Technical Meeting on the Management of Spent Fuel from Shutdown Reactors, Including Those to be Shutdown Prematurely

EVT1701645

Vienna, 11\textsuperscript{th} – 13\textsuperscript{th} June 2018

Laura McManniman
Spent Fuel Management Specialist
NFCMS/NEFW
IAEA actively supports the sustainable, safe, secure, reliable and economic management of SF from nuclear power reactors by providing MSs with relevant technical information (guidance) based on operational experience and best practices about the SF management options

• Through:
  – International conferences and workshops
  – Publication of technical documents and reports
  – The coordination of international research activities through Coordinated Research Projects (CRPs)
  – The management of specific databases

Consultancy Meetings (CSs): experts from MSs that support the IAEA staff to frame and scope the activities to be performed
Nuclear Energy Department

Organizational Chart

More than 200 staff members carry out the work of the Department of Nuclear Energy, which includes three Divisions and ten Sections.

DEPARTMENT OF NUCLEAR ENERGY
Mr. M. CHUDAKOV
Deputy Director General and Head of the Department

DIVISION OF NUCLEAR FUEL CYCLE AND WASTE TECHNOLOGY
Mr. C. XERRI
Director

NUCLEAR FUEL CYCLE AND MATERIALS SECTION
Mr. C. HILL
Section Head

WASTE TECHNOLOGY SECTION
Mr. I. GORDON
Section Head

RESEARCH REACTOR SECTION
Mr. A. BORIO DI TIGUILLE
Section Head

DIVISION OF PLANNING, INFORMATION AND KNOWLEDGE MANAGEMENT
Mr. W. HUANG
Director

NUCLEAR INFORMATION SECTION
Mr. D. SAVIC
Section Head

PLANNING AND ECONOMIC STUDIES SECTION
Mr. G. SHROPSHIRE
Section Head

NUCLEAR KNOWLEDGE MANAGEMENT SECTION
Mr. J. de GROSSOIS
Section Head

DIVISION OF NUCLEAR POWER
Mr. D. HAHN
Director

NUCLEAR INFRASTRUCTURE DEVELOPMENT SECTION
Mr. M. KOYACHEV
Section Head

INPRO SECTION
Mr. J. R. PHILLIPS
Section Head

NUCLEAR POWER TECHNOLOGY DEVELOPMENT SECTION
Mr. S. MONTI
Section Head

NUCLEAR POWER ENGINEERING SECTION
Mr. P. VINCZE
Section Head

Decommissioning and Environmental Remediation
Mr. Vladimir Mishala/Section Head
Spent Fuel Management Team Scope

Division of Nuclear Fuel Cycle & Waste Technology
Director: Mr. Christophe XERRI

Nuclear Fuel Cycle & Materials Section
Section Head: Mr. Clement HILL
- Uranium Production Cycle
- Nuclear Fuel Engineering
- Spent Fuel Management
- Advanced Fuel Cycle

Research Reactor Section
Section Head: Mr. Ram Sharma
- Utilization & Applications
- Modernisation & Innovation
- RR Fuel Cycle
- Operation & Management

Waste Technology Section
Section Head: Mr. Ian GORDON
- Waste Predisposal
- Waste Disposal
- Source Management

Decommissioning and Environmental Remediation Section
Section Head: Mr. Vladimir Mishal
- Decommissioning
- Environmental Remediation
Back-End Fuel Cycle Team

**P&B 2016-2017**

- **Paul Standring**
  - Finished contract in December 2017

- **Anastasia Lazykina**
  - Finished contract in December 2017

- **Arturo Bevilacqua**
  - Finished contract in September 2016

- **Amparo Gonzalez-Espartero**

**P&B 2018-2019**

- **Sophie Gouzy-Portaix**
  - Joint the team in December 2017

- **Laura McManniman**
  - Joint the team in January 2018

- **Amoray Gonzalez-Espartero**
  - Will join the team in Oct-Nov 2018
Scope of work SFM Team

- Storage (until ultimate disposition)
- Reprocessing and recycling current fleet
- Advanced Fuel Cycles for Gen-IV
Activities on SF storage

- CRP (T13014) on “Demonstrating Performance of Spent Fuel and Related Storage System Components During Very Long Term Storage (DEMO)” (2012 – 2016)
  - IAEA has been a member of the ESCP (EPRI) steering committee since 2011
  - 11 RA and 7 RC from 11 Member States
  - Three RCMs: Argentina, Japan, Spain
  - Specific research activities:
    - Stress Corrosion Cracking Mechanisms
    - Concrete Systems
    - Rod Behaviour
    - Bolted Closure Systems
    - Gamma and Neutron Shielding
    - System Demonstration (JPN and USA)
Activities on SF storage

- IAEA CRP (T13016) 2016-2020 on “Spent fuel Performance Assessment and Research (SPAR IV)”
  - Covering all power reactor fuels:
    - MAGNOX, RBMK, WWER, AGR, BWR, PWR, HWR, PHWR
  - Wet and Dry storage systems

- 7 RA and 4 RC from 10 MSs
- RCM-1, Vienna (10-14 October, 2016)
- RCM-2, Seoul (RoK) (9-13 April, 2018)
- The younger participants voiced their appreciation of the peer comments and mentoring offered by the more senior experienced members
At the request of the TWG-NFCO (11th Meeting), the experiences reported over the past 30+ years by the BEFAST and SPAR CRPs have been extracted, reviewed for continued relevance, and consolidated into a new publication.

