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NUCLEAR ENERGY INSTITUTE

May 26, 2017

Mr. Brian J. Benney
Project Manager, Division of Reactor Safety Systems
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Subject: Submittal of NEI 16-03, *Guidance for Monitoring of Fixed Neutron Absorbers in Spent Fuel Pools*, Revision 0, dated August 2016

Project Number: 689

Dear Mr. Benney:

On behalf of the nuclear energy industry, the Nuclear Energy Institute (NEI)[1] submits the attached approved topical report, NEI 16-03-A, *Guidance for Monitoring of Fixed Neutron Absorbers in Spent Fuel Pools,* Revision 0, dated May 2017 for U.S. Nuclear Regulatory Commission acknowledgement as a topical report.

The approved topical report contains the Final Safety Evaluation [1] and the RAI responses from Section 9.5 of NEI 12-16, Revision 1 [2] as Appendix B, in accordance with the instructions provided in the NRC letter dated March 3, 2017.

If you have any questions or require additional information, please contact me.

Sincerely,

Kristopher W. Cummings

[1] NEI is the organization responsible for establishing unified nuclear industry policy on matters affecting the nuclear energy industry, including the regulatory aspects of generic operational and technical issues. NEI's members include all utilities licensed to operate commercial nuclear power plants in the United States, nuclear plant designers, major architect/engineering firms, fuel fabrication facilities, materials licensees, and other organizations and individuals involved in the nuclear energy industry.

VERIFIED TRUE COPY

Attachment

c: Mr. William M. Dean, NRR, NRC
Mr. John Lubinski, NRR/DE, NRC
Mrs. Shana Helton, NRR/DSS, NRC
Mr. Matthew Yoder, NRR/DE/ESGB, NRC
Mr. Alex Chereskin, NRR/DE/ESGB, NRC
Mr. Brian J. Benney, NRR/DPR/PLPB, NRC

References

[1] Letter from Kevin Hseuh (NRC) to Kristopher Cummings (NEI), "Final Safety Evaluation for Nuclear Energy Institute Topical Report NEI 16-03 – Guidance for Monitoring of Fixed Neutron Absorbers in Spent Fuel Pools", March 3, 2017 (ML126354A486).

[2] Letter from Joseph J. Holonich (NRC) to Rod McCullum (NEI), "Request for Additional Information Related to NEI 12-16, 'Guidance for Performing Criticality Analysis of Fuel Storage At Light-Water Reactor Power Plants'", October 14, 2014 (ML14276A013).

NEI 16-03-A, Revision 0

Guidance for Monitoring of Fixed Neutron Absorbers in Spent Fuel Pools

May 2017

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

March 3, 2017

Mr. Kristopher Cummings
Senior Project Manager, Used Fuel Programs
Nuclear Energy Institute
1201 F Street, NW, Suite 1100
Washington, D.C. 20004

SUBJECT: FINAL SAFETY EVALUATION FOR NUCLEAR ENERGY INSTITUTE TOPICAL REPORT NEI 16-03 - GUIDANCE FOR MONITORING OF FIXED NEUTRON ABSORBERS IN SPENT FUEL POOLS (CAC NO. MF8122)

Dear Mr. Cummings:

By letter dated May 10, 2016 (Agencywide Documents Access Management System (ADAMS) Accession No. ML16147A078), as supplemented by letter dated August 30, 2016 (ADAMS Accession No. ML16265A248), the Nuclear Energy Institute (NEI), on behalf of the nuclear industry, submitted NEI 16-03, "Guidance for Monitoring of Fixed Neutron Absorbers in Spent Fuel Pools," Revision 0. The NEI submittal provides guidance for monitoring programs for fixed neutron absorbers in spent fuel pools as a means to demonstrate compliance with the applicable requirements in Title 10 of the *Code of Federal Regulations* Section 50.68, "Criticality Accident Requirements," with respect to the neutron absorbing materials.

By letter dated November 9, 2016 (ADAMS Accession No. ML16280A369), an NRC draft safety evaluation (SE) was provided for your review and comment. By letter dated December 21, 2016 (ADAMS Accession No. ML16356A601), the NEI provided comments (ADAMS Accession No. ML16356A602) on the U.S. Nuclear Regulatory Commission (NRC) draft SE. The comments provided by NEI were related to clarifications and accuracy. No proprietary information was identified in the draft SE. The NRC staff dispositioned the comments as shown in the attachment to the enclosed final SE.

The NRC staff has found that NEI 16-03, Revision 0 is acceptable for referencing in licensing applications for nuclear power plants to the extent specified in the enclosed final SE. The final SE defines the basis for our acceptance of the topical report (TR).

Our acceptance applies only to material provided in the subject TR. We do not intend to repeat our review of the acceptable material described in the TR. When the TR appears as a reference in licensing action requests, our review will ensure that the material presented applies to the specific plant involved. Request for licensing actions that deviate from this TR will be subject to a plant-specific review in accordance with applicable review standards.

In accordance with the guidance provided on the NRC website, we request that NEI publish an approved version within three months of receipt of this letter. The approved version shall incorporate this letter and the enclosed final SE after the title page.

Also, it must contain historical review information, including NRC requests for additional information (RAIs) and your responses. The approved version shall include an "-A" (designating approved) following the TR identification symbol.

As an alternative to including the RAIs and RAI responses behind the title page, if changes to the TR were provided to the NRC staff to support the resolution of RAI responses, and if the NRC staff reviewed and approved those changes as described in the RAI responses, there are two ways that the accepted version can capture the RAIs:

1. The RAIs and RAI responses can be included as an Appendix to the accepted version.
2. The RAIs and RAI responses can be captured in the form of a table (inserted after the final SE) which summarizes the changes as shown in the approved version of the TR. The table should reference the specific RAIs and RAI responses which resulted in any changes, as shown in the accepted version of the TR.

If future changes to the NRC's regulatory requirements affect the acceptability of this TR, NEI will be expected to revise the TR appropriately or justify its continued applicability for subsequent referencing. Licensees referencing this TR would be expected to justify its continued applicability or evaluate their plant using the revised TR.

Sincerely,

Kevin Hsueh

Kevin Hsueh, Chief
Licensing Processes Branch
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

Project No. 689

Enclosure:
Final SE

FINAL SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

NUCLEAR ENERGY INSTITUTE TOPICAL REPORT NEI 16-03

"GUIDANCE FOR MONITORING OF FIXED NEUTRON ABSORBERS

IN SPENT FUEL POOLS"

PROJECT NO. 689

1.0 INTRODUCTION

By letter dated May 10, 2016 (Agencywide Documents Access Management System (ADAMS) Accession No. ML16147A078), as supplemented by letter dated August 30, 2016 (ADAMS Accession No. ML16265A248), the Nuclear Energy Institute (NEI), on behalf of the nuclear industry, submitted NEI 16-03, "Guidance for Monitoring of Fixed Neutron Absorbers in Spent Fuel Pools," Revision 0. The purpose of the document is to provide guidance for licensees to develop an acceptable fixed neutron absorber monitoring program in spent fuel pools (SFPs) as a means to demonstrate compliance with applicable regulations in Section 50.68 of Title 10 of the *Code of Federal Regulations* (10 CFR), "Criticality Accident Requirements," 10 CFR Part 50, Appendix A, General Design Criterion (GDC) 61, "Fuel Storage and Handling and Radioactivity Control," and 10 CFR Part 50, Appendix A, GDC 62 "Prevention of Criticality in Fuel Storage and Handling," with respect to neutron absorbing materials (NAMs).

