Controlling SO3, Slag and Fouling Results in Increased Fuel Flexibility

Howard Benisvy
Regional Sales Manager
SEE Conference
June 24, 2010
Targeted-In Furnace Injection™ Technology for Coal Fired Power Plants
Key Factors Affecting Fuel Flexibility
Case Study
Technology Benefits
Fuel Tech’s Global Activities

- Office Locations
  - Warrenville, IL
  - Stamford, CT
  - Milan, Italy
  - Beijing, China

- Countries where Fuel Tech does business
  - USA
  - Belgium
  - Canada
  - China
  - Czech Republic
  - France
  - Germany
  - Italy
  - Jamaica
  - Mexico
  - Poland
  - Portugal
  - Puerto Rico
  - South Korea
  - Spain
  - Taiwan
  - Turkey
  - United Kingdom
Fuel Tech Overview

- **FUEL CHEM® Technology**
  - Boiler Efficiency and Availability Improvements
  - Slag and Corrosion Reduction
  - Controls SO₃ Emissions and Addresses Related Issues

- Innovative Approaches to Enable Clean Efficient Energy
  - Capital Projects for Multi-Pollutant Control
  - NOₓOUT® Products including SNCR, CASCADE, RRI, ULTRA
  - Burners/OFA/Combustion Modifications

- Flow Modeling and SCR Catalyst Management Services
  - Computational Flow Dynamics and Physical Flow Modeling for Power Plant Systems
  - SCR System Optimization and Catalyst Management Services

- Technology solutions based on Advanced Engineering Computer Visualization and Modeling

- Stock Symbol - FTEK
• Highly reactive magnesium hydroxide Mg(OH)$_2$

• Patented process using Computational Fluid Dynamic Modeling

• Critical Design Criteria
  - Furnace gas flows and temperatures
  - Chemical distribution, particle size and feed rate
MAG Targeted In Furnace Injection (TIFI) Success
NOT Limited to Specific Fuels

Fuels

- Coal – Eastern, ILB, & Western (Including PRB)
- Pet Coke
- Oil – #6
- Black Liquor Recovery
- Municipal Solid Waste
- Tire Derived Fuel
- Wood
- Sludge
- Hazmat Kilns
PROGRAM OBJECTIVES

- SLAGGING REDUCTION
- FOULING REDUCTION
- SO3 REDUCTION
- NOx REDUCTION
- PLUME ABATEMENT
- CORROSION REDUCTION
- AIR HEATER PROTECTION
- HEAT RATE IMPROVEMENT
- FEGT REDUCTION
- PARTICULATE REDUCTION
- EQUIPMENT LIFE
- MAXIMUM WASTE THROUGHPUT
- FUELS FLEXIBILITY
- LOAD SHED ELIMINATION
- DERATE ELIMINATION
- UNPLANNED OUTAGE REDUCTION
- SOOTBLOWER REDUCTION
- EXTENDED CYCLES
- REDUCTION IN CLEANING CYCLES
- EXPLOSIVES REDUCTION
- MAXIMIZE AVAILABILITY
These problems result in substantial costs and lost profitability. Areas affected can include:

- Maintenance
- Repair
- Lost production
- Generating losses
- Fuel
**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 \rightarrow MgO (MP = 5000 F)**
- **Interdispersed within Slag**
  - Prevents slag particles from fusing
  - Creates voids
  - Raises slag viscosity

**Critical Process Parameters**
- Temperature
- O2
- Soot Blowing
- Mg distribution
To Change The Deposit Morphology, The MgO Must Get INTO The Deposit:

Mg Hydroxide Particle

Water

Superheated Water

Evaporation Explodes External Particle into Small (Sub-Micron) Droplets

MgO distributes fully into the Flue Gas

Residence Time for Combustion
ANATOMY OF A TYPICAL INJECTION SYSTEM

INJECTORS

AIR

WATER

MANIFOLDS

Tank

BOOST/RECIRC

CHEMICAL METERING
Grindability (HGI*) of Slag

- Before TIFI – 34
- After TIFI – 54

*Hardgrove Grindability Index (HGI) — A measurement of the relative ease of pulverizing a coal in comparison with a standard coal chosen as 100 grindability. The higher the grindability index, the easier the coal is to grind.
Model Example
Factors Affecting Fuel Flexibility

- Fuel Characteristics - %S, Fusion Temp, Ultimate Analysis- Fe, Ca, Na, V, etc
- Combustion/Excess O2 Balance
- Coal Mill Fineness
- SCR Performance & Conversion Rate
- AIG Tuning
- Ammonia Distribution & Control
- Soot blowers
What Chemistry Is Involved In The Generation Of These Problems?

