Tennessee Valley Authority, 1101 Market Street, Chattanooga, Tennessee 37402

CNL-16-163

November 3, 2016

10 CFR 50.54(f)

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

Browns Ferry Nuclear Plant, Units 1, 2, and 3
Renewed Facility Operating License Nos. DPR-33, DPR-52, and DPR-68
NRC Docket Nos. 50-259, 50-260, and 50-296

Sequoyah Nuclear Plant, Units 1 and 2
Renewed Facility Operating License Nos. DPR-77 and DPR-79
NRC Docket Nos. 50-327 and 50-328

Watts Bar Nuclear Plant, Units 1 and 2
Facility Operating License Nos. NPF-90 and NPF-96
NRC Docket Nos. 50-390 and 50-391

Subject: **Tennessee Valley Authority (TVA) Response to NRC Generic Letter 2016-01, "Monitoring of Neutron-Absorbing Materials in Spent Fuel Pools"**

Reference: NRC Generic Letter 2016-01: Monitoring of Neutron-Absorbing Materials in Spent Fuel Pools, dated April 7, 2016, (ML16097A169)

On April 7, 2016, the NRC issued the referenced generic letter to all power reactor licensees except those that have permanently ceased operation with all power reactor fuel removed from on-site spent fuel pool storage. This letter required response within 210 days, in accordance with Title 10 of the *Code of Federal Regulations*, Section 50.54(f) (10 CFR 50.54(f)).

The purpose of this letter is to respond for TVA nuclear plants Browns Ferry Units 1, 2, and 3, Sequoyah Units 1 and 2, and Watts Bar Units 1 and 2. TVA is responding as a Category 4 addressee in accordance with the referenced generic letter for each TVA site. As a Category 4 licensee, information on the neutron-absorbing material, criticality analysis of record and neutron absorber monitoring program is requested depending on the type of neutron absorber material present and credited in the spent fuel pool.

The spent fuel pool nuclear criticality safety analyses for all TVA nuclear plants credit Boral neutron absorbers, and therefore TVA is required to provide information described in areas 1, 2, and 4 of Appendix A of Generic Letter (GL) 2016-01. Enclosure 1 contains TVA's responses to the requested information for Browns Ferry Nuclear Plant. Enclosure 2 contains TVA's responses to the requested information for Sequoyah Nuclear Plant. Enclosure 3 contains TVA's responses to the requested information for Watts Bar Nuclear Plant.

Please contact Chris Riedl at 423-751-3835, if you have any questions concerning this response.

There are no new regulatory commitments contained in this letter.

I declare under penalty of perjury that the foregoing is true and correct. Executed on the 3rd day of November 2016.

Respectfully,

J. W. Shea
Digitally signed by J. W. Shea
DN: cn=J. W. Shea, o=Tennessee Valley Authority, ou=Nuclear Licensing, email=jwshea@tva.gov, c=US
Date: 2016.11.03 18:51:52 -04'00'

J. W. Shea
Vice President, Nuclear Licensing

Enclosures:

1. Browns Ferry Nuclear Plant, Units 1, 2, and 3, Response to Generic Letter 2016-01
2. Sequoyah Nuclear Plant, Units 1 and 2, Response to Generic Letter 2016-01
3. Watts Bar Nuclear Plant, Units 1 and 2, Response to Generic Letter 2016-01

cc (Enclosures):

NRR Director - NRC Headquarters
NRR JLD Director - NRC Headquarters
NRC Regional Administrator - Region II
NRC Project Manager - Browns Ferry Nuclear Plant
NRC Project Manager - Sequoyah Nuclear Plant
NRC Project Manager - Watts Bar Nuclear Plant
NRC Senior Resident Inspector - Browns Ferry Nuclear Plant
NRC Senior Resident Inspector - Sequoyah Nuclear Plant
NRC Senior Resident Inspector - Watts Bar Nuclear Plant

CNL-16-163

ENCLOSURE 1

BROWNS FERRY NUCLEAR PLANT

UNITS 1, 2, and 3

RESPONSE TO GENERIC LETTER 2016-01

Browns Ferry Nuclear Plant

Units 1, 2, and 3

Response to Generic Letter 2016-01

The following is TVA's response to NRC Generic Letter (GL) 2016-01 for Browns Ferry Nuclear Plant (BFN). TVA has determined that BFN is a Category 4 addressee, as TVA credits neutron-absorbing material in its BFN spent fuel pool (SFP) nuclear criticality safety (NCS) analyses, has no approved license amendment to remove credit for existing neutron-absorbing materials, and does not have an approved technical specification change or license condition that incorporates its neutron-absorbing material monitoring program into its licensing basis. TVA is providing the information requested in GL 2016-01 by answering the relevant requests of GL 2016-01 Appendix A.

To facilitate review, the NRC requests are restated below in bold typeface. For multipart requests, the individual subparts of the NRC request are repeated, in italic text, just before TVA's response to that request. TVA's responses are provided in plain type.

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;**
   b) **neutron-absorbing material specifications, such as:**
      i) **materials of construction, including the certified content of the neutron-absorbing component expressed as weight percent;**
      ii) **minimum certified, minimum as-built, maximum as-built, and nominal as-built areal density of the neutron-absorbing component; and**
      iii) **material characteristics, including porosity, density, and dimensions;**
   c) **qualification testing approach for compatibility with the SFP environment and results from the testing;**
   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**
      ii) **sheathing and degree of physical exposure of neutron-absorbing materials to the SFP environment;**
   e) **current condition of the credited neutron-absorbing material in the SFP, such as:**
      i) **estimated current minimum areal density;**
      ii) **current credited areal density of the neutron-absorbing material in the NCS AOR; and**
      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).**

1.a Manufacturers

The BFN high density spent fuel storage racks (HDFSRs) were supplied by General Electric Uranium Management Company (GEUMCO), a subsidiary of General Electric. All of the Boral plates and coupons were provided by a single supplier, Brooks & Perkins.

Dates of manufacture

The neutron absorber batch(es) installed in the BFN SFP were manufactured in 1977, 1978, 1979, and 1980.

Dates of material installation in the SFP

Racks with these neutron absorbers (57 total) were installed in the SFPs in 1978, 1979, 1980, 1981, 1983, 1984, 1986, and 1999. The first HDFSRs were installed in the Unit 3 pool in 1978. The remainder of the HDFSRs were installed in phases from that time until 1999, as indicated in the table below.

Browns Ferry Rack Installation Data

U1 SFP Racks	S/N	Years Boral batches Manufactured	Year Rack Installed
1	2336-4	1977, 1978	1979
2	9A-2	1977, 1978	1979
3	0005	1979	1983
4	2336-5	1978	1979
5	2336-7	1978, 1979	1979
6	2336-9	1977, 1978	1979
7	0002	1978, 1979	1983
8	0025	1980	1981
9	0019	1978, 1979, 1980	1981
10	0021	1978, 1979, 1980	1983
11	2336-3	1977, 1978	1983
12	0020	1978, 1979, 1980	1981
13	0026	1980	1981
14	0023	1978, 1979, 1980	1983
15	0004	1978, 1979	1983
16	0018	1978, 1979, 1980	1981
17	0024	1980	1981
18	0022	1978, 1979, 1980	1983
19	0001	1978, 1979	1983

U2 SFP Racks	S/N	Years Boral batches Manufactured	Year Rack Installed
1	1A-9	1978, 1979	1999
2	1A-10	1978, 1979	1980
3	1A-6	1978, 1979	1980
4	0009	1978, 1979, 1980	1999
5	1A-11	1979	1980
6	1A-4	1978, 1979	1980
7	1A-8	1979	1980
8	0013	1978, 1979, 1980	1984
9	0002	1979	1984
10	0012	1978, 1979, 1980	1986
11	0003	1979	1986
12	1A-7	1979	1984
13	0001	1979	1984
14	0032	1979, 1980	1986
15	0031	1980	1986
16	1A-5	1978, 1979	1984
17	0016	1979, 1980	1984
18	0017	1979, 1980	1986
19	0029	1979, 1980	1986

U3 SFP Racks	S/N	Years Boral batches Manufactured	Year Rack Installed
1	0035	1979, 1980	1983
2	9A-1	1977, 1978	1978
3	1A-1	1977	1978
4	0030	1978, 1979, 1980	1999
5	2336-6	1978, 1979	1981
6	1A-2	1977	1978
7	1A-3	1977, 1978	1978
8	0028	1979, 1980	1999
9	2336-8	1977, 1978, 1979	1986
10	0006	1978, 1979	1986
11	0034	1978, 1979, 1980	1986
12	0033	1980	1999
13	0015	1979, 1980	1999
14	0010	1978, 1979	1986
15	0027	1980	1986
16	0011	1978, 1979, 1980	1999
17	0014	1978, 1979, 1980	1999
18	0008	1978, 1979	1986
19	0007	1979	1986

1.b Neutron-absorbing material specifications

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

The neutron-absorbing material of construction at BFN is Boral.

