March 17, 2004

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

SUBJECT: DRAFT SAFETY EVALUATION FOR TOPICAL REPORT EMF-2310(P), REVISION 1, "SRP, CHAPTER 15 NON-LOCA METHODOLOGY FOR PRESSURIZED WATER REACTORS" (TAC NO. MC0329)

Dear Mr. Mallay:

By letter dated August 12, 2003, Framatome ANP submitted Topical Report (TR) EMF-2310(P), Revision 1, "SRP, Chapter 15 Non-LOCA Methodology for Pressurized Water Reactors," to the staff for review. Enclosed for Framatome ANP's review and comment is a copy of the staff's draft safety evaluation (SE) for the TR.

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. Number the lines in the marked-up SE sequentially and provide a summary of the proposed changes.

If you have any questions, please contact Michelle C. Honcharik at 301-415-1774.

Sincerely,

/RA/

Stephen Dembek, Chief, Section 2
Project Directorate IV
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Project No. 728

Enclosure: Draft Safety Evaluation

March 17, 2004

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Director, Regulatory Affairs
Framatome ANP
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cc w/encl: See next page

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DRAFT SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

EMF-2310(P), REVISION 1, "SRP CHAPTER 15 NON-LOCA METHODOLOGY

FOR PRESSURIZED WATER REACTORS"

FRAMATOME ANP

PROJECT NO. 728

1.0 INTRODUCTION

By letter dated August 12, 2003 (Reference 1), Framatome ANP (FANP) requested review and approval for referencing in licensing actions Topical Report (TR) EMF-2310(P), Revision 1, "SRP Chapter 15 Non-LOCA Methodology for Pressurized Water Reactors," in particular EMF-2310, Section 5.6 “CVCS Malfunction That Results in a Decrease in the Boron Concentration in the Reactor Coolant (Boron Dilution).”

The noted section has been revised to address the dilution front model used when the residual heat removal (RHR) system is in operation, all control rods are inserted in Modes 4 and 5, and complete mixing of the fluid is assumed prior to entry of the diluted fluid into the core.

EMF-2310(P) methodology incorporates S-RELAP5 as the systems analysis code and was previously reviewed and approved by the NRC staff for application to Chapter 15 non-loss-of-coolant accident (non-LOCA) events on May 11, 2001 (Reference 2).

2.0 REGULATORY BASIS

The regulatory bases for the boron dilution events are found in the General Design Criteria (GDC) (Reference 3) and the Standard Review Plan (SRP) (Reference 4). The specific applicable GDCs are:

(1) GDC 10, *Reactor Design*

(2) GDC 15, *Reactor Coolant System Design*

(3) GDC 26, *Reactivity Control System Redundancy and Capability*

The applicable SRP Section is 15.4.6, "Chemical and Volume Control System Malfunction that Results in a Decrease in Boron Concentration in the Reactor Coolant (PWR)."

3.0 TECHNICAL EVALUATION

FANP has revised Section 5.6 of EMF-2310(P), Revision 0 in three areas. Each is discussed below.

3.1 The Dilution Front Model will be Used when the RHR System is in Operation

When one or more reactor coolant pumps are operating it is assumed that complete, instantaneous mixing of boron with the reactor coolant system (RCS) water occurs. Section 3.3 of this safety evaluation discusses this further. For modes where the RHR, or shutdown cooling system, is in operation, flow rates may not be sufficient to assure complete mixing of the reactor coolant system. Under these conditions the mixing front approach is applied.

The mixing front approach assumes that the diluent mixes with the RCS and results in reduced boron concentration at the mixing location. The dilution is then viewed as a series of dilution fronts progressing through the RCS. Dilution mixture transit time to the bottom of the core is based on the volume and the flow rates of both the diluent and RCS flows. The result is that dilution flows are fully mixed in the lower plenum prior to entrance into the core.

The NRC staff has reviewed the model as presented in EMF-2310(P), Revision 1, Section 5.6, and finds it acceptable. If operator action is required to terminate the transient, the time to dilution below the critical concentration must provide sufficient margin that the operator has the following times to take corrective action:

(a) During refueling: 30 minutes.

(b) During startup, cold shutdown, hot standby, and power operation: 15 minutes.

3.2 All Control Rods will be Assumed to be Inserted in Modes 4 and 5

Control rod insertion is permitted in Modes 4 and 5, but during refueling operations the analysis must assume withdrawal of all control rods. This is stated in SRP Section 15.4.6, Acceptance Criteria, parameter assumption (vi).

FANP has stated that if a plant has procedures that increase the shutdown boron requirements to compensate for a stuck rod, then the critical boron concentration is determined assuming that all rods are inserted for Modes 4 and 5. Otherwise, the critical boron concentration is determined using the assumption that the most reactive rod is stuck in the fully withdrawn position.

