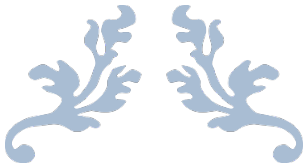

NRC DRAFT REGULATORY GUIDE ON NEW AND SPENT FUEL POOL CRITICALITY ANALYSES

This Draft Regulatory Guide is being released for the sole purpose of the public meeting being conducted June 8, 2020

NEW AND SPENT FUEL POOL CRITICALITY ANALYSES

A. INTRODUCTION

Purpose

This regulatory guide (RG) describes an approach that is acceptable to the staff of the U.S. Nuclear Regulatory Commission (NRC) to demonstrate that NRC regulatory requirements are met for subcriticality of fuel assemblies stored in new fuel vaults and spent fuel pools. It endorses, with clarifications, the Nuclear Energy Institute (NEI) guidance document NEI 12-16, "Guidance for Performing Criticality Analyses of Fuel Storage at Light-Water Reactor Power Plants," Revision 4, (Ref. 1).

Applicability

This RG applies to reactor licensees subject to Title 10 of the *Code of Federal Regulations* (10 CFR) 50.68, "Criticality accident requirements" (Ref. 2), including applicants for combined licenses subject to 10 CFR 52.79, "Contents of applications; technical information in final safety analysis report" (Ref. 5), and 10 CFR 70.24, "Criticality accident requirements" (Ref. 3).

Applicable Rules and Regulations

- 10 CFR Part 50, "Domestic licensing of production and utilization facilities," Appendix A, "General Design Criteria for Nuclear Power Plants," General Design Criterion 62, "Prevention of criticality in fuel storage and handling" (Ref. 4), requires that criticality in the fuel storage and handling system shall be prevented by physical systems or processes, preferably by use of geometrically safe configurations.

- 10 CFR 50.68(b)(2)–(4) contain limits on the k-effective (k_{eff}) for specific fuel storage configurations that licensees must comply with if they do not comply with 10 CFR 70.24 or hold a previously granted exemption.

- 10 CFR 70.24 contains requirements for licensees authorized to possess equal to or greater than amounts of the specified fissile material. A common practice was for commercial power reactor licensees to request exemptions to 10 CFR 70.24. Typically, those exemptions were granted if the licensee demonstrated sufficient subcriticality to criteria very similar to those in 10 CFR 50.68(b)(2)–(4). When the NRC issued 10 CFR 50.68 in 1998, licensees had the option to retain their exemption to 10 CFR 70.24. This guidance applies to the applicable portions of those exemptions.

- 10 CFR 52.79(a)(43) requires that applications for a combined license must include sufficient information to demonstrate compliance with the requirements of 10 CFR 50.68.

Related Guidance

In addition to the NUREG and NUREG/CR documents listed in NEI 12-16, Revision 4, the following documents may include information of use to specific licensees:

- NUREG-1475, Revision 1, "Applying Statistics," issued March 2011 (Ref. 6), provides an overview of different statistical approaches that may be used in demonstrating compliance with the requirement in 10 CFR 50.68 for 95-percent probability, 95-percent confidence, including limitations on their area of applicability.

- NUREG/CR-7108, "An Approach for Validating Actinide and Fission Product Burnup Credit Criticality Safety Analyses—Isotopic Composition Predictions," issued April 2012 (Ref. 7), provides guidance on the expected uncertainty associated with actinides and fission products in nuclear criticality safety analyses where the burnup of the spent fuel assemblies is credited.

- NUREG/CR-6683, "A Critical Review of the Practice of Equating the Reactivity of Spent Fuel to Fresh Fuel in Burnup Credit Criticality Safety Analyses for PWR Spent Fuel Pool Storage," issued September 2012 (Ref. 8), describes limitations to the use of "fresh fuel equivalencing" methods used by some licensees.

