The innovative plasma tilting furnace for treatment of radioactive and problematic chemical waste

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Belgoprocess

- Private company
- Established in 1984
- Operations for 2 sites
- 330 employees
- Turnover: € 50 million
• Processing and temporary storage of radioactive waste: LW, ILW, HLW
• Decommissioning, dismantling & decontamination of obsolete nuclear facilities
• Integrated safety, environment and quality management
• Valorization of know-how
Plasma technology

Features of plasma technology

- Developed in the 60’s for making high intense heat source for testing heat shields for the space industry
- Used for melting into metallurgical industry
- Used as heat source for treatment/melting hazardous waste. Typical temp is 5000°C
- After more than 4 decades first application for radioactive waste treatment was taken into operation in 2004
- With plasma, the organic material is vaporised in volatile hydrocarbons, carbon monoxide, etc. while non-combustible and other inorganic constituents are melted and transformed into glassy slag
Introduction Plasma

- Due to the higher temperature of the plasma the range of applicable complex waste types is much greater → organic material is gasified and iron, concrete, glass and other inorganic material is melted to form a slag.

Applicability of thermal technologies to common waste types

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<tbody>
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<td>NA</td>
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<td>NA</td>
<td>NA</td>
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<tr>
<td>High temperature incineration</td>
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<td>A</td>
<td>A</td>
<td>NA*</td>
<td>A*</td>
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<td>Incineration</td>
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<td>A</td>
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<tr>
<td>Melting</td>
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<td>NA</td>
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<tr>
<td>Molten salt oxidation</td>
<td>A</td>
<td>NA</td>
<td>A</td>
<td>LA</td>
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<tr>
<td>Plasma</td>
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<td>A</td>
<td>A</td>
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<td>A</td>
<td>A</td>
</tr>
<tr>
<td>Pyrolysis</td>
<td>A</td>
<td>NA</td>
<td>A**</td>
<td>A**</td>
<td>A**</td>
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<tr>
<td>Synroc</td>
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<td>A</td>
<td>A</td>
<td>A</td>
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<td>NA</td>
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<tr>
<td>Thermo-chemical treatment</td>
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<td>NA</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>NA</td>
<td>A</td>
</tr>
<tr>
<td>Vitrification</td>
<td>NA</td>
<td>A</td>
<td>A**</td>
<td>A**</td>
<td>A**</td>
<td>NA</td>
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<tr>
<td>Wet combustion</td>
<td>A</td>
<td>NA</td>
<td>A</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>A***</td>
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</tbody>
</table>

A Technology is applicable to this waste type.
NA Technology is not applicable to this waste type.
LA Technology has limited applicability to this waste type.
* Small pieces of inorganic are acceptable without causing damage or plugging of the system
** Applicable only for the granular or powder form of this waste type.
*** Applicable only to organic spent resins

IAEA TECDOC 1527
Plasma technology: Technological benefits

- One single process can treat many RAW streams
  - Applicable to solid organic and inorganic wastes, including asbestos
  - drummed spent resins and liquid wastes
- Process fulfils ALARA principles.
  - Waste packages can be treated “as is” and fed unopened without needed of pre-treatment or sorting out
  - Eliminating risks for contamination and limitation of dose uptake
- A robust waste form is obtained (similar as the vitrification)
  - free from any organic material and liquid/sludge
  - In accordance with the most stringent WAC for long term storage and disposal.
  - Suitable to recondition historical waste which do not fulfil WAC
- High volume reduction factor that minimises the overall cost for storage and final disposal
Industrial facility: Plasma plant ZWILAG in Switzerland

Successfully operated by ZWILAG from mid 2004

- Nowadays: 2 campaigns of 10 weeks per year
- About 500 drums or 100 ton per campaign
- About 140 pours per campaign
- End 2013: Total 8000 drums or 1300 ton
- Run on a commercial base
Industrial facility under construction PMF at Kozloduy NPP

Key project figures

- EPC Turn key project funded by EBRD & KNPP
- Signature of Contract: April 2009
- Supplier: Joint Venture (Iberdrola Ingeniería S.A.U Belgoprocess N.V.)
- Basic project data:
  - Treatment of Low and Intermediate Level Radioactive (Category 2a)
  - Inlet throughput: 65 kg/h, yearly: 250 ton/year
  - VRFs:
    - Un-compacted ≈ 80
    - Compacted ≈ 20
    - Supercompacted ≈ 2
Kozloduy NPP area
Waste to be treated

KNPP Radwaste types to be treated:

- Untreated waste: Organic waste in bags
- Pre-compacted waste: Mixture of organic / inorganic in 200 l steel drums
- Supercompacted waste (organic, wood, concrete)
- Liquid waste such as oils
- Spent resins
- Category 2a (*) 3,23E+05 Bq/kg (Co60: 57%, Cs137: 20%, others: 23%)
- Difficult to sort out (pre-compacted and supercompacted)
Flow diagram PMF

