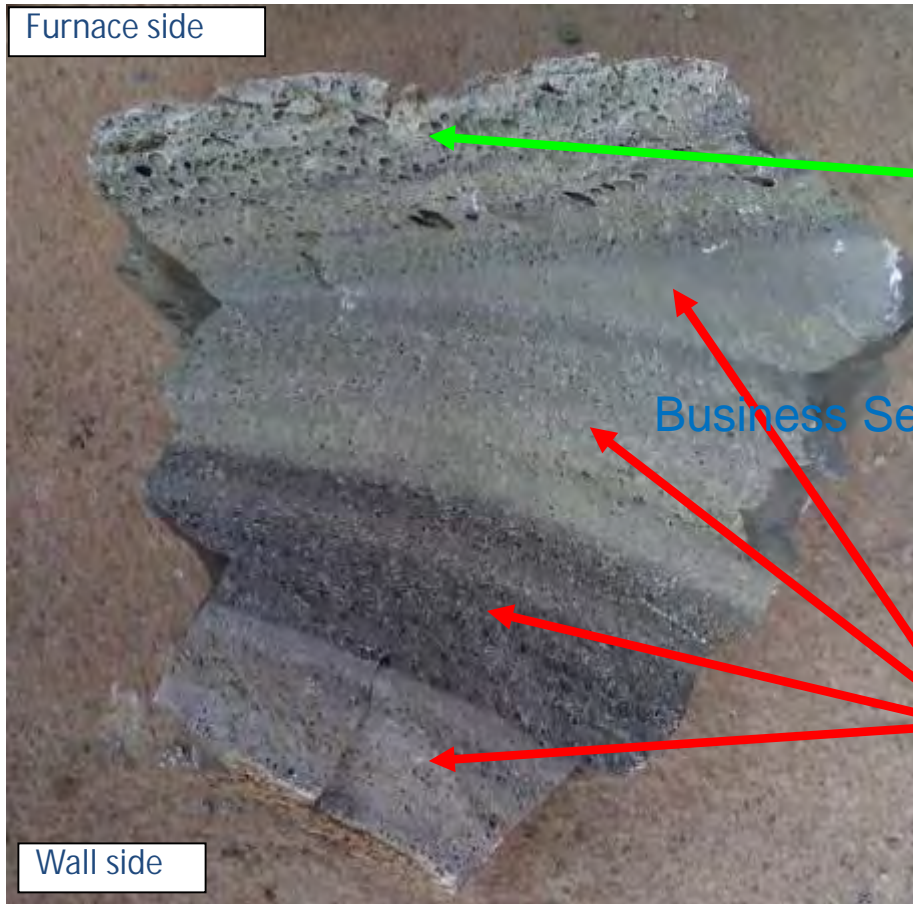
Numerous small pores with thick walls



**Deposit treated with TIFI®**

Larger pores with thin walls

# HARD SLAG FORMATION CONTROLLED



## After TIFI® treatment

- More pores
- Less dense
- Softer
- Easier to crumble/remove
- *Example of friable slag created via TIFI use*



