**Tennessee Valley Authority,** Sequoyah Nuclear Plant, P.O. Box 2000, Soddy Daisy, Tennessee 37384

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10 CFR 50.4
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ATTN: Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

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

Subject: **10 CFR 50.46 Annual Report for Sequoyah Nuclear Plant, Units 1 and 2**

Reference: Letter from TVA to NRC, "10 CFR 50.46 30-Day Report for Sequoyah Nuclear Plant, Units 1 and 2," dated January 18, 2018 (ML18018B158)

The purpose of this letter is to provide the annual report of changes or errors in the emergency core cooling system (ECCS) evaluation model for Sequoyah Nuclear Plant (SQN), Units 1 and 2. In accordance with Title 10 of the Code of Federal Regulations (10 CFR) 50.46, "Acceptance Criteria for ECCS for Light-Water Nuclear Power Reactors," paragraph (a)(3)(ii), the enclosure to this report describes the nature of the change or error and its estimated effect on the limiting ECCS analysis for SQN Units 1 and 2.

There have been no changes made to the calculated peak cladding temperature (PCT) since the submittal of the referenced letter.

10 CFR 50.46(a)(3)(ii) also requires the licensee to provide a proposed schedule for providing a reanalysis or taking other action as may be needed to show compliance with the 10 CFR 50.46 requirements. The enclosure demonstrates that the updated net licensing basis PCT for the large break loss-of-coolant accident is below the 10 CFR 50.46(b)(1) PCT limit of 2200°F. Therefore, TVA has concluded that no proposed schedule for providing reanalysis or other action is required, and no further action is required to show compliance with 10 CFR 50.46 requirements.

There are no new regulatory commitments associated with this submittal. Should you have any questions, please contact Jonathan Johnson, SQN Site Licensing Manager, at (423) 843-8129.

Respectfully,

Anthony L. Williams
Site Vice President
Sequoyah Nuclear Plant

Enclosure: 10 CFR 50.46 2018 Annual Report of Changes in PCT

cc:

NRC Regional Administrator - Region II
NRC Senior Resident Inspector - Sequoyah Nuclear Plant
NRC Project Manager - Sequoyah Nuclear Plant

**ENCLOSURE**

**TENNESSEE VALLEY AUTHORITY (TVA)**
**SEQUOYAH NUCLEAR PLANT (SQN)**
**UNITS 1 AND 2**

**10 CFR 50.46 2018 ANNUAL REPORT OF CHANGES IN PCT**

The loss of coolant accident (LOCA) analyses of record (AORs) are detailed in Topical Reports ANP-2970(P) and ANP-2970Q1(P), “Sequoyah Units 1 and 2 HTP Fuel Realistic Large Break LOCA Analysis,” and ANP-2971(P), “Sequoyah Units 1 and 2 HTP Fuel S-RELAP5 Small Break LOCA Analysis.” These reports were submitted to the Nuclear Regulatory Commission (NRC) as part of SQN Technical Specifications (TS) Change TS-SQN-2011-07 to modify the TS to authorize the use of AREVA High Thermal Performance (HTP) fuel assemblies. The TS change associated with the HTP fuel design and supporting documentation were approved by NRC as documented in the associated Safety Evaluation dated September 26, 2012 (Reference 1).

Table 1 details the changes in the calculated peak cladding temperature (PCT) currently applied to the AOR PCTs. The changes in PCTs since the previous 10 CFR 50.46 Annual Report (Reference 2)[A1] are summarized for SQN Unit 1 and Unit 2 as follows:

- The calculated PCT in the Large Break LOCA (LBLOCA) increased 61°F to a new licensing basis PCT of 2001°F.

- The calculated PCT in the Small Break LOCA (SBLOCA) analysis remains unchanged, with a current licensing basis PCT of 1543°F.

