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IAEA ACTIVITIES TO ASSESS THE PERFORMANCE OF SPENT FUEL AND STORAGE SYSTEMS TO SUPPORT FUTURE TRANSPORTABILITY

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ABSTRACT

This paper will present the activities underway at the IAEA to improve the understanding of the behaviour of spent fuel and associated storage systems over time. Both topics have been addressed and studied in dedicated already completed Coordinated Research Projects (CRP), the results of which provide a good foundation for the two new coordinated projects [1-3].

Research activities on spent fuel, cladding and structural materials behaviour, under wet and dry storage conditions, are currently carried out in the framework of the CRP on "Spent Fuel Research and Assessment" (SFERA, T13020); whereas the CRP (PASSED, T13019) on "Performance Assessment of Storage Systems for Extended Durations" focuses on wet and dry storage systems, with a special attention given to monitoring and inspection activities of dedicated devices.

Both IAEA Coordinated Research Projects aim at supporting the long-term storage and subsequent transportability of spent fuel. Complementary information on on-going IAEA activities on spent fuel management are also included (SMRs, e-ATFs, Spent Fuel Transport and e-Learning Course on Spent Fuel Management).

INTRODUCTION

The duration of spent fuel storage prior to disposition has been steadily increasing over the decades; in the 1980s periods of up to 50 years were foreseen, and today some countries are envisaging periods of up to 300 years. R&D programmes are underway worldwide to ensure continued spent fuel integrity during storage, to develop the scientific basis for an elongation of currently licensed storage durations and provide assurance that spent fuel can be safely and securely stored, transported and conditioned for subsequent fuel cycle steps. The IAEA supports its Member States by facilitating collaboration and information exchange to provide maximum value from these efforts through the Coordinated Research Projects (CRP).

Dissemination of high quality research information and critical peer reviewing, by leading experts in the field, of the results obtained aim at enhancing Member States' capabilities for their decision making in the back end of the fuel cycle.

This paper will present the activities underway at the International Atomic Energy Agency (IAEA) to improve the understanding of the behaviour of spent fuel and associated storage systems over time. R&D activities on spent fuel, cladding and structural materials behaviour, under wet and dry storage conditions, are currently reported through the framework of the CRP "Spent Fuel Research and Assessment" (SFERA, T13020); whereas the CRP on "Performance Assessment of Storage Systems for Extended Durations"

(PASSED, T13019) focuses on structures, systems and components of wet and dry storage systems, with a special attention given to monitoring and inspection activities of dedicated devices. Both IAEA CRPs aim to support the long-term storage and subsequent transportability of spent fuel.

In addition, the IAEA has developed an online course on spent fuel storage and is undertaking activities on spent fuel transportation, management of spent advanced technology fuels (ATFs) and anticipating challenges for managing spent fuel from small modular reactors, especially those based on non-LWRs.

SUMMARY OF CLOSED IAEA COORDINATED RESEARCH PROJECTS ON SPENT FUEL STORAGE

The following summary provides an overview of IAEA efforts in coordinating international R&D activities to enhance international collaboration and sharing of information in the area of spent fuel management, and the results gained.

Demonstrating Performance of Spent Fuel and Related Storage System Components During Very Long Term Storage (2012–2016) [1]

The CRP on "Demonstrating Performance of Spent Fuel and Related Storage System Components During Very Long Term Storage" (DEMO) was designed to be complementary to the Extended Storage Collaboration Programme (ESCP) of the Electric Power Research Institute (EPRI). This CRP addressed different technical areas, according to the "gap analyses" performed by participating MSs. Results reported during the CRP included:

- Studies of chloride induced stress corrosion cracking (CISCC) initiation conditions leading to new data used to resolve some of the inconsistencies in previously reported data.
- Studies into the potential mechanisms for cladding degradation identified oxidation due to residual water in the cask cavity as a potential route to fuel degradation during long term storage. Additional experimental data and analytical work was recommended on this matter.
- Investigations into the thermo-mechanical metal seal behaviour in the long term. demonstrated good performance in relation to leak tightness, even though pressure forces and useable resilience were found to decrease significantly.
- Studies into measuring the ageing of neutron shielding materials utilised various methods, with one such successful method using the measurement of changes in the cross-linking of polymeric materials. Other techniques included an optical technique to observe oxidation of polymeric materials, and the measurement of changes in polymeric material density.

Spent Fuel Performance Assessment and Research, from CRP BEFAST to CRP SPAR IV (1981–2020) [2, 3]

Knowledge of the behaviour and integrity of spent fuel and cladding materials is paramount to ensure that safety functions can be maintained during long term storage and subsequent fuel handling operations. Since 1981, the IAEA has been organizing CRPs on the behaviour of power reactor spent fuel during long term storage, covering the spent fuel generated by all types of power reactors: AGR, CANDU, LWR, MAGNOX, RBMK, and WWER. This was initially undertaken through the three phases of the BEFAST (BEhaviour of spent Fuel Assemblies in Storage) series of CRPs, and later through the four phases of SPAR (Spent fuel Performance Assessment and Research).

