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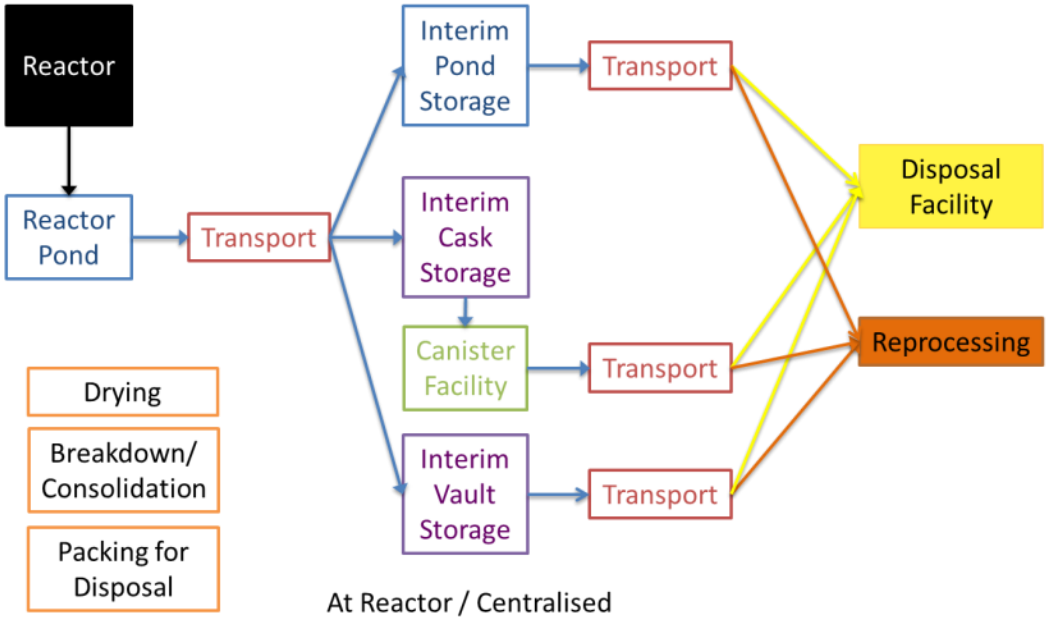
Spent Fuel Storage Capability

Presentation to
CEIDEN Spanish Nuclear Fission Platform
February 2016

David Hambley

Overview

- **Spent Fuel in the UK**
- Spent Fuel Management Studies
- Oxide Fuel
- Metal and Legacy
- Fuel Disposal



UK Reprocessing

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- Since deployment of nuclear power generation, the UK has reprocessed its spent fuel
- Fuel storage has focussed on the short term pending reprocessing (2-10 years)
- The quantity of spent fuel that has been reprocessed is
  - Magnox Fuel ~ 51,700 tHM
  - Oxide Fuel ~ 7,100 tHM
  - Dismantled AGR ~ 5,700 tHM

UK Nuclear Fuel Cycle Position

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- UK has recently changed strategy to pursue an Open Fuel Cycle for all fuels except for the remaining Uranium-Magnox fuel.
- UK is committed to the clean-up and decommissioning of historical civil nuclear legacy and progressing radioactive waste management and disposal
- UK Government recognises nuclear power as a low carbon energy source, and are considering pathways that could deliver up to 75GW installed nuclear capacity by ~2050
- The option for a future transition to a Closed Fuel Cycle remains

https://www.gov.uk/government/publications/the-carbon-plan-reducing-greenhouse-gas-emissions--2
https://www.gov.uk/government/publications/nuclear-energy-research-and-development-roadmap-future-pathways

