Enclosure 7 to E-55112

Proposed Amendment 2, Revision 2
NUHOMS® EOS System
Updated Final Safety Analysis Report Changed Pages

(Public Version)

The only analysis that uses the wet neutron source term is the loading/decontamination stage of the EOS-TCs. After loading/decontamination the EOS-TCs are modeled as dry. No wet neutron sources are provided in the EOS-HSM source term tables because the DSC is always dry when inside the EOS-HSM.

6.2.4 Control Components

Control components may also be included with the PWR FAs. For BWR fuel, the fuel channel and associated attachment hardware is included in the BWR source presented in Section 6.2.2, so it will not be discussed in this section. While CCs do not contain fuel, these items result in a source term, primarily due to activation of the Co-59 impurity in the metal. Allowed CCs are identified in Section 2.1 of the *TS* [6-11].

Any other CC type is acceptable if it can be demonstrated that the source term is *below the CC activity limits provided in TS Table 3 [6-11]*. Also, the total as-loaded decay heat of the system, including CCs, must be less that the heat load zoning configurations defined in *the TS [6-11]*.

Control components may be grouped into two categories: (1) those that extend into the top, plenum and active fuel regions of the fuel assembly, and (2) those that essentially extend only into the top and plenum regions of the FA. The BPRA is used as a representative CC for category (1) and the TPA is used as a representative CC for category (2). The objective is to use these representative CC types to develop Co-60 activity limits for CCs.

The BPRAs are assumed to be burned in two cycles to a total host FA burnup of 50 GWd/MTU. This represents a limiting burnup because the absorber material is completely depleted for this burnup. TPAs do not contain burnable poisons and may be used in multiple host FAs for very long burnups. A cumulative host FA burnup of 300 GWd/MTU is assumed. However, a TPA is primarily located in the top nozzle and plenum region of the core where the flux is depressed and the “effective” burnup of a TPA is significantly less.

A neutron source may be included in CCs, such as an NSA. Typically, the neutron source from an NSA is negligible compared to the neutron source from spent fuel. However, some neutron sources could have comparable source strength relative to the *FAs*. For this purpose, the loading of neutron sources is limited to the interior locations of the EOS-37PTH basket to maximize self shielding. *The inner locations are defined in Figure 6-1.*

Representative BPRA hardware masses are available for three BPRA types:

- B&W 15x15
- WE 17x17 Pyrex
- WE 17x17 WABA

The BPRA hardware masses are provided in Table 6-32.

Proprietary Information on This Page
Withheld Pursuant to 10 CFR 2.390

6.5 Supplemental Information

6.5.1 *PWR Fuel Qualification*

Chapter 6 presents the shielding analysis for design basis fuel. For the EOS-37PTH DSC, HLZC 10 results in bounding EOS-HSM vent dose rates. HLZC 10 features 3.5 kW fuel in the peripheral region. The peripheral region is illustrated in TS Figure 3[6-11].

To provide additional assurance that TS dose rate limits will be met, a relationship between decay heat, burnup, enrichment, cooling time, and source terms is developed for 3.5 kW fuel and provided as a fuel qualification table (FQT). The methodology to develop this FQT is the same as used to develop the design basis source terms.

The purpose of the FQT is solely to provide an additional dose rate constraint. Decay heat for each fuel assembly to be loaded is determined using NRC Regulatory Guide 3.54, ORIGEN-ARP, or other acceptable method.

The FQT developed based on 3.5 kW is a global constraint and is applied to every PWR fuel assembly to be loaded. This FQT is provided as TS Table 7B[6-11].

A range of burnup, enrichment, and cooling time combinations are considered for the inner regions of HLZC 10, as documented in Table 6-8. The design basis source terms in the inner regions are optimized to maximize dose rates. However, dose rates, both transfer cask and storage, are dominated by thermally hot fuel in the peripheral region because inner locations are heavily self-shielded by peripheral fuel assemblies. For HLZC 4, the peripheral region (zone 3) contributes approximately 80% of the dose rate on the side of the EOS-TC125/135. For the EOS-HSM, the peripheral region (zone 3) contributes approximately 95% of the vent dose rate. The peripheral contribution for HLZC 10 would be similar. Because the inner basket locations do not contribute appreciably to the total dose rate, an FQT constraint on the inner basket locations in addition to TS Table 7B is not imposed.

The burnup in the FQT is expressed in units of GWd/FA rather than GWd/MTU. The burnup in GWd/FA is the burnup in GWd/MTU multiplied by the MTU of the fuel assembly. The minimum cooling times are obtained from this table using linear interpolation.

As documented in Section 6.2.8, a small percentage (<0.5%) of fuel assemblies are low-enrichment outlier fuel (LEOF). LEOF is rare, occurring at a rate of approximately 1 per 200 fuel assemblies. To determine if a fuel assembly is LEOF, the enrichment is compared to the minimum value specified in TS Table 7A. LEOF would not affect storage dose rates, which are gamma dominated, but could have a small effect (generally < 5%) on transfer cask dose rates. Based on these considerations, up to 4 LEOFs are allowed in the peripheral region. A minimum of three non-LEOFs shall circumferentially separate LEOFs within the peripheral region. There are no limitations on the number and location of LEOF stored in the inner region.

