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September 20, 2023
E-62225

U. S. Nuclear Regulatory Commission
Attn: Document Control Desk
One White Flint North
11555 Rockville Pike
Rockville, MD 20852

Subject: Consolidated Safety Analysis Report Associated with TN Americas LLC Application for Approval of the TN Eagle Transportation Package (Docket No. 71-9382)

Reference: (1) TN Americas letter E-57970 dated December 30, 2020, "TN Americas LLC Application for Approval of the TN Eagle-STC Transportation Package (Docket No. 71-9382)"

(2) NRC Letter dated May 13, 2022, "Application for Certificate of Compliance for The Model Nos. TN Eagle-STC SC and TN Eagle-STC LC Spent Fuel Packages – First Request for Additional Information (EPID No. L-2021-NEW-0000)"

(3) TN Americas letter E-60914 dated December 9, 2022, "TN Americas LLC Response to Request for Additional Information for TN Eagle-STC Transportation Package Approval Application (Docket No. 71-9382, EPID No. L-2021-NEW-0000)"

In accordance with 10 CFR 71.31, TN Americas LLC submitted an application for Approval for Certificate of Compliance (CoC) No. 9382 for the TN Eagle packaging [1], as supplemented to provide additional changes [2], and as supplemented to provide additional information requested by the NRC to complete the review in accordance with 10 CFR 71.38 [3]. The purpose of this submission is to provide a consolidated TN Eagle Safety Analysis Report (SAR), Revision 0 to reference as the application for CoC No. 9382, Revision 0.

Note that the application and supplements were previously submitted using "STC" in the Model Numbers. The consolidated SAR has eliminated "STC" from the Model Nos. The package design is referred to as the TN Eagle with two different Model Nos. TN Eagle SC and TN Eagle LC.

Furthermore, the consolidated SAR includes Drawing NUH24PT4-71-1003 Revision 0, NUHOMS® 24PT4 Transportable Canister for PWR Fuel Failed Fuel Can (4 sheets), that was previously omitted from the application. The 24PT1 DSC is designed to store and transport 24 intact Westinghouse 14x14 pressurized water reactor (PWR) fuel assemblies (FAs) or up to four damaged or failed fuel assemblies, in a failed fuel canister, as evaluated in the application.

The consolidated TN Eagle SAR Revision 0 is included as Enclosure 1. A public version of the Revision 0 SAR with proprietary information redacted is provided for public availability as Enclosure 2. In accordance with 10 CFR 2.390, TN Americas is providing an affidavit as Enclosure 3, requesting that this proprietary information be withheld from public disclosure. Should the NRC staff require additional information to support review of this application, please contact Peter Vescovi at 336-420-8325 or peter.vescovi@orano.group.

Sincerely,

Don Shaw

Digitally signed by Don Shaw
Date: 2023.09.20 09:43:44 -04'00'

Don Shaw
Licensing Manager

cc: Pierre Saverot (NRC), Senior Project Manager, Division of Fuel Management
Peter Vescovi, TN Americas, Licensing Engineer
Kamran Tavassoli, TN Americas, Project Manager

Enclosures:

1. TN Eagle Safety Analysis Report, Revision 0 (Proprietary Version)
2. TN Eagle Safety Analysis Report, Revision 0 (Public Version)
3. Affidavit Pursuant to 10 CFR 2.390

Enclosure 1 to E-62225

TN Eagle Safety Analysis Report, Revision 0
(Proprietary Version)
Withheld Pursuant to 10 CFR 2.390

Enclosure 2 to E-62225

TN Eagle Safety Analysis Report, Revision 0
(Public Version)

PUBLIC

TN Americas LLC

TN Eagle Safety Analysis Report

Docket Number 71-9382

Revision 0

September 2023

TN AMERICAS LLC
7160 Riverwood Drive, Suite 200 • Columbia, MD 21046

RECORD OF REVISIONS

Revision	E-Document Number	Transmittal Letter Date
0	E-57970	December 30, 2020
	E-58462	April 29, 2021
	E-60914	December 9, 2022
	E-62225	September 20, 2023

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Chapter 1
General Information Evaluation

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General Information Evaluation

1.1 Package Design Information

1.1.1 Purpose of Application

The purpose of this Safety Analysis Report (SAR) application is the approval of the TN Eagle spent nuclear fuel transportation package design for the transportation of dry shielded canisters (DSCs). The Transport Index for the package is greater than 10 and the TN Eagle is shipped using exclusive conveyance.

1.1.2 Proposed Use and Contents

The TN Eagle is designed for the safe off-site transport of spent fuel stored in DSCs that have been approved for dry storage. These DSCs have been previously approved for dry storage or transport in other spent nuclear fuel transportation packagings.

The TN Eagle is designed to allow horizontal transfer of the DSCs to and from horizontal storage modules (HSM).

1.1.3 Package Type and Model Number

The package design is a Type B, fissile material package.

The TN Eagle has two model numbers:

1. TN Eagle LC (Large Canister)
2. TN Eagle SC (Standard Canister)

1.1.4 Package Category

The activity level is greater than 3,000 A2, therefore the TN Eagle Cask is designated Category I for determining the applicable Codes and Standards.

1.1.5 Codes and Standards

Criteria are identified for controlling the design and fabrication of components of shipping containers used for transporting radioactive materials. The criteria have been selected from the American Society of Mechanical Engineers (ASME) Code and are based on the level of radioactive materials being transported and the nuclear safety function of the container's components. Criteria are identified for design and fabrication processes which are related to materials control, forming, heat treatment, examination and acceptance testing. Implementation of the criteria will ensure the structural integrity of shipping containers at levels consistent with the radioactive materials being transported.

The design and fabrication criteria are based on the American Society of Mechanical Engineers Boiler and Pressure Vessel (B&PV) Code (ASME Code) for Category I. The criteria for the component safety groups are as follows:

- Containment is ASME Code Section III, Division 1,Subsection NB
- Criticality is ASME Code Section III, Division 1, Subsection NG
- Other safety is ASME Code Section VIII, Division 1 or Section III, Division 1, Subsection NF

1.1.5.1 ASME and other Standards

ASME Boiler and Pressure Vessel Code, Section III, Division 1, Subsections NB, NC, NF and NG, 2017.

ASME Boiler and Pressure Vessel Code, Section III, Division 1, Subsections NCA, 2017.

ASME Boiler and Pressure Vessel Code, Section II, Materials Specifications, Parts A, B, C and D, 2017.

ASME Boiler and Pressure Vessel Code, Section III, Division 1, Appendices, 2017.

ANSI N14.5, "Leakage Tests on Packages for Shipment of Radioactive Materials," 2014.

Aluminum Standards and Data, Volume 1, The Aluminum Association, 1976.

1.1.5.2 Federal Regulations

Title 10, Code of Federal Regulations, Part 71, "Packaging and Transportation of Radioactive Materials."

Title 49, Code of Federal Regulations, Part 173, "General Requirements for Shipments and Packagings."

Title 49, Code of Federal Regulations, Part 393, "Parts and Accessories."

1.1.5.3 NRC Bulletins, Regulatory Guides, NUREG Documents

NRC Bulletin 96-04, "Chemical, Galvanic, or Other Reactions in Spent Fuel Storage and Transportation Casks," July 5, 1996.

NRC Regulatory Guide 7.4, "Leakage Tests on Packages for Shipments of Radioactive Materials" July 2020.

NRC Regulatory Guide 7.6, "Design Criteria for the Structural Analysis of Shipping Cask Containment Vessels," Revision 2, July 2020.

NRC Regulatory Guide 7.8, "Load Combinations for the Structural Analysis of Shipping Casks," March 1989.

NRC Regulatory Guide 7.9, "Standard Format and Content of Part 71 Applications for Approval of Packaging for Radioactive Material," March 2005.

NRC Regulatory Guide 7.12, “Fracture Toughness Criteria of Base Material for Steel Shipping Cask Containment Vessels,” June 1991.

NUREG/CR-0481, SAND 77-1872, “An Assessment of Stress-Strain Data Suitable for Finite Element Elastic-Plastic Analysis of Shipping Casks,” Sandia National Laboratories, September 1978.

NUREG/CR-2018, SAND 80-1870, “A Comparison of Analytical Techniques for Analyzing a Nuclear Spent-Fuel Shipping Cask Subjected to an End-On Impact,” Sandia National Laboratories, June 1981.

NUREG/CR-3019, UCRL-53044, “Recommended Welding Criteria for Use in the Fabrication of Shipping Containers for Radioactive Materials,” March 1984.

NUREG/CR-3854, UCRL-53544, “Fabrication Criteria for Shipping Containers,” Lawrence Livermore National Laboratories, March 1985.

NUREG/CR-3966, UCID-20639, “Methods for Impact Analysis of Shipping Containers,” Lawrence Livermore National Laboratories, November 1987.

NUREG-766510, SAND76-0427, “Shock and Vibration Environments for Large Shipping Containers on Rail Cars and Trucks,” Sandia National Laboratories, June 1977.

NUREG/CR-6007, UCRL-ID-110637, “Stress Analysis of Closure Bolts for Shipping Casks,” Lawrence Livermore National Laboratory, April 1992.

NUREG/CR-5625, Hermann, et. al., “Technical Support for a Proposed Decay Heat Guide Using SAS2H/ORIGEN-S Data,” September 1994.

Regulatory Guide 7.11, “Fracture Toughness Criteria of Base Material for Ferritic Steel Shipping Cask Containment Vessels with a Maximum Wall Thickness of 4 inches (0.1m),” June 1991.

NUREG/CR-5661, “Recommendations for Preparing the Criticality Safety Evaluation of Transport Packages,” April 1997.

NUREG/CR-6487, “Containment Analysis for Type B Packages used to Transport Various Contents,” November 1996.

NUREG/CR-6801, “Recommendations for Addressing Axial Burnup in PWR Burnup Credit Analyses,” Published March 2003, ORNL/TM-2001/273, March 2003.

NUREG/CR-6800, “Assessment of Reactivity Margins and Loading Curves for PWR Burnup-Credit Cask Designs,” Published March 2003, ORNL/TM-2002/6, March 2003.

Spent Fuel Project Office, Interim Staff Guidance – 11, Revision 3, “Cladding Considerations for the Transportation and Storage of Spent Fuel.”

Spent Fuel Project Office, Interim Staff Guidance – 8, Revision 3, “Burnup Credit in the Criticality Safety Analysis of PWR Spent Fuel in Transport and Storage Casks.”

NUREG/CR-6407, INEL-95/0551, “Classification of Transportation Packaging and Dry Spent Fuel Storage System Components According to Importance to Safety,” February, 1996.

NUREG/CR-0200, Revision 6, ORNL/NUREG/CSD-2/V2/R6, “SCALE: A Modular Code System for Performing Standardized Computer Analysis for Licensing Evaluations for Workstations and Personal Computers,” September 1998.

NUREG-2216, “Standard Review Plan for Spent Fuel Transportation,” August 2020.

NUREG-0612, “Control of Heavy Loads at Nuclear Power Plants,” July 1980.

NUREG-2224, “Dry Storage and Transportation of High Burnup Spent Nuclear Fuel Final Report,” November 2020.

1.1.5.4 Units

International System of Units (SI) is used for the analysis, unless stated otherwise.

ISO 80000-1-2009, Quantities and unites (2009) International Organization for Standardization (ISO).

The International System of Units (SI) – Conversion Factors for General Use (2006) National Institute of Standards and Technology (NIST) Special Publication 1038.

1.1.6 Criticality Safety Index

The package array for both normal conditions of transport and hypothetical accident conditions is infinite. The value of "N" is infinity and the criticality safety index (CSI) is 0.

1.1.7 Quality Assurance Program

TN has an NRC approved quality assurance program (Docket Number 71-0250), which satisfies the requirements of 10 CFR Part 71 Subpart H.

1.2 Package Description

1.2.1 General Packaging Arrangement

The TN Eagle is described in the following paragraphs with “[ ]” representing item numbers on the part list of the SAR drawing found in Section 1.5.

The cavity of the TN Eagle Cask is defined by the forged cask body [100], the primary lid [201], and the ram access cover plate [910]. Safe transport relies on the following parameters:

- The leak-tightness of the containment boundary defined by the forged cask body [100], the primary lid [201] and its lid orifice cover plate [220], the ram access cover plate (RACP) [910], the lid inner seal [G1], orifice cover plate seal [G6], and RACP inner seal [G12] in normal conditions of transport (NCT) and hypothetical accident conditions (HAC).
- The shielding is provided by the steel of the forged cask body, top handing ring [131], the shielding rings [130], bottom ring [180] and bottom closure plate [190], and the neutron shield resin blocks [150; 151] placed in the lodgments of the shielding rings.
- Bottom spacer and top spacer are used (if needed) to limit the axial gap for shorter DSCs.
- A sleeve is used to limit the radial gap of DSCs in TN Eagle SC Casks.

The TN Eagle packaging is designed to transport a maximum heat load of 38.4 kW. The content (including fuel and control components (CCs)) that will be transported in the TN Eagle packaging is presented in Section 1.2.3.

The TN Eagle Cask consists of (proceeding from inner radius to outer):

- A forged cask body that provides the structural integrity of the cask, part of the gamma shielding, and the radioactive material containment function,
- A lid that provides radioactive material containment and gamma shielding,
- Shielding rings that surround the forged cask body to provide additional neutron radiation shielding with the resin blocks and gamma shielding with the steel components,
- Impact limiters placed on each end for use in transport,
- The bottom closure plate, which provides shielding.

The TN Eagle Cask is composed of the following sub-components:

- A forged cask body [100] equipped with a stack of shielding rings [130] shrink fitted onto its outer surface,
- A closure system composed of a primary lid [201], screws [V1] and an RACP [910]. The RACP bolts [V14] onto the forged cask body [100].
  - The primary lid is equipped with:
    - Inner and outer elastomeric seals [G1; G2]
    - A vent hole, closed by a port plug [223] and port plug seal [G5]
    - An orifice cover plate [220] fixed with screws [V5] and equipped with a seal [G6].
  - The ram access cover plate is equipped with:
    - Inner and outer elastomeric seals [G12; G13].
- A top and a bottom impact limiter of similar design ensuring protection of the package containment system. Both are composed of a steel casing enclosing aluminum honeycomb blocks, VYAL B resin, and an adapter.

Table 1-1 describes the TN Eagle items related to safety requirements with their dimensions. A full list of the components, their materials and their classification is provided in Chapter 7.

Forged Cask Body

The body is composed of a forged cask [100] defining the cavity of the TN Eagle, on which is shrink-fitted a stack of shielding rings [130]. The stack is blocked at the bottom of the forged cask by a bottom ring [180] and a bottom closure plate [190] that ensures non-sliding of the assembly.

The forged cask results from a "monobloc" fabrication:

- "Monobloc:" one single forged part [100] made of forged carbon steel.

The dimensions of the forged cask are detailed in Table 1-1. The top edge of the forged cask [100] has a bigger outside diameter than the rest of the part, creating a thicker flange that is machined to accommodate the primary lid. There are 64 M42 threaded holes drilled to allow fixation of the primary lid [201].

The bottom of the forged cask has an opening provided for hydraulic ram access penetration of the cask for DSC loading and unloading operations. An RACP [910] is furnished to seal the opening outside of loading and unloading operations.

The bearing surfaces of the seals of the primary lid [201] and the RACP [910] are protected by a corrosion protection coating. A zinc aluminum coating is applied to the carbon steel surface of the cavity. The rails are used to facilitate loading and unloading by providing a low friction contact surface. The cavity coating is protected from scratching during loading and unloading activities by the rails mounted inside the forged cask body.

Shielding Rings

There are 25 shielding rings [130] made of either carbon steel or cast iron. The cylindrical rings are machined to define an inner lodgment and are three types:

- Type A for TN Eagle LC only with a minimum resin thickness of [ ] and can be fabricated using [ ]
- Type B for TN Eagle SC only with a minimum resin thickness of [ ] and can be fabricated using [ ]
- Type C for TN Eagle SC only with a minimum resin thickness of [ ], and can be fabricated using only [ ]

The dimensions of the rings are detailed in Table 1-1. The ring lodgments are filled with VYAL B neutron shield resin blocks [150; 151]. Drillings are machined through the ring ligaments to ensure air communication between the lodgments of all the stacked rings. All the rings lodgments are connected through holes machined in ring ligaments up to the relieve valves [702] located in the handling ring. The rings lodgments are protected from humidity or water ingress thanks to silicon sealing between the rings. The exposed outer surfaces of the rings are protected from corrosion by painting or coating.

The top handling ring [131] differs from the intermediate rings. It has a recess machined to mate with the shear key on the transport frame instead of a neutron shield resin lodgment machined onto it.

A closing plate [140] follows the last shielding ring to close the bottom lodgment and hold the neutron shield resin blocks in place. It is held in place by the bottom ring [180], followed by the bottom closure plate [190].

<u>Closure System</u>

The closure system is composed of the primary lid [201] equipped with the lid orifice cover plate [220], the ram access cover plate [910], and all the screws associated, mounted onto the forged cask. They create a leak-tightness boundary and a containment boundary.

<u>Primary Lid</u>

The primary lid [201] is a circular disk made of martensitic stainless steel. A centering area is machined on its lower part to allow insertion in the forged cask cavity. The primary lid is equipped with threaded holes to allow handling during loading and unloading operations.

The primary lid is fixed to the forged cask with 64 M42 bolts [V1] equipped with captive washers [R1] and tightened in lodgments machined into the outer flange of the lid. A lid centering pin [111] is mounted on the forged cask body to help mounting the primary lid.

The primary lid is equipped with two elastomeric seals [G1; G2]. The seals are inserted in two grooves carved on the inner surface of the lid. A test port is drilled between the two seals, closed with a test plug [705] equipped with an O-ring seal [G7].

Another port is drilled through the lid and filled with an insert “lid port plug” [223] equipped with a metallic seal [G5]. The lid port plug is maintained in position by a tightening nut [222]. The port is then closed by the lid port cover plate [220] made of martensitic stainless steel and fixed to the primary lid with ten screws M14 [V5]. The port cover is equipped with a double metallic seal [G6], and a test port is drilled between the two seals, closed by a test plug [705] equipped with an O-ring seal [G7].

The primary lid is equipped with a lid spacer [261-265]. The height of the lid spacer “e” can be adjusted with the addition of a thin plate to compensate for small manufacturing differences in DSC length and stay within the maximum allowed gap between the DSC and the primary lid. The lid spacer is not credited for energy absorption.

Top and Bottom Impact Limiters

The purpose of the impact limiters is to protect the TN Eagle containment boundary and the leak tightness boundary from the impacts due to free drops in NCT and HAC. The top and the bottom impact limiters are of similar design.

On both sides, a stainless steel adaptor serves as the interface between the cask and the energy absorbing material – blocks of aluminum honeycomb. A stainless steel casing with gussets attaches to the adapter and encompasses the aluminum honeycomb. A layer of neutron shield resin is placed in the adapter of the impact limiter (IL) for additional shielding. The exposed outer surfaces of the ILs are painted or coated.

During NCT, a relief valve can release produced gases and increased internal pressure due to thermal expansion.

During HAC an increase in pressure is likely and several thermal plug fuses (made out of polyamide 11 or polycetal) are used. During a fire event, these plugs will melt and release the internal pressure (melting temperature is 180 °C +/-10 °C).

Ram Access Cover Plate (RACP)

The RACP is part of the bottom closure system and also allows access for the hydraulic ram for the loading and unloading of the DSC.

Spacers

To accept varying length of the DSCs, spacers could be used (if needed) to limit axial movement of the payload. All the TN Eagle casks are equipped with a lid spacer that can be adjusted with the addition of a thin plate to compensate for small manufacturing differences in DSC length. In addition, a hollow bottom spacer (to accommodate for the ram access) may be used depending on the DCS length.

Sleeve

Because there are different outside diameters (ODs) for the DSCs, an inner sleeve is used for smaller diameter DSCs for TN Eagle SC. The TN Eagle LC will not require a sleeve.

Containment System

The TN Eagle packaging is composed of one leak-tight boundary, illustrated in Figure 1-10. The leak-tight boundary is composed of:

- The thick forged cask [100],

- The primary lid [201] and its inner fluorocarbon seal [G1],
- The lid orifice cover plate [220] and its metallic seal [G6],
- The RACP [910] and its inner-fluorocarbon seal [G12].

The tightening torques of the screws of the leak-tight boundary is given in the drawing in Section 1.5.

The ability of the leak-tight boundary to withstand the regulatory accident conditions is demonstrated in Chapter 2.

The TN Eagle is designed and fabricated to be a leak tight. The cask containment boundary fabrication acceptance criterion is 1.0×10^{-7} ref cm^3/s with a sensitivity of at least 5×10^{-8} ref cm^3/s, which is also verified periodically. The leak-tight design criteria ensure that the cask must be water-tight for the purpose of the criticality evaluation as described in Chapter 6.

The TN Eagle Cask will be handled solely in a horizontal position after the impact limiters are removed and lifted via slings, around the top flange of the forged body and the bottom ring of the cask. It will be transported on a transport frame.

The cask is secured to the transport frame vertically and horizontally with tie down straps, and axially with the shear key located at the bottom on the cask.

Shielding Composition

The gamma shielding is provided by the forged cask body and the steel parts of the rings. The neutron shielding is provided by the neutron shield resin.

Personnel barriers will be used during transport to prevent access to the cask outer surface, and prevent personnel access when the cask surface temperature is above 85 °C (185 °F). The 2-meter dose rate evaluation is performed from the personnel barrier.

The radial shielding, from the inside to the outside of the packaging, is composed of:

- The forged cask body [100]
- The inner part of the shielding ring [130]
- The neutron shield resin blocks [150;151]
- The outer part of the shielding ring [130]

The axial shielding at top end, from the inside to the outside of the packaging, is composed of:

- The primary lid [201]
- The top impact limiter

The axial shielding at bottom end, from the inside to the outside of the packaging, is composed of:

- The bottom of the forged cask body [100]
- The ram access cover plate [910]
- The blocking system of the rings, i.e., the bottom closure plate [190]
- The bottom impact limiter

1.2.2 Operational Features

The TN Eagle package is not considered to be operationally complex and is designed to be compatible with HSM loading/unloading methods. All operational features are readily apparent from inspection of the SAR drawing provided in Section 1.5. The sequential steps to be followed for cask loading, testing, and unloading operations are provided in Chapter 8.

1.2.3 Contents of Packaging

The TN Eagle package is designed to transport DSCs that were designed, fabricated, loaded, and maintained under storage licenses. EOS-37PTH and EOS-89BTH DSCs will be transported in TN Eagle LC, and 32PT, 32PTH1, 24PT1, 24PT4, and FO/FC/FF DSCs will be transported in TN Eagle SC. Several types of boiling water reactor (BWR) fuel assemblies (FAs) with or without fuel channels or pressurized water reactor (PWR) FAs with or without control components (CCs) can be contained in the DSCs.

1.2.3.1 EOS-37PTH DSC

The description of the EOS-37PTH DSC, including detailed basket and content information, is in Appendix 1.6.1.

The primary confinement boundary for the EOS-37PTH DSC consists of the cylindrical shell, the top and bottom inner cover plates, the drain port cover plate, vent plug, and the associated welds. The EOS-37PTH DSC basket structure consists of interlocking slotted plates to form a grid of 37 fuel compartments that house the PWR spent fuel assemblies (SFA). The grid structure is composed of the following: a steel plate, an aluminum plate and a neutron absorber plate. The EOS-37PTH DSC is designed for a maximum heat load of 38.4 kW. The internal basket assembly contains a storage position for each FA.

This DSC is designed to contain INTACT, DAMAGED or FAILED unconsolidated Babcock and Wilcox (B&W) 15x15, Westinghouse (WE) 14x14, WE 15x15, WE 17x17, Combustion Engineering (CE) 14x14, CE 15x15 and CE 16x16 class PWR FAs (with or without CCs) that are enveloped by the FA design characteristics listed in Table 1.6.1-1 (Appendix 1.6.1). Failed fuel shall be stored in a failed fuel canister (FFC).

1.2.3.2 EOS-89BTH DSC

The description of the EOS-89BTH DSC, Including detailed basket and content information, is in Appendix 1.6.2.

1.2.3.3 24PT4 DSC

The description of the 24PT4 DSC, Including detailed basket and content information, is in Appendix 1.6.3.

The 24PT4 DSC consists of a DSC shell assembly and a basket assembly. The shell assembly consists of a cylindrical shell, the inner cover plates of the top and bottom shield plug assemblies and top and bottom outer top cover plates. The 24PT4 basket is designed to accommodate 24 intact, damaged, or failed PWR FAs. The 24PT4 can hold up to 12 damaged or failed FAs in specially designed failed fuel canisters with the balance being loaded with intact fuel. The basket structure consists of circular spacer discs which provide radial support to the guide sleeves and FAs. Poison plates are placed around the guide sleeves for criticality control.

The spent fuel to be transported in the 24PT4 DSC consists of intact (including reconstituted) Westinghouse-CENP 16x16 (CE 16x16) and/or DAMAGED or FAILED CE 16x16 FAs with Zircaloy or ZIRLO™ cladding and UO_2 or $(U,Er)O_2$ or $(U,Gd)O_2$ fuel pellets. Assemblies are with or without integral fuel burnable absorber (IFBA) rods or integral burnable poison rods. The 24PT4 DSC may transport PWR assemblies in any one of the three alternate configurations with a maximum heat load of 1.26 kW per assembly and a maximum heat load of 24 kW per DSC.

1.2.3.4 32PT DSC

The description of the 32PT DSC, Including detailed basket and content information, is in Appendix 1.6.4.

Each 32PT DSC consists of a DSC shell assembly and a basket assembly. The shell assembly consists of a cylindrical shell, the inner cover plates of the top and bottom shield plug assemblies and outer top cover plate. The 32PT baskets are designed to accommodate 32 INTACT PWR FAs with or without control components (CCs); damaged and failed fuels are allowed for the CE 14x14 fuel class in the 24 poison plate configuration. The basket structure consists of a grid assembly of welded stainless steel plates or tubes that accommodate aluminum and/or poison plates and surrounded by support rails.

The 32PT DSC may transport PWR FAs arranged in any of four alternate heat zoning configurations with a maximum decay heat of 2.2 kW per assembly and a maximum heat load of 24 kW per canister. Failed fuel shall be stored in an FFC.

1.2.3.5 32PTH1 DSC

The description of the 32PTH1 DSC, Including detailed Basket Type 1 and Type 2 and content information, is in Appendix 1.6.5.

Each 32PTH1 DSC consists of a DSC shell assembly and a basket assembly. The shell assembly consists of a cylindrical shell, the inner cover plates of the top and bottom shield plug assemblies and outer top cover plate. The 32PTH1 Baskets Type 1 and Type 2 are designed to accommodate 32 INTACT, or up to 16 DAMAGED with the remainder intact, PWR FAs with or without CCs. The baskets structures consist of a welded assembly of stainless steel tubes with the space between adjacent tubes filled with aluminium and neutron poison plates and surrounded by support rails.

The 32PTH1 DSCs may transport up to 32 PWR FAs arranged in any of three alternate heat load zone configurations. Each of the three alternate DSC configurations is designed to transport intact (including reconstituted) and/or DAMAGED PWR FAs. The 32PTH1 DSCs can also accommodate up to a maximum of 16 DAMAGED FAs placed in the center cells of the DSC. The 32PTH1 DSC may transport PWR FAs arranged in any of the three alternate heat zoning configurations with a maximum decay heat of 1.5 kW per assembly and a maximum heat load of 26 kW per canister.

1.2.3.6 FO/FC/FF DSCs

The description of the FO/FC/FF DSC, Including detailed basket and content information, is in Appendix 1.6.6.

Each FO/FC/FF DSC consists of a DSC shell assembly and a basket assembly. Because of the nature of the fuel that is to be transported, three different types of DSCs are designed for the Package: the Fuel-Only (FO) DSC, the Fuel/Control Components (FC) DSC, and the Failed Fuel (FF) DSC. The internal basket assembly contains a storage position for each FA.

The FO-DSC basket assembly consists of 24 guide sleeve assemblies with integral borated neutron absorbing plates, twenty-six spacer discs and four support rods. The FF-DSC is similar to the FC-DSC in most respects with the exception of the basket assembly. The contents of the FO/FC/FF DSC consist of spent reactor fuel in several different forms. The first form of fuel will be INTACT PWR fuel with CCs. The second form of fuel will be INTACT PWR fuel without CCs. The third form of fuel will be DAMAGED or FAILED PWR fuel without CCs.

The FF-DSC basket assembly consists of fifteen carbon steel spacer discs, steel or austenitic stainless steel (SA-240, Type XM-19), four carbon steel or austenitic stainless steel (SA-240, Type XM-19) axial support plates, and thirteen stainless steel failed fuels canisters. The spacer discs maintain the cross-sectional spacing of the FAs and provide lateral support for the FAs and failed fuel canisters. The spacer discs are held in place by the support plates which maintain longitudinal separation. The failed fuel canisters are removable and, therefore, are not permanently attached to the basket assembly or DSC shell.

The maximum allowable cask heat load under any conditions, including storage and on-site transfer use, is 13.5 kW, with a maximum assembly decay heat of 0.764 kW (Type I) or 0.563 kW (Type II) per assembly.

1.2.3.7 24PT1 DSC

The description of the 24PT1 DSC, Including detailed basket and content information, is in Appendix 1.6.7.

The 24PT1-DSC is designed to transport 24 WE 14x14 PWR FAs; UO_2 (stainless steel clad) and Mixed Oxide Zircalloy Clad (MOX UO_2 and PuO_2) FAs, with or without integral CCs. Provisions have been made to accommodate up to four stainless steel clad DAMAGED or FAILED FAs in the 24PT1-DSC. A single damaged or failed WE 14x14 MOX FA may be stored in the 24PT1-DSC with no other damaged/failed assemblies. The 24PT1-DSC shell assembly is a high integrity stainless steel, welded pressure vessel. The internal basket assembly is similar to the FO/FC-DSCs and contains 24 storage positions, one for each FA. The basket is composed of 26 circular spacer discs machined from carbon steel plates; the spacing of the discs has been modified from that used for the FO/FC DSCs to accommodate the WE 14x14 fuel. The 24PT1 DSC may transport PWR FAs arranged in any of the three alternate heat zoning configurations with a maximum decay heat of 0.583 kW per assembly and a maximum heat load of 14 kW per canister.

1.3 Summary of Compliance with 10 CFR Part 71

1.3.1 General Requirements of 10 CFR 71.43

The sections verifying the compliance with the general standards of all packages are indicated below.

Requirement		Section
71.43	**General standards for all packages.**	
(a)	The smallest overall dimension of a package may not be less than 10 cm (4 in.).	2.2.1
(b)	The outside of a package must incorporate a feature, such as a seal, that is not readily breakable and that, while intact, would be evidence that the package has not been opened by unauthorized persons.	2.2.2
(c)	Each package must include a containment system securely closed by a positive fastening device that cannot be opened unintentionally or by a pressure that may arise within the package.	2.2.3
(d)	A package must be made of materials and construction that assure that there will be no significant chemical, galvanic, or other reaction among the packaging components, among package contents, or between the packaging components and the package contents, including possible reaction resulting from inleakage of water, to the maximum credible extent. Account must be taken of the behavior of materials under irradiation.	7.9 7.10

Requirement		Section
71.43	**General standards for all packages.**	
(e)	A package valve or other device, the failure of which would allow radioactive contents to escape, must be protected against unauthorized operation and, except for a pressure relief device, must be provided with an enclosure to retain any leakage.	2.2.4
(f)	A package must be designed, constructed, and prepared for shipment so that under the tests specified in § 71.71 ("Normal conditions of transport") there would be no loss or dispersal of radioactive contents, no significant increase in external surface radiation levels, and no substantial reduction in the effectiveness of the packaging.	2.5
(g)	A package must be designed, constructed, and prepared for transport so that in still air at 38 °C (100 °F) and in the shade, no accessible surface of a package would have a temperature exceeding 50 °C (122 °F) in a nonexclusive use shipment, or 85 °C (185 °F) in an exclusive use shipment.	3.3.4
(h)	A package may not incorporate a feature intended to allow continuous venting during transport.	1.5

1.3.2 Condition of Package after Tests in 10 CFR 71.71 and 10 CFR 71.73

The sections providing descriptions for the physical condition of the package subsequent to the tests specified in 10 CFR 71.71 and 10 CFR 71.73 indicated below.

Requirements		Section
71.71	**Normal conditions of transport.**	
(a)	*Evaluation.* Evaluation of each package design under normal conditions of transport must include a determination of the effect on that design of the conditions and tests specified in this section. Separate specimens may be used for the free drop test, the compression test, and the penetration test, if each specimen is subjected to the water spray test before being subjected to any of the other tests.	2.5
(b)	*Initial conditions.* With respect to the initial conditions for the tests in this section, the demonstration of compliance with the requirements of this part must be based on the ambient temperature preceding and following the tests remaining constant at that value between -29 °C (-20 °F) and +38 °C (+100 °F), which is most unfavorable for the feature under consideration. The initial internal pressure within the containment system must be considered to be the maximum normal operating pressure, unless a lower internal pressure consistent with the ambient temperature considered to precede and follow the tests is more unfavorable.	
(c)	*Conditions and tests.*	
(1)	*Heat.* An ambient temperature of 38 °C (100 °F) in still air, and insolation according to the following table […]	2.5.1
(2)	*Cold.* An ambient temperature of -40°C (-40°F) in still air and shade.	2.5.2
(3)	*Reduced external pressure.* An external pressure of 25 kPa (3.5 lbf/in^2) absolute.	2.5.3

Requirements		Section
(4)	*Increased external pressure.* An external pressure of 140 kPa (20 lbf/in^2) absolute.	2.5.4
(5)	*Vibration.* Vibration normally incident to transport.	2.5.5
(6)	*Water spray.* A water spray that simulates exposure to rainfall of approximately 5 cm/h (2 in/h) for at least 1 hour.	2.5.6
(7)	*Free drop.* Between 1.5 and 2.5 hours after the conclusion of the water spray test, a free drop through the distance specified below onto a flat, essentially unyielding, horizontal surface, striking the surface in a position for which maximum damage is expected.	2.5.7
(8)	*Corner drop.* A free drop onto each corner of the package in succession, or in the case of a cylindrical package onto each quarter of each rim, from a height of 0.3 m (1 ft) onto a flat, essentially unyielding, horizontal surface. This test applies only to fiberboard, wood, or fissile material rectangular packages not exceeding 50 kg (110 lb) and fiberboard, wood, or fissile material cylindrical packages not exceeding 100 kg (220 lb).	2.5.8
(9)	*Compression.* For packages weighing up to 5000 kg (11,000 lbs), the package must be subjected, for a period of 24 hours, to a compressive load applied uniformly to the top and bottom of the package in the position in which the package would normally be transported. The compressive load must be the greater of the following: (i) The equivalent of 5 times the weight of the package; or (ii) The equivalent of 13 kPa (2 lbf/in^2) multiplied by the vertically projected area of the package.	2.5.9
(10)	*Penetration.* Impact of the hemispherical end of a vertical steel cylinder of 3.2 cm (1.25 in.) diameter and 6 kg (13 lb) mass, dropped from a height of 1 m (40 in.) onto the exposed surface of the package that is expected to be most vulnerable to puncture. The long axis of the cylinder must be perpendicular to the package surface.	2.5.10
71.73	**Hypothetical accident conditions.**	**2.6**
(a)	*Test procedures.* Evaluation for hypothetical accident conditions is to be based on sequential application of the tests specified in this section, in the order indicated, to determine their cumulative effect on a package or array of packages. An undamaged specimen may be used for the water immersion tests specified in paragraph (c)(6) of this section.	
(b)	*Test conditions.* With respect to the initial conditions for the tests, except for the water immersion tests, to demonstrate compliance with the requirements of this part during testing, the ambient air temperature before and after the tests must remain constant at that value between -29 °C (-20 °F) and +38 °C (+100 °F) which is most unfavorable for the feature under consideration. The initial internal pressure within the containment system must be the maximum normal operating pressure, unless a lower internal pressure, consistent with the ambient temperature assumed to precede and follow the tests, is more unfavorable.	
(c)	*Tests.* Tests for hypothetical accident conditions must be conducted as follows:	

Requirements		Section
(1)	*Free Drop.* A free drop of the specimen through a distance of 9 m (30 ft) onto a flat, essentially unyielding, horizontal surface, striking the surface in a position for which maximum damage is expected.	2.6.1
(2)	*Crush.* Subjection of the specimen to a dynamic crush test by positioning the specimen on a flat, essentially unyielding horizontal surface so as to suffer maximum damage by the drop of a 500-kg (1100-lb) mass from 9 m (30 ft) onto the specimen. The mass must consist of a solid mild steel plate 1 m (40 in.) by 1 m (40 in.) and must fall in a horizontal attitude. The crush test is required only when the specimen has a mass not greater than 500 kg (1100 lb), an overall density not greater than 1000 kg/m^3 (62.4 lb/ft^3) based on external dimension, and radioactive contents greater than 1000 A2 not as special form radioactive material. For packages containing fissile material, the radioactive contents greater than 1000 A2 criterion does not apply.	2.6.2
(3)	*Puncture.* A free drop of the specimen through a distance of 1 m (40 in.) in a position for which maximum damage is expected, onto the upper end of a solid, vertical, cylindrical, mild steel bar mounted on an essentially unyielding, horizontal surface. The bar must be 15 cm (6 in.) in diameter, with the top horizontal and its edge rounded to a radius of not more than 6 mm (0.25 in.), and of a length as to cause maximum damage to the package, but not less than 20 cm (8 in.) long. The long axis of the bar must be vertical.	2.6.3
(4)	*Thermal.* Exposure of the specimen fully engulfed, except for a simple support system, in a hydrocarbon fuel/air fire of sufficient extent, and in sufficiently quiescent ambient conditions, to provide an average emissivity coefficient of at least 0.9, with an average flame temperature of at least 800 °C (1475 °F) for a period of 30 minutes, or any other thermal test that provides the equivalent total heat input to the package and which provides a time averaged environmental temperature of 800 °C. The fuel source must extend horizontally at least 1 m (40 in.), but may not extend more than 3 m (10 ft), beyond any external surface of the specimen, and the specimen must be positioned 1 m (40 in.) above the surface of the fuel source. For purposes of calculation, the surface absorptivity coefficient must be either that value that the package may be expected to possess if exposed to the fire specified or 0.8, whichever is greater; and the convective coefficient must be that value that may be demonstrated to exist if the package were exposed to the fire specified. Artificial cooling may not be applied after cessation of external heat input, and any combustion of materials of construction, must be allowed to proceed until it terminates naturally.	2.6.4
(5)	*Immersion--fissile material.* For fissile material subject to § 71.55, in those cases where water inleakage has not been assumed for criticality analysis, immersion under a head of water of at least 0.9 m (3 ft) in the attitude for which maximum leakage is expected.	2.6.5

Requirements		Section
(6)	*Immersion--all packages*. A separate, undamaged specimen must be subjected to water pressure equivalent to immersion under a head of water of at least 15 m (50 ft). For test purposes, an external pressure of water of 150 kPa (21.7 lbf/in2) gauge is considered to meet these conditions.	2.6.6

1.3.3 Structural, Thermal, Containment, Shielding, Criticality, Materials

The adequacy of the package design to meet 10 CFR 71 structural requirements is detailed in Chapter 2. Chapter 3 demonstrates meeting the thermal requirements, while Chapters 4, 5, and 6 include the analyses required to show compliance with the containment, shielding, and criticality of 10 CFR 71. Compliance with the material requirements is demonstrated in Chapter 7.

1.3.4 Operational Procedures, Acceptance Tests, and Maintenance

The operational procedures, acceptance tests, and maintenance program detailed in Chapters 8 and 9 ensure that the TN Eagle package complies with the requirements of 10 CFR Part 71.

1.4 Certification Approach for Commercial Spent Nuclear Fuel

The approaches used to demonstrate subcriticality of spent nuclear fuel (SNF) for the 10 CFR 71.55(e) requirement are detailed in Chapter 6 of this SAR.

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Withheld Pursuant to 10 CFR 2.390

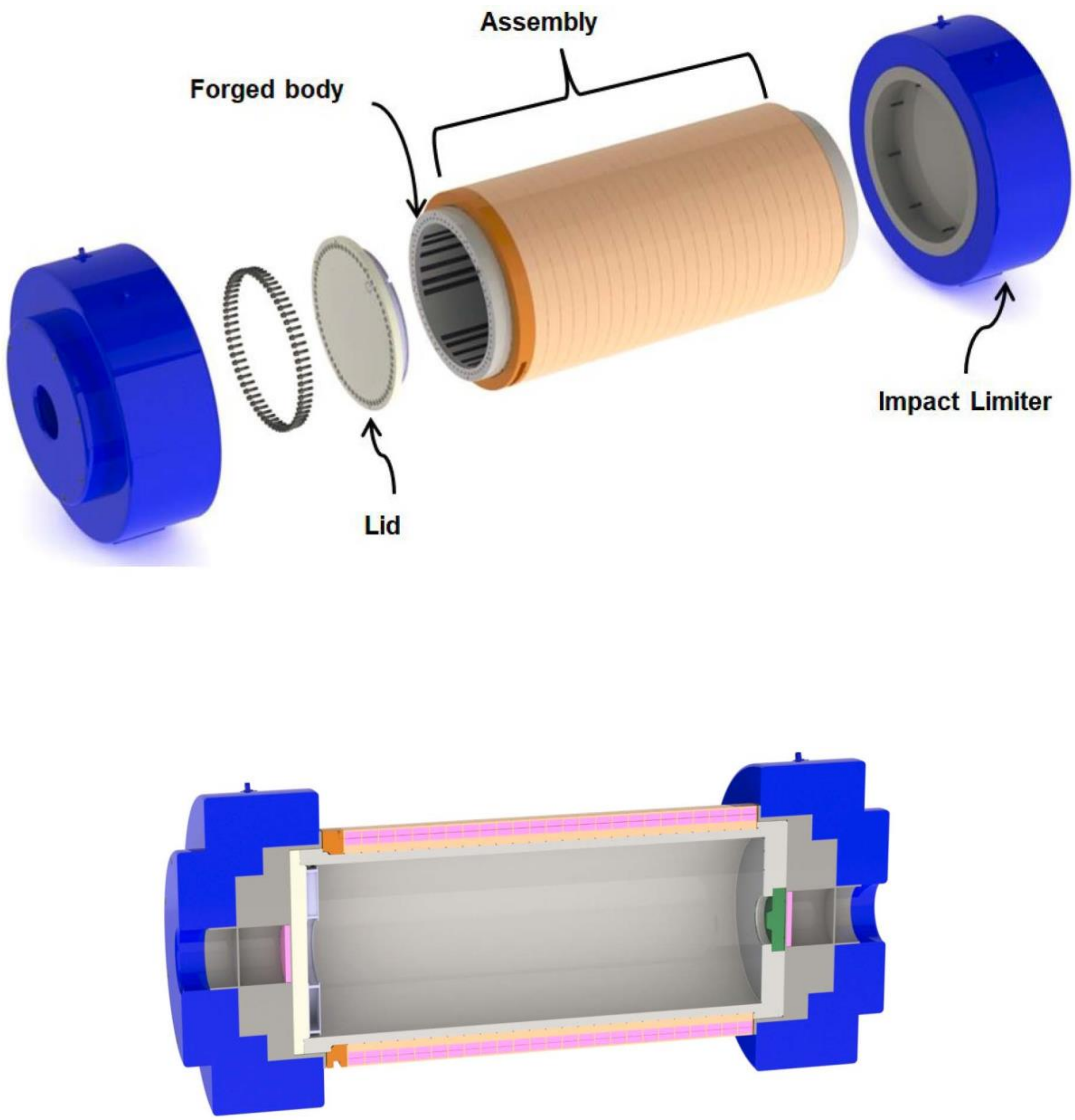


Figure 1-1
TN Eagle General Assembly View

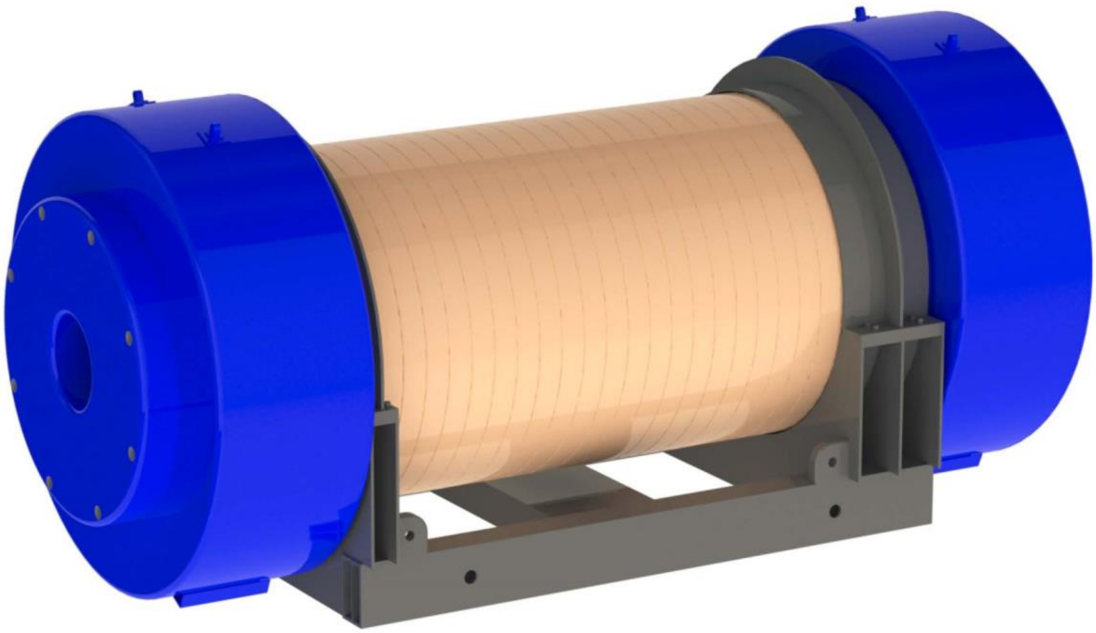


Figure 1-2
TN Eagle on the Transport Frame

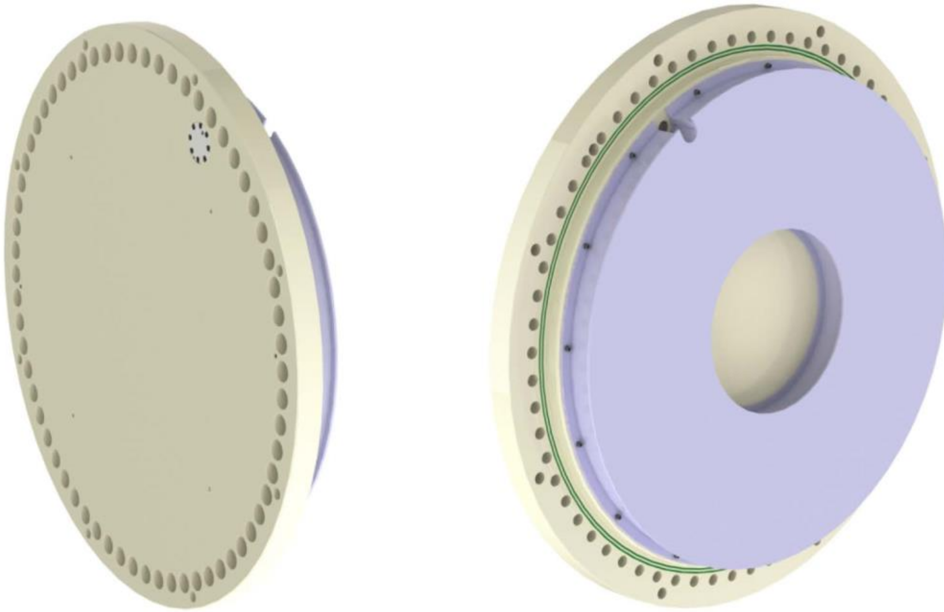


Figure 1-3
TN Eagle Primary Lid Top and Bottom View

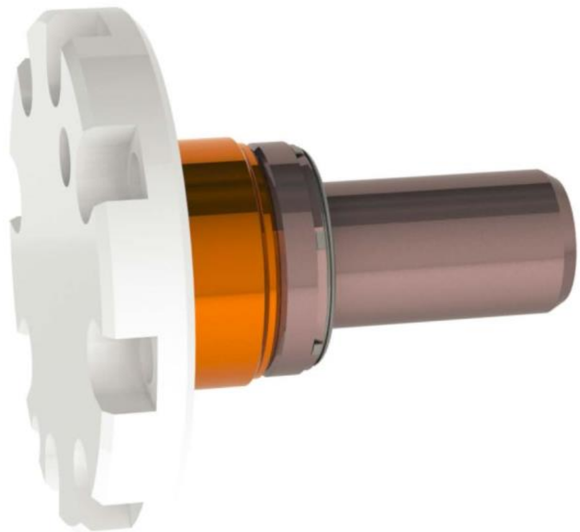


Figure 1-4
TN Eagle Lid Orifice Cover Plate Assembly

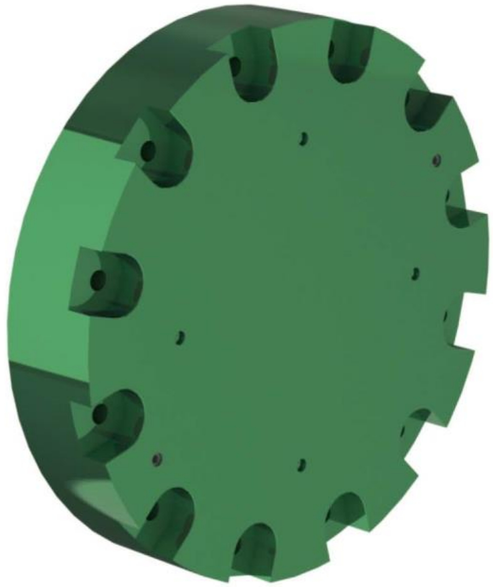


Figure 1-5
TN Eagle Ram Access Cover Plate

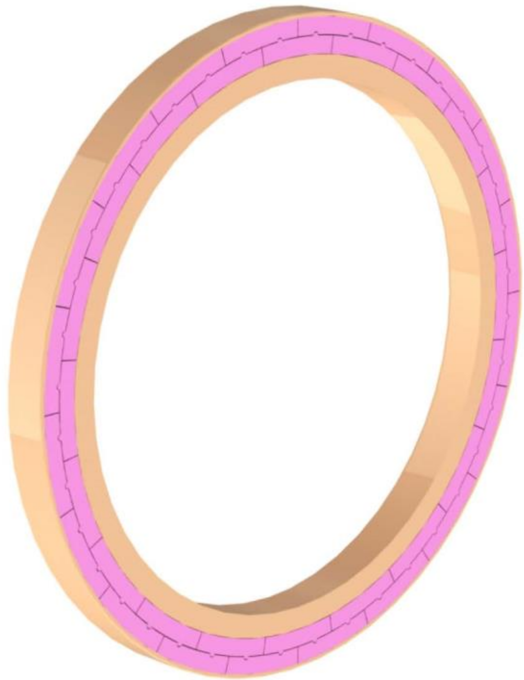


Figure 1-6
TN Eagle Shielding Ring

Figure 1-7
TN Eagle Top Handling Ring

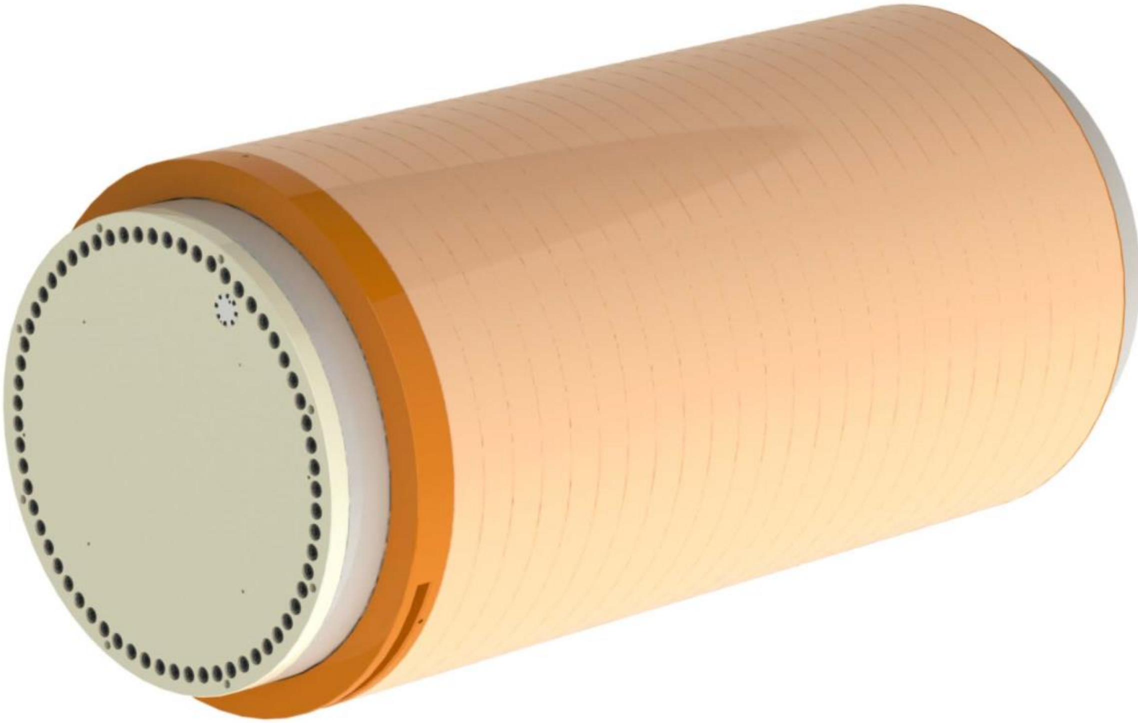


Figure 1-8
TN Eagle Cask Top View

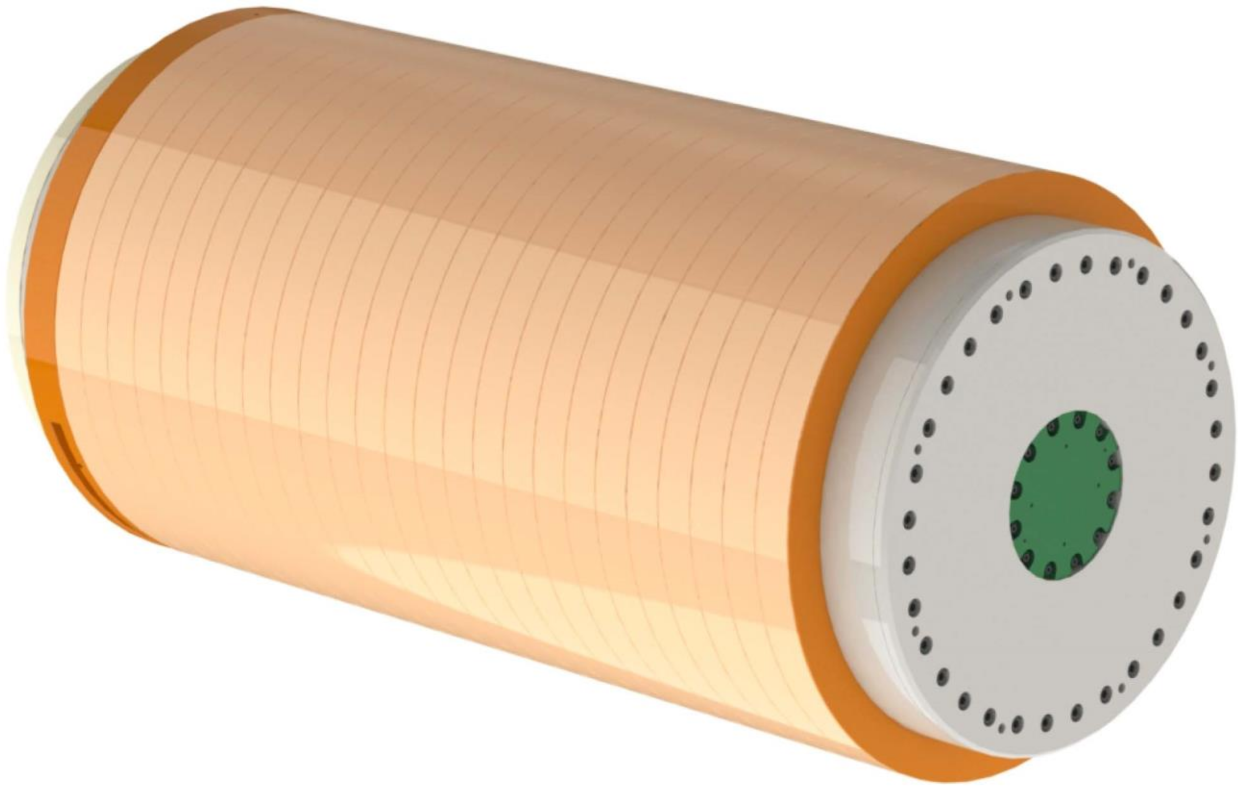
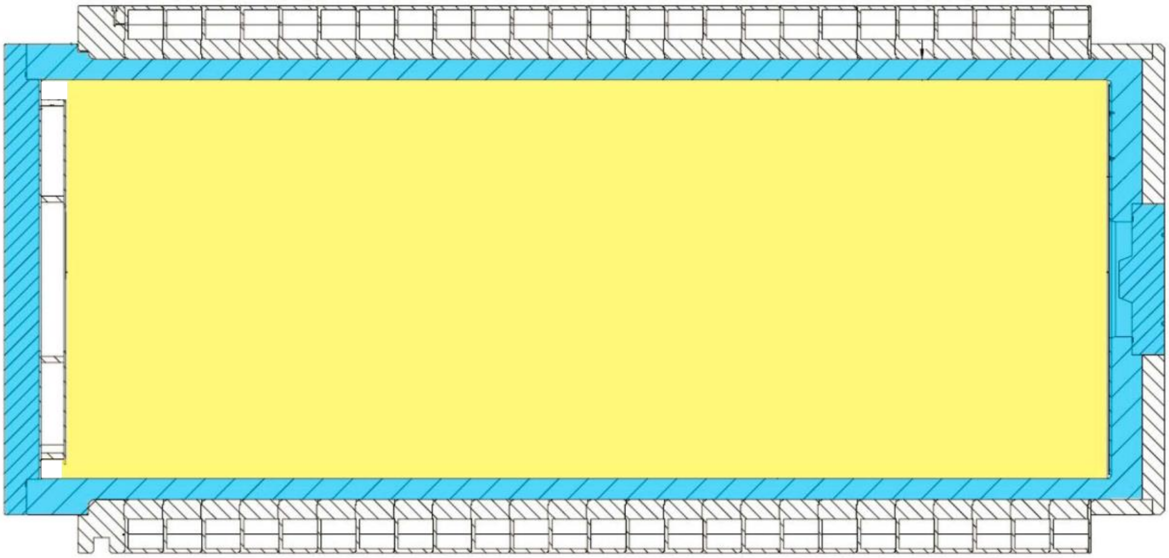


Figure 1-9
TN Eagle Cask Bottom View



Legend: The leak-tight boundary shown in blue comprised of forged cask primary lid and port covers and ram access cover plate.

Figure 1-10
Leak-Tight Boundaries

1.5 Drawings

1.5.1 TN Eagle Cask Drawings

1.5.2 EOS Drawings

1.5.3 24PT1 Drawings

1.5.4 24PT4 Drawings

1.5.5 32PT Drawings

1.5.6 FO and FC Drawings

1.5.7 FF Drawings

1.5.8 32PTH1 Drawings

1.5.1 TN Eagle Cask Drawings

DWG-TNEAGLE01-1100 Rev 0	TN Eagle LC and TN Eagle SC Transport Package (7 Sheets)

8 7 6 5 4 3 2 1

H G F E D C B A

Proprietary and Security Related Information
for Drawing TNEAGLE01-1100, Rev. 0
Withheld Pursuant to 10 CFR 2.390

H G F E D C B A

8 7 6 5 4 3 2 1

1.5.2 EOS Drawings

DWG-EOS01-71-1000 Rev 0	NUHOMS® EOS System Transportable Canister 37PTH DSC Main Assembly (7 sheets)
DWG-EOS01-71-1001 Rev 0	NUHOMS® EOS System Transportable Canister 37PTH DSC Shell Assembly (2 sheets)
DWG-EOS01-71-1005 Rev 0	NUHOMS® EOS System Transportable Canister 89BTH DSC Main Assembly (7 sheets)
DWG-EOS01-71-1006 Rev 0	NUHOMS® EOS System Transportable Canister 89BTH DSC Shell Assembly (2 sheets)
DWG-EOS01-71-1010 Rev 0	NUHOMS® EOS System Transportable Canister 37PTH DSC Basket Assembly (15 sheets)
DWG-EOS01-71-1011 Rev 0	NUHOMS® EOS System Transportable Canister 37PTH Basket Transition Rails (6 sheets)
DWG-EOS01-71-1020 Rev 0	NUHOMS® EOS System Transportable Canister 89BTH DSC Basket Assembly (9 sheets)
DWG-EOS01-71-1021 Rev 0	NUHOMS® EOS System Transportable Canister 89BTH Basket Transition Rails (7 sheets)

Proprietary and Security Related Information for Drawing EOS01-71-1000, Rev. 0 Withheld Pursuant to 10 CFR 2.390

8 7 6 5 4 3 2 1

H G F E D C B A

Proprietary and Security Related Information
for Drawing EOS01-71-1001, Rev. 0
Withheld Pursuant to 10 CFR 2.390

8 7 6 5 4 3 2 1

H G F E D C B A

8 7 6 5 4 3 2 1

H G F E D C B A

Proprietary and Security Related Information
for Drawing EOS01-71-1005, Rev. 0
Withheld Pursuant to 10 CFR 2.390

8 7 6 5 4 3 2 1

8 7 6 5 4 3 2 1

H

G

F

E

Proprietary and Security Related Information
for Drawing EOS01-71-1006, Rev. 0
Withheld Pursuant to 10 CFR 2.390

D

C

B

A

8 7 6 5 4 3 2 1

8 7 6 5 4 3 2 1

H G F E D C B A

Proprietary and Security Related Information for Drawing EOS01-71-1010, Rev. 0 Withheld Pursuant to 10 CFR 2.390

8 7 6 5 4 3 2 1

H G F E D C B A

8 7 6 5 4 3 2 1

H G F E D C B A

Proprietary and Security Related Information
for Drawing EOS01-71-1011, Rev. 0
Withheld Pursuant to 10 CFR 2.390

8 7 6 5 4 3 2 1

H G F E D C B A

8 7 6 5 4 3 2 1

H

G

F

E

Proprietary and Security Related Information
for Drawing EOS01-71-1020, Rev. 0
Withheld Pursuant to 10 CFR 2.390

D

C

B

A

8 7 6 5 4 3 2 1

Proprietary and Security Related Information for Drawing EOS01-71-1021, Rev. 0 Withheld Pursuant to 10 CFR 2.390

1.5.3 24PT1 Drawings

NUH24PT1-71-1000 Rev 0	NUHOMS® 24PT1-DSC Main Assembly (6 sheets)

Proprietary and Security Related Information for Drawing NUH24PT1-71-1000, Rev. 0 Withheld Pursuant to 10 CFR 2.390

1.5.4 24PT4 Drawings

NUH24PT4-71-1001 Rev 1	NUHOMS® 24PT4 Transportable Canister for PWR Fuel Basket Assembly (5 sheets)
NUH24PT4-71-1002 Rev 1	NUHOMS® 24PT4 Transportable Canister for PWR Fuel Main Assembly (8 sheets)
NUH24PT4-71-1003 Rev 0	NUHOMS® 24PT4 Transportable Canister for PWR Fuel Failed Fuel Can (4 sheets)

8 7 6 5 4 3 2 1

H

G

F

E

D

C

B

A

Proprietary and Security Related Information for Drawing NUH24PT4-71-1001, Rev. 1 Withheld Pursuant to 10 CFR 2.390

8 7 6 5 4 3 2 1

8 7 6 5 4 3 2 1

H G F E D C B A

Proprietary and Security Related Information
for Drawing NUH24PT4-71-1002, Rev. 1
Withheld Pursuant to 10 CFR 2.390

8 7 6 5 4 3 2 1

H G F E D C B A

8 7 6 5 4 3 2 1

H G F E D C B A

Proprietary and Security Related Information for Drawing NUH24PT4-71-1003, Rev. 1 Withheld Pursuant to 10 CFR 2.390

1.5.5 32PT Drawings

NUH32PT-71-1000 Rev 1	NUHOMS® 32PT Transportable Canister for PWR Fuel Summary Dimensions (1 sheet)
NUH32PT-71-1001 Rev 2	NUHOMS® 32PT Transportable Canister for PWR Fuel Main Assembly (5 sheets)
NUH32PT-71-1002 Rev 2	NUHOMS® 32PT Transportable Canister for PWR Fuel Shell Assembly (3 sheets) DWG-NUH32PT-71-1003
NUH32PT-71-1003 Rev 2	NUHOMS® 32PT Transportable Canister for PWR Fuel “A” Basket Assembly (16 Poison/16 Compartment Plates) (8 sheets)
NUH32PT-71-1004 Rev 2	NUHOMS® 32PT Transportable Canister for PWR Fuel Aluminum Transition Rail – R90 (2 sheets)
NUH32PT-71-1005 Rev 2	NUHOMS® 32PT Transportable Canister for PWR Fuel Aluminum Transition Rail –R45 (1 sheet)
NUH32PT-71-1006 Rev 2	NUHOMS® 32PT Transportable Canister for PWR Fuel “A/B/C/D” Basket Assembly (20 Poison/12 Compartment Plates) (6 sheets)
NUH32PT-71-1007 Rev 2	NUHOMS® 32PT Transportable Canister for PWR Fuel “A/B/C/D” Basket Assembly (24 Poison/8 Compartment Plates) (8 sheets)

8 7 6 5 4 3 2 1

H G F E D C B A

Proprietary and Security Related Information for Drawing NUH32PT-71-1000, Rev. 1 Withheld Pursuant to 10 CFR 2.390

Proprietary and Security Related Information
for Drawing NUH32PT-71-1001, Rev. 2
Withheld Pursuant to 10 CFR 2.390

Proprietary and Security Related Information for Drawing NUH32PT-71-1002, Rev. 2 Withheld Pursuant to 10 CFR 2.390

Proprietary and Security Related Information for Drawing NUH32PT-71-1003, Rev. 2 Withheld Pursuant to 10 CFR 2.390

Proprietary and Security Related Information for Drawing NUH32PT-71-1004, Rev. 2 Withheld Pursuant to 10 CFR 2.390

8 7 6 5 4 3 2 1

H G F E D C B A

Proprietary and Security Related Information
for Drawing NUH32PT-71-1005, Rev. 2
Withheld Pursuant to 10 CFR 2.390

8 7 6 5 4 3 2 1

H G F E D C B A

Proprietary and Security Related Information
for Drawing NUH32PT-71-1006, Rev. 2
Withheld Pursuant to 10 CFR 2.390

Proprietary and Security Related Information for Drawing NUH32PT-71-1007, Rev. 2 Withheld Pursuant to 10 CFR 2.390

1.5.6 FO and FC Drawings

DWG-NUH24P-FOFC-71-1000 Rev 0	NUHOMS® FO-DSC & FC-DSC for PWR Fuel Main Assembly (5 sheets)

Proprietary and Security Related Information
for Drawing NUH24P-FOFC-71-1000, Rev. 0
Withheld Pursuant to 10 CFR 2.390

1.5.7 FF Drawings

DWG-NUH24P-FF-71-1000 Rev 0	NUHOMS® FF-DSC for PWR Fuel Main Assembly (5 sheets)

Proprietary and Security Related Information
for Drawing NUH24P-FF-71-1000, Rev. 0
Withheld Pursuant to 10 CFR 2.390

1.5.8 32PTH1 Drawings

NUH32PTH1-71-1000 Rev 2	NUHOMS® 32PTH1 Transportable Canister for PWR Fuel Main Assembly (4 sheets)
NUH32PTH1-71-1001 Rev 2	NUHOMS® 32PTH1 Transportable Canister for PWR Fuel Basket Shell Assembly (5 sheets)
NUH32PTH1-71-1002 Rev 2	NUHOMS® 32PTH1 Transportable Canister for PWR Fuel Shell Assembly (4 sheets)
NUH32PTH1-71-1003 Rev 3	NUHOMS® 32PTH1 Transportable Canister for PWR Fuel Basket Assembly (8 sheets)
NUH32PTH1-71-1004 Rev 2	NUHOMS® 32PTH1 Transportable Canister for PWR Fuel Transition Rails (7 sheets) DWG-NUH32PTH1-71-1010
NUH32PTH1-71-1010 Rev 2	NUHOMS® 32PTH1 Transportable Canister for PWR Fuel Alternate Top Closure (6 sheets)

Proprietary and Security Related Information for Drawing NUH32PTH1-71-1000, Rev. 2 Withheld Pursuant to 10 CFR 2.390

8 7 6 5 4 3 2 1

H G F E D C B A

Proprietary and Security Related Information
for Drawing NUH32PTH1-71-1001, Rev. 2
Withheld Pursuant to 10 CFR 2.390

8 7 6 5 4 3 2 1

H G F E D C B A

Proprietary and Security Related Information for Drawing NUH32PTH1-71-1002, Rev. 2 Withheld Pursuant to 10 CFR 2.390

8 7 6 5 4 3 2 1

H G F E D C B A

Proprietary and Security Related Information for Drawing NUH32PTH1-71-1003, Rev. 3 Withheld Pursuant to 10 CFR 2.390

H G F E D C B A

8 7 6 5 4 3 2 1

Proprietary and Security Related Information
for Drawing NUH32PTH1-71-1004, Rev. 2
Withheld Pursuant to 10 CFR 2.390

Proprietary and Security Related Information
for Drawing NUH32PTH1-71-1010, Rev. 2
Withheld Pursuant to 10 CFR 2.390

1.6 APPENDICES

1.6.1 EOS-37PTH DSC

1.6.2 EOS-89BTH DSC

1.6.3. 24PT4 DSC

1.6.4 32PT DSC

1.6.5 32PTH1 DSC

1.6.6 FO, FC, FF DSCs

1.6.7 24PT1 DSC

1.6.8 Code Alternatives

Appendix 1.6.1
EOS-37PTH DSC

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LIST OF FIGURES

1.6.1 EOS-37PTH DSC

1.6.1.1 EOS-37PTH DSC Description

The key design parameters of the EOS-37PTH DSC are listed in Table 1.6.1-1. The primary confinement boundary for the EOS-37PTH DSC consists of the cylindrical shell, the top and bottom inner cover plates, the siphon/drain port cover plate, vent plug, and the associated welds. The top and bottom shield plugs provide shielding for the EOS-37PTH DSC so that occupational doses at the ends are minimized.

The cylindrical shell and inner bottom cover plate confinement boundary welds are fully compliant with Subsection NB of the ASME Code and are made during fabrication. The confinement boundary weld between the shell and the inner top cover (including drain port cover plate and vent plug welds), and the structural attachment weld between the shell and the outer top cover plate (including the test port weld) are in accordance with Alternatives to the ASME code as described in the EOS-37PTH Technical Specifications.

Both drain port cover plate and vent plug welds are made after drying operations are completed.

1.6.1.2 EOS-37PTH DSC Fuel Basket

The EOS-37PTH DSC basket structure consists of interlocking slotted plates to form an egg-crate type structure. The egg-crate structure forms a grid of 37 fuel compartments that house the PWR Spent Fuel Assemblies (SFA). The egg-crate grid structure is composed of one or more of the following: a steel plate, an aluminum plate, and a neutron absorber plate. The steel plates are fabricated from high-strength low-alloy (HSLA) steels such as ASTM A829 Gr 4130 (AISI 4130) steel, hot rolled, heat-treated, and tempered to provide structural support for the FAs. The poison plates are made of borated metal matrix composites (MMCs) and provide the necessary criticality control. The aluminum plates, together with the poison plates, provide a heat conduction path from the fuel assemblies (FA) to the DSC rails and shell.

The aluminum plates of the EOS-37PTH DSC may be offset vertically from the steel and poison plates. This configuration is termed the EOS-37PTH damaged/failed fuel basket. This configuration is used in conjunction with top and bottom end caps to allow for the storage of damaged FAs.

The EOS-37PTH damaged/failed fuel basket configuration is also used in conjunction with failed fuel canisters (FFC) to allow for failed fuel to be stored in the EOS-37PTH DSC. Each FFC is constructed of sheet metal and is provided with a welded bottom closure and a removable top closure that allows lifting of the FFC. The FFC is provided with screens at the bottom and top to contain the failed fuel and allow fill/drainage of water from the FFC during loading operations. The FFC is protected by the fuel compartment tubes and its only function is to confine the failed fuel.

Basket “transition rails” provide the transition between the rectangular basket structure and the cylindrical DSC shell. The transition rails are made of extruded aluminum open or solid sections, which are reinforced with internal steel, as necessary. These transition rails provide the transition to a cylindrical exterior surface to match the inside surface of the DSC shell. The transition rails support the fuel basket egg-crate structure and transfer mechanical loads to the DSC shell. They also provide the thermal conduction path from the basket assembly to the DSC shell wall, making the basket assembly efficient in rejecting heat from its payload. The nominal dimension of each fuel compartment opening is sized to accommodate the limiting assembly with sufficient clearance around the FA.

The EOS-37PTH DSC is designed to be transported for a maximum heat load of 38.4 kW. The internal basket assembly contains a storage position for each FA. The criticality analysis credits the fixed borated neutron absorbing material placed between the FAs. The criticality analysis also employs PWR burnup credit for loading operations. Sub-criticality under normal conditions of transport (NCT) and hypothetical accident conditions (HAC) as defined in 10CFR Part 71 is maintained through the geometric separation of the FAs by the basket assembly, the burnup credit restrictions, and the neutron absorbing capability of the EOS-37PTH DSC materials, as applicable. Based on coating of basket steel plates, poison material and boron loading, and the HLZC, twelve basket configurations are provided for the intact and damaged/failed fuel basket.

1.6.1.3 References

1. American Society of Mechanical Engineers, ASME Boiler and Pressure Vessel Code, Section III, Division 1 - Subsections NB, NG, and NF, ND, and NCA, 2010 Edition through 2011 Addenda, supplemented by Code Case N-635-1.

Table 1.6.1-1
Key Design Parameters of the EOS System Components
(2 pages)

EOS-37PTH DSC	
Overall Length (in.)	197.65
Outside Diameter (in.)	75.50
Cavity Length (in.)	To fit fuel to be stored accounting for irradiation growth and differential thermal growth.
Shell Thickness (in.)	0.5
Design Weight of Loaded EOS-37PTH DSC (lbs.)	120,000
Materials of Construction	Stainless steel or duplex shell assembly and carbon steel internals, carbon steel shield plugs, aluminum
Neutron Absorbing Material	MMC
Internal Atmosphere	Helium
PHYSICAL PARAMETERS:	
FUEL CLASS	Unconsolidated B&W 15x15, WE 14x14, WE 15x15, WE 17x17, CE 14x14, CE 15x15, and CE 16x16 FUEL CLASS PWR fuel assemblies (with or without CCs) that are enveloped by the fuel assembly design characteristics listed in Table 1.6.1-15.
Number of FUEL ASSEMBLIES with CCs	≤ 37
Maximum Assembly plus CC Weight	1900 lbs
DAMAGED FUEL ASSEMBLIES:	Assemblies are PWR assemblies containing fuel rods with known or suspected cladding defects greater that hairline cracks or pinhole leaks. The extent of damage in the fuel assembly, including non-cladding damage, is to be limited so that a fuel assembly maintains its configuration for normal conditions. DAMAGED FUEL assemblies shall also contain top and bottom end fittings. Damaged fuel assemblies may also contain missing or partial fuel rods.
Number and Location of DAMAGED FUEL Assemblies	Maximum of 8 DAMAGED FUEL Assemblies as shown in Figure 1.6.1-1. Balance may be INTACT FUEL, empty slots, or dummy assemblies. The DSC basket cells which store DAMAGED FUEL assemblies are provided with top and bottom end caps.
FAILED FUEL:	Defined as ruptured fuel rods, severed fuel rods, loose fuel pellets, fuel fragments, or fuel assemblies that may not maintain configuration for normal conditions. Failed fuel may contain breached rods, grossly breached rods, or other defects such as missing or partial rods, missing grid spacers, or damaged spacers to the extent that the assembly may not maintain configuration for normal conditions. Failed fuel shall be stored in a failed fuel canister (FFC).
Number and Location of FAILED FUEL	Maximum of 4 FAILED FUEL as shown in Figure 1.6.1-1. Balance may be INTACT FUEL assemblies, empty slots, or dummy assemblies. FAILED FUEL shall be stored in a failed fuel canister (FFC).

