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RS-17-053

10 CFR 50.54(f)

April 27, 2017

ATTN: Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Calvert Cliffs Nuclear Power Plant, Unit 1
Renewed Facility Operating License No. DPR-53
NRC Docket No. 50-317

Nine Mile Point Nuclear Station, Unit 1
Renewed Facility Operating License No. DPR-63
NRC Docket No. 50-220

Oyster Creek Nuclear Generating Station
Renewed Facility Operating License No. DPR-16
NRC Docket Nos. 50-219

Subject: Response to Request for Additional Information Regarding Generic Letter 2016-01

References:

1. NRC Generic Letter 2016-01, "Monitoring of Neutron-Absorbing Materials in Spent Fuel Pools," dated April 7, 2016
2. Letter from P. R. Simpson (Exelon Generation Company, LLC) to U.S. NRC, "Response to Generic Letter 2016-01," dated November 3, 2016
3. Letter from D. A. Broaddus (U.S. NRC), "Generic Letter 2016-01, 'Monitoring of Neutron-Absorbing Materials in Spent Fuel Pools' – Licensee-Reported Category 3 Plants," dated March 9, 2017

On April 7, 2016, the NRC issued Generic Letter (GL) 2016-01, "Monitoring of Neutron-Absorbing Materials in Spent Fuel Pools" (i.e., Reference 1), to address degradation of neutron-absorbing materials in wet storage systems for reactor fuel at power and non-power reactors. Exelon Generation Company, LLC (EGC) provided responses to GL 2016-01 for the stations listed above in Reference 2. In Reference 3, the NRC requested additional information that is needed to complete the review. In response to this request, EGC is providing the attached information.

There are no regulatory commitments contained in this letter. Should you have any questions concerning this letter, please contact Mr. Kenneth M. Nicely at (630) 657-2803.

I declare under penalty of perjury that the foregoing is true and correct. Executed on the 27th day of April 2017.

Respectfully,

Patrick R. Simpson
Manager – Licensing

Attachments:

1. Response to Request for Additional Information for Calvert Cliffs Nuclear Power Plant
2. Response to Request for Additional Information for Nine Mile Point Nuclear Station
3. Response to Request for Additional Information for Oyster Creek Nuclear Generating Station

cc: NRC Regional Administrator – Region I
NRC Regional Administrator – Region III
Senior Resident Inspector – Calvert Cliffs Nuclear Power Plant
Senior Resident Inspector – Nine Mile Point Nuclear Station
Senior Resident Inspector – Oyster Creek Nuclear Generating Station

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:***

The Calvert Cliffs Nuclear Power Plant (CCNPP) Unit 1 SFP (i.e., north pool) contains Carborundum sheets as a neutron-absorbing material (NAM). The sheets are installed in the four double wall compartments of each fuel storage rack cell.

a) ***manufacturers, dates of manufacture, and dates of material installation in the SFP;***

The CCNPP Unit 1 SFP NAM was manufactured by the Carborundum Company. Exact fabrication dates of the sheets are not available. Records indicate a pre-fabrication audit for the NAM was conducted in February 1980, and material certifications by the Carborundum Company for the completed NAM batches used in the CCNPP Unit 1 SFP racks were written on May 15, 1980, and June 2, 1980. Nuclear Energy Services, Inc. (NES) designed and supplied the racks. NES also performed the analyses and provided technical assistance during installation. NES contracted fabrication of the racks to Metal Products Corporation. Bechtel Power Corporation provided engineering assistance in reviewing the SFP structural considerations.

Five hundred of the 830 total rack cells were installed in the Unit 1 SFP by October 1980. The remainder were installed in 1981.

b) ***neutron-absorbing material specifications, such as:***

i) ***materials of construction, including the certified content of the neutron-absorbing component expressed as weight percent;***

The Carborundum sheets are composed of granular boron carbide bonded in a phenol formaldehyde matrix (Bakelite) applied to a fiberglass mat. The typical composition of the material is described in the Carborundum Company report "Handbook of the Effects of In-Pool Exposure on Properties of Boron Carbide-Resin Shielding Materials," which was submitted to the NRC on May 10, 2007, and can be found in ADAMS under accession number ML071440224. The composition is Boron Carbide 64%, Binder 18%, and Fiberglass 18%.

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

The specification required a minimum boron-10 areal density of 0.024 $g^{10}B/cm^2$ and 0.09 inch sheet thickness in each NAM compartment (i.e., 0.012 $g^{10}B/cm^2$ per sheet x 2 sheets). A total of 6650 sheets were procured in two batches. The batch from powder lot B585-65-1 was certified to have an average areal density of 0.0153 $g^{10}B/cm^2$, and the batch from powder lot B585-65-2 was certified to have an average areal density of 0.0144 $g^{10}B/cm^2$. Both certifications indicate that similar material has demonstrated a minimum 0.012 $g^{10}B/cm^2$ after simultaneous exposure to 10^{11} Rad gamma and deionized water. As a result, the actual as-built rack boron-10 loading would be expected to range from 0.0288 to 0.0306 $g^{10}B/cm^2$

(i.e., combination of the two sheets making up the 0.09 inch thickness in each NAM compartment).

iii) material characteristics, including porosity, density, and dimensions;

Complete details on the physical characteristics of the Carborundum sheet material are contained in the Carborundum Company report "Handbook of the Effects of In-Pool Exposure on Properties of Boron Carbide-Resin Shielding Materials," which was submitted to the NRC on May 10, 2007, and can be found in ADAMS under accession number ML071440224. The dimensions of the Carborundum sheets procured for the CCNPP Unit 1 SFP racks were 150 inches long, 6.5 inches wide, and 0.045 inches thick. The total thickness of Carborundum is 0.09 inches.

e) current condition of the credited neutron-absorbing material in the SFP, such as:

A complete summary of all coupon results to date can be found in ADAMS at accession numbers ML12319A474 and ML14119A437.

i) estimated current minimum areal density;

The lowest minimum areal density of those coupons tested is 0.0250 $g^{10}B/cm^2$.

Prior to 2013, areal density was not required to be tested for every coupon. Weight loss measurement was used instead, as it was considered to be more conservative. The original manufacturer test program found that there were no statistically significant changes in length or width of the test samples with irradiation to 10^{11} Rad in deionized water and 10^{10} Rad in borated water. Since coupon length and width do not change significantly with irradiation, the change in coupon weight would be directly proportional to changes in thickness and/or density.

The 2013 areal density was measured due to expanding the scope due to the flow-induced erosion at the inspection holes, as described in Section 1.e.iii below.

ii) current credited areal density of the neutron-absorbing material in the NCS AOR; and

Criticality analyses have assumed the specified minimum areal density of 0.024 $g^{10}B/cm^2$ as the original loading amount. Analyses performed prior to license renewal reduced this amount by 15% (i.e., 0.020 $g^{10}B/cm^2$) to account for boron loss over the original 40 year plant license. The current criticality analyses of record performed after license renewal increased the boron loss to 26.2% (i.e., 0.0177 $g^{10}B/cm^2$) to cover a 70-year service life for the racks. Acceptance criteria of the upper and lower areal densities for each coupon pair is greater than 0.0177 $g^{10}B/cm^2$.

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).

The most recent coupon analysis was completed on December 5, 2013. The initial results of coupon dimension and weight measurements did not meet the acceptance criteria listed in the long term coupon surveillance program. Specifically, the criterion not met was "any change in weight of +/- 26% compared to baseline."

The unexpected coupon weight loss was due to flow-induced erosion caused by an inspection hole in the coupon bracket cover. The NAM in the spent fuel rack is not susceptible to this erosion because there are no inspection holes in the active fuel region. There are inspection holes nine inches above the active fuel region in the racks that had similar erosion noted as visible from the cask loading area. The erosion was to a lesser extent than that seen in the coupons, and Carborundum above the active fuel region is not modeled in the NCS AOR. As of January 2014, it was not expected that flow induced erosion of the sheet extends to areas below the rack inspection hole based on the design of the racks.

