VIRGINIA ELECTRIC AND POWER COMPANY
RICHMOND, VIRGINIA 23261

August 20, 2003

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

Serial No. 03-313A
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
REQUEST FOR ADDITIONAL INFORMATION REGARDING
REALISTIC LARGE BREAK LOSS OF COOLANT ACCIDENT (RLBLOCA) ANALYSIS RESULTS FOR THE PROPOSED TECHNICAL SPECIFICATIONS CHANGES AND EXEMPTION REQUEST FOR USE OF FRAMATOME ANP ADVANCED MARK-BW FUEL**

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. The RLBLOCA information was presented in the form of a supplement to the evaluation report provided in our March 28, 2002 letter (specifically, report Section 7.0). On August 6, 2003, the NRC requested additional information regarding the RLBLOCA results. The requested information is included in Attachment 1 to this letter. The responses provided are applicable to both North Anna Units 1 and 2 even though the RAIs received were only directed at Unit 2.

As we informed your staff in an August 15, 2003 teleconference, please be advised that an input error has been discovered in the RLBLOCA analyses submitted for both North Anna units. This error involved an incorrect calculation of upper plenum and upper head fluid volumes, which was caused by not subtracting the fluid volume contained within the control rod upper guide tube structures. The RLBLOCA reactor vessel model includes a separate fluid node to represent the upper guide tube structures. The corrected results indicate the following changes in calculated PCT for the limiting case: Unit 1 (+33°F); Unit 2 (no change). The detailed results, such as scatter plots, contain minor differences but no difference in basic trends. Dominion considers these changes to be minimal and within the expected variability of results from the RLBLOCA methodology. We anticipate that the NRC staff review performed to date should be negligibly impacted by the identified error. Dominion will submit additional details of the revised results in separate correspondence.

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

A001

license amendment and associated exemptions by September 30, 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,

E. S. Grecheck
Vice President - Nuclear Support Services

Commitments made in this letter:

1. Dominion will submit additional details of the corrected RLBLOCA analysis results for both North Anna units.

Attachments

1. Response to Request for Additional Information, Realistic Large Break LOCA Analysis Results - North Anna

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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 20th day of August, 2003.

My Commission Expires: March 31, 2004.

Maggie McClure
Notary Public

(SEAL)

Attachment 1

Response to Request for Additional Information

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 Responses to NRC Request for Additional Information
North Anna Realistic LBLOCA Analysis

A request for additional information (RAI) was received from the NRC by facsimile on August 6, 2003. It is noted that Framatome ANP (FANP) responses to several RAIs generated during licensing of the RLBLOCA methodology topical report (EMF-2103(P), Reference 1 are relevant to these questions, and are cited below, as appropriate. FANP originally provided these RAI responses to NRC in Reference 2. In Reference 3, NRC issued its SER denoting approval of the methodology documented in topical report EMF-2103. 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. OVERALL APPLICABILITY TO NORTH ANNA 2

Section 7.2.1 of the North Anna Unit 2 (NA-2) submittal provides a plant description and a summary of analysis parameters. This section also refers to Tables 7.2-1, 7.2-2, and 7.2-3, which provide information specific to the LBLOCA analyses performed to define the licensing basis for NA-2 LBLOCA. The submittal also provides Figures 7.2-1 and 7.2-3, which show the NA-2 Realistic LBLOCA methodology (RLBLOCA using the S-RELAP5 computer code) Loop and Reactor Vessel Noding diagrams used for the analyses. The staff requests further information to address the programmatic requirements of 10 CFR 50.46 (c).

Q1. To show that the referenced generically approved LOCA analysis methodologies apply specifically to the NA-2 plant, provide a statement that VEPCO and its vendor have ongoing processes which assure that the ranges and values of input parameters for the NA-2 LOCA analysis bound the ranges and values of the as-operated plant values for those parameters. Furthermore, if the NA-2 plant-specific analyses are based on the model and or analyses of any other plant (i.e., NA-1), then justify that the model or analyses apply to NA-2. (e.g., if the other design has a different vessel internals design the model wouldn't apply to NA-2.)

Response:

Dominion has performed the existing analyses of record for North Anna LBLOCA, using the Westinghouse BASH evaluation model. In support of these analyses, Dominion maintains analysis design basis documentation that is used to ensure the analyzed plant parameters appropriately bound the actual plant values. In addition, Dominion's reload core design process employed between Dominion and Westinghouse includes specific communications of plant design and operational changes that apply to reload cores. The interactions between Dominion and Framatome ANP will be governed by these same processes, which are maintained under Dominion procedural control.