All Indicated Changes are as discussed in letter E-55112

Because LEOF, by definition, is below the minimum enrichments provided in the FQT, minimum cooling times for LEOF are obtained by extrapolating the FQT cooling times using an appropriate method. Because minimum cooling times increase with lower enrichments, this extrapolation provides an additional cooling time penalty.

The overall method for application of this FQT and qualification of LEOF is provided below.

1. *Determine the decay heat of all fuel to be loaded in an EOS-37PTH DSC using NRC Regulatory Guide 3.54, ORIGEN-ARP, or another acceptable method. Confirm the decay heat limit is met for each basket location.*
2. *Determine if LEOF is present in the fuel to be loaded by application of TS Table 7A.*
   a) *Up to 4 LEOF are allowed in the peripheral region. A minimum of three non-LEOFs shall circumferentially separate LEOFs within the peripheral region.*
   b) *There are no limitations on the number and location of LEOF stored in the inner region.*
3. *Verify all fuel to be loaded meets the minimum cooling time of TS Table 7B. Fuel that does not meet the cooling time limitations of this table cannot be loaded.*

This FQT provides an additional constraint to ensure compliance with the dose rate limitations in TS 5.1.2(c).

Examples

Examples to illustrate application of TS Table 7A and TS Table 7B are provided below.

Example 1 (no LEOF)

This example demonstrates how to determine if a fuel assembly is LEOF and how to determine compliance with TS Table 7B.

A fuel assembly has a burnup (BU) of 50 GWd/MTU, 0.45 MTU, enrichment (E) of 3.5%, and a cooling time (CT) of 4 years. Assume the decay heat has been computed and shown to be acceptable for the basket location of interest.

- *The minimum enrichment for 50 GWd/MTU, per TS Table 7A, is 50/16 = 3.125%, which is rounded down to 3.1%. As E = 3.5% > 3.1%, this fuel assembly is within the minimum enrichment bounds of TS Table 7A and is not LEOF.*
- *Burnup in GWd/FA is (50 GWd/MTU)(0.45 MTU) = 22.5 GWd/FA*

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- *Linearly interpolate on enrichment (first) and burnup (second) to determine the minimum cooling time*
- *Linearly interpolating for E = 3.5% in the 22.14 GWd/FA row of TS Table 7B, CT = 2.08 years*
- *Linearly interpolating for E = 3.5% in the 24.6 GWd/FA row of TS Table 7B, CT = 2.30 years*
- *Linearly interpolating for BU = 22.5 GWd/FA between CT = 2.08 years and CT = 2.30 years, the minimum cooling time is CT = 2.11 years.*

Because 4 years > 2.11 years, the fuel assembly meets the TS Table 7B requirements.

Example 2 (with LEOF)

This example demonstrates how to determine if a fuel assembly is LEOF and how to determine compliance with TS Table 7B.

A fuel assembly has a burnup of 50 GWd/MTU, 0.45 MTU, enrichment of 2.9%, and a cooling time of 4 years. Assume the decay heat has been computed and shown to be acceptable for the basket location of interest.

- *The minimum enrichment for 50 GWd/MTU, per TS Table 7A, is 50/16 = 3.125%, which is rounded down to 3.1%. As E = 2.9% < 3.1%, this fuel assembly is LEOF. It is assumed to be the only LEOF to be loaded in this DSC.*
- *Burnup in GWd/FA is (50 GWd/MTU)(0.45 MTU) = 22.5 GWd/FA*
- *Linearly interpolate or extrapolate on enrichment (first) and burnup (second) to determine the minimum cooling time. Because the fuel is LEOF, extrapolation on the enrichment value beyond TS Table 7B is acceptable. Extrapolating to a lower enrichment value increases the minimum cooling time, which is a conservative penalty.*
- *Linearly interpolating for E = 2.9% in the 22.14 GWd/FA row of TS Table 7B, CT = 2.15 years*
- *Linearly extrapolating for E = 2.9% in the 24.6 GWd/FA row of TS Table 7B for the two nearest enrichments, CT = 2.38 years. Other extrapolation methods could be employed, although the data in this row is following a linear trend.*
- *Linearly interpolating for BU = 22.5 GWd/FA between CT = 2.15 years and CT = 2.38 years, the minimum cooling time is CT = 2.18 years.*

Because 4 years > 2.18 years, the fuel assembly meets the TS Table 7B requirements. Because it is the only LEOF assembly in the DSC, it may be stored in the basket location of interest.

A.6.5 Supplemental Information

A.6.5.1 PWR Fuel Qualification

The discussion on PWR fuel qualification in Section 6.5.1 is also applicable to the HSM-MX. The same PWR fuel qualification table (FQT) is used for the EOS-HSM and HSM-MX.

A.6.5.2 References

A.6-1 Oak Ridge National Laboratory, "MCNP/MCNPX – Monte Carlo N-Particle Transport Code System Including MCNP5 1.40 and MCNPX 2.5.0 and Data Libraries," CCC-730, RSICC Computer Code Collection, January 2006.