2.0 REGULATORY EVALUATION

The effectiveness of the NAM installed in SFP storage racks ensures that the effective neutron multiplication factor (k_{eff}) does not exceed the values and assumptions used in the criticality analysis of record (AOR) and other licensing basis documents. The AOR is the basis, in part, for demonstrating compliance with plant technical specifications and with applicable the U.S. Nuclear Regulatory Commission (NRC) regulations. Degradation or deformation of the credited NAM may reduce safety margin and potentially challenge the subcriticality requirement. NAMs utilized in SFP racks exposed to treated water or treated borated water may be susceptible to reduction of neutron absorbing capacity, changes in dimension, and/or loss of material that increases k_{eff}. A monitoring program is implemented to ensure that degradation of the NAM used in SFPs, which could compromise the ability of the NAM to perform its safety function as assumed in the AOR, will be detected. NRC's regulatory requirements and corresponding staff review criteria and guidance for NAM monitoring programs are contained in the following documents:

- 10 CFR 50.68(b)(4), "Criticality accident requirements," states that if the licensee does not credit soluble boron in the SFP criticality AOR, the k_{eff} of the SFP storage racks must not exceed 0.95 at a 95 percent probability, 95 percent confidence level. If the licensee does take credit for soluble boron, the k_{eff} of the SFP storage racks must not exceed 0.95 at a 95 percent probability, 95 percent confidence level, if flooded with borated water, and if flooded with unborated water, the k_{eff} must remain below 1.0 at a 95 percent probability, 95 percent confidence level.

- GDC 61, "Fuel storage and handling and radioactivity control," states that "The fuel storage and handling, radioactive waste, and other systems which may contain radioactivity shall be designed to assure adequate safety under normal and postulated accident conditions. These systems shall be designed (1) with a capability to permit appropriate periodic inspection and testing of components important to safety..."

- GDC 62, "Prevention of Criticality in Fuel Storage and Handling," states that "Criticality in the fuel storage and handling system shall be prevented by physical systems or processes, preferably by use of geometrically safe configurations."

- NUREG-0800, "Standard Review Plan [(SRP)]," Section 9.1.1, Revision 3, "Criticality Safety of Fresh and Spent Fuel Storage and Handling" (ADAMS Accession No. ML070570006) provides guidance regarding the acceptance criteria and review procedures to ensure that the proposed changes satisfy the requirements in 10 CFR 50.68.

- NUREG-0800, "Standard Review Plan," Section 9.1.2, Revision 4, "New and Spent Fuel Storage" (ADAMS Accession No. ML070550057) provides guidance regarding the acceptance criteria and review procedures to ensure that the proposed changes satisfy the requirements in 10 CFR 50.68.

- NUREG-1801, "Generic Aging Lessons Learned (GALL) Report," Revision 2 (ADAMS Accession No. ML103490041) provides guidance on what constitutes an acceptable monitoring program for NAMs providing criticality control in the SFP.

3.0 TECHNICAL EVALUATION

Guidance for developing a NAM monitoring program for NAM in the SFP is provided in NEI 16-03. The purpose of a NAM monitoring program is to verify that the NAM installed in SFPs continues to provide the criticality control relied upon in the AOR, and help to maintain the subcriticality margin in accordance with 10 CFR 50.68 requirements. The guidance provided in NEI 16-03 for a NAM monitoring program, relies on periodic inspection, testing, monitoring, and analysis of the NAM. To accomplish this purpose, the guidance document states that a monitoring program must be capable of identifying unanticipated changes in the absorber material and determining whether anticipated changes can be verified. The guidance recommends the use of coupon testing, in-situ measurement, and/or SFP water chemistry monitoring as a means to monitor potential changes in characteristics of the NAM. The NRC staff reviewed the proposed guidance for what constitutes an acceptable monitoring program and its ability to ensure that potential degradation of SFP NAM will be detected, monitored, and mitigated. The staff determined that an appropriate combination of the three methods listed above (coupon testing, in-situ measurement, and/or SFP water chemistry monitoring) can comprise an effective NAM monitoring program. During the course of the NRC staff's review, there were several topics identified in the guidance that required clarification. A Category 2 public meeting was held with NEI on August 10, 2016, to seek clarification on these topics. The NRC staff and NEI representatives discussed these topics and NEI subsequently submitted a revision to NEI 16-03.

A meeting summary is included as a reference (ADAMS Accession No. ML16209A375) in this safety evaluation (SE) that describes the topics that were discussed at the public meeting, as well as the changes that were made to the guidance document as a result of the discussion.

3.1 Coupon Testing Program

3.1.1 Description of NEI 16-03

The guidance document states that the use of a coupon testing program is the preferred method for a neutron absorber monitoring program. This program consists of small sections (coupons) of the same NAM installed in the SFP, which are attached to a structure (coupon tree) in the SFP. The coupon tree is placed near freshly discharged fuel assemblies in an attempt to accelerate potential degradation mechanisms. The document provides the following criteria for an acceptable coupon program:

- The number of coupons needs to be adequate to allow for sampling at interval for the intended life of the absorbers.
- The sampling intervals are based on the expected rate of material change.
- Performance of coupon testing
    - Basic testing: visual observations, dimensional measurements, and weight
    - Full testing: density measurements, Boron-10 (^{10}B) areal density (AD) measurements, microscopic analysis, and characterization of changes, in addition to the basic testing parameters

The guidance document states that the coupons will be located in the SFP "such that their exposure to parameters controlling change mechanisms is conservative or similar to the in-service neutron absorbers." For neutron attenuation testing, NEI 16-03 provides acceptance criteria for the NAM depending on if there is, or is not, an anticipated loss of ^{10}B AD. The acceptable result for NAMs with expected ^{10}B AD loss is the ^{10}B AD of the test coupon is greater than the ^{10}B AD assumed in the licensee's SFP criticality AOR. For NAM without an expected loss of ^{10}B AD, the acceptable result is the ^{10}B AD of the test coupon is equal to the original ^{10}B AD of the coupon (within measurement uncertainty). Furthermore, the guidance states that the acceptable initial sampling interval for testing of new material (i.e., with a limited, or no, operating history) is up to 5 years, with subsequent intervals up to 10 years. For those materials that have well documented operating experience, do not have a history of degradation or degradation mechanisms, and information on stability of the material condition is well developed, the document states initial and subsequent test intervals up to 10 years are acceptable. The document states that for materials with known degradation mechanisms, or a history of known degradation (e.g., Boraflex, Carborundum, Tetrabor, etc.), the acceptable interval for neutron attenuation testing is at least once every five years. In addition, NEI 16-03 includes neutron attenuation testing in the full testing approach for any NAMs used, as a component of a satisfactory NAM monitoring program.

3.1.2 NRC Staff Evaluation

The NRC staff has evaluated the guidance for the basic and full portions of a coupon testing program. The basic portion of the testing includes methods to monitor the physical condition of

the NAM so that signs of potential degradation may be observed. The full portion of the testing includes neutron attenuation testing for all NAMs that are credited in the SFP criticality analysis that will allow the licensee to detect a potential loss in ^{10}B AD. The staff finds the coupon testing program to be acceptable because it includes measurements of ^{10}B AD and of dimensional changes in the material that can impact the ability of the NAM to perform its function as assumed in the licensee's SFP criticality AOR.