UK R&D and Generation I Fuels

"Exotics" in order of 500 tHM

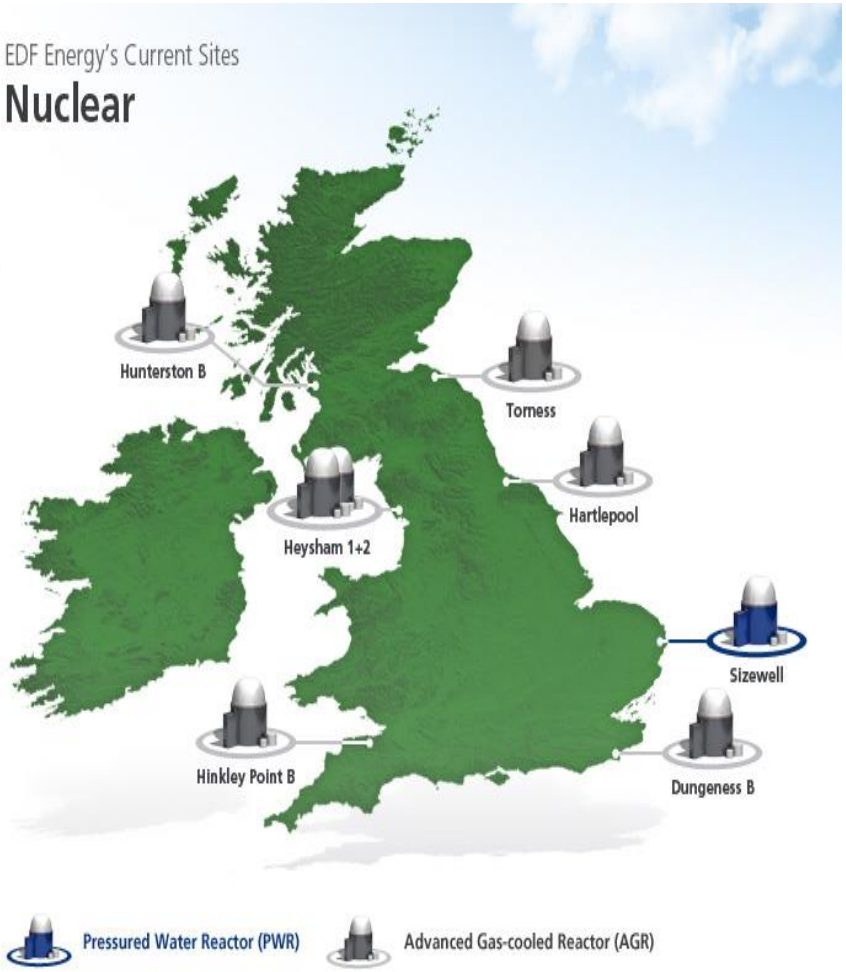
Magnox Fuel 3,800 tHM in April 2012

Images courtesy of NDA

UK Continuing Nuclear Fleet

- AGR fuel
  - 6 stations
  - 880 – 1220 MWe
  - scheduled closure 2018-2023
  - anticipate 5-7 years extension
  - 5,000 - 6,000 tHM

- PWR fuel
  - 1 station
  - 1198 MWe
  - scheduled closure 2035
  - anticipate 20 years extension
  - 1,200tHM



http://www.edfenergy.com/about-us/energy-generation/nuclear-generation/nuclear-power-stations/

UK Fuel Storage – Future

- New Build Programme
  - potential 16 GW capacity by 2030
  - 3.2 GW capacity approved (Hinkley C)
  - may include EPR, AP1000 and ABWR
  - up to 23,500 tHM
- Possibility of Expanded Programme
  - up to 75 GW
  - up to 87,000 tHM
- Reuse Pu fuels
  - Potential for introduction of MOX into new build programme