- NUREG/CR-1547, "Criticality Experiments with Subcritical Clusters of 2.35 Wt% and 4.31 Wt% ^{235}U Enriched UO_2 Rods in Water at a Water-to-Fuel Volume Ratio of 1.6," issued July 1980 (Ref. 9)

- NUREG/CR-7109, "An Approach for Validating Actinide and Fission Product Burnup Credit Criticality Safety Analyses—Criticality (k_{eff}) Predictions" (Ref. 11)

- NUREG CR-7194, "Technical Basis for Peak Reactivity Burnup Credit for BWR Spent Nuclear Fuel in Storage and Transportation Systems," issued April 2015 (Ref. 12)

- RG 1.13, "Spent Fuel Storage Facility Design Basis" (Ref. 13), may be applicable because of its discussion of systems, structures, and components that are relied upon by the nuclear criticality safety analysis.

- Information Notice 1997-77, "Exemptions from the Requirements of Section 70.24 of Title 10 of the Code of Federal Regulations," dated October 10, 1997 (Ref. 14)

Purpose of Regulatory Guides

The NRC issues RGs to describe to the public methods that the staff considers acceptable for use in implementing specific parts of the agency's regulations, to explain techniques that the staff uses in evaluating specific problems or postulated events, and to provide guidance to applicants. Regulatory guides are not substitutes for regulations and compliance with them is not required. Methods and solutions that differ from those set forth in RGs will be deemed acceptable if they provide a basis for the findings required for the issuance or continuance of a permit or license by the Commission.

Paperwork Reduction Act

This RG provides voluntary guidance for implementing the mandatory information collections in 10 CFR Parts 50 and 52 that are subject to the Paperwork Reduction Act of 1995 (44 U.S.C. 3501 et. seq.). These information collections were approved by the Office of Management and Budget (OMB), approval numbers 3150-0011 and 3150-0151. Send comments regarding this information collection to the Information Services Branch (T6-A10M), U.S. Nuclear Regulatory Commission, Washington, DC 20555-0001, or by e-mail to Infocollects.Resource@nrc.gov, and to the OMB reviewer at: OMB Office of Information and Regulatory Affairs (3150-0011 and 3150-0151), Attn: Desk Officer for the

Nuclear Regulatory Commission, 725 17th Street, NW Washington, DC20503; e-mail: oira_submission@omb.eop.gov.

Public Protection Notification

The NRC may not conduct or sponsor, and a person is not required to respond to, a collection of information unless the document requesting or requiring the collection displays a currently valid OMB control number.

B. DISCUSSION

Reason for Issuance

This RG will update and supersede existing interim staff guidance (ISG) and provide applicants with improved clarity about the necessary scope in their efforts to demonstrate compliance with the 10 CFR 50.68(b) requirements for performing criticality analyses of fuel storage at light-water reactor (LWR) power plants and maintain exemptions to 10 CFR 70.24. This RG contains information that can be used by both older plants and newer reactors licensed under both 10 CFR Part 50 and 10 CFR Part 52, "Licenses, certifications, and approvals for nuclear power plants."

Background

Over the years, criticality analyses for LWR power plant spent fuel pool storage racks and new fuel vaults have increased in complexity because of various changes that have significantly reduced margins to the regulatory requirements in 10 CFR 50.68(b), such as high-density storage racks, increased enrichments, and degradation of neutron absorber materials. The lack of explicit NRC guidance and the lack of standardization in spent fuel pool storage requirements led to multiple licensing reviews that exceeded normal review time frames. Therefore, the NRC found it necessary to provide guidance to support the review of methods for performing criticality analyses submitted for demonstrating compliance with 10 CFR 50.68(b). These analyses are integral to the technical foundation for the design of nuclear fuel storage structures, systems and components, and the associated technical specifications in applications (i.e., license amendment requests) submitted to the NRC for review and approval.

In 2011, the NRC issued DSS-ISG-2010-01, "Staff Guidance Regarding the Nuclear Criticality Safety Analysis for Spent Fuel Pools" (Ref. 15), to address this need. The intent of DSS-ISG-2010-01 was to clarify ambiguity in existing guidance and to build upon lessons learned based on licensing reviews at the time. While DSS-ISG-2010-01 provided updated guidance to the NRC staff that was responsive to the increased complexity of more recent spent fuel pool license application analyses and operations, it did not consider all aspects of performing criticality analyses of fuel storage at LWR power plants. Therefore, a comprehensive and more specific guidance document for performing criticality analyses of fuel storage at LWR power plants was still necessary.

