Mobile Pyrolysis Process for Conversion of Biomass into Energy Products

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Technology Development
Amaron Energy’s Advanced Pyrolysis Unit*

- Patented rotary kiln design
  - Reduces operating and capital costs; simplifies operation
- Current prototype unit ½ ton/day capacity
  - 3 years of operation and data collection
- Robust feedstock acceptance
  - 14 varied feedstocks tested

* US Patent 8,298,498 B2
Method and apparatus for achieving fast pyrolysis in indirectly heated rotary reactors

Method and apparatus for fast pyrolysis of biomass in a rotary kiln

0.5 ton/day prototype pyrolysis unit
Overview of Amaron Technology

- Patented flexible heating approach in a rotary kiln design provides for:
  - operation ranging from torrefaction through full pyrolysis
  - a wide variety of feedstock properties
  - limited physical degradation of solid product
Variation of Product Yields with Reactor Temperature*

*Amaron Prototype Kiln Data
Woody Biomass Feedstocks after Processing by Amaron Kiln

Untreated wood

Torrefied wood

Biochar or Pyrolyzed wood
Comparison of Amaron Rotary Reactor Yields with Circulating Fluidized Bed Yields

The 12th International Conference on Fluidization, Vancouver, Canada, 2007
Product Yields Obtained with 0.5 ton/hr Amaron Energy Prototype Unit

<table>
<thead>
<tr>
<th>Material</th>
<th>Test hrs</th>
<th>Typical yields %</th>
<th>C1 oil HHV</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Oil</td>
<td>Char</td>
</tr>
<tr>
<td>Pinion-Juniper wood</td>
<td>176</td>
<td>59</td>
<td>30</td>
</tr>
<tr>
<td>Black Liquor</td>
<td>169</td>
<td>37</td>
<td>38</td>
</tr>
<tr>
<td>Fir pellets</td>
<td>132</td>
<td>62</td>
<td>23</td>
</tr>
<tr>
<td>Fir fines</td>
<td>112</td>
<td>59</td>
<td>19</td>
</tr>
<tr>
<td>Lemna</td>
<td>47</td>
<td>44</td>
<td>28</td>
</tr>
<tr>
<td>Pine shredded</td>
<td>16</td>
<td>58</td>
<td>30</td>
</tr>
<tr>
<td>Pine bark</td>
<td>3</td>
<td>34</td>
<td>36</td>
</tr>
<tr>
<td>MSW sorted</td>
<td>12</td>
<td>54</td>
<td>15</td>
</tr>
<tr>
<td>Brown Grease</td>
<td>12</td>
<td>53</td>
<td>2</td>
</tr>
<tr>
<td>Tire rubber</td>
<td>10</td>
<td>31</td>
<td>42</td>
</tr>
<tr>
<td>Phragmites</td>
<td>10</td>
<td>28</td>
<td>36</td>
</tr>
<tr>
<td>Turkey litter</td>
<td>4</td>
<td>32</td>
<td>49</td>
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<tr>
<td>Aspen</td>
<td>4</td>
<td>43</td>
<td>28</td>
</tr>
<tr>
<td>USU Algae</td>
<td>2</td>
<td>25</td>
<td>51</td>
</tr>
<tr>
<td>Total test hours</td>
<td>708</td>
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Remote Deployment
Mobile Biomass Pyrolysis Units

- **Concept:**
  - Reduce costs of harvesting and processing by utilizing mobile pyrolysis unit(s)
  - Have units capable of servicing multiple co-located sources
    - Forest maintenance, invasive species, farms, poultry and other ranches, etc.
  - Transporting higher-value and higher energy density products (biochar and oil) vs. raw biomass

- **Amaron technology is ideally suited for remote deployment**
  - Simplicity of design and operation
  - Reliability
  - Continuous (not batch) operation => higher throughput
  - Accommodation of wide variety of feedstock materials and forms
  - Low power requirements compared to many other fast pyrolysis technologies

Example - Pinion Pine and Juniper in UT, NV
Conversion of Amaron Prototype to Mobile Platform

Retrofitted to a shipping container, which was then mounted on a trailer for remote deployment.

Shipping container approach will also be useful for remote international deployment.
Initial Field Demonstrations

Ely, Nevada – September, 2013
Kamas, Utah – October, 2013
Commercialization Pathway

- **0.5 TPD Prototype**
  - Initial proof-of-concept
  - Extensive testing on variety of fuels
  - Conversion to mobile platform
  - Field testing – demonstration of stand-alone operation in remote locations
  - Continue to serve as test unit for fuel characterization, etc.

- **20 TPD Commercial Demonstration Unit**
  - Also on mobile platform
  - Financing
    - Sun Grant (USU/Amaron/UofU) – to address P-J issue
    - Private funding
  - Currently in design stage, to be completed Spring of 2014

- **14 field demonstrations currently being planned over the next 18 months in various locations in Nevada, Utah, Idaho and Washington**
20 TPD Commercial Demonstration Unit

0.5 TPD Prototype Unit

20 ft. Long Container

20 TPD Demo Unit

40 ft. Long Container

Conceptual arrangement of 6” I.D. (0.5 TPD) and 24” I.D. (20 TPD) reactors inside shipping containers
Concluding Comments

- Amaron Energy developed working prototype unit
  - Tested extensively
  - Proven capability to effectively process wide range of feedstocks
  - Oil and char products characterized; ongoing research on novel methods for utilization of bio-oil

- Converted to mobile platform
  - Successful field demonstrations of stand-alone operation

- Design underway for 20 TPD commercial (mobile) demonstration unit
  - Completion in Spring 2014

- Technology also readily scales to much larger units that may be more suitable for a permanent installation
Acknowledgements

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- Utah Biomass Resources Group
Questions?