## Before TIFI® treatment

- Tenacious
- Less pores and smaller
- Hard
- More dense



# CFD MODELING DESIGN PROCESS

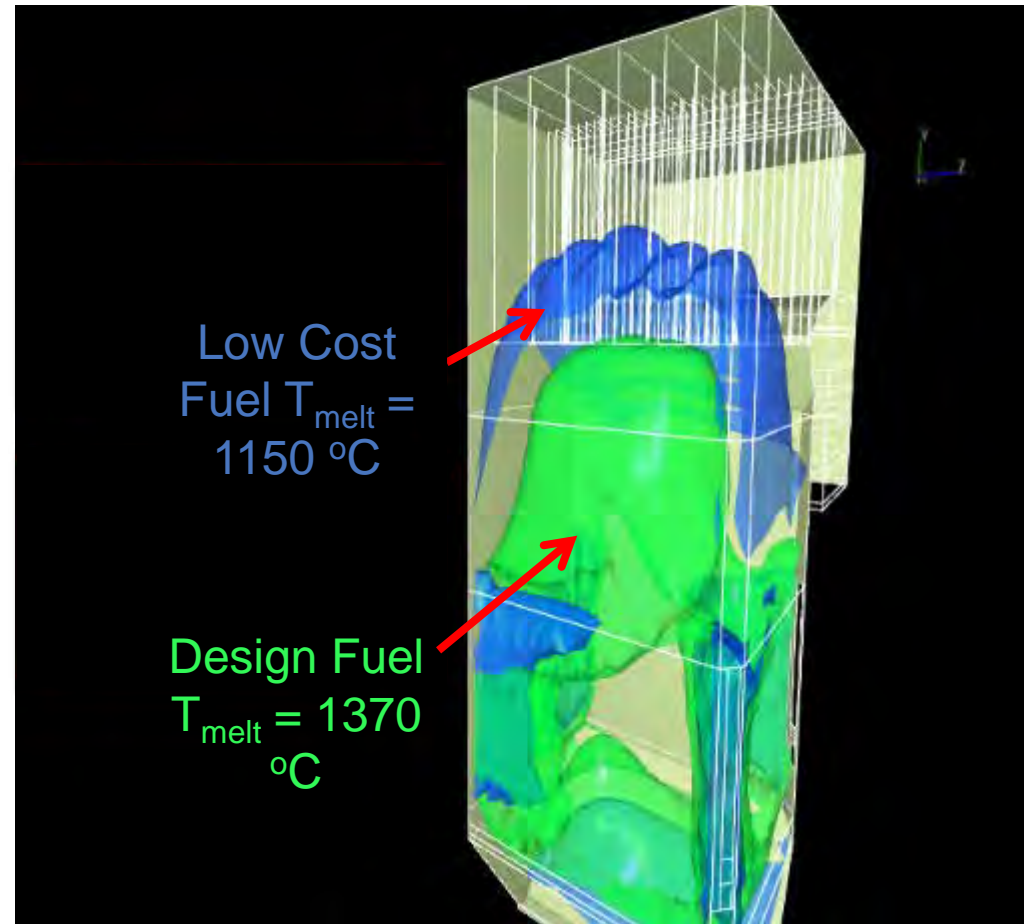
- Design: burn coal with  $T_{\text{fusion}} = 1370^\circ$  (Green)

- Goal: burn coal with  $T_{\text{fusion}} = 1150^\circ\text{C}$  (Blue)

- Less costly fuel (Blue)