Boral is not specified on a weight percent basis of the neutron-absorbing component, therefore this sub-item is not applicable to this material.

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

The as-built values provided below were obtained from available manufacturing records which accounted for 88.08% of the Boral panels.

The minimum certified B-10 areal density is 0.013 g/cm^2.

The minimum as-built B-10 areal density is 0.0155 g/cm^2.

The maximum as-built B-10 areal density is 0.0266 g/cm^2.

The nominal as-built B-10 areal density is 0.0192 g/cm^2.

1.b.iii materials characteristic, including porosity, density and dimensions

There are four Boral plates in each storage tube. Each plate is 152.00" x 5.50" x 0.076". The Boral plates are 0.076" thick, with a 0.056" interior matrix thickness and two outer aluminum layers each 0.010" thick. The minimum certified B-10 areal density is 0.013 g/cm^2. The available vendor documents do not provide porosity information.

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

Brooks & Perkins, Inc. reported testing results, as described in reports 554 and 577. These reports described the qualification testing of materials in the SFP environment and exposure to gamma and neutron radiation. Report 554 is referenced in the EPRI Handbook of Neutron Materials for Spent Nuclear Fuel Transportation Application (Document 1019110, November 2009).

1. Brooks & Perkins, Inc. Spent Fuel Storage Module Corrosion Report - Report No. 554, June 1, 1977. This report documents review of published data regarding the extent of any deterioration that is likely to occur to shielding capability over a forty (40) year period following a water leak in the stainless steel covering.

   Results indicate an expected life to be at least greater than fifty-three (53) years and probably greater than sixty (60) years following a rupture to the water barrier covering.

2. The Suitability of Brooks & Perkins Spent Fuel Storage Module for Use in BWR Storage Pool - Report No. 577, July 21, 1978. Research and testing considering corrosion resistance and irradiation effects on spent fuel storage modules (SFSMs).

   Results of the research and testing that have been conducted indicate that the Brooks & Perkins SFSM is suitable for use in a Boiling Water Reactor (BWR) spent fuel storage pool.

1. d configuration in the SFP

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

Each of the three SFPs at BFN consists of 19 rack modules. The HDFSR modules at BFN employ Boral as the neutron-absorbing media and consist of a matrix of fuel storage tubes arranged in a checkerboard pattern.

The fuel storage tube is made by forming an outer tube and an inner tube of 304 stainless steel (304 SS) which encapsulate plates of Boral on each side of the tube. The Boral consists of a B_4C-Al matrix bonded between two layers of aluminum. The inner and outer tubes are welded together. The completed storage tubes are fastened together by angles welded along the corners and attached to a base plate to form storage modules.

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

Stainless steel sheathing covers the entire neutron-absorbing material. This stainless steel jacket is vented at the top end of the tubes, above the Boral material, to allow SFP water ingress to the neutron absorber and also to allow venting of gas.

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

1.e.i estimated current minimum areal density

Results of BFN coupon testing of the neutron-absorbing material and routine sampling of the SFP environment water chemistry have provided no indication of loss of neutron-absorbing material. Industry OE has also not provided indication of loss of Boraflex neutron-absorbing material. Therefore, the estimated current minimum areal density remains the same as when the material was fabricated and installed in the SFP, which is provided in the response to 1.b.ii (minimum as-built B-10 areal density of 0.0155 g/cm^2)**.**

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

The BFN SFP NCS AOR was conservatively performed on the basis of the minimum areal density of 0.013 g/cm^2 B-10 in the Boral plate.

1.e.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 results of inspections of the test coupons since 1985 have shown no degradation to the Boral cermet used in the HDFSRs and indicate no loss of neutron-absorbing material or functionality, although blisters have been observed. The first test coupons were installed in the Unit 3 SFP in 1983. Since then, TVA has maintained a comprehensive test program for monitoring the performance of Boral cermet in the BFN HDFSRs. Unit 3 SFP is representative of Unit 1 and Unit 2 SFPs because all three have similar and mild chemistry and temperature histories.

Since 1983, there have been a total of 11 inspections on the Boral test coupons installed in the Unit 3 SFP. These inspections are summarized in the table below:

Inspection	Summary
October 1985	Coupons #19 and #31 were removed from U3 SFP and shipped to a hot cell for examination. Thickness measurements were performed and comparisons to pre-exposure measurements indicated some slight deformation of the stainless steel sheath. As required by procedure, the stainless steel sheath was cut away, exposing the Boral cermet plate. Both coupons exhibited blistering of the aluminum cladding on both faces. All the blisters were observed in the central area of the coupons and varied in size, with the largest measuring approximately 1/2" in diameter. Thickness measurements were taken of the blistered areas. The measurements ranged from 96-153 mils, as compared to the nominal thickness of the Boral cermet plate of 80 mils. Three additional coupons, identified as #16, #32 and #38, were removed from U3 SFP. These three coupons along with the originally removed #19 and #31 coupons were shipped to the University of Michigan (U of M) Phoenix Memorial Laboratory. Thickness measurements were taken at the pre-characterization locations on each coupon stainless steel sheath. Coupon #16 exhibited a slight increase between the pre-exposure and post-exposure measurements. After removing the stainless steel sheath, visual examination revealed that while coupons #32 and #38 were not affected, coupon #16 showed blistering. Neutron attenuation measurements and neutron radiographs performed at U of M on all samples were all uniform and showed no evidence of loss of material, even at the blister sites. All five coupons were sent to Brooks & Perkins for B-10 loading analysis. Results were compared to measurements taken during manufacturing of the parent Boral strip and no degradation was evident in the B-10 levels of the coupons. Note that the five coupons removed in October 1985 were destructively examined and were not returned to the BFN Unit 3 SFP.

Inspection	Summary
October 1987	Four new test coupons were installed. Coupon #23 (sheathed coupon) designated as CTA #3. Coupon #24 (sheathed coupon) designated as CTA #4. Coupon 22 was unsheathed, its inside Boral plate was designated as Boral plate Test Assembly (BPTA) #1. Coupon #41 was unsheathed, its inside Boral plate was designated at BPTA #2. Pre-exposure thickness and linear dimension measurements were performed prior to installation. Coupon #30 was removed and unsheathed and re-designated as BPTA #3. Upon unsheathing coupon #30, small blisters (5 totals) were observed and recorded. The blisters were evaluated to not have an effect on function of the Boral cermet. Thickness measurements were performed and recorded on all other coupons. No anomalies reported. All coupons reinserted into the Unit 3 SFP. Recommendation was to continue with six month periodicity of inspection.
June 1988	All sheathed coupons (12 totals) and all three BPTAs removed for examination. No blisters noted on BPTA #1 and BPTA #2. No significant change in size of blisters on BPTA #3. Coupon #29 chosen for unsheathing. Upon unsheathing, five small blisters noted on Coupon #29. All blisters smaller than on BPTA #3 (coupon 30). Coupon #29 re-designated as BPTA #4. No significant changes were found in terms of edge corrosion, blister formation or blister degradation to warrant further additional testing. On existing blisters, there was no indication of growth or degradation from previous baseline data. There was no cracking of the stainless steel material evident on either the exterior or interior surfaces of the unsheathed coupon. There was no significant edge corrosion noted on existing Boral plates. Based on the results of the examination, the recommendation was to extend the next inspection until June 1989. All coupons returned to SFP.
June 1989	All sheathed coupons (11 total) and all four BPTAs removed for examination. Six small blisters noted on BPTA #1 (coupon 22). No blisters noted on BPTA #2 (coupon 41). No significant growth noted of blisters on BPTA #3 (coupon 30) and BPTA #4 (coupon 29). Coupon # 21 selected for unsheathing. Upon unsheathing, six small blisters noted. Coupon #21 re-designated as BPTA #5. Thickness measurements recorded on sheathed coupons and on BPTAs. No anomalies noted. All coupons returned to SFP.
March 1991	All sheathed coupons (10 totals) and all five BPTAs removed for examination. Thickness measurements performed on all sheathed coupons. Coupon #28 selected for unsheathing. Upon unsheathing, six small blisters noted. Coupon #28 re-designated as BPTA #6. Some blister growth noted on coupons 21 (BPTA #5), 22 (BPTA #1), 29 (BPTA #4) and 30 (BPTA #3) compared with June 1989 inspection. Blister growth not considered significant. No blisters noted on coupon #41 (BPTA #2). Thickness measurements recorded on sheathed coupons and on BPTAs. No anomalies noted. All coupons returned to SFP.
July 1992	All sheathed coupons (9 totals) and all six BPTAs removed for examination. Thickness measurements performed on all sheathed coupons. No significant change was observed in measurements of the sheathed coupons so decision was made to not unsheathe any additional coupons. Isolated new blistering was measured on only coupon #28 (BPTA #6). Existing blisters observed on five of the coupons (21, 22, 28, 29 and 30) showed little growth. This was seen as an indication that the blistering process appears to be self-limiting. No blisters noted on coupon #41 (BPTA #2). Thickness measurements recorded on BPTAs. No anomalies noted. Edge corrosion showed very slight growth or very slight decrease between 1992 data and baseline (pre-exposure) data. Extrapolated to 40 years, the maximum corrosion was estimated at a maximum of 1.831 mm. All coupons returned to SFP.
August 1993	All sheathed coupons (9 totals) and all six BPTAs removed for examination. Thickness measurements performed on all sheathed coupons. No significant change was observed in measurements of the sheathed coupons so decision was made to not unsheathe any additional coupons. No new blistering noted. Existing blisters observed on five of the

