Air Emissions: Keeping Ethanol Production “Green”

Presented By:
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Terry Crabtree / Sales Engineer / BK Technologies

Advances in Emission Control and Monitoring Technology for Industrial Sources
Exton, PA
July 9-10, 2008
Background on Anguil Environmental

- Founded in 1978, family owned and operated
- Headquartered in Milwaukee, WI with additional offices across the world
- Committed to Clean Air Technologies & Energy Conservation Systems
- Over 1,600 oxidizers and countless energy recovery systems installed on five different continents in a wide range of industrial processes
Anguil Portfolio

- Regenerative Thermal Oxidizer (RTO)
- Catalytic Oxidizers: Recuperative and Regenerative
- Thermal Recuperative Oxidizer
- Direct-Fired Oxidizers: Multi-Jet and Flameless
- Halogenated / Chlorinated Oxidizer
- Concentrators: Zeolite and Carbon
- Remediation Systems
- Self-Cleaning Ceramic Filters
- Heat Exchangers & Energy Recovery Systems
The Growing Ethanol Market
What Is Oxidation?

Definition: \[ C_nH_{2m} + (n + m/2) O_2 \Rightarrow n CO_2 + mH_2O + \text{heat} \]

**Temperature:** Based on the VOCs that need to be destroyed there is a temperature at which the compounds can be oxidized.

**Time:** Relates to how long a compound needs to be at a certain temperature in order for it to be oxidized.

**Turbulence:** A fixed condition built into the equipment design that ensures a proper mixture of VOCs and oxygen for combustion.

Specific compounds and desired destruction rate efficiency determine temperature and residence time. Proper Oxidation converts hydrocarbons to CO\(_2\) and H\(_2\)O (vapor).
Ethanol Processing Design Considerations

**Identify** Process Characteristics
- VOCs
- CO / CO$_2$
- %O$_2$
- H$_2$O
- Particulate (Size, Organic/Inorganic)
- Temperature
- Corrosives (CO and Organic Acids)

**Understand** Process Parameters
- Operating Schedule
- Plant Heat Balance (Energy Recovery Opportunities)
- Maintenance Schedule
- Down Time Allowance

**Design** for Regulatory Requirements
- VOC
- NO$_X$
- CO
- PM
- SO$_X$
Control Solutions For Ethanol Processing

**Regenerative Thermal Oxidizer (RTO):**
- Two or Multi-Chamber Systems
- Destruction Efficiencies of 98%-99%+ for VOCs, HAPs and CO
- Designed to handle a wet air stream with some particulate.
- Pre-Filters available for higher levels of particulate.
- Thermal Energy Recovery of 95%+ insures low fuel usage, and low NO\textsubscript{X} production.
- Fuel injection system further lowers NO\textsubscript{X}

**Direct Fired Thermal Oxidizer (DFTO) / Heat Recovery Steam Generator (HRSG):**
- Designed to oxidize 99+% of VOCs, HAPS, CO
- Designed to handle a wet air stream with some particulate.
- Generates steam for use in the process.
- Optional turbine produces power for driving electric motors or for distribution within the plant.
Regenerative Thermal Oxidizer (RTO)

2 Chamber Design:
- Air Flow Range:
  - 3,000-70,000 scfm / Single Unit
  - 70,000-500,000 scfm / Multiple Units
- Concentration Range: 0%-25% LEL
- Energy-Efficient Operation
  (True 95%+ Thermal Energy Recovery)
- High Destruction Rate Efficiency (DRE)
RTO Options & Benefits

Options:

• Random Packed or Structured Ceramic Heat Transfer Media
• Forced or Induced Draft Configurations
• Standard Steel or Alloy Construction for Corrosive Applications
• Supplemental Fuel Injection

Benefits:

• Factory Tested
• PLC-Based Controls with Multiple Safety Functions and Recording Features
• Fast Acting, Reliable Valves
• Self Sustains at LELs as low as 3%, Reducing Operating Costs
• Low Pressure Drop Reduces Electrical Consumption
RTO Mode of Operation
2 Chamber RTO Valves

**Types of Valves:**
- Poppet Valves (Horizontal and Vertical)
- Butterfly Valves
- Rotating (Single) Valves

**Modes of Operation**
- Pneumatic
- Hydraulic

**Why Vertical Poppet Valves?**
- Maintenance
- Design
- Cost
2 Chamber RTO Valve Operation
Stainless Steel Construction

RTO Material Selection:

COMPONENTS:
FAN: All 304L Stainless Steel Wetted Parts
POPPET VALVES: All 304L Stainless Steel
INLET FEED DUCT: All 304L Stainless Steel
OUTLET FEED DUCT: Stainless Steel
2 Chamber RTO Design Configuration for Ethanol Applications

Features:
• Two Chamber System
• Stainless Steel Construction
• Online Bake-Out Cleaning

Benefits:
• Process Flexibility
• Corrosion Resistance
• Ease of Maintenance
Test Results:

<table>
<thead>
<tr>
<th>TABLE 3-1</th>
<th>Non-Methane Hydrocarbons Destruction Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>EPA Method 25A</td>
</tr>
<tr>
<td></td>
<td>Anguil Environmental Systems Regenerative Thermal Oxidizer</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Time</th>
<th>Flowrate SCFM</th>
<th>Conc. ppm as CH₄</th>
<th>Loading Rate wet lb/hr³</th>
<th>Flowrate SCFM</th>
<th>Conc. ppm as CH₄</th>
<th>Loading Rate wet lb/hr</th>
<th>Destruction Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run No. 1</td>
<td>0908-1008</td>
<td>19608</td>
<td>1878</td>
<td>91.998</td>
<td>20290</td>
<td>12.7</td>
<td>0.641</td>
</tr>
<tr>
<td>Run No. 2</td>
<td>1040-1140</td>
<td>19407</td>
<td>1750</td>
<td>84.857</td>
<td>20996</td>
<td>15.9</td>
<td>0.833</td>
</tr>
<tr>
<td>Run No. 3</td>
<td>1221-1321</td>
<td>19155</td>
<td>2137</td>
<td>102.287</td>
<td>20704</td>
<td>13.2</td>
<td>0.682</td>
</tr>
<tr>
<td>Average</td>
<td>19390</td>
<td>1922</td>
<td>93.047</td>
<td>20663</td>
<td></td>
<td>0.719</td>
<td>99.22%</td>
</tr>
</tbody>
</table>
2 Chamber RTO Destruction Efficiency

**Test Results:**

<table>
<thead>
<tr>
<th>TEST NO.</th>
<th>INCINERATOR TGNMO RATE</th>
<th>DESTRUCTION EFFICIENCY</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Inlet - lb C/hr</td>
<td>Outlet - lb C/hr</td>
</tr>
<tr>
<td>1</td>
<td>39.5</td>
<td>0.30</td>
</tr>
<tr>
<td>2</td>
<td>43.9</td>
<td>0.28</td>
</tr>
<tr>
<td>3</td>
<td>44.6</td>
<td>0.27</td>
</tr>
<tr>
<td>Avg.</td>
<td>42.7</td>
<td>0.28</td>
</tr>
</tbody>
</table>

The results of the exhaust gas flow measurements are summarized below:

<table>
<thead>
<tr>
<th>TEST NO.</th>
<th>INCINERATOR EXHAUST GAS FLOW RATES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Inlet - sM³/hr</td>
</tr>
<tr>
<td>1</td>
<td>12587</td>
</tr>
<tr>
<td>2</td>
<td>12705</td>
</tr>
<tr>
<td>3</td>
<td>12966</td>
</tr>
</tbody>
</table>
3 Chamber RTO Design
99.5% DESTRUCTION EFFICIENCY – 3 CHAMBER DESIGN

- Six controlled butterfly valves
- Third can is purged following valve change to direct untreated VOCs into purification chamber
- 90 second cycle time per bed
- Shorter cycle time leads to higher thermal efficiency
- Higher destruction efficiencies than 2 chamber design
- Higher capital cost than 2 chamber design
99.5% DESTRUCTION EFFICIENCY – 3 CHAMBER RTO DESIGN
Design Features:

- Fast Acting
- Reliable
- Design Flow: 3,500 ft/min
- Valve Pressure Drop: Maximum of 2” WC
- Motorized or Pneumatic Controlled
- Lockout Device with Pad Lock Provision
BUTTERFLY VALVES – 3 CHAMBER RTO
## Test Results:

<table>
<thead>
<tr>
<th>Test ID</th>
<th>Run 1</th>
<th>Run 2</th>
<th>Run 3</th>
<th>Average</th>
<th>FAIL</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RTO Inlet</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flowrate (scfm)</td>
<td>17.039</td>
<td>16.827</td>
<td>16.955</td>
<td>16.341</td>
<td></td>
</tr>
<tr>
<td>Moisture (%)</td>
<td>0.1%</td>
<td>0.1%</td>
<td>0.1%</td>
<td>0.1%</td>
<td></td>
</tr>
<tr>
<td>Average THC as CH4 (ppm)</td>
<td>419</td>
<td>226</td>
<td>807</td>
<td>484</td>
<td></td>
</tr>
<tr>
<td>THC Loading as CH4 (lbs/hr)</td>
<td>17.8</td>
<td>9.6</td>
<td>34.1</td>
<td>20.5</td>
<td></td>
</tr>
<tr>
<td>MeCl2 (ppm) by EPA Method 18</td>
<td>331</td>
<td>181</td>
<td>269</td>
<td>260</td>
<td></td>
</tr>
<tr>
<td>MeCl2 Loading (lbs/hr)</td>
<td>74.5</td>
<td>40.3</td>
<td>60.3</td>
<td>58.3</td>
<td></td>
</tr>
<tr>
<td><strong>Scrubber Inlet</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max. Calculated HCl Load (lbs/hr)</td>
<td>63.8</td>
<td>34.4</td>
<td>51.8</td>
<td>49.9</td>
<td></td>
</tr>
<tr>
<td><strong>Stack</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flowrate (scfm)</td>
<td>22.591</td>
<td>23.652</td>
<td>23.495</td>
<td>23.246</td>
<td></td>
</tr>
<tr>
<td>Moisture (%)</td>
<td>5.1%</td>
<td>6.5%</td>
<td>8.3%</td>
<td>5.9%</td>
<td></td>
</tr>
<tr>
<td>Average THC as CH4 (ppm)</td>
<td>0.4</td>
<td>0.2</td>
<td>1.3</td>
<td>0.6</td>
<td></td>
</tr>
<tr>
<td>THC Emission Rate as CH4 (lbs/hr)</td>
<td>0.02</td>
<td>0.01</td>
<td>0.08</td>
<td>0.04</td>
<td></td>
</tr>
<tr>
<td>MeCl2 (ppm) by EPA Method 18</td>
<td>1.0</td>
<td>0.6</td>
<td>0.8</td>
<td>0.8</td>
<td></td>
</tr>
<tr>
<td>MeCl2 Emission Rate (lbs/hr)</td>
<td>0.30</td>
<td>0.20</td>
<td>0.24</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>HCl Catch (mg)</td>
<td>&lt;2.9</td>
<td>&lt;2.9</td>
<td>&lt;3.1</td>
<td>&lt;2.97</td>
<td>PASS</td>
</tr>
<tr>
<td>HCl Emission Rate (lbs/hr)</td>
<td>&lt;0.23</td>
<td>&lt;0.26</td>
<td>&lt;0.27</td>
<td>&lt;0.25</td>
<td>PASS</td>
</tr>
<tr>
<td>NOx (ppm)</td>
<td>1.6</td>
<td>1.6</td>
<td>1.1</td>
<td>1.4</td>
<td>PASS</td>
</tr>
<tr>
<td>O2 (%)</td>
<td>20.0</td>
<td>20.1</td>
<td>20.3</td>
<td>20.1</td>
<td>PASS</td>
</tr>
<tr>
<td>NOx Emissions (lbs/MMBtu)</td>
<td>0.038</td>
<td>0.044</td>
<td>0.041</td>
<td>0.041</td>
<td>PASS</td>
</tr>
</tbody>
</table>

### Control Efficiencies

- THC (Permit Limit for NMHC = 99%) | 99.9 | 99.8 | 99.8 | 99.8 | PASS |
- MeCl2 (Permit Limit = 99%) | 99.6 | 99.5 | 99.6 | 99.6 | PASS |
- HCl (Permit Limit = 98%) | >99.6 | >99.3 | >99.5 | >99.5 | PASS |
RTO Heat Recovery Media Options

- Random Packing
- Extruded Honeycomb Monolith
- Multi-Layered Media
Thermal Efficiency Recovery (TER)

\[
\% \text{ TER} = \frac{\text{MoCo (Tc-To)}}{\text{MiCi (Tc - Ti)}}
\]

\% \text{ TER} = \text{Thermal Efficiency}

\text{MoCo} = \text{Thermal Mass flow exhaust rate from RTO}

\text{MiCi} = \text{Thermal Mass flow supply rate into RTO}

\text{Tc} = \text{RTO combustion chamber temperature}

\text{To} = \text{Exhaust temperature leaving RTO}

\text{Ti} = \text{Supply temperature entering RTO}
Media Considerations for Ethanol Processing

- Moisture Content of Process Stream
- Organic and Inorganic Particulate Loading
Media Selection for True 95% TER

- Structured Block
- Extra Depth
- 25 Cell-Lower Layers
- 43 Cell-Upper Layers
Media Installation
Supplemental Fuel Injection

Why Use Supplemental Fuel Injection?

