Collaboration on Aging Management for Extended Storage of Used Fuel

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Abstract

A Memorandum of Understanding (MOU) between the Federal Institute for Materials Research and Testing (BAM) and Argonne National Laboratory (Argonne) was signed in the fall of 2014. Its objectives are to promote cooperation among scientists and specialists at BAM and Argonne and establish a framework for collaboration in the field of advanced technologies associated with the back end of the nuclear fuel cycle. Collaborative activities involving the BAM and Argonne may be implemented through the promotion of joint research activities and scientific workshops and conferences; the exchange of technical information; and visits by scientists, specialists, and graduate, postgraduate, and Ph.D. students. The first Argonne/BAM workshop was held at Argonne in October 2014 to discuss aging management issues related to the long-term dry storage of spent fuel. Major topics for potential collaboration on the extended storage of spent nuclear fuel and its subsequent transportation were identified.

I. INTRODUCTION

More than two decades ago, both Germany and the United States began implementing the interim dry storage of spent (or used) nuclear fuel. However, because there have been delays and uncertainty associated with the availability of a final disposal facility in both countries, the period of interim storage is likely to be extended considerably (i.e., beyond 60 years). Most other countries with operating nuclear power plants face similar situations regarding spent fuel storage. The need to understand and manage the aging of systems, structures, and components (SSCs) in dry storage systems has become a priority. Several organizations — such as the International Atomic Energy Agency (IAEA), U.S. Nuclear Regulatory Commission (NRC), U.S. Department of Energy (DOE), and similar institutions in other countries and in the nuclear industry worldwide — have begun to develop guidance on aging management in order to support the extended storage of spent fuel and its subsequent transportation, which may occur multiple times before its final disposal at geological repositories. In 2009, the Electric Power Research Institute (EPRI) established the Extended Storage Collaboration Program (ESCP) in the United States. The EPRI ESCP international subcommittee, formed in 2010, held 10 biannual meetings between 2010 and May 2014. As of May 2014, there were about 400 ESCP members from more than 20 countries; six subcommittees covered the topics of international collaboration, concrete, chloride-induced stress corrosion cracking, fuels, high-burnup (HBU) demonstration, and nondestructive examinations. The primary goal of ESCP is to share information among its members in order to identify common research and development (R&D) needs and potential areas for "formal" collaboration outside ESCP.

In the fall of 2014, the German Federal Institute for Materials Research and Testing (BAM) and Argonne National Laboratory (Argonne) signed a Memorandum of Understanding (MOU) for cooperation in advanced technologies associated with the back end of the fuel cycle. The objectives of the MOU are to promote cooperation among scientists and specialists at BAM and Argonne and to establish a framework for collaboration in the field of advanced technologies associated with the back end of the nuclear fuel cycle, with applications to (1) the long-term integrity and safety of transport and storage packages for radioactive materials and their anticipated performance with regard to long-term storage and transportation; (2) aging mechanisms that might result in the degradation of materials that are affected by temperature, radiation, and the service environments; and (3) the investigation and characterization of materials in extended storage and their subsequent transportation. Collaborative activities among BAM and Argonne may be implemented through the (1) promotion of joint scientific conferences, workshops, and similar meetings; (2) promotion of joint research activities; (3) exchange of scientific and technical information; and (4) visits by scientists, specialists, and graduate, postgraduate, and Ph.D. students. The first Argonne/BAM workshop was held at Argonne in October 2014 to discuss aging management issues related to the long-term dry storage of spent fuel. Major topics for potential collaboration on

extended storage and subsequent transportation were identified and are described briefly here.

I.A. Guidance Documents on Aging Management

Both BAM [1] and Argonne [2] have been developing guidance documents on aging management associated with the dry storage of spent fuel in the past few years. The stated goals and fundamental approaches of aging management for long-term storage of spent nuclear fuel are essentially the same in these documents. For example, Reference [1], issued by the German Nuclear Waste Management Commission (ESK), states this: "*The central safety element of dry storage of spent fuel and heat-generating radioactive waste are accident-resistant transport and storage casks licensed under traffic law at the time of emplacement and whose transportability must also be ensured for later removal. With the granting of the license, safe enclosure of the radioactive inventory, adequate shielding of ionizing radiation, maintenance of subcriticality, and the safe removal of decay heat are assessed and verified as fundamental protection goals*.

