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1101 Market Street, Chattanooga, Tennessee 37402

CNL-14-097

June 13, 2014

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: **Response to NRC Request for Additional Information Regarding the License Amendment Request to Adopt NFPA 805 Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants for the Browns Ferry Nuclear Plant, Units 1, 2, and 3 (TAC Nos. MF1185, MF1186, and MF1187) - Attachment X and Fire Modeling**

References:

1. Letter from TVA to NRC, "License Amendment Request to Adopt NFPA 805 Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants (2001 Edition) (Technical Specification Change TS-480)," dated March 27, 2013 (ADAMS Accession No. ML13092A393)

2. Letter from TVA to NRC, "Response to NRC Request to Supplement License Amendment Request to Adopt NFPA 805 Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants for the Browns Ferry Nuclear Plant, Units 1, 2, and 3 (TAC Nos. MF1185, MF1186, and MF1187)," dated May 16, 2013 (ADAMS Accession No. ML13141A291)

3. Letter from NRC to TVA, "Browns Ferry Nuclear Plant, Units 1, 2, and 3 - Request for Additional Information Regarding Attachment X Of License Amendment Request to Adopt National Fire Protection Association Standard 805, Performance-Based Standard for Fire Protection for Light Water Reactor Generating Plants (TAC Nos. MF1185, MF1186, and MF1187)," dated May 20, 2014 (ADAMS Accession No. ML14126A388)

4. Letter from NRC to TVA, "Browns Ferry Nuclear Plant, Units 1, 2, and 3 - Request for Additional Information Regarding License Amendment Request to Adopt National Fire Protection Association Standard 805 Performance-Based Standard for Fire Protection for Light Water Reactor Generating Plants (TAC Nos. MF1185, MF1186, and MF1187)," dated May 21, 2014 (ADAMS Accession No. ML14133A526)

By letter dated March 27, 2013 (Reference 1), Tennessee Valley Authority (TVA) submitted a license amendment request (LAR) for Browns Ferry Nuclear Plant (BFN), Units 1, 2, and 3, to transition to National Fire Protection Association Standard (NFPA) 805. In addition, by letter dated May 16, 2013 (Reference 2), TVA provided information to supplement the Reference 1 letter.

By letter dated May 20, 2014 (Reference 3), the Nuclear Regulatory Commission (NRC) requested additional information related to the LAR, Attachment X to support the review of the LAR. The required due date for the responses to this request for additional information (RAI) is June 13, 2014.

By letter dated May 21, 2014 (Reference 4), the NRC requested additional information related to fire modeling to support the review of the LAR. The required due date for the responses to this request for additional information (RAI) is June 30, 2014.

The enclosures to this letter provide the TVA responses to the questions in the Reference 3 and Reference 4 RAIs, with the exception of Containment and Ventilation Branch (SCVB) RAI-10 in Reference 3. The due date for this RAI was extended to July 11, 2014, as discussed in a teleconference between the NRC and TVA on June 5, 2014.

Consistent with the standards set forth in Title 10 of the Code of Federal Regulations (10 CFR), Part 50.92(c), TVA has determined that the additional information, as provided in this letter, does not affect the no significant hazards consideration associated with the proposed application previously provided in Reference 1.

There are no new regulatory commitments contained in this submittal. Please address any questions regarding this submittal to Mr. Edward D. Schrull at (423) 751-3850.

I declare under penalty of perjury that the foregoing is true and correct. Executed on this 13th day of June 2014.

Respectfully,

J. W. Shea
Vice President, Nuclear Licensing

Enclosures:

1. TVA Responses to NRC Request for Additional Information - Attachment X
2. TVA Responses to NRC Request for Additional Information - Fire Modeling

cc (Enclosures):

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

ENCLOSURE 1

Tennessee Valley Authority
Browns Ferry Nuclear Plant, Units 1, 2, and 3
TVA Responses to NRC Request for Additional Information - Attachment X

By letter dated March 27, 2013 (Reference 1), Tennessee Valley Authority (TVA, the licensee) submitted a license amendment request for Browns Ferry Nuclear Plant (BFN), Units 1, 2, and 3, which proposes transition to Title 10 of the Code of Federal Regulations (10 CFR), Section 50.48(c) - NFPA 805, Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants, 2001 Edition.

The current 10 CFR Part 50, Appendix R containment analysis for safe shutdown credits containment accident pressure (CAP) to ensure adequate net positive suction head (NPSH) for the residual heat removal (RHR) pumps. As part of the transition to NFPA 805, the licensee has proposed to eliminate the reliance on CAP credit. The licensee described the elimination of CAP credit in Attachment X (Reference 2) of the Reference 1. The Nuclear Regulatory Commission (NRC) staff has reviewed Attachment X and is requesting responses to the following items to complete its review.

Containment and Ventilation Branch (SCVB) RAI-1

The licensee in Attachment X, Section X.4 states:

> Thermal performance testing of BFN Unit 3 RHR heat exchangers 3A and 3C was performed to determine the acceptability of the current four-year cleaning period and to substantiate the increase to 265 BTU/sec-^{o}F [British Thermal Unit per second-degree Fahrenheit] utilizing the projected heat transfer at limiting conditions.

