On Site Spent Fuel Criticality Analyses
NRR Action Plan

CLOSED
July xx, 2017

TAC No. ME0372	Last Update:	December 2013
	Lead Division:	NRR/DSS
	Supporting Divisions:	NRR/DE
		NRR/DIRS
		NRR/DORL
		NRR/DLR
		NRR/DPR
	Supporting Offices:	NRO
		NMSS
		RES

This action plan is closed. There are items not yet completed, but they are being tracked via their associated regulatory processes and/or through status updates to respond to recommendations in Audit Report OIG-15-A-06, "Audit of NRC's Oversight of Spent Fuel Pools." A final status update of all the open items from the previous December 2013 update to the SFP criticality action plan can be found in the "Milestones" section of this action plan.

GOAL

Reduce regulatory uncertainty associated with the licensing, operation, and maintenance of wet storage systems for fresh and Spent Nuclear Fuel (SNF) at commercial reactor sites.

DESCRIPTION

The initial SFP criticality action plan was issued on May 21, 2010 (ADAMS Accession No. ML101520463). The action plan was updated on several occasions to reflect completion of some activities and the evolution of other activities. The last update was issued on November 22, 2013 (ADAMS Accession No. ML13350A480). Since the milestones in the action plan have evolved over time, the most recent update to the action plan was used to determine which items had not yet been closed out. The "Milestones" section of this update describes the open actions from the last update that have been closed, or are part of ongoing engagement and maintenance activities that are expected to continue. The remaining actions are currently being tracked as part of three ongoing regulatory activities:

1) Develop durable guidance commensurate with the complexity of modern NCS analyses (Draft Regulatory Guide referencing NEI 12-16).
2) Determine the current state of SFP NAM (Generic Letter 2016-01).
3) Develop a consistent legal obligation for licensees to monitor and maintain SFP NAM (TSTF referencing NEI 16-03).

The first two activities are also being tracked by the Office of the Inspector General (OIG) as the mechanism by which two of their recommendations in Audit Report OIG-15-A-06, "Audit of NRC's Oversight of Spent Fuel Pools," will be resolved. The primary NRC role in the final

activity has been completed, with overall completion awaiting Congressional review of NEI 16-03 and action from the Technical Specifications Task Force to submit a traveler to the NRC. When the traveler is submitted, it will be tracked as part of the normal process for NRC review of TSTF travelers. As a result, these activities no longer need to be tracked by an action plan.

BACKGROUND

When the first commercial nuclear power plants were being built, the licensing requirements were a combination of 10 CFR 70.24, Criticality accident requirements, and 10 CFR 50 Appendix A General Design Criteria (GDC) 62, Prevention of criticality in fuel storage and handling (or a pre-GDC equivalent). Initially, the intention was for SNF to be stored for a short time at the reactor site post-irradiation to allow for cooling prior to shipment. With that in mind, SFPs were designed with low-density storage. Low-density storage has large water gaps, referred to as 'flux traps', between the fuel assemblies. Typically, an area for storage of fresh fuel was provided. These New Fuel Storage Vaults (NFSV) were intended for dry storage of the fuel prior to irradiation. There were large gaps between the storage cells in case the NFSV accidently become flooded.

Most, if not all, licensees were granted an exemption to 10 CFR 70.24 as part of their initial license based on a Nuclear Criticality Safety (NCS) analysis that demonstrated sub-criticality through U^{235} loading restrictions and geometry of the low-density storage racks (both SFP and NFSV). The U^{235} loading restrictions and geometry were included in the Design Features section of the Technical Specifications (TSs). The NCS analyses to support these 10 CFR 70.24 exemptions were generally fairly simple models of fresh fuel that primarily relied on the low U^{235} enrichments and large spacing between fuel assemblies to demonstrate that an Inadvertent Criticality Event (ICE) would not occur in the SFP.

