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

CNL-17-035

March 3, 2017

10 CFR 50.90

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

Subject: **Proposed Technical Specifications (TS) Change TS-505 - Request for License Amendments - Extended Power Uprate (EPU) - Supplement 38, Spent Fuel Pool Criticality Safety Analysis - Updated Information**

References:

1. Letter from TVA to NRC, CNL-15-169, "Proposed Technical Specifications (TS) Change TS-505 - Request for License Amendments - Extended Power Uprate (EPU)," dated September 21, 2015 (ML15282A152)
2. Letter from NRC to TVA, “Browns Ferry Nuclear Plant, Units 1, 2, and 3 - Request for Additional Information Related to License Amendment Request Regarding Extended Power Uprate (CAC Nos. MF6741, MF6742, and MF6743),” dated June 21, 2016 (ML16154A544)
3. Letter from TVA to NRC, CNL-16-116, "Proposed Technical Specifications (TS) Change TS-505 - Request for License Amendments - Extended Power Uprate (EPU) - Supplement 25,Responses to Requests for Additional Information," dated July 27, 2016 (ML16210A501)

By the Reference 1 letter, Tennessee Valley Authority (TVA) submitted a license amendment request (LAR) for the Extended Power Uprate (EPU) of Browns Ferry Nuclear Plant (BFN) Units 1, 2 and 3. The proposed LAR modifies the renewed operating licenses to increase the maximum authorized core thermal power level from the current licensed thermal power of 3458 megawatts to 3952 megawatts. The Reference 2 letter provided NRC Requests for Additional Information (RAIs) related to spent fuel pool criticality safety analysis. The Reference 3 letter provided responses to NRC RAIs ESGB-RAI 2, ESGB-RAI 3, SFP-RAI 5, SFP-RAI 11, and SFP-RAI 12 from the Reference 2 letter. Subsequent to the submittal of the Reference 3 letter, as part of implementation of TVA corrective action program actions and as part of the development of the TVA response to NRC Generic Letter 2016-01, “Monitoring of Neutron-Absorbing Materials in Spent Fuel Pools,” additional information was located related to the responses to NRC RAIs SFP RAI 5 and SFP-RAI 12. As a result, the Enclosure to this letter provides updated responses to NRC RAIs SFP-RAI 5 and SFP-RAI 12. The updated responses to NRC RAIs SFP-RAI 5 and SFP-RAI 12 supersede and replace the associated responses provided in the Reference 3 letter. The remaining RAIs responses from Reference 3 are unchanged.

TVA has reviewed the information supporting a finding of no significant hazards consideration and the environmental consideration provided to the NRC in the Reference 1 letter. The supplemental information provided in this submittal does not affect the bases for concluding that the proposed license amendment does not involve a significant hazards consideration. In addition, the supplemental information in this submittal does not affect the bases for concluding that neither an environmental impact statement nor an environmental assessment needs to be prepared in connection with the proposed license amendment. Additionally, in accordance with 10 CFR 50.91(b)(1), TVA is sending a copy of this letter to the Alabama State Department of Public Health.

There are no new regulatory commitments associated with this submittal. If there are any questions or if additional information is needed, please contact Mr. Edward D. Schrull at (423) 751-3850.

I declare under penalty of perjury that the foregoing is true and correct. Executed on the 3rd day of March 2017.

Respectfully,

J. W. Shea
Vice President, Nuclear Licensing

Enclosure: Updated Responses to NRC Requests for Additional Information SFP-RAI 5 and SFP-RAI 12

cc:(Enclosure)

NRC Regional Administrator - Region II
NRC Senior Resident Inspector - Browns Ferry Nuclear Plant
State Health Officer, Alabama Department of Public Health

ENCLOSURE

Updated Responses to NRC Requests for Additional Information
SFP-RAI 5 and SFP-RAI 12

ENCLOSURE

SFP-RAI 5

ANP-3160 states that the Boral is modeled using the design minimum B-10 areal density. The staff was unable to locate information describing how the Boral installed in the BFN SFP racks was verified to meet this minimum value, including any applicable measurement uncertainties. Provide an explanation of how the minimum B-10 areal density used in the SFP criticality analysis bounds all of the Boral plates installed in the BFN SFP racks.

