June 23, 2006

Mr. David A. Christian
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SUBJECT: MILLSTONE POWER STATION, UNIT NOS. 2 AND 3, NORTH ANNA POWER STATION, UNIT NOS. 1 AND 2, AND SURRY POWER STATION, UNIT NOS. 1 AND 2 - CORRECTION TO DOMINION'S FLEET REPORT DOM-NAF-2, "REACTOR CORE THERMAL-HYDRAULICS USING THE VIPRE-D COMPUTER CODE"

Dear Mr. Christian:

On April 4, 2006, the Nuclear Regulatory Commission (NRC) issued Fleet Report DOM-NAF-2, "Reactor Core Thermal-Hydraulics Using the VIPRE-D Computer Code." Subsequently, in its letter dated June 1, 2006, you informed the NRC that the safety evaluation (SE) for Fleet Report DOM-NAF-2 contained several editorial errors, including language that could unnecessarily restrict the use of the fleet report to specific fuel vendors. The corrected pages for this SE are enclosed with this letter. The revisions to the SE are identified by lines in the margin.

Sincerely,

/RA/

Stephen R. Monarque, Project Manager
Plant Licensing Branch II-1
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

Docket Nos. 50-336, 50-423, 50-338
50-339, 50-280, and 50-281

Enclosure:
Safety Evaluation

cc w/encl: See next page

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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATING TO FLEET REPORT DOM-NAF-2

MILLSTONE POWER STATION, UNIT NOS. 2 AND 3

NORTH ANNA POWER STATION, UNIT NOS. 1 AND 2

SURRY POWER STATION, UNIT NOS. 1 AND 2

DOCKET NOS. 50-336, 50-423, 50-338, 50-339, 50-280, AND 50-281

1.0 INTRODUCTION

By letter dated September 30, 2004 (Reference 1), as supplemented by letters dated January 13 (Reference 2), June 30 (Reference 13), and September 8, 2005 (Reference 14), Dominion Nuclear Connecticut, Inc., and Virginia Electric and Power Company (the licensees), submitted a request for Nuclear Regulatory Commission (NRC) staff approval for the application of Fleet Report DOM-NAF-2, "Reactor Core Thermal-Hydraulics Using the VIPRE-D Computer Code," Appendix A, "Qualification of the Framatome Advanced Nuclear Power (F-ANP) BWU Critical Heat Flux (CHF) Correlations," and Appendix B "Qualification of the Westinghouse WRB-1 CHF Correlations in the Dominion VIPRE-D Computer Code." Appendix A includes the VIPRE-D code and correlation departure from nucleate boiling ratio (DNBR) design limits, and Appendix B provides an evaluation of DNBR for the Westinghouse WRB-1 CHF correlations that are applicable to the Westinghouse 15x15 optimized fuel assembly (OFA) fuel bundle.

2.0 REGULATORY EVALUATION

Title 10 of the *Code of Federal Regulations,* Part 50, Section 50.90, requires licensees to submit an application to the NRC whenever they desire to amend the license.

The VIPRE-01 computer code is a core thermal hydraulics computer program developed by the Electric Power Research Institute (EPRI) and approved generically by the NRC staff for the purpose of evaluating departure from nucleate boiling (DNB) for pressurized water reactor (PWR) systems. Since this generic approval did not include specific applications of VIPRE-01 to any particular fuel design, NRC staff review and approval is necessary in order to apply this methodology to a specific fuel design. Therefore, this review addresses the specific application of VIPRE-01 by the licensees to the NRC staff-approved pressurized water reactors (PWR) fuel types in the licensees' nuclear steam supply systems (NSSS).

Corrected by letter dated June 23, 2006

VIPRE-D is the licensees' version of VIPRE-01, which has been enhanced by the addition of several vendor-specific CHF correlations. The licensees intend to utilize the VIPRE-D computer code to assess the DNBR for the Framatome BWU-N, BWU-Z, and BMU-ZM CHF fuel correlations. Additionally, the licensees intend to apply the VIPRE-D code to assess the

Westinghouse WBR-1 CHF correlation for the 15x15 OFA fuel design. The licensees have previously used the COBRA IIIc/MIT computer code (Reference 3) to perform the thermal hydraulic analyses and is submitting this fleet report to replace COBRA IIIc/MIT computer code with the VIPRE-D computer program along with the new CHF correlations for the NRC staff-approved PWR fuel designs. The NRC staff's technical evaluation of the VIPRE-D code and the new CHF fuel correlations is given below.