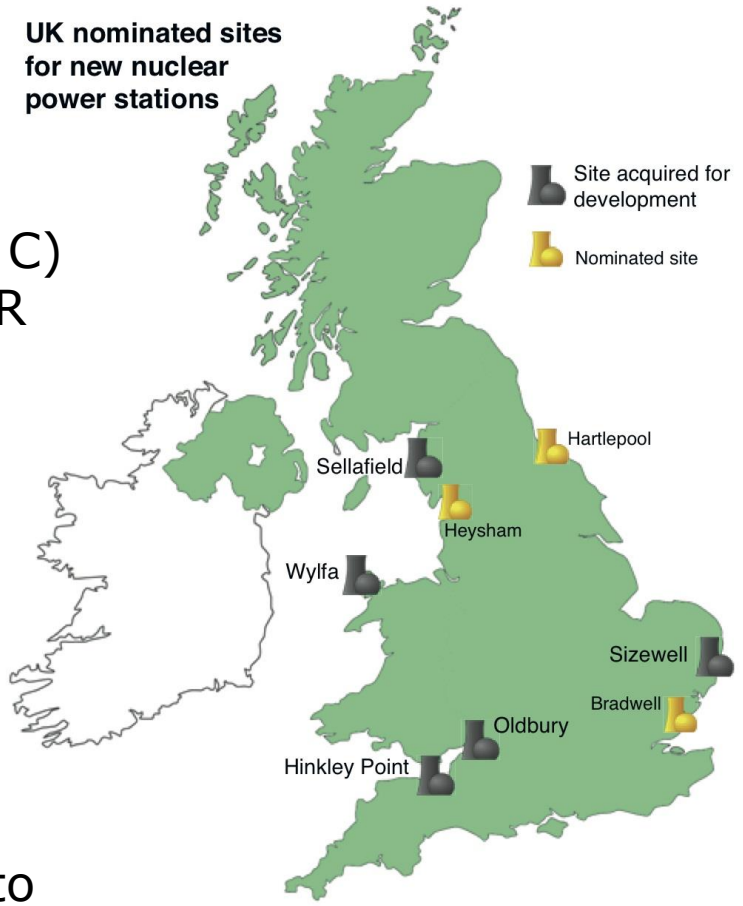


Image courtesy of NAMRC

Future Management of UK Fuel

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AGR

Pond storage capacity (years operation)

- <5

- Short term storage at reactor
- Routine transport of fuel
- **Centralised storage**
- ***Repackage***
- ***Transport***
- ***Disposal***

LWR

Pond storage capacity (years operation)

- SZB ~20
- new build ~10

- Storage at reactor
- **AR storage**
- ***Repackage***
- ***Transport***
- ***Disposal***

GEOLOGICAL DISPOSAL FACILITY

- current & historic nuclear power programme
- HLW from reprocessing
- AGR and non-reprocessible fuel
- LWR from SZB + 16 GWe new

- Site selection in progress
- Operation for ILW 2035
- Receipts of AGR 2075-2090
- *Receipts of LWR >2090*

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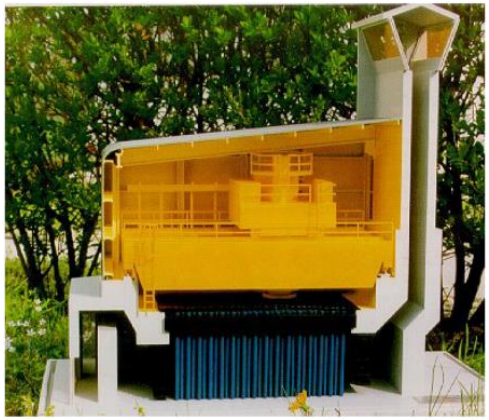

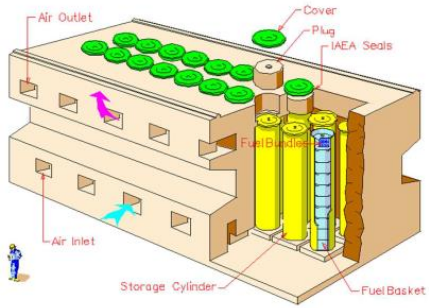

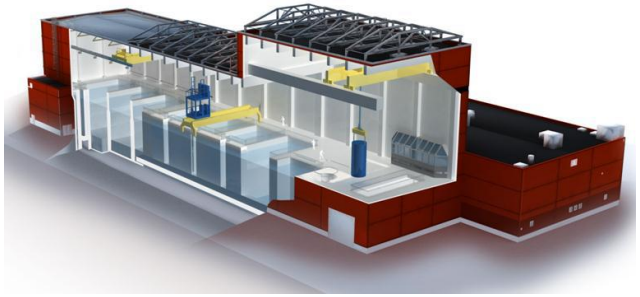

Spent Fuel Management Reviews

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To assist the Nuclear Decommissioning Authority develop strategies for the management of Magnox, AGR and legacy fuels NNL has undertaken reviews of international spent fuel management:

- *Review of international spent fuel storage strategies, 2010*
- *International review of users of stainless steel-clad fuels, 2011*
- *Review of international spent fuel storage and disposal strategies, 2014* *(IAEA Spent Fuel Management Conference 2015 paper 48)*

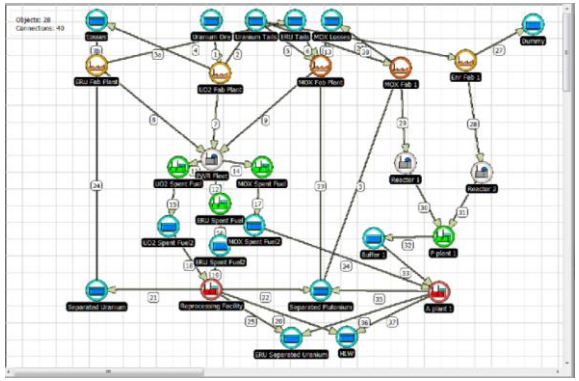
NNL has recently provided advice to the Romanian Nuclear Agency and Radioactive Waste (ANDR). With respect to management of its inventory of spent Candu fuel, involving evaluation of options including, storage and disposal, reprocessing and disposal and reprocessing and recycling into MOX.

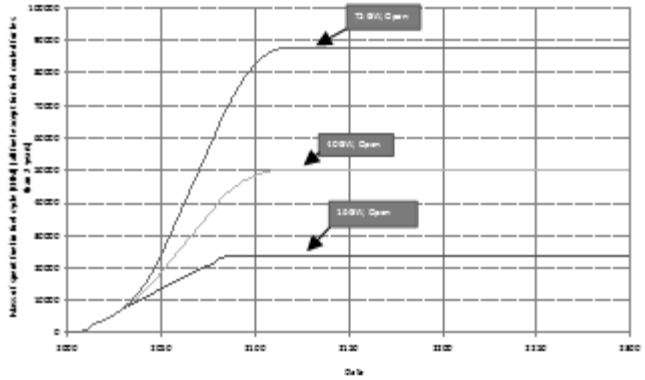
NNL is contributing to the developments of WNA's report on sustainable used fuel management.

Fuel Cycle Modelling

NNL has developed models to understand movements of Magnox and AGR fuel from power reactors in the UK, to the interim storage ponds and reprocessing plants, including transport requirements. These are being used to support strategic and operational planning for current spent fuel management operations. *(Global 2105 paper 5100)*

NNL has developed a generic fuel cycle model, including a range of reactor types and reprocessing facilities. Further developments are addressing detailed modelling of spent fuel storage, repacking and disposal facilities.





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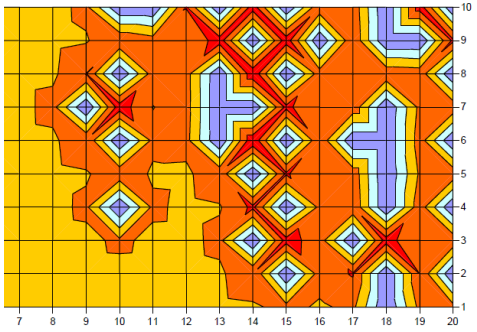

