RAI 3-1

Provide the analysis that demonstrates the fuel/cladding criteria listed in Table 3-5 of the application, for new and modified BWR fuel, that “all fuel to be shipped must have a maximum pre-pressure times the maximum Inside Radius/Thickness product of 9.14 x 1.1145 MPa = 10.18653 MPa or less. Thus, all products must meet the maximum product of allowed pressure multiplied by the Inside Radius/Thickness of 10.18653 MPa.”

Section 4.1.1 of the application indicates that the fuel cladding is the containment boundary. Table 3-5 of the application provides the maximum pressure and cladding dimensions to attain an allowable stress and margin of safety after the hypothetical accident conditions (HACs); some of these parameters have values that have changed approximately 30% to 40% from an earlier application. However, the updated application did not address these changes and there was no analysis provided to show that the criteria described above was appropriate for determining the Table 3-5 parameters of the new and modified fuels.

This information is needed to determine compliance with 10 CFR 71.51 and 71.73.

AREVA Response

Section 3.5.3.2 of FS1-0014159-5.0 states that the maximum allowed cladding stress is limited to 31.1 MPa at HAC and is applicable to fuel shipped in the TN-B1 having zircaloy cladding. This stress limit was based on tests where zircaloy cladding samples filled with 1.1145 MPa helium at room temperature did not burst at a temperature of 800°C. The HAC condition is defined as a maximum temperature of 648°C (921 K) as determined by a transient analysis after thirty minutes from the start of the fire. The use of the 31.1 MPa allowable cladding stress limit at HAC is, therefore, conservative.

The criteria in the Table 3-5 note:

maximum fuel rod pre-pressure * maximum inside radius / thickness ≤ 10.18653 MPa

is a room temperature equivalent of the 31.1 MPa fuel rod cladding allowable stress limit at HAC. By applying the Ideal Gas Law and the empirical formula for calculating hoop stress in thin wall tubing, the room temperature allowable cladding stress limit can be derived from the limit at HAC:

HAC stress allowable = (fuel rod fill pressure absolute * HAC temperature / ambient temperature – 1 atmosphere) * inside cladding radius / cladding thickness

Substituting:

31.1 MPa = (1.1145 MPa * 921K / 293K – 0.101325 MPa) * r/t

Solving for the r/t necessary to achieve the maximum stress allowable:

r/t = 9.14

The maximum cladding stress allowable at room temperature (Table 3-5 note) based on the absolute initial fuel rod fill pressure is:

RT stress allowable = fuel rod fill pressure absolute * r/t

= 1.1145 MPa * 9.14

= 10.18653 MPa (absolute)

Table 3-5 of FS1-0014159-5.0 provides example evaluations of one fuel design type per array size using the limits and methods described in Section 3.5.3. The maximum allowed cladding stress limit, determined by testing, must be met by all fuel designs and has remained unchanged in each revision of the applications. The maximum allowed fuel rod initial fill pressure is dependent on the allowed cladding stress limit and the cladding design. Design differences that can impact the maximum initial fuel rod pressure allowed between fuel design types include cladding ID and OD, and the presence of a liner in the cladding. The use of liner cladding in the evaluation for the 9x9 and 10x10 fuels, therefore, significantly reduced the allowed maximum initial fuel rod fill pressure for these designs. The fuel types shown in Table 3-5 of the application, FS1-0014159-5.0, and other fuel designs were evaluated in FS1-0024572-2.0. AREVA transmitted this document to the USNRC on February 17, 2017, in letter number TJT:17:007 (Timothy J Tate to USNRC Document Control Desk, “Docket No. 71-9372, AREVA TN-B1 Shipping Container, Application For Approval For Incorporation of ATRIUM 11 Fuel Assemblies”).

To clarify Table 3-5 “Maximum Pressure” and the purpose of the new application to add the ATRIUM 11 fuel design, Revision 6.0 of the application uses the results for the 9x9 and 10x10, non-liner clad, fuel designs from the previously approved FS1-0014159-3.0. To provide alignment with these fuel designs, the results for the non-liner clad 11x11 fuel design was also used. Though only non-liner clad fuel design results are shown in the table, the table note requires that all fuel designs must be verified to meet the allowed cladding stress limit, including the requirement to exclude the thickness of the liner from the minimum cladding thickness, as detailed in Section 3.5.3.2 of FS1-0014159-6.0, when determining the maximum internal pressure.

AREVA has also noted the concerns raised about this RAI discussed during 8 June 2017 telephone conference between AREVA and the NRC (Reference July 12, 2017 memo to Anthony Hsia ML17198A317). Those concerns to the SAR have been addressed as follows:

1. The application of the thermal analysis method used for the 11x11 fuel design is unchanged from the prior fuel designs and the use of conservatisms; e.g., exclusion of liner thickness, is limited to the thermal analysis. The bounding condition of these conservatisms is detailed in Section 3.5.3.2 of FS1-0014159.
2. In the structural analysis, reported in Section 6.12.3.1.1 of FS1-0014159, the LS-DYNA ATRIUM 11 model used liner cladding mechanical properties in the analysis. The mechanical properties of liner cladding are lower than that of zirconium alloy cladding. Therefore, the results are conservative for ATRIUM 11 non-liner cladding applications.

3. Concerning the connection between the cladding stress, based on the oven tests of the initial fuel rod designs) and cladding integrity after undergoing the HAC tests, the drop event does not create significant stresses and strains in the radial and circumferential directions of the transverse cross-section, which is the loading plane for the heating period. Therefore, the mechanical deformation during the heating period can be considered independent of the prior small axial bending during the drop event. This is the basis for the analysis in SAR Section 3.5, where results of the closed tube pressure ballooning tests have been used to assess the avoidance of clad rupture due to internal gas pressure. Additional details of this are provided in the response to RAI 3-2.