VIRGINIA ELECTRIC AND POWER COMPANY
RICHMOND, VIRGINIA 23261

September 26, 2003

U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, D.C. 20555

Serial No. 03-313F
NLOS/ETS
Docket Nos. 50-338/339
License Nos. NPF-4/7

VIRGINIA ELECTRIC AND POWER COMPANY (DOMINION)
NORTH ANNA POWER STATION UNITS 1 AND 2
PROPOSED TECHNICAL SPECIFICATIONS CHANGES AND EXEMPTION REQUEST FOR USE OF FRAMATOME ANP ADVANCED MARK-BW FUEL
SUPPLEMENTAL INFORMATION FOR REALISTIC LARGE BREAK LOSS OF COOLANT ACCIDENT (RLBLOCA) ANALYSIS RESULTS

In a May 6, 2003 letter (Serial No. 03-313), Dominion submitted the Realistic Large Break LOCA (RLBLOCA) results for Advanced Mark-BW fuel in North Anna Unit 2 to support the NRC's review of a proposed amendment and exemptions that will permit North Anna Units 1 and 2 to use Framatome ANP Advanced Mark-BW fuel. On August 20, 2003 (Serial No. 03-313A) Dominion provided a response to an August 6, 2003 NRC request for additional information regarding the RLBLOCA results. In an August 28, 2003 meeting to discuss the RLBLOCA analysis results, the NRC staff requested further clarification of Dominion's August 20, 2003 responses. Supplemental information for Questions 1, 5, 9, and 10b was provided on September 5, 2003 (Serial No. 03-313C) and Questions 6 and 11a on September 19, 2003 (Serial No. 03-313D). The attachment to this letter provides the requested clarification for Questions 2, 3, and 4. As noted in our August 20, 2003 letter, this information is applicable to both North Anna Units 1 and 2 even though the RAIs received were specific to Unit 2.

To support the use of Framatome Advanced Mark-BW fuel in North Anna Unit 2, Cycle 17, we respectfully request the NRC to complete their review and approval of the license amendment by October 31, 2003. We appreciate your consideration of our technical and schedular requests. If you have any questions or require additional information, please contact us.

Very truly yours,

Eugene S. Grecheck
Vice President - Nuclear Support Services

Attachment

A001

Commitments made in this letter: None

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SN: 03-313F
Docket Nos.: 50-338/339
Subject: Proposed TS Change – Supplemental Information
Framatome Fuel Transition - RLBLOCA

COMMONWEALTH OF VIRGINIA)
)
COUNTY OF HENRICO)

The foregoing document was acknowledged before me, in and for the County and Commonwealth aforesaid, today by Eugene S. Grecheck, who is Vice President - Nuclear Support Services, of Virginia Electric and Power Company. He has affirmed before me that he is duly authorized to execute and file the foregoing document in behalf of that Company, and that the statements in the document are true to the best of his knowledge and belief.

Acknowledged before me this 26th day of September, 2003.

My Commission Expires: March 31, 2004.

Maggie McClure
Notary Public

(SEAL)

Attachment 1

Supplemental Responses to Request for Additional Information
Questions 2, 3, and 4 of August 20, 2003 letter (Serial No. 03-313A)

Realistic Large Break LOCA Analysis Results – North Anna

Framatome Fuel Transition Program
Technical Specification Change

Virginia Electric and Power Company
(Dominion)
North Anna Power Station Units 1 and 2

Dominion Supplemental Responses to NRC Request for Additional Information
North Anna Realistic LBLOCA Analysis
Questions 2, 3, and 4 of August 20, 2003 letter (Serial No. 03-313A)

In an August 28, 2003 meeting, the NRC staff requested additional information to supplement the responses provided in Dominion's August 20, 2003 letter (Reference 1). The original questions and supplemental responses requested by NRC staff are provided below. The responses provided below are applicable to both North Anna Units 1 and 2, even though the RAIs received were specific to Unit 2.

A. APPLICABILITY OF ANALYTICAL MODELS

Many of the analytical models in the NAPS-2 best estimate LBLOCA methodology are supported by empirical data taken at temperatures less than 1700°F, and by sensitivity studies performed at temperatures less than 1700°F.

The RLBLOCA peak cladding temperature spectrum calculated for NAPS-2 using this methodology extends above 2000°F. At temperatures above 1700°F many of the principal phenomena which influence peak cladding temperature (PCT) change or increase in their influence (e.g., cladding oxidation rate), such that the data and sensitivity studies identified for cladding temperatures lower than 1700°F may not apply.

Q2. Prominent among the phenomena of concern is heat transfer from the rod to the coolant during the dispersed flow film-boiling regime. S-RELAP5 uses the Forslund-Rohsenow model, which was developed using data from a test with geometry and thermal hydraulic conditions that are non-prototypic of the NAPS-2 core. While this model was shown to have only a small effect below 1700°F, this has not been demonstrated for the higher temperatures predicted for the NAPS-2 calculation, which exceed 2000°F. Justify the applicability of the Forslund-Rohsenow model as it is used in the proposed NAPS-2 plant licensing basis methodology. (The S-RELAP5 topical report presented a sensitivity study of the Forslund-Rohsenow model to PCT and quench time to address this concern. However, the analyses for this study were at low temperatures, which are not prototypic of NAPS-2.)