**TABLE 1**

Summary of Changes in LOCA PCTs for Sequoyah Units 1 and 2

| Report Year | Description | LBLOCA PCT (°F) | Change in LBLOCA PCT (°F) | SBLOCA PCT (°F) | Change in SBLOCA PCT (°F) | Notes |
|---|---|---|---|---|---|---|
| 2013 | **New AORs** for AREVA HTP fuel: ANP-2970(P) Rev. 0, ANP-2970Q1(P), Rev. 0, and ANP-2971(P), Rev. 1 | **1950** | ------- | **1470** | ------- | 1 |
| 2012 | Sleicher–Rouse heat transfer correlation equation error | ------- | ------- | ------- | -89 | 2 |
| 2013 | Cathcart-Pawel uncertainty correlation error in RLBLOCA applications | ------- | 0 | ------- | ------- | 3 |
| 2013 | RODEX3a error in treatment of “trapped stack” condition | ------- | -10 | ------- | ------- | 4 |
| 2014 | S-RELAP5 vapor absorptivity correlation | ------- | 0 | ------- | +11 | 5 |
| 2014 | Axial power shape mapping by modal decomposition | ------- | 0 | ------- | ------- | 6 |
| 2015 | Operator action time allowance for restarting the high head ECCS pumps when transferring the pump suctions from the RWST to the containment sump. | ------- | ------- | ------- | +151 | 7 |
| 2017 | M5® LOCA Swelling and Rupture Model (SRM) Update | ------- | 0 | ------- | 0 | 8 |
| 2018 | Higher metal water reaction rate | ------- | +61 | ------- | 0 | 9 |
| **2018** | **Updated Licensing Net PCT** $AOR\ PCT + \sum \Delta\ PCT$ | **2001** | **+51** | **1543** | **+73** | ------- |
| | **Cumulative sum of PCT changes** $\sum\lvert \Delta\ PCT \rvert$ | ------- | **71** | ------- | **251** | ------- |

Notes:

1) New AOR ECCS PCT associated with the use of AREVA W17 HTP Fuel at SQN

   The current SQN, Units 1 and 2, AORs for the AREVA W17 Advanced HTP fuel design are detailed in Topical Reports ANP-2970(P) and ANP-2970Q1(P), "Sequoyah Units 1 and 2 HTP Fuel Realistic Large Break LOCA Analysis," and ANP-2971(P), "Sequoyah Units 1 and 2 HTP Fuel S-RELAP5 Small Break LOCA Analysis." These AORs constitute a reanalysis of the ECCS evaluation models. As such, the cumulative sums of the absolute magnitudes of the PCT changes for both units have been restored to zero for 10 CFR 50.46(a)(3)(ii) reporting purposes. Subsequent changes and errors that affect PCT are detailed in Table 1 of this enclosure.

2) S-RELAP5 Sleicher-Rouse heat transfer correlation equation error

   Sleicher-Rouse is a mathematical correlation used in the S-RELAP computer code for predicting convective heat transfer between the fuel and coolant single-phase vapor. This correlation is applicable to both the LBLOCA and SBLOCA analyses performed with S-RELAP5. During a review of the behavior of the Sleicher-Rouse correlation relative to other single-phase vapor heat transfer correlations, an error was discovered in the form of the correlation used in the S-RELAP5 implementation. The difference is related to the form of the equation for calculating the exponent of the temperature ratio correction term. The S-RELAP form of the Sleicher-Rouse heat transfer correlation has been updated to:

$$n = -[\log 10(Tw/Tg)]^{1/4} + 0.3$$

   This correction resulted in a 35°F reduction in LBLOCA PCT for SQN Units 1 and 2. However, this 35°F reduction in PCT was described in ANP-2970Q1(P) and acknowledged as being included in the analysis by NRC in the Safety Evaluation Report approving SQN Technical Specifications (TS) Change TS-SQN-2011-07. The 35°F reduction for Sleicher-Rouse is therefore applied and reflected in the stated 1950°F AOR PCT for the LBLOCA.

   Correction of the Sleicher-Rouse error in the SBLOCA was not similarly discussed and incorporated during the license amendment process for HTP fuel and therefore is not reflected in the stated AOR value (1470 °F). Instead, the Sleicher-Rouse adjustment for the SBLOCA (-89°F) is explicitly applied to the AOR PCT, as shown in Table 1.