- Reduces combustion air-flow, lowering operating costs
- Lower pilot rate for large burners
- Ultralow NOx emissions
Bake-Out Feature

Recommended for process streams with high boilers or condensables

Off-line bake-out feature

- Runs on reduced airflow of 25%
- Run until cold face reaches 600-900°F then redirect airflow
- Organics will volatilize
- Inorganic ash will remain

Valves and duct need to be insulated or guarded for personnel protection

For induced draft fan, dilution air added prior to reduce temperature
RTO Installations

Regenerative Thermal Oxidizer
Model 100
10,000 SCFM
Ethanol Emissions
RTO Installations

Regenerative Thermal Oxidizer –
3 Chamber
(2) Model 350
70,000 SCFM
With Acid Gas Scrubbers
Pharmaceutical Plant
RTO Installations

Regenerative Thermal Oxidizers

(2) Model 600
120,000 SCFM
Ethanol Processing Application

(Production Photo)
RTO Installations

Regenerative Thermal Oxidizer
Model 600
60,000 SCFM
Ethanol Processing Application
Direct Fired Thermal Oxidizers (DFTO)

Typical Applications Include:

- Air Flow Range: 100-100,000 scfm
- Achievable DRE: 99+% 
- Concentration Range: 15-50+% LEL

Generally Used With:

- High VOC Concentrations
- Low Volume 
- High Destruction Rate Efficiency Requirements
DFTO Advantages & Options

**Advantages:**
- Modular design for system flexibility and future expansion
- Preassembly and factory testing reduces installation costs
- Allen Bradley controls guarantee proper system performance
- High destruction efficiencies for regulation compliance
- Safety shutdowns ensure safe operation

**Options:**
- Heat Exchangers
- Waste Heat Coils
- Heat Recovery Steam Generators
- Insulated Ductwork
- Material of Construction Options for Corrosion Resistance
- High Temperature Acid Gas Scrubbers
DFTO Design
Waste Heat Boiler
DFTO Installations

Direct Fired Thermal Oxidizer

Carbon Desorption System
DFTO Installations

Direct Fired Thermal Oxidizer

Chemical Processing Facility
DFTO Installations

Direct Fired
Thermal Oxidizer
and Scrubber

Chemical Processing
Facility
System Controls

- Allen Bradley Series- Compact Logix PLC with Panel View Plus 1000, color Touch Screen HMI
- Digital Data recorder
- Allen Bradley Variable Frequency Drive
- Phone Modem Diagnostics
Heat & Energy Recovery Options

- Air-to-Air Heat Exchangers (Shell & Tube, Plate Type)
- Air-to-Water Heat Exchangers (Economizers)
- Air-to-Steam Heat Exchangers (Waste Heat Boilers)
- Air-to-Fluid Heat Exchangers (Oil, Glycol Loop)
- Power Generation
- Energy Audits
Heat & Energy Recovery Options

**Typical Applications Include:**

- Recover exhaust stack heat for use in industrial ovens and dryers
- Recover exhaust stack heat for other plant and/or process heating applications
- Upgrade Heat Efficiency of existing VOC control equipment
### Construction Options for Ethanol Processing

<table>
<thead>
<tr>
<th>Material:</th>
<th>Typically Specified For:</th>
</tr>
</thead>
<tbody>
<tr>
<td>409SS</td>
<td>Non corrosive applications up to 700°F (370°C)</td>
</tr>
<tr>
<td>304SS</td>
<td>Non corrosive applications up to 1200°F (650°C)</td>
</tr>
<tr>
<td>316SS</td>
<td>Chloride corrosion resistance up to 1200°F (650°C)</td>
</tr>
<tr>
<td>321SS</td>
<td>Non corrosive applications up to 1800°F (980°C)</td>
</tr>
<tr>
<td>309SS</td>
<td>Additional temperature resistance</td>
</tr>
<tr>
<td>Hastelloy</td>
<td>Specialty alloy for corrosive airstreams</td>
</tr>
<tr>
<td>Other Alloys</td>
<td>254 SMO, AL6XN, 600 &amp; 800 Alloy, 2205 Duplex, and others available upon request</td>
</tr>
</tbody>
</table>
Thank You!