Please provide the following information:

(a) Description of the performance test.
(b) Measured value of the RHR heat exchanger (HX) fouling factor and the length of time from its previous maintenance cleaning.
(c) Correlation (along with its reference) used to extrapolate and determine the worst fouling factor from the required cleaning time for maintaining the HX k-factor above 265 BTU/sec-^{o}F.
(d) Explain what is meant by "utilizing the projected heat transfer at limiting conditions."
(e) What is the projected heat transfer value and its basis, and what are the limiting conditions?

RESPONSE:

(a) Heat exchanger performance tests were conducted on Unit 3 Residual Heat Removal (RHR) heat exchangers 3A and 3C in January 2012. Test protocol followed the guidelines of Electric Power Research Institute (EPRI) TR-107397, "Service Water Heat Exchanger Testing Guidelines," dated March 1998 and EPRI NP-7552, "Heat Exchanger Performance Monitoring Guidelines," dated December 1991. These EPRI guidelines are consistent with the recommendations provided in Generic Letter (GL) 89-13, "Service Water System Problems Affecting Safety-Related Equipment."

A data collection device and temporary test instrumentation were installed to accurately measure RHR System and RHR Service Water (RHRSW) System flows and fluid temperatures at the inlet and outlet of the heat exchangers. The two heat exchangers were individually tested with the RHR System operating in the suppression pool cooling mode during a scheduled High Pressure Cooling Injection (HPCI) System quarterly flow surveillance test. Conducting the test in association with the HPCI surveillance test is beneficial because exhaust steam from the HPCI turbine elevates the suppression pool temperature (increasing the heat transfer rate) and improves test accuracy by maintaining a stable pool temperature during data collection. Multiple flow and temperature data points were recorded during a period of stable operation, which were then used to perform a heat balance calculation across both sides of the heat exchanger, yielding the heat transfer rate, Q. Utilizing Q, measured flows, and data from the heat exchanger manufacturer's data sheet, an overall fouling resistance for each heat exchanger was determined.

(b) The BFN GL 89-13 heat exchanger program requires inspection and cleaning of RHR heat exchangers every five years. In practice, the heat exchangers are inspected and cleaned on a 4-year schedule. The operating history of the 12 RHR heat exchangers among the three BFN units was reviewed to select representative RHR heat exchangers for the testing. Unit 3 RHR heat exchangers 3A and 3C were selected because RHR heat exchanger 3A had been in service for two years and RHR heat exchanger 3C had been in service for four years since their last heat exchanger inspection and cleaning work activity. This resulted in an RHR heat exchanger that was halfway through a service cycle and one that was near the end of a typical 4-year service cycle being tested. The overall fouling resistances were determined to be 0.0005164 hr-ft^2-°F/BTU for RHR heat exchanger 3A and 0.000674 hr-ft^2-°F/BTU for RHR heat exchanger 3C.

(c) TVA previously determined that a k-factor of at least 265 BTU/sec-°F would be sufficient to eliminate the need for Containment Accident Pressure (CAP) credit in the long-term Loss of Coolant Accident (LOCA) containment analysis. Using conventional heat exchanger effectiveness equations, an overall fouling factor of 0.001517 hr-ft^2-°F/BTU corresponds to a k-factor of 265 BTU/sec-°F at the LOCA state point condition (i.e., the RHR heat exchanger operating conditions during a LOCA). The heat exchanger performance test was conducted to measure actual fouling factors to determine if use of higher k-factors for LOCA containment analyses and other containment analyses such as that for Appendix R and NFPA 805 was justified.

A correlation between fouling resistance and required cleaning time has not been developed. However, the use of a worst case fouling resistance of 0.001517 hr-ft^2-°F/BTU is justified by demonstrating a substantial margin between the assumed worst case analysis value and the measured value of 0.000674 hr-ft^2-°F/BTU for RHR heat exchanger 3C, which was near the end of a typical 4-year service cycle. As shown below, this represents a 55.6% fouling factor margin to account for the uncertainty associated with having only two performance test results.

$$\text{Fouling Factor Margin} = \frac{\text{assumed fouling} - \text{measured fouling}}{\text{assumed fouling}} = \frac{0.001517 - .000674}{.001517} \times 100\% = 55.6\%$$

(d) The "limiting condition" in Section X.4 of LAR Attachment X refers to the state point condition associated with the current LOCA analysis (RHR flow of 6500 gpm, RHRSW flow of 4000 gpm, RHRSW temperature of 95°F, 4.57% tube plugging, and suppression pool temperature at 187.4°F). Heat exchanger performance determinations were projected at the LOCA state point condition in order to compare performance with various fouling assumptions. At this reference state point condition, the assumed worst case fouling resistance of 0.001517 hr-ft^2-°F/BTU corresponds to a k-factor value of 265 BTU/sec-°F.

(e) The projected limiting heat transfer value rate (BTU/hr) based on the LOCA state point condition and k-factor=265 BTU/sec-°F is:

Q = k-factor (ΔT_{inlet})
Q = (265 BTU/sec-°F) (187.4 °F - 95°F) (3600 sec/hr)
Q = 8.82E+07 BTU/hr

The heat exchanger operating conditions assumed in the NFPA 805 analysis are different than the LOCA state point condition. The NFPA 805 analysis conditions include RHR Flow of 7500 gpm, RHRSW flow of 4400 gpm, RHRSW temperature of 92°F, and 4.57% tube plugging. The corresponding k-factor value using the fouling resistance of 0.001517 hr-ft^2-°F/BTU at these conditions is 284.5 BTU/sec-°F and the heat transfer rate would be greater.