In accordance with the 2008 NRC safety evaluation for the Carborundum surveillance program, a recovery plan was initiated to: (1) expand the scope of testing, (2) perform areal density testing on original and expanded scope coupons, and (3) determine the cause of the weight loss. After the identified erosion, the following additional actions were established in License Amendment 288 to address actions if another coupon does not meet the established acceptance criteria.

- Perform areal density measurement on coupon regardless if it was scheduled and if the areal density measurement meets the established acceptance criteria, then expansion of the surveillance program will be determined by evaluations done as part of the Corrective Action Program.
- Expand the surveillance program to remove additional coupons for visual examinations, dimensional, weight, and areal density measurements.

Due to the inspection hole erosion on the coupons in 2013, future coupon testing is planned to include measurement of areal density. The procedure change to incorporate this is in progress.

To prevent any further degradation at the inspection holes, bracket covers were fabricated and installed to cover the holes in 2016.

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.

The coupons are extracted from the SFP for examinations that consist of visual, weight, and dimensional determinations. The visual examination consists of inspecting for evidence of gross changes or deterioration. The coupons are dried via air for 48 hours or oven at ~105°C for 2 hours, and then the weight is recorded along with the drying time. Drying in air for 24 hours, or oven for one hour, followed by recording the weight and drying time, is then repeated until the last two weights are within 1% of each other. The weight of each coupon is measured to within 0.001 grams and compared against the sample initial weight using a calibrated scale. The length and width of each sample is measured within 0.001 inch and compared against the sample initial length and width using a calibrated caliper. The loss of mass of the coupons was used as a measure of degradation instead of the areal density because previous experience has indicated that mass loss was more conservative in determining coupon degradation than the change in areal density. The areal density test is performed by NETCO.

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:

v) industry standards used.

No industry standards are referenced in the testing procedures used during coupon surveillance testing at CCNPP Unit 1.

NETCO uses ASTM E2971-16 for areal density tests as a "reference standard" that speaks to the methods used. For testing Carborundum, another standard they use is C-1187 (Current Revision), "Standard Guide for Establishing Surveillance Test Program for Boron-Based Neutron Absorbing Material Systems for Use in Nuclear Spent Fuel Storage Racks."

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

i) If there is visual inspection of inservice material:

The testing performed on coupons requires removing the coupon. Therefore, this section is not applicable.

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;

The company that manufactured the Carborundum sheets conducted a Carborundum qualification program in which test panels were simultaneously exposed to 10^{11} Rad gamma radiation and borated water, simulating a 40-year lifetime similar to what is expected in the SFP. The results of this program showed that the material exhibited chemical stability, boron retention, and mechanical property changes within design specifications.

CCNPP Unit 1 SFP racks contain boron carbide in Carborundum sheets as the NAM. Sample coupons of the Carborundum were included on the Long-Term Surveillance Assembly (LTSA) and are included on the Accelerated Surveillance Assembly (ASA). The LTSA coupon tree was placed in a SFP rack location that was to see typical doses from fuel as the fuel aged in the SFP. The ASA coupon tree was placed among freshly discharged fuel following each refueling and, over time, received higher exposure than the LTSA coupons.

License Amendment 267 included a license condition that required CCNPP to develop a new long-term coupon surveillance program for the Carborundum samples. With only five accelerated sample coupons remaining, the intervals for sampling would have to be increased to allow for a sampling program for the extended life of the plant. Proceeding with these much longer ASA sample intervals (i.e., about every eight years) was not an acceptable approach, and therefore the surveillance program was modified.

The new Carborundum coupon surveillance program would use the remaining accelerated samples from the ASA, on a four-year cycle beginning in 2005, followed by the remaining eight long-term samples from the discontinued LTSA, continuing on a four-year cycle through 2053 (i.e., end of the 70-year life span of the Unit 1 SFP racks). To make the eight long-term samples available for this new surveillance program, the existing LTSA coupon surveillance program was discontinued in 2004. These eight LTSA samples were then subjected to accelerated doses so that they are expected to have exposures comparable to the ASA samples when it is time for the first of these eight to be sampled (i.e., beginning in 2025).

The ASA coupon tree is a fuel assembly sized item that is placed in the spent fuel storage racks. Each of the four sides of the coupon tree has six coupons attached vertically to the outside of the assembly. The samples on each side of the assembly receive dose primarily from the fuel in the storage rack location adjacent to that side.

To accelerate doses to the eight remaining LTSA samples, they were placed onto new coupon trees that will allow the coupons to see higher doses from fuel. The new coupon trees, instead of being placed inside a rack location, were placed in the space between racks in the SFP. This allowed the sample coupons to see dose from the fuel that is in the rack locations on both sides of the coupons. The dose on the accelerated LTSA coupons is expected to exceed the ASA coupons before the ASA coupons are exhausted.

(2) provide the dates of coupon installation for each set of coupons;

Coupon samples were installed by 1981. See discussion above for the two types of coupons and the timeline for how they are planned for use to most accurately represent the spent fuel racks.

(3) if the coupons are returned to the SFP for further evaluation, provide the technical justification for why the reinserted coupons would remain representative of the materials in the rack; and

To support additional testing that may be required in the future, poison samples are returned to the SFP following evaluation, unless the samples are sent off-site for areal density testing.

Coupons that are returned to the SFP after non-destructive testing is performed are not scheduled to be re-used for license adherence. The remaining tests scheduled at CCNPP Unit 1 use a different coupon each time.

(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.

The surveillance program uses the remaining two accelerated samples from the ASA, on a four-year cycle that began in 2005, followed by the remaining eight long-term samples from the discontinued LTSA, continuing on a four-year cycle through 2053 (i.e., end of the 70-year life span of the Unit 1 spent fuel racks).

There are 10 remaining coupon packets, sufficient for testing for the life of the SFP. The coupon packet #24, originally scheduled for testing in 2021, has only two coupons in it instead of four. This is the packet that the expanded scope of testing was taken from for the 2013 coupon testing.

Test Number	Sample Date	Sample Coupon Type
12	2017	Original ASA
13	2021	Original ASA
14	2025	Accelerated LTSA
15	2029	Accelerated LTSA
16	2033	Accelerated LTSA
17	2037	Accelerated LTSA
18	2041	Accelerated LTSA
19	2045	Accelerated LTSA
20	2049	Accelerated LTSA
21	2053	Accelerated LTSA

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.***

The CCNPP Carborundum monitoring program assures that degradation of the Carborundum in the spent fuel racks will not compromise the criticality analysis. The periodicity of testing every four years was approved by NRC as part of the new Long-Term Coupon Surveillance Program for the Unit 1 SFP in Amendment 288 issued in August 2008.

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.***

Each half of the SFP is equipped with vertical spent fuel racks installed on the pool bottom. The fuel rack cells are individual double-walled containers approximately 14 feet long. The inner wall of each cell is made from a 0.06 inch thick sheet of stainless steel formed into a square cross-section container, indented on the corners with an inside dimension of 8.56 inches. The outer, or external, wall is also formed from a stainless steel sheet 0.06 inches thick. Plates of borated, NAM are inserted between the two walls in each of the four spaces formed by the indentations in the inner wall. The plates are made of a boron carbide composite material (Carborundum) and are 6.5 inches wide by 0.09 inches thick. Each plate initially contains at least 0.024 $g^{10}B/cm^2$. The spacing between the cells is maintained at 10 3/32 inches, center to center, by external sheets and welded spacers. The boron plate inserts and assembly spacing help maintain the SFP assemblies in a subcritical condition.

