ENCLOSURE 2

TENNESSEE VALLEY AUTHORITY
SEQUOYAH NUCLEAR PLANT
UNITS 1 AND 2

ANP-2970Q1(NP), Revision 000, Sequoyah Units 1 and 2 HTP Fuel Realistic Large Break LOCA Analysis, April 2012 (Non-Proprietary Version)

ANP-2970Q1(NP)
Revision 000

Sequoyah Units 1 and 2 HTP Fuel Realistic Large Break LOCA Analysis

April 2012

AREVA NP Inc.

AREVA

Nature of Changes

Item	Page	Description and Justification
1.	All	This is a new document.

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1.0 INTRODUCTION

AREVA NP Inc. produced an application of the NRC-approved Realistic Large Break Loss-of-Coolant Accident (RLBLOCA) analysis for the Sequoyah Nuclear (SQN) Plant, Units 1 and 2. SQN is a Westinghouse 4-loop design with a rated thermal power of 3455 Mega Watt Thermal (MWt). The plant containment building is comprised of lower and upper compartments separated by an ice-condenser. Implementation of a full core of AREVA NP 17x17 HTP fuel design at SQN is simulated in the analysis.

SQN operation at a safety analysis power level of 3479 MWt (rated thermal power plus uncertainty), a steam generator tube plugging level of up to 15 percent (%) in all steam generators, a total peaking factor (F_Q) of up to 2.65 (including uncertainty) and a nuclear enthalpy rise factor ($F_{\Delta H}$) of 1.7056 (including uncertainty) with no axial or burnup dependent power peaking limit is supported by the analysis. The analysis demonstrates compliance with regulatory requirements for large break via application of an NRC-approved evaluation methodology (EM) (Ref. 1), predicting acceptable peak cladding temperature, oxidation thickness, and hydrogen generation (Summary Report (Ref. 2)).

Tennessee Valley Authority submitted the RLBLOCA Summary Report to the NRC for review. Section 2.0 contains AREVA NP Inc.'s responses to NRC comments and Section 3.0 provides a summary of this document with recent peak clad temperature (PCT) rackup.

2.0 NRC REVIEW COMMENTS AND AREVA NP'S RESPONSES

2.1 NRC Question 1.

Reference: ANP-2970(P): RAI on Consideration of Fuel Clad Rupture Discussed in Ch. 6

For the subject LAR, the licensee omitted a clad ballooning and rupture model, citing qualitative considerations of the heating and cooling effects of cladding rupture.

The NRC staff position is that rupture, when evaluated in consideration of the limited, but widely ranging data concerning the amount of fuel relocation possible, the heating effects can outweigh the cooling effects when fuel relocation is considered using a bounding assessment. Therefore, it is necessary to consider high fuel relocation packing fractions, either in an explicit uncertainty treatment, or in a bounding sense. If fuel relocation to an 80% packing fraction is considered, the cladding surface will heat more if the fuel clad ruptures.

The NRC staff wants TVA to re-confirm the assessment for SQN that concluded that blowdown and refill ruptures did not occur, and to re-evaluate its assessment for later fuel cladding ruptures using quantitative information that considers the specific cases analyzed for SQN, and also high fuel relocation packing fractions. An accordant treatment of cladding oxidation will also be requested.

<u>Response:</u>

The base case results of ANP-2970 (Ref. 2) are compared with the results sensitivity studies characterizing swelling rupture and relocation (SRR) of fuel fragments in Table 2-1. The SRR sensitivity case applies an 80% packing factor, as requested, and takes no credit for the droplet shatter model (cooling effects). The full [ ] case set is reanalyzed with the same statistical seed that was used in the base analysis in ANP-2970. The limiting cases for the base case and the SRR sensitivity study are compared and indicate an increase in peak cladding temperature (PCT) with a small increase in the transient maximum local oxidation and a small decrease in the core-wide oxidation. With the addition of SRR effects, however, the limiting case has changed, from [ ].

It is widely recognized that, physically, there would be some cooling as a result of steam de-superheating via droplet shattering against the intruding rupture and a related heat transfer enhancement. This cooling mechanism is not credited in the SRR sensitivity studies. It is also recognized that the packing factor of 80% is not anticipated to occur in the SQN RLBLOCA cases due to the M5® cladding strains observed in the rupture cases.

