Overall guidance:

For each unique neutron absorber, licensees that fall into Category 4 need to provide details as in areas indicated in the table at the beginning of Appendix A (repeated below), depending upon the type of absorber implemented and credited for neutron absorption. In the context of this guidance document, a single neutron absorber type listed in the table (i.e., Boral) may be considered as more than one unique absorber type, depending on the physical and dimensional characteristics (i.e. thickness and areal density), date of manufacturing and manufacturing process. For example, a plant that licensed spent fuel storage racks based on an individual neutron absorber type, may have had the racks (and neutron absorber) manufactured and installed at different times. In this case, each installation of the neutron absorber (and rack) would be a unique absorber type, unless sufficient documentation exists to show that each batch of neutron absorber was manufactured to the same specifications, with the same manufacturing process. A single campaign may have multiple lots of the same vintage of neutron absorber. If those lots are manufactured using the same manufacturing process, then these would be considered the same material.

Neutron-Absorbing Material type	Areas of Requested Information				
	(1)	(2)	(3)	(4)	(5)
Boraflex Carborundum Tetrabor	x	x	x	x	X
Boral	x	x*		x	
Borated SS Metamic Boralcan Other metallic matrix composites	x	x*			

* Except for 2(b)(iii).

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*

   Guidance: Provide the manufacturer of the neutron absorber material. Manufacturers of neutron absorbing materials include:

   Boraflex: BISCO
   Carborundum Plate & Sheet: Carborundum Company

Tetrabor: ESK
Boral: AAR, Ceradyne
Borated SS: Bohler Bleche, Carpenter Specialty Metals, ATI (narrow down to BSS made for US plant)
Metamic: Holtec
Boralcan: Rio Tinto Alcan

Date of manufacture: Provide the year the neutron absorber batch(es) were manufactured.

Date of material installation: Provide the year(s) the rack(s) or neutron absorber(s) was installed in the spent fuel pool.

b) neutron-absorbing material specifications:

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

Guidance: For materials of construction, specify the chemical composition of the neutron absorber material (i.e. Aluminum and Boron Carbide for Boral, Metamic, etc). This information should be in the FSAR or license amendment request documentation.

For materials that are manufactured by specifying the neutron absorbing component as weight percent (i.e., Metamic, other metal-matrix components), provide the nominal weight percent of the neutron absorbing element (Boron) as provided in the manufacturing specification or rack drawing.

> "[Material] has a nominal weight percent of [wt%] natural Boron"

For materials that are not specified based on a mass basis, the following response is acceptable:

> "[Material] is not specified on a weight percent basis of the neutron absorbing component, therefore this sub-item is not applicable to this material"

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

Guidance: Typically, the neutron absorber has been specified based on a nominal areal density and a minimum certified areal density, which should be available based on the purchase or manufacturing specification. Minimum and maximum as-built areal density can only be acquired by reviewing the as-manufactured data for each neutron absorbing panel installed in the spent fuel racks (if available). This is likely to be a lengthy and time-consuming activity for most pools that credit the neutron absorber, as there can be thousands of neutron absorber panels in the spent fuel pool. For nominal, minimimum and maximum as-built areal density, this information was not part of the original licensing basis, and is not available.

iii. material characteristics, including porosity, density and dimensions

Guidance: Provide the porosity (if available), mass density (in g/cc or equivalent) and nominal geometrical dimensions (width, axial length, thickness for plate absorbers, length and outer diameter for cylindrical absorbers, (i.e. rods), length, thickness and length of arms for chevron shaped insert absorbers) of the neutron absorbing material. Reference previous documents where this information was provided (LAR submittal or criticality analysis).

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

Guidance: Provide a reference to the qualification report, including ML Accession # in ADAMS, if available. (Industry to identify and provide references for previously supplied qualification reports available in ADAMS – The Neutron Absorber Handbook provides references for Qualification Report for some neutron absorbers).

