GLOBAL PRESENCE

OFFICE LOCATIONS:
- Warrenville, IL, USA (Corporate HQ)
- Stamford, CT, USA
- Durham, NC, USA
- Westlake, OH, USA
- Milan, Italy
- Beijing, China
- Santiago, Chile

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
AGENDA

• Introduction
• SNCR on Large Utility Boilers
  o Unique challenges to Scale-Up
  o Applications
• Advanced SNCR
  o Improvements to traditional SNCR
  o Advanced Injection and Control
• Advanced SNCR: Large Utility Boilers
COMPANY HISTORY

2009 and Earlier

1981: Fuel Tech is Incorporated
1986: Fuel Tech acquires core SNCR patents
1987: Fuel Tech N.V. Parent Holding Company Formed
1990: Fuel Tech enters joint venture with Nalco Chemical
1993: Fuel Tech on NASDAQ Exchange
1996: Fuel Tech opens office in Italy
1998: American Bailey Corporation buyout of Nalco interest

2001 - 2009

2001: 73 Employees
2005: 105 Employees
2006: Fuel Tech becomes U.S. Legal Entity
2007: Fuel Tech Environmental Technologies Co., LTD is created (Beijing, China)
2008: Fuel Tech acquires Flow Tack, LLC and Tackticks, LLC Technologies
2009: Fuel Tech acquires Advanced Combustion Technologies (ACT)

2010 - 2014

2010: 173 Employees
2012: Fuel Tech SPAC (Chile)
2013: 200 Employees
2014: Fuel Tech acquires PECO-FGC

1986:
Fuel Tech acquires core SNCR patents

1990:
Fuel Tech enters joint venture with Nalco Chemical

2009:
Fuel Tech acquires Advanced Combustion Technologies (ACT)
BUSINESS SEGMENTS

FUEL CHEM®
• TIFI® Targeted In-Furnace Injection™ technology
• Boiler efficiency, slag and corrosion reduction, SO₃ abatement
• Focus is on clean, efficient energy and fuel flexibility

Air Pollution Control (APC)
• NOₓ 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
TYPICAL POWER PLANT

Fuel Tech Technologies

- **ASCR™**: Advanced SCR: Combines LNB, OFA, SNCR, AIG, GSG™ + Catalyst
- **AIG**: Ammonia Injection Grid
- **GSG™**: Graduated Straightening Grid
- **HERT™**: High Energy Reagent Technology™
- **LNB**: Low NOx Burners
- **NOx OUT™**: SNCR system using high momentum injectors
- **OFA**: Over-Fire Air
- **ULTRA™**: Safe Ammonia Generation System
- **SCR**: Selective Catalytic Reduction
- **SNCR**: Selective Non-Catalytic Reduction
- **SCR Services**: 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, SO3 mitigation, and fuel flexibility
- **ESP**: Electrostatic precipitator for PM control
- **Wet FGD**: Scrubber to maximize SO2 removal using Flue Gas De-Sulfurization (FGD)
- **Dry FGD**: Scrubber to remove SO2 with less water than Wet FGD
THREE DIMENSIONAL ANALYSIS SUITE

Proprietary Software with Strong IP Protection; Patented Technology
- Provides an intuitive interaction between the Models and the Design Engineers

Chemical Kinetics Code
- Predicts chemical reactions along a specific particle path

Injection Modeling
- Tuned to a variety of Fuel Tech Injector solutions.

Cold Flow Modeling
- Highly accurate physical models that replicate gas flows, injection patterns, etc.

Computational Fluid Dynamics (CFD) Model
- Customized for each boiler
- Predicts particle path
Wide range of NO\textsubscript{x} control technologies allow for custom system configurations specific to customer’s needs.

NO\textsubscript{x} CONTROL TECHNOLOGIES

Patented, state-of-the-art proprietary technologies for multi-pollutant control

Multiple technology options which can be combined as a cost effective means for NO\textsubscript{x} reduction. Systems are backed by performance guarantees.

Technologies Include:

- NO\textsubscript{x}OUT\textsuperscript{®} and HERT\textsuperscript{™} SNCR systems target 20-50% reduction
- Low NO\textsubscript{x} burners and Over-Fire Air systems target 40-70% reduction
- SCR systems target 80%+ reduction
- SCR Catalyst Management Services
- I-NO\textsubscript{x}™ Integrated NO\textsubscript{x} Reduction targets 80%+ reduction
ULTRA™ & XCAM™ SYSTEMS

ULTRA™ Systems: On-site ammonia generation

Urea-based systems which offer a safe and cost effective alternative to ammonia for SCR and FGC applications.