Inspection	Summary
	coupons (21, 22, 28, 29 and 30) showed little growth. This was seen as an indication that the blistering process appears to be self-limiting. No blisters noted on coupon #41 (BPTA #2). Thickness measurements recorded on BPTAs. No anomalies noted. All coupons returned to SFP.
August 1994	All sheathed coupons (9 totals) and all six BPTAs removed for examination. Thickness measurements performed on all sheathed coupons. No significant change was observed in measurements of the sheathed coupons so decision was made to not unsheathe any additional coupons. No new blistering noted. Existing blisters observed on five of the coupons (21, 22, 28, 29 and 30) showed little growth. This was seen as an indication that the blistering process appears to be self-limiting. No blisters noted on coupon #41 (BPTA #2). Thickness measurements recorded on BPTAs. No anomalies noted. All coupons returned to SFP.
December 1995	All sheathed coupons (9 totals) and all six BPTAs removed for examination. Thickness measurements performed on all sheathed coupons. No significant change was observed in measurements of the sheathed coupons so decision was made to not unsheathe any additional coupons. No new blistering noted. Existing blisters observed on five of the coupons (21, 22, 28, 29 and 30) showed little growth. This was seen as an indication that the blistering process appears to be self-limiting. No blisters noted on coupon #41 (BPTA #2). Thickness measurements recorded on BPTAs. No anomalies noted. General plate thicknesses, when extrapolated to the component's design lifetime of 40 years, indicate a maximum increase of just over one millimeter. This indicates there is no concern in the de-bonding of the composite (boron carbide-aluminum) of the Boral plates. All coupons returned to SFP.
October 2003	All sheathed coupons (9 total) and all six BPTAs removed for examination. Thickness measurements performed on all sheathed coupons. No significant change was observed in measurements of the sheathed coupons so decision was made to not unsheathe any additional coupons. No new blistering noted. Existing blisters observed on five of the coupons (21, 22, 28, 29 and 30) showed little growth. This was seen as an indication that the blistering process appears to be self-limiting. No blisters noted on coupon #41 (BPTA #2). Thickness measurements recorded on BPTAs. No anomalies noted. All coupons returned to SFP.
August 2010	Six sheathed coupons (#33, 34, 35, 36, 39, and 40) and three BPTAs (BPTA #4, BPTA #5, and BPTA #6) removed for examination. Thickness measurements performed on all sheathed coupons. No significant change was observed in measurements of the sheathed coupons so decision was made to not unsheathe any additional coupons. No new blistering noted. Existing blisters observed on the three removed BPTA coupons (21, 28, and 29) showed little or no growth. This was seen as an indication that the blistering process appears to be self-limiting. Thickness measurements recorded on BPTAs. No anomalies noted. All inspected coupons returned to SFP.

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

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

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

ii) parameters to be inspected and data collected;

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;

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

v) industry standards used.

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

i) If there is visual inspection of inservice material:

(1) describe the visual inspection performed on each sample; and

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

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;

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

(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

(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.

iii) If RACKLIFE is used:

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

(2) note the frequency at which 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; and

(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.

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 GL 2016-01 statistically significant enough that the result can be extrapolated to the state of the entire pool;

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

(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;

(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

(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); and (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.

2.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.*

A coupon monitoring program is in place at BFN to detect aging/degradation mechanisms of the in-service neutron absorber materials. Surrogate material from the same manufacturing specifications as the as-installed material, in the form of coupons, were placed in a location in the Unit 3 SFP near discharged fuel, which provides exposure to gamma and neutron irradiation within the same water chemistry.

In addition, Industry Operating Experience (OE) with neutron absorbers including participation in industry neutron absorber groups is an integral part of the TVA SFP Neutron Absorber Material Monitoring program. TVA enters applicable OE that indicates deformation or degradation of neutron absorbers into the TVA corrective action program (CAP) for further assessment of impacts, extent of condition, trending, determination of functionality, and implementation of corrective actions.

Also, include a description and technical basis for the technique(s) and method(s) used in the surveillance or monitoring program, including:

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

As a result of BFN License Renewal, BFN is committed to the Generic Aging Lessons Learned (GALL) Report, NUREG-1801 R0. In accordance with NUREG-1801 R0, TVA establishes the current frequency and sample size for performing coupon monitoring based on the trend of the historical data results, considering the parameters identified in 2.a.ii below. TVA procedures 0-TI-116, High Density Fuel Storage System Surveillance Program, and NPG-SPP-08.1, Nuclear Fuel Management, provide the programmatic requirements.

The program does not describe any specific calculations that need to be performed. Change in dimensions are calculated to support the qualitative evaluation.

In its July 27, 2016 response to an Extended Power Uprate (EPU) License Amendment Request (LAR) Request for Additional Information (RAI) (ML16210A501), TVA has indicated that it will accept license conditions for BFN either to perform periodic Boral areal density measurement at least once every ten years or to implement testing in accordance with NEI 16-03, if endorsed by NRC. NEI 16-03 guidance also indicates a ten-year interval is acceptable as follows:

> "For materials that have been used for several years in conditions similar to the pool environment (i.e. their ability to perform is well known), and for which stability of the material condition has been documented, initial and subsequent intervals up to 10 years is acceptable."

2.a.ii *parameters to be inspected and data collected*

In accordance with BFN procedure 0-TI-116, the following parameters are inspected and data collected: thickness and linear measurements, blistering, pitting, corrosion, evidence of cracks, and any other visible anomalies. TVA makes a qualitative evaluation of the data and includes it with the inspection results.

Additionally, in its July 27, 2016 response to an EPU LAR RAI (ML16210A501), TVA specified additional data collection to be performed for EPU operation.

> “TVA will perform areal density measurements on one Boral sample prior to [EPU] implementation at [BFN].
>
> “In addition, as part of the EPU License Amendments, BFN will accept license conditions for performance of periodic Boral areal density measurement worded as follows:
>
>> “The licensee shall, at least once every ten years, withdraw a neutron absorber coupon from the spent fuel pool and perform Boron-10 (B-10) areal density measurement on the coupon. Based on the results of the B-10 areal density measurement, the licensee shall perform any technical evaluations that may be necessary and take appropriate actions using relevant regulatory and licensing processes.”
>
> “However, if NRC endorses NEI 16-03 guidance on neutron absorber monitoring prior to issuance of the EPU license amendments, BFN will accept license conditions for performance of periodic Boral areal density measurement worded as follows:
>
>> “The licensee shall perform tests in accordance with NRC-endorsed NEI 16-03, “Guidance on Neutron Absorber Monitoring.” Based on the results of the testing performed in accordance with NEI 16-03, the licensee shall perform any technical evaluations that may be necessary and take appropriate actions using relevant regulatory and licensing processes.”

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

There has not been a strict “acceptance criteria” associated with the neutron absorber monitoring program. The purpose of the neutron absorber monitoring 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 CAP for further assessment of impacts, extent of condition, trending, determination of functionality, and implementation of corrective actions. TVA’s qualitative evaluation of monitoring results will determine whether the material’s structure and safety function have been maintained within the assumptions of the BFN SFP NCS AOR.

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

A coupon monitoring program and associated procedures are in place as part of the actions for BFN License Renewal to comply with NUREG-1801 Revision 0. For Coupon/Boral plate examinations: Thickness measurements of each sheathed coupon selected are taken and recorded. Thickness and linear measurements of Boral cermet plates selected are taken and recorded. The selected Boral cermet plates are photographed and examined for blistering, pitting corrosion, and other visible anomalies. Location of any blistering of the selected Boral cermet plates is recorded and measurements of the blisters are taken and recorded. Coupon surveillance results are reviewed and evaluated by qualified personnel.

