FINAL SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

TOPICAL REPORT ANP-EMF-93-177(P)(A) REVISION 1, SUPPLEMENT 1(P), REVISION 0,

"MECHANICAL DESIGN FOR BWR [BOILING WATER REACTOR] FUEL CHANNELS

SUPPLEMENT 1: ADVANCED METHODS FOR NEW CHANNEL DESIGNS"

AREVA NP INC.

TAC NO. ME4455

1.0 INTRODUCTION AND BACKGROUND

By letter dated March 26, 2010, AREVA NP, Inc. (AREVA), submitted Topical Report (TR) EMF-93-177(P)(A), Revision 1, Supplement 1(P), Revision 0, "Mechanical Design for BWR Fuel Channels Supplement 1: Advanced Methods for New Channel Designs," for U.S. Nuclear Regulatory Commission (NRC) staff review. The approved TR EMF-93-177 (P)(A), Revision 1, describes the fuel channel box mechanical design methodology for BWRs. The Supplement 1 to EMF-93-177(P)(A), Revision 1, supports a new fuel channel design by making changes to the design description, modifying the bulge evaluation model, and improving the control rod interference analysis method.

The mechanical design methodology in EMF-93-177(P)(A), Revision 1, 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.

Supplement 1 supports a new BWR fuel channel design that has geometric differences from what is described in the original TR. The general design of the channel is similar in that it is a square box with rounded corners that is open at the top and bottom ends but the limiting design parameters in EMF-93-177(P)(A), Revision 1, must be extended to support the use of this new channel. The stress calculation method detailed in the TR also requires changes to allow for the more complex geometry of the new channel design. The control rod interference model is being updated to include the capability of combining the effects of interference at multiple elevations.

The information provided in Supplement 1 does not replace any part of EMF-93-177(P)(A), Revision 1, it only extends or provides minor changes to allow for the analysis of a new fuel channel design.

2.0 Regulatory Evaluation

The NRC staff acceptance criteria are based on NUREG-0800, “Standard Review Plan (SRP),” Section 4.2, “Fuel System Design,” and the General Design Criterion (GDC) within Appendix A to Title 10 of the *Code of Federal Regulations* Part 50. There are four relevant criteria from SRP Section 4.2 applicable to this review: (1) design bases, (2) description and design drawings, (3) design evaluation, and (4) testing, inspection and surveillance plans. GDC 10 establishes that the reactor core and associated coolant, control, and protection systems 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. GDC 27 states that the reactivity control systems shall be designed to have a combined capability, in conjunction with poison addition by the emergency core cooling system, of reliably controlling reactivity changes to assure that under postulated accident conditions and with appropriate margins for stuck rods the capability to cool the core is maintained.

3.0 TECHNICAL EVALUATION

Supplement 1 contains a limited number of changes to the approved methodology present in TR EMF-93-177(P)(A), Revision 1. This limited the scope of the NRC staff’s review to only the relevant criteria that could be affected by the changes.

3.1 Fuel Channel Design

The fuel channel design parameters as presented in TR EMF-93-177(P)(A), Revision 1, are being modified to allow for a slightly thinner wall thickness in the upper portion of the fuel channel. This allows for an increase in the internal flow area and a reduction in parasitic neutron absorption by the channel. The design parameters for the lower part of the channel, where differential pressures are greatest, are not being changed. Adequate structural strength will continue to be maintained by this new channel design as analyzed by the methodology set forth in TR EMF-93-177(P)(A), Revision 1. The methodology will continue to be conservative for the new minimum wall thickness and this thickness is established to ensure that new designs will not extend beyond previous experience with fuel assembly Zircaloy structural components. AREVA also maintains a fuel channel surveillance program in alignment with SRP Section 4.2. This program ensures that fuel channels are performing as predicted by the approved methods.

The NRC staff reviewed the proposed fuel channel design change. Based on the continued applicability of the methods in TR EMF-93-177(P)(A), Revision 1, for calculating fatigue; corrosion and hydriding; fuel channel deformation; loss-of-coolant accident (LOCA) and seismic loads, the new minimum wall thickness is well within the range of previous operating experience with Zircaloy components and in accordance with AREVA’s fuel channel surveillance program. The NRC staff concludes that the fuel channel design change is acceptable.

3.2 Fuel Channel Bulge Analysis Method

The method for calculating channel stresses in TR EMF-93-177(P)(A), Revision 1, must be modified for application to the new channel design. The current method cannot model the more complex geometry of the new design, therefore, a numerical technique based on finite element theory has been proposed. This is consistent with other aspects of the fuel channel methodology that also employ finite element analyses. The creep equations in the model have also been improved and are fit to measured bulge data. Figure 2 of Supplement 1 confirms that the model conservatively predicts bulge over a wide range of operating experience. Data is included for Zircaloy-2 and Zircaloy-4 channels in BWR/3,4,5 and BWR/6 reactor designs ranging from low to high exposure.

The NRC staff reviewed the changes to the fuel channel bulge analysis method. Based on the confirmation that the model predicts bulge conservatively over a wide range of operational data, the NRC staff finds the change to the fuel channel bulge analysis method acceptable.

3.3 Statistical Analysis of Control Rod Interference

The statistical methods for analyzing bow and bulge provided in TR EMF-93-177(P)(A) is not changing, however the control rod interference method is being modified. The new finite element model adds the capability of combining the effects of interference at multiple elevations. This allows for the total amount of interference with the control rod to be accurately determined.
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The evaluation is repeated a **[ ]** times in accordance with the TR EMF-93-177(P)(A) Monte Carlo method. The simulation generates sets of random values that effect control rod interference for each trial. Upon completion of the **[ ]**, the **[ ]** margin to a stuck control blade is reported. AREVA performed sample problems using the updated methodology for several plant types including operation at full 120 percent extended power uprate. The results of the sample problems show that significant margin to a stuck control blade remains for all plants and also for the new channel design.

The NRC staff has reviewed the new control rod interference analysis method. Based on the improvement in the model to combine the effects of interference at multiple elevations, the significant experience base AREVA has using finite element analyses, and the increase in the total number of trials to obtain the **[ ]** margin to a stuck blade, the NRC staff finds the control rod interference analysis method acceptable.

4.0 CONCLUSION

The NRC staff has reviewed the AREVA submittal of the proposed Supplement 1 to EMF-93-177(P)(A), Revision 1, that modifies the design description, bulge model, and control rod interference analysis in the original report. Based on the evaluation above, the NRC staff approves TR EMF-93-177(P)(A), Revision 1, Supplement 1(P), Revision 0.

Attachment: Resolution of Comments

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