October 17, 2000

Mr. T. A. Coleman, Vice President
Government Relations
Framatome Cogema Fuels
3315 Old Forest Road
P.O. Box 10935
Lynchburg, VA 24506-3663

SUBJECT: ACCEPTANCE FOR REFERENCING OF LICENSING TOPICAL REPORT BAW-10133P, REVISION 1, ADDENDA 1 AND 2, "MARK-C FUEL ASSEMBLY LOCA-SEISMIC ANALYSES" (TAC NOS. M99906 AND MA5902)

Dear Mr. Coleman:

The U.S. Nuclear Regulatory Commission (NRC) staff has completed its review of the subject topical report addenda, which were submitted by Framatome Cogema Fuels (FCF) by letters dated September 30, 1997, and May 5, 1999. The staff has found that the addenda are acceptable for referencing in licensing applications to the extent specified and under the limitations delineated in the report addenda and the associated NRC safety evaluation, which is enclosed. The safety evaluation defines the basis for the acceptance of the report addenda. The staff will not repeat its review of the matters described in BAW-10133P, Revision 1, Addenda 1 and 2, when they appear as a reference in license applications, except to ensure that the material presented applies to the specific plant involved.

In accordance with procedures established in NUREG-0390, the NRC requests that FCF publish accepted versions of the submittals, proprietary and non-proprietary, within three months of receipt of this letter. The accepted versions shall incorporate this letter and the enclosed safety evaluation between the title page and the abstract, and an -A (designating accepted) following the report identification symbol. The accepted version shall also incorporate all communications between FCF and the NRC during this review.

Pursuant to 10 CFR 2.790, the staff has determined that the enclosed safety evaluation does not contain proprietary information. However, the staff will delay placing the safety evaluation in the public document room for 10 calendar days from the date of this letter to allow you the opportunity to comment on the proprietary aspects only. If, after that time, you do not request that all or portions of the safety evaluation be withheld from public disclosure in accordance with 10 CFR 2.790, the safety evaluation will be placed in the NRC Public Document Room.

Should our acceptance criteria or regulations change so that our conclusions as to the acceptability of the report are no longer valid, applicants referencing the topical report will be expected to revise and resubmit its respective documentation, or submit justification for the continued applicability of the topical report without revision of the respective documentation.

Should you have any questions or wish further clarification, please call Stewart Bailey at (301) 415-1321.

Sincerely,

/RA by Stephen Dembek for/

Stuart A. Richards, Director
Project Directorate IV & Decommissioning
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Project No. 693

Enclosure: Safety Evaluation

cc w/encl:
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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

TOPICAL REPORT BAW-10133P, REVISION 1, ADDENDA 1 AND 2

"MARK-C FUEL ASSEMBLY LOCA-SEISMIC ANALYSES"

FRAMATOME COGEMA FUELS

PROJECT NO. 693

1.0 INTRODUCTION

By letters dated September 30, 1997, and May 5, 1999 (References 1 and 2), Framatome Cogema Fuels (FCF) submitted Addendum 1 and Addendum 2, respectively, to Topical Report BAW-10133P, "Mark-C Fuel Assembly LOCA-Seismic Analyses," Revision 1, for the U.S. Nuclear Regulatory Commission's (NRC) review and approval. The addenda document changes FCF's currently approved methodology, BAW-10133P, Revision 1 (Reference 3), for analyzing fuel assembly loading during seismic and loss-of-coolant accident (LOCA) conditions in pressurized water reactors (PWRs). Both addenda address modifications to the horizontal LOCA and seismic models. No modifications to the original core bounce or fuel assembly vertical models were proposed. By letters dated January 4 and June 28, 2000, the NRC requested additional information regarding the addenda to the topical report (References 4 and 5). FCF provided additional information by letters dated March 17 and July 20, 2000, in response to the staff's requests for additional information (References 6 and 7).

2.0 EVALUATION

Addendum 1 proposed two modifications to currently approved methods (Reference 3) for modeling LOCA and seismic response of PWR fuel. The first proposed modification is a new method for modeling the stiffness of assembly grid locations. Section 2.1 of this safety evaluation provides the staff's evaluation of this proposed modification. Addendum 1 also proposed an alternate method of treating the fluid effects on fuel response. Previously, only added fluid mass was placed at grid nodes. The new proposed method also adds the effects of hydrodynamic coupling between core baffle plates and assemblies. Section 2.2 provides the staff's evaluation of this modification. Addendum 2 proposed the use of higher damping parameters for the modes involving seismic and LOCA responses. This is due primarily to the demonstrated damping influences of fluid flow in typical PWR operations. Section 2.3 provides the staff's evaluation of this modification. Pacific Northwest National Laboratory (PNNL) was a consultant to the NRC in this review.