Supplemental Response:

During a discussion with the NRC concerning the response to this question at the August 28, 2003 meeting, the NRC requested that the limiting North Anna Unit 2 RLBLOCA calculation be rerun penalizing the total hot rod-to-fluid heat transfer by neglecting rod-to-droplet heat transfer as modeled by the Forslund-Rohsenow correlation. Total hot rod-to-coolant (liquid and vapor) heat transfer is statistically treated in the Framatome ANP RLBLOCA methodology with a bias and uncertainty quantified from FLECHT-SEASET and THTF data. For the North Anna sensitivity case, the rod-to-droplet heat transfer component was set to zero—a bounding, non-physical condition. In this sensitivity study, only the rod-to-droplet heat transfer component was neglected. The rod-to-vapor heat transfer models for radiation and convection were not modified. The result from *this study was a PCT of 2,096°F. This is an increase of 64°F above the reported calculation. Neglecting the rod-to-droplet heat transfer delayed but did not prevent rod quench. The hot rod quenched at approximately 744 seconds compared to about 450 seconds in the original analysis.*

The primary component of the temperature increase is related to the decoupled nature of hot rod modeling in the RLBLOCA methodology. When modeled as decoupled rods, the hydraulic conditions do not reflect the steam de-superheating that would be expected. The FLECHT-SEASET sensitivity studies, presented in the RAI responses for the generic review, were not performed using decoupled rods. As such, these calculations showed the benefit of steam de-superheating on clad temperature.

Q3. The S-RELAP5 approval was based, in part, on assessment against separate and integral effects data. This assessment focused on those phenomena that would govern the PCT response during a LBLOCA transient. The correlations in the S-RELAP5 methodology that predict the evolution of these phenomena depend on a variety of thermal hydraulic parameters, such as temperature, pressure, mass flux, etc. Demonstrate that the range of these parameters covered by the assessment data bounds the range encountered in the NAPS-2 LBLOCA analyses.

Supplemental Response:

Different heat transfer regimes, heat transfer correlations used, and important parameter ranges for the limiting North Anna Unit 2 RLBLOCA case and the range of applicability are shown in Table 2-1. A detailed discussion regarding various heat transfer correlations, their range of applicability and the benchmarks used to validate the correlations are given in response to RAI Question 2 on EMF-2103. From Table 2-1, it can be seen that the parameters for the limiting case are within the range of applicability of the correlations. Although the initial pressure of 2,270 psia in the limiting case is slightly (20 psi) higher than in the LOFT benchmark case, the transient pressure at the time of CHF is within the application range of the Biasi correlation. Prandtl Number ranges are not supplied (Prandtl Number is a thermodynamic variable covered by system pressure and temperature). The range of applicability of vapor super heat is not discussed in the response to RAI Question 2. However, FLECHT-SEASET benchmark Tests 31805 and 31504 (Figures 4.43 and 4.50 in EMF - 2103) show that the maximum measured vapor super heat is more than 1,500°F, which is higher than the maximum vapor super heat in the North Anna limiting case.

As described in Section 3.2.1 in EMF-2100, the droplet diameter is calculated using a Weber number of 4.0, with a lower limit of 0.1 mm. This droplet diameter is used in calculating the interphase drag and heat transfer. For wall heat transfer calculations using the Forslund-Rohsenow correlation, the droplet size is limited to between 0.5 mm and 3.0 mm (see Section 4.7 of EMF-2100). As part of response to RAI Question 123 on EMF-2103, Figure 123.4 shows the droplet diameter variation in the PCT node for the 4-loop sample problem. For the *limiting North Anna Unit 2 case, during the refill and reflood phases, the droplet diameter at the PCT node varied between 0.125 mm and 3.0 mm. This shows that the droplet diameter variation in the North Anna calculation is similar to the variation shown in Figure 123.4. It is to be noted that any uncertainty in the calculation of droplet diameter is implicitly treated in the uncertainty for film boiling heat transfer.*

Condensation in the cold legs and downcomer during ECC injection is dominated by interphase heat transfer between the steam and subcooled liquid. The key parameter for interphase condensation is the liquid side heat transfer coefficient (see Equation 3-155 in EMF-2100, for example) which is treated as a statistical parameter in the RLBLOCA methodology.

The S-RELAP5 code was assessed against several of the W/EPRI 1/3 scale tests that cover typical conditions encountered in the near end-of-blowdown, refill, and reflood phases of LBLOCA. The uncertainty for interphase heat transfer is treated by applying a multiplier with an assumed uniform distribution between the limits of 0.383 and 1.095. This multiplier is applied to the interphase coefficients in the cold legs and downcomer. These tests and the determined uncertainty ranges are discussed in Section 3.8 of EMF-2102. The effect of non-condensable gas on interphase heat transfer was evaluated using the ACHILLES test and it is described in Section 3.15 of EMF-2102. The interphase heat transfer model was further assessed using UPTF Test-8, CCTF Run-54, and LOFT LBLOCA experiments.

