the Energy to Lead

High Efficiency, Low Emissions Combustion for Commercial Hot Water Boilers

ACEEE Hot Water Forum
Portland, OR

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Energy Delivery and Utilization

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gti

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Outline

- Technology Overview
- Burner Development
- Tests on GTI's Boiler Simulator
- Computational Modeling
- Tests on Commercial Scale Boiler at GTI
- Tests at a Commercial Laundry Facility in California
- Conclusions

Gas Technology Institute (GTI) Overview

- Not-for-profit (501c3) R&D organization with 75 year history
- Facilities
  - 18 acre campus near Chicago
  - 200,000 ft^2 with 28 specialized labs
  - Other sites in California, D.C., Texas, Pittsburgh
- Staff
  - 300+ engineers, scientists covering a variety of energy fields

Source: GTI

Source: GTI

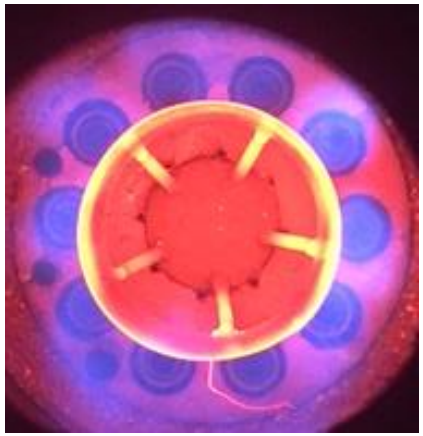
Industrial and Power Lab

Source: GTI

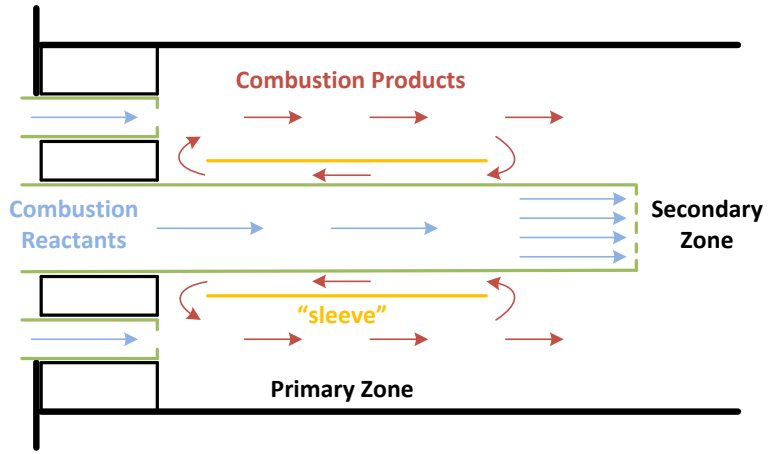
Residential & Commercial Lab

Dynamic Staged Entrainment (DSE) Burner

- Designed specifically for commercial heating applications
- Incorporates dynamic flow geometry for induced entrainment of cooled products of combustion
- Allows combustion staging

