Operational Results from the Transportable Plasma Waste-to-Energy System at Hurlburt Field’s Air Force Special Operations Command

E2S2 Conference
Gillian Holcroft – PyroGenesis Canada
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First mover in the commercialisation of advanced plasma waste to energy systems
PyroGenesis’ proven technology solves two serious global issues

Energy Security → Decentralized approach

Sustainable and cost effective waste management is a global concern
PyroGenesis is a leader in the design, development, manufacture and commercialisation of plasma waste destruction and waste-to-energy systems

- 37 skilled employees (more than 75% are engineers, scientists and technologists)
- 8 technology patents in 38 jurisdictions
- 5 patents pending
- 6 plasma waste destruction systems in operation and/or being commissioned
- 27 plasma torch systems sold to date
PyroGenesis’ Plasma Technology Platforms...

**PAWDS**

**Plasma Arc Waste Destruction System**
- Applicable for Marine Vessels & Mobile Land-Based Units
- Capacity: 0.5-15 tons per day

**PRRS**

**Plasma Resource Recovery System**
- Designed as a Clean and Efficient Waste to Energy Solution
- Transportable & Fixed Land-based Units
- Capacity: 2-100 tons per day (larger systems planned)
PAWDS for **USS Gerald R. Ford**

Developed over 10 years with US Navy

- It works!
- Can be operated by sailors
- Compact, lightweight, one button operation

→ Mobile System for forward operating Army bases
PAWDS Markets

**Marine**
- US Navy Air Craft Carriers
- US Navy Destroyers
- Cruise Lines
- Cargo Ships
- Ferries

**Liquid & Gaseous Wastes**
- Ozone Depleting Substances (CFC’s)
- Sludge Oils
- Liquid Wastes (paints, solvents…)

**Mobile Units**
- Small Isolated Communities
- US Military
- FEMA (Disaster relief)
PRRS - Plasma Resource Recovery System

Medical Waste  MSW  Hazardous Chemicals

Gasification
Thermal conversion of organic matter into synthesis gas consisting primarily of CO and H₂ with only a small amount of oxygen

Synagas (CO & H₂)

Vitrification
Inorganic material is melted at 1600°C to produce an inert slag that is safe for use as a construction material

1. Primary Gasification Furnace using graphite electrodes
2. Secondary Gasification Chamber, with air plasma torch and patented eductor
3. Quench to prevent dioxin and furan formation
4. Air Pollution Control tailored to waste stream

Video of process available at www.pyrogenesis.com

NO SECONDARY WASTE

Heat/Steam

Electricity

Chemical Products
Besides MSW, PRRS is designed to process...
## Target markets

<table>
<thead>
<tr>
<th>Capacity</th>
<th>Markets</th>
</tr>
</thead>
</table>
| **<10**  | • Marine (ships)  
          | • Hospital / Clinical Waste  
          | • Hazardous Waste  
          | • Pharmaceutical Waste  
          | • Apartments, Hotels, Resorts  
          | • Island Communities  
          | • Military- Transportable Units |
| **50**   | • Hazardous Waste  
          | • Industrial Waste  
          | • Island Communities  
          | • Airports |
| **100**  | • Industrial Waste  
          | • Municipal Solid Waste |
The Power of PLASMA

PyroGenesis’ Systems can power the following:

<table>
<thead>
<tr>
<th>Capacity</th>
<th>Electrical Output</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>10</strong> (1,570 households)</td>
<td><img src="image1.png" alt="Image" /> + Powers itself</td>
</tr>
<tr>
<td><strong>50</strong> (7,850 households)</td>
<td><img src="image2.png" alt="Image" /> + 725 homes</td>
</tr>
<tr>
<td><strong>100</strong> (15,700 households)</td>
<td><img src="image3.png" alt="Image" /> + 1,850 homes</td>
</tr>
</tbody>
</table>

= 25 average US households
10.5 TPD Transportable Plasma Waste to Energy System at AFSOC

- Designed to process MSW, Hazardous waste and Medical Waste
- Commissioned in August 2010 and “accepted” by AFSOC in June 2011
- Turn-key project on greenfield site
- PyroGenesis was responsible for facility, permits and plasma system
- 80 by 80 foot facility housing skid-mounted sub-systems
- The PRRS is producing a syngas that can generate electricity through an internal combustion engine

Air Force Special Operations Command (Hurlburt Field)
Hurlburt Field PRRS Layout
PRRS/USAF: Facility Construction

Site – Foundation being poured – Nov. 2009

Storm water Permit, RD&D Permit and Air Construction Permit received in 2009
PRRS/USAF: Facility Construction
PRRS/USAF: Skid-Mounted Design
PRRS/USAF: Plasma Fired Eductor
PRRS/USAF: Graphite Arc Plasma Furnace
Video of Hurlburt Field Operation
Waste Feed Rate vs. Design Capacity

- Processing Rate (kg/h)
- Average processing rate (kg/h)
- Design processing rate (kg/h)
Essentially 100% of waste received was processed
Syngas Composition

System is able to produce a consistent flow and quality of syngas to power the GE Jenbacher gas engine and produce electricity. Only fuel is the garbage. *No other gases are introduced!*

<table>
<thead>
<tr>
<th>Component (% vol/vol)</th>
<th>Simulated value</th>
<th>Average Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO</td>
<td>22</td>
<td>16</td>
</tr>
<tr>
<td>CO2</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>H2</td>
<td>19</td>
<td>20</td>
</tr>
<tr>
<td>N2</td>
<td>52</td>
<td>54</td>
</tr>
</tbody>
</table>
The PRRS is producing a steady, clean flow of syngas that is being used to generate electricity through a GE Jenbacher internal combustion engine.
Syngas Production

- Amount of syngas produced steadily increased from February to September.
- Issue occurred in June with poor quality chemical from sub-supplier.
Certified Results from PRRS Demonstration Plant (treating MSW)

<table>
<thead>
<tr>
<th>Air Pollutants</th>
<th>PYROGENESIS</th>
<th>REGULATION (MONTREAL)</th>
<th>EC Regulation 2000/76/CE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particulate</td>
<td>&lt; 3.5 mg/Rm³</td>
<td>&lt; 15 mg/Rm³</td>
<td>&lt; 10 mg/Rm³</td>
</tr>
<tr>
<td>HCl</td>
<td>0.33 mg/Rm³</td>
<td>&lt; 30 mg/Rm³</td>
<td>&lt; 10 mg/Rm³</td>
</tr>
<tr>
<td>HF</td>
<td>BDL</td>
<td>&lt; 1 mg/Rm³</td>
<td>&lt; 1 mg/Rm³</td>
</tr>
<tr>
<td>SO₂</td>
<td>18 mg/Rm³</td>
<td>&lt; 50 mg/Rm³</td>
<td>&lt; 50 mg/Rm³</td>
</tr>
<tr>
<td>CO</td>
<td>36 mg/Rm³</td>
<td>&lt; 50 mg/Rm³</td>
<td>&lt; 50 mg/Rm³</td>
</tr>
<tr>
<td>NOₓ</td>
<td>124 mg/Rm³</td>
<td>&lt; 200 mg/Rm³</td>
<td>&lt; 400 mg/Rm³</td>
</tr>
<tr>
<td>THC</td>
<td>0.8 µg/Rm³</td>
<td>&lt; 30 µg/Rm³</td>
<td>&lt; 10 mg/Rm³</td>
</tr>
<tr>
<td>Metals</td>
<td>BDL</td>
<td>&lt; 500 µg/Rm³</td>
<td>&lt; 1000 µg/Rm³</td>
</tr>
</tbody>
</table>

1 Rm³ = 1 reference cubic meter at 25°C, 101.3 kPa, dry gas, 11% O₂
1 Nm³ = 1 normal cubic meter at 0°C, 101.3 kPa, dry gas, 11% O₂
# TCLP results from Hurlburt Slag

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>EPA Hazardous Waste #</th>
<th>Regulatory level (mg/L)</th>
<th>Slag concentration (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenic</td>
<td>D004</td>
<td>5.0</td>
<td>0.002</td>
</tr>
<tr>
<td>Barium</td>
<td>D005</td>
<td>100.0</td>
<td>1.253</td>
</tr>
<tr>
<td>Cadmium</td>
<td>D006</td>
<td>1.0</td>
<td>0.001</td>
</tr>
<tr>
<td>Chromium</td>
<td>D007</td>
<td>5.0</td>
<td>0.252</td>
</tr>
<tr>
<td>Lead</td>
<td>D008</td>
<td>5.0</td>
<td>0.004</td>
</tr>
<tr>
<td>Mercury</td>
<td>D009</td>
<td>0.2</td>
<td>0.0002</td>
</tr>
<tr>
<td>Selenium</td>
<td>D010</td>
<td>1.0</td>
<td>0.003</td>
</tr>
<tr>
<td>Silver</td>
<td>D011</td>
<td>5.0</td>
<td>0.010</td>
</tr>
</tbody>
</table>

Winner of 2012 Quebec ADRIQ Partnership & Innovation award
PRRS/USAF: Ribbon-cutting Ceremony

April 26th 2011
Conclusions and next steps

Demonstrated:

- The scalability from 2 TPD pilot unit to a 10.5 TPD Transportable unit. Next scale up 5 to 10 times larger.
- The ability to process un-sorted garbage at a capacity of 10.5 TPD.
- That slag easily achieves EPA’s TCLP limits (orders of magnitude)
- That syngas can be produced from waste with a high enough flow and quality to power an internal combustion engine without the need to supplement with additional gases.
- Gas emissions from Engine were measured by two separate Florida State Certified labs and meet FDEP requirements
- Operation meets all OSHA standards

Next steps

- Follow on 18 month operations contract received in September 2011
- Optimise energy efficiency
- Process hospital waste
- Obtain Treatability Study Permit for hazardous waste processing
Our mission is to provide cutting edge environmental and energy solutions. We aim to sustain our position as the vanguard of innovation and to set new standards within our industry. Through our highly qualified team of experts, we are able to use a customized approach to provide state of the art systems that exceed our customer's unique technological, environmental, and business objectives.