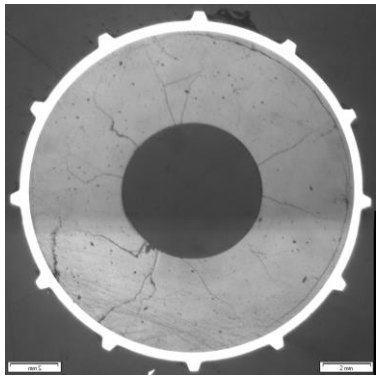

UK Spent Fuel Storage

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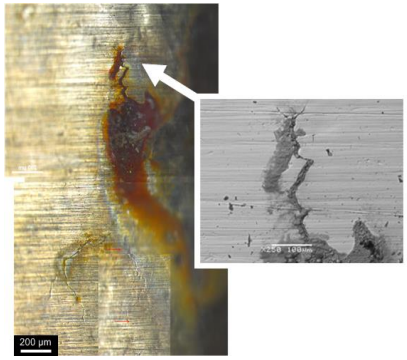
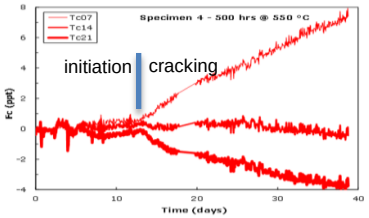
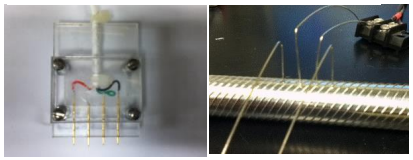
Technical assessments, research and development work and to support the extension of AGR fuel storage from a few years to many decades, including:

- Assessment and application of historical data and technical literature
- Application of reactor fuel performance codes to dry storage
- Experimental work on non-active surrogates, SCC & drying
- Co-ordination and supervision of university-based fundamental research
- Thermal modelling of storage racks
- PIE of reactor fuel
- Development of advanced instrumentation for monitoring of fuel in storage

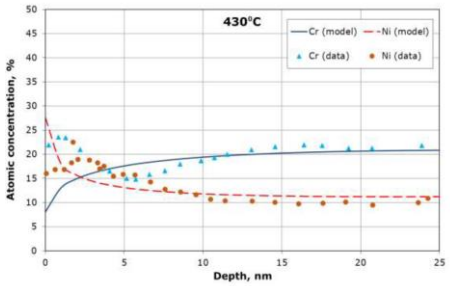


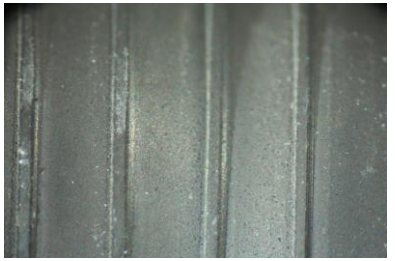


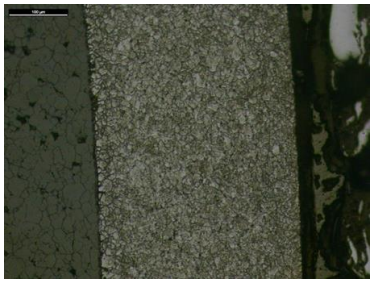


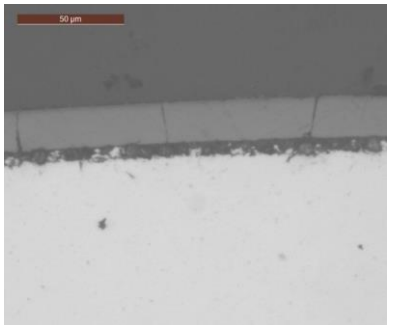
UK Spent Fuel Storage

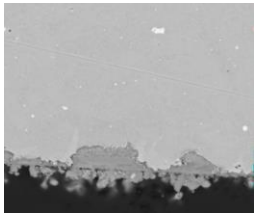
- Examination and testing of stored spent fuel after >20 storage
  - Low power optical examination
  - Microscopy
  - Gamma scanning
  - Drop test
- PIE of high burn-up reactor fuel
  - Microscopy, optical, SEM, TEM
  - Modelling of irradiation effects stainless steel