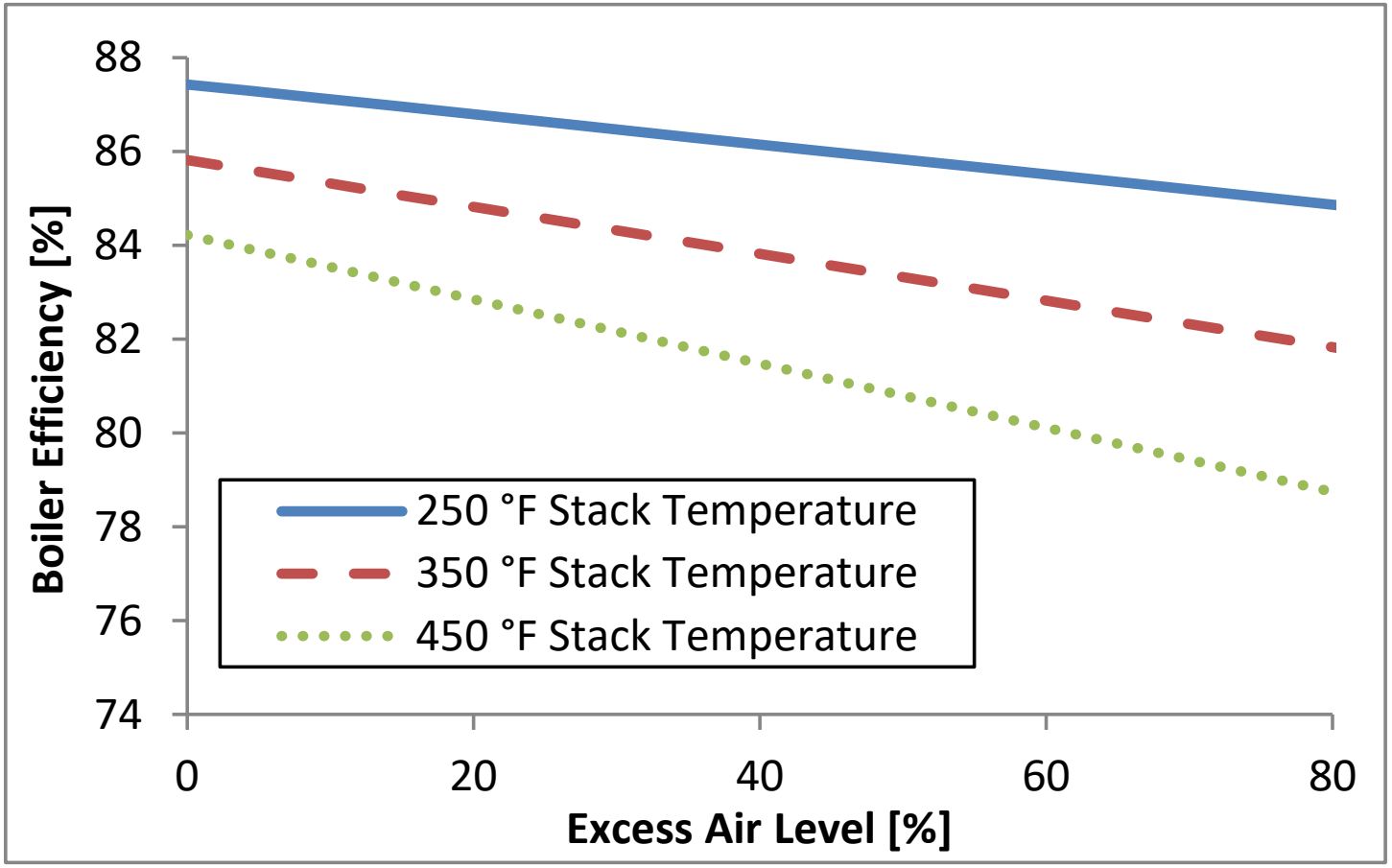


Source: GTI



Source: GTI

Reducing Excess Air Improves Boiler Efficiency



Source: GTI

Burner Development Project

- GTI designed, developed, tested, commissioned and monitored operation for over a year an ultra-low emissions natural gas boiler system for hot water and steam applications
- Boiler/burner rated at 5.25 MMBtu/hr
  - Capable of achieving <9 ppmv NOx
  - CO emissions <20 ppmv
  - Turndown of >4:1
- Successful operation for 10,000+ hours
- Advanced and improved controls and monitoring
- Partners – GTI; Power Flame, Inc.; Mission Linen Supply; Tetra Tech, Inc. and California Boiler