Table 1.6.1-1
Key Design Parameters of the EOS System Components
(2 pages)

Maximum Uranium Loadings per FFC for FAILED FUEL	Per Table 1.6.1-16
RECONSTITUTED FUEL ASSEMBLIES:	
Number of RECONSTITUTED FUEL ASSEMBLIES per DSC	≤ 37
Number of irradiated stainless steel rods per RECONSTITUTED FUEL ASSEMBLY	≤ 5
Control Components (CCs)	Authorized CCs include Burnable Poison Rod Assemblies (BPRAs), Thimble Plug Assemblies (TPAs), Control Rod Assemblies (CRAs), Control Element Assemblies (CEAs), Control Spiders, Rod Cluster Control Assemblies (RCCAs), Axial Power Shaping Rod Assemblies (APSRAs), Orifice Rod Assemblies (ORAs), Peripheral Power Suppression Assemblies (PPSAs), Vibration Suppression Inserts (VSIs), Neutron Source Assemblies (NSAs), and Neutron Sources. Non-fuel hardware that are positioned within the fuel assembly after the fuel assembly is discharged from the core such as Guide Tubes or Instrument Tube Tie Rods or Anchors, Guide Tube Inserts, BPRA Spacer Plates, or devices that are positioned and operated within the fuel assembly during reactor operation such as those listed above are also considered to be authorized CCs. The maximum Co-60 equivalent activity for the CCs stored in the EOS-37PTH DSC is specified in Table 1.6.1-17
Number of INTACT FUEL ASSEMBLIES	≤ 37
Mazimum Uranium Loading	492 kg/assembly
Maximum Assembly plus CC Weight	1900 lbs
THERMAL/RADIOLOGICAL PARAMETERS:	
Maximum Assembly Average Burnup	62 GWd/MTU
Minimum Assembly Average Enrichment	0.60 wt. % U-235
Minimum Cooling Time(1)	Per Table 8.7.1-2 to Table 8.7.1-29.
Decay Heat per DSC	≤ 38.4 kW and as specified for the applicable heat load zone configuration
Heat Load Zone Configuration (HLZC) and Fuel Qualification(1)	Per Figure 1.6.1-1 for HLZC #1 or per Figure 1.6.1-2 for HLZC #2.
Burnup Credit Restriction(1)	Per Table 1.6.1-2 to Table 1.6.1-13
Minimum B-10 Concentration in Poison Plates	Per Table 1.6.1-14

Note:

(1) Minimum cooling time is the longer of the cooling time given in Table 8.7.1-1 to Table 8.7.1-29; the cooling time required to meet the decay heat restrictions provided in Figure 1.6.1-1 or Figure 1.6.1-2; and the cooling time required by Table 1.6.1-2 to Table 1.6.1-13.

Table 1.6.1-2
Maximum Average Initial Enrichment/Burnup Combination for B&W 15×15 FAs in EOS-37PTH DSC Type A – Intact Fuel Assemblies

Fresh Fuel	1.90 wt. % U-235			
Cooling Time	**5 Years**	**10 Years**	**15 Years**	**20 Years**
Burnup (GWd/MTU)	**Fuel Initial Enrichment (wt. % U-235)**			
5	1.95	2.00	2.00	2.00
10	2.20	2.20	2.25	2.25
15	2.40	2.40	2.45	2.50
20	2.95	3.05	3.10	3.15
25	3.25	3.35	3.45	3.50
30	3.55	3.70	3.80	3.85
35	4.05	4.25	4.40	4.50
40	4.65	4.90	5.00	5.00
45	4.95	5.00	-	-
50	5.00	-		

Table 1.6.1-3
Maximum Average Initial Enrichment/Burnup Combinations for Intact B&W 15×15 FAs in EOS-37PTH DSC Type B – Intact Fuel Assemblies

Fresh Fuel	1.95 wt. % U-235			
Cooling Time	**5 Years**	**10 Years**	**15 Years**	**20 Years**
Burnup (GWd/MTU)	**Fuel Initial Enrichment (wt. % U-235)**			
5	2.05	2.05	2.05	2.10
10	2.25	2.30	2.30	2.35
15	2.45	2.50	2.55	2.55
20	3.05	3.15	3.20	3.25
25	3.35	3.50	3.60	3.65
30	3.65	3.80	3.90	4.00
35	4.20	4.40	4.55	4.65
40	4.85	5.00	5.00	5.00
45	5.00	-	-	-

Table 1.6.1-4
Maximum Average Initial Enrichment/Burnup Combinations WE 17×17, WE 15×15, CE 14×14, CE 15×15, and CE 16×16 FAs in EOS-37PTH DSC Type A – Intact Fuel Assemblies

Fresh Fuel	1.95 wt. % U-235			
Cooling Time	**5 Years**	**10 Years**	**15 Years**	**20 Years**
Burnup (GWd/MTU)	**Fuel Initial Enrichment (wt. % U-235)**			
5	2.05	2.05	2.05	2.05
10	2.25	2.30	2.30	2.30
15	2.45	2.50	2.50	2.55
20	3.00	3.10	3.15	3.20
25	3.30	3.45	3.50	3.60
30	3.60	3.75	3.85	3.90
35	4.10	4.30	4.45	4.55
40	4.70	5.00	5.00	5.00
45	5.00	-	-	-

Table 1.6.1-5
Maximum Average Initial Enrichment/Burnup Combinations WE 17×17, WE 15×15, CE 14×14, CE 15×15, and CE 16×16 FAs in EOS-37PTH DSC Type B – Intact Fuel Assemblies

Fresh Fuel	2.00 wt. % U-235			
Cooling Time	**5 Years**	**10 Years**	**15 Years**	**20 Years**
Burnup (GWd/MTU)	**Fuel Initial Enrichment (wt. % U-235)**			
5	2.10	2.10	2.15	2.15
10	2.35	2.35	2.35	2.40
15	2.55	2.55	2.60	2.65
20	3.10	3.20	3.30	3.35
25	3.40	3.55	3.65	3.70
30	3.75	3.90	4.00	4.05
35	4.25	4.50	4.60	4.70
40	4.90	5.00	5.00	5.00
45	5.00	-	-	-

Table 1.6.1-6
Maximum Average Initial Enrichment/Burnup Combinations for WE 14×14 FAs in EOS-37PTH DSC Type A – Intact Fuel Assemblies

Fresh Fuel	2.25 wt. % U-235			
Cooling Time	**5 Years**	**10 Years**	**15 Years**	**20 Years**
Burnup (GWd/MTU)	**Fuel Initial Enrichment (wt. % U-235)**			
5	2.40	2.40	2.40	2.45
10	2.65	2.70	2.70	2.75
15	2.90	2.95	2.95	3.00
20	3.55	3.65	3.75	3.80
25	3.90	4.05	4.15	4.20
30	4.25	4.40	4.50	4.60
35	4.85	5.00	5.00	5.00
40	5.00	-	-	-

Table 1.6.1-7
Maximum Average Initial Enrichment/Burnup Combinations for WE 14×14 FAs in EOS-37PTH DSC Type B – Intact Fuel Assemblies

Fresh Fuel	2.30 wt. % U-235			
Cooling Time	**5 Years**	**10 Years**	**15 Years**	**20 Years**
Burnup (GWd/MTU)	**Fuel Initial Enrichment (wt. % U-235)**			
5	2.50	2.50	2.50	2.50
10	2.75	2.80	2.80	2.80
15	3.00	3.05	3.10	3.10
20	3.70	3.80	3.85	3.90
25	4.05	4.20	4.25	4.35
30	4.40	4.55	4.65	4.75
35	5.00	5.00	5.00	5.00

Table 1.6.1-8
Maximum Average Initial Enrichment/Burnup Combinations for B&W 15×15 FAs in EOS-37PTH DSC Type A – Failed Fuel Assemblies

Fresh Fuel	**Intact (25 FAs)**				**Failed (12 FAs)**			
	1.90 wt. % U-235				1.70 wt. % U-235			
Cooling Time	**5 Years**		**10 Years**		**15 Years**		**20 Years**	
FA Configuration	**Intact (25 FAs)**	**Failed (12 FAs)**	**Intact (25 FAs)**	**Failed (12 FAs)**	**Intact (25 FAs)**	**Failed (12 FAs)**	**Intact (25 FAs)**	**Failed (12 FAs)**
Burnup (GWd/MTU)	**Fuel Initial Enrichment (wt. % U-235)**							
5	1.95	1.60	2.00	1.70	2.00	1.65	2.00	1.70
10	2.20	1.80	2.20	1.80	2.25	1.85	2.25	1.90
15	2.40	1.95	2.40	2.00	2.45	2.05	2.50	2.00
20	2.95	2.45	3.05	2.40	3.10	2.55	3.15	2.50
25	3.25	2.55	3.35	2.70	3.45	2.80	3.50	2.85
30	3.55	2.80	3.70	2.95	3.80	3.05	3.85	3.10
35	4.05	3.20	4.25	3.40	4.40	3.55	4.50	3.60
40	4.65	3.65	4.90	3.85	5.00	4.35	5.00	4.70
45	4.95	4.00	5.00	4.80	5.00	5.00	5.00	5.00
50	5.00	4.95	5.00	5.00	-	-	-	-
55	5.00	5.00	-	-	-	-	-	-

Table 1.6.1-9
Maximum Average Initial Enrichment/Burnup Combinations for B&W 15×15 FAs in EOS-37PTH DSC Type B –Failed Fuel Assemblies

Fresh Fuel	**Intact (25 FAs)**				**Failed (12 FAs)**			
	1.90 wt. % U-235				1.70 wt. % U-235			
Cooling Time	**5 Years**		**10 Years**		**15 Years**		**20 Years**	
FA Configuration	**Intact (25 FAs)**	**Failed (12 FAs)**	**Intact (25 FAs)**	**Failed (12 FAs)**	**Intact (25 FAs)**	**Failed (12 FAs)**	**Intact (25 FAs)**	**Failed (12 FAs)**
Burnup (GWd/MTU)	**Fuel Initial Enrichment (wt. % U-235)**							
5	2.05	1.70	2.05	1.70	2.05	1.75	2.10	1.75
10	2.25	1.80	2.30	1.85	2.30	1.85	2.35	1.95
15	2.45	1.95	2.50	2.00	2.55	2.05	2.55	2.10
20	3.05	2.45	3.15	2.50	3.20	2.60	3.25	2.65
25	3.35	2.65	3.50	2.70	3.60	2.90	3.65	2.95
30	3.65	2.85	3.80	3.05	3.90	3.10	4.00	3.20
35	4.20	3.35	4.40	3.45	4.55	3.65	4.65	3.70
40	4.85	3.80	5.00	4.25	5.00	4.75	5.00	5.00
45	5.00	4.45	5.00	5.00	5.00	5.00	-	-
50	5.00	5.00	-	-	-	-	-	-

Table 1.6.1-10
Maximum Average Initial Enrichment/Burnup Combinations for WE 17×17, WE 15×15, CE 14×14, CE15×15, and CE 16×16 FAs in EOS-37PTH DSC Type A – Failed Fuel Assemblies

Fresh Fuel	**Intact (25 FAs)**				**Failed (12 FAs)**			
	1.95 wt. % U-235				1.75 wt. % U-235			
Cooling Time	**5 Years**		**10 Years**		**15 Years**		**20 Years**	
FA Configuration	**Intact (25 FAs)**	**Failed (12 FAs)**	**Intact (25 FAs)**	**Failed (12 FAs)**	**Intact (25 FAs)**	**Failed (12 FAs)**	**Intact (25 FAs)**	**Failed (12 FAs)**
Burnup (GWd/MTU)	**Fuel Initial Enrichment (wt. % U-235)**							
5	2.05	1.65	2.05	1.65	2.05	1.65	2.05	1.65
10	2.25	1.75	2.30	1.85	2.30	1.80	2.30	1.85
15	2.45	1.85	2.50	1.95	2.50	2.00	2.55	2.00
20	3.00	2.30	3.10	2.40	3.15	2.45	3.20	2.55
25	3.30	2.45	3.45	2.70	3.50	2.75	3.60	2.80
30	3.60	2.80	3.75	2.90	3.85	3.00	3.90	3.05
35	4.10	3.15	4.30	3.40	4.45	3.55	4.55	3.60
40	4.70	3.65	5.00	4.00	5.00	4.50	5.00	4.85
45	5.00	4.05	5.00	4.90	5.00	5.00	5.00	5.00
50	5.00	5.00	5.00	5.00	-	-	-	-

Table 1.6.1-11
Maximum Average Initial Enrichment/Burnup Combinations for WE 17×17, WE 15×15, CE 14×14, CE15×15, and CE 16×16 FAs in EOS-37PTH DSC Type B – Failed Fuel Assemblies

Fresh Fuel	Intact (25 FAs)				Failed (12 FAs)			
	2.00 wt. % U-235				1.65 wt. % U-235			
Cooling Time	**5 Years**		**10 Years**		**15 Years**		**20 Years**	
FA Configuration	**Intact (25 FAs)**	**Failed (12 FAs)**	**Intact (25 FAs)**	**Failed (12 FAs)**	**Intact (25 FAs)**	**Failed (12 FAs)**	**Intact (25 FAs)**	**Failed (12 FAs)**
Burnup (GWd/MTU)	**Fuel Initial Enrichment (wt. % U-235)**							
5	2.10	1.65	2.10	1.70	2.15	1.70	2.15	1.70
10	2.35	1.80	2.35	1.90	2.35	1.90	2.40	1.90
15	2.55	1.95	2.55	2.00	2.60	2.00	2.65	2.00
20	3.10	2.40	3.20	2.45	3.30	2.50	3.35	2.55
25	3.40	2.60	3.55	2.75	3.65	2.85	3.70	2.90
30	3.75	2.80	3.90	3.05	4.00	3.10	4.05	3.25
35	4.25	3.25	4.50	3.45	4.60	3.60	4.70	3.75
40	4.90	3.65	5.00	4.40	5.00	4.85	5.00	5.00
45	5.00	4.50	5.00	5.00	5.00	5.00	-	-
50	5.00	5.00	-	-	-	-	-	-

Table 1.6.1-12
Maximum Average Initial Enrichment/Burnup Combinations for WE 14×14 FAs in EOS-37PTH DSC Type A – Failed Fuel Assemblies

Fresh Fuel	**Intact (25 FAs)**				**Failed (12 FAs)**			
	2.20 wt. % U-235				1.95 wt. % U-235			
Cooling Time	**5 Years**		**10 Years**		**15 Years**		**20 Years**	
FA Configuration	**Intact (25 FAs)**	**Failed (12 FAs)**	**Intact (25 FAs)**	**Failed (12 FAs)**	**Intact (25 FAs)**	**Failed (12 FAs)**	**Intact (25 FAs)**	**Failed (12 FAs)**
Burnup (GWd/MTU)	**Fuel Initial Enrichment (wt. % U-235)**							
5	2.40	1.75	2.40	1.75	2.40	1.75	2.45	1.75
10	2.65	1.85	2.70	1.90	2.70	1.85	2.75	1.90
15	2.90	1.95	2.95	2.05	2.95	2.10	3.00	2.10
20	3.55	2.40	3.65	2.45	3.75	2.60	3.80	2.55
25	3.90	2.50	4.05	2.75	4.15	2.85	4.20	2.85
30	4.25	2.80	4.40	3.05	4.50	3.05	4.60	3.20
35	4.85	3.20	5.00	3.65	5.00	4.00	5.00	4.25
40	5.00	4.60	5.00	5.00	5.00	5.00	5.00	5.00
45	5.00	5.00	-	-	-	-	-	-

Table 1.6.1-13
Maximum Average Initial Enrichment/Burnup Combinations for WE 14×14 FAs in EOS-37PTH DSC Type B – Failed Fuel Assemblies

Fresh Fuel	**Intact (25 FAs)**				**Failed (12 FAs)**			
	2.30 wt. % U-235				1.90 wt. % U-235			
Cooling Time	**5 Years**		**10 Years**		**15 Years**		**20 Years**	
FA Configuration	**Intact (25 FAs)**	**Failed (12 FAs)**	**Intact (25 FAs)**	**Failed (12 FAs)**	**Intact (25 FAs)**	**Failed (12 FAs)**	**Intact (25 FAs)**	**Failed (12 FAs)**
Burnup (GWd/MTU)	**Fuel Initial Enrichment (wt. % U-235)**							
5	2.50	1.75	2.50	1.80	2.50	1.85	2.50	1.80
10	2.75	1.95	2.80	2.00	2.80	1.95	2.80	1.95
15	3.00	2.00	3.05	2.10	3.10	2.10	3.10	2.15
20	3.70	2.40	3.80	2.50	3.85	2.60	3.90	2.65
25	4.05	2.65	4.20	2.80	4.25	2.90	4.35	2.90
30	4.40	2.85	4.55	3.05	4.65	3.15	4.75	3.15
35	5.00	3.45	5.00	4.00	5.00	4.35	5.00	4.55
40	5.00	4.90	5.00	5.00	5.00	5.00	5.00	5.00
45	5.00	5.00	-	-	-	-	-	-

Table 1.6.1-14
Minimum B-10 Content in the Neutron Poison Plates of the EOS-37PTH DSC

Basket Type	Minimum B-10 Content for MMC (mg/cm^2)	B-10 Content Used in Criticality Evaluation (mg/cm^2)
A	28.0	25.2
B	35.0	31.5

Table 1.6.1-15
Fuel Assembly Design Characteristics for the EOS-37PTH DSC

PWR FUEL Class	B&W 15x15	WE 17x17	CE 15x15	WE 15x15	CE 14x14	WE 14x14	CE 16x16
Fissile Material	UO_2	UO_2	UO_2	UO_2	UO_2	UO_2	UO_2
Maximum Number of Fuel Rods	208	264	216	204	176	179	236
Maximum Number of Guide/ Instrument Tubes	17	25	9	21	5	17	5

Table 1.6.1-16
Maximum Uranium Loading per FFC for Failed PWR Fuel

Fuel Assembly Class	Maximum Uranium Loading (MTU)
WE 17x17	0.492
CE 16x16	0.456
BW 15x15	0.492
WE 15x15	0.480
CE 15x15	0.450
CE 14x14	0.400
WE 14x14	0.410

Table 1.6.1-17
Co-60 Equivalent Activity for CCs Stored in the EOS-37PTH DSC

Fuel Region	Maximum Co-60 Activity per Heat Load Zone (1) (Curies/FA)	
	Inner Fuel Locations (2)	Peripheral Fuel Locations
Active Fuel	308	308
Plenum	44.1	14.8
Top Nozzle	18.9	9.5

Notes:
1. Inner/Peripheral fuel locations are shown in Figure 1.6.1-3.
2. Up to 2 NSAs and Neutron Sources shall only be stored in the interior compartments of the basket. Interior compartments are those compartments that are completely surrounded by other compartments, including the corners. There are thirteen interior compartments in the EOS-37PTH DSC for both HLZC #1 and HLZC #2, represented by Zone 1 of HLZC1, shown in Figure 1.6.1-1.

Table 1.6.1-18
PWR Decay Heat for Heat Load Configurations

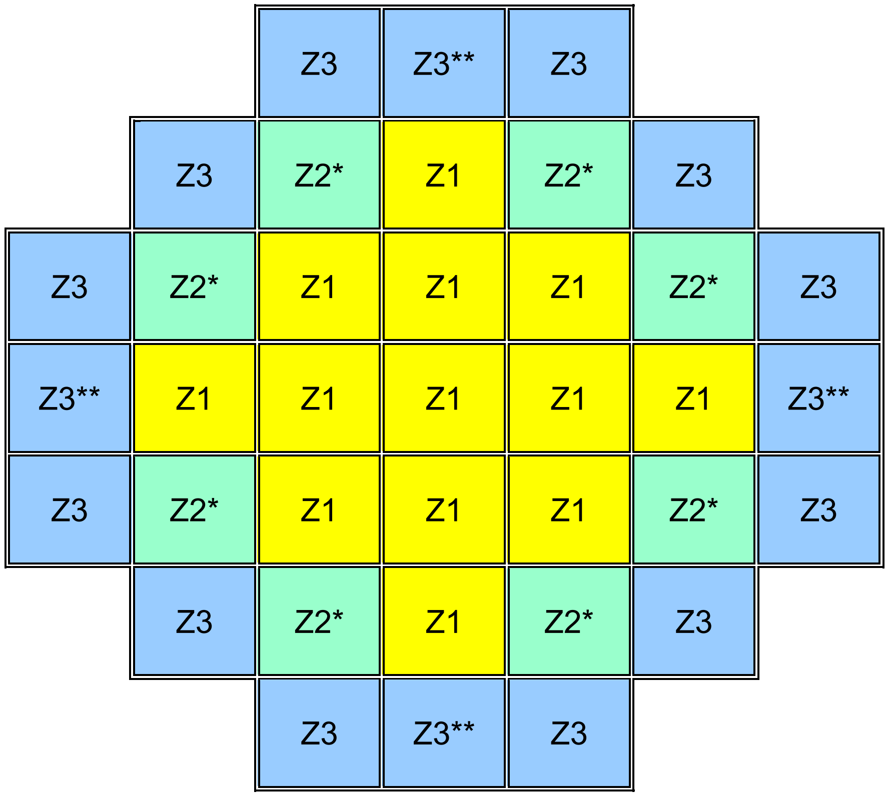
The Decay Heat (DH) in watts is expressed as:

$$F1 = -44.8 + 41.6*X1 - 37.1*X2 + 0.611*X1^2 - 6.80*X1*X2 + 24.0*X2^2$$
$$DH = 1.004*F1*Exp(\{[1-(1.8/X3)]* (-0.575)\}*[(X3-4.5)^{0.169}]*[(X2/X1)^{-0.147}]) + 20$$

where,

F1	Intermediate Function
X1	Assembly Burnup in GWD/MTU
X2	Initial Enrichment in wt. % U-235
X3	Cooling Time in Years (minimum 5 years)

Note:
A uranium loading of 492 kg is employed in the calculation of the decay heat equation. Alternatively, the decay heat can be calculated without employing the decay heat equation, using an approved methodology with actual spent fuel parameters instead of bounding spent fuel parameters.

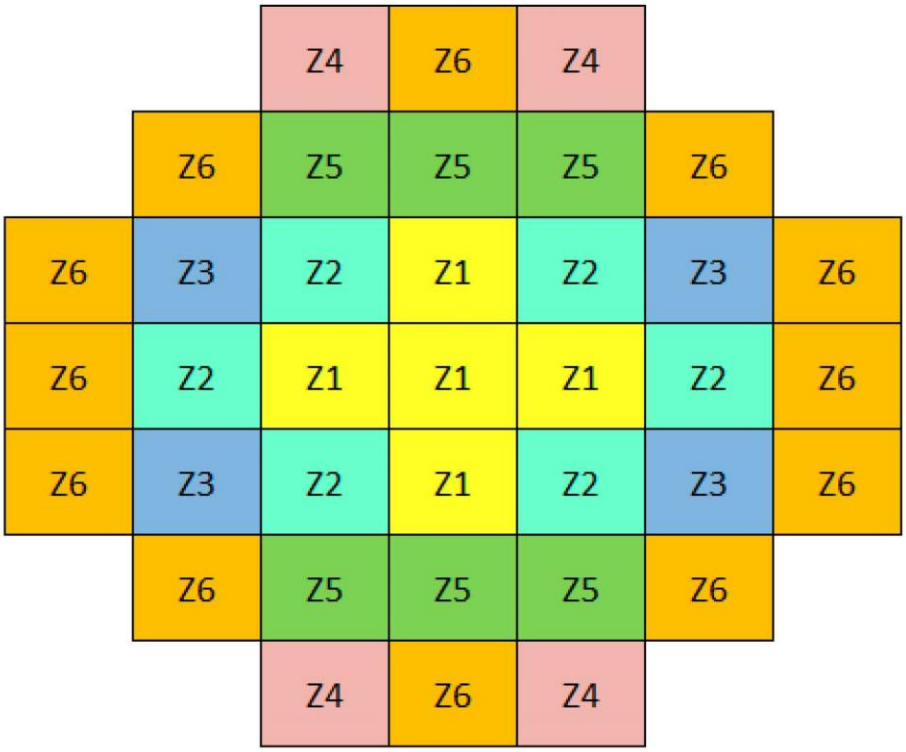


(*) denotes location where INTACT or DAMAGED FUEL can be stored.
(**) denotes location where INTACT or FAILED FUEL can be stored.

Zone Number	1	2 (1)	3 (1)
Maximum Decay Heat (kW/FA plus CCs, if included)(4)(5)	0.8	1.6 (2)	0.95 (3)
Maximum Number of Fuel Assemblies	13	8	16
Maximum Decay Heat per DSC (kW)	38.4		

Notes:
(1) DAMAGED FUEL and FAILED FUEL shall not be loaded in the same DSC.
(2) The maximum allowable heat load per DAMAGED FUEL is 1.35 kW.
(3) The maximum allowable heat load per FAILED FUEL is 0.75 kW.
(4) Decay heat per fuel assembly shall be determined per Table 1.6.1-18.
(5) When storing a CC with the fuel assemblies, reduce allowable decay heat (DH) by heat output of CC.

Figure 1.6.1-1
HLZC1 for EOS-37PTH DSC in TN Eagle LC



Zone Number	1	2	3	4	5	6
Maximum Decay Heat (kW/FA plus CCs, if included)[1][2]	0.7	0.7	1.5	1.5	0.75	0.75
Maximum Number of Fuel Assemblies	5	6	4	4	6	12
Maximum Decay Heat per DSC (kW)	33.2					

Notes:

(1) Decay heat per fuel assembly shall be determined per Table 1.6.1-18.

(2) When storing a CC with the fuel assemblies, reduce allowable decay heat (DH) by heat output of CC.

Figure 1.6.1-2
HLZC2 for EOS-37PTH DSC in TN Eagle LC

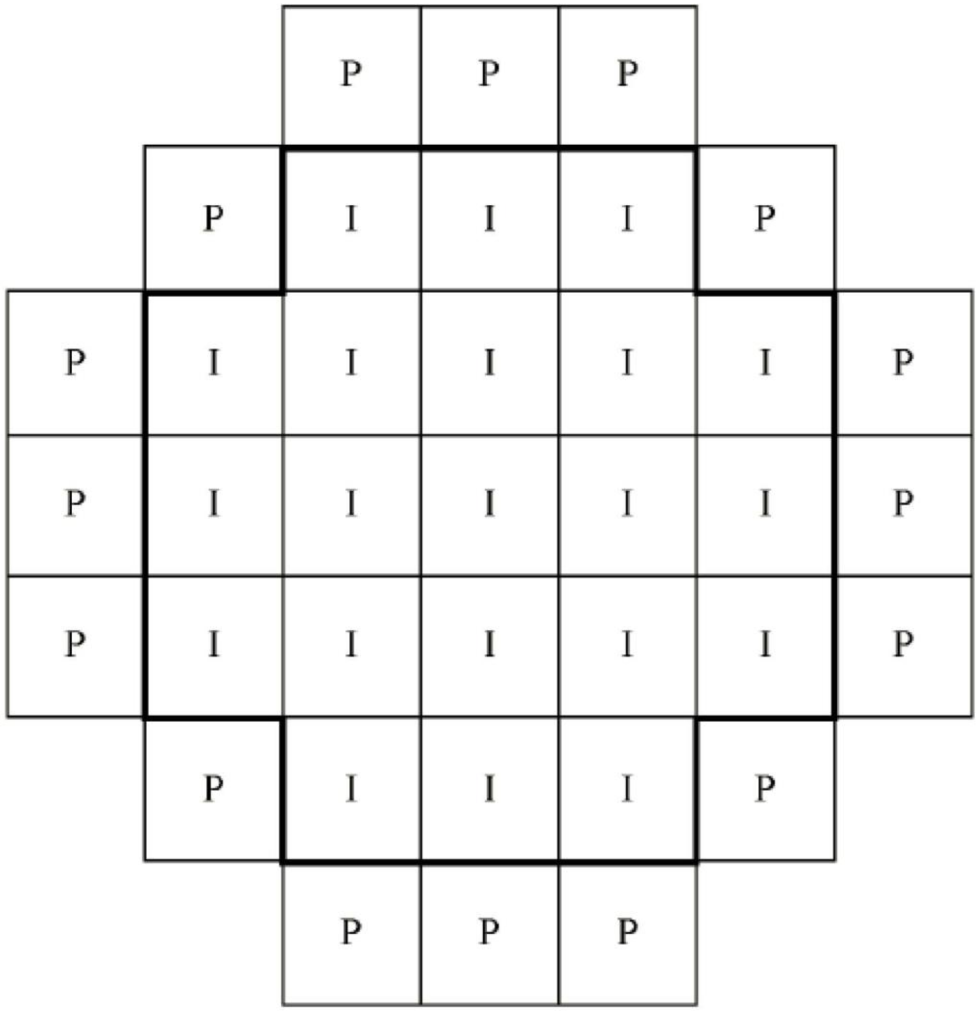


Figure 1.6.1-3
Peripheral (P) and Inner (I) Fuel Locations for the EOS-37PTH DSC

Appendix 1.6.2
EOS-89BTH DSC

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1.6.2 EOS-89BTH DSC

1.6.2.1 EOS-89BTH DSC Description

The key design parameters of the EOS-89BTH DSC are listed in Table 1.6.2-1. The primary confinement boundary for the EOS-89BTH DSC consists of the cylindrical shell, the top and bottom inner cover plates, the drain port cover plate, vent plug, and the associated welds. The outer top and bottom cover plates, test port plug, and associated welds form the redundant confinement boundary. The top and bottom shield plugs provide shielding for the EOS-89BTH DSC to minimize occupational doses at the ends during drying, sealing, handling, and transfer operations.

The cylindrical shell and inner bottom cover plate confinement boundary welds are fully compliant with Subsection NB of the ASME Code and are made during fabrication. The confinement boundary weld between the shell and the inner top cover (including drain port cover plate and vent plug welds), and structural attachment weld between the shell and the outer top cover plate (including the test plug weld) are in accordance with Alternatives to the ASME code as described in EOS-89BTH Technical Specifications.

Both drain port cover plate and vent plug welds are made after drying operations are complete.

1.6.2.2 EOS-89BTH DSC Fuel Basket

The EOS-89BTH DSC basket structure consists of interlocking slotted plates to form an egg-crate-type structure. The egg-crate structure forms a grid of 89 fuel compartments that house the BWR Spent Fuel Assemblies (SFA). The egg-crate grid structure is composed of one or more of the following: a steel plate, an aluminum plate, and a neutron absorber plate. The steel plates are fabricated from HSLA steels such as ASTM A829 Gr 4130 (AISI 4130) steel, hot rolled, heat-treated, and tempered to provide structural support for the FAs. The poison plates are made of borated MMCs or BORAL® and provide the necessary criticality control. The aluminum plates, together with the poison plates, provide a heat conduction path from the FAs to the DSC rails and shell.

Basket “transition rails” provide the transition between the rectangular basket structure and the cylindrical DSC shell. The transition rails are made of extruded aluminum open or solid sections, which are reinforced with internal steel as necessary. These transition rails provide the transition to a cylindrical exterior surface to match the inside surface of the DSC shell. The transition rails support the fuel basket egg-crate structure and transfer mechanical loads to the DSC shell. They also provide the thermal conduction path from the basket assembly to the DSC shell wall, making the basket assembly efficient in rejecting heat from its payload. The nominal dimension of each fuel compartment opening is sized to accommodate the limiting assembly with sufficient clearance around the FA.

The EOS-89BTH DSC is designed to be transported for a maximum heat load of 31.15 kW. The internal basket assembly contains a storage position for each Fuel Assembly (FA). The criticality analysis credits the fixed borated neutron absorbing material placed between the FAs. Sub-criticality under normal conditions of transport (NCT) and hypothetical accident conditions (HAC) as defined in 10 CFR Part 71 is maintained through the geometric separation of the FAs by the basket assembly and the neutron absorbing capability of the EOS-89BTH DSC materials, as applicable. Based on poison material and boron loading, and the HLZC, nine basket types are provided.

1.6.2.3 References

1. American Society of Mechanical Engineers, ASME Boiler and Pressure Vessel Code, Section III, Division 1 - Subsections NB, NG, and NF, ND, and NCA, 2010 Edition through 2011 Addenda, supplemented by Code Case N-635-1.

Table 1.6.2-1
Key Design Parameters of the EOS System Components
(2 Pages)

EOS-89BTH DSC	
Overall Length (in.)	197.65
Outside Diameter (in.)	75.50
Cavity Length (in.)	To fit fuel to be stored accounting for irradiation growth and differential thermal growth.
Shell Thickness (in.)	0.5
Design Weight of Loaded EOS-89BTH DSC (lbs.)	120,000
Materials of Construction	Stainless steel or duplex shell assembly and carbon steel internals, carbon steel shield plugs, aluminum
Neutron Absorbing Material	BORAL™, MMC
Internal Atmosphere	Helium
PHYSICAL PARAMETERS:	
FUEL CLASS	INTACT unconsolidated 7x7, 8x8, 9x9, and 10x10 BWR fuel assemblies (with or without channels) that are enveloped by the FA design characteristics listed in Table 1.6.2-2.
FUEL CONDITION:	
INTACT FUEL	Fuel assembly with no known or suspected cladding defects in excess of pinhole leaks or hairline cracks, and with no missing rods.
RECONSTITUTED FUEL ASSEMBLIES:	
• Number of RECONSTITUTED FUEL ASSEMBLIES per DSC with irradiated stainless steel rods	≤ 89
• Number of irradiated stainless steel rods per RECONSTITUTED FUEL ASSEMBLY	≤ 5
Number of INTACT FUEL ASSEMBLIES	≤ 89
Channels	Fuel may be stored with or without channels and associated channel hardware.
Maximum Uranium Loading	198 kg/assembly
Maximum Assembly Weight with a Channel	705 lbs.
THERMAL/RADIOLOGICAL PARAMETERS:	
Maximum Assembly Average Burnup	62 GWd/MTU
Minimum Assembly Average Enrichment	0.60 wt. % U-235
Minimum Cooling Time[(1)]	Per Table 8.7.2-1
Decay Heat per DSC	≤ 31.15 kW and as specified for the applicable heat load zone configuration

Table 1.6.2-1
Key Design Parameters of the EOS System Components
(2 Pages)

Heat Load Zone Configuration (HLZC) and Fuel Qualification	Per Figure 1.6.2-1 for HLZC #1.
Maximum Lattice Average Initial Fuel Enrichment	Per Table 1.6.2-3
Minimum B-10 Concentration in Poison Plates	Per Table 1.6.2-3

Note:
(1) Minimum cooling time is the longer of the cooling time given in Table 8.7.2-1, and the cooling time required to meet the decay heat restrictions provided in Figure 1.6.2-1.

Table 1.6.2-2
Fuel Assembly Design Characteristics for the EOS-89BTH DSC

BWR Fuel Class	BWR Fuel ID	Example Fuel Designs (1)(2)
7 x 7	GE-7-A	GE-1, G2, GE3
8 x 8	GE-8-A	GE4, XXX-RCN
8 x 8	GE-8-B	GE5, GE-Pres GE-Barrier GE8 Type 1
8 x 8	GE-8-C	GE8 Type II
8 x 8	GE-8-D	GE9, GE10
9 x 9	GE-9-A	GE11, GE13
10 x 10	GE-10-A	GE12, GE14
10 x 10	GE-10-B	GNF2
7 x 7	ENC-7-A	ENC-IIIA
7 x 7	ENC-7-B	ENC-III ENC-IIIE ENC-IIIF
8 x 8	ENC-8-A	ENC Va and Vb
8 x 8	FANP-8-A	FANP 8x8-2
9 x 9	FANP-9-A	FANP-9x9-79/2 FANP-9x9-72 FANP-9x9-80 FANP-9x9-81
9 x 9	FANP-9-B	Siemens QFA ATRIUM 9
10 x 10	FANP-10-A	ATRIUM 10 ATRIUM 10XM
8 x 8	ABB-8-A	SVEA-64
8 x 8	ABB-8-B	SVEA-64
10 x 10	ABB-10-A	SVEA-92 SVEA-96Opt SVEA-100
10 x 10	ABB-10-B	SVEA-92 SVEA-96 SVEA-100
10 x 10	ABB-10-C	SVEA-96Opt2

Notes:
1. Any fuel channel average thickness up to 0.120 inch is acceptable on any of the fuel designs.
2. Example BWR fuel designs are listed herein and are not all-inclusive.

Table 1.6.2-3
Maximum Lattice Average Initial Enrichment for EOS-89BTH DSC

Basket Type	Maximum Lattice Average Enrichment[1] (wt. % U-235)	Minimum B-10 Areal Density (mg/cm^2)	
		MMC	BORAL®
A1 / A2 / A3	4.10	32.7	39.2
B1 / B2 / B3	4.45	41.3	49.6
C1 / C2 / C3	4.80	Not Allowed	60.0

Note:
1. For ABB-10-C Fuel Designs, the enrichment shall be reduced by 0.25 wt. % U-235 for Types A1 / A2 / A3 and Types B1 / B2 / B3 and reduced by 0.20 wt. % U-235 for Types C1 / C2 / C3.

Table 1.6.2-4
BWR Assembly Decay Heat for Heat Load Configurations

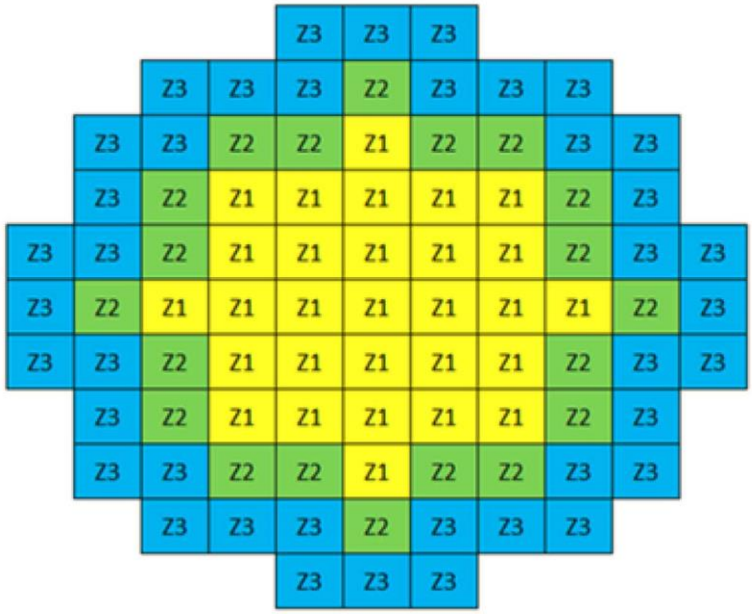
The Decay Heat (DH) in watts is expressed as:

$$F1 = -59.1 + 23.4*X1 - 21.1*X2 + 0.280*X1^2 - 3.52*X1*X2 + 12.4*X2^2$$
$$DH = F1*Exp(\{[1-(1.2/X3)]* (-0.720)\}*[(X3-4.5)^{0.157}]*[(X2/X1)^{-0.132}]) + 10$$

where,

F1	Intermediate Function
X1	Assembly Burnup in GWD/MTU
X2	Initial Enrichment in wt. % U-235
X3	Cooling Time in Years (minimum 5 years)

Note:
A uranium loading of 198 kg is employed in the calculation of the decay heat equation. Alternatively, the decay heat can be calculated without employing the decay heat equation, using an approved methodology with actual spent fuel parameters instead of bounding spent fuel parameters.



Zone Number	1	2	3
Maximum Decay Heat (kW/FA plus channel, if included)(1)	0.35	0.35	0.35
Maximum Number of Fuel Assemblies	29	20	40
Maximum Decay Heat per DSC (kW)	31.15		

Note:
(1) Decay heat per fuel assembly shall be determined using Table 1.6.2-4.

Figure 1.6.2-1
HLZC1 for EOS-89BTH DSC in TN Eagle LC

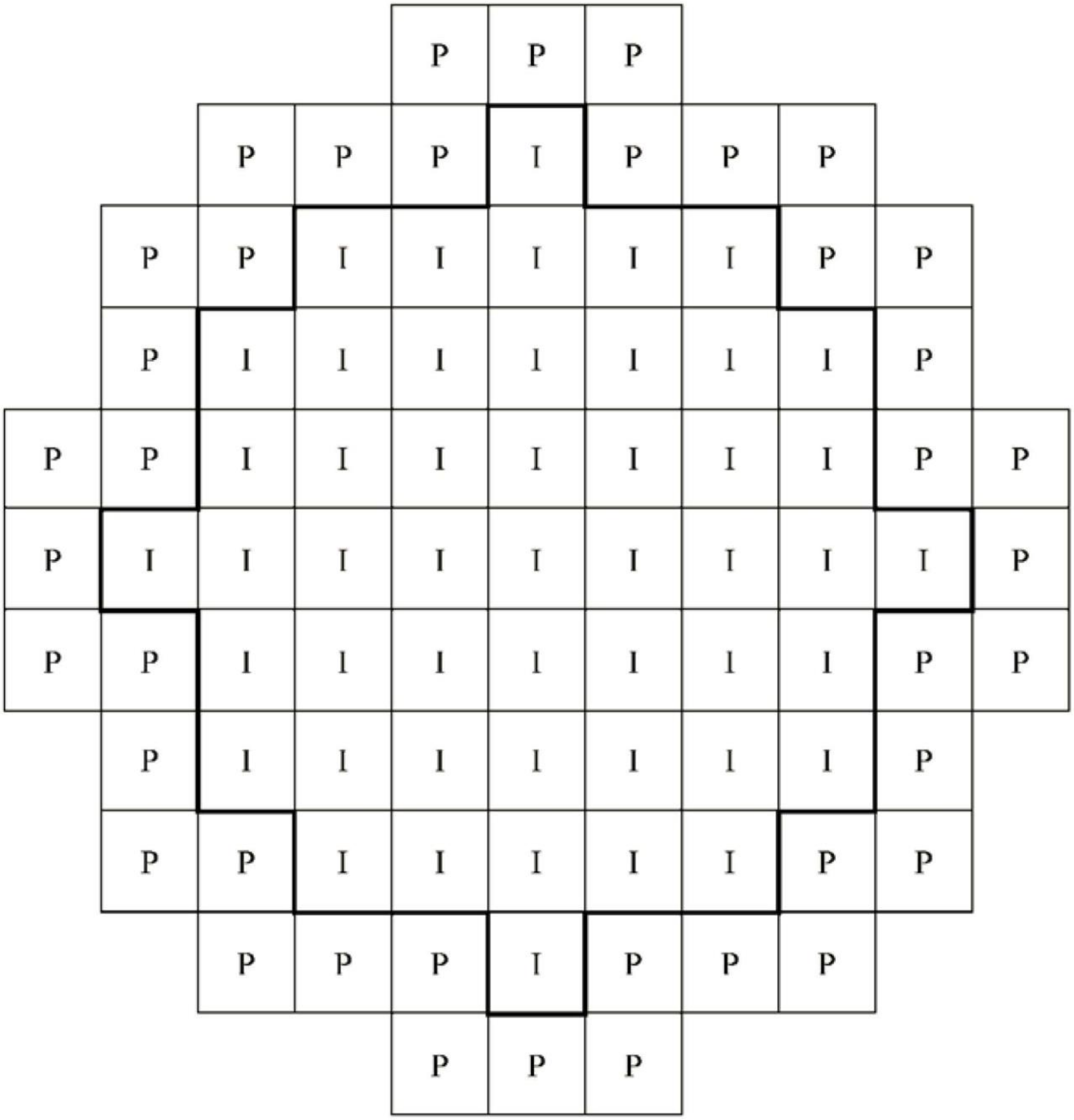


Figure 1.6.2-2
Peripheral and Inner Fuel Location for EOS-89BTH DSC in TN Eagle LC

Appendix 1.6.3.
24PT4 DSC

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1.6.3 24PT4 DSC

1.6.3.1 24PT4 DSC Description

The NUHOMS®-24PT4 DSC consists of a DSC shell assembly and a basket assembly. The shell assembly consists of a cylindrical shell, inner cover plates for the top and bottom shield plug assemblies, and top and bottom outer top cover plates. The DSC shell assembly is designed, fabricated, and inspected in accordance with ASME B&PV Code Subsection NB [1]. The maximum length and the outer diameter of the 24PT4 DSC are approximately 196.3 inches and 67.2 inches, respectively. The shell assembly is a high integrity stainless steel welded pressure vessel that provides containment of radioactive materials, encapsulates the fuel in an inert atmosphere (the canister is back-filled with helium before being seal welded closed), and provides biological shielding (in the axial direction). The 24PT4 DSC has double redundant seal welds that join the shell and the top and bottom cover plate assemblies to seal the canister. The bottom end assembly welds are made during fabrication of the 24PT4 DSC. The top end closure welds are made after fuel loading. Both top plug penetrations (siphon and vent ports) are redundantly sealed after the 24PT4 DSC drying operations are complete.

The canister is designed to contain the fuel basket and fuel assemblies and is completely supported by the transport cask.

1.6.3.2 24PT4 Fuel Basket

The basket structure is designed, fabricated, and inspected in accordance with ASME B&PV Code Subsection NG [1]. The 24PT4 basket is designed to accommodate 24 intact, damaged, and/or failed PWR fuel assemblies. The 24PT4 can hold up to 12 damaged or failed fuel assemblies in specially designed Failed Fuel Canisters with the balance being loaded with intact fuel. The basket structure consists of circular spacer discs which provide radial support to the guide sleeves and fuel assemblies. Poison plates are placed around the guide sleeves for criticality control.

The guide sleeves are open at each end. Therefore, longitudinal fuel assembly/failed fuel loads are applied directly to the canister/cask body and not the basket structure. The fuel assemblies are laterally supported by the guide tubes/failed fuel canister in the circular spacer discs and the canister shell. The guide sleeves are laterally supported by the circular spacer discs and the canister shell. The spacer discs establish and maintain basket orientation. Axial support for the basket assembly is provided by four support rods. Shear keys welded to the inner wall of the 24PT4 DSC mate with notches in top and bottom spacer discs to prevent the basket from rotating during normal operations.

The poison plates are constructed of Boral®, and provide the necessary criticality control.

1.6.3.3 24PT4 DSC Contents

The spent fuel to be transported in the NUHOMS® 24PT4 DSC consists of intact (including reconstituted) Westinghouse-CENP 16x16 (CE 16x16) and/or damaged or failed CE 16x16 fuel assemblies with Zircaloy or ZIRLO™ cladding and UO_2 or $(U,Er)O_2$ or $(U,Gd)O_2$ fuel pellets. Assemblies are with or without integral fuel burnable absorber (IFBA) rods or integral burnable poison rods.

Each 24PT4 DSC can accommodate a maximum of 12 damaged or failed fuel assemblies with the remaining assemblies intact.

Reconstituted assemblies containing up to five replacement irradiated stainless steel rods in place of damaged fuel rods (these rods must displace an amount of water equal to or greater than that displaced by the original fuel rods in the active fuel region of the fuel assembly) or replacement Zircaloy clad uranium rods (any number per assembly) are acceptable for storage in the 24PT4 DSC as either intact or damaged or failed assemblies.

Damaged or failed fuel may include assemblies with known or suspected cladding defects greater than pinhole leaks or hairline cracks or an assembly with partial and/or missing rods (i.e., extra water holes). Damaged or failed fuel assemblies shall be encapsulated in individual failed fuel canisters in locations as shown in Figure 1.6.3-1.

Fuel debris and damaged fuel rods that have been removed from a failed fuel assembly and placed in a rod storage basket are also considered as failed fuel, and therefore shall be encapsulated in individual failed fuel cans as described above. The rod storage baskets consist of an array (typically 9x9 or 10x10) of hollow cylindrical steel tubes axially supported by perforated plates that have approximately the same width of a fuel assembly and span the length of fuel rods. A maximum of 100 PWR fuel rods can be stored in each rod storage basket. The tubes of the rod storage basket shall have a provision to allow for the drainage of water by using either a screen mesh opening or a drainage hole on the bottom of the tubes, or by some other equivalent effective mean. Rod storage baskets may also include IFBA and integral burnable poison rods. Loose fuel debris not contained in a rod storage basket may also be placed in a failed fuel canister provided the size of the debris is larger than the failed fuel canister screen mesh opening. Fuel debris may be associated with any type of UO_2 fuel provided that the maximum uranium content and initial enrichment limits are met.

The specifications and design characteristics of intact, damaged or failed CE 16x16 fuel assemblies acceptable for storage in the 24PT4 DSC are shown in Table 1.6.3-1, Table 1.6.3-2, and Table 1.6.3-3. The fuel to be transported in the 24PT4 DSC is limited to a maximum initial enrichment of 4.85 wt. % U-235. The maximum allowable assembly average burnup is given as a function of initial fuel enrichment but does not exceed 60,000 MWd/MTU. The minimum cooling time is 15 years.

A 24PT4 DSC containing less than 24 fuel assemblies may contain dummy fuel assemblies in fuel assembly slots or empty slots. The dummy fuel assemblies are unirradiated, stainless steel encased structures that approximate the weight and center of gravity of a fuel assembly.

The 24PT4 DSC may transport PWR assemblies in any one of the three alternate configurations shown in Figure 1.6.3-2 through Figure 1.6.3-4 with a maximum heat load of 1.26 kW per assembly and a maximum heat load of 24 kW per DSC.

The cooling times in the fuel qualification table (Table 8.7.3-1) are determined to meet dose rate limits. The minimum cooling time for an assembly is the longer of that given by Table 8.7.3-1 and the cooling time required to meet the decay heat restrictions provided in Figure 1.6.3-2 throughFigure 1.6.3-4 for the heat load zone configuration selected.

As shown in Table1.6.4-4, two different 24PT4 DSC basket configurations are utilized. These configurations differ in the boron loading in the Boral® plates. The minimum areal Boron-10 (B-10) concentrations for the standard (Type A basket) and high (Type B basket) loadings are 0.025 and 0.068 g/cm^2, respectively. Fuel to be transported in the Type A basket is limited to a maximum planar average initial enrichment of 4.1 wt. % U-235. Fuel to be transported in the Type B basket is limited to a planar average initial enrichment of 4.85 wt. % U-235.

Also shown in Table 1.6.3-4 are maximum fuel enrichments versus neutron poison requirements for 24PT4 DSC utilized to transport damaged fuel. These are as follows:

- Up to four damaged or failed fuel assemblies may be transported in a 24PT4 DSC of either B-10 loading without impact upon the maximum allowed U-235 enrichment and without the use of any poison rodlets. For this configuration, the damaged or failed assemblies are transported in Failed Fuel Canisters located at the 45°, 135°, 225°, and 315° azimuth locations (Zone A of Figure 1.6.3-1).
- Five to 12 damaged or failed fuel assemblies may be transported in a 24PT4 DSC of either B-10 loading without the use of poison rodlets if the maximum allowed U-235 enrichment is reduced for the damaged or failed assemblies. The intact assembly enrichment limits remain at their nominal values of 4.1 and 4.85 wt. % for the standard and high B-10 loadings, respectively. Damaged or failed fuel to be transported in the standard B-10 loading 24PT4 DSC is limited to an initial enrichment of 3.7 wt. % U-235, and damaged or failed fuel to be transported in the high B-10 loading 24PT4 DSC is limited to an initial enrichment of 4.1 wt. % U-235. For this configuration, the damaged or failed assemblies are transported in Failed Fuel Canisters located in Zones A and B of Figure 1.6.3-1.
- Five to 12 damaged or failed fuel assemblies may be transported in a 24PT4 DSC of either B-10 loading without impact upon the maximum allowed U-235 enrichment if poison rodlets are utilized. For the Type A basket, a single poison rodlet is inserted into the center guide tube of each intact fuel assembly located in Zone C of Figure 1.6.3-1. For the Type B basket, a poison rodlet is inserted into each of the five guide tubes in each intact fuel assembly located in Zone C of Figure 1.6.3-1. For this configuration, the damaged or failed assemblies are transported in Failed Fuel Canisters located in Zones A and B of Figure 1.6.3-1.

The poison rodlets consist of B_4C (pellets or powder) encased in a 0.75” nominal OD stainless steel tube with a wall thickness of 0.035”. The minimum linear B_4C content is 0.70 g/cm with sufficient length to cover the active fuel length.

Fuel assembly poison rods installed within the guide tubes for criticality control in the spent fuel pool racks may be transported with any intact fuel assembly or damaged or failed fuel assemblies as long as the total assembly weight is less than that specified in Table 1.6.3-1.

Each poison rodlet may include a lifting mechanism to allow insertion into the selected fuel assembly guide tube.

1.6.3.4 References

1. American Society of Mechanical Engineers, ASME Boiler and Pressure Vessel Code, Section III, Division 1 – Subsections NB, NG, and NF, 1992 with Addenda through 1994 with Code Cases N-499-1.

Table 1.6.3-1
PWR Fuel Specification of Intact Fuel to be Transported in the 24PT4 DSC

Fuel Design:	Intact CE 16x16 PWR fuel assembly or equivalent reload fuel that is enveloped by the fuel assembly design characteristics as listed in Table 1.6.3-1 and the following requirements:
Fuel Damaged or Failed:	Fuel with known or suspected cladding damage in excess of pinhole leaks or hairline cracks or an assembly with partial and/or missing rods is not authorized to be transported as “intact PWR Fuel.”
Physical Parameters(1)	
Unirradiated Length (in)	176.8
Maximum Active-Fuel Length (in)	150
Cross Section (in)	8.290
Assembly Weight (lbs)	1500(2) (3)
Maximum Uranium Content (kg)	455.5
No. of Assemblies per DSC	≤ 24 intact assemblies
Fuel Cladding	Zircaloy-4 or ZIRLO™
Reconstituted Fuel Assemblies(5)	Damaged fuel rods replaced by either stainless rods (up to 5 rods per assembly) or Zircaloy clad uranium rods (any number of rods per assembly).
Nuclear and Radiological Parameters	
Maximum Planar Average Initial Enrichment (wt. % U-235)	Per Table 1.6.3-4 and Figure 1.6.3-1
Fuel Assembly Average Burnup and Minimum Cooling Time(4)	Per Table 8.7.3-1 and decay heat restrictions below
Decay Heat(4)	Per Figure 1.6.3-2, Figure 1.6.3-3, or Figure 1.6.3-4

Notes:
(1) Nominal values shown unless stated otherwise.
(2) Does not include weight of Poison Rodlets (25 lbs each) installed in accordance with Table 1.6.3-4.
(3) Includes the weight of fuel assembly Poison Rods installed for 10 CFR 50 criticality control in spent fuel pool racks.
(4) Minimum cooling time is the longer of that given in Table 8.7.3-1 for a given burnup and enrichment of a fuel assembly and that required to meet the decay heat restrictions provided per Figure 1.6.3-2, Figure 1.6.3-3, or Figure 1.6.3-4.
(5) Reconstituted rods shall displace an amount of water equal to or greater than that displaced by the original fuel rods in the active fuel region of the fuel assembly.

Table 1.6.3-2
PWR Fuel Specifications of Damaged or Failed Fuel to be Transported in the 24PT4 DSC

PHYSICAL PARAMETERS: Fuel Design	Damaged or failed CE 16x16 PWR fuel assembly or equivalent reload fuel that is enveloped by the fuel assembly design characteristics as listed in Table 1.6.3-3 and the following requirements:
Fuel Damaged or Failed	Damaged or failed fuel may include assemblies with known or suspected cladding defects greater than pinhole leaks or hairline cracks or an assembly with partial and/or missing rods (i.e., extra water holes). Damaged or failed fuel assemblies shall be encapsulated in individual failed fuel canisters and placed in Zones A and/or B as shown in Figure 1.6.3-1. Fuel debris and damaged fuel rods that have been removed from a damaged fuel assembly and placed in a rod storage basket(6) are also considered as failed fuel, and therefore shall be encapsulated in individual failed fuel canisters. Loose fuel debris not contained in a rod storage basket may also be placed in a failed fuel canister for storage, provided the size of the debris is larger than the failed fuel canister screen mesh opening. Fuel debris may be associated with any type of UO_2 fuel provided that the maximum uranium content and initial enrichment limits are met.
Reconstituted Fuel Assemblies(5)	Damaged fuel rods replaced by either stainless rods (up to 5 rods per assembly) or Zircaloy clad uranium rods (any number of rods per assembly).
Physical Parameters(1)	
Unirradiated Length (in)	176.8
Maximum Active-Fuel Length (in)	150
Cross Section (in)	8.290
Assembly Weight (lb)	1500(2)(3)
Maximum Uranium Content (kg)	455.5
No. of Assemblies per DSC	≤ 12 damaged or failed assemblies, balance intact.
Fuel Cladding	Zircaloy-4 or ZIRLO™
Nuclear and Radiological Parameters	
Maximum Planar Average Initial Enrichment (wt. % U-235)	Per Table 1.6.3-4 and Figure 1.6.3-1
Fuel Assembly Average Burnup and Minimum Cooling Time(4)	Per Table 8.7.3.-1 and decay heat restrictions below:
Decay Heat(4)	Per Figure 1.6.3-2, Figure 1.6.3-3, or Figure 1.6.3-4

Notes:
(1) Nominal values shown unless stated otherwise.
(2) Does not include weight of poison rodlets (25 lb each) installed in accordance with Table 1.6.4-4.
(3) Includes the weight of fuel assembly poison rods installed for 10 CFR Part 50 criticality control in spent fuel pool racks.
(4) Minimum cooling time is the longer of that given in Table 8.7.3-1 for a given burnup and enrichment of a fuel assembly and that required to meet the decay heat restrictions provided in Figure 1.6.3-2, Figure 1.6.3-3, or Figure 1.6.3-4.

(5) Reconstituted rods shall displace an amount of water equal to or greater than that displaced by the original fuel rods in the active fuel region of the fuel assembly.
(6) A maximum of 100 PWR fuel rods can be stored in each rod storage basket.

Table 1.6.3-3
PWR Fuel Assembly Design Characteristics for the NUHOMS®-24PT4 DSC

PWR FUEL Class	CE 16x16
Fissile Material	UO_2 or $(U, Er)O_2$, or $(U, Gd)O_2$
Maximum Number of Fuel Rods	≤ 236
Maximum Number of Guide/ Instrument Tubes	≤ 5

Table 1.6.3-4
Maximum Fuel Enrichment vs Neutron Poison Requirements for the 24PT4 DSC

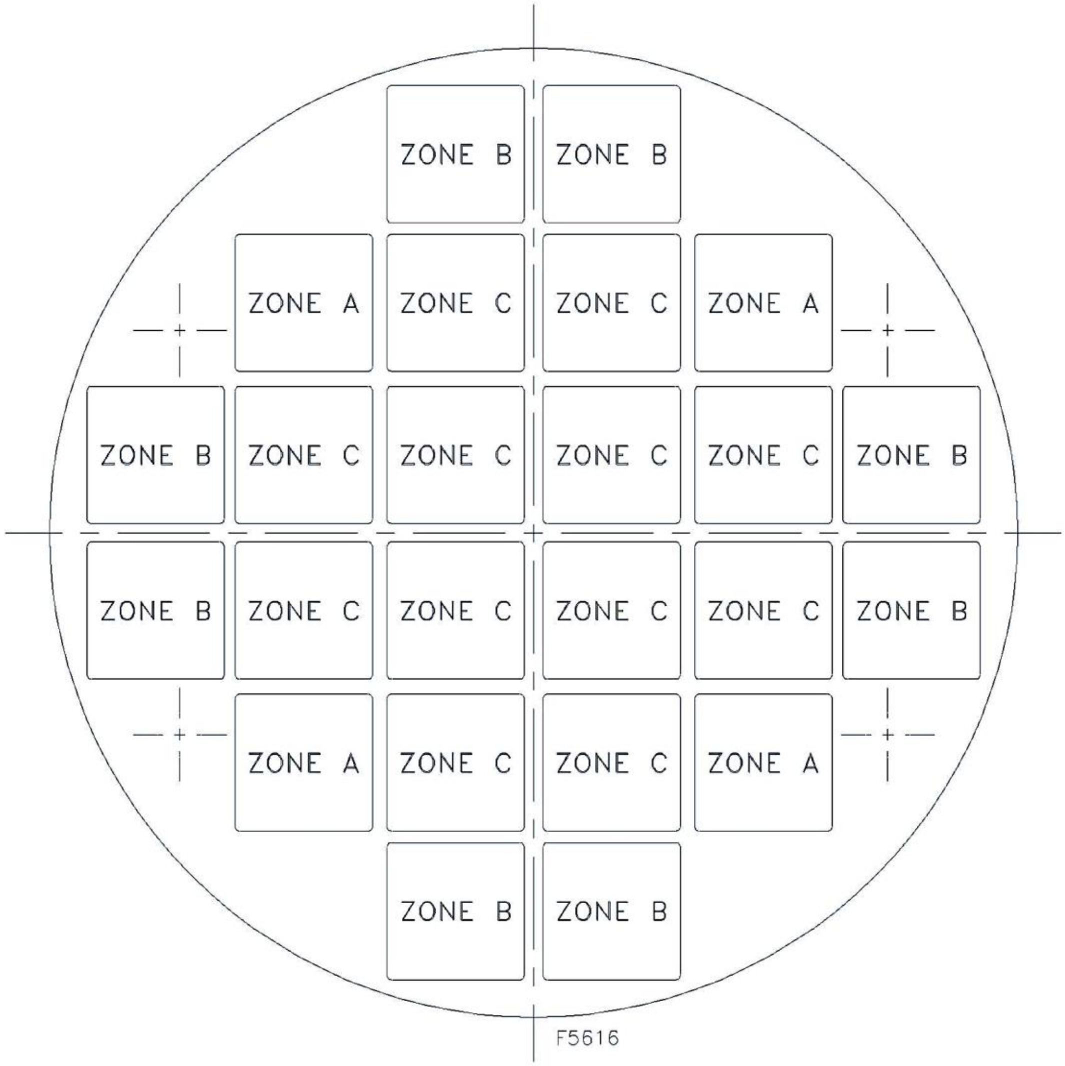
Storage Configuration	Maximum No. of Damaged/Failed Fuel Assemblies[(1)]	Maximum Planar Average Initial Fuel Enrichment (wt. % U-235)	DSC Basket, Minimum BORAL® Areal Density (gm/cm^2)	Minimum No. of Poison Rodlets Required[(2) (3)]
All Intact Fuel Assemblies	0	4.1	.025 (Type A Basket)	0
	0	4.85	.068 (Type B Basket)	0
Combination of Damaged or Failed and Intact Fuel Assemblies	4	4.1	.025 (Type A Basket)	0
	4	4.85	.068 (Type B Basket)	0
	12	3.7 (damaged or failed) 4.1 (intact)	.025 (Type A Basket)	0
	12	4.1 (damaged or failed) 4.85 (intact)	.068 (Type B Basket)	0
	12	4.1	.025 (Type A Basket)	1[(2)] (Located in center guide tube of each intact assembly)
	12	4.85	.068 (Type B Basket)	5[(2)] (Located in all five guide tubes of each intact assembly)

Notes:
(1) See Figure 1.6.3-1 for location of damaged or failed fuel assemblies within the 24PT4 DSC (Zones A and/or B only).
(2) Poison rodlets are only required for a specific DSC configuration with a payload of 5-12 damaged or failed assemblies in combination with maximum fuel enrichment levels as shown. The poison rodlets are to be located within the guide tubes of the Zone C intact assemblies as shown in Figure 1.6.3-1.
(3) The minimum diameter of the poison rodlet is 0.55 inches (1.4 cm) with sufficient length to cover the active fuel length. The minimum diameter of the absorber material in the rodlet is 0.35 inches (0.9 cm) with a minimum linear loading of 0.70 grams B_4C per cm.

Table 1.6.3-5
PWR Assembly Decay Heat for Heat Load Configurations

The Decay Heat (DH) in watts is expressed as: $F1 = -44.8 + 41.6*X1 - 37.1*X2 + 0.611*X1^2 - 6.80*X1*X2 + 24.0*X2^2$ $DH = F1*Exp(\{[1-(1.8/X3)]* -0.575\}*[(X3-4.5)^{0.169}]*[(X2/X1)^{-0.147}]) + 20$ where, F1 Intermediate Function X1 Assembly Burnup in GWd/MTU X2 Initial Enrichment in wt. % U-235 X3 Cooling Time in Years (minimum 15 years)

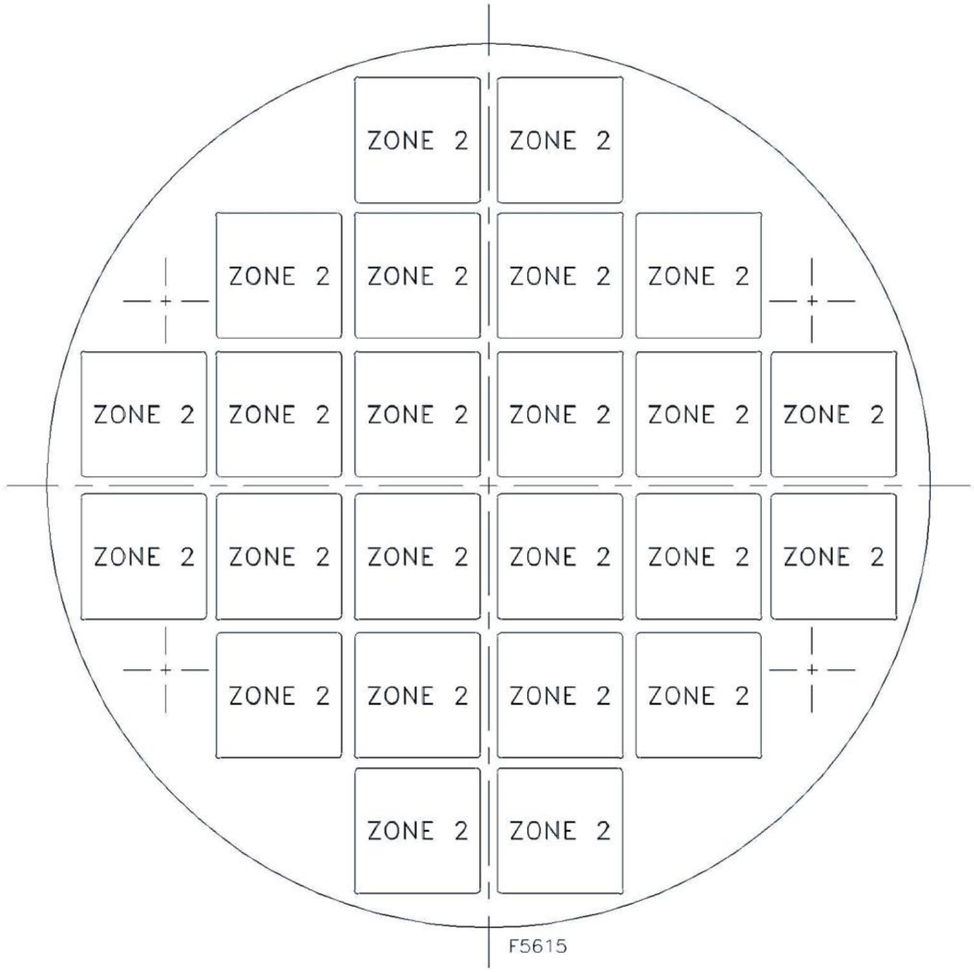
A uranium loading of 490 kg is employed in the calculation of the decay heat equation. Alternatively, decay heat can be calculated without employing the decay heat equation, using an approved methodology with actual spent fuel parameters instead of bounding spent fuel parameters.



Notes:

1. Locations identified as Zone A are for placement of up to 4 damaged or failed fuel assemblies.
2. Locations identified as Zone B are for placement of up to 8 additional damaged or failed fuel assemblies (maximum of 12 damaged or failed fuel assemblies allowed, Zones A and B combined).
3. Locations identified as Zone C are for placement of up to 12 intact fuel assemblies, including 4 empty slots in the center as shown in Figure 1.6.3-4.
4. Poison Rodlets are to be located in the guide tubes of intact fuel assemblies placed in Zone C only per Table 1.6.3-4.

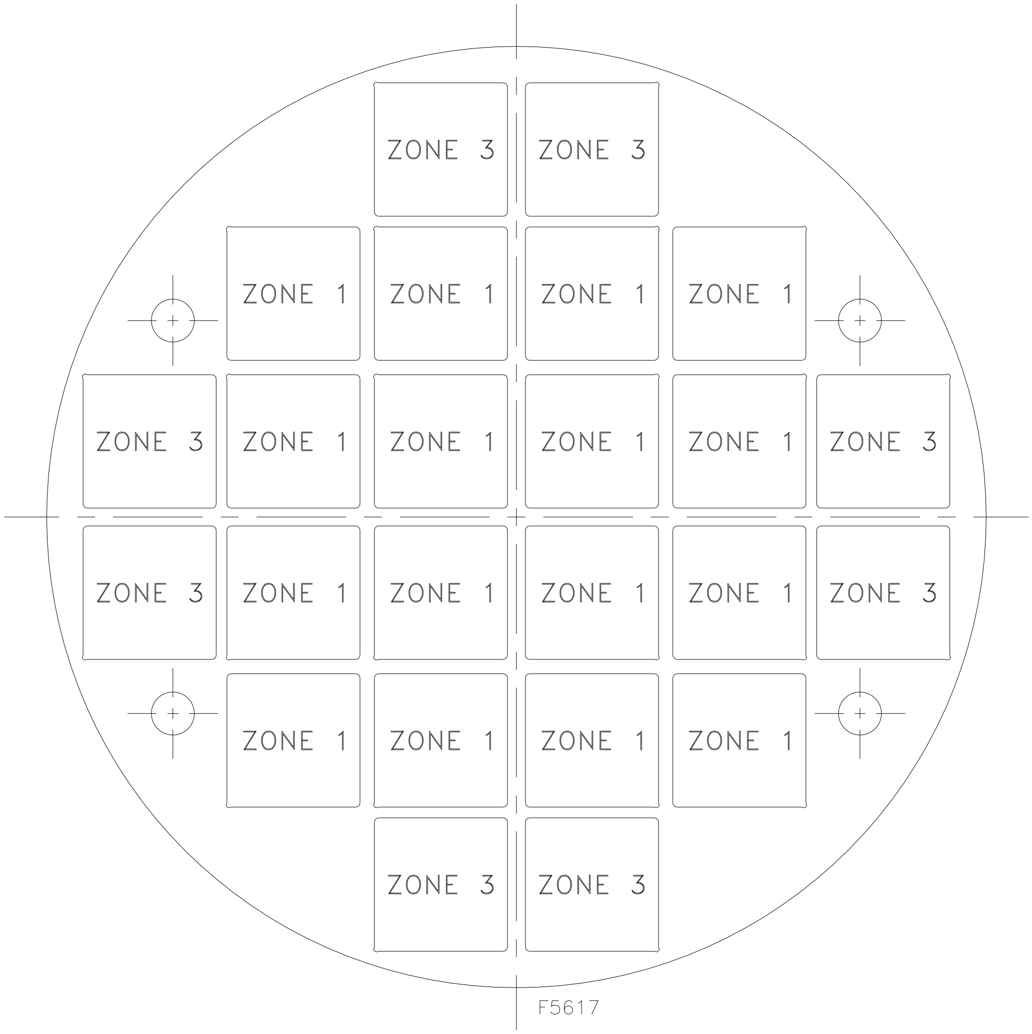
Figure 1.6.3-1
Location of Failed Fuel Canisters Inside the 24PT4 DSC



	Zone 1	Zone 2	Zone 3	Zone 4
Maximum Decay Heat (kWatts / FA) (1)	NA	1.0	NA	NA
Maximum Decay Heat per Zone (kW)	NA	24.0	NA	NA
Maximum Decay Heat per DSC (kW)	24.0			

(1) Decay heat per fuel assembly shall be determined using Table 1.6.3-5.

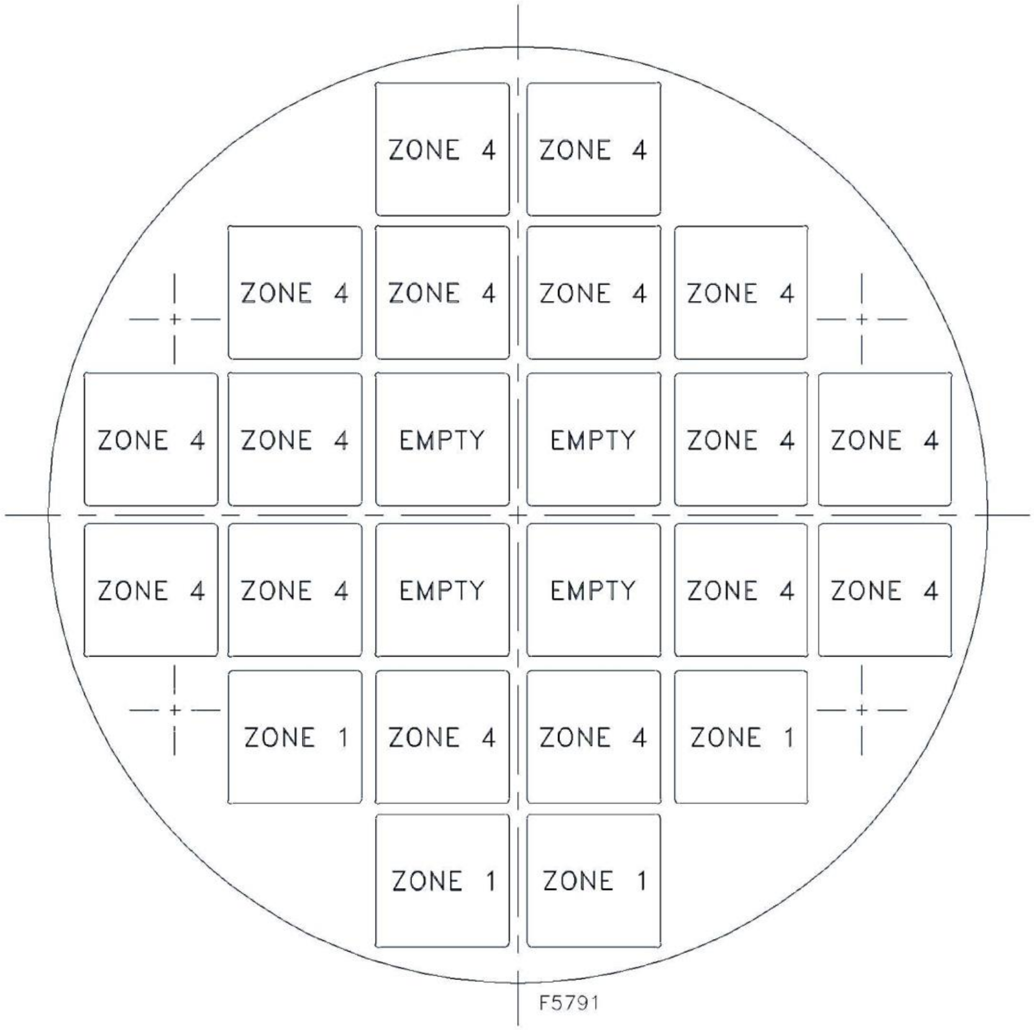
Figure 1.6.3-2
Heat Load Configuration No. 1 for the 24PT4 DSC



	Zone 1	Zone 2	Zone 3	Zone 4
Maximum Decay Heat (kWatts / FA) (1)	0.9	NA	1.2	NA
Maximum Decay Heat per Zone (kW)	14.4	NA	9.6	NA
Maximum Decay Heat per DSC (kW)	24.0			

(1) Decay heat per fuel assembly shall be determined using Table 1.6.3-5.

Figure 1.6.3-3
Heat Load Configuration No. 2 for the 24PT4 DSC



	Zone 1	Zone 2	Zone 3	Zone 4
Maximum Decay Heat (kWatts / FA) [(1)]	0.9	NA	NA	1.26
Maximum Decay Heat per Zone (kW)	3.6	NA	NA	20.16
Maximum Decay Heat per DSC (kW)	24.0			

(1) Decay Heat per fuel assembly shall be determined using Table 1.6.3-5.

Figure 1.6.3-4
Heat Load Configuration No. 3 for the 24PT4 DSC

Appendix 1.6.4
32PT DSC

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1.6.4 32PT DSC

1.6.4.1 32PT DSC Description

Each 32PT DSC consists of a DSC shell assembly and a basket assembly. The shell assembly consists of a cylindrical shell, the inner cover plates of the top and bottom shield plug assemblies, and outer top cover plate. The DSC shell assembly is designed, fabricated, and inspected in accordance with ASME B&PV Code Subsection NB [2]. As shown in Table 1.6.4-1, the 32PT DSC system consists of four design configurations or Types as follows:

- 32PT-S100, Short Canister
- 32PT-L100, Long Canister
- 32PT-S125, Short Canister
- 32PT-L125, Long Canister

Table 1.6.4-1 provides the overall lengths and outer diameters for each 32PT DSC configuration. The shell assemblies are high integrity stainless steel welded pressure vessels that provide confinement of radioactive materials, encapsulate the fuel in an inert atmosphere (the canister is back-filled with helium before being seal welded closed), and provide biological shielding (in axial direction). The 32PT DSCs have double redundant seal welds that join the shell and the top and bottom cover plate assemblies to seal the canister. The bottom end assembly welds are made during fabrication of the 32PT DSCs. The top end closure welds are made after fuel loading. Both top plug penetrations (siphon and vent ports) are redundantly sealed after the 32PT DSC drying operations are complete.

The failed fuel assemblies are to be placed in individual failed fuel canisters (FFCs). Each FFC is constructed of sheet metal and is provided with a welded bottom closure and a removable top closure, which allows lifting of the FFC with the enclosed damaged assembly/debris. The FFC is provided with screens at the bottom and top to contain fuel debris and allow filling/drainage of water from the FFC during loading operations. The FFC is protected by the fuel compartment tubes and its only function is to confine the failed fuel.

The canister is designed to contain its fuel basket and fuel assemblies and is completely supported by the transport cask.

