Attachment 1

RAI 6 Response for PWROG-16043, Revision 2

(PA-ASC-1169) (Non-Proprietary)

(7 total pages including Attachment 1 cover page and RAI 6 response)

A new methodology is being proposed for Westinghouse and CE fuel to credit flowing water damping in mitigation of the degradation in fuel mechanic behavior due to EOL effects on the spacer grids. This methodology is proposed as an option for use in lieu of the still water damping credited in the previously approved methodologies. In order to fully understand how the proposed methodology is intended to conservatively capture the impact of flowing water on fuel assembly vibrations, the NRC staff requests the following information:

RAI Item 6

Section 4.6 of the LTR [

] a,c

Response to 6a

The fuel assembly damping ratio is the measurement of energy dissipation in a mechanical system. To account for the energy dissipation during vibration, the averaged or best estimated damping ratio value is more appropriate to a full core fuel assembly analysis from a physical standpoint. This is different from other local bounding analyses, such as a Departure from Nucleate Boiling (DNB) correlation.

Fuel Assembly (for the AP1000® Plant) Flowing Water Damping Background

[ ] a,c

[

] a,c

[ ] a, c

Figure 1: Damping vs. Velocity Curve that was used for [ ] a, c Model (Reference 1)

Flowing Water Damping Curve for PWROG-16043-P

[

] a, c

[ ]a, c

Figure 2: Damping vs. Velocity Curve for [ ] a, c

Response to 6b

The fuel assembly damping force in flowing water is the summation of the fuel structural damping in air, viscous damping in still water and the hydraulic damping in flowing water as shown in Equation (1). The flowing water damping coefficient measured and used in PWROG-16043-P is also the summation of these three components.

$$F_d = c_s\dot{x} + c_v\dot{x} + c_h\dot{x} \qquad (1)$$

c_s – The structural damping coefficient in air, due to material and friction damping.
c_v – The viscous damping coefficient in still water
c_h – The hydraulic damping coefficient in flowing water, which primarily increases with the axial flow velocity

All three damping coefficients in Equation (1) are neither constant nor linear. All tests that were performed by other fuel vendors concluded that the water temperature has a small effect on fuel assembly damping. Babcock & Wilcox's paper (Reference 2) concluded that damping is minimally affected by temperature ranges from 68°F to 600°F. The Mitsubishi Heavy Industries' topical report (Reference 3) concluded "that the temperature effect of AFD (Axial Flow Damping) appears to be very small up to the reactor operating condition from the maximum test temperature." The flowing water damping tests performed by Westinghouse are consistent with this conclusion.

Test data trend curve fitting

[

] a, c

1) [

] a, c

[ ] a, c

Figure 3: Damping vs Density at [ ] a, c (Figure 4-14 of PWROG-16043-P)

2) [

] a, c

Table 1: The average damping ratios at different temperatures at [ ] a, c

[ ] a, c

3) [

] a, c

A discussion of the conservatism in the 600°F damping curve

[

] a, c

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] a, c

[ ] a, c

Figure 4: Damping Ratio vs. Coastdown Time
for a Typical Westinghouse 3-Loop Unit (Figure 4-21 of PWROG-16043-P)

Summary and Conclusions

[ ] a, c

References

5. [ ] a, c

6. F. E. Stokes and R. A. King, “PWR Fuel Assembly Dynamic Characteristics,” International Conference on Vibration in Nuclear Power Plants, Keswick, United Kingdom, May 9-12, 1978 (BNES), Page 31.

7. MUAP-13020-NP (R0), “Axial Flow Damping Test of the Full Scale US-APWR Fuel Assembly,” August 2013, Page 3-2.

8. WCAP-9401-P-A, “Verification Testing and Analyses of the 17 x 17 Optimized Fuel Assembly,” August 1981.