3) Cathcart-Pawel uncertainty correlation error in RLBLOCA applications

   For Realistic LBLOCA (RLBLOCA) analyses, the rate-dependent correlation developed by Cathcart-Pawel is used to model the metal-water reaction during a LOCA. The rate constants for the Cathcart-Pawel equation are determined experimentally and the data are subjected to a statistical analysis to determine the relevant uncertainty parameters for the derived correlation. The RLBLOCA analysis uses a log-normal function for the uncertainty multiplier applied to the rate constant. The formula and standard deviation were found to be incorrect.

   Analysis of the error confirmed that the effect on previous RLBLOCA analyses was negligible. There is no change to the LBLOCA PCT value for SQN, Units 1 and 2, from this error. This error did not apply to the SBLOCA analysis.

4) RODEX3a error in treatment of “trapped stack” condition

A “trapped stack” condition exists when any fuel rod contains a gap dimension that is calculated to be less than 0.5 mil with open gaps lying at lower axial levels. If this condition exists, then a trapped stack model is applied. However, a coding error was identified that essentially deactivated the trapped stack model. Although the effect of this error is small, it was determined that it could be conservative or non-conservative depending on the steady-state initial stored energy.

A development version of S-RELAP5 was prepared with the correct evaluation of the trapped stack model and several code validation and plant sample problems were repeated. Analysis of the identified coding error using this updated version of S-RELAP5 determined that it was conservative for SQN and resulted in a 10°F reduction in PCT for the LBLOCA. This error is not applicable to the SBLOCA analysis because it uses RODEX2 rather than RODEX3a.

5) S-RELAP5 vapor absorptivity correlation

The vapor absorptivity correlation applied to the S-RELAP5 based methodologies used in S-RELAP5 was being applied outside of its intended range of applicability. Specifically, there was no limit on the pressure at which the correlation was applied. The correlation is provided in the S-RELAP5 Models and Correlation Code Manual. The equation used for the absorption coefficient of vapor contains the pressure term that is truncated in order to obtain the correct emissivity values for an optically thick steam. No lower pressure limit on the vapor absorptivity correlation is required as the correlation is developed for optically thin gases, which already applies at low pressures. Results show that limiting the vapor absorptivity correlation to within its intended pressure range allows S-RELAP5 to predict the wall temperatures for the Thermal-Hydraulic Test Facility within the uncertainty bands or above the uncertainty bands (conservative). A development version of S-RELAP5 was prepared containing the pressure limit for the calculation of the vapor absorptivity in order to assess the effect on the current AOR for SBLOCA. The PCT increase was developed by comparing the AOR after the Sleicher-Rouse error correction with the new PCT results obtained with the corrected version of S-RELAP5. The limiting case and multiple break sizes around the limiting case were rerun with the developmental code version of S-RELAP5.

For RLBLOCA, single phase steam only exists for a very limited time just before the beginning of reflood. During the majority of the blowdown phase and during the entire reflood phase, which are the important RLBLOCA phases, the core is in a dispersed flow regime. The S-RELAP5 methodology uses the FLECHT-SEASET reflood tests to determine the heat transfer bias and uncertainty under these conditions. In addition, the transient progression is quick and the system depressurizes in the first few seconds after the break opening. As a result of the fast depressurization, the amount of time that the correlation for vapor absorptivity used in RLBLOCA is applied outside of the range of applicability is limited and therefore the results predicted in the AOR remain valid.

The estimated effect of this change on the SQN Unit 1 and Unit 2 SBLOCA analysis calculated peak cladding temperature is +11°F.

6) Axial power shape mapping by modal decomposition

In 2014, AREVA identified the axial power shapes being used in the LBLOCA analysis were significantly different from the shapes predicted by the core design. These shapes are dependent on the time in cycle and cover both top and bottom peaked shapes. The shapes are generated in a 24-node format and the methodology selects an axial shape based on a sampled time in cycle, a sampled skew (i.e., top/bottom) and a sampled heat flux hot channel factor. Two bounding axial curves are determined from the sorted axial shapes and then a 24-node shape is interpolated between the two bounding curves. The 24-node axial power shape is subsequently mapped to the number of heat structure nodes and elevation points required by S-RELAP5 (40 to 52 nodes). The mapping procedure used is called modal decomposition and it uses a set of orthogonal sine functions to perform the mapping.

