UPDATE

6-4 Clarify if axial and horizontal variations of enrichment are allowed in the ATRIUM fuel assembly. If so, provide justification that the assumptions in the uniform axial enrichment analyses bound the axially varied enrichment configurations.

One of the requested allowable new contents for the TN-B1 package is the ATRIUM BWR fuel assembly. As a common design feature, BWR fuel assembly designs often include variation of fuel enrichment along the axial direction as well as across the planar direction. However, it is not clear from the application if the ATRIUM fuel has this feature. The applicant needs to clarify whether axial and horizontal variations of enrichment are allowed in the ATRIUM fuel assembly. If so, the applicant needs to provide updated criticality safety analyses for the case of axial varying enrichment or justify that the assumptions in the uniform axial and horizontal enrichment is bounding.

This information is needed to determine compliance with 10 CFR 71.55(a), 71.55(b), 71.55(d), 71.55(d), 71.59(a), 71.59(b), and 71.59(c).

SUMMARY OF CLARIFICATION CALL WITH NRC

When asked for clarification from the NRC criticality reviewer, the following items were discussed:

1. The reviewer suggested that AREVA read NUREG/CR-7224. Based on this document, the reviewer expressed concerned that using a 5wt% U235 enrichment would not yield the most reactive lattice.
2. The reviewer expressed concerned that AREVA did not consider axial blankets.
3. The reviewer questioned whether the SAR stated that the ATRIUM-11 assembly contained axial variation.
4. The reviewer expressed concerned that the different axial regions were not considered. The different axial regions are defined by the number of fuel rods in the lattice. The number of fuel rods changes due to the number and lengths of the partial length rods. The reviewer explained that NUREG/CR-7224 referred to these different axial regions as “vanish zones”.

Overall, the reviewer would like more reassurance that the different axial zones were thoroughly considered when determining the gadolinia rod requirements per enrichment (see Table 6-1, Table 6-57, and page 421/511 of FS1-0014159, Revision 5.0).

UPDATED PROPOSED RESPONSE:

Section 6.12 of FS1-0014159, Revision 5.0 is dedicated to the criticality analysis of the ATRIUM-11 fuel assembly. Section 6.12.3.1.1 describes the fuel assembly model. Within this section (on page 399/511), three distinct axial regions are defined due to the presence of the long and short partial-length rods. The 11x11 assembly design is typical of BWR fuel in that the U235 enrichment varies both radially and axially.

For all calculations in the criticality analysis sensitivity studies, a uniform enrichment of 5 wt% was used in all radial locations, including UO_2-Gd_2O_3 rods. This is a conservative assumption since lower enrichments would remove fissile material from the system and decrease the reactivity.

Sensitivity studies were completed with 5 wt% U235 in all radial and axial locations. Twelve UO_2-Gd_2O_3 rods were located in each axial region. The most reactive configuration using these conditions was determined for each distinct axial region. The 3-D assembly was then built using the most reactive configuration for each region.

For the sensitivity studies, these conditions are valid. The sensitivity of the results for each parameter is expected to be consistent regardless of the radial and axial variation. Since the highest possible enrichment is used with a consistent number of UO_2-Gd_2O_3 rods for each axial region, lowering the enrichment in either the radial or axial direction will lower the reactivity of the system while yielding comparable trends in behavior for the results calculated for a variation in a particular parameter (e.g., clad outer diameter, foam liner thickness).

After determining the limiting parameters, the final step of the criticality analysis was to determine the number of UO_2-Gd_2O_3 rods needed to maintain the system reactivity below the USL. The results of this are seen in Table 6-1, in Table 6-57, and on page 421/511 of FS1-0014159, Revision 5.0. The UO_2-Gd_2O_3 rod requirements were established by considering each axial region separately and then combining the most reactive configurations for each axial region into a 3-D model. For these cases, all axial regions contain the same U235 enrichment.

Different UO_2-Gd_2O_3 rod loading patterns were considered for each enrichment with the given UO_2-Gd_2O_3 rod number requirement for each axial region. While numerous loading patterns were investigated for each enrichment / UO_2-Gd_2O_3 rod number, only the three most reactive lattices for each axial region are shown in Figure 6-68 through Figure 6-79, one figure for each enrichment. These are considered the “2-D” results.

Finally the most reactive “2-D” lattices for each axial region are combined in a full “3-D” model to demonstrate that the system remains below the USL with the given UO_2-Gd_2O_3 rod requirement for that enrichment. The results are provided in Table 6-79 of the report.

As stated on page 422 of the report, for each enrichment of a 3-D lattice, the number of UO_2-Gd_2O_3 rods are selected such that the reactivity is close to, and below, the USL. Thus, the maximum reactivities for each enrichment are necessarily similar.

The maximum $k + 2\sigma$ of 0.93810 was found to occur for the 5 wt% enrichment with 13 UO_2-Gd_2O_3 rods. This configuration is calculated for an axially uniform enrichment. RAI 6-4 questions whether this configuration bounds an assembly that has axially varying enrichments. To answer this question, the maximum reactive “2-D” lattice for each axial region over all enrichments / UO_2-Gd_2O_3 rod requirements was determined. For the bottom and middle axial regions, the maximum reactive “2-D” lattices were found for the 5 wt% enrichment with 13 UO_2-Gd_2O_3 rods. For the top axial region, the maximum reactive “2-D” lattice occurred for the 3.3 wt% enrichment with 3 UO_2-Gd_2O_3 rods.

Since the top axial region used in the 5wt% limiting case was not the most reactive “2-D” lattice, an additional calculation was performed that models each of the maximum “2-D” lattices for each axial region. In other words, the limiting case documented in the report was varied such that the top axial region contained 3.3 wt% enrichment and 3 UO_2-Gd_2O_3 rods. The results of this calculation are shown below:

	k_{eff}	σ	$k_{eff} + 2\sigma$
Uniform axial enrichment	0.93805	0.00051	0.93907
Bottom and middle axial regions: 5 wt%, 13 UO_2-Gd_2O_3 rods Top axial region: 3.3 wt%, 3 UO_2-Gd_2O_3 rods	0.93843	0.00046	0.93935
Uniform – axially varied	-0.00038	0.00069	

[a] square root of the sum of the squares of the σ values.

As can be seen in this table, while the variable axial enrichment configuration shows a slightly higher absolute k_{eff} value, the result is statistically the same as for the uniform axial enrichment. The $k_{eff} + 2\sigma$ for both cases is below the USL of 0.94094.

This configuration bounds all axially varying enrichment configurations. Any alternative lattice description adhering to the UO_2-Gd_2O_3 rods requirements would lower the reactivity of the lattice and would, thus, lower the reactivity of the system.

This same logic applies to the use of natural uranium blankets. Addition of the blankets is expected to decrease the reactivity of the system. To add a blanket region, a portion of the 5wt% U235 enriched fuel would be removed to accommodate the natural enriched blanket. A calculation using the limiting 5wt% axially uniform case with 6” approximately naturally enriched axial blankets was performed. The results are shown below:

	k_{eff}	σ	$k_{eff} + 2\sigma$
Uniform axial enrichment, no blankets	0.93805	0.00051	0.93907
~naturally enriched blankets, 6-in.	0.93175	0.00046	0.93267
No blankets – blankets	0.00630	0.00069 [a]	

[a] square root of the sum of the squares of the σ values.

As expected, addition of the axial blankets lowers the reactivity of the system. Thus, the criticality analysis bounds 11x11 fuel assemblies that contain blanket regions.