CASA Presentation
Rethinking Air Pollution Control:
Energy Production from Low Value Waste Streams

May 2015

Bringing energy and the environment into harmony.
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KG2 3G Externally Fired
KG2 3G – MT250

- Over 1,000 units sold
- Outstanding reputation for durability
- Demonstrates 98 to 99 percent availability
- Start-up reliability of 99.3 percent
- Hydrodynamic bearing arrangement, with both bearings in the “cold end”

- No Risk of Oil Coking or Exhaust Fires
- Negligible Oil Consumption
- Minimal Post-lube
System Details – Basic Info – KG2 3G/EF

Gas Turbine
- Radial Compressor and Turbine
- Operating Speed: 25,500 RPM
- Exhaust Temperature: 315°C
- Oil lubricated Bearings
- Power: 2,000kW Shaft Output
- High Tolerance to H2S and Siloxanes

Power Oxidizer
- CE rated pressure vessel and pipes
- Internal vessel temperature: 1010°C
- Inlet temperature: 595°C
- Outlet Temperature: 955°C
- Load Bank: 2,000kW
- Skin temperature of pipes < 150°C
System Details – Basic Info, EC250/333

Gas Turbine
- Radial Compressor and Turbine
- Operating Speed: 45,600rpm
- Exhaust Temperature: 243°C/266°C
- Oil lubricated Bearings
- Power: 250kW/333 kW
- Air flow: 2.13/2.4 kg/s
- Electrical Efficiency: 26% /30%(LHV)

Power Oxidizer
- CE rated pressure vessel and pipes
- Internal vessel temperature: 1010°C
- Inlet temperature: 595°C
- Outlet Temperature: 955°C
- Load Bank: 300 kW
- Skin temperature of pipes < 150°C
Power Oxidizer Technology

Destroys low concentration fuels (CH4 down to 5%) & fugitive emission sources
Near-zero NOx
Ultra-low CO & VOC’s (Direct injection configuration)
Only known Gas Turbine technology capable of CARB 2013 (Direct injection configuration)
Simplified fuel supply:
  o Can eliminate fuel compressor
  o Simplifies siloxane removal – Pre-Treatment not required
  o H2S tolerant
Robust against fuel supply instabilities
Enables fuel flexibility
Can operate on a wide variety of fuels from 5% methane to 100% propane
**Power Oxidation is Different from Combustion**

Combustion is burning of high quality fuels, a flame with intense heat and associated pollution

*Power Oxidation* is different:
- A lower temperature, slower process than combustion
- Distributed reaction at very low fuel concentrations
- Long reaction time allows releasing all heat and chemical energy from fuel
- No flame; no pollutants

<table>
<thead>
<tr>
<th></th>
<th>Operating Temperature Range</th>
<th>Reaction Time</th>
<th>Pollution</th>
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</thead>
<tbody>
<tr>
<td>Open Flame</td>
<td>1500°C+</td>
<td>Very Short (milliseconds)</td>
<td>Worst</td>
</tr>
<tr>
<td>Lean Combustion</td>
<td>1300°C+</td>
<td>Very Short (milliseconds)</td>
<td>Medium</td>
</tr>
<tr>
<td>Flameless Combustion</td>
<td>1200°C+</td>
<td>Very Short (milliseconds)</td>
<td>Low</td>
</tr>
<tr>
<td><strong>Power Oxidation</strong></td>
<td><strong>Below 1000°C</strong></td>
<td><strong>Long (seconds)</strong></td>
<td><strong>Near Zero</strong></td>
</tr>
</tbody>
</table>
The dilute gas (input) does not have a high enough energy content for combustion.

Combustion is a rapid reaction that happens in milliseconds and produces pollutants as part of output.

Oxidation is a similar chemical reaction to Combustion, but more steady. In our process, it happens in seconds, it produces heat, and it removes the pollutants from the incoming gas.
**Ener-Core Power Oxidizer Fuel Range Advantage**

Power Oxidizer is tolerant of gas composition and variation by design.

