TIFI® Targeted In-Furnace Injection™ Program
Applicability for EPA’s Clean Power Plan
Agenda

- Impacts of slag and fouling
- Slag and fouling control technologies
  - TIFI® Targeted In Furnace Injection™
  - What is TIFI?
  - How does TIFI work?
  - Case studies
- Impact on unit operating efficiency
- Impact on CO₂ reduction
- Conclusions
Slag and Fouling Mechanism

- **Slag deposition**
  - Condensation of molten, viscous inorganic species on colder surfaces (e.g. heat transfer tubes)
  - Typically on water walls, superheater tubes, reheater tubes

- **Fouling**
  - Deposition of gaseous species onto colder surfaces (e.g. heat transfer tubes)
  - Typically on primary reheater, economizer, air preheater

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![Diagram showing Flue Gas Flow with Slag and Fouling regions](image)

**Flue Gas Flow**

- Entrained molten liquid and solid ash particles

\[ T_{\text{skin}} < T' < T'' < T_{\text{gas}} \]
Impacts of Slag/Fouling on Unit Operations

- **Restricted gas flow path**
  - Build up between tubes results in pressure differential
  - Induced draft (ID) fan load increases to maintain prescribed draft

- **Reduced heat transfer efficiency**
  - Diminished heat absorption
  - Decreased steam output
  - Decreased heat rate
  - Decreased energy output
    - Lower MW per ton of fuel fired
    - Increased firing rate to achieve desired MW output
    - Increased CO\textsubscript{2} emissions (as well as other pollutants)

- **Safety**
  - Explosive de-slagging
  - Slag falls can result in water wall tube leaks
  - Boiler shutdowns
TIFI® Targeted In-Furnace Injection™

TIFI nozzle injecting magnesium hydroxide
Slag/Fouling Control with TIFI

- Targeted injection towards problem areas
  - Mg(OH)₂ or dual reagent slurry injection
  - Efficient chemical utilization
  - Small quantities of chemical (sub-stoichiometric for slag control)
- Deposit control and SO₃ plume mitigation
  - Furnace to stack
- Increased unit efficiency
  - Increased unit availability/higher MW with constant fuel flow
  - Lower operating costs
  - Optimized heat transfer
  - CO₂ reduction
- Fuel flexibility
  - Ability to fire opportunity fuels with low ash fusion temperatures
  - Co-firing applications
  - Slagging and fouling control with biomass fuels
- Safety
  - Eliminate explosive de-slagging
  - Eliminate slag falls that can result in boiler damage/tube leak
Key Technologies to Control Slagging & Fouling

- Computational fluid dynamics (CFD)
- Injection technology
- Chemical technology
- Combustion expertise
Targeting Chemistry to Problem Areas

- Fuel analyses and combustion data used to predict problem areas
  - Visual inspections are used to tune model
- TIFI Program is designed to specifically target problem areas
Opportunity to Switch Fuels

- **Design**: burn coal with $T_{\text{fusion}} = 2500^\circ\text{F}$ (Green)

- **Goal**: burn coal with $T_{\text{fusion}} = 2100^\circ\text{F}$ (Blue)

- Less costly fuel (Blue)

- Ability to co-fire different fuels:
  - Biomass
  - Oil
  - Coal
  - RDF
  - TDF

![Diagram showing design and low cost fuel temperatures]
Sootblowing Effectiveness

Unit 2 with TIFI

Unit 3
TIFI History in Slag/Fouling/Corrosion Control

• 20+ years of continuous treatment

• 100+ boilers successfully treated
  o Utility boilers 150 MW to 1300 MW
  o Industrial boilers : 10 MW to 100 MW

• Demonstration of ROI
  o Ability to fire opportunity fuel/fuel blends
  o Increase net heat rate (NHI)
  o Increase boiler efficiency
  o Minimize corrosion
Case 1: 500+ MW Utility Boiler
Fuel Switching History

• 2004: Plant signed long term contract for new coal
  o Increased iron content by 75%
    ▪ 1 lbs/MMBtu vs. 0.6 lbs/MMBtu
      – Boiler design: 0.56 lbs/MMBtu
  o Decreased ash fusion temperature
    ▪ From 2300 °F to 2000-2100°F
    ▪ Boiler Design: 2500°F

• Slag removal conducted with explosives
• Large particle ash (LPA) forced SCR on-line cleaning
Case 1: Goals

- Large utility boiler (> 500 MW)

- Goals for TIFI
  - Reduce $\text{SO}_3$-related opacity
  - Reduce LPA and fouling in SCR
  - Reduce the coal-related slag and fouling issues
  - Increase fuel flexibility
    - Long term contract for high iron, high sulfur fuel