Subsequent changes in federal policy forced licensees to maintain on-site storage of SNF for much longer times than initially envisioned. That led licensees to request NRC approval for addition of storage capacity to their SFP, often by installation of high density storage racks. To facilitate the submittal and review of those license amendments, the NRC issued an April 14, 1978, Letter to All Power Reactor Licensees from B. K. Grimes, "OT Position for Review and Acceptance of Spent Fuel Storage and Handling Applications" (Note it was subsequently retitled Generic Letter (GL) 1978-11, "Guidance on Spent Fuel Pool Modifications"). GL 1978-11 was modified in January 1979 by GL 1979-04, "Referencing 4/14/78 Letter – Modifications to NRC Guidance "Review and Acceptance of Spent Fuel Pool Storage and Handling". GL 1979-04 modified some of the acceptance criteria for the review, but did not modify any of the guidance pertaining to the NCS analysis. An update to the Standard Review Plan (SRP) was issued in July of 1981. Since this time, virtually all licensees have modified their SFP for high-density storage. At some plants, the current licensed SFP storage capacity is for as much as five times more fuel assemblies than the original licensed storage capacity.

While there are differences in high-density storage rack designs, there are several commonalities. High-density storage rack designs typically use a permanently installed neutron-absorbing material (NAM) panels between the fuel assemblies. Pressurized-Water Reactor (PWR) SFPs typically have two regions. Region 1 is for fresh or lightly burned fuel. This region has a small flux trap between adjacent storage cells and may also contain two NAM panels between the fuel assemblies. Region 2 has no flux trap and typically includes one NAM panel between the fuel assemblies. PWR SFPs frequently incorporate the effects of fuel assembly burnup and soluble boron in the SFP in the SFP criticality analyses to demonstrate that the regulatory requirement is met. Boiling-Water Reactor (BWR) SFPs are similar to the

PWR Region 2 design. BWR SFP criticality analyses are different in that they assume that every storage location is filled with a limiting fuel assembly. BWR fuel assemblies typically contain a significant amount of gadolinium, which is a strong neutron absorber. Because of the gadolinium, BWR fuel assemblies are more reactive after the gadolinium has been 'burned' out during irradiation in an operating reactor. Therefore, the limiting fuel assembly is based on either a gadolinium-free U^{235} loading or a depletion to peak reactivity.

As licensees incorporated further changes to their licensing basis to capture increased U^{235} enrichments, fuel design changes, power uprates, NAM, and other operating strategies, some industry guidance was developed for use by licensees. The first such effort was a vendor Topical Report, Westinghouse Commercial Atomic Power (WCAP)-14416-NP-A, Westinghouse Spent Fuel Rack Criticality Analysis Methodology, which the NRC approved in 1996. WCAP-14416 was non-proprietary in its entirety and was occasionally used by others to perform SFP NCS analysis. Later, Westinghouse determined that the methodology in WCAP-14416-NP-A was non-conservative. Westinghouse notified its customers through Nuclear Safety Advisory Letter, NSAL-00-015, dated November 2, 2000. In a July 27, 2001, letter to Westinghouse (ADAMS ML01208337) the NRC withdrew its approval of WCAP-14416-NP-A. While the July 27, 2001, NRC letter acknowledges Westinghouse's guidance on compensatory measures to accommodate the non-conservativism in WCAP-14416-NP-A, the letter stops short of endorsing those actions. However, licensees were not required to provide any information about the specific impact on their SFP NCS analysis of record.

Prior to the withdrawal of NRC approval of WCAP-14416-NP-A, the NRC developed internal guidance in an internal NRC Memorandum from L. Kopp to T. Collins, "Guidance on the Regulatory Requirements for Criticality Analysis of Fuel Storage at Light-Water Reactor Power Plants," August 19, 1998. At some point, that memorandum became public and was adopted by the industry as de facto guidance. This internal memorandum is known colloquially as the 'Kopp Letter,' after the author. However, the guidance in the Kopp Letter was not incorporated into a formal NRC guidance document, and the basis for the guidance was not captured. The NRC staff eventually issued Interim Staff Guidance (ISG) DSS-2010-01 to consolidate and expand on the existing technical bases for NRC review and approval of SFP NCS analyses (including the Kopp letter).

In addition to the ongoing development of regulatory guidance, the NRC issued a new regulation regarding storage of nuclear fuel at commercial reactors: 10 CFR 50.68, Criticality accident requirements, in November 1998. Essentially, 10 CFR 50.68 codified the acceptance criteria the NRC had been using to grant exemptions to 10 CFR 70.24. 10 CFR 50.68 did not alter any 10 CFR 70.24 exemptions, but rather, gave licensees the option to convert their 10 CFR 70.24 exemptions to 10 CFR 50.68 compliance.

