December 8, 2004

Mr. James F. Mallay
Director, Regulatory Affairs
Framatome ANP
3815 Old Forest Road
Lynchburg, VA 24501

SUBJECT: DRAFT SAFETY EVALUATION FOR FRAMATOME ANP APPENDIX A TO TOPICAL REPORT EMF-92-153(P)(A), “HTP: DEPARTURE FROM NUCLEATE BOILING CORRELATION FOR HIGH THERMAL PERFORMANCE FUEL” (TAC NO. MC3223)

Dear Mr. Mallay:

By letter dated May 19, 2004, and its supplement dated September 30, 2004, Framatome ANP (FANP) submitted Appendix A to Topical Report (TR) EMF-92-153(P)(A), “HTP: Departure From Nucleate Boiling Correlation For High Thermal Performance Fuel," to the staff for review. Enclosed for FANP’s review and comment is a copy of the staff's draft safety evaluation (SE) for Appendix A to TR EMF-92-153(P)(A).

Pursuant to 10 CFR 2.390, we have determined that the enclosed draft SE does not contain proprietary information. However, we will delay placing the draft SE in the public document room for a period of ten working days from the date of this letter to provide you with the opportunity to comment on the proprietary aspects. If you believe that any information in the enclosure is proprietary, please identify such information line-by-line and define the basis pursuant to the criteria of 10 CFR 2.390. After ten working days, the draft SE will be made publicly available, and an additional ten working days are provided to you to comment on any factual errors or clarity concerns contained in the SE. The final SE will be issued after making any necessary changes and will be made publicly available. The staff's disposition of your comments on the draft SE will be discussed in the final SE.

To facilitate the staff's review of your comments, please provide a marked-up copy of the draft SE showing proposed changes and provide a summary table of the proposed changes.

In the event of any comments or questions, please contact Michelle Honcharik at (301) 415-1774.

Sincerely,

/RA/

Robert A. Gramm, Chief, Section 2
Project Directorate IV
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Project No. 728

Enclosure: Draft Safety Evaluation

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Director, Regulatory Affairs
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DRAFT SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

APPENDIX A TO EMF-92-153(P)(A), "HTP: DEPARTURE FROM NUCLEATE BOILING CORRELATION FOR HIGH THERMAL PERFORMANCE FUEL"

FRAMATOME ANP

PROJECT NO. 728

1.0 INTRODUCTION

By letter dated May 19, 2004 (Reference 1), as supplemented by letter dated September 30, 2004 (Reference 2), Framatome ANP (FANP) submitted Appendix A to Topical Report (TR) EMF-92-153(P)(A), "HTP: Departure From Nucleate Boiling Correlation For High Thermal Performance Fuel" for NRC staff review. Appendix A to EMF-92-153(P)(A) proposes the extension of the range of applicability of three independent variables in the high thermal performance (HTP)-departure from nucleate boiling (DNB) correlation. The HTP-DNB correlation has been found acceptable by the NRC staff for use in DNB analysis of HTP fuels for pressurized water reactors (PWRs); its development is documented in EMF-92-153(P)(A) issued in March 1994 (Reference 3).

The DNB-based operational and safety limits, established for each nuclear power plant operating with HTP fuel, provide hot pin/hot subchannel protection for acceptable plant operation. These limits are based on the evaluation of the local coolant conditions that satisfy the HTP-DNB correlation's range of applicability. Under certain conditions, plant performance analyses can predict local coolant conditions that fall outside of the DNB correlation's range of applicability. FANP has submitted Appendix A to TR EMF-92-153(P)(A) to address these situations and ensure regulatory compliance.

2.0 REGULATORY EVALUATION

The primary purpose of the nuclear fuel in operating nuclear reactors is to generate heat. This heat, generated from nuclear fission, must be transferred from the fuel pellet to the surrounding cladding and coolant. In order to maintain safe operation of PWRs, the subcooled flow boiling that occurs must be maintained in the nucleate boiling regime. The point at which the boiling regime changes from nucleate boiling to film boiling is defined as the DNB. The heat flux at this point is called the critical heat flux (CHF). In the film boiling regime, the rate of heat transfer from the fuel cladding is dramatically reduced, resulting in a rapid increase in cladding temperature that can compromise cladding integrity.