The North Anna Unit 2 plant-specific analyses are based only on the model and/or analyses of North Anna Unit 2. The Unit 2 LOCA models were built based on Dominion-supplied Unit 2 plant-specific data. Results of a

separate Unit 1 analysis were submitted via Dominion letter 03-407, dated July 18, 2003.

B. APPLICABILITY OF ANALYTICAL MODELS

Many of the analytical models in the NA-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 NA-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 NA-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 NA-2 calculation, which exceed 2000°F. Justify the applicability of the Forslund-Rohsenow model as it is used in the proposed NA-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 NA-2.)

Response:

The issue embodied in this question was addressed during the generic licensing review of FANP's RLBLOCA topical report EMF-2103. The treatment of heat transfer during dispersed flow film boiling, Forslund-Rohsenow, was found acceptable by NRC staff. Please refer to Reference 2 (responses to Questions 21 and 22). A synopsis of the material is presented below and its applicability to North Anna Units 1 and 2 demonstrated.

Film boiling heat transfer is treated in the FANP RLBLOCA methodology as an important large break LOCA phenomenon. FANP's CSAU-based methodology requires that code accuracy be quantified (as bias and uncertainty) as related to the use of specific models and correlations describing all highly important LBLOCA phenomena. The results of code accuracy studies are then explicitly applied to the analysis methodology.

To support the generic review of the RLBLOCA methodology, FANP provided the staff with the "S-RELAP5 Code Verification and Validation" document (Reference 6). This document provides extensive code assessment analysis using S-RELAP5 for RLBLOCA applications. Results and discussion are provided for over 130 separate- and integral-effects

tests. Section 5.1.17 describes the FANP methods and results for the quantification of code accuracy in the prediction of the total fuel-to-coolant heat transfer during film boiling conditions. The results are based on code-to-data comparisons applying the FLECHT-SEASET, FLECHT-Skewed, and ORNL-THTF reflood tests as described in Sections 3.1 and 3.2 of Reference 6. A number of these tests, including those with low reflooding rates such as FLECHT-SEASET tests 31805, 31504, and 32013, resulted in temperatures exceeding 2,000°F. The FLECHT-SEASET test 31805 reported temperatures exceeding 2,200°F. Clearly, the test benchmarks that established the validity of the RLBLOCA heat transfer methodology, including Forslund-Rohsenow, included temperatures at and above those predicted in the North Anna Units 1 and 2 analysis.

The FLECHT-related and THTF test programs were designed using modern fuel assembly characteristics. The test programs considered both 15x15 and 17x17 fuel assembly designs. The 17x17 design is prototypic of the two 17x17 fuel designs (Westinghouse NAIF and FANP Advanced Mark-BW) to be used in North Anna Units 1 and 2. Hence, the RLBLOCA methodology was benchmarked for a fuel assembly design typical of those used in North Anna Units 1 and 2.

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 NA-2 LBLOCA analyses.

Response:

The phenomena that govern PCT response are fuel rod decay power, fuel stored energy, clad-to-coolant heat transfer and clad oxidation. All four processes are considered important LBLOCA phenomena. Code accuracy for these processes is summarized in Table 4.19 of Reference 1. The ranges of applicability of these process models are summarized as follows:

- The range of applicability of the fuel model is dependent only on burnup; hence, it is independent of any North Anna Units 1 and 2 plant-specific conditions.

- The decay heat model is based on the ANSI/ANS 1979 standard, a simple model providing realistic, but conservatively bounding (high) results. It is independent of any plant-specific conditions.

- The range of applicability for the Cathcart-Pawel clad oxidation correlation is given in NUREG-1230 (Compendium of ECCS Research) as 1,000 – 1,300 C (~1,830 – 2,370 °F). Again, the application of the clad

oxidation model is independent of any North Anna Units 1 and 2 plant-specific conditions.