Metamic – Holtec Report
Boral - ?
Carborundum - ?
Boraflex – ?

d) configuration in the SFP

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

Guidance: Describe the physical/geometric configuration of the neutron absorbing material in the storage racks. This information is likely contained in the license amendment request for the neutron absorbing material (racks or inserts) but may also be available in the FSAR. The response should utilize previous descriptions of the physical configuration provided previously to the NRC, such as:

> "The neutron absorber is contained in stainless steel sheathing that is attached to the spent fuel storage walls via tack welds"
>
> "The neutron absorbing material is in the form of inserts that cover two of the four sides of the storage cell walls. They are held in place through frictional forces between the insert and the storage cell wall or storage cell sheathing"

"The neutron absorbing material is in the form of rodlets that are inserted into the guide tubes/water rods of the spent fuel assembly."

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

Guidance: Indicate whether the sheathing covers the entire neutron absorbing material and whether sections and/or portions of the neutron absorber is open to the spent fuel pool environment. Indicate approximate amount of the neutron absorber that is not covered by sheathing and are therefore exposed to the SFP environment. Indicate whether the sheathing allows water ingress to the neutron absorber, or whether the sheathing prevents water ingress.

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

i. estimated current minimum areal density

Gudiance: If there is no indication of degradation that leads to loss of the neutron absorber material from the results of coupon testing, in-situ measurements or water chemistry, the following statement is applicable:

"Results of [coupon testing/in-situ measurements/water chemistry/industry experience to date] of the neutron absorber have provided no indication of loss of neutron absorbing material. Therefore, the estimated current minimum areal density is the same as when the material was fabricated and installed in the SFP, which is provided in the response to #1.

In the event of degradation (i.e., Boraflex), provide the most recent estimate of the minimum areal density from in-situ measurements, coupon testing results or RACKLIFE.

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

Guidance: Provide the areal density used in NCS AOR for each unique neutron absorber and areal density.

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)

Guidance: Provide a summary of the results of previous coupon testing or in-situ measurements for the items provided in the list in parenthesis.

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:*

Guidance: **(Task Force to develop a short description of the types of neutron absorber monitoring programs)**:

Coupon monitoring: Surrogate material from the same manufacturing lot as the as-installed material. Able to detect aging/degradation mechanisms that the in-service neutron absorber materials experience. Coupon tree intended to be placed in a location in the spent fuel pool near freshly discharged fuel, which provides exposure to gamma and neutron irradiation and higher than average water temperatures.

Blackness testing: Detects physical changes in the in-service neutron absorbers. Able to detect large cracks (>~1 inch), loss of large amounts of material through dissolution, shrinkage. Not able to detect blisters, small cracks or small localized areas of degradation.

BADGER testing: Similar to blackness testing, however able to determine the areal density of the neutron absorber panel. Has similar limitations on ability to detect small localized indications of degradation.

RACKLIFE: **(TBD)**

Water chemistry monitoring: **(TBD)**

Industry Operating Experience Sharing **(TBD)**

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

Guidance: The frequency of inspections (visual, coupons or in-situ) was initially determined based on qualification testing of the neutron absorber material prior to first use, which typically includes accelerated corrosion testing (at higher temperature). Based upon the qualification testing, frequency for new neutron absorber materials were established on a relatively frequent basis, between 2 and 5 years. As operational experience of the neutron absorber was gathered, and actual in-service experience was obtained, subsequent licensees were allowed to have less frequent inspection intervals. Eventually, some materials were deemed of sufficient robustness to not require a monitoring program (NRC letter from Laurence I. Kopp to Dr. Krishna P. Singh, dated February 16, 1995 (NRC Accession # 9502230383) and NRC letter from Anthony C. Attard to Korea Hydro & Nuclear Power Company, dated October 2, 2003 (provided upon request). Many licensees that implemented BORAL therefore were not required to have a monitoring program. However, those licensees continue to participate in industry operating experience sharing forums, such as EPRI's Neutron Absorber Users Group (NAUG) and spent fuel pool chemistry is monitored on a regular basis.

Calculations is in regard to any mathematical conversion made as part of a surveillance program (i.e., RACKLIFE calculation or conversion of count rate into areal density).

Ask for clarification from NRC on what is meant by calculation.