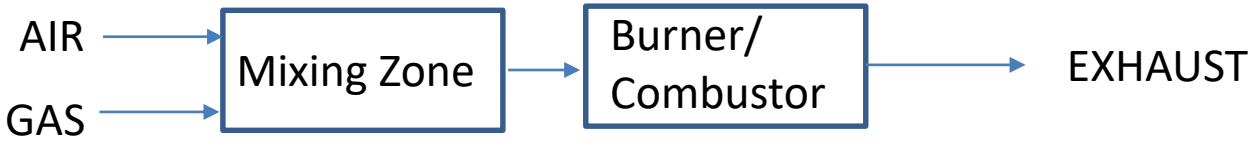
Testing on Boiler Simulator at GTI

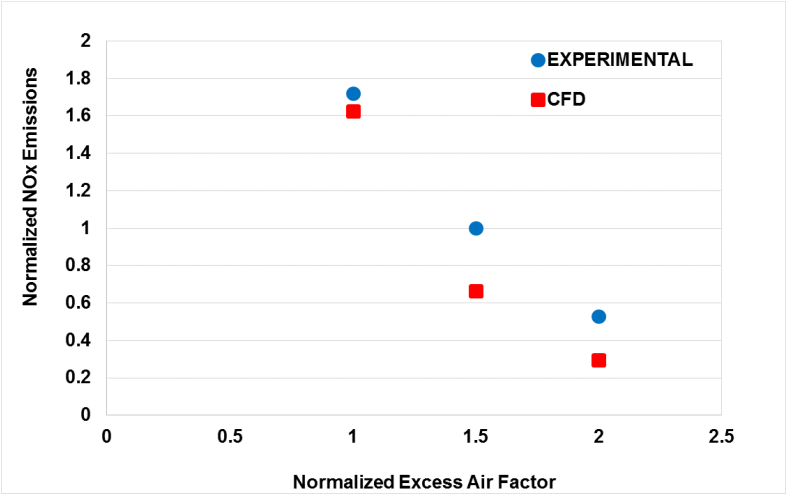
- Testing performed at GTI on a boiler simulator capable of full firing rate
- Measurements included:
  - Emissions
  - Turndown
  - Efficiency
  - Operating characteristics
  - Pressure drop
- Design improvements performed with multiple design iterations
- Testing also provided data for developing and evaluating computational model

Source: GTI

Computation Model Development and Validation

Actual Mixing – Air and natural gas introduced separately as in commercial systems





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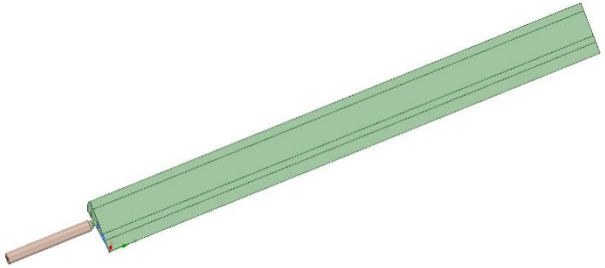