The NRC staff also determined the acceptance criteria for the coupon testing program provided in NEI 16-03 is acceptable. The acceptance criteria provides reasonable assurance that the assumptions regarding the AD of the NAM in the licensee's SFP criticality AOR will be maintained, because the acceptance criteria show that the material is either not losing ^{10}B AD (for materials not expected to lose ^{10}B AD), or the ^{10}B AD is still above the ^{10}B AD assumed in the licensee's SFP criticality AOR (for NAM anticipated to lose ^{10}B AD). In addition, the NRC staff recognizes that if a coupon being tested approaches the ^{10}B AD value used in the licensee's SFP criticality AOR, the licensee would likely need to perform further evaluations and/or take additional corrective actions to provide reasonable assurance that the in-service NAM will not degrade below the ^{10}B AD assumed in the licensee's SFP criticality AOR. Guidance on additional corrective actions that may be necessary is given in Section 2.3, "Evaluating Neutron Absorber Test Results," of NEI 16-03, and this guidance is evaluated in Section 3.3 of this SE.

3.2 In-Situ Measurement Program

3.2.1 Description of NEI 16-03

The NEI guidance document states that in-situ measurement is another method that can be used to confirm ^{10}B AD of NAM. It further states that this method can be used to supplement coupon monitoring to extend the coupon testing interval, permit greater reliance on basic testing, or in lieu of coupon testing for plants that may no longer have coupons in the SFP. It also states that in-situ measurement can be used instead of coupon testing if coupons do not exist.

The guidance states that all in-situ measurement campaigns are to be performed at an acceptable interval and on an adequate number of panels. The guidance gives two options for determining what constitutes an adequate number of panels. The first option uses the methodology of NUREG-6698 (ADAMS Accession No. ML050250061) to measure a minimum of 59 panels to provide 95/95 confidence limits. The second option selects the panels with the greatest exposure (top 5%) to parameters that influence degradation (e.g., neutron fluence, temperature, time). The amount of panels will be no less than one percent of the total panels in the SFP, although more panels can be tested from other areas of the SFP to gain a more representative sampling. The guidance also states sources of uncertainty in the in-situ measurement will be identified and quantified.

The sampling interval will be based upon the NAM credited in the SFP. New materials with minimal operating experience will have an initial test interval that does not exceed 5 years, with subsequent intervals up to 10 years (with appropriate operating experience). For materials with known histories of degradation and known degradation mechanisms, test intervals do not exceed 5 years. For other materials that do not have known histories of degradation or known

degradation mechanisms test intervals will not exceed 10 years. The guidance also states that if used in conjunction with a coupon monitoring program, the in-situ sampling interval can be longer.

The NEI document also provides acceptance criteria for in-situ measurements. It states that for NAMs that do not have potential degradation mechanisms for loss of ^{10}B AD, results of the in-situ measurements are acceptable if the nominal measured ^{10}B AD is greater than or equal to the value assumed in the licensee's criticality AOR (within measurement uncertainties). For materials that have potential degradation mechanisms that result in loss of ^{10}B AD, results are considered acceptable if the nominal measured ^{10}B AD minus measurement uncertainty is greater than the ^{10}B AD in the licensee's criticality AOR.

3.2.2 NRC Staff Evaluation

The NRC staff has reviewed the guidance for performing in-situ measurement testing and finds it to be acceptable, because it allows for detection of degradation mechanisms, potential loss of neutron absorption capacity (e.g. loss of ^{10}B), and ensure the NAM will continue to provide the criticality control relied upon in the AOR. The NRC staff reviewed the methodology recommended for determining the number of panels that may be selected for in-situ inspection and finds it to be acceptable because it is based in part on guidance provided in NUREG-6698, "Guide for Validation of Nuclear Criticality Safety Calculational Methodology," or on selecting panels that have experienced the greatest exposure to the SFP environment. The NRC staff also finds that depending on the population of NAM panels in the SFP, a licensee may need to measure more than the minimum of 59 panels in order to produce 95/95 confidence limits. The method used for selecting the panels for in-situ testing is used to obtain data that is bounding or representative of the entire NAM in the SFP.

In addition, the NRC staff has determined that the proposed testing intervals (intervals not to exceed 10 years for materials with no known history of degradation/degradation mechanisms, and 5 years for materials with a known history of degradation/degradation mechanisms or for new materials (i.e., no operating history)) are acceptable and consistent with NRC guidance in the GALL Report, Revision 2. The neutron attenuation testing must be performed on the intervals as described in the document, regardless of how the licensee uses the in-situ monitoring program (e.g., in conjunction with coupons, without coupon program, or other reasons as described in NEI 16-03). The statement in the guidance that the in-situ sampling interval can be longer if used in conjunction with a coupon program does not obviate the need to perform neutron attenuation testing on intervals not to exceed 5 or 10 years (depending on the NAM used and associated operating experience).

In addition, the NRC staff finds it to be acceptable to identify and evaluate sources of uncertainty in order to assess the reliability of the instruments and methodology used to the collect the data. Sources of uncertainty can greatly impact results and confidence in the data collected, especially as it relates to the subcriticality margin.

3.3 Evaluating Neutron Absorber Test Results

3.3.1 Description of NEI 16-03

The guidance document states that the test results from neutron absorber monitoring may fall within the following categories:

1) Confirmation that no material changes are occurring,
2) Confirmation that anticipated changes are occurring, and/or
3) Identification that unanticipated changes are occurring.

Furthermore, the guidance document states that the testing results will be compared to the AOR input (i.e., ^{10}B AD assumed in criticality AOR). If no changes, or if anticipated changes are occurring, then the guidance assumes that the material continues to be adequately represented in the AOR.

The guidance document also describes the additional actions that may be necessary when unanticipated changes in the NAM are identified. It states that there are certain technical evaluations that may be necessary in addition to any required regulatory or licensing processes. The technical evaluations include a determination if these changes may result in a loss of ^{10}B AD. Any potential impacts of a loss of ^{10}B AD on the SFP criticality AOR will be evaluated and addressed through licensee processes. In addition, the results of monitoring and testing are to be evaluated and trended, regardless of potential impact on the SFP criticality AOR. If the unanticipated changes do not appear to result in the loss of ^{10}B AD, the changes will still be evaluated for impacts on the SFP criticality AOR. The effects on the SFP criticality AOR due to potential dimensional changes of the NAM, or other material in the SFP, are evaluated and addressed in accordance with licensee processes.

3.3.2 NRC Staff Evaluation

The NRC staff has reviewed the actions described in the guidance for when potential degradation is detected in the neutron absorbing material as potential degradation of the NAM may impact ^{10}B AD assumptions in the SFP criticality AOR. The NRC staff finds the actions described in the guidance acceptable because they will be able to identify anticipated, and unanticipated changes in order to provide information that will allow a licensee to determine whether or not the neutron absorbing material is performing its safety function as assumed in the AOR.

The NRC staff has also determined that it is necessary to evaluate and trend the results of ^{10}B AD measurements from neutron attenuation testing in the NAM as described in NEI 16-03. The NRC staff finds the methods, and requirement, to trend data acceptable because it will provide information regarding the potential degradation mechanism(s) and rate for the NAM in the SFP. This information will also help to provide reasonable assurance that the ^{10}B AD of the NAM will not decrease below the value assumed in the SFP criticality AOR between the specified test intervals for neutron attenuation testing. In addition, this data can identify previously un-evaluated degradation mechanisms that may have an impact on the SFP criticality AOR.

The actions described above ensure, in part, that the ability of the NAM to provide the criticality control relied upon in the AOR, is maintained.

3.4 Technical Evaluation Conclusion

The NRC staff has determined that in order for a NAM monitoring program to be acceptable, the licensee must perform neutron attenuation testing at the intervals stated in NEI 16-03. The NRC staff finds the interval for inspection and testing acceptable because the frequency is determined based on the neutron absorbing material credited, and operating experience of that material. Depending on the material used, the interval for neutron attenuation testing will not exceed 5 years (for materials with a history of known degradation or a known degradation mechanism, and new materials), or 10 years (for other materials that do not have a history of degradation, or a known degradation mechanism). Periodic neutron attenuation testing, and the intervals described in NEI 16-03 are consistent with staff guidance (i.e., the GALL Report, Revision 2). Licensees must request site-specific NRC review and approval to extend the interval of any neutron attenuation testing past the approved intervals, as described in NEI 16-03.