3.0 TECHNICAL EVALUATION

In order to evaluate DNB in the licensees' NSSS for the NRC staff-approved PWR fuel types, the NRC staff reviewed the application of the VIPRE-D code along with the various pertinent code correlations and models, fuel-specific CHF correlations, and DNBR design limits.

The VIPRE-D code is a modified version of the VIPRE-01 code which is a finite volume subchannel thermal hydraulics code with the specific capability to model a three-dimensional core and other component geometries. With the appropriate boundary conditions from a systems code such as RETRAN, VIPRE-01 computes the flow, void, pressure, and temperature distribution of the fluid through the core to ultimately compute the minimum DNB for steady state and transient conditions. The VIPRE-01 code also contains a fuel rod model that computes the radial and axial temperature distribution that is coupled to the cladding surface heat transfer coefficient correlations and CHF correlations that are particular to a given fuel rod and bundle design with the objective of determinating DNB following a non-loss-of-coolant accident (LOCA) transient event.

In order to compute the single and two-phase flow conditions that develop during transients undergoing a potential DNB, various two-phase flow models for handling subcooled and bulk boiling are available for use in the code, as well as convective heat transfer correlations for single and two-phase flow conditions. Correlations are also included in the code to deal with turbulent mixing, axial and cross-flow resistance, and form loss coefficients. As such, the NRC staff's review consisted of reviewing the CHF correlations and the various fluid flow and heat transfer options in the code to assure the correlations and models were validated over the range of conditions for those transients for which DNB is to be evaluated.

It is also noted that the licensees did not modify any of the phenomenological models or correlations in VIPRE-01. The licensees only added the new CHF correlations (Reference 1, Appendix A and Reference 2, Appendix B) to accommodate the DNBR assessments of the NRC staff-approved PWR fuel types. No other changes were made to VIPRE-01 in constructing the new VIPRE-D code.

3.1 Code Usage

The licensees indicated it plans to use the VIPRE-D code for the following applications.
(1) Perform an analysis of 14x14, 15x15, and 17x17 fuel in PWR reactors.

(2) Perform an analysis of DNBR for statistical and deterministic transients in the Updated Final Safety Analysis Report (UFSAR), as identified in Table 1, below. Additional DNBR transients that are plant specific may be analyzed in a plant-specific application that would be submitted to the NRC staff for review and approval.

3.3 Compliance with the VIPRE-01 Safety Evaluation Report (SER)

In order to meet the NRC staff's requirements listed in the VIPRE-01 SER (References 4 and 5), the licensees will apply the VIPRE-D code for PWR licensing applications under the following conditions:

(1) The application of VIPRE-D is limited to PWR licensing calculations with heat transfer regimes up to CHF. VIPRE-D cannot be used for post-CHF calculations or for boiling-water-reactor calculations.

(2) VIPRE-D analyses will use only those DNB correlations reviewed and approved by the NRC staff in this SER. These correlations include the Framatome BWU-N, BWU-Z, and BMU-ZM CHF and the Westinghouse WRB-1 fuel CHF correlations.

(3) The Framatome BWU CHF correlations, which have been specifically developed for use with the Framatome Advanced Mark-BW fuel, were used in the 12-channel model. There are three BWU CHF correlations that constitute the licensing basis for the Framatome Advanced Mark-BW fuel assembly. These correlations use the same basic equation, but are fit to different databases (References 6 and 7). VIPRE-D applies different BWU correlations at different axial levels, according to the following guidelines:

- BWU-N, which is only applicable in the presence of non-mixing vane grids (MVG), is used from the beginning of the heated length to the leading edge of the first structural MVG (Reference 6).

- BWU-Z, which is the enhanced mixing vane correlation, is used from the leading edge of the first structural MVG to the leading edge of the second structural MVG (Reference 6).

- BWU-ZM, which is just BWU-Z with a multiplicative enhancement factor and is applicable in the presence of mid-span mixing grids (MSMGs), is used from the leading edge of the second structural MVG to the leading edge of the last structural MVG (Reference 7).

- For the uppermost span, in which the end of heated length occurs less than one grid span beyond the last MVG, the BWU-Z correlation is used with a grid spacing equal to the effective grid spacing (the distance from the last grid to the end of the heated length) (Reference 6).

Corrected by letter dated June 23, 2006

(4) As required by the NRC staff in Reference 4, the following model options were reviewed and justified by the licensees for use in the DNB evaluation of the NRC staff-approved PWR fuels.

- Radial Nodalization: The licensees utilize 1/8th core symmetry and the model is applicable to the 14x14, 15x15, and 17x17 fuel arrays. These guidelines are consistent with the previously approved COBRA models (Reference 3). Benchmark calculations with the Framatome LYNXT code (References 8 and 9) verified this modeling approach.

