UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

April 14, 2016

Mr. Joseph W. Shea
Vice President, Nuclear Licensing
Tennessee Valley Authority
1101 Market Street, LP 3R-C
Chattanooga, TN 37402-2801

SUBJECT: 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)

Dear Mr. Shea:

By letter dated September 21, 2015 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML15282A152), as supplemented by letters dated November 13, December 15, and December 18, 2015 (ADAMS Accession Nos. ML15317A361, ML15351A113, and ML15355A413, respectively), Tennessee Valley Authority (TVA, the licensee) submitted a license amendment request (LAR) for the Browns Ferry Nuclear Plant, Units 1, 2, and 3. The proposed amendment would increase the authorized maximum steady-state reactor core power level for each unit from 3,458 megawatts thermal (MWt) to 3,952 MWt. This LAR represents an increase of approximately 20 percent above the original licensed thermal power level of 3,293 MWt, and an increase of approximately 14.3 percent above the current licensed thermal power level of 3,458 MWt.

The U.S. Nuclear Regulatory Commission (NRC) staff has reviewed the licensee's submittals and determined that additional information is needed. On March 3, 2016, the NRC staff forwarded, by electronic mail, a draft request for additional information (RAI) to TVA. On March 15, 2016, the NRC staff held a conference call to provide the licensee with an opportunity to clarify any portion of the draft RAI and discuss the timeframe for which TVA may provide the requested information. As agreed by NRC and TVA staff during the conference call, TVA will respond to the enclosed RAI by April 27, 2016.

If you have any questions, please contact me at 301-415-1447 or Farideh.Saba@nrc.gov.

Sincerely,

Farideh E. Saba

Farideh E. Saba, Senior Project Manager
Plant Licensing Branch II-2
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

Docket Nos. 50-259, 50-260, and 50-296

Enclosure:
Request for Additional Information

cc w/enclosure: Distribution via Listserv

REQUEST FOR ADDITIONAL INFORMATION

LICENSE AMENDMENT REQUEST REGARDING EXTENDED POWER UPRATE

TENNESSEE VALLEY AUTHORITY

BROWNS FERRY NUCLEAR PLANT, UNITS 1, 2, AND 3

DOCKET NOS. 50-259, 50-260, AND 50-296

By letter dated September 21, 2015 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML15282A152), as supplemented by letters dated November 13, December 15, and December 18, 2015 (ADAMS Accession Nos. ML15317A361, ML15351A113, and ML15355A413, respectively), Tennessee Valley Authority (TVA, the licensee) submitted a license amendment request (LAR) for the Browns Ferry Nuclear Plant (BFN), Units 1, 2, and 3. The proposed amendment would increase the authorized maximum steady-state reactor core power level for each unit from 3,458 megawatts thermal (MWt) to 3,952 MWt. This LAR represents an increase of approximately 20 percent above the original licensed thermal power level of 3,293 MWt, and an increase of approximately 14.3 percent above the current licensed thermal power level of 3,458 MWt.

The U.S. Nuclear Regulatory Commission (NRC) staff from the Probabilistic Risk Assessment Licensing Branch (APLA), Division of Risk Assessment, Office of Nuclear Reactor Regulation, reviewed the information the licensee provided and determined that the following additional information is required in order to complete the evaluation.

APLA-Request for Additional Information (RAI) 01

In accordance with Appendix D of Standard Review Plan (SRP), Chapter 19.2, "Review of Risk Information Used to Support Permanent Plant-Specific Changes to the Licensing Basis: General Guidance," dated June 2007, the NRC staff reviews the risk evaluations of BFN, Units 1, 2, and 3, extended power uprate (EPU) to determine if "special circumstances" are created by the proposed EPU that would potentially rebut the presumption of adequate protection from compliance with the regulations and other license requirements. Therefore, the licensee's risk evaluations need to be sufficient for the staff to conclude that the risk impact from internal events, external events, and shutdown operations is acceptable and does not create special circumstances.