A significant driver of the continued need to develop SFP NCS analysis guidance was the discovery of significant degradation in some of the NAM used in many SFPs. NAM materials are composed of a neutron-absorbing component, generally ^{10}B as boron carbide, in a matrix. Both metal matrix and nonmetal matrix materials are used. When the first rounds of SFP re-racking were occurring, there were several different NAM being used: boron carbide in a silicone polymer (e.g., Boraflex); boron carbide in a phenol formaldehyde resin matrix (e.g., Carborundum); a cermet of boron carbide and aluminum (e.g., Boral®), and borated Stainless Steel (SS). Boraflex was the most prevalent. In the 1980s, Boraflex was the first NAM to exhibit significant degradation, as documented in Information Notice (IN) 87-43, IN 93-70, IN 95-38, and GL 96-04. Subsequently, degradation or deformation was found in other NAMs, as documented in IN 09-26.

PWRs typically submitted LARs to either remove all credit for Boraflex or to credit degraded Boraflex. This led to complex analyses of various storage configurations collocated in the SFP, each dependent upon one or more of the following; U^{235} loading, geometry, fresh poison loading, burnup, decay of certain isotopes, SFP soluble boron, degraded Boraflex, and interface requirements between the various storage configurations. Several licensees had a dozen or more pages in the Design Features section of their TS describing the storage requirements. BWRs eventually found it necessary to follow suit.

In the past decade or so, there has been a lot of research commissioned by the Office of Nuclear Material Safety and Safeguards' Division of Spent Fuel Management (previously Division of Spent Fuel Storage and Transportation) regarding NCS for storage and transportation casks. This work highlights key aspects of modern NCS analyses, and much of it is applicable to SFP NCS. In addition, the Office of NRR's Division of Engineering (DE) commissioned research into NAM degradation and monitoring methods to identify and trend existing degradation.

As the NRC knowledge base for SFP NCS expanded, a large number of SFP NCS analyses and NAM aging management programs came before the NRC for review as part of LARs and License Renewal Applications. The NRC staff noted the applications contained technical issues. Additionally, the applications were removing conservatism in some areas without considering the methodology holistically for areas of non-conservatism that may no longer be supported without the conservatism in another area. During the same time period, licensee's difficulties with managing their NAM began to surface. The NRC issued two escalated enforcement actions and Confirmatory Action Letters to licensees due to deficiencies in maintaining their NAM. Several other violations were cited, as well as a number of non-cited violations. It was apparent that some licensees were not properly capturing all relevant considerations in their SFP NCS analyses, and some licensees were not meeting their commitments to monitor the NAM. This led to issuance of additional Information Notices (INs 2011-03, 2012-13, and 2014-09).

REGULATORY OUTCOME

SFP Criticality Analysis

As part of this action plan, the following documents have been issued to provide improved guidance on acceptable SFP NCS analysis practices:

- Final ISG "DSS-ISG-2010-01: Staff Guidance Regarding the Nuclear Criticality Safety Analysis Accompanying Spent Fuel Pool License Amendment Requests" (NRR/DSS)
- NUREG/CR-7108: "An Approach for Validating Actinide and Fission Product Burnup Credit Criticality Safety Analyses-Isotopic Composition Predictions" (NRR/DSS)
- NUREG/CR-7109: "An Approach for Validating Actinide and Fission Product Burnup Credit Criticality Safety Analyses-Criticality (Keff) Predictions" (NRR/DSS)
- Information Notice 2011-03, "Nonconservative Criticality Safety Analyses for Fuel Storage" (NRR/DSS)
- Information Notice 2014-09: "Spent Fuel Storage or Transportation System Misloading" (NRR/DSS)

While these documents consolidate much of the current guidance for NRC staff with respect to SFP criticality analyses, a number of areas are reliant on engineering judgement and/or are not well defined. The NRC staff is currently reviewing a guidance document submitted by Nuclear Energy Institute, Nuclear Energy Institute (NEI) 12-16, "Guidance for Performing Criticality Analyses of Fuel Storage at Light-Water Reactor Power Plants." The intent is for the NRC to endorse this document, with any appropriate limitations and conditions, via a Regulatory Guide (RG). This RG would then supplant the ISG, the Kopp letter, and other legacy NRC guidance.