The NRC staff also finds that it would not meet the acceptance criteria in a NAM monitoring program for the measurement uncertainty to result in a ^{10}B AD value that is lower than the assumed value in the SFP criticality AOR. The staff expects that if a given test result shows a ^{10}B AD value lower than the value assumed in the SFP criticality AOR, the licensee will take the appropriate corrective actions in accordance with licensee programs and processes.

Based on its review of NEI 16-03, the NRC staff has determined that a NAM monitoring program meeting the provisions in NEI 16-03 will allow a licensee to reasonably ensure that the ability of the NAM to provide the criticality control relied upon in the AOR, is maintained, thus demonstrating compliance with the subcriticality requirements of 10 CFR 50.68.

4.0 CONCLUSION

The NRC staff has reviewed NEI 16-03, and the proposed methods for developing a NAM monitoring program. A NAM monitoring program implementing the proposed guidance provides reasonable assurance that such program will be able to detect degradation of neutron absorbing material, and provides assurance that the ability of the NAM to provide the criticality control relied upon in the AOR, is maintained. The NRC staff finds that the requirements of 10 CFR 50.68(b)(4), GDC 61, and GDC 62, as well as the guidance provided in SRP 9.1.1, SRP 9.1.2, and the GALL, Revision 2, with respect to NAMs and the NAM monitoring program, are satisfied. Therefore, the NRC staff finds the proposed guidance in NEI 16-03 acceptable for developing a NAM monitoring program.

5.0 REFERENCES

1. Letter from Kristopher W. Cummings to Timothy J. McGinty, "Submittal of NEI 16-03, Guidance for Monitoring of Fixed Neutron Absorbers in Spent Fuel Pools, Draft A, dated May 2016," May 10, 2016 (ADAMS Accession No. ML16147A078).

2. Letter from Kristopher W. Cummings to Brian J. Benney, "Submittal of NEI 16-03, Guidance for Monitoring of Fixed Neutron Absorbers in Spent Fuel Pools, Revision 0, dated August 2016," August 30, 2016 (ADAMS Accession No. ML16265A248).

3. U.S. Code of Federal Regulations, "Criticality accident requirements," Title 10 of the *Code of Federal Regulations*, Section 50.68(b)(4).

4. U.S. Code of Federal Regulations, "Domestic Licensing of Production and Utilization Facilities – Proposed General Design Criteria for Nuclear Power Plants," Part 50, Appendix A.

5. U.S. Nuclear Regulatory Commission, "Standard Review Plan, Section 9.1.1, Criticality Safety of Fresh and Spent Fuel Storage and Handling," NUREG-0800, Revision 3, March 2007 (ADAMS Accession No. ML070570006).

6. U.S. Nuclear Regulatory Commission, "Standard Review Plan, Section 9.1.2, New and Spent Fuel Storage," NUREG-0800, Revision 4, March 2007 (ADAMS Accession No. ML070550057).

7. U.S. Nuclear Regulatory Commission, "Generic Aging Lessons Learned (GALL) Report," NUREG-1801, Revision 2, December 2010 (ADAMS Accession No. ML103490041).

8. U.S. Nuclear Regulatory Commission Category 2 Public Meeting, 'Summary of August 10, 2016, Meeting with the Nuclear Energy Institute to Discuss NEI 16-03, "Guidance for Monitoring of Fixed Neutron Absorbers in Spent Fuel Pools,"' September 27, 2016 (ADAMS Accession No. ML16209A375).

9. U.S. Nuclear Regulatory Commission, "Guide for Validation of Nuclear Criticality Safety Calculational Methodology," NUREG/CR-6698, January 2001 (ADAMS Accession No. ML050250061).

Principle Contributor: Alex Chereskin, NRR/DE/ESGB

Date: March 3, 2017

NEI 16-03 Comment Resolution on Draft Safety Evaluation

Comment Number	Location	Comment	Comment Resolution
1	Safety Evaluation (SE) Page 1, Section 2.0, line 27	Insert "continued effectiveness of the"	Incorporate in part – revise insert to say "effectiveness of the"
2	SE Page 1, Section 2.0, line 27	Replace "monitor" with "material"	Incorporate comment – this was editorial.
3	SE Page 1, Section 2.0, line 34	Add "/or"	Incorporate comment – this was editorial.
4	SE Page 2, Section 2.0, line 24	Replace "credited for" with "providing"	Incorporate comment – this was editorial.
5	SE Page 2, Section 3.0, line 30	Delete "perform its safety function (i.e., criticality control) as assumed" and replace with "(provide the criticality control) relied upon"	Incorporate comment – this was editorial.
6	SE Page 2, Section 3.0, lines 32-33	Delete "to ensure that the required subcriticality margin is maintained in accordance with 10 CFR 50.68 requirements"	Incorporate in part – Delete the recommended part and add ", and help to maintain the subcriticality margin in accordance with 10 CFR 50.68 requirements."
7	SE Page 2, Section 3.0, line 36	Delete "a combination" and replace with "the use"	Incorporate comment – this was editorial.
8	SE Page 2, Section 3.0, line 37	Add "/or"	Incorporate comment – this was editorial.
9	SE Page 2, Section 3.0, line 42	Add "/or"	Incorporate comment – this was editorial.
10	SE Page 4, Section 3.1.2, line 9	Add "s"	Incorporate comment – this was editorial.
11	SE Page 4, Section 3.1.2, line 10	Add "regarding the AD of the NAM"	Incorporate comment – The U.S. Nuclear Regulatory Commission (NRC) staff agrees that this clarifies the intent of the Neutron Absorbing Material (NAM) monitoring program only applies to the assumptions regarding the NAM in the licensee's Spent Fuel Pool (SFP) criticality Analysis of Record (AOR).

Attachment

Comment Number	Location	Comment	Comment Resolution
12	SE Page 4, Section 3.1.2, lines 13-15	"Is it not clear what this statement means. The wording in Section 3.1.1, Page 3, lines 30-32 provides more clarity. (i.e., within measurement uncertainty). The last bullet in Section 2.1 of [Nuclear Energy Institute Topical Report NEI 16-03] NEI 16-03 provides the acceptance criteria for the neutron absorber monitoring program. The measurement uncertainty could result in an areal density lower than the value assumed in the AOR, however, whether this is acceptable or not depends on whether the NAM is or is not "anticipated to have a loss of ^{10}B areal density" [last bullet of Section 2.1] No wording change is proposed, because the intent of the NRC statement is not clear."	Partially Incorporate Comment – the intent of the NRC staff is to make it clear that when incorporating measurement uncertainty into the as-measured ^{10}B AD value, a value lower than assumed in the SFP criticality analysis AOR would not meet the acceptance criteria, regardless of the NAM used, or type of monitoring program (coupons or in-situ testing). Therefore, the staff has deleted these lines from Section 3.1.2, and created new text in Section 3.4 "Technical Evaluation Conclusion" to clarify this position. The text reads as follows "The NRC staff also finds that it would not meet the acceptance criteria in a NAM monitoring program for the measurement uncertainty to result in a ^{10}B AD value that is lower than the assumed value in the SFP criticality AOR. The staff expects that if a given test result shows a ^{10}B AD value lower than the value assumed in the SFP criticality AOR, the licensee will take the appropriate corrective actions in accordance with licensee programs and processes."
13	SE Page 4, Section 3.1.2, line 16	Delete "limit as stated" and replace with "value used"	Incorporate comment – this was editorial.
14	SE Page 4, Section 3.1.2, lines 19-20	Revise to read "degrade below the ^{10}B AD assumed in the licensee's SFP criticality AOR."	Incorporate comment – this was editorial.
15	SE Page 5, Section 3.2.2, lines 19-20	Delete "perform its safety function" and replace with	Incorporate comment – this was editorial.