**FUEL ELEMENTS=PROBLEMS**

- Sodium
- Sulfur
- Calcium
- Vanadium
- Potassium
- Iron
- Phosphorus
- Chloride
- Zinc/Heavy Metals
Good combustion with balanced excess oxygen control is critical to minimizing reducing conditions.

Poor Coal Mill Fineness can also increase reducing conditions.

Typical fusion temperatures of Eastern Bituminous coals are approximately 300°F less in reducing conditions.

Reducing conditions create more slag & fouling.

Slag and fouling can interfere with furnace gas flow, and can increase opportunities for additional reducing conditions.
Good Combustion is hard to maintain while burning low fusion coals.

Slag and fouling change Furnace gas flow characteristics & Excess O2 distribution.

Managing slag & unit cleanliness aids in minimizing negative effects of poor combustion.
Effect of O2 Variation
A-Side
B-side
SCR OUTLET

Effect of O2 Variation
A-Side B-side

SO3 Data
SCR Exit

R² = 0.3418

SO3 @ 3% O2 (ppm)

O2 (%)
Inlet SCR Temperatures & Affect on SO3

Babcock-Hitachi K.K.

Gas flow rate: 5415714 lb/h
Gas temp.: 741 deg. F
Inlet NOx: 211 ppmvd (@3% O2)
SO2: 1126 ppmvd (@23% O2)
O2: 3.88%, dry
$SO_3$ & $H_2SO_4$ Formation

- Fuel - %Sulfur
- Excess $O_2$
- Moisture
- Furnace temperature
- Slag control – Metals Present
- Catalyst Oxidation Rate & Relationship to Temperature- # of Layers present
- Load Profile – low & high load conditions
- Boiler tuning – combustion control
ABS Formation

• Need all factors that influence SO3 formation.
• Catalyst Performance
• SCR Inlet Temperatures
• O₂ control & Inlet NOx
• Ammonia Control System – AIG tuning.
• Ammonia Slip
• Load conditions – high & low load
Catalyst Life Cycle

- As Catalyst becomes deactivated, ammonia slip will occur.
- Ammonia slip in the presence of SO\textsubscript{3} will form ABS & influence Air Heater fouling.
- The greater the ammonia slip & fuel sulfur concentration, the faster AH DP will Rise.
- Typically becomes more significant with fuel sulfur content above 1.5%.
TIFI reduces $\text{SO}_3$ and $\text{H}_2\text{SO}_4$

- Lower Furnace Temperature
  - Decreased Oxidation Rate
  - Lower SCR SO$_2$ Conversion Rate
- More Balanced Furnace
  - Reduced Excess Oxygen
- Reduced Slag and Iron Deposits
  - Less Catalytic Oxidation
- Direct Reaction with MgO
  - $\text{MgO} + \text{SO}_3 \Rightarrow \text{MgSO}_4$
TIFI Helps Management of Catalyst Life Cycle

- Magnesium Chemistry very similar to Calcium which helps reduce catalyst poisoning from Arsenic.
- A Cleaner Furnace Reduces SCR Inlet Temperatures & SO₂ Conversion Rate
- Reduces ABS formation by Reducing SO₃ - Direct Reaction with MgO
  \[ \text{MgO} + \text{SO}_3 \rightarrow \text{MgSO}_4 \]
TIFI™ Targeted In-Furnace Injection™ at Santee Cooper, Cross Station
TIFI Program Objectives

Primary:
- SO$_3$ mitigation for Opacity Control
- Slag and furnace fouling
- Popcorn Ash (LPA) and SCR fouling

Secondary:
- Fuel Flexibility
- Unit Efficiency
- Unit Capability
Cross Station Unit 1

- Unit 1 - 600 MW opposed wall fired unit
- Staged combustion low-NOx burners
- Popcorn Ash problems (LPA) at air-heater
- Persistent problems with burner eyebrows, burner fires, furnace imbalance
- Addition of an SCR in 2003
- SCR blinded by LPA
Cross Station Unit 2

- Unit 2 - 600 MW T-fired unit
- Eastern Kentucky Bituminous coal
- Close-coupled Over-Fired Air
- Addition of an SCR in 2003
Fuel Switching