- **The range of applicability of the models and correlations used to predict clad-to-coolant heat transfer are dependent on North Anna Units 1 and 2 plant specific parameters. Tables 7.2-4 and 7.2-5 in the Dominion submittal are provided in compliance to an RLBLOCA SER restriction requiring "a table that contains the plant-specific parameters and the range of the values considered for the selected parameter during the topical report approval process." The values in Table 7.2-5 demonstrate that the North Anna Units 1 and 2 analyses are within the generic bounds presented in Table 7.2-4.**

  The heat transfer issue was specifically addressed during the generic review of the FANP RLBLOCA methodology topical report EMF-2103. FANP responded to a question (Reference 2, RAI Number 2), regarding the range-of-applicability of clad-to-coolant total heat transfer.

  Note: Heat transfer correlations are not first-order dependent on temperature. The correlations are used to determine clad temperature dynamics. For this reason, temperature is not considered an independent parameter for describing the range of applicability of a particular correlation. Nonetheless, the database supporting the application of S-RELAP5 to RLBLOCA simulations includes a number of tests that recorded clad temperature greater than 2,000°F.

  It is concluded that the North Anna Units 1 and 2 analysis results are within the bounds of the approved RLBLOCA methodology.

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 NA-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.

Response:

The issue of radiation heat transfer was raised and addressed during the licensing review of the RLBLOCA methodology. Please refer to Reference 2 (RAI Number 20).

Rod-to-rod radiation heat transfer is a component of the total clad heat transfer. The FANP PIRT team did not identify rod-to-rod radiation as being an important LBLOCA phenomenon. Validation of the code bias as evaluated during CSAU Step 9, Evaluation of Code Accuracy, generally shows that S-RELAP5 simulation of integral-effects tests continues to overpredict clad temperature, particularly at high temperatures and high

core elevations where rod-to-rod heat transfer would be most likely to contribute to total clad heat transfer. These validation studies are presented in the FANP RLBLOCA methodology topical report EMF-2103 (Reference 1), Section 4.3.4. The geometry of the North Anna Units 1 and 2 fuel and core designs does not present unique configurations that increase rod-to-rod radiation effects for these plant-specific analyses. The phenomena treatment accepted by NRC in issuing the SER for EMF-2103 is applicable to North Anna 1 and 2, and the plant-specific conditions will not create undue heat transfer credit during reflood.

Q5. The methodology does not consider pellet fragmentation and relocation (including relocation to the ruptured zone). By ignoring both of these effects and using a fixed value of gap conductance at the higher PCTs calculated in the NA-2 analyses, the NA-2 model may underestimate the LBLOCA limiting PCT and oxidation values. Sensitivity studies supporting the absence of these phenomena from the S-RELAP5 methodology were performed at PCTs not prototypic of the NA-2 analyses. Address this NA-2 LBLOCA methodology concern.

Response:

The issue of fuel pellet fragmentation and relocation was discussed and resolved during the review of topical report EMF-2103. Please refer to the Reference 2 response on RAI Number 131 on the RLBLOCA methodology. It compares experimental results with and without fuel relocation.

A key point in the RAI (Number 131) response is that heatup rates in both calculations (i.e., with and without fuel relocation) after rupture remain less than the rates prior to rupture. The rupture and relocation event is a singular occurrence providing a large one-time clad temperature benefit plus a residual benefit due to an increase in rod surface area. Not modeling this phenomenon is an inherent conservatism in the FANP RLBLOCA methodology. In addition, test data, including data supporting the NUREG-630 swelling and rupture model, clearly show that fuel ruptures occur at clad temperatures around 1,600 – 1,700°F which is well below regulatory acceptance limits. For this reason, sensitivity studies performed by FANP were prototypic of the conditions for swelling and rupture. Hence, applying a swelling and rupture model in the North Anna Units 1 and 2 analyses would show rupture at clad temperatures consistent with test data and with the sensitivity studies performed to support the RLBLOCA methodology. Above the rupture temperature, fuel rod rupture with pellet relocation remains a benefit that is independent of the clad temperatures predicted in the North Anna Units 1 and 2 plant-specific analyses.

Q6. The NA-2 LBLOCA calculations were ranged down to 0.1 ft^2 which is below the minimum range in the current NA-2 LBLOCA. This size for NA-2 falls in the current SBLOCA range. The supporting demonstration plant analyses for the Framatome ANP RLBLOCA were accepted to this small size because for the demonstration plant the phenomena that were predicted to occur were indicative

of a LBLOCA rather than a SBLOCA. NA-2 must justify that the ranging of break size for application of the Framatome ANP RLBLOCA methodology does not result in phenomena occurring that are typical of a SBLOCA.