In response to probabilistic risk assessment (PRA) RAI 24 associated with the TVA's LAR to transition to National Fire Protection Association 805, "Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants" (ADAMS Accession No. ML14363A057), the licensee provided the results of a composite analysis that shows the integrated impact on the fire risk (i.e., core damage frequency (CDF), large early release frequency (LERF), change in CDF (ΔCDF), and change in LERF (ΔLERF)) after replacing identified methods and weaknesses with alternative methods that are acceptable to the NRC. It is not clear from Section 1.2.3, "FPRA Quality," and Section A.2, "FPRA Technical Adequacy," in Attachment 44, "Probabilistic Risk Assessment," of the EPU LAR whether the fire PRA (FPRA) model used for the EPU risk evaluation (hereafter referred to as EPU FPRA)

incorporated the modeling changes reflected in the composite analysis in the response to PRA RAI 24. Provide the following additional information:

a. Clarify whether the EPU FPRA model incorporated the modeling changes identified in the composite analysis in the response to PRA RAI 24. If the EPU FPRA model did not include these modeling changes, then (1) provide updated EPU risk results (including sensitivity analyses) using the EPU FPRA model updated for these changes, or (2) explain how these modeling changes would not significantly impact the EPU risk results.

b. Indicate whether a peer review(s) has been performed for those modeling changes identified in the composite analysis. As applicable, provide a list of the facts and observations (F&Os) from this peer review(s), and explain how these F&Os were dispositioned for this application. If a peer review was not performed for these modeling changes, then provide sufficient information for NRC staff to compare the technical adequacy of the analysis to Regulatory Guide (RG) 1.200, "An Approach for Determining the Technical Adequacy of Probabilistic Risk Assessment Results for Risk-Informed Activities," or justify why a peer review was not necessary (e.g., explain why modeling change is not considered a PRA "upgrade").

APLA-RAI 02

In accordance with Appendix D of the SRP for the review of Safety Analysis Reports for Nuclear Power Plant, Chapter 19.2, the NRC staff reviews the BFN EPU risk evaluations to determine if "special circumstances" are created by the proposed EPU that would potentially rebut the presumption of adequate protection from compliance with the regulations and other license requirements. Therefore, the licensee's risk evaluations need to be sufficient for the staff to conclude that the risk impact from internal events, external events, and shutdown operations is acceptable and does not create special circumstances.

Section 4.1.3, "Accident Sequences," in Attachment 44 of the EPU LAR states:

> However, BFN uses a relatively simplified approach for LOOP recovery based on early recovery or late recovery of offsite power (30 minutes or 4 hours). It was concluded that the change in power would not impact the LOOP recovery file.

It is not clear to the staff why the change in reactor power does not impact the loss of offsite power (LOOP) recovery file. Describe the simplified approach for LOOP recovery, and justify why the change in power due to the EPU does not impact LOOP recovery.

APLA-RAI 03

In accordance with Appendix D of SRP, Chapter 19.2, the NRC staff reviews the BFN EPU risk evaluations to determine if "special circumstances" are created by the proposed EPU that would potentially rebut the presumption of adequate protection from compliance with the regulations and other license requirements. Therefore, the licensee's risk evaluations need to be sufficient

for the staff to conclude that the risk impact from internal events, external events, and shutdown operations is acceptable and does not create special circumstances.

a. Changes in human error probabilities (HEPs) due to the EPU is a significant contributor to the change in risk. Section 4.1.6, "Human Error Probabilities," in Attachment 44 of the EPU LAR states:

> All operator actions in the model were screened to determine the impact from EPU. However, the analysis focused additional scrutiny on several operator actions that were considered significant to the results. The operator actions identified for explicit review were selected based on the following criteria: "Time critical evolutions (i.e., less than 45 minutes available) action."

The description of the approach for screening operator actions is not clear in Section 4.1.6 of LAR Attachment 44. For example, it is not clear how "all operator actions in the model were screened," or what is meant by "45 minutes available." Clarify the approach for screening all operator actions. In this discussion, provide the basis for using a time critical evolution of 45 minutes, and explain what this time represents (e.g., system time window (T_{sw}) or time available for action (T_{avail})). Also, justify why risk-significant operator actions (e.g., operator actions having a high Fussell-Vesely or a high-risk achievement worth importance to CDF or LERF) were not considered for detailed review.

b. Section 4.2.4, "Post Fire Human Error Probabilities," in Attachment 44 of the EPU LAR states:

> All human failure events (HFEs) in the FPRA model were reviewed and considered for modification for the FPRA EPU impact study. HFEs that satisfy either of the following conditions were selected for detailed review:
> - Fussell-Vesely importance greater than 5E-03, or
> - T_{sw} less than 40 min.

The description of the approach for screening operator actions in Section 4.2.4 of LAR Attachment 44 is not fully understood. Provide the basis for using a system time window of 40 minutes in identifying operator actions for detailed review. Also, justify why risk-significant operator actions based on a high-risk achievement worth (RAW) (e.g., RAW importance to CDF or LERF greater than 2) were not considered for detailed review.

APLA-RAI 04

In accordance with Appendix D of SRP, Chapter 19.2, the NRC staff reviews the BFN EPU risk evaluations to determine if "special circumstances" are created by the proposed EPU that would potentially rebut the presumption of adequate protection from compliance with the regulations and other license requirements. Therefore, the licensee's risk evaluations need to be sufficient

for the staff to conclude that the risk impact from internal events, external events, and shutdown operations is acceptable and does not create special circumstances.

Section 4.6, "EPU Impact to Shutdown Risk," in Attachment 44 of the EPU LAR states that Reference 27 in Attachment 44 evaluates the impact on shutdown risk due to changes in the offsite alternating current (AC) recovery failure probabilities, and assessed a bounding ΔCDF of approximately 1 percent due to the EPU. Describe this bounding analysis. Also include in this discussion (1) how the offsite AC recovery failure probabilities were changed as a result of the EPU and (2) how this analysis is bounding.

APLA-RAI 05

In accordance with Appendix D of SRP, Chapter 19.2, the NRC staff reviews the BFN EPU risk evaluations to determine if "special circumstances" are created by the proposed EPU that would potentially rebut the presumption of adequate protection from compliance with the regulations and other license requirements. Therefore, the licensee's risk evaluations need to be sufficient for the staff to conclude that the risk impact from internal events, external events, and shutdown operations is acceptable and does not create special circumstances.

Section 5.4, "Seismic Risk," in Attachment 44 of the EPU LAR states that a conservative bounding analysis was applied to estimate an upper value for seismic CDFs. Describe this bounding analysis. Also include in this discussion:

a. Specific values applied to estimate the seismic CDFs;
b. Whether modifications to the containment/drywell/suppression pool structures as a result of the EPU are considered; and
c. How this analysis is bounding.

APLA-RAI 06

In accordance with Appendix D of SRP, Chapter 19.2, the NRC staff reviews the BFN EPU risk evaluations to determine if "special circumstances" are created by the proposed EPU that would potentially rebut the presumption of adequate protection from compliance with the regulations and other license requirements. Therefore, the licensee's risk evaluations need to be sufficient for the staff to conclude that the risk impact from internal events, external events, and shutdown operations is acceptable and does not create special circumstances.

Based on the discussion in Section 4.1.6, "Human Error Probabilities," and Section 5.7.4, "Uncertainties," in Attachment 44 of the EPU LAR, the minimum joint HEP (JHEP) of 1.0E-7 was retained in the internal events PRA for comparison of results between the current licensed thermal power (CLTP) and EPU cases and because the large number of independent operator errors and associated combinations skew the results in a conservative direction. The results of sensitivity analyses on JHEPs were presented in Section 5.7.1.7, "Sensitivity for Minimum JHEP ("Floor Values")," of EPU LAR Attachment 44 using minimum JHEP values of 0 and 1E-06. These sensitivity analyses showed that the risk results are sensitive to the number of JHEPs and the minimum JHEP assumed. The following observations were made in regard to the licensee's treatment of minimum JHEP in the internal events PRA:

- RG 1.174, Revision 2, "An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis," states that, "the results of the sensitivity studies should confirm that the guidelines are still met even under the alternative assumptions (i.e., change generally remains in the appropriate region)." The ΔCDFs and ΔLERFs from the sensitivity analyses in Tables 5-26 and 5-27 in Attachment 44 of the EPU LAR are relative to the EPU base case and not relative to the CLTP base case. As such, the staff could not confirm that the results from these sensitivity analyses still meet the risk acceptance guidelines of RG 1.174, Revision 2.