The motivation behind this recommendation was to have all the relevant information in one referenceable source. This was particularly viewed as being valuable for those engaged on developing safety assessments.
Activities on SF storage

- IAEA CRP (T21028) on "Ageing Management Programmes for Spent Fuel Dry Storage Systems"
  - Overall Objective is to develop the technical basis and methodology to enable guidance to be provided to Member States on how to generate an ageing management programme for spent fuel dry storage systems
  - October 2016 until October 2019
  - RCM-1 held in Vienna, October 2017, 5 RA and 2 RC from 5 Member States
  - RCM-2 will be in ANL (Chicago, USA, April 2019)
Activities related to Fukushima accident

- IAEA CRP (T13015) initiated February 2016 on “Management of Severely Damaged Spent Fuel and Corium”
- Overall objective
  - To expand the existing knowledge base and identify optimal approaches for managing severely damaged spent fuel
- 2016 to 2019
- 7 RA and 2 RC from 6 MSs
- RCM-1, Vienna (13-16 February 2017)
- RCM-2, Japan, hosted by JAEA (October, 2018)

Value
Sharing experiences and knowledge TMI, Chernobyl and Fukushima, damaged fuel management strategies
Activities on SF storage

New activities planned

- **Update Documents: Spent Fuel Storage Guide**
  - Guidebook on Spent Fuel Storage (IAEA TRS 240, 1991)
    - Should recognize the evolution of SF storage and the fact that storage lifetimes are much longer than anticipated in 1991

- **Shut down NPPs for phasing out Nuclear Energy or for economical reasons**
  - Technical Meeting on premature shutdown of nuclear power plants, June 2018
    - Experience, impacts, lessons-learned, and guidance
Drafting a Guidance Doc on How to Develop BEFC cost elements

- In collaboration with PESS
- CM to Review the Status of Development and Deployment of Methodologies to Assess Costs in the Back-end of the FC, 4-8 September 2017, Vienna
- Draft the scope and outline of the document
- Target audience: Member States – newcomers or small programme states
- CM in October 2018 and TM on Q1 or Q2 2019
- Annex
  - Excel Spreadsheet
  - Simple NPV to enable customers to see what happens (impacts) when you change key parameters
Advanced Fuel Cycles

- Economically viable:
  - Recycling of valuable materials
- Safe
- Environment-friendly:
  - Waste burden minimization
- Proliferation resistant
- Flexible to adapt to any policy evolution

**Fast Reactor Fuel Cycle**

- Sustainable nuclear power
- Effective utilisation of uranium resources
- Burning of minor actinides: reduction of waste volume and toxicity

**LWR Open Fuel Cycle**

- Enrichment
- Fuel Fabrication
- Power Plant
- Electricity
- Spent Fuel Storage
- Waste Immobilization
Drafting a NES on FC Options for Waste Burden Minimisation

**Title:** “Existing and Advanced Nuclear Fuel Cycle Technical Options for Waste Burden Minimisation”

To draft a concise and brief report aimed at reviewing and updating the technological developments in current and advanced fuel cycles to provide policy and decision makers with information about how different FC strategies can minimise the burden of generated waste.

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![Diagram](image-url)

- **Uranium Ore (mine)**
- **FP**
- **P&T of MA**
- **Spent Fuel Direct disposal**
- **LLFP P&T (Option 6)**
- **Cs+Sr Separation (Option 5)**
- **MA Multi-Recycling (Option 4)**
- **U-Pu Multi-Recycling (Option 3)**
- **Conventional Mono-Recycling (Option 2)**
- **Direct Disposal (Option 1)**

