Early Evolution of the Westinghouse Plasma Gasifier – Lessons Learned from Eco Valley, Japan

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Alter NRG Open House
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HISTORY OF PLASMA DIRECT MELTING REACTOR (PDMR) DEVELOPMENT

1997
- PDMR Development Agreement - Hitachi Metals & WPC

1998
- WPC Testing – Madison PA
- Yoshii Test Plant Construction
- Eco Valley - environmental assessment

1999
- Yoshii – one year of MSW testing
- Eco Valley – 7 meetings with Residents

2000
- Yoshii – JWRF certification received in September
- Eco Valley – construction began
- Mihama-Mikata – presentation to government

2001
- Mihama-Mikata – construction began

2002
- Plasma Component Manufacturing Agreement – Hitachi Metals & WPC
- Eco Valley – commissioning
- Mihama-Mikata - commissioning

2003
- Eco Valley - operational (ASR & MSW)
- Mihama-Mikata – operational (MSW & Sludge)

2004
- Eco Valley – freeboard refractory replaced

2005
- Eco Valley – bottom shape remodeled & refractory structure of PFMR changed
- Refractory materials of Afterburner changed

2006
- Plant tours begin
- Eco Valley – refractory materials of Afterburner changed
- Mihama-Mikata – 3 year guarantee ended

2007 TO DATE
- Eco Valley – temperature control changed during commercial operation
- Operating successfully with no issues
Utilization of Westinghouse Plasma torches at the Hitachi Metals gasification facility in Mihama-Mikata, Japan.

Plasma gasification of 20 tpd MSW and 4 tpd of waste water sludge, where the syngas is combusted and the resulting heat is used to dry sewage sludge.

Validation of the Westinghouse Plasma Gasification Solution by a well-respected Fortune 500 Company, Air Products and Chemicals, utilizing a combined cycle configuration, which provides greater energy efficiency compared to incineration.

Scale-up of the existing reference facilities to a 950 tpd facility which will produce 50MW of electricity. This is enough electricity to power 50,000 homes, and a meaningful scale to attract the interest of other large industrial companies.
ECO VALLEY UTASHINAI WTE FACILITY

- Built over two years, it was commissioned in 2002 and operated from 2003 to December, 2013.

- The Eco-Valley facility was designed to process MSW and auto shredder residue.

- Eco-Valley operated two gasifiers, each with 4 Marc-3a Plasma Systems.

<table>
<thead>
<tr>
<th>Specifications of the Eco-Valley, Utashinai Facility</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Capacity</strong></td>
</tr>
<tr>
<td><strong>Number of trains</strong></td>
</tr>
<tr>
<td><strong>Power Generated</strong></td>
</tr>
<tr>
<td><strong>Power Exported</strong></td>
</tr>
</tbody>
</table>

Inside the Eco-Valley, Utashinai Facility
UTASHINAI OPERATING PROBLEMS IN EARLY YEARS WERE NOT EXPERIENCED AT MIHAMA MIKATA. THREE KEY PROBLEMS UNIQUE TO UTASHINAI WERE:

- Bottom diameter too large

- Suboptimal refractory configuration

- Particulate carryover causing slagging
OPERATIONAL ISSUE #1: BOTTOM DIAMETER TOO LARGE

Original

- Blind/cold spots cause slag to harden
- Plasma Torches
- 2300 mm

Modified

- Reduced Bottom Diameter
- Uniform hot zone creates continuous slag flow
- 1600 mm
OPERATIONAL ISSUE #1: BOTTOM DIAMETER TOO LARGE

Slag Buildup on Reactor Bottom Section

Slag Close-up Below Torch Tuyeres

Slag Tapping – smooth flow
OPERATIONAL ISSUE #2: INCORRECT REFRACTORY CONFIGURATION

<table>
<thead>
<tr>
<th>Zone</th>
<th>Original Structure</th>
<th>Material</th>
<th>Improvement Structure</th>
<th>Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freeboard Zone</td>
<td>3 layers</td>
<td>1\textsuperscript{st} layer High Almina</td>
<td>3 layers</td>
<td>1\textsuperscript{st} layer High Almina</td>
</tr>
<tr>
<td></td>
<td>2\textsuperscript{nd} layer SiO\textsubscript{2}/Al\textsubscript{2}O\textsubscript{3}</td>
<td>2\textsuperscript{nd} layer SiO\textsubscript{2}/Al\textsubscript{2}O\textsubscript{3}</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3\textsuperscript{rd} layer insulation</td>
<td>3\textsuperscript{rd} layer insulation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gasification Zone</td>
<td>3 layers</td>
<td>1\textsuperscript{st} layer High Almina</td>
<td>3 layers</td>
<td>1\textsuperscript{st} layer SiC</td>
</tr>
<tr>
<td></td>
<td>2\textsuperscript{nd} layer SiO\textsubscript{2}/Al\textsubscript{2}O\textsubscript{3}</td>
<td>2\textsuperscript{nd} layer SiO\textsubscript{2}/Al\textsubscript{2}O\textsubscript{3}</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3\textsuperscript{rd} layer insulation</td>
<td>3\textsuperscript{rd} layer insulation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Melting Zone</td>
<td>2 layers plus water wall</td>
<td>1\textsuperscript{st} layer High Almina</td>
<td>2 layers plus water wall</td>
<td>1\textsuperscript{st} layer SiC</td>
</tr>
<tr>
<td></td>
<td>2\textsuperscript{nd} layer SiC</td>
<td>2\textsuperscript{nd} layer High Almina</td>
<td></td>
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</tr>
</tbody>
</table>

Very short life span in the Melting and Gasification Zones

Life span increased to 4 years in the Melting and Gasification Zones
OPERATIONAL ISSUE #3: PARTICULATE CARRY-OVER

<table>
<thead>
<tr>
<th>Improvement</th>
<th>Method</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>A:</td>
<td>feed pipe for prevention of short pass</td>
<td>• ash carry-over was reduced by 50%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• feed pipe melted</td>
</tr>
<tr>
<td>B:</td>
<td>Temperature Control of exiting syngas 1000°C 750~800°C</td>
<td>• not molten but accumulated inside</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• not molten and not accumulated</td>
</tr>
</tbody>
</table>
OPERATIONAL ISSUE #3: PARTICULATE CARRY-OVER

Slag and Ash Accumulation Inside the Afterburner

Before modification – large accumulation

After modification – accumulation reduced
ENHANCED GASIFIER DESIGN – TEES VALLEY

Syngas

3 Seconds Residence Time (No furans or dioxins)

Vitrified Slag

Wide freeboard to reduce carryover, and partial quench to solidify molten material reducing fouling/corrosion downstream

Air or Oxygen

Plasma Torch

Refractory: Utashinai Experience Incorporated in New Design

Side Feed Reduces Carryover

Proper Bottom Size – Even Heat Distribution and no Slagging Advanced Thermal Modeling

ALTER NRG

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