Source: GTI

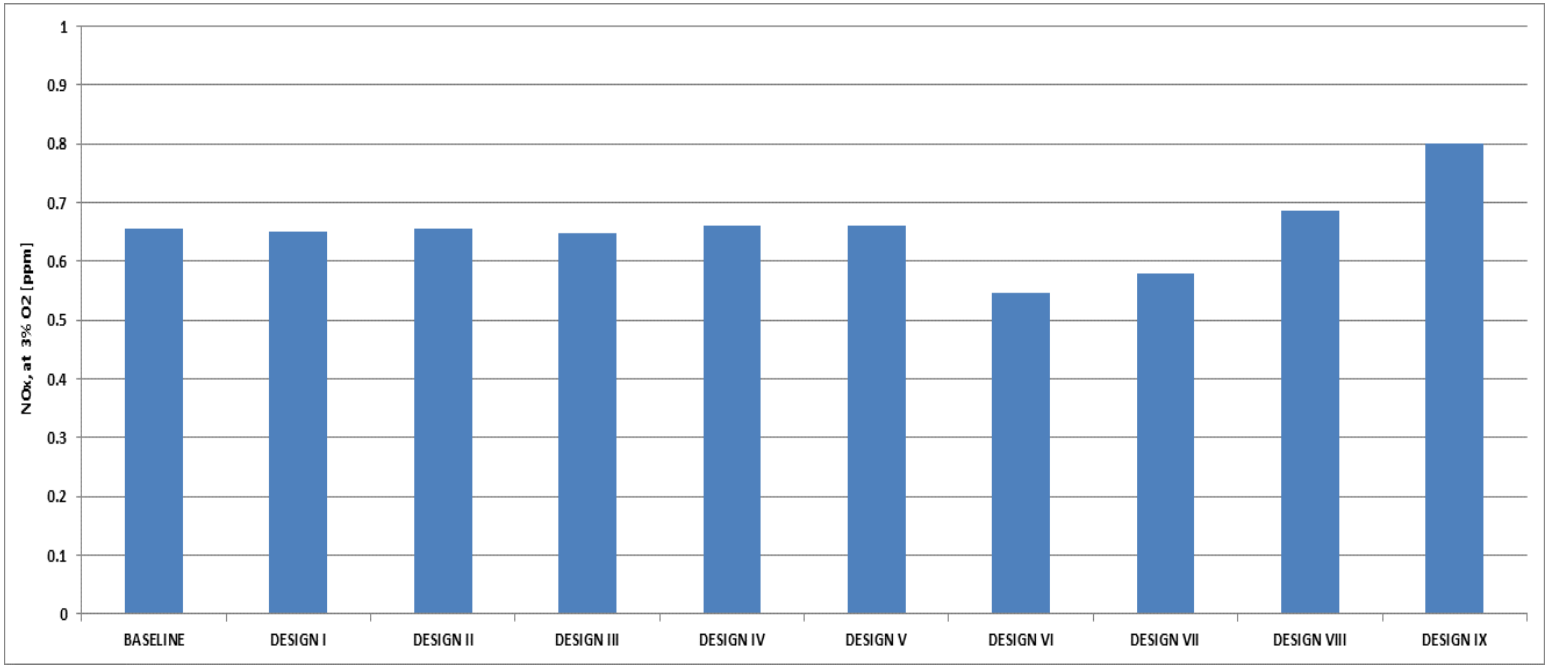
A section of the design was modeled

Model showed good agreement with experimental NOx and pressure drop measurements for well mixed combustion

Computational NOx Prediction for Design Changes

> NOx emissions were evaluated for design changes to the burner

> Designs showing lowest NOx emissions were experimentally evaluated



Source: GTI

Selected Laboratory Test Results

Test performance data for DSE system					
Load [%]	25	52	68	84	100
Excess Air [%]	25	25	24	28	33
CO [ppmv]	60	5	7	3	2
NOx [ppmv]	7.4	7.0	8.5	8.6	7.7

Source: GTI

Testing on Commercial Boiler at GTI

- A commercial scale boiler with controls, gas train and flow valves was acquired and installed at GTI
- The nominal 5.25 MMBtu/hr DSE burner with its own controls was installed on the boiler
- Performance testing was conducted to compare and evaluate boiler/burner performance with boiler simulator results

Source: GTI, all

Boiler/Burner Controls

Boiler controls and boiler were operated independently of GTI controls to allow maximum flexibility during performance testing

