Novel Approach for Biomass Synthesis Gas Cleaning for Liquid Fuel Applications

May 22, 2013
Thermo-chemical Platform Review
Presented by: Ben Phillips, Emery Energy
Lyman Frost, Ceramatec
Project Overview

Timeline
- Start Date – 9/30/2008
- Completion Date – Dec 2012
- Construction – 100% complete
- Project – 100% complete

Barriers Addressed
1. Tt-C – Gasification of Wood, Biorefinery Residue Streams and Low Sugar Biomass
2. Tt-F – Syngas Cleanup & Conditioning
3. Tt-H – Validation of Syngas Quality

Budget
Total Project Funding
$1,734,459 DOE
$1,853,350 Contractor
Funding received in FY11
$293,161
Funding for FY12
$137,102.84

Partners
- Western Research Institute
- Ceramatec
- Idaho National Laboratory (sampling via FWP)
Goals and Objectives

1. Demonstrate the ability of a cold plasma reformer to destroy tars and oils in syngas produced by biomass gasification.
   - Obtain operating data that documents destruction and provides a heat and mass balance. Use these to determine cost benefits relative to alternative processes.
   - Optimize the operation of the cold plasma reformer

   *Success will eliminate the need for catalyst reforming/ tar removal by water quench*

2. Use Syngas cleaned by the cold plasma reformer for liquid fuel production
   - Obtain operating data in an existing liquid fuel synthesis pilot plant
   - Identify commercial opportunities
   - Continue reformer data analysis to identify possible process improvements.
1 - Approach

Flowsheet

- Bulk Oxygen
- Steam
- Feed Bin
- Bucket Elevator
- Gasifier
- Roto-Disc Valves
- Ash Discharge
- Bypass
- Reformer
- WRI Alcohols
- Flare
2 - Technical Accomplishments/Results

Completed Tasks
1. Installed pilot plant
2. Modified plasma reformer design
3. Built & installed plasma reformer
4. Startup
5. Ran gasifier and obtained data
6. Submitted Report
Completed Installation
2- Technical Accomplishments (cont’d)

In-situ plasma reformer assembly

3-Stage plasma with quench stage

Plasma Electrodes
Injection Nozzles
Spray Nozzle
2 - Technical Accomplishments (cont’d)

Cold Plasma GlidArc Operation

Electrode

↑

gas

Electrode

↑

gas

↑

ignition

→

expansion & work

→

extinction

↑

extinction
gas

electrode

↑

ignition

CERAMATEC
TOMORROW'S CERAMIC SYSTEMS
2 - Technical Accomplishments (cont’d)

Directly reform tars & oils

1. Air or Oxygen
2. Biomass or Other feed
3. Gasification Unit
4. Non-thermal Plasma Reformer
5. Clean Synthesis Gas
6. Fischer Tropsch synthesis
7. Methanation
8. Electric Power Generation
9. Reheat Air or Oxygen
Laboratory scale plasma reformer

Simulated gasifier stream

- Bottled synthesis gas
- Toluene injection
- Steam, O$_2$, or air to obtain temperature
- GC analysis of toluene destruction and CGE
### Best combination

<table>
<thead>
<tr>
<th>Run</th>
<th>Dry Gas L/min</th>
<th>Air In L/min</th>
<th>O₂ In L/min</th>
<th>H₂O In g/min</th>
<th>Toluene In g/min</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>50</td>
<td>52</td>
<td>0</td>
<td>1.7</td>
<td>5.9</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Run</th>
<th>H₂</th>
<th>N₂</th>
<th>CO</th>
<th>CO₂</th>
<th>Toluene</th>
<th>CH₄</th>
<th>H₂O</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>12</td>
<td>54</td>
<td>21</td>
<td>7</td>
<td>0</td>
<td>.3</td>
<td>6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Run</th>
<th>LHV Gas In kW</th>
<th>LHV Gas Out kW</th>
<th>Thermal Eff Percent</th>
<th>Toluene % Destroyed</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>5.02</td>
<td>5.87</td>
<td>117</td>
<td>100</td>
</tr>
</tbody>
</table>

- Run 4 had good destruction and good efficiency
2 - Technical Accomplishments (cont’d)

• Conversion of BTX and other hydrocarbons very good in laboratory
  – 92% methane (near equilibrium limit)
  – 96% ethane
  – 100% (to detection limit) of other C2-C4
  – 98% benzene
  – 99% toluene
  – 100% (to detection limit) of xylenes
2 - Technical Accomplishments (cont’d)