Response:

The approved RLBLOCA methodology calls for total break area to be ranged from twice the pipe cross sectional area to ten percent of the pipe area. Break modeling is shown in Figure 7.2-1; note the two break junctions. Total break area is the sum of the two break junction areas. For North Anna Units 1 and 2, this results in a lower bound total break area of approximately 0.42 ft^2.

The lower bound for the total break area was established for the North Anna Units 1 and 2 analyses consistent with the approved modeling approach. Proper modeling is confirmed in the scatter plots of operational parameters and PCT versus break size that were included in the Dominion submittals. For Unit 1, see Figures 7.2-4 and 7.2-6; for Unit 2, see Figures 7.2-19 and 7.2-21. Each figure shows a break area of about 0.21 ft^2 per break junction for a total break area of approximately 0.42ft^2.

A ten percent pipe break area is a reasonable transition break size. For North Anna, it results in about a 9-inch diameter break. Common SBLOCA characteristics—such as loop seals, periods of natural circulation cooling and no rapid DNB immediately after transient initiation—are rarely, if ever, observed in analyses of or tests simulating break sizes approaching ten percent of the RCS cold leg pipe area. As part of the FANP RLBLOCA SER compliance requirement to check analysis calculations for blowdown quench, clad temperature plots were examined. There were no instances in which the clad temperature trends indicated any phenomena exclusive to SBLOCAs. The break treatment accepted by the NRC in issuing the SER for topical report EMF-2103 (Reference 3) is applicable to North Anna 1 and 2.

Additional break area information was provided during the generic review of the FANP RLBLOCA methodology topical report EMF-2103. The material is contained in Reference 2 (response to RAI question Number 25).

Q7. Has a counter current flow limitation (CCFL) violation warning been implemented in the NA-2 LBLOCA methodology consistent with the Framatome ANP commitment dated December 20, 2002?

Response:

To comply with the SER requirement to implement a CCFL warning in the methodology, the RLBLOCA analysis guideline requires the analyst to generate an occurrence-based scatter plot of downcomer velocities versus the applicable CCFL velocity as Wallis parameters <u>for all cases</u>. The plot shows the CCFL condition at the junctions under both broken and intact cold leg nozzles. Any case exhibiting gross violation of the Wallis model cannot be used without further justification. The CCFL scatter plot for the

reported case is documented in the uncertainty analysis calculation notebook.

For the North Anna Units 1 and 2 RLBLOCA analyses, this guideline directive was complied with strictly and no significant CCFL violations were observed in the set of 59 cases.

Reference 2 (response to RAI question Number 65) provides material regarding CCFL in the downcomer. The occurrence-based scatter plots created for the North Anna Units 1 and 2 analyses were prepared applying the same methods used to generate the corresponding plots shown in Reference 2 (response to RAI Number 65).

Q8. The LBLOCA submittal did not address slot breaks at the top and side of the pipe. Please justify why these breaks are not considered for the NA-2 LBLOCA response.

Response:

The RLBLOCA SER requires that FANP "evaluate the effect of the deep loop seal on the slot breaks." The SER also states that the "evaluation may be based on relevant engineering experience and should be documented in either the RLBLOCA guidelines or plant-specific calculation file." The North Anna Units 1 and 2 analyses complied with this SER requirement.

Slot breaks at the top and side of the cold leg piping were evaluated generically, based on relevant engineering experience for 3- and 4-loop re-circulating steam generator plants. Results were documented in the RLBLOCA guidelines.

In summary, the evaluation concluded that, due to the loop steam velocities, the RCS suction piping cannot accumulate significant liquid inventory for several hours following the establishment of long-term cooling. Furthermore, the core swell level, at the low RCS pressures following LBLOCA, prevents a core uncovering for downcomer levels below the core mid-plane for several days. The methodology applied for RLBLOCA represents a slightly conservative evaluation for top and side breaks because the reduced potential for ECCS spillage is not considered.

The NAPS (North Anna Power Station) units were considered in this evaluation. For the generic assessment documented in the RLBLOCA guideline, a conservative PCT estimate of less than 1,600°F was obtained. This result is well below the clad temperature acceptance limits and below the temperature range where significant clad oxidation can occur. In general, following the initial characteristic LBLOCA recovery, top and slot breaks behave similar to SBLOCA events. Without Appendix K restrictions, the long-term behavior of top and side break simulations applying the RLBLOCA methodology will always be bounded by limiting SBLOCA analyses.

