Spent fuel characterization with the emphasis on Russian type of reactors

(Project theses)

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Areas of interest

1. SNF composition
2. Cladding degradation
# SNF generation

<table>
<thead>
<tr>
<th>Czech Republic</th>
<th>Duration of operation (y)</th>
<th>End of operation (y)</th>
<th>No of assemblies</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPP Dukovany (4x 440 WWER)</td>
<td>50</td>
<td>2035</td>
<td>17494</td>
</tr>
<tr>
<td>NPP Temelín (2x 1000 WWER)</td>
<td>50</td>
<td>2052</td>
<td>4174</td>
</tr>
<tr>
<td>New NPP‘s (2 units &gt;1000 MWe)</td>
<td>60</td>
<td>2095</td>
<td>min. 3770 max. 5328</td>
</tr>
<tr>
<td>Total (some 7 500 t)</td>
<td></td>
<td></td>
<td>min. 25438 max. 26996</td>
</tr>
</tbody>
</table>

**Ukraine:**
- 13 VVER-1000 reactors
- 2 VVER- 440 reactors
- 3 RBMK-1500 reactors + 1 damaged

**Lithuania:**
- 2 RBMK-1500 reactors
Comparison of two inventory calculations in the CR – heat output
Goals

• Benchmarking calculations using different codes
• Verification of calculated values by sample measurements
• Establishment of joint methodology for SNF inventory determination
Cladding issues: Challenges

**NPP operator:**
Increasing fuel burn-up \(\rightarrow\) more intensive degradation during campaign

**Nuclear regulator:**
To what extent can fuel cladding be considered as an engineered barrier?

**Project goal:**
Based on operational performance of Zr-alloy cladding to assess its residual barrier and containment functions under simulated deep geological repository conditions
Cladding degradation mechanisms

Hydriding of Zircaloy
• During operation – being studied
• In repository conditions – need to define scenarios and propose a testing programme for characterisation of the Zr-hydride layer

Corrosion of Zircaloy and SS cladding
• During operation – being studied (demineralised water)
• In long term – a testing programme to be proposed using granitic water
Objectives

• Description of Zr-hydride layer and its anticipated evolution during disposal
• Experimental assessment of barrier functions of Zr-alloy cladding in contact with simulated deep repository aqueous environment under a range of conditions
• Identification of principal types of corrosion interaction between Zr-alloy and simulated aqueous environment
• SS cladding degradation studies
Potential processes to be investigated

- Growth of Zr-hydride layer during operation and geological disposal
- Zr alloy performance during anaerobic \times aerobic periods of disposal
- Corrosion effects of ground water species
- Corrosion effects of water radiolysis products
- Evaluation of mechanical damages due to higher burn-up, temperature, pressure, and irradiation and their impact on corrosion processes
Work to be performed

- Mapping of hydride layers created during operation and in simulated disposal environment
- Assessment of dry oxidation period influence on residual barrier functions of cladding
- Experimental tests of cladding interaction with simulated deep repository environment under a range of conditions (temperature, pressure, different concentrations of aggressive components as Cl, $O_2$, $\gamma$) using in-situ applied electrochemical methods
- Comparative experimental tests of irradiated Zr-alloy and SS samples
- Analysis of generated corrosion products
Anticipated team

- Research Centre Rez, Czech Republic
- University of Chemical Technology, Prague, Czech Republic
- Department of Nuclear Physics and Energy of National Academy of Sciences of Ukraine (National Scientific Centre «Kharkov physical – technical institute»)
- Institute of Environmental Geochemistry, Kiev, Ukraine
- Institute for Safety Problems of Nuclear Power Plants, Chernobyl, Ukraine
- Centre for Physical Sciences and Technology, Lithuania
Capabilities CV Rez

- Modelling codes for SNF inventory
- Hot cells
- Research reactor irradiation capacities
- Emission electron microscopy (hot/cold)
- Anaerobic boxes (cold)
- Optical microscopy (hot/cold)
- Metallographic measurements (hot/cold)
- Experience in metallographic measurement of irradiated materials (reactor surveillance samples)
- Experience in evaluation of irradiated Zr alloy cladding (WWER 440 reactor conditions)
Capabilities of UChT

- Corrosion and material protection in energy production systems
- Corrosion problems in steam generators of nuclear power plants
- Moessbauer spectroscopy of corrosion products and metal-inhibitor interaction products
- Acoustic emission of stress corrosion cracking
- Electrochemical studies of corrosion processes (impedance spectroscopy, polarization techniques)
- Autoclaves
- Experience in evaluating operational corrosion of Zr-alloy cladding (cold)
Capabilities of Ukrainian institutions

- Codes for SNF inventory calculation
- Radiation Monitoring System
- Emission electron microscopy
- Spectrometric measuring systems for $\alpha$, $\beta$, $\gamma$
- Neutron analysis
- Sampling of RBMK SNF
- Sampling of irradiated Zircaloy
Summary

- An international team has been put together to manage the issue of SNF inventory and long term performance of fuel cladding focusing on Russian type of reactors
- The team has theoretical capabilities (codes) and practical experience in dealing with those issues
- The team has facilities and equipment allowing to reach the project goals