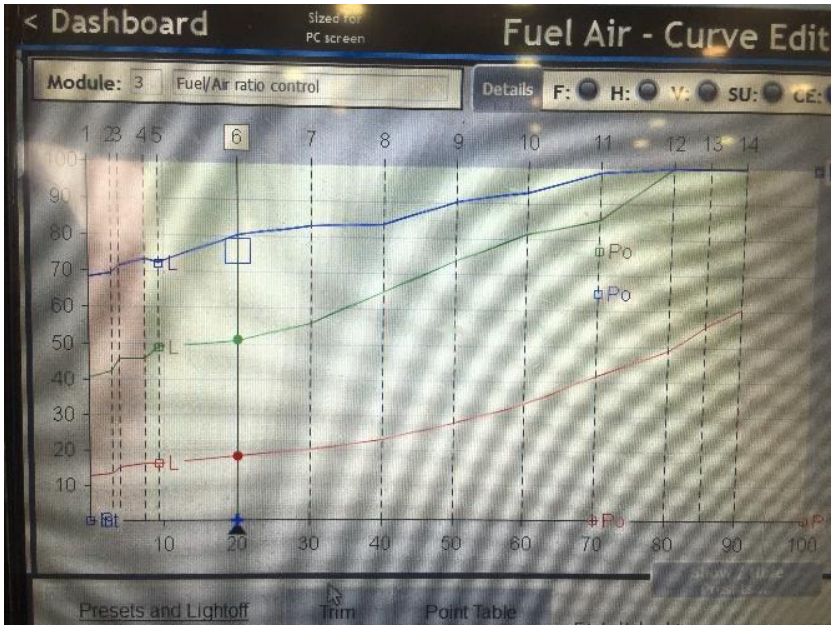
Source: GTI

Source: GTI

Boiler Tuning

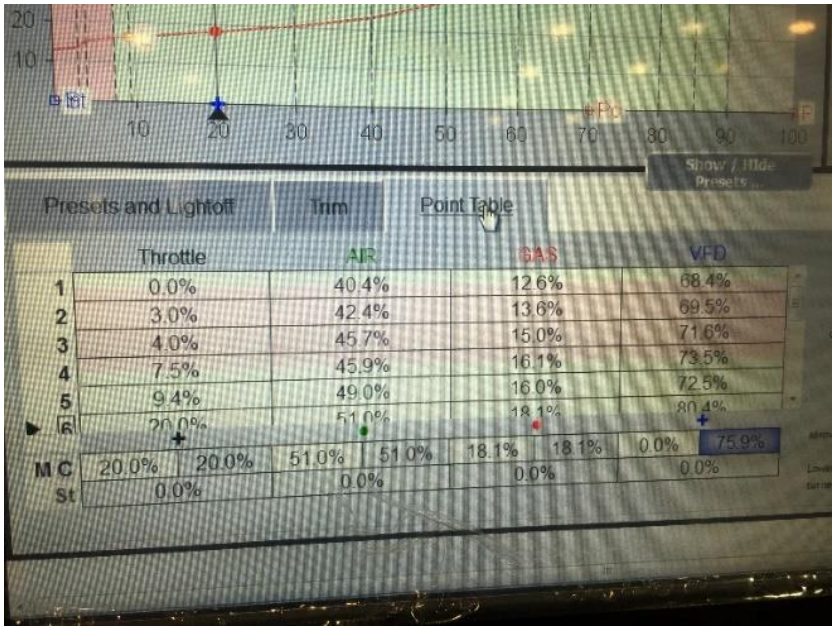
Fuel/Air ratio and trim controls were employed to tune boiler/burner operation