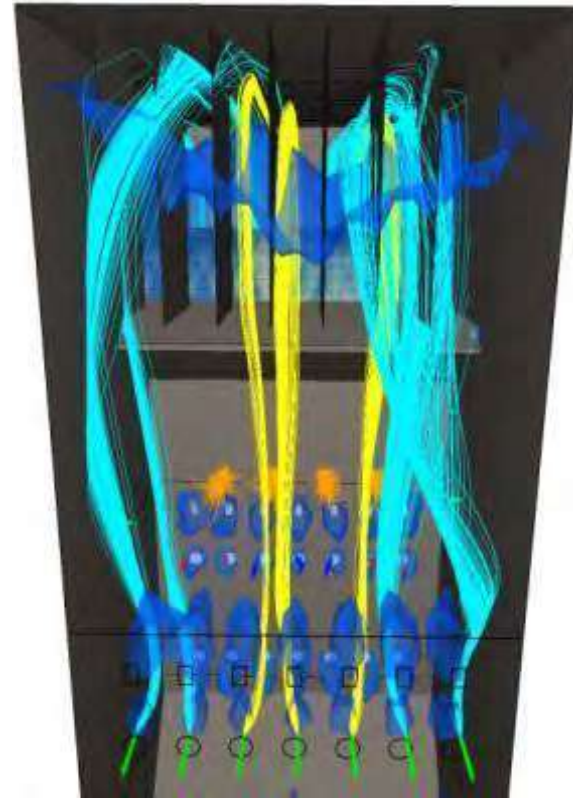
- Ability to co-fire different fuels

- Biomass
- Oil
- Coal
- RDF
- TDF



# INJECTION MODELING DESIGN PROCESS

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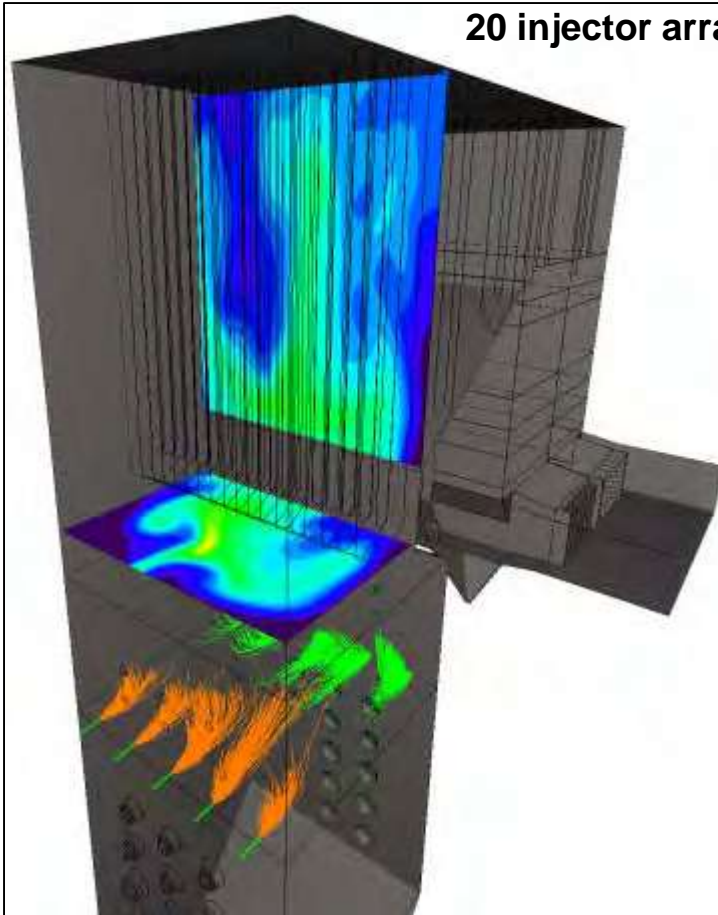


- Fuel analyses/combustion/laboratory data used to predict problem areas
    - Visual inspections are used to validate/tune model
  - TIFI program is designed to specifically target problem areas
-

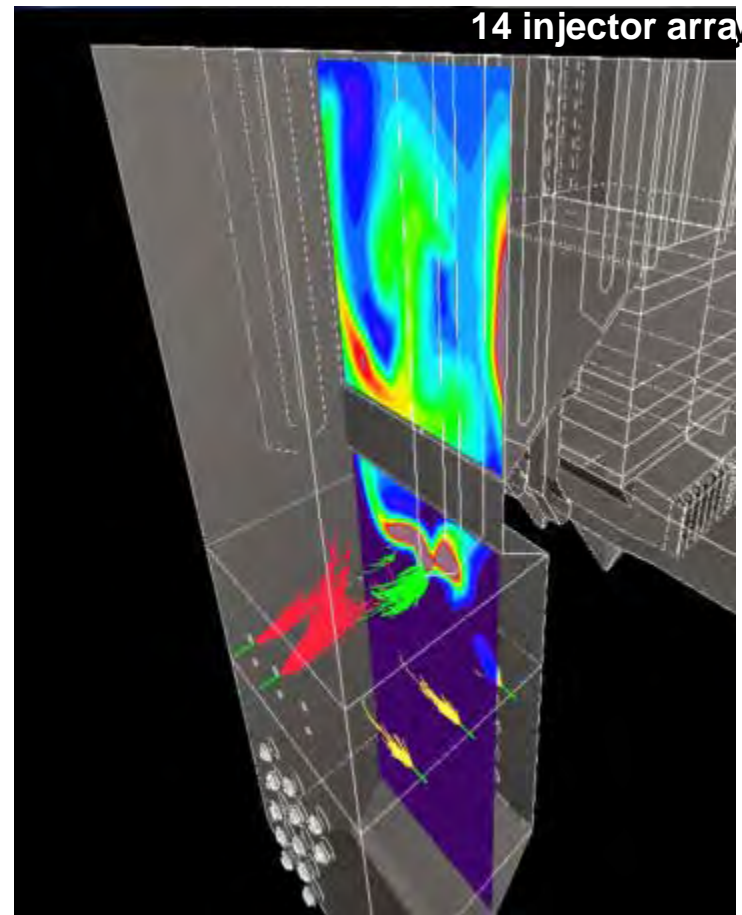
# OPTIMIZING THE INJECTION STRATEGY

## Right Half Furnace Model Upper Furnace Chemical Coverage

20 injector array



14 injector array



# TIFI® PROGRAM EQUIPMENT

Reagent tanks



Injectors



Manifolds



Compressed air  
 $Q < 0,75 \text{ m}^3/\text{min}/\text{injector}$ ;  $P > 6 \text{ bar}$

