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RBG-47720

November 2, 2016

U.S. Nuclear Regulatory Commission
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SUBJECT: Response to Generic Letter 2016-01, "Monitoring of Neutron Absorbing Materials in Spent Fuel Pools"
River Bend Station – Unit 1
Docket No. 50-458
License No. NPF-47

REFERENCE: 1. NRC letter, Generic Letter 2016-01, Monitoring of Neutron Absorbing Materials in Spent Fuel Pool (April 7, 2016)

Dear Sir or Madam:

On April 7, 2016, the NRC issued Reference 1 to all power reactor licensees except those that have permanently ceased operation with all power reactor fuel removed from on-site spent fuel pool storage.

The purpose of this letter is to provide a response for River Bend Station – Unit 1 (RBS). RBS was determined to be a Category 4 licensee in accordance with Reference 1. As a Category 4 licensee, information on the neutron absorber material, criticality analysis of record, and neutron absorber monitoring program was requested, depending on the type of neutron absorber material present and credited in the spent fuel pool. The RBS spent fuel pool credits Boraflex, and therefore is required to provide information in areas 1 through 5. The attachment contains the responses to the requested information.

This letter contains no new regulatory commitments. If you have any questions regarding this submittal, please contact Tim Schenk at 225-381-4177.

I declare under penalty of perjury that the foregoing is true and correct. Executed on November 2, 2016.

Sincerely,

MLC / dhw

RBF1-16-0140

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Attachment to RBG-47720
Response to Generic Letter 2016-01
November 2, 2016

River Bend Station
Response to Requested Information in for Generic Letter 2016-01

A. – Background

On April 7, 2016, the U.S. Nuclear Regulatory Commission (NRC) issued Generic Letter 2016-01, "Monitoring of Neutron-Absorbing Materials in Spent Fuel Pools" (GL-2016-01). The following information provides the River Bend Station (RBS) response to the GL-2016-01, including the applicable Areas of Requested Information (ARI) in Appendix A. This response has been developed based on a reasonable search of the plant's records, including docketed information.

B. Category 4 Licensee - GL 2016-01, Appendix A Response

ARI 1

1. Describe the neutron-absorbing material credited in the spent fuel pool (SFP) nuclear criticality safety (NCS) analysis of record (AOR) and its configuration in the SFP, including the following:

a. manufacturers, dates of manufacture, and dates of material installation in the SFP

Response

The credited neutron-absorbing material is Boraflex, and was manufactured by BISCO in 1984. The installation of Boraflex in the spent fuel pool at RBS was completed in July 1985.

b. neutron-absorbing material specifications:

i. materials of construction, including the certified content of the neutron absorbing component expressed as weight percent

Response

Cell enclosure material: ASME SA-240 (or equivalent ASTM designation per NCA-1221.1), Type 304, cold rolled sheet, No. 2D finish.

Wrapper plate material: ASME SA-240 (or equivalent ASTM designation per NCA-1221.1), Type 304, No. 2 finish, cold rolled strip.

Boraflex may have, as an interim step in the assembly process, been temporarily bonded to the wrapper by applying beads of silastic 732 RTV adhesive sealant or equivalent, equally spaced along the perimeter of the wrapper.

The Boraflex is comprised of a polymeric silicone encapsulant entraining and fixing fine particles of boron carbide in a homogeneous, stable matrix. The encapsulant is a polydimethyl siloxane.

The chemical requirements of the B_4C including B_{10} content shall be as follows:

Chemical Requirements	Weight Percent
Total Boron	73.0 min.
B_{10} Content	Naturally occurring and as determined by analysis.
Boric Oxide	0.5 max
Iron	1.0 max
Total boron plus total carbon	98.0 min
Fluorine	25 μg/g max.
Chlorine	75 μg/g max.

The B_{10} content is not specified on a weight percent basis of the neutron absorbing component. See response to 1.b.ii for minimum required areal density.

ii. minimum certified, minimum as-built, maximum as-built and nominal as-built areal density of the neutron-absorbing component

Response

The minimum required Boraflex sheet B_{10} areal density per the Westinghouse vendor drawing is 0.02 g/cm^2 for a sheet thickness of 0.078" + 0.010". The Westinghouse requirement for the material states that the minimum B_{10} areal density shall be per Westinghouse drawing.

After a reasonable search of plant records, including docketed information, RBS determined that the as-built areal density was not part of the original licensing basis or previously requested by NRC as part of the licensing action that approved the neutron absorber monitoring program.

iii. material characteristics, including porosity, density and dimensions

Response

The Boraflex used in rack fabrication is in the form of sheets with dimensions 145.00 in. ± 0.25 in. high, 5.100 in. ± 0.075 in. wide, and 0.078 in. ± 0.010 in. thick.