SCVB RAI-2

The licensee in Attachment X, Section X.4 states:

> A parametric evaluation of the RHR heat exchangers using a conservative fouling factor equivalent to 265 BTU/sec-^{o}F was subsequently performed.

Provide the following information:

(a) Description of the parametric evaluation of the RHR HXs.
(b) How was the fouling factor equivalent to HX k-factor of 265 BTU/sec-^{o}F determined, and how much was the conservatism in the fouling factor?

RESPONSE:

(a) The TVA heat exchanger tube plugging calculation was revised to include k-factor tables for a wide range of RHR temperatures, RHRSW temperatures, system flows, and tube plugging percentages using the newly established worst case fouling resistance of 0.001517 hr-ft^2-°F/BTU. The revision provides pre-calculated k-factor values for use in suppression pool temperature analyses. This is the parametric study that is referred to in LAR Attachment X, Section X.4.

(b) As discussed in the response to SCVB RAI-1, part c (in this enclosure), using conventional heat exchanger effectiveness equations, a 0.001517 hr-ft^2-°F/BTU fouling factor is equivalent to a heat exchanger k-factor of 265 BTU/sec-°F at the LOCA state point condition. The margin between the assumed worst case fouling resistance (0.001517 hr-ft^2-°F/BTU) used for calculating heat exchanger performance and the measured fouling factor for RHR heat exchanger 3C (the worst of the two RHR heat exchangers tested) is:

$$\text{Fouling Factor Margin} = \frac{\text{assumed fouling} - \text{measured fouling}}{\text{assumed fouling}} = \frac{0.001517 - .000674}{.001517} \times 100\% = 55.6\%$$

SCVB RAI-3

The licensee in Attachment X, Section X.4 states:

> The k-factor for residual heat removal service water (RHRSW) temperature of 92° F, 4400 gpm [gallons per minute] RHRSW flow, maximum tube plugging, and 7500 gpm RHR flow is approximately 284.5 BTU/sec-°F.

Provide the following information:

(a) What is the value of the fouling factor that is used for calculating k-factor of 284.5 BTU/sec-°F?
(b) What is the k-factor for a clean RHR HX with zero fouling and none of the tubes plugged?
(c) Confirm that the maximum value of fouling factor is used in calculating k-factor of 284.5 BTU/sec-°F. If not, justify.
(d) Confirm that 4400 gpm and 7500 gpm flows for RHRSW and RHR, respectively, are the most conservative values on which the k-factor of 284.5 BTU/sec-°F is based. Also, confirm that it will not be less than 284.5 BTU/sec-°F for any of the RHR operating modes. Confirm that the k-factor of 284.5 BTU/sec-°F is based on conservative parameters and it will vary with parameters or RHR operating modes. If not, justify.

RESPONSE:

(a) The k-factor of 284.5 BTU/sec-°F corresponds to the revised worst case fouling resistance of 0.001517 hr-ft^2-°F/BTU at the NFPA-805 analysis state point condition (i.e., RHR flow of 7500 gpm, RHRSW flow of 4400 gpm, RHRSW temperature of 92°F, and maximum tube plugging of 4.57%).

(b) The k-factor for a clean RHR heat exchanger (i.e., zero fouling and no tubes plugged) is estimated to be 372 BTU/sec-°F for the NFPA-805 analysis state point condition (defined in the response to part (a) above).

(c) The worst case (i.e., maximum value) fouling resistance of 0.001517 hr-ft^2-°F/BTU was used in calculating the 284.5 BTU/sec-°F k-factor value.

(d) Quarterly RHRSW pump surveillance testing is conducted to demonstrate that each pump can deliver a flow of at least 4500 gpm. TVA flow calculations show that a flow of 4500 gpm is achievable based on the most limiting RHRSW pump alignment when two RHRSW pumps are supplying a single RHRSW header. For conservatism, the RHRSW flow used in the k-factor determination is based on 4400 gpm.

The RHR System is credited in two operating modes for NFPA 805 containment analyses: Alternate Shutdown Cooling (ASDC) mode and Suppression Pool Cooling (SPC) mode. RHR pump surveillance testing is conducted in SPC mode at ≥ 9000 gpm. The maximum RHR flow rate in ASDC mode is calculated to be 9100 gpm. Therefore, 7500 gpm is within the system capability for an RHR pump in the SPC and ASDC modes.

TVA confirms that: 1) the k-factor of 284.5 BTU/sec-°F is based on the conservative flow inputs of 4400 gpm for RHRSW and 7500 gpm for RHR; 2) the k-factor will not be less than 284.5 BTU/sec-°F in the SPC or ASDC mode; 3) the k-factor of 284.5 BTU/sec-°F is based on the conservative parameters identified in the responses to part (a) and part (c) above and does vary with flow and RHR operating mode.

SCVB RAI-4

BFN Surveillance Requirement 3.7.2.1 requires the average water temperature of ultimate heat sink to be less than or equal to 95°F. Also Reference 3, Enclosure 1, page E1-10, item c specifies the service water temperature to be 95°F for containment analysis. Revise the NFPA 805 analysis using 95°F as RHRSW temperature or provide justification for using 92°F instead of 95°F.