TVA Response:

In the Reference 1 letter, TVA described the method used to ensure the Boron-10 (B-10) areal density of the Boral plates installed in the BFN SFP racks bounds the minimum areal density specified for the Boral plates (i.e., the minimum B-10 areal density assumed in the SFP criticality safety analysis). Section 3, Materials, of Reference 1 states, in part:

> "To provide assurance that specification Boral* sheet is utilized during tube fabrication, a special quality control program is in effect at the manufacturer's facility. Samples of each Boral sheet are chemically analyzed to determine the B^{10} content. These data are evaluated to verify that the samples are statistically representative of the entire area of the Boral plate and that B^{10} content, at a 95% confidence level, meets of exceeds specification requirements. Analyses are also performed to establish the correlation between the B^{10} content and the thickness of the Boral sample. The Boral sheets are dimensionally inspected and the thickness data are statistically analyzed to verify the sheet meets the minimum thickness requirement over its entire area at a 95% confidence level. These thickness data are also compared with the correlation data to provide additional assurance that the B^{10} content meets or exceeds specification requirements. Before each piece of Boral is inserted into a tube assembly it is verified that each inspection has been successfully performed. Presence of the neutron absorber material in the fabricated fuel storage module is verified by dimensional inspection and by visual examination."
>
> ______
>
> "*Product of Brooks & Perkins, Inc. consisting of a layer of B_4C-Al matrix bonded between two layers of aluminum."

Reference

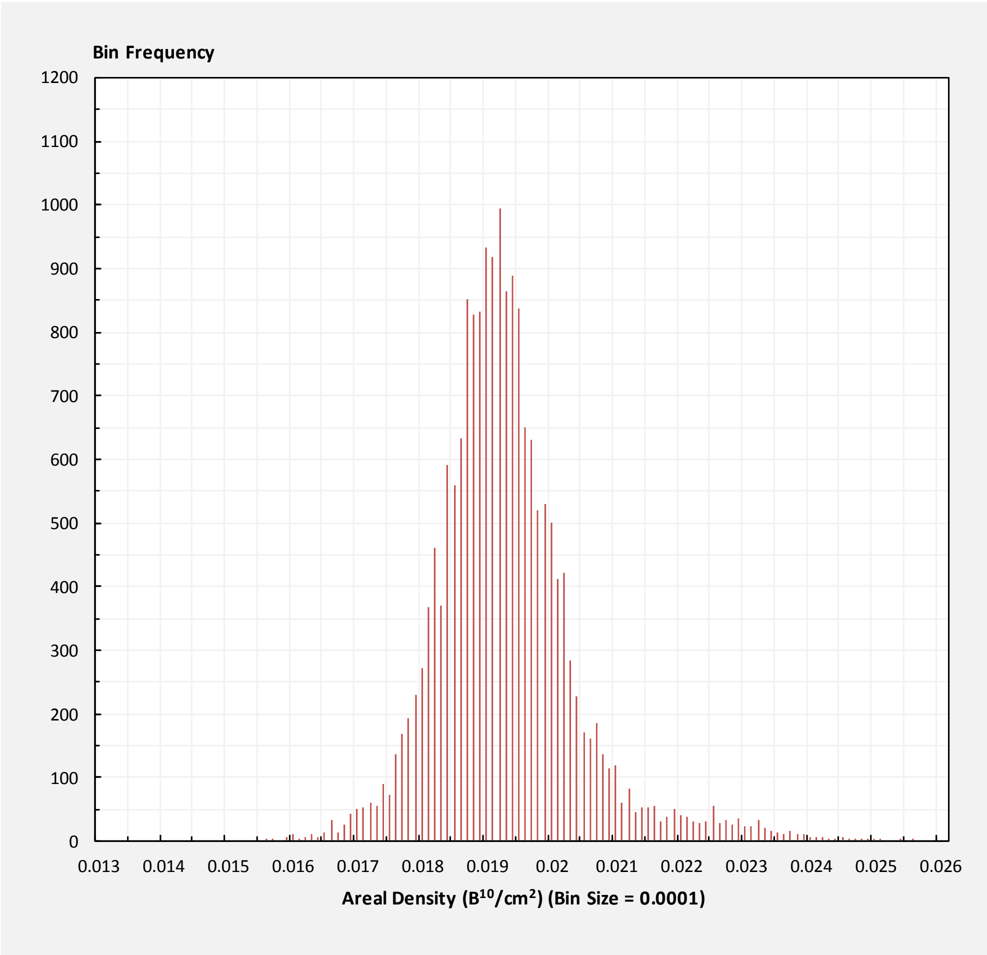
1. Letter from TVA to NRC, "Revised Design Basis And Environmental Assessment for the Proposed High Density Fuel Storage System," dated December 2, 1977 (ADAMS Accession No. 4008006709)

TVA Response to RAI-SFP 5 Rev. 1:

Since the original response to this RAI was submitted, records were recovered from the manufacturer pertaining to Boral plates utilized in the BFN racks. The BFN SFP racks contain a total of 20,940 Boral plates.

