



UNIVERSITY OF LEEDS

This is a repository copy of *Nuclear fuel cycle: A UK perspective*.

White Rose Research Online URL for this paper:
<http://eprints.whiterose.ac.uk/97077/>

Version: Presentation

Conference or Workshop Item:

Hanson, BC (2014) Nuclear fuel cycle: A UK perspective. In: 247th National Spring Meeting of the American Chemical Society (ACS), 16-20 Mar 2014, Dallas, TX, USA.

Reuse

Unless indicated otherwise, fulltext items are protected by copyright with all rights reserved. The copyright exception in section 29 of the Copyright, Designs and Patents Act 1988 allows the making of a single copy solely for the purpose of non-commercial research or private study within the limits of fair dealing. The publisher or other rights-holder may allow further reproduction and re-use of this version - refer to the White Rose Research Online record for this item. Where records identify the publisher as the copyright holder, users can verify any specific terms of use on the publisher's website.

Takedown

If you consider content in White Rose Research Online to be in breach of UK law, please notify us by emailing eprints@whiterose.ac.uk including the URL of the record and the reason for the withdrawal request.



eprints@whiterose.ac.uk
<https://eprints.whiterose.ac.uk/>



247th ACS Symposium

The nuclear fuel cycle – a UK perspective

Bruce Hanson

Professor of Nuclear Process Engineering



Contents

- Catch-up
 - Past and current UK policy
 - Technologies in use
- Future
 - Near-medium term
 - Long term

Past and current policies

- 1956 Calder Hall power station open by HM The Queen
- 1962-1971 Nine Magnox power stations opened
- 1976-1988 Seven Advanced Gas Reactors opened
- 1996 Sizewell B (PWR) commissioned
- State owned Central Electricity Generating Board (CEGB)

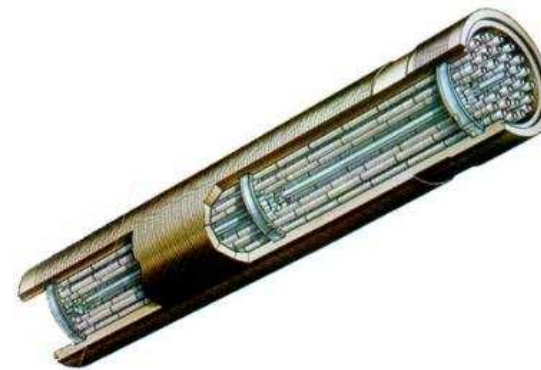
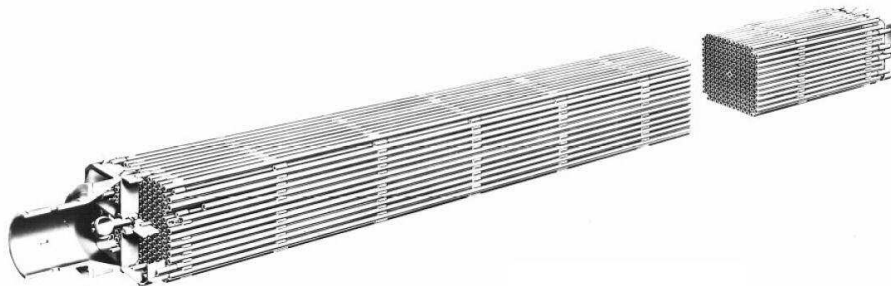


Image source:
Sellafield Ltd

Past and current policies

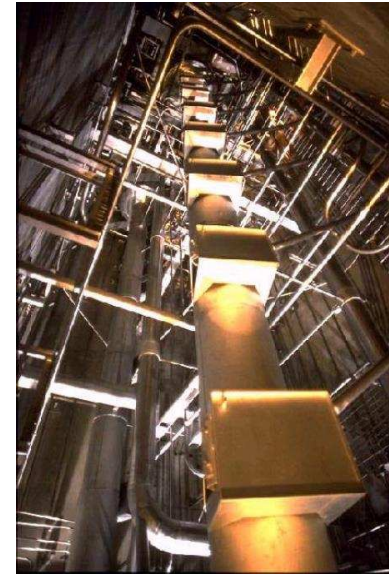
- 1959 Dounreay Fast Reactor goes critical
- 1977 Prototype Fast Reactor reaches full power (200MW)
- 1964 PUREX reprocessing of Magnox fuel at Sellafield (Windscale)
- 1993 PUREX reprocessing of oxide fuel (AGR & overseas LWR) at Sellafield



