<u>Question</u>

RAI 4.7.3-1a (Fluence Effects for Reactor Vessel Internals)

<u>Background</u> - SRP-LR Section 4.7.3.1.2 states that for a TLAA disposition pursuant to 10 CFR 54.21(c)(1)(ii), the applicant shall provide a sufficient description of the analysis and document the results of the reanalysis to show that it is satisfactory for the 60-year period.

By letter dated March 26, 2018 (ADAMS ML18087A188), applicant submitted it responses to numerous RAIs (including 4.7.3-1 and 4.7.3-2). In its responses to RAI 4.7.3-2 and part 4 of RAI 4.7.3-1, the applicant provided a summary of the fluence projections for the various core support structure (CSS) components. The applicant stated that components that were projected to remain within the fluence thresholds do not require consideration beyond meeting the American Society of Mechanical Engineers Code requirements.

Additionally, the applicant indicated that the neutron fluence values for several of the CSS components have been projected to exceed the fluence criteria, and that these components must be evaluated to determine whether they meet the additional criteria that are required to be assessed by the CSS design specification.

<u>Issue</u> **-** For RVI components and welds that have been projected to exceed the fluence threshold values, the applicant has not described the design basis methodology used to determine whether these components and welds would meet the additional criteria of the CSS design specification. Additionally, the applicant did not identify the additional criteria (e.g., acceptance limits for the strain or weld quality factor parameters requiring assessment) that the components and welds need to meet or provide the component-specific and weld-specific results of the additional analyses, as compared to the additional criteria, to demonstrate that those criteria are met.

<u>Request</u> - Provide the following additional information for each CSS base metal or weld component that has been projected to exceed the fluence threshold value for the component at the end of the period of extended operation.

1. Describe the design specification methodology that applies to each component and identify the additional design parameter or parameters required to be assessed by the design specification.
2. Provide the acceptance limits or acceptance criteria that apply to the component design parameters requiring further assessment.
3. Provide the calculated component-specific values for the parameters requiring further assessment by the design specification, as assessed for or projected through the end of the period of extended operation.

<u>Response</u>

The irradiation of Type 304 stainless steel based material to fluences greater than [[ ]] at boiling water reactor (BWR) operating temperatures results in reduced ductility and a corresponding decrease in the strain hardening exponent. Therefore, to avoid tensile instability in Type 304 stainless steel structures irradiated to fluences greater than [[ ]], the strain resulting from the combined primary and secondary stresses should be limited to less than the criteria based on the uniform strain capability of the material at the appropriate service conditions. For the Type 308 stainless steel weld material irradiated to fluences greater than [[ ]] at BWR operating temperatures, the strain resulting from the combined primary and secondary stresses should be limited to less than the criteria based on the uniform strain capability of the material at the appropriate service conditions.

The reactor vessel internals (RVI) CSS were evaluated according to the CSS design specification. For austenitic stainless steel subjected to a neutron fluence [[ ]], the base material requires no special consideration in addition to meeting the American Society of Mechanical Engineers (ASME) Code requirements. For austenitic stainless steel components with a neutron fluence [[ ]], the weld material requires no special consideration.

The design specification states that when a fluence [[ ]], that portion of the component and the weld exposed to this greater fluence shall meet the following strain criteria in the design specification in addition to the ASME Code requirements.

[[

]]

where,

P_m = Primary membrane stress
P_b = Primary bending stress
Q_m = Secondary membrane stress
Q = Secondary stress (including membrane and bending)
E = Elastic modulus
ε_{unif} = Uniform elongation

The uniform elongation ε_{unif} has [[

]]

The specification states that SS-308 or SS-308L welds subjected to a neutron fluence [[ ]] shall either be limited to [[ ]] resulting from any operating and accident load or be [[ ]] as determined by Table NG-3352-1 of the ASME Boiler and Pressure Vessel (B&PV) Code, Section III, Subsection NG.