**Graph:** Relative radiotoxicity over time (years).
<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
<th>Degree of processing / separations</th>
<th>Fuel cycle impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Open fuel cycle</td>
<td>Waste conditioning only – no separations</td>
<td>All SNF to GDF; no resource conservation (U, GDF space)</td>
</tr>
<tr>
<td>2</td>
<td>(Pu) Mono-recycling</td>
<td>Single recycle of thermal (U,Pu) MOX fuels</td>
<td>Small savings in U utilization and GDF space; spent MOX fuel generated</td>
</tr>
<tr>
<td>3</td>
<td>(Pu) Multi-recycling</td>
<td>Multi-recycling of U and Pu in FRs and LWRs fuels</td>
<td>Optimize resource utilization (use of DU); stabilization of Pu inventory; requires transition to FRs</td>
</tr>
<tr>
<td>4</td>
<td>Minor actinide recycling</td>
<td>Recycling of minor actinides</td>
<td>Reduction long term heat loading, reduced GDF space; requires accelerator driven systems (ADS) or FRs</td>
</tr>
<tr>
<td>5</td>
<td>Fission product (FP) separation</td>
<td>Separation of heat generating FPs, LLFP (I, Tc, Ru) for recycle or decay storage</td>
<td>Optimized GDF space; decay storage facilities needed</td>
</tr>
<tr>
<td>6</td>
<td>Partitioning and Transmutation</td>
<td>Separation of residual radionuclides for burning in (ADS)</td>
<td>Theoretical maximum benefits in WBM; requires advanced technologies including ADS</td>
</tr>
</tbody>
</table>
Advanced Fuel Cycles

New CRP on Advanced Fuel Cycles

• To identify fuel cycle options for aqueous and pyro processes and factors that influence technology choice to be deployed (cooling time, burn-up, etc)

• Impact of new developments in fuel fabrication (accident tolerant fuels, new cladding materials, etc) in the BEFC

• Comparison of different cycle options against different criteria (wastes produced, non-proliferation aspects, TRL, scale up)

• Different approaches for recycling valuable FP's
Integrated approach to the BEFC
New activities planned

- There is a need to look at the back end of the fuel cycle in a fully integrated manner including items such as retrievability, transportation, storage, recycling and disposal
  - Previous activity IAEA-TECDOC-1774, published in 2015 (material gathered before 2011)
  - TM in July 2018

Logistics: New activities planned

- Technical and operational issues related to the transportation of HBU and irradiated MOX fuels
- Related to Nuclear Materials (samples, fuels, …)
  - Transboundary transportation
  - Denials of shipments
Main Activity in 2017
Organisation of the 3rd International Conference on Fast Reactors and Related Fuel Cycles (FR17) Yekaterinburg, RF, 26-29 June 2017

Scientific Secretaries:
• Vladimir Kriventsev (NPTDS, IAEA)
• Amparo Gonzalez-Espartero (NFCMS, IAEA)

Statistics of the Conference:
• 449 Scientific papers presented:  
  - 243 Orals and 206 Posters  
• 558 Participants from 27 MSs  
• 18 participants from 6 International Organisations including the IAEA  
• 94 grants requested from 28 countries. 36 Grants awarded  
• Technical tour BN-800 and BN-600  
• YGE panel with 6 orals presentations
Plenary Session

Track 1. Innovative fast reactor designs
Track 2. Fast reactor operation and decommissioning
Track 3. Fast reactor safety
Track 4. Fuel cycle: sustainability, environmental considerations and waste management issues
Track 5. Fast reactor materials (fuels and structures) and technology
Track 6. Test Reactors, Experiments, modelling and simulations
Track 7. Fast reactors and Fuel Cycles: economics, deployment and proliferation issues
Track 8. Professional development and knowledge management

50+ Technical Sessions
Comprehensive Curriculum Map on SF and RW Management, Decommissioning and Environmental Remediation
E-Learning material on Spent Fuel Management

Nuclear Fuel Components

- Ceramic pellets of UO₂, enriched in ²³⁵U about 10 mm in diameter and 10–15 mm height.
- The pellets are stacked in fuel rods made from Zircaloy that are about 4 m long.
- The fuel rods are assembled together in a fuel assembly that can be handled as an entity.
- A 1000 MW(e) PWR core typically contains between 200 and 250 fuel assemblies.

Approximately 40 SNF assemblies containing about 20 tonnes of uranium are discharged as SNF every year.

- Simopt multimedia company
- EB funds
- Translation to Japanese, Russian, French, Spanish
Complementary with other fields

- Support to newcomer countries to develop their Nuclear Programmes (NENP/NIDS)
Spent Fuel Management Network

Welcome to the IAEA International Network on Spent Fuel Management - SFM

The spent fuel management (SFM) network is a forum for the sharing of practical experience and international developments on spent fuel management.

Its main objectives are to facilitate the efficient exchange of information, communication and cooperation amongst professionals working in the back end of the fuel cycle – from its removal from a reactor core to its final disposition (i.e. SNF wet and dry storage, transportation, handling and retrieval, reprocessing and recycling, economics of the back-end of nuclear fuel cycle, damaged SNF management, stakeholders involvement, communication issues, etc.)

The establishment of the SFM Net is aimed at fostering safe, sustainable and efficient spent nuclear fuel management practices across all IAEA Member States.

For further information or questions please contact SFM.Contact.Point@iaea.org.