The typical Boraflex Physical characteristics with the standard B10 loading identified in Item 1.b.ii are as follows:

Modulus of Elasticity	1000 psi
Tensile Strength	200 psi
Specific Gravity	1.7 (grams/cc)
Hardness	75 Shore A
Temperature Stability	300°F minimum without variable distortion

No value for porosity is provided in available vendor documentation.

c. qualification testing approach for compatibility with the SFP environment and results from the testing

Response

The BISCO qualification report from 1981 presented data showing an exposure of Boraflex in air to 2.81 x 10^8 rads gamma from a spent fuel source that resulted in no significant physical changes, nor in the generation of any gas.

The study also presented data showing irradiation to a level of 1.03 x 10^{11} rads gamma with a substantial concurrent neutron flux in air, deionized water, and borated water environments. This caused an increase in hardness and a change of the tensile strength of Boraflex. It was observed that a certain amount of gas is generated, but beyond the level of approximately 1 x 10^{10} rads gamma, the rate of gas generation did not exceed the rate observed when a sample container filled with borated or deionized water only was irradiated.

Neutron attenuation measurement results indicate no discernable trend or effect by any environment of any variation of boron content within the Boraflex related to a change in attenuation. Most of the measurement data correlated within confidence limits to the extent that it may be concluded that neither irradiation, environment nor Boraflex composition has any effect on the neutron transmission, through a dose of 1.03x10^{11} Rads.

Based on the studies undertaken, no evidence was determined that indicated the deterioration of Boraflex occurring using a cumulative irradiation in excess of 1 x 10^{11} rads gamma thereby resulting in a negative effect regarding the suitability of Boraflex as a neutron shielding material.

However, due to unexpected behavior of Boraflex being observed at two sites, in the early 90's, EPRI undertook an evaluation which provided a clearer understanding of the gap phenomenon, including the range of maximum gap size and the axial distribution of gaps. It was further demonstrated that the reactivity effect of such gaps is very small, usually within the existing design basis of most spent fuel racks.

d. configuration in the SFP

i. method of integrating neutron-absorbing material into racks (e.g., inserts, welded in place, spot welded in place, rodlets)

Response

The Boraflex sheet is oriented on the outside of the cell enclosure along the active fuel length. The wrapper plate is spot welded to the outside of the cell enclosure forming the encapsulation for the Boraflex. A water tight seal is not provided between the wrappers and enclosures.

ii. sheathing and degree of physical exposure of neutron absorbing materials to the spent fuel pool environment

Response

As the wrapper plate is spot welded, a water tight seal is not provided between the wrappers and enclosures and the Boraflex will be exposed to the pool water environment.

e. current condition of the credited neutron-absorbing material in the SFP

i. estimated current minimum areal density

Response

The most recent RACKLIFE calculation shows the peak panel at a 12.39% B_4C loss on November 16, 2014, which corresponds to an areal density of 0.0175 g/cm^2. This conversion is described in the response to ARI 2.b.iii.4. Trending of previous RACKLIFE calculations shows an approximate increase of 1% B_4C loss per year, so the estimated current areal density is 0.0171 g/cm^2.

ii. current credited areal density of the neutron-absorbing material in the NCS AOR

Response

The areal density used in the NCS AOR is 0.018 g/cm^2 (10% loss from the minimum design value). However, an evaluation was performed to show that when using a reduced reactivity design basis assembly and an areal density of 0.016 g/cm^2 (20% loss from the minimum design value), the system reactivity was less than the original design basis assembly with an areal density of 0.018 g/cm^2. Thus, the current credited areal density is 0.016 g/cm^2.

iii. recorded degradation and deformations of the neutron-absorbing material in the SFP (e.g., blisters, swelling, gaps, cracks, loss of material, loss of neutron-attenuation capability)

Response

Accelerated Exposure Surveillance Program (AES)

Minor degradation has been observed in the coupons that were tested towards the end of the AES program. Cracking and edge erosion resulting in a loss of more than 10% of the original coupon weight occurred in several coupons. These coupons were sent to a vendor for neutron attenuation measurements and all results showed that the Boron-10 content exceeded the minimum required value in SFP criticality analysis. The last available report showed an average coupon B-10 loading of 0.0242 g/cm^2.

It should be noted that the SFP racks are not expected to receive the same level of accumulated radiation exposure as the coupons from the AES program until ~40 years of use, which would be after the planned completed installation date of neutron absorbing inserts and removal of credit for Boraflex.

Long-Term Surveillance Program (LTS)

No degradation has been observed in the LTS coupons. All visual, hardness, weight, length, and thickness inspections to date have passed procedural requirements and no neutron attenuation measurements have been required.

BADGER Test

Although not part of the official monitoring program, a BADGER test was performed in 2009. Some cracks, gaps, and local dissolution were seen in the BADGER results. Some indications of material loss were seen, but the measured areal densities were close to the minimum certified value. The largest individual gap measured was just above 1.8 inches and the largest cumulative gap measured was 4.8 inches.

ARI 2

2. Describe the surveillance or monitoring program used to confirm that the credited neutron-absorbing material is performing its safety function, including the frequency, limitations, and accuracy of the methodologies used.

a. Provide the technical basis for the surveillance or monitoring method, including a description of how the method can detect degradation mechanisms that affect the material's ability to perform its safety function. Also, include a description and technical basis for the technique(s) and method(s) used in the surveillance or monitoring program, including:

i. approach used to determine frequency, calculations and sample size

Response

RBS uses SFP coupons for both an Accelerated Exposure Surveillance Program (AES) and a Long-Term Surveillance Program (LTS) for monitoring of the neutron absorber material in the SFP racks. The programs were designed on the guidance available in Brand Industrial Services, Inc. (BISCO) Report #748-34 and EPRI Report NP-6159 for Boraflex materials. As implemented, the program provides for coupon inspections, which are designed to indicate the general condition of the Boraflex and to reveal any gross or unusual degradation.

Both the AES and LTS surveillance programs each use an 11-coupon holder assembly that holds a total of 33 coupons. During each sample period, three coupons are removed from a coupon holder for examination. To reach exposure levels of 2.4 x 10^{11} rads will require the testing of 24 out of the 33 of the available coupons from each surveillance program. This exposure level in the RBS program is beyond the qualification exposure (see ARI 1.c), and represents the cumulative exposure expected to be reached by end of the surveillance program. This leaves nine spare coupons available at the end of each surveillance program for a total of three additional tests if required.

The AES coupons were withdrawn from the SFP and analyzed prior to the end of each cycle from Cycles 2-9 (~ every 18 months). An exposure level of 2.4 x 10^{11} rads was expected to be reached by the time the last coupon was removed for the AES coupons. The purpose of this evaluation method is to simulate the effects of cycling freshly discharged fuel into the same cell once every 5 years for a period of 40 years.

Based on the vendor recommended surveillance frequency, the LTS coupons are withdrawn from the SFP and analyzed every 5 years ±1 year with the first analysis being completed in 1993. The LTS coupons are expected to reach 2.4 x 10^{11} rads at the end of the current operating license. This provides at least eight evaluations over a 40 year operational period.

To ensure that the 5 percent sub-criticality margin can be maintained for the life of the spent fuel storage racks, RBS monitors spent fuel pool silica levels and performs RACKLIFE evaluations. Silica levels are monitored weekly, and RACKLIFE evaluations are performed once per cycle. Each RACKLIFE evaluation includes projections to confirm acceptable performance through the next evaluation period.

ii. parameters to be inspected and data collected

Response

Pre-Irradiation

Every coupon for both the AES and LTS coupon assemblies were examined to establish the pre-irradiated coupon initial examination baseline test data. This data consists of the following:

1. Visual observation
2. Hardness measurement
3. Dimensional measurement
4. Weight measurement

Post-Irradiation

The post-irradiation examination is performed by RBS site personnel. The post-irradiation examination of exposed Boraflex samples consists of visual observation, hardness, weight, and dimensional measurements. If it is concluded that excessive boron loss has occurred based on the visual observation, hardness, and dimensional measurements, then additional testing is performed to determine the B-10 loading in a conservative manner.

- Visual Examination

  Visual examination of the Boraflex material inspects for evidence of gross changes or deterioration. The degree of sample deterioration is classified as follows:

  1. Surface texture uniform both sides; no visible discoloration.
  2. Surface texture uniform both sides; visible discoloration.

3. Minor deterioration of surface, either side, but no appreciable amount of material missing, (minor cracking is allowed).
4. Deterioration of material consisting of cracking, separation, or tears, but no appreciable loss of material.
5. Serious deterioration of material evidenced by craters, voids, and significant loss of material.
6. Conditions more severe than above.

- Hardness

  The hardness of a Boraflex coupon is determined by the use of a calibrated Shore durometer Type A gauge or equivalent at a location approximately one inch inset from the top and 1/2 inch from the side of the coupon. A similar hardness measurement is to be made at a location near the bottom of the same coupon. At each of the locations described, three separate measurements are made and recorded.