For a statistical analysis with [
] highest PCT (Section 5.2 of the EM (Ref. 1)). Of the [ ] cases, only four cases in the SRR sensitivity study resulted in PCT greater than 1800 degrees Farenheit (^{o}F) as evidenced

in Figure 2-1. None of the cases of the SRR sensitivity study resulted in cladding rupture occurrence within the blowdown period. The earliest ruptures do, however, coincide approximately with the beginning of core recovery.

Figure 2-2 illustrates the rupture node cladding temperature response for the limiting case (41) associated with the SRR sensitivity study. In the figure, comparison is made with Case 41 of the base-case analysis in ANP-2970 (Ref. 2). Hot pin pressure is also plotted in this figure to indicate the time of rupture. The cladding ruptures at approximately 50 seconds, relocating fuel and increasing power locally. Cladding heatup at ~50 to ~90 seconds increases significantly as a result of SRR. At present, only the heat load associated with fuel relocation is considered in the fuel rod heat conduction solution. Mass addition at the rupture location is conservatively ignored. The clad heatup rate is artificially high during adiabatic heatup as a result of this conservatism. Figure 2-3 is included to demonstrate successful clad quenches for the Case 41.

Table 3-1 contains the resulting PCT including penalty that results from the position recommended by NRC Question 1.

Table 2-1: Results of Swelling, Rupture and Relocation Sensitivity Study, Packing Fraction = 0.8

Figure 2-1: Histogram of Cases for the SRR Sensitivity Studies

Figure 2-2: Rupture Node Cladding Temperature Response for Limiting SRR Case 41

Figure 2-3: Rupture Node Cladding Temperature Response for Limiting SRR Case 41, To Quench

2.2 NRC Question 2.

The NRC staff also wants to ask TVA about Figure 3-19 of ANP-2970(P), which shows a decreasing downcomer liquid level from 700-800s. The NRC staff would like to know what is causing the negative trend, and to confirm that it does not continue beyond the analyzed period.

Response:

Figure 3-19 of Reference 2 shows an increase in downcomer collapsed liquid level from 250 seconds to about 700 seconds. After 700 seconds, the level first increases slightly then decreases through transient termination (800 seconds). This trend coincides approximately with the time that the core quenches. The core quench reduces the steam temperature and the flow to the break. This causes a reduction in the containment pressure. Subsequently, the downcomer level increases.

The mixture of water and steam in the downcomer rises up to the level of the break and part of the mass is lost through the break. Thus, the level decreases. Once the containment pressure stabilizes, the flow through the break also stabilizes. The level in the downcomer then starts to rise slowly from ~800 seconds. The perturbation in the downcomer level transient is brief, occurring over a limited time period.

The transient was re-run to extend transient termination to 1200 seconds. Downcomer liquid level is stable-to-increasing out to termination as illustrated in Figure 2-4. A better measure of a stable cooling inventory is the reactor vessel mass. Figure 2-5 shows that that water from the Emergency Core Cooling System (ECCS) is sufficient to slowly fill the vessel and maintain core covery.

Figure 2-4: Downcomer Liquid Level for the Limiting Case, Extended Transient

Figure 2-5: Reactor Vessel Liquid Mass for the Limiting Case, Extended Transient

2.3 Sleicher-Rouse Error Adjustment

The Sleicher-Rouse heat transfer correlation is used in S-RELAP5 for predicting convective heat transfer to single-phase vapor. An error was discovered in the coding of the correlation and the S-RELAP5 form of the Sleicher-Rouse heat transfer correlation is now updated as follows:

$$n = -[\log10(Tw/Tg)]1/4 + 0.3$$

[

] This approach leads to a reduction in PCT of 35 °F for SQN.

Note that the effect of the Sleicher-Rouse error has been evaluated for other recent RLBLOCA applications and included in previous responses to NRC questions, notably Reference 3.

3.0 SEQUOYAH PCT SUMMARY

Table 3-1 reports the RLBLOCA PCT rackup for SQN, beginning fuel cycle 19. The basis of the rackup is the limiting case from ANP-2970 (Ref. 2). The maximum PCT assessment possible for the range of sensitivities examined for swell, rupture, and relocation (see NRC Question 1, Section 2.1) is applied. Also included in the rackup is the AREVA PCT assessment for an error in the S-RELAP5 application of the Sleicher-Rouse correlation for heat transfer from the cladding surface to vapor in the coolant channel (see Section 2.3). The rackup leads to a total net PCT of 1950 °F for SQN.