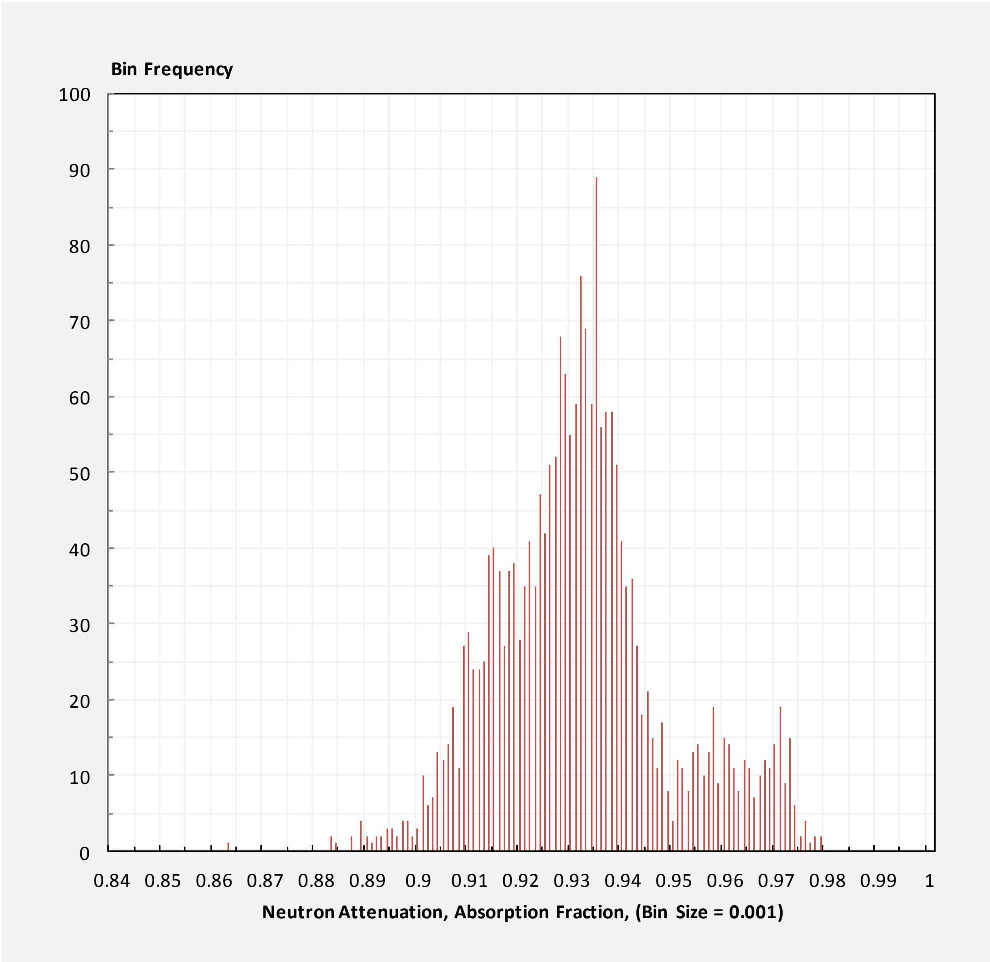
With respect to verifying the minimum B^{10} areal density of the Boral plates, the associated Contract Specification states Boral plates can be certified by either chemical analysis or neutron transmission/(attenuation) measurement. The minimum required acceptable areal density value is 0.013 B^{10}/cm^2 per the associated Contract Specification and the minimum acceptable inspection value is 0.0135 B^{10}/cm^2, per the Brooks & Perkins, Inc. inspection procedure.

Utilizing the rack manufacturing data originally documented in support of the TVA response to NRC Generic Letter 2016-01 (TVA letter to NRC, “Tennessee Valley Authority (TVA) Response to NRC Generic Letter 2016-01, Monitoring of Neutron-Absorbing Materials in Spent Fuel Pools,” dated November 3, 2016 (ML16308A477)), the following histogram can be generated for the 18,572 plates of BFN areal density measurement data.