- Guidance in NUREG-1792, "Good Practices for Implementing Human Reliability Analysis (HRA)," recommends JHEP values should not be below 1E-05, because, "it is typically hard to defend that other dependent failure modes that are not usually treated ... cannot occur." Table 4-4 of Electric Power Research Institute (EPRI) 1021081, "Establishing Minimum Acceptable Values for Probabilities of Human Failure Events," provides a lower limiting value of 1E-06 for sequences with a "very low" level of dependence. This issue was also raised in F&O 4-21 from the internal events PRA peer review listed in Table A-1 in Attachment 44 of the EPU LAR. The NRC staff notes that underestimation of minimum JHEP could result in non-conservative risk results (i.e., CDF, LERF, ΔCDF, and ΔLERF).

- Furthermore, the staff has considered the licensee's response to NFPA 805 PRA RAIs 01.v and 24 (ADAMS Accession No. ML14363A057 (dated December 17, 2004)). In this response, the licensee addressed the minimum JHEP in the FPRA by updating the FPRA to apply a floor value of 1E-05 to all HEP combinations that do not include long-term decay heat removal (DHR) HFEs or those HFEs cued and guided by Severe Accident Mitigation Guideline (SAMG) procedures. For the remaining combinations, a floor value of 1.0E-06 was applied, given that a low dependency exists between long-term DHR and SAMG actions and other earlier actions. The NRC staff concluded in its safety evaluation dated October 28, 2015 (ADAMS Accession No. ML15212A796), that the FPRA included an acceptable minimum JHEP value; however, these changes were not incorporated in the internal events PRA.

Given the issues identified above regarding the licensee's treatment of minimum JHEP in the internal events PRA, provide one of the following:

a. For JHEP values below 1.0E-05 used in the PRA for the sensitivity analyses in Table 5-27 of LAR Attachment 44 (which uses the 1E-06 floor), provide a detailed justification(s) for why use of the NUREG-1792 lower value guideline (i.e., minimum JHEP value of 1E-05) is inapplicable for this application. In this discussion, also include: an estimate of the number of these JHEPs below 1.0E-05, and provide at least two different examples where your justification is applied. For those JHEP values where inapplicability of the NUREG-1792 lower value guideline cannot be justified, explain how underestimating those JHEPs (e.g., using a floor of 1E-06 rather than a floor of 1E-05) impacts the risk results (i.e., CDF, LERF, ΔCDF, and ΔLERF) of this application. In addition, provide the CDF, LERF, ΔCDF, and ΔLERF between the EPU and CLTP cases using the 1E-06 floor, and confirm that these results, combined with the risks from other hazards (i.e., fires, seismic, shutdown, and other external events), still meet the risk

acceptance guidelines of RG 1.174, Revision 2. If RG 1.174 risk acceptance guidelines are exceeded, please provide a detailed justification to support the conclusion that no "special circumstances" are created by the proposed EPU. Include a discussion of which metrics are exceeded and the conservatisms in the analysis and the risk significance of these conservatisms.

b. Alternatively, provide the internal events PRA results between the EPU and CLTP cases (i.e., CDF, LERF, ΔCDF, and ΔLERF) where both use a minimum JHEP value of 1E-05 (or use a minimum JHEP consistent with the approach used for the licensee's FPRA) and confirm that these results, combined with the risks from other hazards (i.e., fires, seismic, shutdown, and other external events), still meet the risk acceptance guidelines of RG 1.174, Revision 2. If RG 1.174 risk acceptance guidelines are exceeded, then please provide a detailed justification to support the conclusion that no "special circumstances" are created by the proposed EPU. Include a discussion of which metrics are exceeded and the conservatisms in the analysis and the risk significance of these conservatisms.