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.***

CCNPP has a coupon surveillance program to test the condition of the Carborundum material. The cumulative results of the coupon surveillance program indicated that the Carborundum sheets had experienced no significant dimensional changes since their implementation. Thus, no dimensional changes of the Carborundum sheets are assumed in the NCS AOR for the purpose of determining the 26% weight loss acceptance criteria. Amendment 288 later introduced a +/- 0.5 inch acceptance criteria for length/width of the Carborundum coupons. This acceptance criteria was determined using the NCS AOR method and models and was based on defining the amount of width reduction in all sheets at the initial minimum areal density (0.024 $g^{10}B/cm^2$) that could be tolerated while remaining within the NCS AOR k_{eff} results for 26% weight loss.

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

The CCNPP Unit 1 NCS AOR, CA06011 Revision 0, which can be found in ADAMS at accession number ML031270300, includes a "Poison Loading" uncertainty of 10% to account for uncertainty in the measurement of boron content of the sheets. This is described in Section 9.B.7 of the analysis. Note that most of the KENO cases in the analysis assumed the areal boron-10 loading was 0.020 $g^{10}B/cm^2$ and a bias was developed and included in the rackup of biases and uncertainties (see page 39 of the analysis) to extend the calculated results to an areal density of 0.0177 $g^{10}B/cm^2$. An additional case at 0.0159 $g^{10}B/cm^2$ was run to develop the 10% poison loading uncertainty for this level of degradation.

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

The NCS AOR assumes that all panels are equally degraded.

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).***

The double contingency principle was applied, which required two unlikely, independent, concurrent events to produce a criticality accident. The double contingency principle means that realistic conditions may be assumed. Accidents included dropping of a fuel assembly on top of the racks, abnormal placement of a fuel assembly in the SFP, a cask or heavy object drop onto the SFP racks, effect of tornado or earthquake on the deformation and relative position of the fuel racks, and loss of cooling systems or flow unless single failure proof.

The Carborundum monitoring program assures that degradation of the Carborundum in the spent fuel racks does not compromise the criticality analysis in support of the design of the spent fuel storage racks.

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:***

See the CCNPP Unit 1 criticality analysis, CA06011 Revision 0, in ADAMS at accession number ML031270300 for more detail. The off-normal / accident cases covered are listed below.

- Fuel Misloading Accident
- Abnormal Placement of a Fuel Assembly in the SFP Racks
- Horizontal Assembly Drop Accident

- Vertical Assembly Drop Accident
- Cask or Heavy Object Drop onto the SFP Racks
- Boron Dilution Accident
- Loss of Coolant Accident
- Loss of Cooling Accident
- Natural Phenomena Incident

The double contingency principle was applied to the Horizontal Assembly Drop Accident. This allowed taking total credit for the presence of soluble boron in evaluating this accident condition.

The Natural Phenomena Incident discusses that the SFP racks are Seismic Category 1 and are supported in such a manner as to preclude a reduction in separation under either the Operating Basis or Safe Shutdown Earthquake. No sudden loss of all Carborundum was considered for any natural phenomenon. The double contingency principle could be applied in this situation to demonstrate $k < 0.95$ in a manner similar to fuel drop.

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:

The periodic Carborundum surveillance confirms assumptions in the NCS AOR. It does not assess the ability of the NAM's performance in a design basis event.

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;***

   Nine Mile Point Unit 1 (NMP1) employs one type of Boraflex SFP rack. There are two racks remaining in the NMP1 SFP that use Boraflex as the neutron-absorbing material (NAM), one 11x18 rack and one 12x18 rack.

   The Boraflex material in NMP1 SFP racks was manufactured by BISCO (Brand Industrial Services, Inc.) in 1982. The two Boraflex racks were made by US Tool & Die. The Boraflex racks were installed in 1984.

   b) ***neutron-absorbing material specifications, such as:***

      i) ***materials of construction, including the certified content of the neutron-absorbing component expressed as weight percent;***

      The Boraflex material's contents were not specified on a weight percent basis of the neutron-absorbing component.

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

      The Boraflex material's certified minimum areal density is 0.0217 $g^{10}B/cm^2$. The average as-fabricated areal density from production records is 0.0254 $g^{10}B/cm^2$. The minimum and maximum batch as-built areal densities are 0.0251 $g^{10}B/cm^2$ and 0.0257 $g^{10}B/cm^2$, respectively.

      iii) ***material characteristics, including porosity, density, and dimensions;***

      The Boraflex panels (i.e., two in each Boraflex panel holder) are 134 inches long, 11.25 inches wide, and 0.110 inches thick (maximum). The width is 11.25 inches because each Boraflex panel holder is positioned next to two side-by-side bundles.

      After a reasonable search of the plant's records, including docketed information, Exelon Generation Company, LLC (EGC) determined that the Boraflex porosity and density were not part of the original licensing basis or previously requested by the NRC as part of the licensing action that approved the neutron absorber monitoring programs.

   c) ***qualification testing approach for compatibility with the SFP environment and results from the testing;***

   After a reasonable search of the plant's records, including docketed information, EGC determined that the Boraflex qualification testing plans were not part of the original licensing basis or previously requested by the NRC as part of the licensing action that approved the neutron absorber monitoring programs.

d) configuration in the SFP, such as:

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

The Boraflex poison for the NMP1 racks is contained in individually built modules that hold two sheets of poison in an envelope made of stainless steel. These modules are placed between the rows of rack cells such that each cell has poison plates on two opposing sides and other fuel bundles on the remaining opposing sides (i.e., not including rack boundaries). The envelopes that hold the Boraflex are vented on the top and bottom to prevent build-up of any gasses generated.

ii) sheathing and degree of physical exposure of neutron-absorbing materials to the SFP environment;

The Boraflex poison envelopes are vented and are thus filled with SFP water. The somewhat unique design of this rack does limit the rate of the water exchange into and out of the envelope more than most other rack designs. This is a fact that has been supported by the relatively slow rate of degradation of the NMP1 Boraflex in the two racks that remain.

e) current condition of the credited neutron-absorbing material in the SFP, such as:

i) estimated current minimum areal density;

Based on Boraflex Areal Density Gauge for Evaluating Racks (BADGER) testing, RACKLIFE, and coupon data, the current estimated minimum areal density of Boraflex in the NMP1 racks is conservatively estimated at 0.0244 $g^{10}B/cm^2$ (i.e., RACKLIFE estimate for a date of December 31, 2018 – the nearest conservative RACKLIFE statepoint in the existing model).

ii) current credited areal density of the neutron-absorbing material in the NCS AOR; and

The current credited areal density of Boraflex is 0.0217 $g^{10}B/cm^2$.

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).

Both coupon testing and BADGER in-situ testing are used to track the material condition of the NMP1 Boraflex racks. The following listing summarizes the findings of deformations or degradation in the Boraflex materials from these tests. Note that the significant coupon edge degradation has been expected based on the history of other industry Boraflex coupon programs. The amount of edge dissolution is not reflective of expectations for the actual panels due to the small size of the coupons and the fact that the coupons are much more exposed to the SFP water than the material in the SFP racks. This expectation has been supported by the findings from the BADGER testing. The coupons continue to provide important information for the areal density behavior of the material in areas not impacted by edge dissolution.

NMP1 has removed and tested 20 Boraflex coupons to date with the most recent coupon measurement performed in 2016. The results from this most recent coupon test are representative of issues identified with the coupon material as Boraflex degradation has advanced.

- The physical description of the coupon included that it leaves a powdery residue when touched and was characterized as delicate.
- There were significant percent losses to the width and length of the coupon due to edge dissolution.
- The thickness of the coupon was larger than the original thickness due to densification earlier in life and any surface dissolution has been limited in extent.
- The coupon weight loss was commensurate with the loss of material due to edge dissolution.
- The areal density of the coupon was measured to be 18.43% greater than the minimum certified areal density.

The most recent BADGER test performed in 2008 reported areal densities that were all significantly larger than the 0.0217 $g^{10}B/cm^2$ minimum certified areal density. The minimum measured panel areal density was 0.0250 $g^{10}B/cm^2$. The BADGER testing identified only four panels with gaps in the 45 panels that were tested. All gaps were less than 1/2-inch in length.

