Sellafield Ltd

Novel Processes for the Treatment of ILW

Topics for today

- The challenge
- Current technology
- Polymeric encapsulation
- Hot Isostatic pressing
- Thermal treatment
- Conclusions

The ILW challenge at Sellafield

SIXEP Magnox Sludge	Magnesium salts
SIXEP Sand/Clino	Clinoptilolote and sand
Magnox Pond Sludge	Magnesium salts
Plutonium Contaminated Materials	General process waste from alpha plants
Pile Fuel Cladding Silo	Al, Magnesium, Graphite, Uranium & other
Future decommissioning wastes	Concrete, brickwork, plant equipment
Contaminated soils	Soils
Pond solids	Spent fuel, skips, isotope cartridges & zeolite
Miscellaneous orphans	Various
Pile Fuel storage pond waste	Spent fuel pond sludge
Magnox Swarf Storage Silo	Various ILW forms from sludges to solids

Challenges

Silo wastes from historic reprocessing activities

Plutonium contaminated wastes from current operations

Challenges

Sludges from legacy storage facilities

Current Waste Treatment Processes

Encapsulation in grout is used on 4 plants at Sellafield for a variety of wastes from flocs to compacted plutonium contaminated waste

Polymer Encapsulation

Polymeric Encapsulation – Currently Used and In development Resins

- Trawsfynydd IX resin encapsulation in VERI (Vinyl Ester Styrene) – left
- Pile Fuel encapsulation trials in Epoxy - below

Polymer Encapsulation – Other Options

- Thermoplastic encapsulant – top right.
- Water absorbing surfactants in polymer – below right.
- Silicone Rubber encapsulant in progress – below left.

Alternative Encapsulants

- Magnesium Phosphate
  - Possible alternative to OPC for the encapsulation of mild steel, aluminium and metallic uranium.
  - Showing promise but an appreciable amount of work still to be done
- Alumino silicate Geopolymers

Geopolymers

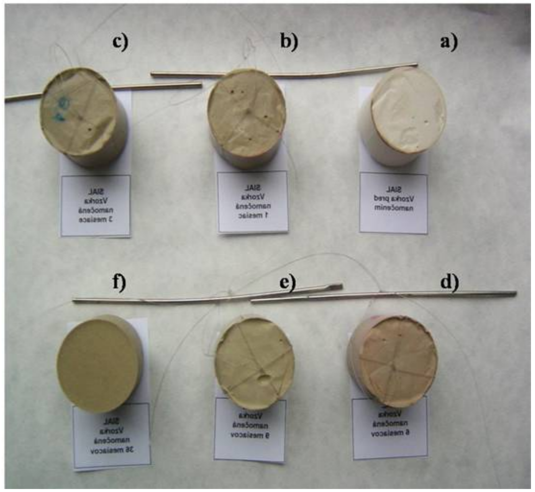
“crystalline aluminosilicates partially dissolved in a concentrated alkaline medium to produce an amorphous geopolymeric gel interspersed with undissolved crystalline particles”

- Many variants of geopolymer available and can be tailored to suit the waste.
- Under investigation for use in the UK
- SIAL* licensed in Czech and Slovak Republic
- Industrial application:
  - Sludge from NPP A-1 – in inorganic and organic coolant
  - Sludge from NPP V-2
  - Sludge and spent resins from NPP Temelin
  - Oil and sludge from NPP Mochovce

- *SIAL registered trademark of AMEC Nuclear Slovakia s.r.o.

SIAL matrix

- Typical characteristics (20% waste loading) –
  - Compressive strength – 10MPa (24 hours)
    15-30 MPa (28 days)
  - Leach resistance - Li index (ANSI16.1 1986)
    - 9 -10 ^{137}Cs
    - 12 -14 ^{90}Sr
    - 14 -18 ^{241}Am, ^{239}Pu
  - Radiation stability to 10MGy
  - Microbial stability and resistance
  - Minimum expansion of product
  - No free liquids
  - Long-term self-recovery of cracks
  - No heat evolution on maturing



Consolidation using Hot Isostatic Pressing

Ceramics for Pu Residues – Process steps

Size Reduction → Calcination → Blending → Granulation → HIP









Performance - Pilot stage

Innovation through collaboration – NNL, Sheffield University and ANSTO

Ceramics for Pu Residues – Product Characteristics

Product

- Flexible wasteform, either full ceramic or a glass-ceramic
  - Zirconolite ($CaZrTi_2O_7$) as Pu host phase,
  - alumino-borosilicate glass as a flexible matrix.

- Pu fully immobilised (chemically bound) in ceramic phase, impurities partition to glass phase

Proliferation Resistance

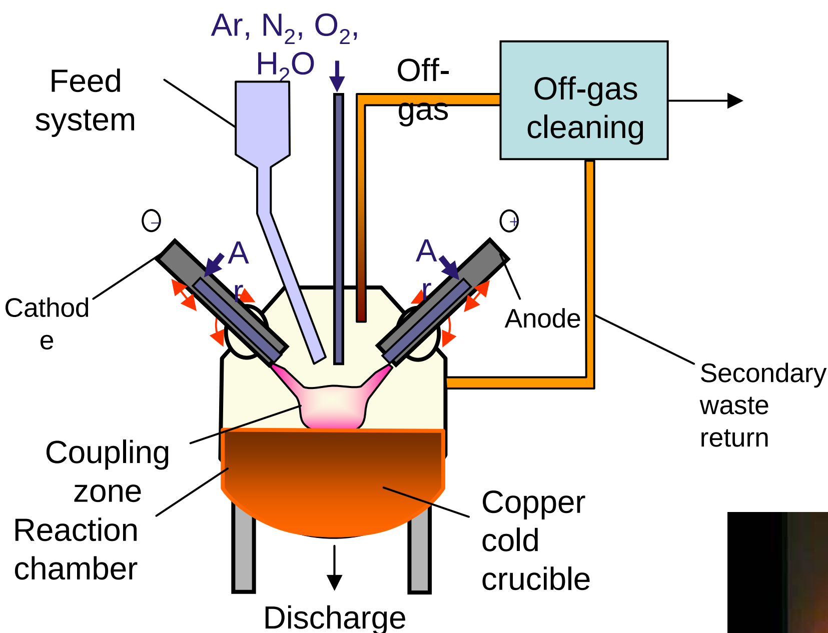
- Normalised Pu leach rates 10^{-5} to 10^{-4} g m^{-2} d^{-1}
- 2 to 3 orders of magnitude better than HLW glass