Compliance with the requirements for the safe operation of the storage facility, made mandatory with the storage licence, is to be ensured by the safety management of the operator. For subsequent storage, significant operational boundary conditions arise from cask manufacturing, loading and handling. Both the operators and the authorities with their authorized experts have adequate instruments for the exchange of experience across the facilities.... As part of regulatory supervision, the condition of the storage facility and its operation is continuously monitored for compliance with the provisions of the licensing decisions. In this context, the necessity of implementation of new safety-related knowledge resulting from operating experience is also examined by the operator and the authorities.

The periodic safety review of the storage facility includes deterministic considerations on the current safety status of the storage facility. Probabilistic considerations are usually not required since there are mainly passive safety functions in place. Active measures exclusively serve to monitor the condition (e.g., the lid sealing system) and the boundary conditions (e.g., ventilation, environmental influences).... Ageing management comprises continuous measures during operation with the aim to manage ageing effects and to ensure the required quality of systems and components.... Measures for non-accessible areas of containers and inventories are not covered by these guidelines. Reporting on experiences/implementations of ageing management has to take place within the framework of the periodic safety review."

Reference [1] complements the basic German guidance document [3] that addresses the technical concept and safety requirements for all dry cask storage systems for spent nuclear fuel and high-level waste (HLW). These requirements and recommendations are considered by the German licensing authority, the Federal Office for Radiation Protection (BfS), and are implemented by site-specific licenses.

On the other hand, Reference [2], prepared by Argonne for the DOE Used Fuel Disposition Campaign R&D program, states this: "*The goal of the aging management report is to help establish the technical basis for extended long-term storage and subsequent transportation of used fuel, which may occur multiple times before final disposal at a mined repository or geological disposal facility. It is suggested that future efforts should include development of additional time-limited aging analyses (TLAAs) and Aging Management Programs (AMPs) that may be deemed necessary, and further evaluation of the adequacy of the recommended TLAAs and AMPs that may need augmentation. Industry and site-specific operating experience of the various dry cask storage systems (DCSSs) at Independent Spent Fuel Storage Installations (ISFSIs) located across the country should be periodically examined to (a) ascertain the potential aging effects on the SSCs in the DCSSs, thereby enabling a compilation of existing aging management activities, and (b) assess these activities' adequacy for extended long-term storage and subsequent transportation of used fuel.*"

U.S. industry incorporated the Reference [2] aging management report, by reference, into NEI 14-03: "Industry Guidance for Operations-Based Aging Management for Dry Cask Storage" [4] to augment Title 10 of the *Code of Federal Regulations* (CFR) Part 72 license and the Certificate of Compliance (CoC) renewal review guidance in NUREG-1927 [5], "Standard Review Plan for Renewal of Used Fuel Dry Cask Storage System License and Certificate of Compliance," Section 3.0, "Aging Management Review." Revision 0 of NEI 14-03 was submitted for the NRC's endorsement in September 2014. The NRC plans to update NUREG-1927 and will acknowledge the aging management report as it develops its own NUREG report on aging management for public release and comment in 2015 [6].

Note that NEI 14-03 introduces "tollgates" into the Part 72 license and CoC renewal process. "Tollgate" is a new term created by the nuclear industry to address the fact that the applicability of potential dry cask storage aging mechanisms may not be able to be verified at the time license and CoC renewal applications are submitted. This information would enhance the current understanding of the future state of dry spent fuel and the

canisters that contain it. Tollgates are part of a learning, operations-based aging management program implemented by licensees via requirements in the renewed license or CoC and associated final safety analysis report. These requirements obligate the licensees to perform periodic assessments of the aggregate state of knowledge of aging-related operational experience, research, monitoring, and inspections to ascertain the ability of in-scope DCSS design SSCs to continue performing their intended safety functions throughout the requested period of extended operation. While the words being used may be different, the periodic safety review of the storage facility mentioned in Reference [1] shares the same basic philosophy as that of the periodic examination of industry and site-specific operating experience mentioned in the aging management report [2] and the tollgates in NEI 14-03 [4].