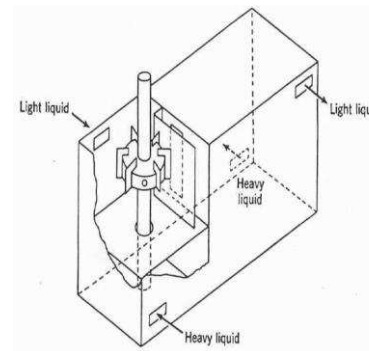
Technologies in use

Thorp & Magnox reprocessing

- Dissolution of fuel in nitric acid
 - Magnox fuel – continuous, after cladding stripped
 - Oxide fuel – batchwise
- Separation of U/Pu/fission products, using PUREX
 - Pulsed columns for areas where liquors have a high fissile content
 - Mixer settlers



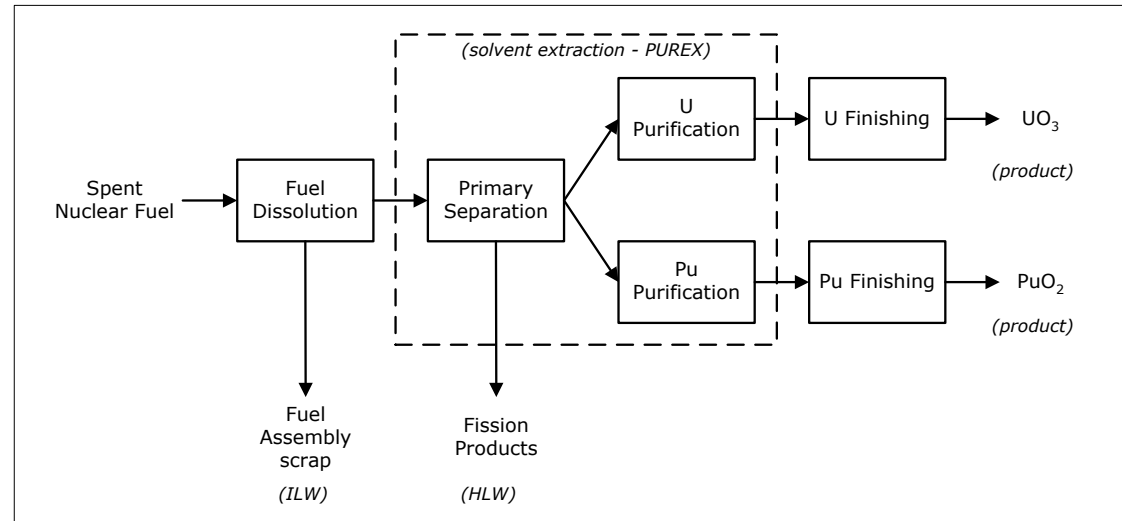
Pulse column at La Hague UP3 plant



PUREX – the basics

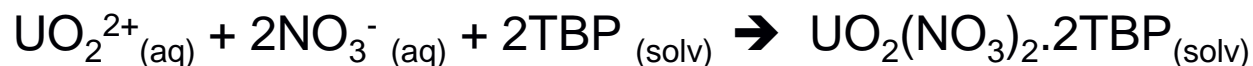
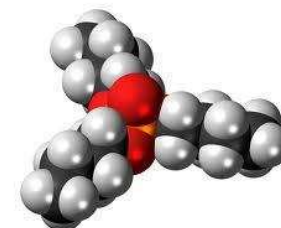
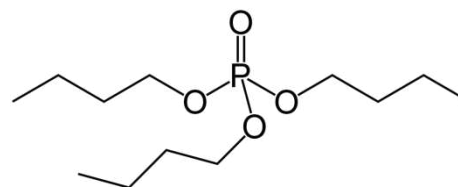
Separations