Table 3-1: SQN PCT Rackup

Source	PCT (°F)
ANP-2970(P) Revision 0	1941
Maximum Assessment for Swell, Rupture, Relocation	+44
UFSAR Analysis of Record PCT	1985
Sleicher Rouse 10CFR50.46 Error Assessment	-35
Updated Licensing Net PCT	1950

4.0 REFERENCES

1. EMF-2103(P)(A) Revision 0, "Realistic Large Break LOCA Methodology," Framatome ANP, Inc.
2. ANP-2970(P) Revision 0, "Sequoyah Units 1 and 2 HTP Fuel Realistic Large Break LOCA Analysis."
3. ANP-3011Q1(NP) Revision 000, "Harris Nuclear Plant Unit 1 Realistic Large Break LOCA Analysis," Enclosure 4 Response to Request for Additional Information (Non-Proprietary) ADAMS Accession Number ML12067A180.

ENCLOSURE 3

TENNESSEE VALLEY AUTHORITY
SEQUOYAH NUCLEAR PLANT
UNITS 1 AND 2

AREVA NP Affidavit

Attached is the affidavit supporting the request to withhold the proprietary information included in Enclosure 1 from public disclosure in accordance with 10 CFR 2.390, "Public inspections, exemptions, requests for withholding," paragraph (a)(4).

AFFIDAVIT

COMMONWEALTH OF VIRGINIA)
) ss.
COUNTY OF CAMPBELL)

1. My name is Gayle F. Elliott. I am Manager, Product Licensing, for AREVA NP Inc. (AREVA NP) and as such I am authorized to execute this Affidavit.

2. I am familiar with the criteria applied by AREVA NP to determine whether certain AREVA NP information is proprietary. I am familiar with the policies established by AREVA NP to ensure the proper application of these criteria.

3. I am familiar with the AREVA NP information contained in the "ANP-2970Q1(P) Revision 000, Sequoyah Units 1 and 2 HTP Fuel Realistic Large Break LOCA Analysis," and referred to herein as "Document." Information contained in this Document has been classified by AREVA NP as proprietary in accordance with the policies established by AREVA NP for the control and protection of proprietary and confidential information.

4. This Document contains information of a proprietary and confidential nature and is of the type customarily held in confidence by AREVA NP and not made available to the public. Based on my experience, I am aware that other companies regard information of the kind contained in this Document as proprietary and confidential.

5. This Document has been made available to the U.S. Nuclear Regulatory Commission in confidence with the request that the information contained in this Document be withheld from public disclosure. The request for withholding of proprietary information is made in accordance with 10 CFR 2.390. The information for which withholding from disclosure is

requested qualifies under 10 CFR 2.390(a)(4) "Trade secrets and commercial or financial information":

6. The following criteria are customarily applied by AREVA NP to determine whether information should be classified as proprietary:

(a) The information reveals details of AREVA NP's research and development plans and programs or their results.

(b) Use of the information by a competitor would permit the competitor to significantly reduce its expenditures, in time or resources, to design, produce, or market a similar product or service.

(c) The information includes test data or analytical techniques concerning a process, methodology, or component, the application of which results in a competitive advantage for AREVA NP.

(d) The information reveals certain distinguishing aspects of a process, methodology, or component, the exclusive use of which provides a competitive advantage for AREVA NP in product optimization or marketability.

(e) The information is vital to a competitive advantage held by AREVA NP, would be helpful to competitors to AREVA NP, and would likely cause substantial harm to the competitive position of AREVA NP.

The information in the Document is considered proprietary for the reasons set forth in paragraphs 6(b) and 6(c) above.

7. In accordance with AREVA NP's policies governing the protection and control of information, proprietary information contained in this Document has been made available, on a limited basis, to others outside AREVA NP only as required and under suitable agreement providing for nondisclosure and limited use of the information.

8. AREVA NP policy requires that proprietary information be kept in a secured file or area and distributed on a need-to-know basis.

9. The foregoing statements are true and correct to the best of my knowledge, information, and belief.

SUBSCRIBED before me this 20th

day of April 2012.

Kathleen A. Bennett
NOTARY PUBLIC, COMMONWEALTH OF VIRGINIA
MY COMMISSION EXPIRES: 8/31/2015
Reg. #110864

KATHLEEN ANN BENNETT
Notary Public
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My Commission Expires Aug 31, 2015