August 23, 2005

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

SUBJECT: FINAL 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:

By letter dated January 14, 2005, FANP submitted TR EMF-93-177(P), Revision 1, "Mechanical Design for BWR Fuel Channels," to the U.S. Nuclear Regulatory Commission (NRC) staff. By letter dated July 20, 2005, an NRC draft safety evaluation (SE) regarding our approval of EMF-93-177(P), Revision 1, was provided for your review and comments. FANP had no comments on the draft SE.

The NRC staff has found that EMF-93-177, Revision 1, is acceptable for referencing in licensing applications for General Electric-designed BWRs to the extent specified and under the limitations delineated in the TR and in the enclosed final SE. The final SE defines the basis for acceptance of the TR.

Our acceptance applies only to material provided in the subject TR. We do not intend to repeat our review of the acceptable material described in the TR. When the TR appears as a reference in license applications, our review will ensure that the material presented applies to the specific plant involved. License amendment requests that deviate from this TR will be subject to a plant-specific review in accordance with applicable review standards.

In accordance with the guidance provided on the NRC website, we request that FANP publish accepted proprietary and non-proprietary versions of this TR within three months of receipt of this letter. The accepted versions shall incorporate this letter and the enclosed final SE after the title page. Also, they must contain historical review information, including NRC requests for additional information and your responses. The accepted versions shall include an "-A" (designating accepted) following the TR identification symbol.

If future changes to the NRC's regulatory requirements affect the acceptability of this TR, FANP and/or licensees referencing it will be expected to revise the TR appropriately, or justify its continued applicability for subsequent referencing.

Sincerely,

/RA/
Herbert N. Berkow, Director
Project Directorate IV
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Project No. 728

Enclosure: Final SE

If future changes to the NRC's regulatory requirements affect the acceptability of this TR, FANP and/or licensees referencing it will be expected to revise the TR appropriately, or justify its continued applicability for subsequent referencing.

Sincerely,
/RA/
Herbert N. Berkow, Director
Project Directorate IV
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Project No. 728

Enclosure: Final SE

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ADAMS ACCESSION NO.:ML052370370 **NRR-043** *No substantive changes

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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

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

"MECHANICAL DESIGN FOR BWR [BOILING-WATER REACTOR] 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 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 to 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 were 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. 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 supplement, and approves the use of this TR, given the following limitations and conditions:

(1) The fuel channel TR methods and criteria may be applied to fuel channel designs similar to the configuration of 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. FANP will not use Zircaloy-2 or Zircaloy-4 material for channels that have less strength than specified in the TR, and if the strength of the material is greater than that in the TR FANP will not take credit for the additional strength without NRC staff review.

(2) Updates to channel bulge and bow data are permitted without review by the NRC staff; however, 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: August 23, 2005