July 20, 2005

Mr. Ronnie L. Gardner, Manager
Site Operations and Regulatory Affairs
Framatome ANP
3315 Old Forest Road
Lynchburg, VA 24501

SUBJECT: DRAFT SAFETY EVALUATION FOR FRAMATOME ANP (FANP), TOPICAL REPORT (TR) EMF-93-177(P), REVISION 1, "MECHANICAL DESIGN FOR BWR [BOILING-WATER REACTOR] FUEL CHANNELS" (TAC NO. MC5665)

Dear Mr. Gardner:

On January 14, 2005, FANP submitted EMF-93-177(P), Revision 1, "Mechanical Design for BWR Fuel Channels," to the Nuclear Regulatory Commission (NRC) staff for review. Enclosed for FANP's review and comment is a copy of the NRC staff's draft safety evaluation (SE) for the TR.

Pursuant to Section 2.390 of Title 10 of the *Code of Federal Regulations* (10 CFR), 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 10 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 10 working days, the draft SE will be made publicly available, and an additional 10 working days are provided to you to comment on any factual errors or clarity concerns contained in the draft SE. The final SE will be issued after making any necessary changes and will be made publicly available. The NRC staff's disposition of your comments on the draft SE will be discussed in the final SE.

To facilitate the NRC 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.

If you have any questions, please contact Michelle C. 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 SE

July 20, 2005

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DRAFT SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

TOPICAL REPORT EMF-93-177(P), REVISION 1

"MECHANICAL DESIGN FOR BWR FUEL CHANNELS"

FRAMATOME ANP

PROJECT NO. 0728

1.0 INTRODUCTION AND BACKGROUND

By letter dated January 14, 2005 (Agencywide Documents Access Management System (ADAMS) accession no. ML050240012), and supplemented by letter dated April 22, 2005 (ADAMS accession no. ML051160272), Framatome ANP (FANP) submitted to the U.S. Nuclear Regulatory Commission (NRC) a revision to the licensing topical report (TR) EMF-93-177(P)(A), Revision 1, "Mechanical Design for BWR [boiling-water reactor] Fuel Channels," for review and approval. The approved TR describes the fuel channel box mechanical design methodology for BWRs. Revision 1 to the TR corrects an error in determining the allowable differential pressure across the channel wall.

The mechanical design methodology in the TR includes design criteria and analytical methods for evaluating fuel channel mechanical performance. The design criteria consist of stress and strain limits, fatigue, corrosion and hydrogen pickup, and dimensional changes for normal operation, anticipated operational occurrences (AOOs), and accident conditions. An aspect of the mechanical performance is to determine the fuel channel strength, which is the ability to withstand the differential pressure across the channel wall.

There are two approaches in determining the fuel channel strength: (1) a deformation analysis of preventing interference with control blades, and (2) a stress or load analysis of preventing collapse failure. The first approach establishes an allowable differential pressure across the channel wall using the ABAQUS finite element code such that the resulting deformation would not interfere with the control blade insertion. For the second approach, the standard approach would be to use the American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME Code) stress limits and perform a linear elastic stress analysis. However, the modern fuel channels cannot meet the stringent ASME Code requirements due to the thin sheath structure design. FANP resorted to other options in the ASME Code. The options include plastic analysis and limit analysis in determining collapse loads. The limit analysis is a special case of plastic analysis in which the material is assumed to be in an ideally plastic flow with no strain hardening assumed. The analyses showed that the first approach, the deformation analysis, provided the most conservative result, i.e. the lowest numerical result, for the channel strength.

FANP recently discovered that an error was made in the limit analysis in EMF-93-177(P)(A). As discussed during the March 23, 2005, meeting (ADAMS accession no. ML051380416) the limit

analysis used a large deflection solution method and the analysis was carried into post-buckling regime. These were inconsistent with the requirements in the ASME Code. In fact, FANP performed a plastic analysis and labeled it a limit analysis. FANP submitted EMF-93-177(P), Revision 1 to revise the analyses and provide other administrative changes.