Comment Number	Location	Comment	Comment Resolution
		"provide the criticality control relied upon in the AOR."	
16	SE Page 5, Section 3.2.2, line 24	Delete "and" and replace with "or"	Incorporate comment – this clarifies that either option may be used, and not both
17	SE Page 5, Section 3.2.2, lines 25-27	NEI asked for clarification on this statement as NEI feels that 59 randomly sampled panels, independent of pool size, provide a 95/95 confidence limit according to NUREG-6698.	Reject comment – NUREG-6698 states "... at **least** 59 critical experiments will need to be included in the validation in order to attain a 95% degree of confidence the 95% of the population lies above the smallest observed value" (emphasis added). The NRC staff statement in the SE means that this topical report does not allow for only testing 59 panels without a licensee evaluation that shows how it produces 95/95 confidence limits. Licensees need to evaluate their sampling procedures to ensure they produce 95/95 confidence limits regardless of the number of panels selected. Additionally, Option 1 in Section 2.2 on page 5 of NEI 16-03, Revision 0, states that the licensee can "Take a measurement of a minimum of 59 panels...." This statement is not consistent with the comment from NEI.
18	SE Page 6, Section 3.3.1, line 22	Delete "procedures" and replace with "processes."	Incorporate comment – this was editorial.
19	SE Page 6, Section 3.3.1, line 27	Delete "procedures" and replace with "processes."	Incorporate comment – this was editorial.
20	SE Page 7, Section 3.3.2, lines 1-2	Delete "perform its safety function as assumed" and replace with "provide the criticality control relied upon"	Incorporate comment – this was editorial.
21	SE Page 7, Section 3.4, line 21	Delete "perform its safety function as assumed" and	Incorporate comment – this was editorial.

Comment Number	Location	Comment	Comment Resolution
		replace with "provide the criticality control relied upon"	
22	SE Page 7, Section 4.0, line 28	Delete "implanting" and replace with "implementing"	Incorporate comment – this was editorial.
23	SE Page 7, Section 4.0, lines 30-31	Delete "perform its safety function as assumed" and replace with "provide the criticality control relied upon"	Incorporate comment – this was editorial.
24	SE Page 8, Section 5.0, line 10	Replace "9.1.1" with "9.1.2"	Incorporate comment – this was editorial.
25	SE Page 8, Section 5.0, lines 22-23	Replace "Safe Calculation" with "Safety Calculational"	Incorporate comment – this was editorial.

NEI 16-03-A, Revision 0

Nuclear Energy Institute

Guidance for Monitoring of Fixed Neutron Absorbers in Spent Fuel Pools

May 2017

ACKNOWLEDGEMENTS

This guidance was developed by the NEI Criticality Task Force. We also recognize the direct participation of the licensees and vendors who contributed to the development of the guidance. The dedicated and timely effort of the many participants, including management support of the effort, is greatly appreciated. Finally, we would like to thank the U.S. Nuclear Regulatory Commission for providing feedback during a series of public meetings between September 2013 and February 2014 and RAIs on the neutron absorber monitoring program contained in NEI 12-16 that led to this guidance document.

NOTICE

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FOREWORD

This guidance describes acceptable methods that may be used by industry to monitor fixed neutron absorbers in PWR and BWR spent fuel pools to ensure that aging effects and corrosion and/or other degradation mechanisms are identified and evaluated prior to loss of the intended safety function.

At the request of Nuclear Regulatory Commission staff [14], this document was created as a stand-alone guidance document from Section 9.5 of NEI 12-16, Revision 1, which was submitted to the NRC for endorsement in April 2014. The proposed monitoring program contained herein has been updated based upon discussions with the NRC with input from responses to NRC Requests for Additional Information, dated November 16, 2015 (Adams Accession number ML15273A056). Individual vendors or licensees may deviate from the method supplied herein, with appropriate justification and approval by the NRC.

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APPENDIX A: RESPONSES TO NRC RAIS A-1

ABBREVIATIONS AND ACRONYMS

BWR	Boiling Water Reactor
CAP	Corrective Action Program
CFR	Code of Federal Regulations
EPRI	Electric Power Research Institute
ISG	Interim Staff Guidance
LAR	License Amendment Request
LWR	Light Water Reactor
NEI	Nuclear Energy Institute
NRC	Nuclear Regulatory Commission
PWR	Pressurized Water Reactor
QA	Quality Assurance
SFP	Spent Fuel Pool

1 INTRODUCTION

1.1 PURPOSE

This document provides acceptable methods for monitoring of neutron absorbers in spent fuel storage rack at nuclear power plants. This guidance is applicable to both Boiling Water Reactor (BWR) and Pressurized Water Reactor (PWR) spent fuel pools.

This document is developed to provide comprehensive and durable guidance to improve consistency and clarity for implementing neutron absorber monitoring programs. It is envisioned that this guidance will be reviewed and approved as a Topical Report by the NRC in accordance with NRR Office Instruction LIC-500 [15].

1.2 BACKGROUND

Spent fuel storage racks were originally designed to preclude a criticality event through geometric separation and neutronic decoupling of the spent fuel assemblies by a large distance, with no neutron absorbers. However, as reprocessing no longer became a viable option and the federal regulatory progress was delayed, nuclear plants were faced with storing a greater number of discharged spent fuel assemblies in the spent fuel pool. Since the original racks utilized geometric spacing as the primary method of criticality control, a large part of the spent fuel pool was not efficiently utilized for storage.

Beginning in the late 1970s, industry proposed installing high-density storage racks in the spent fuel pool to accommodate the discharged fuel. Since the fuel assemblies were now placed closer together, other means needed to be employed to preclude a criticality event, namely fixed neutron absorbers installed between each storage cell. Many types of neutron absorbers have been used over the past four decades, but in all cases, the primary neutron absorbing isotope is ^{10}B, which has a large thermal cross-section, and therefore is ideal for absorbing neutrons in the spent fuel pool (i.e., in a system with a strong moderator such as water).

In conjunction with the use of fixed neutron absorbers, the NRC required continual demonstration of the efficacy of the installed neutron absorber, through monitoring of the behavior of the neutron absorber via coupons or in-situ measurements [9]. The frequency of inspections and criteria for inspection was determined on a case-by-case basis, depending upon the type of material, historical operating experience for the specific material to be used, and other factors during the license amendment request process. In some cases, sufficient operating experience was acquired over several decades to allow individual licensees not to need coupons or in-situ examinations, but to rely on the collective industry experience.

With nuclear power reactors, and their associated spent fuel pools, undergoing license renewal for an additional 20 years, the NRC developed guidance of fixed neutron absorbers to support aging management programs for spent fuel pools in NUREG-1801, Revision 2 [10].