Fuel/Air Control Output



Source: GTI

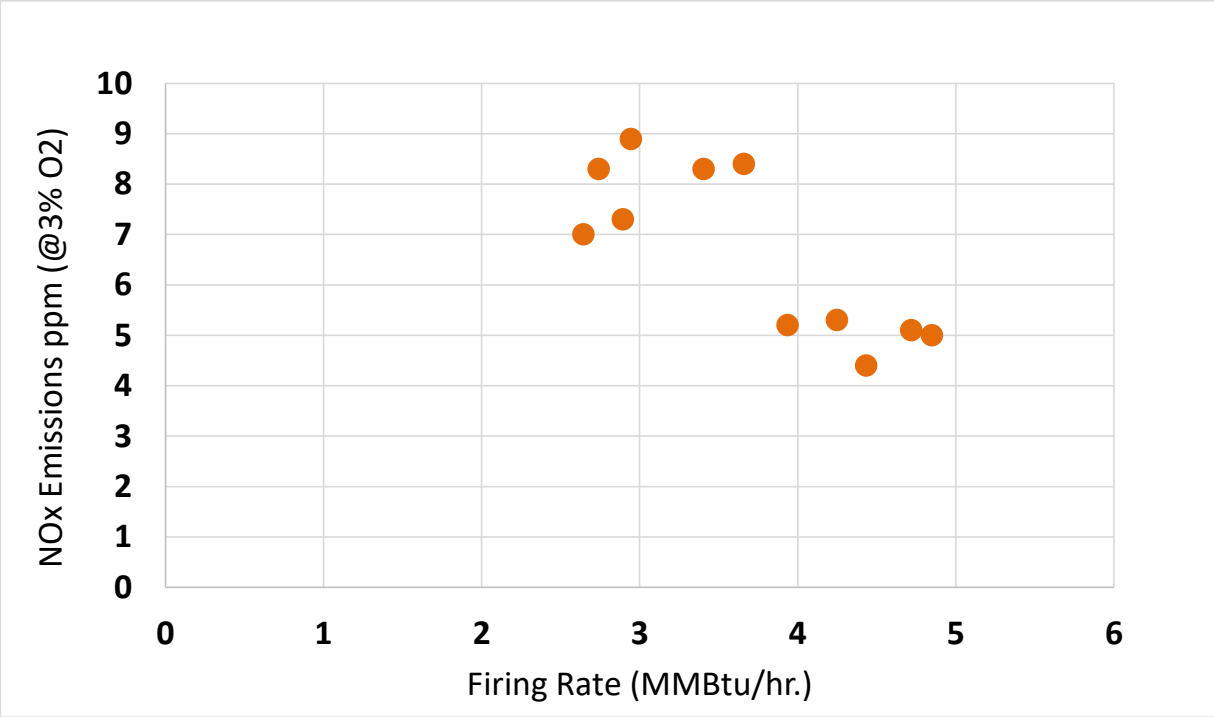
Fuel/Air Trim Control Output



Source: GTI

NOx Emissions

Results were consistent with those from the boiler simulator, achieving <5 ppmv NOx at full fire



Source: GTI

Shipping to Host Facility

- Complete boiler/burner system with controls was loaded on a flat bed truck as one unit and shipped to the host facility in California

Source: GTI

Installation and Commissioning at the Laundry Facility

- Building and air quality permits were acquired
- Boiler with DSE burner was unloaded and installed in the boiler room
- All electrical and mechanical connections were completed and the system was commissioned




Source: GTI, all

On-Site Boiler Tuning

Boiler/burner was tuned to recommended operating specifications using feed water, air/fuel ratio and trim controls

