July 14, 2016

I-NOx™ Integrated NOx Reduction Technology

FUEL TECH
Technologies to enable clean efficient energy

McIlvaine PacifiCorp Webinar No. 1

COMMERCIAL PRODUCTS

Advanced Modeling Services – All Technologies

Combustion Technologies, Targeted In-Furnace Injection for Slag and Fouling Control

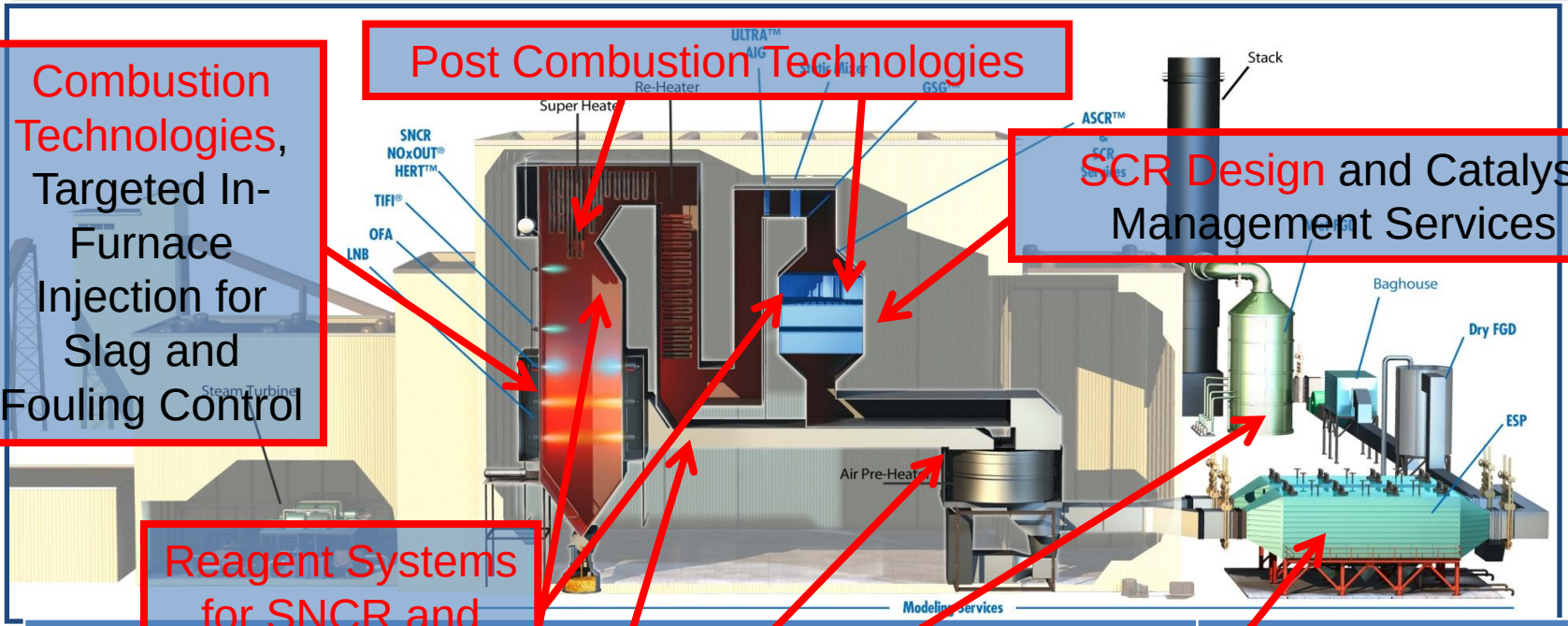
Post Combustion Technologies

SCR Design and Catalyst Management Services

Reagent Systems for SNCR and SCR (ULTRA™)

