## AMP 137 MONITORING OF NEUTRON-ABSORBING MATERIALS OTHER THAN BORAFLEX (VERSION 2020)

### Programme Description

A monitoring programme is implemented to assure that degradation of the neutron-absorbing material used in spent fuel pools that could compromise the criticality analysis will be detected. This AMP relies on periodic inspection, testing, monitoring, and analysis of the criticality design to assure that the required sub-criticality margin, based on national regulations, is maintained during the period of license renewal. This AMP applies to neutron-absorbing materials other than Boraflex which is addressed by AMP 126.

### Evaluation and Technical Basis

1. ***Scope of the ageing management programme based on understanding ageing:***

This programme manages the effects of ageing on neutron-absorbing components/materials used in spent fuel racks, other than Boraflex, these materials include Boral, Metamic, Maxus, boron steel, and Carborundum [1, 2, 3]. US NRC Information Notice 2009-26 discusses the degradation of Carborundum as well as deformation of Boral panels in spent fuel pools [4].

1. ***Preventive actions to minimize and control ageing degradation:***

This programme is a condition monitoring programme hence there are no preventative actions. To manage ageing degradation some parameters are monitored. For these materials, gamma irradiation and/or long-term exposure to the wet pool environment may cause loss of material and changes in dimensions (such as gap formation, formation of blisters, pits and bulges) that could result in loss of neutron-absorbing capability of the material. The parameters monitored include the physical condition of the neutron-absorbing materials, such as in-situ gap formation, geometric changes in the material (formation of blisters, pits, and bulges) as observed from coupons or in situ, decreased boron areal density, etc. The parameters monitored are directly related to determination of the loss of material or loss of neutron absorption capability of the material(s).

1. ***Detection of ageing effects:***

A neutron absorber monitoring programme 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, [5] 2) In-situ measurements of the neutron absorbing capability of the installed neutron absorber panels, [5] 3) Spent fuel pool water chemistry monitoring. Alternative approaches are also acceptable if adequately justified.

A monitoring programme consists of identifying original 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.

‘Guidance for Monitoring of Fixed Neutron Absorbers in Spent Fuel Pools’ NEI 16-03, Revision 0 [9], provides details for:

1. Coupon Testing Programme
2. In-situ Measurement Programme
3. Evaluating Neutron Absorber Test Results

The US Nuclear Regulatory Commission (USNRC) reviewed NEI 16-03 and concluded that the programme described in NEI 16-03 would provide reasonable assurance for detecting degradation of neutron absorbing materials [10]. Once any alternative approaches are complete, NEI 16-03 will be revised to include alternative approaches for monitoring and will be re-submitted to the regulatory review for official endorsement.

1. ***Mitigating ageing effects:***

This AMP is a condition monitoring programme. Therefore, there are no preventative measures.

1. ***Monitoring and trending of ageing effects:***

The measurements from periodic inspections and analysis are compared to baseline information or prior measurements and analysis for trend analysis. The approach for relating the measurements to the performance of the spent fuel neutron absorber materials is specified by the applicant, considering differences in exposure conditions, vented/non-vented test samples, and spent fuel racks, etc.

1. ***Acceptance criteria:***

Although the goal is to ensure maintenance of the required sub-criticality margin for the spent fuel pool, based on national regulations, the specific acceptance criteria for the measurements and analyses are specified by the applicant.

1. ***Corrective actions:***

Corrective actions are initiated if the results from measurements and analysis indicate that the required sub-criticality margin cannot be maintained because of current or projected future degradation of the neutron-absorbing material. Corrective actions may consist of providing additional neutron-absorbing capacity with an alternate material, or applying other options, which are available to maintain the sub-criticality margin. As discussed in the Appendix for GALL, the staff finds the requirements of 10 CFR Part 50, Appendix B [11], acceptable to address the corrective actions.

1. ***Operating experience feedback and feedback of research and development results:***

This AMP addresses the industry-wide generic experience. Relevant plant-specific operating experience is considered in the development of the plant AMP to ensure the AMP is adequate for the plant. The plant implements a feedback process to periodically evaluate plant and industry-wide operating experience and research and development (R&D) results, and, as necessary, either modifies the plant AMP or takes additional actions (e.g. develop a new plant-specific AMP) to ensure the continued effectiveness of the ageing management.

Applicants for license renewal reference plant-specific operating experience and industry experience to provide reasonable assurance that the programme is able to detect degradation of the neutron absorbing material in the applicant’s spent fuel pool. Some of the industry operating experience that can be included is listed below:

* Loss of material from the neutron absorbing material has been observed, including loss of aluminum, which was detected by monitoring the aluminum concentration in the spent fuel pool. One instance of this is documented in [12].
* Based on coupon analysis, blistering has also been noted at several plants [12, 13]. EPRI recently conducted a research project where coupons and actual panels from Zion spent fuel pool were collected and compared against each other to determine 1) the condition of panels, 2) how well coupons represent the panels, to evaluate the adequacy of coupon monitoring programme. Although, one of the coupons showed a small blister, none of the actual panels that resided in the pool over 22 years showed neither blisters nor signs of significant degradation [14-15]. There were no statistically significant changes in areal densities, compared to certified manufactured original values prior to insertion to the pool. Study also concluded that coupons are adequately representing the neutron absorber panels and can be used as effective monitoring technique.
* EPRI also performed a study to evaluate the impact of blisters and pits, observed by the industry [13], on the spent fuel pool reactivity [6, 16]. The study demonstrated that impact of blisters and pits observed to date is negligible. Additionally, study was performed for hypothetical scenarios to determine when pits/blisters will have any impact on reactivity. The results indicated that for any statistically significant impact, blister and pit sizes need to be several orders of magnitudes larger [6].
* EPRI recently completed a five-year accelerated corrosion test on the neutron absorber material BORAL® to evaluate the corrosion performance of BORAL® over timeframes greater than 60 years. The test program included BWR and PWR conditions, different manufacturing vintages of BORAL®, and un-encapsulated and encapsulated (simulating a wrapper plate). The accelerated test was conducted at a water temperature of about 91°C for five years. The results found blisters developed on some coupons after 2 years, while pitting of the aluminum cladding was observed after the first year. After 5 years, some pits were found to penetrate the aluminum cladding to the core material, yet no statistically significant loss of B-10 was observed for any of the coupons from year 1 to 5. In addition, some test coupons had the aluminum cladding removed to expose the core material directly to the spent fuel pool water conditions. Even for clad removed coupons, there was no statistically significant change in areal density after five years [17, 18].
* The significant loss of neutron-absorbing capacity of the plate-type carborundum material has been described in [3, 12].

The applicant describes how the monitoring programme described above is capable of detecting the aforementioned degradation mechanisms.

The programme includes provisions for continuing review of plant-specific and industry-wide operating experience [3, 12-13], and research and development results [6-7, 13-15, 19], such that impact on the programme is evaluated and any necessary actions or modifications to the programme are performed.

Additionally, EPRI is currently working on the development of an industrywide learning aging management program (i-LAMP) as an alternative monitoring approach (6, 7). This program will encompass all the known neutron absorbing materials in the industry. In this program, pools that do not know have coupons will identify similar pools, based on absorber properties and water chemistry, and use their coupon analysis as part of monitoring program. The industry committed to the full development of i-LAMP as part of Generic Letter [8] closure.

1. ***Quality management:***

Administrative controls, quality assurance procedures, review and approval processes, are implemented in accordance with the different national regulatory requirements (e.g., 10 CFR 50, Appendix B [11]).

### References

[1] Handbook of Neutron Absorber Materials for Spent Nuclear Fuel Transportation and Storage Applications: 2009 Edition. EPRI, Palo Alto, CA: 2009. 1019110.

[2] M. Eyre, D. Nagasawa, T. Yamazaki, A. Herfurth, “5-Year Accelerated Corrosion Testing of MAXUS® for Spent Fuel Pool and Dry Cask Performance ,” Proceedings of the 19th International Symposium on the Packaging and Transportation of Radioactive Materials PATRAM 2019, August 4-9, 2019, New Orleans, LA USA.

