UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
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November 27, 2018

Mr. Edward McGinnis
Principal Deputy Assistant Secretary for Nuclear Energy
U.S. Department of Energy
1000 Independence Ave., SW
Washington, DC 20585

Dear Mr. McGinnis:

The U.S. Nuclear Waste Technical Review Board (Board) held its 2018 Fall Meeting on October 24, 2018, in Albuquerque, New Mexico, to review information on recent U.S. Department of Energy (DOE) research and development (R&D) activities related to managing and disposing of commercial spent nuclear fuel (SNF). The public meeting included presentations by representatives of DOE and four national laboratories. The meeting agenda, presentation materials, archived recording of the webcast, and materials submitted by members of the public as part of the meeting record are available on the Board's website at https://www.nwtrb.gov/meetings/past-meetings/fall-2018-board-meeting---october-24-2018. The meeting transcript will be posted on the same web page in the near future.

The Board extends its appreciation to your staff and the technical experts from the national laboratories for their work preparing for the meeting and providing informative presentations. The Board also thanks them for supporting a technical fact-finding meeting that was held on August 22, 2018, in Las Vegas, Nevada. This fact-finding meeting involved more detailed presentations of technical issues related to managing and disposing of commercial SNF and enabled the Board to better prepare for the October 24 public meeting. We also thank the Sandia National Laboratories (SNL) staff for providing an informative tour of SNL experimental facilities in Albuquerque, New Mexico, on October 25, 2018.

Background

During the past few years, DOE has conducted several R&D activities related to the management and disposal of commercial SNF. First, DOE has been doing research, including the High-Burnup Spent Nuclear Fuel Data Project (HDRP), to determine the performance and potential degradation of high-burnup SNF during extended storage and subsequent transportation. In 2016, the Board held two fact-finding meetings and a public meeting to hear from DOE and its contractors from the national laboratories on the initial results of the HDRP and to discuss with them the issues pertaining to resolving several technical information needs related to understanding the performance of high-burnup SNF during extended storage and transportation. After the public meeting, the Board sent to DOE a letter with recommendations.[1] Since that

[1] May 23, 2016, Board letter to Acting Assistant Secretary John Kotek following up the Board Meeting held February 17, 2016. In the letter, the Board recommended "that DOE make transparent how it integrates the results from Nuclear Energy University Programs, and other relevant U.S. and foreign research activities into its overall research program on high-burnup fuel degradation." At the October 24, 2018, public meeting, DOE discussed how it addressed this recommendation.

time, DOE and its contractors have made significant progress on obtaining the required data, including those related to cask drying, thermal measurements and modeling, hydride reorientation, and SNF rod non-destructive and destructive evaluations.

Second, DOE recently completed a test that transported an Equipos Nucleares Sociedad Anónima (ENSA) SNF cask containing simulated SNF assemblies from Spain to the United States, via truck, barge, cargo ship, and train, supplemented by additional testing at the Transportation Technology Center in Pueblo, Colorado. The purpose of the tests was to determine the actual stresses SNF may experience during normal conditions of transport.

Third, DOE has been evaluating the technical feasibility of direct disposal of SNF in dual-purpose canisters (DPCs) in a geologic repository. In the United States, the majority of SNF already in dry storage, as well as nearly all SNF currently being placed into dry storage, are in DPCs. DPCs containing SNF can be stored in licensed storage overpacks or vaults, and also can be transported to an interim storage facility or a geologic repository in licensed transportation overpacks. Direct disposal of SNF in DPCs, sealed in disposal overpacks, is a possible alternative to repackaging the SNF into other containers prior to disposal in a repository.