The NRC staff finds this consistent with the requirements of GDC 26 and guidance of SRP Section 15.4.6, Acceptance Criteria and, therefore, is acceptable.

3.3 Complete Mixing of the Fluid is Assumed Prior to Entry of the Diluted Fluid into the Core

Support of the complete mixing model is based on supporting calculations performed with the STAR-CD computational fluid dynamics (CFD) code for the International Standard Problem ISP-43. ISP-43 is a voluntary participation problem of a test performed at the University of

Maryland 2x4 Thermal-Hydraulic Loop. The test was performed by holding the vessel coolant at a constant temperature of 347K (165°F) while injecting water into one cold leg. Mixing was determined through thermocouple measurements. Boron was not injected in this test, but the measure of success in predicting the test is to predict the temperature distribution as measured by the exit of the downcomer.

Results of the STAR-CD simulation indicate very close agreement with the test data over most of the range of the test. The initial temperature, the end state temperature, and time of the end state temperature are predicted very accurately. There is a few percent difference in the slope of the temperature decay as the entering fluid mixes. The difference is not significant, however, and demonstrates that the complete mixing assumption is valid for the flow conditions in the test.

FANP, in Attachment A of Reference 1, has stated that "[t]he analysis of a boron dilution event depends on the rate of dilution and the plant design. The plant layout dictates whether the dilution can be treated symmetrically or asymmetrically....If the charging line for residual heat removal flow is not in the same cold leg as the dilution flow, or if the RHR flow is distributed across the other cold legs, the boron dilution event is asymmetrical." Review of the specific application of the EMF-2310(P) methodology must be performed to ensure the situation warrants use of the complete mixing assumption. The complete mixing model cannot be used under asymmetric conditions.

4.0 CONDITIONS

The NRC staff notes that a generic TR describing a code such as S-RELAP5 cannot provide full justification for each specific individual plant application. When a license amendment is necessary in order to use the S-RELAP5 based methodology, the individual licensee or applicant must provide justification for the specific application of the code which is expected to include:

(1) Nodalization: Specific guidelines used to develop the plant-specific nodalization. Deviations from the reference plant must be described and defended.

(2) Chosen Parameters and Conservative Nature of Input Parameters: A table that contains the plant-specific parameters and the range of the values considered for the selected parameter during the TR approval process. When plant-specific parameters are outside the range used in demonstrating acceptable code performance, the licensee or applicant will submit sensitivity studies to show the effects of that deviation.

(3) Calculated Results: The licensee or applicant using the approved methodology must submit the results of the plant-specific analyses of the reactor vessel peak pressure.

The parameters and assumptions used in the analytical model should be suitably conservative. The following values and assumptions are considered acceptable:

(1) For analyses during power operation, the initial power level is rated output (licensed core thermal power) plus an allowance of 2 percent, or justified amount, to account for power-measurement uncertainty.

(2) The boron dilution is assumed to occur at the maximum possible rate.

(3) The core burnup and corresponding boron concentration are selected to yield the most limiting combination of moderator temperature coefficient, void coefficient, Doppler coefficient, axial power profile, and radial power distribution.

(4) All fuel assemblies are installed in the core.

(5) A conservatively low value is assumed for the reactor coolant volume.

(6) For analyses during refueling, all control rods are withdrawn from the core.

(7) For analyses during power operation, the minimum shutdown margin allowed by the technical specifications is assumed to exist prior to the initiation of boron dilution.

(8) For each event analyzed, a conservatively high reactivity addition rate is assumed taking into account the effect of increasing boron worth with dilution.

(9) Conservative scram characteristics are assumed, i.e., maximum delay time with the most reactive rod held out of the core.

5.0 CONCLUSIONS

The NRC staff concludes that the S-RELAP5 code is capable of addressing the thermal-hydraulic response of the boron dilution event in a conservative manner and is, therefore, approved for reference in licensing actions.

6.0 REFERENCES

(1) Letter from Framatome ANP to NRC, Requesting Review of EMF-2310(P) Revision 1, "SRP Chapter 15 Non-LOCA Methodology for Pressurized Water Reactors," August 12, 2003 (ADAMS Accession No. ML032460852).

(2) Letter from NRC to Framatome ANP, Acceptance for Referencing of Licensing Topical Report EMF-2310(P), Revision 0, "SRP Chapter 15 Non-LOCA Methodology For Pressurized Water Reactors" (TAC No. MA7192)," May 11, 2001 (ADAMS Accession No. ML033580677).

(3) Title 10 of the *Code of Federal Regulations* Appendix A to Part 50, General Design Criteria for Nuclear Power Plants.

(4) NUREG-0800, Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants, Revision 2, April 1996.

Principal Contributor: Ralph Landry

Date: