Tetronics Plasma Vitrification Technology in the Management and Conditioning of Nuclear Waste

Tim Johnson
Technical Director

Thermal Treatment of Radioactive Wastes Symposium
12 Dec 2013
Tetronics

- Global leader in the application of DC Plasma Arc technology
- Established 1964 in Oxfordshire, UK with a R&D focus
- Acquisition by InvestSelect in 2004, triggered significant investment, move to new bespoke facilities in Swindon, UK
- Comprehensive and sophisticated R&D trial facilities
- Mature technology platform with a securely protected IP
- Experienced process design, engineering and manufacturing staff complemented by project management, commercial and environmental regulatory expertise
Tetronics Applications

Metal recovery:
- Precious metals, base metals

Environmental treatment:
- Incinerator ash, air pollution control residues
- Dusts and slags from metallurgical industries
- Others, including asbestos, spent pot liner, organics, etc.
- Nuclear ILW

Clean heating:
- Continuous casting of steel, nanopowders, high quality silica glass, etc.
- 80+ installations globally, up to 30,000 tonne per year capacity
- Two-year TSB-funded project with Costain on nuclearisation of Tetronics’ plasma arc technology now in progress
Plasma in the Nuclear and Hazardous Waste Sector

- A versatile method for the treatment of a wide variety of nuclear wastes
- Controllable, contained and fully instrumented process
- Minimal material addition to the waste stream and significant volume reduction of the packaged waste stream
- The vitrified product(s) from hazardous wastes, are passively stable, dense and environmentally robust
- Complements the NDA’s objective to deliver cost effective and accelerated nuclear site decommissioning
Plasma Technology in the Nuclear Sector

- Flexible and tolerant technology to deal with legacy arisings
  - Solid and liquid wastes of variable composition
  - Inorganic and/or organic wastes
  - Electrically conductive or non-conductive wastes
  - Low gas flows for smaller off gas systems
  - Avoidance of water-cooled plasma devices in vessel
  - Allows for variety of material removal methods to suit application

- Maximum hazard reduction and wasteform passive stability
  - High density product
  - Glassy, vitrified form for low leachability
  - High homogeneity
  - High retention of radionuclides
### Tetronics’ Nuclear Waste Projects

<table>
<thead>
<tr>
<th>Date</th>
<th>Partner</th>
<th>Waste</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan 2004 – Mar 2004</td>
<td>Nexia Solutions</td>
<td>Plutonium containing materials</td>
</tr>
<tr>
<td>Dec 2004 – Mar 2005</td>
<td>Nexia Solutions</td>
<td>High-CI Plutonium containing materials</td>
</tr>
<tr>
<td>Jul 2005 – Sep 2005</td>
<td>BNG</td>
<td>Asbestos containing materials</td>
</tr>
<tr>
<td>2006 – 2007</td>
<td>Costain</td>
<td>Sellafield sludge: B29, B30 and SIXEP (spent clinoptilolite)</td>
</tr>
<tr>
<td>July 2008; Feb 2010</td>
<td>Hinkley Point A</td>
<td>Spent ion exchange resin</td>
</tr>
<tr>
<td>Sep 2008</td>
<td>WMT</td>
<td>Grout Encapsulated Magnox Swarf</td>
</tr>
<tr>
<td>Feb 2011 – Mar 2011</td>
<td>Sellafield</td>
<td>High Metallic ILW Trials</td>
</tr>
</tbody>
</table>
TWIN ELECTRODE MELTING SYSTEM
Twin Electrode Plasma Vitrification of Nuclear Waste

- Feed system
- Ar, N₂, O₂, H₂O
- off gas
- Cathode
- Ar
- Ar
- Anode
- Coupling zone
- Reaction chamber
- Tilt or remove
- Copper cold crucible

© Tetronics International 2013
www.tetronics.com | +44 (0)1793 238500
Summary of Prototype Plant

- Purged negative pressure loss-in-weight feeding equipment
- Twin electrode DC plasma furnace
- PID control of oxidant addition for gasification
- Cold-crucible containment vessel (copper, 600m ID)
- Negative pressure operation, temperature approx. 1600°C
- Input power up to 500 kW
- 50 mm OD graphite electrode – consumption < 3kg/MWh
- Two-axis electrode positioning for arc length control
- Comprehensive integrated off-gas handling facilities
Twin Electrode Melting Projects

- PCM and highly chlorinated PCM
- Sellafield sludge: B29, B30, SIXEP (spent clinoptilolite)
- Grout encapsulated Magnox swarf
- Ion exchange resins
- High metallic ILW
Typical Experimental Method

- The twin electrode DC plasma system activated
- Steady state conditions obtained immediately
- Host slag material gradually fed to the crucible and vitrified
- Oxidants used to ensure the formation of an inorganic final waste-form
- Simulant fed in to produce the required final waste-form
- Operational data obtained from the SCADA
- Emissions data obtained from the MCerts contractor
- The final waste-form analysed by XRF/Leco, XRD, SEM/microprobe etc.
PCM - Product Characteristics

A final PCM waste-form loading of 25 – 85 % was achieved with:
- A low residual carbon content – good thermal treatment and passively stable
- A high mass accountability including a high level of cerium retention
- A uniform cerium distribution
- A high density product (~2600 kg m⁻³) of semi-crystalline appearance
- Anorthite as the dominating crystalline phase
Results

- The plasma process is tolerant of heterogeneous materials, including highly chlorinated and organic-containing wastes
- Uniform, stable, dense inorganic final waste-form
- Good volume reduction
- The plasma technology is robust and reliable
- Cerium retention high and unaffected by the volumes of gas produced and/or the presence of chlorine
- Tetronics’ plasma technology is an effective means of converting a range of ILW waste into a stable, final waste-form with a large reduction in volume of the packaged product compared with alternative treatment methods
SINGLE ELECTRODE MELTING SYSTEM
Tetronics DC Plasma Furnace
Asbestos Containing Material - Summary of Prototype Plant

- Negative pressure ACM feeding enclosure with 3 stage air-lock
- Single electrode DC plasma furnace with hearth return electrode, 300 kg capacity
- Plasma furnace lined with castable refractory (650 mm ID)
- Negative pressure operation, temperature approx. 1600°C
- Input power up to 500 kW for the trial
- Thermal losses of 90 kW at 1600°C
- 70 mm OD graphite electrode – consumable < 2kg/MWh
- Servo electrode position / arc length control
- Comprehensive integrated off-gas handling facilities
ACM - Experimental Method

- Preheat furnace and flush with simulant slag at 1600°C
- Tap molten vitrified material and cool the Installation for live test
- Obtain steady state operational conditions
- Preheat furnace and acquire occupation and environmental monitoring for baseline
- Start to feed the different types of ACM product and associated polymorphs individually up to 55%w/w waste loading
- Obtain SCADA operation data
- Obtain emissions data from MCerts contractor
- Take samples of the vitrified product for analysis by polarised light microscopy (PLM), XRD and SEM
ACM - Results

- No evidence of asbestos minerals was detected in the samples by PLM, XRD and SEM i.e.
  - No fibrous morphology or ghost fibres were detected by PLM and SEM
  - No asbestos-mineral crystal structures found in the bulk of the sample by XRD
- Health & Safety Executive recommended ‘ACOP technique’ confirmed the absence of asbestos minerals
- Analysis was undertaken by independent UKAS accredited labs
- The product had a vitreous lustre and a density of ~2600 kg m\(^{-3}\)
Thank you

Marston Gate
South Marston Park
Stirling Road
Swindon, SN3 4DE

Tel : +44 (0)1793 238500