ESP Rebuild and Flue Gas Conditioning Systems

Flue Gas Flow Troubleshooting & Ash Mitigation



Fuel Tech Technologies		Non-Fuel Tech Supplied
• **ASCR™ Advanced SCR:** System which combines LNB + OFA + SNCR + AIG + GSG™ + Catalyst • **AIG:** Ammonia Injection Grid • **GSG™:** Graduated Straightening Grid • **HERT™:** SNCR system using high energy injectors • **LNB:** Low NOx Burners • **NOxOUT®:** SNCR system using high momentum injectors • **ULTRA™:** Urea-based ammonia generation system for SCR • **SCR:** Selective Catalytic Reduction • **SNCR:** Selective Non-Catalytic Reduction	• **SCR Services:** Selective Catalytic Reduction Services which include: optimizing process design, catalyst selection, and improving the overall performance of SCR • **Static Mixer:** Equipment used to mix temperature, velocity, and NOx to optimize SCR performance ahead of the AIG • **TIFI Targeted In-Furnace Injection™:** Chemical Injection Programs used to target slag control SO_3 mitigation and fuel flexibility	• **Baghouse:** Controls Particulate Matter (PM) emissions • **ESP:** Electrostatic Precipitator for PM control • **Wet FGD:** Scrubber to maximize SO_2 removal using Flue Gas De-Sulfurization (FGD) • **Dry FGD:** Scrubber to remove SO_2 with less water than Wet FGD

FUEL TECH'S I-NOx TECHNOLOGY

- Combustion Modifications
  - Low NOx Burners and Over Fire Air for Wall Fired Units
  - Combustion Modifications and Separated Over Fire Air for T-Fired Units
  - Additional Modifications and Combustion Tuning to Reduce NOx Further
- Selective Non-Catalytic Reduction of NOx (SNCR)
  - In-Furnace Injection – Furnace is Reactor
  - Low Capital Cost
  - Additional NOx Reduction / Optimized Reagent Consumption when Combined w/ASCR
- ASCR™ Advanced Selective Catalytic Reduction of NOx
  - Single Layer of Catalyst Where Applicable
  - In-Duct Arrangement with Proper Flow and Ash Distribution
- Combining Multiple Technologies Requires Technical "Know-How" and Commercial Experience

I-NOx CHALLENGES AND BENEFITS

- Design Must Be Truly Integrated:
  - SNCR Design Must Account for Combustion Output and Varying Operational Conditions of Typical Boiler
  - SCR Design Must Account for SNCR Output and Varying Operational Conditions of the In-Furnace Combustion and SNCR Systems as Boiler Conditions Fluctuate
- Challenges:
  - Physical Space Limitations for In-Duct Reactor
  - Highly Maldistributed NOx and NH_3 from Boiler
  - Increased SCR Velocity Due to Restrictions in Catalyst Installation Space
  - Both Require Expert Knowledge in the Design of All of the Technologies being combined
  - Computational and Experimental Fluid Dynamics Modeling Coupled with Flow Distribution Device Optimization
- Benefits:
  - Integrated Technologies Provide Lower Capital Cost w/ NOx Reductions Ranging from 50 – 80%
  - Optimized Reagent Consumption, Lower dP, Reduced Catalyst Replacement, Lower SO_2-SO_3 Oxidation, Lower Minimum Operating Temperatures, Etc.

FUEL TECH I-NOx COMMERCIAL EXPERIENCE

- Reliant Energy Seward Station (1999)
  - 147 MW T-Fired Unit
  - SNCR + SCR, 55% NOx Reduction
- AES Greenidge (2005)
  - 115 MW T-Fired
  - Significantly Improved Chemical Utilization w/ASCR
  - Combustion Modifications + SNCR + ASCR, >60% NOx Reduction
- China Light and Power Castle Peak (2010)
  - Four (4) 680 MW Wall Fired Units
  - Boosted OFA, ASCR, and ULTRA Urea Conversion
  - ASCR Provided 40% NOx Reduction
- China Steel Corporation, Taiwan (2014)
  - Three (3) 80 MW T-Fired Units
  - Four (4) Sub-Systems Deployed – Combustion Modifications, New SOFA System, SNCR, and ASCR
  - > 78% Total NOx Reduction

Question & Answer - Thank You

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