- Weight & Dimensional Measurements

  Each Boraflex coupon is measured for thickness at a location midway along the length of the right edge of the coupon. A calibrated micrometer is used with a resolution of 0.001 gram. Three separate measurements are taken of each coupon. The length measurement is performed at a location 1/2 inch inset from the side of the coupon. A calibrated instrument is used with a minimum resolution of 0.001 inch. The Boraflex coupon is weighed with a calibrated instrument with a minimum resolution of 0.001 gram.

iii. acceptance criteria of the program and how they ensure that the material's structure and safety function are maintained within the assumptions of the NCS AOR

Response

The monitoring program was designed to determine the extent of degradation in the neutron absorbing material. Results that indicate unanticipated degradation or deformation are occurring will be entered into the corrective action program for further assessment of impacts, extent of condition, trending, determination of functionality, and implementation of corrective actions. The monitoring program measures the critical parameters of the neutron absorber to show it continues to meet the AOR assumptions. The corrective action program will be used confirm the safety function in the presence of degradation outside the AOR assumptions.

The acceptance criterion for RACKLIFE calculations is that the B_4C loss for all panels must be less than the limit through the next evaluation period. The current limit of 20% loss is discussed in the response to ARI 1.e.ii.

A. Coupon Acceptance Criteria Part I

Excessive degradation is determined to occur if the acceptance criteria for Boraflex measurements are not met. These criteria are described as follows:

1. Visual classification Level 1, 2, or 3 is acceptable (see the response to ARI 2.a.ii for details on these classifications).
2. Hardness is greater than or equal to the initial unirradiated value.
3. Weight loss does not exceed 10% of the original unirradiated value.
4. Average length measurement represents a shrinkage of less than or equal to 4.1%
5. Average of measured thickness is greater than 0.068 inches.

B. Coupon Acceptance Criteria Part II

If any Part 1 acceptance criteria in are not satisfied, additional testing is performed to confirm the minimum Boron-10 areal density is greater than 0.018 gm/cm. If this areal density requirement is not met, then a Condition Report will be initiated to address the AOR and coupon monitoring program.

iv. monitoring and trending of the surveillance or monitoring program data

Response

No additional monitoring or trending of individual coupons is performed following the initial evaluation after removal from the SFP. However, RACKLIFE silica results and B_4C loss results are trended with each cycle update. Based on this trending, a yearly B_4C loss of approximately 1% has been seen. The results of the coupon examinations are pass or fail. Results for the visual observation, dimensional measurement, hardness measurement, weight measurement, and, if required, Boron-10 areal density test are recorded.

The majority of the AES and all of the LTS SFP coupon surveillance tests have passed the Acceptance Criteria Part I described in ARI 2.a.iii. In the few instances where additional testing was required on an AES coupon to determine its areal density, it was found that these coupons had maintained a B-10 areal density greater than 0.018 gm/cm^2, and thus concluded that the SFP criticality assumptions acceptance criteria were met for those coupons.

It is noted that the most recently tested long term surveillance coupon in 2013 passed all visual, dimensional, hardness and weight requirements (see ARI 2.a.iii) and did not require additional Boron-10 areal density testing.

v. industry standards used

Response

The RBS SFP coupon surveillance program is based upon Brand Industrial Services, Inc. (BISCO) Report #748-34 and Electrical Power Research Institute (EPRI) Report NP-6159, "An Assessment of Boraflex Performance in Spent Nuclear Fuel Storage Racks". This vendor guidance provides an overall description of the physical requirements of the coupons, the long term and accelerated coupon surveillances, and the coupon evaluation.

EPRI NP-6159 provides guidance for development of guidelines for Boraflex coupon surveillance programs. The RBS surveillance program, as described in the responses to ARI 2 a) i, ii, iii, and iv, is consistent with the EPRI recommendations. The EPRI report recommends development of acceptance criteria based on assumptions used in the SFP criticality analysis. Coupon measurements may be compared with the following assumptions used in the criticality analysis:

- minimum Boron-10 loading
- minimum sheet width
- minimum sheet length
- minimum sheet thickness

The EPRI report concludes that the results of the coupon measurements are acceptable if the measured coupon data exceed the minimum range implicit in the SFP criticality analysis.