The minimum measured areal density was 0.0155 B^{10}/cm^2. The distribution mean is 0.0192 B^{10}/cm^2 with a standard deviation of 0.001088 B^{10}/cm^2. The minimum manufactured value is ~20% greater than the contractual manufactured minimum requirement. The distribution indicates that the manufacturing process assures the contractual minimum requirement was easily met. It should be noted that the minimum value of 0.013 B^{10}/cm^2 is greater than 5σ below the mean. Of the remaining 2,368 plates, neutron attenuation data was found for 2,096 plates.

Utilizing the rack manufacturing data originally documented in support of the TVA response to NRC Generic Letter 2016-01 dated November 3, 2016, a histogram can be generated for BFN Neutron Transmission/Attenuation measurements.



The minimum measured Neutron Attenuation fraction was 86.25%. The distribution mean is 93.16% with a standard deviation of 1.693%. While the official Neutron Attenuation → B^{10}/cm^2 conversion has not been recovered, it should be noted that a fraction of 84% is a little greater than 5σ below the mean. The distribution of Neutron Attenuation values is similar to areal density indicating the manufacturing process ensured contractual requirements were met.

Even if all Neutron Attenuation values are assumed to be at the lower areal density bound of 0.013 B^{10}/cm^2, it does not automatically mean an additional conservative uncertainty, below the lower bound, is physically meaningful.

There are 272 Boral plates where neither areal density or Neutron Attenuation data could be determined at this time, primarily due to illegible source documents. Because all the plates in the BFN SFP racks were manufactured to the same contractual requirements, utilizing the same manufacturing processes, there is reasonable assurance that these remaining plates would lie within the above discussed distributions. Consequently, there is no physical basis for application of uncertainty penalties below 0.013 B^{10}/cm^2 (particularly in light of the fact that the minimum pass/fail B^{10} areal density inspection criterion was 0.0135 B^{10}/cm^2).

SFP-RAI 12

In response to SFP-RAI 2, the licensee indicated a review of plant records showed that the Boral verification testing was inconclusive for some cell locations on six BFN SFP storage modules. In order to evaluate these cell locations, a statistical analysis was performed to determine the probability that no more than one Boral plate is missing. The staff notes that if a single Boral plate is missing, then this would become part of the normal condition and should be evaluated as such. Since such a normal condition could result in a more limiting accident condition, provide the following:

a. The locations of the cells for which the Boral verification testing was inconclusive.

b. The statistical analysis performed to evaluate the cell locations for which the Boral verification testing was inconclusive.

c. A technical justification for the assumption that the normal BFN SFP rack condition does not include any missing Boral plates.

d. As part of an audit performed May 10 - 11, 2016, TVA provided draft documentation that included information to address one missing Boral panel as part of the normal condition. In addition to submitting this information on the docket, the NRC staff requests the following information:

i. A discussion of the applicability of the Edwin I. Hatch Nuclear Power Plant (Hatch) testing results to the BFN SFPs, more specifically addressing how the licensee has determined that the manufacturing process used to fabricate the SFP racks delivered to Hatch is the same as those delivered to BFN, and

ii. Information about any similar testing results from other sites that the licensee may be aware of.

TVA Response:

a. During the installation of the High Density Spent Fuel Racks (HDSFRs) at BFN Units 1, 2, and 3, testing was conducted to verify the presence of Boral plates in the racks. The tests were conducted using a neutron source in conjunction with four neutron detectors. The source was placed inside one of the tubes and the neutron signal strength in the four detectors was used to validate the presence (or absence) of the Boral plates.

As noted in the BFN response to SFP-RAI 2, testing in some cell locations in six racks (five in BFN Unit 1 and one in BFN Unit 3) proved inconclusive due to the proximity of irradiated fuel to the detectors (see Table 1 for details). Note that each unverified cell (i.e., Boral tube) location results in four unverified Boral plates because a tube has one Boral plate on each of the four walls. In the presence of gamma radiation, the detectors become "saturated" and their reading drops to zero, resulting in no signal and thus, an indeterminate Boral verification. This event occurred to some cell locations for six racks, as shown below:

ENCLOSURE

Table 1, Unverified Boral Plates and Rack Location

Rack Size and Serial Number		Unit/Rack	Unverified Boral Plates	Installed	Tested
13x13	0002	1/4	52	<4/25/1983	6/1983
13x13	0005	1/1	52	<4/25/1983	6/1983
13x17	0021	1/9	148	<4/25/1983	6/1983
13x17	0022	1/17	104	<4/25/1983	6/1983
13x17	0023	1/13	156	<4/25/1983	6/1983
13x17	2336-6*	3/5	136	10/26/1981	10/26/1981

*Rack inspection details are shown in Table 2.