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:***

   The Boraflex program utilizes a coupon analysis methodology. The coupons are periodically removed from the SFP, sent to a qualified laboratory, and analyzed for the acceptance criteria discussed in the response to 2(a)(iii) below. The practice at NMP1 is to surround the coupons with fuel assemblies that would logically produce the highest local gamma flux expected in the NMP1 SFP. These would include recently-discharged assemblies that have high relative power fractions. One coupon is removed and tested every two years (i.e., as a function of the NMP1 refueling outage frequency). Use of one coupon allows NMP1 to both conduct coupon analyses through current end-of-life (2029) and to keep four spare coupons in reserve in the event of an inconclusive analysis.

   The NAM monitoring plan for the Boraflex material also includes BADGER in-situ testing along with the use of the EPRI RACKLIFE program and the coupon testing already mentioned. BADGER testing is a method for measuring the boron-10 areal density of in-rack Boraflex panels, and also provides data on cracking, gaps, and local dissolution in the panels. The Boraflex Rack Life Extension code (RACKLIFE) is used to predict the panel average areal density loss due to dissolution in the SFP panels given a specific SFP rack environmental history. These methods are used in conjunction to apply the mechanistic areal density loss model (RACKLIFE) as calibrated to the actual Boraflex coupon measured areal densities to predict future SFP panel degradation levels. The BADGER data is used to verify that the coupon results are sufficiently representative of the in-rack Boraflex panel behavior. The RACKLIFE predictions are compared to coupon measurements on a more frequent schedule (i.e., each cycle). The measurements and predictions are used to ensure that the NCS AOR assumed areal densities are maintained or corrective actions are taken to empty impacted SFP cells of fuel or the SFP NCS AOR updated if possible. These tools are being used as interim measures to allow time to implement a final corrective action that will remove the SFP rack's reliance on Boraflex credit for fuel criticality safety purposes.

EPRI's RACKLIFE program is a mechanistic code that predicts the Boraflex panel average degradation due to the silica matrix dissolution for every panel in the SFP based on the following primary effects on the panels:

- Gamma radiation dose from spent fuel,
- Time spent in the SFP environment,
- The SFP housed fuel history (end-of-cycle power levels – feeds gamma source, etc.)
- SFP water temperature,
- SFP water pH,
- Silica levels in the SFP water,
- Silica removal rate from SFP water by fresh water exchange and filtering systems, and
- The rate of bulk SFP water exchange with the water cavity surrounding the Boraflex panel.

Per the user's manual, the RACKLIFE code "simulates the loss of the criticality controlling neutron absorber boron carbide from Boraflex as the latter dissolves in the spent fuel pool water. The boron carbide itself does not dissolve in water, but the silica matrix that binds it does, particularly after irradiation. Since silica can be measured in the pool water, silica dissolution and transport can be simulated based on the measured data, and from the results the amount of boron carbide loss from each panel can be calculated."

Thus the RACKLIFE code is performing a complex silica chemical balance within the SFP and rack panel cavities to predict the rate of dissolution of the material from the Boraflex once the molecular structure has been broken down due to the gamma radiation field in the SFP.

The BADGER in-situ testing system provides measurements of individual Boraflex panel boron-10 areal densities based on readings of neutron attenuation from a known source. The physical BADGER system has a neutron source assembly (^{252}Cf) and a detector assembly with multiple boron trifluoride (BF_3) detectors. The neutron transmission rates through the Boraflex are used to determine the boron-10 areal density. Because of the multiple detector arrangement in the BADGER detector head and the measurements being taken axially over the panel length, some degree of localized deformations can be identified (e.g., cracking, gaps, localized dissolution, scalloping).

The predictor/measurement methods are utilized together in the following manner.

- The initial RACKLIFE model is created from input from the plant and run to determine the Boraflex panel doses in the SFP. These results help choose the population of panels to be inspected using the BADGER system.
- The RACKLIFE model is calibrated to the Boraflex coupon results.
- The BADGER system is used to measure the boron-10 areal density of a significant number of Boraflex panels in the SFP. The BADGER testing also provides localized data on the Boraflex panels that includes cracking, gap distribution, and size. The BADGER data is used to validate that the coupon results are matching the actual measured panel results.

i) approach used to determine frequency, calculations, and sample size;

The frequency of the coupon measurements (i.e., once every cycle – every two years) was established as part of the NMP license renewal process. As listed above in 2.a, this also provides additional coupons to test if questionable results are identified from a sample.

The sample size of panels for BADGER testing was 45 panels for the most recent testing in 2008. This represents greater than 5% of the Boraflex panels in the SFP since only two racks exist (i.e., North = 11x18 cells and South=12x18 cells). The number of test panels was chosen in order to provide a good representation of the panels in the racks. Measuring these 45 panels provided data over the full spectrum of predicted gamma radiation dose and much of the predicted boron carbide loss range. This is a much larger fraction of panels tested than is listed in the guidance given in NEI 16-03 (i.e., 1% option).

Calculations are performed using the RACKLIFE code every cycle at NMP1 to project future Boraflex degradation levels and for comparison with coupon and/or BADGER data. The RACKLIFE code is calibrated to the coupon areal density data and compared against the BADGER data when available. Significant changes in the SFP state can drive additional RACKLIFE cases as needed.

The frequency of BADGER testing for Boraflex in NMP1 was initially set at once prior to the period of extended operation and then every eight years after that. However, based on the low amount of degradation that has been experienced and projected, the coupon results are being utilized in conjunction with the RACKLIFE projections to justify not performing a BADGER test at the first eight year interval. This is due to the fact that the site is in the process of removing all Boraflex credit for the NMP1 racks and no degradation of significance is expected, based on station trending (i.e., SFP chemistry and BADGER results), in the time leading up to the new NCS AOR approval with no Boraflex credit.

ii) parameters to be inspected and data collected;

Boraflex Coupon Testing

The following inspection and data collection is performed for each Boraflex coupon.

- Visual inspection
- Length and width
- Thickness
- Dry weight
- Density
- Neutron attenuation boron-10 areal density

BADGER Testing

The following inspection and data collection is performed for each BADGER test.

- Panel average boron-10 areal density
- Detector specific normalized neutron transmission traces (for identification of localized defects in the Boraflex panels)
- Panel lengths and widths (derived data)
- The presence of cracking, gaps, or areas of local dissolution (derived data)

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;

The acceptance criteria for the coupon testing are as follows.

- Visual: No gross loss of material evident. Color change from black to grey and the formation of small cracks are acceptable.
- Δ% Length: ≤ 4% decrease
- Δ% Width: ≤ 10.137% decrease
- Thickness: ≥ 0.080 inches
- Density: (1) ≤ 2.076 g/cc (120% of pre-characterized), (2) ≥ previous coupon density
- Minimum boron-10 areal density: ≥ 0.0217 $g^{10}B/cm^2$

The acceptance criteria for the BADGER testing are as follows.

- Panel shrinkage ≤ 4%
- Total panel gaps for any single panel ≤ 4 inches
- Minimum boron-10 areal density: ≥ 0.0217 $g^{10}B/cm^2$

The acceptance criteria for the Boraflex coupons are based on preserving the in-rack panels in a form that is bounded by the NCS AOR assumptions.

The acceptance criteria for the BADGER testing comes directly from the assumptions made in the criticality safety analysis that are meant to bound the actual changes in the panel measurements.

Because the acceptance criteria are based on the NCS AOR assumptions, they directly protect the analysis parameters used to ensure the safety function of the Boraflex.

iv) monitoring and trending of the surveillance or monitoring program data; and

The findings of the coupon monitoring and BADGER testing are subject to trend analysis to determine if there are any unexpected correlations.

v) industry standards used.

The following industry standards are used in the coupon testing.