2.0 REGULATORY EVALUATION

The fuel system consists of arrays of fuel rods including fuel pellets and tubular cladding, spacer grids, end plates, and reactivity control rods. The objectives of the fuel system safety review are to provide assurance that (1) the fuel system is not damaged as a result of normal operation and AOOs, (2) fuel system damage is never so severe as to prevent control rod insertion when it is required, (3) the number of fuel rod failures is not underestimated for postulated accidents, and (4) coolability is always maintained. The NRC staff acceptance criteria are based on the NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants," Section 4.2, "Fuel System Design." These criteria include three parts: (1) design bases that describe specified acceptable fuel design limits as described in General Design Criterion 10 to Appendix A of Title 10 of the *Code of Federal Regulations* Part 50, (2) design evaluation that demonstrates that the design bases are met, and (3) testing, inspection, and surveillance plans that show that there are adequate monitoring and surveillance of irradiated fuel. The design bases include (1) fuel system damage, (2) fuel rod failure, and (3) fuel coolability. Dimensional changes of the fuel channel must be included in the design analysis to establish operational tolerances, which are part of the requirements in the design bases.

3.0 TECHNICAL EVALUATION

3.1 Deformation Analysis Allowable Pressure

As mentioned above, the allowable differential pressure is determined by preventing interference with control blades in a deformation analysis. The deformation analysis involves the use of a finite element code. In Revision 1 of the TR, FANP selected the ANSYS code, instead of ABAQUS, to calculate the allowable differential pressure. The result showed that there was only minor differences between ANSYS and ABAQUS results in the allowable differential pressure analysis. The NRC staff confirmed that the deformation analysis is still the bounding analysis with the use of the ANSYS code.

The NRC staff reviewed the deformation analysis. Based on the use of ANSYS, a finite element code that is well known and widely accepted in the industry, the NRC staff concludes that the deformation analysis in determining the allowable differential pressure across the channel wall is acceptable for the TR.

3.2 Plastic Analysis Collapse Load

In the TR, the collapse load for the revised plastic analysis is determined by following procedures dictated by the ASME Code for normal operation, AOOs, and accident conditions. There is no more limiting analysis in the revised plastic analysis. The revised plastic analysis uses large deflection, strain hardening, and double-elastic slope features as allowed in the

ASME Code to determine the collapse load. The results showed two collapse loads: one for normal operation and AOOs, and the other for accident conditions. However, both loads are higher than the loads obtained from the deformation analysis, which indicates that the deformation analysis consistently provides the most conservative result for the channel strength.

The NRC staff reviewed the procedures and analysis. Based on the consistency with the ASME Code, the NRC staff concludes that the plastic analysis used in determining the collapse load is acceptable for EMF-93-177(P), Revision 1.

3.3 Administrative Changes

FANP proposed several minor administrative changes in the TR. None of the administrative changes affect the outcomes of the technical analyses. The NRC staff reviewed the changes. Based on the fact of no technical involvement, the NRC staff concludes that the administrative changes are acceptable for EMF-93-177(P), Revision 1.

4.0 LIMITATIONS AND CONDITIONS

The NRC staff has reviewed the TR and supplements, and approves the use of this TR given the following limitations and conditions:

(1) The fuel channel topical report methods and criteria may be applied to similar fuel channel designs with a like configuration - a square box with radiused corners open at the top and bottom ends. The wall thicknesses shall fall within the range of current designs. The channels shall be fabricated from either Zircaloy-2 or Zircaloy-4. The material properties in the topical report shall conservatively apply to the channel design.

(2) FANP shall resubmit the channel bulge and bow data statistics if the two-sigma upper and lower bounds change by more than one standard deviation.

(3) This TR is approved using ABAQUS or ANSYS codes in the deformation analysis. The use of other codes in the deformation analysis, i.e., NASTRAN, is beyond the current approval.

5.0 CONCLUSION

The NRC staff has reviewed the FANP submittal of the proposed revision of allowable differential pressure across the channel wall. Based on the NRC staff evaluation, the NRC staff approves the proposed revision of allowable differential pressure in determining the fuel channel strength and administrative changes in EMF-93-177(P), Revision 1.

Principal Contributor: S. Wu

Date: July 20, 2005