## AMP 126 BORAFLEX MONITORING (VERSION 2017)

**Programme Description**

Many neutron-absorbing materials, such as Boraflex, Boral, Metamic, boron steel and carborundum, are used in spent fuel pools. This AMP addresses ageing management of spent fuel pools using Boraflex as the neutron-absorber material. AMP 137 addresses ageing management of spent fuel pools using other than Boraflex.

For Boraflex panels in spent fuel storage racks, gamma irradiation and long-term exposure to the wet fuel pool environment cause shrinkage [1-2] resulting in gap formation, gradual degradation of the polymer matrix, and the release of silica to the spent fuel storage pool water [3]. This results in the loss of boron carbide in the neutron absorber sheets. A monitoring programme for the Boraflex panels in the spent fuel storage racks is implemented to assure that no unexpected degradation of the Boraflex material compromises the criticality analysis in support of the design of spent fuel storage racks. This AMP relies on periodic inspection, testing, monitoring, and analysis of the criticality design to assure that the required subcriticality margin is maintained. Therefore, this AMP includes: (a) completing sampling and analysis for silica levels in the spent fuel pool water on a regular basis, such as monthly, quarterly, or annually (depending on Boraflex panel condition), and trending the results by using a predictive code, such as EPRI RACKLIFE [4]; and (b) performing neutron attenuation testing or blackness testing to determine gap formation in Boraflex panels or measuring the boron areal density.

### Evaluation and Technical Basis

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

This programme manages reduction in neutron-absorbing capacity due to degradation in sheets of neutron-absorbing material made of Boraflex affixed to spent fuel racks.

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

This programme is a performance monitoring programme and does not include preventive actions.

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

Ageing effects on Boraflex panels are detected by monitoring silica levels [3] in the spent fuel storage pool on a regular basis, such as monthly, quarterly, or annually (depending on Boraflex panel condition); by performing blackness testing to measure gap formation or measuring boron areal density on a frequency determined by the material condition of the Boraflex panels, with a minimum frequency of once every 5 years; and by applying predictive methods to the measured results. The amount of boron carbide present in the Boraflex panels is determined through direct measurement of boron areal density by blackness testing or by periodic verification of boron loss through areal density measurement techniques. Frequent Boraflex testing is sufficient to ensure that Boraflex panel degradation does not compromise criticality analysis for the spent fuel pool storage racks. Additionally, changes in the level of silica present in the spent fuel pool water provide an indication of changes in the rate of degradation of Boraflex panels.

The experience with Boraflex panels indicates that coupon surveillance programmes are not reliable. Therefore, this programme relies on the three methods cited above.

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

The periodic inspection measurements and analysis are compared to values of previous measurements and analysis providing a continued level of data for trend analysis. Sampling and analysis for silica levels in spent fuel pool water is performed on a regular basis, such as monthly, quarterly or annually and the results are trended. Silica concentration is monitored against time to trend degradation. Rapid increases of silica concentration may indicate accelerated Boraflex degradation. The frequency to perform boron-10 areal density testing will be determined by the material condition of the Boraflex panels not to exceed specific period, e.g. 5 years.

Surveillance of neutron-absorbing material degradation can involve the use of monitoring methods to assess or measure degradation of the material and computer codes to model and predict the condition of the materials used in the SFP. For Boraflex, a combination of the RACKLIFE [4] computer code and the Boron Areal Density Gauge for Evaluating Racks (BADGER) in-situ measurement tool has been employed to manage degradation. The RACKLIFE computer code was developed in the mid-1990s to track and predict the loss of Boraflex and to manage the storage patterns of spent fuel in the SFP. The BADGER system was originally designed, assembled, and tested in the early to mid-1990s by Northeast Technologies Company (now a subsidiary of Curtiss–Wright) as a nondestructive scoping tool to evaluate neutron-absorbing materials placed in spent fuel racks. Although BADGER was designed and is employed primarily to measure the degradation of Boraflex, it is theoretically applicable to any neutron-absorbing material and has been used for Carborundum and Boral®. Other surveillance methods include testing of representative coupon samples. These tests may include dimensional, neutron attenuation, and weight tests.

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

Mitigation of Boraflex degradation may be accomplished through use of neutron absorber inserts or a completely new spent fuel rack system using a different neutron absorber [5]. For PWRs, absorption effects from the borated spent fuel pool water can be credited for criticality calculations, depending on the national requirements.

1. ***Acceptance criteria:***

The subcriticality margin of the spent fuel racks is maintained consistent with national requirements.

1. ***Corrective actions:***

Corrective actions are initiated if the required subcriticality margin cannot be maintained because of the current or projected future degradation. Corrective actions consist of providing additional neutron-absorbing capacity or modified geometric configurations to maintain the required subcriticality margin.

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

This AMP addresses the industry-wide generic operating 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 (i.e., develop a new plant-specific AMP) to ensure the continued effectiveness of the ageing management.