Low alkali water  
 $100 \div 120 \text{ l/h}/\text{injector}$ ;  $P > 2 \text{ bar}$

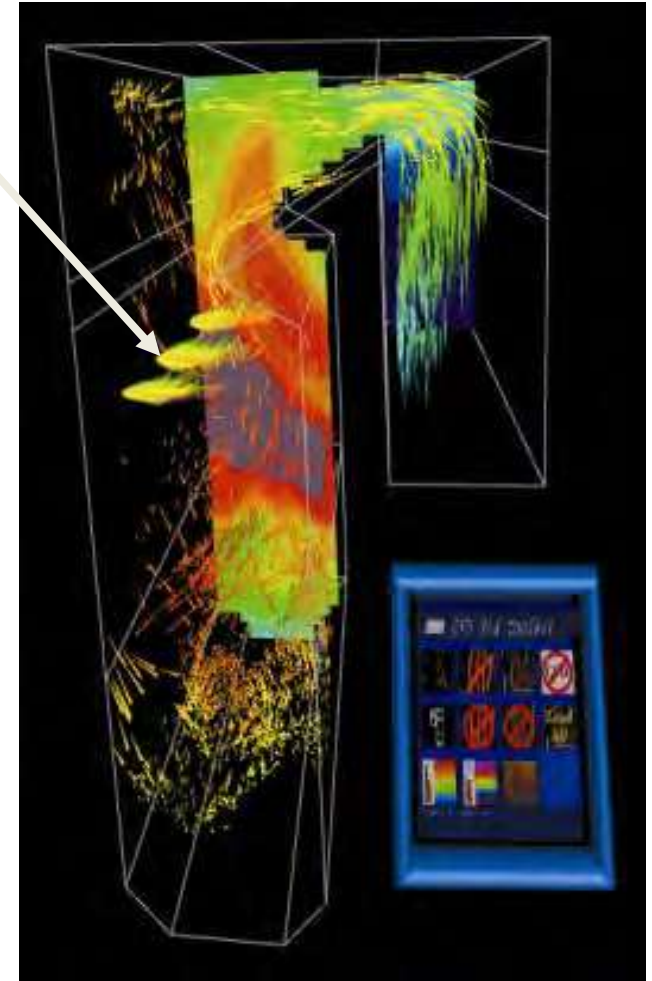
Re-circulation  
module



Chemical metering  
module



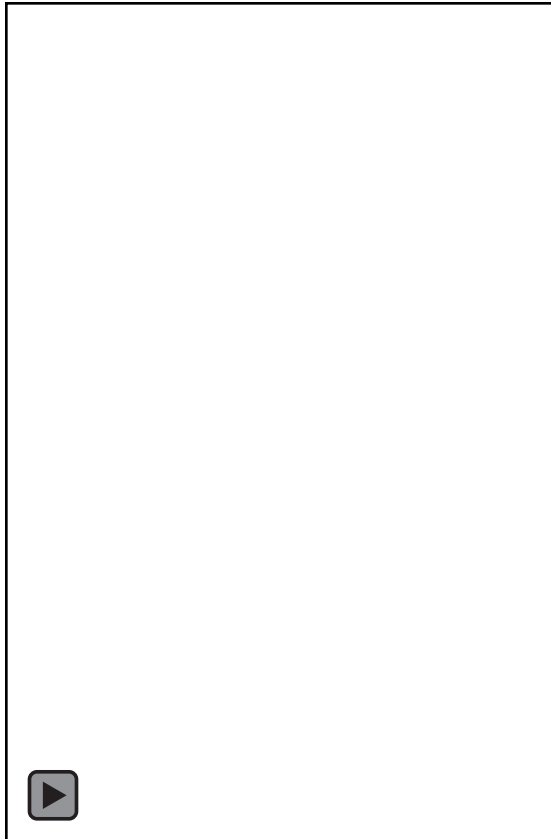
Chemical reagent



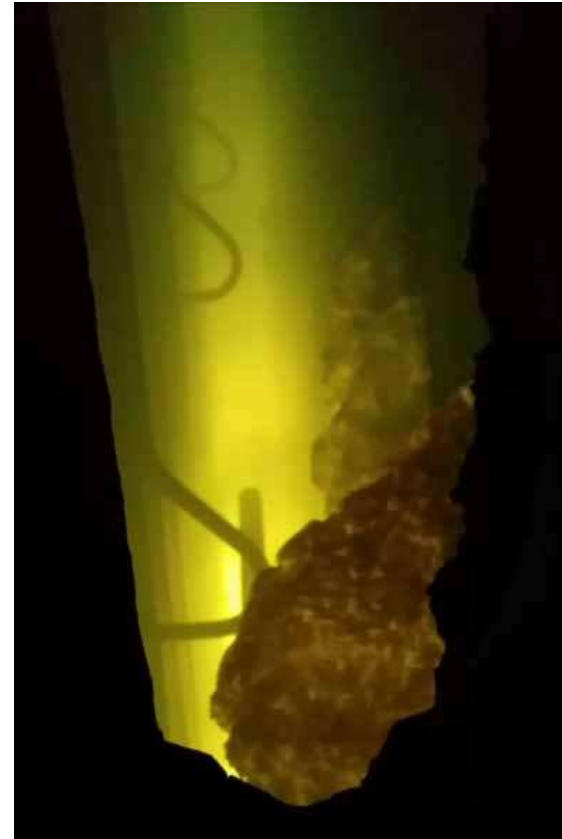
# IMPACTS OF TIFI® ON SOOTBLOWING (800 MW UNIT)

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Unit 2 - Treated



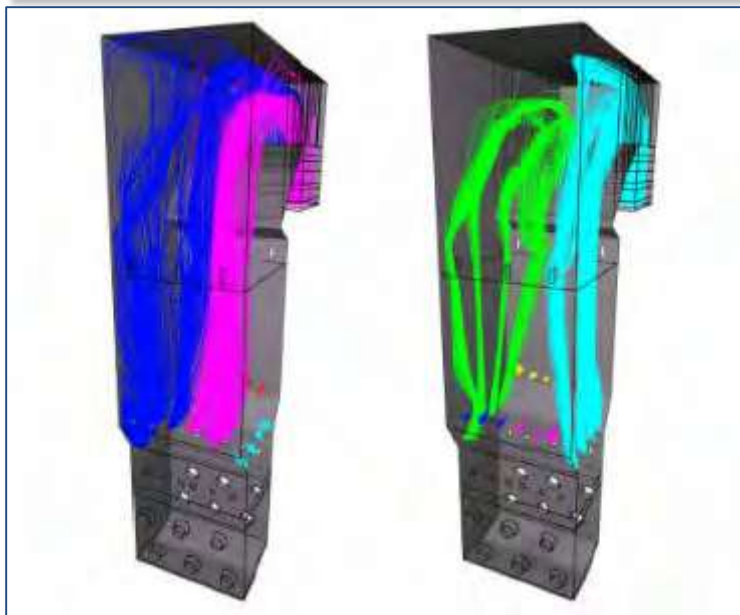
Unit 3 - Untreated



<http://www.ftek.com/images/ftek/media/en-US/video/BoilerOperationsVideo.mp4>

# TIFI® Program Case Study

*Basin Electric – Leland Olds Generating Station, Unit 2*



## Performance Improvements

- Over 58% Run Time > than 400MW (Compared to 29% Before Program)
- 45% Production Gain
- 120-180 Btu/kWh Decrease in Heat Rate
- Eliminated One Annual Cleaning Outage and Remaining Outages Shortened
- Reduced Sootblowing, Rodding, Shot Gun Cleaning & Blasting
- 5% decrease in ID fan power
- A 15 – 18% decrease in NOx emissions

