AFRC 2013 Industrial Combustion Symposium
Kauai, HI
September 23-25, 2013

The World’s First Flameless Crude Heater

Great Southern Flameless, LLC
Combustion Patents
Co-inventor and assignor of record

William C. Gibson
Robert L. Gibson
Method and Apparatus for Controlling Gas Flow Patterns Inside a Heater Chamber and Equalizing Radiant Heat Flux to a Double Fired Coil

U.S. Patent: 8,128,399
Date of Issue: March, 2012

William C. Gibson
Robert L. Gibson
Method to Facilitate Flameless Combustion Absent Catalyst or High Temperature Oxidant

U.S. Patent: 6,796,789
Original Filing: January, 2003

William C. Gibson
Multiple Purpose Burner Process and Apparatus

U.S. Patent: 5,284,438
Original Filing: January, 1992

William C. Gibson
Nitrogen Oxide Control Using Internally Recirculated Flue Gas

U.S. Patent: 5,135,387
Original Filing: October, 1989
The World’s First Flameless Crude Heater

US Patent No. 8,128,399
(additional patents pending)
Great Southern’s last presentation to the AFRC was 4 years ago in June 2009.

Flameless Heater technology has now been commercially and technically proven for refinery and petrochemical heaters.
PROJECT GOALS

- Meet industry standards for average and peak radiant section flux rates
- Meet industry standards for safety, reliability, operability and maintainability
- Automate the transition from conventional firing to staged firing and to flameless firing
- Automate the change from flameless firing back to conventional firing.
PROJECT GOALS

- Operates at 15% excess air with varying compositions of refinery fuel gas
- NOx emissions of 4-8 ppmvd with 850°F preheated combustion air
- No SCR required
- Meet all end user’s design specifications:
DESIGN SPECIFICATIONS

- Total Absorbed Duty: 9.5 MMBtu/hr
- Process Flow Rate: 3,442 BPD
- Process Inlet Temp: 385 °F
- Process Inlet Pressure: 137 psig
- Process Outlet Temp: 705 °F
- Process Outlet Pressure: 35 psig
- Draft: Balanced Draft System
- Combustion Air Temp: 873 °F
- Fuel: Refinery Fuel Gas, 904-1000 Btu/scf (LHV)
- Fired Duty: 10.4 MMBtu/hr (LHV) with preheated air
- Excess Air: 15%
- Stack Temperature: 300 °F
- Efficiency: 91.0% (LHV)
KEY MILESTONES OF TECHNOLOGY DEVELOPMENT

- Early 90’s - Observation of flameless combustion and computer modeling confirming performance (extremely low NOx without an SCR and 91% LHV efficiency)
- January 23, 2012 - Receipt of first flameless heater order
- March 6, 2012 - Issuance of flameless heater patent
KEY MILESTONES

- July 31, 2012 - Start of field construction
- October 1, 2012 - Delivery of Flameless Heater
- February 27, 2013 - Lighting of pilots
- February 27, 2013 - Conventional Combustion
- April 22, 2013 - Flameless Combustion
ADVANCES IN TECHNOLOGY

- Design and build a conventional heater that can operate in the flameless mode without additional training for operators.
- Design and build a heater to operate in the flameless mode that is safer than any current heater with a conventional flame created by traditional burners (burner tiles/necessity of flame stabilization).
ADVANCES IN TECHNOLOGY

- Patent pending 3-way valve to automate the change from conventional combustion to staged combustion and then to flameless combustion.
- Patented dimpled refractory pattern to pin the flue gas in circulation against the heater wall, increase radiant view angles and reduce radiant peak to average flux rates.
Flameless Nozzle Groups (FNG’s) to replace conventional burners. FNG’s provide stable combustion in all firing modes:

- Conventional ambient air
- Conventional air preheat
- Staged fuel air preheat
- Flameless air preheat
ADVANCES IN TECHNOLOGY

- Convection section bypass and diverter dampers to increase turndown capability in the flameless mode.
- Proven technology firing real refinery fuel gas in crude heater service.
ADVANCES IN TECHNOLOGY

- Automated monitoring system to detect loss of flameless combustion and switch back to conventional firing mode.