• INL on-site testing of Emery Gasifier Reformer
  – Sample pre- and post-reformer
  – Collect impinger train samples and CEMS
  – Survey relative concentrations before and after reformer

• Test Equipment
  – Continuous Emissions Monitoring (CO, CH4, THC)
  – IPA impinger train samples for semi-volatiles
• Gasifier generally operating at steady state
• THC represents sum of CH$_4$ and other hydrocarbons converted to CH$_4$
• Noncondensible THC gases range from 0.5-1.5% above CH$_4$ when converted to CH$_4$-equivalent
2 – Technical Accomplishments (cont’d)

- Gas bag samples (foil bags) collected – results support CEMS results

<table>
<thead>
<tr>
<th>Corrected Samples:</th>
<th>H2</th>
<th>CO</th>
<th>CO₂</th>
<th>Methane</th>
<th>Ethane</th>
<th>Ethene</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Pre-reformer</td>
<td>30.03</td>
<td>31.35</td>
<td>29.19</td>
<td>3.44</td>
<td>0.15</td>
<td>0.49</td>
</tr>
<tr>
<td>Corrected Post Reformer</td>
<td>28.80</td>
<td>35.57</td>
<td>26.24</td>
<td>3.69</td>
<td>0.13</td>
<td>0.65</td>
</tr>
</tbody>
</table>

- Liquid Impinger Samples
  - Polynuclear aromatic compounds are generally reduced
  - Styrene (intermediate product of naphthalene decomposition) appears to increase as naphthalene decreases

<table>
<thead>
<tr>
<th>Compound</th>
<th>Pre-Reformer</th>
<th>Post Reformer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetic Acid</td>
<td>34697</td>
<td>53924</td>
</tr>
<tr>
<td>Toluene</td>
<td>69729</td>
<td>48902</td>
</tr>
<tr>
<td>Styrene</td>
<td>9455</td>
<td>15910</td>
</tr>
<tr>
<td>Phenol</td>
<td>24289</td>
<td>23763</td>
</tr>
<tr>
<td>Benzene, 1-propynyl-...</td>
<td>53432</td>
<td>39708</td>
</tr>
<tr>
<td>Napthalene</td>
<td>130962</td>
<td>76698</td>
</tr>
</tbody>
</table>
3 - Relevance

- The expected output of the project will enable the large-scale production of cleaner syn-gas that is more compatible with down-stream processes for the production of energy or liquid fuels.

From MYPP 2012
3 – Relevance (cont’d)

• Program Mission:
  – “Transform our renewable biomass resources into commercially viable, high-performance biofuels… through targeted research, development, demonstration, and deployment supported through public and private partnerships.
  – Enable sustainable, nationwide production of advanced biofuels

• This project focuses on demonstration and deployment of a full-scale biomass conversion platform for production of a high quality gaseous intermediate.

• This addresses specific areas of the MYPP 2012:
  – Gt. C. High-Temperature Gas Production from Biomass
  – Gt. F. Gas Cleanup and Conditioning
  – Gt. H. Validation of Syngas Quality
4 - Critical Success Factors

- Critical success factors include the ability of this process to economically and efficiently eliminate unwanted heavier hydrocarbons from the syngas stream.

- Potential challenges:
  - Biomass feed specifications can affect overall quality of syngas
  - Process parameters must be explored to optimize production and process efficiency.

- This project is continuing to demonstrate viability in the production of biofuels, and continuing work will further demonstrate the importance of this technology for biofuels and bioenergy production.
5 - Future Work

• No Future Work is Planned

Summary

• Plasma Reformer:
  – Meets objectives of BETO per MYPP 2012
  – Technology demonstrated on full-size system
  – Work continues with other partners
(Not a template slide – for information purposes only)

• The following slides are to be included in your submission for Peer Evaluation purposes, but will **not** be part of your oral presentation

• You may refer to them during the Q&A period if they are helpful to you in explaining certain points
Project Delays

• Project was delayed twice due to weather and the need to make additional gasifier modifications.

<table>
<thead>
<tr>
<th>TASK</th>
<th>PLANNED - LAST PEER REVIEW</th>
<th>TASK ACTUALLY INITIATED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commissioning</td>
<td>May 2011</td>
<td>December 2011</td>
</tr>
<tr>
<td>Initial Runs</td>
<td>June 2011</td>
<td>August 2012</td>
</tr>
<tr>
<td>Reformer Runs</td>
<td>September 2011</td>
<td>November 2012</td>
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Contact Information

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