RESPONSE:

The 95°F value cited in Reference 3, Enclosure 1, page E1-10, item c is the RHRSW/Ultimate Heat Sink (UHS) temperature used in the BFN LOCA containment analyses. For special events analyses such as Appendix R and NFPA 805, the use of more realistic input values and assumptions is allowed as discussed in the NRC memorandum dated March 15, 2011, "SECY-11-0014 - Use of Containment Accident Pressure in Analyzing Emergency Core Cooling System and Containment Heat Removal System Pump Performance in Postulated Accidents," Enclosure 1 (ADAMS Accession Number ML102110167). For the NFPA 805 containment analyses, using 92°F as a realistic value for UHS temperature is consistent with the NRC discussion in SECY-11-0014, Enclosure 1.

The 92°F value is based on the 95% nonexceedance probability from a statistical analysis of 6.1 years of Tennessee River water temperature data between 2000 and 2005, and serves as an appropriate basis for establishing a realistic upper bound value for UHS temperature. The seasonal variation of river water temperature is consistent; a large amount of historical data is available to make statistical predictions. A probability distribution was developed from the river temperature data and was used to predict the frequency of occurrence as a function of temperature. This probability distribution was previously provided to the NRC in a TVA letter dated July 21, 2006, "Browns Ferry Nuclear Plant, Units 1, 2, and 3 - Technical Specifications Changes TS-431 and TS-418 - Extended Power Uprate - Response to Round 6 Request for Additional Information" (ADAMS Accession Number ML062090071). The probability distribution shows that the river temperature is not expected to exceed 92°F for 95% of the time. No data points in the dataset exceeded 90°F.

The inputs used in the current BFN Appendix R analysis have been previously transmitted to the NRC in submittals related to the Extended Power Uprate license amendment requests. In particular, TVA's submittal dated August 31, 2006, "Browns Ferry Nuclear Plant - Units 1, 2, and 3 - Extended Power Uprate - Technical Specifications Changes TS-431 and TS-418 - Replacement Documentation" (ADAMS Accession Number ML062510371) provided the NRC with copies of the BFN NPSH calculations for LOCA and the special events including Appendix R. Section 6.2.3 of TVA calculation MDQ099920060011R1, "Transient NPSH/Containment Pressure Evaluation of RHR and Core Spray Pumps," which is attached to the August 31, 2006, submittal, documents the 92°F value as the RHRSW/UHS temperature for the Appendix R containment analysis. The NRC subsequently addressed the use of this 92°F temperature value for special event analyses as indicated on page 76 of the NRC Safety Evaluation dated March 6, 2007, "Browns Ferry Nuclear Plant, Unit 1 - Issuance of Amendment Regarding Five Percent Uprate (TAC No. MD3048) (TS-431)" (ADAMS Accession No. ML063350404). Therefore, TVA concludes that continued use of the 92°F UHS temperature for the NFPA 805 analyses is acceptable.

SCVB RAI-5

The licensee in Attachment X, Section X.4 states:

> Because thermal performance testing was performed on only two BFN Unit 3 RHR heat exchangers, the BFN Units 1, 2, and 3 RHR heat exchangers will be subject to a performance monitoring program to provide assurance that fouling that could affect the required heat transfer rate is detected and corrected in a timely manner. Therefore, TVA commits to revise the RHR heat exchanger performance monitoring program for the BFN Unit 1, 2, and 3 RHR heat exchangers to be consistent with the assumptions of the NFPA 805 NPSH, Containment Parameters, and AREVA Fuel PCT [peak cladding temperature] Analysis calculation related to the RHR heat exchanger k-factor within 6 months following approval of this amendment request.

Describe the revised BFN Units 1, 2, and 3 RHR HXs performance monitoring program that will assure that fouling factor and tube plugging would not exceed their worst values assumed in calculating k-factor of 284.5 BTU/sec-°F.

RESPONSE:

The revised performance monitoring program has not been developed at this time. Commitment 2 in Enclosure 2 to TVA letter dated May 16, 2013, "Response to NRC Request to Supplement License Amendment Request to Adopt NFPA 805 Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants for the Browns Ferry Nuclear Plant, Units 1, 2, and 3 (TAC Nos. MF1185, MF1186, and MF1187)" (ADAMS Accession No. ML13141A291), provides the TVA commitment to revise the program that monitors the RHR heat exchanger performance. The commitment states that "TVA will revise the program that monitors BFN Residual Heat Removal (RHR) heat exchanger performance for consistency with the assumptions of the NFPA 805 Net Positive Suction Head (NPSH), Containment Parameters, and AREVA Fuel peak centerline temperature (PCT) Analysis calculation related to the RHR heat exchanger k-factor within 6 months following NRC approval of the NFPA 805 amendment request." TVA intends to include, as requirements in the program, periodic heat exchanger inspections and heat exchanger performance testing requirements to ensure fouling factor assumptions and tube plugging assumptions in the NFPA 805 containment analysis remain valid.