Board Meeting Presentations

At the Board's 2018 Fall Meeting in Albuquerque, staff from DOE and the national laboratories provided to the Board an update on the results of and conclusions from the work that has been completed and on the progress of on-going research. The first presentation was by William Boyle [DOE Office of Nuclear Energy (DOE-NE)], who provided an update on DOE's spent fuel and waste disposition program. In a following presentation, Brady Hanson [Pacific Northwest National Laboratory (PNNL)] described the recent results of and future plans for the HDRP. These included the measurements and computer modeling of the temperatures inside the TN-Americas (Orano) TN-32 SNF cask that was loaded with actual high-burnup SNF. He also discussed sampling of gas inside the cask. Samuel Durbin (SNL) followed with a presentation on the thermal-hydraulic measurements conducted using a scaled test assembly at SNL that simulates a dry-storage cask for boiling water reactor fuel. The simulator uses electrical heaters shaped like fuel rods as a heat source instead of actual spent fuel. The measurements were done to verify the accuracy of computational modeling that, for example, can be used to calculate the temperatures of materials in dry-storage casks.

Next, Rose Montgomery [Oak Ridge National Laboratory (ORNL)] presented the initial results of post-irradiation characterization of "sister rods," which are fuel rods that have been removed from assemblies that went into the HDRP dry-storage cask or from assemblies with similar irradiation histories. The characterization included visual examinations, gamma radiation scans, eddy current scans, and measurements of rod diameter, free volume, internal pressure, and gas transmission. Michael Billone [Argonne National Laboratory (ANL)] ended the morning session with a presentation on recent results of and future plans for tests related to hydride reorientation in SNF cladding. This testing is part of efforts to better understand changes in cladding properties and degradation mechanisms due to hydride reorientation, and the potential implications for cladding integrity during transport following extended storage.

Sylvia Saltzstein (SNL) started the afternoon session with an overview presentation of the ENSA cask multimodal transport test. Nicholas Klymyshyn (PNNL) then discussed the results of the test, concluding that the data show the shock and vibration loads on the SNF rods during normal conditions of transport are below the level at which damage to the SNF would be expected to occur. He also discussed the use of the test data to validate structural response models, which will be used to evaluate the impact of similar shock and vibration loads on other fuel types and during transportation operations using other conveyance systems. In the following presentation, Ned Larson (DOE-NE) summarized the work DOE has completed and the path forward for DOE R&D on storage and transportation activities, including how the work completed and planned will serve as a basis to understand high-burnup SNF performance during extended storage and subsequent transportation for conditions differing from those experimentally observed.

The presentations then shifted to the subject of direct disposal of commercial SNF in DPCs. Timothy Gunter (DOE-NE) and Ernest Hardin (SNL) gave an overview of past DOE R&D activities on direct disposal of commercial SNF in DPCs. They summarized the recommendations that came out of those activities, as well as the planned activities for fiscal year 2019. The last presentations were by John Scaglione (ORNL) and Laura Price (SNL), who described ongoing DOE studies to address one of the main technical challenges related to direct disposal of SNF in DPCs—the risks from nuclear criticality during the repository post-closure period. The studies include evaluating the use of fillers to prevent moderator (i.e., water) intrusion into DPCs and, thus, prevent post-closure criticality, and performing DPC criticality consequence analyses to understand the potential impacts of criticality on repository performance.

Board Observations

The Board commends the speakers for their well-organized presentations that explained clearly the background and rationale for the projects, provided succinct summaries of the results and the implications of those results, and discussed future work to address the remaining technical uncertainties. Mr. Larson's presentation was particularly helpful in highlighting the connections among the presentations on high-burnup fuel and the ENSA cask multimodal transport test and their implications for the overall DOE R&D program on storage and transportation.[2] It is evident DOE's integrated approach to its storage and transportation R&D efforts, using both experiments and modeling and involving multiple national laboratories and universities, is effective in addressing a variety of technical issues related to the performance of high-burnup SNF during extended storage and during transport.

Based on the presentations and discussions at the meeting, the Board offers several sets of observations noted below and organized around common themes.

[2] Mr. Larson's presentation addressed the Board's 2016 recommendation by making transparent how DOE integrates the results of its various partnerships (e.g., universities, national labs, and international collaborators) into its overall research program on high-burnup fuel degradation.