Note that while Boraflex coupon visual examination, weight, and hardness testing are of importance for Boraflex coupon testing to detect potential boron loss, these parameters are not used as inputs to the criticality analysis. Consequently, use of acceptance criteria based on the criticality analysis dimensional assumptions will provide a supplemental check of Boraflex degradation.

b. For the following monitoring methods, include these additional discussion items:

i. If there is visual inspection of in-service material:

1. Describe the visual inspection performed on each sample.

2. Describe the scope of the inspection (i.e., number of panels or inspection points per inspection period).

Response

No visual inspections of in-service material are performed at RBS. This item does not apply at RBS.

ii. If there is a coupon monitoring program:

1. Provide a description and technical basis for how the coupons are representative of the material in the racks. Include in the discussion, the material radiation exposure levels, SFP environment conditions, exposure to the SFP water, location of the coupons, configuration of the coupons (e.g., jacketing or sheathing, venting bolted on, glued on, or free in the jacket, water flow past the material, bends, shapes, galvanic considerations, and stress-relaxation considerations), and dimensions of the coupons.

Response

The surveillance coupon assemblies are representative of the Boraflex material in the racks as the Boraflex material is held between two pieces of stainless steel held together with screws and nuts in a pattern similar to the spot welding of the wrapper plate to the cell enclosure. Cumulative radiation exposure for the coupons is not monitored. The coupons are oriented on a coupon holder extending the length of active fuel. Eleven coupons are mounted on each coupon holder. Given the similarities in coupon configuration to rack configuration, i.e. the Boraflex material between two pieces of stainless steel joined at intervals with no edge seal, the exposure of the coupon to the pool environment is representative of the exposure of the Boraflex in the racks to the pool environment. Each coupon holder is 6" long and 4.5" wide and contains three Boraflex coupons. The coupons are approximately 4" long, 1" wide, and 0.078" thick. Each coupon rack holds 11 coupon assemblies. The coupons are located in cells with one wall having no Boraflex material with the coupons facing the non-poison wall.

2. Provide the dates of coupon installation for each set of coupons.

Response

Both hanger assemblies were installed and surrounded by spent fuel assemblies in Refueling Outage 1, which began on September 14, 1987.

3. If the coupons are returned to the SFP for further evaluation, provide the technical justification of why the reinserted coupons would remain representative of the materials in the rack.

Response

Coupons are not returned to the SFP after being removed for testing. This item does not apply to RBS.

4. Provide the number of coupons remaining to be tested and whether there are enough coupons for testing for the life of the SFP. Also provide the schedule for coupon removal and testing.

Response

Accelerated Exposure Surveillance Program (AES)

The AES program was completed during Cycle 9. There are currently three coupon holders remaining containing three coupons each (nine coupons total). There is currently no schedule or plan in place to test the remaining coupons from the AES program.

Long-term Surveillance Program (LTS)

There are enough coupons remaining for the remaining current operating license. The LTS program is still ongoing and has three more surveillances scheduled going out to the end of the current operating license. There are six remaining coupon holders containing three coupons each (18 coupons total). The table below contains a list of all the coupon holders for the LTS program and the years when the coupons were tested or are scheduled to be tested.

RBS plans to place neutron absorbing inserts into the Boraflex racks and implement a new monitoring program for the inserts. With these inserts, Boraflex would no longer be credited, and thus a Boraflex monitoring program would no longer be needed. The new monitoring program for the insert material is expected to be similar to programs implemented recently at several US nuclear plants, and would contain enough coupons to last the life of the SFP.

Long-term Surveillance Program Schedule

Coupon Holder ID No.	1991 - 1993	1996 - 1998	2001 - 2003	2006 - 2008	2011 - 2013	2016 - 2018	2021 - 2023	2026 - 2028	Spares
A-1	X								
A-2		X							
A-3			X						
A-4				X					
A-5					X				
A-6						X			
A-7							X		
A-8								X	
A-9									X
A-10									X
A-11									X

iii. If RACKLIFE is used:

1. Note the version of RACKLIFE being used (e.g., 1.10, 2.1).

Response

The version of RACKLIFE used at RBS is 2.0.

2. Note the frequency at which the RACKLIFE code is run.

Response

RACKLIFE is run once per cycle.

3. Describe the confirmatory testing (e.g., in-situ testing) being performed and how the results confirm that RACKLIFE is conservative or representative with respect to neutron attenuation.

Response

In-situ testing was performed in 2009 to confirm the Boraflex panels are degrading as expected. The results were benchmarked to RACKLIFE, as described in the response to (4) below, to ensure the RACKLIFE predictions were representative of the actual condition of the Boraflex with respect to neutron attenuation.