It is concluded that slot breaks would not cause an oxidation concern for North Anna Units 1 and 2.

Q9. The qualitative discussion in the NA-2 submittal is not sufficient to demonstrate that a mixed core has been fully assessed. The NA-2 licensing basis LBLOCA methodology must be shown to be able to analyze all fuel in the NA-2 core, not just the hot assembly. Provide values for PCT and total oxidation (including pre-LOCA, LOCA cladding outside, and cladding post-rupture inside oxidation) for the non-Framatome fuel in the core, and indicate how these values were determined.

Response:

The proposed licensing basis approach for North Anna involves use of LBLOCA methodologies that are specifically applicable for each of the two fuel types in the core. The resident Westinghouse North Anna Improved Fuel (NAIF) is analyzed with the BASH methodology. The Framatome ANP Advanced Mark-BW fuel is analyzed with the RLBLOCA methodology. The Framatome ANP analysis documented in Section 7.2 of Reference 4 modeled a mixed core configuration that directly included mixed core effects on the Advanced Mark-BW fuel. The results of the RLBLOCA analysis also indicate that flow is diverted away from the higher pressure drop Advanced Mark-BW fuel into the Westinghouse fuel. This phenomenon creates a net penalizing effect on the Advanced Mark-BW fuel, which is included in the reported results for Advanced Mark-BW. This physical difference in fuel design features creates a net cooling benefit for the NAIF when in a mixed core with Advanced Mark-BW. Dominion chose not to quantify this expected credit to the NAIF fuel. The existing results for the NAIF fuel, which were calculated from analysis of a full core of NAIF, remain conservative for NAIF in a mixed core with Advanced Mark-BW.

The qualitative discussion in the North Anna Units 1 and 2 submittals concludes that the existing analysis of the Westinghouse fuel remains valid. The PCT and oxidation values from the analysis of record for the co-resident Westinghouse NAIF may be found in Section 15.4.1 of the current NAPS UFSAR. These results were calculated using the Westinghouse BASH LBLOCA ECCS Evaluation Model. These values have been modified to account for changes and errors in the Westinghouse LBLOCA ECCS Evaluation Model, per the requirements of 10 CFR 50.46(a)(3)(ii). The most recent report of these changes was provided to the NRC in a letter dated May 21, 2003 (Reference 5). This report documented licensing basis PCTs for NA-1 and NA-2 LBLOCA of 2154°F and 2152°F, respectively. This report did not provide cladding oxidation results. A bounding maximum hot rod oxidation value of 7.6% has been calculated for the Westinghouse fuel in NA-1 and NA-2 using the Westinghouse BASH LBLOCA ECCS Evaluation Model and includes both inside and outside cladding oxidation. This result includes the effects of the BASH-EM Transient Extension associated with downcomer boiling. It is noted that these results do not reflect explicitly the operation of Westinghouse fuel as once-burned or twice-burned

assemblies. Fuel assemblies in the initial loading as fresh fuel are limiting due to the dominant mitigating effect of reduced pellet initial temperature with increased burnup and the effect of rod power (i.e., peaking factor) reduction associated with increased burnup. Therefore, the existing analyses are bounding for Westinghouse fuel in transition cores.

The pre-existing cladding oxidation is accommodated in the following fashion. For each North Anna reload cycle, Westinghouse performs cycle specific fuel rod design calculations that confirm all Westinghouse fuel rod design criteria are satisfied. To verify compliance with the 17% cladding oxidation limit, these cycle specific calculations ensure the amount of fuel cladding oxidation (i.e., the pre-LOCA local oxidation) does not exceed a predetermined limit. The assessment also evaluates the potential for pellet-clad gap reopening. For the transition cores that contain both Framatome and Westinghouse fuel, Dominion will continue to provide Westinghouse with information regarding specific Westinghouse fuel assemblies that are scheduled for reuse as well as the planned operating conditions. Westinghouse will perform cycle specific reload evaluations for their fuel in North Anna Units 1 and 2 to confirm compliance with the Westinghouse fuel rod design criteria, including the limits on oxidation and rod internal pressure / gap reopening. The limit on upper bound oxide thickness is set to ensure that the sum of the pre-transient and post-LOCA oxidation will not exceed 17%.