The NEI, in collaboration with the Electric Power Research Institute (EPRI), developed NEI 12-16 to fill this regulatory need. This guidance document represents the NEI's effort to codify current practices in nuclear criticality analyses for fuel storage in vaults or pools and to establish a technical basis for certain positions. The most recent version of NEI 12-16—Revision 4—incorporated the final NRC-approved version of an EPRI methodology to determine the depletion uncertainty. The NEI submitted NEI 12-16 to the NRC with the intent that NRC would endorse it for use through an RG. Therefore, this RG describes the limitations to what the NRC would consider to be an acceptable use of the guidance described in NEI 12-16, Revision 4, for use in demonstrating compliance with 10 CFR 50.68(b) requirements.

Harmonization with International Standards

The International Atomic Energy Agency (IAEA) works with member states and other partners to promote the safe, secure, and peaceful use of nuclear technologies. The IAEA develops safety standards for protecting people and the environment from harmful effects of ionizing radiation by ensuring appropriate prevention and/or mitigation of inadvertent criticality events. These standards provide a system of safety fundamentals, safety requirements, and safety guides reflecting an international

consensus on what constitutes a high level of safety. This system includes technical principles and guidance to be considered for the design of accident monitoring instrumentation of nuclear power plants:

- IAEA Safety Standards Series No. SSG-27, "Criticality Safety in the Handling of Fissile Material," issued 2014 (Ref. 16).

This RG incorporates similar design and performance guidelines and is consistent with the safety principles provided in this publication.

Documents Discussed in Staff Regulatory Guidance

This RG endorses, in part, the use of NEI 12-16, Revision 4, which is a third party guidance document. NEI 12-16 may contain references to other codes, standards or third party guidance documents ("secondary references"). If a secondary reference has itself been incorporated by reference into NRC regulations as a requirement, then licensees and applicants must comply with that standard as set forth in the regulation. If the secondary reference has been endorsed in a RG as an acceptable approach for meeting an NRC requirement, then the standard constitutes a method acceptable to the NRC staff for meeting that regulatory requirement as described in the specific RG. If the secondary reference has neither been incorporated by reference into NRC regulations nor endorsed in a RG, then the secondary reference is neither a legally-binding requirement nor a "generic" NRC approved acceptable approach for meeting an NRC requirement. However, licensees and applicants may consider and use the information in the secondary reference, if appropriately justified, consistent with current regulatory practice, and consistent with applicable NRC requirements.

C. STAFF REGULATORY GUIDANCE

1. NEI 12-16, Revision 4

The NRC staff considers the guidance in NEI 12-16, Revision 4, generally acceptable as a means for demonstrating compliance with the requirements in 10 CFR 50.68(b). However, the NRC staff is providing clarification or exceptions to certain statements, as discussed below:

a. NEI 12-16, Revision 4, Section 1.4, states that the double contingency principle, as applied to criticality accidents, means, in part, that licensees do not need to consider the simultaneous occurrence of two independent and unlikely conditions. The example provided discusses conditions that are controlled through technical specification requirements. A licensee may consider certain conditions to be unlikely conditions, such as the possibility that a burnable absorber panel may not have been correctly installed. However, if no controls or documents exist to preclude such a condition, then the licensee should treat it as part of the normal condition.

b. The last paragraph of Section 1.6 discusses the concept of using a "graded" licensing approach to use risk insights, which is consistent with current licensing practices. Licensees may need to establish how they will maintain any excess safety margins being used to justify assumptions or simplifications when they update the analyses, using their approved methodology, to accommodate changes in the fuel storage characteristics.