In a reactor core, many parameters have an effect on the actual point at which DNB or CHF occurs. Core flow rate, coolant pressure, and thermodynamic quality can all cause changes in

the CHF value. Because of this complexity, no mechanistic model presently exists that fully describes the physical phenomena, making it impossible to predict the CHF with 100 percent accuracy. To obtain a reasonable prediction, the relationships between the relevant independent variables and actual experimental CHF observations have been correlated. The range of applicability of the independent variables in these correlations is based solely on the range over which the actual experimental CHF observations were recorded.

General Design Criterion (GDC) 10 of Appendix A to Part 50 of Title 10 of the *Code of Federal Regulations* (10 CFR) states that “the reactor core ... shall be designed with appropriate margin to assure that specified acceptable fuel design limits are not exceeded during any condition of normal operation, including the effects of anticipated operational occurrences [AOO].”

NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants," (SRP) Section 4.2, "Fuel System Design" and Section 4.4, "Thermal and Hydraulic Design," give the criteria and practices found acceptable by the NCR staff for meeting GDC 10.

In terms of the specific evaluation of Appendix A to EMF-92-153(P)(A), as stated in SRP Sections 4.2 and 4.4, the NRC staff finds that CHF correlations should be developed such that there is a 95 percent probability at the 95 percent confidence level that the hot rod in the core does not experience DNB during normal operation or AOOs.

3.0 TECHNICAL EVALUATION

FANP used a series of methods to justify extending the range of applicability of the HTP-DNB correlation. Desired was the extension of both the upper and lower limits of pressure and thermodynamic quality and the extension of the lower limit for mass velocity. For extending the regions of upper quality, lower mass velocity, and lower pressure, a new database consisting of additional experimental data was used to compare with CHF predictions made using the HTP-DNB correlation. These experimental data points were recorded experimental CHF occurrences that were gathered but not used in developing the HTP-DNB correlation.   For extending the regions that remained, regions of lower quality and higher pressure, different techniques, such as trend analysis, extrapolation, and statistics were employed as justification. The following discussion addresses each of the methods presented and gives the rationale for the resulting conclusions.

The HTP-DNB correlation, as approved, was developed using a set of data points obtained in multiple tests conducted at the Columbia Heat Transfer Facility. In addition to this data, additional data points were also obtained in some of the tests but were not utilized in establishing the correlation. This “New” data was filtered to ensure that it adequately represented the full range of fuel design parameters. What resulted was a new database consisting of data points indicating measured CHF values for local conditions of 1400 pounds per square inch-atmosphere (psia) and ranging over the proposed upper quality and lower mass velocity regions. As a first step, the NRC staff independently verified the completeness and applicability of this new database in serving as a basis for making generic conclusions about the HTP-DNB correlation. The NRC staff used Stein’s procedure (Reference 4) to determine if the new database contained enough points in the extended regions and a histogram plot to determine if the new database sufficiently represented the range of approved

assembly geometries. The results of Stein's procedure showed that the new database was adequately populated in the extended regions. The histogram, comprised of the average predicted to measured (P/M) CHF values for each of the experimental test sections, showed that the new database conservatively represented the test sections. Although there was no extended data for five of the tests, comparisons indicated that in no case did the differing geometry produce a non-conservative trend when the HTP-DNB correlation was applied to the extended data. Therefore, the NRC staff concludes that the new database is acceptable as a basis for assessing the predictive accuracy of the HTP-DNB correlation over the entire range of approved assembly geometries.

To justify extending the regions of upper quality, lower mass velocity, and lower pressure, the values describing the local conditions producing CHF were taken from the new database and entered into the HTP-DNB correlation's polynomial equation. The ranges of each of these independent variables were as follows: pressure values ranged from 1385 psia to 1430 psia, thermodynamic quality values ranged from -0.019 to 0.515, and mass velocity values ranged from 0.498 million pounds per hour per square foot (Mlb/hr-ft^2) to 3.542 Mlb/hr-ft^2. The resulting CHF predictions were then compared with the measured CHF values from the new database. The P/M ratios were plotted over the respective ranges of each of the independent variables. These plots showed no biasing trends and an average P/M ratio less than 1.0, implying predictive conservatism in the extended regions. The NRC staff used the tables of data provided by FANP to independently confirm these results and found that they were acceptable. The NRC staff concludes that, while data for pressures between 1415 psia and 1775 psia are missing, the new data at 1400 psia stand as verification that the HTP-DNB correlation adequately predicts CHF in the proposed extended regions of lower pressure, higher quality, and lower mass velocity.