The NRC staff's intent is for the RG and NEI 12-16 to expand on the information already presented in the ISG to provide detail where necessary. In addition, some specific areas have been flagged that need a stronger technical basis, including the following:

- Reactivity uncertainty
- Actinide and fission product validation
- Fuel geometry changes due to irradiation
- Wall reflection effect
- Monte Carlo convergence
- Treatment of fuel spacers
- Fuel rod temperature distribution

These areas are expected to be addressed as part of the final NRC regulatory guidance document on SFP criticality analyses, expected to be complete in early 2018. Completion of the final NRC regulatory guidance document is being tracked by OIG to verify that one of their recommendations from Audit Report OIG-15-A-06 is resolved. The NRC staff sends biannual update memos to OIG reporting the current status of the actions intended to resolve audit report recommendations, which are publicly available via the OIG website. When each update memo is sent and accepted by OIG, a new EDO ticket is generated to track the next update memo. This process will not be closed out until the NRC adequately addresses the OIG audit report recommendations.

<u>NAM Degradation</u>

The ability of licensees to control the material condition of any permanently installed NAM that is credited for maintaining sub-criticality is essential for the prevention of an ICE. Past events have shown that multiple licensees have had challenges in identifying and managing degradation or deformation of their NAM. In the case of several licensees, the issue was elevated to the point where enforcement actions were taken for failure to maintain control of the material condition of the permanently installed NAMs. Nuclear Reactor Regulation (NRR)/DE has the lead for establishing guidance with respect to the material condition of the NAM. RES has been assisting in research to identify and characterize the degradation/deformation issues that may affect criticality.

The initial spent fuel criticality analysis action plan indicated that management at the time determined that the resolution of criticality activities should be separate from the neutron absorber degradation issues. This decision reflected the differences between resolution of analytical or methodology deficiencies for criticality analyses and on-going material degradation issues for neutron absorbers. However, much of the NRR/DE work affects SFP NCS analyses in that appropriately monitoring and managing the condition of any NAM credited for criticality control is necessary to ensure that the SFP NCS analyses remain applicable to a site. The

following documents made significant contributions to the evolution of the NRC's knowledge base related to NAM monitoring and degradation:

- Information Notice 2009-26, "Degradation of Neutron-Absorbing Materials in the Spent Fuel Pool" (NRR/DE)
- Revision 2 of NUREG-1801, "Generic Aging Lessons Learned (GALL) Report" (NRR/DLR - incorporates staff guidance on aging management for all neutron-absorbing materials)
- Information Notice 2012-13: "Boraflex Degradation Surveillance Programs and Corrective Actions in the Spent Fuel Pool" (NRR/DE)
- Technical Letter Report "Boraflex, RACKLIFE, and BADGER: Description and Uncertainties" (RES/DE)
- Technical Letter Report "Initial Assessment of Uncertainties Associated with BADGER Methodology" (RES/DE)
- Technical Letter Report "Monitoring Degradation of Phenolic Resin-Based Neutron Absorbers in Spent Nuclear Fuel Pools" (RES/DE)

The multiple issues identified at different sites, combined with the continuing evolution of the state of the NRC's technical knowledge and staff positions regarding the degradation and deformation of NAMs installed in SFP racks, resulted in the issuance of GL 2016-01 in April 2016. All licensees have submitted their responses to the NRC. As of March 2017, the NRC staff had reviewed about half of the responses and sent closeout letters to 28 sites (51 units). The remaining responses are being evaluated to determine if any further regulatory action is necessary to ensure compliance with the NRC subcriticality requirement for all operating SFPs. The issuance of the GL, along with the follow up efforts, are being closely coordinated with NRR/DE, and any relevant information will be provided to RES to assist them in their research. Final closeout of the GL for all licensees is expected by the end of May 2018. Completion of the final NRC regulatory guidance document is being tracked by OIG to verify that one of their recommendations from Audit Report OIG-15-A-06 is resolved. The NRC staff sends biannual update memos to OIG reporting the current status of the actions intended to resolve audit report recommendations, which are publicly available via the OIG website. When each update memo is sent and accepted by OIG, a new EDO ticket is generated to track the next update memo. This process will not be closed out until the NRC adequately addresses the OIG audit report recommendations.