References [1, 2, 4, and 5] are guidance documents that deal with aging management for the long-term dry storage of spent nuclear fuel. There are other guidance documents in Germany [3], the United States [7, 8], and the IAEA [9] that address the safety requirements and the design and review of the dry storage systems and facilities for spent nuclear fuel. These guidance documents are generally reviewed and updated over time to incorporate changes in regulations, national standards and codes, and technology and advances in knowledge, so they should be followed closely by those participating in the BAM/Argonne collaborative activities.

I.B. Storage R&D-Sharing Database

The focus on aging and storage R&D in Germany and the United States is influenced by the storage system design: a dual-purpose cask (DPC) for storage and transport operation in Germany [3], and more than a dozen U.S. DCSS designs that are of two general types: (1) self-contained shielded metallic casks with bolted closure without an overpack and (2) metallic canisters with a separate overpack to provide radiation shielding and physical protection [2]. There are differences in the materials used to construct the casks (e.g., ductile cast iron for DPCs and stainless steel and carbon steel, or concrete, for canisters, bolted cask, and overpacks in the DCSSs). However, there are also similarities in the functional materials used in the DPC and DCSSs (e.g., elastomeric O-ring seals and polymeric neutron shielding materials). DPCs and DCSSs contain spent fuel assemblies and internal baskets and thus share the same concerns about maintaining the spent fuel configuration, cladding integrity, and fuel retrievability after long-term storage. Whereas all of the DPCs in Germany are stored indoors (at the 12 on-site and 2 former central spent fuel storage facilities as well as at Julich Research Center and Interim Storage North for the Russian pressurized water reactor [Voda Voda Ernergo Reactor (VVER)] fuel, the DCSSs in the United States are placed outdoors on concrete pads at 71 ISFSIs in 34 states.

Several areas have been identified for potential joint R&D on storage that might involve the exchange of personnel and use of facilities at BAM and Argonne. The areas include studies of the mechanical properties of HBU fuel and claddings, studies of the long-term performance of elastomeric O-ring seals and polymeric neutron shielding materials, numerical simulations of the structural and thermal performance of dry cask systems in storage and during post-storage transportation, and studies of advanced surveillance technologies for monitoring and inspecting dry storage systems during extended storage and subsequent transportation. Already a wealth of data on those topics was published and shared by BAM and Argonne staff members at the 2013 17th International Symposium on Packaging and Transportation of Radioactive Materials (PATRAM) [10].

I.C. Joint Conference Activities

Both BAM and Argonne staff members regularly attend annual international conferences, such as the Waste Management Symposia, International High Level Radioactive Waste Management Conference, American Society of Mechanical Engineers (ASME) Pressure Vessel and Piping (PVP) Conference, Institute of Nuclear Material Management (INMM) Meeting, and International Symposium on PATRAM, which is held once every 3 years. In addition, senior staff members of BAM and Argonne attend the EPRI ESCP meetings twice a year. Side meetings can be held on these occasions to discuss progress and plan future collaborative activities. For the July 2015 ASME PVP Conference in Boston, Argonne will organize the technical sessions in the Operations, Applications, and Components (OAC) Subcommittee 4 for the transportation, storage, and disposal of radioactive materials. Current OAC-4 plans are to include the following technical sessions:

- Structural Analysis of Transportation Packaging and Storage Casks (1–2 sessions)
- Thermal Analysis of Transportation Packaging and Storage Casks (1–2 sessions)
- Effects of Hydrides on HBU Cladding Mechanical Properties (1 session)
- Aging Effects and Management of Dry Cask Storage Systems for Long-Term Storage (1–2 sessions)

Both BAM and Argonne staff members plan to submit papers to the 2015 ASME PVP Conference. Contributions of papers are also expected from authors at other institutions and from countries other than Germany and the United States.

II. SUMMARY AND CONCLUSIONS

After the establishment of an MOU between BAM and Argonne in the fall of 2014, the first Argonne/BAM workshop was held at Argonne in October 2014 to discuss aging management issues related to long-term dry spent fuel storage. Major topics identified for potential collaboration on extended storage and subsequent transportation of spent nuclear fuel are: (1) Guidance documents on aging management, (2) Storage R&D – sharing database, and (3) Joint conference activities. Specific collaborative activities were also identified in each of these three topical areas for follow-on actions. Collaboration of scientists and specialists between BAM and Argonne are expected to yield benefits not only to their respective institutions and government sponsors, but also to other countries and the international community that share the concerns of aging management for extended long-term storage of spent nuclear fuel and subsequent transportation.

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