1.3 APPLICABLE REGULATIONS

The following regulations are applicable to neutron absorber materials for nuclear fuel storage at LWR facilities:

- Title 10 of the *Code of Federal Regulations* (10 CFR) 50 Appendix A, General Design Criteria for Nuclear Power Plants Criterion 61, "Fuel Storage and Handling and Radioactivity Control." [4]

- Title 10 of the *Code of Federal Regulations* (10 CFR) 50 Appendix A, General Design Criteria for Nuclear Power Plants Criterion 62, "Prevention of Criticality in Fuel Storage and Handling." [3]

- Title 10 of the *Code of Federal Regulations* (10 CFR) 50 Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants." [5]

- Title 10 of the *Code of Federal Regulations* (10 CFR) 50.36, "Technical Specifications." [6]

It is noted that in addition to the applicable regulations, the NRC has developed associated staff review guidance associated with neutron absorbers for nuclear fuel storage at LWR facilities.

- NUREG-0800, Standard Review Plan, Section 9.1.1, "Criticality Safety of Fresh and Spent Fuel Storage and Handling," Revision 4. [8]

- NUREG-0800, Standard Review Plan, Section 9.1.2, "New and Spent Fuel Storage," Revision 3. [9]

- NUREG-1801, Revision 2, "Generic Aging Lesson Learned (GALL) Report," Revision 2, December 2010. [10]

2 NEUTRON ABSORBER MONITORING PROGRAMS[1]

Neutron absorbers serve as an important material to control reactivity in most spent fuel pool storage racks. Neutron absorber monitoring programs are developed with the purpose of verifying that the neutron absorbers continue to provide the criticality control relied upon in the criticality analyses. To accomplish this, the monitoring program must be capable of identifying whether changes to the material are occurring, and if those changes are occurring that the anticipated characteristics of change can be verified.

A neutron absorber monitoring program may rely on a combination of the following approaches: 1) Installation of a neutron absorber coupon tree with periodic removal and testing of neutron absorber coupons; 2) In-situ measurements of the neutron absorbing capability of the installed neutron absorber panels, 3) Spent fuel pool water chemistry monitoring. Alternative approaches are also acceptable if adequately justified. A monitoring program consists of identifying original

[1] While these guidelines for neutron absorber monitoring programs are intended for initial license applications and license amendment requests that install new neutron absorber materials, they may be useful for licensee's consideration in license renewal applications under 10 CFR Part 54.

material characteristics and testing, awareness of ongoing research and development, participation in industry groups that share operating experience amongst plants, and evaluation of the relevance of outside data on the in-service material. Acceptance criteria provide the basis for the comparison of results in order to determine whether material performance is acceptable or actions are necessary to address performance issues.

2.1 COUPON TESTING PROGRAM

Use of coupons is the preferred method for a neutron absorber monitoring program. The coupon testing program consists of a population of small sections of the same neutron absorber installed in the storage racks. These coupons can either be encased in the same material as the storage rack structure, to simulate the geometry of the storage rack, or they may remain fully exposed to the spent fuel pool environment. The coupons are generally attached to a structure that can be placed in a spent fuel rack storage cell, referred to as a "coupon tree". The coupon tree is placed in a location in the spent fuel pool, near freshly discharged fuel assemblies, to generate an accelerated rate of accumulated exposure to those parameters that may impact aging/degradation mechanisms.

A coupon testing program consists of the following elements:

- The number of coupons needs to be sufficient to provide sampling at an appropriate interval for the intended life of the neutron absorber. The intended life of the neutron absorber is based upon the amount of time the neutron absorber will be relied upon to provide criticality control. This is typically the life of the plant (including license renewal) plus some additional time to permit off-loading the spent fuel pool during decommissioning.

- Sampling intervals are based upon the expected rate of material changes, which may be influenced by the qualification testing of the material. For new materials that do not have applicable operating experience in conditions similar to the pool environment (i.e. their ability to perform over time is not well known), the initial interval of 5 years, with subsequent intervals up to 10 years is acceptable. For materials that have been used for several years in conditions similar to the pool environment (i.e. their ability to perform is well known), and for which stability of the material condition has been documented, initial and subsequent intervals up to 10 years is acceptable.

- Coupon testing is categorized as a combination of basic and full testing. The coupon testing is used to identify whether unanticipated changes are occurring. If they are, the condition of the neutron absorber material is determined to evaluate further actions. The extent to which each of these is utilized are determined based upon the operating history of the material, as follows:

  a) Basic testing consists of visual observations, dimensional measurements, and weight that may be performed at the spent fuel pool. These parameters focus on identification of whether changes are occurring in the materials. Basic testing is appropriate when previous testing and operating experience of the material indicates that there are no degradation mechanisms that would result in loss of ^{10}B areal density that would affect reactivity. Basic testing will occur at least every 10 years.

b) Full testing may consist of a combination of mass-density measurements, ^{10}B areal density measurements, microscopic analysis, and characterization of changes, in addition to the basic testing parameters. These parameters focus on quantifying changes if they are occurring in the materials. Basic testing may be used in combination with full testing for materials that have degradation resulting in loss of ^{10}B areal density to extend the interval of full testing, if appropriately justified. The ^{10}B areal density measurement will occur at least every ten years.* For materials with known degradation or degradation mechanisms that impact the efficacy of the neutron absorber (e.g., Boraflex, Carborundum, Tetrabor or other phenolic resin based materials), the measurement of the areal density at least once every 5 years is acceptable.

*Note: Licensees that are nearing exhaustion of the originally installed coupons in the spent fuel pool, and have a compelling need to extend the life of the neutron absorber coupon monitoring program, may seek NRC review and approval of an exception to the prescribed periodic areal density measurements. This exception would be explored on a site-specific basis, subject to NRC review and approval, supported by the data from the previous neutron absorber coupon measurements that the neutron absorber will continue to serve its intended safety function and that any precursors to degradation will be captured by basic testing. Additionally, this exception may warrant more frequent basic testing, depending upon the experience obtained from previous coupon measurements.

- The location of the coupons is such that their exposure to parameters controlling change mechanisms (e.g., gamma fluence, temperature) is conservative or similar to the in-service neutron absorbers.

- Results are acceptable to confirm the continued performance of neutron absorber materials if either:

  a) For materials that are not anticipated to have a loss of ^{10}B areal density; the ^{10}B areal density of the test coupon is the same as its original ^{10}B areal density (within the uncertainty of the measurement).

  b) For materials that are anticipated to have a loss of ^{10}B areal density; the ^{10}B areal density of the test coupon is greater than the ^{10}B areal density used in the criticality analysis.

2.2 IN-SITU MEASUREMENT PROGRAM

In-situ measurement is another acceptable method for confirming ^{10}B areal density of neutron absorber material. In-situ measurement is used to identify whether changes are occurring, and if they are, to determine the condition of the neutron absorber material. There are two potential uses for in-situ measurements:

1. Supplement coupon monitoring to extend the coupon testing interval or permit greater reliance on basic testing.

2. In lieu of coupon testing if coupons do not exist (i.e., coupons never existed or coupons have been exhausted from periodic coupon testing).

The in-situ measurement program consists of the following elements:

- In-situ measurement campaigns include an adequate number of panels and at an acceptable interval. Two options are available for determining an adequate number of panels:
    - Option 1: Take a measurement of a minimum of 59 panels, based on the methodology of NUREG-6698 to provide a 95% degree of confidence that 95% of the population is above the smallest observed value.
    - Option 2: Selectively choose panels to be tested that have experienced the greatest exposure (within the top 5%) to those parameters that influence degradation (i.e., radiation fluence, temperature, time). The number of panels selected consist of no less than 1% of the total number of panels in the spent fuel pool. Additional panels can be selected from other areas of the spent fuel pool to gain a more representative sampling of the spent fuel pool.
- It is recommended that in-situ measurement campaigns consider the availability of equipment to reach storage locations, minimization of spent fuel transfers and separation of the measured storage cells from other spent fuel to minimize signal noise and eliminate corruption of the results by background radiation.
- The sampling interval is based upon the expected rate of material change, which may be influenced based upon the qualification testing of the material. For new materials that do not have a lot of operating experience in conditions similar to the pool environment (i.e. their ability to perform is not well known), the initial interval of 5 years, with subsequent intervals up to 10 years is acceptable. For materials that have been used for several years in conditions similar to the pool environment (i.e., their ability to perform is well known), and for which stability in the material condition has been documented, initial and subsequent intervals up to 10 years is acceptable. For materials with known degradation or degradation mechanisms that impact the efficacy of the neutron absorber (e.g., Boraflex, Carborundum, Tetrabor or other phenolic resin based materials), a testing interval of 5 years is acceptable.
- Note that the sampling interval can be longer if used in conjunction with coupons.
- Sources of measurement uncertainty are to be identified and the degree of uncertainty quantified.