• New Coal in 2004
  ▶ Increased Iron Load (lbs iron/MBTU = \( \frac{\% Fe_2O_3 \times (% Ash/100)}{(BTU/lbs/10,000)} \))
    ➢ 1 lbs/10^6 BTU vs. 0.6 lbs/10^6 BTU
    ➢ Boiler Design: 0.56 lbs/10^6 BTU
  ▶ Decreased Ash Fusion Temperature
    ➢ 2000-2100°F vs. 2300°F
    ➢ Boiler Design: 2500°F

• Slag removal with explosives
• LPA forced SCR on-line cleaning
**SO₃ Concentrations at High Load**

**Unit #2 SO₃ Concentrations at 580 MW**

- **Economizer Outlet**
  - Baseline: 22 ppm
  - 5.0 lbs/ton: 11 ppm

- **SCR Outlet**
  - Baseline: 27 ppm
  - 5.0 lbs/ton: 10 ppm

- **Air Heater Outlet**
  - Baseline: 7 ppm
  - 5.0 lbs/ton: 4 ppm
SO$_3$ Concentrations at 430MW

Unit #2 SO3 Concentrations at 430 MW

SO$_3$ [ppm]

Baseline | 5.0 lbs/ton

Economizer Outlet | SCR Outlet | Air Heater Outlet

Baseline | 5.0 lbs/ton
Hard Slag Formation Has Been Controlled

Before TIFI slag

After TIFI treatment slag
SCR Pressure Drop - Popcorn Ash

NET MW vs. SCR DP

Baseline
TIFI Treatment

DATE

4/18/05  5/2/05  5/19/05  6/27/05  7/11/05  10/1/05  11/17/05  12/14/05  2/15/06  4/18/06  5/2/06  5/19/05  6/27/05  7/11/06  8/23/06  9/29/06  11/17/06  12/22/06  2/4/07  3/28/07

0  10  20  30  40  50  60  70

0  5  10  15  20  25

DP (in. H2O)

Net MW  SCR "A" DP  SCR "B" DP

NET MW

0  100  200  300  400  500  600  700
Unit 1 Boiler Efficiency

Boiler Efficiency Comparison

Percent - %

Net MW

4/16/05 to 4/16/06
4/16/06 to 4/16/07 Treated
Average Net Heat Rate
Improved by 120 BTU/kWhr

![Graph showing the average net heat rate improved by 120 BTU/kWhr, with data points for 4/16/05 to 4/16/06 and 4/16/06 to 4/16/07 treated.]
APH Inlet Temps Across the Load Range

Air Heater B Averaged Inlet Gas Temperature

- 4/16/05 to 4/16/06
- 4/16/06 to 4/16/07 Treated
TIFI Case Study Results

- Reduced SO₃ related opacity
- Reduced SO₃ at the AH Inlet by more than 65%
- Reduced Total Toxic Release (TTR) by 20%
  - 35% reduction in H₂SO₄
- Increased MW capability by 44.5 MWe
- Increased boiler efficiency by 0.65%
- Improved Heat Rate by 120 BTU/kWhr
Case Study Results

- Allowed Fuel Blending:
  - lower Fusion T, lower HV, higher Fe Coal
- Contributed to the reduction of popcorn ash
- Reduced outage cleaning time more than 50 percent
- Reduced clinker growth and Grinder maintenance
- Greatly improved ash handling characteristics
- Significantly reduced slag from higher slag forming coals
Summary

- While pursuing the environmental concern of SO$_3$ Opacity control, this program was able to generate very significant benefits.

- TIFI successfully contributed greater than 4 to 1 Return on Investment (ROI) from improved unit performance and additional savings from increased fuel flexibility.
Can TIFI Improve Control of:

- $\text{SO}_3$
- ABS
- AH DP

YES
TIFI Clean up Of Air Heater
Load vs Dewpoint

ABS
Cat Layer Added
Sulfuric Acid
AH DP Went Down from 17.8 to 14.7
Conclusions

- Fuel Flexibility is achievable
- Need to Manage Slag/Fouling, & SO3 in the Furnace and throughout the whole unit.
- Need to select your catalyst based on the fuels burned & fuel flexibility desired. Conversion rates are important on higher sulfur fuels
- Manage Catalyst Life Cycle
- Optimize Combustion
- TIFI can expand operating range of boiler on numerous fuels beyond design spec
Questions