## Design and Implementation

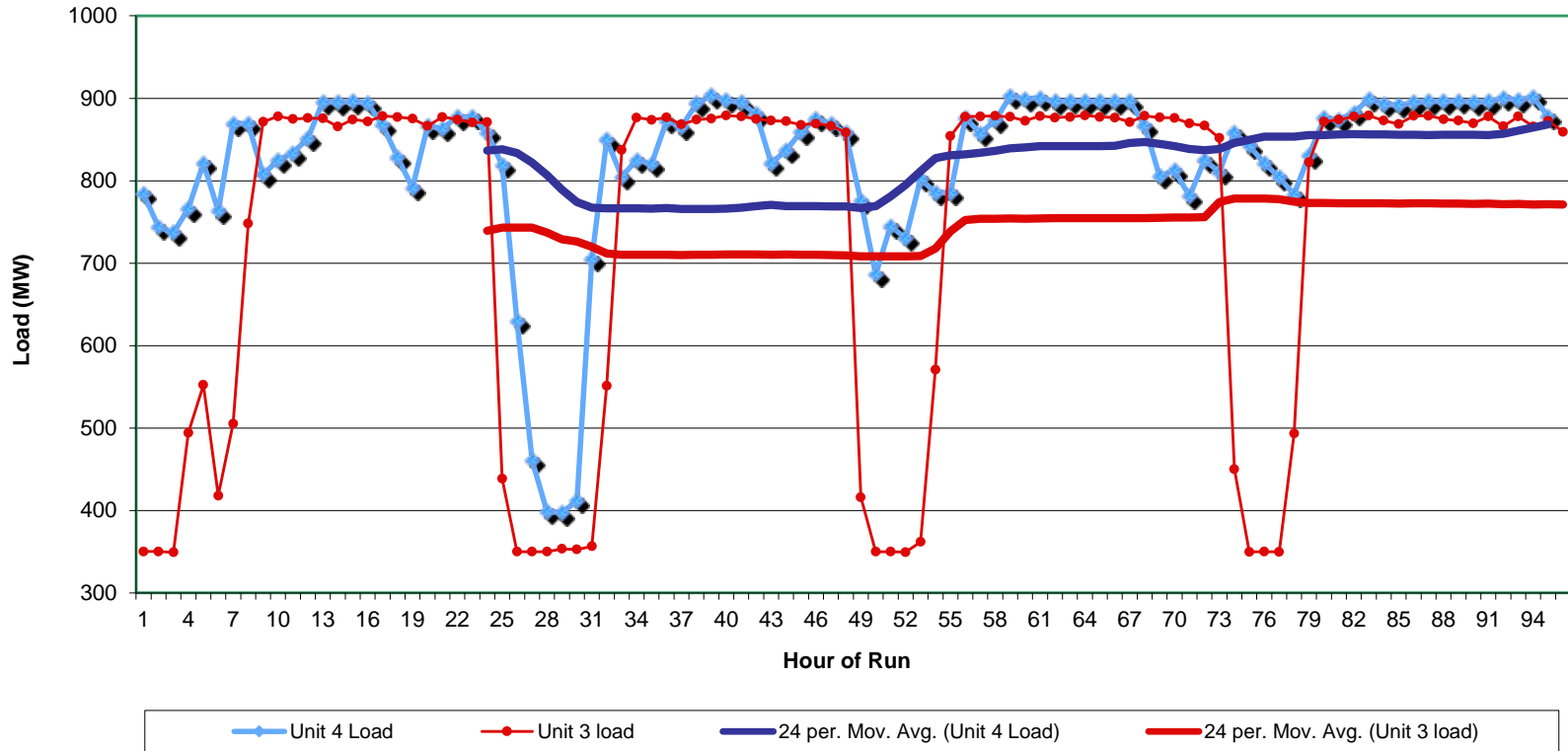
- Computational Fluid Dynamics Model of Boiler
- Optimized Chemical Feed Program using TIFI MG™
- Soot Blower Optimization Team
- Injection Rate Adjusted Based on Incoming Coal Properties
- 10-Point Boiler Grading Scale Based on Slag

Surveys

# TIFI® Program Case Study

## Georgia Power Plant Scherer, Unit 3 (Untreated) vs Unit 4 (Treated)

Georgia Power Plant Scherer  
Twin 900 MW Units



These identical 900 MW units burning PRB were forced to take nightly derates for deslagging as evidenced by this graph of load over a 4 day period. Unit 4 at this point was treated with the Fuel Chem TIFI program and shifted to load demand following instead of the previous forced derate for deslagging. Unit 3 remained untreated and continued the required derates. The moving average lines for each unit illustrate the ability of Unit 4 to deliver an additional 80-100 MW on a sustained basis avoiding substantial purchased power costs.

# TIFI® TREATMENT SUMMARY

- ∅ Fuel flexibility
- ∅ Availability gain
- ∅ Efficiency gain
- ∅ Maintenance benefit
- ∅ Environmental Improvement



Furnace After TIFI® Treatment



Initial Chemical Feed



TIFI Injection



After 24 Hours



# *Questions & Answers*