SCVB RAI-6

The licensee in Attachment X does not clearly state the computer code used for the NFPA 805 analysis. Please describe the methodology, including the computer code used. Provide justification if there is a methodology change from the current licensing basis analysis methodology. Also list any other changes (along with justifications) in input parameters and assumptions in the NFPA 805 analysis besides those listed in Tables 3 and 4 of Attachment X.

RESPONSE:

The following are descriptions of the overall calculation methodology and TVA computer codes, and a summary of other changes between the NFPA 805 analysis and the current Appendix R analysis. There was no methodology change from the current licensing basis analysis methodology.

As indicated in Table 3 and Table 4 of Appendix X in the NFPA 805 LAR, the containment analyses for Appendix R and NFPA 805 were performed by General Electric Hitachi (GEH) using their SHEX model. The SHEX model output includes suppression pool water temperature, containment air space temperature, and drywell and wetwell pressures. NFPA 805 Cases 1 and 2 used a k-factor of 270 BTU/sec-°F in the containment analysis. The SHEX model output for the NFPA 805 Case 3 containment analysis used a k-factor of 289 BTU/sec-°F. This value was subsequently adjusted to a k-factor of 270 BTU/sec-°F using a TVA suppression pool heat balance calculation model. The TVA heat balance model was benchmarked against SHEX model results and is used to evaluate the effects of small changes to SHEX model case inputs such as k-factor and UHS temperature.

The Appendix R and the NFPA 805 calculations both used TVA's MultiFlow hydraulic flow balance software to determine the piping head loss and the pressure at the RHR pump suction. Pump available NPSH (NPSHa) is calculated using the pump suction pressure output from the MultiFlow software, wetwell pressure from the SHEX model output, and water vapor pressure corresponding to the suppression pool water temperature output from the SHEX model output. However, because credit is not taken for CAP in the NFPA 805 analyses, the wetwell is assumed to be at atmospheric pressure and the calculated wetwell pressure output from the SHEX model is not used in determining NPSHa. Although the water velocity head at the inlet of the RHR pump was not included in calculating NPSHa in the Appendix R analysis, the NFPA 805 NPSHa calculations included water velocity head, resulting in a small increase (i.e., 0.5 feet) in NPSHa at the NFPA 805 state point condition.

SCVB RAI-7

Provide the basis for selecting each of the three cases identified in Attachment X, Section X.5 for NFPA 805 containment analysis. Confirm that any other possible (or postulated) NFPA 805 analysis case that requires containment cooling will have acceptable NPSH margin for the pumps used.

RESPONSE:

The NFPA 805 containment analysis was performed to support the Nuclear Safety Capability Assessment (NSCA). The NSCA establishes the success criteria and timing requirements for the credited Fire Safe Shutdown (FSSD) paths to demonstrate that the FSSD paths will achieve and maintain the plant in a safe and stable condition. TVA confirmed that the cases chosen for analysis bound the range of operator actions, action timing, equipment availability, and spurious operation assumed in the NSCA for all of the fire areas.

Containment parameters of interest for fire events are peak suppression pool temperature, drywell temperature, and peak containment pressure. Because no credit is being taken for CAP in the NFPA 805 analyses, wetwell pressure is assumed to be atmospheric and calculated wetwell pressure is not a factor in determining NPSHa. Peak suppression pool temperature is the only containment analysis parameter used in the NPSH evaluation.

The following provides the basis for selecting the three cases that are analyzed for NFPA 805.

<u>NFPA 805 Case 1 - Early Reactor Depressurization with ASDC</u>

Case 1 corresponds to the EPU Appendix R case that resulted in the highest suppression pool temperature and minimum NPSHa for the RHR pumps. Therefore, this case was repeated for NFPA 805 to determine whether it would be limiting at the current licensed thermal power condition.

In the Case 1 analysis scenario, no high pressure injection systems are assumed to be available and the reactor must be depressurized early in the event sequence to allow use of a low pressure injection system (i.e., RHR) to reflood the reactor. Following depressurization, RHR is aligned to the ASDC mode for long-term containment heat removal. In the ASDC mode, suppression pool water is injected into the reactor vessel, the vessel is flooded up to the steam line elevation, and reactor water inventory is returned to the suppression pool via the Main Steam Relief Valve lines. The early reactor depressurization and direct mixing of the suppression pool volume with the reactor vessel water inventory in ASDC mode results in an increased suppression pool temperature relative to Case 2 and moderate NPSH pump margin as shown in Attachment X, Table 2 of the LAR.

<u>NFPA 805 Case 2 – High Pressure Systems Available and Delayed Reactor Depressurization</u>

In the Case 2 analysis scenario, high pressure injection remains available, thus the fire safe shutdown procedures use high pressure injection to maintain vessel inventory. Injection of external water inventory (i.e., condensate storage tank water) results in a lower peak suppression pool temperature because the cooler external injection water mixes with the primary system water inventory and the added water mass increases the net heat sink water volume in containment. Because the water supply inventory available to the high pressure systems is limited, a transition to a low pressure system such as RHR will eventually be necessary for long-term reactor inventory makeup. Because Case 2 involves an extended time with the reactor at pressure and temperature, it was specifically analyzed to verify drywell temperature would stay within design limits. As shown in Attachment X, Table 2 of the LAR, Case 2 resulted in a comparatively low peak suppression pool temperature with several feet of RHR pump NPSH margin. Therefore, it was not a limiting NPSH case.