1.6.4.2 32PT Fuel Basket

The basket structures are designed, fabricated, and inspected in accordance with ASME B&PV Code Subsection NG [1]. The overall lengths and diameters of the baskets for each canister configuration are provided in Table 1.6.4-1. The 32PT baskets are designed to accommodate 32 intact and/or damaged and/or failed PWR fuel assemblies with or without Control Components (CCs). The basket structure consists of a grid assembly of welded stainless steel plates or tubes that accommodate aluminum and/or poison plates and is surrounded by support rails.

The basket structure is open at each end. Therefore, longitudinal fuel assembly loads are applied directly to the canister/cask body and not the fuel basket structure. The fuel assemblies are laterally supported by the stainless steel grid/tube assembly. The basket is laterally supported by the basket rails and the canister shell. The aluminum basket rails are oriented parallel to the axis of the canister, and are attached to the periphery of the basket to provide support and to establish and maintain basket orientation.

A shear key, welded to the inner wall of the DSC, mates with a notch in one of the basket support rails to prevent the basket from rotating during normal operations.

Each fuel compartment accommodates aluminum and/or neutron absorbing poison plates. Two different arrangements are possible, based on the number and orientation of the poison plates within the DSC. These are described as the 16 or 24 poison plate (PP) configurations. The poison plates are constructed from borated aluminum, or an aluminum/B_4C metal matrix composite, and provide a heat conduction path from the fuel assemblies to the canister wall, as well as criticality control.

1.6.4.3 32PT DSC Contents

Each of the NUHOMS®-32PT DSC configurations is designed to transport 32 intact PWR fuel assemblies, with or without CCs, damaged and failed fuels are allowed for the CE 14x14 fuel class in the 24 poison plate configuration, with the characteristics described in Table 1.6.4-2. CE 14x14 fuels can also be transported in the 32PT DSC. The CCs include Burnable Poison Rod Assemblies (BPRAs), Thimble Plug Assemblies (TPAs), Control Rod Assemblies (CRAs), Rod Cluster Control Assemblies (RCCAs), Axial Power Shaping Rod Assemblies (APSRAs), Orifice Rod Assemblies (ORAs), Vibration Suppression Inserts (VSIs), Neutron Source Assemblies (NSAs), and Neutron Sources. Nonfuel hardware that are positioned within the fuel assembly after the fuel assembly is discharged from the core, such as Guide Tube or Instrument Tube Tie Rods or Anchors, Guide Tube Inserts, BPRA Spacer Plates, or devices that are positioned and operated within the fuel assembly during reactor operation such as those listed above, are also considered as CCs.

The NUHOMS®-32PT DSC may transport PWR fuel assemblies arranged in any of four alternate heat zone configurations with a maximum decay heat of 2.2 kW per assembly and a maximum heat load of 24 kW per canister. The heat load zone configurations are shown in Figure 1.6.4-1 through Figure 1.6.4-4. The NUHOMS®-32PT DSC is inerted and backfilled with helium at the time of loading.

The maximum fuel assembly weight with a CC is 1682 lb.

All four NUHOMS®-32PT DSC design configurations have the same minimum boron content for the poison neutron plates. The minimum B-10 content for the poison plates is 0.0070 g/cm^2. A basket may contain 0, 4, 8, or 16 Poison Rod Assemblies (PRAs) and is designated a Type A, Type B, Type C, or Type D basket, respectively. The required B-10 content per rod of PRA and minimum number of PRAs for a given fuel assembly type are described in Table 1.6.4-5.

Reconstituted fuel assemblies with up to five solid stainless steel rods or an unlimited number of lower enrichment UO_2 rods that replace fuel rods are acceptable for the 32PT DSC payload. The replacement lower enrichment UO_2 rods shall have an initial wt. % U-235 less than or equal to that specified for fresh fuel in Table 1.6.4-6. CE 15x15 fuel assemblies with plugging clusters are also acceptable.

1.6.4.4 References

1. American Society of Mechanical Engineers, ASME Boiler and Pressure Vessel Code, Section III, Division 1 – Subsections NB, NG, and NF, 1998 edition including 2000 Addenda, supplemented by Code Case N-595-2.

Table 1.6.4-1
Nominal Dimensions and Weight of the NUHOMS®-32PT DSC

	32PT DSC Design Configuration			
	32PT-S100	**32PT-S125**	**32PT-L100**	**32PT-L125**
Canister Length (in.)	186.55 maximum	186.55 maximum	192.55 maximum	192.55 maximum
Outside Diameter (in.)	67.25	67.25	67.25	67.25
Cavity Length (in.)	169.6	167.1	175.6	173.1
Cavity Diameter (in.)	66.19	66.19	66.19	66.19
Basket Length (in.)	168.6	166.1	174.6	172.1
Basket Diameter (in.)	65.94	65.94	65.94	65.94

Table 1.6.4-2
PWR Fuel Assembly Characteristics for Fuel in the 32PT DSC

PHYSICAL PARAMETERS: Fuel Class	 Intact (including reconstituted) B&W 15x15, WE 17x17, CE 15x15, WE 15x15, CE 14x14, and WE 14x14 class PWR assemblies or equivalent reload fuel manufactured by same or other vendors that are enveloped by the fuel assembly design characteristics listed in Table 1.6.4-3. Damaged and/or failed fuel assemblies beyond the definitions contained below are not authorized for transport.
Damaged Fuel	Damaged CE 14x14 PWR fuel assemblies are assemblies containing missing or partial fuel rods, fuel rods with known or suspected cladding defects greater than hairline cracks or pinhole leaks. The extent of damage in the fuel assembly, including non-cladding damage, is to be limited in such a way that a fuel assembly is able to be handled by normal means. Missing fuel rods are allowed. The extent of damage in the fuel rods is to be limited such that a fuel pellet is not able to pass through the damaged cladding during handling and retrievability is ensured following normal and off-normal conditions. Damaged fuel assemblies shall also contain top and bottom end fittings or nozzles or tie plates depending on the fuel type.
Failed Fuel	Failed CE 14x14 fuel is defined as ruptured fuel rods, severed fuel rods, loose fuel pellets, or fuel assemblies that cannot be handled by normal means. Fuel assemblies may contain breached rods, grossly breached rods, and other defects such as missing or partial rods, missing grid spacers, or damaged spacers to the extent that the assembly cannot be handled by normal means. Fuel debris and fuel rods that have been removed from a fuel assembly and placed in a rod storage basket are also considered as failed fuel. Loose fuel debris not contained in a rod storage basket must be placed in a failed fuel canister for storage, provided the size of the debris is larger than the failed fuel canister screen mesh opening and it is located at a position of at least 4” above the top of the bottom shield plug of the DSC. Fuel debris may be associated with any type of UO_2 fuel provided that the maximum uranium content and initial enrichment limits are met. The total weight of each failed fuel canister plus all its contents shall be less than 1682 lb.
Reconstituted Fuel Assemblies[(2)]	≤ 32 assemblies per DSC with up to five stainless steel rods per assembly or unlimited number of lower enrichment UO_2 rods per assembly. Reconstituted assemblies containing an unlimited number of replacement lower enrichment UO_2 rods which have an initial wt. % U-235 less than or equal to that specified for fresh fuel in Table 1.6.4-6 are qualified.

Control Components (CCs)	• Up to 32 CCs are authorized for storage in 32PT DSCs. • Authorized CCs include Burnable Poison Rod Assemblies (BPRAs), Thimble Plug Assemblies, (TPAs), Control Rod Assemblies (CRAs), Rod Cluster Control Assemblies (RCCAs), Axial Power Shaping Rod Assemblies (APSRAs), Orifice Rod Assemblies (ORAs), Vibration Suppression Inserts (VSIs), Neutron Source Assemblies (NSAs), and Neutron Sources. Nonfuel hardware that are positioned within the fuel assembly after the fuel assembly is discharged from the core, such as Guide Tube or Instrument Tube Tie Rods or Anchors, Guide Tube Inserts, BPRA Spacer Plates, or devices that are positioned and operated within the fuel assembly during reactor operation such as those listed above, are also considered as CCs. • Design basis thermal and radiological characteristics for the CCs are listed in Table 1.6.4-4.
Maximum Assembly plus CC Weight	-1365 lb for 32PT-S100 and 32PT-L100 DSC System -1682 lb for 32PT-S125 and 32PT-L125 DSC System
Number of Intact Assemblies	≤ 32
Number and Location of Damaged Assemblies	Maximum of 28 damaged fuel assemblies as shown in Figure 1.6.4-5. Balance may be intact assemblies, empty slots, or dummy assemblies as specified in Figure 1.6.4-1, Figure 1.6.4-2, Figure 1.6.4-3, or Figure 1.6.4-4. The DSC basket cells that store damaged fuel assemblies are provided with top and bottom end caps to ensure retrievability.
Number and Location of Failed Assemblies	Maximum of eight failed fuel assemblies as shown in Figure 1.6.4-5. Balance may be intact and/or damaged fuel assemblies, empty slots, or dummy assemblies as specified in Figure 1.6.4-2. Failed fuel assembly/fuel debris is loaded in an individual failed fuel canister (FFC).
CC Damage	CCs with cladding failures are acceptable for loading.
THERMAL/RADIOLOGICAL PARAMETERS:	
Fuel Assembly Average Burnup and Minimum Cooling Time, with or without CCs(1)	Per Table 8.7.3-1 and decay heat and burnup credit restrictions below.
Decay Heat(1)	Per Figure 1.6.4-1, Figure 1.6.4-2, Figure 1.6.4-3, or Figure 1.6.4-4.
Burnup Credit and Criticality Restrictions(1)	Table 1.6.4-6 The maximum cooling time shall not exceed 160 years.

Notes:

(1) Minimum cooling time is the longer of the cooling time given in Table 8.7.3-1; the cooling time required to meet the decay heat restrictions provided in Figure 1.6.4-1, Figure 1.6.4-2, Figure 1.6.4-3, or Figure 1.6.4-4; and the cooling time required by Table 1.6.4-6 through Table 1.6.4-9.

(2) Reconstituted rods shall displace an amount of water equal to or greater than that displaced by the original fuel rods in the active fuel region of the fuel assembly.

Table 1.6.4-3
PWR Fuel Assembly Design Characteristics for the NUHOMS®-32PT DSC

PWR FUEL Class	B&W 15x15	WE 17x17	CE 15x15	WE 15x15	CE 14x14	WE 14x14
Fissile Material	UO_2	UO_2	UO_2	UO_2	UO_2	UO_2
Maximum Number of Fuel Rods	208	264	216	204	176	179
Maximum Number of Guide/ Instrument Tubes	16	24	8	20	5(1)	16
Maximum MTU/Assembly	0.475	0.475	0.475	0.475	0.475	0.475

(1) Guide and/or instrument tubes were not modeled in the criticality analysis KENO calculations.

Table 1.6.4-4
Thermal and Radiological Characteristics for Control Components Transported in the NUHOMS®-32PT DSCs

Parameter	BPRAs, NSAs, CRAs, RCCAs, VSIs, Neutron Sources, and APSRAs(1), (2)	TPAs and ORAs
Maximum Gamma Source (γ/sec/assembly)	3.89E+13(3)	4.19E+12(4)
Decay Heat (Watts/assembly)	8.0	8.0

Note:
(1) 4.57 E+13 ((γ/sec/assembly) for control rods with AIC absorber materials).
(2) Up to 2 NSAs and neutron sources shall only be stored in the interior compartments of the basket. Interior compartments are those compartments that are completely surrounded by other compartments, including the corners (e.g., thirteen interior compartments in Zone 1 of HLZC1 for the EOS-37PTH DSC shown in Figure 1.6.1-1).
(3) A sum of gamma sources from active fuel/plenum/top nozzle regions shown in Table 5.6.1-9.
(4) A sum of gamma sources from plenum/top nozzle regions shown in Table 5.6.1-9.

Table 1.6.4-5
Poison Rod Assembly (PRA) Minimum Absorber Loading

Assembly Class	Minimum Number of Rods/PRA	Minimum B_4C Content per Rod (g/cm)
WE 17x17	24	0.79
B&W 15x15	16	0.96
WE 15x15	20	0.96
CE 14x14	5	4.19
WE 14x14	16	0.96

Table 1.6.4-6
Maximum Planar Average Initial Enrichment/Minimum Burnup Combinations - Intact Fuel NUHOMS®-32PT
Part 1 of 2

	WE 17x17, WE 15x15, B&W 15x15, and CE 15x15 Assembly Classes				
Enrichment (Wt. % U-235)	**16 PP NO PRA**	**24 PP NO PRA (1)**	**24 PP 04 PRA**	**24 PP 08 PRA**	**24 PP 16 PRA**
1.35	fresh	–	–	–	–
1.45	–	fresh	–	–	–
1.55	–	–	fresh	–	–
1.65	–	–	–	fresh	–
1.95	–	–	–	–	fresh
	Burnup (GWD/MTU) 40 Years Decay		**Burnup (GWD/MTU) 30 Years Decay**		**Burnup (GWD/MTU) 15 Years Decay**
2.00	21	19	19	14	6
2.25	26	23	20	19	11
2.50	31	28	23	20	16
2.75	32	31	28	23	19
3.00	37	34	31	27	21
3.25	39	38	33	31	23
3.50	41	39	37	32	26
3.75	45	42	39	36	30
4.00	–	45	41	39	31
4.20	–	–	43	39	34
4.40	–	–	–	41	37
4.60	–	–	–	44	39
4.80	–	–	–	–	40
5.00	–	–	–	–	41

Table 1.6.4-6
Maximum Planar Average Initial Enrichment/Minimum Burnup Combinations - Intact Fuel NUHOMS®-32PT
Part 2 of 2

	WE 14x14 Assembly Class			
Enrichment (Wt. % U-235)	**16 PP NO PRA**	**24 PP NO PRA**	**24 PP 04 PRA 24 PP 08 PRA**	**24 PP 16 PRA (see note)**
1.55	fresh	–	–	–
1.70	–	fresh	–	–
1.80	–	–	fresh	–
1.85	–	–	–	fresh
	Burnup (GWd/MTU), 40 Years Decay		**Burnup (GWd/MTU), 15 Years Decay**	
2.00	19	15	10	6
2.25	20	19	16	11
2.50	23	20	19	16
2.75	27	24	20	19
3.00	31	28	24	21
3.25	32	31	29	23
3.50	36	33	31	26
3.75	39	37	34	30
4.00	40	39	38	31
4.20	43	40	39	34
4.40	–	42	40	37
4.60	–	45	43	39
4.80	–	–	45	40
5.00	–	–	–	41

Notes:

- Use burnup and enrichment to look up minimum cooling time in years. Licensee is responsible for ensuring that uncertainties in fuel enrichment and burnup are conservatively applied in determination of actual values for these parameters (uncertainty in enrichment to be added and uncertainty in burnup to be subtracted).
- Interpolation can be performed to determine the burnup for enrichment values (between 2.00 wt. % U-235 and 5.00 wt. % U-235) that are not explicitly shown herein. Alternatively, the burnup value corresponding to the next higher enrichment may be utilized.
- Extrapolation shall not be performed to determine burnup requirements.
- The burnup of the “fresh” assemblies is 0. For a given configuration, the enrichment corresponding to “fresh” in this table is the maximum enrichment above which a burnup value is needed for fuel assemblies to qualify for transportation.
- Fuel assemblies with accumulated control rod insertion duration less than or equal to one-half of their total irradiation time are authorized content, provided an additional burnup of 3 GWd/MTU is added to the minimum burnup requirements described above. Fuel assemblies with accumulated control rod insertion duration greater than one-half of their total irradiation time are not authorized.

Table 1.6.4-7
Maximum Planar Average Initial Enrichment/Minimum Burnup Combinations CE14x14 – Intact Fuel
NUHOMS®-32PT – 24PP, No PRA

Intact Fresh Fuel	1.8 wt. % U-235			
Cooling Time	5 Years	10 Years	15 Years	20 Years
Burnup (GWd/MTU)	Fuel Initial Enrichment (wt. % U-235)			
5	1.75	1.80	1.80	1.80
10	1.90	1.95	2.00	2.00
15	2.05	2.10	2.15	2.20
20	2.40	2.60	2.65	2.75
25	2.80	2.95	3.05	3.10
30	3.25	3.45	3.60	3.65
35	3.65	3.85	4.00	4.10
40	4.25	4.55	4.75	4.85
45	4.60	4.90	5.00	5.00
50	5.00	5.00	-	-
55	-	-	-	-

Table 1.6.4-8
Maximum Planar Average Initial Enrichment/Minimum Burnup Combinations CE14x14 – Damaged Fuel
NUHOMS®-32PT – 24PP, No PRA

4 Damaged Fuels

Fresh Fuel	1.75 wt. % U-235			
Cooling Time	**5 Years**	**10 Years**	**15 Years**	**20 Years**
Burnup (GWd/MTU)	**Damaged Fuel Initial Enrichment (wt. % U-235)**			
5	1.55	1.60	1.55	1.60
10	1.65	1.70	1.70	1.70
15	1.75	1.85	1.85	1.90
20	2.10	2.20	2.30	2.40
25	2.30	2.40	2.60	2.70
30	2.80	3.05	3.15	3.20
35	3.15	3.35	3.50	3.55
40	3.80	3.85	4.00	4.25
45	4.05	4.25	5.00	5.00
50	4.50	5.00	-	-
55	5.00	-	-	-

Note: The enrichments tabulated in this table apply only to damaged fuel assemblies while the intact fuels enrichments remain at the values provided per Table 1.6.4-7. For example, for burnup of 50 GWd/MTU, 5 years cooling time, the maximum initial enrichment for the 4 damaged fuels is 4.50 wt% while it is 5.00 wt% for the 28 intact fuels per Table 1.6.4-7.

28 Damaged Fuels

Fresh Fuel	1.70 wt. % U-235			
Cooling Time	**5 Years**	**10 Years**	**15 Years**	**20 Years**
Burnup (GWd/MTU)	**Damaged Fuel Initial Enrichment (wt. % U-235)**			
5	1.60	1.60	1.65	1.65
10	1.70	1.75	1.80	1.80
20	2.15	2.25	2.35	2.40
25	2.45	2.55	2.65	2.70
30	2.85	3.05	3.15	3.20
35	3.15	3.35	3.50	3.60
40	**3.75**	3.95	4.10	4.20
45	4.05	4.30	4.50	4.70
50	4.35	4.75	5.00	5.00
55	4.70	5.00	-	-

Note: The enrichments tabulated in this table apply only to damaged fuel assemblies while the intact fuels enrichments remain at the values provided per Table 1.6.4-7. For example, for burnup of 50 GWd/MTU, 5 years cooling time, the maximum initial enrichment for the 28 damaged fuels is 4.35 wt% while it is 5.00 wt% for the 4 intact fuels per Table 1.6.4-7.

Table 1.6.4-9
Maximum Planar Average Initial Enrichment/Minimum Burnup Combinations CE14x14 – Failed Fuel
NUHOMS®-32PT – 24PP, No PRA

Fresh Fuel	**1.65 wt. % U-235**			
Cooling Time	**5 Years**	**10 Years**	**15 Years**	**20 Years**
Burnup (GWd/MTU)	**Failed Fuel Initial Enrichment (wt. % U-235)**			
5	1.55	**1.60**	1.45	1.65
10	1.70	1.70	1.70	1.70
15	1.80	1.85	1.85	1.90
20	2.15	2.10	2.25	2.35
25	2.30	2.35	2.65	2.65
30	2.80	3.05	3.10	3.05
35	3.10	3.25	3.45	3.35
40	3.65	3.80	4.10	4.30
45	4.05	4.15	5.00	5.00
50	4.85	5.00	-	-
55	5.00	-	-	-

Note: The enrichments tabulated in this table apply only to failed fuel assemblies while the intact fuels enrichments remain at the values provided per Table 1.6.4-7. For example, for burnup of 50 GWd/MTU, 5 years cooling time, the maximum initial enrichment for the 8 failed fuels is 4.85 wt% while it is 5.00 wt% for the 24 intact fuels per Table 1.6.4-7.

Table 1.6.4-10
PWR Assembly Decay Heat for Heat Load Configurations

The Decay Heat (DH) in watts is expressed as:

$$F1 = -44.8 + 41.6*X1 - 37.1*X2 + 0.611*X1^2 - 6.80*X1*X2 + 24.0*X2^2$$
$$DH = F1*\mathrm{Exp}(\{[1-(1.8/X3)]* -0.575\}*[(X3-4.5)^{0.169}]*[(X2/X1)^{-0.147}]) + 20$$

where,

F1 Intermediate Function
X1 Assembly Burnup in GWd/MTU
X2 Initial Enrichment in wt. % U-235
X3 Cooling Time in Years (minimum 10 years)

Note:
Even though a minimum cooling time of 10 years is used, the minimum cooling time requirement for criticality from Table 1.6.4-6 is 15 years.
A uranium loading of 490 kg is employed in the calculation of the decay heat equation. Alternatively, decay heat can be calculated without employing the decay heat equation by using an approved methodology with actual spent fuel parameters instead of bounding spent fuel parameters.

	Zone 2*	Zone 2*	Zone 2*	Zone 2*	
Zone 2*	Zone 1*	Zone 1*	Zone 1*	Zone 1*	Zone 2*
Zone 2*	Zone 1*	Zone 1	Zone 1	Zone 1*	Zone 2*
Zone 2*	Zone 1*	Zone 1	Zone 1	Zone 1*	Zone 2*
Zone 2*	Zone 1*	Zone 1*	Zone 1*	Zone 1*	Zone 2*
	Zone 2*	Zone 2*	Zone 2*	Zone 2*	

*Denotes locations where intact or damaged FAs may be stored.

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Max. Decay Heat / FA (kW)(1)(2)	0.63	0.87	N/A	N/A	N/A	N/A
Max. Decay Heat / Zone (kW)	10.08	13.92	N/A	N/A	N/A	N/A
Max. Decay Heat / DSC (kW)	24.0					

(1) Decay heat per fuel assembly shall be determined by Table 1.6.4-10.
(2) When storing a CC with the fuel assembly, reduce allowable decay heat (DH) by 8 watts to account for the CC.
(3) Up to 28 damaged FAs may be stored in Zone 1 and Zone 2 only.

Figure 1.6.4-1
Heat Load Zone Configuration No. 1 for 32PT DSC

	Zone 2**	Zone 1*	Zone 1*	Zone 2**	
Zone 2**	Zone 1*	Zone 1*	Zone 1*	Zone 1*	Zone 2**
Zone 1*	Zone 1*	Zone 1	Zone 1	Zone 1*	Zone 1*
Zone 1*	Zone 1*	Zone 1	Zone 1	Zone 1*	Zone 1*
Zone 2**	Zone 1*	Zone 1*	Zone 1*	Zone 1*	Zone 2**
	Zone 2**	Zone 1*	Zone 1*	Zone 2**	

* Denotes locations where intact or damaged FAs may be stored.

** Denotes loacations where intact or damaged FAs or FFCs may be stored.

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Max. Decay Heat / FA (kW)(1)(2)	0.6	1.2	N/A	N/A	N/A	N/A
Max. Decay Heat / Zone (kW)	14.4	9.6	N/A	N/A	N/A	N/A
Max. Decay Heat / DSC (kW)	24.0					

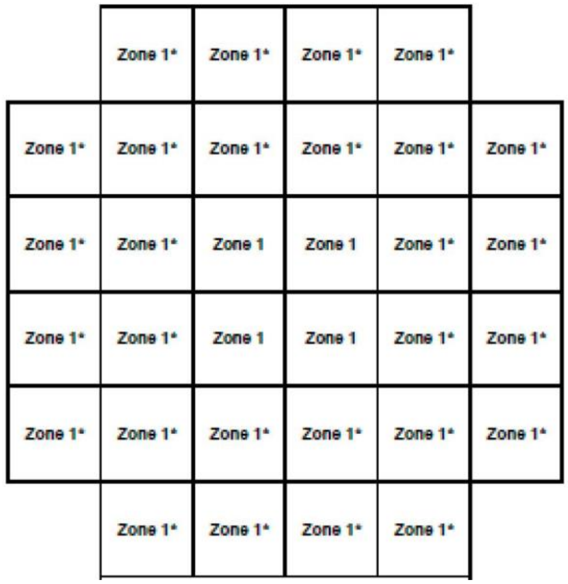
(1) Decay Heat per fuel assembly shall be determined by Table 1.6.4-10.

(2) When storing a CC with the fuel assembly, reduce allowable decay heat (DH) by 8 watts to account for the CC.

(3) Up to 28 damaged FAs may be stored in Zone 1 and Zone 2 only. When storing damaged FAs in Zone 1, intact FAs or Failed Fuel Canisters (FFCs) may be stored in the remaining Zone 1 and Zone 2 locations.

(4) Up to eight FFCs may be stored in Zone 2 only. When storing FFCs in Zone 2, intact or damaged FAs may be stored in the remaining Zone 1 and Zone 2 locations.

Figure 1.6.4-2
Heat Load Zone Configuration No. 2 for 32PT DSC



* Denotes locations where intact or damaged FAs may be stored.

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Max. Decay Heat / FA (kW)	0.7	N/A	N/A	N/A	N/A	N/A
Max. Decay Heat / Zone (kW)	22.4	N/A	N/A	N/A	N/A	N/A
Max. Decay Heat / DSC (kW)	22.4					

(1) Decay Heat per fuel assembly shall be determined by Table 1.6.4-10.
(2) When storing a CC with the fuel assembly, reduce allowable decay heat (DH) by 8 watts to account for the CC.
(3) Up to two damaged FAs may be stored in Zone 1 only.

Figure 1.6.4-3
Heat Load Zone Configuration No. 3 for 32PT DSC

	Zone 3	**Zone 5***	**Zone 5***	**Zone 3**	
Zone 3	**Zone 2***	**Zone 2***	**Zone 2***	**Zone 2***	**Zone 3**
Zone 5*	**Zone 2***	**Zone 1**	**Zone 1**	**Zone 2***	**Zone 5***
Zone 5*	**Zone 2***	**Zone 1**	**Zone 1**	**Zone 2***	**Zone 5***
Zone 4	**Zone 2***	**Zone 2***	**Zone 2***	**Zone 2***	**Zone 4**
	Zone 4	**Zone 5***	**Zone 5***	**Zone 4**	

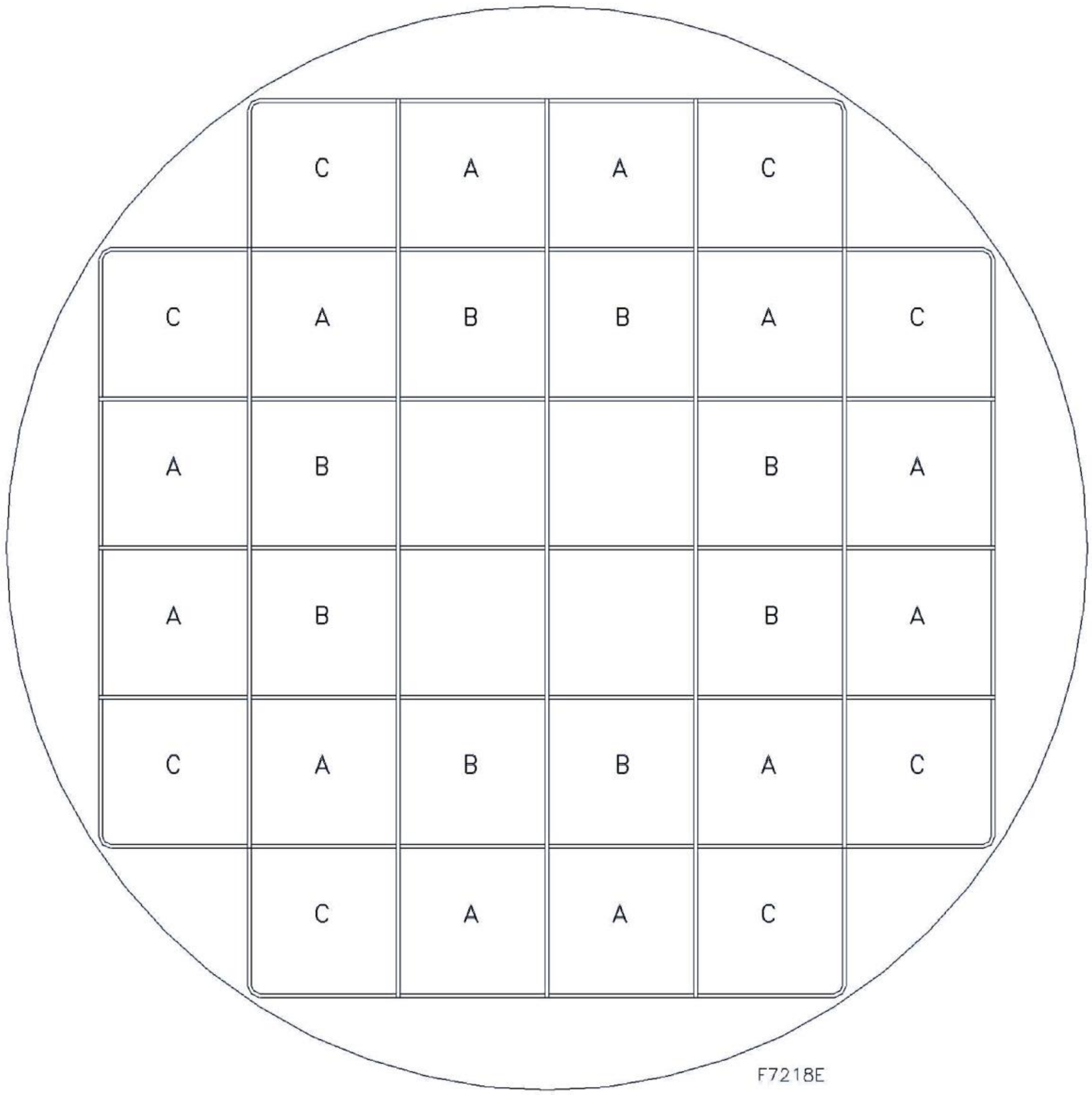
* Denotes where damaged FAs may be stored.

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
Max. Decay Heat / FA (kW)	0.40	0.60	2.20	1.70	0.8[(2)]
Max. Decay Heat / DSC (kW)	24[(1)]				

Notes:

(1) Adjust payload to maintain the total DSC heat load within the specified limit.
(2) If damaged FAs are loaded in any Zone 2 or Zone 5 locations, the maximum allowable decay heat per FA in Zone 5 is 0.6 kW.
(3) Up to 20 damaged FAs may be stored in Zones 2 and 5 only.

Figure 1.6.4-4
Heat Load Zone Configuration 4 for 32PT DSC



Notes:

(1) The “C” locations shall be employed when loading up to eight FFCs
(2) The “B” locations and “C” locations shall be employed when loading up to 16 damaged fuel assemblies.
(3) The “A” locations, “B” locations, and “C” locations shall be employed when loading greater than 16 and up to 28 damaged fuel assemblies.

Figure 1.6.4-5
Location of Damaged and Failed Fuel Assemblies inside -32PT DSC

Appendix 1.6.5
32PTH1 DSC

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1.6.5 32PTH1 DSC

1.6.5.1 32PTH1 DSC Description

Each 32PTH1 DSC consists of a DSC shell assembly and a basket assembly. The shell assembly consists of a cylindrical shell, the inner cover plates of the top and bottom shield plug assemblies, and outer top cover plate. The DSC shell assembly is designed, fabricated, and inspected in accordance with ASME B&PV Code Subsection NB [2]. As shown in Table 1.6.5-1, the 32PTH1 DSC system consists of three design configurations as follows:

- 32PTH1-S, Short DSC
- 32PTH1-M, Medium DSC
- 32PTH1-L, Long DSC

Table 1.6.5-1 provides the overall lengths and outer diameters for each 32PTH1 DSC configuration. The shell assemblies are high integrity stainless steel welded pressure vessels that provide confinement of radioactive materials, encapsulate the fuel in an inert atmosphere (the canister is back-filled with helium before being seal welded closed), and provide biological shielding (in axial direction). The 32PTH1 DSCs have double redundant seal welds that join the shell and the top and bottom cover plate assemblies to seal the canister. The bottom end assembly welds are made during fabrication of the 32PTH1 DSCs. The top end closure welds are made after fuel loading. Both top plug penetrations (siphon and vent ports) are redundantly sealed after the 32PTH1 DSC drying operations are complete.

The canister is designed to contain its fuel basket and fuel assemblies and is completely supported by the transport cask.

1.6.5.2 32PTH1 DSC Fuel Basket

The basket structures are designed, fabricated, and inspected in accordance with ASME B&PV Code Subsection NG [1]. The overall lengths and diameters of the baskets for each canister configuration are provided in Table 1.6.5-1. The 32PTH1 baskets are designed to accommodate 32 intact, or up to 16 damaged with the remainder intact, PWR fuel assemblies with or without Control Components. The basket structure consists of a welded assembly of stainless steel tubes with the space between adjacent tubes filled with aluminum and neutron poison plates and surrounded by support rails.

The basket structure is open at each end. Therefore, longitudinal fuel assembly loads are applied directly to the canister/cask body and not the fuel basket structure. The fuel assemblies are laterally supported by the stainless steel tube assembly. The basket is laterally supported by the basket rails and the canister shell. The stainless steel and aluminum basket rails are oriented parallel to the axis of the canister and are attached to the periphery of the basket to provide support and to establish and maintain basket orientation.

Shear keys, welded to the inner wall of the DSC, mate with notches in the basket support rails to prevent the basket from rotating during normal operations.

Aluminum and/or neutron absorbing poison plates are sandwiched between the fuel compartments. Table 1.6.5-5 provides the minimum B10 content as a function of basket type and poison plate material. Table 1.6.5-6 provides the maximum allowable heat load for the various 32PHT1 DSC configurations for transport.

1.6.5.3 32PTH1 DSC Contents

Each of the three alternate DSC configurations is designed to transport intact (including reconstituted) and/or damaged PWR fuel assemblies as specified in Table 1.6.5-2 and Table 1.6.5-4. The fuel to be transported is limited to a maximum assembly average initial enrichment of 5.0 wt. % U-235. The maximum allowable assembly average burnup is limited to 62 GWd/MTU and the minimum cooling time requirements are given in Table 1.6.5-2. Each of the DSC types is designed to transport control components (CCs) with thermal and radiological characteristics as listed in Table 1.6.5-3. The CCs include burnable poison rod assemblies (BPRAs), thimble plug assemblies (TPAs), control rod assemblies (CRAs), rod cluster control assemblies (RCCAs), axial power shaping rod assemblies (APSRAs), orifice rod assemblies (ORAs), vibration suppression inserts (VSIs), neutron source assemblies (NSAs), and neutron sources. Nonfuel hardware that are positioned within the fuel assembly after the fuel assembly is discharged from the core, such as guide tube or instrument tube tie rods or anchors, guide tube inserts, BPRA spacer plates, or devices that are positioned and operated within the fuel assembly during reactor operation such as those listed above, are also considered as CCs.

Reconstituted assemblies containing up to five replacement irradiated stainless steel rods per assembly, or unlimited number of lower enrichment UO_2 rods instead of Zircaloy clad enriched UO_2 rods, or Zr rods, or Zr pellets, or unirradiated stainless steel rods are acceptable for storage in the 32PTH1 DSC as intact fuel assemblies. The stainless steel rods are assumed to have two-thirds the irradiation time as the remaining fuel rods of the assembly.

The replacement lower enrichment UO_2 rods shall have an initial wt. % U-235 less than or equal to that specified for fresh fuel in Table 1.6.5-7. The replacement lower enrichment UO_2 rods are assumed to be fresh for criticality safety purposes. The replacement lower enrichment UO_2 rods can be at any location in the fuel assemblies. The maximum number of reconstituted fuel assemblies per DSC is 32.

The NUHOMS®-32PTH1 DSCs can also accommodate up to a maximum of 16 damaged fuel assemblies placed in the center cells of the DSC as shown in Figure 1.6.5-1 through Figure 1.6.5-3. Damaged PWR fuel assemblies are assemblies containing missing or partial fuel rods, or fuel rods with known or suspected cladding defects greater than hairline cracks, or pinhole leaks. The extent of damage in the fuel assembly is to be limited such that a fuel assembly is able to be handled by normal means. The DSC basket cells, which accommodate damaged fuel assemblies, are provided with top and bottom end caps.

A 32PTH1 DSC containing less than 32 fuel assemblies may contain dummy fuel assemblies in the empty slots. The dummy assemblies are unirradiated, stainless steel encased structures that approximate the weight and center of gravity of a fuel assembly.

The 32PTH1 DSC basket is designed with two options: Type 1 basket with solid aluminum transition rails and Type 2 basket with steel transition rails including aluminum inserts. The Type 1 basket is the preferred option for canisters with high decay heat loads, since the solid aluminum rails allow a more direct heat conduction path from the basket edge to the DSC shell.

The NUHOMS®-32PTH1 DSCs may transport up to 32 PWR fuel assemblies arranged in any of the three alternate heat load zone configurations (HLZC) as shown in Figure 1.6.5-1 through Figure 1.6.5-3. The maximum allowed heat load for the various 32PTH1 system configurations are presented in Table 1.6.5-6.

The cooling times determined by fuel qualification table (Table 8.7.3-1) are developed to meet dose rate limits only. The minimum cooling time for an assembly is the longer of that given by Table 8.7.3-1 and the cooling time required to meet the decay heat restrictions provided in Figure 1.6.5-1 through Figure 1.6.5-3 for the heat load zone configuration selected.

1.6.5.4 References

1. American Society of Mechanical Engineers, ASME Boiler and Pressure Vessel Code, Section III, Division 1 – Subsections NB, NG, and NF, 1998 edition including 2000 Addenda.

Table 1.6.5-1
Key Design Parameters of the NUHOMS®-32PTH1 System

Parameter	32PTH1 DSC Type		
	32PTH1-S	**32PTH1-M**	**32PTH1-L**
DSC Length (in)	185.75 (Maximum)	193.00 (Maximum)	198.50 (Maximum)
DSC Outside Diameter (in)	69.75	69.75	69.75
DSC Cavity Length (in)	164.38	171.63	181.38
Basket Length (in)	162.00	169.00	178.75
Basket Diameter (in)	68.50	68.50	68.50

Note: Unless stated otherwise, nominal values are provided.

Table 1.6.5-2
PWR Fuel Specification for Fuel to be Transported in the NUHOMS®-32PTH1 DSC

PHYSICAL PARAMETERS: Fuel Class	 Intact or damaged unconsolidated B&W 15x15, WE 17x17, CE 15x15, WE 15x15, CE 14x14, WE 14x14, and CE 16x16 class PWR assemblies (with or without control components) that are enveloped by the fuel assembly design characteristics listed in Table 1.6.5-4. Reloaded fuel manufactured by the same or other vendors but enveloped by the design characteristics listed in Table 1.6.5-4 is also acceptable. Damaged fuel assemblies beyond the definition contained below are not authorized for transport.
Damaged Fuel	Damaged PWR fuel assemblies are assemblies containing missing or partial fuel rods or fuel rods with known or suspected cladding defects greater than hairline cracks or pinhole leaks. The extent of damage in the fuel assembly is to be limited such that a fuel assembly is able to be handled by normal means. Damaged fuel assemblies shall also contain top and bottom end fittings or nozzles or tie plates depending on the fuel type.
RECONSTITUTED FUEL ASSEMBLIES(2): Maximum Number of Irradiated Stainless Steel Rods per Reconstituted Fuel Assembly	 5
Maximum Number of Reconstituted Assemblies per DSC with Unlimited Number of Low Enriched UO_2 Rods, or Zr Rods, or Zr Pellets, or Unirradiated Stainless Steel Rods. Reconstituted assemblies containing an unlimited number of replacement lower enrichment UO_2 rods which have an initial wt. % U-235 less than or equal to that specified for fresh fuel in Table 1.6.5-8 are qualified.	32
Control Components (CCs)	Up to 32 CCs are authorized for storage in 32PTH1-S, 32PTH1-M, and 32PTH1-L DSCs. Authorized CCs include Burnable Poison Rod Assemblies (BPRAs), Thimble Plug Assemblies (TPAs), Control Rod Assemblies (CRAs), Rod Cluster Control Assemblies (RCCAs), Axial Power Shaping Rod Assemblies (APSRAs), Orifice Rod Assemblies (ORAs), Vibration Suppression Inserts (VSIs), Neutron Source Assemblies (NSAs), and Neutron Sources. Nonfuel hardware that are positioned within the fuel assembly after the fuel assembly is discharged from the core such as Guide Tube or Instrument Tube Tie Rods or Anchors, Guide Tube Inserts, BPRA Spacer Plates, or devices that are positioned and operated within the fuel

	assembly during reactor operation such as those listed above are also considered as CCs. Design basis thermal and radiological characteristics for the CCs are listed in Table 1.6.5-3.
Number of Intact Assemblies	≤32
Number and Location of Damaged Assemblies	Up to 16 damaged fuel assemblies. Balance may be intact fuel assemblies, or dummy assemblies which are authorized for storage in 32PTH1 DSC. Damaged fuel assemblies are to be placed in the center 16 locations as shown in Figure 1.6.5-1, Figure 1.6.5-2, and Figure 1.6.5-3. The DSC basket cells which accommodate damaged fuel assemblies are provided with top and bottom end caps.
Maximum Assembly plus CC Weight	1715 lb
THERMAL/RADIOLOGICAL PARAMETERS: Fuel Assembly Average Burnup and minimum Cooling Time(1)	Per Table 8.7.3-1 and decay heat and burnup credit restrictions below.
Decay Heat(1)	Per Figure 1.6.5-1, Figure 1.6.5-2, or Figure 1.6.5-3.
Burnup Credit Restrictions(1)	Per Table 1.6.5-7 for Intact Fuel Assemblies and per Table 1.6.5-8 for Damaged Fuel Assemblies. The maximum cooling time shall not exceed 160 years.

Note:

(1) Minimum cooling time is the longer of the cooling time given in Table 8.7.3-1; the cooling time required to meet the decay heat restrictions provided in Figure 1.6.5-1, Figure 1.6.5-2, or Figure 1.6.5-3; and the cooling time required by Table 1.6.5-7 or Table 1.6.5-8.

(2) Reconstituted rods shall displace an amount of water equal to or greater than that displaced by the original fuel rods in the active fuel region of the fuel assembly.

Table 1.6.5-3
Thermal and Radiological Characteristics for Control Components Transported in the NUHOMS®-32PTH1 DSC

Parameter	BPRAs, NSAs, CRAs, RCCAs, VSIs, APSRAs, and Neutron Sources(1) (2)	TPAs and ORAs
Maximum Gamma Source (γ/sec/assembly)	3.90E+13(3)	4.19E+12(4)
Decay Heat (Watts/assembly)	8.0	8.0

Note:
(1) 4.57 E+13 ((γ/sec/assembly) for control rods with AIC absorber materials).
(2) Up to 2 NSAs and neutron sources shall only be stored in the interior compartments of the basket. Interior compartments are those compartments that are completely surrounded by other compartments, including the corners (e.g., thirteen interior compartments in Zone 1 of HLZC1 for the EOS-37PTH DSC shown in Figure 1.6.1-1).
(3) A sum of gamma sources from active fuel/plenum/top nozzle regions shown in Table 5.6.1-9.
(4) A sum of gamma sources from plenum/top nozzle regions shown in Table 5.6.1-9.

Table 1.6.5-4
PWR Fuel Assembly Design Characteristics for the NUHOMS®-32PTH1 DSC

PWR FUEL Class	B&W 15x15	WE 17x17	CE 15x15	WE 15x15	CE 14x14	WE 14x14	CE 16x16
Fissile Material	UO_2	UO_2	UO_2	UO_2	UO_2	UO_2	UO_2
Maximum Number of Fuel Rods	208	264	216	204	176	179	236
Maximum Number of Guide/Instrument Tubes	16	24	8	20	4	16	4
Maximum MTU/Assembly	0.49	0.482	0.482	0.482	0.482	0.482	0.482

Table 1.6.5-5
B10 Specification for the NUHOMS®-32PTH1 Poison Plates

32PTH1 DSC Basket Type	Minimum B10 Areal Density for Boral® (mg/cm²)	Minimum B10 Areal Density for B-Al(1) (mg/cm²)
1A or 2A	9.0	7.0
1B or 2B	19.0	15.0
1C or 2C	25.0	20.0
1D or 2D	N/A	32.0
1E or 2E	N/A	50.0

Note:
(1) B-Al = Metal Matrix Composites and Borated Aluminum Alloys.

Table 1.6.5-6
Maximum Allowable Heat Load for the NUHOMS®-32PTH1 System

System Configuration	32PTH1 DSC Type	32PTH1 Basket Type(1),(2)	Max. Heat Load (kW) per DSC
1	32PTH1-S, 32PTH1-M, or 32PTH1-L	1A, 1B, or 1C or 1D or 1E	26.0 (HLZC 1 and 2 with intact or damaged fuel)
			24.0 (HLZC 3 with intact or damaged fuel)
2	32PTH1-S, 32PTH1-M, or 32PTH1-L	2A, 2B, or 2C or 2D or 2E	24.0 (HLZC 2)
			24.0 (HLZC 3)

Notes:
(1) Basket Type 1 (1A, 1B, 1C, 1D, 1E) has aluminum transition rails in the DSC basket.
(2) Basket Type 2 (2A, 2B, 2C, 2D, 2E) has steel transition rails in the DSC basket.

Table 1.6.5-7
Maximum Planar Average Initial Enrichment/Minimum Burnup Combinations - NUHOMS®-32PTH1 – Intact Fuel Assemblies
(Part 1 of 2)

Enrichment (wt. % U-235)	WE 17x17, WE 15x15, BW 15x15, CE 14x14, CE 15x15, and CE 16x16 Fuel Assembly Classes									
	Type A	Type B	Type C	Type D	Type E	Type A	Type B	Type C	Type D	Type E
1.55	fresh	–	–	–	–	fresh	–	–	–	–
1.70	–	fresh	–	–	–	–	fresh	–	–	–
1.75	–	–	fresh	–	–	–	–	fresh		–
1.80	–	–	–	fresh	–	–	–	–	fresh	–
1.90	–	–	–	–	fresh	–	–	–	–	fresh
	Burnup (GWd/MTU), 15 years decay					**Burnup (GWd/MTU), 30 years decay**				
2.00	20	18	15	12	9	19	16	14	11	8
2.25	23	19	19	18	15	20	19	19	17	14
2.50	28	23	21	19	19	25	20	19	19	19
2.75	31	27	25	22	20	30	25	23	20	19
3.00	35	31	30	27	24	31	29	27	24	22
3.25	39	34	32	31	28	35	31	31	29	25
3.50	40	39	36	32	31	39	34	33	31	30
3.75	44	40	39	36	33	40	39	36	33	31
4.00	49	43	41	39	37	43	40	39	37	34
4.20	–	46	44	40	39	46	41	40	39	36
4.40	–	48	46	43	40	49	44	42	40	39
4.60	–	–	49	47	42	–	47	45	41	40
4.80	–	–	–	48	45	–	49	47	44	41
5.00	–	–	–	50	47	–	–	50	46	43

Table 1.6.5-7
Maximum Planar Average Initial Enrichment/Minimum Burnup Combinations - NUHOMS®-32PTH1 – Intact Fuel Assemblies
(Part 2 of 2)

Enrichment (wt. % U-235)	WE 14x14 Assembly Class					
	Type A	Type B	Type C	Type A	Type B	Type C
1.80	fresh	–	–	fresh	–	–
1.95	–	fresh	fresh	–	fresh	fresh
	Burnup (GWd/MTU), 15 years decay			**Burnup (GWd/MTU), 30 years decay**		
2.00	12	7	6	11	7	5
2.25	18	13	11	17	12	11
2.50	19	19	17	19	17	15
2.75	23	19	19	21	19	19
3.00	27	22	20	25	20	19
3.25	31	26	24	29	24	23
3.50	33	30	28	31	28	26
3.75	37	32	31	33	31	29
4.00	39	35	33	37	32	31
4.20	40	38	36	39	35	33
4.40	43	39	38	40	38	35
4.60	50	40	39	42	39	38
4.80	–	43	41	44	40	39
5.00	–	45	43	–	42	40

Notes:

- Use burnup and enrichment to look up minimum cooling time in years. Licensee is responsible for ensuring that uncertainties in fuel enrichment and burnup are conservatively applied in determination of actual values for these parameters (uncertainty in enrichment to be added and uncertainty in burnup to be subtracted).
- Interpolation can be performed to determine the burnup for enrichment values (between 2.00 wt. % U-235 and 5.00 wt. % U-235) that are not explicitly shown herein. Alternatively, the burnup value corresponding to the next higher enrichment may be utilized.
- Extrapolation shall not be performed to determine burnup requirements.
- Burnup of the "fresh" assemblies is 0. For a given configuration, the enrichment corresponding to "fresh" in this table is the maximum enrichment above which a burnup value is needed for fuel assemblies to qualify for transportation.
- Fuel assemblies with accumulated control rod insertion duration less than or equal to one-half of their total irradiation time are authorized content provided an additional burnup of 3 GWd/MTU is added to the minimum burnup requirements described above. Fuel assemblies with accumulated control rod insertion duration greater than one-half of their total irradiation time are not authorized.
- This table cannot be used to determine minimum burnup requirements when damaged fuel assemblies are loaded. Table 1.6.5-8 shall be used for this purpose.

Table 1.6.5-8
Maximum Planar Average Initial Enrichment/Minimum Burnup Combinations - NUHOMS®-32PTH1 – Damaged Fuel Assemblies
(Part 1 of 2)

Enrichment (wt. % U-235)	WE 17x17, WE 15x15, BW 15x15, CE 14x14, CE 15x15, and CE 16x16 Fuel Assembly Classes									
	Type A	**Type B**	**Type C**	**Type D**	**Type E**	**Type A**	**Type B**	**Type C**	**Type D**	**Type E**
1.55	fresh	–	–	–	–	fresh	–	–	–	
1.65	–	fresh	–	–	–	–	fresh	–	–	
1.70	–		fresh	–	–	–	–	fresh		
1.80	–		–	fresh	–	–	–	–	fresh	
1.85	–		–	–	fresh	–	–	–	–	fresh
	Burnup (GWd/MTU), 15 years decay					**Burnup (GWd/MTU), 30 years decay**				
2.00	21	19	19	16	12	19	19	18	14	11
2.25	27	22	20	19	19	24	19	19	19	18
2.50	31	28	26	23	21	29	25	23	20	19
2.75	36	32	31	28	25	32	30	28	25	23
3.00	39	36	34	32	31	36	32	31	30	27
3.25	43	40	39	35	33	39	36	35	32	31
3.50	47	44	42	39	37	43	39	39	33	34
3.75	–	48	46	42	39	47	41	40	36	38
4.00	–	–	49	46	42	–	46	44	39	39
4.20	–	–	–	49	45	–	49	47	41	41
4.40	–		–	–	49	–	–	50	44	44
4.60	–		–	–	–	–	–	–	47	47
4.80	–		–	–	–	–	–	–	–	50
5.00	–		–	–	–		–	–	–	–

Table 1.6.5-8
Maximum Planar Average Initial Enrichment/Minimum Burnup Combinations - NUHOMS®-32PTH1 – Damaged Fuel Assemblies
(Part 2 of 2)

Enrichment (wt. % U-235)	WE 14x14 assembly class									
	Type A	Type B	Type C	Type D	Type E	Type A	Type B	Type C	Type D	Type E
1.60	fresh	–	–	fresh	–	–	fresh	–	–	fresh
1.70	–	fresh	–	–	fresh	–	–	fresh	–	–
1.75	–	–	fresh	–	–	fresh	–	–	fresh	–
	Burnup (GWd/MTU), 15 years decay					Burnup (GWd/MTU), 30 years decay				
2.00	19	19	17	16	12	19	17	16	14	11
2.25	25	21	19	19	19	22	19	19	19	18
2.50	31	26	24	23	21	28	23	22	20	19
2.75	35	31	30	28	25	31	28	27	25	23
3.00	39	34	33	32	31	35	31	31	30	27
3.25	42	39	39	35	33	39	35	34	32	31
3.50	46	41	40	39	37	41	39	38	33	34
3.75	50	46	44	42	39	46	41	39	36	38
4.00	–	50	48	46	42	50	45	43	39	39
4.20	–	–	–	49	45	–	48	46	41	41
4.40	–	–	–	–	49	–	–	50	44	44
4.60	–	–	–	–	–	–	–	–	47	47
4.80	–	–	–	–	–	–	–	–	–	50
5.00	–	–	–	–	–	–	–	–	–	–

Notes:

- Use burnup and enrichment to look up minimum cooling time in years. Licensee is responsible for ensuring that uncertainties in fuel enrichment and burnup are conservatively applied in determination of actual values for these parameters (uncertainty in enrichment to be added and uncertainty in burnup to be subtracted).
- Interpolation can be performed to determine the burnup for enrichment values (between 2.00 wt. % U-235 and 5.00 wt. % U-235) that are not explicitly shown herein. Alternatively, the burnup value corresponding to the next higher enrichment may be utilized.
- Extrapolation shall not be performed to determine burnup requirements.
- Burnup of the “fresh” assemblies is 0. For a given configuration, the enrichment corresponding to “fresh” in this table is the maximum enrichment above which a burnup value is needed for fuel assemblies to qualify for transportation.
- Fuel assemblies with accumulated control rod insertion duration less than or equal to one-half of their total irradiation time are authorized content provided an additional burnup of 3 GWd/MTU is added to the minimum burnup requirements described above. Fuel assemblies with accumulated control rod insertion duration greater than one-half of their total irradiation time are not authorized.
- This table is used to determine the minimum burnup requirements for all fuel assemblies (intact and damaged) whenever damaged fuel assemblies are loaded.

Table 1.6.5-9
PWR Decay Heat for Heat Load Configurations

The Decay Heat (DH) in watts is expressed as:

$$F1 = -44.8 + 41.6*X1 - 37.1*X2 + 0.611*X1^2 - 6.80*X1*X2 + 24.0*X2^2$$
$$DH = F1*Exp(\{[1-(1.8/X3)]* -0.575\}*[(X3-4.5)^{0.169}]*[(X2/X1)^{-0.147}]) + 20$$

where,

F1 Intermediate Function
X1 Assembly Burnup in GWd/MTU
X2 Initial Enrichment in wt. % U-235
X3 Cooling Time in Years (minimum 10 years)

Note:
Even though cooling times less than 15 years are shown in this table, the minimum cooling time requirement for criticality from Table 1.6.5-7 and Table 1.6.5-8 for transportation is 15 years.
A uranium loading of 490 kg is employed in the calculation of the decay heat equation. Alternatively, the decay heat can be calculated without employing the decay heat equation by using an approved methodology with actual spent fuel parameters instead of bounding spent fuel parameters.

	Z6	Z6	Z6	Z6	
Z6	Z5*	Z5*	Z5*	Z5*	Z6
Z6	Z5*	Z1*	Z1*	Z5*	Z6
Z6	Z5*	Z1*	Z1*	Z5*	Z6
Z6	Z5*	Z5*	Z5*	Z5*	Z6
	Z6	Z6	Z6	Z6	

* Denotes only locations where damaged fuel assembly can be transported.

	Zone 1	**Zone 2**	**Zone 3**	**Zone 4**	**Zone 5**	**Zone 6**
Maximum Decay Heat (kW/FA)(1)(2)	0.6	NA	NA	NA	1.3(3)	1.5
Maximum Decay Heat per Zone (kW)	2.4	NA	NA	NA	15.6	24.0
Maximum Decay Heat per DSC (kW)	26.0(4)					

(1) Decay heat per fuel assembly shall be determined per Table 1.6.5-9.
(2) When storing a CC with the fuel assemblies, reduce allowable decay heat (DH) by heat output of CC.
(3) 1.2 kW per FA is the maximum decay heat allowed for damaged fuel assemblies.
(4) Adjust payload to maintain 26.0 kW/DSC heat load.

Figure 1.6.5-1
Heat Load Zone Configuration No. 1 for 32PTH1-S, 32PTH1-M, and 32PTH1-L DSCs
(Type 1 Baskets)

	Z4	Z4	Z4	Z4	
Z4	Z4*	Z4*	Z4*	Z4*	Z4
Z4	Z4*	Z3*	Z3*	Z4*	Z4
Z4	Z4*	Z3*	Z3*	Z4*	Z4
Z4	Z4*	Z4*	Z4*	Z4*	Z4
	Z4	Z4	Z4	Z4	

* Denotes only locations where damaged fuel assembly can be transported.

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Maximum Decay Heat (kW/FA)[1][2]	NA	NA	0.96	0.98	NA	NA
Maximum Decay Heat per Zone (kW)	NA	NA	3.84	26.0[3]	NA	NA
Maximum Decay Heat per DSC (kW)	26.0[4]					

(1) Decay heat per fuel assembly shall be determined per Table 1.6.5-9.
(2) When storing a CC with the fuel assemblies, reduce allowable decay heat (DH) by heat output of CC.
(3) Maximum listed is for Type 1 Basket Only. Type 2 Basket shall be limited to 24.0 kW.
(4) Adjust payload to maintain these maximum per DSC heat load.

Figure 1.6.5-2
Heat Load Zone Configuration No. 2 for 32PTH1-S, 32PTH1-M, and 32PTH1-L DSCs (Type 1 or Type 2 Baskets)

	Z2	**Z2**	**Z2**	**Z2**	
Z2	**Z2***	**Z2***	**Z2***	**Z2***	**Z2**
Z2	**Z2***	**Z2***	**Z2***	**Z2***	**Z2**
Z2	**Z2***	**Z2***	**Z2***	**Z2***	**Z2**
Z2	**Z2***	**Z2***	**Z2***	**Z2***	**Z2**
	Z2	**Z2**	**Z2**	**Z2**	

* Denotes only locations where damaged fuel assembly can be transported.

	Zone 1	**Zone 2**	**Zone 3**	**Zone 4**	**Zone 5**	**Zone 6**
Maximum Decay Heat (kW/FA)[(1)(2)]	NA	0.8	NA	NA	NA	NA
Maximum Decay Heat per Zone (kW)	NA	24.0	NA	NA	NA	NA
Maximum Decay Heat per DSC (kW)	24.0[(3)]					

(1) Decay Heat per fuel assembly shall be determined per Table 1.6.5-9.
(2) When storing a CC with the fuel assemblies, reduce allowable decay heat (DH) by heat output of CC.
(3) Adjust payload to maintain 24.0 kW/DSC heat load.

Figure 1.6.5-3
Heat Load Zone Configuration No. 3 for 32PTH1-S, 32PTH1-M, and 32PTH1-L DSCs (Type 1 or Type 2 Baskets)

Appendix 1.6.6
FO, FC, FF DSCs

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1.6.6 FO, FC, FF DSCs

1.6.6.1 Dry Shielded Canisters

The DSCs are high integrity stainless steel, welded pressure vessels that provide confinement of the radioactive materials, encapsulate the fuel in an inert atmosphere, and provide axial biological shielding during DSC closure, transfer operations, storage, and transport. Because of the nature of the fuel that is to be transported, three different types of DSCs are designed for the Package. All three DSCs have an outside diameter of 67.19 inches and are 186.2 inches long. The shell is composed of 5/8-inch austenitic stainless steel. The cylindrical shell and the top and bottom cover plate assemblies form the pressure retaining boundary for the spent fuel and cover gas. The DSCs are equipped with two shielded end plugs so that the occupational doses at the ends are minimized for drying, sealing, and handling operations. The DSCs have double, redundant seal welds which join the shell and the top and bottom shield plug and cover plate assemblies to seal the canister. The bottom end assembly welds are made during fabrication of the DSC. The top end closure welds are made after fuel loading. Both top plug penetrations (siphon and vent ports) are redundantly sealed after the DSC drying operations are complete. Other than for biological shielding purposes, the pressure containment capability of the DSC shell assembly is conservatively neglected for transportation.

The internal basket assembly contains a storage position for each fuel assembly. The basket is composed of circular spacer discs machined from thick carbon steel plates or, alternatively, austenitic stainless steel, SA-240, Type XM-19 for the FF-DSC only. Axial support for the DSC basket is provided by four high strength stainless steel support rods (FO and FC DSC) and four carbon steel or austenitic stainless steel, SA-240, Type XM-19 (FF DSC) support plates which extend over the full length of the DSC cavity and bear on the canister top and bottom end assemblies. All of the DSCs are inerted with helium before being sealed. Carbon steel components of each DSC basket assembly are coated with a thin corrosion resistant layer of nickel to provide corrosion resistance for the short time that the DSC is in the spent fuel pool for fuel loading. After the DSC is drained, dried, inerted, and sealed for storage or transportation, there is no mechanism available for corrosion of the carbon steel components.

On the bottom of each DSC there is a grapple ring which allows the DSC to be transferred in and out of the NUHOMS® storage modules from the cask horizontally.

1.6.6.2 Fuel-Only (FO) Dry Shielded Canister

The FO DSC has a cavity length of 167 inches and has solid steel shield plugs at both ends. The FO DSC is capable of carrying 24 intact PWR spent fuel assemblies as described in Section 1.6.6.5. The FO DSC basket assembly consists of 24 guide sleeve assemblies with integral borated neutron absorbing plates, 26 spacer discs, and four support rods. The spacer discs have machined openings which allow the guide sleeves and the fixed borated neutron absorber plates to pass through. No borated materials are used for structural load carrying members.

1.6.6.3 Fuel/Control Components (FC) Dry Shielded Canister

The FC DSC has an internal cavity length of 173 inches to accommodate fuel with control components. To obtain this increased cavity length, the shield plugs are a composite of lead and steel. The support rods are six inches longer above the top spacer disc than those in the FO DSC. The FC DSC has a capacity of 24 intact PWR spent fuel assemblies with control components as described in Section 1.6.6.5. To ensure that guide sleeve displacements during a top end drop do not uncover the active portion of the fuel assemblies, four 6.25-inch lengths of angle, or formed plates, protrude above the top of each guide sleeve. Angles are used to preclude interference of the fuel handling grapple during insertion and removal of fuel assemblies. All other features of the FC DSC are the same as those of the FO DSC.

1.6.6.4 Failed Fuel (FF) Dry Shielded Canister

The FF DSC is similar to the FC DSC in most respects with the exception of the basket assembly. The internal cavity length is 173 inches. The FF DSC shell assembly, bottom shield plug, top shield plug, grapple ring, drain and vent ports, and outer cover plate are similar to the FC DSC shell assembly.

The FF DSC shell and top and bottom end assemblies enclose a basket assembly which serves as the structural support for the fuel assemblies. The fuel assemblies may be normal intact fuel, fuel with known or suspected cladding defects greater than hairline cracks or pinhole leaks, or with cracked, bulging, or discolored cladding. Prior to loading fuel in the DSCs, assemblies will be visually inspected to document that cladding damage is limited to no more than 15 fuel pins of the assembly. Inspection will be performed only once, prior to placement of fuel in the DSC. DSCs may be placed in storage and transported anytime thereafter without further fuel inspection. Because of the fuel cladding defects, individual (screened) fuel canisters are provided to confine any loose material, maintain the geometry for criticality control in accordance with Chapter 6 of this SAR, and facilitate loading and unloading operations.

The FF DSC basket assembly consists of 15 carbon steel spacer discs, steel or austenitic stainless steel (SA-240, Type XM-19), four carbon steel or austenitic stainless steel (SA-240, Type XM-19) axial support plates, and 13 stainless steel failed fuel canisters. The spacer discs maintain the cross-sectional spacing of the fuel assemblies and provide lateral support for the fuel assemblies and failed fuel canisters. The spacer discs are held in place by the support plates, which maintain longitudinal separation. The failed fuel canisters are removable and, therefore, are not permanently attached to the basket assembly or DSC shell.

The carbon steel spacer discs in the FF DSC have 13 square cut-outs. Additionally, the four support plates are fitted between cut-outs in the spacer discs. These plates have the same function as the support rods in the FOand FC DSC designs. Support plates are welded between the spacer discs at the 45°, 135°, 225°, and 315° azimuth positions.

The FF DSC failed fuel canister consists of a seam-welded stainless steel tube with a welded bottom lid assembly and a welded removable top lid assembly. The canisters do not contain any borated neutron absorbing materials. They provide for the confinement of the fuel pellets/shards by means of a fixed bottom screen and a removable top screen. The bottom lid and top lid stainless steel screens allow for dewatering of the failed fuel canister. The bottom end of the canister includes provisions for fuel support. The fuel canister lid is fitted with a fuel handling type pintle to interface with the plant fuel handling equipment for placement of the lid and handling of the removable fuel canister.

1.6.6.5 Contents of Packaging

The contents of the FO, FC, and FF DSC packaging as described above consist of spent reactor fuel. This fuel is in several different forms. The first form of fuel will be intact Pressurized Water Reactor (PWR) fuel with control components. The second form of fuel will be intact PWR fuel without control components. The third form of fuel will be damaged or failed PWR fuel without control components. Each of these forms of fuel is described below and will be placed in different types of canisters as previously described.

1.6.6.6 Intact PWR Fuel Assemblies

The fuel design included in this payload is B&W 15X15 PWR fuel with a maximum initial enrichment of 3.43% by weight of U-235. The fuel will have a maximum burnup of 40,000 megawatt days per metric ton of initial heavy metal (MWd/MTIHM). The fuel will have been decayed for a time sufficient to meet the thermal criteria defined below. The minimum acceptable cooling time is 15 years. The maximum allowable cask heat load under any conditions, including storage and on-site transfer use, is 13.5 kW, with a maximum assembly decay heat of 0.764 kW (Type I) or 0.563 kW (Type II). Intact fuel assemblies include those with minor cladding damage, including pinhole leaks and hairline cracks, provided the cladding integrity is sufficient to prevent significant fuel particulate release. Each FO DSC will contain 24 of the intact fuel assemblies described in this section. Where an FO DSC is to be loaded with fewer than 24 fuel assemblies, dummy fuel assemblies will be installed in the unoccupied spaces. These dummy assemblies will have the same nominal weight as a standard fuel assembly to maintain the symmetric weight distribution in the FO DSC.

Fuel assemblies are separated into two types, Type I and Type II. Type I assemblies are those assemblies which meet the 0.764 kW assembly heat load limit, but not the cask average (0.563 kW per assembly) heat load limit. Type II assemblies are those assemblies which meet the 0.563 kW per assembly cask average decay heat limit. As shown in Figure 1.6.6-1, Type I assemblies shall only be loaded into the inner four fuel cells of the FO DSC. Type II assemblies may be loaded into any fuel cell in the FO DSC. Cooling times necessary to reach these heat loads are tabulated versus burnup in Fuel Qualification Tables.

1.6.6.7 Intact PWR Fuel Assemblies with Control Components

The fuel design included in this payload is B&W 15X15 PWR fuel, including control components, with a maximum initial enrichment of 3.43% by weight of U-235. The fuel will have a maximum burnup of 40,000 megawatt days per metric ton of initial heavy metal (MWd/MTIHM). The fuel will have been decayed for a time sufficient to meet the thermal criteria defined below. The minimum acceptable cooling time is 15 years. The maximum allowable cask heat load (including contributions from control components) under any conditions, including storage and on-site transfer use, is 13.5 kW, with a maximum assembly decay heat of 0.764 kW (Type I) or 0.563 kW (Type II). Intact fuel assemblies include those with minor cladding damage, including pinhole leaks and hairline cracks, provided the cladding integrity is sufficient to prevent significant fuel particulate release. Each FC DSC will contain 24 of the intact fuel assemblies described in this section. Where an FC DSC is to be loaded with fewer than 24 fuel assemblies, dummy fuel assemblies will be installed in the unoccupied spaces. These dummy assemblies will have the same nominal weight as a standard fuel assembly to maintain the symmetric weight distribution in the FC DSC.

Fuel assemblies are separated into two types, Type I and Type II. Type I assemblies are those assemblies which meet the 0.764 kW assembly heat load limit, but not the cask average (0.563 kW per assembly) heat load limit. Type II assemblies are those assemblies which meet the 0.563 kW per assembly cask average decay heat limit. As shown in Figure 1.6.6-1, Type I assemblies shall only be loaded into the inner four fuel cells of the FC DSC. Type II assemblies may be loaded into any fuel cell in the FC DSC. Cooling times necessary to reach these heat loads are tabulated versus burnup in Fuel Qualification Tables.

Details of the fuel characteristics can be found in Table 1.6.6-2. Design basis thermal and radiological characteristics for the control components are listed in Table 1.6.6-3.

1.6.6.8 Damaged/Failed PWR Fuel Assemblies

The fuel design included in this payload is B&W 15X15 PWR fuel with a maximum initial enrichment of 3.43% by weight of U-235. The fuel will have a maximum burnup of 40,000 megawatt days per metric ton of initial heavy metal (MWd/MTIHM). The fuel will have been decayed for a time sufficient to meet the thermal criteria defined below. The minimum acceptable cooling time is 15 years. The maximum allowable assembly decay heat for this payload is 0.764 kW. Each FF DSC will contain 13 of the damaged or failed fuel assemblies described in this section or the intact fuel assemblies described in Section 1.6.6.6 (either Type I or Type II assemblies may be placed in any of the 13 openings in the FF DSC shown in Figure 1.6.6-2). Where an FF DSC is to be loaded with fewer than 13 fuel assemblies, dummy fuel assemblies will be installed in the unoccupied spaces. These dummy assemblies will have the same nominal weight as a standard fuel assembly to maintain the symmetric weight distribution in the FF DSC.

Damaged or failed fuel assemblies contain fuel rods with known or suspected cladding defects greater than hairline cracks or pinhole leaks, or with cracked, bulging, or discolored cladding. The FF DSC contains individual fuel canisters which confine any gross fuel particles to a known, subcritical volume during off-normal and accident conditions and facilitate handling and retrievability. The criticality analysis provided in Chapter 6 requires that cladding damage be limited to no more than 15 fuel pins of the assembly. Visual inspection of assemblies will be performed once, prior to placement of the fuel in the DSC, which may then be placed in storage and transported anytime thereafter without further fuel inspection. Spent fuel with plutonium in excess of 20 curies per package in the form of debris, particles, loose pellets, and fragmented rods or assemblies are not authorized.

1.6.6.9 References

1. American Society of Mechanical Engineers, ASME Boiler and Pressure Vessel Code, Section III, Division 1 - Subsections NB, NG, and NF, 1992 Edition with 1993 Addenda.

Table 1.6.6-1
Maximum Fuel Loading Parameters

Parameter	Value
Number of Assemblies, FO/FC DSCs	≤ 24
Number of Assemblies, FF DSC	≤ 13
Enrichment, w/o U-235	≤ 3.43%
Minimum Burnup	0
Design Basis Fuel	B&W 15x15
Maximum Number of Failed Rods (FF DSC only)	15/assy
Maximum MTU/Assembly	0.466

Table 1.6.6-2
Fuel Characteristics

PWR FUEL Class	B&W 15x15
Fissile Material	UO_2
Maximum Number of Fuel Rods	208
Maximum Number of Guide/Instrument Tubes	16

Table 1.6.6-3
Thermal and Radiological Characteristics for Control Components Transported in the FC DSC

Parameter	BPRAs, NSAs, CRAs, RCCAs, VSIs, Neutron Sources, and APSRAs(1)(2)	TPAs and ORAs
Maximum Gamma Source (γ/sec/assembly)	3.89E+13 (3)	4.19E+12 (4)
Decay Heat (Watts/assembly)	8.0	8.0

Note:
(1) 4.57 E+13 ((γ/sec/assembly) for control rods with AIC absorber materials).
(2) Up to 2 neutron source assemblies (NSAs) and neutron sources shall only be stored in the interior compartments of the basket. Interior compartments are those compartments that are completely surrounded by other compartments, including the corners (e.g., thirteen interior compartments in Zone 1 of HLZC1 for the EOS-37PTH DSC shown in Figure 1.6.1-1).
(3) A sum of gamma sources from active fuel/plenum/top nozzle regions shown in Table 5.6.1-9.
(4) A sum of gamma sources from plenum/top nozzle regions shown in Table 5.6.1-9.

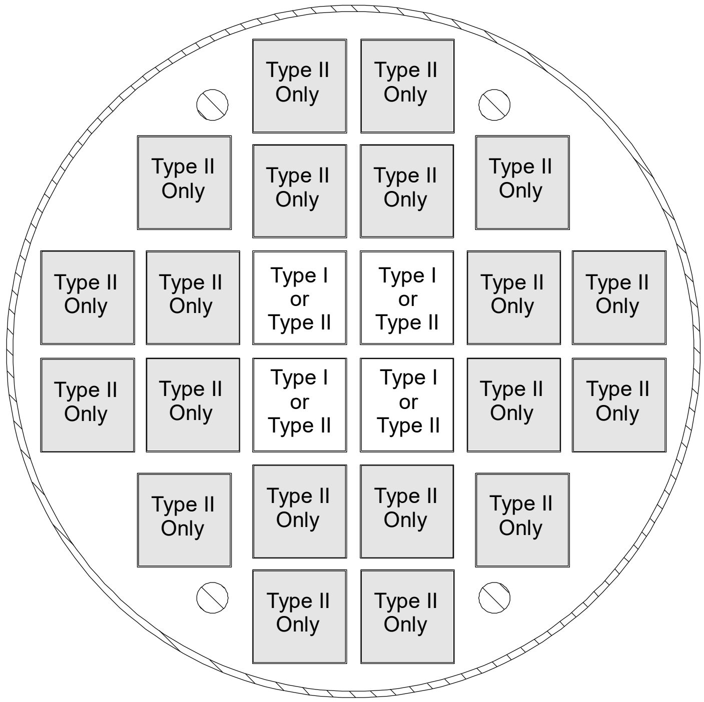

Figure 1.6.6-1
Required FO DSC and FC DSC Fuel Loading Pattern

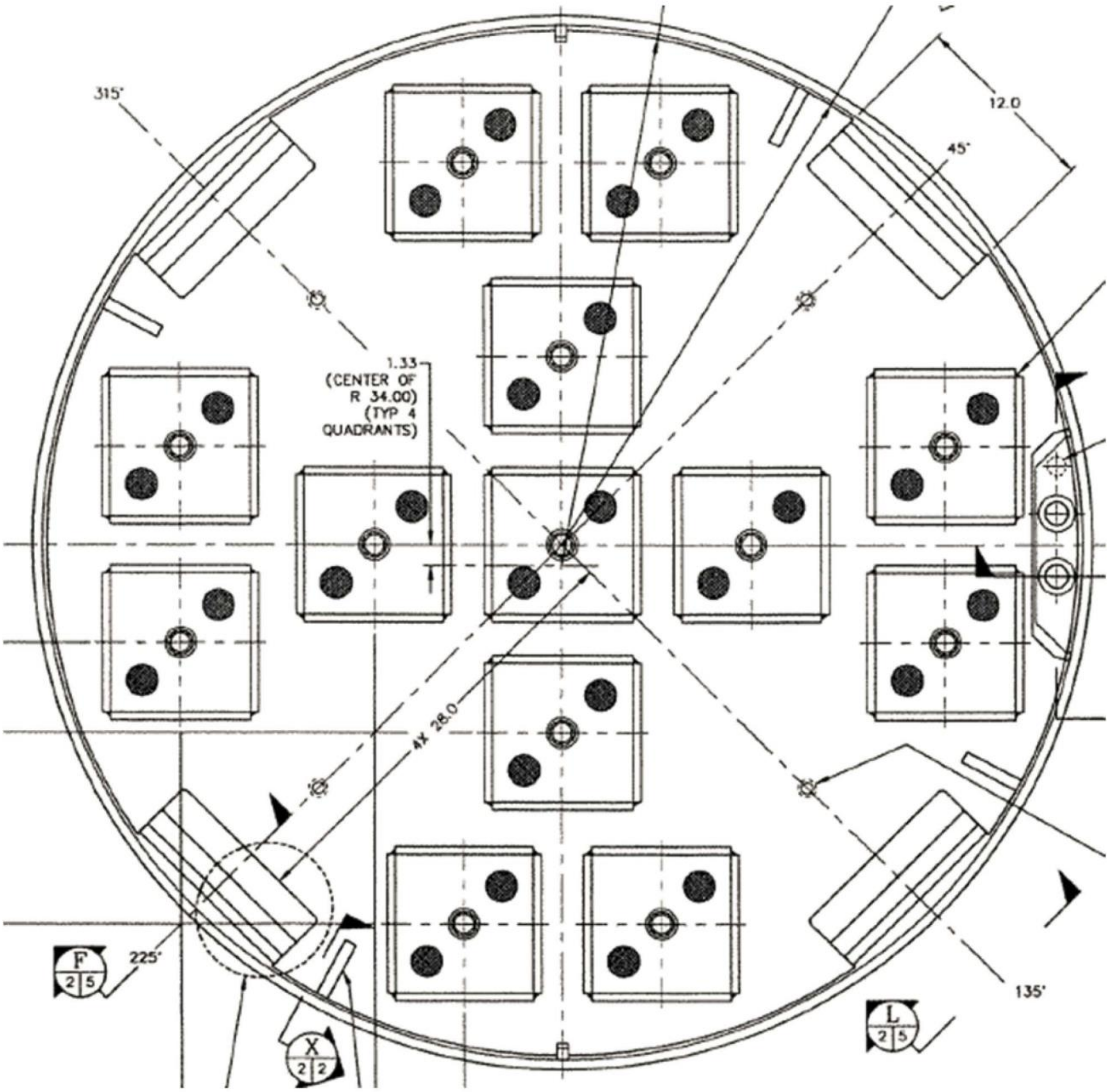

Figure 1.6.6-2
Failed Fuel Loading Configuration

Appendix 1.6.7
24PT1 DSC

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1.6.7 24PT1 DSC

1.6.7.1 24PT1 DSC Description

The 24PT1-DSC is designed to store and transport 24 WE 14x14 PWR fuel assemblies, either UO_2 (stainless steel clad) or Pu-UO_2 Mixed Oxide (MOX) Zircaloy clad fuel pellets, with or without integral control components. Provisions have been made to accommodate up to four stainless steel clad damaged or failed fuel assemblies or one damaged or failed Zircaloy clad MOX assembly in lieu of an equal number of undamaged fuel assemblies in the 24PT1-DSC. The 24PT1-DSC shell assembly is a high integrity stainless steel, welded pressure vessel similar to the FO, FC, and FF DSCs described in section 1.6.6. It provides confinement of radioactive materials; encapsulates the fuel in an inert atmosphere; and provides biological shielding during DSC closure, transfer, storage, and transport operations. As an integral welded vessel, the canister shell assembly provides containment for the fuel; however, no credit other than biological shielding is taken for this additional containment boundary in this transportation SAR. The 24PT1-DSC basket consists of circular spacer disc plates, which provide structural support for the fuel and the guide sleeves in the lateral direction. Axial support for the spacer discs is provided by four support rods, which extend over the full length of the cavity and bear on the canister top and bottom assemblies.