The SFP environment is monitored periodically so that the impact on the performance of the neutron absorber material can be correlated.

In addition, Industry OE with neutron absorbers including participation in industry neutron absorber groups is an integral part of the TVA SFP Neutron Absorber Material Monitoring program. TVA enters applicable OE that indicates deformation or degradation of neutron absorbers into the TVA CAP for further assessment of impacts, extent of condition, trending, determination of functionality, and implementation of corrective actions.

2.a.v industry standards used

The BFN HDFS Surveillance Program (0-TI-116) does not discuss or refer to any specific industry standards. The site program is consistent with applicable guidance in EPRI Technical Report TR-1019110, "Handbook of Neutron Absorber Materials for Spent Nuclear Fuel Transportation and Storage Applications," and 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."

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

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

No visual inspection is performed of in-service material at BFN, because the rack design has the material encased in sheathing where the material is not visible.

2.b.i.1 Describe the visual inspection perform on each sample

N/A

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

N/A

2.b.ii If there is coupon monitoring program

2.b.ii.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.*

Sixteen sheathed test coupons were supplied by the HDFSR manufacturer and are of the same metallurgical condition as the HDFSR in thickness, chemistry, finish and temper. Each test coupon had small holes drilled through one of the stainless steel sheath covering the Boral cermet, which allows exposure of the Boral cermet to the SFP water environment and simulates the configuration of the Boral cermet in the BFN HDFSRs. Closure welds on the coupons were performed using the same procedures used for the construction of the HDFSRs. The dimensions of the Boral cermet in the test coupons are nominally 6" by 6" by 0.083" thick. The Coupon Test Assembly (CTA) consists of a hanger containing one or more coupons fastened to a stainless steel rope. The CTA is lowered into the SFP next to an HDFSR cell containing a previously exposed bundle, and is next fastened to the railing at the side of the SFP. Another hanger used is the Boral plate Test Assembly (BPTA), which is similar to the CTA described above except it consists of bare Boral cermet plate(s) rather than encased coupons (the stainless steel outer sheath is removed from the front and back of the coupon).

A review of the fuel assembly movements since plant start-up was performed to determine what the total Core Average Exposure (CAVEX) was for each of the three SFPs. The information is tabularized below:

Unit	Estimated CAVEX HDFSR Installation (1978) Up To Coupon Installation (1983) (MWD/ST)	Estimated CAVEX Post Coupon Installation (MWD/ST)	Estimated Total CAVEX (MWD/ST)	Delta Total Exposure from Unit 3 Coupons (%)
1	23,353	41,561	64,914	-54.4%
2	14,720	170,985	185,708	+23.4%
3	26,569	142,247	168,816	+15.7%

All three SFPs have similar and mild chemistry and temperature histories so the Unit 3 SFP Boral coupons are representative of the Boral plates in all three SFPs when considering long term environmental impacts. The inspections that have been performed on the Unit 3 coupons have shown very little or no change in corrosion. Similarities in the pool environments provide assurance that the Boral plates in the Unit 1 and 2 SFPs remain in acceptable physical condition as well.

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

Sixteen coupons were installed in the Unit 3 SFP in 1983. Two additional coupons and two bare Boral plates were installed in the Unit 3 SFP in 1987.

2.b.ii.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.*

The BFN coupon monitoring program includes poolside examination of the Boral test coupons (and bare Boral plates as appropriate). Coupon(s) retrieved for a poolside examination are typically reinserted into the SFP. The poolside examination of these coupons consists of:

a. Visual Observations looking for signs of blistering, pitting, loss of material, anomalies, etc. The front and back of each coupon are photographed. Any anomalies are documented.

b. Dimensional Measurements (length, width, and thickness) of each coupon are recorded.

c. Dimensional Measurements (length, width, and thickness) of any anomaly (such as a blister) are recorded.

None of the tests performed on the retrieved coupon(s) for poolside examination alter the neutron-absorbing material or expose the coupon material to an environment significantly different than the SFP environment for an extended period of time. In addition, the coupons are not dried for these tests, so the material is not altered.

2.b.ii.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.*

BFN currently has nine Boral sheathed test coupons and six bare Boral cermet plates in the Unit 3 SFP.

Based on the current EPU proposed schedule of testing once every 10 years and the results to date, TVA anticipates there are enough coupons for the surveillance program for the life of the SFP. (BFN Unit 3 is currently licensed to operate until 2036.)

2.b.iii *If RACKLIFE is used:*

RACKLIFE is only applicable to the Boraflex neutron absorber material. BFN uses Boral as the sole neutron absorber material in the SFP storage racks. No response to this section is required.

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

TVA does not perform in-situ testing of credited neutron-absorbing material at BFN. No response to this section is required.

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.**

   TVA uses Boral as the credited neutron absorber material. TVA does not credit any Boraflex, Carborundum, or Tetrabor. No response to this section is required.

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.**

   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.**

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

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

4.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 basis for modeling the neutron absorber material in the BFN SFP NCS AOR is the as-manufactured condition. Manufacturing Reactivity Uncertainties (Δk_{tol}) include uncertainties related to Boral manufacturing tolerances (Boral sheet width and Boral thickness). No additional uncertainties are included for areal density, because the certified minimum areal density is used.

No degradation of the neutron-absorbing material has been identified.

For material deformation, Boral blister uncertainties are captured as a component of the applicable system uncertainties.

The blister modeling was as follows:

A uniform 0.055" void region has been used for the BFN SFP NCS AOR analysis, as a conservative model of this potential blistering condition*. Calculations indicate that this level of void on all the Boral plates in the pool would increase reactivity by 0.004 ± 0.001 Δk. This effect is included in the Δk_{sys} parameters in the calculation of $k_{95/95}$.

* A uniform void with a 0.055 inch height bounds the condition of having a 1/8 inch high blister with a spherical cross section on every 1.25"x1.25" unit cell on one side of a Boral plate (i.e., 1.25" diameter blisters with a height of 1/8" packed edge to edge). This, in turn, would be equivalent to each side of the Boral plate having

blisters of this size with 50% area coverage. This conservatively bounds the results from the stainless steel clad coupon surveillances performed at BFN, on an average basis.

4.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.*

As noted in response 2.a.iii above, there are no strict acceptance criteria. TVA procedure 0-TI-116 specifies measurements to be made and identifies considerations for a qualitative evaluation of monitoring results that is included with the results of the coupon examination. Those considerations include general condition of the coupon, corrosion, cracks, possible debonding, blistering, pitting, and other visible anomalies. This qualitative evaluation of monitoring results will determine whether the material's structure and safety function have been maintained within the assumptions of the BFN SFP NCS AOR.

See response 1.e.iii for a summary of the 11 Boral test coupon inspections performed to date.

Coupon monitoring has identified that blisters could form on the surface of the Boral plates. This deformation of the Boral plate will displace water and therefore affect the reactivity of the storage racks. The impact of blisters on Boral plates was evaluated and their worth was included as a direct adder in the $k_{95/95}$ equation.

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

Bias and uncertainty of the monitoring program are not included in the original BFN SFP NCS AOR.

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

Degradation has not been observed in the BFN coupons. Therefore, degradation is not accounted for in the BFN SFP NCS AOR.

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). . . .**

   TVA uses Boral as the credited neutron absorber material. TVA does not credit any Boraflex, Carborundum, or Tetrabor. No response to this section is required.

CNL-16-163

ENCLOSURE 2

SEQUOYAH NUCLEAR PLANT

UNITS 1 AND 2

RESPONSE TO GENERIC LETTER 2016-01

Sequoyah Nuclear Plant

Units 1 and 2

Response to Generic Letter 2016-01

The following is TVA's response to NRC Generic Letter (GL) 2016-01 for Sequoyah Nuclear Plant (SQN). TVA is responding to GL 2016-01 for SQN as a Category 4 addressee, as TVA credits neutron-absorbing material in its SQN spent fuel pool (SFP) nuclear criticality safety (NCS) analyses and has no approved license amendment to remove credit for existing neutron-absorbing materials. TVA has an approved license condition for each SQN unit to implement License Renewal commitments, which include an enhanced neutron-absorbing material monitoring program, by March 17, 2020, before entering the period of extended operation. TVA is providing the information requested in GL 2016-01 by answering the relevant requests of GL 2016-01 Appendix A.

To facilitate review, the NRC requests are restated below in bold typeface. For multipart requests, the individual subparts of the NRC request are repeated, in italic text, just before TVA's response to that request. TVA's responses are provided in plain type.