- Axial Nodalization: Node size is limited to a maximum of 6 inches.

- Fuel Rod Model: The licensees will use the dummy fuel rod model which requires the surface heat flux as input, computed by the RETRAN code. RETRAN accounts for the fuel conduction, gap conductance, and associated delayed energy transport effects. This approach is consistent with previously approved licensees' methodologies (Reference 3). Also, the analysis assumes that 97.4 percent of the reactor power is generated in the fuel while 2.6 percent is generated in the coolant, consistent with the previously approved COBRA modeling techniques.

- Power Distribution: A chopped cosine axial power shape is typically used. The power distribution is modeled to limit the cross flow and mixing in the hot channel since the peak $F_{\Delta H}$ is also applied to the thimble and hot cell. This results in a conservative calculation of DNBR. Also since the data is limited with respect to top peaked axial profiles, the licensees utilize the Tong F-factor to correct for non-uniform axial power shapes, which has been previously approved by the NRC staff. The licensees also performed benchmark comparisons between VIPRE-D/BWU and LYNXT/BWU and VIPRE-D/WRB-1 with COBRA/WRB-1 using symmetric and non-symmetric axial power shapes that show no dependency on the shape of the power distribution.

- Turbulent Mixing: The turbulent mixing factor is 0.0 as opposed to the VIPRE Manual recommended value of 0.8. This produces a conservative calculation since momentum mixing is precluded with this assumption. The turbulent mixing for single-phase fluid in single channels is set to 0.038 (range 0.0 to 0.1). This is the default model approved in the original generic VIPRE SER. For flow paths connected to lumped channels, turbulent mixing is set to zero for conservatism.

- Axial Hydraulic Losses and Cross-Flow Resistance: For axial cross flow, the McAdams correlation is used to approximate the Colebrook smooth pipe formulation for single-phase axial friction. Lateral resistance is computed by the Idle Chik empirical correlation (Reference 10) for bundle circular tubes in a vertical column.

- Form Loss Coefficients: These are obtained from the vendor for the particular fuel bundle designs. VIPRE-D properly places the losses at the top of the cell, or at the boundaries between the cells where the grids are located. Varying the location of the grid resistance upward or downward showed an insignificant change in DNBR (much less than the 5 percent uncertainty associated with thermal-hydraulic codes in this application).

- Two-Phase Flow and Heat Transfer Correlations: The licensees will use the following models to compute CHF for the specific fuel types: EPRI Subcooled Void Model, EPRI Bulk Boiling Void Model, and the EPRI Two-Phase Friction Multiplier. No hot wall friction correlation is used. Results of the comparisons of VIPRE-D with LYNXT justify this choice of correlations and models since this combination produced the lowest standard deviation in DNBR with a value of 0.89 percent. The slip model is not to be employed and cannot be used. The Dittus-Boelter single-phase heat-transfer correlation is also used.

-Engineering Factors: The licensees include the following factors which adversely affect DNBR: Local Heat Flux Hot Channel Factor, Engineering Enthalpy-Rise Hot Channel Factor, Stack Height Reduction, and Inlet Flow Reduction. These factors are fuel

These correlations are to be used over the following thermal hydraulic conditions:

Table 4: Range of validity for BWU-Z, BWU-ZM and BWU-N

	BWU-Z	**BWU-ZM**	**BWU-N**
Pressure [psia]	400 to 2,465	400 to 2,465	788 to 2,616
Mass Velocity [Mlbm/hr-ft^2]	0.36 to 3.55	0.47 to 3.55	0.25 to 3.83
Thermodynamic Quality at CHF	Less than 0.74	Less than 0.68	Less than 0.70
Applicability	Mixing Vane Grids	Mid-Span Mixing Grids	Non-Mixing Vane Grids

The WRB-1 correlation is applicable to the Westinghouse 15x15 OFA fuel assemblies at Surry Power Station, Unit Nos. 1 and 2. The DNBR limit was found to be 1.17 and was the same as the limits computed using the previously approved methodologies of the licensees (COBRA of Reference 11) and Westinghouse (THINC and VIPRE-01). The range of applicability of the WRB-1 correlation is summarized below in Table 5.

Table 5: Range of VIPRE-D / WRB-1 Benchmark State points

VARIABLE	**RANGE**
Pressure [psia]	1440 to 2490
Mass Velocity [Mlbm/hr-ft^2]	0.9 to 3.7
Thermodynamic Quality at CHF	$\leq$0.30
Local Heat Flux [Mbtu/hr-ft^2]	$\leq$1.00
Mixing Vane Grid [in]	> 13.0

By letter dated January 13, 2005, the licensees imposed the following additional restrictions on the use of the VIPRE-D/WRB-1 correlation.