4. Provide the current minimum RACKLIFE predicted areal density of the neutron-absorbing material in the SFP. Discuss how this areal density is calculated in RACKLIFE. Include in the discussion whether the areal densities calculated in RACKLIFE are based on the actual as-manufactured areal density of each panel, the nominal areal density of all of the panels, the minimum certified areal density, the minimum as-manufactured areal density, or the areal density credited by the NCS AOR. Also discuss the use of the escape coefficient and the total silica rate of Boraflex degradation in the SFP

Response

The most recent RACKLIFE calculation shows the peak panel at a 12.39% B_4C loss on November 16, 2014, which corresponds to an areal density of 0.0175 g/cm^2. This areal density is calculated using the minimum design areal density of 0.020 g/cm^2 reduced by the percent loss. The calculation internal to RACKLIFE to determine the percent B_4C loss is described in Section 3 of EPRI report TR-107333.

After the BADGER test, the RACKLIFE results were benchmarked to the BADGER measured results. The escape coefficient used in the time period from 2006 forward was then reduced to reduce the bias between the RACKLIFE predicted loss and the BADGER measured losses. The escape coefficients used prior to 2006 were left the same, as the silica trended well with those escape coefficients. The silica trends are analyzed with each RACKLIFE update to ensure they are still accurately represented by the RACKLIFE prediction.

iv. If in-situ testing with a neutron source and detector is used (e.g., BADGER testing, blackness testing):

1. Describe the method and criteria for choosing panels to be tested and include whether the most susceptible panels are chosen to be tested. Provide the statistical

sampling plan that accounts for both sampling and measurement error and consideration of potential correlation in sample results. State whether it is statistically significant enough that the result can be extrapolated to the state of the entire pool.

Response

The official monitoring program at RBS does not include in situ testing with a neutron source and detector, but focuses on coupons placed in the SFP and RACKLIFE evaluations. However, it should be noted that while not part of the official monitoring program at RBS, a BADGER test was performed to validate the assumptions in the NCS AOR as described in ARI 4 b). Panels selected for that BADGER test were not based on a statistical sampling plan. The 25 panels selected covered a wide range of dose values but the selected panels were strongly biased to high doses and B_4C losses based on RACKLIFE calculations.

2. State if the results of the in-situ testing are trended and whether there is repeat panel testing from campaign to campaign.

Response

Only one BADGER test campaign has been performed at RBS, thus no trending or repeat measurements have been performed.

3. Describe the sources of uncertainties when using the in-situ testing device and how they are incorporated in the testing results. Include the uncertainties outlined in the technical letter report titled "Initial Assessment of Uncertainties Associated with BADGER Methodology," September 30, 2012 (Agency wide Access and Management Systems Accession No. ML12254A064). Discuss the effect of rack cell deformation and detector or head misalignment, such as tilt, twist, offset, or other misalignments of the heads and how they are managed and accounted for in the analysis.

Response

RBS utilized the first generation BADGER equipment and methodology for its test in 2009. While the uncertainties associated with areal density in the first generation BADGER are described in general terms in the BADGER report, the specific components are not described in detail, nor are they quantified. These uncertainties are not included in the AOR; however, the AOR is based on a conservative fuel design reactivity and has significant margin to the regulatory limit of 5% subcriticality margin.

4. Describe the calibration of the in-situ testing device, including the following:

    a. Describe how the materials used in the calibration standard compare to the SFP rack materials and how any differences are accounted for in the calibration and results.

Response

The calibration cell used is not built for the specific racks at RBS, and thus there may be minor differences in cell design, dimensions and distances between the source and detectors. The materials used, Boraflex and stainless steel, are the same as the in-service material. The differences in the calibration cell and the actual rack are accounted for by the use of a reference panel. The reference panel is chosen to be a panel that is expected to be representative of the as-built areal density that has not had fuel in close proximity, so there is essentially no accumulated dose. The reference panel results provide the baseline for comparison with other rack panels.

b. Describe how potential material changes in the SFP rack materials caused by degradation or aging are accounted for in the calibration and results.

Response

The calibration cell includes variations in Boron content in order to establish a detector calibration curve to account for areal density changes in the installed Boraflex panels. A similar calibration is provided for gaps in the Boraflex. Experience indicates the system does respond to local features in the Boraflex (local dissolution, partial gaps), however, the accuracy of these responses have not been determined.

c. If the calibration includes the in-situ measurement of an SFP rack "reference panel", explain the following:

i. the methodology for selecting the reference panel(s) and how the reference panels are verified to meet the requirements,

Response

The reference panel is chosen to be an unirradiated or very low dose panel that is expected to be representative of the as built condition. The panel dose is verified based on RACKLIFE predictions. However, since as-built areal density values for individual panels are not available, there is no way to verify the specific panel initial areal density.

ii. whether all surveillance campaigns use the same reference panel(s)

Response

Only one BADGER test campaign has been performed at RBS, so this item is N/A.

iii. If the same reference panels are not used for each measurement surveillance, describe how the use of different reference panels affects the ability to make comparisons from one campaign to the next.