c. Section 2 discusses acceptance criteria for new fuel vault storage and states that one of the situations for which an evaluation does not need to be performed in accordance with 10 CFR 50.68(b) is when a licensee has been granted an exemption to 10 CFR 70.24. This would be true if the licensee maintains the conditions upon which the exemption was based. If the conditions deviate significantly from the conditions for which the exemption was justified, then the licensee may need to justify why the exemption is still valid or perform an evaluation.

d. Section 3.1.3 discusses the treatment of nuclides credited in the depletion and criticality analysis. NEI 12-16 provides no guidance on the treatment of lumped fission products, which may be used in certain depletion codes. The NRC has previously accepted approaches in which the lumped fission products are included in the depletion calculations but removed from the isotopic compositions before use in the criticality analysis. Any other treatment of lumped fission products should be justified separately from the treatment of individual actinides and fission products.

e. Section 4.2.3 states that the depletion bias and uncertainty described in this section account for all uncertainties associated with depletion. If licensees are following the guidance in Section 4.3.1 about treatment of the depletion parameters, this statement would be acceptable. Licensees that do not follow this guidance should justify that they are adequately accounting for the depletion uncertainties.

f. Section 4.3.1 discusses the lattice-specific parameters that should be accounted for when considering which types of lattices to evaluate. This should not be considered a complete list of parameters. Each unique axial plane in the bundle designs should be evaluated. For example, some bundle designs may use different fuel rod pitches at different axial planes, and this should also be considered when selecting lattices for evaluation.

g. Section 5.1.6 discusses a conservative approach to modeling integral burnable absorbers using nominal dimensions combined with a minimum absorber loading. In order to meet the 95-percent

probability, 95-percent confidence requirement of 10 CFR 50.68, the minimum absorber loading should be based on the lower 95/95 threshold of the manufacturing tolerance range, or the manufacturing tolerances should be evaluated and treated as an uncertainty.

h. Section 5.2.2 states that credit can be taken for radial leakage near the walls of the spent fuel pool for allowing lower burnup fuel requirements on the periphery of the spent fuel pool. Licensees that adopt this approach should include the spent fuel pool wall in their nuclear criticality safety analyses to account for the weak neutron reflection capability of the concrete wall, unless the distance between fuel and the spent fuel pool wall is sufficiently large to assure that the influence of the wall on criticality is not significant.

i. Section 5.2.2.4 provides recommendations on the treatment of eccentric positioning for fuel assemblies within spent fuel pool cells. The recommendations are acceptable as general guidelines; however, the NRC expects licensees to consider any unique aspects of the configuration being analyzed that may lead to a more limiting eccentric positioning. The NRC does not endorse a generic justification for not analyzing specific configuration based on a qualitative assessment of probability.

j. Section 6.3 appears to have an error in the third sentence of the first paragraph. The limiting condition may or may not be a misload event, but the NRC agrees that the limiting abnormal condition will be the accident that requires the highest soluble boron to meet regulatory requirements.

k. Section 9.4 lists some parameters that may need to be verified as part of post irradiation fuel characterization activities. One of the parameters is "soluble boron (burnup averaged)." The NRC endorses use of cycle burnup averaged soluble boron, consistent with Section 4.2.1, but the agency does not endorse other interpretations of the phrase "burnup averaged," such as averaging across the whole burnup range for a given fuel assembly.

l. Section A.1 provides recommendations for the validation of computer codes used for nuclear criticality safety analyses, as well as referencing NUREG/CR-6698, "Guide for Validation of Nuclear Criticality Safety Calculational Methodology," issued January 2001, for additional information. An important aspect of validation that is not covered in much detail is the importance of selecting appropriately representative benchmarks and critical experiments, especially when performing trend evaluation. Licensees may need to consider smaller sets of data to avoid confounding effects that obscure trends or that lead to conclusions based on data that are not highly representative of the spent fuel pool geometry and compositions of interest.