APLA-RAI 07

In accordance with Appendix D of SRP, Chapter 19.2, the NRC staff reviews the BFN EPU risk evaluations to determine if "special circumstances" are created by the proposed EPU that would potentially rebut the presumption of adequate protection from compliance with the regulations and other license requirements. Therefore, the licensee's risk evaluations need to be sufficient for the staff to conclude that the risk impact from internal events, external events, and shutdown operations is acceptable and does not create special circumstances.

RG 1.174, Revision 2, states that, "the results of the sensitivity studies should confirm that the guidelines are still met even under the alternative assumptions." Section 5.7.1.4, "Sensitivity for Impact to Transient Initiators," and Section 5.7.1.6, "Sensitivity for Impact to LOCA [Loss-of-Coolant Accident] Frequencies," in Attachment 44 of the EPU LAR provides the results of various sensitivity analyses. However, the ΔCDF and ΔLERF results from these sensitivity analyses are relative to the "base case EPU [internal events] PRA" rather than the base case CLTP PRA, which is needed to confirm that the risk acceptance guidelines of RG 1.174 are still met. Based on a comparison of the results between the sensitivity cases in Sections 5.7.1.4 and 5.7.1.6 and the associated CLTP base cases in Table 5-15 in Attachment 44, the total ΔCDF and ΔLERF (for internal events and fires) may exceed the risk acceptance guidelines of RG 1.174 for some sensitivity cases (e.g., total ΔLERF for loss of feedwater in Units 1 and 2; total ΔLERF for loss of condenser vacuum, total and partial loss of condensate in Units 1, 2 and 3; total ΔLERF for excessive feedwater flow in Units 1 and 2; total ΔLERF for inadvertent Main Steam Isolation Valve closure in Units 1 and 2; total ΔLERF for LOCA in Unit 1).

For the sensitivity analyses in Sections 5.7.1.4 and 5.7.1.6 in Attachment 44 of the EPU LAR, provide the ΔCDF and ΔLERF relative to the CLTP base case, and confirm that the results of these sensitivity analyses, combined with the risks from other hazards (i.e., fires, seismic, shutdown, and other external events), still meet the risk acceptance guidelines of RG 1.174, Revision 2. If RG 1.174 risk acceptance guidelines are exceeded, then please provide a detailed justification to support the conclusion that no "special circumstances" are created by the

proposed EPU, and include a discussion of which metrics are exceeded and the conservatisms in the analysis and the risk significance of these conservatisms.

APLA-RAI 08

In accordance with Appendix D of SRP, Chapter 19.2, the NRC staff reviews the BFN EPU risk evaluations to determine if "special circumstances" are created by the proposed EPU that would potentially rebut the presumption of adequate protection from compliance with the regulations and other license requirements. Therefore, the licensee's risk evaluations need to be sufficient for the staff to conclude that the risk impact from internal events, external events, and shutdown operations is acceptable and does not create special circumstances.

Section 2.5.5, "Comparisons with Acceptance Guidelines," of RG 1.174, Revision 2, states that, "the appropriate numerical measures to use in the initial comparison of the PRA results to the acceptance guidelines are mean values." However, the licensee compared point estimate values against the risk acceptance guidelines of RG 1.174. The licensee did perform a parametric uncertainty assessment in Section A.3, "Parametric, Model, and Completeness Uncertainties," of LAR Attachment 44 to estimate the mean risk values for this application and stated:

> The results of these analyses show that the mean results and point estimates are approximately equal ... Therefore, the point estimates are suitable for calculating delta risks. The conclusions drawn when comparing the point estimates and the propagated means with the RG 1.174 acceptance guidelines would not be different.

Based on the staff's observations, point estimates may not always be suitable for calculating the total risk and the change in risk for this application. For example, the Unit 1 mean total ΔLERF (i.e., 2.34E-07 + 8.15E-07 = 1.05E-06, from Tables A-3 and A-4 of LAR Attachment 44) exceeds the risk acceptance guidelines of RG 1.174. The Unit 1 point estimate total ΔLERF (i.e., 1.70E-07 + 6.04E-07 = 7.74E-07, from Tables A-3 and A-4 of LAR Attachment 44) meets these acceptance guidelines. Another example, the estimated total LERF and ΔLERF values for the EPU baseline case and the associated sensitivity analyses, are close to or exceed the RG 1.174 acceptance guidelines as pointed out in the previous RAIs; therefore, the use of mean risk values may be more appropriate in these cases.

