UK Irradiated Materials Archive

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University of Oxford

MRF meeting – CCFE - 7th July 2015
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Background

• Establishment of National Nuclear User Facility for accessible study of active materials
• Initiative within Bristol-Oxford NRC to retain ex-Magnox reactor steel pressure vessel surveillance specimens
• Specimens of known pedigree with up to 40 years of service exposure
• Materials well suited for use in future university-based research programmes
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NNUF - IMAG

• A “working group” of NNUF
• Current committee:
  – (co-chair) Peter Flewitt - University of Bristol
  – (co-chair) Steve Roberts - University of Oxford
  – Chair of NNUF, currently Robin Grimes – Imperial College, FCO
  – NIRO representative, currently Andrew Brown
  – NDA representative, currently Beth Ripper
  – CCFE representative, currently Martin O’Brien
  – NNL representative, currently Dominic Rhodes
  – University representative, currently Simon Pimblott - University of Manchester.
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## Magnox steel vessels – operating periods

<table>
<thead>
<tr>
<th>Station</th>
<th>RPV</th>
<th>Start-up date</th>
<th>Closure date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Berkeley</td>
<td>Steel</td>
<td>1962</td>
<td>1989</td>
</tr>
<tr>
<td>Bradwell</td>
<td>Steel</td>
<td>1962</td>
<td>2002</td>
</tr>
<tr>
<td>Dungeness A</td>
<td>Steel</td>
<td>1965</td>
<td>2006</td>
</tr>
<tr>
<td>Hinkley Point A</td>
<td>Steel</td>
<td>1965</td>
<td>1999</td>
</tr>
<tr>
<td>Trawsfynydd</td>
<td>Steel</td>
<td>1965</td>
<td>1991</td>
</tr>
<tr>
<td>Sizewell A</td>
<td>Steel</td>
<td>1966</td>
<td>2006</td>
</tr>
<tr>
<td>Oldbury</td>
<td>Concrete</td>
<td>1967</td>
<td>2012</td>
</tr>
<tr>
<td>Wylfa</td>
<td>Concrete</td>
<td>1971</td>
<td>-----</td>
</tr>
</tbody>
</table>
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Magnox steel vessels – nominal compositions

- Design and construction standard
  - Non-nuclear BS1500 Class 1
- RPV materials
  - Plain carbon-manganese steel plates and forgings
  - Manual metal arc (MMA) or automatic submerged arc (SAW) welds

<table>
<thead>
<tr>
<th>Composition /wt%</th>
<th>C</th>
<th>Mn</th>
<th>Si</th>
<th>S</th>
<th>P</th>
<th>Cu</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plate</td>
<td>0.09-0.17</td>
<td>1.04-1.32</td>
<td>0.10-0.60</td>
<td>0.02-0.04</td>
<td>0.01-0.04</td>
<td>0.03-0.15</td>
</tr>
<tr>
<td>Forging</td>
<td>0.18</td>
<td>1.30</td>
<td>0.36</td>
<td>0.024</td>
<td>0.024</td>
<td>0.10</td>
</tr>
<tr>
<td>MMA</td>
<td>0.086</td>
<td>0.91</td>
<td>0.91</td>
<td>0.022</td>
<td>0.025</td>
<td>0.08</td>
</tr>
<tr>
<td>SAW</td>
<td>0.088</td>
<td>1.49</td>
<td>1.49</td>
<td>0.037</td>
<td>0.031</td>
<td>0.23</td>
</tr>
</tbody>
</table>
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Magnox steel vessels – operating conditions

- Magnox RPVs experienced a wide range of irradiation temperatures, neutron doses and neutron energy spectra
- Surveillance schemes were designed to cover this range
  - Withdrawn periodically

<table>
<thead>
<tr>
<th>Canister location</th>
<th>Irradiation temperature /°C</th>
<th>Dose rate /dpa.s⁻¹ x10¹³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Above core</td>
<td>330-360</td>
<td>3.2-4.9</td>
</tr>
<tr>
<td>Side core</td>
<td>198-355</td>
<td>7.3-26</td>
</tr>
<tr>
<td>Subcore</td>
<td>165-223</td>
<td>0.94-49</td>
</tr>
</tbody>
</table>
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Magnox specimens

• Specimen listing has been evaluated
  – Composition
  – Charpy and tensile specimens with linked test data
  – More than 8000 specimens
    • Plate material
    • Forged material
    • Manual metal arc welds
  – Irradiation temperatures 170 - 360°C
  – Doses unirradiated plus irradiated, range 10 to 400 x10^{-5} dpa
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Magnox specimen - selection

• Specimens are distributed in cans within overpacks
• Currently stored at Sellafield
  – Well-documented but no system to what is where
• “1st division” specimens
  – kept / tested below 50°C after irradiation
  – ~500 specimens
• “2nd division” specimens
  – kept / tested below 100°C after irradiation
  – ~150 specimens
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Graphite reactor core

• In addition there are graphite reactor core samples
• Pile Grade A graphite reactor core bricks
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Graphite core

- Measurement scheme made provision for property changes
  - Graphite samples inserted in special reactor core channels were withdrawn for testing at approved intervals
  - Irradiated samples trepanned from individual core bricks
  - A large number of unirradiated samples of graphite representative of the individual reactor cores
  - Measure of properties
    - Physical
    - Chemical
    - Mechanical
  - Up to 40 years of service exposure
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Other specimens for inclusion in Archive?

• Graphite
  – Database of AGR archive materials being compiled

• Dounreay fast reactor components
  – Status not yet clear

• Tungsten
  – ISIS targets being evaluated

• Anything else!
  – Suggestions sought
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Next steps

• Following NDA clearance, make Magnox specimen list available
  – Via NNUF website

• A virtual (distributed) or physical (centralised) archive?
  – **Virtual** – Low initial cost, continuing moderate storage costs, access to chosen specimens difficult and repeatedly expensive
  – **Physical** – High initial cost (~£10M), building and unpacking/sorting, continuing moderate storage costs, only pedigree specimens, access to chosen specimens much easier

• Researchers to decide value for future research projects using available specimens
  – How useful will the archive be?
  – What could be added to it?
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Further information

• Contacts
  – steve.roberts@materials.ox.ac.uk
  – peter.flewitt@bristol.ac.uk

• Website
  – NNUF website: www.nnuf.ac.uk

• Many thanks to Malcolm Wootton, Magnox Limited, for maintaining and making available the Magnox RPV materials database