m. Section A.2.2 states that startup critical data from boiling-water reactors (BWRs) can be used to benchmark depletion codes and compute a bias and bias uncertainty. While the NRC agrees in principle that comparing measured and predicted criticals can provide useful information about the accuracy and precision of the depletion codes, the document provides no clear guidance on how to accomplish this. This is also not a commonly accepted practice. Therefore, licensees that use such an approach would need to provide technical justification to the NRC for review and approval, including why the critical data are applicable to the compositions and to which geometries the benchmarking is intended be applicable.

n. Section A.4 discusses use of a secondary code as an intermediate means to validate the primary code used for the nuclear criticality safety analyses. This is not an approach that the NRC has recently received for review and approval, and there is no justification for this approach. Nuclear

criticality safety analyses would need to be performed with a code that is sufficiently flexible to model interface and accident conditions, which typically means that they are also flexible enough to model critical benchmarks and experiments. Therefore, the NRC does not endorse this approach as a generally acceptable means of validating a code intended specifically for use in the nuclear criticality safety analyses (as opposed to use in the generation of spent fuel isotopic compositions or screening of fuel lattices for evaluation).

o. NEI 12-16 provides many recommendations that are based on analyses performed using typical geometries and compositions associated with spent fuel pools and bundle designs that are currently in widespread use in the United States (i.e., cylindrical uranium dioxide fuel pellets enclosed in zirconium alloy tubes). Novel configurations and concepts, such as accident-tolerant fuel designs, may require justification for continued use of the assumptions. For example, dispositions of specific uncertainties as not significant may no longer be valid, simplifying assumptions may become nonconservative, and additional uncertainties may need to be considered. Licensees are responsible for justifying use of the guidance in NEI 12-16 in any such applications.

2. Other Documents Referenced in NEI 12-16, Revision 4

As discussed in Section B of this RG, in the paragraph titled, "Documents Discussed in Staff Regulatory Guidance," NEI 12-16, Revision 4, references other documents; however, the NRC's endorsement of NEI 12-16, Revision 4, is not an endorsement of the referenced documents, unless the NRC was the original issuer of the document.

NEI 12-16, Revision 4, includes some general conclusions based on sensitivity studies performed to support the guidance. While appropriate for clarifying the technical basis for some of the recommendations, the NRC's endorsement of NEI 12-16, Revision 4, should not be considered a determination that the conclusions are applicable for all licensees. A licensee should ensure that a conclusion is applicable to its particular circumstances before implementing the guidance associated with that conclusion.

Appendix B to NEI 12-16, Revision 4, includes an example to supplement the guidance. While appropriate for illustrating and reinforcing the guidance in NEI 12-16, Revision 4, the NRC's endorsement of NEI 12-16, Revision 4, should not be considered a determination that the examples are applicable for all licensees. A licensee should ensure that an example is applicable to its particular circumstances before implementing the guidance as described in an example.

D. IMPLEMENTATION

The NRC staff may use this RG as a reference in its regulatory processes, such as licensing, inspection, or enforcement. However, the NRC staff does not intend to use the guidance in this RG to support NRC staff actions in a manner that would constitute backfitting, as that term is defined in 10 CFR 50.109, "Backfitting," and as described in NRC Management Directive 8.4, "Management of Backfitting, Forward Fitting, Issue Finality, and Information Requests," dated September 20, 2019 (Ref. 17), nor does the NRC staff intend to use the guidance to affect the issue finality of an approval under 10 CFR Part 52. The staff also does not intend to use the guidance to support NRC staff actions in a manner that constitutes forward fitting, as that term is defined and described in Management Directive 8.4. If a licensee believes that the NRC is using this RG in a manner inconsistent with the discussion in this Implementation section, then the licensee may file a backfitting or forward-fitting appeal with the NRC in accordance with the process in Management Directive 8.4.

REFERENCES[1]

1. Nuclear Energy Institute, NEI 12-16, "Guidance for Performing Criticality Analyses of Fuel Storage at Light-Water Reactor Power Plants," Revision 4, Washington, DC.