<u>NAM Monitoring Program Obligation</u>

The GL is expected to provide the NRC with the ability to ensure that regulatory compliance is assured in the near future. However, long-term guidance is needed for monitoring of NAMs installed in SFPs and credited for regulatory compliance. NRR/DE has already developed some guidance that became incorporated in the Generic Aging Lessons Learned (GALL) Report, but that guidance is primarily used when a licensee applies for a license renewal pursuant to 10 CFR 54. As a result, a need exists to establish guidance that applies to all regulatory processes associated with operating SFPs. Given the safety significance that NAMs play in preventing an ICE, the NRC staff believes that the TS would be an appropriate location for a description of the minimum standards that must be met to assure safety.

The NRC staff and industry reached a consensus that guidance would be developed by the industry addressing NAM monitoring programs and be submitted to the NRC for approval. This guidance was originally included as part of the overall guidance document on SFP criticality

analyses (NEI 12-16), but subsequently was formed into a separate document, NEI 16-03, "Guidance for Monitoring of Fixed Neutron Absorbers in Spent Fuel Pools." The NRC staff has completed their review and documented their approval of NEI 16-03 in a safety evaluation (ADAMS Accession No. ML16354A486). The Technical Specification Task Force (TSTF) intends to use this guidance as a basis for a proposed TSTF traveler so the Standard Technical Specifications (STSs) can be updated to reflect the addition of a description of the minimum standards for monitoring of NAM installed in the SFP. Once the TSTF submits the traveler to the NRC, the subsequent NRC staff actions will be tracked under the normal TSTF review process.

MILESTONES

The following table contains a list of all action items associated with to this action plan and information on how each item has been addressed.

Item	Completion Date	Notes
Information Notice on Misloading Events	6/20/2014	ADAMS Accession No. ML14121A469
Information Notice on EPU Effect on SFP Criticality	n/a	Determined to be unnecessary in light of existing guidance in ISG-DSS-2010-01.
Generic Letter on Neutron Absorbers	Issued 4/7/2016 (ML16097A169); Target closeout spring 2018	This action is being tracked by OIG (see "Regulatory Outcome – NAM Degradation" section for further discussion). EDO tickets are used to track required biannual update memos to OIG.
Technical Specification Review	NRC SE approving NAM monitoring program guidance in NEI 16-03 issued 3/3/2017 (ML16354A486)	When a TSTF traveler is submitted for review, NRC staff actions will be tracked under the normal TSTF tracking process (see "Regulatory Outcome – NAM Monitoring Program Obligation" section for further discussion).
Consolidation of regulatory guidance	Criticality analysis guidance (see NEI 12-16 item, below) will be incorporated into SRP 9.1.1 and 9.1.2 after NRC endorsement. The update will include any necessary changes in the SRP to align with NEI 12-16, as endorsed by the NRC.	This action is being tracked by OIG (see "Regulatory Outcome – SFP Criticality Analysis" section for further discussion). EDO tickets are used to track required biannual update memos to OIG.

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Participation in ANS 8.27 Standards Committee	Most recent version of ANS 8.27 was approved on November 10, 2015.	The NRC staff participated in the working group on behalf of SFP criticality for the NRC.
Nuclear Criticality Safety Technical Advisory Group	The TAG has been organized with representatives from NMSS, NRR, RES, and NRO to share information related to criticality.	The NRC staff has organized the TAG. Meetings occur on a bi-annual basis.
Review and endorsement of NEI 12-16	Scheduled to be complete in early 2018.	This action is being tracked by OIG (see "Regulatory Outcome – SFP Criticality Analysis" section for further discussion). EDO tickets are used to track required biannual update memos to OIG.
Review of Westinghouse criticality topical report	n/a	Westinghouse withdrew the document.
Review of EPRI depletion validation methodology	Scheduled to be complete prior to endorsement of NEI 12-16.	NEI 12-16 references the EPRI depletion validation methodology, so NRC approval of this methodology is a requirement for completion of the NEI 12-16 review. This action is being tracked by OIG (see "Regulatory Outcome – SFP Criticality Analysis" section for further discussion). EDO tickets are used to track required biannual update memos to OIG.
Develop a Significance Determination Process (SDP) related to SFPs including NAM degradation	n/a	Since the last update to this action plan, Inspection Procedures 60715 and 60801 have been approved with guidance related to neutron absorbers and their monitoring. The closeout of the Generic Letter is expected to lead to any additional regulatory actions necessary to resolve the outstanding issues with NAM degradation. At this time, adequate guidance is expected to exist to assist the regional staff in applying the ROP to SFP oversight.