In the evaluation for this issue, the mapping of the axial power shapes generated by the modal decomposition method was compared to a linear interpolation method for mapping the axial power shapes. It was concluded that linear interpolation provides a significantly better fit for the axial shapes. Although modal decomposition does not represent the axial shapes as well, it remains conservative for the case set performed for the SQN AOR.

The effect of this change on the SQN Unit 1 and Unit 2 LBLOCA analysis calculated peak cladding temperature is 0°F. The SBLOCA analysis is unaffected by this error.

7) Operator action time allowance for restarting the high head ECCS pumps when transferring the pump suctions from the refueling water storage tank (RWST) to the containment sump.

The design of the ECCS provides for automatic transfer of the low head ECCS pump suctions from the RWST to the containment sump. The transfer of the high head ECCS pump suctions from the RWST to the containment sump is a manual action. During the automatic transfer of the low head ECCS pump suctions from the RWST to the containment sump, a postulated failure to close of one of the RWST supply isolation valves results in the need to shutdown the high head ECCS pumps until their suctions can be aligned to the containment sump.

The effect of this interruption of the high head ECCS pump injection on the SQN Unit 1 and 2 SBLOCA analysis calculated peak cladding temperature is 151°F. The LBLOCA analysis is unaffected by this interruption of the high head ECCS pump injection.

8) Update to the M5® LOCA Swelling and Rupture Model

AREVA updated the M5® LOCA Swelling and Rupture Model (SRM). The SRM was approved by the NRC in the early 2000s as part of the M5® Licensing Topical Report, BAW-10227, Rev. 1 (P)(A). Additional M5® cladding rupture test data has been obtained since the model's approval. Upon review of the data and the SRM's use in LOCA analysis, it was determined that certain of aspects of the model would need to be revised. Following the same approach as was used to develop the original model, an updated SRM was developed to take into account the additional M5® cladding rupture test data. The model changes do not change the predicted occurrence or conditions at the time of rupture, but do affect the post-rupture cladding characteristics for certain rupture temperatures.

The change in the SRM on the SQN Unit 1 and 2 RLBLOCA and SBLOCA calculated PCT is 0°F.

9) Higher metal water reaction rate

In 2017, an error was discovered in the S-RELAP5 calculations of oxidation due to high temperature metal-water reaction. In a LOCA event, the cladding can swell (and potentially rupture) due to the difference in pressure between the fuel and the system which causes the clad to thin. The clad radius increases, while the thickness decreases. It was discovered that the S-RELAP5 oxidation calculations used cold cladding dimensions and therefore, did not fully account for the swelling phenomena. The error can lead to an under-prediction of the oxidation and heat from the metal-water reaction.

The evaluation of the licensing basis analysis, inclusive of previous analysis errors and changes yielded an increase to the LBLOCA PCT of 61°F. The SBLOCA PCT was estimated to increase by 0°F. These PCT changes were previously reported in Reference 3.

References:


1. NRC letter to TVA, "Sequoyah Nuclear Plant, Units 1 and 2 - Issuance of Amendments to Revise the Technical Specification to Allow Use of AREVA Advanced W17 High Thermal Performance Fuel (TS-SQN-2011-07) (TAC Nos. ME6538 and ME6539)," dated September 26, 2012 [ML12249A394, ML12249A415]

2. TVA letter to NRC, CNL-17-145, “10 CFR 50.46 Annual Report for Sequoyah Nuclear Plant, Units 1 and 2,” dated November 28, 2017 [ML17332A033]

3. TVA letter to NRC, “10 CFR 50.46 30-Day Report for Sequoyah Nuclear Plant, Units 1 and 2,” dated January 18, 2018 [ML18018B158]