[3] UNITED STATES NUCLEAR REGULATORY COMMISSION, NUREG–2191, Generic Aging Lessons Learned for Subsequent License Renewal (GALL-SLR) Report, Final Report, 2017

[4] UNITED STATES NUCLEAR REGULATORY COMMISSION, Information Notice 2009-26, “Degradation of Neutron-Absorbing Materials in the Spent Fuel Pool”, USNRC 2009.

[5] ASTM E2971-16, Standard Test Method for Determination of Effective Boron-10 Areal Density in Aluminum Neutron Absorbers using Neutron Attenuation Measurements. ASTM International, West Conshohocken, PA, 2016.

[6] Evaluation of the Impact of Neutron Absorber Material Blistering and Pitting on Spent Fuel Pool Reactivity. EPRI, Palo Alto, CA: 2018. 3002013119.

[7] Roadmap for the Industrywide Learning Aging Management Program (i-LAMP): For Neutron Absorber Materials in Spent Fuel Pools. EPRI, Palo Alto, CA: 2018. 3002013122.

[8] UNITED STATES NUCLEAR REGULATORY COMMISSION, “NRC Generic Letter 2016-01: Monitoring Of Neutron-Absorbing Materials In Spent Fuel Pools,” USNRC, April 7, 2016.

[9] Nuclear Energy Institute, NEI 16-03, Revision 0, “Guidance for Monitoring of Fixed Neutron Absorbers in Spent Fuel Pools”, August 2016.

[10] Letter from Kevin Hsueh, USNRC, to Kristopher Cummings, NEI, Draft Safety Evaluation for Nuclear Energy Institute Topical Report NEI 16-01 Guidance for Monitoring of Fixed Neutron Absorbers in Spent Fuel Pools, dated November 9, 2016.

[11] UNITED STATES NUCLEAR REGULATORY COMMISSION, 10 CFR Part 50, Appendix B, Quality Assurance criteria for Nuclear Power plants, Office of the Federal, Register, National Archives and Records Administration, UNRC, Latest Edition.

[12] UNITED STATES NUCLEAR REGULATORY COMMISSION, Generic ageing Lessons Learned (GALL) Report, NUREG-1801, Revision 2, Section XI.M40, “Monitoring of Neutron-Absorbing Materials Other than Boraflex,” USNRC, December 2010.

[13] Overview of BORAL® Performance Based Upon Surveillance Coupon Measurements. EPRI, Palo Alto, CA: 2010. 1021052.

[14] Evaluation of BORAL® Coupons from Zion Spent Fuel Pool. EPRI, Palo Alto, CA: 2016. 3002008195.

[15]Evaluation of BORAL® Panels from Zion Spent Fuel Pool and Comparison to Zion Coupons*.* EPRI, Palo Alto, CA: 2016. 3002008196.

[16] H. Akkurt, M. Wenner, A. Blanco, “Evaluation of the Impact of Neutron Absorber Material Blistering and Pitting on Spent Fuel Pool Reactivity,”, Proceedings of the ICNC 2019 - 11th International conference on Nuclear Criticality Safety, September 15-20, 2019 – Paris, France.

[17] H. Akkurt, A. Quigley, and M. Harris, "Accelerated Corrosion Tests to Evaluate the Long-Term Performance of BORAL® in Spent Fuel Pools,” Proceedings of the 19th International Symposium on the Packaging and Transportation of Radioactive Materials PATRAM 2019, August 4-9, 2019, New Orleans, LA USA.

[18] Accelerated Corrosion Test Results for BORAL Coupons: Results from Years 1-5. EPRI, Palo Alto, CA: 3002018496, to be published in 2020.

[19] H. Akkurt and E. Wong, “Industrywide global efforts toward long-term monitoring of neutron absorber materials in spent fuel pools,” Proceedings of IAEA 2019 spent fuel management conference, 2019.