NRC IN 87-43 addresses the problems of development of tears and gaps (average 25.4-50.8 mm, with the largest 101.6 mm) in Boraflex sheets due to gamma radiation-induced shrinkage of the material [6]. Several cases have been identified of significant degradation of Boraflex test coupons due to accelerated dissolution of Boraflex caused by pool water flow through panel enclosures and high accumulated gamma dose [7-11]. Two spent fuel rack cells with about 12 years of service have only 40 % of the Boraflex remaining.

To address Boraflex degradation in 2010, the licensee for Peach Bottom Atomic Power Station,Units 2 and 3 performed an operability determination (OD) based on the RACKLIFE surveillance programme that concluded it would maintain sufficient margin to criticality in its SFP until 2014.

However, the NRC’s review of the OD concluded that the licensee did not accurately project the rate of Boraflex degradation and used several non-conservative assumptions in the analysis.

The licensee performed a re-analysis and determined that several Boraflex panels had degraded below TS requirements. As a result, the licensee declared multiple cells in the SFP inoperable, relocated spent fuel assemblies to maintain appropriate margin, and established additional administrative controls to govern use of affected cells. The NRC issued a violation associated with the licensee’s failure to implement corrective actions to prevent the Boraflex panels from degrading below the TS requirements [12]. To provide a long-term solution for this issue, the licensee requested and the NRC approved a license amendment that included installation of rack inserts and removal of credit for Boraflex as a neutron-absorbing material.

The experience with Boraflex panels indicates that coupon surveillance programmes are not reliable. Therefore, the measurement of boron areal density correlated, through a predictive code, with silica levels in the pool water, is verified. These monitoring programmes provide assurance that degradation of Boraflex sheets is monitored so that appropriate actions can be taken in a timely manner if significant loss of neutron-absorbing capability is occurring. These monitoring programmes provide reasonable assurance that the Boraflex sheets maintain their integrity and are effective in performing their intended function.

At the time when this AMP was produced, no relevant R&D was identified. Current methods are to replace the Boraflex or use the boron to determine sub criticality in the spent fuel pool.

1. ***Quality management:***

Site quality assurance procedures, review and approval processes, and administrative controls are implemented in accordance with the different national regulatory requirements (e.g., 10 CFR 50, Appendix B [13]).

### References

1. ELECTRIC POWER RESEARCH INSTITUTE, An Assessment of Boraflex Performance in Spent-Nuclear-Fuel Storage Racks, NP-6159, EPRI, Palo Alto, CA, December 14, 1988.
2. ELECTRIC POWER RESEARCH INSTITUTE, Boraflex Test Results and Evaluation, EPRI TR-101986, EPRI, Palo Alto, CA, March 1, 1993.
3. ELECTRIC POWER RESEARCH INSTITUTE, Guidelines for Boraflex Use in Spent-Fuel Storage Racks, EPRI TR-103300, EPRI, Palo Alto, CA, December 1, 1993.
4. ELECTRIC POWER RESEARCH INSTITUTE, Guidance and Recommended Procedure for Maintaining and Using RACKLIFE Version 1.10, EPRI TR-1003413, EPRI, Palo Alto, CA, April 2002.
5. ELECTRIC POWER RESEARCH INSTITUTE, Handbook of Neutron Absorber Materials for Spent Nuclear Fuel Transportation and Storage Applications: 2009 Edition, EPRI TR-1019110, EPRI, Palo Alto, CA, 2009.
6. UNITED STATES NUCLEAR REGULATORY COMMISSION, Information Notice 87-43, Gaps in Neutron Absorbing Material in High Density Spent Fuel Storage Racks, USNRC, September 8, 1987.
7. UNITED STATES NUCLEAR REGULATORY COMMISSION, Information Notice 93-70, Degradation of Boraflex Neutron Absorber Coupons, USNRC, September 10, 1993.
8. UNITED STATES NUCLEAR REGULATORY COMMISSION, Information Notice 95-38, Degradation of Boraflex Neutron Absorber in Spent Fuel Storage Racks, USNRC, September 8, 1995.
9. UNITED STATES NUCLEAR REGULATORY COMMISSION, Generic Letter 96-04, Boraflex Degradation in Spent Fuel Pool Storage Racks, USNRC, June 26, 1996.
10. UNITED STATES NUCLEAR REGULATORY COMMISSION, Information Notice 2012-13, Boraflex Degradation Surveillance Programs and Corrective Actions in the Spent Fuel Pool, USNRC, August 10, 2012.
11. UNITED STATES NUCLEAR REGULATORY COMMISSION, Generic Letter 2016-01: Monitoring of Neutron-Absorber Materials in Spent Fuel Pools, USNRC, April 7, 2016.
12. NRC Integrated Inspection Report from NRC to Pacilio, M.J., “Peach Bottom Atomic Power Station- NRC Integrated Inspection Report 0500277/2012002 and 0500278/2012002,” May 7, 2012, ADAMS Accession No. ML 12129A016.
13. 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, USNRC, Latest Edition.