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;**
   b) **neutron-absorbing material specifications, such as:**
      i) **materials of construction, including the certified content of the neutron-absorbing component expressed as weight percent;**
      ii) **minimum certified, minimum as-built, maximum as-built, and nominal as-built areal density of the neutron-absorbing component; and**
      iii) **material characteristics, including porosity, density, and dimensions;**
   c) **qualification testing approach for compatibility with the SFP environment and results from the testing;**
   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**
      ii) **sheathing and degree of physical exposure of neutron-absorbing materials to the SFP environment;**
   e) **current condition of the credited neutron-absorbing material in the SFP, such as:**
      i) **estimated current minimum areal density;**
      ii) **current credited areal density of the neutron-absorbing material in the NCS AOR; and**
      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).**

1.a Manufacturers

The SQN high density spent fuel storage racks (HDFSRs) were provided by Holtec, with the neutron-absorbing material Boral (fashioned into neutron-absorbing panels integral with the storage racks), manufactured by AAR Brooks & Perkins.

Dates of manufacture

The Boral material was manufactured in 1992.

Dates of material installation in the SFP

The first of the current SFP racks was installed in the SQN SFP in 1994 and the other eleven were installed in 1995.

1.b Neutron-absorbing material specifications

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

The neutron-absorbing material of construction utilized in the Holtec International supplied racks for SQN is Boral, with this material procured in sheets (from vendor AAR Brooks & Perkins) and manufactured as panels for use in construction of the racks. The lots of boron carbide material used to construct the Boral panels have a B-10 content of 18.57 to 18.63 weight percent, based on the AAR Brooks & Perkins certificate of compliance documentation.

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

The minimum areal density certified value is per the Holtec Purchase Specification for the Boral material specified for the construction of the SQN rack modules. The minimum as-built and maximum as-built areal density values are determined from the available data for the Boral panels. As-built records are available for a total of 532 (11.82%) of the 4499 Boral panels used to construct the SQN Holtec racks. The nominal as-built areal density value is documented in the SQN SFP NCS AOR report.

Minimum Certified Areal Density:	0.030 g/cm^2
Minimum As-Built Areal Density:	0.0307 g/cm^2
Maximum As-Built Areal Density:	0.0367 g/cm^2
Nominal As-Built (Statistical) Areal Density:	0.03388 g/cm^2

1.b.iii material characteristics, including porosity, density, and dimensions

The SQN HDFSR system utilizes the neutron-absorbing material Boral. The Boral material was manufactured as panels specified at 7.500" wide by 144" long, with the panel thickness specified as 0.101". The minimum B-10 areal density is specified as 0.030 g/cm^2. The available vendor documents do not provide porosity information.

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

Brooks & Perkins, Inc. reported testing results, as described in reports 554, 578 and 624. These reports described the qualification testing of materials in the SFP environment and exposure to gamma and neutron radiation. These reports are referenced in the EPRI Handbook of Neutron Absorber Materials for Spent Nuclear Fuel Transportation and Storage Application (Document 1019110, November 2009) which summarizes Boral qualification testing and in-service experience (coupon programs) over a range of Boiling Water Reactor (BWR) and Pressurized Water Reactor (PWR) SFP conditions. The reports were also referenced in the SQN License Amendment Request submittal to the NRC as part of the SQN spent fuel storage capacity increase (TVA letter to NRC, March 27, 1992, Request for License Amendment to Technical Specifications (TS) - Spent-Fuel Pool Storage Capacity Increase, NRC Accession No. 9204010283).

1. Brooks & Perkins, Inc. Spent Fuel Storage Module Corrosion Report - Report No. 554, June 1, 1977. This report documents review of published data regarding the extent of any deterioration that is likely to occur to shielding capability over a forty-year period following a water leak in the stainless steel covering.

   Results indicate an expected life to be at least greater than fifty three (53) years and probably greater than sixty (60) years following a rupture to the water barrier covering.

2. The Suitability of Brooks & Perkins Spent Fuel Storage Module for Use in PWR Storage Pool - Report No. 578, July 7, 1978. Research and testing considering corrosion resistance and irradiation effects on spent fuel storage modules

   Results of the research and testing that have been conducted indicate that the Brooks & Perkins Spent Fuel Storage Module (SFSM) is suitable for use in a PWR spent fuel storage pool.

3. "Boral Neutron Absorber/Shielding Material - Product Performance Report," Report No. 624, July 20, 1982 This report describes testing performed to demonstrate service life relative to the SFP environment (resistance to general, galvanic, pitting, crevice, intergranular and stress corrosion) and neutron and gamma irradiation (accelerated testing that showed no physical or chemical changes as a result of exposure).

1.d configuration in the SFP

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

The SQN HDFSR system is composed of twelve rack modules. Each module consists of fuel storage cell locations (manufactured as square boxes using austenitic stainless steel) that hold the fuel assemblies. A single panel of neutron-absorbing material (Boral) is located between storage cell locations and the adjacent cells are fusion spot-welded together. Each Boral panel is additionally supported at the bottom by a stainless steel strip of the same thickness as the Boral panel. On the periphery box walls of each module, Boral panels are mounted under a stainless steel sheathing that is attached to the box walls via fusion spot welds on the vertical sides and by fusion welding on the top and bottom of the sheathing.

1.d.ii sheathing and degree of physical exposure of neutron-absorbing materials to the SFP environment

All Boral panel locations are covered by the rack walls or sheathing but are vented to allow SFP water ingress to the neutron absorber and also to allow venting of gas.

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

1.e.i estimated current minimum areal density

Results of SQN coupon testing of the neutron absorber material (neutron attenuation testing at vendor facility) and routine sampling of the SFP environment water chemistry have provided no indication of loss of neutron-absorbing material, although blisters have been observed. Industry OE has also not provided indication of loss of Boral neutron-absorbing material. Therefore, the estimated current minimum areal density remains the same as when the material was fabricated and installed in the SFP, which is provided in the response to 1.b.ii (minimum as-built areal density of 0.0307 g/cm^2).

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

The SQN SFP NCS AOR was conservatively performed on the basis of the as-built (statistical) nominal B-10 areal density of 0.03388 g/cm^2. Manufacturing tolerances were addressed as uncertainties in the analysis.

1.e.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 results of inspections of SQN test coupons have shown no degradation to the Boral used in the HDFSRs and indicate no loss of neutron-absorbing material or functionality, although small blisters were noted. As noted in response 4.a below, analysis has indicated that that Boral panel blisters have a negligible effect on a rack's criticality analysis. Coupons were installed in the SQN SFP at the same time the racks were installed (1995). Coupon inspections and / or laboratory testing began in 2016, with a total of two Boral test coupons inspected. These inspections / testing results are summarized in the table below:

Inspection	Summary
May 2016	Basic Surveillance at SQN: Coupon #1 (JS201041-2-2) and #2 (ID213731-2-3) were removed from the coupon tree and unsheathed. Coupon#1 - small blisters (5 total), Coupon#2 – small blisters (3 total) were recorded. No pitting corrosion

Inspection	Summary
	observed on either coupon. No visual anomalies noted, no areas of coupon (plate) thinning. No stainless steel material (sheathing) corrosion. Length / width dimension measurements performed, recorded for both coupons, with less than 0.1% changes. Thickness measurements on Coupon#1 recorded as ~ $\pm$ 1% increase. Coupon#2 dimensions documented in June 2016 inspection. Acceptance criteria met for thickness (increase in thickness at any point should not exceed 10% of the initial thickness at that point). Coupon#1 re-sheathed and reinserted into the SFP. Coupon#2 re-sheathed, sent offsite for laboratory testing.
June 2016	Coupon#2 (ID213731-2-3) - to offsite laboratory for analysis. Neutron-attenuation (blackness) testing performed. Post-irradiation average result for B-10 areal density within +/-2% of the density value measured as against the manufacturing pre-characterization testing. Additionally, the post-irradiation areal density result is within +/-1% of the stated B-10 content of 0.0346 g/cm^2 on the AAR Advanced Structures / Brooks & Perkins Company issued Certificate of Compliance for Coupon#2. Conclusion: Acceptance criteria met for B-10 areal density (a decrease of no more that 5% in B-10 areal density using neutron attenuation testing); therefore, no indication of loss of functionality of the material due to absence of B-10 isotope content. Length / width measurements performed, recorded $\leq$ 0.2% changes. Thickness measurements recorded, ranging from -1.35 to 4.22% increase. Acceptance criteria met for thickness (increase in thickness at any point should not exceed 10% of the initial thickness at that point). Visual results - coupon in good condition, noted slight occurrences of blisters (report stated ‘typical of Boral as known throughout the industry’). No visual signs of edge degradation. No significant general corrosion, galvanic interaction or pitting corrosion recognized. Although the coupon was not dried, decision was made to not return coupon to SQN SFP.