2. *U.S. Code of Federal Regulations* (CFR), "Domestic licensing of production and utilization facilities," Part 50, Chapter 1, Title 10, "Energy"

3. CFR, "Domestic licensing of special nuclear material," Part 70, Chapter 1, Title 10, "Energy"

4. 10 CFR Part 50, "Domestic licensing of production and utilization facilities," Appendix A, "General Design Criteria for Nuclear Power Plants," General Design Criterion (GDC) 62, "Prevention of criticality in fuel storage and handling"

5. CFR, "Licenses, Certifications, and Approvals for Nuclear Power Plants," Part 52, Chapter 1, Title 10, "Energy"

6. U.S. Nuclear Regulatory Commission (NRC), NUREG-1475, "Applying Statistics," Revision 1, Washington, DC, March 2011.

7. NUREG/CR-7108, "An Approach for Validating Actinide and Fission Product Burnup Credit Criticality Safety Analyses—Isotopic Composition Predictions," ORNL/TM-2011/509, Oak Ridge National Laboratory, Washington, DC, April 2012. (ADAMS Accession No. ML12116A124)

8. NUREG/CR-6683, "A Critical Review of the Practice of Equating the Reactivity of Spent Fuel to Fresh Fuel in Burnup Credit Criticality Safety Analyses for PWR Spent Fuel Pool Storage," ORNL/TM-2000/230, Oak Ridge National Laboratory, Washington, DC, September 2012.

9. NUREG/CR-1547, "Criticality Experiments with Subcritical Clusters of 2.35 Wt% and 4.31 Wt% ^{235}U Enriched UO_2 Rods in Water at a Water-to-Fuel Volume Ratio of 1.6," PNL-3314, Pacific Northwest National Laboratory, Washington, DC, July 1980.

10. NUREG/CR-7108, "An Approach for Validating Actinide and Fission Product Burnup Credit Criticality Safety Analyses—Isotopic Composition Predictions," ORNL/TM-2011/509, Oak Ridge National Laboratory, Washington, DC, April 2012.

11. NUREG/CR-7109, "An Approach for Validating Actinide and Fission Product Burnup Credit Criticality Safety Analyses—Criticality (keff) Predictions," ORNL/TM-2011/514, Oak Ridge National Laboratory, Washington, DC April 2012.

1 Publicly available NRC published documents are available electronically through the NRC Library on the NRC's public Web site at http://www.nrc.gov/reading-rm/doc-collections/ and through the NRC's Agencywide Documents Access and Management System (ADAMS) at http://www.nrc.gov/reading-rm/adams.html. The documents can also be viewed online or printed for a fee in the NRC's Public Document Room (PDR) at 11555 Rockville Pike, Rockville, MD. For problems with ADAMS, contact the PDR staff at 301-415-4737 or (800) 397-4209; fax (301) 415-3548; or e-mail pdr.resource@nrc.gov.

12. NUREG/CR-7194, "Technical Basis for Peak Reactivity Burnup Credit for BWR Spent Nuclear Fuel in Storage and Transportation Systems," ," ORNL/TM-2014/240, Oak Ridge National Laboratory, Washington, DC, April 2015.

13. NRC, Regulatory Guide 1.13, "Spent Fuel Storage Facility Design Basis," Washington, DC.

14. NRC, Information Notice 1997-77, "Exemptions from the Requirements of Section 70.24 of Title 10 of the Code of Federal Regulations," Washington, DC, October 10, 1997.

15. NRC, DSS-ISG-2010-01, "Staff Guidance Regarding the Nuclear Criticality Safety Analysis for Spent Fuel Pools," Washington, DC, October 13, 2011.

16. International Atomic Energy Agency (IAEA) Safety Standards Series No. SSG-27, "Criticality Safety in the Handling of Fissile Material," Vienna, Austria, 2014.[2]

17. NRC, Management Directive 8.4, "Management of Backfitting, Forward Fitting, Issue Finality, and Information Requests," Washington, DC, September 20, 2019.

2 Copies of International Atomic Energy Agency (IAEA) documents may be obtained through their Web site: WWW.IAEA.Org/ or by writing the International Atomic Energy Agency, P.O. Box 100 Wagramer Strasse 5, A-1400 Vienna, Austria.