CURRENT STATUS: Closed

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REFERENCES

1. 10 CFR 50.36, Technical Specifications.
2. 10 CFR 50.68, Criticality Accident Requirements.
3. 10 CFR 50 Appendix A, General Design Criteria for Nuclear Power Plants.
4. 10 CFR 70.24, Criticality Accident Requirements.
5. SRP 9.1.1, Criticality Safety of Fresh and Spent Fuel Storage and Handling.
6. SRP 9.1.2, New and Spent Fuel Storage.
7. Regulatory Guide 1.13, Spent Fuel Storage Facility Design Basis.
8. NRC Memorandum from L. Kopp to T. Collins, Guidance on the Regulatory Requirements for Criticality Analysis of Fuel Storage at Light-Water Reactor Power Plants," August 19, 1998. (ADAMS Accession No. ML003728001)
9. DSS-ISG-2010-01, Staff Guidance Regarding the Nuclear Criticality Safety Analysis Accompanying Spent Fuel Pool License Amendment Requests.
10. Information Notice 1987-43, "Gaps in Neutron-Absorbing Material in High-Density Spent Fuel Storage Racks," September 8, 1987.
11. Information Notice 1993-70, "Degradation of Boraflex Neutron Absorber Coupons," September 10, 1993.
12. Information Notice 1995-38, "Degradation of Boraflex Neutron Absorber in Spent Fuel Storage Racks," September 8, 1995.
13. Information Notice 2009-26, "Degradation of NAMs in the Spent Fuel Pool," October 28, 2009.
14. Information Notice 2011-03, "Nonconservative Criticality Safety Analyses for Fuel Storage," February 16, 2011.
15. Information Notice 2012-13, "Boraflex Degradation Surveillance Programs and Corrective Actions in the Spent Fuel Pool," August 10, 2012.
16. Information Notice 2014-09, "Spent Fuel Storage or Transportation System Misloading," June 20, 2014.

17. GL 1978-11, “Guidance on Spent Fuel Pool Modifications,” April 14, 1978.
18. GL 1979-04, Referencing 4/14/78 Letter – Modifications to NRC Guidance "Review and Acceptance of Spent Fuel Pool Storage and Handling," January 18, 1979.
19. GL 1996-04, “Boraflex Degradation in Spent Fuel Pool Storage Racks,” June 26, 1996.
20. GL 2016-01, “Monitoring of Neutron-Absorbing Materials in Spent Fuel Pools,” April 7, 2016.
21. RIS 2001-012, “Nonconservatism in Pressurized-Water Reactor Spent Fuel Storage Pool Reactivity Equivalencing Calculations,” May 18, 2001.
22. RIS 2005-005, “Regulatory Issues Regarding Criticality Analyses for Spent Fuel Pools and Independent Spent Fuel Storage Installations,” March 23, 2005.
23. NUREG/CR-6665, “Review and Prioritization of Technical Issues Related to Burnup Credit for LWR Fuel,” February 2000.
24. NUREG/CR-6698, “Guide for Validation of Nuclear Criticality Safety Calculational Methodology,” January 2001.
25. NUREG/CR-6801, “Recommendations for Addressing Axial Burnup in PWR Burnup Credit Analysis,” March 2003.
26. NUREG/CR-6811, “Strategies for Application of Isotopic Uncertainties in Burnup Credit,” June 2003.
27. NUREG/CR-6979, “Evaluation of the French Haut Taux de Combustion (HTC) Critical Experiment Data,” September 2008.
28. NUREG/CR-7108, “An Approach for Validating Actinide and Fission Product Burnup Credit Criticality Safety Analyses-Isotopic Composition Predictions,” April 2012.
29. NUREG/CR-7109, “An Approach for Validating Actinide and Fission Product Burnup Credit Criticality Safety Analyses-Criticality (Keff) Predictions,” April 2012.
30. Technical Letter Report, “Boraflex, RACKLIFE, and BADGER: Description and Uncertainties,” September 2012.
31. Technical Letter Report, “Initial Assessment of Uncertainties Associated with BADGER Methodology,” September 2012.
32. Technical Letter Report, “Monitoring Degradation of Phenolic Resin-Based Neutron Absorbers in Spent Nuclear Fuel Pools,” June 2013.
33. EPRI TR-1013721, 2009 Handbook of Neutron Absorber Materials for Spent Nuclear Fuel Transportation and Storage Applications, November 2009.