The sample size of inspection depends upon the type of inspection. Neutron absorbers inspect one, possible two coupons per inspection period. In-situ measurements typically sample a representative portion of the spent fuel pool, especially areas where fresh fuel has been repetitively or more frequently discharged after shutdown (i.e., such as flux trap racks in PWR spent fuel pools).

ii. parameters to be inspected and data collected

Guidance: Provide a list of the parameters measured and a summary of the data collected as part of the neutron absorber monitoring program. For coupon testing programs, such parameters are visual observations, dimensional measurements, weight, density, ^{10}B areal density, microscopic analysis, and characterization of changes. For in-situ measurements, parameters are size and axial location of gaps (blackness testing), and ^{10}B areal density (BADGER). Reference back to answer on 1(e)(iii)

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

Guidance: There has not been a strict "acceptance criteria" associated with most neutron absorber monitoring programs, in that the purpose of the neutron absorber program is to determine whether degradation is occurring in the neutron absorber material and for any results that indicate deformation or degradation to be entered into the licensee corrective action program for further assessment of impacts, extent of condition, trending, determination of functionality, and implementation of corrective actions.

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

Guidance: Provide a description of the part of your organization that is responsible for the monitoring program, how they ensure that the program is being implemented and how information from the program is evaluated. Response should indicate what level of comparison is performed from inspection to inspection. For coupon testing programs, there is generally little trending performed, because of the destructive examination of the coupon, unless coupons are being observed using basic testing and then returned to the spent fuel pool. For in-situ testing, trending is possible provided that a number of panels are repetitively tested from inspection to inspection.

v. industry standards used

Guidance: The following standards are used in the context of neutron absorber monitoring programs:

- ASTM E2971-14 "Standard Test Method for Determination of Effective Boron-10 Areal Density in Aluminum Neutron Absorbers using Neutron Attenuation Measurements"
- ASTM C1187-15, "Standard Guide for Establishing Surveillance Test Program for Boron-Based Neutron Absorbing Material Systems for Use in Nuclear Fuel Storage Racks In a Pool Environment"
- Standard for testing of Aluminum based materials (TBD).

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

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

1. Describe the visual inspection performed on each sample.

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

Guidance: This request is in reference to visual inspections of neutron absorber material in service (versus visual inspections of coupons). Some spent fuel storage racks were manufactured with a small hole removed from the sheathing for the purposes of allowing a visual inspection of the enclosed neutron absorber. Another design contained sheathing that did not cover the entire width of the neutron absorber (it only covered the edges of the absorber along the axial length). Neutron absorber inserts may also have visual inspections. For (1), provide a description of any visual examinations of the in-service neutron absorber, including frequency of inspections and description of how the inspection is performed. For (2), provide the number of neutron absorbers inspected during each inspection.

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.*

Guidance: Coupons have been manufactured from the same lot/batch of material used to manufacture panels for the spent fuel pool. Provide a comparison of the physical configuration of the coupons and how it compares to the in-service panels. Provide the physical dimensions of the coupons. For material radiation exposure and SFP environment conditions, provide a qualitative description/justification of the location of the coupon tree and exposure to parameters that lead to aging effects.

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

Guidance: Provide the year the coupons were installed in the spent fuel pool. If this was at the same time that the racks/inserts were installed, refer to the installation date of the neutron absorber in Item #1.

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

Guidance: A technical justification would rely upon the performance of tests that do not alter the neutron absorbing material or expose the material to an environment significantly different than the spent fuel pool environment for a significant period of time. Poolside examination of neutron absorbers or coupons are considered acceptable given the limited exposure to an environment different than the spent fuel pool environment.

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.

Guidance: Provide the number of remaining coupons and the schedule for coupon removal and testing. A response to the question of "enough coupons for testing for the life of the SFP" may not be a definitive answer, given that some licensees may undergo second license renewal, and decommissioning may extend an additional period of time after the shutdown of the operating reactor, depending on the approach of an individual licensee to operate and decommission the nuclear plant, including the spent fuel pool. I.e., there is not a reliably definable period of time for the spent fuel pool. Provide the current licensed life of the operating reactor. An acceptable response would be to indicate the number of remaining coupons and the remaining licensed operating life of the reactor.

iii. If RACKLIFE is used:

Guidance: This item, 2(b)(iii) is only in reference to Boraflex. RACKLIFE is not applicable to other neutron absorbing materials since it is based on silica measurements in the spent fuel pool water. For licensees with neutron absorbers other than Boraflex, the following statement is acceptable:

> "RACKLIFE is only applicable to the Boraflex neutron absorber material, and therefore is not applicable to [material]."