Additionally, Section 1.2.10, "Interpretation of Results Technical Elements," of RG 1.200, Revision 2, states:

> The sensitivity of the model results to model boundary conditions and other assumptions is evaluated, using sensitivity analyses to look at assumptions both individually and in logical combinations. The combinations analyzed are chosen

to account for interactions among the variables. NUREG-1855 provides guidance on the treatment of uncertainties associated with PRA.

However, the sensitivity analyses in Section 5.7.1, "Internal Events PRA Sensitivity Analyses," in Attachment 44 of the EPU LAR did not consider combined effects from the impact of EPU conditions.

The NRC staff requests that the licensee perform a sensitivity analysis(es) using the internal events PRA that considers the combined effects from the impact of EPU conditions (i.e., combined impacts from sensitivity studies in Sections 5.7.1.4 and 5.7.1.6 of LAR Attachment 44). This sensitivity analysis(es) should also take into consideration: (1) the use of minimum JHEP values in response to PRA RAI 06, and (2) the assessment of mean risk values where the state-of-knowledge correlation can be important (e.g., in the assessment of LERF and ΔLERF). Describe this sensitivity analysis(es); provide the associated risk results (i.e., CDF, LERF, ΔCDF, and ΔLERF); and confirm that these results, combined with the risks from other hazards (i.e., fires, seismic, shutdown, and other external events) still meet the risk acceptance guidelines of RG 1.174, Revision 2. (Note: the ΔCDF and ΔLERF should be relative to the CLTP base case, and the approach used to address minimum JHEP is expected to be similar for the EPU and CLTP cases, since this is a modeling attribute that impacts both cases.) If RG 1.174 risk acceptance guidelines are exceeded, then please provide a detailed justification to support the conclusion that no "special circumstances" are created by the proposed EPU, and include a discussion of which metrics are exceeded and the conservatisms in the analysis and the risk significance of these conservatisms.

APLA-RAI 09

In accordance with Appendix D of SRP, Chapter 19.2, the NRC staff reviews the BFN EPU risk evaluations to determine if "special circumstances" are created by the proposed EPU that would potentially rebut the presumption of adequate protection from compliance with the regulations and other license requirements. Therefore, the licensee's risk evaluations need to be sufficient for the staff to conclude that the risk impact from internal events, external events, and shutdown operations is acceptable and does not create special circumstances.

As discussed in Attachment 44 of the EPU LAR, the change in risk results for this application is driven by the change in HEPs as a result of the EPU. This demonstrates the importance of calculating realistic changes in HEPs. In order to confirm the reasonableness of these calculations and to understand why the increase in some HEPs are much larger than others, the staff requests that the licensee explain how the following HEPs were quantified for both the EPU and CLTP cases, provide sufficient detail and numerical values to understand the basis for these HEPs:

- HFA_0HCIINIT30, "Operator Fails to Initiate HPI (30 Min)," in the internal events PRA and listed in Table 4-4 of LAR Attachment 44.

- HFA_0002RPV_LVL, "Operator Fails to Maintain RPV Level," in the internal events PRA and listed in Table 4-4 of LAR Attachment 44.

- JHEP COMBINATION_1195, "HEP dependency factor for HFA_0HCIINIT30, HFA_0002RPV_LVL," in the internal events PRA and listed in Table 4-5 of LAR Attachment 44.

- HFFA0ASD_RCIC, "Operator Fails to Start RCIC," in the FPRA and listed in Table 4-10 of LAR Attachment 44.

- HFFA0RHRCS_LPP, "Oper Fails to Bypass ECCS Low Pressure Permissive," in the FPRA and listed in Table 4-10 of LAR Attachment 44.

If you have any questions, please contact me at 301-415-1447 or Farideh.Saba@nrc.gov.

Sincerely,

/RA/

Farideh E. Saba, Senior Project Manager
Plant Licensing Branch II-2
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

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Enclosure:
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