- Conveying, shredding and teeding system (A)
- Primary Treatment chamber with Plasma system (B)
- Off-gas cooling and cleaning system (C)
- Slag collection and cooling system (D)
Most significant equipment in KNPP PMF

- **Plasma treatment chamber** > fix furnace with tilt design
- **Torch** > 500 kW non-transferred arc plasma torch; temp 5000°C
- **Feeding system** > continuos through a 2 stage shredder
- **Off-gas system** > based on CILVA facility at Belgoprocess site
- **Slag collection chamber** > based on ZWILAG design
Main equipment: Non transferrable torch
Main equipment: Shredder components

- Primary and secondary shredder
- Screw feeder
- Driving force is system has to accept 200 L Drums
Main equipment: Secondary Chamber (STC) and Off Gas System

- STC and off gas similar as conventional radwaste incinerators (based on CILVA incinerator at BP site))
- STC ➔ the syngas, hydrocarbons containing Cl and S are oxidized to primary components such as CO2, H2O, SO2 and HCl
- Off gas:
  - Boiler
  - Bag filter and HEPA filters
  - Scrubber unit
  - Extraction fans
  - DENOX
- Released gases ➔ Directive 2000/76/EC
Main equipment: Secondary chamber (STC) and off gas system
## Emissions level

<table>
<thead>
<tr>
<th>mg/Nm³ (1) corrected to 11% O₂</th>
<th>EC Directive 2000/76/EC</th>
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<tbody>
<tr>
<td></td>
<td>Daily average values</td>
</tr>
<tr>
<td>Total dust</td>
<td>10</td>
</tr>
<tr>
<td>CO</td>
<td>50</td>
</tr>
<tr>
<td>TOC</td>
<td>10</td>
</tr>
<tr>
<td>HCl</td>
<td>10</td>
</tr>
<tr>
<td>HF</td>
<td>1</td>
</tr>
<tr>
<td>SO₂</td>
<td>50</td>
</tr>
<tr>
<td>NOX</td>
<td>400</td>
</tr>
<tr>
<td>Heavy metals</td>
<td></td>
</tr>
<tr>
<td>∑ Cd, TI</td>
<td>0,05 (2)</td>
</tr>
<tr>
<td>Hg</td>
<td>0,05 (2)</td>
</tr>
<tr>
<td>∑ Sb, As, Pb, Cr, Cu, Mn, Ni V</td>
<td>0,5 (2)</td>
</tr>
<tr>
<td>Dioxins and furanen : ng/Nm³</td>
<td>0,1 (3)</td>
</tr>
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</table>

(1) Emissions are standardized at the following conditions: temperature: 273 °K; pressure: 101,3 kPa; 11 % O₂; dry gas
(2) average values over sample period min. 30 min. – max. 8 hours
(3) average values over sample period min. 6 hours – max. 8 hours
Inplantation in building AB-2
Project Planning PMF facility

- EIA (environmental report) 2010
- ISAR (safety report) Rev1 2010
- Approval Detailed Design: 07/05/2012
- FAT testing major equipment: April-June 2013
- Transport equipment to Kozloduy: Sept - Dec 2013
- Civil works: Aug 2015
- Commissioning and SAT in KNPP: mid 2016
FAT Slag Collection Chamber
FAT Shredder
FAT Shredder

- Purpose is shredding:
  - bagged waste,
  - drummed organic / inorganic waste (metal, concrete, building material, brics)
  - Supercompacted wood and concrete
- Total shredded: at least 50 drums
- Shredded metals and concrete, brics send to Morcenx for integration test

Video drum 5655.

Video feeder tube 5654.
FAT Off Gas

- Biggest mechanical and PLC part of the PMF facility
- Tests were carried on particularly:
  - PLC program
  - Simulation alarms
  - Control algorithm such as underpressure control, temperature control
  - Taking over redundant equipment
FAT and integration test Plasma furnace and feeder

Integration test with screw feeder July 2013
FAT and integration test Plasma furnace and feeder

- Testing with only inorganic waste
- Test with different compositions which are representative for the real RA waste:
  - Concrete, soil, sand, Al, Steel (with and without additives)
  - Concrete, steel, brick (with and without additives)
  - Concrete, building debries, steel, additives
- Prepare batches of 500kg → about 200 L of slag; 170 L is poured rest stays in furnace
- Torch has operated for about 200h; easily another 200h → far above guaranteed lifetime of 100h of the upstream electrode
FAT and integration test Plasma furnace and feeder

Video screw feeder
Video feed pipe.5996
Video camera pouring.5953
Video inside furnace_6012
Video melting
Conclusions

- FAT test of major equipment and different compositions was successfully carried out and is an important milestone for the project.
- Integration test with plasma furnace and screw feeder give good confidence into the future operation of the PMF facility and shows the system is proven technology.
- We are acting as a process provider and take care for full integration of the radioactive waste treatment and use plasma torches as a tool.