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

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

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

ii) parameters to be inspected and data collected;

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;

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

v) industry standards used.

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

i) If there is visual inspection of inservice material:

(1) describe the visual inspection performed on each sample; and

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

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;

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

(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

(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.

iii) If RACKLIFE is used:

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

(2) note the frequency at which 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; and

(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.

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 GL 2016-01 statistically significant enough that the result can be extrapolated to the state of the entire pool;

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

(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;

(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

(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); and (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.

2.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.

A coupon monitoring program is in place at SQN to detect aging/degradation mechanisms of the in-service neutron absorber material. Surrogate material from the same manufacturing specifications as the as-installed material, in the form of coupons, are placed in a location in the SFP near discharged fuel, which provides exposure to gamma and neutron irradiation within the same water chemistry.

In addition, Industry Operating Experience (OE) with neutron absorbers including participation in industry neutron absorber groups is an integral part of the TVA SFP Neutron Absorber Material Monitoring program. TVA enters applicable OE that indicates deformation or degradation of neutron absorbers into the TVA CAP for further assessment of impacts, extent of condition, trending, determination of functionality, and implementation of corrective actions.

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

As a result of SQN License Renewal, SQN is committed to NUREG-1801, R2. In accordance with NUREG-1801, R2, SQN establishes the current frequency and sample size for performing coupon monitoring based on the trend of the historical data results, considering the parameters identified in 2.a.ii below, and with the frequency of coupon surveillance tests not to exceed 10 years. The sampling criteria are specified in the TVA procedures that govern the SQN coupon monitoring program. TVA procedures 0-TI-NUC-000-009.0, Spent Fuel Pool Coupon Tree Surveillance, and NPG SPP 08.1, Nuclear Fuel Management, provide the programmatic requirements.

The program does not describe any specific calculations that need to be performed. Change in dimensions and areal density are calculated to verify the acceptance criteria.

2.a.ii parameters to be inspected and data collected

In accordance with SQN procedure 0-TI-NUC-000-009.0, inspection parameters and data collected include: visual observations, dimensional measurements, weight and density measurements, determination of B-10 areal density (g/cm^2), and characterization of changes (differences between pre-characterization testing and post-SFP exposure).

2.a.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 in the SQN coupon monitoring program procedures (0-TI-NUC-000-009.0 and NPG SPP 08.1) are as follows:

For each measurement location, as well as the coupon average, compare the test results with the baseline measurements (pre-characterization data).

A. An increase in thickness at any point should not exceed 10% of the initial thickness at that point.

B. A decrease of no more than 5% in B-10 areal density, as determined by neutron attenuation, if neutron attenuation testing is required.

Procedure 0-TI-NUC-000-009.0 also specifies that the remaining measurement parameters (visual or photographic evidence of unusual surface pitting, corrosion, or edge deterioration, unaccountable weight loss in excess of the measurement accuracy) serve a supporting role and should be examined for early indications of neutron absorber degradation which would suggest a need for a change in measurement schedule or retrieval of multiple coupons for verification.

Boral is not anticipated to have a loss of B-10 areal density; therefore, the B-10 areal density of the test coupon should be the same as its original B-10 areal density (within the uncertainty of the measurement). These results indicate the material structure and safety function is maintained and the AOR remains valid.

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

A coupon monitoring program and associated procedures are in place (as part of the actions to comply with NUREG-1801 Revision 2 and with NUREG-2181 during the License Renewal process for SQN) such that trending shall be performed on the results of coupon surveillance activities. As part of this coupon monitoring program, routine sampling and trending of the SFP environment water chemistry is used to monitor the performance of the neutron-absorbing material. Parameters that are monitored include: Aluminum (ppb), Boron (ppm), pH, and SFP temperature.

These surveillance activities and associated programs will be used in the trending of neutron absorber data and in determining the frequency and type of additional coupon testing, in order to determine the rate (if any) of degradation and take action as needed to maintain the neutron-absorbing material safety function.

In addition, Industry OE with neutron absorbers including participation in industry neutron absorber groups is an integral part of the TVA SFP Neutron Absorber Material Monitoring program. TVA enters applicable OE that indicates deformation or degradation of neutron absorbers into the TVA CAP for further assessment of impacts, extent of condition, trending, determination of functionality, and implementation of corrective actions.

2.a.v industry standards used

The SQN Spent Fuel Coupon Tree Surveillance program (0-TI-NUC-000-009.0) does not discuss or refer to any specific industry standards. The site monitoring program is consistent with applicable guidance in EPRI Technical Report TR-1019110, “Handbook of SNF Neutron Absorbers.” Laboratory testing recently performed by the vendor (Holtec), follows guidance provided in industry standards. The following standards were used in the performance of the testing:

- ASTM E992-11 “Standard Specification for Boron-Based Neutron Absorbing Material Systems for Use in Nuclear Spent Fuel Storage Racks”
- 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”

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

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

No visual inspection is performed of in-service material at SQN, because the rack design has the material encased between adjacent cell locations or beneath sheathing so that the material is not visible.

2.b.i.1 Describe the visual inspection performed on each sample

N/A

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

N/A

2.b.ii If there is a coupon monitoring program

2.b.ii.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.

Test coupons were supplied by Holtec and are located in the SQN SFP on a device called the Coupon Tree (CPT). The test coupons are from the same lots of neutron-absorbing material (Boral) used for the construction of the SQN HDFSRs. Each test coupon is sandwiched between stainless steel sheathing (same material used in containing Boral panels in the SQN HDFSRs), with the sheathing joined together via stainless steel screws, allowing removal of the coupon. The configuration of the sheathing allows exposure of the Boral coupons to the SFP water environment and simulates the configuration of the Boral material between adjacent cells in the SQN HDFSRs. The CPT is lowered into an SFP cell surrounded by cells containing previously exposed bundles. The CPT upper fitting rests on the top of the SFP racks with the coupons suspended below, with the coupons positioned axially within the central fuel zone of the surrounding discharged fuel assemblies, thus receiving a reasonably uniform gamma flux exposure. Based on coupon pre-characterization measurements provided by Holtec, the coupons have nominal dimensions of 12" by 6" by 0.102" thick.

Vendor guidance was utilized that provided instructions for the CPT irradiation schedule. The Holtec vendor-supplied coupon surveillance program provides an accelerated irradiation schedule that includes surrounding the CPT with eight freshly discharged fuel assemblies that have been among the higher specific power in the core. The CPT was actively managed by being surrounded by freshly discharged fuel assemblies after each of the first five refueling outages following installation of the Holtec HDFSRs. Additionally, due to the current fuel movement restrictions of B.5.b thermal dispersion requirements, the proximity of the CPT to freshly irradiated fuel is limited. In order to ensure that the CPT receives the highest possible exposure, the CPT is located in the SFP so that two of the eight surrounding fuel assemblies are discharged assemblies from the most recent refueling outage, with one of these assemblies face-adjacent to the CPT. After this placement is made, the CPT remains in this location until the next refueling outage. In summary, the test coupons are expected to have experienced a slightly higher radiation dose than the Boral panels in the SFP rack modules.

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

The coupons were installed in the SQN SFP on May 16, 1995.

2.b.ii.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.

The SQN coupon monitoring program includes poolside examination of the Boral coupons manufactured from the same lots of the neutron-absorbing material used in the SQN HDFSR system. Coupon(s) retrieved for a poolside examination are typically reinserted into the SFP and in the same configuration as when retrieved. The poolside examination of these coupons consists of:

a. Visual Observations looking for signs of blistering, pitting, bulging, discoloration, loss of material, etc. The front and back of each coupon is photographed. Any anomalies are documented.

b. Dimensional Measurements (length, width, and thickness) of each coupon are recorded.

c. Dimensional Measurements (length, width, and height) of any anomaly (such as a blister) are recorded.

d. Weight (without drying) of each coupon is recorded.

None of the tests performed on the retrieved coupon(s) for poolside examination alter the neutron-absorbing material or expose the coupon material to an environment significantly different than the SFP environment for an extended period of time. In addition, the coupons are not dried for these tests, so the material is not altered.

The coupon that was sent to offsite laboratories / test facilities was not returned to the SFP after performance of tests on the neutron-absorbing material. For a typical offsite coupon examination, the tests performed are fully non-destructive and should cause no degradation of the coupon. However, because of the length of time the coupon was removed from the SFP, as well as the potential effects of changes in the environment (hot/wet to cool/dry), the coupon was not returned to the SFP for reuse as a representative surveillance coupon.