The 24PT1-DSC has an outside diameter of 67.19 inches and an overall length of 186.5 inches. The 24PT1-DSC has an internal cavity length of 167 inches and solid carbon steel shield plugs at each end. The shell and cover plates are fabricated from 5/8-inch Type 316 stainless steel instead of the Type 304 used for the FO, FC, and FF DSCs. The cylindrical shell, including the top and bottom cover plate assemblies, forms the pressure retaining boundary for the spent fuel and cover gas. The 24PT1-DSC is equipped with top and bottom shield plugs so that the occupational doses at the ends are minimized for drying, sealing, handling, and transfer operations. Redundant welds join the shell and the top cover plate assemblies to form the confinement boundary. The cylindrical shell and inner bottom cover plate confinement boundary welds are made during fabrication of the DSC and are fully compliant to Subsection NB of the ASME Code. The top closure confinement welds are made after fuel loading. Both top plug penetrations (siphon and vent ports) are welded after DSC drying operations are complete. Other than for biological shielding purposes, the pressure containment capability of the DSC shell assembly is conservatively neglected for transportation.

The internal basket assembly is similar to the FO/FC DSCs and contains 24 storage positions, one for each fuel assembly. The basket is composed of 26 circular spacer discs machined from carbon steel plates; the spacing of the discs has been modified from that used for the FO/FC DSCs to accommodate the WE 14x14 fuel. Axial support for the spacer discs is provided by four high strength stainless steel support rods, which extend over the full length of the DSC cavity and bear on the canister top and bottom end assemblies. The 24PT1-DSC basket assembly includes 24 guide sleeve assemblies with integral borated neutron absorbing panels. The spacer discs have openings that allow the guide sleeves and the fixed borated neutron absorber panels to pass through. No borated materials are used for structural load carrying members.

The DSC cavity is inerted with helium before being sealed. Carbon steel components are coated with a thin corrosion resistant layer of nickel to provide corrosion resistance for the short time that the DSC is in the spent fuel pool for fuel loading. After the DSC is drained, dried, inerted, and sealed for storage or transportation, there is no mechanism available for corrosion of the carbon steel components.

On the bottom of each DSC there is a grapple ring which allows the DSC to be transferred horizontally in and out of the NUHOMS® storage modules from the cask.

The 24PT1-DSC is capable of storing and transporting up to 24 WE 14x14 intact fuel assemblies (UO_2 or MOX) including control components. Up to four stainless clad damaged or failed fuel assemblies or one zircaloy clad MOX assembly may be placed in the outside corner spacer disc openings at the 45°, 135°, 225°, and 315° azimuth locations.

The Failed Fuel Canisters used in the 24PT1-DSC are similar to those used in the FF DSC, described in section 1.6.6 of this SAR, but with a smaller cross section to fit into the 24PT1-DSC guide sleeves and a different screen configuration at the bottom of the can (the FF DSC has two screened openings on the bottom plate while the 24PT1-DSC has an opening in the bottom plate and two openings in opposing side plates near the bottom of the can). The 24PT1-DSC Failed Fuel Canisters consist of seam-welded stainless steel tubes with a welded bottom lid assembly and a welded removable top lid assembly. The canisters do not contain any borated neutron absorbing materials. They provide for the confinement of the fuel pellets/shards by means of fixed bottom screens and a removable top screen. The bottom lid and top lid stainless steel screens allow for dewatering of the Failed Fuel Canisters. The bottom end of each canister includes provisions for fuel support. The fuel canister top lids are fitted with lifting provisions that interface with plant fuel handling equipment for placement of the lid and handling of the removable fuel canister. The top lid also incorporates the top fuel spacer.

1.6.7.2 Description of Spent Fuel Assemblies

The fuel design included in the 24PT1-DSC payload is WE 14x14 stainless steel clad (SC) UO_2 fuel assemblies and Mixed Oxide Zircalloy Clad (MOX, UO_2 and PuO_2) fuel assemblies with/or without control components meeting the enrichment and burnup parameters listed in Table 1.6.7-1. Minimum cooling time is also listed in the fuel qualification table (Table 8.7.3-1) to meet dose rate limits. Stainless steel clad fuel may also include Integral Fuel Burnable Absorber consisting of Boron coated fuel pellets.

Intact fuel assemblies include those with minor cladding damage, including pinhole leaks and hairline cracks, provided the cladding integrity is sufficient to prevent significant fuel particulate release. The 24PT1-DSC may be loaded with fewer than 24 fuel assemblies as long as dummy fuel assemblies are installed in all unoccupied spaces, except that two spaces may remain empty. These two empty spaces must be located on opposing symmetrical locations with respect to the 0° - 180° and 90° - 270° axes. The dummy assemblies shall have the same nominal weight as a standard fuel assembly to maintain the symmetric weight distribution in the 24PT1-DSC.

The 24PT1-DSC may include up to four damaged or failed WE 14x14 stainless steel clad (SC) fuel assemblies together with intact WE 14x14 SC fuel and/or dummy fuel assemblies based on the limitations specified above. A single damaged or failed WE 14x14 MOX fuel assembly may be stored in the 24PT1-DSC with no other damaged or failed assemblies. Damaged or failed fuel assemblies must be contained in 24PT1-DSC failed fuel canisters and are limited to the guide sleeves located in the four outside corner locations along the 45°, 135°, 225°, and 315° azimuth locations. In all cases, there may be two empty guide sleeves symmetrically located such that 22 guide sleeves contain intact fuel, dummy fuel assemblies, or failed fuel canisters.

Damaged or failed fuel stored in a 24PT1-DSC includes assemblies with known or suspected cladding defects greater than a hairline crack or a pinhole leak up to and including broken rods, portions of broken rods, and rods with missing sections. Individual fuel rods or portions of fuel rods may be stored individually in a failed fuel canister. The failed fuel canisters in which the damaged or failed fuel is stored confine gross fuel particles to a known, subcritical volume during off-normal and accident conditions and facilitate handling and retrievability. The criticality analysis provided in Chapter 6 requires that cladding damage be limited to no more than 14 fuel pins in an assembly. Visual inspection of assemblies will be performed once, prior to placement of the fuel in the DSC, which may then be placed in storage and transported anytime thereafter without further fuel inspection.

Table 1.6.7-2 provides details of fuel dimensions, weights, and shielding source terms.

1.6.7.3 Maximum Decay Heat

The maximum design basis decay heat for WE 14x14 fuel stored in the 24PT1-DSC is 14.0 kW. The maximum allowable decay heat for a single assembly, including control components, is 0.583 kW.

1.6.7.4 References

1. American Society of Mechanical Engineers, ASME Boiler and Pressure Vessel Code, Section III, Division 1 - Subsections NB, NG, and NF, 1992 Edition with Addenda through 1994, supplemented by Code Case N-595-1.

Table 1.6.7-1
WE 14x14 Spent Fuel Assembly Description

Fuel Type	Maximum Enrichment (weight %)	Minimum Enrichment (weight %)	Maximum Burnup (MWd/ MTU)	Minimum Cooling Time[1] / Max Heat Load per cask / Max Assembly Heat Load (incl. control components[1])
WE 14x14 Stainless Steel Clad (SC) (may include Integral Fuel Burnable Absorber, boron coated fuel pellets)	4.05 U-235	3.76 U-235	45,000	39 years/14 kW/ 0.583 kW
		3.36 U-235	40,000	
		3.12 U-235	35,000	
WE 14x14 MOX	0.71 U-235 • 2.84 Fissile Pu (64 rods) • 3.10 Fissile Pu (92 rods) • 3.31 Fissile Pu (24 rods)	• 2.78 Fissile Pu (64 rods) • 3.05 Fissile Pu (92 rods) • 3.25 Fissile Pu (24 rods)	25,000	39 years/13.706 kW/ 0.294 kW

Notes:
(1) Control component cooling time must be a minimum of 10 years.

Table 1.6.7-2
Westinghouse Fuel Dimensions, Weights and Source Terms

Parameter	WE 14x14 SC(1)	WE 14x14 MOX(1)
Number of Rods	180	180
Cross Section (in)	7.763x7.763	7.763x7.763
Unirradiated Length (in)	138.5	138.5
Fuel Rod Pitch (in)	0.556	0.556
Fuel Rod O.D. (in)	0.422	0.422
Clad Material	Type 304 SS	Zircaloy-4
Clad Thickness (in)	0.0165	0.0243
Pellet O.D. (in)	0.3835	0.3659
Max. initial U-235 Enrichment (wt%)	4.0	Note 2
Theoretical Density (%)	93-95	91
Active Fuel Length (in)	120	119.4
Max. U Content (kg)	375	Note 3
Ave. U Content (kg)	366.3	Note 3
Assembly Weight (lbs)	1210	1150
Max. Assembly Weight incl. NFAH(4) (lbs)	1320	1320

NFAH Source Term

Parameter	Rod Cluster Control Assemblies (RCCAs)	Thimble Plugs (TPs)	Neutron Source Assemblies (NSAs)
Gamma Source (γ/sec/assy)	7.60E+12	5.04E+12	1.20E+13
Decay heat (Watts)	1.90	1.2	1.66

(1) Nominal values shown unless stated otherwise.
(2) Mixed-Oxide assemblies with 0.71 weight % U-235 and fissile Pu weight of 2.84 weight % (64 rods), 3.10 weight % (92 rods), and 3.31 weight % (24 rods).
(3) Total weight of Pu is 11.24 kg and the total weight of U is 311.225 kg.
(4) Weights of TPAs and NSAs are enveloped by RCCAs.
(5) Up to 2 NSAs shall only be stored in the interior compartments of the basket. Interior compartments are those compartments that are completely surrounded by other compartments, including the corners (e.g., thirteen interior compartments in Zone 1 of HLZC1 for the EOS-37PTH DSC shown in Figure 1.6.1-1).

Chapter 2
Structural Evaluation

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Chapter 2
Structural Evaluation

2.1 Description of Structural Design

This chapter, including its appendices, contains the structural evaluation of the TN Eagle packaging. This evaluation consists of numerical analyses which demonstrate that the TN Eagle packaging satisfies applicable 10 CFR Part 71 requirements for a Type B(U) fissile material packaging.

2.1.1 Descriptive Information Including Weights and Centers of Gravity

The structural integrity of the TN Eagle packaging under normal conditions of transport (NCT) and hypothetical accident conditions (HAC) specified in 10 CFR Part 71 is shown to meet the design criteria described in 2.1.2.1. The TN Eagle consists of three major structural components: the cask body, one of several transportable dry shielded canisters (DSCs), and the ILs (top and bottom). Each DSC consists of a shell assembly and a basket assembly. These components are described in detail in Chapter 1.

Numerical analyses have been performed for the NCT and HAC, as well as for the lifting and tie-down loads. In general, numerical analyses have been performed for the regulatory events. These analyses of the TN Eagle packaging are summarized in the main body of this section and are described in detail in the appendices to this chapter (see complete list in Section 2.11).

2.1.1.1 Cask

The design of the cask described in Chapter 1, shows the overall transport configuration of the TN Eagle packaging. Key details of the various components of cask used in the structural analysis are provide also provided in Chapter 1 on the engineering drawings for package approval. A detailed parts list is shown on each drawing that includes all the parts with materials and codes to be considered in the analyses.

The cask is a cylindrical assembly that is open at the top end and includes a ram access at the bottom for loading and unloading operations. The forged cask body, which acts as the main component of the containment boundary, is made of [ ] The open top and bottom ends of the cask are sealed closed with the primary lid and the ram access cover plate, which are made of [ ] A series of shielding rings shrink fitted on the cylindrical forged body. These rings consist of a structural section made of [ ] and are filled with Vyal B resin for shielding purposes. The resin is not credited for structural loads.

The top ring on the cask, ahead of the shielding rings, is the handling ring which is made of [ ] This ring is fitted with a shear key slot that interfaces with the transport skid to restrain the cask from axial movement the cask during transportation. These shielding rings and handling ring are axially held into place by the flange of the forged cask body on the top end, and the presence of the bottom ring and bottom closure plate on the bottom end. The bottom closure plate is bolted to the base of the cask and is made of [ ]

The containment boundary of the TN Eagle is described in detail in Section 1.2.1 of Chapter 1 and it consists of the forged cask body, the primary lid and its bolts, and the RACP and its bolts and seals.

There are two configurations of the TN Eagle Cask, the Large Canister (LC) and the Standard Canister (SC). The designs are similar, except for the shell thickness of the forged cask body, the design of the shielding rings, and the overall length of the cavity. The LC and SC configurations are shown on engineering drawings in Chapter 1.

2.1.1.2 Impact Limiters

The TN Eagle packaging includes an impact limiter (IL) at each end of the cask body. The ILs are identical to each other, except for the location of the bolts attaching them to the cask body. The ILs consist of three main components. These are the adapter assembly, the AH blocks, and the stainless steel shell. The adapter assembly acts as the structural fixture that supports and attaches the rest of the IL to the ends of the cask. The adapter assembly is made of [ ] The stainless steel shell contains the AH blocks and keeps them in place.

The length and outside diameter of the ILs are sized to limit the cask impact loads resulting from the 1 ft NCT and 30 ft HAC drop events so that the containment vessel (and the non-containment structures) meet the design criteria.

The IL and bolts are designed to withstand the impact loads and to prevent separation of the limiters from the cask during an impact. The design of the ILs and bolts are specified on engineering drawings in Chapter 1.

2.1.1.3 Dry Shielded Canisters

The TN Eagle will accommodate several different DSCs, each containing a unique payload. The DSCs consist of an outer shell assembly that contains a basket which, in turn, supports the spent fuel assemblies (FAs). A detailed description of each DSC is provided in Chapter 1.

Detailed drawings for all DSCs are located in Chapter 1.

The shell assembly is a welded stainless steel pressure vessel that provides confinement of radioactive material, maintains inert atmosphere inside the shell, and provides biological shielding in the axial direction. [ ]

The basket is an assembly of stainless steel fuel compartments separated by poison plates and surrounded by support rails, depending on the specific design, and is designed to accommodate various numbers of pressurized water reactor (PWR) or boiling water reactor (BWR) fuel assemblies.

The basket structure is open at each end. Therefore, longitudinal fuel assembly loads are applied directly to the DSC end plates and not to the fuel basket structure. The fuel assemblies are laterally supported in the fuel compartments, and the basket is laterally supported by the support rails and the DSC shell.

2.1.1.4 Weights and Centers of Gravity

The calculated weights and centers of gravity for major components of the TN Eagle cask are presented in Table 2-1 and Table 2-2. Table 2-1 contains the information regarding the LC configuration of the TN Eagle while Table 2-2 contains the information for the SC configuration. The table also summarizes the weights and center of gravity locations for each of the DSCs considered for the TN Eagle. The center of gravity is taken in the axial direction with an origin at the interior face of the bottom of the forged body with a positive value indicating a direction toward the top of the cask. The maximum calculated weight of the loaded TN Eagle package occurs when the SC configuration is loaded with a 32PTH1-Short DSC. This weight of [ ] is bounding and will be considered in all structural calculations of the TN Eagle Cask.

2.1.2 Identification of Codes and Standards for Package Design

The cask containment and confinement components (i.e., forged cask body, primary lid, RACP, and primary lid and RACP bolts) and the shell, top outer/inner plates, inner bottom cover plate, siphon vent block, and siphon/vent port cover plate of the DSC are designed, fabricated, and inspected in accordance with the ASME Code Subsection NB to the maximum practical extent. The baskets are designed, fabricated, and inspected in accordance with ASME Code Subsection NG to the maximum practical extent. The top handling ring is designed as per ASME Code Subsection NF and fabricated and inspected as per ASME Code Subsection NB, to the maximum practical extent. Other cask components, such as the shielding rings, bottom closure plate and its bolts, bottom ring, and closing plate, are designed, fabricated, and inspected in accordance with ASME Code Subsection NF to the maximum practical extent. DSC components, such as outer bottom cover, top and bottom shield plugs, are not governed by the ASME Code. [ ]

2.1.2.1 Basic Design Criteria

2.1.2.1.1 Cask Containment Vessel

The containment vessel is described in Chapter 4 and is designed to the maximum practical extent as an ASME Class I component in accordance with the rules of the ASME Boiler and Pressure Vessel Code, Section III, Subsection NB [8]. The Subsection NB rules for materials, design, fabrication, and examination are applied to all containment boundary components to the maximum practical extent. In addition, the design meets the requirements of Regulatory Guides 7.6 [2] and 7.8 [3]. The containment boundary bolts meet the design requirements of [5]. The design criteria established in this paragraph and used in the appendices of this chapter ensure that the containment boundary remains leak tight under both NCT and HAC. The design criteria of the cask containment vessel are summarized in Table 2-3 and Table 2-4.

2.1.2.1.2 Cask Non-Containment Structure

Certain components such as the shielding rings, bottom closure plate and its bolts, top handling ring, bottom ring, and closing plate are not part of the containment vessel but do have structural functions. These components, referred to as non-containment structures, are required to withstand the containment environmental loads, and in some cases share the loads with the containment vessel. The non-containment structures are designed, fabricated, and inspected in accordance with the ASME Code Subsection NF [10], to the maximum practical extent. The top handling ring is fabricated and inspected as per ASME Code Subsection NB [8], to the maximum practical extent.

2.1.2.1.3 DSC Shell Assembly

The TN Eagle Cask is designed to carry the following DSCs:

- EOS-37PTH and EOS-89BTH licensed for storage in [17].
- 32PTH1, 32PT, and 24PT4 licensed for transportation in [15] and their respective storage licenses.
- FO/FC/FF and 24PT1 licensed for transportation in [16] and their respective storage licenses.

The components of each DSC including the shell, the top outer/inner cover plates, the inner bottom cover plate, the siphon vent block, and the siphon/vent port cover plate are designed, fabricated, and inspected in accordance with the applicable year versions of ASME Code Subsection NB and code alternatives specified in Section 1.6 of Chapter 1 to the maximum practical extent. Design criteria and methodologies specified in [15], [16], and [17] are followed in this license for new structural evaluations. The design criteria for the DSC shell assemblies are summarized in Table 2-3.

2.1.2.1.4 DSC Baskets

The baskets for all of the DSCs are designed, fabricated, and inspected in accordance with the ASME Code Subsection NG to the maximum practical extent with the applicable code year and code alternatives specified in Section 1.6 of Chapter 1.

The fuel compartment response to compressive loads is evaluated to ensure that buckling will not occur under HAC. Basket assembly allowable buckling loads are evaluated based on non-linear, large displacement, quasi-static analysis models using ANSYS or LS-DYNA by following the methodologies specified in [15], [16], and [17].

The design criteria for the DSC baskets are summarized in Table 2-5 and Table 2-6.

2.1.2.1.5 Impact Limiters

The TN Eagle is provided with an IL at each end of the cask body. The IL stainless steel shells and gussets and adapter are designed to position and confine the AH blocks. The stainless steel shells are designed to support and protect the AH blocks under normal environmental conditions. The adapter is designed to provide the means of attachment to the cask body. The IL and its bolts are designed to withstand the applied loads and to prevent separation of the limiters from the cask during an impact. The design criteria of the IL and its bolts are specified in Appendix 2.11.3.

2.1.2.1.6 Tie-Down Devices

The top handling ring and shielding rings are classified as tie-down devices as per 10 CFR 71.45 (b). As per 10 CFR 71.45 (b), any system of tie-down devices that is a structural part of the package must be capable of withstanding, without generating stress in any material of the package in excess of its yield strength given a static force applied to its center of gravity with the following components:

- 10 g longitudinal acceleration in the direction of travel
- 2 g vertical acceleration
- 5 g lateral acceleration perpendicular to the direction of travel

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Withheld Pursuant to 10 CFR 2.390

2.2 General Requirements for all packages

This section demonstrates that the TN Eagle Cask complies with the general requirements for all packages as specified in 10 CFR 71.43.

2.2.1 Minimum Package Size

The overall size of the TN Eagle Cask without the ILs is [ ] in length with a diameter of [ ]. Both of these dimensions are greater than 10 cm (4 in.), and therefore the minimum size requirements set forth by 10 CFR 71.43 (a) are satisfied.

2.2.2 Tamper-Indicating Feature

The main access path into the TN Eagle package is through the primary lid. Other entry points include the lid orifice cover plate, test port plugs, and the ram access cover plate. During transportation, the ILs will completely cover the top and bottom ends of the cask preventing access to the primary lid, lid orifice cover plate, test port plugs, and the ram access cover plate. A security wire seal is installed through the guide tubes on both the top and bottom ILs preventing access to the IL bolts. With this seal intact, it demonstrates that there has been no unauthorized entry or purposeful tampering with the package. This tamper-indication feature satisfies the requirement of 10 CFR 71.43 (b).

2.2.3 Positive Closure

All bolts leading to access into the containment vessel have a large preload applied that will protect against any inadvertent opening. These include the effects from shock, vibration, thermal expansion, and internal and external pressure. The torque on these bolts will prevent any loosening except when deliberately loosened with a wrench. As described in Section 2.2.2, the TN Eagle includes tamper-indicating features that will show any unauthorized access to the cask. Therefore, the TN Eagle cask cannot be inadvertently accessed and any evidence of unauthorized access will be detected. The positive closure satisfies the requirements included in 10 CFR 71.43 (c).

2.2.4 Package Valve

The TN Eagle cask does not have any valves or other device whose failure would allow for the escape of radioactive material. Due to this, the requirements of 10 CFR 71.43 (e) are met.

2.3 Lifting and Tie-Down Standards for All Packages

This section describes and evaluates the lifting devices used for the TN Eagle, as well as tie-down devices used to secure the package during transportation.

2.3.1 Lifting Devices

For on-site lifting and transfer operations, the TN Eagle Cask will only ever be lifted in the horizontal orientation. Due to this, the TN Eagle will be lifted using two slings, one around the top flange of the forged cask body and the other around the bottom ring.

According to 10 CFR 71.45 (a), a minimum factor of safety of three against yield is required for all lifting attachments, which are structural parts of the package. The package must also be designed in such a way that failure of any lifting device under excessive load will not impair the ability of the package to meet other requirements of 10 CFR Part 71.

The analysis of the effect of the lifting loads on the flange of the forged cask body and the bottom ring are shown in Appendices 2.11.1 and 2.11.9, respectively. These evaluations show that during a lifting load scenario, the cask parts meet a minimum factor of safety of three against the yield, as per 10 CFR 71.45 (a).

2.3.2 Tie-Down Devices

In addition to the examination of the effects of shock loads, certain components need to consider special loads required for tie-down devices as presented in 2.1.2.1.6.

During transportation, the TN Eagle package will be situated on a transport frame.

In order to account for the longitudinal acceleration, the transport frame includes a shear key that sets into the top handling ring of the TN Eagle package. This interaction on the handling ring due to the presence of a shear key during a 10 g longitudinal acceleration is analyzed.

In order to restrict movement during the vertical and lateral accelerations, the TN Eagle package rests on a pair of saddles and restrained by latches on the top side. The front saddle/latch is aligned with the top handling ring and the rear saddle/latch is aligned with the shielding rings at the bottom of the cask.

Since both the handling ring and shielding ring are seen as integral to the restraint of the cask during transportation, these two components are evaluated for the loads defined by 10 CFR 71.45 (b). Appendix 2.11.9 details the evaluation of these tie-down devices and shows that the stresses endured by these parts is less than yield and therefore meets the criteria set forth by 10 CFR 71.45 (b).

2.4 General Considerations for Structural Evaluation of Packaging

The structural evaluations for the TN Eagle Cask and its contents for NCT and HAC are performed in the appendices of this chapter. Initial conditions and load combinations are considered as per [3] to the maximum practical extend. The design criteria followed are described in Section 2.1.2.1 and are based on [2] and the appropriate ASME codes to maximum practical extend. The evaluation methods and interpretations of results for both the cask and its internals are based on previously approved licenses, such as [15], [16], and [17]. Detail descriptions of the structural evaluations and introduction and justification of other design criteria, load combinations, and methodologies are specified in the appendices of this chapter.

2.4.1 Evaluation by Analysis

The structural evaluation for the TN Eagle is performed by analysis by utilizing two computational modeling software, ANSYS [13] and LS-DYNA [14] and [17]. Detailed information of the computational models used can be found in appendices of this chapter.

2.4.2 Evaluation by Test

The TN Eagle is not evaluated structurally by test; therefore, this is section is not applicable for this license.

2.5 Normal Conditions of Transport

This section describes the response of the TN Eagle Cask to the loading conditions specified by 10 CFR 71.71. The design criteria established for the TN Eagle for the NCT are described in Section 2.1.2.1 These criteria are selected to ensure that the package performance standards specified by 10 CFR 71.43 and 71.51 are satisfied. Under NCT there is no loss or dispersal of radioactive contents, no significant increase in external radiation levels, no substantial reduction in the effectiveness of the package, and no substantial changes affecting the ability of the package to withstand hypothetical accident conditions.

Detailed structural analyses of the TN Eagle packaging components are provided in the appendices to this chapter. The limiting results from these analyses are used in their respective appendices to quantify package performance in response to the NCT load combinations, specified in 10 CFR 71.71 and Regulatory Guide 7.8. In all cases, the acceptability of the TN Eagle package design with respect to established criteria, and consequently with respect to 10 CFR Part 71 performance standards is demonstrated.

2.5.1 Heat

Chapter 3 describes the thermal analyses performed for the TN Eagle subjected to hot environment conditions (ambient temperature +38 °C). The thermal analysis results are used to support various aspects of the structural evaluations as described in the following subsections.

Allowable stresses for packaging components are a function of the component temperatures. They are based on calculated maximum temperatures or conservatively selected higher temperatures. Table 3-8 of Chapter 3 summarizes maximum temperatures calculated for the TN Eagle subjected to hot environment conditions. These temperatures are used to establish the allowable stress values for every NCT evaluated in this Safety Analysis Report. Temperatures from the analyses of Chapter 3 are applied on finite element (FE) models in Appendix 2.11.1 for the estimation of thermal stresses.

The thermal expansion evaluations of the TN Eagle Cask cavity and DSCs in both the radial and axial directions are described in Appendix 2.11.14. Based on the results of these analyses, there is adequate clearance between the various components of the DSC and cask to allow free thermal expansion. Consequently, no significant stress will develop in the TN Eagle Cask due to thermal expansion of the DSCs.

[ ]

2.5.2 Cold

Chapter 3 describes the thermal analyses performed for the TN Eagle subjected to cold environment conditions (ambient temperature -40 °C). Temperatures from the analyses of Chapter 3 are applied on FE models of Appendix 2.11.1 for the estimation of thermal stresses. The differential thermal expansion of the cask and the outer rings is addressed as per Section 2.5.1

2.5.3 Reduced External Pressure

10 CFR 71.71 (c) (3) requires the evaluation of the package for a reduced external pressure of 25 kPa absolute. The maximum normal operating pressure (MNOP) is mentioned in Table 3-12 of Chapter 3 and is equal to 12.1 psig (= 83.5 kPa). The greatest possible pressure difference is 159.9 kPa (= 83.5 kPa + 101.325 kPa – 25 kPa) outwards. The analyses in Appendix 2.11.1 consider a bounding outward pressure of 210 kPa applied at the inner surfaces of the cask cavity.

2.5.4 Increased External Pressure

10 CFR 71.71 (c) (4) requires the evaluation of the package for an increased external pressure of 140 kPa absolute. A cask cavity pressure of 0 kPa absolute is considered. The greatest possible pressure difference is 140 kPa inwards. The analyses in Appendix 2.11.1 consider a bounding inwards pressure of 175 kPa applied at the outer surfaces of the cask.

2.5.5 Vibration and Fatigue

The evaluation of the package design for the effects of vibration (and shock) normally incident to transport is based on the rail car accelerations for vibration and shock specified in [4]. The peak accelerations for vibration per direction are 0.19 g longitudinal, 0.19 transverse, and 0.37 g vertical. The maximum accelerations for shocks are 4.7 g longitudinal, 4.7 transverse, and 4.7 g vertical.

The accelerations due to vibration and shocks are considered at the center of gravity of the package and their effect is considered as reaction loads on the cask at its interface with the saddles, latches, and shear key. These accelerations are used in the structural analyses for the containment boundary in Appendix 2.11.1 and combined with other load cases as shown in Table 2.11.1-3. They are also used in the analyses of the primary lid and ram access cover plate bolts in Appendix 2.11.4.

Fatigue evaluation for the containment boundary is documented in detail in Appendix 2.11.8 for the containment boundary (excluding bolts) and in Appendix 2.11.4 for the primary lid and ram access cover plate bolts.

[ ]

2.5.6 Water Spray

All exterior surfaces of the TN Eagle cask are metallic and with silicone sealant between the rings and, therefore, not affected by soaking. Additionally, the outer shells and the adapter of the ILs completely enclose the aluminum honeycomb (AH). Therefore, no structural degradation will result from water absorption. The water spray condition is therefore of no consequence to the TN Eagle cask.

2.5.7 Free Drop

The TN Eagle Cask is always at a horizontal position during handling. Therefore, only the 1 ft side drop is considered as a credible event. For this event the ILs are attached. The cask is analyzed in LS-DYNA [14] described in detail in Appendix 2.11.3. The stress analysis is performed in Appendix 2.11.1 and combined with other load cases as shown in Table 2.11.1-3. The 1 ft side drop is not a credible event for the primary lid and RACP bolts.

[ ]

2.5.8 Corner Drop

This test does not apply to the TN Eagle Cask since the mass of the package is in excess of 100 kg.

2.5.9 Compression

This test does not apply to the TN Eagle cask since the mass of the package is in excess of 5,000 kg.

2.5.10 Penetration

Due to lack of sensitive external protuberances, the one-meter drop of a 6 kg steel cylinder of 32 mm diameter with a hemispherical head is of negligible consequence to the TN Eagle Cask.

2.5.11 Fabrication Stresses

The TN Eagle Cask is subjected to fabrication stresses due to the shrink fit of the top handling ring, shielding rings, closing plate, and bottom ring on the forged cask body.
[

]

2.5.12 Primary Lid and Ram Access Cover Plate Bolts NCT Analysis

The lid bolts are analyzed in Appendix 2.11.4 for the NCT loading conditions as described in NUREG/CR-6007 [5].

The bolt preload is calculated to withstand the bounding NCT load combination and to maintain a compressive force on the closure joint. Based on the results in Appendix 2.11.4, it is shown that a positive (compressive) load is maintained during NCT conditions and therefore preserving the leak-tight boundary.

[ ]

A summary of the calculated stresses for the primary lid and ram access cover plate bolts for NCT loads is located in Appendix 2.11.4.

2.5.13 DSC Shell Assembly NCT Analysis

The DSC shell assembly are analyzed for a combination of the inertia loads resulting from the 1 ft free drop, internal and external pressures and thermal loads.The side drop on the bottom rails at the 180° direction is the only credible event. The inertia loads applied on the canisters are amplified by the corresponding dynamic load factors (DLFs) calculated in Appendix 2.11.6. The stress analyses for the canisters are presented in Appendices 2.11.10 and 2.11.11.

2.5.14 DSC Baskets NCT Analysis

The DSC baskets are analyzed for a combination of the inertia loads resulting from the 1 ft free drop and thermal loads. The side drop on the bottom rails at the 180° direction is the only credible event. The inertia loads applied on the baskets are amplified by the corresponding DLFs calculated in Appendix 2.11.6. The stress analyses for the DSC baskets are presented in Appendices 2.11.10 and 2.11.12.

2.5.15 Fuel Assemblies NCT Analysis

The FAs are analyzed for the inertia loads resulting from the 1 ft free drop. As per Section 2.5.7 only the 1 ft side drop is a credible event for the TN Eagle. The analyses for the FAs are presented in Sections 2.11.13.

2.6 Hypothetical Accident Conditions

This section describes the response of the TN Eagle Cask for the hypothetical accident condition loads specified by 10 CFR 71.73. The design criteria established for the TN Eagle packaging for the HAC are described in Section 2.1.2.1. These criteria are selected to ensure that the packaging performance standards specified by 10 CFR 71.51 are satisfied.

Detailed structural analyses of the TN Eagle packaging components are provided in the appendices to this chapter. The limiting results from these analyses are used in their respective appendices to quantify package performance in response to the HAC loads. In all cases, the acceptability of the TN Eagle Cask design with respect to HAC loads is demonstrated.

2.6.1 Free Drop

The response of the TN Eagle Cask is evaluated for a free drop from a height of 30 feet onto an unyielding surface at various orientations. The rigid body accelerations at the TN Eagle Cask are determined in the LS-DYNA [14] analyses presented in Appendix 2.11.3. The drop orientations analyzed are:

- End drop onto primary lid end
- End drop onto bottom end
- Side drop
- Center of gravity (CG) over corner drop on primary lid end
- CG over corner drop on bottom end
- 10° slap-down impact on primary lid end
- 10° slap-down impact on bottom end
- 20° slap-down impact on primary lid end
- 20° slap-down impact on bottom end

Appendix 2.11.3 demonstrates adequacy of the IL from preventing the cask from a hard impact on an unyielding surface and the ability of the IL bolts to keep the IL attached on the cask after the drops. The stress analyses of the containment boundary and its bolts are performed in Appendices 2.11.2 and 2.11.4.

The inertia loading on the cask is amplified and applied on its contents using the DLF evaluation performed in Appendix 2.11.6. [

]

2.6.2 Crush

This test does not apply to the TN Eagle since the mass of the package is in excess of 5,000 kg.

2.6.3 Puncture

An evaluation of the puncture drop as specified by 10 CFR 71.73(c) (3) is presented in Appendix 2.11.5 where the most onerous cases of drop from a distance of 1 m onto a vertical puncture bar are considered. [ ] The specified puncture bar is a 150 mm diameter solid, vertical, cylindrical, mild steel bar.

2.6.4 Thermal

Chapter 3 describes the thermal analyses performed for the TN Eagle subjected to thermal fire accident case. These thermal analysis results are used to support various aspects of the structural evaluations. The structural evaluation of the effects of thermal fire accident case as per Note 5 of Table 1 of [3] is performed in Appendix 2.11.2. The material properties used in the analysis are taken at [ ], which bounds the maximum temperatures of the containment boundary for HAC shown in Table 3-16 of Chapter 3. The analysis considers an internal pressure of [ ] pressure for HAC shown in Table 3-12 of Chapter 3.

2.6.5 Immersion – Fissile Material

The DSC and cask stresses for this immersion condition with a head of water at 0.9 m are bounded by the immersion condition for all packages (water head at least 15 m) described in Section 2.6.6.

2.6.6 Immersion – All Material

The immersion loading condition results in an external pressure applied to the body corresponding to a 15 m head of water (150 kPa). This TN Eagle Cask is analyzed for [ ] external pressure in Appendix 2.11.2. [ ]

2.6.7 Primary Lid and Ram Access Cover Plate Bolts

The primary lid and RACP bolts are analyzed in Appendix 2.11.4 for the HAC loading conditions as described in NUREG/CR-6007 [5].

The primary lid and RACP bolts are evaluated for the 30 ft HAC drop case as well as the immersion load case. The puncture load case is not analyzed as the ILs will encase both the lid and ram access cover plate during transportation and will take the puncture load. Appendix 2.11.3 shows that the bounding scenario is the 30 ft corner drop and that the calculated stresses in the bolts are less than the allowables as per [5].

A summary of the calculated stresses for the primary lid and ram access cover plate bolts for HAC loads is located in Appendix 2.11.4.

2.6.8 DSC Shell Assemblies HAC Analysis

The DSC shell assemblies are analyzed for a combination of the inertia loads resulting from the 30 ft free drop, internal and external pressures. The canisters are designed for side and end drops at acceleration magnitudes that bound all other drops orientations. The inertia loads applied on the canisters are amplified by the corresponding DLFs calculated in Appendix 2.11.6. The stress analyses for the DSC canisters are presented in Appendices 2.11.10 and 2.11.11.

2.6.9 DSC Baskets HAC Analysis

The DSC baskets are analyzed for the inertia loads resulting from the 30 ft free drop. The DSC canisters are designed for side and end drops at acceleration magnitudes that bound all other drops orientations. The inertia loads applied on the baskets are amplified by the corresponding DLFs calculated in Appendix 2.11.6. The stress analyses for the DSC baskets are presented in Appendices 2.11.10 and 2.11.12.

2.6.10 Fuel Assemblies HAC Analysis

[

]

2.7 Air Transport Accident Conditions for Fissile Material

This section does not apply to the TN Eagle cask because the package will not be transported by air. Thus, the requirements specified in 10 CFR 71.55 (f) are not evaluated.

2.8 Special Requirements for Type B Packages Containing More Than 10^5 A_2

This section does not apply to the TN Eagle Cask because the package will not transport irradiated nuclear fuel with activity greater than 10^5 A_2 curies. Thus, the requirements of 10 CFR 71.61 are not evaluated.

2.9 Air Transport of Plutonium

This section does not apply to the TN Eagle cask because the package will not be transported by air. Thus, the requirements specified in 10 CFR 71.74 are not evaluated.

2.10 References

1. 10 CFR Part 71, Packaging and Transportation of Radioactive Material.

2. NRC, Regulatory Guide 7.6, Revision 1, “Design Criteria for the Structural Analysis of Shipping Cask Containment Vessels,” 1978.

3. NRC, Regulatory Guide 7.8, Revision 1, “Load Combinations for the Structural Analysis of Shipping Casks for Radioactive Material,” 1989.

4. NRC, NUREG 766510, “Shock and Vibration Environments for Large Shipping Containers on Rail Cars and Trucks,” 1977.

5. NRC, NUREG/CR-6007, “Stress Analysis of Closure Bolts for Shipping Casks,” 1992.

6. **[**

   ]

7. ASME, B&PVC, Section II, Part D, 2017.

8. ASME, B&PVC, Section III, Division 1, Subsection NB, 2017.

9. ASME, B&PVC, Section III, Division 1, Subsection NG, 2017.

10. ASME, B&PVC, Section III, Division 1, Subsection NF, 2017.

11. ASME, B&PVC, Section III, Appendices, 2017.

12. ASME, B&PVC, Section XI, Div. 1, “Rules for inspection and Testing of Components of Light-Water-Cooled Plants,” 2017.

13. ANSYS Computer Code and User’s Manual, Release 17.1.

14. LS-DYNA Version 7.0.0, Revision 79055.

15. Orano TN, “NUHOMS®-MP197 Transportation Package Safety Analysis Report,” Revision 20. Docket No. 07109302.

16. Orano TN, “Safety Analysis Report for the NUHOMS®-MP187 Multi-Purpose Cask,” Revision 17. Docket No. 07109255.

17. Orano TN, “NUHOMS® EOS System Updated Final Safety Analysis Report”, Revision 3. Docket No. 07201042.

18. NRC, NUREG/CR-1815, “Recommendations for Protecting Against Failure by Brittle Fracture in Ferritic Steel Shipping Containers Up to Four Inches Thick,” 1981.

Table 2-1
TN Eagle LC Configuration Calculated Weights and Centers of Gravity

Component		Weight (kg)	CG (mm)[1]
Cask Body (No Lid, Ram Access Cover Plate, or ILs)		[	
Cask Lid[2]			
Ram Access Cover Plate[2]			
Top IL[2]			
Bottom IL[2]			
Contents (Maximum Loaded DSC and Spacer, if Required)	EOS 37PTH – Short[3]		
	EOS 37PTH – Medium		
	EOS 89BTH – Short		
	EOS 89BTH – Medium		
Fully Loaded TN Eagle (with Maximum Content Weight)[3]			]

(1) Axial CG taken with respect to the origin located at the interior surface of the bottom of the forged body with a positive value indicating a direction toward the top of the cask.
(2) Includes the attachment bolts for the component.
(3) [
]

Table 2-2
TN Eagle SC Configuration Calculated Weights and Centers of Gravity

Component		Weight (kg)	CG (mm)(1)
Cask Body (No Lid, Ram Access Cover Plate, or ILs)		[	
Cask Lid(2)			
Ram Access Cover Plate(2)			
Top IL(2)			
Bottom IL(2)			
Contents (Maximum Loaded DSC, Sleeve, and Spacer, if Required)	FC		
	FO		
	FF		
	24PT1		
	24PT4		
	32PT – S100		
	32PT – S125		
	32PT – L100		
	32PT – L125		
	32PTH1 – Short (3)		
	32PTH1 – Medium		
	32PTH1 – Long		
Fully Loaded TN Eagle (with Maximum Content Weight)(3)			]

(1) Axial CG taken with respect to the origin located at the interior surface of the bottom of the forged body with a positive value indicating a direction toward the top of the cask.
(2) Includes the attachment bolts for the component.
(3) [ ]

Table 2-3
Containment Vessel and DSC Shell Stress Limits [3]

Classification	Stress Intensity Limit
NCT (Level A)[1]	
P_m	S_m
P_l	1.5 S_m
(P_m or P_l)+P_b	1.5 S_m
(P_m or P_l)+P_b+Q	3.0 S_m
(P_m or P_l)+P_b+Q+F	S_a
Shear Stress	0.6 S_m
Bearing Stress	S_y
HAC (Level D)[2]	
P_m	Lesser of 2.4 S_m or 0.7 S_u
P_l	Lesser of 3.6 S_m or S_u
(P_m or P_l)+P_b	Lesser of 3.6 S_m or S_u
Shear Stress	0.42 S_u

Notes:

1. Classification and stress limits are defined in [2] and [8]. [ ]
2. Classification of stress limits are defined in [2] and Appendix XXVIII of [11].
3. [ ]

Table 2-4
Containment Bolt Stress Limits (1)

Classification	Stress Intensity Limit
NCT (Level A)(1)	
Average Tensile Stress	2/3 S_y
Average Shear Stress	0.4 S_y
Combined Stress Intensity	0.9 S_y
Bearing Stress	S_y
HAC (Level D)(2)	
Average Tensile Stress	Lesser of S_y or 0.7 S_u
Average Shear Stress	Lesser of 0.6 S_y or 0.42 S_u
Combined Stress Intensity	S_u
Combined Shear and Tension	$R_t^2 + R_s^2 < 1$

Notes:
1. Classification and stress limits are defined in [5].
2. R_t is the ratio of the average tensile stress to allowable average tensile stress and R_s is the ratio of the average shear stress to allowable average shear stress.

Table 2-5
DSC Basket Stress Limits (3)

Classification	Stress Intensity Limit
NCT (Level A)(1)	
P_m	S_m
P_l	1.5 S_m
(P_m or P_l)+P_b	1.5 S_m
(P_m or P_l)+P_b+Q	3.0 S_m
(P_m or P_l)+P_b+Q+F	S_a
Shear Stress	0.6 S_m
HAC (Level D)(2)(4)	
P_m	Lesser of 2.4 S_m or 0.7 S_u
P_l	Lesser of 3.6 S_m or S_u
(P_m or P_l)+P_b	Lesser of 3.6 S_m or S_u
Shear Stress	0.42 S_u

Notes:
1. Classification and stress limits are defined in [8]. [

   ]
2. Classification of stress limits are defined in Appendix XXVII of [11].
3. Criteria used for DSC baskets in [15], [16], and [17] are also applicable.
4. [

   ]

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2.11 APPENDICES

2.11.1 TN EAGLE CASK NCT EVALUATION

2.11.2 TN EAGLE CASK HAC EVALUATION

2.11.3 TN EAGLE CASK DROP ANALYSES

2.11.4 PRIMARY LID AND RAM ACCESS COVER PLATE BOLT STRESS EVALUATION

2.11.5 TN EAGLE CASK PUNCTURE EVALUATION

2.11.6 TN EAGLE DYNAMIC LOAD FACTOR DETERMINATION

2.11.7 TN EAGLE CASK FINITE ELEMENT MODEL

2.11.8 TN EAGLE CONTAINMENT BOUNDARY FATIGUE EVALUATION

2.11.9 NON-CONTAINMENT BOUNDARY EVALUATION

2.11.10 EVALUATION OF NON-EOS CONTENTS FOR TRANSPORTATION IN THE TN EAGLE CASK

2.11.11 EOS-37PTH AND EOS-89BTH DSC SHELL NCT AND HAC EVALUATION

2.11.12 EOS BASKET NCT AND HAC EVALUATION

2.11.13 TN EAGLE EVALUATION OF THE FUEL ASSEMBLIES UNDER IMPACT LOADS

2.11.14 TN EAGLE CASK THERMAL EXPANSION EVALUATION

Appendix 2.11.1
TN Eagle Cask NCT Evaluation

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2.11.1 TN Eagle Cask NCT Evaluation

2.11.1.1 Introduction

The objective of this appendix is to demonstrate the structural adequacy of the TN Eagle transportation cask against Normal Conditions of Transport (NCT) loads as per 10 CFR 71.71 requirements.

2.11.1.2 Cask and FE Model Description

Material properties of the modeled parts can be found in Chapter 7.

2.11.1.3 Design Criteria

The acceptability of the packaging design is assessed by stress criteria based on ASME code, Section III, Subsection NB requirements [4]. These criteria are tabulated in Table 2.11.1-1 and applied to obtain the stress allowables for each part, which are shown in Table 2.11.1-2.

2.11.1.4 Load Cases and Combinations

Analyzed load cases represent a range of limiting mechanical and thermal loading conditions along with their combinations that are compliant with regulatory requirements and serving as structural design bases for the TN Eagle transportation cask packaging at normal transport conditions [1].

Table 2.11.1-3 lists all performed load cases and combinations.

2.11.1.4.1 DSC Mass

The weight of the contents of the TN Eagle is applied on the inner surface of the forged cask body [ ] The pressure is assumed to be uniform along the entire longitudinal span of the cask cavity. The weight that is considered for this anlaysis bounds the maximum weight of a DSC that will fit into the TN Eagle, [ ] as per Section 2.1.1.4 of Chapter 2.

2.11.1.4.2 Impact Limiter (IL) Mass

The IL [ ] the top and the bottom. This bounds the calculated mass of the IL as per Section 2.1.1.4 of Chapter 2.

[ ]

For accelerations in the axial direction of the forged body, the weight of the IL is applied as follows:

[ ]

2.11.1.4.3 Reaction due to 3 g lifting

The reaction due to 3 g lifting is applied in the same area as the IL weight. See previous section for details.

[ ]

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[ ]

2.11.1.4.10 1 ft Free Drop

The TN Eagle cask is also evaluated for a 1 ft free drop as per the requirements of [1]. The analyses for the 1 ft free drop are [ ]. Stresses from Appendix 2.11.3 are used in this calculation, combined appropriately with other load cases, and assessed against the NCT stress criteria. [ ]

2.11.1.5 Boundary Conditions

The purpose of the boundary conditions is to simulate symmetry and to prevent rigid body movement. All cases that use a symmetrical model incorporate symmetrical boundary conditions at the plane of symmetry.

To prevent rigid body motion, a few nodes are constrained in the vertical and axial direction for each load case. The reaction loads on these nodes are numerically insignificant.

2.11.1.6 Stress Results

The screened stress combination results from all possible load combinations for the forged body and the primary lid are shown in Table 2.11.1-4 and Table 2.11.1-5 and compared to the allowables.

2.11.1.7 Conclusion

The stress assessments documented in Table 2.11.1-4 and Table 2.11.1-5 show that the TN Eagle transportation cask package satisfies imposed ASME and 10 CFR 71.45 stress criteria for normal conditions of transport.

2.11.1.8 References

1. NRC, Regulatory Guide 7.8, Revision 1, “Load Combinations for the Structural Analysis of Shipping Casks for Radioactive Material,” 1989.

2. NRC, Regulatory Guide 7.6, Revision 1, “Design Criteria for Structural Analysis of Shipping Cask Containment Vessels,” 1978.

3. Welding Research Council, Bulletin-429, “Design Criteria Guidelines for Application,” 1998.

4. ASME, B&PVC, Section III, Division 1, Subsection NB, 2017.

5. ASME, B&PVC, Section III, Appendices, 2017.

6. NRC, NUREG-766510, “Shock and Vibration Environment for Large Shipping Containers on Rail Cars and Trucks,” 1977.

7. **[**

]

8. ANSYS Computer Code and User’s Manual, Release 17.1.

Table 2.11.1-1
TN Eagle Cask Containment

Stress Category	Allowable Stress
Primary Membrane General P_m Local P_L	 S_m $1.5*S_m$
Primary Membrane + Bending (P_m or P_L) + P_b	 $1.5*S_m$
Range of Primary + Secondary (P_m or P_L) + P_b +Q	$3.0*S_m$
Bearing Stress	S_y
Average Shear Stress	$0.6*S_m$

Table 2.11.1-2
TN Eagle Cask Acceptance Criteria

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Appendix 2.11.2
TN Eagle Cask HAC Evaluation

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2.11.2 TN Eagle Cask HAC Evaluation

2.11.2.1 Introduction

This appendix documents the structural evaluation of the TN Eagle for the loading conditions specified in 10 CFR 71.73 and the load combinations outlined in Table 1 of [5]. The stress criteria used are as per [4], Article NB-3000 of [6] and Mandatory Appendix XXVII of [7].

This appendix uses the finite element (FE) model from Appendix 2.11.1 for all load cases **[**

]

This appendix evaluates the containment boundary of the TN Eagle, except for the primary lid and ram access cover plate (RACP) bolts, which are evaluated in Appendix 2.11.4.

2.11.2.2 Analyses

2.11.2.2.1 30 ft Free Drops

The 30 ft free drop load combination evaluates the TN Eagle containment boundary for the set of 30 ft drops presented in Appendix 2.11.3. **[**

]

[

]

2.11.2.2.2 Fire Accident

The fire accident load combination evaluates the TN Eagle containment boundary at post-fire steady-state conditions at 30 minutes after the fire. An internal pressure of [ ] is applied on the inner surface of the containment boundary. This pressure bounds the internal pressure of [ ] presented in Section 3.4.4.1 of Chapter 3. [ ] The weights of the cask (including the non-modelled parts), internals (i.e., canister, basket, and fuel assemblies (FAs)), and impact limiters (ILs) are included in the load combination.

2.11.2.2.3 Immersion

The Immersion load combination evaluates the TN Eagle containment boundary for immersion under a head of water of at least 15 m. An external pressure of [ ] This pressure bounds the external pressure of 150 kPa required by 10 CFR 71.73 (c) (6). The weights of the cask (including the non-modelled parts), internals (i.e., canister, basket, and FAs), and ILs are included in the load combination. [ ]

2.11.2.2.4 Summary of HAC Evaluations

The stress results from the HAC load combinations, shown in Table 2.11.2-3, meet the stress criteria for a hypothetical accident condition (HAC) set by [4], Article NB-3000 of [6] and Mandatory Appendix XXVII of [7]. These results show that the HAC load combination specified in Table 1 of [5] do not adversely affect the structural integrity of the containment boundary.

2.11.2.3 References

1. LS-DYNA Version R7.0, Keyword User’s Manual, Volume I.

2. LS-DYNA Version R7.0, Keyword User’s Manual, Volume II, “Material Models.”

3. ANSYS Computer Code and User’s Manual, Release 17.1.

4. NRC, Regulatory Guide 7.6, Rev. 1, “Design Criteria for the Structural Analysis of Shipping Cask Containment Vessels,” 1978.

5. NRC, Regulatory Guide 7.8, Rev. 1, “Load Combinations for the Structural Analysis of Shipping Casks for Radioactive Material,” 1989.

6. ASME, B&PVC, Section III, Division 1, Subsection NB, 2017.

7. ASME, B&PVC, Section III, Appendices 2017.

Table 2.11.2-1
Allowable Stresses for HAC

Stress Category	Allowable Stress
Primary Membrane Stress P_m(1)	min($2.4S_m$;$0.7S_u$)
Primary Membrane (or Local Membrane) + Bending (P_m or P_L) + P_b(1)	min($3.6S_m$;S_u)
Average Shear Stress	<$0.42S_u$
Bearing Stress	N/A

Notes:
1. Allowables stresses as per [4].

Table 2.11.2-2
Stress Allowables

Table 2.11.2-3
Stress Results Table

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Appendix 2.11.3
TN Eagle Cask Drop Analyses

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2.11.3 TN Eagle Cask Drop Analyses

2.11.3.1 Introduction

This appendix documents the analyses for the TN Eagle cask for the 1 ft normal conditions of transfer (NCT) and 30 ft hypothetical accident conditions (HAC) free drop events required by 10 CFR 71.71 (c) (7) and 10 CFR 71.73 (c) (1), respectively.

The free drop events analyzed are:

1. 30 ft End Drop
2. 30 ft Side Drop
3. 30 ft Center-of-Gravity (CG)-over-Corner Drop
4. 30 ft 10° Slap-Down
5. 30 ft 20° Slap-Down
6. 1 ft Side Drop

This appendix discusses the following:

1. The adequacy of the impact limiters (ILs) to prevent hard impact of the transportation cask with a flat, unyielding, horizontal surface.
2. The determination of the upper bound rigid body accelerations on the transportation cask.
3. The adequacy of the IL bolts for the 1 ft NCT and the 30 ft HAC free drops.
4. The adequacy of the adapter of the IL for the 1 ft NCT and the 30 ft HAC free drops.

The free drop events are analyzed for the following two temperature conditions:

<u>COLD conditions (bounding rigid body accelerations):</u>

[ ]

<u>HOT conditions (bound hard impact):</u>

[ ]

The AH material properties are shown in Table 2.11.7-6.

2.11.3.2 Finite Element Model Description and Setup

The finite element (FE) model used in this appendix is described in detail in Appendix 2.11.7. The model setup for the drop analyses is described in detail in this appendix.

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2.11.3.3 Analyses Results

2.11.3.3.1 Accelerations, Deformations, and Energy Plots

2.11.3.3.2 IL Bolt Evaluation

The purpose of this section is to evaluate the structural adequacy of the IL bolts for NCT and HAC. The allowable criteria for the IL bolts for NCT and HAC are shown in Table 2.11.3-2 and Table 2.11.3-3, respectively.

[ ]

Based on the above, the IL adapter is adequate for the HAC drop events.

2.11.3.4 References

1. [ ]

2. ASME Guidance Document (Draft), “Use of Explicit Finite Element Analysis for the Evaluations of Nuclear Transport and Storage Packages in Energy-Limited Impact Events.”

3. LS-DYNA Version R7.0, Keyword User’s Manual, Volume I.

4. LS-DYNA Version R7.0, Keyword User’s Manual, Volume II, “Material Models.”

5. NRC, Regulatory Guide 7.6, Rev. 1, “Design Criteria for the Structural Analysis of Shipping Cask Containment Vessels,” 1978.

6. NRC, Regulatory Guide 7.8, Rev. 1, “Load Combinations for the Structural Analysis of Shipping Casks for Radioactive Material,” 1989.

7. NRC, NUREG/CR-3966, “Methods for Impact Analysis of Shipping Containers,” 1987.

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Appendix 2.11.4
Primary Lid and Ram Access Cover Plate Bolt Stress Evaluation

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2.11.4 Primary Lid and Ram Access Cover Plate Bolt Stress Evaluation

2.11.4.1 Introduction

This appendix analyzes the ability of the primary lid and the ram access cover plate (RACP) bolts to maintain a leak-tight seal under NCT and HAC events. This appendix also evaluates the stresses on the bolt threads as well as bolt fatigue. The stress analysis is performed in accordance with NUREG/CR-6007 [1].

Chapter 1 contains reference drawings used for the primary lid and RACP bolt analysis.

The bolt materials and mechanical properties are listed in Table 2.11.4-1. The complete list of design inputs and their values used in this calculation are listed in Table 2.11.4-3 and Table 2.11.4-4 for the primary lid and RACP, respectively.

2.11.4.2 Methodology

The following ways to minimize bolt forces and bolt failures for shipping casks are taken directly from page xiii of [1]. All of the following design methods are employed in the TN Eagle closure system:

- Protect primary lid from direct impact to minimize bolt forces generated by free drops and puncture drops.
- Use materials with similar thermal properties for the closure bolts, the primary lid, and the cask wall to minimize the bolt forces generated by fire accident.
- Apply a sufficiently large bolt preload to minimize fatigue and loosening of the bolts by vibrations.
- Lubricate bolt threads to reduce the required preload torque and to increase the predictability of the achieved preload.
- Use primary lid design which minimizes the prying actions of applied loads.
- When choosing a bolt preload, pay special attention to the interactions between the preload and the thermal load and between the preload and the prying action.

The following evaluations are made in this calculation:

- Bolt preload
- Gasket seating load
- Internal pressure loads
- Temperature loads
- Impact load
- Puncture load
- External pressure load
- Thread engagement length evaluation
- Bearing stress

- Load combinations for normal and accident conditions
- Bolt stresses and allowable stresses

The following load combinations are considered in the analysis:

1. Preload + Temperature Load (Normal Conditions)
2. Internal Pressure + Impact Load (Accident Conditions)
3. External Pressure (Accident Conditions)

2.11.4.3 Primary Lid Bolt Evaluation

2.11.4.3.1 Individual Load Calculations

<u>Bolt Preload</u>

The method of analysis is described in Table 4.1 of [1].

Bolt preload for minimum torque:

Bolt preload for maximum torque:

Residual torsional moment for minimum torque:

Residual torsional moment for maximum torque:

<u>Gasket Seating Load</u>

An elastomer O-ring is used and therefore the gasket seating load is negligible as described in Section 2.3 of [1].

<u>Internal Pressure Load</u>

The analysis is described in Table 4.3 of [1].

The internal pressure of the cask is [ ], which is based on the maximum normal operating pressure established in Section 2.5.3 of Chapter 2. To maximize the effect of the internal pressure, the external pressure of the cask is assumed to be 0 MPa.

The non-prying tensile bolt force:

[ ]

The fixed-edge primary lid force:

[ ]

The fixed-edge primary lid moment:

[ ]

<u>Temperature Load</u>

The analysis is described in Table 4.4 of [1].

[ ]

The non-prying tensile bolt force:

[ ]

Impact Load

The analysis is described in Tables 4.5 and 4.6 of [1].

For this evaluation, the corner drop is analyzed with a drop angle of 70°. Only the accident condition is considered in this evaluation because it is the bounding case.
[ ]

The weight of the contents and the weight of the primary lid are taken to be
[ ] These values bound the weights presented in Section 2.1.1.4 of Chapter 2.

The non-prying tensile bolt force:

[ ]

The fixed-edge primary lid force:

[ ]

The fixed-edge primary lid moment:

[ ]

Puncture Load

[ ]

External Pressure Load (Immersion)

The analysis is described in Table 4.3 of [1].

[ ] To maximize the effect of the external pressure, the internal pressure of the cask is taken to be 0 MPa.

[ ]

Additional Prying Bolt Force

The analysis is described in Table 2.1 of [1].

Bending Moment Bolt Force

The analysis is described in Table 2.2 of [1].

The bending moment bolt force:

Summary

The individual loads acting on the closure bolts of the primary lid calculated in Section 2.11.4.3.1 are listed in Table 2.11.4-5.

2.11.4.3.2 Load Combinations

The analysis is described in Table 4.9 of [1].

A summary of normal and accident load combinations is shown in Table 2.11.4-6.

2.11.4.3.3 Stress Calculations

The analysis is described in Table 5.1 of [1].

Allowable Stresses

The allowable stresses for the primary lid bolts can be seen in Table 2.11.4-2.

Average Tensile Stress

The average tensile stress caused by the tensile bolt force F_a for normal conditions:

[ ]

The average tensile stress caused by the tensile bolt force F_a for accident conditions:

[ ]

Bending Stress

The bending stress caused by the bending bolt moment M_{bb} for normal conditions:

[ ]

Shear Stress

For both normal and accident conditions, the average shear stress caused by the shear bolt force F_s:

[ ]

For both normal and accident conditions, the maximum shear stress caused by the torsional moment M_{tr}:

[ ]

Maximum Combined Stress Intensity

For normal conditions, the maximum stress intensity combines tension, shear, bending, and residual torsion:

[ ]

Stress Ratios

In order to meet the stress ratio requirement, the following relationship must hold true for both normal and accident conditions as per [1].

$$R_t^{\,2} + R_s^{\,2} < 1$$

For normal conditions:

[ ]

For accident conditions:

[ ]

Bearing Stress Under Bolt Head

[ ]

Summary

The various stresses calculated in Section 2.11.4.3.3 are shown in Table 2.11.4-10.

2.11.4.3.4 Fatigue Analysis

The purpose of the fatigue analysis is to show quantitatively that the fatigue damage to the primary lid bolts during NCT is acceptable. This is done by considering the fatigue damage factor for each NCT event. [ ]

Preload

Since the bolt preload stress applied to the TN Eagle primary lid bolts is higher than all of the other NCT condition loads evaluated in this calculation, the stress in the bolts will never exceed the bolt preload stress.

[ ]

For the empty cask, the maximum normal condition bolt stress intensity is:

[ ]

<u>Rail Car Shock and Vibration</u>

Since the TN Eagle will be shipped by railcar, the shock and vibration loads are considered.

According to [4], a peak shock loading of 4.7g in the longitudinal direction should be assumed for rail car transport. [ ]

In [4] it is mentioned that a shock loading can be expected nine times every 100 miles of transport via railcar. [ ]

According to [4], the peak vibration load on the deck of a rail car in the longitudinal direction is 0.19g. [ ]

<u>Damage Factor Calculation</u>

The following damage factors are computed based on the stress and cyclic history described above.

For a cycle that goes from 0 to $+S_{bi}$, S_a can be calculated as follows:

$$S_a = 0.5 \times S_{bi} \times K_F \times K_E$$

[ ]

Using the calculated values of S_a along with the fatigue curve in Figure I-9.4M of [2], the number of allowable cycles N is determined for each load case.

Based on the allowable cycles, Table 2.11.4-9 calculates the damage factor for each load case. Since the total damage factor is less than one, the TN Eagle primary lid bolts will not fail due to fatigue.

2.11.4.3.5 Minimum Engagement Length

[ ]

The minimum required thread engagement length of the bolting system:

[ ]

2.11.4.4 Ram Access Cover Plate Bolt Evaluation

The methodology used in the analysis for the RACP bolts is the same as was used for the primary lid bolts in Section 2.11.4.3.

2.11.4.4.1 Individual Load Calculations

Bolt Preload

[ ]

Bolt preload for minimum torque:

[ ]

Bolt preload for maximum torque:

[ ]

Residual torsional moment for minimum torque:

[ ]

Residual torsional moment for maximum torque:

[ ]

Gasket Seating Load

An elastomer O-ring is used and therefore the gasket seating load is negligible.

Internal Pressure Load

The internal pressure of the cask is 0.210 MPa, which is based on the maximum normal operating pressure established in Section 2.5.3 of Chapter 2. [

]

The non-prying tensile bolt force:

[ ]

[ ]

The fixed-edge primary lid force:

[ ]

The fixed-edge primary lid moment:

[ ]

<u>Temperature Load</u>

[ ]

The non-prying tensile bolt force:

[ ]

<u>Impact Load</u>

For this evaluation, the corner drop is analyzed with a drop angle of 70°. Only the accident condition is considered in this evaluation because it is the bounding case.
[ ]

During an impact scenario, the load of the contents will be applied to the base of the cask body and not to the RACP. Therefore, the only weight attributed to the impact scenario on the bolts of the RACP is that of the RACP itself, which is taken to be [ ] This value bounds the weight reported in Section 2.1.1.4 of Chapter 2.

The non-prying tensile bolt force:

[ ]

The RACP shoulder takes the shear force, so the shear on the bolts is considered to be 0.

[ ]

The fixed-edge primary lid force:

[ ]

The fixed-edge primary lid moment:

[ ]

<u>Puncture Load</u>

[ ]

<u>External Pressure Load (Immersion)</u>

[ ] To maximize the effect of the external pressure, the internal pressure of the cask is taken to be 0 MPa.

[ ]

The fixed-edge primary lid force:

[ ]

The fixed-edge primary lid moment:

[ ]

Additional Prying Bolt Force

Bending Moment Bolt Force

The bending moment bolt force:

Summary

The individual loads acting on the closure bolts of the RACP calculated in Section 2.11.4.4.1 are listed in Table 2.11.4-7.

2.11.4.4.2 Load Combinations

A summary of normal and accident load combinations is shown in Table 2.11.4-8.

2.11.4.4.3 Stress Calculations

Allowable Stresses

The allowable stresses for the RACP bolts can be seen in Table 2.11.4-2.

Average Tensile Stress

The average tensile stress caused by the tensile bolt force F_a for normal conditions:

The average tensile stress caused by the tensile bolt force F_a for accident conditions:

Bending Stress

The bending stress caused by the bending bolt moment M_{bb} for normal conditions:

Shear Stress

For both normal and accident conditions, the maximum shear stress caused by the torsional moment M_{tr}:

Maximum Combined Stress Intensity

For normal conditions, the maximum stress intensity combines tension, shear, bending, and residual torsion:

Stress Ratios

In order to meet the stress ratio requirement, the following relationship must hold true for both normal and accident conditions as per [1].

$$R_t{}^2 + R_s{}^2 < 1$$

For normal conditions:

For accident conditions:

Bearing Stress Under Bolt Head

Summary

The various stresses calculated in Section 2.11.4.4.3 are shown in Table 2.11.4-10.

2.11.4.4.4 Fatigue Analysis

The only cyclic load experienced by the RACP bolts is from the tightening and loosening of the preload. [

]

2.11.4.4.5 Minimum Engagement Length

The analysis is described on page 1490 of [3].

2.11.4.5 Conclusion

A summary of the bolt stresses for the primary lid and the RACP calculated above is summarized in Table 2.11.4-10.

For the required preloads:

- Bolt stresses meet the acceptance criteria of [1].
- A compressive load is maintained during all load combinations, [
  ]
- The bolt thread engagement length is acceptable [
  ]

2.11.4.6 References

1. NRC, NUREG/CR-6007, "Stress Analysis of Closure Bolts for Shipping Casks," 1992.

2. ASME, Boiler and Pressure Vessel Code, Section III, Appendices, 2017.

3. Oberg, E., Jones, F.D., Horton, H.L., and Ryffel, H.H., “Machinery's Handbook: A Reference Book for the Mechanical Engineer, Designer, Manufacturing Engineer, Draftsman, Toolmaker, and Machinist,” 26th Edition, 2000.

4. NRC, NUREG-766510, “Shock and Vibration Environment for Large Shipping Containers on Rail Cars and Trucks,” 1977.

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Appendix 2.11.5
TN Eagle Cask Puncture Evaluation

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2.11.5 TN Eagle Cask Puncture Evaluation

This appendix demonstrates that the thicknesses of the Forged Cask Body, Primary Lid, and Ram Access Cover Plate (RACP) are adequate against puncture due to a 1 m drop on a 150 mm (= 6 in) mild steel bar as per 10 CFR 71.73.

Furthermore, a damaged area for the shielding rings is estimated for use in the shielding evaluation.

2.11.5.1 Computations

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[ ]

2.11.5.2 Conclusions

The acceleration [ ] due to puncture is small compared to the accelerations due to a 30 ft free drop calculated in Appendix 2.11.3. Therefore, the global stresses that result from inertial forces are bounded by those from the 30 ft free drop.

The margins of safety against bending and shear for the Forged Cask Body and Primary Lid and the required thickness against puncture is [ ] show adequacy against puncture.

In conclusion, the containment boundary (i.e., Forged Cask Body, Primary Lid, and RACP) of the TN Eagle Transportation Cask meets the puncture criteria due to a 1 m drop on a 150 mm (= 6 in) mild steel bar set in 10 CFR 71.73.

2.11.5.3 References

1. Orano TN, “TN-40 Transportation Packaging – Safety Analysis Report,” Revision 16. Docket No. 07109313

2. NRC, Regulatory Guide 7.6, Rev. 1, “Design Criteria for the Structural Analysis of Shipping Cask Containment Vessels”, 1978.

3. ASME, B&PVC, Section II, Part D, “Properties (Metric),” 2017.

4. ASME, B&PVC, Section III, Appendices 2017.

5. ORNL TM-1312 Vol. 3, “Structural Analysis of Shipping Casks Vol. 3 – Effects of Jacket Physical Properties and Curvature on Puncture Resistance,” 1968.

6. BC-TOP-9A Rev. 2, Topical Report – Design of Structures for Missile Impact,” 1974.

7. W.C. Young & R.G. Budynas, “Roark’s Formulas for Stress and Strain”, Seventh Edition.

8. ASME, B&PVC, Section III, Div. 1, Subsection NF, “Supports,” 2017.

Appendix 2.11.6
TN Eagle Dynamic Load Factor Determination

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2.11.6 TN Eagle Dynamic Load Factor Determination for EOS DSCs

2.11.6.1 Introduction

This appendix determines the dynamic load factor (DLF) for the TN Eagle EOS transport package internals. The DLF accounts for the difference of rigid body acceleration between the TN Eagle cask and canisters, baskets, and fuel during the cask drop events.

The DLF is calculated using a spring-mass-damper finite element model. **[**

] DLF is calculated based on the ratio between the maximum dynamic displacement (u_{max} dynamic) and the maximum static displacement (u_{max} static). **[**

] The duration of the input signals is based on the acceleration time-histories of the drops from Appendix 2.11.3.

Three components of the TN Eagle internals with the longest and most significant natural periods are the canister, basket, and fuel assemblies. The DLFs for each component are calculated separately. DLFs for the fuel assemblies are determined in Appendix 2.11.13.

DLF is evaluated for two load cases; longitudinal vibration due to an end drop and transverse vibration due to a side drop or slap down. **[**

]

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The DLFs for the DSC Shell Assemblies and Baskets for each drop orientation are shown in Table 2.11.6-3 and Table 2.11.6-4, respectively.

2.11.6.5 References

1. ANSYS Computer Code and User's Manual, Release 17.1.

2. Blevins R.D., "Formulas for Natural Frequency and Mode Shape," Van Nostrand Reinhold Company, 1979.

3. NRC, NUREG/CR-3966, "Methods for Impact Analysis of Shipping Containers," 1987.

Table 2.11.6-1
EOS Baskets Axial Drop Frequency

Basket Type	Length of the Basket (m)	Weight (kg)	Volume (m^3)	Avg. Mass Density (kg/m^3)	Young's Modulus @ 260°C (GPa)	Natural Frequency (Hz)
EOS-37PTH	[ ]	[ ]	[ ]	3959	186.2	[ ]
EOS-89BTH	[ ]	[ ]	[ ]	4286	186.2	[ ]

Table 2.11.6-2
Natural Frequencies of the EOS Baskets during Side Drop

Basket Type	Frequency for [ ] (Hz.)	Frequency for [ ] (Hz.)
EOS-37PTH	[ ]	[ ]
EOS-89BTH	[ ]	[ ]

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Appendix 2.11.7
TN Eagle Cask Finite Element Model

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2.11.7 TN Eagle Cask Finite Element Model

This appendix describes the finite element (FE) model used for the LS-DYNA drop simulations of the TN Eagle Cask.

2.11.7.1 TN Eagle Cask Model

2.11.7.1.1 Description

Proprietary Information on Pages 2.11.7-2 and 2.11.7-3
Withheld Pursuant to 10 CFR 2.390

2.11.7.1.7 Contacts

2.11.7.2 References

2. ASME Guidance Document (Draft), “Use of Explicit Finite Element Analysis for the Evaluations of Nuclear Transport and Storage Packages in Energy-Limited Impact Events.”

3. LS-DYNA Version R7.0, Keyword User’s Manual, Volume I.

4. LS-DYNA Version R7.0, Keyword User’s Manual, Volume II, “Material Models.”

5. NRC, Regulatory Guide 7.6, Rev. 1, “Design Criteria for the Structural Analysis of Shipping Cask Containment Vessels,” 1978.

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Appendix 2.11.8
TN Eagle Containment Boundary Fatigue Evaluation

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2.11.8 TN Eagle Containment Boundary Fatigue Evaluation

2.11.8.1 Introduction

The purpose of the fatigue analysis is to show that the containment boundary stresses are within acceptable NCT fatigue limits. This is done by determining the fatigue usage factor for each NCT event for the containment boundary at locations with the highest stress. The cumulative fatigue damage or usage factor for all NCT events is determined by adding the fatigue usage factors for the individual NCT events, assuming that the maximum stress intensities occur at the same location.

The total fatigue damage factor acceptable limit (i.e., sum of the individual usage factors for a given number of round–trip shipments) for the TN Eagle Transportation Cask is 1.0.

[
]

The fatigue analysis is based on the procedure described in [1] and Section XIII-3520 and Mandatory Appendix I of [3]. When determining the stress cycles, consideration is given to the superposition of individual loads which can occur together and produce a total stress intensity range greater than the stress intensity range of individual loads. The maximum stress intensities for all individual loads are combined simultaneously. The sequence of events for the fatigue evaluation is:

1. Bolt preload
2. Dead Weight
3. Pressure fluctuations
4. Temperature fluctuations
5. Vibration
6. Shock
7. 1-foot drop

The maximum stresses for the TN Eagle containment boundary for each NCT load case are based on the load cases mentioned in Appendix 2.11.1.

2.11.8.2 Calculations

2.11.8.2.1 Bolt Preload

[
]

2.11.8.2.2 Dead Weight (Loading)

[

]

2.11.8.2.3 Pressure Fluctuations

[

]

2.11.8.2.4 Temperature Fluctuations

2.11.8.2.5 Vibration

[

]

2.11.8.2.6 Shock Loads

[

]

2.11.8.2.7 1 Ft Drop

[

]

2.11.8.2.8 Usage Factor Calculation

The damage factors are summarized in Table 2.11.8-1 and Table 2.11.8-2 and computed based on the stresses and cyclic histories described in Sections 2.11.8.2.1 to 2.11.8.2.8 and the fatigue curve shown in Figure I-9.1M of [3]. The parameter n is the number of cycles for each load case, *N* is taken from Figure I-9.1M [3], and S_a is defined in the following way:

If one cycle goes from 0 to +S.I., then $S_a = \left(\frac{1}{2}\right) \times S.I. \times K_F \times K_E$. If one cycle goes from –S.I. to +S.I., then $S_a = S.I. \times K_F \times K_E$, where K_E is the correction factor for modulus of elasticity.

[

]

[ ]

2.11.8.3 Conclusion

The total damage factor is less than one as shown in Table 2.11.8-1 and Table 2.11.8-2. Therefore, the containment boundary of the TN Eagle Transportation Cask is adequate with respect to fatigue [

]

2.11.8.4 References

1. NCR, Regulatory Guide 7.6, Rev. 1, “Design Criteria for the Structural Analysis of Shipping Cask Containment Vessels,” 1978.

2. NRC, NUREG-766510, “Shock and Vibration Environments for Large Shipping Containers on Rail Cars and Trucks,” 1977.

3. ASME, B&PVC, Section III, Appendices, 2017.

4. [ ]

Proprietary Information on Pages 2.11.8-5 through 2.11.8-13
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Appendix 2.11.9
Non-Containment Boundary Evaluation

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2.11.9 Non-Containment Boundary Evaluation

2.11.9.1 Introduction

This appendix analyzes the stresses in various parts of the cask including the shielding rings, handling ring, closing ring, and the bottom closure plate. These stresses include fabrication stress due to the shrink fit, transportation stresses, and lifting stresses.

2.11.9.2 Design Criteria

2.11.9.2.1 Geometry

All dimensions considered in this analysis are nominal as per the cask drawing in Chapter 1, except for the radii values of the ring and forged cask body interface used in the shrink fit analysis. These are taken as the values that result in the largest interference between the rings and forged cask body, resulting in the maximum shrink fit stresses.

Key dimensions used in this analysis are shown in Table 2.11.9-4.

2.11.9.2.2 Mass

[

]

2.11.9.2.3 Material Properties

Material properties are taken from Chapter 7 and are tabulated in Table 2.11.9-1 and Table 2.11.9-2. Table 2.11.9-1 shows the properties and temperatures considered for the shrink fit analysis of the various rings and forged cask body. Table 2.11.9-2 shows the mechanical properties used for the allowables of the stress calculations.
[

]

2.11.9.2.4 Allowable Stresses

The allowable stresses are shown in Table 2.11.9-3 for the various parts and materials analyzed in this appendix. **[**

]

2.11.9.3 Methodology

Hand calculations are performed on various structural parts of the cask to ensure they meet the criteria mentioned in Section 2.11.9.2.4.