- ASTM C-1187, Standard Guide for Establishing Surveillance Test Program for Boron-Based Neutron Absorbing Material Systems for Use in Nuclear Spent Fuel Storage Racks
- ASTM D-297, Standard Methods for Rubber Products—Chemical Analysis
- ASTM D-618, Standard Method of Conditioning Plastic for Testing
- ASTM D-883, Standard Definitions of Terms Relating to Plastics
- ASTM D-1042, Standard Test Method for Linear Dimensional Changes of Plastics Caused by Exposure to Heat and Moisture
- ASTM D-1349, Standard Practice for Rubber-Standard Temperatures for Testing
- ASTM D-3767, Standard Practice for Rubber-Measurement of Dimensions

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

iii) If RACKLIFE is used:

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

EPRI RACKLIFE code version 2.0 is used to model Boraflex degradation in the NMP1 SFP racks.

(2) note the frequency at which the RACKLIFE code is run;

The RACKLIFE code is run every cycle, which is currently equivalent to every two years, at a minimum.

(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; and

At NMP1, RACKLIFE is compared against the coupon testing results every two years to confirm/calibrate the RACKLIFE model. The RACKLIFE model is calibrated to stay representative of the trend in the coupon areal density change. This is achieved through the adjustment of the RACKLIFE model's factor representing the exchange rate of the water in/out of the Boraflex containing envelopes or cells.

The BADGER testing is completed on a confirmatory basis to ensure that the coupon testing program sufficiently captures the actual behavior of the in-rack Boraflex material.

(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.

The current RACKLIFE estimated minimum areal density of Boraflex in the NMP1 racks is 0.0244 $g^{10}B/cm^2$ (i.e., estimate for a date of December 31, 2018). This is the peak loss predicted by RACKLIFE on December 31, 2018, and using a minimum as-built areal density of 0.0251 $g^{10}B/cm^2$ as a starting point. The reviewing data for the origin of the RACKLIFE model's geometry file and its basis for the data input for the Boraflex panels the exact areal density for the Boraflex panels was not located in the documentation. Back calculations, depending on the data used for such items as the atomic abundance of boron-10 in boron, show that the model was set up using the nominal as-built areal density, which was the practice near that time, of 0.0254 $g^{10}B/cm^2$. The NMP1 RACKLIFE model has not been converted to use the minimum as-built areal density basis for the Boraflex panel dimensions as there is currently ample margin to the minimum certified areal density used in the NCS AOR analyses and the credit for all Boraflex is soon to be removed from the NCS AOR. The escape coefficient is used to keep the RACKLIFE predicted pool silica level very close to the actual level for the projections. This is because the RACKLIFE model for NMP1 is set to be a best estimate prediction of the areal density loss in the panels as measured by the Boraflex coupons. This is only possible because NMP1 still has valid coupon data for Boraflex.

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

The following information is based on the BADGER testing process/equipment used in the one test campaign performed for the NMP1 two remaining Boraflex racks in 2008.

(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;

The description of the panel selection is given above in the response to 2.a.i. The selection of the sampling population is in compliance with one of the two options from the NEI 16-03 guidance (i.e., ≥1% of panels selected). The selection of panels covers the most susceptible panels (i.e., high total gamma exposure) and also includes samples covering gamma exposures to very low levels. This population is not ≥ 59 panels and as such does not meet the non-parametric data criteria for statistical significance at a 95/95 level. The use of this population as representative of all panels in the two Boraflex racks has been found acceptable per NEI 16-03.

(2) state if the results of the in-situ testing are trended and whether there is repeat panel testing from campaign to campaign;

There has only been one BADGER test at NMP1 for the Boraflex racks. Therefore, there are no repeat measurements possible. Trend analysis was performed for the 2008 NMP1 BADGER test results.

(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 (Agencywide Document Access and Management System 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; and

The sources of uncertainties that are listed, and are applicable to NMP1, are managed by doing the utmost to reduce the uncertainty sources to the lowest possible levels through procedural controls of the testing. However, the measurement uncertainties provided from the BADGER vendor are strictly derived from the propagation of uncertainty from the axial neutron count samples to the production of the resultant panel average areal density value. No ex post facto adjustment of the test data was performed other than to review the test data for significant outlier data that might have needed to be removed from the analysis.

(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;

The calibration cell utilized at NMP1 contains Boraflex of known areal densities and gap sections of known size, both representative of what is in the SFP cell walls. The calibration cell is formed such that there is no need to account for differences between the calibration cell materials and the SFP rack materials.

(b) describe how potential material changes in the SFP rack materials caused by degradation or aging are accounted for in the calibration and results; and

There are no known calibration modifications made for this question's postulated SFP rack material potential degradation or aging changes. The known aging issues with the Boraflex are being measured by the system after having been calibrated to multiple known areal density Boraflex standards in the calibration cell. There are no known SFP aging mechanisms that would impact the stainless steel structure of the racks that would need to be accounted for in the calibration or results.

(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;

The BADGER test performed at NMP1 used a reference panel for the test. The reference panel was chosen as it was a known low or zero dose panel to be used to adjust the calibration cell results for any differences that may exist in the actual rack versus the calibration cell, such as the stainless steel structure/wrapper thickness, distances between the source and detectors. The reference panel's low dose is determined using RACKLIFE to model all past fuel stored in each location in the SFP. The function for determining the boron-10 areal density considers the calibration input from both the calibration cell and the reference panel.

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

There has only been one BADGER test campaign for the NMP1 two remaining Boraflex racks and thus only one reference panel has been used for all testing.

(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.

This question is not applicable due to the performance of only one BADGER test for NMP1 Boraflex racks.

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.

The Boraflex coupon measurement interval of one coupon every cycle (i.e., 2 years) has been set to be aggressive so that any increase in the rate of panel thinning would be identified and accounted for before the 0.95 k limit was challenged. Past NMP1 coupon history has shown a very slow dissolution rate for the panel faces. The aggressive coupon measurements are coupled with the update of RACKLIFE every cycle (i.e., when bulk changes in the SFP loading are made – rarely at other times). This allows for the model to be kept current with the impacts from the outages which are large compared to other routine drivers (i.e., outages have hot fuel placement in the pool and a removal of essentially all soluble silica from the SFP). The BADGER campaign frequency was set at one every eight years based on the standard 5 year period for Boraflex, a known degrading material, as extended through credit for an active coupon program. These time periods are sufficient to ensure that the SFP NCS AOR degradation assumptions remain bounding based on the known trends formed from the past surveillances of this material in the NMP1 SFP.

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.

The NCS AOR includes calculations that account for a specified level of Boraflex degradation as follows:

- All panels experience a 4% decrease in length due to shrinkage
  - o 4 inches (3% out of the 4%) of this shrinkage show up as single gaps in each panel. These gaps are assigned a distribution similar to what was seen at Quad Cities at the time the analysis was performed (the occurrence of gaps skewed toward upper 3/4 of the bundle height.
  - o The remaining 1% shrinkage was evenly split and applied to the top and bottom of every panel.
- All Boraflex panels experience a width shrinkage of 4% (from the nominal as-built width) due to shrinkage.
- No credit is taken for the increase in the Boraflex panel density which accompanies the gamma radiation induced material shrinkage.

The current NCS AOR does not account for any Boraflex panels with areal densities less than the minimum certified areal density. To date the coupon and BADGER measurement results have shown near 13% conservatism in the NCS AOR by their use of the minimum certified areal density in their calculations.

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.***

If the results of any facet of the coupon monitoring and surveillance program shows that the assumptions included in the NCS AOR are not bounding, the instance is documented in the Corrective Action Program. From this, the appropriate actions to ensure nuclear criticality safety are addressed, both the immediate and long-term aspects. This includes results from BADGER, RACKLIFE projections, or coupon measurements.

The acceptance criteria and their basis for the coupon monitoring are discussed in Sections 2.a.ii and 2.a.iii above. As described there, these are based on protecting the assumptions in the NCS AOR as listed in Section 4.a above. Instances of not meeting the coupon testing criteria must be addressed in all cases to show that the NCS AOR continues to protect (i.e., is bounding to) the current condition, or additional analyses will be performed to ensure a safe condition is maintained (e.g., in operability space and/or via an NCS AOR update or license amendment).