Response

Only one BADGER test campaign has been performed at RBS, so this item is N/A.

ARI 3

3. For any Boraflex, Carborundum, or Tetrabor being credited, describe the technical basis for determining the interval of surveillance or monitoring for the credited neutron-absorbing material. Include a justification of why the material properties of the neutron-absorbing material will continue to be consistent with the assumptions in the SFP NCS AOR between surveillances or monitoring intervals.

Response

The interval of surveillance for the RBS SFP coupon surveillance program is based on vendor guidance, which provides an overall description of the physical requirements of the coupons, the long term and accelerated coupon surveillances, and the coupon evaluation. The interval is provided in the response to ARI 2.a.i.

Based on the 2009 BADGER test, the areal density is conservatively calculated by RACKLIFE and the measured gap sizes were less than the AOR assumptions. The AOR is based on a conservative fuel design reactivity and has significant margin to the regulatory limit of 5% subcriticality margin, which would support potential long term increases in gap size. However, RBS has elected to eliminate credit for Boraflex based on projected long term performance. Neutron absorber insert designs are currently under development along with project plans for this installation.

ARI 4

4. For any Boraflex, Carborundum, Tetrabor, or Boral being credited, describe how the credited neutron-absorbing material is modeled in the SFP NCS AOR, and how the monitoring or surveillance program ensures that the actual condition of the neutron-absorbing material is bounded by the NCS AOR:

a. Describe the technical basis for the method of modeling the neutron-absorbing material in the NCS AOR. Discuss whether the modeling addresses degraded neutron-absorbing material, including loss of material, deformation of material (such as blisters, gaps, cracks, and shrinkage), and localized effects, such as non-uniform degradation.

Response

Minimum as-designed Boraflex dimensions are used, with a 4.1% shrinkage applied to the width. The NCS AOR originally assumed a 90% of the minimum design areal loading. However, an evaluation was performed to show that when using a reduced reactivity design basis assembly

and an areal density of 0.016 g/cm^2 (20% loss from the minimum design value), the system reactivity was less than the original design basis assembly with an areal density of 0.018 g/cm^2. In addition, the NCS AOR results continue to bound all legacy fuel in the RBS SFP and reload fuel currently in the RBS core with consideration of 20% Boron loss. Thus, the Boron-10 content is assumed to be 80% of the minimum design areal loading. Each panel is assumed to have a single 6" gap. The gaps are assumed to be randomly distributed within the central 50% of the panel length. These assumptions are conservative when compared to the values derived by EPRI, which projected maximum shrinkage to be 4.1%, which converts to a cumulative gap size of approximately 6 inches for the RBS Boraflex.

b. Describe how the results of the monitoring or surveillance program are used to ensure that the actual condition of the neutron absorbing material is bounded by the SFP NCS AOR. If a coupon monitoring program is used, provide a description and technical basis for the coupon tests and acceptance criteria used to ensure the material properties of the neutron-absorbing material are maintained within the assumptions of the NCS AOR. Include a discussion on the measured dimensional changes, visual inspection, observed surface corrosion, observed degradation or deformation of the material (e.g., blistering, bulging, pitting, or warping), and neutron-attenuation measurements of the coupons.

Response

The technical basis for the coupon program is discussed in the response to ARI 2 a) i, and the acceptance criteria are given in the response to ARI 2 a) iii. Results of the coupon program are discussed in the response to ARI 1 e) iii and 2 a) iv.

BADGER measurements are not included in the official Boraflex monitoring program. However, the results of the BADGER test conducted in 2009 confirmed the RACKLIFE areal density predictions were, on average, conservatively biased, and that the gap assumptions in the AOR were conservative. The RBS RACKLIFE calculations performed to date have demonstrated that the B_4C loss is not greater than 20%, nor is the loss projected to reach 20% prior to the planned date of completion of the installation of neutron absorbing rack inserts.

c. Describe how the bias and uncertainty of the monitoring or surveillance program are used in the SFP NCS AOR.

Response

No bias or uncertainty from the monitoring program is included in the NCS AOR. However, the NCS AOR is based on a conservative fuel design reactivity and has significant margin to the regulatory limit of 5% subcriticality margin.

d. Describe how the degradation in adjacent panels is correlated and accounted for in the NCS AOR.

Response

The degradation in adjacent panels was not an explicit consideration used in the NCS AOR at RBS. However, the analysis assumes all panels have experienced uniform thinning and width shrinkage of 4.1%. It also assumes all panel have one large 6" gap so the gap size and number of gap assumptions simulate complete correlation between adjacent panels. The gap location is artificially constrained to the central 50% (~6 feet) of each panel. This approach results in significant co-location of gaps in adjacent panels.