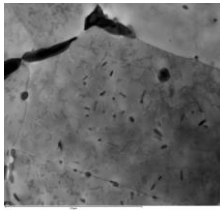


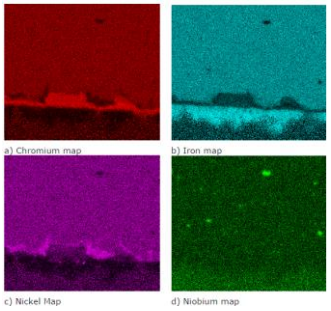


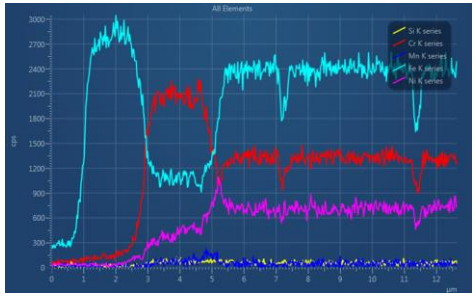


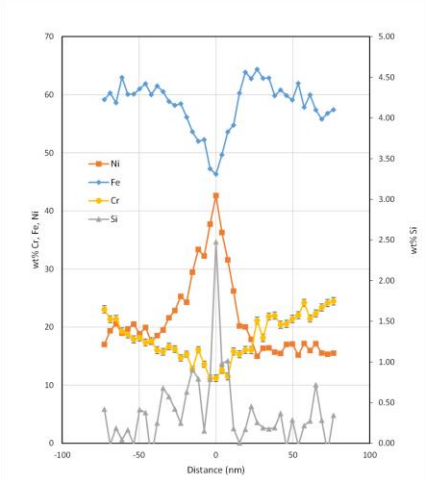


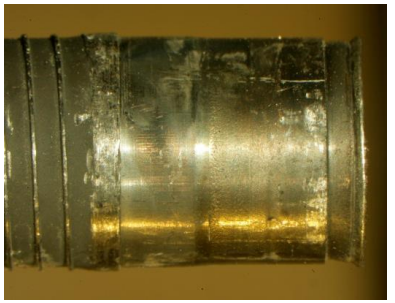








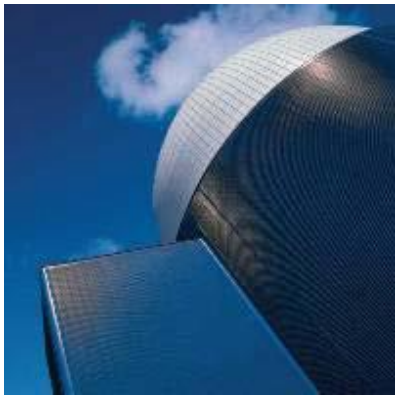




Spent Fuel Storage-LWR

Historically UK based power generation has been dominated by gas-cooled reactors. However NNL is undertaking work relevant to LWR spent fuel, including

- application of fuel performance modelling to LWR fuel in dry storage, for EDF with respect to dry storage of Sizewell B fuel
- development of monitoring techniques for dry storage and cask systems
- participation in international programmes on LWR storage, e.g.
  - EPRI Extended Storage Collaboration
  - Programme IAEA Coordinated research Programme (CRP) on Demonstrating Performance of Spent Fuel and Related Storage System Components during Very Long Term Storage (IAEA CRP T13014
  - CRP on corium and damaged fuel



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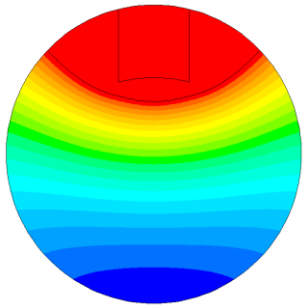
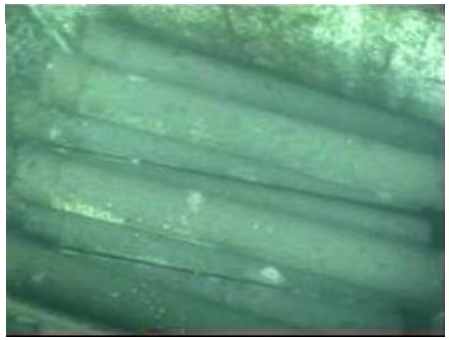
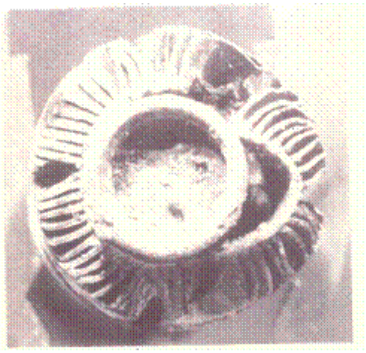