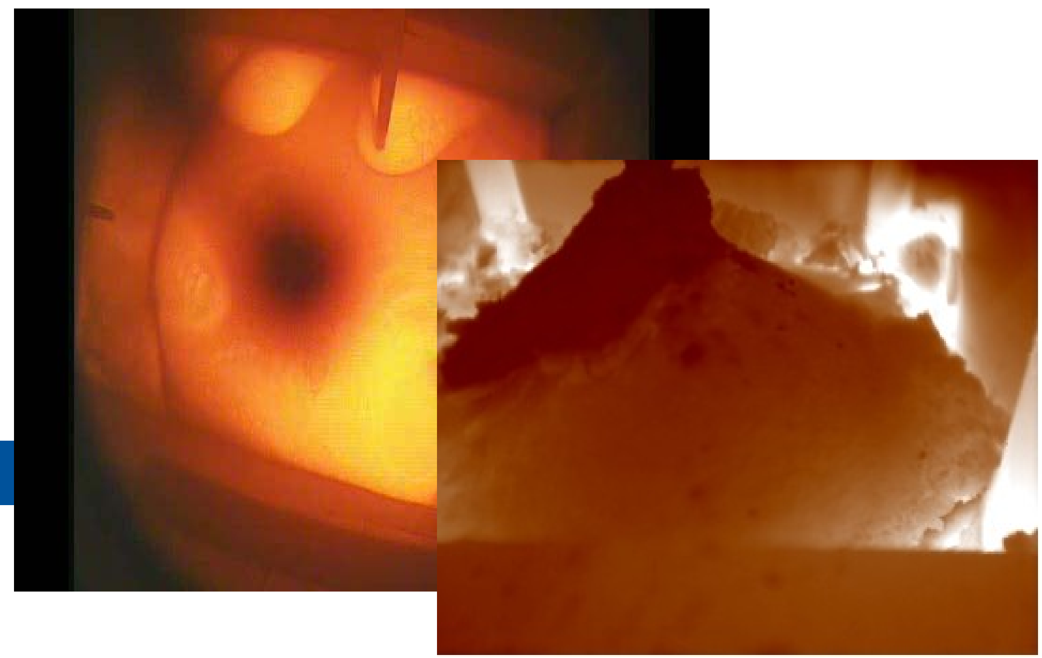
Ceramics

- Durable - Replicates a natural rock formation still containing natural U after ~3 billion years
- Wide processing window to handle variety of chemical feed stocks
- Highly uniform product with homogenous distribution of plutonium
- Multi stage process required

Thermal Treatment

High temperature waste immobilisation technologies





Technology	Technology Suppliers	Nuclear Track record
Plasma	Retech “PACT”	Zwilag & Tsuruga
Joule Heating	IS Inc “Geomelt”	Hanford, Maralinga etc
Joule Heating Melter	Energy Solutions	Hanford, Sav’ River, West Valley
Plasma	Phoenix Solutions	JAERI, Japan
Steam Reformation	“Thor” Studsvik	Erwin, TN, & Idaho USA
Calcine - HIP	ANSTO “Synroc”	Sellafield, Idaho, Australia
Calcination	Areva	Cap la Hague
Plasma	Tetronics	PCM & SIXEP Research
Plasma	PAM 200 - KAERI	Inactive LLW/PCM/ILW
Induction Heating CC	CEA/Areva/KHNP	LILW - Ulchin Power Plant
Plasma	EER Ltd/Radon	LILW in Russia
Plasma	MSE TA Inc	Hazardous Chemical
Induction Melter	Kurion	Trials for DOE (Hanford)

Products - Glass, Ceramics or Mixtures

Ceramic from Magnox Sludge Surrogate - magnesium silicates and titanates

Borosilicate glass incorporating Surrogates of Magnox Sludge and Plutonium Contaminated Waste

Summary of thermal treatment

Advantages	Disadvantages
• Minimal pre treatment requirements • Large feed envelope • Destruction of reactive material • The final waste form is robust, free of organic material. • Product is suitable for long term storage and disposal. • Volume reduction from 3 to 100 fold • Minimal secondary wastes • Lifetime costs can be less than encapsulation technologies	• Capital cost • Nuclearisation • Off gas system required to minimise gaseous discharges • Process controls need to be carefully designed to compensate for the feed variables • Waste characterisation

Conclusions

- Sellafield currently uses encapsulation and vitrification processes for a number of ILW and HLW materials
- Alternative options being evaluated for difficult waste forms and with the possibility of improving the process and waste form
- Alternative encapsulants such as polymers offer benefits especially for metallic wastes forms and resins
- HIPping has been demonstrated to convert plutonium wastes into durable ceramics
- Thermal processes have benefits of volume reduction and durability but nuclear maturity for ILW is limited