Spent Fuel Management and Storage Development in UK

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• Summary
Magnox NPPs – UK 1st Generation

- CO₂ Gas Cooled
- Graphite Moderator
- 2 Operational Stations (4 are being defuelled)
- Uranium Metal Fuel
- Magnesium Alloy Clad

Wylfa NPP
Picture courtesy of Magnox North Ltd
Advanced Gas Reactor (AGR) – UK 2nd Generation

- CO₂ Gas Cooled
- Graphite Moderator
- 7 Operational Stations

- UO₂ fuel
- Stainless Steel Clad

Hunterston B
Picture courtesy of British Energy Group plc
Pressurised Water Reactor (PWR)- UK 3rd Generation

• Light Water Cooled and Moderator
• 1 Operating Station
• UO₂ fuel
• Zircaloy Clad

Sizewell B
Picture courtesy of British Energy Group plc
Nuclear is ~19% of UK Electricity Generating Capacity
(10 sites announced for new nuclear build by the Energy and Climate Secretary (09.11.09))
Experimental Spent fuel from the UK Power Development Programmes

Steam Generating Heavy Water Reactor – Winfrith Site

Windscale AGR

PFR – Picture courtesy of DSRL/NDA

DFR – Picture courtesy of DSRL/NDA
Spent Fuel Management Strategies - UK

- PWR (Managed by British Energy - EDF)
  - Open Cycle
- Magnox (Managed by Sellafield Ltd)
  - Closed Cycle
- AGR (Managed by Sellafield Ltd)
  - Closed Cycle (Until end of Thorp Operations)
  - Open Cycle (Non-reprocessed AGR fuel)
- Exotics (Various e.g. Dounreay Site Restoration Ltd)
  - Closed Cycle (e.g. Dounreay Fast Reactor)
  - Open Cycle (e.g. Prototype Fast Reactor fuel)
- New Build
  - Closed Cycle (Planning assumption)
UK Strategy for Spent Fuels Management

- February 2006 the Nuclear Decommissioning Authority (NDA) announced the intention to undertake a comprehensive long term spent fuel management review
- **Objective**
  - To identify the key issues associated with the management of spent fuel and to propose an approach that will lead to the development of a long term integrated plan
- **NDA has established**
  - Topic Overview Group for ‘Nuclear Materials and Spent Fuel’
  - Spent Fuels Management is subdivided into three further topics
    - Magnox Fuel
    - Oxide Fuel
    - Exotic Fuel
  - National Stakeholder Group (NSG)
  - Site Stakeholder Group (SSG)
SFM – PWR (Sizewell B)

- At Reactor storage capacity is expected to be full around 2015
- 2009, Public consultation of the options
  ('Sizewell B Dry Fuel Store' www.british-energy.com)
- Preferred option was to dry store spent fuel in casks in a purpose built building
  - Capacity for up to 3,500 SFAs/200 containers
- February 2010, Planning application was made to the Secretary of State for the Department of Energy and Climate Change (DECC)
- June 2010, Holtec International was awarded a contract to manage the safety case production

Example - Ventilated Dry Cask System
SFM at Sellafield – Magnox, AGR & LWR

• Containerised Storage
  – **LWR** is stored in Multi-element Bottles (MEBs)
    • Boral
    • Boronated Stainless Steel (BSS)
  – **Magnox & AGR** are stored in skips and containers
SFM- Magnox Operating Plan (MOP 8)

- Wet Fuel Stock Policy
- Limit amount in wet storage to 800tU +/- 50tU by April 2010
- Recognises that prolonged storage could result in fuel deterioration which leads to slower reprocessing and increased discharges
  - $\text{Mg} + \text{H}_2\text{O} \rightarrow \text{Mg(OH)}_2 + \text{H}_2 \uparrow$

