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Christopher S Bajwa for

SUBJECT: TECHNICAL REPORT: EVALUATION OF INCREASED PEAK TEMPERATURES FOR SPENT FUEL CLADDING PERFORMANCE DURING DRY STORAGE

This memorandum transmits the technical report, "Evaluation of Increased Peak Temperatures for Spent Fuel Cladding Performance during Dry Storage" (Reference [1]). This report was prepared by the Pacific Northwest National Laboratory (PNNL) for the NRC's Office of Nuclear Regulatory Research (RES), in response to a request by the Office of Nuclear Material Safety and Safeguards (NMSS) for support in assessing margins in spent fuel performance.

The NMSS staff requested this study to enhance its understanding of the safety margins associated with the peak cladding temperature (PCT) limit that is defined in the NRC's standard review plan for storage (NUREG-2215, Reference [2]). The 400°C [752°F] limit was established to provide reasonable assurance that cladding integrity will be maintained during normal conditions of spent fuel storage and short-term loading operations (e.g., drying, backfilling with inert gas, and transfer of the cask to the storage pad), in accordance with 10 CFR 72.122(h)(1), 72.122(l) and 72.124(a). An improved understanding of the PCT safety margins can support the staff's efforts to further risk-inform its evaluations of storage system designs.

The PNNL study uses fuel performance modeling (the Fuel Analysis under Steady-state and Transients (FAST) code [3]) rather than physical testing of spent fuel cladding that has been exposed to elevated temperatures. The staff recognizes that sole reliance on fuel performance modeling to estimate the fuel cladding response to cask drying conditions may not be fully representative of conditions in dry storage. Nonetheless, the PNNL study could be useful to

inform ongoing efforts (including regulatory research) related to leveraging risk insights within the NRC's regulatory framework. Specifically, the PNNL study may be useful in assessing alternative criteria for fuel cladding performance.

Technical Report Summary:

In accordance with a Research Assistance Request between NMSS and RES, PNNL delivered a technical report titled, "Evaluation of Increased Peak Temperatures for Spent Fuel Cladding Performance during Dry Storage." The report:

- Documents calculations using the FAST code to predict cladding hoop stresses at PCTs that exceed the current values in NRC guidance (i.e., 425°C [797°F] and 450°C [842°F] for normal conditions of storage; 600°C [1,112°F] for off-normal and accident conditions of storage).

- Predicts the relative impact of the higher cladding stresses and higher cladding temperatures on age-related phenomena for spent fuel cladding and assembly hardware, as discussed in NUREG-2214, "Managing Aging Processes in Storage (MAPS) Report" (Reference [4]).

The report concludes that:

- The FAST code calculations demonstrate that the age-related phenomena primarily driven by cladding hoop stress, including hydride reorientation, delayed hydride cracking, thermal and athermal (low-temperature) creep, and localized mechanical overload, are not expected to compromise cladding integrity for the evaluated higher PCTs (i.e., 425°C [797°F] and 450°C [842°F]) during normal conditions for a 60-year dry storage period.

- Other age-related phenomena for cladding that are not driven by hoop stress (i.e., radiation embrittlement, fatigue, oxidation, pitting corrosion, galvanic corrosion, and stress corrosion cracking) and age-related phenomena for assembly hardware (i.e., creep, fatigue, hydriding, general corrosion, stress corrosion cracking, and radiation embrittlement) are also not expected to compromise fuel assembly integrity for the evaluated higher PCTs during normal conditions for a 60-year dry storage period.

Staff Plans:

The staff plans to use the information in the subject report as follows:

- For licensing actions that involve the PCT acceptance criterion in NUREG-2215, the staff could consider use of the information in the subject technical report when risk-informing safety reviews on a case-by-case basis. The staff could use the knowledge that there is potential margin on cladding performance at 400°C [752°F]. In such considerations, the staff will ensure that the technical basis in the subject report is applicable to the applicants' safety analyses. In some cases, the staff may also need to consider additional technical information, beyond that provided in the subject report, to reach a finding of reasonable assurance of adequate protection of public health and safety.

- The staff does not intend to revise the 400°C [752°F] PCT criterion in NUREG-2215 at this time. The staff notes that the subject report's conclusions are based, in part, on fuel performance modeling rather than physical testing of cladding that has been exposed to elevated temperatures. The 400°C [752°F] PCT criterion is supported by a significant amount of testing. Nonetheless, the staff may reassess this criterion depending on the results of the Phenomena Identification and Ranking Table (PIRT) exercise and the industry activities discussed below.

- The NRC and the nuclear community plan to complete a PIRT exercise in early 2022 on alternative fuel cladding thermal metrics, after which the NRC will reassess the PCT criterion in NUREG-2215. During the PIRT activity, experts on fuel cladding performance will evaluate all available information (including the subject report) to identify, characterize, and rank the phenomena most relevant to cladding integrity. As discussed in the April 13, 2021, workshop on spent fuel performance margins (Reference [5]), the Electric Power Research Institute (EPRI) has proposed to discuss the issue of regulatory implementation of the PIRT results in the EPRI-sponsored Extended Storage and Collaboration Program steering committee and recommend an approach to adopt any identified new metrics (e.g., topical report).

References:

1. Wells, B.E., Phillips, N.R., and Geelhood, K.J., "Evaluation of Increased Peak Temperatures for Spent Fuel Cladding Performance during Dry Storage," PNNL-30430, Pacific Northwest National Laboratory, September 2020 (ADAMS Accession No. ML20276A067).

2. NRC, "Standard Review Plan for Spent Fuel Dry Storage Systems and Facilities – Final Report," NUREG-2215, February 2020 (ADAMS Accession No. ML20121A190).

3. I.E. Porter, et al., "FAST-1.0: A Computer Code for Thermal-Mechanical Nuclear Fuel Analysis under Steady-state and Transients," PNNL-29720, Pacific Northwest National Laboratory, March 2020 (ADAMS Accession No. ML20099A088).

4. NRC, "Managing Aging Processes in Storage (MAPS) Report," NUREG-2214, U.S. Nuclear Regulatory Commission, July 2019 (ADAMS Accession No. ML19214A111).

5. EPRI, "Gross Rupture PIRT Update," Workshop between the U.S. Nuclear Regulatory Commission and Nuclear Energy Institute on Spent Fuel Performance Margins, April 13, 2021 (ADAMS Accession No. ML21139A109).

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