Obtaining Data to Advance Understanding of SNF Behavior during Storage, Transportation, and Disposal

The Board is impressed with DOE's level of international engagement in its R&D program and with DOE's collaborations and partnerships with other organizations, particularly in the Extended Storage Collaboration Program (ESCP).[3] DOE's participation in the ENSA cask transport test and the planned SNF cask drop tests by the German Federal Institute for Materials Research and Testing [Bundesanstalt für Materialforschung und –prüfung (BAM)] in Germany are also noteworthy. DOE showed constructive flexibility in accelerating its plan to undertake the ENSA cask transport test in order to take advantage of Spanish and Korean interest in and available funding for the test. These collaborations help leverage DOE resources by enabling DOE to have access to potentially useful data from other organizations or programs and by avoiding duplication of research undertaken elsewhere. The Board encourages DOE to maintain awareness of other opportunities for international collaborative research.

The results presented at the meeting on the HDRP, the ENSA cask transport test, and the dry-cask simulator experiment demonstrate the great value of carrying out full-scale experiments to generate high-quality data that are useful for validating models. Much can be learned from these types of experiments, in addition to laboratory based single-effect experiments to obtain a more fundamental understanding. The Board encourages DOE to continue to focus on high-value opportunities to obtain experimental data that will better support its understanding of SNF behavior during storage, transportation, and disposal.

The Board commends DOE for its efforts to obtain more data on the detailed characteristics of SNF discharged from commercial U.S. nuclear power plants through a new call for nuclear utilities to submit Form GC-859, "Nuclear Fuel Data Survey," particularly since a similar effort to acquire SNF data from the utilities was last conducted in 2013. The Board also believes it important for DOE to make it a priority to gain access to new fuel design information and post-irradiation examination results needed to support the efforts of national laboratories to understand SNF characteristics, such as the potential for hydride reorientation and criticality analysis of loaded DPCs. The Board recognizes this effort will require access to proprietary information, which would require the agreement and participation of fuel fabricators and other organizations.

Performance and Potential Degradation of High-Burnup SNF during Storage and Transportation

For the fuel and cladding types included in the HDRP testing, DOE is making significant progress toward developing the technical bases to support the extended storage and subsequent transportation of commercial SNF. There is generally good integration of DOE

[3] ESCP, which is sponsored by the Electric Power Research Institute, is a group of organizations in the United States and other countries representing the nuclear industry, national governments, research laboratories, and suppliers of dry-storage systems for SNF. ESCP is investigating aging effects and mitigation options for the extended storage and transportation of SNF and high-level radioactive waste (HLW).

R&D activities on high-burnup SNF, high-quality data are being acquired, and the ongoing HDRP cask monitoring and sister rod testing will provide additional useful information.

During his presentation, Mr. Larson indicated DOE is coming to the conclusion, based on currently available data, that high-burnup SNF cladding will remain intact and its integrity will not be challenged during extended storage and subsequent transport under normal conditions. The data presented at the meeting show that the measured temperatures and hoop stresses on the HDRP SNF cladding are much lower than expected, such that the extent of cladding hydride reorientation in commercial SNF likely will be insufficient to make the cladding brittle enough to cause failure. Also, the ENSA cask multimodal transport test results suggest that the stresses on the SNF cladding during transportation will be too low to cause cladding failure. However, DOE has not completed its ongoing assessment to demonstrate that the surrogate materials used in the ENSA cask transport test produced the loads that would be experienced by actual SNF during transportation.

It is not clear to the Board that the HDRP cask results and sister rod testing can resolve all the issues that apply to the entire SNF inventory, which has cladding types and fuel burnups more diverse than those of the SNF loaded into the HDRP cask. Mr. Larson and other speakers at the meeting indicated that variability in cladding alloys, their associated manufacturing techniques, and other factors that could impact cladding integrity but which were not addressed by the HDRP study, will be evaluated using numerical models. However, the Board notes that fuel performance modeling is not included in the numerical modeling described at the meeting. While there appears to be tight integration of the DOE experimental program with model validation for the cask thermal-hydraulics and the fuel structural response, there is an apparent lack of such integration with respect to fuel performance modeling. Further, a lack of understanding of the fundamental mechanisms associated with high-burnup fuel performance during storage and subsequent transportation, such as the hydrogen and hydride behavior in SNF cladding, will limit applicability of DOE program results to other cladding types. To be noted is that experimental data are needed to develop the material models used by fuel performance models.