<table>
<thead>
<tr>
<th>Site</th>
<th>Start Bulk Defuelling</th>
<th>Last Fuel Off-site</th>
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<tr>
<td>Calder Hall</td>
<td>October 2012</td>
<td>May 2015</td>
</tr>
<tr>
<td>Chapelcross</td>
<td>April 2008</td>
<td>August 2011</td>
</tr>
<tr>
<td>Dungeness A</td>
<td>April 2008</td>
<td>March 2011</td>
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<tr>
<td>Oldbury</td>
<td>April 2011</td>
<td>September 2013</td>
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<tr>
<td>Sizewell A</td>
<td>July 2009</td>
<td>June 2012</td>
</tr>
<tr>
<td>Wylfa</td>
<td>August 2011</td>
<td>January 2015</td>
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<tr>
<td>Sellafield</td>
<td>completes reprocessing around January 2016</td>
<td></td>
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</tbody>
</table>
SFM Sellafield Ltd – Examples of R&D

- Development of a Contingency Option for the management of Magnox Fuel
  - The reference case position is Magnox fuel is reprocessed
  - The current plant is 46 years old and has reprocessed >44,000tU
  - Given the age of the plant there is a risk that some Magnox fuel may not be reprocessed
  - There is a need for a contingency to be available that could be deployed in a relatively short time frame
  - Build-on developed technology for metal fuel. In this case a variation to the Hanford MCO

Hanford Multi Canister Over-pack (MCO)
Picture courtesy of Hanford.gov

Magnox Contingency Development
SFM Sellafield Ltd – Examples of R&D

• Hanford MCO developed for degraded Zirconium clad uranium metal fuel

• Development of a Magnox fuel canister
  – 26 intact fuel elements

• Resolution of Technical Issues
  – Drying of wetted Magnox fuel
    • Free Water
    • Physically adsorbed water
    • Chemically adsorbed water (tightly bound to Mg(OH)₂)
  – Canister Chemistry Evolution

Magnox Contingency Development
SFM Sellafield Ltd – Examples of R&D

- At the beginning of storage some irradiated AGR fuel pins and structural components are left sensitised
  - In wet storage sensitised pins are susceptible to corrosion through inter-granular attack (iga)

- Pre-requisites for iga
  - Must have a sensitised microstructure (through wall to lead to failure)
    - Radiation Induced Segregation (RIS) is observed to occur on 20Cr/25Ni/Nb stainless steel cladding in the temperature range 350°C to 520°C; peak effect at 420°C
    - Some elements of a 7-8 element stringer affected
  - Linked to an applied mechanical stress
    - Failure sites normally associated with areas of stress
  - Must be exposed to a corrosive environment
    - For example Chloride

Unirradiated Steel

Irradiated Steel (350-450°C)

AGR Alternative Corrosion Inhibitor Development
SFM Sellafield Ltd – Examples of R&D

• To prevent the potential for AGR fuel to corrode during wet storage, the corrosion inhibitor sodium hydroxide is deployed at Sellafield where practicable

• The exception is Thorp Receipt & Storage (TR&S) where a reprocessing buffer is stored in demineralised water

• Sodium Hydroxide cannot be deployed in TR&S due to compatibility issue with LWR MEBs
SFM Sellafield Ltd – Examples of R&D

**AGR Fuel Corrosion**
- Demonstrate Feasibility (inactive)
- Demonstrate inhibits propagating iga and look at operating envelope (active)
- Confirmation at plant-scale Lead containers (active)

**Plant & Process Compatibility**

**Materials & Biological Assessment**
- HAZAP
- Full Audit of plant materials
- Corrosion & Biogrowth studies (key/potentially susceptible materials)

**Plant Implementation**
- Develop Safety Case

**AGR Alternative Corrosion Inhibitor Development**
SFM Sellafield Ltd – Examples of R&D

Corrosion testing performed by NNL for Sellafield Ltd

Alternative Corrosion Inhibitor Development
- Hot laboratory studies
SFM Sellafield Ltd – Examples of R&D

Alternative Corrosion Inhibitor Development
-Plant scale demonstration
Summary

• Provided an over-view of Nuclear Power Generation in the UK

• Out-lined Spent Fuel Management in the UK
  – SFM Strategies
  – SFM Practices

• Given two examples of R&D in support of spent fuel management at Sellafield

• Thank you for listening