Attachment 1

RAIs 1, 2 and 3 Responses for PWROG-16043, Revision 2

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

(12 total pages including Attachment 1 cover page and RAIs 1, 2 and 3 responses)

RAI 1

The most significant aspect of the proposed methodology to address EOL effects on the spacer grids is the use of simulated EOL grids, which are grids that have been [[ ]] a, c to simulate the most important non-conservative EOL effect due to irradiation, grid spring relaxation. In order for the simulated EOL grids to accurately capture the limiting behavior of irradiated grids, the structural characteristics of the simulated EOL grids must be similar to, or more conservative than, the irradiated grids. In order to verify this, the NRC staff requests the following information:

The [[ ]] a, c protocol is not detailed in the LTR. In Section 2.1, the LTR states that the "process for compiling PIE data and specifying target cell size is consistent with that was used for the AP1000 EOL issues that was previously approved by the NRC." However, the exact [[ ]] a, c protocol is unclear. Please provide the specifications for the [[ ]] a, c process, including [[ ]] a, c

Response to RAI 1

The [ ] a, c of the simulated End of Life (EOL) grids for the AP1000® plant and the simulated EOL grids discussed in PWROG-16043-P was performed in accordance with a Westinghouse thermal cell sizing procedure. The procedure is used to thermally size grid cells to simulate EOL grid conditions for fuel assembly hydraulic loop tests.

[ ] a, c. The process is shown in Figure 1. [ ] a, c

The mechanical structure characteristics of simulated EOL grids is similar to, or more conservative than, the irradiated grids. [ ] a, c Therefore, the grid material characteristics of Young's modulus and Poisson's ratio are not impacted by the grid [ ] a, c process. The Young's modulus is one of main parameters which determine the grid impact stiffness.

[ ] a, c

Figure 1. [ ] [a, c]

Since the [ ] [a, c] This may result in a slight reduction in the grid impact strength, which is conservative.

The [ ] [a, c] target cell sizes or gap sizes are varied depending on the Post Irradiation Examination (PIE) data and types of grid designs. [ ] [a, c]

3. [.] [a, c]
4. [.] [a, c]

Overall, the [ ] [a, c] for cell sizes will have no impact or a minimally conservative impact on the grid strap material mechanical properties.

RAI 2

Fuel assemblies that are loaded in certain areas of the core may experience steep radial neutron flux gradients. As such, the EOL effects due to irradiation of the spacer grids may not be sufficiently uniform to result in spacer grid behavior consistent with simulated EOL grids using the **[[** **]]** a, c method. Please characterize the expected variation due to radial neutron flux gradients in typical PWR cores, and discuss how this may impact the spacer grid structural behavior (e.g., if gaps exist at one corner of a fuel assembly but not at the opposite corner, explain what the effect on the failure mechanism might be).

Response to RAI 2

b. "expected variation due to radial neutron flux gradients in typical PWR cores"

The fuel rods in a fuel assembly may experience steep radial neutron flux gradients in some core locations during some cycles. However, the grid gap size formation (due to grid spring relaxation, rod diameter creep and grid growth) is a long-term and slow process which occurs over the entire irradiated life of a fuel assembly.

The typical irradiated lifetime of a fuel assembly is at least 4 years during which it will be rotated to different locations in the core and experience different flux gradients and orientations. Therefore, a radial neutron flux gradient effect on the grid cell size at the fuel assembly EOL condition is not expected to occur.

To confirm that the neuron flux gradient effect does not occur, two sets of PIE data, fuel rod burnup vs. cell gap size, were reviewed. Fuel rod burnup at EOL is the accumulated effect of neutron flux. [

]. a, c

The first example is a [ ] a, c for which the measured gap results and corresponding fuel rod burnups are given in Figure 2. A sample of ten fuel rods in different locations in the fuel assembly with different fuel rod burnups is shown in Figure 2. [

] a, c

Figure 2 also shows that [

.] a, c

a, c

Figure 2. Measured [ ] a, c

The second example is for a [ ] a, c The measured gap results and corresponding fuel rod burnups are given in Figure 3. A sample of ten fuel rods in different locations in the fuel assembly with different fuel rod burnups is shown in Figure 3. [

] a, c

Figure 3 also shows that [

]$^{a, c}$

a, c

Figure 3. Measured [**]$^{a, c}$**

[

.]a, c

c. "how this may impact the spacer grid structural behavior"

The grid impact occurs on the grid side surfaces. For example, a grid is impacted in the X direction as shown in Figure 4. The impact force is shared by the whole column A (from cell A1 to cell A17) and is transferred to the whole grid through all columns (from Column A to Column Q). Therefore, the cell gap size differences in a grid would have a small impact on the overall structural behavior of a spacer grid.

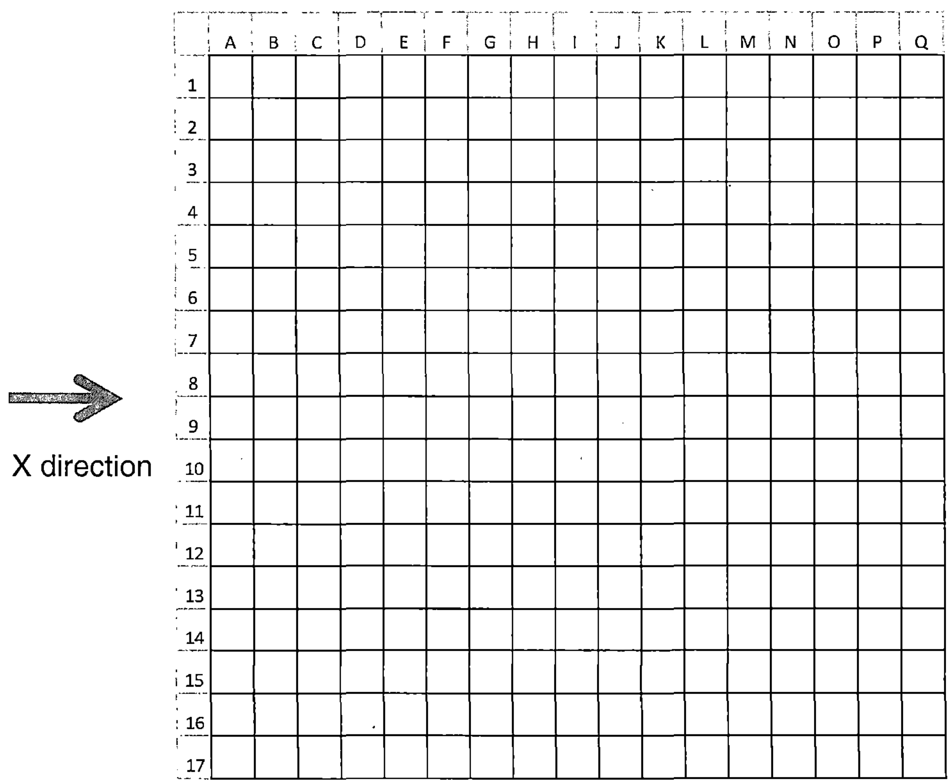

Figure 4. Example of Grid Impact

The [ ]a, c cell gaps for simulating the EOL grids are also varied across grid locations. The pre-sized cells realistically represent the measured cell gap characteristics from the PIE data, such as random distribution, gap size range, etc. [ ]a, c
[

.]a, c

[ ] a, c

Figure 5. Measured [ ] a, c

[

.] a, c

Overall, the grid impact between two fuel assemblies and a fuel assembly to a baffle plate occur on the side surface of the grid. The impact surface transfers the impact force through all the grid straps (which are parallel and perpendicular to the impact direction). The average gap size in each column and each row for a simulated EOL grid is similar. Therefore, [

."] a, c

RAI 3

Section 2.1 of the LTR presents PIE data from selected fuel assemblies and an analysis approach that can be used to determine a target average cell size for the simulated EOL spacer grids. This approach is intended for use with any fuel assembly design, but no specific guidance is provided on how the PIE data set should be characterized for a given fuel assembly design. Please provide guidance on the expectations for what would constitute an acceptably robust set of PIE data for the purpose of establishing a bounding target average cell size for all fuel assemblies of the specified design type.

Response to RAI 3

The grid target cell size is determined based on the PIE data using a statistical method. For example, the grid target cell size for [ ] a, c fuel assembly is determined by the following steps:

4. [

.] a, c

5. Calculate the upper 95% confidence limit for the true mean in order to account for the scatter in the database. The upper 95% confidence limit is calculated based on the statistical formula given below.

$$MidGrid_{upper95} = MidGrid_{avg} + \frac{STD \times T_{n-1}}{\sqrt{N}}$$

Where:

$MidGrid_{upper95}$ ----- Upper 95 confidence mean of the grid cell gap size from the PIE data

$MidGrid_{avg}$ ----- Average grid cell gap size from the PIE data

STD ----- Standard deviation of the grid cell gap size from the PIE data

T ----- Student T value determined by the sample size

N ------ Sample size

n-1 ------ Sample size minus one

[

] a, c

6. [

.] a, c

[ ]a, c

Figure 6. [

] a, c

To ensure that the simulated EOL grids meet the target cell gap value, the average cell gaps should be higher than the target cell gap value. For an additional conservatism, the lower 95% confidence limit on the true mean of tested grid cell gaps was confirmed to be higher than the target value. The simulated average and lower 95% cell gaps for a [

.] a, c

In general, the effect of the sample size is incorporated into the statistical method through the "Student T" value in the formula above. Smaller sample sizes will have a larger Student T value. For example, [

.][a, c]

Table 2. Example of the Gap Size Target Value Utilizing

[ ][a, c]

a, c

a, c

Figure 7. Sample [ ][a, c]

Based on the discussions above, [ ] a, c is sufficient.

References:

2. [.]a, c