[ ]

2.11.9.3.2 Shock Loads

Shock loads are NCT events that occur during transportation of the TN Eagle cask. These loads on the cask are caused by the railcar during travel. Based on NUREG-766510, the shock loads can be considered as 4.7 g in all directions (vertical, transverse, and longitudinal) [2]. [ ]

2.11.9.3.3 Tie-Down Loads

Tie-Down loads are NCT events that occur during transportation of the TN Eagle cask. These are special requirements set forth by 10 CFR 71.45(b) for parts of the cask that are considered structurally integral to the attachment and restraint of the cask to the railcar. In this case, the attachment to the transport frame, as it is what connects the TN Eagle cask to the railcar.

Based on the requirements of 10 CFR 71.45(b), the tie-down loads of 2 g vertical, 5 g horizontal, and 10 g longitudinal are considered components of the overall static force. Therefore, all component loads are considered to happen simultaneously. [ ] The resulting stress on the cask is then compared to the yield stress of the parts in question.

[ ]

2.11.9.3.4 Lifting Loads

Lifting loads are NCT events that occur during operational handling of the cask and follow the requirements set forth by 10 CFR 71.45(a).

The TN Eagle cask will be lifted in the horizontal orientation when loaded and, during this lifting process, there will be two straps that will support the cask on both the top and the bottom. One strap will support the cask at the bottom ring. The other strap will support the cask at the flange of the forged cask body and will not be accounted for in this calculation as it is explored in Appendix 2.11.1. 10 CFR 71.45(a) states that these parts considered for lifting must be designed for a factor of safety of three against yield. So for this analysis it is assumed that the parts will experience a 3 g load and the resulting stress will then be compared against yield.

2.11.9.4 Reaction Forces due to Transportation

During transportation, the TN Eagle cask will be resting on two saddles of the transport frame. Then a tie-down latch is put into place on both the front saddle and rear saddle to restrict the cask on the top side. These saddles and latches will restrict movement of the cask in both the vertical and transverse directions. To restrict movement in the longitudinal direction, there is a shear key embedded in the front saddle. On the saddles and latches there are bearing pads. These pads help distribute the load evenly along the area in contact.

A static force analysis is performed to calculate the reaction forces on the various parts of the cask as a result of the transportation loads. This is done for both the shock loads and the tie-down loads. These forces are then used in Section 2.11.9.5 through Section 2.11.9.9 to evaluate the stresses on the structural components of the non-containment boundary.

2.11.9.5 Handling Ring

Since the handling ring is considered a tie-down device as described in Section 2.11.9.3.3, the appropriate NCT transportation loads of 2 g, vertical, 5 g transverse, and 10 g longitudinal are applied. **[**

]

All resulting stresses of the handling ring from Section 2.11.9.5.1 to Section 2.11.9.5.6 are listed in Table 2.11.9-5.

2.11.9.5.1 Radial Stress

Interaction of the handling ring with the bearing pads during vertical and transverse accelerations results in a radial stress in the handling ring. **[**

]

2.11.9.5.2 Shear Stress

The shear stress that occurs in the handling ring is a result of the interface with the shear key. **[**

]

2.11.9.5.3 Bending Stress

Bending stress on the handling ring is caused by the interface of the shear key with the pocket of the handling ring during the longitudinal tie-down load. **[**

]

2.11.9.5.4 Bearing Stress from the Shear Key

The bearing stress between the shear key and the handling ring is calculated based on the reaction load from the 10 g longitudinal acceleration. **[**

]

2.11.9.5.5 Bearing Stress from the Flange of the Forged Cask Body

The bearing stress between the handling ring and the flange of the forged cask body is also evaluated for the 10 g longitudinal acceleration. **[**

]

2.11.9.5.6 Stress Intensity

[ ]

2.11.9.6 Shielding Rings

[ ]

For the shielding rings, both shock loads and tie-down loads are evaluated. The shock loads are also combined with stresses due to shrink fitting of the rings on the forged cask body.

All resulting stresses of the shielding rings from Section 2.11.9.6.1 to Section 2.11.9.6.4 are listed in Table 2.11.9-5.

2.11.9.6.1 Shrink Fit

The shrink fit analysis for the shielding rings is performed based on the methodology described in Section 2.11.9.3.1.

[ ]

2.11.9.6.2 Shock Loads

<u>Radial</u>

Similar to Section 2.11.9.5.1, the load is assumed to be applied at the location of the bearing pads in contact with the shielding rings. [ ]

Longitudinal

[

]

2.11.9.6.3 Tie-Down Loads

The tie-down loads follow the same methodology as in Section 2.11.9.6.2 but with reaction forces due to the increased accelerations. [

]

2.11.9.6.4 Stress Intensity

Using the methodology described in Section 2.11.9.3.5 results in a stress intensity equal to 151.7 MPa for the shielding rings.

2.11.9.7 Bottom Ring

All resulting stresses of the bottom ring from Section 2.11.9.7.1 to Section 2.11.9.7.4 are listed in Table 2.11.9-5.

2.11.9.7.1 Shrink Fit

The shrink fit analysis for the bottom ring is performed based on the methodology described in Section 2.11.9.3.1.

2.11.9.7.2 Shock Loads

[

]

2.11.9.7.3 Lifting Loads

Based on the methodology in Section 2.11.9.3.4 and the criteria set forth by 10 CFR 71.45(a), the bottom ring is analyzed for a 3 g load and compared against yield. [

]

2.11.9.7.4 Stress Intensity

[

]

2.11.9.8 Bottom Closure Plate

All resulting stresses of the bottom closure plate from Section 2.11.9.8.1 to Section 2.11.9.8.4 are listed in Table 2.11.9-5.

2.11.9.8.1 Shear Stress

The shear stress on the flange of the bottom closure plate is assessed for the longitudinal shock load of 4.7 g. [

]

2.11.9.8.2 Bending Stress

The bending stress on the bottom closure plate is caused by the interface of the bottom ring with the flange of the bottom closure plate during a longitudinal shock load. [

]

2.11.9.8.3 Bearing Stress from the Bottom Ring

The bearing stress between the bottom closure plate and the bottom ring is evaluated for the 4.7 g longitudinal acceleration. [

]

2.11.9.8.4 Stress Intensity

2.11.9.9 Bottom Closure Plate Bolts

The resulting stresses of the bottom closure plate bolts from Section 2.11.9.9.1 and Section 2.11.9.9.2 are listed in Table 2.11.9-5.

2.11.9.9.1 Preload

The method of analysis is described in Table 4.1 of [4].

[

]

2.11.9.9.2 Shock Load

The shock load stress on the bottom closure plate bolts is caused by the longitudinal acceleration of the cask. [

]

2.11.9.10 Conclusion

The stresses of the various parts calculated above are summarized in Table 2.11.9-5. The parts that are considered tie-down devices (handling ring and shielding rings) meet the acceptable stress criteria set forth by 10 CFR 71.45(b). The bottom ring meets the criteria set forth by 10 CFR 71.45(a) for lifting attachments. All parts analyzed in this calculation meet the criteria for shock loads as described in [2].

[

]

2.11.9.11 References

1. ASME, Boiler and Pressure Vessel Code, Section III, Division 1, Subsection NF, 2017.

2. NRC, NUREG-766510, “Shock and Vibration Environments for Large Shipping Containers on Rail Cars and Trucks,” 1977.

3. [ ]

4. NRC, NUREG/CR-6007, “Stress Analysis of Closure Bolts for Shipping Casks,” 1992.

Proprietary Information on Pages 2.11.9-10 and 2.11.9-11
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Table 2.11.9-4
List of Parameters and Their Nomenclature

Parameter Details	Value
Vertical acceleration due to shock loads (g)	4.7
Transverse acceleration due to shock loads (g)	4.7
Longitudinal acceleration due to shock loads (g)	4.7
Vertical acceleration due to tie-down loads (g)	2
Transverse acceleration due to tie-down loads (g)	5
Longitudinal acceleration due to tie-down loads (g)	10
Total mass of loaded TN Eagle cask (kg)	165,000

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Appendix 2.11.10
Evaluation of Non-EOS Contents for Transportation in the TN Eagle Cask

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2.11.10 Evaluation of Non-EOS Contents for Transportation in the TN Eagle Cask

This appendix evaluates the structural integrity of the non-EOS contents for transportation in the TN Eagle cask. Non-EOS contents include the 32PT, 32PTH1, and 24PT4 canisters and baskets licensed in [1] and the FO, FC, FF, and 24PT1 canisters and baskets licensed in [2].

This appendix focuses on showing the structural adequacy of the non-EOS contents for the NCT and HAC accelerations based on a 1 ft drop and 30 ft drop, respectively. The structural integrity for NCT is evaluated only for a 1 ft side drop as per Section 2.5.7.

The accelerations considered are based on the maximum accelerations at the cask shown in Table 2.11.3-1. [

]

The DLF of the non-EOS contents is based on the methodology described in Appendix 2.11.6. The natural frequencies considered are taken from [1] and [2].

2.11.10.1 Non-EOS Contents – Canisters

2.11.10.1.1 32PTH1 Canister

Proprietary Information on Pages 2.11.10-2 through 2.11.10-13
Withheld Pursuant to 10 CFR 2.390

2.11.10.2.6 24PT1 Basket

2.11.10.3 Conclusions

This appendix shows the DSC canisters and baskets of the non-EOS contents (i.e., 32PT, 32PTH1, 24PT4, FO, FC, FF, and 24PT1) are structurally adequate for the NCT and HAC free drops while in the TN Eagle transportation cask.

The analyses performed in [1] for the 32PT, 32PTH1, and 24PT4 are bounding. The analyses performed in [2] for the FO, FC, FF, and 24PT1 are bounding.

2.11.10.4 References

1. Orano TN, "NUHOMS®-MP197 Transportation Packaging Safety Analysis Report," Revision 20. Docket No. 07109302

2. Orano TN, "NUHOMS®-MP187 Multi-Purpose Cask Transportation Package Safety Analysis Report," Revision 17. Docket No. 07109255

3. ANSYS Computer Code and User's Manual, Release 17.1.

4. ASME, B&PVC, Section III, Subsection NG and Appendices, 1998 Edition with 2000 Addenda.

Proprietary Information on Pages 2.11.10-15 and 2.11.10-16
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Appendix 2.11.11
EOS-37PTH and EOS-89BTH DSC Shell NCT and HAC Evaluation

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2.11.11 EOS-37PTH and EOS-89BTH DSC Shell NCT and HAC Evaluation

2.11.11.1 Introduction

The purpose of this appendix is to assess the structural integrity of the EOS-37PTH and EOS-89BTH DSCs loaded in the TN Eagle transportation cask under normal conditions of transport (NCT) and hypothetical accident conditions (HAC). The NCT and HAC loads are as per 10 CFR Part 71 requirements. The calculated stresses are compared against applicable ASME code stress limits [1].

2.11.11.2 NCT

2.11.11.2.1 Model Description

Geometry

[ ]

DSC Mass

The weight considered for this anlaysis bounds the maximum weight of a DSC that will fit into the TN Eagle, which is [ ] as per Section 2.1.1.4 of Chapter 2.

Material Properties

The mechanical properties of the structural materials of the EOS DSC as a function of temperature can be found in Chapter 7.

2.11.11.2.2 Methodology

Load Cases

The following load cases are analyzed in this calculation:

NCT Side Drop

A 0.3 meter (1 foot) side drop on the bottom rails is considered to ensure the adequacy of the design for 10 CFR Part 71 requirements. Only the drop onto the bottom rails is analyzed as it is considered the only feasible scenario for the NCT drop event. Bounding g-loads of 25 g are considered for NCT side drops.

[

]

Boundary Conditions

Boundary condition for structural analysis

Symmetric boundary conditions are applied in the model. [

]

Boundary condition for thermal analysis

The boundary conditions for the thermal analysis are symmetry boundary conditions along with two nodes on which minimal boundary constraint is applied to prevent rigid body motion.

Load Combinations

Load combinations considered are as per [1] and are shown in Table 2.11.11-6.

Stress Criteria

The acceptability of the package design is assessed by the stress criteria shown in Table 2.11.11-1 to Table 2.11.11-3. The criteria are based on ASME code, Section III, Subsection NB requirements [1].

The weld between the lifting lug plate and the DSC shell is evaluated and the results are compared against the allowables shown in Table 2.11.11-3.

<u>Triaxial Stresses</u>

The algebraic sum of the three principle stresses, $\sigma_1 + \sigma_2 + \sigma_3$, for primary loads shall be less than 4^*S_m as per Table 2.11.11-1. This requirement is applicable only to NB 3222 of Service Level A [1].

This evaluation is required to address the special case where all three values of principle stresses have relatively large tension values (positively signed). It should be noted that, conservatively, the compression stresses (negatively signed) are treated as zero MPa. In these cases, stress intensity values ($\sigma_1 - \sigma_3$) may be relatively low because the signed values of σ_1 and σ_3 cancel one another, yet still the possibility of triaxial tensile failure may occur. The triaxial stress check limits the magnitude of the stresses that may cause this type of failure.

2.11.11.2.3 Computations

<u>Side Drop with Internal Pressure</u>

[**]** This value is used in conjunction with the side drop cases and the results are tabulated in Table 2.11.11-9.

<u>Side Drop with External Pressure</u>

The pressure at the first rail location is calculated the same as the value from Section 2.11.11.2.3.1, **[** **]** The results for the side drop with external pressure are tabulated in Table 2.11.11-10.

<u>Thermal Stress Evaluation</u>

Thermal stress evaluations for hot and cold conditions have been performed and are reported in Table 2.11.11-7 and Table 2.11.11-8.

<u>Bearing Stress Evaluation</u>

Bearing stress is calculated based on the contact of the DSC at the first rail location due to the initial contact with this rail. It is calculated based on the reactions of the entire system on the rail.

[**]**

2.11.11.2.4 Summary

The results of the NCT load combinations involving side drops, pressure, and thermal loads are summarized in Table 2.11.11-11 and Table 2.11.11-12.

2.11.11.3 HAC

[ ]

2.11.11.4 Conclusions

For the controlling NCT load combinations, stress results for each component of the DSC shell assembly are summarized in Table 2.11.11-11 and Table 2.11.11-12.

The EOS DSC is acceptable for the NCT loads and combinations described in Table 2.11.11-4 through Table 2.11.11-6 and hence structurally adequate for transportation loading conditions.

The reconciliation of all HAC loads acting on EOS DSCs with the TN Eagle transportation cask concludes that the structural integrity of EOS DSCs in [3] for the EOS transfer cask is also qualified for the TN Eagle cask.

2.11.11.5 References

1. ASME, Boiler and Pressure Vessel Code, Section III, Division 1, Subsection NB, 2010 with 2011 Addenda.

2. ANSYS Computer Code and User’s Manual, Release 17.1.

3. TN Americas LLC, “NUHOMS® EOS System Updated Final Safety Analysis Report,” Revision 3. Docket No. 07201042.

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Table 2.11.11-4
Load Cases for Thermal Stress Analysis (TSA)

Load Case	Loading Condition	Service Level
LC1	Hot Thermal Environment	A
LC2	Cold Thermal Environment	A

Table 2.11.11-5
Load Cases for Side Drop Normal Conditions of Transport (NCT)

Load Case	Loading Condition	Service Level	Case Description
LC3	[ ]	A	[ ]
LC4	[ ]	A	[ ]

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Appendix 2.11.12
EOS Basket NCT and HAC Evaluation

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2.11.12 EOS Basket NCT and HAC Evaluation

2.11.12.1 Introduction

This appendix determines the structural integrity of the EOS-37PTH and EOS-89BTH baskets loaded in the TN Eagle transportation cask for various load configurations under normal conditions of transport (NCT) and hypothetical accident condition (HAC) loads as per 10 CFR Part 71 requirements.

2.11.12.2 Model Description

2.11.12.2.1 Geometry

The key dimensions used in the model for the EOS-37PTH and EOS-89BTH are taken from the drawings of the baskets in Chapter 1. For the location and sizing of the cask rails, the information is taken from the cask drawing in Chapter 1 for the LC (Large Canister) configuration.

2.11.12.2.2 FE Model

2.11.12.2.3 Material Properties

The mechanical properties of structural materials used for the basket assembly and canister as a function of temperature are shown in Chapter 7.

2.11.12.2.4 Fuel Data

Chapter 1 provides design characteristics for the types of PWR and BWR fuel assemblies to be considered for EOS-37PTH and EOS-89BTH basket assemblies, respectively. [

] Appendix 1.6.1 and Appendix 1.6.2 contain the technical details of the fuel.

2.11.12.3 NCT

2.11.12.3.1 Methodology

The methodology is similar to what was considered in [2].

2.11.12.3.1.1 Analysis Model Description for Side Loads

[ ]

Only the side drop onto the bottom rails is considered as it is considered the only feasible scenario during the 1 foot NCT side drop.

2.11.12.3.1.2 Analysis Model Description for Thermal Loads

For the NCT analysis, temperature data is taken from the thermal evaluation in Section 3.3 of Chapter 3. The axial location of the hottest temperatures is considered for the thermal stress analysis and component evaluations.

[ ]

2.11.12.3.1.3 Criteria

The basis for allowable stresses is obtained from ASME Section III, Division 1, Subsection NG [1]. The criteria are summarized in Table 2.11.12-1. In accordance with NG-3222 and Note 9 of Figure NG-3221-1, the Limit Analysis provisions of NG-3228 may be used for Level A service limits. Allowable stresses for the threaded fasteners used to connect the transition rails to the basket grid structure are from Section NG-3230 of [1] and are summarized in Table 2.11.12-2.

2.11.12.3.1.4 Limit Load Analysis

2.11.12.3.2 Results

<u>Elastic Stress Analysis Results</u>

2.11.12.4 HAC

2.11.12.4.1 Methodology

2.11.12.4.1.1 Side Drop

2.11.12.4.1.2 End Drop

2.11.12.4.1.3 Criteria

2.11.12.4.2 Results

2.11.12.4.2.1 Side Drop

2.11.12.4.2.2 Buckling Load Analysis

Summaries of the buckling analysis results are shown in Table 2.11.12-9 for the EOS-37PTH and EOS-89BTH baskets. [

]

2.11.12.4.2.3 Adjacent Compartment Relative Displacements

Maximum relative displacements for those adjacent compartments that have moved closer together are tabulated in Table 2.11.12-10 for EOS-37PTH and EOS-89BTH baskets. [

]

2.11.12.5 Conclusion

NCT

[

]

Maximum stress intensities are reported in Table 2.11.12-7. A comparison of stress intensities to the corresponding allowable values indicate that all load conditions show acceptable stress levels, as applicable. [

]

HAC

Finite element analyses for the EOS-37PTH and EOS-89BTH basket assemblies are completed for all accident side drop transport conditions. A reaction force balance confirmed the correctness of total load applied to the model for the side load cases. [

]

2.11.12.6 References

1. ASME, Boiler and Pressure Vessel Code, Section III, Division 1, Subsection NG, 2010 with 2011 Addenda.

2. Orano TN, "NUHOMS® EOS System Updated Final Safety Analysis Report," Revision 3, Docket No. 07201042.

3. ANSYS Computer Code and User's Manual, Release 17.1.

Table 2.11.12-1
NCT Basket Stress Design Criteria

Stress Category	Allowable Stresses
Primary Membrane P_m (1)	S_m
Primary Membrane + Bending $P_m + P_b$ (1)	1.5 S_m
Range of Primary + Secondary $P_m + P_b + Q$	3.0 S_m (2)
Bearing Stress	S_y
Avg. Pure Shear Stress Primary	0.6 S_m
Max. Pure Shear Stress Primary	0.8 S_m
Max. Pure Shear Stress Intensity Primary + Secondary	3.0 S_m
Compression or Buckling	N/A (3)

[ ]

Table 2.11.12-2
NCT Threaded Fastener Stress Design Criteria

Stress Category	Allowable Stresses
Primary + Secondary Membrane $P_m + Q_m$	min(0.9 S_y, 2/3 S_u)
Primary + Secondary Shear $P_m + Q_m$	0.6 S_y
Primary + Secondary Bearing $P_m + Q_m$	2.7 S_y
Primary Membrane P_m	S_m
Primary Shear P_m	0.6 S_m
Primary + Secondary Membrane + Bending $P_m + Q_m + P_b + Q_b$	min(1.2 S_y, 8/9 S_u)

Table 2.11.12-3
HAC Basket Stress Design Criteria

Stress Category	Allowable Stresses
Primary Membrane P_m	0.7 S_u(1)
Primary Membrane + Bending $P_m + P_b$	0.9 S_u(1)
Range of Primary + Secondary $P_m + P_b + Q$	N/A(2)
Bearing Stress	N/A(2)
Compression or Buckling	Note 3

[ ]

Table 2.11.12-4
HAC Basket Grid Plate Strain Design Criteria

[ ]

Proprietary Information on Pages 2.11.12-9 through 2.11.12-15
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Appendix 2.11.13
TN Eagle Evaluation of the Fuel Assemblies under Impact Loads

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2.11.13 TN Eagle Evaluation of the Fuel Assemblies under Impact Loads

[

]

The contents of the TN Eagle Cask are described in Chapter 1. This appendix groups the contents and in extension the FA as follows:

Group Name	Contents
EOS	EOS-37PTH and EOS-89BTH DSCs
MP197HB	32PT, 32PTH1, and 24PT4 DSCs
MP187	FO/FC/FF and 24PT1 DSCs

2.11.13.1 EOS Fuel Assemblies

2.11.13.2 MP197HB Fuel Assemblies

2.11.13.3 MP187 Fuel Assemblies

[ ]

2.11.13.4 Conclusion

The [ ] of the contents in groups EOS, MP197HB, and MP187 is structural adequate [ ] when loaded in the TN Eagle Cask.

2.11.13.5 References

1. Orano TN, “NUHOMS®-MP197 Transportation Packaging Safety Analysis Report,” Revision 20. Docket No. 07109302

2. Orano TN, “NUHOMS® EOS System Updated Final Safety Analysis Report,” Revision 3. Docket No. 07201042

3. Orano TN, “Updated Final Safety Analysis Report for the Standardized Advanced NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel,” Revision 9. Docket No. 07201029

Appendix 2.11.14
TN Eagle Cask Thermal Expansion Evaluation

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2.11.14 TN Eagle Cask Thermal Expansion Evaluation

2.11.14.1 Purpose

In this appendix, the thermal expansion of the components of the TN Eagle Cask is evaluated. The thermal loads considered are the +38 °C (100 °F) and -40 °C (-40 °F) ambient normal condition of transport (NCT) temperature distribution computed in Chapter 3. The results of LCs #1 and #3 in Table 3-3 are used for the thermal expansion calculations for NCT with +38 °C (100 °F) and -40 °C (-40 °F), respectively. The average volumetric temperatures of the DSC shell, cask spacer, and cask shell are obtained from the bounding normal hot condition LC #1 and normal cold condition LC #3 in Table 3-3. The methodology applied is identical to Section A.2.13.10 of [1]. Cask shell is the cylindrical part of the Forged Cask Body excluding the bottom.

[

]

2.11.14.2 Radial Thermal Expansion

The thermal expansions of the DSC and cask spacer in radial direction are given by the following formulas:

$$OD_{DSC,Hot} = OD_{DSC}[1 + \alpha_{DSC}(T_{avg,DSC} - T_{ref})]$$

$$OD_{SD,Hot} = OD_{SD}[1 + \alpha_{SD}(T_{avg,SD} - T_{ref})]$$

Thermal expansions of TN Eagle Cask shell in radial directions are given by:

$$ID_{Cask,Hot} = ID_{Cask}[1 + \alpha_{Cask}(T_{avg,Cask} - T_{ref})]$$

Diametrical hot gap in radial direction between DSC shell and cask shell is:

$$\Delta_{HOT\_GAP1,RADIAL} = ID_{Cask,Hot} - OD_{DSC,Hot}$$

Diametrical hot gap in radial direction between cask spacer and cask shell is:

$$\Delta_{HOT\_GAP2,RADIAL} = ID_{Cask,Hot} - OD_{SD,Hot}$$

The results of the radial thermal expansion are presented in Table 2.11.14-2.

2.11.14.3 Axial Thermal Expansion

The thermal expansions of the DSC and cask spacer in the axial direction are given by:

$$L_{DSC,Hot} = L_{DSC}[1 + \alpha_{DSC}(T_{avg,DSC} - T_{ref})]$$

$$L_{SD,Hot} = L_{SD}[1 + \alpha_{SD}(T_{avg,SD} - T_{ref})]$$

Thermal expansions of TN Eagle Cask shell in the axial directions are given by:

$$L_{Cask,Hot} = L_{Cask}[1 + \alpha_{Cask}(T_{avg,Cask} - T_{ref})]$$

The axial hot gap between cask spacer and DSC and cask shell is:

$$\Delta_{HOT\_GAP,AXIAL} = L_{Cask,Hot} - (L_{DSC,Hot} + L_{SD,Hot})$$

The results of the radial thermal expansion are presented in Table 2.11.14-3.

2.11.14.4 Nomenclature

$T_{ref} = 70°F$	: Reference Temperature, °F
$T_{avg,DSC}$	: Volumetric average temperature of DSC shell, °F
$T_{avg,Cask}$	: Volumetric average temperature of TN Eagle cask shell, °F
$T_{avg,SD}$	: Volumetric average temperature of cask spacer, °F
α_{DSC}	: Thermal expansion coefficient of DSC shell material as per Table 8-6 of [2] 10^{-6} $°F^{-1}$
α_{Cask}	: Thermal expansion coefficient of TN Eagle cask body material as per Table 7-1, 10^{-6} $°F^{-1}$
α_{SD}	: Thermal expansion coefficient of cask spacer material as per Table 7-5, 10^{-6} $°F^{-1}$
$OD_{DSC,Hot}$	: Hot outer diameter of DSC shell, in.
OD_{DSC}	: Outer diameter of DSC shell at reference temperature, in.
$OD_{SD,Hot}$	: Hot outer diameter of cask spacer, in.
OD_{SD}	: Outer diameter of cask spacer at reference temperature, in.
$L_{DSC,Hot}$	: Hot length of the DSC shell, in.
L_{DSC}	: Length of the DSC shell at reference temperature, in.
$ID_{Cask,Hot}$	: Hot inner diameter of TN Eagle cask shell, in.
ID_{Cask}	: Inner diameter of TN Eagle cask shell at reference temperature, in.
$L_{Cask,Hot}$	: Hot TN Eagle cask cavity length, in.
L_{Cask}	: TN Eagle cask cavity length at reference temperature, in.
$L_{SD,Hot}$	: Hot Length of the cask spacer, in.
L_{SD}	: Length of the cask spacer at reference temperature, in.
$\Delta_{HOT\_GAP,RADIAL}$	: Diametrical hot gap in radial direction between DSC/cask spacer and cask shell, in.

$\Delta_{GAP,RADIAL}$: Diametrical gap in radial direction between DSC/cask spacer and cask shell at reference temperature, in.

$\Delta_{HOT\_GAP,AXIAL}$: Axial hot gap between the DSC and cask inner cavity, in.

$\Delta_{GAP,AXIAL}$: Axial gap between the DSC and cask inner cavity at reference temperature, in.

2.11.14.5 Conclusion

Based on the results shown in Table 2.11.14-2 and Table 2.11.14-3, there is adequate clearance between the various components of the canister and cask to allow a free thermal expansion. Consequently, no stress will develop in the TN Eagle cask due to thermal expansion of any of the DSCs considered for transportation in the TN Eagle Cask.

2.11.14.6 References

1. Orano TN, "NUHOMS®-MP197 Transportation Packaging Safety Analysis Report," Revision 20. Docket No. 07109302

2. Orano TN, "NUHOMS® EOS System Updated Final Safety Analysis Report," Revision 3. Docket No. 07201042

Table 2.11.14-1
Dimensions Used in Calculating Thermal Expansion

Components	Heat Load (kW)	OD (in.)	L (in.)	$ID_{Cask\ Shell}$ (in.)	$L_{Cask\ Cavity}$ (in.)	Diametrical Gap in TN Eagle Model (in.)	Axial Gap in TN Eagle Model (in.)
DSC Shell	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Cask spacer			[ ]				

Table 2.11.14-2
Diametrical Gaps between EOS-37PTH DSC and TN Eagle Cask Shell at 100 °F and -40 °F Ambient Temperatures and HLZC #1 (38.4 kW)

[ ]

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Chapter 3
Thermal Evaluation

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Chapter 3
Thermal Evaluation

This chapter presents the thermal evaluations to demonstrate that the TN Eagle cask meets thermal requirements of 10 CFR Part 71 [6] for transportation of boiling water reactor (BWR) and pressurized water reactor (PWR) spent fuel assemblies (FAs) within the following DSCs: EOS-37PTH, EOS-89BTH, 32PT, 32PTH1, 24PT4, 24PT1, and FO/FC/FF DSCs.

The TN Eagle cask has two types depending on the DSC size:

- TN Eagle LC (Large Canister)
- TN Eagle SC (Standard Canister)

The maximum heat load per DSC allowed for transportation in TN Eagle cask varies for different DSC types from 13.5 kW to 38.4 kW. The table below summarizes the maximum heat load per DSC for transportation in comparison with maximums allowed for storage.

Maximum Heat Load per DSC

DSC type	TN Eagle Cask Type	Max. Heat Load for Transport (kW)	Max. Heat Load for Storage (kW)
EOS-37PTH	LC	38.4	50.0 [1]
EOS-89BTH	LC	31.15	43.6 [1]
32PT	SC	24.0	24.0 [2]
32PTH1 Type 1	SC	26.0	40.8 [2]
32PTH1 Type 2	SC	24.0	31.2 [2]
24PT4	SC	24.0	24.0 [3]
24PT1	SC	14.0	14.0 [3]
FO/FC/FF	SC	13.5	13.5 [4]

For all DSC types, this evaluation demonstrates that DSC component temperatures are within material temperature limits and fuel cladding temperatures meet the thermal requirements of ISG-11 [5].

Section 3.1 describes the thermal design in details. Section 3.2 lists the material properties used in the thermal evaluations, the specifications of components, and thermal design limits of TN Eagle cask and DSC components.

Section 3.3 through Appendix 3.6.4 evaluate the thermal performance of the TN Eagle LC loaded with the EOS-37PTH or EOS-89BTH DSCs. The thermal evaluations presented in Section 3.3 for normal conditions of transport (NCT) and Section 3.4 for hypothetical accident conditions (HAC) are performed assuming that the FAs remain intact. These evaluations demonstrate that the fuel cladding temperatures remain below the allowable limits given in ISG-11 [5] and the cask component temperatures remain below all operating limits, if the physical configuration of the FAs is not altered. Appendix 3.6.1 presents the mesh sensitivity study on the thermal model of the TN Eagle LC loaded with the EOS-37PTH DSC. Appendix 3.6.2 studies the effects of the punctures on the TN Eagle cask during accident fire conditions. The thermal evaluations presented in Appendix 3.6.3 are performed assuming high burnup (HBU) reconfigured FAs during transportation for both NCT and HAC. These evaluations demonstrate that the containment of the TN Eagle cask is maintained during transportation for NCT and HAC, and the cask component temperatures remain below all operating limits when the FAs are assumed to be reconfigured. Appendix 3.6.4 evaluates the thermal performance of the TN Eagle LC loaded with the EOS-37PTH DSC with damaged or failed fuels under NCT and HAC.

Appendix 3.6.5 evaluates the thermal performance of the TN Eagle SC loaded with non-EOS DSCs mentioned above.

The thermal evaluations provide assurance that all applicable regulatory requirements specified in 10 CFR Part 71 under NCT and HAC in [6] are satisfied.

The unit system used in the thermal models in ANSYS FLUENT [7] is International System of Units (SI); however, the imperial unit system is used for reporting the results from thermal evaluations.

3.1 Description of the Thermal Design

The TN Eagle cask is designed to passively reject decay heat under NCT and HAC while maintaining packaging temperatures and pressures within specified limits. Objectives of the thermal analyses performed for this evaluation include:

a. Determination of maximum component temperatures with respect to cask materials limits to ensure components perform their intended safety functions,

b. Determination of temperature distributions to support the calculation of thermal stresses,

c. Determination of the cask and DSC cavity gas temperature to support containment pressure calculations, and

d. Determination of the maximum fuel cladding temperature.

Chapter 1 presents the principal design bases for the TN Eagle cask.

The NCT ambient temperature range is –20 °F to 100 °F (-29 °C to 38 °C) per 10 CFR 71.71(b) [6]. In general, all the thermal criteria are associated with maximum temperature limits and not minimum temperatures. All materials can be subjected to the minimum environment temperature of -40 °F (-40 °C) without adverse effects as required by 10 CFR 71.71 (c)(2) [6].

Thermal performance of the TN Eagle cask with various DSCs is evaluated based on ANSYS FLUENT computer code [7].

3.1.1 Design Features

3.1.1.1 TN Eagle Cask

The TN Eagle cask includes optional features such as an internal sleeve to accommodate DSC types with outer diameter (OD) smaller than [ ] The cask design features for different DSC types considered for transportation in TN Eagle cask are listed in the table below.

TN Eagle Cask Design Features

DSC Type		Max. DSC Heat Load for Transport (kW)
TN Eagle LC		
EOS-37PTH (1)		38.4
EOS-89BTH (2)		31.15
TN Eagle SC		
24PT4 (3)		24.0
32PT (4)		24.0
32PTH1 Type 1 (5)		26.0
32PTH1 Type 2 (5)		24.0
FO/FC/FF (6)		13.5
24PT1 (7)		14.0

Notes:
(1) See Appendix 1.6.1 for detailed description of EOS-37PTH DSC
(2) See Appendix 1.6.2 for detailed description of EOS-89BTH DSC
(3) See Appendix 1.6.3 for detailed description of 24PT4 DSC
(4) See Appendix 1.6.4 for detailed description of 32PT DSC
(5) See Appendix 1.6.5 for detailed description of 32PTH1 DSC
(6) See Appendix 1.6.6 for detailed description of FO/FC/FF DSCs
(7) See Appendix 1.6.7 for detailed description of 24PT1 DSC

The TN Eagle cask consists of a forged body which conducts the decay heat to the cask outer surface. The other thermal design feature of the cask is the conduction path created by the shielding rings that contain the neutron shielding material as described in Chapter 5. The neutron shielding resin blocks are placed in the lodgments of the shielding rings. The shielding rings are designed to shrink fit tightly against the steel shell surfaces, thus improving the heat transfer across the neutron shield.

Heat dissipates from the packaging outer surfaces via natural convection and radiation. The outer surfaces of the shielding rings are painted white to enhance the thermal radiation exchange with ambient.

The design of the impact limiters is described in Chapter 1, Section 1.2.1. These components are included in the thermal analysis because of their contribution as a thermal insulator. The impact limiters provide protection to the lid and bottom regions from the external heat input due to fire during the HAC thermal event.

A personnel barrier prevents access to the outer surfaces of the cask body. The barrier, which consists of a stainless steel mesh attached to stainless steel tubing, encloses the cask body between the impact limiters, and has an open area fraction of approximately 80%.

The gaps considered in the thermal model of the TN Eagle cask are described in Section 3.3.1.1.

3.1.1.2 EOS-37PTH DSC

The description of the EOS-37PTH DSC design is documented in Appendix 1.6.1. The EOS-37PTH DSC is analyzed based on a maximum heat load of 38.4 kW from 37 PWR FAs with a maximum heat load of 1.6 kW per assembly. The authorized heat load zone configurations (HLZCs) for the transportation of the EOS-37PTH DSC in the TN Eagle LC are provided in Figures 1.6.1-1 and 1.6.1-2 in Appendix 1.6.1. EOS-37PTH DSC basket types 1, 2, 3, and 4H and baskets with equivalent thermal properties are allowed to be transported in the TN Eagle LC with intact, HBU reconfigured, damaged, or failed fuels.

[ ]

[ ]

3.1.1.3 EOS-89BTH DSC

The description of the EOS-89BTH DSC design is documented in Appendix 1.6.2. The EOS-89BTH DSC is analyzed based on a maximum heat load of 31.15 kW from 89 BWR FAs with a maximum heat load of 0.35 kW per assembly. The authorized HLZC for the transportation of the EOS-89BTH DSC in the TN Eagle LC is provided in Figure 1.6.2-1 in Appendix 1.6.2. EOS-89BTH DSC basket types 1, 2, and 3 are allowed to be transported in the TN Eagle LC with intact fuels.

[ ]

3.1.1.4 Other Non-EOS DSC Types

Other non-EOS DSCs including 24PT4, 32PT, 32PTH1, FO/FC/FF, and 24PT1 DSCs are allowed to be transported in the TN Eagle SC with internal sleeves. The design features of 32PT and 32PTH1 DSCs are discussed in Sections M.1.2.1 and U.1.2.1 of [2], respectively. The design features of 24PT1 and 24PT4 DSCs are discussed in Sections 1.2.1.1 and A.1.2.1.1 of [3], respectively. The design features of FO/FC/FF DSCs are discussed in Section 1.2.2 of Volume I of [4]. The detailed descriptions of these DSCs are documented in Appendix 1.6.3 through Appendix 1.6.7.

3.1.2 Codes and Standards

The complete list of codes and standards which are applicable to the TN Eagle cask is documented in Section 1.1.5. The codes and standards that are used in all aspects of the thermal design and evaluation of the package are listed below:

- Spent Fuel Project Office, Interim Staff Guidance – 11, Rev 3, “Cladding Considerations for the Transportation and Storage of Spent Fuel.”
- NUREG-2216, “Standard Review Plan for Spent Fuel Transportation,” August, 2020.
- NUREG-2224, “Dry Storage and Transportation of High Burnup Spent Nuclear Fuel Final Report,” November 2020.
- NUREG-2152, “Computational Fluid Dynamics Best Practice Guidelines for Dry Cask Applications,” March 2013.
- American Society of Mechanical Engineers, “Standard for Verification and Validation in Computational Fluid Dynamics and Heat Transfer,” ASME V&V 20-2009, November 30th, 2009.
- ASME Boiler and Pressure Vessel Code, Section II, Materials Specifications, Part D, 2017.

3.1.3 Content Heat Load Specification

The thermal analysis for the TN Eagle cask loaded with the DSCs listed in the table in Section 3.1.1.1 is based on a range of maximum total heat load of 13.5 kW to 38.4 kW per DSC.

The maximum decay heat loads for transport of the EOS-37PTH and EOS-89BTH DSCs in the TN Eagle LC are, respectively, 38.4 kW and 31.15 kW as shown in Sections 3.1.1.2 and 3.1.1.3.

The maximum decay heat loads for transport of the 24PT4, 32PT, 32PTH1 Type 1 and Type 2 DSCs in the TN Eagle SC are, respectively, 24.0 kW, 24.0 kW, 26.0 kW and 24.0 kW as shown in Section 3.1.1.1 based on [8]. The maximum decay heat loads for transport of the FO/FC/FF and 24PT1 DSCs in the TN Eagle SC are, respectively, 13.5 kW and 14.0 kW as shown in Section 3.1.1.4 based on [9].

The permitted HLZCs for all DSCs are listed in Chapter 1, Appendix 1.6.1 through Appendix 1.6.7. These design basis HLZCs are symmetrical and show maximum allowable heat load per FA and per DSC, which result in bounding maximum fuel cladding and DSC component temperatures.

[

]

Section 3.3 through Appendix 3.6.4 present the thermal evaluations of the EOS-37PTH and EOS-89BTH DSCs transported in the TN Eagle LC. Section 3.6.5 evaluates the thermal performance of the TN Eagle SC loaded with non-EOS DSCs. These analyses demonstrate that the maximum temperatures and pressures for various DSC types under transport conditions of 10 CFR 71 [6] remain below the allowable thermal design limits in Section 3.2.3.

Summaries of the maximum temperatures and pressures are provided in Section 3.1.4 and Section 3.1.5, respectively. The thermal evaluation concludes that for the maximum heat loads listed in Section 3.1.1.1, all design criteria listed in Section 3.2.3 are satisfied.

3.1.4 Summary Tables of Temperatures

The maximum temperatures of the TN Eagle LC and EOS-37PTH/EOS-89BTH DSC components for NCT are summarized in Table 3-8 and Table 3-10. The component temperatures remain within the allowable range for NCT.

The maximum TN Eagle cask and DSC component temperatures for cold conditions at -40°F ambient without insolance are presented in Table 3-8. These temperatures are used for the structural evaluation.

The maximum accessible surface temperatures under shade are 149 °F and 161 °F for impact limiter shell and personnel barrier as calculated in Section 3.3.4.

The maximum HAC transient temperatures of the TN Eagle LC and EOS-37PTH/EOS-89BTH components are summarized in Table 3-16, Table 3-19, and Table 3.6.3-4 for intact fuels in EOS-37PTH DSC, intact fuels in EOS-89BTH DSC, and HBU reconfigured fuels, respectively. The resins are assumed to be decomposed or charred after fire accident. Therefore, the maximum temperatures for resins are irrelevant for HAC. The maximum fuel cladding and seal temperatures remain below the allowable limits and ensure the integrity of the fuel cladding and the containment boundary for HAC.

3.1.5 Summary Tables of Pressures in the Containment Vessel

The bounding maximum internal pressures inside the TN Eagle cask cavity are calculated in Section 3.3.3 for NCT and Section 3.4.4 for HAC. The bounding maximum internal pressures of the TN Eagle cask cavity are summarized in Table 3-12. The maximum pressures inside DSC cavities of EOS-37PTH and EOS-89BTH DSCs are listed in Table 3-13.These pressures remain below the design pressures for NCT and HAC considered for the structural evaluation.

3.2 Material Properties and Component Specifications

Proprietary Information on Pages 3-10 through 3-29
Withheld Pursuant to 10 CFR 2.390

[

]

3.2.2 Specifications of Components

The components for which thermal technical specifications are necessary are the TN Eagle containment seals and poison plates used in DSC baskets.

3.2.2.1 TN Eagle TC

The seals used in the packaging are the Fluorocarbon seals (Viton O-rings and metallic seals). The Fluorocarbon seals will have a minimum and maximum temperature rating of -40 °F and 400 °F, respectively.

The metallic seals will have a minimum and maximum temperature rating of -40 °F and 572 °F, respectively.

3.2.2.2 EOS-37PTH and EOS-89BTH DSCs

[

]

3.2.3 Thermal Design Limits of Package Materials and Components

Several thermal design criteria are established for the TN Eagle cask to ensure that the package meets all its functional and safety requirements. These are:

- Maximum fuel cladding temperature limits of 752 °F (400 °C) for NCT and 1,058 °°F (570 °C) for HAC are considered for the FAs with an inert cover gas as concluded in ISG-11 [5]. The maximum fuel cladding temperature limit of 752 °F (400 °C) is considered for HBU FAs under NCT. However, HBU reconfigured fuels, whose physical integrity may not be guaranteed under HAC, are conservatively assumed as rubble. Therefore, the above maximum fuel cladding temperature limit of 1,058 °F (570 °C) for HAC is not applicable to the HBU reconfigured fuels.
- Containment of radioactive material and gases is a major design requirement. Seal temperatures must be maintained within specified limits to satisfy the leak-tight containment requirement. A maximum temperature limit of 400 °F (204 °C) is considered for the Fluorocarbon seals (Viton O-rings) in the containment vessel ([11] and [12]) for NCT and HAC. A maximum seal temperature of 572 °F (300 °C) is considered for all metallic seals for thermal evaluation for NCT and HAC.
- To maintain the stability of the neutron shield resin, a maximum allowable temperature of 320 °F (160 °C) is considered for the neutron shield VYAL-B resin [13] for NCT. The neutron shield resin are assumed to disintegrate completely after the HAC fire, therefore, are not taken credit in heat transfer. The above VYAL-B temperature limit is not applicable to HAC.
- In accordance with 10 CFR 71.43(g) [6] the maximum temperature of the accessible packaging surfaces in the shade is limited to 185 °F (85 °C).
- The recommended temperature design limit for the aluminum honeycomb in the impact limiter is 248 °F (120 °C) under NCT, per manufacturer's recommendations [20].
- The maximum DSC cavity internal design pressures are summarized below:

DSC	Design Pressure (psig)	
	NCT (3% rods ruptured)	**HAC (100% rods ruptured)**
EOS-37PTH and EOS-89BTH DSCs [1]	20	130
24PT4 [3]	20	100
32PT [2]	15	125
32PTH1 Type 1 and Type 2 [2]	15	140
FO/FC/FF [4]	10	50
24PT1 [3]	10	60

3.3 Thermal Evaluation under Normal Conditions of Transport

The NCT ambient conditions are used to determine the maximum fuel cladding temperature, the maximum TN Eagle cask and DSC temperatures, the containment pressure, and the thermal stresses. These steady state environmental conditions correspond to maximum daily averaged ambient temperature of 100 °F and to 10 CFR 71.71(c)(1) [6] insolation averaged over a 24-hour period.

Ambient conditions for NCT are taken from 10 CFR 71 [6] and applied to the boundaries of the cask model. These conditions are listed Table 3-3.

This section discusses the thermal evaluations of the EOS-37PTH and EOS-89BTH DSCs transported in TN Eagle LC under NCT.

Proprietary Information on Pages 3-33 through 3-50
Withheld Pursuant to 10 CFR 2.390

3.4 Thermal Evaluation under Hypothetical Accident Conditions

The thermal performances of the TN Eagle LC loaded with the EOS-37PTH DSC with heat load up to 38.4 kW and the EOS-89BTH DSC with heat load up to 31.15 kW are evaluated in this section under the HAC described in 10 CFR 71.73 [6]. This evaluation is performed primarily to demonstrate the containment integrity of the TN Eagle cask for HAC. This is assured as long as the seal temperatures remain below the long-term temperature limits presented in Section 3.2.3, 400 °F (204 °C) for the Fluorocarbon seals and 572 °F (300° C) for the metallic seals, and the DSC cavity pressures are less than the design pressure as specified in Section 3.2.3.

The evaluations are presented in Appendix 3.6.3.3 for the case that the physical integrity of the HBU fuel assemblies may not be guaranteed. For the case of intact fuels and HBU fuel assemblies whose physical configuration is not altered, the thermal evaluations are presented below for HAC.

Proprietary Information on Pages 3-52 through 3-59
Withheld Pursuant to 10 CFR 2.390

3.5 References

1. Orano TN, "NUHOMS® EOS System Updated Final Safety Analysis Report," Revision 3. Docket No. 07201042.

2. Orano TN, "Updated Final Safety Analysis Report for the Standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel," Revision 18. Docket No. 07201004.

3. Orano TN, "Updated Final Safety Analysis Report for the Standardized Advanced NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel," Revision 9. Docket No. 07201029.

4. Rancho Seco Nuclear Generating Station, "Rancho Seco Independent Spent Fuel Storage Installation Final Safety Analysis Report," Revision 6. Docket No. 07200011.

5. U.S. NRC, Spent Fuel Project Office, Interim Staff Guidance, ISG-11, Rev 3, Cladding Considerations for the Transportation and Storage of Spent Fuel.

6. U.S. Code of Federal Regulations, Part 71, Title 10, "Packaging and Transportation of Radioactive Material."

7. ANSYS FLUENT, Version 17.1, ANSYS, Inc.

8. Orano TN, "NUHOMS®-MP197 Transportation Package Safety Analysis Report," Revision 20. Docket No. 07109302.

9. Orano TN, "Safety Analysis Report for the NUHOMS®-MP187 Multi-Purpose Cask," Revision 17. Docket No. 07109255.

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11. Parker O-ring Handbook 5700, Y2000 Edition, 1999.

12. Parker O-ring Division, Material Report Number KJ0835, 1989.

13. Test Report, Properties to be Considered for Safety for Resin VYAL-B, Transnuclear International, Report No. DI/RI-A-1-5-02, Rev. 1, 2006.

14. SolidWorks 2017, Dassault Systèmes SolidWorks Corporation, September 2016.

15. ANSYS DesignModeler, Version 17.1, ANSYS, Inc.

16. ANSYS ICEM CFD, Version 17.1, ANSYS, Inc.

17. USNRC, "Computational Fluid Dynamics Best Practice Guidelines for Dry Cask Applications," NUREG-2152, March 2013.

18. Gregory, et al., Thermal Measurements in a Series of Long Pool Fires, SANDIA Report, SAND 85-0196, TTC-0659, 1987.

19. USNRC, “Dry Storage and Transportation of High Burnup Spent Nuclear Fuel Final Report,” NUREG-2224, November 2020.

20. TR-1004453, “Benchmarking of the Constitutive Model of Biaxial Aluminum Honeycomb.”

21. ASME Boiler and Pressure Vessel Code, Section II, Material Specifications, Part D, 2017.

Proprietary Information on Pages 3-62 and 3-63
Withheld Pursuant to 10 CFR 2.390

Table 3-2
Solar Insolance on Curved and Flat Surfaces

Surface Type	Solar Insolance over 12 hrs ($gcal/cm^2$)	Solar Insolance over 24 hrs (W/m^2)	Solar Absorptivity --	Solar Flux Applied (W/m^2)
Curved, Painted	400	193.65	0.613	118.707
Flat, Vertical, Painted	200	96.83	0.613	59.357

Table 3-3
Load Cases of Normal Conditions of Transport of EOS-37PTH DSC in TN Eagle LC with Impact Limiters

Load Case #	HLZC #	Ambient Temperature (°F)	Insolance	Purpose
1	1	100	Yes	Maximum Component Temperatures for HLZC #1
2 (1)	2	100	Yes	Maximum Component Temperatures for HLZC #2
3	1	-40	No	Maximum Thermal Stress for Structural Analysis

Note:
(1) The maximum heat load per DSC for HLZC # 2 is limited to 33.2 kW, which is lower compared to the maximum heat load of 38.4 kW for HLZC # 1. Hence, Load Case #2 is bounded by Load Case #1.

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Table 3-6
Characteristic Lengths Defined for Exterior Boundary Conditions of TN Eagle LC and Top and Bottom Impact Limiters

Table 3-7
Load Cases of EOS-89BTH DSC Loaded in TN Eagle LC with Impact Limiters

Load Case #	HLZC #	Ambient Temperature (°F)	Insolance	Description
1	1	100	Yes	Bounding Load Case for NCT

Proprietary Information on Pages 3-67 through 3-94
Withheld Pursuant to 10 CFR 2.390

3.6 APPENDICES

Proprietary Information on Pages 3.6.1-i and Pages 3.6.1-1 through 3.6.1-6
Withheld Pursuant to 10 CFR 2.390

Proprietary Information on Pages 3.6.2-i and Pages 3.6.2-1 through 3.6.2-6
Withheld Pursuant to 10 CFR 2.390

Appendix 3.6.3
Thermal Evaluation of High Burnup Fuel Assemblies

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3.6.3 Thermal Evaluation of High Burnup Fuel Assemblies

The TN Eagle Cask is designed to transport and store low burnup fuel assemblies (FAs) with burnup ≤ 45 GWd/MTU and high burnup (HBU) FAs with burnup > 45 GWd/MTU. To bound the uncertainties in the physical configuration of the FAs due to the paucity of the structural properties of the HBU fuel assemblies for normal conditions of transport (NCT) and hypothetical accident condition (HAC), thermal evaluations are performed to bound both possible configurations. For the case that the physical configuration of the FAs is not altered (for both low burnup and HBU FAs), the thermal evaluations presented for NCT in Section 3.3 and for HAC in Section 3.4 remain valid for HBU FAs.

If the physical integrity of the FAs may not be guaranteed, the evaluations presented in this appendix are performed to provide assurance that the containment of the TN Eagle Cask is maintained during transportation of HBU FAs for NCT and HAC.

3.6.3.1 Methodology

This section presents the thermal evaluations necessary to demonstrate the containment of the TN Eagle Cask during transportation due to the physical reconfiguration of the FAs by considering various scenarios.

Proprietary Information on Pages 3.6.3-2 and 3.6.3-3
Withheld Pursuant to 10 CFR 2.390

3.6.3.4 References

1. Orano TN, "NUHOMS® EOS System Updated Final Safety Analysis Report", Revision 3. Docket No. 07201042.

2. USNRC, "Dry Storage and Transportation of High Burnup Spent Nuclear Fuel Final Report," NUREG-2224, November 2020.

3. Oak Ridge National Laboratory, "Effect of Fuel Failure on Criticality Safety and Radiation Dose for Spent Fuel Casks," by K.R. Elam, J.C. Wagner and C.V. Parks, NUREG/CR-6835 (ORNL/TM-2002/255), September 2003.

Table 3.6.3-1
Load Cases for Transport of EOS-37PTH DSC in TN Eagle LC with HBU Reconfigured FAs and HLZC 1 under HAC

Load Case #	Operating Condition	Ambient Temp. (°F)	Insolance	Fuel Configuration	Description	Duration
1T	HAC –initial condition	100	YES	Top Configuration	[	Steady-state
2T	HAC-FIRE transient	1475	NO			30 minutes
3T	HAC-Cool down transient	100	YES			50 hours
1B	HAC –initial condition	100	YES	Bottom Configuration		Steady-state
2B	HAC-FIRE transient	1475	NO			30 minutes
3B	HAC-Cool down transient	100	YES		]	50 hours

Proprietary Information on Pages 3.6.3-6 through 3.6.3-15
Withheld Pursuant to 10 CFR 2.390

Appendix 3.6.4
Thermal Evaluation of Damaged and Failed Fuel Assemblies in TN Eagle LC

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3.6.4 Thermal Evaluation of Damaged and Failed Fuel Assemblies in TN Eagle LC

According to Heat Load Zone Configuration (HLZC) 1 shown in Figure 1.6.1-1, EOS-37PTH Dry Shielded Canister (DSC) can accommodate up to eight damaged fuel assemblies (FAs), or four failed fuel canisters (FFCs), along with intact FAs. It should be noted that damaged FAs and FFCs shall not be stored in the same DSC. EOS-89BTH DSC is not allowed to store damaged and failed FAs. This appendix evaluates the thermal performance of the TN Eagle Large Canister (LC) loaded with the EOS-37PTH DSC with damaged or failed FAs under normal conditions of transport (NCT) and hypothetical accident condition (HAC).

3.6.4.1 Damaged Fuel

HLZC 1 can accommodate a combination of intact FAs along with damaged FAs. It can be loaded with up to eight damaged FAs as noted in Figure 1.6.1-1.

3.6.4.2 Failed Fuel

HLZC 1 can accommodate a combination of intact FAs along with FFCs. It can be loaded with up to four FFCs as noted in Figure 1.6.1-1. [

]

[

]

[

]

3.6.4.3 Conclusion

[

] Therefore, the design criteria specified in Section 3.2.3 are satisfied and the containment of the TN Eagle LC with the EOS-37PTH DSC with damaged and failed FAs is assured.

3.6.4.4 References

1. Orano TN, "NUHOMS® EOS System Updated Final Safety Analysis Report," Revision 3. Docket No. 07201042.

2. Orano TN, "NUHOMS® EOS System Generic Technical Specifications," CoC 1042 Appendix A, Amendment 1.

Appendix 3.6.5
Thermal Evaluation of TN Eagle SC with Non-EOS DSCs

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3.6.5 Thermal Evaluation of TN Eagle SC with Non-EOS DSCs

As discussed in Section 1.1, the TN Eagle Large Canister (LC) is designed for the transport of spent fuels stored in the EOS-37PTH and EOS-89BTH DSCs, and the TN Eagle Standard Canister (SC) is used for the transport of the non-EOS dry shielded canisters (DSCs) including 24PT4, 32PT, 32PTH1, FO/FC/FF, and 24PT1 DSCs. The main Chapter 3 presents the thermal evaluations of the EOS-37PTH and EOS-89BTH DSCs in the TN Eagle LC. This appendix presents the thermal performance of the non-EOS DSCs transported in the TN Eagle SC.

DSC types 24PT4, 32PT, 32PTH1 Type 1 and 2, FO/FC/FF, and 24PT1 are evaluated in [1], [2], and [3] for storage/transfer conditions under 10 CFR Part 72 requirements, and in [4] and [5] for transportation under 10 CFR Part 71 requirements. The following table lists the previously approved 10 CFR Part 72 and 10 CFR Part 71 Safety Analysis Reports (SARs) for these DSCs.

Approved 10 CFR Part 71 and 10 CFR Part 72 SARs for DSCs

DSC Type	10 CFR Part 71	10 CFR Part 72
24PT4	CoC 9302 [4], Appendix A	CoC 1029 [2], Appendix A
32PT		CoC 1004 [1], Appendix M
32PTH1 Type 1 and 2		CoC 1004 [1], Appendix U
FO/FC/FF	CoC 9255 [5], Chapters 1 through 8	SNM-2510 [3]
24PT1	CoC 9255 [5], Appendix A	CoC 1029 [2], Chapters 1 through 14

Proprietary Information on Pages 3.6.5-2 through 3.6.5-7
Withheld Pursuant to 10 CFR 2.390

3.6.5.3 References

1. Orano TN, "Updated Final Safety Analysis Report for the Standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel," Revision 18, Docket No. 07201004.

2. Orano TN, "Updated Final Safety Analysis Report for the Standardized Advanced NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel," Revision 9, Docket No. 07201029.

3. Rancho Seco Nuclear Generating Station, "Rancho Seco Independent Spent Fuel Storage Installation Final Safety Analysis Report," Revision 6, Docket No. 07200011.

4. Orano TN, "NUHOMS®-MP197 Transportation Package Safety Analysis Report," Revision 20, Docket No. 07109302.

5. Orano TN, "Safety Analysis Report for the NUHOMS®-MP187 Multi-Purpose Cask," Revision 17. Docket No. 07109255.

6. ANSYS ICEM CFD, Version 17.1, ANSYS, Inc.

7. ANSYS FLUENT, Version 17.1, ANSYS, Inc.

8. Orano TN, "NUHOMS® EOS System Updated Final Safety Analysis Report," Revision 3, Docket No. 07201042.

Table 3.6.5-1
Comparison of Decay Heat Generation Rates in Homogenized DSC Basket

DSC Type	10 CFR Part 71 Max. Heat Load (kW)				Reference
24PT4	24				Section A.4.4.3.1 of [2]
32PT	24				Section M.4.4.1.6 of [1]
32PTH1 Type 1	26				Section U.4.5.2 of [1]
32PTH1 Type 2	24				Section U.4.5.2 of [1]
FO/FC/FF	13.5 (1)				Section 3.4.1.1 of [5]
24PT1	14 (2)				Section A3.4.1.A of [5]

Table 3.6.5-2
Design Load Cases of 32PTH1 DSC in TN Eagle SC with Impact Limiters under NCT

Load Case #		Ambient Temperature (°F)	
1		100	
2		100	
3		100	

Proprietary Information on Pages 3.6.5-11 through 3.6.5-21
Withheld Pursuant to 10 CFR 2.390

Chapter 4
Containment Evaluation

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Chapter 4
Containment Evaluation

4.1 Description of Containment System

4.1.1 Containment Boundary

The TN Eagle will transport EOS-37PTH, EOS-89 BTH, 32PT, 32PTH1, 24 PT4, 24PT1, FO, FC, and FF dry storage canisters (DSCs) whose content, including fuel type, fuel amount, percent enrichment, burnup, cool time and decay heat that have been stored are described in Appendix 1.6. While the DSC boundary consists of a welded vessel, it is not being credited for containment of radioactive material during transportation operations.

The containment boundary of the TN Eagle, shown in Figure 4-1 consists of a thick forged body, a primary lid, a lid orifice cover plate, a ram access cover plate, and the associated closure seals. The containment vessel is assembled with bolted connections and there are no associated welds. The containment vessel prevents leakage of radioactive material from the cask cavity. It also maintains an inert atmosphere (helium) in the cask cavity. Dimensions and materials of the containment vessel are provided in Table 4-1.

The containment vessel is designed, fabricated, examined and tested in accordance with the requirements of Regulatory Guides 7.6 [1], 7.8 [2], and subsection NB of the ASME Code [3] to the maximum practical extent. Even though this section of the code is not strictly applicable to transport casks, it is the intent to follow Section III, Subsection NB of the code as closely as possible for design and construction of the containment vessel. Exceptions to the ASME Code are discussed in Chapter 1.

The materials of construction meet the requirements of Section III, Subsection NB-2000 and Section II, Material Specifications or the corresponding ASTM specifications. The containment vessel is fabricated and examined to the maximum pratical extent in accordance with NB-2500, NB-4000, and NB-5000 [3] and ASTM A350 [5].

The cask may be fabricated by other than N-stamp holders and materials may be supplied by other than ASME certificate holders. Thus, the requirements of NCA are not imposed. TN's quality assurance requirements, which are based on 10 CFR Part 71 subpart H and NQA-1, are imposed in lieu of the requirements of NCA-3850. Surveillances are performed by TN personnel.

4.1.2 Containment Penetrations

The penetrations into the containment boundary include the primary lid, the lid orifice cover plate, and the ram access cover plate. The entire containment vessel, including each penetration is designed to maintain a leak rate not to exceed 1×10^{-7} ref cm^3/s, which is considered to be leak-tight in ANSI N14.5 [6]. To obtain these seal requirements, each penetration has an O-ring seal type closure.

The components used to close each of the containment boundary penetrations are protected by the impact limiters and also by being recessed into the thick lid and body material. There are no devices that allow continuous venting of the cask.

4.1.3 Containment Seals

The lid orifice cover plate seal, and the inner seals in the primary lid and ram access cover plate, are the primary containment boundary seals. Outer seals are provided in the primary lid and ram access cover plate to facilitate leak testing of the inner containment seals. There are test ports provided in between the inner and outer seals for the primary lid, ram access cover plate, and lid orifice cover plate, although the test ports are not part of the containment boundary.

All the seals used in the TN Eagle Cask containment boundary are static face seals. The seal areas are designed to experience no significant plastic deformation under normal and accident loads, as demonstrated in Chapter 2. The dovetail grooves in the cask lid and the ram access closure plate, as detailed in the applicable drawings for package approval, are intended to retain the seals during installation. The volume of the grooves is controlled to allow the mating metal surfaces to contact under bolts loads, thereby providing uniform seal deformation in the final installation condition.

The seals used are fluorocarbon elastomer in the primary lid and ram access closure plate and a metallic seal for the lid orifice cover plate. The metallic seal is not used for the higher temperature limit but rather to support TN industrial standardization effort for such components.

Fluorocarbon has good sealing proprieties from -40 °C (-40 °F) up to 204 °C (400 °F) for the seal configuration used in the cask. The metallic seals will have a minimum and maximum temperature rating of -40 °C (-40 °F) up to 300 °C (572 °F), respectively. Further properties of the seals are presented in Chapter 7. The seal materials are such that significant chemical or galvanic reactions will not occur.

4.1.4 Closure

The primary lid is attached to the cask body with sixty four (64) SA-540 Grade B23 Class 2, SA-540 Grade B24 Class 2, or 1.6580 M42 bolts. Closure of the ram access closure plate is accomplished by twelve (12) SA-540 Grade B23 Class 2, SA-540 Grade B24 Class 2, or 1.6580 M24 bolts. The lid orifice cover plate is closed by ten (10) SA-540 Grade B23 Class 2, SA-540 Grade B24 Class 2, or 1.6580 M14 bolts. The torques required for these closures are provided in the applicable drawings for package approval. All these positively secure the containment system during normal and accident conditions and cannot be opened unintentionally. The closure bolt analysis is presented in Appendix 2.11.4.

4.2 Containement under Normal Condition of Transport

The TN Eagle is designed and tested for a leak rate not to exceed 1×10^{-7} ref cm^3/s, which is considered to be leak-tight in ANSI N14.5 [6]. The acceptance criterion for fabrication verification and periodic verification and periodic leak test of the TN Eagle containment boundary shall be 1.0×10^{-7} ref cm^3/s with a sensitivity of at least 5×10^{-8} ref cm^3/s.

Additionally, the structural and thermal analyses presented in Chapter 2 and 3, respectively, demonstrate that the cask remains leak-tight under any of the normal conditions of transport, which ensures there will be no release of radioactive material or ingress of water during transportation.

The allowed contents for the TN Eagle are DSCs that were welded closed. Therefore, the pressure in the TN Eagle when loaded with a DSC is from the helium that has been backfilled into the evacuated cask cavity to a maximum pressure of 24.1 kPa (3.5 psig) at the end of loading. As shown in Chapter 3, if the TN Eagle contains design basis fuel at thermal equilibrium, the cask cavity helium temperature with 38 °C (100 °F) ambient air and maximum solar load is 151 °C (304 °F). The maximum normal operating pressure is calculated in Chapter 3 to be 83.4 kPa (12.1 psig) and the analyses in Chapter 2 demonstrate that the TN Eagle Cask effectively maintains containment leak-tight integrity with a cavity pressure of 83.4 kPa (12.1 psig).

The fluorocarbon seals in the primary lid and ram access cover plate are not explicitly specified in the thermal models. To be conservative, the maximum temperature for the NCT evaluations of the primary lid 96 °C (204 °F) is considered as maximum temperature of the primary lid seal and lid orifice cover plate seal which are located inside the primary lid. Similarly, the maximum temperature of the ram access cover plate, 105 °C (221 °F), is considered as the maximum temperature of the ram access cover plate seal. Both of these are much less than the temperature limit of the fluorocarbon seals.

Since the TN Eagle is not loaded underwater and is only designed to transport previously loaded and closed DSCs, there will be no water or organic material inside the containment vessel that could generate combustible gases during transportation.

4.3 Containment under Hypothetical Accident Conditions

There is no need to explicitly determine the source term available for release since the TN Eagle is designed and tested to be leak-tight per ANSI N14.5 [6]. The results of the structural and thermal analyses presented in Chapters 2 and 3, respectively, demonstrate that the package will remain leak-tight and, thus, meet the leakage criteria of 10 CFR 71.51 and prevent ingress of water for all the hypothetical accident condition (HAC).

The pressure in the TN Eagle Cask is from helium that has been backfilled into an evacuated cask cavity to a maximum pressure of 24.1 kPa (3.5 psig) at the end of loading. If the TN Eagle Cask contains design basis fuel at thermal equilibrium, the cask cavity helium temperature with 38 °C (100 °F) ambient air and maximum solar load is 171 °C (340 °F). While the maximum normal operating pressure was found to be 83.4 kPa (12.1 psig), Chapter 3 demonstrates that the internal pressure increases to a maximum of 91.7 kPa (13.3 psig) during the fire test. The analyses in Chapter 2 demonstrate that the TN Eagle Cask effectively maintains containment integrity with a cavity pressure of 91.7 kPa (13.3 psig). In Chapter 2, a conservative approach is used and the analyses are computed with a bounding 900 kPa (130 psig).

During the HAC fire evaluation, the peak maximum temp of the primary lid seal, ram access cover plate seal, and lid orifice cover plate seal reach to 179 °C (354 °F) at 1.9 hrs., 153 °C (307 °F) at 10.1 hrs., and 158 °C (317 °F) at 4.6 hrs., respectively, after the end of the 30-minute fire. All of these peak seal temperature remain within the allowable design limit of the associated seals.

4.4 Leakage Rate Tests

The TN Eagle leakage testing is performed in accordance with the requirements of ANSI N14.5 [6]. Personnel performing the tests will be qualified and certified in leakage testing in accordance with SNT-TC-1A [7].

As described earlier, the acceptance criterion for the fabrication, periodic, and maintenance leak testing is a leak rate of less than $1x10^{-7}$ ref cm^3/s with a sensitivity of $5x10^{-8}$ ref cm^3/s, or better. The acceptance criterion for the pre-shipment leak testing is no detectable leakage when tested to a sensitivity of at least 1×10^{-3} ref cm^3/s.

4.5 References

1. NRC Regulatory Guide 7.6, “Design Criteria for Structural Analysis of Shipping Cask Containment Vessels,” Revision 1, March 1978.

2. NRC Regulatory Guide 7.8, “Load Combinations for the Structural Analysis of Shipping Casks for Radioactive Material,” Revision 1, March 1989.

3. ASME B&PVC, Section III, Division 1, Subsection NB, 2017 Edition.

4. ASME B&PVC, Section III, Appendices, 2017 Edition.

5. ASTM A350/A350M-02b, “Standard Specification for Carbon and Low-Alloy Steel Forgings, Requiring Notch Toughness Testing for Piping Components.”

6. ANSI N14.5-2014, “American National Standard for Radioactive Materials – Leakage Tests on Packages for Shipment,” American National Standards Institute, Inc., New York, 2014.

7. SNT-TC-1A “American Society for Nondestructive Testing, Personnel Qualification and Certification in Nondestructive Testing.”

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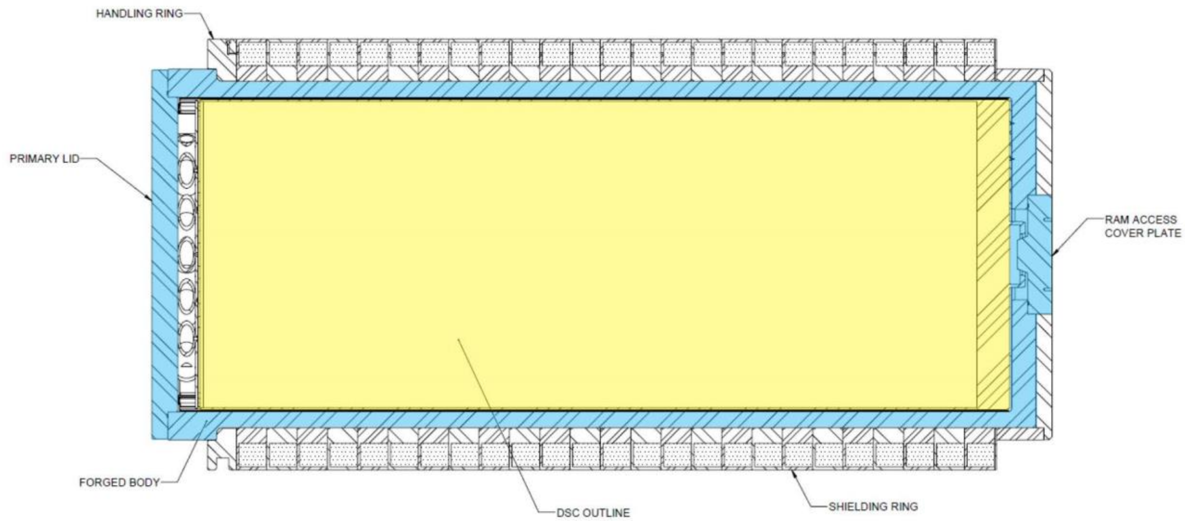

Figure 4-1
Leak-Tight Boundaries
(the containment boundary is shown in blue)

Chapter 5
Shielding Evaluation

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Shielding Evaluation

The TN Eagle cask includes two configurations: TN Eagle Large Canister (LC) and TN Eagle Standard Canister (SC). The TN Eagle LC is designed to host the EOS-37PTH Dry Shielded Canister (DSC) and the EOS-89BTH DSC, and the TN Eagle SC is designed to host other DSCs of TN products, including the FC/FO/FF DSC, the 24PT1 DSC, the 24PT4 DSC, the 32PT DSC, and the 32PTH1 DSC.

The dose rates around the TN Eagle cask are in compliance with the applicable requirements of 10 CFR Part 71 for exclusive-use transportation in an open transport vehicle [1].

This chapter describes the shielding evaluation of the TN Eagle LC transportation package, which includes the TN Eagle LC and the authorized contents. The shielding evaluation of the TN Eagle SC transportation package is described in Appendix 5.6, Section 5.6.1.

5.1 Description of the Shielding Design

The TN Eagle cask, including both the TN Eagle LC and the TN Eagle SC, consists of (proceeding from inner radius to outer):

- a forged cask body that provides the structural integrity of the cask, the gamma shielding, and the radioactive material containment function,
- a lid which provides radioactive material containment,
- shielding rings that surround the forged cask body to provide additional gamma and neutron radiation shielding, and
- impact limiters with adapters placed on each end for use in transport.

The TN Eagle cask is designed to allow horizontal transport of the DSCs loaded with spent fuel assemblies (FAs) in accordance with the requirements of 10 CFR 71 [1]. The authorized contents acceptable for transport are described in Chapter 1, Section 1.2.3. Drawings of the TN Eagle cask and the allowed DSCs are available in Chapter 1, Section 1.5.

The TN Eagle LC is designed to host the EOS-37PTH DSC and the EOS-89BTH DSC. The EOS-37PTH DSC is designed to accommodate up to 37 intact, up to 8 damaged, and up to 4 failed PWR FAs with uranium dioxide (UO_2) fuels, zirconium alloy claddings, and with or without control components (CCs). The EOS-89BTH DSC is designed to accommodate up to 89 intact BWR FAs with uranium dioxide (UO_2) fuels, zirconium alloy claddings, and with or without fuel channels.

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5.1.1 Package Design Features

Shielding for the TN Eagle LC transportation package at the cask side is provided mainly by the forged cask body and the shielding rings surrounding the forged cask body. Shielding for gamma radiation is provided by the forged cask body shell and the shielding ring steel. For the neutron shielding, borated VYAL-B resin blocks are provided in the shielding rings surrounding the forged cask body radially.

Gamma shielding at the cask ends is provided by the steel top and bottom assemblies of the TN Eagle cask and axial ends of the DSCs. VYAL-B resin plates are also provided [ ] at both ends to provide additional neutron shielding at the cask ends.

Additional shielding around the cask is provided by [ ] inside the impact limiters and the adapters.

Minimum dimensions are generally applied in the model configurations. A full discussion and description of the models used in the shielding evaluation is contained in Section 5.3.1. Minimum boron and hydrogen content are applied in the shielding models, and material properties used in the shielding evaluation of the TN Eagle LC transportation package are described in detail in Section 5.3.2.

5.1.2 Summary Table of Maximum Radiation Levels

5.1.2.1 Regulatory Limits

The dose rate limits for transportation of the TN Eagle cask in an exclusive-use open vehicle are obtained from 10 CFR 71.47(b) and 10 CFR 71.51(a)(2) [1] and are listed as follows.

- Dose rate at any point on the external surface of the package under normal conditions is 200 mrem/hr (maximum).
- Dose rate at any point on the vertical planes projected from the outer edges, including the top and underside, under normal conditions is 200 mrem/hr (maximum).
- Dose rate at any point 2 meters from the vertical planes projected from the outer edges, excluding the top and underside, under normal conditions is 10 mrem/hr (maximum).

- Dose rate at occupied spaces under normal conditions is 2 mrem/hr (maximum).
- External dose rate at any point 1 m from the package external surface under hypothetical accident conditions is 1000 mrem/hr (maximum).

5.1.2.2 Maxima

NCT and HAC dose rates are computed for exclusive-use transport in an open vehicle. Due to different package conditions under NCT and under HAC, the external surfaces of the package are different for NCT scenarios and HAC scenarios. Model configurations are described in Section 5.3.1.

The maximum radiation dose rates for NCT and HAC scenarios are compared to the regulation limits in Table 5-1.

The maximum NCT dose rate for normally occupied spaces is dependent on the distance from where the package is located to the occupied spaces, which varies between transport modes and actual equipment being used. If the occupied spaces are closer than the minimum separation distance reported in Table 5-2, then operational controls are necessary to ensure either that the dose rate is reduced below 2 mrem/hr or that the carrier has to implement the radiation dosimetry requirements of 10 CFR 71.47(b)(4) and 49 CFR 173.441(b)(4).

5.2 Source Specification

There are five principal sources of radiation associated with transport of spent nuclear fuel that are of concern for radiation protection.

1. Primary gamma radiation from spent fuel.
2. Primary neutron radiation from spent fuel (both alpha-n reactions and spontaneous fission).
3. Gamma radiation from activated fuel structural materials and fuel inserts.
4. Capture gamma radiation produced by attenuation of neutrons by shielding material of the cask.
5. Neutrons produced by sub-critical multiplication in the fuel.

The authorized PWR and BWR fuels are summarized in this section. Source terms development for PWR and BWR fuels are described accordingly in following sections. Gamma sources are summarized in Section 5.2.7 and neutron sources are summarized in Section 5.2.8. Selection of the bounding source terms for shielding evaluation are described in detail in Section 5.4.1.2.

Fuel types that are authorized for transportation in the TN Eagle LC are provided in Chapter 1, Section 1.2.3. These fuel types may be divided into PWR and BWR fuel types. The list of authorized fuels is summarized below.

PWR

- Westinghouse (WE) 14x14 class
- WE 15x15 class
- WE 17x17 class
- Babcock & Wilcox (B&W) 15x15 class
- Combustion Engineering (CE) 14x14 class
- CE 15x15 class
- CE 16x16 class

BWR

- 7x7 lattice array type
- 8x8 lattice array type
- 9x9 lattice array type
- 10x10 lattice array type

Control components (CCs) are allowed to be stored within a PWR FA. Examples of CCs include burnable poison rod assemblies (BPRAs) and thimble plug assemblies. Control components typically have a Co-60 source because of its light element activation, which contributes substantially to the dose rates. Control components with hafnium or silver-indium-cadmium (Ag-In-Cd or AIC) as absorber materials may have different gamma spectrum after irradiation due to activation of hafnium and silver. A neutron source may also be included in CCs, such as a neutron source assembly (NSA). Additional sources from CCs may increase dose rates, and additional cooling time is determined to compensate for the effect of CCs.

BWR fuel does not include CCs other than the fuel channel, which is conservatively included in the source term of the fuel assembly.

For high burnup (HBU) fuel (i.e., with an assembly average burnup value more than 45 GWd/MTU) that has been in dry storage longer than 20 years, hypothetical reconfiguration of HBU fuel is modeled [

] additional cooling time [ ] is applied to compensate for impact on the dose rates around the cask.