A.6-2 CoC 1042 Appendix A, NUHOMS® EOS System Generic Technical Specifications, Amendment *2*.

A.6-3 ADVANTG – An Automated Variance Reduction Parameter Generator, Oak Ridge National Laboratory, August 2015.

B.6.5 Supplemental Information

B.6.5.1 61BTH DSC Fuel Qualification

Chapter B.6 presents the shielding analysis for design basis fuel. A highly conservative approach is employed in which a hybrid HLZC is developed using the maximum heat loads from HLZC 1 through 10. The hybrid HLZC is illustrated in Figure B.6-1. A 61BTH DSC could not be loaded in this manner due to thermal limitations. For instance, if 1.2 kW fuel is loaded, the peripheral region is limited to 0.393 kW/FA (see Figure 4J in the TS [B.6-6]).

Although a highly conservative approach is employed to compute HSM-MX dose rates using the 61BTH DSC, the dose rates are below the dose rates computed for the EOS-DSCs (EOS-37PTH and EOS-89BTH), see Table B.6-16 and Table B.6-17. The TS dose rate limits in TS Section 5.1.2(c) are based upon EOS-DSC dose rates. Nevertheless, to provide additional assurance that TS dose rate limits will be met, a relationship between decay heat, burnup, enrichment, cooling time, and bounding source terms is developed and provided as fuel qualification tables (FQTs). The methodology to develop these FQTs is the same as used to develop the design basis source terms.

A heat load of 0.54 kW/FA is modeled on the periphery, while the maximum heat load of 1.2 kW/FA is modeled within interior locations, see Figure B.6-1. Following the methodology developed for the EOS-37PTH DSC (see Section 6.5.1), FQTs are developed for both the maximum heat load (1.2 kW/FA) and maximum peripheral heat load (0.54 kW/FA).

The purpose of the FQTs is solely to provide an additional dose rate constraint. Decay heat for each fuel assembly to be loaded is determined using NRC Regulatory Guide 3.54, ORIGEN-ARP, or other acceptable method.

The FQT developed based on 1.2 kW is a global constraint and is applied to every fuel assembly to be loaded in the 61BTH DSC. This FQT is provided as TS Table 19. The 0.54 kW FQT is applicable only to fuel located in peripheral locations of HLZC 2, 4, 5, 6, 7, and 8 and is provided as TS Table 20. The peripheral locations are defined in TS Figure 6. TS Table 20 does not apply to HLZC 1, 3, 9, or 10, or to the interior locations of any HLZC.

The burnup in the FQTs is expressed in units of GWd/FA rather than GWd/MTU. The burnup in GWd/FA is the burnup in GWd/MTU multiplied by the MTU of the fuel assembly. The minimum cooling times are obtained from these tables using linear interpolation.

All Indicated Changes are as discussed in letter E-55112

As documented in Section 6.2.8, a small percentage (<0.5%) of fuel assemblies are low-enrichment outlier fuel (LEOF). Based on Table 6-60, LEOF BWR fuel is rare, as only ~30 have been generated over the past 40 years. To determine if a fuel assembly is LEOF, the enrichment is compared against the minimum value specified in TS Table 18. LEOF would not affect storage dose rates, which are gamma dominated, but could have a small effect (generally < 5%) on transfer cask dose rates. Based on these considerations, up to 4 LEOFs are allowed in the peripheral region. A minimum of five non-LEOFs shall circumferentially separate LEOFs within the peripheral region. There are no limitations on the number and location of LEOF stored in the inner region.

Because LEOF, by definition, is below the minimum enrichments provided in the FQTs, minimum cooling times for LEOF are obtained by extrapolating the FQT cooling times using an appropriate method. Because minimum cooling times increase with lower enrichments, this extrapolation provides an additional cooling time penalty.

The overall method for application of these FQTs and qualification of LEOF is provided below.

1. *Determine the decay heat of all fuel to be loaded in an 61BTH DSC using NRC Regulatory Guide 3.54, ORIGEN-ARP, or another acceptable method. Confirm the decay heat limit is met for each basket location.*
2. *Determine if LEOF is present in the fuel to be loaded by application of TS Table 18.*
   a) *Up to 4 LEOF are allowed in the peripheral region. A minimum of five non-LEOFs shall circumferentially separate LEOFs within the peripheral region.*
   b) *There are no limitations on the number and location of LEOF stored in the inner region.*
3. *Verify all fuel to be loaded meets the minimum cooling time of TS Table 19. Fuel that does not meet the cooling time limitations of this table cannot be loaded.*
4. *For fuel in the peripheral locations of HLZC 2, 4, 5, 6, 7, and 8, verify all fuel to be loaded meets the minimum cooling time of TS Table 20. This table does not apply to HLZC 1, 3, 9, or 10, or to the interior locations of any HLZC.*

Interpolation and/or extrapolation of the FQT cooling times is acceptable, as needed. These FQTs provide an additional constraint to ensure compliance with the dose rate limitations in TS 5.1.2(c).