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

No bias or uncertainty from the monitoring program is currently included in the NCS AOR. The NCS AOR is based on the limiting fuel type and utilizes a very conservative boron-10 areal density, which introduces conservatism into the analysis. This conservatism to the 0.95 k limit provides margin that protects against not specifically accounting for the monitoring program biases and uncertainties.

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

The NCS AOR accounts for the degradation of adjacent panels as follows.

- All panels are given a 4% decrease in length due to shrinkage
    - 4 inches (3% out of the 4%) of this shrinkage show up as single gaps that have been assigned a radial and axial distribution over four quarter axial segments of the fuel in the model. All gaps that are co-resident in the same axial segment occur at the same axial position. In assigning the radial distribution of axial gaps, the analysis determined the highest impact distribution (mix of adjacent/clumped gaps versus a wider distribution) and utilized it for the k impact calculation.
    - The remaining 1% shrinkage was evenly split and applied to the top and bottom of every panel (these occur in all panels and thus are adjacent).
- All Boraflex panels experience width shrinkage of 4% from the nominal as-built width due to shrinkage (all panels are impacted and thus are adjacent).
- No credit is taken for the increase in the Boraflex panel density which accompanies the gamma radiation induced material shrinkage (all panels are impacted and thus are adjacent).

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).

The design-basis events that will be discussed are seismic events, loss of SFP cooling, and the fuel assembly drop onto the SFP racks.

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;

<u>Seismic Events</u>

EPRI has shown by direct measurements of the material properties of Boraflex (TR-109927) that the material retains the flexural strength and Young's Modulus sufficient to make the failure probability from a seismic event essentially zero. This is in large part due to the design of the SFP Boraflex racks which were made such that the Boraflex material is not subject to outside loads as it is protected inside its envelope formed by the stainless steel that surrounds it. Because the material does not fail, there is no anticipated shifting or settling of the Boraflex in relation to the fuel due to breakage. It is conceivable that panels that already contain gaps could settle in the downward direction to effectively bring a larger single gap towards the top of the panel envelope. This physical condition is equivalent to or bounded by assumed NCS AOR gap distribution as described in 4.a above as all panels that have gaps are not expected to settle in a seismic event. Thus the seismic event would have no negative impact on the criticality safety of the fuel in the Boraflex racks at NMP1. Note that the highest predicted Boraflex degradation amount is currently < 3%, thus the thinning of the Boraflex panels will not be such that pieces of a panel could overlap each other within the envelope where they reside.

Fuel Assembly Drop

The impact of a fuel assembly drop event would be localized and bounded by the seismic event impact. The Boraflex panels are shielded from direct impact from a dropping fuel assembly by the structural portion of the SFP racks at the top of the racks, as well as by the fuel resident in the SFP racks if the bundle drops in a populated area. Thus the bundle drop accident would have no negative impact on the criticality safety of the fuel in the Boraflex racks at NMP1.

ii) increased dissolution or corrosion; and

The impact of the increased solubility of Boraflex in the hot SFP water in a loss of SFP cooling event would be a short lived issue, not lasting long enough to cause a wholesale impact on the state of the Boraflex in the SFP racks. Thus the loss of SFP cooling accident would have no negative impact on the criticality safety of the fuel in the Boraflex racks at NMP1.

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

Based on the information above, none of the design basis events are expected to cause any Boraflex state changes or loss of material properties.

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;

The Boraflex in the EPRI analysis (TR-109927) was tested in its degraded state. No additional monitoring is needed to protect the Boraflex material from the impact of a design basis event.

ii) parameters monitored;

No parameters are monitored specifically for the purpose of protecting the Boraflex material against the impact from a design basis event. The previously specified parameters are sufficient to ensure that the Boraflex remains protected in the event of a design basis event.

iii) acceptance criteria; and

No acceptance criteria have been set specifically for the purpose of protecting the Boraflex material against the impact from a design basis event.

iv) intervals of monitoring.

The interval for BADGER testing has not been set specifically for the purpose of protecting the Boraflex material against the impact from a design basis event. The previously discussed monitoring interval ensures that the Boraflex remains protected in the event of a design basis event.

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:

b) neutron-absorbing material specifications, such as:

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

The Boraflex material's contents were not specified on a weight percent basis of the neutron-absorbing component.

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

The Boraflex material's original minimum certified areal density is 0.009 g^{10}B/cm^2. The batch minimum as-built boron-10 areal density is 0.0110 g^{10}B/cm^2. The batch maximum as-built boron-10 areal density is 0.0116 g^{10}B/cm^2. The nominal as-built (average) boron-10 areal density is 0.0112 g^{10}B/cm^2.

iii) material characteristics, including porosity, density, and dimensions;

The Boraflex panel nominal as-built size was 0.0428 inches thick, 5.5625 inches wide and 140.5 inches long.

After a reasonable search of the plant's records, including docketed information, Exelon Generation Company, LLC (EGC) determined that the Boraflex porosity and density were not part of the original licensing basis or previously requested by the NRC as part of the licensing action that approved the neutron absorber monitoring programs.

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

After a reasonable search of the plant's records, including docketed information, EGC determined that the Boraflex qualification testing plans were not part of the original licensing basis or previously requested by the NRC as part of the licensing action that approved the neutron absorber monitoring programs.

Brand Industrial Services Inc. (BISCO) performed generic (i.e., not plant specific) qualification testing for Boraflex that can be found in References 9-67, and 9-72 to 9-77 to the EPRI Handbook of Neutron Absorber Materials for Spent Nuclear Fuel Transportation and Storage Applications (2009 Edition).

d) configuration in the SFP, such as:

ii) sheathing and degree of physical exposure of neutron-absorbing materials to the SFP environment;

The picture frame design of the Boraflex racks typically provided a tighter fit and thus less water exchange between the cavity and the bulk pool water, as compared to the wrapper plate design. However, the Boraflex material was still subject to some water exchange which is evident by the degradation of the material (i.e., silica in the SFP water and decreased boron-10 areal density in the Boraflex).

e) current condition of the credited neutron-absorbing material in the SFP, such as:

i) estimated current minimum areal density;

The most recent Boraflex Areal Density Gauge for Evaluating Racks (BADGER) test at Oyster Creek in 2014 measured the average areal density of all panels tested (i.e., 60 panels) to be 0.0134 $g^{10}B/cm^2$ panel average areal density and 0.0101 $g^{10}B/cm^2$ for a minimum panel average areal density.

ii) current credited areal density of the neutron-absorbing material in the NCS AOR; and

The current credited Oyster Creek Boraflex neutron-absorbing material (NAM) areal density in the NCS AOR is 0.01114 $g^{10}B/cm^2$, which is the nominal design Boraflex areal density with a 25% degradation penalty applied to it. Oyster Creek currently has engineering evaluations and an operability evaluation in place to address the specific degradation of the material below the original areal density. This is a temporary measure until the NCS AOR is updated to no longer credit any Boraflex in the SFP.

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).

The Oyster Creek BADGER testing has been performed in the years 1997, 2001, 2005, 2008, 2011 and 2014. This testing has revealed general panel loss of material (thinning), cracking and gaps, as well as some local dissolution. The most recent reviewed and approved results (2014) provided the following characterization of the Boraflex in the SFP racks.

- Average measured areal density: 0.0134 $g^{10}B/cm^2$
- Minimum measured areal density: 0.0101 $g^{10}B/cm^2$ (0.0074 $g^{10}B/cm^2$ with -3σ applied)

- Gap/Crack characterization:
  - Single gaps range from 0.00 – 5.60 inches with one at 10.03 inches
    - The 10.03 inch gap is indicative of washout dissolution of Boraflex impacting the small gap that was originally at this location.
  - Cumulative panel gap size ranges from 0.00 – 15.4 inches with one at 19.1 inches

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:***

The NAM monitoring plan for the Boraflex material includes BADGER in-situ testing along with the use of the EPRI RACKLIFE program. BADGER testing is a method for measuring the boron-10 areal density of in-rack Boraflex panels, and also provides data on cracking, gaps, and local dissolution in the panels. The Boraflex Rack Life Extension code (RACKLIFE) is used to predict the panel average areal density loss in the SFP panels given a specific SFP rack environmental history. These two tools are used in conjunction to apply the mechanistic areal density loss model (RACKLIFE) as calibrated to the actual in-rack areal density measurements (BADGER) to predict future SFP panel degradation levels. The measurements and predictions are used to ensure that the NCS AOR assumed areal densities are maintained or corrective actions are taken to empty impacted SFP cells of fuel or the SFP NCS AOR updated if possible. These tools are being used as an interim measure to allow time to implement a final corrective action that will remove the SFP rack's reliance on Boraflex credit for fuel criticality safety purposes.

EPRI's RACKLIFE program is a mechanistic code that predicts the Boraflex panel average degradation due to the silica matrix dissolution for every panel in the SFP based on the following primary effects on the panels:

- Gamma radiation dose from spent fuel,
- Time spent in the SFP environment,
- The SFP housed fuel history (end-of-cycle power levels – feeds gamma source, etc.)
- SFP water temperature,
- SFP water pH,
- Silica levels in the SFP water,
- Silica removal rate from SFP water by fresh water exchange and filtering systems, and
- The rate of bulk SFP water exchange with the water cavity surrounding the Boraflex panel.

Per the user's manual, the RACKLIFE code "simulates the loss of the criticality controlling neutron absorber boron carbide from Boraflex as the latter dissolves in the spent fuel pool water. The boron carbide itself does not dissolve in water, but the silica matrix that binds it does, particularly after irradiation. Since silica can be measured in the pool water, silica dissolution and transport can be simulated based on the measured data, and from the results the amount of boron carbide loss from each panel can be calculated."

Thus the RACKLIFE code is performing a complex silica chemical balance within the SFP and rack panel cavities to predict the rate of dissolution of the material from the Boraflex once the molecular structure has been broken down due to the gamma radiation field in the SFP.

The BADGER in-situ testing system provides measurements of individual Boraflex panel boron-10 areal densities based on readings of neutron attenuation from a known source. The physical BADGER system has a neutron source assembly (^{252}Cf) and a detector assembly with multiple boron trifluoride (BF_3) detectors. The neutron transmission rates through the Boraflex are used to determine the boron-10 areal density. Because of the multiple detector arrangement in the BADGER detector head and the measurements being taken axially over the panel length, some degree of localized deformations can be identified (e.g., cracking, gaps, localized dissolution, scalloping).

The predictor/measurement methods are utilized together in the following manner.

- The initial RACKLIFE model is created from input from the plant and run to determine the Boraflex panel doses in the SFP. These results help choose the population of panels to be inspected using the BADGER system.
- The BADGER system is used to measure the boron-10 areal density of a statistically significant number of Boraflex panels in the SFP. The BADGER testing also provides localized data on the Boraflex panels that includes cracking, gap distribution, and size.

i) approach used to determine frequency, calculations, and sample size;

The Oyster Creek Boraflex monitoring program is documented in the plant's license renewal application and is consistent with the timing requirements listed in the Generic Aging Lessons Learned (GALL) report (i.e., NUREG-1801, Revision 1, 2005, Section XI.M22). Oyster Creek performs the BADGER testing campaigns every three years versus the listed maximum of every five years in the GALL report.

Calculations are performed using the RACKLIFE code periodically at Oyster Creek to project future Boraflex degradation levels in the racks. The RACKLIFE code is calibrated to the BADGER data each time a test is run. The RACKLIFE results are maintained conservative to BADGER results to account for uncertainties in the BADGER testing methodology. The maximum periodicity is every two years (i.e., coincident with outage driven fuel moves). However, significant changes in the SFP environment (e.g., fuel movements among racks) can trigger a reanalysis using RACKLIFE to check for detrimental impacts.

The sample size of panels for BADGER testing has been maintained at ≥59 panels for recent tests. This is based on the BADGER test data being non-parametric and requiring sufficient data for the results to be representative with a 95% probability at a 95% confidence level. This is consistent with the guidance given in NEI 16-03.

ii) parameters to be inspected and data collected;

The Boraflex panels are subject to five acceptance test criteria taken from the criticality safety analysis of record.

1. Measured average uniform thinning loss is less than 14%
2. Measured maximum panel thinning loss is less than 16%
3. Maximum measured gap size is less than 1-2/3 inches
4. Average size of all measured gaps is 1.5 inches or less
5. Total panel shrinkage is less than 4 inches

The data collected is what is needed to verify compliance with the acceptance criteria listed. This includes SFP data needed to enable RACKLIFE to form projections of Boraflex degradation levels. For the BADGER testing and RACKLIFE projections, the percent uniform panel thinning is a one-to-one function of the percent areal density loss (parameter available from the neutron transmission ratio measurements).

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;

The acceptance criteria are listed in 2.a.ii above, which come directly from the NCS AOR to ensure that what was assumed in the NCS AOR remains bounding for the actual Boraflex rack conditions. These criteria focus on the Boraflex material retaining both the boron-10 areal density assumed in the AOR and the 2D cross sectional area coverage that is impacted by gaps and shrinkage (i.e., both in magnitude and distribution). Any violation of one of the acceptance criteria will trigger the plant to respond to correct the situation, beginning with the entry of the issue in the Corrective Action Program.

iv) monitoring and trending of the surveillance or monitoring program data; and

Each time a BADGER test is performed, a subset of panels that were included in the previous BADGER test are tested. This provides a direct comparison of the level of degradation seen in individual panels in the time since the previous test.

v) industry standards used.

No industry standards were referred to by either the BADGER or the RACKLIFE documentation.

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

iii) If RACKLIFE is used:

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

Oyster Creek utilizes the EPRI RACKLIFE code version 2.1 (also referred to as 2.1.1 at times) to model Boraflex degradation in the SFP racks.

(2) note the frequency at which the RACKLIFE code is run;

Station procedures dictate that the RACKLIFE model should be updated after significant fuel moves and at least once every two years. Oyster Creek maintains as much of the recent discharged fuel as possible in the Boral SFP racks to minimize the Boraflex degradation rate. Typically the RACKLIFE model is updated at outage time. This may be performed in two steps to provide predictions to guide fuel placement during outage and post-outage moves (e.g., B.5.b) and then after the post-outage moves to provide the most accurate prediction possible through the next refuel outage. The Oyster Creek RACKLIFE model may be updated at any time between outages when the assumptions made in the previous model need updated (e.g., unexpected fuel moves, chemistry changes identified in monthly reports, etc.). The RACKLIFE model is also updated in conjunction with BADGER tests to validate the accuracy of the model against the BADGER data.

(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; and

The results from each BADGER test are compared to a RACKLIFE model run for the same state point (i.e., date). The comparison is made between the RACKLIFE predicted panel average degradation and the BADGER measured panel degradation. The confirmation that the RACKLIFE model is conservative can be made if the RACKLIFE projections show a prediction of the degradation level that is in the range 12-20% (target = 16%) higher than what the BADGER measurements show (larger amounts of conservatism may also be acceptable). Equivalent levels of conservatism may be credited towards this value if they exist, but are implemented in other forms (e.g., a penalty which is included in the NCS AOR to account specifically for the RACKLIFE / BADGER offset). This requisite level of conservatism was originally formulated based on the BADGER measurement 1-sigma uncertainty being ~8% (i.e., using the original BADGER system prior to the 2014 test which uses the improved BADGER system).

(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.

The current minimum RACKLIFE predicted areal density is equivalent to the peak predicted degradation of 21.63% (i.e., as of February 28, 2017). This is degradation from the minimum as-built areal density, which the RACKLIFE model is based on, and thus is equal to 0.0110 $g^{10}B/cm^2$ * (1 – 0.2163) = 0.0086 $g^{10}B/cm^2$. Note that the leading cells with this much predicted degradation have been taken out of service, or other measures taken such as emptying cells around the area, to provide full assurance of the maintenance of the 5% subcritical margin at all times in the SFP. There is also currently an Operability Evaluation in place at Oyster Creek which provides fuel type dependent Boraflex degradation limits that are being implemented to provide a finer level of protection based on an extension of the NCS AOR analysis. This is a temporary situation until the NCS AOR can be updated to remove all credit for Boraflex in the SFP.

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

Note that the information below are based on the BADGER setup in the 2014 Oyster Creek campaign.

(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;

As described above in 2.a.i, the number of panels to test is chosen to provide a statistically meaningful test result at 95/95 given a non-parametric distribution of sample data, which is a minimum of 59 panels. Typically more than the minimum amount of panels are measured (i.e., 60-70 panels) to cover any data that might need to be discarded and to cover a sufficient number of panels of interest (i.e., overlap with previously measured panels and a mixture of panels containing the worst anticipated degradation and also medium and low duty gamma dose panels. Using this method of selection of the panel population leads to a result that can be extrapolated to the rest of the SFP at a 95% confidence level.

(2) state if the results of the in-situ testing are trended and whether there is repeat panel testing from campaign to campaign;

In-situ results are subject to trending, though this is not procedurally required. There are also, as stated earlier, a number of panels that are repeat tests from the previous BADGER campaign.

(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 (Agencywide Document Access and Management System 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; and

The 2012 NRC technical letter report (TLR) titled, "Initial Assessment of Uncertainties Associated with BADGER Methodology," was created before the current version of the BADGER test apparatus was generated in 2013. Many of the improvements in the BADGER test apparatus were targeted at sources of uncertainty that the TLR calls out (e.g., detector and source head designs with spring force rollers designed to maintain a consistent geometry when measuring cells, additional shielding to reduce bleeding of source neutrons around the Boraflex panel, and upgraded water tight shielded cables from the detectors to reduce noise or failure in the detector system). The sources of uncertainties that are listed are managed by doing the utmost to reduce the uncertainty sources to the lowest possible levels. Other than that the measurement uncertainties provided from the BADGER vendor are strictly derived from the propagation of uncertainty from the axial neutron count samples to the production of the resultant panel average areal density value.

(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;

The calibration cell utilized at Oyster Creek contains Boraflex of known areal densities and gap sections of known size, both representative of what is in the SFP cell walls. The calibration cell is formed such that there is no need to account for differences between the calibration cell materials and the SFP rack materials.

(b) describe how potential material changes in the SFP rack materials caused by degradation or aging are accounted for in the calibration and results; and

There are no known calibration modifications made for postulated SFP rack material potential aging changes. The known aging issues with the Boraflex are measured by the system after having been calibrated to multiple areal density known Boraflex samples in the calibration cells. There are no known SFP aging mechanisms that would impact the stainless steel structure of the racks that would need to be accounted for in the calibration or results.

(c) if the calibration includes the in-situ measurement of an SFP rack "reference panel," explain the following:

A reference panel is not used.

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.

The NCS AOR includes the supplemental calculations that provide a lookup matrix for determining the acceptability of a panel's degradation based on the known margin to 0.95. The parameters that are key to the degradation condition calculations are as follows.

- 3D KENO cases run to determine the reactivity impact of degradation
- Uniform thinning cases created for 0% - 25% material loss
- Uniform thinning cases that also include coplanar gaps in the Boraflex – 0 to 10 gaps of size 0 to 2.5 inches high
- Additional cases with three gaps modeled at 3.5 inches with uniform thinning up to 30%

Panels with specific measurements can then be compared with the reactivity impact tables and a determination of the acceptability of the degradation level made.

In the 2014 BADGER test there were many cells that were identified that did not meet the NCS AOR acceptance criterial as discussed in Section 2.a.ii. This was entered into the Corrective Action Program and an operability evaluation was prepared to address the operability of the SFP rack cells with degraded Boraflex. Currently, an Operability Evaluation is in place to provided additional margin to the 0.95 limit by analyzing each fuel type present in the SFP separately using the NCS AOR methodology and then assigning a Boraflex degradation acceptance criterial for the cells in the SFP based on the fuel type stored in that cell. In addition, the most recent dry cask loading campaign focused on removing fuel types that had the least amount of criticality safety margin from the SFP. These actions together have provided more margin for fuel storage criticality than was available from the NCS AOR alone. This is an interim condition that will exist until the updated NCS AOR can be completed that no longer credits any Boraflex for SFP reactivity control.

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.

This information is addressed above in Section 4.a along with the NCS AOR criteria listed in Section 2.a.ii. No coupons are in use at Oyster Creek for the Boraflex material.

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

No bias or uncertainty from the monitoring program is included in the NCS AOR. The NCS AOR is based on the limiting fuel type which introduces conservatism into the analysis. Some of this conservatism has been removed in the Operability Evaluation by moving to fuel type dependent acceptance criteria for Boraflex degradation.

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).

The design-basis events discussed below are seismic events, loss of SFP cooling, and the fuel assembly drop onto the SFP racks.

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;

<u>Seismic Events</u>

EPRI has shown by direct measurements of the material properties of Boraflex (TR-109927) that the material retains the flexural strength and Young's Modulus sufficient to make the failure probability from a seismic event essentially zero. This is in large part due to the design of the SFP Boraflex racks which were made such that the Boraflex material is not subject to outside loads as it is protected inside its envelope formed by the stainless steel that surrounds it. Because the material does not fail, there is no anticipated shifting or settling of the Boraflex in relation to the fuel due to breakage. It is conceivable that panels that already contain gaps could settle in the downward direction to effectively bring a larger single gap towards the top of the panel envelope. This physical setup is bounded by the fact that the NCS AOR and Operability Evaluation assume that the modeled gaps are in the axial center of the fuel bundle active region. This area has the least amount of leakage for the neutrons, especially compared to the top end of the bundles which essentially have only water above them. Thus the seismic event would have no negative impact on the criticality safety of the fuel in the Boraflex racks at Oyster Creek. Note that the highest amount of Boraflex degradation is limited to 29%, from the Operability Evaluation in place, and thus the thinning of the Boraflex panels will not be such that pieces of a panel could overlap each other within the envelope that holds it. This is a temporary situation until the NCS AOR can be updated to remove all credit for Boraflex in the SFP.

Fuel Assembly Drop

The impact of a fuel assembly drop event would be localized and bounded by the seismic event impact. The Boraflex panels are shielded from direct impact from a dropping fuel assembly by the structural portion of the SFP racks at the top of the racks, as well as by the fuel resident in the SFP racks if the bundle drops in a populated area. Thus the bundle drop accident would have no negative impact on the criticality safety of the fuel in the Boraflex racks at Oyster Creek.

ii) increased dissolution or corrosion; and

The impact of the increased solubility of Boraflex in the hot SFP water in a loss of SFP cooling event would be a short lived issue, not lasting long enough to cause a wholesale impact on the state of the Boraflex in the SFP racks. Thus the loss of SFP cooling accident would have no negative impact on the criticality safety of the fuel in the Boraflex racks at Oyster Creek.

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

Based on the information above, none of the design basis events are expected to cause any Boraflex state changes or loss of material properties.

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;

The Boraflex in the EPRI analysis (TR-109927) was tested in its degraded state. No additional monitoring is needed to protect the Boraflex material from the impact of a design basis event.

ii) parameters monitored;

No parameters are monitored specifically for the purpose of protecting the Boraflex material against the impact from a design basis event.

iii) acceptance criteria; and

No acceptance criteria have been set specifically for the purpose of protecting the Boraflex material against the impact from a design basis event.

iv) intervals of monitoring.

The interval for BADGER testing has not been set specifically for the purpose of protecting the Boraflex material against the impact from a design basis event.