More work also is needed to quantify the amount and form of moisture that remains in a dry-storage cask following drying performed according to typical industry practices. The Board encourages DOE to conduct more research on that topic and determine its implications for the long-term storage, transportation, and disposal of commercial SNF.

DOE indicated that, given that the temperatures in the HDRP cask are lower than originally planned, it may not be worthwhile to open the cask and assess the condition of its contents after 10 years of storage. The Board believes that opening the cask and examining the fuel after a decade of storage would still be very useful if for no other reason than to confirm predictions of minimal changes in fuel performance and to build public confidence in fuel integrity after extended storage. Also, DOE indicated no additional sampling of the gas inside the HDRP cask is planned until the end of the storage period prior to transportation. The Board encourages DOE to continue to consider the possibility of obtaining gas samples from the HDRP cask or SNF casks at other nuclear power plant sites.

Further details about these and other Board observations, findings, and associated recommendations on high-burnup fuel will be included in a Board report on this topic that is planned to be published in 2019.

Integration of DOE Storage and Transportation R&D Results into DOE Disposal R&D Activities

As noted above, there appears to be generally good integration of DOE R&D activities on storage and transportation of high-burnup SNF. However, the results from these R&D activities have not yet been integrated into the DOE R&D program on SNF disposal. For example, the HDRP thermal measurements indicate the temperatures inside dry-storage canisters are lower than previously have been assumed in at least some cases. Because thermal management is a key consideration in the design and operation of any geologic repository, the lower than expected canister temperatures may have implications for repository design and operation that need to be evaluated by DOE.

Direct Disposal of Commercial Spent Nuclear Fuel in Dual-Purpose Canisters

The DOE R&D on direct disposal of SNF in DPCs will be useful in considering the potential for directly disposing of the DPCs, rather than repackaging the SNF. Direct disposal could decrease the cost of SNF disposal, reduce the complexity of the SNF management system, reduce risks resulting from the additional handling operations required for repackaging, lower the cumulative worker dose, and decrease the amount of secondary waste. However, the Board notes that a decision to accommodate large packages in a repository would place some significant constraints on repository design and may limit the range of geologic environments that can be considered for repository development.

The R&D work DOE has completed indicates there are engineering solutions to some of the technical challenges posed by direct disposal of SNF in DPCs. On this basis, DOE has eliminated a number of technical issues from consideration in future evaluations. One exception is post-closure criticality. For many years, approaches to meeting criticality requirements have focused on showing that the probability of a criticality event is acceptably small. At this meeting, the Board heard that DOE is now beginning an effort to evaluate the consequences of a post-closure criticality event if it were to occur. The Board concurs with DOE that it is important to evaluate the consequences of post-closure criticality to provide a basis for determining its impact on post-closure repository performance. More specifically, DOE indicated that it will conduct consequence analyses of DPC criticality, including developing a capability for multiphysics modeling of DPC criticality and a generic performance assessment model that can include simulation of the effects of potential DPC criticality in the post-closure period. The Board considers this work a step in the right direction, but notes that multiphysics modeling will face technical challenges, particularly with model validation and in the treatment of uncertainties. The work is at the beginning stages, and the Board will follow this and other DOE R&D efforts on direct disposal of SNF in DPCs with great interest.

Thank you again for the participation of DOE and national laboratory staff at our October meeting. We look forward to continuing our ongoing review of DOE's technical activities related to the management and disposal of SNF and HLW.

Sincerely,

{signed by}

Jean M. Bahr
Chair