In the five BFN Unit 1 racks, the exact location of the unverified cells is not currently known. TVA is researching original construction and testing information for the racks in an attempt to determine the locations of the unverified cells.

For Rack 2336-6 in BFN Unit 3, the test record (strip chart) identified the following.

- Test results for the following cells were inconclusive as indicated by the strip chart reading 0% for at least one detector and being annotated on the strip chart as being near irradiated fuel.
  L1, L3, L5, L7, L9, L11, L13, L15
  M2, M4, M6, M8, M10, M12, M14, M16
  N1, N3, N5, N7, N9, N11, N13, N15, N17
  K2, K4, K6
- Cell L17 and the entire K row had readings that were approximately 1/2 of the normal readings of cells not affected by adjacent fuel. These cells are being considered inconclusive.

The following table illustrates the unverified cell locations for this particular rack.

Table 2, Unit 3 Rack 2336-6 Unverified Cell Locations

A1		A3		A5		A7		A9		A11		A13		A15		A17
	B2		B4		B6		B8		B10		B12		B14		B16	
C1		C3		C5		C7		C9		C11		C13		C15		C17
	D2		D4		D6		D8		D10		D12		D14		D16	
E1		E3		E5		E7		E9		E11		E13		E15		E17
	F2		F4		F6		F8		F10		F12		F14		F16	
G1		G3		G5		G7		G9		G11		G13		G15		G17
	H2		H4		H6		H8		H10		H12		H14		H16	
J1		J3		J5		J7		J9		J11		J13		J15		J17
	K2		K4		K6		K8		K10		K12		K14		K16	
L1		L3		L5		L7		L9		L11		L13		L15		L17
	M2		M4		M6		M8		M10		M12		M14		M16	
N1		N3		N5		N7		N9		N11		N13		N15		N17

It is anticipated that the unverified cell positions in the BFN Unit 1 racks are located in similar positions, that is, along one or more sides of the racks that bordered other racks with spent fuel, but those locations cannot be verified at this time.

b. Because of this issue of unverified cells, the vendor at that time, GEUMCO, performed a probability analysis to determine the likelihood that there are, in fact, multiple Boral plates missing from the racks. The analysis used a binomial probability function to determine what the probability was for certain numbers of Boral plates to be missing. This type of analysis is typical for manufacturing process errors. It should also be noted that all of the Boral plates and tubes used in fabrication of the racks were provided by the same manufacturer with the same processes and procedures. This is important to note because this further establishes the validity of the methodology and provides greater confidence that all of the Boral plates were properly installed.

In order to perform this type of an analysis, a failure rate had to be established. In this case, a “failure” is defined as a missing Boral plate. The failure rate was established based on prior testing history. Prior to performing the analysis, a total of 36 separate racks that contained 17,304 pieces of Boral had been tested by GEUMCO at Plant Hatch and BFN. In all cases of these inspections, the tubes were shown to contain the required Boral plates, so they were all “successes” in terms of probability. In order to obtain a failure rate for the probability equation, it was assumed that the very next Boral plate was missing. This equates to one failure in 17,305 tries, or a process failure rate of 5.78×10^{-5}. Once the failure rate is established, the following equation describes the probability for missing Boral plates.

$$P(x;p,n) = \binom{n}{x} \times (p^x) \times (1-p)^{(n-x)} \; for \; x = 0,1,2,3 \ldots$$

Where P = probability for a given outcome (in this case, for x missing plates)
x =number of missing plates
n = sample size
p = process failure rate

Also, $\binom{n}{x} = \frac{n!}{x!(n-x)!}$

Setting the sample size equal to the number of unverified Boral plates for each rack, the following table of probabilities can be generated:

Where R = the number of missing Boral plates

For racks with 52 unverified plates:

Number of assumed missing Plates (R)	Probability of the number of missing plates equal to R	Probability of missing plates being equal to or less than R	Probability of missing plates being equal to or greater than R
0	0.996999512	9.96999512E-01	1.000000000000
1	0.002996069	9.99995581E-01	0.003000488211

For racks with 104 unverified plates:

Number of missing Plates (R)	Probability of the number of missing plates equal to R	Probability of missing plates being equal to or less than R	Probability of missing plates being equal to or greater than R
0	0.994008027	9.94008027E-01	1.000000000000
1	0.005974158	9.99982185E-01	0.005991973493

For racks with 136 unverified plates:

Number of missing Plates (R)	Probability of the number of missing plates equal to R	Probability of missing plates being equal to or less than R	Probability of missing plates being equal to or greater than R
0	0.992171576	9.92171576E-01	1.000000000000
1	0.007797927	9.99969503E-01	0.007828424392

For racks with 148 unverified plates:

Number of missing Plates (R)	Probability of the number of missing plates equal to R	Probability of missing plates being equal to or less than R	Probability of missing plates being equal to or greater than R
0	0.991483782	9.91483782E-01	1.000000000000
1	0.008480097	9.99963879E-01	0.008516218415

For racks with 156 unverified plates:

Number of missing Plates (R)	Probability of the number of missing plates equal to R	Probability of missing plates being equal to or less than R	Probability of missing plates being equal to or greater than R
0	0.991025517	9.91025517E-01	1.000000000000
1	0.008934349	9.99959866E-01	0.008974482858

By using the same methodology and applying it to the SFPs for BFN Units 1 and 3 considering the total number of unverified plates in each SFP, the probability of a single missing plate in the SFPs can be calculated. As derived from Table 1, the BFN Unit 1 SFP contains 512 Boral plates that were not verified and BFN Unit 3 SFP contains 136 Boral plates that were not verified. The probability of a missing plate in BFN Unit 1 is 0.0287 providing 97.127% confidence that one or less plates are missing. The probability of a missing plate in BFN Unit 3 is 0.0078, providing 99.220% confidence that one or less plates are missing.

Note: The GEUMCO probability analysis utilized the number of verified plates as the sample size in the binomial distribution formula; however, the number of unverified plates should have been used. This resulted in incorrect, but conservative values. This conservatism resulted in a greater probability of having missing Boral plates, when in actuality the probability of missing plates is slightly less. This issue has been entered into the TVA Corrective Action Program (CAP).

c. Based on the results described above (response to item b) and the additional successful rack tests that have been performed at BFN alone, there is high confidence that all of the Boral plates were installed in the tubes and thus, in the HDSFRs.

As additional evidence that all of the Boral plates are installed, a Nuclear Regulatory Commission (NRC) special safety inspection in 1983 (documented in Inspection Report Nos. 50-259/83-18, 50-260/83-18 and 50-296/83-18, dated July 13, 1983) questioned whether all of the Boral plates had been installed in the HDSFRs at BFN. This inspection resulted in Notice of Violation (NOV 83-18). During an enforcement meeting held on June 1, 1983, the NRC documented the following.

> "It was brought out during the meeting that TVA has the Quality Assurance (QA) records that verify the correct Boral content of the fuel racks during manufacture and the licensee considers the Boral testing in the fuel pool backup certification of the fuel racks."

TVA provided these QA records to the NRC following the meeting and the NRC documented the following.

> "Subsequent to the meeting, the licensee provided copies of the QA records verifying correct Boral content. These records were reviewed by the senior resident and by Region II personnel and were found to be adequate indications for the safe use of the high density fuel racks."

These quotations indicate, at that time, TVA was in possession of documentation to satisfy the NRC reviewers that the BFN Unit 1 HDSFRs had sufficient Boral content and it was present in the racks.

Therefore, based on the evidence provided above, there is reasonable assurance that all of the Boral plates were properly installed in the BFN HDSFRs.

However, as discussed in the response to NRC RAI SFP-RAI 2 (submitted by TVA letter to NRC dated March 8, 2016), the failure to maintain complete permanent records of the Boral verification testing and the inconclusive testing of tubes in the storage modules has been entered into the TVA CAP. Actions will be taken to resolve these issues associated with the SFP storage module Boral plate configuration in accordance with the CAP. This condition is considered a nonconforming condition. As a result, the actions taken will be to restore compliance with the design and analysis basis. The actions from the associated CAP Condition Report (CR 1136812) require demonstrating Boral plates are installed in all required locations consistent with the CSA assumptions (i.e., no Boral plates are missing).

d. The BFN and Hatch HDSFRs were supplied by GEUMCO, a subsidiary of General Electric. All of the Boral plates and coupons were provided by a single supplier that had patented the process for manufacturing Boral and were the only supplier of record for that product during the time frame when the BFN and Hatch HDSFRs were manufactured. Based on GEUMCO Product Quality Certification records, all of the BFN racks were certified prior to the end of 1983.