XCAM™ Extractive Ammonia Monitoring Systems

Accurate ammonia monitoring systems that combine the best of extractive and TDL measurement for SNCR and SCR systems.
In-furnace, Post-combustion Control
  - Injection of Aqueous Urea Droplets
  - 25 – 70% NOx Reduction
  - Many Injection Options:
    - Compressed Air
    - Mechanical
    - Multiple Nozzle Lances – Water Cooled
  - Package Boilers to Utility Boilers (>525 units)
  - Option for Aqueous or Anhydrous Ammonia
SCALE-UP TO LARGE FURNACES

• Extensive Models predict effective zone
  o Dependent on Temperature, NOx, CO
  o Validated with field measurements

• Chemical distribution in effective zone
  o Requires a suite of injector options

• Large furnaces offer unique challenges
  o Low NOx baseline
  o High gas temperatures (and often high CO)
  o Very large plan area
TEMPERATURE WINDOW 150ppm CO
TEMPERATURE WINDOW 500ppm CO
MULTIPLE NOZZLE LANCE
WATER-COOLED
MULTIPLE NOZZLE LANCE RETRACT MECHANISM
• Continuously improving applications on large utility furnaces since 1999
• NOx baselines have decreased
• LNBs have generally caused higher CO
• NOx emissions limits have decreased
• NOx reductions still average 30%
• Wide variation in required reduction
  o Client needs determine system design
FUEL TECH SNCR ON UNITS > 400MW

Average NOx reduction of 30%

Total MW installed

Average Controlled NOx [mg/Nm³]
Ex #1 LARGE UTILITY BOILERS – 2013

- Two 620MWg PRB-fired, Riley-turbo units
  - Baselines of 310mg/Nm3, @ 3% O2
- Single zone of wall-injection
  - 25% reduction on one unit
  - 13% reduction on the other, identical unit
- Performance highly dependent on slag
  - Higher upper furnace gas temperatures
  - Higher CO concentration
ADDITIONAL INJECTION POINTS
• Second zone of air-atomized wall-injectors
• Third zone: multiple nozzle lances (MNLs)
  o 36% reduction on both units to 200mg/Nm3
  o Operation dependent on furnace conditions
  o Ammonia slip below permit limits
• Additional wall-injectors
  o Installed to provide control to 50% MCR
Ex #2 LARGE UTILITY BOILERS – 2013

• B&W 620MWg PRB, Opposed-wall-fired
  o Baseline is 235mg/Nm3, @ 3% O2
• Single zone of mechanical wall-injectors
  o 25% reduction target achieved
  o < 180 mg/Nm3 controlled NOx
• Additional zone of air-atomized injectors
  o Reduction target maintained
  o Chemical use decreased by 35%
INJECTION MODELING
LARGE UTILITY BOILERS

- Approximately 50 large coal-fired units
  - 10% of Fuel Tech’s installed base
  - As large as 850MWg, majority > 600MWg
  - Bituminous
  - Lignite
  - Subbituminous, including PRB
  - Other: Appalachian, Chinese, blends
- Oil-fired
- Biomass
HIGH PERFORMANCE ADVANCED-SNCR

The Measures of SNCR Performance:

• NOx Reduction
• Chemical Utilization
• Ammonia Slip
• Multiple Load Operation
• Operating Cost
• Capital Cost
HIGH PERFORMANCE SNCR

• Utilizes Advanced Diagnostics and Controls
  o Acoustic/Laser Temperature/CO Profiles
  o Individual Injector Control
  o Continuous Ammonia Measurements
• Detailed Injector Control
• Range of Injector Types
  o Maximize NOx Reduction
  o Improve Chemical Utilization
INDIVIDUAL INJECTOR CONTROL
DEVELOPED FOR WASTE COMBUSTION
UTILITY FURNACE TEMPERATURES
LARGE BIOMASS UTILITY APPLICATION

• Blend of fuels provides varied baselines
• Temperature profile augments control:
  o Air-atomized wall-injectors only
  o Unit Load was primary control
• Individual Injector control and selection
  o Improved NOx reduction above 30%
  o Improved chemical utilization
  o Reduced ammonia slip
SNCR is very effective on large furnaces
  - Fuel Tech, Inc. has nearly 30GW of SNCR experience on units > 400MW
  - Average NOx reduction of 30%

Sophisticated design and control:
  - Simple systems to operate
  - Guaranteed performance over the load range
  - Low capital cost solution
LARGE UTILITY SNCR APPLICATIONS

• SNCR integrates well with other APC:
  o Low-NOx Burners require further reduction
  o SCR reactors can be made smaller
  o SCR catalyst life can be extended

• SNCR supports fuel diversity
  o Biomass fuels or blends
  o Co-firing Tires or waste gases
Questions?

John M. Boyle, Ph.D.