To justify extending the region of higher pressure, FANP employed a sequence of techniques. First, an analysis of trends was used to establish which of the independent variables could be extrapolated. Next, a traditional correlation verification technique was used to determine the direction and length of the extrapolation. Finally, the physical consequences of extrapolating the given independent variables were examined. However, after a thorough review, the NRC staff finds this procedure unacceptable. None of the steps lead to the quantitative assurance of a 95 percent probability at a 95 percent confidence level that the fuel in the core would not experience DNB. Because the correlation is primarily a statistical fit to data, not a mechanistic expression of the physical behavior, the conclusions reached by FANP serve only to characterize the developing database.

4.0 CONCLUSION

The staff has reviewed Appendix A to TR EMF-92-153(P)(A) to assess the acceptability of the justifications therein for extending the range of applicability of the HTP-DNB correlation. The NRC staff concludes as follows:

(1) Based on the comparisons with the additional data, the quantitative statistical assurances continue to be met by the correlation in the regions of lower pressure, higher quality, and lower mass velocity. Therefore, the independent variables of the HTP-DNB correlation can be extended as depicted in Table 1. The HTP-DNB correlation safety limit will remain at 1.141 over these extended regions.

Table 1

Range of Independent Variables for the HTP-DNB Correlation with the Extension of the Upper Quality, Lower Mass Velocity, and Pressure Limits

Independent Variable	**As Approved**		**Extended**	
	Minimum Value	Maximum Value	Minimum Value	Maximum Value
System Pressure, psia	1775	2425	***1385***	2425
Mass Velocity, Mlb/hr-ft^2	0.936	3.573	***0.498***	3.573
Thermodynamic Quality	-0.125	0.358	-	***0.515***

(2) The necessary statistical assurances were not given for local coolant conditions where the pressure is greater than 2425 psia. Therefore, the HTP-DNB correlation's maximum pressure value must remain unchanged.

(3) Actions for analyzing the operating conditions outside of the approved ranges of the maximum pressure (2425 psia) but less than 2600 psia are stated below. Extrapolations below the minimum quality range using the process described in Reference 3 are permitted with no lower limit. Any other extrapolation requires a plant-specific review.

When pressures greater than the upper pressure limit of 2425 psia but less than 2600 psia are encountered, all of the local coolant conditions are calculated at the upper pressure limit of 2425 psia using the NRC-approved thermal hydraulic code and then used in the calculation of the HTP CHF.

5.0 REFERENCES

1. Letter from J. F. Mallay (FANP) to U.S. Nuclear Regulatory Commission (NRC), "Request for Review and Approval of Appendix A to EMF-92-153(P)(A), HTP: Departure From Nucleate Boiling Correlation for High Thermal Performance Fuel," dated May 19, 2004. (ADAMS Accession No. ML042710372)

2. Letter from J. F. Mallay (FANP) to NRC, "Response to Request for Additional Information - Appendix A to EMF-92-153(P)(A), HTP: Departure From Nucleate Boiling Correlation for High Thermal Performance Fuel," dated September 30, 2004. (ADAMS Accession No. ML042780403)

3. EMF-92-153(P)(A) and Supplement 1, "HTP: Departure from Nucleate Boiling Correlation for High Thermal Performance Fuel," Siemens Power Corporation, March 1994. (ADAMS Accession No. for cover letter 9403240220, for non-proprietary version of report 9403240222, for proprietary version of report 9403240226)

4. Lurie, D., Moore, R. H., *Applying Statistics* (NUREG-1475), USNRC, dated February 28,1994. (ADAMS Accession No. 9405310242)

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S. Marshall

Date: December 8, 2004