Q10. Table 7.2-2, 3.0 "Accident Boundary Conditions" lists the refueling water storage tank (RWST) temperature as less than/equal to 60°F. The NA-2 Technical Specification Surveillance Requirement 3.5.4.1 assures this value is not exceeded by requiring the RWST temperature to be greater than/equal to 40°F and less than/equal to 50°F.

a. How does the RWST water temperature affect the LBLOCA analyses?

Response:

The RWST temperature is treated as nominal or biased high in RLBLOCA calculations. RWST fluid is used as a source of NSSS energy removal during a LOCA transient, i.e., a core cooling mechanism. Therefore, increasing RWST temperature decreases ECCS subcooling, which is conservative. ECCS subcooling may influence cold leg condensation rates; however, cold leg condensation is a sampled parameter and the realistic variations expected in RWST temperature would not significantly alter condensation rates relative to the sampling range.

b. Describe how the effect of water at this low temperature has been considered in boron precipitation analyses.

Response:

The RWST is one of several water sources that are assumed to discharge to the containment sump in the North Anna boron precipitation analysis. The analysis approach involves a time-dependent calculation of sump and core boron concentrations, assuming that safety injection flow equals core boiloff caused by core decay heat. The existing calculation accounts for the allowable Technical Specification range of 40-50°F by assuming the RWST temperature is 45°F (midpoint of the range). The analysis includes an additional assumption that the sump fluid at the start of the calculation is at 14.7 psia and 70°F, which represents a long-term stable condition. Existing containment transient analyses indicate that the post-LOCA sump fluid temperature is significantly greater than 70°F prior to entering the long-term recirculation cooling mode (see UFSAR Figure 6.3-10). Assumption of this long-term sump condition maximizes both the initial sump fluid density and boron concentration, which conservatively maximizes core boron concentrations, and thus minimizes the calculated time to reach the precipitation limit. The calculation method includes an adjustment for all input tank volumes and boron concentrations from their initial conditions to the assumed 70°F condition. This adjustment accommodates the different initial temperature conditions of the various tanks, so that their boric acid content is appropriately accounted for in the initial sump conditions, and thus correctly included in the transient calculation of sump and core boric acid concentrations.

Q11. Downcomer Boiling - The containment pressure in Figure 7.2-33 indicates that the containment pressure is at about 30 psia and continues to decline at 200 seconds into the limiting LBLOCA. Figures 7.2-23, 7.2-30, and 7.2-32 seem to indicate that downcomer boiling occurs at about 375 seconds into the transient. The containment plot ends at 200 seconds and it appears from Figures 7.2-23 and 7.2-32 that the calculation was terminated at ~460 seconds. At ~460 seconds, the PCT drops to ~450°F. At this time, the (extrapolated) containment pressure is 30 psia or less. The saturation temperature at 30 psia is ~250°F or less, but the drop in PCT stops at ~450°F. 10 CFR 50.46 requires that analyses to be run until the core is quenched.

a. Extend the analysis results tables and graphs, particularly Table 7.2-11 and Figure 7.2-33, to beyond the time that stable and sustained quench is established.

Response:

By the conclusion of the limiting North Anna Units 1 and 2 LBLOCA calculations, the event has gone through all the phenomenological characteristics of a LBLOCA. The calculation is terminated by an analysis guideline rule that was established for identifying core quench following PCT. Part of that logic tests for when the maximum clad temperature of the hot rod drops below 500°F. That temperature, 500°F, bounds the T_{min} point (note, T_{min} is also a statistically treated parameter in the FANP RLBLOCA methodology). Once heat transfer has crossed from film boiling to

transition boiling, rod temperatures will rapidly cool to saturation. No changes in ECCS delivery and no new phenomena are expected; hence, there is no reason to believe that the calculation has not run its course.

For the limiting RLBLOCA Unit 2 transient (the event times are reported in Table 7.2-11), the core quench/calculation termination time is 457 seconds. Figure 7.2-33 is re-plotted below on an extended time scale.