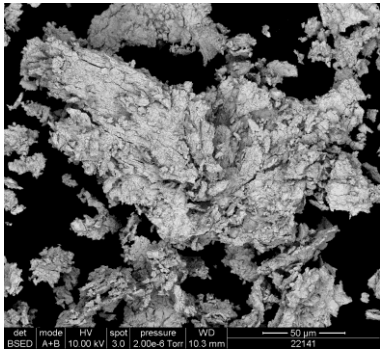


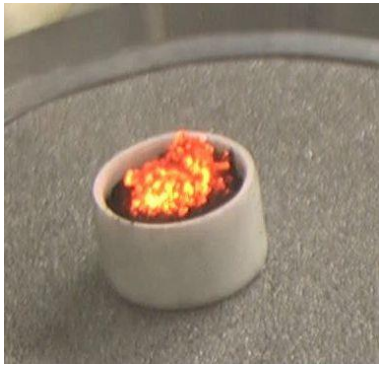


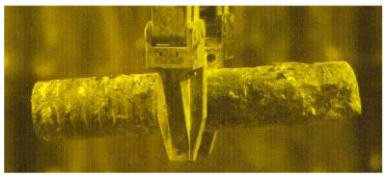
UK Metal Fuel

NNL's expertise, based on >40 years of PIE of Magnox fuel elements, is now being applied to legacy fuels and contingency plans for reprocessing options, including:

- technical underpinning for dry storage of legacy Magnox fuel, including
  - Evolution of fuel in storage
  - Radiolysis of residual water
  - Modelling of pressure & temperature through life
- technical assessments and experimental work on hazardous uranium corrosion products (e.g. uranium hydrides) to support options for
  - Treatment of legacy corroded metal fuels and fuel residues
  - Storage of legacy and corroded fuel and uranium corrosion products
- remediation of high hazard legacy and corroded fuel to assist decommissioning of UK research sites
- development of new storage options



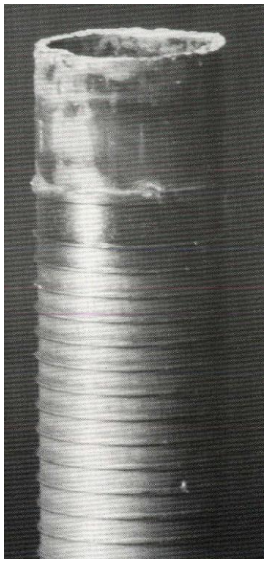


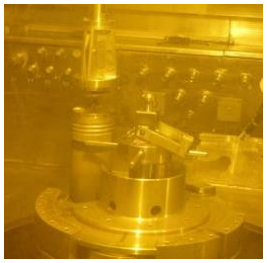


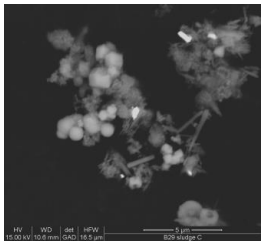
‘Exotic’ Fuels

The UK has a wide range of spent fuels arising from the development of reactors and fuel cycle technologies. NNL uses its historic expertise and unique national capabilities to support the development of safe storage options for these fuels:

- Assessment of non-standard fuel compositions, e.g.
  - Carbide fuels
  - Fast reactor fuels
  - Fuel manufacturing residues
- Treatment of small quantities of non-standard fuels to
  - Characterise aged fuels
  - Characterise corrosion products
  - Develop treatments for degraded fuel components to ensure compatibility with disposal requirements
  - Repackage fuels to meet modern storage requirements
- Modelling of degraded fuel evolution on exposure to pond water