<u>NFPA 805 Case 3 – Condensate System Available</u>

Case 3 is similar to Case 1 except that the condensate system continues to run after the reactor scram. With high pressure injection not available, as the reactor is depressurized early in the event, it is assumed that the entire feedwater and condenser inventory is injected into the reactor. This assumption results in a higher suppression pool temperature than in Case 1 because the additional injected water inventory is at elevated temperature, thus adding more heat to the containment. After the feedwater and condenser inventory is consumed, RHR operating in ASDC mode is used for core cooling and long-term containment heat removal.

Because Case 3 further maximizes suppression pool temperature, it was selected to calculate NPSH margin. As shown in Attachment X Table 2 of the LAR, Case 3 resulted in the highest suppression pool temperature and was the limiting NFPA 805 NPSH case.

SCVB RAI-8

The following table shows five input parameters extracted from Table 4 of Attachment X whose values are not consistent within the three cases and/or are different from those in Enclosure 1 of TVA letter dated April 10, 2009 (Reference 3). For example, initial wetwell airspace volume in Reference 3 is different from those in Cases 1, 2, and 3. However, initial drywell pressure for Cases 1 and 3 is not consistent with values in Case 2 and Reference 3. Justify the inconsistencies within the three analyzed cases and also with the values in Enclosure 1 of Reference 3, or revise the values to be consistent.

Parameter	Cases 1 & 3	Case 2	Reference 3, Enclosure 1
Initial suppression pool volume corresponding to minimum suppression pool level	122,940 cubic feet (ft^3)	122,940 ft^3	121,500 ft^3 (page E1-6, item 3.a.1)
Initial wetwell airspace volume	127,860 ft^3	127,860 ft^3	129,300 ft^3 (page E1-7, item 3.c.2)
Initial drywell pressure	15.5 pounds per square inch, absolute (psia)	17 psia	17 psia (page E1-5, item 2.b.6)
Initial drywell relative humidity	50%	20%	20% (page E1-5, item 2.d.5)
Initial wetwell pressure	14.4 psia	15.9 psia	15.9 psia (page E1-7, item 3.d.6)

RESPONSE:

The parameter values in Reference 3, Enclosure 1, were provided to the NRC in a TVA submittal dated April 10, 2009, "Browns Ferry Nuclear Plant (BFN) - Units 1, 2, And 3 – Technical Specifications (TS) Changes TS-431 and TS-418 - Extended Power Uprate (EPU) - Transmittal of Containment Parameters and Total Shutdown Power Fractions" (ADAMS Accession Number ML091060381) that transmitted the values used as inputs in the original Safety Analysis for the Power Uprate containment analyses for the design basis LOCA analyses in the original license amendments referenced above. Special events analyses such as Appendix R (and subsequently the NFPA 805 analyses) use realistic values for some input parameters as discussed in the response to SCVB RAI-4 (in this enclosure). A discussion of each of the input parameters listed in the NRC RAI is provided below.

<u>Initial Suppression Pool Volume Corresponding to Minimum Suppression Pool Level</u>

The initial suppression pool volume of 122,940 ft^3 used in both the Appendix R analysis and in the NFPA 805 analysis Cases 1, 2, and 3 is the volume of water in the suppression pool corresponding to the Technical Specifications minimum pool level with a minimum drywell-to-wetwell pressure differential established. A smaller, more conservative pool volume value of 121,500 ft^3 has traditionally been used in the BFN LOCA analyses.

Initial Wetwell Airspace Volume

The 127,860 ft^3 wetwell airspace volume used in both the Appendix R analysis and in the NFPA 805 analysis Cases 1, 2, and 3 is the total suppression chamber volume less the 122,940 ft^3 volume occupied by the initial suppression pool water volume. The 129,300 ft^3 wetwell airspace volume used in the LOCA analyses is the total suppression chamber total suppression chamber volume less the 121,500 ft^3 used as the initial pool volume in the LOCA analyses.

Initial Drywell Pressure

The Appendix R NPSH analysis and the NFPA 805 NPSH analyses Cases 1 and 3 use 15.5 psia pressure for initial drywell pressure. This value corresponds to the minimum assumed wetwell pressure of 14.4 psia (i.e., atmospheric pressure) plus the minimum 1.1 psia differential pressure between the drywell and wetwell. Minimum initial containment pressures (i.e., drywell and wetwell) are used to minimize noncondensible gases in the containment and minimize wetwell pressure for NPSHa. This does not affect the NPSH calculation because CAP is not credited.

For the LOCA analyses, a separate containment analysis was performed to show the containment design limits (e.g., pressure and temperature) were not exceeded. This analysis used the higher initial drywell pressure of 17 psia as an initial condition for conservatism to maximize containment pressure. For LOCA NPSHa calculations, the LOCA analyses used the same 15.5 psia/14.4 psia initial conditions that are used in the Appendix R NPSHa analysis and NFPA 805 NPSHa analysis Cases 1 and 3.

NFPA 805 Case 2 uses the higher LOCA analyses initial condition of 17 psia to maximize drywell temperature and pressure. Case 2 is not limiting for suppression pool temperature and does not affect the NPSH calculation because CAP is not credited, but is bounding for drywell temperature as described in the response to SCVB RAI-7 (in this enclosure).