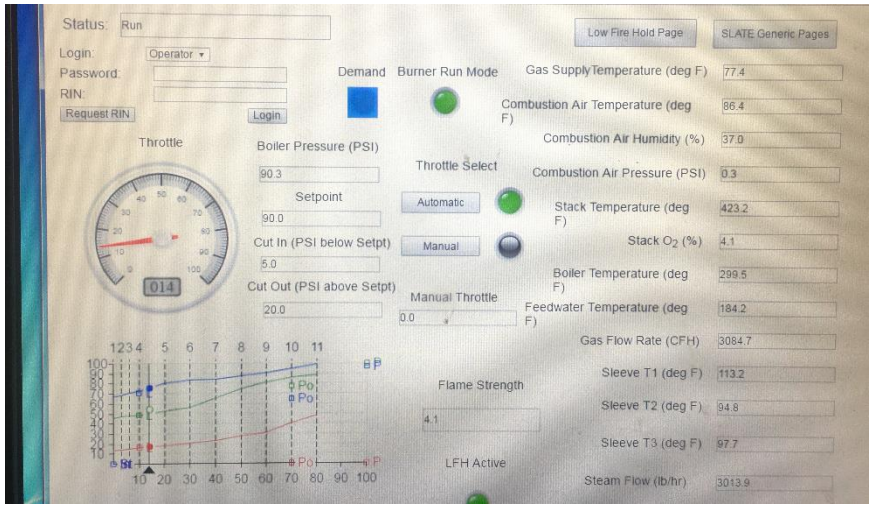
Natural Gas Roots Meter

Source: GTI

Boiler/Burner at the Laundry Facility

Source: GTI

Boiler Performance Monitor Display



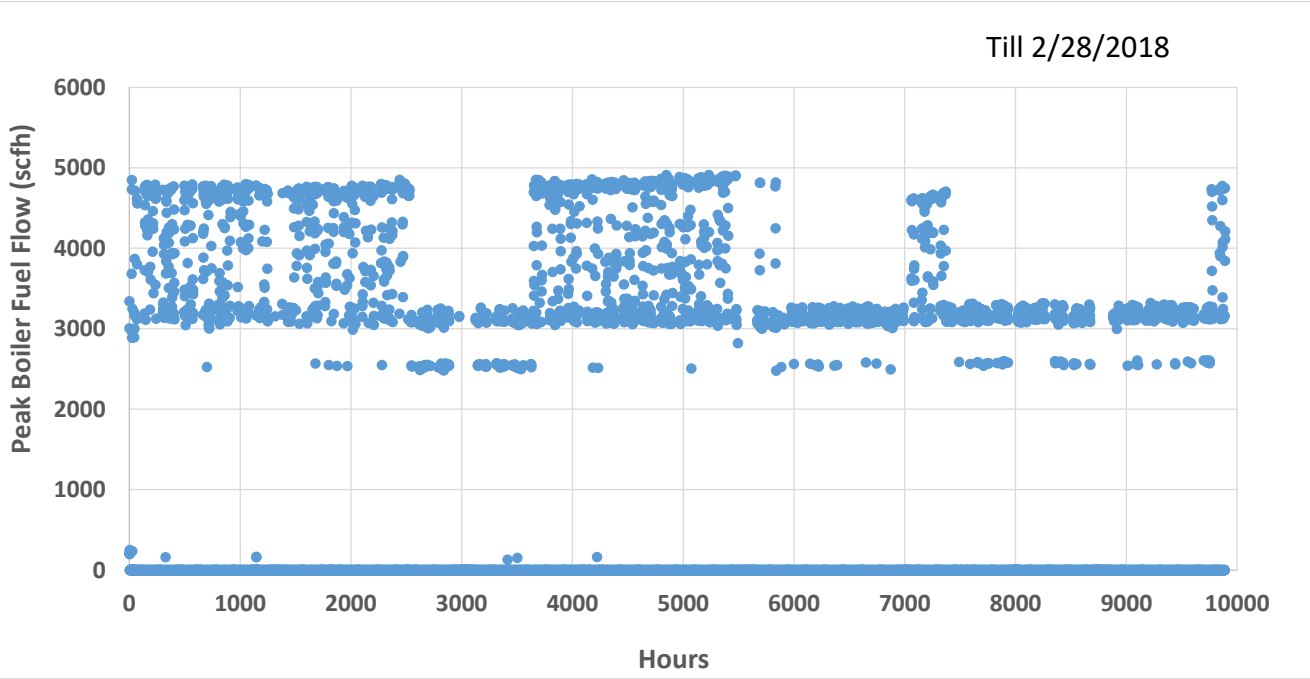
Source: GTI

Independent Third Party Testing

- Source testing was carried out by Almega Environmental for process parameters, stack gas parameters and NOx, CO and VOC emissions
  - Firing rate – 4.87 MMBtu/hr (92.7% of rated capacity)
  - Stack gas temperature – 413°F
  - O_2 – 5.1%
  - CO_2 – 9.2%
  - NOx – 8.6 ppmv
  - CO – <10 ppmv
  - VOC – <0.1 ppmv