5.2.1 Computer Programs

Source terms are generated using the ORIGEN-ARP module of SCALE6.0 [3]. ORIGEN-ARP is a control module for the ORIGEN-S computer program. ORIGEN-ARP allows a simplified input description that can rapidly compute source terms and decay heat compared to a full two-dimensional SCALE6.0/TRITON calculation.

Prior to using ORIGEN-ARP, detailed two-dimensional models of the design basis PWR and BWR FAs have been developed in TRITON using the FA design data, and TRITON is used to generate ORIGEN-ARP data libraries as a function of burnup and enrichment [4]. These libraries are collapsed from the ENDF/B-VII 238-group cross section library and are used by ORIGEN-ARP to compute the source terms.

5.2.2 PWR and BWR Source Terms

[

]

Sources are developed for a variety of different enrichments. For a particular U-235 enrichment, the uranium fuel loading is distributed according to the following relationship from the SCALE 6.0 manual:

- wt. % U-234 = 0.0089 * wt. % U-235
- wt. % U-236 = 0.0046 * wt. % U-235
- wt. % U-238 = 100 – wt. % U-234 – wt. % U-235 – wt. % U-236

The source term inputs used to generate the source term and calculate the dose rate contribution are based on the light element mass provided in Table 5-7 and Table 5-8 for PWR and BWR fuel, respectively. [

]

[ ]

The source term is a complex function of burnup, enrichment, and cooling time (BECT) and has both a gamma and neutron component. Source terms, particularly the neutron component, are maximized when using lower enrichments for a given burnup.

PWR DBSs are reported in Table 5-9 through Table 5-18. BWR DBSs are reported in Table 5-19 through Table 5-21. Details of how the DBSs are determined from the fuel qualification tables (FQTs) are described in Section 5.4.1.2.

The gamma radiation spectrum is presented with an 18 energy group structure consistent with the SCALE 27n-18g cross section library energy grouping structure. The lower boundary energy range in this library is 0.05 MeV, and the upper energy range is 8.00 to 10.00 MeV.

The “raw” neutron source computed by ORIGEN-ARP is scaled by applying neutron peaking factors and subcritical neutron multiplication, which are derived in Section 5.2.3. The scaled neutron sources are used in the detailed Monte Carlo N-Particle (MCNP) dose rate calculations. Only the total neutron source magnitude is reported because the Cm-244 spectrum is used in all dose rate calculations for simplicity because the neutron source is almost entirely due to Cm-244 decay. [

]

5.2.3 Axial Source Distributions and Subcritical Neutron Multiplication

ORIGEN-ARP is used to compute source terms for the average assembly burnup. However, an FA will exhibit an axial burnup profile in which the fuel is more highly burned near the axial center of the FA and less burned near the ends. This axial burnup profile must be taken into account when performing dose rate calculations, as the dose rate will typically peak near the maximum of this distribution.

The PWR axial burnup profile is taken from NUREG/CR-6801 [9] for fuel in the burnup range 26-30 GWd/MTU and is provided in Table 5-22. As fuel is more highly peaked for lower burnups, this distribution is more conservative than a flatter high burnup distribution. The gamma source term varies proportionally to axial burnup, while neutron source terms vary exponentially with burnup by a power of 4.0 to 4.2 [10]. Therefore, the burnup profile is used as the gamma axial source distribution, while the neutron axial source distribution is derived as the burnup profile raised to the power of 4.2.

The average value of the neutron source distribution, the neutron peaking factor, is 1.215 for the axial burnup profile shown in Table 5-22. This value has a physical meaning, as it is the ratio of the total neutron source from an FA with the given axial burnup profile to an assembly with a flat burnup profile. The neutron source term as computed by ORIGEN-ARP is for a flat burnup profile (average assembly burnup). Therefore, the “raw” PWR neutron source computed by ORIGEN-ARP is scaled by the neutron peaking factor to account for the burnup profile. Based on axial burnup profiles from Table 2 of NUREG/CR-6801 [9], neutron peaking factors are calculated for all burnup groups for PWR and neutron peaking factors are conservatively selected for the burnup groups shown in Table 5-24.

[ ]

The BWR axial burnup profile is taken from [11] [

]

ORIGEN-ARP does not account for subcritical neutron multiplication. Subcritical neutron multiplication is taken into account [

] The applied k_{eff} values are shown in Table 5-25 and Table 5-26 for PWR and BWR, respectively.

5.2.4 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 5.2.2, 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 as part of the authorized contents in Chapter 1, Section 1.2.3.

Any other CC type is acceptable if it can be demonstrated that the source term is bounded by the source terms presented in this analysis. Also, the total as-loaded decay heat of the system, including CCs, must be less than the heat load zone configurations defined in the HLZCs as shown in Figure 5-1 and Figure 5-2.

Control components may be grouped into two categories: (1) those that extend into the top, plenum, and active fuel regions of the FA; 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 BPRA hardware masses are provided in Table 5-27.

The TPA hardware masses are provided in Table 5-28.

Elemental compositions for Zircaloy-4, Inconel-718, Inconel X-750, and 304 stainless steel are provided in Table 5-5. [ ]

The poison is assumed to be Pyrex® (borosilicate glass). The elemental composition is obtained from [13] and is reproduced in Table 5-29.

The plenum and top regions are outside the active core and experience a reduced flux. The ratio of the flux in each region to the active fuel flux is provided in Table 5-6.

The source terms are computed using ORIGEN-ARP and the B&W 15x15 library. A separate ORIGEN-ARP input file is developed for each hardware type and region.

As-loaded CC source terms should limit the computed Co-60 activity to values bounded by the results of this analysis, as follows:

- Inner/Peripheral Zones in Figure 5-4: 308 Ci Co-60 per CC in the active fuel region
- Inner Zone in Figure 5-4: 63.0 Ci Co-60 per CC in the combined plenum/top region
- Peripheral Zone in Figure 5-4: 24.3 Ci Co-60 per CC in the combined plenum/top region

The Co-60 activity in Table 5-32 is expressed in terms of “equivalent Co-60 activity” [

]

5.2.5 Reconstituted Fuel

Reconstituted FAs are assemblies in which one or more fuel rods have become damaged in service and are replaced with natural uranium rods, lower enriched rods, and non-fuel rods including stainless steel rods. The stainless steel rods may be either irradiated or non-irradiated. [

]

[ ]

5.2.6 High Burnup Fuel

For HBU fuel, hypothetical reconfiguration scenarios under NCT according to NUREG-2224 [2] are analyzed. [

]

Model configurations of HBU fuel are described in Section 5.3.1.1.

5.2.7 Gamma Source

The gamma radiation spectrum is presented with an 18 energy group structure consistent with the SCALE 27n-18g cross section library energy grouping structure. The lower boundary energy range in this library is 0.05 MeV, and the upper energy range is 8.00 to 10.00 MeV.

In the shielding models for gamma sources, gamma sources from spent fuel and from activated fuel structural materials are calculated as described in Section 5.2.2. For the scenarios when CCs are loaded with the fuel assemblies, gamma sources from the CCs described in Section 5.2.4 are combined with the gamma sources from the fuel assemblies in the shielding models.

The secondary gammas due to attenuation of neutrons by shielding material have been included in the MCNP models by running the MCNP models in coupled neutron-photon mode, therefore dedicated models with the secondary gamma sources are not needed.

5.2.8 Neutron Source

The neutron source energy distribution used in the shielding analysis is based on the Cm-244 Watt fission spectrum in the MCNP models. The strength of the neutron sources used in the shielding analysis is calculated using ORIGEN-ARP as described in above sections.

The "raw" neutron source computed by ORIGEN-ARP is scaled by applying neutron peaking factors and subcritical neutron multiplication. Neutron peaking factors to account for the burnup dependent, neutron axial profile are developed and discussed in Section 5.2.3. Sub-critical multiplication of the neutron is also developed and discussed in Section 5.2.3.

[ ]

5.3 Model Specification

MCNP5 [8] is used to perform detailed three-dimensional dose rate calculations for the TN Eagle LC transportation system. All relevant details of the EOS-37PTH DSC, EOS 89BTH DSC, and the TN Eagle LC are modeled explicitly.

Separate primary gamma and neutron models are developed. The TN Eagle LC neutron models are run in coupled neutron-photon mode so that the secondary gamma dose rate from (n,γ) reactions may be computed. **[**

]

5.3.1 Configuration of Source and Shielding

Detailed TN Eagle LC MCNP models are developed for the following two configurations:

- TN Eagle LC with EOS-37PTH DSC
- TN Eagle LC with EOS-89BTH DSC

The EOS-37PTH DSC and EOS-89BTH DSC are modeled explicitly, including the steel basket structure, aluminum plates, metal matrix composite (MMC) **[**

] transition rails, and shield plugs. Key dimensions used to develop the DSC models are summarized in Table 5-35, and figures illustrating the basic MCNP model are provided in Figure 5-6 through Figure 5-12. The figures illustrate the TN Eagle LC with the EOS-37PTH DSC, although the TN Eagle LC with the EOS-89BTH DSC configurations are similar.

[ ]

Different basket compartments may have different plate thicknesses, but only the minimum plate thickness used in the design is modeled in MCNP. [

] This results in conservative calculation of dose rates.

The TN Eagle LC features a forged cask body, a primary lid, a ram access cover plate, and a bottom closure plate. Minimum dimensions are modeled for the forged cask body shell thickness, the forged cask body bottom thickness, and the ram access cover plate thickness. [

]

The TN Eagle LC also features 25 radial shielding rings shrink-fitted onto the outer surface of the forged cask body to provide gamma and neutron shielding at the cask side, shown in Figure 5-9. [

] VYAL-B resin blocks are filled in the shielding rings to provide neutron shielding at the cask side.

A top and a bottom impact limiter of similar design are provided for the TN Eagle LC, shown in Figure 5-8, Figure 5-10, and Figure 5-11, to ensure protection of the package containment system. [

]

The TN Eagle LC is modeled explicitly, and key dimensions used to develop the TN Eagle LC models are provided in Table 5-36.

[

]

Model configurations for NCT and HAC scenarios are described with further details below in Section 5.3.1.1 and Section 5.3.1.2, respectively.

5.3.1.1 NCT

The EOS-37PTH DSC is designed to accommodate up to 37 intact, up to 8 damaged, and up to 4 failed PWR FAs with uranium dioxide (UO_2) fuels, zirconium alloy claddings, and with or without control components (CCs); and the EOS-89BTH DSC is designed to accommodate up to 89 intact BWR FAs with uranium dioxide (UO_2) fuels, zirconium alloy claddings, and with or without fuel channels.

[ ]

Figures illustrating the MCNP models for the EOS-37PTH DSC with failed fuel are provided in Figure 5-13 and Figure 5-14. [

]

[ ]

[ ]

For high burnup (HBU) fuel (i.e., with an assembly average burnup value more than 45 GWd/MTU) that has been in dry storage longer than 20 years, four hypothetical reconfiguration scenarios under NCT [ ]

[ ]

5.3.1.2 HAC

Figures illustrating the MCNP model under HAC are provided in Figure 5-15 through Figure 5-17. The figures illustrate the TN Eagle LC with the EOS-37PTH DSC, although the TN Eagle LC with the EOS-89BTH DSC configurations are similar.

5.3.2 Material Properties

Basic materials used in the models, such as 304 stainless steel, carbon steel, and cast iron, are obtained from PNNL-15870 [7] and are summarized in Table 5-37. Densities of 304 stainless steel, carbon steel, and cast iron are set to be 7.75, 7.75, and 7.20 g/cm^3, respectively, according to material requirements in Chapter 7. Dry air and helium gas are modeled as void. Aluminum is used in the basket plates with a density of 2.7 g/cm^3.

The metal matrix composite (MMC) poison and honeycomb inside the adapter are summarized in Table 5-38. [

]

Borated neutron shielding material (VYAL-B) is used [

] for neutron shielding. [

] The elemental composition of the VYAL-B resin is shown in Table 5-39. The minimum weight fraction of hydrogen and boron is applied in the shielding models, as well as the minimum density of the resin.

The FAs are homogenized for simplicity. [

] The masses used for the homogenization are obtained from Table 5-3 and Table 5-4 for PWR and BWR fuel, respectively.

[ ]

[ ] The homogenized PWR fuel compositions are provided in Table 5-40. The homogenized BWR fuel compositions are provided in Table 5-41.

For failed fuel configuration [ ] fuel assembly is compressed [ ] The homogenized fuel compositions are provided in Table 5-42 for PWR and BWR fuel.

[ ] Therefore, the compressed active fuel region has a higher density than intact fuel. Properties of the compressed active fuel region for failed fuel configurations [ ] are summarized and compared to intact fuel in Table 5-43 and Table 5-44 for PWR and BWR fuel, respectively.

For the reconfigured HBU fuel under NCT in the four reconfiguration scenarios, [ ] the homogenized PWR reconfigured fuel compositions are provided in Table 5-45 through Table 5-48, respectively, and the homogenized BWR reconfigured fuel compositions are provided in Table 5-49 through Table 5-52, respectively.

[ ]

5.4 Shielding Evaluation

5.4.1 Methods

MCNP5 v1.40 is used in the shielding analysis [8]. MCNP5 is a Monte Carlo transport program that allows full three-dimensional modeling of the TN Eagle System. Therefore, no geometrical approximations are necessary when developing the shielding models.

The EOS-DSC baskets are zoned by heat load. [

] The heat load zone configurations (HLZCs) are shown in Figure 5-1 and Figure 5-2 for the EOS-37PTH DSC, and Figure 5-3 for the EOS-89BTH DSC. Two different HLZCs are defined for the EOS-37PTH DSC to offer more flexible loading options.

Response functions are generated by using MCNP models for each zone of the HLZCs and are described in detail in Section 5.4.1.1. [

] Generation of the FQTs and DBSs is described in detail in Section 5.4.1.2.

5.4.1.1 Response Functions

The response functions (RFs) are calculated [

]

[

]

The response functions are generated for both gamma and neutron sources. [

]

The response functions are generated for each zone of each HLZC. [

]

[ ]

Each response function gives dose rates per source particle [

]

The response functions are provided in Table 5-53 through Table 5-64. The response functions are benchmarked with MCNP models by comparing the dose rates predicted by using the response functions and the dose rates estimated by the MCNP models. [

]

The comparison between the response function prediction and the MCNP model estimation is provided in Table 5-67 through Table 5-69. [

] In general, the difference between the RF prediction and the MCNP estimation is very small, [
]

5.4.1.2 Fuel Qualification Table Generation and Design Basis Sources

A fuel qualification table (FQT) lists minimum cooling time required for each burnup and enrichment combination to meet thermal and shielding restrictions. One FQT is generated for each loading plan of each zone of each HLZC of the EOS DSCs. There are five loading schemes shown in the last five columns of Table 5-70, depending on the loading plan, the HLZC, and the DSC. [

]

The FQTs for the TN Eagle LC are only used to ensure the shielding performance of the TN Eagle LC. The decay heat of the FA loaded can be calculated by using decay heat equations documented in Section 5.4.4.6 to ensure that the decay heat limit is met.

PWR DBSs are reported in Table 5-9 through Table 5-18.

BWR DBSs are reported in Table 5-19 through Table 5-21.

In this equation, CT_{low} and CT_{high} correspond to the cooling times in the fuel qualification tables for the low and high fuel loadings.

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5.4.1.5 Additional Cooling Time for FAs loaded with CCs

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5.4.1.6 Reconstituted Fuel

5.4.1.7 High Burnup Fuel

5.4.2 Input and Output Data

MCNP models are built for the model parameters described in Section 5.3 and source terms described in Section 5.2 for shielding evaluations. Different scenarios are analyzed to cover different cask conditions, and fuel conditions under both NCT and HAC, to demonstrate the compliance of the TN Eagle LC transportation package with the regulation dose rate limits. Details of analyzed scenarios are described below in Section 5.4.4.

5.4.3 Flux-to-Dose-Rate Conversion

MCNP5 is used to compute the neutron or gamma flux at the location of interest and the flux is converted to a dose rate using ANSI/ANS-6.1.1-1977 flux-to-dose rate conversion factors [17]. These factors are provided in Table 5-76. Results are computed in the units mrem/hr.

5.4.4 External Radiation Levels

In this section, dose rates around the TN Eagle LC transportation system are analyzed and presented for different cask conditions and fuel conditions. Results for intact, damaged, and failed fuel under NCT and HAC are presented in Section 5.4.4.1 and Section 5.4.4.2, respectively. Demonstration analysis is documented in Section 5.4.4.3 for FAs with CCs. Additional analysis for HBU fuel that has been in dry storage for more than 20 years is presented in Section 5.4.4.4. Section 5.4.4.5 includes the sensitivity analysis for local resin high temperature.

5.4.4.1 NCT

The TN Eagle LC is designed for exclusive-use open transport. [

]

Tallies are set according to the package external surfaces as shown in Figure 5-19. For NCT scenarios, a few mesh tallies are set to report dose rates at locations of interest:

The maximum dose rates from the package external surfaces at the cask side and the cask ends are reported [

]

With the DBSs determined in Section 5.4.1.2, model configurations described in Section 5.3.1, and material properties described in Section 5.3.2, various NCT scenarios shown in Table 5-77 are analyzed, depending on fuel configuration, fuel loading position, and DSC location inside the cask.

The total dose rates from all NCT scenarios in Table 5-77 are reported in Table 5-78 and Table 5-79 for the vehicle (package) surface, and the 2 m from vehicle surface, respectively, for both the EOS-37PTH DSC and EOS-89BTH DSC. The maximum dose rates at the cask top end, the cask side, and the cask bottom end are marked as bold fonts separately for the EOS-37PTH DSC and EOS-89BTH DSC. [

]

The overall maximum dose rate for the 2 m from vehicle surface is 9.4 mrem/hr,
[

]

The maximum dose rates from all NCT scenarios and the dose rate breakdown are summarized in Table 5-80 and Table 5-81, for the EOS-37PTH DSC and EOS-89BTH DSC, respectively. [

]

The dose rate distributions on the cask side for the EOS-37PTH DSC are shown in Figure 5-21 and Figure 5-22 [ ] The dose rate distributions on the cask side for the EOS-89BTH DSC are shown in Figure 5-23 and Figure 5-24 [ ]

5.4.4.2 HAC

[ ]

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5.4.4.3 Fuel Assemblies with Control Components in the EOS-37PTH DSC

5.4.4.4 High Burnup Fuel

5.4.4.5 Sensitivity Analysis for Temperature Impact on Resin

5.4.4.6 Decay Heat Restrictions

Decay heat value for a fuel assembly can be obtained by using the decay heat equation (DHE) from Section A.5.5.3 of [20]. The DHE is only a function of the fuel assembly (FA), and is independent of cask design; therefore, the DHE from the reference can be applied to the FAs loaded in the TN Eagle LC. Two DHEs are established in [20] for BWR (maximum of 0.198 MTU) and PWR (maximum of 0.490 MTU) FAs. The DHE for PWR fuel is established on data relevant to the design basis PWR FA but with a fuel loading of 0.490 MTU/assembly by performing nonlinear regression analysis. To apply the DHE to the design basis PWR FA with a fuel loading of 0.492 MTU/assembly, a scaling factor of 1.004 (=0.492/0.490) is applied.

5.4.4.6.1 PWR Decay Heat Equation

The decay heat (DH) in watts for PWR fuel is expressed as:

$$DH_{PWR} = 1.004 \times F_1 \; exp\left[G\left(1-\frac{1.8}{x_3}\right)(x_3-4.5)^H\left(\frac{x_2}{x_1}\right)^I\right]+20,$$

where,

$$F_1 = A + Bx_1 + Cx_2 + Dx_1^2 + Ex_1x_2 + Fx_2^2,$$

x_1 equals the assembly average burnup in GWd/MTU,

x_2 equals the initial enrichment in wt. % U-235,

x_3 equals the cooling time in years,

$A = -44.8$,

$B = 41.6$,

$C = -37.1$,

$D = 0.611$,

$E = -6.80$,

$F = 24.0$,

$G = -0.575$,

$H = 0.169$, and

$I = -0.147$.

The equation above includes 20 watts as the last term to cover the uncertainty from the regression calculations. The minimum cooling time for the decay heat calculation is 5 years.

Alternatively, the decay heat can be calculated without employing the DHE, using an approved methodology with actual spent fuel parameters instead of bounding spent fuel parameters.

5.4.4.6.2 BWR Decay Heat Equation

The decay heat (DH) in watts for BWR fuel is expressed as:

$$DH_{BWR} = F_1 \exp\left[G\left(1 - \frac{1.2}{x_3}\right)(x_3 - 4.5)^H \left(\frac{x_2}{x_1}\right)^I\right] + 10,$$

where,

$$F_1 = A + Bx_1 + Cx_2 + Dx_1^2 + Ex_1x_2 + Fx_2^2,$$

x_1 equals the assembly average burnup in GWd/MTU,

x_2 equals the initial enrichment in wt. % U-235,

x_3 equals the cooling time in years,

$A = -59.1$,

$B = 23.4$,

$C = -21.1$,

$D = 0.280$,

$E = -3.52$,

$F = 12.4$,

$G = -0.720$,

$H = 0.157$, and

$$I = -0.132\,.$$

The calculation uncertainty is 10 watts. It is added to the equation above as the last term. The minimum cooling time for decay heat calculation is 5 years.

Alternatively, the decay heat can be calculated without employing the decay heat equation, using an approved methodology with actual spent fuel parameters instead of bounding spent fuel parameters.

5.5 References

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17. ANSI/ANS-6.1.1-1977, “American National Standard Neutron and Gamma-Ray Flux-to-Dose-Rate Factors,” American National Standards Institute, Inc., New York, New York.

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19. TN Document, DI-83016-006, “Neutron Sources,” Rev. 0

20. TN Americas LLC, “NUHOMS®-MP197 Transportation Packaging Safety Analysis Report,” Revision 20.

Table 5-1
Maximum Dose Rates of TN Eagle LC

Location	Limit (mrem/hr) (Exclusive Use Open Transport)	Maximum Total Dose Rate (mrem/hr)
External surface of the package (NCT)	200	126
Vertical planes projected from outer edges, including the top and underside (NCT)	200	126
2 meters from the vertical planes projected from outer edges (NCT)	10	9.4
1 meter from the surface of the package (HAC)	1000	714

Table 5-2
Minimum Distance to Package External Surfaces for 2 mrem/hr Dose Rate

Location	Distance to Package External Surface (m)	[ ]
Cask Side	7.1	[ ]
Cask Top	1.8	[ ]
Cask Bottom	2.7	[ ]

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Table 5-6
Flux Scaling Factors

Region	PWR	BWR
Top Nozzle	0.1	0.1
Plenum	0.2	0.2
Active Fuel	1.0	1.0
Bottom Nozzle	0.2	0.15

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Table 5-9
EOS-37PTH DSC DBS: P1

Burnup (GWd/MTU)			62			
Enrichment (wt. % U-235)			3.8			
Cooling Time (yr)			31.72			
Gamma Source Term, g/(sec*FA)						
E_{min}, MeV	**to**	**E_{max}, MeV**	**Bottom Nozzle**	**In-core**	**Plenum**	**Top Nozzle**
1.00E-02	to	5.00E-02	4.85E+09	7.18E+14	7.52E+09	2.96E+09
5.00E-02	to	1.00E-01	6.50E+08	2.15E+14	5.37E+08	3.86E+08
1.00E-01	to	2.00E-01	1.79E+08	1.27E+14	1.57E+08	9.55E+07
2.00E-01	to	3.00E-01	1.07E+07	3.90E+13	1.29E+07	5.78E+06
3.00E-01	to	4.00E-01	1.55E+07	2.61E+13	1.26E+07	6.54E+06
4.00E-01	to	6.00E-01	1.06E+08	1.95E+13	7.17E+07	1.68E+06
6.00E-01	to	8.00E-01	1.84E+09	1.39E+15	9.08E+09	1.51E+09
8.00E-01	to	1.00E+00	1.73E+09	1.06E+13	8.74E+09	1.46E+09
1.00E+00	to	1.33E+00	1.82E+11	1.57E+13	1.26E+11	1.07E+11
1.33E+00	to	1.66E+00	5.15E+10	1.55E+12	3.54E+10	3.02E+10
1.66E+00	to	2.00E+00	1.51E+02	6.68E+10	9.82E+01	5.65E-03
2.00E+00	to	2.50E+00	1.23E+06	3.47E+09	8.48E+05	7.24E+05
2.50E+00	to	3.00E+00	1.05E+03	8.13E+08	7.24E+02	6.18E+02
3.00E+00	to	4.00E+00	9.34E-06	5.21E+07	4.64E-05	7.69E-06
4.00E+00	to	5.00E+00	6.67E-27	1.76E+07	4.34E-27	0.00E+00
5.00E+00	to	6.50E+00	1.92E-27	7.05E+06	1.25E-27	0.00E+00
6.50E+00	to	8.00E+00	2.45E-28	1.38E+06	1.59E-28	0.00E+00
8.00E+00	to	1.00E+01	3.26E-29	2.94E+05	2.12E-29	0.00E+00
Total Gamma, g/(sec*FA)			2.44E+11	2.56E+15	1.88E+11	1.44E+11
Total Neutron Source Term, n/(sec*FA)						
Raw ORIGEN-ARP source for uniform burnup						5.15E+08
Treated with peaking factor [ ] and k_{eff} [ ]						8.46E+08

Table 5-10
EOS-37PTH DSC DBS: P2

Burnup (GWd/MTU)			62			
Enrichment (wt. % U-235)			3.8			
Cooling Time (yr)			7.01			
Gamma Source Term, g/(sec*FA)						
E_{min}, MeV	**to**	**E_{max}, MeV**	**Bottom Nozzle**	**In-core**	**Plenum**	**Top Nozzle**
1.00E-02	to	5.00E-02	1.82E+11	1.56E+15	1.31E+11	4.98E+10
5.00E-02	to	1.00E-01	1.69E+10	4.24E+14	1.16E+10	9.53E+09
1.00E-01	to	2.00E-01	1.43E+10	3.34E+14	9.46E+09	2.32E+09
2.00E-01	to	3.00E-01	9.30E+08	9.36E+13	6.18E+08	1.15E+08
3.00E-01	to	4.00E-01	2.69E+09	5.93E+13	1.76E+09	1.50E+08
4.00E-01	to	6.00E-01	5.48E+10	7.80E+14	3.57E+10	1.07E+07
6.00E-01	to	8.00E-01	3.04E+10	3.26E+15	2.77E+10	1.51E+09
8.00E-01	to	1.00E+00	2.83E+10	3.81E+14	1.34E+10	1.66E+10
1.00E+00	to	1.33E+00	4.70E+12	1.46E+14	3.24E+12	2.77E+12
1.33E+00	to	1.66E+00	1.33E+12	3.60E+13	9.15E+11	7.81E+11
1.66E+00	to	2.00E+00	2.78E+02	5.32E+11	1.82E+02	3.41E-01
2.00E+00	to	2.50E+00	3.18E+07	5.91E+11	2.19E+07	1.87E+07
2.50E+00	to	3.00E+00	2.72E+04	3.40E+10	1.87E+04	1.60E+04
3.00E+00	to	4.00E+00	1.57E-05	3.22E+09	7.81E-05	1.30E-05
4.00E+00	to	5.00E+00	6.67E-27	4.41E+07	4.34E-27	0.00E+00
5.00E+00	to	6.50E+00	1.92E-27	1.77E+07	1.25E-27	0.00E+00
6.50E+00	to	8.00E+00	2.45E-28	3.47E+06	1.59E-28	0.00E+00
8.00E+00	to	1.00E+01	3.26E-29	7.37E+05	2.12E-29	0.00E+00
Total Gamma, g/(sec*FA)			6.36E+12	7.07E+15	4.39E+12	3.63E+12
Total Neutron Source Term, n/(sec*FA)						
Raw ORIGEN-ARP source for uniform burnup						1.29E+09
Treated with peaking factor [ ] and k_{eff} [ ]						2.11E+09

Table 5-11
EOS-37PTH DSC DBS: P3

Burnup (GWd/MTU)			62			
Enrichment (wt. % U-235)			3.8			
Cooling Time (yr)			22.99			
Gamma Source Term, g/(sec*FA)						
E_{min}, MeV	**to**	**E_{max}, MeV**	**Bottom Nozzle**	**In-core**	**Plenum**	**Top Nozzle**
1.00E-02	to	5.00E-02	1.34E+10	8.88E+14	1.45E+10	7.18E+09
5.00E-02	to	1.00E-01	2.00E+09	2.55E+14	1.47E+09	1.18E+09
1.00E-01	to	2.00E-01	6.63E+08	1.64E+14	4.84E+08	2.87E+08
2.00E-01	to	3.00E-01	3.82E+07	4.96E+13	3.13E+07	1.53E+07
3.00E-01	to	4.00E-01	7.41E+07	3.25E+13	5.15E+07	1.90E+07
4.00E-01	to	6.00E-01	9.50E+08	2.91E+13	6.21E+08	2.46E+06
6.00E-01	to	8.00E-01	2.28E+09	1.70E+15	9.37E+09	1.51E+09
8.00E-01	to	1.00E+00	1.75E+09	2.02E+13	8.75E+09	1.47E+09
1.00E+00	to	1.33E+00	5.75E+11	3.14E+13	3.96E+11	3.38E+11
1.33E+00	to	1.66E+00	1.62E+11	3.21E+12	1.12E+11	9.54E+10
1.66E+00	to	2.00E+00	1.87E+02	8.38E+10	1.22E+02	6.94E-03
2.00E+00	to	2.50E+00	3.88E+06	4.34E+09	2.67E+06	2.28E+06
2.50E+00	to	3.00E+00	3.32E+03	8.94E+08	2.28E+03	1.95E+03
3.00E+00	to	4.00E+00	1.12E-05	7.17E+07	5.58E-05	9.25E-06
4.00E+00	to	5.00E+00	6.67E-27	2.42E+07	4.34E-27	0.00E+00
5.00E+00	to	6.50E+00	1.92E-27	9.71E+06	1.25E-27	0.00E+00
6.50E+00	to	8.00E+00	2.45E-28	1.91E+06	1.59E-28	0.00E+00
8.00E+00	to	1.00E+01	3.26E-29	4.05E+05	2.12E-29	0.00E+00
Total Gamma, g/(sec*FA)			7.59E+11	3.18E+15	5.43E+11	4.45E+11
Total Neutron Source Term, n/(sec*FA)						
Raw ORIGEN-ARP source for uniform burnup						7.06E+08
Treated with peaking factor [ ] and k_{eff} [ ]						1.16E+09

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Table 5-19
EOS-89BTH DSC DBS: B1

Burnup (GWd/MTU)			62			
Enrichment (wt. % U-235)			3.8			
Cooling Time (yr)			23.24			
Gamma Source Term, g/(sec*FA)						
E_{min}, MeV	**to**	**E_{max}, MeV**	**Bottom Nozzle**	**In-core**	**Plenum**	**Top Nozzle**
1.00E-02	to	5.00E-02	4.53E+09	3.55E+14	2.10E+09	1.87E+09
5.00E-02	to	1.00E-01	8.18E+08	1.00E+14	2.65E+08	3.09E+08
1.00E-01	to	2.00E-01	2.12E+08	6.56E+13	1.38E+08	8.43E+07
2.00E-01	to	3.00E-01	1.11E+07	2.00E+13	8.57E+06	4.61E+06
3.00E-01	to	4.00E-01	1.66E+07	1.34E+13	2.19E+07	7.35E+06
4.00E-01	to	6.00E-01	7.85E+07	1.14E+13	3.99E+08	5.21E+07
6.00E-01	to	8.00E-01	5.07E+07	6.82E+14	2.08E+08	8.30E+07
8.00E-01	to	1.00E+00	2.02E+07	6.64E+12	3.44E+06	5.79E+07
1.00E+00	to	1.33E+00	2.38E+11	1.01E+13	7.57E+10	8.96E+10
1.33E+00	to	1.66E+00	6.72E+10	1.10E+12	2.14E+10	2.53E+10
1.66E+00	to	2.00E+00	1.49E+01	3.43E+10	7.73E+01	9.96E+00
2.00E+00	to	2.50E+00	1.61E+06	1.78E+09	5.11E+05	6.05E+05
2.50E+00	to	3.00E+00	1.37E+03	2.75E+08	4.37E+02	5.17E+02
3.00E+00	to	4.00E+00	9.50E-07	2.51E+07	9.74E-08	5.36E-06
4.00E+00	to	5.00E+00	4.27E-28	8.47E+06	2.21E-27	2.85E-28
5.00E+00	to	6.50E+00	1.23E-28	3.40E+06	6.37E-28	8.20E-29
6.50E+00	to	8.00E+00	1.56E-29	6.67E+05	8.10E-29	1.04E-29
8.00E+00	to	1.00E+01	2.09E-30	1.42E+05	1.08E-29	1.39E-30
Total Gamma, g/(sec*FA)			3.11E+11	1.27E+15	1.00E+11	1.18E+11
Total Neutron Source Term, n/(sec*FA)						
Raw ORIGEN-ARP source for uniform burnup						2.47E+08
Treated with peaking factor [ ] and k_{eff} [ ]						3.77E+08

Table 5-20
EOS-89BTH DSC DBS: B2

Burnup (GWd/MTU)			62			
Enrichment (wt. % U-235)			3.8			
Cooling Time (yr)			10.26			
Gamma Source Term, g/(sec*FA)						
E_{min}, MeV	**to**	**E_{max}, MeV**	**Bottom Nozzle**	**In-core**	**Plenum**	**Top Nozzle**
1.00E-02	to	5.00E-02	2.65E+10	5.16E+14	2.59E+10	1.12E+10
5.00E-02	to	1.00E-01	4.54E+09	1.40E+14	1.56E+09	1.72E+09
1.00E-01	to	2.00E-01	1.49E+09	1.03E+14	2.38E+09	6.75E+08
2.00E-01	to	3.00E-01	8.22E+07	2.98E+13	1.62E+08	3.91E+07
3.00E-01	to	4.00E-01	1.63E+08	1.92E+13	5.00E+08	8.83E+07
4.00E-01	to	6.00E-01	2.08E+09	1.07E+14	1.08E+10	1.39E+09
6.00E-01	to	8.00E-01	1.10E+09	1.02E+15	5.61E+09	7.79E+08
8.00E-01	to	1.00E+00	7.55E+08	5.54E+13	2.26E+08	2.88E+08
1.00E+00	to	1.33E+00	1.31E+12	3.28E+13	4.17E+11	4.94E+11
1.33E+00	to	1.66E+00	3.70E+11	6.30E+12	1.18E+11	1.39E+11
1.66E+00	to	2.00E+00	2.06E+01	6.51E+10	1.07E+02	1.37E+01
2.00E+00	to	2.50E+00	8.86E+06	2.08E+10	2.82E+06	3.34E+06
2.50E+00	to	3.00E+00	7.57E+03	1.71E+09	2.41E+03	2.85E+03
3.00E+00	to	4.00E+00	1.25E-06	1.74E+08	1.28E-07	7.04E-06
4.00E+00	to	5.00E+00	4.27E-28	1.38E+07	2.21E-27	2.85E-28
5.00E+00	to	6.50E+00	1.23E-28	5.52E+06	6.37E-28	8.20E-29
6.50E+00	to	8.00E+00	1.56E-29	1.08E+06	8.10E-29	1.04E-29
8.00E+00	to	1.00E+01	2.09E-30	2.30E+05	1.08E-29	1.39E-30
Total Gamma, g/(sec*FA)			1.72E+12	2.03E+15	5.82E+11	6.50E+11
Total Neutron Source Term, n/(sec*FA)						
Raw ORIGEN-ARP source for uniform burnup						4.01E+08
Treated with peaking factor [ ] and k_{eff} [ ]						6.12E+08

Table 5-21
EOS-89BTH DSC DBS: B3

Burnup (GWd/MTU)			62			
Enrichment (wt. % U-235)			3.8			
Cooling Time (yr)			26.28			
Gamma Source Term, g/(sec*FA)						
E_{min}, MeV	**to**	**E_{max}, MeV**	**Bottom Nozzle**	**In-core**	**Plenum**	**Top Nozzle**
1.00E-02	to	5.00E-02	3.10E+09	3.29E+14	1.30E+09	1.31E+09
5.00E-02	to	1.00E-01	5.49E+08	9.38E+13	1.77E+08	2.07E+08
1.00E-01	to	2.00E-01	1.39E+08	6.00E+13	7.70E+07	5.46E+07
2.00E-01	to	3.00E-01	7.32E+06	1.84E+13	4.67E+06	3.02E+06
3.00E-01	to	4.00E-01	1.05E+07	1.24E+13	1.10E+07	4.53E+06
4.00E-01	to	6.00E-01	3.68E+07	9.67E+12	1.85E+08	2.44E+07
6.00E-01	to	8.00E-01	2.90E+07	6.34E+14	9.63E+07	6.85E+07
8.00E-01	to	1.00E+00	1.67E+07	5.23E+12	2.33E+06	5.65E+07
1.00E+00	to	1.33E+00	1.60E+11	7.90E+12	5.07E+10	6.00E+10
1.33E+00	to	1.66E+00	4.50E+10	8.42E+11	1.43E+10	1.70E+10
1.66E+00	to	2.00E+00	1.39E+01	3.18E+10	7.17E+01	9.25E+00
2.00E+00	to	2.50E+00	1.08E+06	1.65E+09	3.43E+05	4.06E+05
2.50E+00	to	3.00E+00	9.21E+02	2.63E+08	2.93E+02	3.47E+02
3.00E+00	to	4.00E+00	8.91E-07	2.25E+07	9.14E-08	5.02E-06
4.00E+00	to	5.00E+00	4.27E-28	7.58E+06	2.21E-27	2.85E-28
5.00E+00	to	6.50E+00	1.23E-28	3.04E+06	6.37E-28	8.20E-29
6.50E+00	to	8.00E+00	1.56E-29	5.97E+05	8.10E-29	1.04E-29
8.00E+00	to	1.00E+01	2.09E-30	1.27E+05	1.08E-29	1.39E-30
Total Gamma, g/(sec*FA)			2.09E+11	1.17E+15	6.71E+10	7.89E+10
Total Neutron Source Term, n/(sec*FA)						
Raw ORIGEN-ARP source for uniform burnup						2.21E+08
Treated with peaking factor [ ] and k_{eff} [ ]						3.38E+08

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Table 5-31
CC Co 60 Activity and Decay Heat

Parameter	BPRA			TPA	
	Active Fuel	Plenum	Top	Plenum	Top
Co-60 (Ci)	308	14.8	9.5	44.1	18.9
Decay Heat (watts)	4.8	0.2	0.1	0.7	0.3

Table 5-32
CC Source Term

E_{min} (MeV)	Zone	Inner/Peripheral Zones in Figure 5-4	Inner Zone in Figure 5-4	Peripheral Zone in Figure 5-4	Inner Zone in Figure 5-4	Peripheral Zone in Figure 5-4
	Equivalent Co-60 (Ci)	308	44.1	14.8	18.9	9.5
	E_{max} (MeV)	Active Fuel (γ/s-CC)	Plenum (γ/s-CC)	Plenum (γ/s-CC)	Top (γ/s-CC)	Top (γ/s-CC)
1.00E-02	5.00E-02	3.133E+11	4.540E+10	1.502E+10	2.061E+10	9.702E+09
5.00E-02	1.00E-01	6.183E+10	8.841E+09	2.965E+09	3.795E+09	1.911E+09
1.00E-01	2.00E-01	1.504E+10	2.145E+09	7.211E+08	9.226E+08	4.648E+08
2.00E-01	3.00E-01	7.435E+08	1.068E+08	3.565E+07	4.682E+07	2.300E+07
3.00E-01	4.00E-01	9.718E+08	1.397E+08	4.660E+07	6.024E+07	3.005E+07
4.00E-01	6.00E-01	7.218E+07	1.113E+07	3.288E+06	5.563E+06	2.144E+06
6.00E-01	8.00E-01	2.770E+07	5.117E+06	1.328E+06	1.497E+09	7.527E+06
8.00E-01	1.00E+00	1.640E+10	1.172E+09	7.865E+08	1.849E+09	5.047E+08
1.00E+00	1.33E+00	1.798E+13	2.573E+12	8.624E+11	1.100E+12	5.559E+11
1.33E+00	1.66E+00	5.078E+12	7.267E+11	2.435E+11	3.106E+11	1.570E+11
1.66E+00	2.00E+00	3.510E+00	3.100E-05	1.936E-05	2.716E-03	2.344E-04
2.00E+00	2.50E+00	1.215E+08	1.739E+07	5.827E+06	7.432E+06	3.756E+06
2.50E+00	3.00E+00	1.038E+05	1.486E+04	4.979E+03	6.350E+03	3.210E+03
3.00E+00	4.00E+00	1.322E-02	3.488E-11	1.102E-11	1.051E-06	9.764E-07
4.00E+00	5.00E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
5.00E+00	6.50E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
6.50E+00	8.00E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
8.00E+00	1.00E+01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
	Total	2.347E+13	3.358E+12	1.125E+12	1.439E+12	7.256E+11

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Table 5-74
Additional Cooling Time for FAs with CCs in the EOS-37PTH DSC (year)

Ratio to CC DBS (1)	Zone 3, HLZC 1, Plan 1	Zone 3, HLZC 1, Plan 2
1	6.52	4.76
0.75	4.60	3.40
0.5	2.89	2.15
0.25	1.39	1.01
0.1	0.57	0.41
0	0.00	0.00
Ratio to CC DBS	**Zone 4, HLZC 2, Plan 1**	**Zone 4, HLZC 2, Plan 2**
1	3.05	3.28
0.75	2.19	2.35
0.5	1.39	1.49
0.25	0.68	0.71
0.1	0.27	0.30
0	0.00	0.00
Ratio to CC DBS	**Zone 6, HLZC 2, Plan 1**	**Zone 6, HLZC 2, Plan 2**
1	18.65	11.49
0.75	12.64	8.00
0.5	7.59	5.02
0.25	3.51	2.29
0.1	1.55	0.98
0	0.00	0.00

Note: (1)
Ratio of as loaded CC equivalent Co-60 activity to the CC DBS equivalent Co-60 activity in Table 5-32.

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Table 5-76
ANSI/ANS 6.1.1 1977 Flux to Dose Rate Conversion Factors

E (MeV)	Neutron Factors (mrem/hr)/(n/cm^2-s)	E (MeV)	Neutron Factors (mrem/hr)/(n/cm^2-s)
2.50E-08	3.67E-03	0.5	9.26E-02
1.00E-07	3.67E-03	1.0	1.32E-01
1.00E-06	4.46E-03	2.5	1.25E-01
1.00E-05	4.54E-03	5.0	1.56E-01
1.00E-04	4.18E-03	7.0	1.47E-01
0.001	3.76E-03	10.0	1.47E-01
0.01	3.56E-03	14.0	2.08E-01
0.1	2.17E-02	20.0	2.27E-01
E (MeV)	**Gamma Factors (mrem/hr)/(γ/cm^2-s)**	**E (MeV)**	**Gamma Factors (mrem/hr)/(γ/cm^2-s)**
0.01	3.96E-03	1.4	2.51E-03
0.03	5.82E-04	1.8	2.99E-03
0.05	2.90E-04	2.2	3.42E-03
0.07	2.58E-04	2.6	3.82E-03
0.1	2.83E-04	2.8	4.01E-03
0.15	3.79E-04	3.25	4.41E-03
0.2	5.01E-04	3.75	4.83E-03
0.25	6.31E-04	4.25	5.23E-03
0.3	7.59E-04	4.75	5.60E-03
0.35	8.78E-04	5.0	5.80E-03
0.4	9.85E-04	5.25	6.01E-03
0.45	1.08E-03	5.75	6.37E-03
0.5	1.17E-03	6.25	6.74E-03
0.55	1.27E-03	6.75	7.11E-03
0.6	1.36E-03	7.5	7.66E-03
0.65	1.44E-03	9.0	8.77E-03
0.7	1.52E-03	11.0	1.03E-02
0.8	1.68E-03	13.0	1.18E-02
1.0	1.98E-03	15.0	1.33E-02

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Table 5-80
Dose Rate Breakdown for EOS-37PTH DSC (NCT)

Vehicle (Package) Surface (mrem/hr), Limit = 200 mrem/hr (1)			
	Top End (2)	Side	Bottom End
Gamma	0.01 (9.6%)	27.46 (2.8%)	0.02 (7.7%)
Neutron	3.72 (1.4%)	20.43 (1.1%)	19.79 (0.8%)
(n,g)	0.45 (6.7%)	7.21 (2.6%)	1.90 (4.4%)
Total	**4.18 (1.5%)**	**55.10 (1.5%)**	**21.71 (0.8%)**
2 m from Vehicle Surface (mrem/hr), Limit = 10 mrem/hr			
	Top End	Side	Bottom End
Gamma	0.09 (0.6%)	4.14 (1.1%)	<0.01 (9.4%)
Neutron	0.47 (0.3%)	3.51 (1.3%)	1.78 (1.3%)
(n,g)	0.07 (1.0%)	1.70 (6.3%)	0.14 (7.8%)
Total	**0.64 (0.2%)**	**9.36 (1.3%)**	**1.92 (1.3%)**

Note:
(1) Numbers in parentheses show relative errors of the estimation dose rates.
(2) Dose rates of Top End, Side, and Bottom End may come from different scenarios.

Table 5-81
Dose Rate Breakdown for EOS-89BTH DSC (NCT)

Vehicle (Package) Surface (mrem/hr), Limit = 200 mrem/hr (1)			
	Top End (2)	Side	Bottom End
Gamma	0.01 (8.4%)	18.92 (3.1%)	0.04 (13.2%)
Neutron	1.61 (1.7%)	22.23 (1.1%)	34.21 (0.6%)
(n,g)	0.19 (11.3%)	7.28 (3.1%)	3.24 (3.2%)
Total	**1.80 (1.9%)**	**48.44 (1.4%)**	**37.48 (0.7%)**
2 m from Vehicle Surface (mrem/hr), Limit = 10 mrem/hr			
	Top End	Side	Bottom End
Gamma	0.09 (0.6%)	4.41 (2.6%)	<0.01 (33.1%)
Neutron	0.26 (0.3%)	3.57 (1.1%)	2.78 (1.1%)
(n,g)	0.04 (1.2%)	1.13 (2.2%)	0.25 (5.7%)
Total	**0.39 (0.3%)**	**9.11 (1.4%)**	**3.03 (1.1%)**

Notes:
(1) Numbers in parentheses show relative errors of the estimation dose rates.
(2) Dose rates of Top End, Side, and Bottom End may come from different scenarios.

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Withheld Pursuant to 10 CFR 2.390

Table 5-84
Dose Rate Breakdown for EOS-37PTH DSC (HAC)

1 m from Ext. Surface (mrem/hr), HAC Limit = 1000 mrem/hr (1)			
	Top End (2)	Side	Bottom End
Gamma	0.02 (25.1%)	499.35 (1.5%)	0.01 (33.5%)
Neutron	50.32 (0.5%)	207.78 (0.8%)	60.04 (0.4%)
(n,g)	1.96 (2.3%)	6.39 (2.7%)	2.03 (2.2%)
Total	**52.29 (0.5%)**	**713.52 (1.1%)**	**62.07 (0.4%)**

Note:
(1) numbers in parentheses show relative errors of the estimation dose rates
(2) Dose rates of Top End, Side, and Bottom End may come from different scenarios

Table 5-85
Dose Rate Breakdown for EOS-89BTH DSC (HAC)

1 m from Ext. Surface (mrem/hr), HAC Limit = 1000 mrem/hr (1)			
	Top End (2)	Side	Bottom End
Gamma	0.01 (8.5%)	440.54 (1.2%)	0.01 (19.5%)
Neutron	45.85 (0.4%)	199.84 (0.8%)	48.95 (1.0%)
(n,g)	1.77 (2.2%)	5.49 (3.1%)	1.58 (6.0%)
Total	**47.63 (0.4%)**	**645.87 (0.9%)**	**50.54 (1.0%)**

Note: (1) numbers in parentheses show relative errors of the estimation dose rates
(2) Dose rates of Top End, Side, and Bottom End may come from different scenarios

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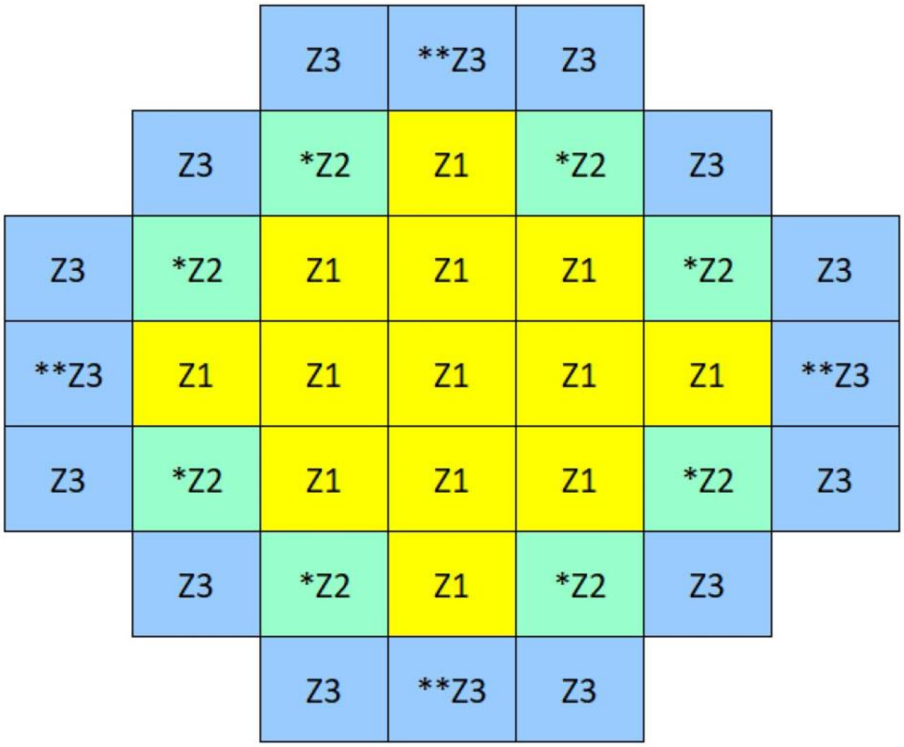
Withheld Pursuant to 10 CFR 2.390

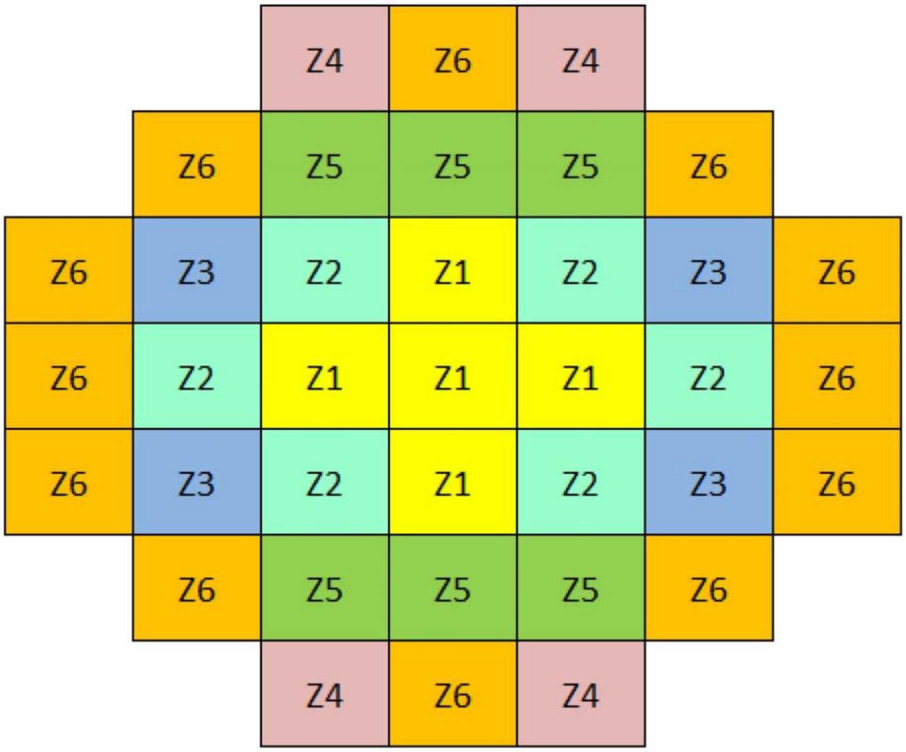


(*) denotes location where INTACT or DAMAGED FUEL can be stored
(**) denotes location where INTACT or FAILED FUEL can be stored

Zone Number	1	2 (1)	3
Maximum Decay Heat (kW/FA plus CCs, if included)	0.8	1.6 (2)	0.95 (3)
Maximum Number of FAs	13	8	16
Maximum Decay Heat per DSC (kW)	38.4		

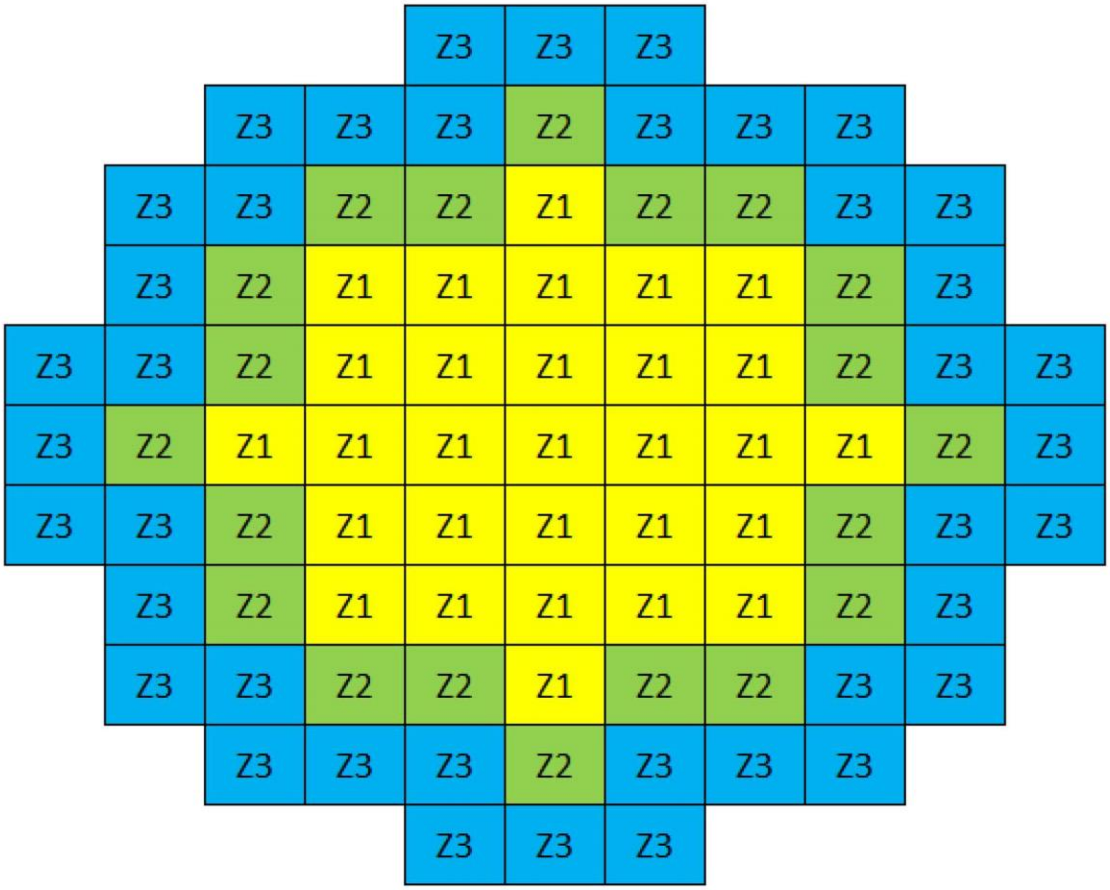
Notes:
(1) DAMAGED FUEL and FAILED FUEL shall not be loaded in the same DSC.
(2) The maximum allowable heat load per Damaged FA is 1.35 kW.
(3) The maximum allowable heat load per Failed FA is 0.75 kW.

Figure 5-1
EOS-37PTH Heat Load Zone Configuration #1



Zone Number	1	2	3	4	5	6
Maximum Decay Heat (kW/FA plus CCs, if included)	0.7	0.7	1.5	1.5	0.75	0.75
Maximum Number of FAs	5	6	4	4	6	12
Maximum Decay Heat per DSC (kW)	33.2					

Figure 5-2
EOS-37PTH Heat Load Zone Configuration #2



Zone Number	1	2	3
Maximum Decay Heat (kW/FA plus channel, if included)	0.35	0.35	0.35
Maximum Number of FAs	29	20	40
Maximum Decay Heat per DSC (kW)	31.15		

Figure 5-3
EOS-89BTH Heat Load Zone Configuration #1

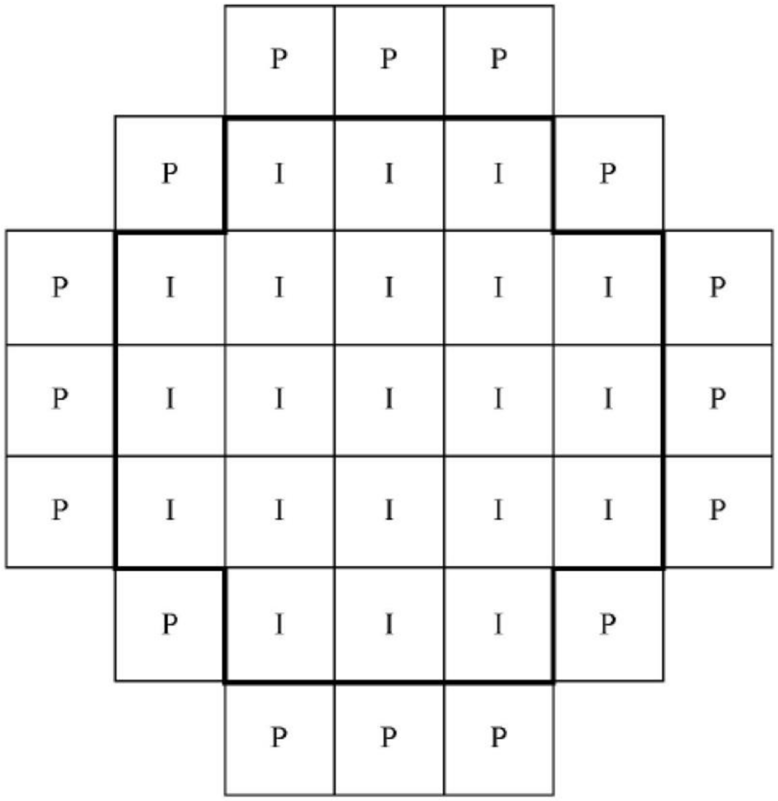


Figure 5-4
Peripheral and Inner Fuel Locations for the EOS-37PTH DSC

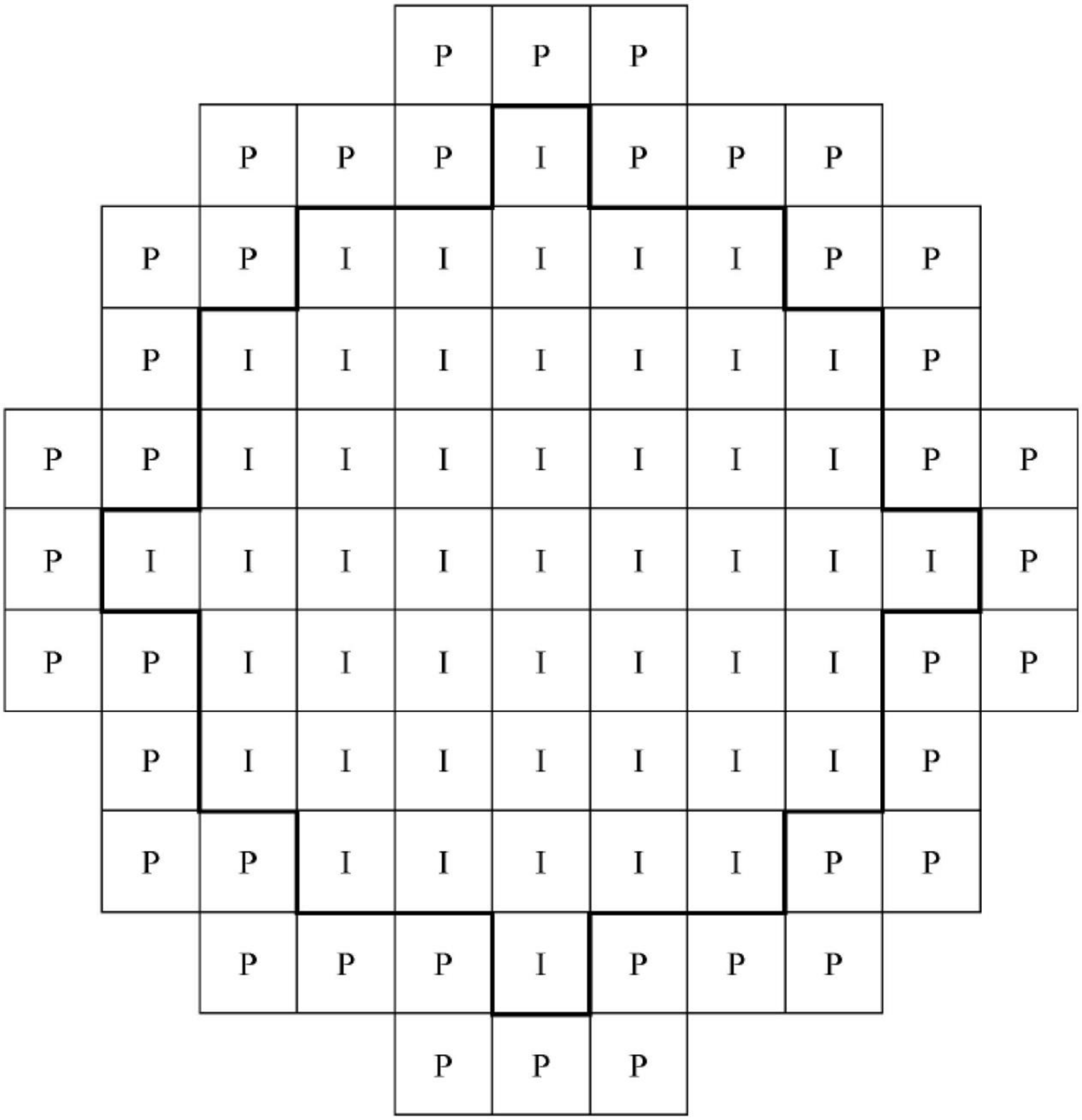


Figure 5-5
Peripheral and Inner Fuel Locations for the EOS-89BTH DSC

Proprietary Information on Pages 5-150 through 5-173
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5.6 Appendices

5.6.1 Shielding Evaluation for TN Eagle SC

Appendix 5.6.1
Shielding Evaluation for TN Eagle SC

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5.6.1 Shielding Evaluation for TN Eagle SC

The TN Eagle cask includes two configurations: TN Eagle Large Canister (LC) and TN Eagle Standard Canister (SC). The TN Eagle LC is designed to host the EOS-37PTH DSC and the EOS-89BTH DSC, and the TN Eagle SC is designed to host other DSCs of TN products, including the FC/FO/FF DSC, the 24PT1 DSC, the 24PT4 DSC, the 32PT DSC, and the 32PTH1 DSC.

The dose rates around the TN Eagle cask are in compliance with the applicable requirements of 10 CFR Part 71 for exclusive-use transportation in an open transport vehicle [1].

This section describes the shielding evaluation of the TN Eagle SC transportation package, which includes the TN Eagle SC and the authorized contents. The shielding evaluation of the TN Eagle LC transportation package is described in Chapter 5.

5.6.1.1 Description of the Shielding Design

The TN Eagle cask, including both the TN Eagle LC and the TN Eagle SC, consists of (proceeding from inner radius to outer):

- a forged cask body that provides the structural integrity of the cask, the gamma shielding, and the radioactive material containment function,
- a lid which provides radioactive material containment,
- shielding rings that surround the forged cask body to provide additional gamma and neutron radiation shielding, and
- impact limiters with adapters placed on each end for use in transport.

The TN Eagle cask is designed to allow horizontal transport of the DSCs loaded with spent fuel assemblies (FAs) in accordance with the requirements of 10 CFR 71 [1]. The authorized contents acceptable for transport are described in Chapter 1, Section 1.2.3. Drawings of the TN Eagle cask and the allowed DSCs are available in Chapter 1, Section 1.5. The main differences between the TN Eagle LC and the TN Eagle SC are the forged cask body shell thickness and the neutron shielding rings, which are discussed with more details in Section 5.6.1.3.1. The TN Eagle SC has two design options for the neutron shielding rings: shielding ring type B and shielding ring type C. The impact limiters are the same for the TN Eagle SC and the TN Eagle LC.

The TN Eagle LC is designed to host the EOS-37PTH DSC and the EOS-89BTH DSC. The EOS-37PTH DSC is designed to accommodate up to 37 intact, up to 8 damaged, and up to 4 failed PWR FAs with uranium dioxide (UO_2) fuels, zirconium alloy claddings, and with or without control components (CCs). The EOS-89BTH DSC is designed to accommodate up to 89 intact BWR FAs with UO_2 fuels, zirconium alloy claddings, and with or without fuel channels.

The TN Eagle SC is designed to host other DSCs of TN products, including the FC/FO/FF DSC, the 24PT1 DSC, the 24PT4 DSC, the 32PT DSC, and the 32PTH1 DSC.

The FC/FO/FF DSCs consist of one for 24 B&W 15x15 PWR intact fuel without control components (FO DSC), one for 24 B&W 15x15 PWR intact fuel with control components (FC DSC), and one for 13 B&W 15x15 PWR damaged fuel or failed fuel (FF DSC). The FF DSC contains individual fuel cans which confine any gross fuel particles.

The 24PT1 DSC is designed to store and transport 24 intact WE 14x14 PWR FAs or up to 4 damaged or failed fuel, UO_2 (stainless steel clad) fuel pellets, with or without integral control components. The 24PT1 DSC is also designed to store and transport 24 intact WE 14x14 PWR FAs or up to 1 damaged or failed fuel, Pu-UO_2 Mixed Oxide (MOX) Zircaloy clad fuel pellets, with or without integral control components. Individual fuel rods or portions of fuel rods may be stored individually in a failed fuel can (FFC). Damaged or failed FAs must be contained in 24PT1 DSC FFCs and are limited to the guide-sleeves located in the four outside corner locations along the 45°, 135°, 225° and 315° azimuth locations.

The 24PT4 DSC is designed to accommodate 24 intact and/or up to 12 damaged or failed CE 16x16 PWR FAs. The 24PT4 can hold up to 12 damaged or failed FAs in specially designed FFCs with the balance being loaded with intact fuel.

The 32PT DSC is designed to store 32 intact and/or up to 28 damaged and/or up to 8 failed, B&W 15x15, WE 17x17, CE 15x15, WE 15x15, CE 14x14, and WE 14x14 class, PWR FAs with or without CCs. The failed FAs are to be placed in individual FFCs.

The 32PTH1 DSC is designed to accommodate 32 intact, or up to 16 damaged with the remainder intact, B&W 15x15, WE 17x17, CE 15x15, WE 15x15, CE 14x14, WE 14x14, and CE 16x16 class PWR FAs with or without Control Components.

[ ]

5.6.1.1.1 Package Design Features

Similar to the TN Eagle LC, shielding for the TN Eagle SC transportation package at the cask side is provided mainly by the forged cask body and the shielding rings surrounding the forged cask body. Shielding for gamma radiation is provided by the forged cask body shell and the shielding ring steel. For the neutron shielding, borated VYAL-B resin blocks are provided in the shielding rings surrounding the forged cask body radially.

Gamma shielding at the cask ends is provided by the steel top and bottom assemblies of the TN Eagle cask and axial ends of the DSCs. VYAL-B resin plates are also provided [ ] at both ends to provide additional neutron shielding at the cask ends.

Additional shielding around the cask is provided by the [ ] the impact limiters and the adapters.

Minimum dimensions are generally applied in the model configurations. A full discussion and description of the models used in the shielding evaluation is contained in Section 5.6.1.3.2. Minimum boron and hydrogen content are applied in the shielding models, and material properties used in the shielding evaluation of the TN Eagle SC transportation package are described in detail in Section 5.6.1.3.3.

5.6.1.1.2 Summary Table of Maximum Radiation Levels

5.6.1.1.2.1 Regulatory Limits

The dose rate limits for transportation of the TN Eagle cask in an exclusive-use open vehicle are obtained from 10 CFR 71.47(b) and 10 CFR 71.51(a)(2) [1] and are listed as follows.

- Dose rate at any point on the external surface of the package under normal conditions is 200 mrem/hr (maximum).
- Dose rate at any point on the vertical planes projected from the outer edges, including the top and underside, under normal conditions is 200 mrem/hr (maximum).
- Dose rate at any point 2 meters from the vertical planes projected from the outer edges, excluding the top and underside, under normal conditions is 10 mrem/hr (maximum).
- Dose rate at occupied spaces under normal conditions is 2 mrem/hr (maximum).
- External dose rate at any point 1 m from the package external surface under hypothetical accident conditions is 1000 mrem/hr (maximum).

5.6.1.1.2.2 Maxima

NCT and HAC dose rates are computed for exclusive-use transport in an open vehicle. Due to different package conditions under NCT and under HAC, the external surfaces of the package are different for NCT scenarios and HAC scenarios. Model configurations are described in Section 5.6.1.3.2.

The maximum radiation dose rates for NCT and HAC scenarios from the TN Eagle SC are compared to the maximum dose rates from the TN Eagle LC and the regulation limits in Table 5.6.1-1.

[

]

The maximum NCT dose rate for normally occupied spaces is dependent on the distance from where the package is located to the occupied spaces, which varies between transport modes and actual equipment being used. [

] If the occupied spaces are closer than the separation distance reported in Table 5-2 of Chapter 5, then operational controls are necessary to ensure either that the dose rate is reduced below 2 mrem/hr or that the carrier has to implement the radiation dosimetry requirements of 10 CFR 71.47(b)(4) and 49 CFR 173.441(b)(4).

5.6.1.2 Source Specification

Fuel types that are authorized for transportation in the TN Eagle LC and the TN Eagle SC are provided in Chapter 1, Section 1.2.3. The authorized PWR fuel is summarized in Table 5.6.1-2 for both the TN Eagle LC and the TN Eagle SC. The list of all authorized PWR fuels is summarized below.

PWR

- Westinghouse (WE) 14x14 class
- WE 15x15 class
- WE 17x17 class
- Babcock & Wilcox (B&W) 15x15 class
- Combustion Engineering (CE) 14x14 class
- CE 15x15 class
- CE 16x16 class

[

]

[ ]

CCs are allowed to be stored within a PWR FA. Examples of CCs include burnable poison rod assemblies (BPRAs) and thimble plug assemblies. Control components typically have a Co-60 source because of its light element activation, which contributes substantially to the dose rates. Control components with hafnium or silver-indium-cadmium (Ag-In-Cd, or AIC) as absorber materials may have different gamma spectrum after irradiation due to activation of Hafnium and Silver. A neutron source may also be included in CCs, such as a neutron source assembly (NSA). Design basis sources for CCs are developed and the CC DBS is included in all shielding evaluation of the TN Eagle SC.

Reconstituted fuel is allowed in all FA positions. Reconstituted FAs are assemblies in which one or more fuel rods have become damaged in service and are replaced with natural uranium rods, lower enriched rods, stainless steel rods, or other non-fuel rods. The stainless steel rods may be either irradiated or non-irradiated. [

]

5.6.1.2.1 Computer Programs

Same as the TN Eagle LC, source terms are generated using the ORIGEN-ARP module of SCALE6.0 [3] for the shielding evaluation of the TN Eagle SC. Same ORIGEN-ARP libraries are applied for source term generation of the TN Eagle SC and the TN Eagle LC. Other details have been described in Chapter 5, Section 5.2.1.

5.6.1.2.2 PWR Source Terms

[ ]

[ ] The FQT for the DSCs loaded in the TN Eagle SC is shown in Chapter 8, Appendix 8.7.3, Table 8.7.3-1 and not repeated here.

[ ]

[

] From the FQT for the TN Eagle SC, the following BECTs are selected to generate the DBSs for NCT analysis of the TN Eagle SC:

PWR DBSs are reported in Table 5.6.1-3 through Table 5.6.1-8.

The gamma radiation spectrum is presented with an 18 energy group structure consistent with the SCALE 27n-18g cross section library energy grouping structure. The lower boundary energy range in this library is 0.05 MeV, and the upper energy range is 8.00 to 10.00 MeV.

The “raw” neutron source computed by ORIGEN-ARP is scaled by applying neutron peaking factors and subcritical neutron multiplication, which are derived in Section 5.6.1.2.3. The scaled neutron sources are used in the detailed MCNP dose rate calculations. Only the total neutron source magnitude is reported because the Cm-244 spectrum is used in all dose rate calculations for simplicity because the neutron source is almost entirely due to Cm-244 decay. [

]

5.6.1.2.3 Axial Source Distributions and Subcritical Neutron Multiplication

ORIGEN-ARP is used to compute source terms for the average assembly burnup. However, an FA will exhibit an axial burnup profile in which the fuel is more highly burned near the axial center of the FA and less burned near the ends. This axial burnup profile must be taken into account when performing dose rate calculations, as the dose rate will typically peak near the maximum of this distribution.

The PWR axial burnup profile and the neutron peaking factors selected for the shielding evaluation have been described in Chapter 5, Section 5.2.3, and details are not repeated here.

ORIGEN-ARP does not account for subcritical neutron multiplication. [

] Details of the k_{eff} value calculation have been presented in Chapter 5, Section 5.2.3, and are not repeated here.

5.6.1.2.4 Control Components

Control components may also be included with the PWR FAs. 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 as part of the authorized contents in Chapter 1, Section 1.2.3.

Radiological source in Table 5.6.1-9 bounds any CC authorized for loading in the TN Eagle SC. [

]

[ ]

Combined radiological sources of the PWR fuel DBS and the CC DBS are applied in the shielding evaluation of the TN Eagle SC.

5.6.1.2.5 Reconstituted Fuel

Reconstituted FAs are assemblies in which one or more fuel rods have become damaged in service and are replaced with natural uranium rods, lower enriched rods, and non-fuel rods including stainless steel rods. The stainless steel rods may be either irradiated or non-irradiated. [

] Details of the material compositions and source calculations have been described in Chapter 5, Section 5.2.5, and are not repeated here.

The sources terms of reconstituted fuel [

] are calculated and listed in Table 5.6.1-10 through Table 5.6.1-13 for shielding evaluation of reconstituted fuel reported in Section 5.6.1.4.4.1.

5.6.1.2.6 High Burnup Fuel

5.6.1.2.7 Gamma Source

The gamma radiation spectrum is presented with an 18 energy group structure consistent with the SCALE 27n-18g cross section library energy grouping structure. The lower boundary energy range in this library is 0.05 MeV, and the upper energy range is 8.00 to 10.00 MeV.

In the shielding models for gamma sources, gamma sources from spent fuel and from activated fuel structural materials are calculated as described in Section 5.6.1.2.2. For all shielding evaluation, the CC DBS described in Section 5.6.1.2.4 is combined with the gamma sources from the FAs in the shielding models.

The secondary gammas due to attenuation of neutrons by shielding material have been included in the MCNP models by running the MCNP models in coupled neutron-photon mode, therefore dedicated models with the secondary gamma sources are not needed.

5.6.1.2.8 Neutron Source

The neutron source energy distribution used in the shielding analysis is based on the Cm-244 Watt fission spectrum in the MCNP models. The strength of the neutron sources used in the shielding analysis is calculated using ORIGEN-ARP as described in above sections.

5.6.1.3 Model Specification

Same as the TN Eagle LC, MCNP5 [4] is used to perform detailed three-dimensional dose rate calculations for the TN Eagle SC transportation system. All relevant details of the DSC and the TN Eagle SC are modeled explicitly.

Separate primary gamma and neutron models are developed. The TN Eagle SC neutron models are run in coupled neutron-photon mode so that the secondary gamma dose rate from (n,γ) reactions may be computed. [

]

5.6.1.3.1 Design Basis System

The TN Eagle SC is designed to host the FO/FC/FF DSC, the 24PT1 DSC, the 24PT4 DSC, the 32PT DSC, and the 32PTH1 DSC.

A design basis system is selected in this section for the shielding evaluation of the TN Eagle SC transportation system, such that the dose rates from the design basis system bound the dose rates from the TN Eagle SC loaded with all authorized contents.

Proprietary Information on Pages 5.6.1-13 and 5.6.1-14
Withheld Pursuant to 10 CFR 2.390

5.6.1.3.2 Configuration of Source and Shielding

Detailed TN Eagle SC MCNP models are developed for the design basis system. All FAs are uniformly loaded in the DSC with the design basis source terms from both the FAs and the CCs. Mass of the CCs is not included in the shielding models to ignore self-shielding increase from the inserted CCs.

The [ ] DSC is modeled explicitly, including the steel basket structure, aluminum plates, metal matrix composite (MMC) plates [ ], transition rails, and shield plugs. Key dimensions used to develop the DSC models are summarized in Table 5.6.1-18. [ ]

The TN Eagle SC is also modeled explicitly, and key dimensions used to develop the TN Eagle SC models are provided in Table 5.6.1-19. [ ] The impact limiters are the same for the TN Eagle SC and the TN Eagle LC.