Initial Drywell Relative Humidity (RH)

For the Appendix R NPSH analysis and the NFPA 805 NPSH analyses Cases 1 and 3, an RH value of 50% is used. This value is based on a TVA parametric analysis that concluded that the maximum RH that could exist in the drywell without producing condensation in excess of allowable Technical Specifications unidentified leakage limits is 45.5%. Maximum initial drywell RH is used to minimize noncondensible gases in the containment and minimize wetwell pressure for NPSHa. This does not affect the NPSH calculation because CAP is not credited.

For the LOCA analyses, a separate containment analysis was performed to show the design limits (e.g., pressure and temperature) were not exceeded. This analysis used a low RH of 20% as an initial condition for conservatism to maximize containment pressure. A low RH increases the initial amount of noncondensible gases in containment, which maximizes the analyzed peak containment pressure. For NPSHa calculations, the LOCA analyses also used a maximum value of 50%, or in some cases a more conservative value of 100%.

NFPA 805 Case 2 uses a lower RH of 20% to maximize drywell temperature and pressure. Case 2 is not limiting for suppression pool temperature and does not affect the NPSHa calculation because CAP is not credited, but is bounding for drywell temperature as described in the response to SCVB RAI-7 (in this enclosure).

Initial Wetwell Pressure

The Appendix R NPSH analysis and the NFPA 805 NPSH analyses Cases 1 and 3 use 14.4 psia pressure for initial wetwell pressure. This value corresponds to the minimum assumed wetwell pressure of 14.4 psia (i.e., atmospheric pressure). Minimum initial containment pressures (i.e., drywell and wetwell) are used to minimize noncondensible gases in the containment and minimize wetwell pressure for NPSHa. This does not affect the NPSH calculation because CAP is not credited.

For the LOCA analyses, a separate containment analysis was performed to show the containment design limits (e.g., pressure and temperature) were not exceeded. This analysis used the higher initial wetwell pressure of 15.9 psia as an initial condition for conservatism to maximize containment pressure. For NPSHa calculations, the LOCA analyses used the same 15.5 psia/14.4 psia initial conditions that are used in the fire analyses.

NFPA 805 Case 2 uses the higher LOCA initial condition of 15.9 psia to maximize drywell temperature and pressure. Case 2 is not limiting for suppression pool temperature and does not affect the NPSH calculation because CAP is not credited, but is bounding for drywell temperature as described in the response to SCVB RAI-7 (in this enclosure).

SCVB RAI-9

Referring to the parameters in SCVB RAI-8, explain how the following input parameters to the cases analyzed are conservative for minimizing the available NPSH for the RHR pumps.

(a) Initial suppression pool volume corresponding to minimum suppression pool level
(b) Initial drywell pressure
(c) Initial drywell temperature
(d) Initial drywell relative humidity
(e) Initial wetwell pressure
(f) Initial wetwell temperature
(g) Initial wetwell relative humidity

RESPONSE:

Discussions are provided below for each of the above input parameters and the basis for conservatism in the value. Because no credit is taken for CAP in the NFPA 805 NPSH analyses, suppression pool water temperature is the only output from the containment analysis that is used to calculate NPSHa. Therefore, of the listed parameters, NPSHa is sensitive only to the initial suppression pool volume and the initial suppression pool temperature. Initial containment pressures, airspace volumes and temperatures, and RH are not important factors in calculating the peak suppression pool temperature and the non-CAP credited RHR pump NPSHa. However, inputs are still chosen to minimize CAP in Cases 1 and 3 where NPSHa is of interest.

(a) Initial suppression pool volume corresponding to minimum suppression pool level

The initial suppression pool volume corresponding to minimum suppression pool level used in the NFPA 805 analyses is 122,940 ft^3. This corresponds to the Technical Specifications minimum allowed suppression pool volume with a minimum drywell-to-wetwell differential pressure of 1.1 psia established. Using a minimum suppression pool volume is conservative because a minimum volume (i.e., heat sink) results in higher peak suppression pool water temperatures.

(b) Initial drywell pressure

The initial drywell pressure used in NFPA 805 Cases 1 and 3 is 15.5 psia. This value corresponds to the minimum wetwell pressure of 14.4 psia (i.e., atmospheric pressure) plus a minimum 1.1 psia differential pressure between the drywell and wetwell. Minimum initial containment pressures (i.e., drywell and wetwell) are conservative because they minimize noncondensible gases in the containment and minimize wetwell pressure for NPSHa. This does not affect the NPSH calculation because CAP is not credited.

(c) Initial drywell temperature

The initial drywell temperature used in the NFPA 805 analyses is 150ºF, which is the highest drywell temperature allowed by Technical Specifications. A high drywell temperature is conservative because the capacity of the drywell components to act as heat sinks is minimized, which increases peak suppression pool temperature.

(d) Initial drywell relative humidity

The initial drywell RH used in NFPA-805 Cases 1 and 3 is 50% and in NFPA 805 Case 2 is 20%. For Cases 1 and 3, where RHR pump NPSH is of interest, higher initial RH values are more conservative because high RH reduces the amount of noncondensible gases in containment and reduces containment pressure during the event. The 50% maximum RH value is based on a TVA parametric analysis that concluded that the maximum RH that could exist in the drywell without producing condensation in excess of allowable Technical Specifications unidentified leakage limits is 45.5%. NFPA 805 Case 2 uses a low RH to maximize drywell temperature. Case 2 is not limiting for suppression pool temperature and the RH value does not affect the NPSH calculation because CAP is not credited.