2.1 Spacer Grid Dynamic Model

Addendum 1 describes a change in the structural model of the fuel assemblies to modify the nature of their response due to assembly-to-assembly impact at grid locations. This applies to the horizontal core model only, and no changes are being made for the vertical and core bounce model described in Reference 3. This modification essentially deals with the parameters K and C in Addendum 1. This modification will produce a more realistic response, especially when an assembly is struck (at a grid location) from opposite sides by adjacent assemblies or core baffle plates. The previously-used grid stiffness that is being revised is described in Appendix A of Reference 3, and the change involves only one K parameter and one C parameter for the horizontal model. The previous spring constant K was tri-linear, while the new method uses constant spring-constant values. The proposed model used experimental techniques that were similar to those used in the original approved methodology to obtain these parameters.

For the various K and C values in the proposed model, there were two constraint equations (Equations 3-11 and 3-12 of Addendum 1) based on a lumped parameter grid dynamic model (shown in Figure 3-1 of Addendum 1). One equation relates to the three stiffness parameters and another equation relates to the damping parameters. Test data from two separate dynamic tests, the dynamic crush test and the lateral pluck test, in conjunction with these constraint equations were used to supply information needed to acquire all K and C values.

The lateral pluck test was performed at room temperature. Data was later corrected for typical PWR accident conditions. The test used a prototype assembly with clamped end conditions typical of reactor core tie down conditions. The assembly was displaced at the center, released and allowed to impact rigid plates at various grid locations. Dynamic load and displacement time history data were taken for a variety of initial mid-span displacements. A computer model was constructed and used to model the various tests with various values of K and C. The values that best matched the experimental data were chosen. Since the mass associated with each grid element was known, this also yielded the damping ratio. These room temperature values were scaled to values reflecting accident conditions by assuming that the stiffness was proportional to Young's modulus values and also by assuming that the damping ratio was temperature invariant. The staff considers this approach acceptable based on the conservative assumptions.

It should be noted that the system damping due to reactor water does not play a role in these values. Damping due to reactor water is treated differently by selecting specific modal damping parameters for consideration. Thus, the fact that the pluck testing was done in air rather than water does not invalidate the data because the K and C values do not consider fluid effects. The staff considers this approach conservative and thus acceptable. Modal damping due to fluid effects is discussed in Section 2.3 of this safety evaluation.

Based on the conservative assumptions and acceptable test results, the staff concludes that the spacer grid dynamic model described in Addendum 1 to Topical Report BAW-10133P, Revision 1 is an adequate model for modeling fuel assembly and baffle plate impacts at grid elevations for seismic and LOCA analysis.

2.2 Hydrodynamic Coupling Model

The proposed model is described in Sections 2.2.2.1 and 2.2.2.2 of Addendum 1. A more detailed description is contained in Attachment 2 of Reference 6. The later reference provides much greater technical detail of the coupling model. The original approved core model of Reference 3 did not assume any hydrodynamic coupling between the baffle plates and the fuel assemblies. The fluid effects were simply treated by adding mass to the beam nodes to match experimentally determined natural frequencies. Core baffle plate motion would only load the outer assemblies and then only if the corresponding gaps between fuel assemblies and core baffle plate were in the closed position.

The proposed model is much more realistic than the one described in Reference 3. In addition to adding mass to the assembly beam nodes (different masses from those of the original model), coupling between the core baffle plates and each of the assemblies is treated by applying a load vector based upon the core baffle motion time history and information from a separate fluid flow model.

This fluid flow model represented a two dimensional (horizontal) slice of an assembly array. For the model concerned, flow was assumed to be non-viscous and incompressible, which is a conservative approach. For small motion amplitudes, the governing equations for this fluid motion results in a Laplace's equation which can be readily solved to yield velocity and pressure distribution in the fluid. Results from this model are then used to arrive at mass terms to be added to the assemblies and to the baffle in cases where loads on the baffle consist of force versus time histories. The analysis showed that there was very little assembly-to-assembly hydrodynamic coupling. The staff considers that assumption of non-viscous and incompressible fluid flow is conservative and thus acceptable.

FCF performed audit calculations of dynamic loading cases simulating safe shutdown earthquake (SSE), surge line break (SLB), and safety injection line break (SILB). Both horizontal loading directions were considered. In Reference 6, impact forces using the proposed model were compared to those generated by using the currently approved model of Reference 3. The results showed that there is a reduction in maximum grid forces for the relatively long duration of SSE. However, there were no significant differences for the SLB and SILB cases as compared to the previously approved model. Thus, the hydrodynamic coupling is considered to have minimal effect on the combined loading of seismic and LOCA on fuel assemblies. Based on the small change in combined loading when compared to the approved model, the staff considers the audit calculations to be acceptable.