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

Guidance: Provide the version of RACKLIFE used currently.

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

Guidance: Provide how often the RACKLIFE code is run.

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.

Guidance: Describe how the RACKLIFE predictions are compared to in-situ measurements of the neutron absorber areal density. This is a licensee specific response depending on how RACKLIFE predictions are being used.

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

Guidance: Provide the most recent estimate of the neutron absorber areal density provided by RACKLIFE. Provide a brief description of how the areal density is calculated (TBD – Add description from NRC document, LAR submittal or RAI Responses). Provide the starting value of the areal density of the neutron absorber (i.e., pre-degradation) and what this value is based upon (i.e., the nominal areal density of all of the panels, the minimum certified areal density, the minimum as-manufactured areal density or other). Describe how the escape coefficient is used in determining the neutron absorber areal density.

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

1. *Describe the method and criteria for choosing panels to be tested and include whether the most susceptible panels are chosen to be tested. Provide the statistical sampling plan that accounts for both sampling and measurement error and consideration of potential correlation in sample results. State whether it is statistically significant enough that the result can be extrapolated to the state of the entire pool.*

Guidance: NEI 12-16 and the RAI responses (Reference to RAI Response) on the neutron absorber program provide two potential methods for determining the number of panels to be tested as part of an in-situ monitoring program. Method 1 relies on testing a statistically significant number of panels, which is determined to be 59 panels, regardless of pool size. Method two relies on testing at least 1% of the total number of panels, and selecting from those panels that have the greatest exposure to those parameters that contribute to aging mechanisms. Generally, there has been no acceptance criteria or strict requirement on the number of in-service panels to be tested.

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

Guidance: Confirm whether trending and repeat panel testing is performed

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

Guidance: The only documentation of uncertainties associated with in-situ devices is the NRC Technical Letter Report cited in the request for information. The level of information needed to address the request for information in this section is likely needed from the vendor that performed the in-situ measurements.

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.*

Guidance: Describe the calibration cell configuration and similarities or differences compared to the spent fuel rack configuration.

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

Guidance: Typically a calibration cell has neutron absorbers of known areal density (from laboratory neutron attenuation testing) of different values. Since in-situ measurements a detecting the level of neutron absorbing elements (typically ^{10}B) other materials have a limited impact on the results of the measurements. The in-situ measurement is intended to detect the presence and amount of neutron absorbing elements.

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,*

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

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.*

Guidance: This response is licensee specific depending on whether a "reference panel" in the spent fuel rack was tested. This is applicable to the first generation of BADGER measurements.

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.*

Guidance: The response to this item will be licensee specific depending upon the level of neutron absorber credited, the amount of degradation observed and the expected degradation rate of the neutron absorber.

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.

Guidance: For materials that have not experienced degradation, the basis of modelling is in the as-manufactured condition. For material deformation, describe the modeling performed to address any material deformation included in operability assessments or functionality determinations that would have been entered into the corrective action process when the results of coupon testing or in-situ measurements were obtained indicating possible degradation. Describe how those calculations were performed.

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.

Guidance: Provide a comparison of the results of the monitoring program (extent of degradation or deformation of material) to the analysis performed to address the observed degradation/deformation.

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

Guidance: The bias and uncertainty of monitoring program are not typically included in the original criticality analysis of record. Indicate whether the bias and/or uncertainty of the monitoring program is included in the NCS AOR.

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

Guidance: Provide details of how the neutron absorber degradation is modelled in the AOR with respect to observed degradation compared to modelled 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).

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

ii. increased dissolution or corrosion

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

Guidance: The neutron absorber sheathing provides stability and ensures that the neutron absorber remains in place under design basis events. EPRI has performed an evaluation of the performance of degraded Boraflex under seismic conditions (Reference). There are no design basis events that would change the state of the neutron absorber material with respect to i, ii, iii.

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

ii. parameters monitored

iii. acceptance criteria

iv. intervals of monitoring

Guidance: The intent of the monitoring program was never to ensure that the material can accommodate the stressors of a design-basis event. The monitoring program detects for actual and potential degradation and/or deformation of the neutron absorber. If the material is performing consistently with industry research (details provided in the EPRI Neutron Absorber Handbook), then it is reasonable to expect that the material is performing in a similar manner structurally to the as-manufactured condition.