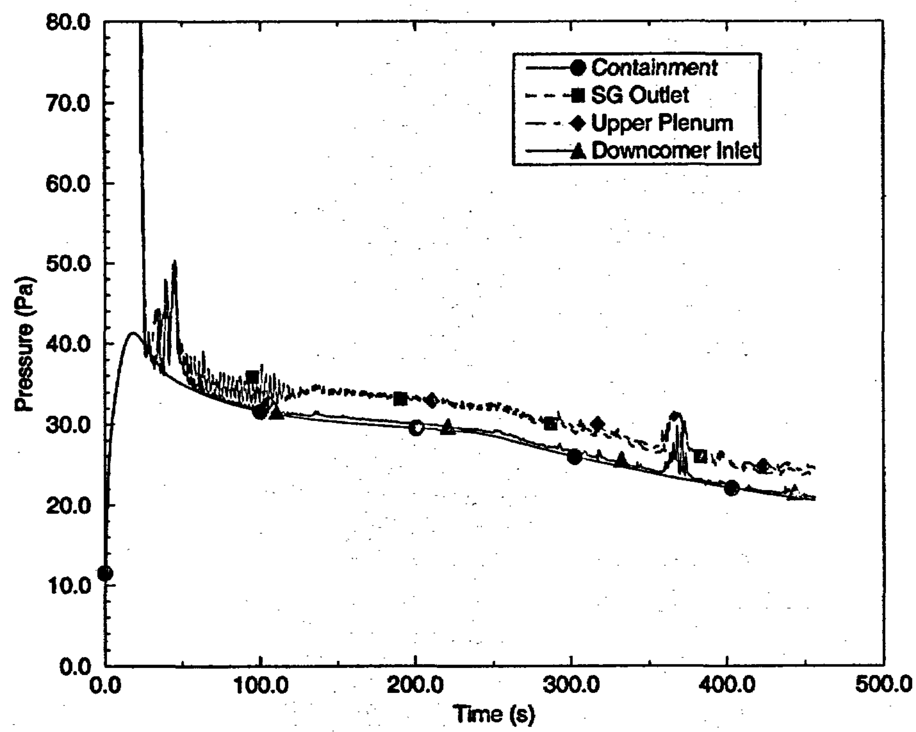

Figure 7.2-33: NAPS Unit 2 Containment and Loop Pressures for the Limiting Break

NRC staff studies using RELAP5 indicate that a downcomer lateral crossflow resistance coefficient value of 0.2 to 0.3 is appropriate for PWRs.

b. Identify and justify the crossflow resistance coefficient value used for the NA-2 LBLOCA calculation (including during downcomer boiling).

Response:

The downcomer cross flow resistance coefficients used in the RLBLOCA North Anna Unit 2 analysis were zero, consistent with the approved evaluation model sample problems.

The acceptability of using a zero form loss coefficient was addressed during the generic licensing review of EMF-2103. For the review, two case studies were performed to determine clad temperature sensitivity to best estimate cross flow form loss resistances (friction is inherently treated in S-RELAP5). One set of calculations was performed using a zero form loss coefficient, the other using an Idel'chek derived value of 0.1167. The

discussion of this study was provided to the NRC in Reference 2 (response to RAI question Number 27 on downcomer boiling).

The form loss calculation for the three azimuthal junctions in the downcomer applies the Idel'chek reference for flow through a curved pipe or rectangular duct. Using an angle of curvature of 120°, results in a form loss of 0.1167. The two case studies applied the limiting calculations for the 3-loop sample problem (presented in EMF-2103, Appendix D) and from a RLBLOCA analysis of a low containment pressure plant (similar to North Anna Unit 2). The results of the study showed essentially no PCT impact.

Q12. The upper core plate modeling assumptions for the NA-2 can significantly affect the characteristic LOCA transient and/or LOCA results. A variety of upper core plate designs are available for NA-2.

Q12-a. It is not clear from LBLOCA Figure 7.2-3 and SBLOCA Figure7.3-2b what specific upper core plate is used for NA-2. Identify the specific upper core plate design used in NA-2.

Response:

The upper internals assembly consists of the following components: upper support plate, upper core plate, upper support columns, rod control cluster guide tubes, and core exit thermocouple columns. The upper support plate is a heavy structural member consisting of a flange and a thick flat plate connected by a cylindrical shell. The upper support plate is the transition member between the Rod Drive System control rod drive mechanisms (CRDMs) located on the vessel head and the upper internals assembly. The upper core plate is a relatively thin flat plate located at the bottom of the upper internals assembly. With the fuel assemblies and the RCC guide tubes aligned by the upper core plate, a transition is made for the control rods to enter the fuel assemblies from the guide tubes. Flow holes for passage of coolant are present at each fuel assembly location. The upper support columns are the structural tie between the upper core plate and the upper support plate. The columns have conveyance tubing and junction supports for the core exit thermocouples. The thermocouples are installed over flow mixing columns attached to the upper core plate. The rod control cluster guide tubes are designed to guide the control rods into and out of the fuel assemblies without restriction, binding, or wear. In addition, the tubes provide core outlet flow via holes in the guide tube extensions. The guide tubes extend through the upper support plate and rest on the upper core plate.