[ ]

Model configurations for NCT and HAC scenarios are described with further details below.

5.6.1.3.2.1 NCT

Intact, damaged, and failed fuel may be loaded in different DSCs in the TN Eagle SC.

As described in Chapter 1:

5.6.1.3.2.2 HAC

Other model configurations for HAC analysis of the TN Eagle SC are the same as the model configurations of the TN Eagle LC. Details have been described in Chapter 5, Section 5.3.2.2 and are not repeated here.

5.6.1.3.3 Material Properties

Material properties used in the MCNP models of the TN Eagle SC are the same as the ones used for the TN Eagle LC, which have been described in Chapter 5, Section 5.3.3 and are not repeated here.

5.6.1.4 Shielding Evaluation

5.6.1.4.1 Methods

MCNP5 v1.40 is used in the shielding analysis [4]. MCNP5 is a Monte Carlo transport program that allows full three-dimensional modeling of the TN Eagle System. Therefore, no geometrical approximations are necessary when developing the shielding models.

With the source terms generated in Section 5.6.1.2 and model configurations developed in Section 5.6.1.3, shielding evaluation is performed for the TN Eagle SC and external dose rates are provided in Section 5.6.1.4.4 for both NCT and HAC analysis.

5.6.1.4.2 Input and Output Data

MCNP models are built for the model parameters described in Section 5.6.1.3 and source terms described in Section 5.6.1.2 for shielding evaluations. Different scenarios are analyzed to cover different cask conditions, and fuel conditions under both NCT and HAC, to demonstrate the compliance of the TN Eagle SC transportation package with the regulation dose rate limits. Details of analyzed scenarios are described below in Section 5.6.1.4.4.

5.6.1.4.3 Flux-to-Dose-Rate Conversion

MCNP5 is used to compute the neutron or gamma flux at the location of interest and the flux is converted to a dose rate using ANSI/ANS-6.1.1-1977 [6] flux-to-dose rate conversion factors, which have been provided in Chapter 5, Section 5.4.3 and are not repeated here. Results are computed in the units mrem/hr.

5.6.1.4.4 External Radiation Levels

In this section, dose rates around the TN Eagle SC transportation system are analyzed and presented for different cask conditions and fuel conditions. Results for intact, damaged, and failed fuel are presented in Section 5.6.1.4.4.1 for NCT analysis and Section 5.6.1.4.4.2 for HAC analysis.

5.6.1.4.4.1 NCT

The external dimensions of the TN Eagle SC are the same as the TN Eagle LC in the shielding models. All tallies are also the same for both TN Eagle casks. Details have been provided in Chapter 5, Section 5.4.4.1 and are not repeated here.

[ ]

With the DBSs determined in Section 5.6.1.2.2 for fuel and Section 5.6.1.2.4 for CCs, model configurations described in Section 5.6.1.3.2, and material properties described in Section 5.6.1.3.3, various NCT scenarios shown in Table 5.6.1-20 are analyzed, depending on fuel configuration, fuel loading position, and DSC location inside the cask. The CC DBS is combined with the fuel DBS for all scenarios. Reconstituted fuel is analyzed [ ].

The total dose rates from all NCT scenarios in Table 5.6.1-20 are reported in Table 5.6.1-21 and Table 5.6.1-22 at the vehicle (package) surface, and the 2 m from vehicle surface, respectively. The maximum dose rates at the cask top end, the cask side, and the cask bottom end are marked as bold fonts. [ ]

[ ]

[

]

The overall maximum dose rate at the 2 m from vehicle surface is 6.8 mrem/hr from the scenario with failed fuel, which is well below the regulation limit of 10 mrem/hr.

The dose rate breakdown for maximum dose rates is summarized in Table 5.6.1-23.

[

]

5.6.1.4.4.2 HAC

The external dimensions of the TN Eagle SC under HAC are the same as the TN Eagle LC under HAC in the shielding models. All tallies are also the same for both TN Eagle casks. Details have been provided in Chapter 5, Section 5.4.4.2 and are not repeated here.

Maximum dose rates are reported on “1 m from Ext. Surface”, to be compared to the regulation limits. Definitions of the surface are provided in Chapter 5, Section 5.4.4.2.

With the DBSs determined in Section 5.6.1.2.2 for fuel and Section 5.6.1.2.4 for CCs, model configurations described in Section 5.6.1.3.2, and material properties described in Section 5.6.1.3.3, various HAC scenarios shown in Table 5.6.1-25 are analyzed. [

]

The total dose rates from all HAC scenarios in Table 5.6.1-25 are reported in Table 5.6.1-26 and Table 5.6.1-26a for the 1 m from Ext. Surface. [

]

The overall maximum dose rate at the 1 m from Ext. Surface is 395 mrem/hr from the scenario with intact fuel, which is below the regulation limit of 1000 mrem/hr.

The dose rate breakdown for the maximum HAC dose rate scenario is summarized in Table 5.6.1-27 and Table 5.6.1-27a. [
]

5.6.1.5 Decay Heat Restrictions

The equation above includes 20 watts as the last term to cover the uncertainty from the regression calculations. The minimum cooling time for the decay heat calculation is 5 years.

Alternatively, the decay heat can be calculated without employing the decay heat equation, using an approved methodology with actual spent fuel parameters instead of bounding spent fuel parameters.

The DHE does not apply to MOX and an approved method shall be used to calculate the decay heat of MOX.

5.6.1.6 References

1. Title 10, Code of Federal Regulations, Part 71, *Packaging and Transportation of Radioactive Materials*.

2. NUREG 2224, “Dry Storage and Transportation of High Burnup Spent Nuclear Fuel Final Repor,” November 2020.

3. SCALE 6: Modular Code System for Performing Standardized Computer Analyses for Licensing Evaluation for Workstations and Personal Computers, Oak Ridge National Laboratory, Radiation Shielding Information Center Code Package CCC-750, February 2009.

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

5. NUREG/CR-6835, “Effects of Fuel Failure on Criticality Safety and Radiation Dose for Spent Fuel Casks,” September 2003.

6. ANSI/ANS-6.1.1-1977, “American National Standard Neutron and Gamma-Ray Flux-to-Dose-Rate Factors,” American National Standards Institute, Inc., New York, New York.

7. ORNL/TM-2013/416, Rev. 1, ADVANTG – An Automated Variance Reduction Parameter Generator, Oak Ridge National Laboratory.

8. TN Document, DI-83016-006, “Neutron Sources,” Rev. 0.

9. TN Americas LLC, “NUHOMS®-MP197 TRANSPORTATION PACKAGING SAFETY ANALYSIS REPORT,” Revision 20.

Table 5.6.1-1
Maximum Dose Rates of TN Eagle Cask

Location	Limit (mrem/hr) (Exclusive Use Open Transport)	Maximum Total Dose Rate (mrem/hr)	
		TN Eagle LC	TN Eagle SC
External surface of the package (NCT)	200	126	105
Vertical planes projected from outer edges, including the top and underside (NCT)	200	126	105
2 meters from the vertical planes projected from outer edges (NCT)	10	9.4	6.8
1 meter from the surface of the package (HAC)	1000	714	395

Table 5.6.1-2
Authorized PWR Fuel in TN Eagle Cask

Proprietary Information on Pages 5.6.1-24 through 5.6.1-50
Withheld Pursuant to 10 CFR 2.390

Chapter 6
Criticality Evaluation

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Chapter 6
Criticality Evaluation

NOTE: References in this chapter are shown as [1], [2], etc. and refer to the reference list in Section 6.7.

6.1 Description of Criticality Design

6.1.1 Design Features

The content of the package is the dry shielded canister (DSC) that has been loaded in the spent fuel pool and transferred to a dry storage system. The DSC is transferred from dry storage directly into the TN Eagle. The DSC is transported to another dry storage facility where it is transferred from the TN Eagle directly into a dry storage system. The routine operation of the TN Eagle does not involve any operations in the spent fuel pool, and there is no mechanism for water to enter the DSC during transfers between the cask and dry storage system.

6.1.1.1 Configuration

6.1.1.2 Neutron Absorption

Boron plates may be incorporated into the DSC basket to provide neutron absorption when water fills the cask cavity.

6.1.1.3 Water Barrier

6.1.1.4 Burnup Credit

Guidance provided in NUREG-2216 [5] is followed, unless stated otherwise, to develop loading tables for PWR fuel assemblies. The DSC is verified to have been loaded with PWR fuel assemblies that meet the loading tables. Burnup credit is not considered for normal and accident transport conditions because the contents are dry and subcritical.

6.1.1.5 Fissile Material Packages for Air Transport

Not applicable. No air transport of TN Eagle is allowed.

6.1.1.6 Summary of Design Features

	Routine operation (71.55(b))	Normal condition of transport (71.55(d))	Hypothetical accident condition (71.55(e))

6.1.2 Summary of Criticality Evaluation

Summary of Criticality Evaluations for Single Package – Routine Operation (71.55(b))

Contents	k_{eff}	USL	Reference Appendix
EOS-89BTH DSC	0.9398	0.9418	6.8.1
EOS-37PTH DSC	0.9413	0.9423	6.8.2
FO-FF-FC DSC	0.9374	0.9500	6.8.3
24PT1 DSC	0.9111	0.9500	6.8.3
24PT4 DSC	0.9393	0.9411	6.8.4
32PTH1 DSC	0.9375	0.9412	6.8.4
32PT DSC	0.9419	0.9423	6.8.5

Summary of Criticality Evaluations for Single Package – Normal Condition of Transport (71.55(d))

Contents	k_{eff}	USL	Reference Appendix
EOS-89BTH DSC	0.7030	0.9418	6.8.1
EOS-37PTH DSC	0.7151	0.9417	6.8.2
FO-FF-FC DSC	0.9374(1)	0.9500	6.8.3
24PT1 DSC	0.9111(1)	0.9500	6.8.3
24PT4 DSC	0.6861	0.9412	6.8.4
32PTH1 DSC	0.6702	0.9412	6.8.4
32PT DSC	0.7534	0.9417	6.8.5

Summary of Criticality Evaluations for Single Package – Hypothetical Accident Condition (71.55(e))

Contents	k_{eff}	USL	Reference Appendix
EOS-89BTH DSC	0.7030	0.9418	6.8.1
EOS-37PTH DSC	0.7151	0.9417	6.8.2
FO-FF-FC DSC	0.9497(1)	0.9500	6.8.3
24PT1 DSC	0.9392(1)	0.9500	6.8.3
24PT4 DSC	0.6861	0.9412	6.8.4
32PTH1 DSC	0.6702	0.9412	6.8.4
32PT DSC	0.7534	0.9417	6.8.5

Summary of Criticality Evaluations for Package Array– Normal Condition of Transport (71.55(d))

Contents	k_{eff}	USL	Reference Appendix
EOS-89BTH DSC	0.7030	0.9418	6.8.1
EOS-37PTH DSC	0.7151	0.9417	6.8.2
FO-FF-FC DSC	0.9374(1)	0.9500	6.8.3
24PT1 DSC	0.9111(1)	0.9500	6.8.3
24PT4 DSC	0.6861	0.9412	6.8.4
32PTH1 DSC	0.6702	0.9412	6.8.4
32PT DSC	0.7534	0.9417	6.8.5

Summary of Criticality Evaluations for Package Array– Hypothetical Accident Condition (71.55(e))

Contents	k_{eff}	USL	Reference Appendix
EOS-89BTH DSC	0.7030	0.9418	6.8.1
EOS-37PTH DSC	0.7151	0.9417	6.8.2
FO-FF-FC DSC	0.94968(1)	0.9500	6.8.3
24PT1 DSC	0.9392(1)	0.9500	6.8.3
24PT4 DSC	0.6861	0.9412	6.8.4
32PTH1 DSC	0.6702	0.9412	6.8.4
32PT DSC	0.7534	0.9417	6.8.5

Note:
(1) Analysis performed with water in-leakage

6.1.3 Criticality Safety Index

The package array for both normal conditions of transport and hypothetical accident conditions is infinite. The value of “N” is infinity and the criticality safety index (CSI) is 0.

6.2 Fissile Material Contents

The following sections discuss the fissile material contents in the EOS-89BTH and EOS-37PTH DSCs. For other DSCs’ contents, see their respective appendices listed in Section 6.8.

The methodology employed to ensure the subcriticality of the EOS-89BTH is based on a “fresh fuel” representation of the spent fuel assemblies. For this DSC, the fuel assemblies are modeled with fresh (unirradiated) fuel.

The methodology employed to ensure the subcriticality of the EOS-37PTH DSCs is based on “burned fuel” representation of the spent fuel assemblies. Credit for the negative reactivity of the fuel assemblies as a result of irradiation, or “burnup credit,” is employed in these calculations. The maximum burnup “credited” in these analyses does not exceed 60 GWd/MTU. The minimum required loading time is 5 years. A maximum cooling time limit of 40 years is imposed to ensure that the burnup credit criticality analysis is applicable. This limit is only used in the analysis, and does not prevent transporting fuel that has been cooled in excess of 40 years.

6.2.1 Fresh Fuel Methodology

For the EOS-89BTH DSC, the system’s criticality safety is ensured by both fixed neutron absorbers and favorable geometry. Fresh fuel is assumed (no burnup credit is taken) in the evaluation. The fixed neutron absorber is present in the form of borated aluminum alloy or a boron-carbide/aluminum metal matrix composite or BORAL®. These materials are ideal for long-term use in radiation and thermal environments of a DSC.

The criticality analysis for the transfer and storage of the EOS-89BTH DSC has been previously performed in a generic transfer cask [2]. These analyses along with a description of the contents, calculation models, and criticality analysis results are presented in Appendix 6.8.1. The generic cask consists of an inner stainless steel shell and lead gamma shield, a stainless steel structural shell, and a liquid neutron shield. These criticality calculations consider that the neutron shielding is stripped away and the casks (without the neutron shield) are “brought” closer together when reflective boundary conditions are employed. The TN Eagle transport cask consists of steel and a solid neutron shielding. The structural analysis calculations in Chapter 2, Appendix A.2.13.1 for the NCT and HAC for the cask demonstrate that the neutron shield shell remains in place, thereby maintaining a larger separation distance between casks (in a cask array for HAC). This implies that these criticality calculations with the modeled cask arrays are adequate and bounding for the TN Eagle cask.

EOS-89BTH contents, calculational methods, and criticality analysis when transported within a TN Eagle transport cask are presented in Appendix 6.8.1.

The calculations determine k_{eff} with the CSAS5 control module of SCALE 6.0 [3] for various configurations and initial enrichments, including all uncertainties to assure criticality safety under all credible conditions.

The results of the evaluation demonstrate that the maximum k_{eff} including statistical uncertainty is less than the upper subcriticality limit (USL) determined from a statistical analysis of benchmark criticality experiments. The statistical analysis procedure includes a confidence band with an administrative safety margin of 0.05.

6.2.2 Burnup Credit Methodology

The criticality analysis for the transfer of EOS-37PTH [2] has been previously performed in a generic transfer cask utilizing fixed neutron absorbers in the basket, soluble boron in the pool water, and favorable basket geometry. This methodology is modified to add credit for the negative reactivity due to the burnup of fuel ('burnup" credit) while not using soluble boron credit. This analysis along with a description of the contents, calculation models, and criticality analysis results for the EOS-37PTH DSC is presented in Appendix 6.8.2.

Taking credit for fuel assembly burnup or "burnup credit" requires a different analytical approach for criticality analysis than is used in traditional analysis with a fresh fuel assumption. For fresh fuel, the only key fuel parameters to be taken into account in the analyses are the initial enrichment and the most reactive fuel configuration. The analysis of burned fuel must include consideration of the most reactive assembly as a function of burnup, end effects (underburned fuel at the ends), reactor operating history, fuel composition, initial enrichment, and cooling time. Therefore, additional calculations and codes are required for burned fuel to determine the isotopic composition of the burned fuel as a function of fuel design, initial enrichment, burnup, and cooling time using an assumed bounding reactor operating history. These are termed as "depletion" calculations.

The PWR burnup credit methodology outlined in Interim Staff Guidance (ISG)-8 [6], incorporated in Section 6.4.7 of [5], is used as the basis for the EOS-37PTH burnup credit evaluation.

The burnup credit analysis includes:

- Limits for the licensing basis applicable to PWR UO_2 fuel assembly enriched up to 5 wt % U-235, irradiated up to an assembly-average burnup value of 60 GWd/MTU, cooled up to 40 years. The evaluation is based on limited actinide and fission product compositions shown in Table 6.8.2-18 consistently to Table 6.2 of [5].
- Licensing-basis model assumptions including appropriate axial burnup profiles, presence of burnable absorbers or control rods during irradiation, and appropriate bounding depletion parameters encompassing actual irradiation histories.

- Code validation – isotopic depletion. The evaluations are performed using SCALE 6.1 [4] and the ENDF/B-VII nuclear data. TSUNAMI three-dimensional (3D) calculations are performed for the application and experiment models to demonstrate the similarity of the EOS-37PTH DSC system application to the GBC-32 generic burnup credit cask, allowing the use of isotopic depletion code bias in Table 6-3 of [5] per Table 6-5 of [5].
- Code validation – k_{eff} determination. The criticality analysis is performed using the CSAS5 sequence of SCALE 6.1 [4] and the ENDF/B-VII 238-energy-group library. Bias and bias uncertainty associated with the major actinides are based on the validation set of experiments outlined in NUREG-7109 [7] including Mix Uranium and Plutonium experiments and HTC (Haux Taux de Combusiton) experiments. The actinide and fission product code validation meets the recommendation in Table 6-6 of [5], allowing the use of a bias equal to 1.5% of minor actinide and fission product worth.
- Loading curve and burnup verification. The burnup credit analysis results in loading curves which define the minimum “required” fuel assembly burnup as a function of initial enrichment, cooling time, and fuel assembly design.

Because fuel assembly burnup is a derived quantity, it is necessary that the appropriate (and conservative) value be assigned to the fuel assembly to ensure that only the eligible assemblies are loaded. This is also necessitated by the fact that fuel assembly burnup measurements prior to transportation may not be practical for previously loaded DSCs. The “minimum” burnup is assigned to the fuel assembly after accounting for all calculational uncertainties.

Appropriate and conservative assignment of fuel assembly burnup along with independent verification of all parameters for loading fuel assemblies is absolutely essential to ensure that the risk of fuel assembly misloading is minimized or eliminated when burnup credit is employed in the criticality safety analyses. This is different from the fresh fuel criticality analyses where “any” fuel assembly burnup (not credited) can be employed as a margin against misloading events.

6.3 General Considerations

The following sections discuss general consideration regarding the criticality analysis for the EOS-89BTH and EOS-37PTH DSCs. For other DSCs, see their respective appendices listed in Section 6.8.

6.3.1 Model Configuration

The analytical results reported in Chapter 2 demonstrate that the cask containment boundary and canister structure do not experience any significant distortion under hypothetical accident conditions. The fuel assembly drop analyses documented in Chapter 2 also demonstrate that the fuel rods do not experience enough deformation to cause a change in the fuel geometry. Therefore, for both normal and hypothetical accident conditions the TN Eagle cask, geometry is identical except for the neutron shield. The neutron shield is conservatively removed and the interstitial space modeled as water. Therefore, the deformation does not result in a more reactive configuration of the fuel assemblies modeled in the KENO models.

To demonstrate compliance with the requirements specified in Section 71.55(b) of 10 CFR Part 71, the fuel assemblies are modelled in the appropriate conditions (moderation and configurations) for intact and failed fuels as detailed in Section 6.8.2.4.1 for the EOS-37PTH DSC. The HAC and NCT analyses for compliance with the requirements specified in Section 71.55(e) and (d) of 10 CFR Part 71 are documented in Section 6.8.2.9.

The detailed assumptions employed in the criticality calculations for the EOS-37PTH DSC are presented in Section 6.8.2.4.1.

To demonstrate compliance with the requirements specified in Section 71.55(b) of 10 CFR Part 71, the fuel assemblies are modelled in the appropriate conditions (moderation and configurations) for intact fuels as detailed in Section 6.8.1.2.1 for the EOS-89BTH DSC. The HAC and NCT analyses for compliance with the requirements specified in Section 71.55(e) and (d) of 10 CFR Part 71 are documented in Sections 6.8.1.3 through 6.8.1.5.

The detailed assumptions employed in the criticality calculations for the EOS-89BTH DSC are discussed in Section 6.8.1.2.1.

6.3.2 Material Properties

The following sections discuss general consideration regarding the criticality analysis for the EOS-89BTH and EOS-37PTH DSCs. For other DSCs, see their respective appendices listed in Section 6.8.

The physical and nuclear data required for the criticality analysis including fuel assembly data, basket material composition, basket dimensions, and cross section data are described in Section 6.8.1.2.2 for the EOS-89BTH and Section 6.8.2.3.1 for the EOS-37PTH.

6.3.3 Computer Codes and Cross-Section Libraries

The following sections discuss general consideration regarding the criticality analysis for the EOS-89BTH and EOS-37PTH DSCs. For other DSCs, see their respective appendices listed in Section 6.8.

The computer codes and cross-section libraries employed for the EOS-89BTH criticality analysis are discussed in Section 6.8.1.2.3.

The computer codes and cross-section libraries employed for the EOS-37PTH criticality analysis are discussed in Section 6.8.2.3.

6.3.4 Demonstration of Maximum Reactivity

The following sections discuss general consideration regarding the criticality analysis for the EOS-89BTH and EOS-37PTH DSCs. For other DSCs, see their respective appendices listed in Section 6.8.

The criticality calculations for the EOS-89BTH DSC are performed with CSAS5 modules in SCALE 6.0, [3], Section 6.8.1.2.3. The Monte Carlo calculations performed with CSAS5 (KENO V.a) use a flat neutron starting distribution. The total number of histories traced for each calculation is at least 1,000,000. This minimum number of histories is sufficient to achieve source convergence and produce standard deviations of less than 0.0010. The maximum k_{eff} for the calculation is determined with the following formula:

$$k_{eff} = k_{KENO} + 2\sigma_{KENO}$$

The USL determined for the fresh fuel critical experiments with SCALE 6.0 is 0.9418 considering 51 critical experiments with un-borated system.

Detailed USL determination is presented in Section 6.8.1.7.2.

The criticality calculations for the EOS-37PTH DSC are performed with STARBUCS and CSAS5 modules in SCALE 6.1.3, [4] with consideration for burnup credit. The Monte Carlo calculations performed use a flat neutron starting distribution. The total number of histories traced for each calculation is at least 1,000,000. This number of histories is sufficient to achieve source convergence and produce standard deviations of less than 0.0005. The maximum k_{eff} for the calculation is determined with the following formula:

$$k_{eff} = k_{KENO} + 2\sigma_{KENO} + \text{Biases and Biases Uncertainties}$$

A detailed description of the SCALE 6.1.3 criticality code benchmarking using criticality experiments for fresh fuel assumption and burnup credit analysis is provided in Section 6.8.2.5. The criticality code validation is performed according to [7] to obtain the bias that results from the calculation of the benchmark experiments and the bias uncertainty that incorporates several other elements of uncertainty including a confidence interval. **[**

]

The USL determined for the fresh fuel critical experiments with SCALE 6.1.3 is 0.9417, considering 51 critical experiments with un-borated system.

The USL determined for the burnup credit analysis with SCALE 6.1.3 due to major actinides is 0.9423.

The detailed USL determination is presented in Section 6.8.2.4.2.1

6.4 Single Package Evaluation

The criticality evaluation demonstrates that a single package is subcritical in the as-designed condition for compliance with 10 CFR 71.55(b) and under both normal conditions of transport and hypothetical accident conditions for compliance with 10 CFR 71.55(d) and (e), respectively. Package array evaluation using mirror reflection for the boundary condition provides reflection by the package materials and any water interspersed between the packages in the array. Representing the full water reflection as the mirror reflection is at least as reactive as full water reflection on all sides of the package.

6.4.1 Routine Operation

6.4.2 Normal Condition of Transport

6.4.3 Hypothetical Accident Condition

6.5 Evaluation of Package Arrays

6.5.1 Evaluation of Package Arrays under Normal Conditions of Transport

The configuration of packaging and contents is the same as for the single package evaluation. An infinite package array is subcritical.

6.5.2 Package Arrays under Hypothetical Accident Conditions

The configuration of packaging and contents is the same as for the single package evaluation. An infinite package array is subcritical.

6.5.3 Package Array Results and Criticality Safety Index

The design has a CSI (given in 10 CFR 71.59(b) as CSI = 50/“N”) of 0 because “N” is infinity (∞).

6.6 Benchmark Evaluation

The following sections discuss general consideration regarding the criticality analysis for the EOS-89BTH and EOS-37PTH DSCs. For other DSCs, see their respective appendices listed in Section 6.8.

6.6.1 Applicability of Benchmark Experiments

This section summarizes evaluations performed for benchmarking the various computer codes utilized in the criticality analysis. A description of the benchmarking analyses performed in support of the criticality analyses for the DSCs where burnup is not credited is provided in Section 6.3.1. All other subsections describe the various analyses that are performed in support of the burnup credit criticality analyses.

6.6.1.1 Fresh Fuel Benchmarks

The CSAS5 module of the SCALE 6 [3] computer code system is employed to perform the criticality safety analysis of the EOS-89BTH DSC. **[**

]

A comprehensive discussion of the benchmark calculations performed for the EOS-89BTH DSC is presented in Section 6.8.1.7.1.

6.6.1.2 Burnup Credit Benchmarks

The critical experiments appropriate for burnup credit criticality analysis suggested in [7] and [8] are employed for the validation of the use of SCALE 6.1.3 [4] and the 238 group ENDF/B-VII library.

[

]

A comprehensive discussion of the benchmark calculations performed for the EOS-37PTH DSC is presented in Appendix 6.8.2.5.

6.6.2 Bias Determination

The following biases are applicable to the burnup credit of the TN Eagle cask with EOS-37PTH DSC payload.

The bias and bias uncertainty associated with major actinides is determined using the burnup credit benchmarks described in Section 6.8.2.4.2.1.

The bias and bias uncertainty associated with minor actinides and fission products credit conservatively 1.5% of minor actinides and fission product worth, as SCALE 6.1.3/ENDF/B-VII cross-section library is used, and design similar to GBC-32 and credited minor actinides and fission products < 0.1 in k_{eff} are shown as required in Table 6-6 of [5], Section 6.8.2.4.2.2.

The bias and bias uncertainty associated isotopic depletion shown in Table 6-3 of [5] is credited, as SCALE 6.1.3/ENDF/B-VII cross-section library is used, and design similar to GBC-32 are shown as required in Table 6-5 of [5], Section 6.8.2.4.2.2.

The bias and bias uncertainty associated with minor actinides and fission products and the bias and bias uncertainty associated isotopic depletion are to be added to the $k_{keno} + \sigma_{keno}$.

The USL including 5% administrative margin and major actinides bias and bias uncertainty is 0.9423.

6.7 References

1. 10 CFR 71, Packaging and Transportation of Radioactive Materials.

2. TN Americas LLC, NUHOMS® EOS System Updated Final Safety Analysis Report, Docket Number 72-1042, Revision 3.

3. Oak Ridge National Laboratory, RSIC Computer Code Collection, “SCALE: A Modular Code System for Performing Standardized Computer Analysis for Licensing Evaluations for Workstations and Personal Computers,” NUREG/CR-0200, Revision 6, ORNL/NUREG/CSD-2/V2/R6.

4. ORNL, “Scale: a Comprehensive Modeling and Simulation Suite for Nuclear Safety Analysis and Design,” ORNL/TM-2005/39 Version 6.1, June, 2011.

5. US NRC, “Standard Review Plan for Transportation Packages for Spent Fuel and Radioactive Material,” NUREG-2216.

6. US NRC Division of Spent Fuel Storage and Transportation Interim Staff Guidance, “Burnup Credit in the Criticality Safety Analyses of PWR Spent Fuel in Transportation and Storage Casks,” ISG-8 Revision 3.

7. US NRC, “An Approach for Validating Actinide and Fission Product Burnup Credit Criticality Safety Analyses – Criticality (k_{eff}) Predictions,” NUREG/CR-7109.

8. US NRC, “Evaluation of the French Haut Taux de Combustion Safety Analyses – Criticality (HTC) Critical Experiment Data,” NUREG/CR-6979.

6.8 APPENDICES

6.8.1 EOS-89BTH DSC CRITICALITY EVALUATION

6.8.2 NUHOMS® EOS-37PTH DSC CRITICALITY EVALUATION

6.8.3 FO, FC, FF AND 24PT1 DSCS CRITICALITY EVALUATION

6.8.4 24PT4, 32PTH1 DSCS CRITICALITY EVALUATION

6.8.5 32PT DSC CRITICALITY EVALUATION

Appendix 6.8.1
EOS-89BTH DSC Criticality Evaluation

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6.8.1 EOS-89BTH DSC Criticality Evaluation

NOTE: References in this Appendix are shown as [1], [2], etc. and refer to the reference list in Section 6.8.1.8.

This Appendix 6.8.1 to Chapter 6 demonstrates that the TN Eagle cask when loaded with the EOS-89BTH DSC meets the criticality requirements specified in Sections 71.55 and 71.59 of 10 CFR Part 71 [1].

6.8.1.1 Fissile Material Contents

The EOS-89BTH DSC in the TN Eagle cask is designed to accommodate up to 89 intact BWR fuel assemblies with and without channels, channel fasteners. The DSCs are of variable length to match the length of the fuel to be stored. Reconstituted fuel assemblies (natural uranium, lower enriched rods, zircaloy rods, zircaloy pellets, irradiated and non-irradiated SS rods) can also be loaded into in the EOS-89BTH DSC. The BWR fuel assemblies that can be accommodated by the EOS-89BTH DSC are listed in Table 6.8.1-2.

Since the authorized fuel assemblies for the EOS-89BTH DSC span a wide variety of fuel types and configurations, a representative fuel assembly was used to determine the maximum allowable enrichment in [2], after comparing k_{eff} values for all the fuel assemblies listed. The maximum allowable enrichment was obtained using the GNF2 10x10 FA, except for the KKL-BWR 11/16 and SVEA-96Opt2 FAs (classified with a BWR fuel identification of ABB-10-C, see Table 6.8.1-2).

6.8.1.2 General Considerations

The EOS-89BTH DSC is designed to accommodate up to 89 BWR intact fuel assemblies. It consists of a shell assembly and an internal basket assembly for housing the fuel assemblies. The basket is made up of interlocking slotted plates that form an egg-crate type structure. This structure is made up of steel plates, aluminum plates for heat transfer, and a neutron poison plate for criticality control.

The TN Eagle cask has a large inner diameter meant to accommodate larger diameter DSCs. It consists of a thick carbon steel forged body, shrink fitted rings for gamma and neutron shielding, and the use of a neutron shielding resin material. It also includes aluminum honeycomb impact limiters. The radial cross section of the EOS-89BTH DSC in the TN Eagle cask is shown in Figure 6.8.1-1.

6.8.1.2.1 Model Configuration

The following subsections describe the physical models and materials of the NUHOMS® EOS system used for input to the CSAS5 module of SCALE 6.0 [3] to perform the criticality evaluation.

The nominal dimensions of the DSC and the TN Eagle cask models are summarized in Table 6.8.1-3.

EOS-89BTH DSC

The poison plates in the EOS-89BTH DSC are made of aluminum/B_4C metal matrix composite (MMC) or BORAL® that provides the necessary criticality control during loading and unloading operations. Cast or extruded aluminum open section transition rails, which are reinforced with internal steel pipes/tubes, as necessary, provide the transition to a rounded surface to match the DSC shell's inside surface. The length of the DSC shell/basket assemblies can be customized to accommodate different fuel assembly lengths. The basket utilizes an aluminum/B_4C MMC or BORAL® as its neutron poison material. These materials are ideal for long-term use in radiation and thermal environments of a dry storage canister. The required B-10 loading is a function of assembly lattice average enrichment as determined in Chapter 7 of [2] and the material compositions for different basket types are listed in Table 6.8.1-1.

The following assumptions are employed in the criticality calculations:

- Fresh fuel is assumed. No credit is taken for fissile depletion, fission product poison, or burnable absorbers.
- For intact fuels, fuel rods are filled with full density fresh water in the pellet-clad gap.
- The neutron shield and steel neutron shield jacket (outer skin) of the cask are conservatively removed and infinite arrays of casks are pushed close together with external moderator (unborated water) in the interstitial spaces.
- The MMC poison plates are modeled with minimum specified B-10 reduced to 90%.

- Temperature is 20 °C (293K).
- All steel and aluminum alloys of the basket structure are modeled as SS304 and aluminum, respectively. While these compositions, which are provided in the SCALE 6.0 standard composition library, have small differences with compositions of the various steels and aluminum, they have negligible effect on the results of the calculation.
- All zirconium based materials in the fuel are modeled as Zircaloy-2 for BWR fuel evaluations. The small differences in the composition of the various clad/guide compartment materials have negligible effect on the results of the calculations.
- Omission of grid plates, spacers, and hardware in the FA.
- No integral burnable absorbers, such as gadolina, erbia, or any other absorbers, are included.
- The fuel rods are modeled assuming a stack density of 96.5% theoretical density with no allowance for dishing or chamfer in the fuel rod model, which conservatively bounds the total fuel content in the FA authorized for storage.
- Only one section of height (12 in.) equal to one egg-crate section of the basket is modeled with periodic boundary conditions at the axial boundaries (top and bottom) and reflective boundary conditions at the radial boundaries (sides) to represent infinite long FAs and infinite arrays of package.
- For intact fuel, the pins are modeled assuming the maximum lattice average enrichment uniformily everywhere in the lattice. Natural uranium blankets, gadolinia, integral fuel burnable absorber, erbia, or any other burnable absorber rods and axial or radial enrichment zones are modeled as uranium with the maximum lattice average enrichment.
- Water density is at optimum internal, gap, and external moderator density.

6.8.1.2.2 Material Properties

The materials modeled are listed in Table 6.8.1-4 and Table 6.8.1-5.

There are three basket types specified for the EOS-89BTH DSC. The EOS-89BTH DSC criticality safety is ensured by fixed neutron absorbers and favorable geometry. The baskets manufactured with MMC are designated M1-A and M1-B, while the baskets manufactured with BORAL® plates are designated M1-A, M1-B, and M2-A, as shown in Table 6.8.1-1. In criticality evaluations, credit is taken only for 90% of B-10 areal density in the MMC and 75% in the BORAL® poison plates.

6.8.1.2.3 Computer Codes and Cross-Section Libraries

The criticality safety analysis of the EOS-89BTH system used the CSAS5 module of the SCALE 6.0 system of codes [3]. The CSAS5 control module allows simplified data input to the functional modules BONAMI, NITAWL, and KENO V.a. These modules process the required cross section data and calculate the k_{eff} of the system. BONAMI performs resonance self-shielding calculations for nuclides that have Bondarenko data associated with their cross sections. NITAWL applies a Nordheim resonance self-shielding correction to nuclides having resonance parameters. Finally, KENO V.a calculates the effective neutron multiplication factor (k_{eff}) of a three-dimensional system.

The DSC and TC were explicitly modeled using the appropriate geometry options in KENO V.a of the CSAS5 module in SCALE 6.0 [3]. The Oak Ridge National Laboratory (ORNL) SCALE 6.0 code package [3] contains a standard material data library for common elements, compounds, and mixtures. All the materials used for the cask and canister analysis are available in this data library.

The CSAS5 control module of SCALE 6.0 [3] is used to calculate the effective multiplication factor (k_{eff}) of the fuel in the DSC and TC. The CSAS5 control module allows simplified data input to the functional modules BONAMI, NITAWL, and KENO V.a. These modules process the required cross sections and calculate the k_{eff} of the system. The BONAMI module performs resonance self-shielding calculations for nuclides that have Bondarenko data associated with their cross sections. The NITAWL module applies Nordheim resonance self-shielding correction to nuclides having resonance parameters. Finally, the KENO V.a sequence calculates the k_{eff} of a three dimensional system. Enough neutron histories are run so that the standard deviation is below 0.0010 for all calculations.

Table 6.8.1-4 and Table 6.8.1-5 list the pertinent data for criticality analysis for all authorized fuel assembly types in the EOS-89BTH as transported in the TN Eagle cask.

The criticality analysis used the 44-group cross-section library built into the SCALE system. ORNL used ENDF/B-V data to develop this broad-group library specifically for criticality analysis of a wide variety of thermal systems.

6.8.1.2.4 Demonstration of Maximum Reactivity

The criticality evaluation is based on the criticality evaluation performed for the EOS-89BTH DSC in the EOS-TC in Chapter 7 of [2]. In Chapter 7 of [2], the most reactive configuration (MRC) and boron loading – enrichment combinations were determined for BWR fuel assemblies in the EOS-89BTH DSC for normal, off-normal, and accident conditions of loading, transfer, and storage. Here, criticality analysis is performed on the EOS-89BTH DSC in its MRC, and housing the most reactive fuels (MRFs), within the TN Eagle cask to determine if the results of the aforementioned criticality analysis will bound the EOS-89BTH DSC in the TN Eagle cask for normal, off-normal, and accident conditions of loading, transfer, and storage. A few other representative configurations are also included in the analysis.

The Monte Carlo calculations performed with CSAS5 (KENO V.a) use a flat neutron starting distribution. The total number of histories traced for each calculation is at least 1,000,000. This minimum number of histories is sufficient to achieve source convergence and produce standard deviations of less than 0.0010. The maximum k_{eff} for the calculation is determined with the following formula:

$$k_{eff} = k_{KENO} + 2\sigma_{KENO}$$

6.8.1.2.4.1 Determination of MRC

[ ]

[ ]

6.8.1.2.4.2 Determination of the Maximum Initial Enrichment for BWR Fuel Assemblies

From Section 7.4.4 of [2], the design basis KENO model with the GNF-2 fuel assembly design was used to determine the maximum allowable initial enrichment for the three allowable fixed poison loadings. Additionally, separate enrichment limits were determined for the ABB-10-C type BWR fuel assemblies. These representative cases from Section 7.4.4 of [2] were re-run after replacing the EOS-TC with the TN Eagle cask to demonstrate that the results from Section 7.4.4 of [2] bound the EOS-89BTH system with the TN Eagle cask, as shown in Table 6.8.1-11. The representative cases are modified according to the MRC with respect to moderator densities determined earlier.

6.8.1.2.5 Criticality Results

The upper subcriticality limit (USL) determined for BWR fresh fuel critical experiments is 0.9418.

[ ]

The criterion for sub-criticality is that

$$k_{KENO} + 2\sigma_{KENO} < USL.$$

From Table 6.8.1-11, for the most reactive case with the TN Eagle cask,

$$k_{KENO} + 2\sigma_{KENO} = 0.9341 + 2\ (0.0009) = 0.9359 < 0.9418.$$

6.8.1.3 Single Package Evaluation

6.8.1.4 Evaluation of Package Arrays under Normal Conditions of Transport

6.8.1.5 Package Arrays under Hypothetical Accident Conditions

6.8.1.5.1 Configuration

6.8.1.5.2 Results

The EOS-89BTH DSC in the TN Eagle cask is shown to be subcritical for an infinite array of infinitely long flooded undamaged casks after being subjected to hypothetical accident conditions. Since “N” is equal to ∞, as required by 10 CFR Part 71.59(a)(2), two times “N,” or an infinite array of packages, is shown to be subcritical with the fissile material in its MRC, optimum water moderation, and close full water reflection consistent with its damaged condition. A CSI of 0 (less than 50) ensures that, per 10 CFR Part 71.59(b)(1), the package may be shipped by a carrier in a nonexclusive conveyance from criticality safety point of view.

6.8.1.6 Fissile Material Packages for Air Transport

Not applicable. No air transport of TN Eagle is allowed.

6.8.1.7 Benchmark Evaluation

6.8.1.7.1 Applicability of Benchmark Experiments

Proprietary Information on This Page
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The area of applicability is evaluated by comparing the parameter values with the calculation model specifications. The range of parameters values are tabulated in Table 6.8.1-7a for the critical experiments selected for fresh fuel analysis. The fuel pitch values are 1.295 cm (GNF2 assembly), 1.30048 cm (KK11 and Optima2-v1 assembly) cm whereas the range of fuel pitch values selected for fresh fuel analysis is 1.30 cm to 2.54 cm. The fuel rod radii are 0.4445 cm (GNF2 assembly), 0.42545 cm (KK11), and 0.42418 cm (Optima2-v1 assembly) whereas the range of fuel rod radius selected for fresh fuel analysis is 0.395 cm to 0.633 cm. The assembly separation ranges from 2.34363 cm (GNF2 assembly), 2.31623 cm (KK11 and Optima2-v1 assembly) whereas the range of assembly separation values selected for fresh fuel analysis is 2.690 cm to 15.393 cm. the fuel enrichment analyzed in the calculation ranges from 4.10 wt. % U-235 to 4.80 wt. % U-235; whereas the range of fuel enrichment selected for fresh fuel analysis is 2.35 wt. % U-235 to 4.74 wt. % U-235. The values of hydrogen to fissile density ratio, moderator to fuel ratio, AEG and EALF vary depending on the fuel enrichment specification in the calculation.

Though the parameters fall slightly outside of the range, the USL calculated from these critical experiments are applicable since these experiments are suggested by NRC in Ref. [6].

Trending analysis is performed to determine the effectiveness of each parameter in explaining variations in calculated k_{eff} values. The correlation coefficient |r| provides a measure of statistical correlation between each parameter and variations in the calculated k_{eff} values. A correlation value of |r| = 0 implies no correlation, and a value of |r| = 1 implies strong correlation.

[ ]

6.8.1.7.2 Bias Determiniation

The results in Table 6.8.1-8 indicate that there is little correlation. The k_{eff} values are normally distributed and, therefore, a single-sided lower tolerance limit USL is computed according to the methodology described in [5].

According to [5], the USL is obtained by computing a single-sided tolerance lower limit above which a defined fraction of the true population (95%) of k_{eff} is expected to lie, with a prescribed confidence (95%) and within the area of applicability (a tolerance band), when a relationship between a calculated k_{eff} and independent variable can be determined, or nonparametric statistical treatment when the data do not follow a normal distribution. The independent parameters utilized for the tolerance band method are EALF, fuel pitch, assembly separation, U-235 enrichment, and moderator-to-fuel volume ratio. It is demonstrated in this calculation that a relationship or correlation does not exist between calculated k_{eff} and the independent parameters. The k_{eff} values are normally distributed, however, and therefore it is possible to obtain a single-sided lower tolerance limit as a USL.

According to [5], the single-sided lower tolerance limit is defined by:

$$\mathrm{K_L} = \overline{\mathrm{k}}_{\mathrm{eff}} - \mathrm{US_p}$$

If $\overline{\mathrm{k}}_{\mathrm{eff}} \geq 1$, then $\mathrm{K_L} = 1 - \mathrm{US_p}$

Where:

S_p = square root of pooled variance
U = one-sided lower tolerance factor. This value is dependent on number of data points; for greater than 50 data points, Table 2.1 in Ref. [5] indicates a value of 2.065.

Then:

$$\mathrm{USL} = \mathrm{K_L} - \Delta_{\mathrm{SM}} - \Delta_{\mathrm{AOA}}$$

Δ_{SM} = Administrative margin
Δ_{AOA} = Margin added for extending the area of applicability of experiments and is zero as it applies to the system application herein.

The weighted mean k_{eff} value is calculated as:

$$\overline{\mathrm{k}}_{\mathrm{eff}} = \frac{\sum \frac{1}{\sigma_i^2} \mathrm{k}_{\mathrm{eff}_i}}{\sum \frac{1}{\sigma_i^2}}$$

Where:

$\mathrm{k}_{\mathrm{eff}_i}$ and σ_i are the i[th] calculated $\mathrm{k}_{\mathrm{eff}}$ and associated uncertainty.

The square root of the pooled variance is:

$$\mathrm{S_P} = \sqrt{s^2 - \overline{\sigma}^2}$$

The average total uncertainty $\overline{\sigma}^2$ for the given uncertainties is calculated as:

$$\overline{\sigma}^2 = \frac{n}{\sum \frac{1}{\sigma_i^2}}$$

Note that similar to the methodology in [5], experimental uncertainty is assumed to be zero.

The variance about the mean is computed as:

$$\mathrm{S}^2 = \frac{\frac{1}{n-1} \sum \frac{1}{\sigma_i^2} (\mathrm{k}_{\mathrm{eff}_i} - \overline{\mathrm{k}}_{\mathrm{eff}})^2}{\frac{1}{n} \sum \frac{1}{\sigma_i^2}}$$

The USL thus calculated using the equations above is presented in Table 6.8.1-9.

The USL determined for BWR fresh fuel critical experiments is 0.9418.

6.8.1.8 References

1. 10 CFR 71, Packaging and Transportation of Radioactive Materials.

2. TN Americas LLC, NUHOMS® EOS System Updated Final Safety Analysis Report, Docket Number 72-1042, Revision 3.

3. Oak Ridge National Laboratory, RSIC Computer Code Collection, “SCALE: A Modular Code System for Performing Standardized Computer Analysis for Licensing Evaluations for Workstations and Personal Computers,” NUREG/CR-0200, Revision 6, ORNL/NUREG/CSD-2/V2/R6.

4. International Handbook of Evaluated Criticality Safety Benchmark Experiments (IHECSBE), NEA-1486/15, NEA Nuclear Science Committee, September 2016.

5. US NRC, NUREG/CR-6698, “Guide for Validation of Nuclear Criticality Safety Calculational Methodology”, January 2001.

6. J.M. Scaglione, D.E. Mueller, J.C. Wagner, W.J. Marshall, “An Approach for Validating Actinide and Fission Product Burnup Credit Criticality Safety Analyses-Criticality Predictions,” NUREG/CR 7109, April 2012.

Table 6.8.1-1
EOS-89BTH Minimum B-10 Content in the Neutron Poison Plates

Basket Type	B-10 Content Used in Criticality Evaluation (mg/cm^2)	Minimum B-10 Areal Density (mg/cm^2)	
		MMC	BORAL®
M1-A	29.4	32.7	39.2
M1-B	37.2	41.3	49.6
M2-A	45.0	-	60.0

Proprietary Information on Pages 6.8.1-14 and 6.8.1-15
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Table 6.8.1-4
Material Property Data

Material	Density g/cm³	Element	Weight %	Atom Density (atom/b-cm)
UO_2 (Enrichment - 5.0 wt%, 96.5% of theoretical density)	10.5764	U-235	4.408	1.19431E-03
		U-238	83.742	2.24053E-02
		O	11.850	4.71992E-02
Zircaloy-2	6.56	Zr	98.250	4.25479E-02
		Sn	1.450	4.82542E-04
		Fe	0.135	9.55002E-05
		Cr	0.100	7.59773E-05
		Ni	0.055	3.70193E-05
		Hf	0.010	2.21330E-06
Water	0.9982	H	11.1	6.67531E-02
		O	88.9	3.33765E-02
Carbon Steel	7.8212	Fe	99.0	8.34978E-02
		C	1.0	3.92153E-03
Stainless Steel (SS304)	7.94	C	0.080	3.18488E-04
		Si	1.000	1.70251E-03
		P	0.045	6.94688E-05
		Cr	19.000	1.74726E-02
		Mn	2.000	1.74072E-03
		Fe	68.375	5.85446E-02
		Ni	9.500	7.74021E-03

Table 6.8.1-5
Poison Material Property Data

Table 6.8.1-6
Comparison of Materials used in Design Calculation and Benchmark Models

	System Application	**Benchmark KENO V.a Models**
Tank/Canister	Carbon steel	none
Support structures	6061-aluminum plates Stainless steel Concrete Poison plates in aluminium matrix	6061-aluminum plates 1100-aluminum plates 5052-aluminum plates D16-aluminum alloy plates Acrylic support plates Lucite plates
Fuel	UO_2	UO_2
Clad	Stainless steel Zircaloy-4 Zircaloy-2	Stainless steel Zircaloy-4 Zircaloy-2 6061-aluminum
Moderator	Pure water Water with soluble boron	Pure water Water with soluble boron
Reflecting material	Water Steel	Water Lead Steel Depleted uranium

Table 6.8.1-7
Benchmark Experimental KENO V.a Simulation Results
(2 Pages)

Experiment Name	Enrichment (wt. % U-235)	Pitch (cm)	Assembly Separation (cm)	Soluble Boron (ppm)	Mod./Fuel Ratio	AEG	EALF (eV)	k_{eff}	σ
LCT-001-001	2.35	2.032	-	0	2.918	36.24	9.64E-02	0.9954	0.0009
LCT-001-002	2.35	2.032	11.92	0	2.918	36.26	9.56E-02	0.9951	0.0009
LCT-001-003	2.35	2.032	8.41	0	2.918	36.29	9.46E-02	0.9955	0.0009
LCT-001-004	2.35	2.032	10.05	0	2.918	36.27	9.53E-02	0.9946	0.0009
LCT-001-005	2.35	2.032	6.39	0	2.918	36.31	9.40E-00	0.9932	0.0009
LCT-001-006	2.35	2.032	8.01	0	2.918	36.27	9.53E-02	0.9955	0.0009
LCT-001-007	2.35	2.032	4.46	0	2.918	36.32	9.35E-02	0.9935	0.0008
LCT-001-008	2.35	2.032	7.57	0	2.918	36.30	9.42E-02	0.9926	0.0008
LCT-002-001	4.31	2.54	-	0	3.882	35.74	1.14E-01	0.9948	0.0010
LCT-002-002	4.31	2.54	-	0	3.882	35.74	1.14E-01	0.9977	0.0009
LCT-002-003	4.31	2.54	-	0	3.882	35.74	1.14E-01	0.9975	0.0009
LCT-002-004	4.31	2.54	10.62	0	3.882	35.77	1.13E-01	0.9969	0.0010
LCT-002-005	4.31	2.54	7.11	0	3.882	35.77	1.13E-01	0.9969	0.0010
LCT-010-005	4.31	2.54	14.26	0	3.882	33.42	3.90E-01	0.9988	0.0011
LCT-010-016	4.31	1.892	15.39	0	1.597	33.39	2.94E-01	1.0005	0.0009
LCT-010-017	4.31	1.892	15.36	0	1.597	33.46	2.87E-01	0.9999	0.0009
LCT-010-018	4.31	1.892	14.97	0	1.597	33.50	2.83E-01	0.9986	0.0009
LCT-010-019	4.31	1.892	13.34	0	1.597	33.58	2.76E-01	0.9983	0.0010
LCT-017-003	2.35	2.032	10.51	0	2.918	36.29	9.46E-02	0.9985	0.0008
LCT-017-004	2.35	2.032	11.09	0	2.918	34.74	2.13E-01	0.9947	0.0009
LCT-017-005	2.35	2.032	13.19	0	2.918	35.01	1.86E-01	0.9975	0.0009
LCT-017-006	2.35	2.032	13.37	0	2.918	35.15	1.74E-01	0.9989	0.0007
LCT-017-007	2.35	2.032	12.96	0	2.918	35.24	1.66E-01	0.9977	0.0008
LCT-017-008	2.35	2.032	9.95	0	2.918	35.62	1.36E-01	0.9938	0.0010
LCT-017-009	2.35	2.032	7.82	0	2.918	36.02	1.10E-01	0.9945	0.0008
LCT-017-010	2.35	2.032	9.89	0	2.918	36.15	9.93E-02	0.9996	0.0009
LCT-017-011	2.35	2.032	10.44	0	2.918	36.20	9.75E-02	0.9994	0.0009

Table 6.8.1-7
Benchmark Experimental KENO V.a Simulation Results
(2 Pages)

Experiment Name	Enrichment (wt. % U-235)	Pitch (cm)	Assembly Separation (cm)	Soluble Boron (ppm)	Mod./Fuel Ratio	AEG	EALF (eV)	k_{eff}	σ
LCT-017-012	2.35	2.032	10.44	0	2.918	36.23	9.63E-02	0.9976	0.0008
LCT-017-013	2.35	2.032	9.6	0	2.918	36.28	9.48E-02	0.9964	0.0008
LCT-017-014	2.35	2.032	8.75	0	2.918	36.29	9.43E-02	0.9959	0.0008
LCT-017-015	2.35	1.684	8.57	0	1.600	34.74	1.79E-01	0.9962	0.0010
LCT-017-016	2.35	1.684	9.17	0	1.600	34.82	1.74E-01	0.9974	0.0009
LCT-017-017	2.35	1.684	9.1	0	1.600	34.89	1.69E-01	0.9983	0.0008
LCT-017-019	2.35	1.684	8.87	0	1.600	34.97	1.64E-01	0.9960	0.0009
LCT-017-020	2.35	1.684	8.65	0	1.600	35.00	1.63E-01	0.9933	0.0010
LCT-017-021	2.35	1.684	8.13	0	1.600	35.03	1.61E-01	0.9939	0.0008
LCT-017-022	2.35	1.684	7.26	0	1.600	35.05	1.60E-01	0.9932	0.0009
LCT-017-023	2.35	1.684	9.65	0	1.600	34.85	1.72E-01	0.9998	0.0009
LCT-017-024	2.35	1.684	9.7	0	1.600	34.93	1.67E-01	0.9977	0.0009
LCT-017-025	2.35	1.684	8.09	0	1.600	35.06	1.59E-01	0.9936	0.0009
LCT-017-028	2.35	1.684	7.65	0	1.600	33.88	3.02E-01	0.9953	0.0008
LCT-017-029	2.35	1.684	9.09	0	1.600	34.16	2.62E-01	0.9963	0.0010
LCT-042-001	2.35	1.684	8.28	0	1.600	34.86	1.72E-01	0.9965	0.0008
LCT-042-002	2.35	1.684	4.8	0	1.600	34.76	1.78E-01	0.9965	0.0009
LCT-042-003	2.35	1.684	2.69	0	1.600	34.68	1.85E-01	0.9962	0.0009
LCT-042-004	2.35	1.684	2.98	0	1.600	34.69	1.83E-01	0.9980	0.0009
LCT-042-005	2.35	1.684	3.86	0	1.600	34.74	1.79E-01	0.9975	0.0008
LCT-042-006	2.35	1.684	7.79	0	1.600	34.84	1.72E-01	0.9975	0.0009
LCT-042-007	2.35	1.684	5.43	0	1.600	34.78	1.77E-01	0.9966	0.0008
LCT-050-001	4.738	1.3	-	0	2.032	34.24	2.04E-01	0.9964	0.0010
LCT-050-002	4.738	1.3	-	0	2.032	34.35	1.95E-01	0.9939	0.0010

Table 6.8.1-7a
Benchmark Experiments – Range of Applicability

Parameter	Range of Applicability for Fresh Fuel Assumptions	EOS-89BTH Parameters
Fuel Enrichment (wt.%U-235)	2.35 – 4.74	4.10 – 4.80
Fuel Rod Radius (cm)	0.395 – 0.633	0.42418 – 0.4445
Fuel Pitch (cm)	1.30 – 2.54	1.295 - 1.30048
Assembly Separation (cm)	2.690 – 15.393	2.31623 - 2.34363
AEG	33.39 – 36.32	(1)
EALF (eV)	0.09 – 0.39	(1)
Hydrogen to Fissile Density Ratio (H/X)	49.47 – 455.58	(1)
Moderator to Fuel Ratio	1.60 – 3.88	(1)

1. Values varies depending on the fuel enrichment specification

Table 6.8.1-8
Correlation Coefficients |r| for Independent Parameters

Parameter	EOS-89BTH
U-235 Enrichment	0.317
Pitch (cm)	0.1241
Moderator to Fuel Volume Ratio	0.0510
AEG	0.3876
EALF	0.3861
Assembly Separation (cm)	0.4843

Table 6.8.1-9
USL Determined using Computational Method for Critical Experiments with Fresh Fuel Assumptions

Parameter	Value (Intact Fuel)
n	51
Δ_{SM}	0.05
$\bar{\sigma}^2$	7.58E-07
$\bar{k}_{eff}$	0.99641
s^2	4.01E-06
S_P	2.20E-03
One sided tolerance (U)	2.065
U^*S_P	4.55E-03
USL	**0.94186**

Table 6.8.1-10
Most Reactive Configuration

Model Description	k_{KENO}	σ	k_{eff}
Internal Moderator Density (IMD)			
IMD = 1%	0.4330	0.0003	0.4337
IMD = 10%	0.4766	0.0004	0.4774
IMD = 20%	0.5380	0.0005	0.539
IMD = 30%	0.6100	0.0006	0.6113
IMD = 40%	0.6768	0.0007	0.6781
IMD = 50%	0.7375	0.0008	0.7391
IMD = 60%	0.7905	0.0008	0.7921
IMD = 70%	0.8351	0.0009	0.8368
IMD = 80%	0.8731	0.0008	0.8748
IMD = 90%	0.9051	0.0008	0.9067
IMD = 100%	**0.9357**	**0.001**	**0.9377**
DSC-TC Gap Moderator Density (GMD)			
GMD = 0% (Void)	0.9370	0.0008	0.9386
GMD = 1%	**0.9375**	**0.0008**	**0.9391**
GMD = 10%	0.9354	0.0009	0.9372
GMD = 20%	0.9364	0.0009	0.9382
GMD = 30%	0.9372	0.0008	0.9388
GMD = 40%	0.9361	0.0009	0.9379
GMD = 50%	0.9344	0.0008	0.936
GMD = 60%	0.9338	0.0009	0.9356
GMD = 70%	0.9360	0.0009	0.9378
GMD = 80%	0.9342	0.0008	0.9358
GMD = 90%	0.9348	0.0008	0.9364
GMD = 100%	0.9357	0.001	0.9377
External Moderator Density (EMD)			
EMD = 0% (Void)	0.9400	0.0009	0.9418
EMD = 1%	**0.9401**	**0.0009**	**0.9419**
EMD = 10%	0.9377	0.0010	0.9397
EMD = 20%	0.9373	0.0008	0.9389
EMD = 30%	0.9377	0.0008	0.9393
EMD = 40%	0.9355	0.0009	0.9373
EMD = 50%	0.9354	0.0009	0.9371
EMD = 60%	0.9372	0.0008	0.9389
EMD = 70%	0.9375	0.0009	0.9392
EMD = 80%	0.9388	0.0008	0.9404
EMD = 90%	0.9369	0.0008	0.9386
EMD = 100%	0.9375	0.0008	0.9391

Table 6.8.1-11
Determination of Minimum Poison Loading Requirement

Basket Type	Enrichment (wt% U-235)	B-10 content (mg/cm^2)	TN Eagle Results			EOS-TC Results			Difference: EOS TC – TN Eagle
			k_{KENO}	σ	k_{eff}	k_{KENO}	σ	k_{eff}	
MMC	4.10%	29.4	0.9285	0.0009	0.9304	0.9343	0.0008	0.9359	0.0056
	4.45%	37.2	0.9309	0.0008	0.9325	0.9369	0.0009	0.9387	0.0062
Boral	4.80%	45.0	0.9313	0.0008	0.9330	**0.9382**	**0.0008**	**0.9398**	**0.0069**
MMC	3.85%	29.4	0.9243	0.0008	0.9259	0.9253	0.0008	0.9269	0.0010
			0.9257	0.0008	0.9273	0.9271	0.0008	0.9287	0.0014
	4.25%	37.2	0.9306	0.0008	0.9321	0.9329	0.0009	0.9347	0.0025
			0.9314	0.0008	0.9330	0.9320	0.0008	0.9336	0.0006
Boral	4.55%	45.0	**0.9341**	**0.0009**	**0.9359**	0.9334	0.0009	0.9352	-0.0007
			0.9340	0.0008	0.9356	0.9347	0.0008	0.9363	0.0007

Table 6.8.1-12
EOS-89BTH Maximum Lattice Average Initial Enrichment

Basket Type	Maximum Lattice Average Initial Enrichment (wt.% U-235) [(1)]
M1-A	4.10
M1-B	4.45
M2-A	4.80

Note:
1. For ABB-10-C FAs, the enrichment shall be reduced by 0.25 wt. % U-235 for Type M1-A and M2-A and 0.20 wt. % U-235 for Type M1-B.

Proprietary Information on Pages 6.8.1-24 through 6.8.1-27
Withheld Pursuant to 10 CFR 2.390

Appendix 6.8.2
NUHOMS® EOS-37PTH DSC Criticality Evaluation

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LIST OF TABLES

LIST OF FIGURES

6.8.2 NUHOMS® EOS-37PTH DSC Criticality Evaluation

NOTE: References in this Appendix are shown as [1], [2], etc. and refer to the reference list in Section 6.8.2.5.

This Appendix 6.8.2 to Chapter 6 demonstrates that the TN Eagle Cask, when loaded with the NUHOMS® EOS-37PTH Dry Shielded Canister (DSC) payload, meets the criticality requirements specified in the Sections 71.55 and 71.59 of 10 CFR Part 71 [1]. This is done by ensuring that the effective multiplication factor (k_{eff}) of the most reactive configuration of the system stays below the Upper Subcritical Limit (USL). The USL includes a confidence band with an administrative safety margin of 0.05. The design has a Criticality Safety Index (CSI), given in 10 CFR 71.59(b) as CSI = 50/“N” of 0 because “N” is infinity (∞). The number “N” is based on all of the following conditions being satisfied, assuming packages are stacked together in any arrangement and with close full reflection on all sides of the stack by water:

1. Five times “N” undamaged packages with nothing between the packages are subcritical;
2. Two times “N” damaged packages, if each package is subjected to the tests specified in 10 CFR Part 71.73 (HAC) is subcritical with optimum interspersed hydrogenous moderation; and
3. The value of “N” cannot be less than 0.5.

Burnup credit is employed in the criticality analysis to demonstrate compliance with the sub-criticality requirements of 10 CFR 71.55 (b). The criticality analysis of the NUHOMS® EOS-37PTH DSC follows the burnup credit approach for pressurized water reactor (PWR) fuels described in ISG 08 [6] and incorporated in NUREG-2216 [7].

[

] These calculations are documented in Section 6.8.2.9.

6.8.2.1 Discussion and Results

The NUHOMS® EOS-37PTH DSC is designed to accommodate up to 37 PWR fuel assemblies (FAs). It consists of a shell assembly, and an internal basket assembly for housing the FAs. The basket is made up of interlocking slotted plates that form an egg-crate type structure. This structure is made up of steel plates, aluminum plates for heat transfer and a neutron poison plate for criticality control.

The basket uses Al-B_4C metal matrix composite (MMC) as its neutron poison material. This material is ideal for long-term use in radiation and thermal environments of a dry cask storage system. The minimum required boron-10 loading for Type A DSC is 0.028 g/cm^2 (90% credit is taken in the criticality analysis or 0.0252 g/cm^2) for MMC and for Type B DSC is 0.035 g/cm^2 (90% credit is taken in the criticality analysis or 0.0315 g/cm^2) for MMC.

The TN Eagle has a large inner diameter meant to accommodate larger diameter DSCs or bare fuel baskets. It consists of a thick carbon steel forged body, shrink fitted rings for gamma and neutron shielding, and the use of an improved neutron shielding resin material. It also includes dedicated aluminum honeycomb impact limiters. The radial cross section of the NUHOMS® EOS-37PTH DSC in the TN Eagle Cask is shown in Figure 6.8.2-1.

The NUHOMS® EOS-37PTH DSC in the TN Eagle Cask is shown to be subcritical for an infinite array of infinitely long undamaged casks after being subjected to hypothetical accident conditions. Since “N” is equal to ∞, as required by 10 CFR Part 71.59(a)(2), two times “N” or an infinite array of packages is shown to be subcritical with the fissile material in its most reactive configuration, and close full water reflection consistent with its damaged condition. A CSI of 0 (less than 50) ensures that, per 10 CFR Part 71.59 (b)(1).

Table 6.8.2-1 lists the FAs considered as authorized contents of the NUHOMS® EOS-37PTH DSC. The criticality analysis is performed using three bounding FA classes identified in Table 6.8.2-1. These are the Babcock & Wilcox (BW) 15x15, Westinghouse (WE) 17x17 and the WE 14x14 fuel classes. The results of the WE 17x17 fuel class bound those of the WE 15x15, Combustion Engineering (CE) 14x14, CE 16x16 and CE 15x15 fuel classes.

A maximum of four failed or eight damaged fuel assemblies are authorized to store along with intact FAs in the NUHOMS® EOS-37PTH DSC. Conservative approach is followed for damaged and failed fuel criticality analysis by having 12 failed FAs instead of eight damaged or four failed FAs. The damaged and failed fuel loading curve is developed by loading the EOS-37PTH DSC with 12 FAs in failed fuel configuration along with 25 intact FAs.

Criticality calculations are performed to determine the minimum assembly average burnup as a function of initial enrichment and cooling time for the three FA classes which are listed in Table 1.6.1-2 throughTable 1.6.1-7 for intact fuels and Table 1.6.1.8 through Table 1.6.1-13 for intact and failed fuels. The calculations determine k_{eff} with the CSAS5 control module of SCALE 6.1.3 [3] for each assembly class and initial enrichment, including all uncertainties to assure criticality safety under all credible conditions.

Control components (CCs) are also authorized for storage in the NUHOMS® EOS-37PTH DSC. The authorized CCs are burnable poison rod assemblies (BPRAs), control rod assemblies (CRAs), thimble plug assemblies (TPAs), axial power shaping rod assemblies (APSRAs), control element assemblies (CEAs), vibration suppressor inserts (VSIs), orifice rod assemblies (ORAs), neutron source assemblies (NSAs), and neutron sources.

The results of the evaluation demonstrate that the maximum k_{eff}, including statistical uncertainty, is less than the upper subcriticality limit (USL) determined from a statistical analysis of benchmark criticality experiments. The statistical analysis procedure includes a confidence band with an administrative safety margin of 0.05.

6.8.2.2 Package Fuel Loading

The NUHOMS® EOS-37PTH DSC is capable of storing and transporting a maximum of 37 intact PWR fuel assemblies (FAs). In addition, a maximum of eight damaged or four failed and remaining intact (for a total of 37) PWR FAs can also be transported within the NUHOMS® EOS-37PTH DSC. Reconstituted FAs with replacement rods that displace an equal amount of water as the original rods are also authorized for storage and are bounded by the intact fuel, for criticality purposes. A detailed listing of the contents of the NUHOMS® EOS-37PTH DSC is provided in Table 6.8.2-2.

For all the FA classes, CCs are also included as authorized contents. The only change to the package fuel loading to evaluate the addition of these CCs would be to replace the water in the guide tubes with $^{11}B_4C$. Since these CCs displace moderator in the assembly guide and or instrument tubes, an evaluation is not needed to determine the potential impact of storage of CCs that extend into the active fuel region on the system reactivity. The presence of these CCs such as CRAs, CEAs and BPRAs will results in a reduction in the reactivity of the FAs. CCs that do not extend into the active fuel region of the assembly do not have any effect on the reactivity of the system as evaluated because only the active fuel region is modeled in this evaluation with reflective boundary conditions making the model infinite in both the axial and radial directions. Additionally, the presence of non-multiplying sources like the NSAs has no impact on criticality calculations. Therefore, CCs are not included in any of the criticality models.

The criticality analysis is performed using three fuel assembly types, WE 14x14 STD, B&W 15x15 Mark B-10 and WE 17x17 Robust Fuel Assembly (RFA).

6.8.2.3 Model Specification

The evaluations are performed using SCALE 6.1.3 [3] and ENDF/B-VII nuclear data. The SCALE 6.1.3 capabilities used include automated sequences to produce problem-dependent multi-group cross-section data and analysis sequences for Monte Carlo neutron transport (CSAS5) and burnup-credit criticality safety (STARBUCS). The 238-group cross-section library based on the ENDF/B-VII nuclear data, 44-group cross section library based on the ENDF/B-V nuclear data and the resonance cross-section methodology employing CENTRM are used.

The STARBUCS sequence is used to determine U-235 wt. % enrichment values for various burnup and cooling times. STARBUCS enables modelling of the phenomena important to burnup credit and allows analysts to investigate the impact on criticality safety of various assumptions related to the burnup credit calculation methodology. The STARBUCS sequence provides a burnup credit loading curve search capability in addition to its initial capability of performing criticality safety analyses employing burnup credit. This capability may be used to determine the combination of assembly initial enrichment and discharge burnup values that result in a user-specified k_{eff} values. STARBUCS uses the ORIGEN-ARP method to rapidly generate fuel compositions as a function of fuel mixture initial enrichment, burnup and cooling time. ORIGEN-ARP libraries for the STARBUCS calculations are obtained by performing TRITON depletion calculations for the PWR assembly types used in the safety analysis models and for a range of fuel initial enrichment and assembly average burnup values.

The following subsections describe the physical models and materials of the NUHOMS® EOS-37PTH DSC within the TN Eagle Dual Purpose Cask used for the input to the STARBUCS or CSAS5 module of SCALE 6.1.3 [3] to perform the criticality evaluations.

6.8.2.3.1 Description of the Calculational Models

The NUHOMS® EOS-37PTH DSC and the TN Eagle are explicitly modeled using the appropriate geometry options in KENO V.a module in SCALE 6.1.3. The nominal dimensions of the EOS-37PTH DSC and the TN Eagle are summarized in Table 6.8.2-3. The materials used in the models are listed in Table 6.8.2-4 and Table 6.8.2-5.

In the STARBUCS model, the fuel pin is divided into 18 axial zones. The axial profiles differ for different burnup values, tabulated in Table 6.8.2-6. The STARBUCS built-in axial profiles are obtained from [3]. An additional set of 18-zone burnup profile for fuel burnup ≥ 38 GWd/MTU is used from [9]. Biases and biases uncertainties associated with minor actinides and fission products worth and isotopics validation from [7] are added to the calculated $k_{eff,}$ see Section 6.8.2.4.2.2. The USL is developed considering administrative margin of 5% and biases and biases uncertainties for major actinides, see Section 6.8.2.4.2.1.

Intact Fuel Assemblies

The FA types, WE 14x14 STD, B&W 15x15 Mark B-10 and WE 17x17 RFA, which are authorized to store in EOS-37PTH DSC are used in this evaluation. These are the most reactive fuel assembly types in fuel assembly classes determined in [2]. The fuel rods are filled with 100% density fresh water in the pellet-cladding gap with no soluble boron content. The most reactive intact fuel configuration determined in [2] along with the modifications to model the FA axial burnup distribution is utilized to develop the loading curves.

Failed Fuel Assemblies

A maximum of four failed or eight damaged FAs are authorized to store along with intact FAs in the EOS-37PTH DSC. The criticality analysis is performed with 12 failed and 25 intact FAs loaded in the DSC for the conservative purpose. The locations of the failed FAs are shown in Figure 6.8.2-5. The instrument and guide tubes are removed and empty spaces are filled with identical fuel rods to complete the fuel rods array. Sensitivity study is performed in this evaluation to determine the most reactive failed FA configuration. The sensitivity evaluations involve the study of effect of presence of Zircaloy-4 clad, fuel rod pitch variation and missing rods.

6.8.2.3.2 Package Regional Densities

The Oak Ridge National Laboratory (ORNL) SCALE 6.1.3 code package [3] contains a standard material data library for common elements, compounds, and mixtures. All the materials used for the cask and canister analyses are available in this data library. The DSC model does not include the top shell or closure lid, the bottom shell or the resin shielding rings. The gap between the casks contains unborated water. For the TC, the neutron skin and shield are assumed to have vanished under accident loading conditions.

A list of the relevant materials used for the criticality evaluation is provided in Table 6.8.2-4 and Table 6.8.2-5. The poison plate material specifications are modeled considering a 90% B-10 credit for the B-10 loading in the MMC.

6.8.2.4 Criticality Calculations

This section describes the models used for the criticality analysis. The analyses are performed with the STARBUCS and the CSAS5 modules of the SCALE 6.1.3 computer package [3]. The USL is calculated for the TN Eagle system based on the critical experiments benchmarked with fresh fuel and burnup credit assumptions in Section 6.8.2.5. The most reactive PWR fuels and most reactive EOS-37PTH DSC configuration determined in [5] is used.

6.8.2.4.1 Calculational Model

Criticality Calculations with Fresh Fuel

The fresh fuel criticality analysis is performed using the CSAS5 module of SCALE 6.1.3. The maximum allowable fresh fuel enrichment is determined for B&W 15x15, WE 14x14 and WE 17x17 fuel classes in intact and failed fuel configurations. The USL determined using fresh fuel assumptions in Section 6.8.2.4.2.1 is used.

Criticality Calculations with Burnup Credit

This section describes the analysis methodology utilized for the criticality analysis by taking credit for depletion of fissile material in FAs loaded in the EOS-37PTH DSC. The loading curves in terms of initial fuel enrichment as a function of average burnup and cooling times for B&W 15x15, WE 17x17 and WE 14x14 fuel classes intact and failed fuel are determined based on the most reactive assembly in the most reactive DSC configuration. The criticality model includes the full active fuel length of the FA for the purpose of burnup credit. The criticality safety analysis for the TN Eagle cask loaded with the EOS-37PTH DSC is performed with pure water flooding the entire cavity.

A total of 28 isotopes are included in the material description of the burned FA, which includes 12 actinides and 16 fission products, listed Table 6.8.2-7. Loading curves show the acceptable combinations of average burnup and initial fuel enrichment for any cooling period after fuel assembly discharge. The acceptable combinations of average burnups and initial fuel enrichments for intact and failed fuel are developed using the STARBUCS module with ORIGEN-ARP libraries generated using TRITON simulations. The ORIGEN-ARP libraries for B&W 15x15 Mark B-10, WE 14x14 STD and WE 17x17 RFA FAs are developed in Section 6.8.2.7, which are used in the STARBUCS models. The loading curves are developed for cooling periods of 5, 10, 15 and 20 years. The maximum initial fuel enrichment is determined for burnups 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55 and 60 GWd/MTU. For each assembly type, the averaged burnup value, and the initial enrichment value satisfying the USL and all applicable biases and bias uncertainties associated with burnup credit are determined. The USL and all applicable biases and bias uncertainties are discussed in Section 6.8.2.4.2.1 and Section 6.8.2.4.2.2.

The failed fuel loading curve is developed for EOS-37PTH DSC loaded with 12 FAs in failed fuel configuration along with 25 intact FAs. The locations of the failed FAs are shown in Figure 6.8.2-5. CSAS5 module of SCALE 6.1.3 computer software is used for failed fuel criticality analysis. The material composition of discharged intact and failed fuel for specific burnup for failed fuel criticality analysis is obtained from STARBUCS simulations. A sensitivity study is performed to determine the most reactive failed fuel rod configuration and failed FA configuration. The upper limit for the maximum enrichment value for the failed fuel is the maximum enrichment value determined for the corresponding intact fuel.

Computer Codes

The evaluations are performed using SCALE 6.1.3 [3] and the ENDF/B-VII nuclear data. The burnup credit criticality analysis for intact fuel is performed using the STARBUCS module, the burnup credit criticality analysis for failed fuel is performed using CSAS5 module (material composition using STARBUCS) and the fresh fuel criticality analysis is performed using CSAS5 control module of SCALE 6.1.3 [3].

The STARBUCS sequence provides a burnup credit loading curve search capability in addition to its initial capability of performing criticality safety analysis employing burnup credit. STARBUCS uses ORIGEN-ARP sequence to deplete the FA with given irradiation history and assigned ORIGEN-ARP libraries. The spent fuel compositions obtained after depletions are applied in the given KENO V.a models for criticality safety calculations.

The CSAS5 control module is used to calculate the effective neutron multiplication factor (k_{eff}) of the fuel in the TN Eagle cask. The CSAS5 control module allows simplified data input to the functional modules BONAMI, CENTRM and KENO V.a. These modules process the required cross sections and calculate the k_{eff} of the system. BONAMI performs resonance self-shielding calculations for nuclides that have Bondarenko data associated with their cross sections. CENTRM provides the neutron spectra for processing self-shielded multigroup cross sections. Finally, KENO V.a calculates the k_{eff} of a three-dimensional system. A sufficiently large number of neutron histories are run so that the standard deviation is below 0.0005 for all evaluations.

Physical and Nuclear Data

The criticality analysis uses the 238 group ENDF/B-VII cross-section library and 44-group ENDF/B-V cross-section library. The material definitions for fuel, cladding, EOS-37PTH DSC and TN Eagle cask structural material are available in the SCALE 6.1.3, [3], standard composition library. Details of materials of fuel and component design are included in Table 6.8.2-4 and Table 6.8.2-5. The EOS-37PTH DSC basket aluminum and stainless steel alloy types differ from the model where the aluminum and stainless steel definitions from standard composition library are used. From a criticality stand point these differences are not important.

Bases and Assumptions

The analytical results reported in Chapter 2 demonstrate that the cask containment boundary and canister structure do not experience any significant distortion under hypothetical accident conditions. The FA drop analyses documented in Chapter 2, also demonstrate that the fuel rods do not experience enough deformation to cause a change in the fuel geometry. Therefore, for both normal and hypothetical accident conditions the TN Eagle cask geometry is identical except for the neutron shield. The neutron shield is conservatively removed and the interstitial space modeled as water. Therefore, the deformation does not result in a more reactive configuration of the FAs modeled in the KENO models.

To demonstrate compliance with the requirements specified in Section 71.55 (b) of 10 CFR Part 71, the FAs are modelled in the appropriate conditions (moderation and configurations) for intact and failed fuels as detailed in Section 6.8.2.4.2.3. The HAC and NCT analyses for compliance with the requirements specified in Section 71.55 (e) and (d) of 10 CFR Part 71 are documented in Section 6.8.2.9.