A comparison of HDSFR documentation from BFN and the Hatch plant verified that the physical properties of the Hatch tubes are identical to the BFN tubes and that both construction and testing requirements reference the same GE specification (C5445-HDFSS). Because of the lattice design of the HDFSR racks, the Boral containing tubes are an integral part of the rack structure. The racks cannot be assembled without all of the tubes in place for a given rack dimension (i.e., 13x13 or 13x17). Each rack constructed under the C5445-HDFSS specification were built with the same connection details for rack assembly as were the Boral tubes. As such, assurance is provided that the requirements for fabrication of the Boral plates, the assembly of the racks and the testing performed for neutron absorption results were similar for both facilities. Therefore, the Hatch HDSFR testing results may be applied to the BFN SFP racks.

TVA does not have access to similar testing results from other sites. In response to this RAI, TVA contacted personnel at the Brunswick, Vermont Yankee, Hatch, Monticello, and Pilgrim plants in order to obtain information regarding initial HDSFR installation testing results. However, TVA was not successful in obtaining this information. The Hatch testing information that supported the analysis discussed in response to item b above was supplied from GEUMCO records.

TVA Response to RAI-SFP 12 Rev. 1 (Addendum):

a. Since the original response to this RAI was submitted, BFN has validated the existence of Boral plates by a review of the original rack manufacturing records. The tube manufacturer, Brooks & Perkins (AAR Corporation), assigned a serial number (SN) and provided an inspection data sheet for each tube. These inspection data sheets contain such information as the SNs for each of the four Boral plates installed in each tube, and the grams B_4C/cm^2 and grams B^{10}/cm^2 for each Boral plate. General Electric, AVEL, and Chicago Bridge and Iron rack manufacturing documents recorded the location of each tube placed in the racks. There are a total of 20,940 Boral plates used in the SFP racks and all but 401 of the plates were verified by the manufacturing documentation. For these 401 plates, the documentation was either illegible or the sheet was missing.

(It should be noted that 229 of these 401 plates with illegible/missing documentation were successfully dry tested with the neutron source and detector method described in the TVA response to RAI-SFP 12 Rev.0. However, all 401 plates were treated as having illegible/missing documentation in the statistical analysis provided below.)

b. A statistical analysis was performed to evaluate the 401 Boral plates that could not be verified by a review of their manufacturing records. NUREG/CR-1475, Revision 1, Applying Statistics, Section 22.8 explains how to calculate a confidence interval when a normal approximation does not apply. However, it does not appear that the equations included in Section 22.8 should be used to determine the confidence interval when y=0, i.e., for a sample with no defects, because the equations included in section 22.8 address conditions where 0<y<n. NUREG/CR-1475 Revision 1, section 22.9 explains how to calculate an upper confidence limit for a sample with no defects, i.e., y=0. Therefore, equation 22.29 of NUREG/CR-1475, Revision 1, is utilized:

$$\pi_U = 1 - e^{ln(\alpha)/n} \qquad (22.29)$$

where α=0.05 (for 95% confidence) and n=20,940-401=20,539, which is the size of the sample without defect. Solving equation 22.29, yields:

$$\pi_U = 0.000146 = 0.0146\%$$

Therefore, there is a 95% confidence that no more than 0.0146% of all the plates are missing. Put in terms of the plates being installed, there is a 95% confidence that 99.9854% of the plates are installed. This meets the 95/95 test. Therefore, this statistical analysis shows that it is acceptable to assume that all Boral plates are installed in the BFN SFP racks.

c. Statistical analysis has shown that there is a 95% confidence that 99.9854% of the Boral plates are installed which meets the 95/95 test. Therefore it is acceptable to assume that all Boral plates are installed in the BFN SFP racks.

d. The above statistical analysis that shows it is acceptable to assume that all Boral plates are installed in the BFN SFP racks used only data from BFN SFP racks. Use of testing results or data from other nuclear facilities is no longer necessary.