Additional criteria for in-situ measurements depend upon the performance of the neutron absorber material, specifically whether material changes result in a degradation of the ^{10}B areal density.

A. For materials where operating experience indicates that potential change mechanisms do not result in a loss of ^{10}B areal density, in-situ measurements are used to confirm their presence and provide validation of the original as-manufactured areal density. Results confirm the continued performance of neutron absorber materials if the nominal measured ^{10}B areal density is equal to or greater than the ^{10}B areal density assumed in the criticality analysis, within the uncertainties of the measurement.

B. For materials where operating experience indicates that degradation mechanisms may result in a loss of ^{10}B areal density, in-situ measurements are used to determine the amount of ^{10}B areal density remaining. Results confirm that potential loss of ^{10}B has not resulted in the loss of the neutron absorber material's ability to perform its criticality control function if the nominal measured ^{10}B areal density minus the measurement uncertainty is greater than the ^{10}B areal density assumed in the criticality analysis.

2.3 EVALUATING NEUTRON ABSORBER TEST RESULTS

For either coupon testing or in-situ measurements, results from neutron absorber monitoring fall within the broad categories of 1) confirmation that no material changes are occurring; 2) confirmation that anticipated changes are occurring; and/or 3) identification that unanticipated changes are occurring. Relevant processes are used to evaluate results of the monitoring program with the criticality analysis input. If no changes, or if anticipated changes are occurring that have already been accounted for, then the material condition continues to be adequately represented in the criticality analysis.

If unanticipated changes are identified (either new mechanisms or anticipated mechanisms at rates or levels beyond those anticipated), then additional actions may be necessary. In addition to relevant regulatory and licensing processes (e.g., corrective action program, reporting requirements, the 10 CFR 50.59 [7] process, operability determination or functionality assessment), the following technical evaluations may be necessary:

- Determine if unanticipated changes could result in a loss of ^{10}B areal density. Evaluation of the effects of ^{10}B areal density on the criticality analysis are to be performed and addressed through appropriate licensee processes. Additionally, monitoring or test results that indicate potential degradation are evaluated and trended, even if it does not challenge the criticality safety analysis.

- Determine if unanticipated changes not resulting in loss of ^{10}B areal density have an impact on the criticality analyses. Dimensional or non-neutron absorbing material changes (e.g. formation of gaps, localized displacement of moderator, or superficial scratches) may have no or little impact on the criticality analyses. However, the potential effects of these changes on the criticality analysis are evaluated and addressed through appropriate licensee processes.

3 REFERENCES

3.1 REGULATIONS

1. Title 10 of the *Code of Federal Regulations* (10 CFR) 50.68, Criticality Accident Requirements.

2. Title 10 of the *Code of Federal Regulations* (10 CFR) 70.24, Criticality Accident Requirements.

3. Title 10 of the *Code of Federal Regulations* (10 CFR) 50 Appendix A, General Design Criteria for Nuclear Power Plants Criterion 62, Prevention of Criticality in Fuel Storage and Handling.

4. Title 10 of the *Code of Federal Regulations* (10 CFR) 50 Appendix A, General Design Criteria for Nuclear Power Plants Criterion 61, Fuel Storage and Handling and Radioactivity Control.

5. Title 10 of the *Code of Federal Regulations* (10 CFR) 50 Appendix B, Quality Assurance for Nuclear Power Plants and Fuel Reprocessing Plants.

6. Title 10 of the *Code of Federal Regulations* (10 CFR) 50.36, Technical Specifications.

7. Title 10 of the *Code of Federal Regulations* (10 CFR) 50.59, Changes, Tests and Experiments.

3.2 NUREGs

8. NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition," Section 9.1.1, "Criticality Safety of Fresh and Spent Fuel Storage and Handling," Revision 3, March 2007.

9. NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition," Section 9.1.2, "New and Spent Fuel Storage," Revision 4, March 2007.

10. NUREG-1801, "Generic Aging Lessons Learned (GALL) Report," Revision 2, December 2010

3.3 OTHER

11. 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.

12. "Handbook of Neutron Absorber Materials for Spent Nuclear Fuel Transportation and Storage Applications," EPRI, Palo Alto, CA: 2009. 1019110.

13. "Strategy for Managing the Long-Term Use of Boral® in Spent Fuel Storage Pools," EPRI, Palo Alto, CA: 2012. 1025204.

14. "Summary of October 21, 2015, Public Meeting with Nuclear Energy Institute on NEI 12-16, Revision 1, 'Guidance for Performing Criticality Analysis of Fuel Storage at Light-Water Reactor Power Plants'", ML15294A491

15. NRR Office Instruction, LIC-500, Revision 5, "Topical Report Process", ML13158A296

APPENDIX A

(7 pages)

Responses to NRC RAIs for NEI 16-03[2]

[2] These RAIs and the associated responses were developed during the NRC review of Section 9.5 of NEI 12-16, Revision 1. NEI 16-03 was based on Section 9.5 of NEI 12-16, Revision 1 and input from responses to NRC Requests for Additional Information, dated October 14, 2014 (Adams Accession number ML14276A013)

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NUCLEAR ENERGY INSTITUTE

June 3, 2015

Mr. Joseph Holonich
Senior Project Manager, Division of Reactor Safety Systems
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Subject: Responses to Requests for Additional Information Related to NEI 12-16, *Guidance for Performing Criticality Analyses of Fuel Storage at Light-Water Reactor Power Plants*

Project Number: 689

Dear Mr. Holonich:

By letter dated October 14, 2014, the NRC provided Request for Additional Information Related to NEI 12-16, *Guidance for Performing Criticality Analyses of Fuel Storage at Light-Water Reactor Power Plants*. The attachment to this letter contains the responses to those RAIs.

As discussed previously with the NRC during the public meetings between September 2013 and February 2014, we request to resolve any further questions and clarification on these reports via audit, as this will provide the most effective resolution of any outstanding issues.