The fast neutron fluence values at 54 effective full power years (EFPY) (equivalent to 60 years of plant operation at 90% capacity factor) were calculated for internal CSS components and summarized in Table 1 below.

Table 1: RVI Core Support Structures Neutron Fluence

Item No.	Core Support Structure Component	Fast Fluence at 54 EFPY (n/cm^2)
1	Shroud	4.07E+21
2	[[	
		]]
3	Core Plate	5.88E+20
	Core Plate Wedges	8.36E+20
4	Top Guide/Grid	4.50E+21
5	[[	]]
6	Control Rod Guide Tube	2.32E+21
7	Orificed Fuel Support	7.64E+21
8	Peripheral Fuel Support	8.52E+20

The fluence values of the following internal CSS components exceeded [[ ]] for base material, and [[ ]] for weld material:

- Shroud
- Core Plate
- Top Guide / Grid
- Control Rod Guide Tube (CRGT)
- Orificed Fuel Support (OFS)
- Peripheral Fuel Support (PFS)

The primary and secondary stresses of the CSS components at the current licensed thermal power are the inputs used to calculate the strains at Normal/Upset, Emergency and Faulted conditions. The primary and secondary stresses are fluence-independent parameters. The strains of the components that exceed the fluence limit at 60 years of plant operation were calculated. The calculated strains are compared with the allowable strains in Table 2. The calculated strains are less than the allowable strains.

Table 2: Fluence Effect Evaluation Results (Strain)

Item No.	Core Support Structure Component[1]	Service Level[2]	Category[3]	Calculated Strain (in/in)	Allowable Strain[3] (in/in)
1	Shroud	N/U	$(P_m+Q_m) / E$	[[	
		N/U	$(P_m+P_b+Q) / E$		
		E	$(P_m+Q_m) / E$		
		E	$(P_m+P_b+Q) / E$		
		F	$(P_m+Q_m) / E$		
		F	$(P_m+P_b+Q) / E$		
2	Core Plate	U	$(P_m+Q_m) / E$		
		U	$(P_m+P_b+Q) / E$		
		E	$(P_m+Q_m) / E$		
		E	$(P_m+P_b+Q) / E$		
		F	$(P_m+Q_m) / E$		
		F	$(P_m+P_b+Q) / E$		
3	Top Guide/Grid	U	$(P_m+Q_m) / E$		
		U	$(P_m+P_b+Q) / E$		
		E	$(P_m+Q_m) / E$		
		E	$(P_m+P_b+Q) / E$		
		F	$(P_m+Q_m) / E$		
		F	$(P_m+P_b+Q) / E$		
4	Control Rod Guide Tube (CRGT)[4]	U	$(P_m+Q_m) / E$		
		U	$(P_m+P_b+Q) / E$		
		E	$(P_m+Q_m) / E$		
		E	$(P_m+P_b+Q) / E$		
		F	$(P_m+Q_m) / E$		
		F	$(P_m+P_b+Q) / E$		
5	Orificed Fuel Support (OFS)	U	$(P_m+Q_m) / E$		
		U	$(P_m+P_b+Q) / E$		
		F	$(P_m+Q_m) / E$		
		F	$(P_m+P_b+Q) / E$		]]
6	Peripheral Fuel Support (PFS)	Bounded by Orificed Fuel Support			

Notes:

1. The most limiting location of the components is reported.
2. N = Normal condition, U = Upset condition, E = Emergency condition, F = Faulted condition.
3. Based on the fluence effect acceptance criteria.
4. P_m+Q_m stress was not calculated in the design basis. Therefore, P_m+P_b+Q stress was conservatively used as P_m+Q_m stress.

The limiting welds of the shroud and the top guide/grid subjected to the fluence [[ ]] The limiting weld stress of the control rod guide tube subjected to the fluence [[ ]]

In summary, all RVI CSS components meet the acceptance criteria of the design specification for the neutron fluence effect.