Corrected by letter dated June 23, 2006

(1) VIPRE-D/WRB-1 will not be used when the local heat flux exceeds 1.0 Mbtu/hr-ft^2, and

(2) VIPRE-D/WRB-1 will not be used for fuel with less than a 13-inch mixing vane grid spacing.

The licensees imposed these restrictions as a result of the constraints the NRC staff placed on the use of Reference 11, in its letter dated July 25, 1989.

The previously approved W-3 correlation will be used when conditions fall outside the range of the WRB-1 correlation. Specifically, the W-3 correlation will be applied to the lower portion of the fuel assemblies in the RWSC event because of the bottom peaked axial power profile assumed and the MSLB event because of the low pressures encountered. The W-3 will use a limit of 1.3 for the rod withdrawl event. For the MSLB, the limit of 1.45 will be used for pressures 500 to 1000 psia and the limit of 1.3 will be used for pressures above 1000 psia. |

Benchmarking of the VIPRE-D code with the results of the COBRA code for the events listed in Table 1 above (except the MSLB event) showed an average deviation of less than 0.6 percent in DNBR with a maximum deviation of 3.75 percent. This is within the uncertainty for thermal hydraulic codes used to perform analyses of this nature. For the MSLB, the comparison with COBRA using the W-3 correlation, showed the maximum deviation was 1.5 percent.

The licensees utilized a One-Sided Tolerance theory for the VIPRE-D fuel correlation DNBR design limits given above. This theory allows the licensees to calculate a DNBR limit such that values equal to the design limit avoids DNB with a 95-percent probability at a 95-percent confidence level. All of the statistical techniques utilized in the design limit determinations assumed that the original data distribution is normal. As such the licensees verified that the overall measured-to-predicted CHF ratios were also normally distributed evaluated through the use of a “D” normality test.

Following the review of References 1 and 2, Requests for Additional Information (RAIs) were sent to the licensees requesting supplemental information regarding the review of the VIRPE-D code model options and usage, the statistical evaluation of the DNBR design limits specific to each fuel type, and the benchmarking evaluations. The RAI responses are documented in Reference 13 and the staff found these responses to be acceptable.

Lastly, an error was uncovered by Framatome in their LYNXT computer code, the results of which, were used by the licensees to qualify portions of the licensees' VIPRE-D code. The licensees' assessment of the impact of the error, reported to the NRC staff in Reference 14, shows that the error does not affect the LYNXT/BWU code or correlation limits. Furthermore, the maximum change in any numerical value reported in Reference 1, Section 5, regarding benchmark DNBR calculations between LYNXT and VIPRE-D, was found to be 0.02 percent. Appendix B of Reference 2 is not affected by this error. The NRC staff agrees that the impact of the error has a negligible effect on the calculated differences between the VIPRE-D and LYNXT DNBR benchmarking calculations.

4.0 CONCLUSION

The NRC staff finds the proposed use of the VIPRE-D code to evaluate DNBR for selected PWR transients is acceptable. Furthermore, the NRC staff finds the modifications to VIPRE-D to evaluate the Framatome BWU fuel using the BWU-Z, BWU-ZM, and BWU-N CHF correlations as well as the Westinghouse 15x15 OFA fuel using the WRB-1 correlation to also be acceptable. The VIPRE-D fuel design limits are also found to be acceptable by the NRC staff for NRC staff-approved PWR fuel types. The use of the licensees' VIPRE-D code is limited to only these CHF correlations. The VIPRE-D code can be used subject to the models and options specified in DOM-NAF-2, Rev. 0, Sections 4.0 through and including, Section 4.12 (Reference 1). Evaluation of the Framatome fuel using the BWU-Z, BWU-ZM, and BWU-N CHF correlations is subject to the DNBR limits and ranges given in Section A.5 of DOM-NAF-2, Rev. 0 (Reference 1). Use of the VIPRE-D code is also approved for evaluating the Westinghouse 15x15 OFA fuel using the WRB-1 CHF correlation subject to the DNBR limits and evaluation ranges given in Tables B.8-1 and B.8-2 of DOM-NAF-2, Rev. 0.0 Appendix B (Reference 2). The WRB-1 correlation is limited by the following restrictions: (1) VIPRE-D/WRB-1 will not be used when the local heat flux exceeds 1.0 MBTU/hr-ft^2, and (2) VIPRE-D/WRB-1 will not be used for fuel with less than a 13-inch mixing vane grid spacing, as discussed in Reference 2 Section B.3. The W-3 correlation will also be used when the

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