The key parameter for the condensation correlation is the liquid velocity. The W/EPRI test conditions are given in Table 3.8.1 of EMF-2102. The maximum S-RELAP5 calculated liquid velocity for these tests was 80 ft/s in the test section downstream from the injection point (Component 180 in Figure 3.8.2 of EMF-2102). The maximum liquid velocity in the intact cold leg between the injection location and the downcomer is 74 ft/s for the limiting North Anna Unit 2 case. Thus, the North Anna calculated liquid velocity is bounded by the maximum velocity for which the condensation correlations were assessed.

Table 2-1 Heat Transfer Parameters for the North Anna Unit 2 Limiting RLBLOCA Case (values in braces represent range of applicability from response to Question 2 on EMF-2103)

Time (s)	0.0 - 0.5	0.5 – 26	26 – 31	31 - Quench
LOCA Phase	Early Blowdown	Blowdown	Refill	Reflood
Heat Transfer Mode	CHF	Film Boiling	Single-Phase	Film Boiling
Heat Transfer Correlations	Biasi	Forsuland-Rohsenow Modified-Bromley Sleicher-Rouse Natural Convection Radiation (Sun)	Sleicher-Rouse Natural Convection Radiation (Sun)	Same as for Blowdown
Maximum LHGR (kw/ft)	<13.5 {q_{CHF}}[1]	< 1.7 {<2.2}	< 0.7 {<2.2}	< 0.7 {<2.2}
Pressure (psia)	1,650 – 2,270 {<2,250}	40 – 1,650 {<2,250}	~ 40	25 – 50 {<2,250}
Core Inlet Mass Flux (kg/s-m^2)	1,400 – 3,600 {<6,000}	0.0 – 1,400 {<4,250}	~ 0	0.0 – 1,400 {<4,250}
Vapor Reynolds Number	0.0 - 30,000[3]	< 10^5 {< 10^6}	< 3,000 {< 10^6}	100 - 13,000 {< 10^6}
Liquid Reynolds Number[2]	27,000-430,000	0 - 27,000	0	0 - 36,000
Liquid Prandtl Number	1.1 - 1.2	1.1 - 1.32	1.32	1.32 - 1.5
Vapor Prandtl Number	1.5 - 2.9	0.88 – 1.5	~ 0.9	0.88 - 1.0
Vapor Super Heat (°F)			< 1,450	< 1,450

(1) Conservatively biased parameter as per the FANP RLBLOCA methodology (EMF-2103)
(2) Not important in post-CHF heat transfer
(3) Not important in pre-CHF heat transfer

Q4. The convective heat transfer coefficient used in the Framatome ANP RLBLOCA methodology does not extract the effect of radiation heat transfer. Experimental test cases exist for which it can be shown that inclusion of radiation heat transfer in the convective heat transfer coefficient results in non-conservative reflood heat transfer. Confirm that the NAPS-2 fuel and core configuration will not result in reflood heat transfer that takes undue credit for the inclusion of radiation heat transfer in the convective heat transfer coefficient.

Supplemental Response:

During a discussion with the NRC concerning the response to this question at the August 28, 2003 meeting, the NRC requested a demonstration of the relative rod-to-rod radiation component related to system and assembly design differences between the FLECHT-SEASET and the Advanced Mark-BW fuel assembly scheduled for use in the North Anna Unit 2 plant. Framatome ANP has performed a rod-to-rod radiation analysis applying the results from the North Anna Unit 2 RLBLOCA analysis. The analysis applies the R2RRAD code, provided by the NRC, for predicting rod-to-rod radiation. This code was modified to: a) examine 6x6 assembly arrays (rather than 5x5), b) account for the larger diameter guide tube rods, and c) calculate an assembly average radiant heat transfer coefficient. A separate code validation study was performed applying results from the FLECHT-SEASET test 31504. The code results from R2RRAD showed good agreement with results reported in the FLECHT-SEASET data report. The key parameters from the North Anna RLBLOCA analysis modeled in the R2RRAD code are given in the following table.

North Anna Unit 2 Key Temperatures

Temperatures	*°F*
Hot Rod	*2,032*
Hot Assembly	*1,838*
Guide Tube	*1,650*
Boundary	*1,650*

For this case, the North Anna Unit 2 PCT result is very similar to the FLECHT-SEASET test 31504 result at 80 seconds—a suitable comparison point having a relative high radiative heat transfer component. Test 31504 was chosen for its alignment with the North Anna results (PCT and guide tube temperatures) not for radiative heat transfer maximization. The assembly average rod-to-rod radiant heat transfer coefficients at the time of PCT are 2.52 BTU/hr-ft^2-R and 1.92 BTU/hr-ft^2-R, respectively for North Anna Unit 2 and FLECHT-SEASET test 31504. The North Anna Unit 2 calculation shows that under the conditions calculated in the RLBLOCA analysis, the rod-to-rod radiation component is about 33 percent higher than the FLECHT-SEASET result. In general, the modeled FLECHT-SEASET result is improved (lower radiation component) over the actual test conditions since the cooler peripheral rods, exposed to the largest radiant heat transfer, were removed from consideration in the development of code uncertainties.