The design characteristics of the upper support plate, upper core plate, upper support columns, rod control cluster guide tubes, and core exit thermocouple columns were documented by Dominion and provided to Framatome. The design information included the number and type of columns and guide tubes, number and type of flow holes, flow areas,

material thicknesses and weights, and other various dimensions (heights, diameters, etc.).

Q12-b. Identify in LBLOCA Figure 7.2-3 and SBLOCA Figure 7.3-2b how the NA-2 upper core plate is represented in the NA-2 LBLOCA and SBLOCA models. Location of the hot assembly/ hot rod with respect to the upper core plate in the NA-2 LOCA models can significantly affect the calculated LOCA results for NA-2.

Response:

With regard to LOCA modeling, the upper core plate is a flow area, resistance, and heat source/sink device. In this context, the North Anna Units 1 and 2 core plate is not unique. Modeling the plate requires no departures from the approved large and small break evaluation models.

The upper plenum nodalization used in the FANP RLBLOCA methodology is described in Reference 1, Section 4.2.4.4 and is illustrated in Figure 4.8. It was specifically designed to support modeling of the asymmetries of upper core plates and accompanying structure in the upper plenum.

The SBLOCA nodalization is as represented in Figure 7.3-2b. The upper core plate resistance and flow area is accounted for and appropriately apportioned to the junctions connecting the hot and average core channels to the upper plenum.

Q12-c. Discuss where the hot assembly/ hot rod is located in relation to the NA-2 upper core plate and its design features. Show that the NA-2 modeling assumption is not non-conservative.

Response:

The phenomenological concern relevant to LOCA is liquid fallback. Asymmetry in the upper core plate and upper plenum structure can preferentially deliver more liquid fallback to certain assemblies. To address this uncertainty, the design characteristics of the actual upper core plate were considered in modeling the junction flow paths and volume characteristics. For RLBLOCA analysis, the hot assembly is <u>always</u> modeled as located under a standpipe or mixer vane, i.e., beneath a structure that will restrict appreciable liquid fallback. During the generic review of the RLBLOCA methodology topical report EMF-2103, FANP responded to two questions related to this subject. Please refer to Reference 2 (response to questions Number 39 and Number 113).

The SBLOCA evaluation model also requires a restriction on liquid fallback into the hot channel. The evaluation model sets the reverse flow k_{factor} for the junction connecting the hot channel to the upper plenum to a value of 200. This accomplishes the same goal—limiting liquid fallback—as described above for the large break model.

REFERENCES

1. Topical Report EMF-2103(P), Revision 0, "Realistic Large Break LOCA Methodology for Pressurized Water Reactors," August 2001.

2. Letter, James F. Mallay (Framatome) to USNRC, "Responses to a Request for Additional Information on EMG-2103(P) Revision 0, 'Realistic Large Break LOCA Methodology for Pressurized Water Reactors,' (TAC No. MB2865," December 20, 2002.

3. Letter, USNRC to James F. Mallay (Framatome), "Safety Evaluation on Framatome ANP Topical Report EMF-2103(P) Revision 0, 'Realistic Large Break LOCA Methodology for Pressurized Water Reactors,' (TAC No. MB7554)," April 9, 2003

4. Letter, Leslie N. Hartz (Dominion) to USNRC, "Virginia Electric and Power Company, North Anna Power Station Units 1 and 2, Realistic Large Break Loss of Coolant Accident (RLBLOCA) Analysis Results for the Proposed Technical Specifications Changes and Exemption Request for Use of Framatome ANP Advanced Mark-BW Fuel," Serial No. 03-313, May 6, 2003.

5. Letter, Leslie N. Hartz (Dominion) to USNRC, "Virginia Electric and Power Company, North Anna Power Station Units 1 and 2, Surry Power Station Units 1 and 2, Reporting of ECCS Model Changes Pursuant to 10 CFR 50.46," May 21, 2003.

6. EMF-2102(P), Revision 0, "S-RELAP5: Code Verification and Validation," August 2001.