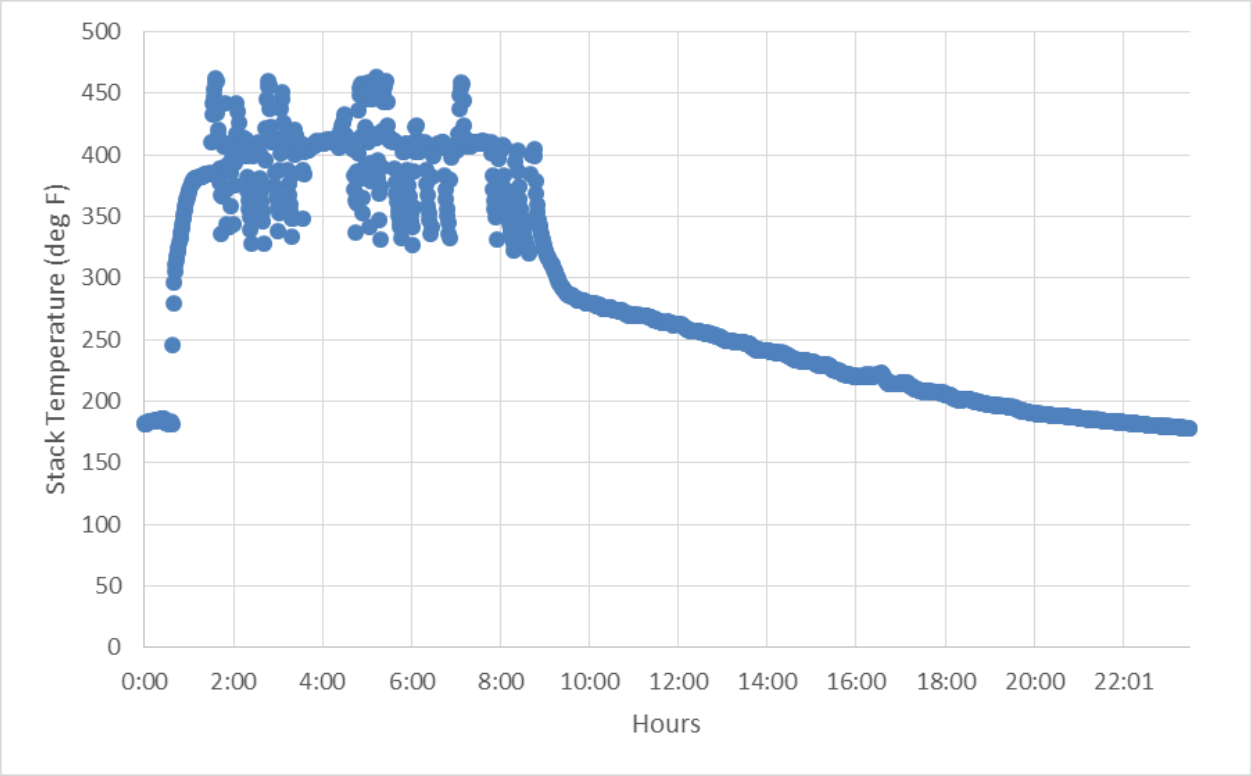
On Site Continuous Operation – Fuel Flow Cycling

- Completed 10,000+ hours on-site field operation
- Achieved stable cyclic operation with advanced controls



Source: GTI

On Site Continuous Operation – Stack Temperature



Source: GTI

Conclusions

- Based on tests carried out on a commercial scale burner at GTI and in the field, it is concluded that:
  - GTI's DSE combustion concept can be employed in commercial scale boilers with potential to provide sub 9 ppmv NOx, with low CO, high turndown ratio and improved system thermal efficiency
  - A nominal 5.25 MMBtu/hr DSE burner has logged over 10,000 hours of operation in laboratory and field settings, demonstrating its commercial viability

Questions ?