- No flame operation eliminates acoustic issues associated with higher energy density gases
- Gas energy value can vary
- Long reaction time and designed thermal capacity give oxidizer stability during changing gas compositions

<table>
<thead>
<tr>
<th>Gas Heating Value (Btu/scf)</th>
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<tbody>
<tr>
<td>15</td>
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<table>
<thead>
<tr>
<th>Gas Sources</th>
<th>Tail Gas</th>
<th>High CO₂ Associated Gas</th>
<th>Natural Gas</th>
<th>Associated Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil Fields</td>
<td></td>
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<tr>
<td>Biogas</td>
<td></td>
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<tr>
<td>Coal Mine</td>
<td></td>
<td></td>
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<tr>
<td>VAM</td>
<td>Abandoned</td>
<td>Seams/Bed/Closed/Active</td>
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<thead>
<tr>
<th>Varying fuel quality causes operational issues</th>
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<tbody>
<tr>
<td>Comb Stability Issues</td>
<td>Combustor Acoustic Issues</td>
</tr>
<tr>
<td>Controls Adjustments</td>
<td></td>
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<tr>
<td>Standard Operation</td>
<td>Operational issues due to higher hydrocarbons causing knocking</td>
</tr>
</tbody>
</table>

- Gas Turbines: Varying fuel quality causes operational issues
- Reciprocating Engines: Varying fuel quality causes operational issues

- Ener-Core, Inc: "Distributed Reaction (No Oxidation Acoustics)"
  - Accepts varying fuel qualities during operation

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"Gradual Oxidation (Low Btu Capability)"

"Distributed Reaction (No Oxidation Acoustics)"

**Bringing energy and the environment into harmony.**
Fort Benning Demonstration 2012
Low Btu Methane Landfill Gas

Closed Army Base landfill with varying 18-24% methane; past problems with fugitive methane
- 250kW system successfully completed demonstration program in 2012

DoD Environmental Security Technology Certification Program (ESTCP) and Southern Research Institute (SRI) documented successful results

Key technology features demonstrated: low emissions & low Btu operations
Siloxane Content - 12.4-12.9 mg/m3
Attero Landfill 2014
Schinnen, Netherlands

Closed landfill with below 30% methane
Siloxane Content – 3.73 mg/m³
Past problems with reciprocating engines running inconsistently
First Commercially sold unit
250kW system was successfully installed and is currently operating
Ultra-Low Btu Phase 1 Pilot for Oil & Gas Customer

Customer is interested in utilizing Ener-Core’s Oxidation technology
Generate clean power from a casing gas emitted during a proprietary oil extraction process
Reduce CO2 footprint of process
Preventing methane venting
Avoiding gas blending for destruction (adding natural gas just to destroy methane vent)
Maintain air emissions below regulations with Low NOx exhaust

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<thead>
<tr>
<th></th>
<th>1st Condition</th>
<th>2nd Condition</th>
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<tbody>
<tr>
<td>Methane (CH4)</td>
<td>7.75%</td>
<td>5.80%</td>
</tr>
<tr>
<td>Nitrogen (N2)</td>
<td>84.20%</td>
<td>91.15%</td>
</tr>
<tr>
<td>Carbon Dioxide (CO2)</td>
<td>8.00%</td>
<td>3.00%</td>
</tr>
<tr>
<td>LHV (Btu/scf)</td>
<td>71</td>
<td>53</td>
</tr>
<tr>
<td>Steady run time (hr)</td>
<td>5.5</td>
<td>3</td>
</tr>
</tbody>
</table>
"The Stockton cogeneration system will replace most of the electricity we currently purchase from the grid and will reduce our energy costs by an estimated three to four million dollars per year… Rather than destroying waste gases, we will reuse them as a source of process energy, reducing cost and improving profitability."

Neil Koehler, Pacific Ethanol President and CEO
Thank-You

Questions?

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