(e) Initial wetwell pressure

Initial wetwell pressure is assumed to be at its minimum of 14.4 psia (i.e., atmospheric pressure). Minimum initial containment pressures (i.e., drywell and wetwell) are conservative because they minimize noncondensible gases in the containment and minimize wetwell pressure for NPSHa. This does not affect the NPSH calculation because CAP is not credited.

(f) Initial wetwell temperature

The initial wetwell airspace temperature in the NFPA 805 analyses is 95ºF. The wetwell airspace is assumed to be in equilibrium with suppression pool water at the highest temperature allowed by Technical Specifications (i.e., 95ºF). This is conservative because a high initial air temperature reduces the amount of noncondensible gases and reduces containment pressure during the event. This does not affect the NPSH calculation because CAP is not credited.

(g) Initial wetwell relative humidity

The initial wetwell RH is 100%. The wetwell airspace is in continuous contact with the suppression pool water so the RH approaches 100%. This is conservative because higher RH minimizes noncondensible gases and reduces containment pressure during the event. This does not affect the NPSH calculation because CAP is not credited.

REFERENCES

1. Letter from TVA to NRC dated March 27, 2013, "License Amendment Request to Adopt NFPA 805 Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants (2001 Edition) (Technical Specification Change TS-480)" (ADAMS Accession No ML13092A393)

2. Tennessee Valley Authority Browns Ferry Nuclear Plant Units 1, 2 and 3, "Transition to 10 CFR 50.48(c) - NFPA 805 Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants, 2001 Edition," dated March 27, 2013 (ADAMS Accession Number ML13092A392)

3. Letter from TVA to NRC dated April 10, 2009, "Browns Ferry Nuclear Plant (BFN) - Units 1, 2, And 3 – Technical Specifications (TS) Changes TS-431 and TS-418 - Extended Power Uprate (EPU) - Transmittal of Containment Parameters and Total Shutdown Power Fractions (TAC NOS. MD5262, MD5263, AND MD5264)" (ADAMS Accession Number ML091060381)

ENCLOSURE 2

Tennessee Valley Authority
Browns Ferry Nuclear Plant, Units 1, 2, and 3
TVA Responses to NRC Request for Additional Information - Fire Modeling

Fire Modeling (FM) RAI 01.01

By letter dated December 20, 2013 (ADAMS Accession No. ML13361A093), the licensee responded to FM RAI 01(b)(i) and stated that, "Only fire propagation to stacks immediately adjacent to the source have been modeled, in accordance with FAQ [Frequently Asked Question] 08-0049." Explain how "immediately adjacent" is defined in this context, and describe the sequence of ignition of the bottom tray and vertical fire propagation that was assumed for an adjacent stack.

RESPONSE:

The use of the term "immediately adjacent" trays is consistent with the guidance in FAQ 08-0049, Configuration 2 that defines "immediately adjacent" as "two adjacent vertical stacks of horizontal cable tray separated nominally in accordance with Regulatory Guide 1.75 where both of the tray stacks being modeled are located directly above a fire ignition source such that both trays would be either fully or at least partially immersed in the fire plume."

Ignition timing and flame propagation of adjacent stacks was modeled consistent with NUREG/CR-6850, Section R.4.2.2 for thermoset cables, i.e., fire propagation to the first (bottom) tray in the adjacent stack was assumed to occur concurrently with fire propagation to the third tray in the original stack.

For thermoplastic cables, fire propagation to the first tray in an adjacent stack was assumed to occur one minute after ignition of the first tray in the original stack. Subsequent trays in the adjacent stack were assumed to mimic continued fire growth in the first stack, at one minute intervals.

FM RAI 02.01

By letter dated December 20, 2013 (ADAMS Accession No. ML13361A093), the licensee responded to FM RAI 02.c and referred to NUREG/CR-6850, "EPRI [Electric Power Research Institute]/NRC-RES [Office of Nuclear Regulatory Research] Fire PRA [Probabilistic Risk Assessment] Methodology for Nuclear Power Facilities," Appendix Q, Section Q.2.2 to substantiate the damage delay time that was assumed for the covered trays. However, the delay time that is recommended in NUREG/CR-6850, Section Q.2.2 should only be used for qualified cable. Confirm that all cables for which the delay time in NUREG/CR-6850 was used are qualified cables. If any cables for which the delay time in NUREG/CR-6850 was used are not qualified cables, provide a technical justification for the delay time assumed.

RESPONSE:

All cables that use the delay time guidance in NUREG/CR-6850, Section Q.2.2, are qualified cables.

Covered trays containing unqualified cables are credited with a delay time of four minutes. This 4-minute delay time is based on the test results that are documented in NUREG/CR-0381, "A Preliminary Report on Fire Protection Research Program Fire Barriers and Fire Retardant Coatings Tests." No tests that were performed on PVC (i.e., unqualified) cables with a solid bottom tray and no coating had a time to electrical short or a time to ignition that was less than four minutes.