Sincerely,

Kristopher W. Cummings

Attachment

c: Mr. William M. Dean, NRR, NRC
Ms. Jennifer Uhle, NRR, NRC
Mr. Timothy J. McGinty, NRR/DSS, NRC
Mr. Robert M. Taylor, NRR/DSS, NRC
Mr. Christopher Jackson, NRR/DSS/SRXB, NRC

Response to Request for Additional Information
Regarding NEI 12-16, *Guidance for Performing Criticality Analyses of Fuel Storage at Light-Water Reactor Power Plants*

NRC Questions and Responses:

1. *On page 36, Section 9.5.1.b of its letter dated April 18, 2014, the guidance document states that basic testing is appropriate when previous testing and operating experience of the material indicates that no degradation mechanism would result in loss of Boron-10. The staff understands this to mean that tests for neutron-absorbing capacity may be discontinued in the program because basic testing does not include testing for neutron attenuation. Please discuss whether neutron attenuation testing will be performed in addition to basic testing and whether it will be performed at intervals not exceeding 10 years.*

Response:

The guidance provided in NEI 12-16 is not intended to imply a discontinuation of the neutron absorber monitoring program. Rather, the intent is to define a program that is reflective of the condition and operating experience of the specific type of material used in the spent fuel storage rack. Utilities that have coupon monitoring programs in use for many years, if not decades, have continued to remove coupons for off-site testing in accordance with their neutron absorber monitoring program approved by the NRC. The original coupon tree was typically designed to have a sufficient number of coupons to allow for periodic removal for testing within the licensed term of the reactor. However, the number of coupons was not necessarily sufficient for extended operations due to license renewal (and possibly second license renewal), or if additional coupons were removed for further investigation of corrosion or corrosion precursors. As fewer coupons become available it has become apparent that removing coupons from the coupon tree for destructive examination was short-sighted for neutron absorbers that do not show any indication of degradation that would affect the functionality or effectiveness of the neutron absorber. Therefore, the implementation of basic testing is intended to rectify this issue by providing an initial evaluation of a coupon through visual and dimensional testing that would identify any precursors or advance indication of degradation that would lead to loss of ^{10}B. If no such indication is observed through basic testing of the coupon, then that coupon could be returned to the spent fuel pool for additional in-pool exposure, thereby extending the life of the coupon tree and the coupon monitoring program. One of the key features of basic testing is to ensure that the coupon is not exposed to conditions that are non-representative of the spent fuel pool environment (such as by drying or desiccation) that would no longer make that coupon representative of in-service material.

If basic testing indicates that there are degradation mechanisms present indicating a loss of ^{10}B that would affect the functionality and effectiveness of the neutron absorber, then that coupon would be more extensively examined in accordance with the requirements for full testing to determine the extent and ramifications of those visually observed degradation mechanisms from basic testing. Such indications would be loss of weight, large amounts of pitting holes combined with visually observed loss of the neutron absorbing element in the material, observed brittleness, crumbling of the material, etc. A sensitivity study to determine the size and extent of blistering or pitting that would result in a loss of neutron absorber efficacy is currently in progress. The results of this sensitivity study will be made available to the NRC once completed. Basic testing would be performed no less than every ten years,

based upon the experience and history of the specific material. Therefore, neutron attenuation testing would be performed at an interval dependent upon the operating experience of visual and dimensional testing performed during basic testing and will be reserved for those situations where degradation would actually be observed.

The usefulness of employing a graded testing program for coupons can best be illustrated through an example of applying this program to Boral. For many years, if not decades, coupon testing of Boral has not shown any indications of degradation that impacts the functionality or effectiveness of the neutron absorber. Some surface discoloration, small pits, and slight dimensional changes have been observed. With a graded approach in place, these coupons can be returned to the spent fuel pool for additional exposure and subsequently removed in later years for additional observation. An added advantage of a graded testing approach is that subsequent measuring of the same coupon will allow for trending of results. Under this approach, Boral coupons that begin to show blistering or pitting of the aluminum cladding can be observed on a regular basis. Any such observation will be entered into the licensee's corrective action program and will trigger the use of full testing to determine whether the blistering results in a loss of the functionality and effectiveness of the neutron absorber. After the full testing and evaluation of the results, a licensee can then make a determination as to whether to institute full testing on a continual basis or to continue to implement basic testing on the original frequency or a more frequent basis.

2. *On page 36, Section 9.5.2, first bullet, of its letter dated' April 18, 2014, the guidance document states that in-situ measurement of Boron-10 areal density should be performed on an appropriate statistical sample. Please discuss the methodology used in determining an appropriate/acceptable statistical sample.*

Response:

This statement in the guidance document will be modified and expanded to provide two possible options for defining the number of panels to be measured via in-situ examination.

The first option would define a statistically significant sample based upon the methodology contained in NUREG/CR-6698. In the discussion on non-parametric statistical treatment (p.14), it concludes that a sample size of 59 measurements will "...attain a 95% degree of confidence that 95% of the population is above the smallest observed value". This is a conservative approach to defining the minimum number of panels as it applies nonparametric statistics, versus applying a statistical approach to the expected normal distribution of installed panels in the spent fuel pool.

The second option takes credit for the operational experience that many types of neutron absorbers have material degradation processes that are known to be dependent upon radiation, temperature and time. A licensee may selectively choose in-service panels to be tested that have experienced the greatest level of exposure to those variables that influence degradation. These are typically panels that are adjacent to storage locations where freshly discharged spent fuel is placed, especially if this has occurred on a repeating basis. For completeness, the licensee could also choose to select additional panels for testing that are not at leading locations to gain a more representative sample of the spent fuel pool. However, provided that leading neutron absorbers are selected for examination by in-situ measurements, it is recommended that 1% of the panels be selected for in-situ measurement, at a minimum.

In both of these options, consideration should be made to accommodate the availability of equipment to reach storage locations, minimization of spent fuel transfers and separation of the measured storage cells from other spent fuel to minimize signal noise and eliminate corruption of the results by background radiation.

To provide for these options, the first and second bullet of Section 9.5.2 of NEI 12-16 will be replaced with:

- In-situ measurement campaigns should be performed on an adequate number of panels and at an acceptable interval. Two options are available for determining an adequate number of panels:
    - Option 1: Take a measurement of a minimum of 59 panels, based on the methodology of NUREG-6698 to provide a 95% degree of confidence that 95% of the population is above the smallest observed value.
    - Option 2: Selectively choose panels to be tested that have experienced the greatest exposure (within the top 5%) to those parameters that influence degradation (i.e., radiation fluence, temperature, time). The number of panels selected should be no less than 1% of the total number of panels in the spent fuel pool. Additional panels can be selected from other areas of the spent fuel pool to gain a more representative sampling of the spent fuel pool.

- In-situ measurement campaigns should consider the availability of equipment to reach storage locations, minimization of spent fuel transfers and separation of the measured storage cells from other spent fuel to minimize signal noise and eliminate corruption of the results by background radiation.

3. *U.S. Nuclear Regulatory Commission guidance (i.e., Generic Aging Lessons Learned Report 1801) recommends basing the frequency for inspection and testing of neutron-absorbing material capacity on the condition of the material and operating experience, not to exceed 10 years. In the Nuclear Energy Institute letter dated April 18, 2014, the guidance document provides little guidance for maximum test intervals for materials that are known to degrade and the rate of degradation is not fully understood. Please discuss whether guidance will be provided on maximum test intervals for materials that are known to experience significant degradation and rate of degradation is not fully understood.*

Response:

Industry agrees with the guidance provided in NUREG-1801, "Generic Aging Lessons Learned", which recommends basing the frequency for inspection and testing of neutron absorbing material capacity on the condition of the material and operating experience, not to exceed ten years. Any material that begins to show degradation that affects the function and efficacy of the neutron absorber would need to be evaluated in more detail, with conservative degradation rates determined. Observations and measurements obtained from the neutron absorber monitoring program (either coupons or in-situ) will help to determine the appropriate degradation rate. Any further inspection frequency would need to be based on these future evaluations, therefore it is not possible to specify a numerical value as to the maximum test intervals for materials that are known to experience significant degradation, but for which the rate of degradation is not fully understood.

Any licensee that observes degradation in a material whether expected or not, would rely on the corrective action program and 10CFR21 reporting requirements in accordance with their 10CFR 50, Appendix B Quality Assurance Program. Through this process, the licensee would develop the appropriate test intervals to ensure that the spent fuel pool complies with 10CFR 50.68.