Featured Publications

- TECDOC-1717 (2015)
- TECDOC-1774 (2015)
- STI/PUB/P1691 (2015)
- STI/PUB/1506 (2013)
- TECDOC-1725 (2013)
- STI/PUB/1523 (2012)

Beginnings of a Fuel Cycle

- TECDOC-1717 (2015)
- STI/PUB/1710 (2015)
- STI/PUB/1691 (2015)

Current Highlights

- IAEA-TECDOC-1725 (2013)
- TECDOC-1774 (2015)
- STI/PUB/1506 (2013)

- TECDOC-1717 (2015)
- STI/PUB/1710 (2015)

- IAEA-TECDOC-1725 (2013)
- TECDOC-1774 (2015)
- STI/PUB/1506 (2013)

Events 2018

- Second Research Coordination Meeting on Spent Fuel Performance Assessment and Research (09-13 April, Seoul, Rep. of Korea)
- Technical Meeting on the Management of Spent Fuel at Shutdown Reactor Sites, including those to be Shut Down Prematurely (11-12 June, Vienna, Austria)
- Technical Meeting on Integrated Approaches to the Back-End of the Fuel Cycle (17-19 July, Vienna, Austria)
- Second Research Coordination Meeting on Management of Severely Damaged Spent Fuel and Contam (05-09 November, Japan)

Active CRPs

- Ageing Management Programmes for Dry New Storage Systems (AMP, T21005)
- Severely Damaged Fuel and Contam (CORRM, T13915)
- Spent Fuel Performance Assessment and Research (SPAR-IV, T13016)

To join our ongoing CRPs click here.

IAEA Spent Fuel Management Network
https://nucleus.iaea.org/sites/connect/SFMpublic/Pages/default.aspx
For SFM-Net members:

Review of documents, post advanced draft reports, information repository ...
Training Activities

• 4th (2016) and 5th (2017) Joint IAEA-Rosatom Meeting for Young Scientists, Moscow and Saint Petersburg (Russia)

• ICTP/IAEA Workshop on Radiation Effects in Nuclear Waste Forms and their Consequences for Storage and Disposal, 13-14 May 2016, Trieste (Italy)

• Joint ICTP/IAEA Nuclear Energy Management School (2016 and 2017) Trieste (Italy)
Thank you for your kind attention!
Technical Meeting on the Management of Spent Fuel from Shutdown Reactors, Including Those to be Shutdown Prematurely

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Laura McManniman
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NFCMS/NEFW
Permanently Shutdown Reactors

- There are 166 permanently shutdown reactors in 20 member states
  - 3 of those MS no longer have any power reactors
  - Around 50% are located in the Member States represented at this meeting
Permanently Shutdown Reactors

Source: IAEA PRIS Database 08/06/2018
Background

• Varied reasons for shutdown
  – Planned shutdown (end of accountancy life or corporate decision)
    • Magnox fleet (UK)
  – Premature shutdown (political, economic…)
    • Germany (Belgium, Switzerland…)
  – Unplanned shutdown (Regulatory, economic, political…)
    • Japan, USA, Italy, Lithuania
Background

- **TWG-NFCO**
  - Technical Working Group on Nuclear Fuel Cycle Options and Spent Fuel Management
  - Owned by DDG-NE
  - Provides advice to DDG-NE on work programmes in the section
  - Agenda item at 13th Meeting on premature or early reactor shutdown

- Recommended NFCMS considered developing a better understanding of the consequences of unplanned or premature shutdown of reactors to inform the industry

- In addition to the management of spent fuel at premature shutdown NPP sites, it was also recognized that there are issues associated with spent fuel management at sites where the power reactor has been decommissioned; particularly the ability to rework storage packages if a fault were to develop.
Background

• Consultancy meeting held 27\textsuperscript{th} February – 1\textsuperscript{st} March 2017

• Identified a range of issues:
  – Transition from power reactor operator to storage operator
  – Management of partially burnt or fresh fuel
  – Management of damaged fuel
  – Institutional issues (taxation, loss of income)
  – Level of investment in the event of a shutdown situation
  – Management of pool stocks as reactor goes towards shutdown
  – Larger stores required as cask payloads reduce
Meeting Objectives

• Objectives of this meeting
  – Share technical information on spent fuel storage systems at shutdown reactor sites and practices, particularly lessons learned from Member States;
  – Explore the issues raised at the consultancy meeting
  – Share progress on R&D on storage of spent fuel at shutdown reactor sites and identify any potential gaps;
  – Collect information to update global inventories of spent fuel at shutdown reactor sites

• The main outcomes of this meeting are to improve the understanding & capabilities of Member States to address the challenges of safe and effective management of their spent fuel stored at shutdown reactor sites, and to enhance their preparedness for premature or unplanned reactor shutdown.
Thank you for your kind attention!