- Success of first unit prompted adoption of TIFI on additional three units
Hard Slag Formation Controlled

Before TIFI treatment
- Tenacious
- Fewer pores
- Hard
- Dense
- Glassy

After TIFI treatment
- Lighter
- Softer
- Easier to crumble

Furnace side

Wall side
Superheater Tubes: TIFI vs. No Treatment

Baseline

TIFI (Day 4)

Infrared (IR) Camera Images of Slagging at Secondary Superheater
Boiler Efficiency: TIFI vs. Baseline

- Increase in boiler efficiency between 0.51% - 0.77%
- Increase achievable full load by 44.5 MW\(_e\) with treatment
Improvement in Net Heat Rates

- Annual average improvement ~ 120 Btu/kWh
  - Approximately 1.25% improvement
  - Sustained for nine years
SCR Pressure Drop - Popcorn Ash

NET MW vs. SCR DP

Baseline
TIFI Treatment

SCR Diff. Pressure (in. H$_2$O)

DATE

4/16/05 5/26/05 7/19/05 8/27/05 10/7/05 11/7/05 12/14/05 2/5/06 4/7/06 6/3/06 7/11/06 8/23/06 9/29/06 11/7/06 12/22/05 2/4/07 3/28/07

NET MW

0 100 200 300 400 500 600 700

SCR "A" DP
SCR "B" DP

Net MW

FUEL TECH
Technologies to enable clean efficient energy
Additional Efficiency Gains at Case 1

- Steam attemperation spray flow decreased
- Reduced parasitic demand for ID and FD fans
Case Study Conclusions

- Allowed fuel blending:
  - Lower $T_{\text{fusion}}$, higher Fe, higher S coal
- Contributed to the reduction of LPA
  - More efficient SCR operation
  - No online cleaning necessary with treatment
- Reduced outage cleaning time > 50%
- Reduced clinker growth
- Greatly improved ash handling characteristics
- Reduced slag with higher slag forming coals
TIFI Case Study Conclusions

- Reduced SO$_3$ related opacity
- Reduced SO$_3$ at the AH Inlet by more than 65%
- Reduced Total Toxic Release (TTR) by 20%
  - 35% reduction in H$_2$SO$_4$
- Increased MW capability by 44.5 MW$_e$
  - fuel switching caused de-rates to control slag
- Increased boiler efficiency by 0.51-0.77%
- Improved net heat rate by 120 Btu/kWhr
Case 2: 900+ MW Utility Boiler
Case 2: Goals

- Large utility boiler (900+ MW)
- Goals for TIFI
  - Increase fuel flexibility
    - Long term contract for high iron, high sulfur fuel
  - Fan output limitation
    - Restricted to < 0.8 in. H₂O across reheater tubes
Comparison of Slag Deposits: TIFI vs. Baseline

Baseline (no treatment)  Treated with TIFI
Reheater $\Delta p$ vs. Net MW

- Reheater $\Delta p$ maintained below 0.8 in. H$_2$O with low cost fuel
## Demonstration Results (Fuel Blend 1)

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<thead>
<tr>
<th>First Demo Run</th>
<th>TIFI XP (20-Apr to 2-June-2009)</th>
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## Demonstration Results (Fuel Blend 2)

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<td>Dry Gas Losses</td>
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<td><strong>Boiler Eff. (Heat Loss Method)</strong></td>
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Image: FUEL TECH

**Technologies to enable clean efficient energy**
Impact of TIFI on Superheater Spray Flow

- Improved heat transfer
  - Reduced spray flows to maintain steam temperatures in superheater
Owing to greater efficiency, less fuel is required to generate equivalent MW

- TIFI-1: treated, fuel blend 1
- Baseline-2: no treatment, fuel blend 2
- TIFI-2: treated, fuel blend 2

Note: No baseline for TIFI-1 b/c severe slagging shut down unit

- Owing to greater efficiency, less fuel is required to generate equivalent MW
• Decrease in CO₂ emissions by 3%-7% with treatment
Summary

- **Targeted In-Furnace Injection (TIFI)**
  - Targeted injection of Mg(OH)$_2$ or dual chemical feed program
  - Targets slag/fouling/corrosion in furnace and convective section
  - SO$_3$ abatement
- **Combustion optimization and slag/fouling control can:**
  - Increase heat transfer and boiler efficiency (0.5%-2%)
  - Decrease fuel input required for load maintenance
  - Decrease parasitic demand by ID and FD fans
  - Water savings from decreased attemperation spray flows
- **Slag control can be an integral part of the solution for limiting CO$_2$ emissions from fossil fuel combustion units**