- Automated monitoring system to determine permissives for changing from conventional combustion, to staged fuel combustion to flameless combustion.
AND SIGNIFICANTLY:

- Pricing that is not greater than conventional double fired heaters with balanced draft air preheat systems.
- Proven NOx between 4-8 ppmvd (without an SCR) with 850°F air preheat firing refinery fuel gas.
- Overall heater efficiency equal to 91% (LHV)
Significant equalization of radiant section heat flux and significant reduction in tube metal temperatures.
PRESENTATION OF DATA

- Plan view of heater
- CFD modeling
- Tabulation of performance data
- Still photos of operation and NOx emission read-outs
- Movie clip of actual operation
Conventional Combustion

Flameless Combustion

Horizontal planes are spaced at approximately 2.92" intervals.
CFD MODELING
Temperature Comparison between Conventional and Flameless Firing at Fuel Nozzle Elevation

Conventional Combustion  Flameless Combustion
Horizontal planes are spaced at approximately 2.92” intervals.
Conventional Combustion

CFD MODELING
Iso-Surfaces of 1500 ppm CO Colored by Temperature

Flameless Combustion
**TABULATION OF PERFORMANCE DATA**

Radiant Coil Configuration: Double Fired  
Fired Duty: 10.4 MMBtu/hr  
Fuel Gas Comp: Typical Refinery Fuel Gas  
Excess Air: 15%

<table>
<thead>
<tr>
<th></th>
<th>Conventional Firing Balanced Draft, APH</th>
<th>Staged Firing Balanced Draft, APH</th>
<th>Flameless Firing Balanced Draft, APH</th>
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<tbody>
<tr>
<td>Combustion Air Temp, °F</td>
<td>804</td>
<td>893</td>
<td>909</td>
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<tr>
<td>Avg Radiant Lower Level Temp, °F</td>
<td>1488</td>
<td>1627</td>
<td>1669</td>
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<tr>
<td>Avg Radiant Mid Level Temp, °F</td>
<td>2050</td>
<td>1826</td>
<td>1476</td>
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<tr>
<td>Avg Radiant Upper Level Temp, °F</td>
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<tr>
<td>O₂% (dry)</td>
<td>3.7</td>
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<tr>
<td>NOₓ, ppmvd</td>
<td>77</td>
<td>49</td>
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THERMAL SCAN of UPPER TUBE TEMPERATURES

Conventional Firing

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<tr>
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UNIT | Crude
--- | ---
FURNACE | FH0060
LEVEL
CELL
END | EAST
PORT | NORTH
WALL

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<tr>
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<tr>
<td>SP 05</td>
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THERMAL SCAN of MID-SECTION TUBE TEMPERATURES

Conventional Firing
THERMAL SCAN of LOWER TUBE TEMPERATURES

Conventional Firing
PROPRIETARY WALL TEXTURING

US Patent No. 8,128,399
(additional patents pending)
CONVENTIONAL FIRING MODE - View From Across Heater

- 10.4 MMBtu/hr Fired Duty
- 804 deg F Combustion Air Temperature
- 3.7% excess O2
- 77 ppm NOx
STAGED FIRING MODE - View From Behind FNG

- 10.4 MMBtu/hr Fired Duty
- 893 deg F Combustion Air Temperature
- 2.6% excess O₂
- 49 ppm NOx
FLAMELESS FIRING MODE - View From Behind FNG

- 10.4 MMBtu/hr Fired Duty
- 909 deg F Combustion Air Temperature
- 2.4% excess O2
- 4 ppm NOx
FLAMELESS FIRING MODE - View From Across Heater
FLAMELESS FIRING NOx EMISSIONS (Portable Analyzer)

OXY: 02.9% NOx: 4PPM
VIDEO CLIP OF ACTUAL OPERATION

Flameless.mpg
NEXT FLAMELESS HEATER

- Heater design symmetry
- Scale up
Scale Up

<table>
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<tr>
<th>Symmetry Modules</th>
<th>Capacity</th>
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<tbody>
<tr>
<td>1</td>
<td>10 MMBtu/Hour</td>
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<tr>
<td>2</td>
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<tr>
<td>3</td>
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<td>12</td>
<td>120 MMBtu/Hour</td>
</tr>
<tr>
<td>24</td>
<td>240 MMBtu/Hour</td>
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Questions and Answers

Great Southern Technologies, LLC
Great Southern Flameless, LLC
Great Southern Independent, LLC

www.GreatSouthernGroup.com

Significantly different companies.