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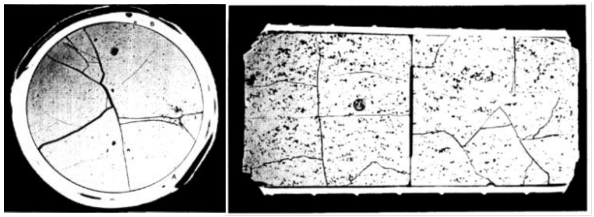
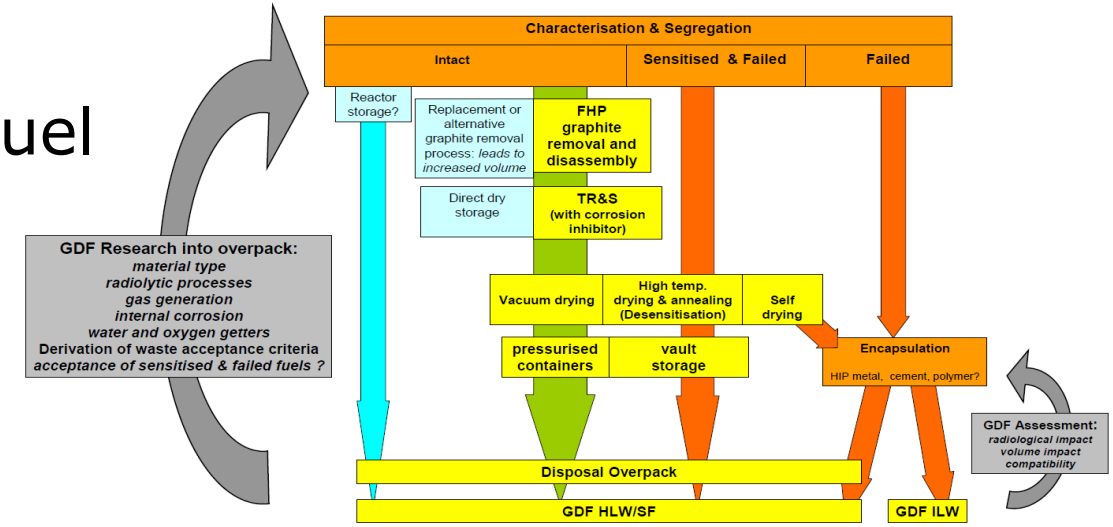
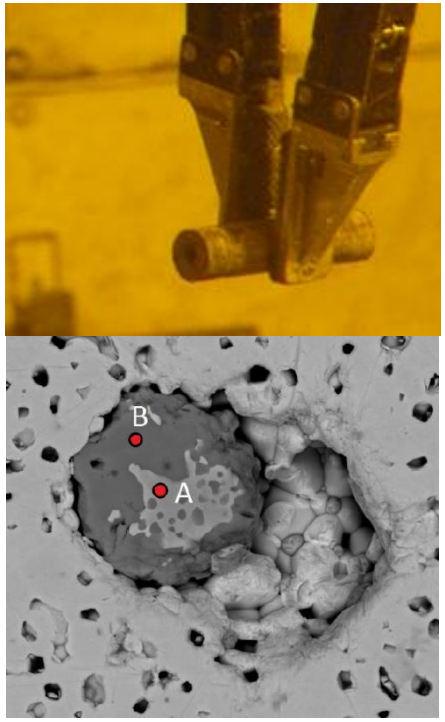




Approach to Spent Fuel Disposal

- Geological disposal of higher activity radioactive waste is UK Government policy. Earliest spent fuel disposal assumed from ~2075
- Inventory of Spent Fuel for disposal is assumed to be ~ 11,200m^3 packaged volume, based on existing reactor arisings and legacy material
- NNL has undertaken disposability option studies for UK fuels and assessments of the evolution of package fuels
- NNL is leading re-building of UK capability for R&D on spent fuel disposal behaviour including
  - with UK universities to compare the dissolution behaviour of UK's AGR fuel and LWR fuel
  - Measurement of dissolution rates of irradiated AGR fuel to complement university-based R&D
  - Leading edge radiolysis R&D



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Thank you for your attention

Any questions ?

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