Furthermore, the seismic responses using the proposed model were compared with those from the approved model and with test results. The proposed model provides conservative results relative to the test results, and is in better agreement with the test results than the approved model. Thus, the proposed model provides a more realistic approach to evaluating the accident conditions.

Based on the realistic approach, conservative assumptions, and acceptable audit calculations, the staff concludes that the hydrodynamic coupling model proposed in Addendum 1 to Topical Report BAW-10133P, Revision 1 is acceptable for seismic and LOCA analysis.

2.3 Fuel Assembly Damping Values

The fuel assembly dynamic response model described in the approved methodology (Reference 3) is based on an assumption of Rayleigh equivalent damping technique. This assumption is widely used in practice and is implemented by assuming that the damping matrix is a linear combination of the mass and stiffness. The two involved weight functions were determined from two natural frequencies and corresponding damping ratios. Addendum 2 proposed to modify the Reference 3 model by increasing the damping ratios to account for axial flow conditions. Although this could produce lower impact loading on fuel assemblies, it has been observed that such axial flow patterns indeed exist in simulated flow tests.

FCF has performed a substantial amount of fuel assembly damping testing, as was reported in Addendum 2 and in Attachment 1 of Reference 7. In addition to testing for the effects of flow rate on damping, FCF also studied other effects including temperature, dynamic amplitude, and hydrodynamic coupling in air testing environment. Testing facilities included the Control Rod Drive Line facility, a test facility called FAME at FCF's site, and the Hermes test loop facility in France. The FAME facility performs in-air resonance testing only. The FAME and Hermes facilities are capable of full-scale flow testing. All facilities employ appropriate mounting techniques to simulate in-reactor structural conditions.

There were three modes in the damping ratio in the approved methodology. However, only the first and third mode damping ratios contributed to the loading, while the second mode damping ratio had no effect on the loading. The first mode damping ratio was calculated from pluck testing and measurements of the decay of successive oscillations, which is also called the log decrement method. At all the test facilities, the results showed that the first mode damping ratio had test values higher than the value used in the approved methodology for typical PWR accident conditions. The proposed value for the first mode is slightly higher than the value in the approved methodology and still below the test values. The staff considers this increase acceptable because a conservative margin is maintained.

For the third mode damping ratio, in-air resonance testing was performed. The test results indicated that the damping ratios of the first and third modes were very similar. The proposed value for the third mode is also slightly higher than the value in the approved methodology, but still below the test values. The staff considers this increase acceptable because conservative margin is still maintained.

The combined effect of the slightly higher first and third mode damping ratios results in reduced seismic loads as expected, but little change in LOCA loads. Thus, the net effect of the combined seismic and LOCA loads will not significantly vary from the previous results in the approved methodology. Based on the applicable test facilities results, the conservative margins maintained, and the small effect on the overall analysis, the staff concludes that the proposed values for the first and third mode damping ratios are acceptable for seismic and LOCA analysis.

3.0 CONCLUSION

The staff has reviewed Addendum 1 and Addendum 2 to Topical Report BAW-10133P, "Mark-C Fuel Assembly LOCA-Seismic Analyses," Revision 1 and concludes that both addenda are acceptable for incorporation into the overall methodology described in BAW-10133P, Revision 1, for seismic and LOCA licensing applications.

4.0 REFERENCES

1. Framatome Cogema Fuels, "Submittal of Topical Report BAW-10133P, Rev. 1, Addendum 1, Mark-C Fuel Assembly LOCA-Seismic Analyses," September 30, 1997.

2. Framatome Cogema Fuels, "Addendum 2 to BAW-10133P, Rev. 1 Mark-C Fuel Assembly LOCA-Seismic Analyses," May 5, 1999.

3. Shah, S. J., Lide, R. E., "Mark-C Fuel Assembly LOCA–Seismic Analyses," BAW-10133PA, Rev. 1, June 1986.

4. Letter from Stewart Bailey to T. A. Coleman, "Request For Additional Information – Framatome Topical Report BAW-10133P, Addendum 1, Mark C Fuel Assembly LOCA-Seismic Analysis, Revision 1 (TAC No. M99906)," January 4, 2000.

5. Letter from Stewart Bailey to T. A. Coleman, "Request For Additional Information – Framatome Topical Report BAW-10133P, Addendum 2, Mark-C Fuel Assembly LOCA-Seismic Analysis (TAC Nos. M99906 and MA5902)," June 28, 2000.

6. Framatome Cogema Fuels, "Responses to Nuclear Regulatory Commission Questions on BAW-10133P, Revision 1, Addendum 1," March 17, 2000.

7. Framatome Cogema Fuels, "Responses to Nuclear Regulatory Commission Questions on BAW-10133P, Revision 1, Addendum 2, Mark-C Fuel Assembly LOCA and Seismic Analysis," July 20, 2000.

Principal Contributor: S. Wu

Date: October 17, 2000