ARI 5

5. For any Boraflex, Carborundum, or Tetrabor being credited, describe the technical basis for concluding that the safety function for the credited neutron-absorbing material in the SFP will be maintained during design-basis events (e.g., seismic events, loss of SFP cooling, fuel assembly drop accidents, and any other plant-specific design-basis events that may affect the neutron-absorbing material).

a. For each design-basis event that would have an effect on the neutron-absorbing material, describe the technical basis for determining the effects of the design-basis event on the material condition of the neutron-absorbing material during the design-basis event, including:

i. shifting or settling relative to the active fuel

Response

Seismic events

The flexural strength and Young's Modulus of irradiated Boraflex have been measured on specimens having been exposed to a range of gamma doses up to >3 x 10^{10} rads. Conservative assumptions were applied in determining how the strains in the structural stainless steel are transferred to the Boraflex, and using experimentally determined values of Young's Modulus, the peak stresses in the Boraflex were computed. In all cases the calculated Boraflex stresses were less than the threshold failure stress by a substantial margin. Generally, this provides the overall basis for considering any effect on the Boraflex neutron-absorbing material during a seismic event.

Slumping or shifting of Boraflex during a seismic event is not considered in the current NCS AOR. However, is not expected that Boraflex will slump or shift based on the discussion above.

Fuel Assembly Drop Accident

Analyses were performed to assess the damage to the fuel storage racks due to the postulated fuel drops. One "shallow" drop and one "deep" drop events were identified and studied. The impact on the rack structure was evaluated using the LS-DYNA code. The "shallow" drop, which simulates an assembly falling on the top of the rack, results indicate that the plastic deformation of the impacted cell wall is about 24 inches measured from the top of the rack. The "deep" drop event, which simulates an assembly falling through an empty cell and impacting the base plate,

results show that the rack does not experience any gross failure. The maximum deformation of the rack baseplate due to the "deep" drop is found to be 3.73 inches, which will not cause the stored fuel assemblies and the baseplate to be in contact with the SFP liner.

The Shallow Drop Event discussed above was considered in the RBS AOR. It was assumed that a new fuel assembly, traveling over the SFR, drops through the stratum of water before impacting the upper portion of the rack in the pool. The calculated maximum damaged depth of the poison panel wall is 24" measured from the top of the rack, assuming all cells are empty to maximize the damage. This configuration bounds a horizontally oriented drop since the damage would occur over a large surface area (~24 cells). Since damage to the top (~14") of the rack has no reactivity consequence, this configuration is bounded by the vertically oriented drop. The Shallow Drop Event analysis demonstrates that the RBS high density fuel racks remain adequately subcritical for the base fuel assembly and meet the requirement of NUREG-0800 and the RBS Technical Specifications (i.e., keff ≤ 0.95 under normal and abnormal conditions including all uncertainties).

ii. increased dissolution or corrosion

Response

The loss of cooling to the spent fuel pool would result in a gradual increase in pool water temperature. However, due to the short duration of such an event, this limits the impact on the overall performance of the neutron-absorbing material.

iii. changes of state or loss of material properties that hinder the neutron-absorbing material's ability to perform its safety function

Response

The design basis event answers are provided in the responses to ARI 5.a.i and ii. No mechanism has been identified that would result in the neutron absorbing material's to undergo a 'change in state' (i.e., consideration for the neutron absorbing material moving from a solid to powder or liquid form).

b. Describe how the monitoring program ensures that the current material condition of the neutron-absorbing material will accommodate the stressors during a design-basis event and remain within the assumptions of the NCS AOR, including:

i. monitoring methodology

Response

The responses to ARI 5.a demonstrate that the neutron-absorbing material will adequately accommodate stressors during a design basis event. Therefore, the assumptions in the NCS AOR will continue to be met during these types of events.

ii. parameters monitored

Response

The assumptions used in the NCS AOR will ensure that the monitored parameters, as described in the monitoring program in the response to ARI 2.a.ii, remain applicable following a design basis event. The parameters monitored would not be impacted by a seismic event.

iii. acceptance criteria

Response

The acceptance criteria for the overall monitoring program are described in the response to ARI 2.a.iii, and would be unchanged as a result of a design basis event.

iv. intervals of monitoring

Response

The intervals of monitoring for the overall monitoring program is described in the response to ARI 2.a.i and a change to these intervals would be evaluated following a design basis event.

References:

[1] (GL) 2016-01, "Monitoring of Neutron-Absorbing Materials in Spent Fuel Pools" [ML16097A169]