2.b.ii.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.

TVA currently has eleven Boral test coupons in the SQN SFP.

Based on the current schedule of testing (determined by the results of prior coupon surveillance tests, but not to exceed 10 years) and including results to-date, TVA anticipates there are enough coupons for the surveillance program for the life of the SFP, accounting for Unit 1 operation through 2040 and Unit 2 operation through 2041.

2.b.iii If RACKLIFE is used: . . .

RACKLIFE is only applicable to the Boraflex neutron absorber material. SQN uses Boral as the sole neutron absorber material in the SFP storage racks. No response to this section is required.

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

TVA does not perform in-situ testing of credited neutron-absorbing material at SQN. No response to this section is required.

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.**

   TVA uses Boral as the credited neutron absorber material at SQN. TVA does not credit any Boraflex, Carborundum, or Tetrabor. No response to this section is required.

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.

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.

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

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

4.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 basis of modeling the neutron absorber material in the SQN SFP NCS AOR is the as-manufactured condition.

Manufacturing reactivity uncertainties associated with manufacturing tolerances were addressed in the SQN SFP NCS AOR. The uncertainties associated with the Boral panels included the minimum B-10 areal density and Boral panel widths.

No degradation of the neutron-absorbing material has been identified. Therefore, the SQN SFP NCS AOR does not explicitly reflect degraded or deformed neutron-absorbing material. However, a modeling analysis was performed for the Watts Bar Nuclear Plant (WBN) fuel storage racks, which are of the flux-trap design and can be affected by small changes in the dimensions of the flux trap. In response to NRC Information Notice (IN) 2009-26, the modeling analysis assumed the presence of blisters on the Boral panels in these WBN racks. Holtec performed a criticality evaluation of the effect of blisters on the panels. This evaluation concluded that Boral panel blisters have a negligible effect on a rack’s criticality analysis.

Because the flux trap design is generally more susceptible to reactivity impacts from water displacement than the SQN high density fuel rack design, TVA has concluded that the WBN evaluation indicates blisters on Boral panels would have a negligible effect on the SQN SFP NCS AOR.

4.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.*

Coupon inspections and / or laboratory testing began in 2016, with a total of two inspections on the Boral test coupons installed in the SQN SFP. These inspection/testing results were summarized in response 1.e.iii, and indicate no recorded loss of neutron-absorbing material or functionality, and support the manufacturing reactivity uncertainties associated with manufacturing tolerances addressed in the SQN SFP NCS AOR. Additionally, as stated above in the response to Question 4.a, an evaluation concluded that Boral blisters have a negligible effect on the SFP NCS AOR.

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

Bias and uncertainty of the monitoring program are not included in the original SQN SFP NCS AOR.

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

Degradation has not been observed in the SQN coupons. Therefore, degradation is not accounted for in the SQN SFP NCS AOR.

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). . . .**

   TVA uses Boral as the credited neutron absorber material at SQN. TVA does not credit any Boraflex, Carborundum, or Tetrabor. No response to this section is required.

CNL-16-163

ENCLOSURE 3

WATTS BAR NUCLEAR PLANT

UNITS 1 AND 2

RESPONSE TO GENERIC LETTER 2016-01

Watts Bar Nuclear Plant

Units 1 and 2

Response to Generic Letter 2016-01

The following is TVA's response to NRC Generic Letter (GL) 2016-01 for Watts Bar Nuclear Plant (WBN). TVA has determined that WBN is a Category 4 addressee, as WBN credits neutron-absorbing material in its spent fuel pool (SFP) nuclear criticality safety (NCS) analyses, has no approved license amendment to remove credit for existing neutron-absorbing materials, and does not have an approved technical specification change or license condition that incorporates its neutron-absorbing material monitoring program into its licensing basis. TVA is providing the information requested in GL 2016-01 by answering the relevant requests of GL 2016-01 Appendix A.

To facilitate review, the NRC requests are restated below in bold typeface. For multipart requests, the individual subparts of the NRC request are repeated, in italic text, just before TVA's response to that request. TVA's responses are provided in plain type.

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;**
   b) **neutron-absorbing material specifications, such as:**
      i) **materials of construction, including the certified content of the neutron-absorbing component expressed as weight percent;**
      ii) **minimum certified, minimum as-built, maximum as-built, and nominal as-built areal density of the neutron-absorbing component; and**
      iii) **material characteristics, including porosity, density, and dimensions;**
   c) **qualification testing approach for compatibility with the SFP environment and results from the testing;**
   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**
      ii) **sheathing and degree of physical exposure of neutron-absorbing materials to the SFP environment;**
   e) **current condition of the credited neutron-absorbing material in the SFP, such as:**
      i) **estimated current minimum areal density;**
      ii) **current credited areal density of the neutron-absorbing material in the NCS AOR; and**
      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).**

1.a Manufacturers

The Boral neutron absorber material used in the WBN SFP Racks was manufactured by Brooks & Perkins, Inc.

Dates of manufacture

The neutron absorber batches were manufactured in 1979.

Dates of material installation in the SFP

The Programmed and Remote Systems Corp. (PaR) racks were initially installed in November 1980, at Sequoyah Nuclear (SQN) Plant and removed from December 1994 through March 1995. Subsequently, in 1997, the racks were installed in the WBN SFP.

1.b Neutron-absorbing material specifications

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

The neutron absorber material used in the WBN Spent Fuel Storage Racks is Boral (Alloy 1100 Aluminum and B_4C).

The Boral has a nominal weight percent of 70% natural Boron according to the PaR Design & Fabrication Criteria.

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

The minimum areal density certified value is per the PaR Purchase Specification for the Boral material specified for the construction of the WBN rack modules. The minimum as-built and maximum as-built areal density values are determined from the available data for the Boral panels. As-built records are available for a total of 5052 panels of the installed 5544 (91.13%).

Minimum Certified B-10 Areal Density:	0.0233 g/cm^2
Minimum As-Built B-10 Areal Density:	0.0233 g/cm^2
Maximum As-Built B-10 Areal Density:	0.0286 g/cm^2
Nominal As-Built B-10 (Statistical) Areal Density:	0.0248 g/cm^2

1.b.iii material characteristics, including porosity, density and dimensions

The WBN fuel storage racks utilize the neutron-absorbing material Boral. The Boral material was manufactured as panels specified at 8.625" wide by 147" long, with the panel thickness specified as 0.1". The minimum B 10 areal density is specified as 0.0233 g/cm2. The available vendor documents do not provide porosity information.

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

Brooks & Perkins, Inc. reported testing results, as described in reports 554, 561 and 578. These reports described the qualification testing of materials in the SFP environment and exposure to gamma and neutron radiation. Reports 554 and 578 are referenced in the EPRI Handbook of Neutron Materials for Spent Nuclear Fuel Transportation Application (Document 1019110, November 2009).

1. Brooks & Perkins, Inc. Spent Fuel Storage Module Corrosion Report - Report No. 554, June 1, 1977. This report documents review of published data regarding the extent of any deterioration that is likely to occur to shielding capability over a forty-year period following a water leak in the stainless steel covering.

   Results indicate an expected life to be at least greater than fifty-three years and probably greater than sixty years following a rupture to the water barrier covering.

2. Storage Module Corrosion Testing Final Report - Report No. 561. Testing conducted in accordance with BPS-384 to substantiate the ability of the storage module to resist the environment of a Boiling Water Reactor (BWR) and Pressurized Water Reactor (PWR) fuel storage pool considering a postulated leak in the stainless steel covering and the most adverse environmental conditions likely to occur in the storage pool.

   This report concluded that the "results of the test program confirmed the anticipated reactions of the materials to the pH of the test solutions. Namely, no reaction with Stainless Steel, Aluminum and BORAL™ showing the greatest reaction with the highest pH, and Cadmium being dissolved at the lowest pH."

3. The Suitability of Brooks & Perkins Spent Fuel Storage Module for Use in PWR Storage Pool - Report No. 578, July 7, 1978. Research and testing considering corrosion resistance and irradiation effects on spent fuel storage modules

   Results of the research and testing that have been conducted indicate that the Brooks & Perkins Spent Fuel Storage Module (SFSM) is suitable for use in a PWR spent fuel storage pool.

1.d configuration in the SFP

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

The WBN fuel storage rack system is composed of 24 rack modules. Each module consists of fuel storage cell locations that hold the assemblies. The spent fuel storage cell consists of two concentric, square stainless steel tubes (304 SS) sealed welded at the ends. The four Boral plates are located in the void existing between the tubes. Initially the Boral plates were in a watertight void. In 1997, for use at WBN, holes were drilled into the upper part of the can at the top of the Boral plates to vent the void space and allow SFP water ingress to the neutron absorber and also to allow venting of gas.

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

The 304 SS sheathing covers the Boral plate completely; however, the poison cans are vented above the Boral plates to allow SFP water ingress to the neutron absorber and also to allow venting of gas.

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

1.e.i estimated current minimum areal density

Monitoring of WBN SFP water chemistry trends have provided no indication of loss of neutron-absorbing material. Industry OE has also not provided indication of loss of Boral neutron-absorbing material. Therefore, the estimated current minimum areal density remains the same as when the material was fabricated and installed in the SFP, which is provided in the response to 1.b.ii (minimum as-built areal density of 0.0233 g/cm^2).

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

The WBN SFP NCS AOR was conservatively performed on the basis of the minimum areal density of 0.0233 g/cm^2 in the Boral plate.

1.e.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)

As stated in the response to 1.e.i, there is no indication of degradation of the neutron absorber material in the SFP.

There is no coupon inspection program at WBN to identify visible deformations, but because of the nature of industry experience with Boral neutron absorber plates, TVA conservatively assumed blisters would be present on the Boral plates in the WBN SFP when evaluating NRC Information Notice (IN) 2009-26, Degradation of Neutron-Absorbing Materials in the Spent Fuel Pool. Holtec, who performed the WBN SFP NCS AOR, performed a criticality evaluation of the effect of blisters on the Boral plates. This evaluation concluded that Boral blisters have a negligible effect on a rack's criticality analysis.

The WBN PaR racks are of the flux-trap design and can be affected by small changes in the dimensions of the flux trap, which makes this a bounding design for this blister effect.

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

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

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

ii) parameters to be inspected and data collected;

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;

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

v) industry standards used.

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

i) If there is visual inspection of inservice material:

(1) describe the visual inspection performed on each sample; and GL 2016-01

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

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;

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

(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

(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.

iii) If RACKLIFE is used:

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

(2) note the frequency at which 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; and

(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.

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 GL 2016-01 statistically significant enough that the result can be extrapolated to the state of the entire pool;

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

(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;

(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

(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); and (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.

2.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.*

At the time of WBN rack licensing, a neutron absorber monitoring program was not required. Therefore, WBN does not have Boral coupons. WBN follows the guidance provided in NPG-SPP-08.1, Nuclear Fuel Management, Attachment 8, Spent Fuel Pool Neutron Absorber Material Monitoring Program, which requires periodic monitoring and trending of the SFP environment for pH, bulk SFP temperature, (average, minimum, maximum), and aluminum. Fuel handling is also monitored for restriction of the cell size by monitoring the binding and drag forces while inserting or removing fuel in the spent fuel storage racks.

In addition, Industry Operating Experience (OE) with neutron absorbers including participation in industry neutron absorber groups is an integral part of the TVA SFP Neutron Absorber Material Monitoring program. TVA enters applicable OE that indicates deformation or degradation of neutron absorbers into the TVA CAP for further assessment of impacts, extent of condition, trending, determination of functionality, and implementation of corrective actions.

Also, include a description and technical basis for the technique(s) and method(s) used in the surveillance or monitoring program, including:

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

At the time the WBN LAR for the PaR racks was approved 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). Many licensees that implemented Boral (such as WBN) were therefore not required to have a monitoring program. However, TVA continues to participate in industry OE sharing forums, such as the Electric Power Research Institute (EPRI) Neutron Absorber Users Group (NAUG), reviews industry OE, and monitors SFP chemistry on a regular basis.

2.a.ii *parameters to be inspected and data collected*

No coupon monitoring program exists at WBN because no coupons were installed. However, routine sampling and trending of SFP environment water chemistry is used to monitor performance of the neutron absorber material. Parameters that are monitored include Aluminum (ppb), boron (ppm), pH, and SFP temperature. Additionally, fuel assembly drag forces in the Spent Fuel Storage Racks are monitored during poolside fuel movements. The TVA Corrective Action Program (CAP) is used to document any unusual difficulties encountered when moving fuel within the SFP racks.

2.a.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

There has not been a strict "acceptance criteria" associated with neutron absorber monitoring program. The purpose of the neutron absorber monitoring 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 TVA CAP for further assessment of impacts, extent of condition, trending, determination of functionality, and implementation of corrective actions.

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

No coupon monitoring program exists at WBN because no coupons were installed. However, routine sampling and trending of SFP environment water chemistry is used to monitor performance of the neutron absorber material. Parameters that are monitored include Aluminum (ppb), boron (ppm), pH, and SFP temperature.

An increasing trend or spike in the aluminum could indicate degradation of the Boral aluminum sheathing. The pH is monitored for spikes which would indicate contaminant(s) that could affect the acidity of the SFP and thus the aluminum oxide of the Boral sheathing. Difficulties encountered when moving fuel within the SFP racks could indicate bulging of the cell walls, which could indicate trapped gas from the neutron absorber. Since using the PaR Spent Fuel Storage Racks at WBN, there has been complete freedom of new and spent fuel movement in and out of the SFP Storage cells that are not restricted because they have not been drag tested or because they are damaged cells.

In addition, Industry Operating Experience (OE) with neutron absorbers including participation in industry neutron absorber groups is an integral part of the TVA SFP Neutron Absorber Material Monitoring program. TVA enters applicable OE that indicates deformation or degradation of neutron absorbers into the TVA CAP for further assessment of impacts, extent of condition, trending, determination of functionality, and implementation of corrective actions.

2.a.v industry standards used

The following two guidelines are used by WBN in the context of neutron absorber monitoring. These Guidelines are used by the chemistry department in the measurements of aluminum and pH in the SFP.

1. Westinghouse Supplement to EPRI PWR Guidelines Rev 5 Table, 6 MTLS-131 Rev 4.

2. EPRI PWR Primary Water Chemistry Guidelines Rev 7 (Document 3002000505, April 2014).

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

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

No visual inspection is performed of in-service material at WBN, because the rack design has the neutron-absorbing material encased between two concentric, square tubes where it is not visible.

2.b.i.1 Describe the visual inspection performed on each sample

N/A

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

N/A

2.b.ii If there is a coupon monitoring program

As stated in 2.a, WBN does not have Boral coupons. Therefore, there is no coupon monitoring program at WBN.

2.b.ii.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.

N/A

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

N/A

2.b.ii.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.

N/A

2.b.ii.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.

N/A

2.b.iii If RACKLIFE is used: . . .

RACKLIFE is only applicable to the Boraflex neutron absorber material. WBN uses Boral as the sole neutron absorber material in the SFP storage racks. No response to this section is required.

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

TVA does not perform in-situ testing of credited neutron-absorbing material at WBN. No response to this section is required.

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**

   TVA uses Boral as the credited neutron absorber material at WBN. TVA does not credit any Boraflex, Carborundum, or Tetrabor. No response to this section is required.

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:*

4.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 basis of modeling the neutron absorber material in the WBN SFP NCS AOR is the as-manufactured condition.

Manufacturing Reactivity Uncertainties (Δk_{eff}) contains the as-manufactured condition for the Boral uncertainties (Boral plate width and Boral thickness components).

No degradation of the neutron-absorbing material has been identified. Therefore, the WBN SFP NCS AOR does not explicitly reflect degraded or deformed neutron-absorbing material. However, a modeling analysis was performed for the WBN fuel storage racks, which are of the flux-trap design and can be affected by small changes in the dimensions of the flux trap. In response to NRC Information Notice (IN) 2009-26, the modeling analysis assumed the presence of blisters on the Boral panels in these WBN racks. Holtec performed a criticality evaluation of the effect of blisters on the panels. This evaluation concluded that Boral panel blisters have a negligible effect on a rack's criticality analysis.

4.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.*

No coupon monitoring program exists at WBN. Operating Experience (OE) from TVA Nuclear plants (BFN and SQN), other Nuclear Industry OE, and WBN Chemistry data, are monitored to ensure that the actual condition of the Boral is bounded in the WBN SFP NCS AOR. All OE items will continue to be entered into the TVA CAP. As stated above in 4.a, an evaluation concluded that Boral blisters have a negligible effect on a rack's criticality analysis.

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

Bias and uncertainty of the monitoring program are not included in the original WBN SFP NCS AOR.

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

There is no indication that degradation exists in the WBN Boral material; therefore, degradation in adjacent panels is not accounted for in the WBN SFP NCS AOR.

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). . . .

TVA uses Boral as the credited neutron absorber material at WBN. TVA does not credit any Boraflex, Carborundum, or Tetrabor. No response to this section is required.