- Uranium (VI) and Plutonium (IV) nitrate form chemical complexes in a solvent phase of Tri-Butyl Phosphate (TBP) and Odourless Kerosene (OK)
- Primary separation (1st cycle) – U/Pu from fission products, then U – Pu split
- Secondary separations (2nd & 3rd cycles) – U purification (Np removal), Pu purification (Tc removal)



PUREX – the basics

Separations



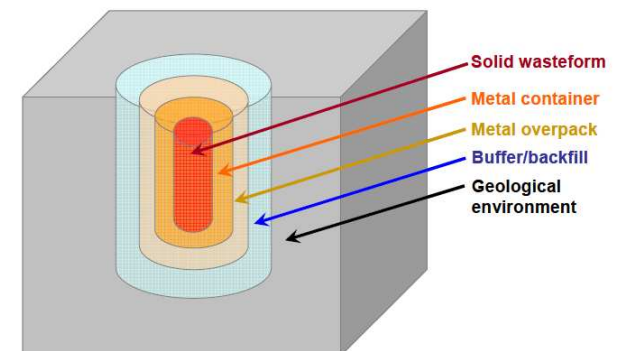
- High degree of separation achieved, decontamination factor = 5000
- Pu/U separation process is based on reducing Pu(IV) to Pu(III) which is inextractable in solvent.
- Reductant used is uranous nitrate (U(IV)), stabilised by hydrazine



Research challenges

Legacy wastes and the end of reprocessing

- Closure of Fast Reactor development programme in 1994, led to stockpile of civil separated Pu (as oxide)
 - 105 tonnes, stored at Sellafield
 - Recycle into thermal Mixed Oxide fuel requires clean up (^{241}Am)
- Planned cessation of reprocessing (Magnox 2014, Thorp 2018) will leave about 6,600t spent fuel AGR
- Fuel from new build + Sizewell B – direct disposal
 - Waste form development & repository concept





The Future

- The UK Government has committed to reduce carbon emissions by over a third, on 1990 levels, by 2020 and to continue on a path towards an 80% by 2050
- UK is embarking on a new nuclear build programme that could range:
 - From 16GWe replacement with LWRs – open fuel cycle
 - Up to 75GWe expansion with LWRs and Gen IV - closed fuel cycle for 80% carbon reduction target
- RCUK funded research programmes: **DISTINCTIVE, PACIFIC, REFINE**

Source:

Nuclear Energy Research and Development Roadmap:
Future Pathways, HM Government



Collaborative Research Programme in: Decommissioning, Immobilisation and Storage solutions for Nuclear waste Inventories (DISTINCTIVE)

Funded by EPSRC and Industry - £8.3M

Principle Investigator: Prof. Mike Fairweather (University of Leeds)





Post reprocessing era (near to medium term)

Collaborative Research Programme in: Decommissioning, Immobilisation and Storage solutions for Nuclear waste Inventories (DISTINCTIVE)

- AGR, Magnox and Exotic Spent Fuels - options for the management of the UK's AGR, Magnox and Exotic Spent Fuels
 - Wet Fuel Storage Issues
 - Transitions to Dry Fuel Storage
 - Long-term Storage Effects and Exotic Fuels
- PuO₂ and Fuel Residues
- Legacy Ponds and Silo Wastes
- Structural Integrity



Transition to a closed fuel cycle (medium to long term)

- Advanced aqueous recycle - PACIFIC
- Pyrochemical processing - REFINE



Providing A nuclear fuel Cycle In the uk For Implementing Carbon reduction (PACIFIC)