These CRPs represent the collation of storage performance data and operational experience of participating Member States over 40 years.

Ageing Management Programmes for Dry Storage Systems the CRP AMP (2016-2021)

Another challenge faced in Member States is the transportation of dual purpose casks (DPC) or storage canisters after storage periods longer than initially planned. Some of these systems will be operating past their original design lifetime, therefore the safe recovery (for canisters) and onward transportation will be reliant on being able to demonstrate that transport requirements can be met.

The CRP enabled relevant experience of ageing management of existing systems to be collected and shared. The approaches, constraints, and timeframes to develop and implement ageing management programmes (AMPs) for spent fuel dry storage systems were gathered during the CRP from the participants. Monitoring and inspection techniques currently used or developed in participating countries were collected and discussed. In order to enable the implementation of efficient AMPs, the systems, structures and components (SSCs) of typical dry spent fuel storage systems were described and listed. R&D activities and results in participating countries to support the continued use of spent fuel dry storage systems and related to ageing management were presented and discussed during the meetings.

SUMMARY OF ON-GOING IAEA COORDINATED RESEARCH PROJECTS ON SPENT FUEL STORAGE

Spent Fuel Assessment and Research, the CRP SFERA (2021-2026, open for proposals)

Continuing the work of the BEFAST and SPAR CRPs, SFERA aims to sustain and improve Member States' technical knowledge base on the long-term behaviour of power reactor spent fuel through sharing and disseminating information, reporting topical research carried out in participating Member States, and documenting ongoing spent fuel performance.

Performance Assessment of Storage Systems for Extended Durations the CRP PASSED (2022-2027, open for proposals)

Complementing SFERA, the PASSED CRP aims to expand the scope of the AMP-DSS CRP from dry storage systems to wet storage systems to all topics relevant to systems performance. This includes methods of inspection, the usage of novel sensors, and methods for mitigation and repair. The CRP aims to sustain and improve IAEA Member States' technical knowledge base on the long term behaviour of spent fuel storage systems, in addition to inspection and monitoring technologies.

COMPLEMENTARY ON-GOING IAEA ACTIVITIES ON SPENT FUEL MANAGEMENT

Small Modular Reactor Spent fuel cycle backend preparations

In support of SMR development efforts, IAEA is conducting activities to bring attention to the challenges in the back end of the fuel cycle and enabling information exchange between fuel cycle experts. Currently, there are four main groups of fuel types anticipated for use in SMRs: a downsized version of light water reactor type fuels; fuels based on Uranium oxide utilizing higher enrichment; fuels based on pebble beds, and fuels fabricated from new materials. While the first group can be draw from experiences of managing commercial LWR fuels, the complexity of SMR spent fuel management will increase through these groups as higher enrichments and new materials are introduced that have only limited handling, storage, and processing available experience to date.

Backend Challenges for evolutionary Advanced Technology Fuels (e-ATFs)

Following the Fukushima accident, development work commenced to improve fuel safety under a variety of operational scenarios. The new fuels developed, termed advanced technology fuels (ATFs), are based on improved cladding and new fuel materials. Those utilising enhanced claddings and higher enriched UOX for service in the current LWR fleets are termed 'evolutionary ATFs' (eATFs) and are currently under reactor testing. Their widespread deployment is anticipated in the coming years. The IAEA is organizing activities addressing the back end of the fuel cycle for these fuels so that opportunities and challenges can be shared amongst experts.

Experiences on Spent Fuel Transport

The transport of spent fuel is often a topic of high visibility, and in order to support Member States in preparing for future transport operations, the IAEA conducted a series of meetings to gather international experiences regarding transport of radioactive material over the last decades. Countries with established transport regimes have contributed case studies summarizing their experience. General recommendations on the specificities of transporting higher-burnup or mixed-oxide fuels and the subsequent impact have also been contributed. The case studies provide operational experience on the organization of transport campaigns and highlight the importance of timely planning and preparation.

IAEA's e-Learning Tools on Spent Fuel Management [4]

The development and maintenance of scientific, technical, and engineering skills is paramount to ensuring ongoing safety in the nuclear fuel cycle. With an ageing workforce, the industry is seeing an influx of young professionals and the support of their development going forward is essential in promoting safe and sustainable nuclear power.

The IAEA actively supports its Member States on technical knowledge preservation and its transfer to enhance the capabilities of professionals, especially in the young generation. In the field of SFM, e-Learning has proved to be a suitable tool for addressing multiple target audiences, from the general public that would like to receive reliable information, to professionals at different levels of knowledge and experience. The material is currently available in English, Russian, and Japanese, with French and Spanish versions currently in production.

REFERENCES

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[4] Course: Course on Spent Fuel Storage (iaea.org)