Funded by EPSRC and Industry - £3.75M

Principle Investigators: Prof. Tim Abram (University of Manchester) - Fuels

Prof. Bruce Hanson (University of Leeds) - Separations

Imperial College
London



Rolls-Royce



Providing A nuclear fuel Cycle In the uk For Implementing Carbon reduction (PACIFIC) – Fuels Theme

| | Title of Project | Lead Investigator | Partners |
|---|--|-------------------|--|
| In-Reactor Damage Effects in Advanced Ceramic Fuels and Coatings | | | |
| 1 | Fuel Modelling | R Grimes | Imperial College, Cambridge Manchester, Leeds Westinghouse |
| 2 | Thin Film and Fuel Pellet Sample Manufacture | T Scott | Bristol, Manchester, NNL |
| 3 | Advanced TRISO Coated Particle Fuel | P Xiao | Manchester, NNL |
| 4 | Materials Characterisation and Irradiation | T Abram | Manchester, Bristol, NNL |
| In-Reactor Damage Effects in Cladding Materials | | | |
| 1 | Mechanistic Study of Pellet-Cladding Interaction | M Preuss | Manchester, Imperial College, Westinghouse |

Providing A nuclear fuel Cycle In the uk For Implementing Carbon reduction (PACIFIC) – Separations Theme

| Research Area | Title of Project | Lead Investigator | University |
|---------------------------|--|-------------------|------------|
| Minor actinide separation | Direct monitoring of speciation in fuel cycle separations | S Faulkner | Oxford |
| | Optimising Interfacial Transfer Kinetics During Nuclear Separations | C Boxall | Lancaster |
| | Actinide behaviour and radiolysis effects of complexants in advanced separations | C Sharrad | Manchester |
| | Actinide Separation and Selective Extraction Technology (ASSET) | L Harwood | Reading |

Providing A nuclear fuel Cycle In the uk For Implementing Carbon reduction (PACIFIC) – Separations Theme

| Research Area | Title of Project | Lead Investigator | University |
|--|---|-------------------|------------|
| Advanced separations technology | Developing a better understanding of conventional solvent extraction technology | B Hanson | Leeds |
| | Intensified separation using impinging jets | P Angeli | UCL |
| | Development of high efficiency coalescers and settlers | B Hanson | Leeds |
| | Continuous Chromatographic Separation of Actinides and Fission Products | H Eccles | Uclan |

Providing A nuclear fuel Cycle In the uk For Implementing Carbon reduction (PACIFIC) – Separations Theme

| Research Area | Title of Project | Lead Investigator | University |
|-----------------------------------|---|-------------------|------------|
| Product conversion to fuel | The Conversion of Mixed Fuel Oxides to Fuels and Fuel precursors using Molten Salt systems | A Mount | Edinburgh |
| | Electro-reduction of spent nuclear fuel oxides for separation and conversion to fuel precursors | D Brett | UCL |
| | Decontamination and immobilisation of pyroprocessing wastes | N Hyatt | Sheffield |

A coordinated materials programme for the sustainable REduction of spent Fuel vital In a closed loop Nuclear Energy cycle (REFINE)

Funded by EPSRC - £2.75M

Principle Investigator: Prof. Andrew Mount (University of Edinburgh)



The University of
Nottingham



UNIVERSITY OF
CAMBRIDGE



A coordinated materials programme for the sustainable REduction of spent Fuel vital In a closed loop Nuclear Energy cycle (REFINE)

- Direct Electrochemical Reduction: Understanding and controlling interactions in MSs, forming solid state materials cleanly and efficiently, specifically electroactive materials for enhanced electrochemical separation in the electrorefiner;
- Electrorefining & Speciation: Specific solid state materials production by dissolution and deposition of selected species with controlled composition and morphology, specifically ensuring proliferation resistance. Dissolution of stable materials, specifically Gen IV fuels (ceramic, nitride and carbide fuels) and production and characterisation of the MS soluble species;
- Analysis: Establishment of molten salt analysis techniques, specifically the in-line sensing technology required for PR systems with modelling to understand molten salt materials processes.



Future programmes

- Nuclear Innovation Research Office (NIRO) - define a national programme of nuclear energy R&D for the UK.



Thank you for your attention

Acknowledgements

- EPSRC
- Prof. Mike Fairweather (DISTINCTIVE)
- Prof. Tim Abram (PACIFIC)
- Prof. Andrew Mount (REFINE)