The following assumptions are employed in the criticality calculations:

A. The entire model is assigned a temperature of 293 K.

B. Omission of grid plates, spacers and hardware in the FA.

C. No credit is taken for burnable absorbers.

D. The fuel pins are modelled assuming 18 axial burnup zones.

E. All fuel rods are assumed to be filled with 100% pure water in the fuel/cladding gap to account for the possibility of water being entrained in the fuel pin and because it has a slight positive effect on reactivity.

F. Internal and external moderator at full water density.

G. Only the active fuel length of each assembly type is explicitly modelled. The presence of the plenum, end fittings, channels above and below the active fuel reduce the k_{eff} of the system; therefore; these regions are modelled as water or the reflective boundary conditions. For the cases with reflective boundary condition, the model is effectively infinitely long.

H. The neutron shield of the cask is conservatively removed and infinite arrays of the casks are pushed close together with external moderator (unborated water) in the interstitial spaces.

I. All steel and aluminium alloys of the basket structure are modelled as SS304 and aluminium, respectively. While these compositions, which are provided in the SCALE 6.1.3 standard composition library, have small differences with compositions of the various steels and aluminium, they have negligible effect on the results of the calculation.

J. All zirconium-based materials in the fuel are modelled as Zircaloy-4. The small differences in the composition of the various clad/guide compartment materials have negligible effect on the results of the calculations.

K. The fuel rods are modelled assuming a stack density of 97.5% theoretical density with no allowance for dishing or chamfer in the fuel rod model, which conservatively bounds the total fuel content in the FA authorized for storage.

L. Impact limiters on the cask ends are not included because they have negligible effect on the k_{eff} of the system.

In addition, the assumptions that are relevant to the failed fuel analysis part of this evaluation are as follows:

A. The cask containment boundary does not experience any significant distortion under hypothetical accident conditions.

B. Fuel rods are filled with full density fresh water in the pellet-cladding gap when the cladding is considered. The Zircaloy-4 clad is replaced with fresh water when the clad is removed.

C. The instrument and guide tubes are removed and empty spaces are housed with identical fuel rods to complete the fuel rods array.

D. A maximum of four failed or eight damaged FAs are authorized to store along with intact FAs in the EOS-37PTH DSC. The criticality analysis is performed with 12 failed and 25 intact FAs loaded in the DSC for the conservative purpose.

Determination of k_{eff}

The criticality calculations are performed with STARBUCS and CSAS5 modules in SCALE 6.1.3. The Monte Carlo calculations performed use a flat neutron starting distribution. The total number of histories traced for each calculation is at least 1,000,000. This number of histories is sufficient to achieve source convergence and produce standard deviations of less than 0.0005. The maximum k_{eff} for the calculation is determined with the following formula:

$$k_{eff} = k_{KENO} + 2\sigma_{KENO}$$

6.8.2.4.2 Fuel Loading Optimization

6.8.2.4.2.1 Calculation of USL

A detailed description of the SCALE 6.1.3 criticality code benchmarking using criticality experiments for fresh fuel assumption and burnup credit analysis is provided in Section 6.8.2.5. [

]

[ ]

For burnup credit, the criticality analysis relies on 28 actinides and fission products listed in Table 6A-1, for major actinides, and Table 6A-2, for minor actinides and fission products, of [7] and reproduced as Table 6.8.2-7.

[ ]

According to [5], the Upper Subcriticality Limit (USL) is obtained by computing a single-sided tolerance lower limit above which a defined fraction of the true population (95%) of k_{eff} is expected to lie, with a prescribed confidence (95%) and within the area of applicability (a tolerance band), when a relationship between a calculated k_{eff} and independent variable can be determined, or nonparametric statistical treatment when the data do not follow a normal distribution. The independent parameters utilized for the tolerance band method are energy of average lethargy of fission (EALF), average fission energy group (AEG), fuel pitch, assembly separation, U-235 enrichment, moderator-to-fuel volume ratio, hydrogen to fissile ratio and plutonium content (Pu/U+Pu). The k_{eff} values of the criticality experiments are examined to determine correlation against the independent parameters in Section 6.8.2.5. The results in Section 6.8.2.5 indicate that there is little correlation. The k_{eff} values are normally distributed and therefore, a single-sided lower tolerance limit USL is computed according to the methodology described in [5].

According to [5], the USL is defined by:

$$USL = K_L - \Delta_{SM} - \Delta_{AOA}$$

Δ_{SM} is an administrative margin,

Δ_{AOA} is a margin added for extending the area of applicability of experiments and is zero as it applies to the system application, herein.

K_L is the single-sided lower tolerance limit, defined as:

$$K_L = \overline{k_{KENO}} - US_P$$

$$\text{If } \overline{\mathrm{k_{KENO}}} \geq 1, \text{then } \mathrm{K_L} = 1 - \mathrm{US_P}$$

Where, $\overline{\mathrm{k_{KENO}}}$ = weighted mean k_{KENO} value determined by,

$$\overline{k_{KENO}} = \frac{\sum \frac{1}{\sigma_i^2} k_{KENOi}}{\sum \frac{1}{\sigma_i^2}}$$

Where, k_{KENO} is the criticality value resulted from the KENO simulation and σ is the standard deviation value associated with k_{KENO},

U is the single-sided lower tolerance factor, 2.065 for n=50 [5], used for conservativeness,

S_P is the square root of pooled variance defined by,

$$S_P = \sqrt{S^2 + \bar{\sigma}^2}$$

The variance about the mean, S^2 is computed as:

$$S^2 = \frac{\frac{1}{n-1}\sum\frac{1}{\sigma_i^2}\left(k_{KENO_i} - \overline{k_{KENO}}\right)^2}{\frac{1}{n}\sum\frac{1}{\sigma_i^2}}$$

The average total uncertainty, $\bar{\sigma}^2$ for the given uncertainties is computed as:

$$\bar{\sigma}^2 = \frac{n}{\sum\frac{1}{\sigma_i^2}}$$

The USL with fresh fuel assumptions thus calculated using the methodology described in [5] is presented in Table 6.8.2-9. The USL with fresh fuel assumptions is 0.94173.

For the burnup credit criticality analysis, the USL is evaluated considering bias due to major actinides.

$$USL = k_{limit} - \left(\beta + \Delta k_{\beta}\right) - \Delta km$$

(β+ Δk_{β}) = Code bias and bias uncertainty due to major actinides calculated from benchmark criticality experiments.

Δk_m = administrative margin = 0.05.

The USL for burnup credit analysis is presented in Table 6.8.2-8. The USL for burnup credit analysis is 0.94236.

6.8.2.4.2.2 Biases and Biases Uncertainties for Burnup Credit Analysis

Additional bias and bias uncertainty due to minor actinide and fission products associated with the code validation for k_{eff} determination and bias and bias uncertainty associated to the code validation for isotopic depletion should be addressed and added to the calculated package k_{eff}.

Section 6.4.7.4 of [7] regarding minor actinide and fission product states that it is acceptable to credit the minor actinide and fission product nuclides listed in Table 6-2 of [7] provided that the bias and bias uncertainty associated with the major actinides is determined as performed in Section 6.8.2.4.2.1. Further, the bias from these minor actinides and fission products is conservatively covered by 1.5 percent of the minor actinides and fission products worth provided per Table 6.6 of [7]:

- SCALE code package with ENDF/B-VII cross-section library are used,
- The similarity between the current design and the virtual GBC-32 cask is shown
- and the credited minor actinide and fission product worth is < 0.1 in k_{eff} are shown – Table 6.6 of [7]

No additional uncertainty in the bias is needed. The bias due to minor actinide and fission products (Δk_x) is to be added to the calculated package k_{eff} ($k_{KENO} + 2\sigma_{KENO}$).

The minor actinide and fission product worth is shown in Section 6.8.2.5.6.

Section 6.4.7.3 of [7] regarding the code validation for isotopic depletion states that, instead of an explicit benchmarking analysis, it is acceptable to use the bias (βi) and bias uncertainty (Δki) values shown in Tables 6-3 of [7] provided:

- SCALE/TRITON and ENDF/B-VII cross-section library are used,
- And the similarity between the current design and the virtual GBC-32 cask is shown.

The burnup-dependent bias and bias uncertainty due to isotopic depletion code validation is to be added to the calculated package k_{eff} ($k_{KENO} + 2\sigma_{KENO}$). The similarity between the current design and the virtual GBC-32 cask is shown in Section 6.8.2.7.

In summary, for burnup credit analysis, the criterion for subcriticality is that:

$$k_{eff} + (\beta_i + \Delta k_i) + \Delta k_x < USL$$

$$k_{KENO} + 2\sigma_{KENO} + (\beta_i + \Delta k_i) + \Delta k_x < k_{limit} - (\beta + \Delta k_\beta) - \Delta km$$

6.8.2.4.2.3 Determination of the Most Reactive Failed Fuel Configuration

6.8.2.4.2.4 Determination of Maximum Initial Enrichment for each Fuel

The most reactive EOS-37PTH DSC configuration and most reactive FA type for each fuel assembly class is determined in [2]. In this evaluation, the maximum initial enrichment as a function of discharge burnup is evaluated for the B&W 15x15 Mark B-10, WE 14x14 STD and WE 17x17 RFA FAs loaded in the EOS-37PTH DSC in TN Eagle Cask. The STARBUCS control module of SCALE 6.1.3 [3] is used to perform the burnup credit criticality analysis for the EOS-37PTH DSC loaded with intact FAs. The fresh fuel criticality analysis and the burnup credit analysis for failed fuel are performed using CSAS5 control module of SCALE 6.1.3 [3]. The STARBUCS control module is used to obtain the depleted fuel composition of failed fuel to be used in KENO V.a models for failed fuel burnup credit criticality analysis.

References [6-7] state that an important outcome from the burnup credit criticality safety analysis is the loading curves with the minimum burnup requirements for a given initial enrichment and cooling time. The loading curves are determined by ensuring that the maximum expected k_{eff} is less than the USL.

Nuclides of Importance

Based on the results presented in [8], the nuclides listed in Table 6.8.2-7 are the actinides and fission products important to burnup credit criticality analysis. Note that these are the credited isotopes of the fuel composition in the criticality analysis. During depletion, ISG-8 [6] states that the code must ensure that all the transmutation and decay chains during burnup must be tracked. This is due to the fact that the burnup-dependent cross sections generated for the next cycle burnup depend on the neutron spectrum, which is impacted by the actinide and fission product content at current cycle. The burnup credit may be taken by using actinide-only depletion or actinide and fission product depletion. Since there are sufficient data to validate the use of both actinides and fission products, the TN Eagle criticality evaluation is evaluated by taking credit for isotopes listed in Table 6.8.2-7.

Burnup and Enrichment Limits

ISG-8 [6] states that the available radio-chemical assay data support assembly-average burnups of up to 60 GWd/MTU and enrichments of up to 5 wt. % U-235. The local burnups for the assembly may be higher but the assembly-average burnup shall not exceed 60 GWd/MTU. This limit is only used in the analysis, and does not prevent transporting fuel with assembly-average burnup in excess of 60 GWd/MTU.

Horizontal Burnup Profiles

The effect on FAs discharged from the periphery of the reactor core where differences in neutron flux in this region relative to the rest of the core may result in significant variations in horizontal burnup after a cycle of operation. The discussion in [6] indicates that for large systems such as the EOS-37PTH DSC, horizontal loading bias has little impact on burnup credit evaluations and therefore zero horizontal bias is assigned for the burnup credit analysis.

Axial Burnup Profiles

ISG-8 [6] points to [12], where axial burnup profiles are presented based on an evaluation of 4% of FAs discharged through 1994 (~45,000 FAs) and uses as SCALE 6.1.3 built-in burnup dependent axial profiles. These data are used in [9] to state that:

- The survey of FAs in [12] provides a representative sampling of discharged assemblies. This conclusion is reached in [9] based on:
  - Fuel vendor/reactor design,
  - Type of operation (i.e., first cycles, out-in fuel management, and low-leakage fuel management),
  - Burnup and enrichment ranges,
  - Use of burnable absorbers (including different absorber types), and
  - Exposure to control rods (CRs) (including axial power shaping rods (APSRs)).
- Although limited data exist for burnup values greater than 40 GWd/MTU and initial enrichments greater than 4 wt. % U-235, the profiles resulting in the highest reactivity at intermediate burnup values will yield the highest reactivity at higher burnups.

In addition to the SCALE 6.1.3 built-in burnup-dependent axial profiles, the evaluations herein employ an additional axial profile for burnups greater than 38 GWd/MTU using 38 to 42 GWd/MTU range from [3]. Note that the SCALE 6.1.3 built-in axial profiles are also from the same reference and this evaluation adds one more profile to use more representative axial profiles for higher burnup fuel. The 18-section burnup-dependent axial correction factors are shown in Table 6.8.2-6.

Loading Curves

Loading curves present the acceptable combinations of assembly average burnup, and initial enrichment for loading FAs. The STARBUCS control module is used with ORIGEN-ARP to develop loading curves for various BECTs for EOS-37PTH DSC loaded with intact FAs. The CSAS5 module is used to develop loading curves for various BECTs for EOS-37PTH DSC loaded with failed FAs. The STARBUCS control module is used to obtain the depleted fuel composition of failed fuel to be used in KENO V.a models for failed fuel burnup credit criticality analysis. The run time is determined by the uncertainty cutoff of 0.0005. The burnup is used as an input to determine the maximum allowable initial enrichment that satisfies the USL. The cooling times considered are 5, 10, 15 and 20 years. In addition, maximum allowable initial enrichment for fresh fuel that satisfies the USL is also evaluated.

6.8.2.4.3 Criticality Results

The burnup criticality analyses is performed to develop loading curves for the WE 14x14, B&W 15x15 and WE 17x17 intact and FAs loaded in EOS-37PTH DSC placed inside TN Eagle. The initial U-235 enrichment is estimated for B&W 15x15, WE 14x14 and WE 17x17 FAs for fresh fuel and for burnups ranging from 5 GWd/MTU to 60 GWd/MTU. The loading curves are developed for 5, 10, 15 and 20 years of cooling time.

The failed fuel loading curves are developed for EOS-37PTH DSC loaded with 12 FAs in failed fuel configuration along with 25 intact FAs. Sensitivity study is performed to determine the reactive failed fuel rod configuration between fuel rods with Zircaloy-4 clad and without clad. The results obtained are tabulated in Table 6.8.2-10 and conclude that the fuel rods without cladding as more reactive. The sensitivity study is performed to determine the most reactive FA configuration, which involved fuel rod pitch expansion and missing fuel rods. The results obtained are tabulated in Table 6.8.2-11, Table 6.8.2-12 and Table 6.8.2-13, respectively for B&W 15x15, WE 14x14 and WE 17x17 FAs loaded in Type A DSC. The results obtained are tabulated in Table 6.8.2-14, Table 6.8.2-15 and Table 6.8.2-16, respectively for B&W 15x15, WE 14x14 and WE 17x17 FAs loaded in Type B DSC. The most reactive failed fuel configuration obtained for B&W 15x15, WE 14x14 and WE 17x17 FAs are used in developing loading curves for failed fuel.

The loading curves for the EOS-37PTH DSC types, Type A and Type B loaded with B&W 15x15 intact FAs are summarized and provided in Table 1.6.1-2 and Table 1.6.1-3, respectively. Figure 6.8.2-8 through Figure 6.8.2-11, respectively, represent the loading curve for 5, 10, 15 and 20 years of cooling period for B&W 15x15 intact fuel loaded in Type A DSCs. Figure 6.8.2-12 through Figure 6.8.2-15, respectively, represent the loading curve for 5, 10, 15 and 20 years of cooling period for B&W 15x15 intact fuel loaded in Type B DSCs.

The loading curves for the EOS-37PTH DSC types, Type A and Type B loaded with B&W 15x15 Mark B-10 failed FAs are summarized and provided in Table 1.6.1-8 and Table 1.6.1.9, respectively. Figure 6.8.2-16 through Figure 6.8.2-19, respectively, represent the loading curve for 5, 10, 15 and 20 years of cooling period for B&W 15x15 Mark B-10 failed fuel loaded in Type A DSCs. Figure 6.8.2-20 through Figure 6.8.2-23, respectively, represent the loading curve for 5, 10, 15 and 20 years of cooling period for B&W 15x15 Mark B-10 failed fuel loaded in Type B DSCs.

The loading curves for the EOS-37PTH DSC types, Type A and Type B loaded with WE 17x17 fuel class intact FAs are summarized and provided in Table 1.6.1-4 and Table 1.6.1.5, respectively. Figure 6.8.2-24 through Figure 6.8.2-27, respectively, represents the loading curve for 5, 10, 15 and 20 years of cooling period for WE 17x17 RFA intact fuel loaded in Type A DSCs. Figure 6.8.2-28 through Figure 6.8.2-31, respectively, represent the loading curve for 5, 10, 15 and 20 years of cooling period for WE 17x17 intact fuel loaded in Type B DSCs. Loading curves for WE 17x17 fuel class are applicable to WE 15x15, CE 14x14, CE 15x15 and CE 16x16 fuel classes.

The loading curves for the EOS-37PTH DSC types, Type A and Type B loaded with WE 17x17 fuel class failed FAs are summarized and provided in Table 1.6.1.10 and Table 1.6.1.11, respectively. Figure 6.8.2-32 through Figure 6.8.2-35, respectively, represent the loading curve for 5, 10, 15 and 20 years of cooling period for WE 17x17 RFA failed fuel loaded in Type A DSCs. Figure 6.8.2-36 through Figure 6.8.2-39, respectively, represent the loading curve for 5, 10, 15 and 20 years of cooling period for WE 17x17 failed fuel loaded in Type B DSCs. Loading curves for WE 17x17 fuel class are applicable to WE 15x15, CE 14x14, CE 15x15 and CE 16x16 fuel classes.

The loading curves for the EOS-37PTH DSC types, Type A and Type B loaded with WE 14x14 intact FAs are summarized and provided in Table 1.6.1-7 and Table 1.6.1-8, respectively. Figure 6.8.2-40 through Figure 6.8.2-43, respectively, represent the loading curve, which is average burnup as a function of initial fuel enrichment for 5, 10, 15 and 20 years of cooling period for WE 14x14 intact fuel loaded in Type A DSCs. Figure 6.8.2-44 through Figure 6.8.2-47, respectively, represent the loading curve for 5, 10, 15 and 20 years of cooling period for WE 14x14 intact fuel loaded in Type B DSCs.

The loading curves for the EOS-37PTH DSC types, Type A and Type B loaded with WE 14x14 failed FAs are summarized and provided in Table 1.6.1-12 and Table 1.6.1-13, respectively. Figure 6.8.2-48 through Figure 6.8.2-51, respectively, represent the loading curve for 5, 10, 15 and 20 years of cooling period for WE 14x14 STD failed fuel loaded in Type A DSCs. Figure 6.8.2-52 through Figure 6.8.2-55, respectively, represent the loading curve for 5, 10, 15 and 20 years of cooling period for WE 14x14 failed fuel loaded in Type B DSCs.

The results for the loading curves calculations are shown in Table 6.8.2-42 through Table 6.8.2-53. [

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The criterion for subcriticality is that:

$$k_{eff} + (\beta_i + \Delta k_i) + \Delta k_x < USL$$

where USL is the upper subcriticality limit established by an analysis of benchmark criticality experiments,

Δk_x is the code bias due to minor actinides and fission products, 0.1 x 0.015 = 0.0015,

And $(\beta_i + \Delta k_i)$ is the burnup-dependent bias and bias uncertainty for isotopics validation shown in Table 6-3 of [7].

$$k_{KENO} + 2\sigma_{KENO} + (\beta_i + \Delta k_i) + 0.0015 < 0.94236$$

6.8.2.5 Critical Benchmark Experiments and applicable biases

This section summarizes evaluations performed for benchmarking the various computer codes utilized in the criticality analysis. A description of the benchmarking analyses performed in support of the criticality analyses for the TN Eagle transport cask where fresh fuel is considered is provided in Section 6.8.2.5.1. The description of the benchmarking analyses performed in support of burnup credit is provided in Section 6.8.2.5.2. For both fresh fuel and burnup credit evaluations, the upper subcriticality limit (USL) is also determined.

6.8.2.5.1 Fresh Fuel Benchmarks

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6.8.2.5.2 Burnup Credit Benchmarks

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A comprehensive discussion of the benchmark calculations performed for the TN Eagle is presented in Section 6.8.2.5.3 and a comprehensive discussion of the USL value calculation is presented in Section 6.8.2.4.2.1.

6.8.2.5.3 Criticality Benchmark Evaluation

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The area of applicability is evaluated by comparing the parameter values with the calculation model specifications. The parameters of interest are fuel enrichment, fuel pitch, fuel rod radius, assembly separation, hydrogen to fissile density ratio, moderator to fuel ratio, AEG and EALF for USL evaluation with fresh fuel assumptions. The range of parameters values are tabulated in Table 6.8.2-20a for the critical experiments selected for fresh fuel analysis. The fuel pitch is 1.41224 cm, 1.44272 cm and 1.25984 cm for WE 14x14 STD, B&W 15x15 Mark B10 and WE 17x17 RFA fuel assembly; whereas the range of fuel pitch values selected for fresh fuel analysis is 1.30 cm to 2.54 cm. The fuel rod radius is 0.53594 cm, 0.54610 cm and 0.47498 cm for WE 14x14 STD, B&W 15x15 Mark B10 and WE 17x17 RFA fuel assembly; whereas the range of fuel rod radius selected for fresh fuel analysis is 0.395 cm to 0.633 cm. The assembly separation ranges from 0.3048 cm to 0.8331 cm for WE 14x14 STD, B&W 15x15 Mark B10 and WE 17x17 RFA fuel assembly; whereas the range of assembly separation values selected for fresh fuel analysis is 2.690 cm to 15.393 cm. The fuel enrichment analyzed in the calculation ranges from 1.60 wt. % U-235 to 5.00 wt. % U-235; whereas the range of fuel enrichment selected for fresh fuel analysis is 2.35 wt. % U-235 to 4.74 wt. % U-235. The values of hydrogen to fissile density ratio, moderator to fuel ratio, AEG and EALF vary depending on the fuel enrichment specification in the calculation.

The parameters of interest are fuel enrichment, fuel pitch, fuel rod radius, plutonium content, hydrogen to fissile density ratio, moderator to fuel ratio, AEG and EALF. The range of parameters values are tabulated in Table 6.8.2-20a for the critical experiments selected for burnup credit analysis. The fuel pitch is 1.41224 cm, 1.44272 cm and 1.25984 cm for WE 14x14 STD, B&W 15x15 Mark B10 and WE 17x17 RFA fuel assembly; whereas the range of fuel pitch values selected for fresh fuel analysis is 1.30 cm to 4.32 cm. The fuel rod radius is 0.53594 cm, 0.54610 cm and 0.47498 cm for WE 14x14 STD, B&W 15x15 Mark B10 and WE 17x17 RFA fuel assembly; whereas the range of fuel rod radius selected for fresh fuel analysis is 0.395 cm to 0.641 cm. The fuel enrichment analyzed in the calculation ranges from 1.60 wt. % U-235 to 5.00 wt. % U235; whereas the range of fuel enrichment selected for fresh fuel analysis is 0.16 wt. % U-235 to 1.59 wt. % U-235. The values of hydrogen to fissile density ratio, moderator to fuel ratio, plutonium content, AEG and EALF vary depending on the fuel enrichment specification in the calculation. Even though some parameters fall outside the AOA, the USL calculated using these critical experiments are applicable here, since these are the critical experiments suggested by NRC in Ref. [10].

The values of the parameters of interest are collected either from experimental descriptions ([1] and [10]) or from KENO simulation outputs of the selected critical experiments. Using the values of parameters, trending analysis is performed for parameters against k_{KENO} obtained for each experiment.

6.8.2.5.4 Results of the Benchmark Calculations

The values of the parameters of interest are tabulated in Table 6.8.2-17 and Table 6.8.2-18 for critical experiments for fresh fuel analysis; and Table 6.8.2-19 and Table 6.8.2-20 for critical experiments for burnup credit analysis. These values are used to plot k_{eff} versus experimental parameters graphs for experiments with fresh fuel and burnup credit assumptions. Figure 6.8.2-56 through Figure 6.8.2-63 demonstrate the trend in k_{eff} as a function of various experimental parameters for critical experiments for fresh fuel analysis; and Figure 6.8.2-64 through Figure 6.8.2-71 for critical experiments for burnup credit analysis.

6.8.2.5.5 Determination of Correlation Coefficient

The parameters of interest and the k_{eff} values are taken from refs. [4, 1] and KENO output. Trending analysis is performed by plotting the graph of k_{eff} value as a function of experimental parameters of interest in MS® Excel. The correlation coefficient is then obtained by determining r^2 value by using trend line option in the graph and also "correl ()" function available in MS® EXCEL

The trending analysis is performed by determining correlation coefficient between k_{eff} and various experimental parameters. These values obtained are tabulated in Table 6.8.2-21 and Table 6.8.2-22 for PWR fresh fuel and PWR burnup credit analysis, respectively. The highest correlation coefficient is obtained for k_{eff} versus FA separation value for fresh fuel analysis, and k_{eff} versus moderator to fuel ratio value for PWR burnup credit analysis.

6.8.2.5.6 Minor Actinides and Fission Products Worth

The code bias and bias uncertainty due to minor actinides and fission products may be computed as 1.5% of the worth provided the credited minor actinides and fission products worth not greater than 0.1 in k_{eff}.

To demonstrate that the minor actinides and fission product worth is less than 0.1, criticality simulations are performed using STARBUCS for a range of burnups and cooling time combinations, at a fixed fuel enrichment (5.00 wt. % U-235). For each BECT combination, two cases are run, one including only major actinides in the calculation, and other including major actinides, minor actinides and fission products, selected in accordance with Table 6.8.2-7. The differences in k_{eff} from both cases give the minor actinide and fission product worth. The code bias due to minor actinides and fission products is calculated based on the results presented in Table 6.8.2-23. The highest value of minor actinide and fission product worth (Δk_{eff}) is 0.104, which satisfy the condition. Therefore, the bias and bias uncertainty of the criticality code associated with minor actinides and fission products, 0.0015 (=1.5%x0.1) is used.

6.8.2.6 ORIGEN-ARP Cross-Section Libraries

Fuel Assembly Classes

TRITON Depletion Parameters

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Development of ORIGEN-ARP Libraries

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6.8.2.7 Code Validation – Isotopic depletion

According to ISG-8, [6], the purpose of the validation of the depletion analysis code is to:

- Determine if the code is capable of modelling the depletion environment of FAs by performing depletion of FAs from which measurement has been obtained through radiochemical assay,
- Quantify bias and bias uncertainty of the isotopic depletion calculation code against the depletion parameters, FA design characteristics, initial enrichment, and cooling time.

ISG-8, [6], states that, if it can be shown that the system considered is similar to the GBC-32, a virtual generic 32-PWR compartment cask that is used in the NUREGs to generate bias and bias uncertainties, after which the NUREG-generated bias and bias uncertainties can be used. This similarity approach is used in this evaluation.

ISG-8, [6], presents a list of burnup-dependent bias and bias uncertainties of the isotopic depletion calculation that may be used, provided the following conditions are met:

- The applicant uses the same depletion code and cross-section library as was used in NUREG/CR-7108 [16] (SCALE/TRITON and the ENDF/B-V or -VII cross-section library),
- The applicant can justify that its design is similar to the hypothetical GBC-32 system design used as the basis for the NUREG/CR-7108 [16] isotopic depletion validation, and credit is limited to the specific nuclides listed in Table 6.8.2-7.

The outlines of the methodology to demonstrate similarity among two or more systems may be found in [17] and [10]. In both cases, the GBC-32 is compared to criticality experiments. The traditional approach is to provide a qualitative description of the physical system. These could be the presence of certain isotopes in the fuel or material of construction, geometry of the fuel and other materials, and global parameters such as hydrogen-to-fissile nuclide ratio (H/X), moderator-to-fuel ratio (Vm/Vf), AEG, and energy of average lethargy of neutrons causing fission EALF. The hydrogen-to-fissile number density ratios will be computed using the isotopic densities of hydrogen and U-235 and Pu-239 in each axial region of the fuel rod. The axially-averaged H/X ratio is obtained by multiplying the ratio of isotopic densities with the moderator-to-fuel ratio.

The STARBUCS module of SCALE 6.1.3, [3], is used to determine U-235 wt. % enrichment values for six burnups: 10, 20, 30, 40, 50, 60 GWD/MTU and a cooling time of five years such that the k_{eff} value stays below the USL of 0.9400. The 238-group cross-section library based on the ENDF/B-VII.0 nuclear data and the resonance cross-section methodology employing CENTRM are used. The FAs used for both the systems are ‘WE17 OFA’.

The STARBUCS outputs provide burnup dependent isotopic densities after depletion. The material compositions obtained from the STARBUCS outputs are used in the KENO runs performed. These cases are run using the CSAS5 module of SCALE 6.1.3, [3]. KENO cases are run for each of the burnups: 10, 20, 30, 40, 50, 60 GWD/MTU. The outputs of these runs are used to determine the hydrogen-to-fissile nuclide ratio (H/X), average fission energy group (AEG), and energy of average lethargy of neutrons causing fission (EALF). EALF and AEG are both obtained from the output of the KENO runs. The axially-averaged ratio of hydrogen to the sum of U-235 and Pu-239 number densities are used to obtain the H/X ratio.

The burnup-dependent global neutronic parameters are presented in Table 6.8.2-31 to Table 6.8.2-35. The table includes the final k_{eff} as well as EALF and AEG comparisons.

Additionally, a sensitivity and uncertainty (S/U) tool is used to generate a parameter that quantifies the similarity of the two systems. From [3]: “The technique compares the detailed sensitivity data for the two systems, giving greater weight to comparisons of sensitivities for nuclides and reactions with the highest nuclear data uncertainties.” The correlation coefficient, c_k obtained from this process indicates the degree of similarity by the following standards: c_k greater than or equal to 0.9 indicates similar systems, c_k between 0.8 and 0.9 indicates marginally similar and less than 0.8 is not recommended for use. The system application is the TN Eagle TC loaded with EOS-37PTH, while the “experiment” is the GBC-32.

The TSUNAMI-3D module of SCALE 6.1.3, [3], has been used for performing the similarity analysis. TSUNAMI-3D calculations are performed for the application and experiment models. Isotopic number densities obtained from the STARBUCS outputs are used for the TSUNAMI-3D models as well. Direct perturbation calculations are used to confirm the adequacy of the sensitivity data files. Direct perturbation calculations involve varying the composition information around the nominal value and using the resulting k_{eff} value variations to calculate the total sensitivity. The direct perturbation results are compared with the TSUNAMI sensitivity results to confirm the adequacy of the sensitivity data. Finally, TSUNAMI-3D generates sensitivity data files (.sdf), which contains the energy-dependent sensitivity coefficients for each value of burnup.

The .sdf files generated by TSUNAMI-3D for the two systems in the previous step are used by TSUNAMI-IP to determine a c_k value at each burnup. The TSUNAMI-IP module of SCALE 6.1.3, [3], was used to calculate detailed k_{eff} uncertainty information for the application model. The correlation factor, C_k quantifies correlations in uncertainties by propagating the tabulated cross-section-uncertainty information to the calculated k_{eff} value of a given system via the energy-dependent sensitivity coefficients.

This evaluation demonstrates similarity by comparing the global parameters, as well as by determining the sensitivity and uncertainty. The ck parameters generated from the sensitivity and uncertainty calculation, which indicate high degree of similarity, are provided in Table 6.8.2-36.

The results satisfy the requirements of ISG-8, [6], thereby allowing the user to adopt the results from Table 3 of the ISG-8, [6], in preparing system-specific loading requirements with burnup credit.

6.8.2.8 Misload Analysis

This section presents a misload analysis of the TN Eagle cask system loaded with NUHOMS® EOS-37PTH DSC containing 37 B&W 15x15 FAs. ISG8, [6], provides the basic criteria to study the single and multiple misload events. The single misload is studied by misloading one assembly which is severely underburned and highly reactive. The multiple misload is studied by misloading all assemblies with moderately burned FAs.

Equal reactivity curves are developed to perform the single and multiple misload analysis. These curves developed for single and multiple misload events are superimposed on the U.S. commercial PWR fleet, spent fuel inventory graph. The resulting graphs are used to quantify the number of FAs falling above and below the equal reactivity curve. The equal reactivity curves are generated for both Type A (with 28 mg B-10/cm^2) and Type B (with 35 mg B-10/cm^2) basket types.

B&W 15x15 assembly is the most reactive assembly as compared to WE 14x14 and WE 17x17 assemblies as can be seen from the loading curves generated in Section 6.8.2.4.3. Hence, the misload burnup loading curve is generated for B&W 15x15 assemblies with the assumption of five years cooling time. Burnup credit methodology described in Section 6.8.2.4.3 is used to develop the misload burnup loading curve.

STARBUCS and CSAS5 modules available with SCALE 6.1.3 [3] code are used to perform the analysis. Since CSAS5 cannot be used for burnup credit analysis, STARBUCS is used to get the composition of the burned fuel. Since this is misload analysis, the k_{eff} obtained is compared to the USL value calculated in Section 6.8.2.4.2.1 with 0.02 as administrative margin.

ISG8 [6] has a set of recommendations for performing misload analysis:

1. The misload evaluation should be based on a reliable and relatively recent estimate of the discharged PWR fuel population.
2. It should evaluate both single severely underburned misload and multiple moderately burned misload events.
3. The single severely underburned assembly should be chosen such that any assembly average burnup and initial enrichment along an equal reactivity curve bound 95% of the discharged fuel population considered unacceptable for loading in a particular storage or transportation system with 95% confidence.
4. For the evaluation of the application system with multiple moderately underburned assemblies, misloaded SNF should be assumed to make up at least 50% of the system payload, and should be chosen such that the assembly average burnups and initial enrichments along the equal reactivity curve bound 90% of the total discharged fuel population.
5. Experience with identified code errors and an understanding of uncertainties in cross section data and their impacts on reactivity indicates that an administrative margin of at least 0.02 is necessary for analyses to show subcriticality with misload.

6.8.2.8.1 Equal Reactivity Curves

6.8.2.8.2 Determining Maximum Allowable Enrichment

6.8.2.8.3 Quantifying the Qualified Assemblies

6.8.2.9 Evaluations under NCT and HAC

This section describes the evaluations under Hypothetical Accident Conditions (HAC) and Normal Conditions of Transport performed for the TN Eagle transport package with the EOS-37 PTH DSC

6.8.2.9.1 Package Arrays under Hypothetical Accident Conditions

6.8.2.9.2 Package Arrays under Normal Conditions of Transport

6.8.2.9.3 Single Package Evaluation

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16. US NRC, NUREG/CR-7108, "An Approach for Validating Actinide and Fission Product Burnup Credit Criticality Safety Analyses-Isotopic Composition Predictions," April 2012.

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Table 6.8.2-1
FAs Authorized for Loading in the NUHOMS® EOS-37PTH DSC

Assembly Type[(1)]	Array	Assembly Class
Framatome 17x17 Mark BW	17x17	WE 17x17
Westinghouse 17x17 LOPAR/Standard	17x17	WE 17x17
Westinghouse 17x17 OFA/Vantage 5[(2)]	17x17	WE 17x17
Westinghouse 17x17 RFA	17x17	WE 17x17
B&W 17x17 Mark C	17x17	BW 15x15
ATMEA 1, AM100	17x17	
Doel 3/Doel 4/Tihange2/Tihange 3	17x17	
ENRESA, ASCO	17x17	
Step II	17x17	
B&W 15x15 Mark B2-B11	15x15	BW15x15
Exxon/ANF (ANP) 15x15 WE	15x15	WE 15x15
Westinghouse 15x15 LOPAR/OFA/DRFA/Vantage 5	15x15	WE 15x15
Westinghouse 15x15 Standard/ZC	15x15	WE 15x15
Step I Type A	15x15	
Tihange 1	15x15	
CE 15x15 Palisades	15x15	CE 15x15
Exxon/ANF (ANP) 15x15 CE	15x15	CE 15x15
Exxon/ANF (ANP) 14x14 Top Rod	14x14	WE 14x14
Exxon/ANF (ANP) 14x14 WE	14x14	WE 14x14
Westinghouse 14x14 OFA	14x14	WE 14x14
Westinghouse 14x14 Standard/LOPAR/ZCA/ZCB	14x14	WE 14x14
Doel 1 and 2	14x14	
Step I Type A	14x14	
CE 14x14 Fort Calhoun	14x14	CE 14x14
CE 14x14 Standard/Generic/St. Lucie	14x14	CE 14x14
Framatome-ANP 14x14 CE	14x14	CE 14x14
AREVA Design	16x16	
Westinghouse Design	16x16	WE 16x16
CE 16x16 Standard	16x16	CE 16x16
CE 16x16 System 80	16x16	CE 16x16

Notes:
(1) Reload fuel from other manufacturers with these parameters are also acceptable.
(2) Includes all Vantage version (5, +, ++, 5H, etc.).

Table 6.8.2-2
Design Input for B&W, WE 17x17 and WE 14x14 Fuel Classes

Parameter	WE 14x14 STD	B&W 15x15 Mark B-10	WE 17x17 RFA
Assembly Pitch (cm)	19.8196	21.7969	21.5000
Number of Fuel Rods	179	208	264
Guide Tubes per FA	16	16	24
Instrument Tubes per FA	1	1	1
Fuel Cell Pitch (cm)	1.4122	1.4427	1.2598
Pellet Outer Radius (OR) (cm)	0.4647	0.4743	0.4096
Fuel Rod Clad Inner Radius (IR) (cm)	0.4742	0.4826	0.4178
Fuel Rod Clad OR (cm)	0.5359	0.5461	0.4750
Fuel Rod Clad Material	Zirc-4	Zirc-4	Zirc-4
Guide Tube IR (cm)	0.6414	0.6325	0.5715
Guide Tube OR (cm)	0.6845	0.6731	0.6121
Guide Tube Material	Zirc-4	Zirc-4	Zirc-4
Instrument Tube IR (cm)	0.4750	0.5601	0.5715
Instrument Tube OR (cm)	0.5359	0.6261	0.6121
Instrument Tube Material	Zirc-4	Zirc-4	Zirc-4

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Table 6.8.2-4
Material Property Data

Material	ID	Density (g/cm^3)	Element	Wt. %	Atom Density (atoms/b-cm)
UO_2 (Enrichment - 5.0 wt%, 96.5% of theoretical density)	1	10.5764	U-235	1.32	3.6202E-04
			U-238	86.82	2.3473E-02
			O	11.85	4.7670E-02
Zircaloy-4	2	6.56	Zr	98.24	4.2539E-02
			Sn	1.45	4.8254E-04
			Fe	0.21	1.4856E-04
			Cr	0.10	7.5977E-05
			Hf	0.01	2.2134E-06
Water (Pellet-Clad Gap)	3	0.9982	O	88.89	3.3377E-02
			H	11.11	6.6753E-02
Stainless Steel (SS304)	4	7.94	Fe	68.40	5.8546E-02
			Cr	18.93	1.7472E-02
			C	0.08	3.1849E-04
			Si	1.01	1.7025E-03
			P	0.05	6.9469E-05
			Mn	2.00	1.7407E-03
			Ni	9.54	7.7401E-03
Water (Internal & External Moderator)	5 & 10	0.9982	O	88.89	3.3377E-02
			H	11.11	6.6753E-02
Aluminum	8	2.702	Al	100.00	6.0307E-02
Carbon Steel	12	7.8212	Fe	98.99	8.3498E-02
			C	1.01	3.9215E-03

Table 6.8.2-5
Poison Material Property Data

Table 6.8.2-6
Burnup-Dependent Axial Correction Factors for 18 Axial Zones

Axial Zone No.	Fraction of Core Height	Source: STARBUCS			Source: Ref. [9]
		< 18 GWd/MTU	18 - 30 GWd/MTU	30 - 38 GWd/MTU	Burnup ≥ 38 GWd/MTU
		1	2	3	4
1	0.0278	0.649	0.668	0.652	0.660
2	0.0833	1.044	1.034	0.967	0.936
3	0.1389	1.208	1.150	1.074	1.045
4	0.1944	1.215	1.094	1.103	1.080
5	0.2500	1.214	1.053	1.108	1.091
6	0.3056	1.208	1.048	1.106	1.093
7	0.3611	1.197	1.064	1.102	1.092
8	0.4167	1.189	1.095	1.097	1.090
9	0.4722	1.188	1.121	1.094	1.089
10	0.5278	1.192	1.135	1.094	1.088
11	0.5833	1.195	1.140	1.095	1.088
12	0.6389	1.190	1.138	1.096	1.086
13	0.6944	1.156	1.130	1.095	1.084
14	0.7500	1.022	1.106	1.086	1.077
15	0.8056	0.756	1.049	1.059	1.057
16	0.8611	0.614	0.933	0.971	0.996
17	0.9167	0.481	0.669	0.738	0.823
18	0.9722	0.284	0.373	0.462	0.525

Table 6.8.2-7
List of Isotopes used for Burnup Credit Calculations

Nuclides for Major Actinide-Only Burnup Credit				
U-234	U-235	U-238	Pu-238	Pu-239
Pu-240	Pu-241	Pu-242	Am-241	
Additional Nuclides for Minor Actinide and Fission Product Burnup Credit				
Mo-95	Tc-99	Ru-101	Rh-103	Ag-109
Cs-133	Sm-147	Sm-149	Sm-150	Sm-151
Sm-152	Nd-143	Nd-145	Eu-151	Eu-153
Gd-155	U-236	Am-243	Np-237	

Table 6.8.2-8
USL Calculations with Burnup Credit Assumptions

[ ]	[ ]
[ ]	[ ]
[ ]	[ ]
[ ]	[ ]
[ ]	[ ]
[ ]	[ ]
Upper Sub-Critical Limit	**0.94236**

Table 6.8.2-9
USL Calculation with Fresh Fuel Assumptions

[ ]	[ ]
[ ]	[ ]
[ ]	[ ]
[ ]	[ ]
[ ]	[ ]
[ ]	[ ]
Upper Sub-Critical Limit	**0.94173**

Proprietary Information on Pages 6.8.2-39 through 6.8.2-42
Withheld Pursuant to 10 CFR 2.390

Table 6.8.2-17
Experimental Parameters of Critical Experiments with Fresh Fuel Assumptions from KENO V.a/KENO-VI outputs
2 pages

EALF (eV)	AEG	k_{KENO}	STDEV	k_{eff}
0.0964	36.24	0.99542	0.00085	0.99712
0.0956	36.26	0.99512	0.00091	0.99694
0.0946	36.29	0.99549	0.00085	0.99719
0.0953	36.27	0.99455	0.00085	0.99625
0.0940	36.31	0.99323	0.00093	0.99509
0.0953	36.27	0.99545	0.00085	0.99715
0.0935	36.32	0.99350	0.00080	0.99510
0.0942	36.30	0.99255	0.00082	0.99419
0.1141	35.74	0.99480	0.00100	0.99680
0.1142	35.74	0.99767	0.00089	0.99945
0.1139	35.74	0.99751	0.00093	0.99937
0.1128	35.77	0.99690	0.00100	0.99890
0.1128	35.77	0.99690	0.00100	0.99890
0.3897	33.42	0.99880	0.00110	1.00100
0.2944	33.39	1.00054	0.00092	1.00238
0.2868	33.46	0.99991	0.00091	1.00173
0.2830	33.50	0.99859	0.00091	1.00041
0.2757	33.58	0.99832	0.00099	1.00030
0.0946	36.29	0.99852	0.00078	1.00008
0.2133	34.74	0.99466	0.00085	0.99636
0.1863	35.01	0.99751	0.00085	0.99921
0.1741	35.15	0.99887	0.00073	1.00033
0.1664	35.24	0.99773	0.00082	0.99937
0.1364	35.62	0.99380	0.00100	0.99580
0.1101	36.02	0.99449	0.00078	0.99605
0.0993	36.15	0.99955	0.00086	1.00127
0.0975	36.20	0.99935	0.00093	1.00121
0.0963	36.23	0.99755	0.00082	0.99919
0.0948	36.28	0.99640	0.00075	0.99790
0.0943	36.29	0.99594	0.00081	0.99756
0.1794	34.74	0.99620	0.00100	0.99820
0.1739	34.82	0.99736	0.00092	0.99920
0.1690	34.89	0.99833	0.00077	0.99987
0.1641	34.97	0.99595	0.00089	0.99773
0.1627	35.00	0.99330	0.00100	0.99530
0.1613	35.03	0.99385	0.00076	0.99537
0.1603	35.05	0.99321	0.00086	0.99493
0.1725	34.85	0.99984	0.00086	1.00156
0.1669	34.93	0.99773	0.00086	0.99945
0.1590	35.06	0.99356	0.00086	0.99528

Table 6.8.2-17
Experimental Parameters of Critical Experiments with Fresh Fuel Assumptions from KENO V.a/KENO-VI outputs
2 pages

EALF (eV)	AEG	k_{KENO}	STDEV	k_{eff}
0.3022	33.88	0.99533	0.00079	0.99691
0.2622	34.16	0.99634	0.00095	0.99824
0.1716	34.86	0.99647	0.00084	0.99815
0.1778	34.76	0.99648	0.00087	0.99822
0.1846	34.68	0.99621	0.00086	0.99793
0.1834	34.69	0.99801	0.00092	0.99985
0.1793	34.74	0.99753	0.00083	0.99919
0.1724	34.84	0.99754	0.00088	0.99930
0.1768	34.78	0.99657	0.00075	0.99807
0.2041	34.24	0.99640	0.00100	0.99840
0.1952	34.35	0.99390	0.00100	0.99590

Table 6.8.2-18
Experimental Parameters of Critical Experiments with Fresh Fuel Assumptions from KENO V.a/KENO-VI Inputs
2 Pages

Fuel Radius (cm)	Pitch (cm)	Enrichment (wt. %)	Assembly Separation (cm)	H/X * Mod/Fuel Ratio	Mod/Fuel Ratio
0.559	2.032	2.350	-	398.96	2.918
0.559	2.032	2.350	11.920	398.96	2.918
0.559	2.032	2.350	8.410	398.96	2.918
0.559	2.032	2.350	10.050	398.96	2.918
0.559	2.032	2.350	6.390	398.96	2.918
0.559	2.032	2.350	8.010	398.96	2.918
0.559	2.032	2.350	4.460	398.96	2.918
0.559	2.032	2.350	7.570	398.96	2.918
0.633	2.540	4.310	-	256.34	3.882
0.633	2.540	4.310	-	256.34	3.882
0.633	2.540	4.310	-	256.34	3.882
0.633	2.540	4.310	10.620	256.34	3.882
0.633	2.540	4.310	7.110	256.34	3.882
0.633	2.540	4.310	14.255	455.58	3.882
0.633	1.892	4.310	15.393	187.41	1.597
0.633	1.892	4.310	15.363	187.41	1.597
0.633	1.892	4.310	14.973	187.41	1.597
0.633	1.892	4.310	13.343	187.41	1.597
0.559	2.032	2.350	10.510	398.96	2.918
0.559	2.032	2.350	11.090	398.96	2.918
0.559	2.032	2.350	13.190	398.96	2.918
0.559	2.032	2.350	13.370	398.96	2.918
0.559	2.032	2.350	12.960	398.96	2.918
0.559	2.032	2.350	9.950	398.96	2.918
0.559	2.032	2.350	7.820	398.96	2.918
0.559	2.032	2.350	9.888	398.96	2.918
0.559	2.032	2.350	10.438	398.96	2.918
0.559	2.032	2.350	10.438	398.96	2.918
0.559	2.032	2.350	9.598	398.96	2.918
0.559	2.032	2.350	8.748	398.96	2.918
0.559	1.684	2.350	8.566	218.71	1.600
0.559	1.684	2.350	9.166	218.71	1.600
0.559	1.684	2.350	9.096	218.71	1.600
0.559	1.684	2.350	8.866	218.71	1.600
0.559	1.684	2.350	8.646	218.71	1.600
0.559	1.684	2.350	8.126	218.71	1.600
0.559	1.684	2.350	7.256	218.71	1.600
0.559	1.684	2.350	9.646	218.71	1.600
0.559	1.684	2.350	9.696	218.71	1.600

Table 6.8.2-18
Experimental Parameters of Critical Experiments with Fresh Fuel Assumptions from KENO V.a/KENO-VI Inputs
2 Pages

[

Fuel Radius (cm)	Pitch (cm)	Enrichment (wt. %)	Assembly Separation (cm)	H/X * Mod/Fuel Ratio	Mod/Fuel Ratio
0.559	1.684	2.350	8.086	218.71	1.600
0.559	1.684	2.350	7.646	49.47	1.600
0.559	1.684	2.350	9.086	49.47	1.600
0.559	1.684	2.350	8.280	218.71	1.600
0.559	1.684	2.350	4.800	218.71	1.600
0.559	1.684	2.350	2.690	218.71	1.600
0.559	1.684	2.350	2.980	218.71	1.600
0.559	1.684	2.350	3.860	218.71	1.600
0.559	1.684	2.350	7.790	96.11	1.600
0.559	1.684	2.350	5.430	96.11	1.600
0.395	1.300	4.738	-	122.10	2.032
0.395	1.300	4.738	-	122.10	2.032

]

Table 6.8.2-19
Experimental Parameters of Critical Experiments with Burnup Credit Assumptions from KENO V.a/KENO-VI Outputs
4 Pages

	EALF (eV)	AEG	k_{KENO}	STDEV	k_{eff}
	0.53	190.56	1.00103	0.00049	1.00201
	0.71	187.25	1.00146	0.00049	1.00244
	0.19	203.13	1.00230	0.00046	1.00322
	0.27	198.95	1.00632	0.00048	1.00728
	0.13	206.94	1.00378	0.00049	1.00476
	0.18	203.91	1.00525	0.00049	1.00623
	0.14	206.27	0.99550	0.00047	0.99644
	0.14	206.33	0.99632	0.00049	0.99730
	0.14	206.42	0.99592	0.00049	0.99690
	0.12	208.47	0.99575	0.00049	0.99673
	0.11	208.52	0.99693	0.00049	0.99791
	0.11	208.62	0.99761	0.00049	0.99859
	0.09	211.22	0.99656	0.00049	0.99754
	0.09	211.29	0.99739	0.00049	0.99837
	0.09	211.35	0.99848	0.00049	0.99946
	0.08	212.89	0.99768	0.00049	0.99866
	0.08	212.92	0.99792	0.00049	0.99890
	0.37	194.68	1.00222	0.00049	1.00320
	0.25	199.71	1.00009	0.00048	1.00105
	0.17	204.18	1.00606	0.00049	1.00704
	0.14	206.33	1.00283	0.00049	1.00381
	0.11	209.81	1.00509	0.00049	1.00607
	0.09	211.47	1.00559	0.00049	1.00657
	0.09	212.01	1.00634	0.00049	1.00732
	0.36	195.42	0.99692	0.00048	0.99788
	0.19	202.96	1.00110	0.00049	1.00208
	0.14	206.63	0.99781	0.00049	0.99879
	0.12	208.47	1.00362	0.00049	1.00460
	0.10	210.75	1.00334	0.00049	1.00432
	0.09	211.35	1.00070	0.00049	1.00168
	0.14	206.71	0.99449	0.00048	0.99545
	0.14	206.68	0.99389	0.00048	0.99485
	0.14	206.71	0.99434	0.00049	0.99532
	0.14	206.65	0.99177	0.00048	0.99273
	0.14	206.63	0.99180	0.00047	0.99274
	0.14	206.60	0.99166	0.00049	0.99264
	0.14	206.70	0.99238	0.00049	0.99336
	0.14	206.65	0.99201	0.00049	0.99299
	0.14	206.61	0.99169	0.00049	0.99267
	0.14	206.62	0.99371	0.00049	0.99469

Table 6.8.2-19
Experimental Parameters of Critical Experiments with Burnup Credit Assumptions from KENO V.a/KENO-VI Outputs
4 Pages

	EALF (eV)	AEG	k_{KENO}	STDEV	k_{eff}
	0.10	210.77	0.99844	0.00049	0.99942
	0.10	210.77	0.99748	0.00049	0.99846
	0.10	210.76	0.99688	0.00049	0.99786
	0.10	210.73	0.99526	0.00049	0.99624
	0.10	210.70	0.99446	0.00049	0.99544
	0.10	210.69	0.99351	0.00049	0.99449
	0.10	210.75	0.99719	0.00049	0.99817
	0.10	210.72	0.99512	0.00049	0.99610
	0.10	210.72	0.99549	0.00049	0.99647
	0.10	210.73	0.99518	0.00049	0.99616
	0.19	202.82	1.00263	0.00049	1.00361
	0.14	206.59	0.99942	0.00049	1.00040
	0.12	208.47	1.00093	0.00049	1.00191
	0.10	210.71	1.00043	0.00047	1.00137
	0.09	211.29	0.99843	0.00049	0.99941
	0.38	194.63	0.99777	0.00049	0.99875
	0.19	202.64	0.99863	0.00047	0.99957
	0.14	206.44	0.99849	0.00049	0.99947
	0.12	208.34	1.00198	0.00049	1.00296
	0.10	210.67	1.00296	0.00049	1.00394
	0.09	211.24	1.00152	0.00049	1.00250
	0.14	206.52	0.99646	0.00049	0.99744
	0.14	206.49	0.99753	0.00049	0.99851
	0.14	206.47	0.99645	0.00049	0.99743
	0.14	206.45	0.99602	0.00046	0.99694
	0.14	206.42	0.99634	0.00049	0.99732
	0.14	206.44	0.99600	0.00049	0.99698
	0.14	206.48	0.99664	0.00049	0.99762
	0.14	206.48	0.99610	0.00048	0.99706
	0.14	206.43	0.99652	0.00049	0.99750
	0.14	206.41	0.99499	0.00049	0.99597
	0.52	191.57	0.99943	0.00049	1.00041
	0.29	198.14	0.99658	0.00049	0.99756
	0.15	205.54	0.99728	0.00049	0.99826
	0.12	208.64	0.99656	0.00049	0.99754
	0.09	210.83	0.99893	0.00049	0.99991
	0.09	211.43	0.99005	0.00049	0.99103
	0.07	213.40	0.99905	0.00049	1.00003
	0.07	213.92	0.99853	0.00044	0.99941
	0.07	213.96	0.99953	0.00049	1.00051

Table 6.8.2-19
Experimental Parameters of Critical Experiments with Burnup Credit Assumptions from KENO V.a/KENO-VI Outputs
4 Pages

EALF (eV)	AEG	k_{KENO}	STDEV	k_{eff}
0.08	211.14	0.99870	0.00049	0.99968
0.08	211.44	0.99955	0.00048	1.00051
0.08	211.55	0.99924	0.00046	1.00016
0.10	209.01	0.99866	0.00049	0.99964
0.10	209.23	1.00020	0.00046	1.00112
0.10	209.32	0.99925	0.00047	1.00019
0.14	205.36	0.99916	0.00049	1.00014
0.14	205.77	0.99929	0.00049	1.00027
0.13	205.92	0.99854	0.00049	0.99952
0.26	198.29	0.99773	0.00049	0.99871
0.23	199.40	0.99777	0.00048	0.99873
0.23	199.59	0.99765	0.00049	0.99863
0.10	209.11	0.99927	0.00046	1.00019
0.10	209.36	0.99976	0.00049	1.00074
0.10	209.11	0.99677	0.00049	0.99775
0.12	206.86	0.99754	0.00049	0.99852
0.14	205.44	1.00260	0.00049	1.00358
0.13	206.50	0.99993	0.00049	1.00091
0.12	206.98	1.00055	0.00048	1.00151
0.13	205.95	0.99918	0.00049	1.00016
0.13	206.28	1.00009	0.00049	1.00107
0.11	207.93	0.99973	0.00048	1.00069
0.11	208.05	0.99971	0.00048	1.00067
0.11	208.00	0.99862	0.00049	0.99960
0.11	208.10	0.99912	0.00049	1.00010
0.11	208.16	0.99987	0.00049	1.00085
0.11	208.36	0.99856	0.00049	0.99954
0.11	208.55	0.99792	0.00049	0.99890
0.10	208.79	0.99859	0.00048	0.99955
0.10	209.06	0.99867	0.00049	0.99965
0.10	208.79	0.99845	0.00045	0.99935
0.11	208.57	1.00129	0.00049	1.00227
0.11	207.77	1.00175	0.00049	1.00273
0.15	204.44	0.99972	0.00049	1.00070
0.13	206.46	0.99839	0.00049	0.99937
0.12	207.62	0.99914	0.00049	1.00012
0.15	204.34	1.00108	0.00047	1.00202
0.15	204.60	0.99787	0.00049	0.99885
0.15	204.94	0.99815	0.00049	0.99913
0.14	205.24	0.99872	0.00049	0.99970

Table 6.8.2-19
Experimental Parameters of Critical Experiments with Burnup Credit Assumptions from KENO V.a/KENO-VI Outputs
4 Pages

	EALF (eV)	AEG	k_{KENO}	STDEV	k_{eff}
	0.14	205.48	0.99822	0.00049	0.99920
	0.13	205.94	0.99849	0.00049	0.99947
	0.13	206.13	0.99808	0.00047	0.99902
	0.14	205.57	0.99739	0.00049	0.99837
	0.14	205.68	0.99763	0.00049	0.99861
	0.14	205.71	0.99655	0.00049	0.99753
	0.14	205.80	0.99574	0.00049	0.99672
	0.13	205.84	1.00018	0.00049	1.00116
	0.13	205.81	1.00107	0.00049	1.00205
	0.13	205.89	0.99974	0.00049	1.00072
	0.13	206.24	0.99644	0.00045	0.99734
	0.13	205.95	0.99687	0.00049	0.99785
	0.15	204.28	1.00158	0.00048	1.00254
	0.15	204.49	0.99736	0.00049	0.99834
	0.15	204.80	0.99749	0.00049	0.99847
	0.14	205.16	0.99797	0.00042	0.99881
	0.14	205.42	0.99776	0.00049	0.99874
	0.14	205.53	0.99670	0.00049	0.99768
	0.14	205.64	0.99692	0.00049	0.99790
	0.14	205.74	0.99578	0.00049	0.99676
	0.13	205.86	0.99625	0.00049	0.99723
	0.13	205.86	0.99797	0.00049	0.99895
	0.13	206.07	0.99794	0.00048	0.99890
	0.14	205.77	1.00061	0.00049	1.00159
	0.13	205.88	0.99494	0.00049	0.99592
	0.17	202.70	1.00092	0.00049	1.00190
	0.17	203.21	1.00066	0.00045	1.00156
	0.16	203.81	0.99881	0.00049	0.99979
	0.16	203.72	0.99928	0.00049	1.00026
	0.16	203.82	0.99931	0.00045	1.00021
	0.16	203.90	1.00118	0.00049	1.00216
	0.16	203.97	1.00021	0.00049	1.00119
	0.14	204.94	0.99721	0.00046	0.99813
	0.13	205.84	0.99964	0.00047	1.00058
	0.13	206.38	0.99948	0.00049	1.00046
	0.13	206.69	0.99926	0.00049	1.00024
	0.12	206.91	0.99888	0.00049	0.99986

Table 6.8.2-20
Experimental Parameters of Critical Experiments with Burnup Credit Assumptions from KENO V.a/KENO-VI Inputs
5 Pages

	Fuel Radius (cm)	Pitch (cm)	Enrichment (wt. %)	H/X * Mod/Fuel Ratio	Mod/Fuel Ratio	Pu/(U+Pu)
	0.6414	1.7780	0.71	146.63	1.1946	0.02
	0.6414	1.7780	0.71	146.58	1.1946	0.02
	0.6414	2.2091	0.71	309.90	2.5249	0.02
	0.6414	2.2091	0.71	309.75	2.5249	0.02
	0.6414	2.5145	0.71	446.89	3.6410	0.02
	0.6414	2.5145	0.71	446.73	3.6410	0.02
	0.5325	1.8250	0.71	437.88	2.4201	0.03
	0.5325	1.8250	0.71	437.88	2.4201	0.03
	0.5325	1.8250	0.71	437.88	2.4201	0.03
	0.5325	1.9560	0.71	538.48	2.9761	0.03
	0.5325	1.9560	0.71	538.48	2.9761	0.03
	0.5325	1.9560	0.71	538.48	2.9761	0.03
	0.5325	2.2250	0.71	766.92	4.2387	0.03
	0.5325	2.2250	0.71	766.92	4.2387	0.03
	0.5325	2.2250	0.71	766.92	4.2387	0.03
	0.5325	2.4740	0.71	1004.57	5.5521	0.03
	0.5325	2.4740	0.71	1004.57	5.5521	0.03
	0.6318	2.1590	0.71	165.70	1.9313	0.04
	0.6318	2.3622	0.71	220.13	2.5656	0.04
	0.6318	2.6670	0.71	310.94	3.6242	0.04
	0.6318	2.9032	0.71	388.90	4.5327	0.04
	0.6318	3.5204	0.71	623.79	7.2706	0.04
	0.6318	4.0640	0.71	868.04	10.1173	0.04
	0.6318	4.3180	0.71	994.17	11.5875	0.04
	0.6414	2.0320	0.71	186.01	1.5154	0.02
	0.6414	2.3622	0.71	305.36	2.4878	0.02
	0.6414	2.6670	0.71	431.45	3.5152	0.02
	0.6414	2.9032	0.71	539.69	4.3970	0.02
	0.6414	3.3528	0.71	771.05	6.2819	0.02
	0.6414	3.5204	0.71	865.83	7.0541	0.02
	0.6414	2.6670	0.71	431.45	3.5152	0.02
	0.6414	2.6670	0.71	431.45	3.5152	0.02
	0.6414	2.6670	0.71	431.45	3.5152	0.02
	0.6414	2.6670	0.71	431.45	3.5152	0.02
	0.6414	2.6670	0.71	431.45	3.5152	0.02
	0.6414	2.6670	0.71	431.45	3.5152	0.02
	0.6414	2.6670	0.71	431.45	3.5152	0.02
	0.6414	2.6670	0.71	431.45	3.5152	0.02
	0.6414	2.6670	0.71	431.45	3.5152	0.02

Table 6.8.2-20
Experimental Parameters of Critical Experiments with Burnup Credit Assumptions from KENO V.a/KENO-VI Inputs
5 Pages

Fuel Radius (cm)	Pitch (cm)	Enrichment (wt. %)	H/X * Mod/Fuel Ratio	Mod/Fuel Ratio	Pu/(U+Pu)
0.6414	2.6670	0.71	431.45	3.5152	0.02
0.6414	3.3528	0.71	771.05	6.2819	0.02
0.6414	3.3528	0.71	771.05	6.2819	0.02
0.6414	3.3528	0.71	771.05	6.2819	0.02
0.6414	3.3528	0.71	771.05	6.2819	0.02
0.6414	3.3528	0.71	771.05	6.2819	0.02
0.6414	3.3528	0.71	771.05	6.2819	0.02
0.6414	3.3528	0.71	771.05	6.2819	0.02
0.6414	3.3528	0.71	771.05	6.2819	0.02
0.6414	3.3528	0.71	771.05	6.2819	0.02
0.6414	3.3528	0.71	771.05	6.2819	0.02
0.6414	2.3622	0.71	337.05	2.4878	0.02
0.6414	2.6670	0.71	475.96	3.5152	0.02
0.6414	2.9032	0.71	595.63	4.3969	0.02
0.6414	3.3528	0.71	849.98	6.2819	0.02
0.6414	3.5204	0.71	954.71	7.0539	0.02
0.6414	2.0320	0.71	223.04	1.5154	0.02
0.6414	2.3622	0.71	366.15	2.4878	0.02
0.6414	2.6670	0.71	517.35	3.5152	0.02
0.6414	2.9032	0.71	647.12	4.3969	0.02
0.6414	3.3528	0.71	924.55	6.2819	0.02
0.6414	3.5204	0.71	1038.17	7.0539	0.02
0.6414	2.6670	0.71	517.35	3.5152	0.02
0.6414	2.6670	0.71	517.35	3.5152	0.02
0.6414	2.6670	0.71	517.35	3.5152	0.02
0.6414	2.6670	0.71	517.35	3.5152	0.02
0.6414	2.6670	0.71	517.35	3.5152	0.02
0.6414	2.6670	0.71	517.35	3.5152	0.02
0.6414	2.6670	0.71	517.35	3.5152	0.02
0.6414	2.6670	0.71	517.35	3.5152	0.02
0.6414	2.6670	0.71	517.35	3.5152	0.02
0.6414	2.6670	0.71	517.35	3.5152	0.02
0.4724	1.3970	0.16	227.51	1.1112	0.01
0.4724	1.5240	0.16	321.32	1.5694	0.01
0.4724	1.8034	0.16	556.40	2.7176	0.01
0.4724	2.0320	0.16	778.10	3.8005	0.01
0.4724	2.2860	0.16	1055.43	5.1551	0.01
0.4724	2.3622	0.16	1144.99	5.5925	0.01

Table 6.8.2-20
Experimental Parameters of Critical Experiments with Burnup Credit Assumptions from KENO V.a/KENO-VI Inputs
5 Pages

	Fuel Radius (cm)	Pitch (cm)	Enrichment (wt. %)	H/X * Mod/Fuel Ratio	Mod/Fuel Ratio	Pu/(U+Pu)
	0.3970	2.3000	1.57	1175.71	9.2522	0.01
	0.3970	2.3000	1.57	1175.71	9.2522	0.01
	0.3970	2.3000	1.57	1175.71	9.2522	0.01
	0.3970	1.9000	1.57	744.56	5.8593	0.01
	0.3970	1.9000	1.57	744.56	5.8593	0.01
	0.3970	1.9000	1.57	744.56	5.8593	0.01
	0.3970	1.7000	1.57	559.78	4.4051	0.01
	0.3970	1.7000	1.57	559.78	4.4051	0.01
	0.3970	1.7000	1.57	559.78	4.4051	0.01
	0.3970	1.5000	1.57	395.53	3.1126	0.01
	0.3970	1.5000	1.57	395.53	3.1126	0.01
	0.3970	1.5000	1.57	395.53	3.1126	0.01
	0.3970	1.3000	1.57	251.81	1.9816	0.01
	0.3970	1.3000	1.57	251.81	1.9816	0.01
	0.3970	1.3000	1.57	251.81	1.9816	0.01
	0.3970	1.7000	1.57	559.78	4.4051	0.01
	0.3970	1.7000	1.57	559.78	4.4051	0.01
	0.3970	1.7000	1.57	559.78	4.4051	0.01
	0.3970	1.6000	1.57	475.09	3.7387	0.01
	0.3970	1.6000	1.57	475.09	3.7387	0.01
	0.3970	1.6000	1.57	475.09	3.7387	0.01
	0.3970	1.6000	1.57	475.09	3.7387	0.01
	0.3970	1.6000	1.57	475.09	3.7387	0.01
	0.3970	1.6000	1.57	475.09	3.7387	0.01
	0.3970	1.6000	1.57	475.09	3.7387	0.01
	0.3970	1.6000	1.57	475.09	3.7387	0.01
	0.3970	1.6000	1.57	475.09	3.7387	0.01
	0.3970	1.6000	1.57	475.09	3.7387	0.01
	0.3970	1.6000	1.57	475.09	3.7387	0.01
	0.3970	1.6000	1.57	475.09	3.7387	0.01
	0.3970	1.6000	1.57	475.09	3.7387	0.01
	0.3970	1.6000	1.57	475.09	3.7387	0.01
	0.3970	1.6000	1.57	475.09	3.7387	0.01
	0.3970	1.6000	1.57	475.09	3.7387	0.01
	0.3970	1.6000	1.57	475.09	3.7387	0.01
	0.3970	1.6000	1.57	475.09	3.7387	0.01
	0.3970	1.6000	1.57	475.09	3.7387	0.01
	0.3970	1.6000	1.57	475.09	3.7387	0.01
	0.3970	1.6000	1.57	475.09	3.7387	0.01

Table 6.8.2-20
Experimental Parameters of Critical Experiments with Burnup Credit Assumptions from KENO V.a/KENO-VI Inputs
5 Pages

	Fuel Radius (cm)	Pitch (cm)	Enrichment (wt. %)	H/X * Mod/Fuel Ratio	Mod/Fuel Ratio	Pu/(U+Pu)
	0.3970	1.6000	1.57	475.09	3.7387	0.01
	0.3970	1.6000	1.57	475.09	3.7387	0.01
	0.3970	1.6000	1.57	475.09	3.7387	0.01
	0.3970	1.6000	1.57	475.09	3.7387	0.01
	0.3970	1.6000	1.57	475.09	3.7387	0.01
	0.3970	1.6000	1.57	475.09	3.7387	0.01
	0.3970	1.6000	1.57	475.09	3.7387	0.01
	0.3970	1.6000	1.57	475.09	3.7387	0.01
	0.3970	1.6000	1.57	475.09	3.7387	0.01
	0.3970	1.6000	1.57	475.09	3.7387	0.01
	0.3970	1.6000	1.57	475.09	3.7387	0.01
	0.3970	1.6000	1.57	475.09	3.7387	0.01
	0.3970	1.6000	1.57	475.09	3.7387	0.01
	0.3970	1.6000	1.57	475.09	3.7387	0.01
	0.3970	1.6000	1.57	475.09	3.7387	0.01
	0.3970	1.6000	1.57	475.09	3.7387	0.01
	0.3970	1.6000	1.57	475.09	3.7387	0.01
	0.3970	1.6000	1.57	475.09	3.7387	0.01
	0.3970	1.6000	1.57	475.09	3.7387	0. 01
	0.3970	1.6000	1.57	475.09	3.7387	0.01
	0.3970	1.6000	1.57	475.09	3.7387	0.01
	0.3970	1.6000	1.57	475.09	3.7387	0.01
	0.3970	1.6000	1.57	475.09	3.7387	0.01
	0.3970	1.6000	1.57	475.09	3.7387	0.01
	0.3970	1.6000	1.57	475.09	3.7387	0.01
	0.3970	1.6000	1.57	475.09	3.7387	0.01
	0.3970	1.6000	1.57	475.09	3.7387	0.01
	0.3970	1.6000	1.57	475.09	3.7387	0.01
	0.3970	1.6000	1.57	475.09	3.7387	0.01
	0.3970	1.6000	1.57	475.09	3.7387	0.01
	0.3970	1.6000	1.57	475.09	3.7387	0.01
	0.3970	1.6000	1.57	475.09	3.7387	0.01
	0.3970	1.6000	1.57	475.09	3.7387	0.01
	0.3970	1.6000	1.57	475.09	3.7387	0.01
	0.3970	1.6000	1.57	475.09	3.7387	0.01
	0.3970	1.6000	1.57	475.09	3.7387	0.01
	0.3970	1.6000	1.57	475.09	3.7387	0.01
	0.3970	1.6000	1.57	475.09	3.7387	0.01
	0.3970	1.6000	1.57	475.09	3.7387	0.01

Table 6.8.2-20
Experimental Parameters of Critical Experiments with Burnup Credit Assumptions from KENO V.a/KENO-VI Inputs
5 Pages

Fuel Radius (cm)	Pitch (cm)	Enrichment (wt. %)	H/X * Mod/Fuel Ratio	Mod/Fuel Ratio	Pu/(U+Pu)
0.3970	1.6000	1.57	475.09	3.7387	0.01
0.3970	1.6000	1.57	475.09	3.7387	0.01

Table 6.8.2-20a
Range of Applicability For fresh and Burnup Credit Assumptions

Parameter	Range of Applicability		EOS-37PTH Parameters
	Fresh Fuel Assumptions	Burnup Credit Assumptions	
Fuel Enrichment (wt. % U-235)	2.35 – 4.74	0.16 – 1.59	1.60 – 5.0
Fuel Rod Radius (cm)	0.395 – 0.633	0.397 – 0.641	0.47498 - 0.54610
Fuel Pitch (cm)	1.30 – 2.54	1.30 – 4.32	1.25984 - 1.44272
Assembly Separation (cm)	2.690 – 15.393	-	0.3048 - 0.8331
AEG	33.39 – 36.32	187 - 214	(1)
EALF (eV)	0.09 – 0.39	0.07 – 0.71	(1)
Hydrogen to Fissile Density Ratio (H/X)	49.47 – 455.58	134.40 – 1204.74	(1)
Moderator to Fuel Ratio	1.60 – 3.88	1.11 – 11.59	(1)
Plutonium Content	-	0.01 – 0.04	(1)

1. Values varies depending on the fuel enrichment specification

Table 6.8.2-21
Correlation Coefficient determined from Critical Experiments with Fresh Fuel Assumptions

Parameters	Irl
Mod./Fuel Ratio	0.1751
(H/X) * (Mod/Fuel Ratio)	0.1261
Pitch	0.0314
Enrichment	0.2768
Fuel Radius	0.3514
EALF	0.3838
AEG	0.4254
Assembly Separation	**0.4418**

Table 6.8.2-22
Correlation Coefficient determined from Critical Experiments with Burnup Credit Assumptions – PWR Fuel

Parameters	Irl
Pitch	0.0009
(H/X) * (Mod/Fuel Ratio)	0.0088
Fuel Radius	0.0721
Pu Wt. Fraction	0.1105
AEG	0.1183
EALF	0.1347
Enrichment	0.1500
Mod./Fuel Ratio	**0.1586**

Table 6.8.2-23
Calculation of Minor Actinide and Fission Product Worth

Cooling Time (Yrs.)	Burnup (GWd/MTU)	Major Actinides Only			Including Minor Actinide & Fission Product			Minor Actinide & Fission Product Worth
		k_{KENO}	σ	k_{eff}	k_{KENO}	σ	k_{eff}	
5	10	1.1484	0.0005	1.1494	1.1115	0.0004	1.1124	0.037
	15	1.1325	0.0005	1.1335	1.0904	0.0005	1.0913	0.042
	30	1.0739	0.0005	1.0749	1.0028	0.0005	1.0037	0.071
	50	**1.0071**	**0.0005**	**1.0080**	**0.9030**	**0.0004**	**0.9037**	**0.104**
10	10	1.1473	0.0005	1.1482	1.1103	0.0005	1.1113	0.037
	15	1.1304	0.0005	1.1314	1.0883	0.0004	1.0891	0.042
	30	1.0628	0.0005	1.0638	0.9951	0.0005	0.9960	0.068
	50	**0.9870**	**0.0005**	**0.9880**	**0.8852**	**0.0004**	**0.8860**	**0.102**
15	10	1.1444	0.0005	1.1454	1.1096	0.0004	1.1104	0.035
	15	1.1283	0.0005	1.1293	1.0874	0.0004	1.0882	0.041
	30	1.0575	0.0005	1.0584	0.9898	0.0005	0.9907	0.068
	50	**0.9732**	**0.0005**	**0.9741**	**0.8739**	**0.0005**	**0.8749**	**0.099**
20	10	1.1447	0.0005	1.1457	1.1088	0.0005	1.1098	0.036
	15	1.1272	0.0005	1.1281	1.0854	0.0005	1.0864	0.042
	30	1.0533	0.0004	1.0540	0.9848	0.0005	0.9857	0.068
	50	**0.9625**	**0.0005**	**0.9634**	**0.8646**	**0.0005**	**0.8655**	**0.098**

Table 6.8.2-24
Design Input for the Burnable Poison Rod in the WE 14x14 Fuel Class

BP Material	B_2O_3-SiO_2	
Boron Loading	12.5 wt. % B_2O_3, 0.00624 g B-10/cm	
BP Density (g/cc)	2.299	
BPR Clad Material	SS-304	
BPR Inner Clad IR (cm)	0.283845*	Air
BPR Inner Clad OR (cm)	0.300355**	SS-304
BP Inner Radius (cm)	0.309880	Air
BP Outer Radius (cm)	0.494030	B_2O_3-SiO_2
BPR Outer Clad IR (cm)	0.499618	Air
BPR Outer Clad OR (cm)	0.547370	SS-304

Note: The B_2O_3-SiO_2 absorber material is smeared between the inner and outer clad regions by adjusting its density by the ratio of the actual area and smeared area. B_2O_3-SiO_2 absorber material density of 2.13 g/cc is used in T-DEPL models.

* The inner radius of the inner clad is modeled equal to 0.28321 cm in the T-DEPL model.
** The outer radius of the inner clad is modeled equal to 0.29972 cm in the T-DEPL model. Thickness of inner clad (SS-304) is conserved.

Table 6.8.2-25
Design Input for the Control Rod Fingers in the WE 14x14 Fuel Class

Zone Number	Material	Outer Radius (cm)
1	Ag-In-Cd*	0.495935
2	Gap	0.499618
3	SS-304	0.547370

* Material Composition (wt. %): Ag (80%) – In (15%) – Cd (5%).

Table 6.8.2-26
Design Input for the Burnable Poison Rod in the B&W 15x15 Fuel Class

BP Material	B_4C-Al_2O_3
BP density (g/cc)	3.70
BP Radius (cm)	0.4318
BPR Clad Material	Zr-4
BPR Clad IR (cm)	0.4572
BPR Clad OR (cm)	0.5461

Table 6.8.2-27
Design Input for the Control Rod Fingers in the B&W 15x15 Mark B-10 Fuel Assembly

Absorber Material	Ag (80%) - In (15%) – Cd (5%)
Absorber Pellet Radius (cm)	0.49784
Cladding (SS-304) IR (cm)	0.50546
Cladding (SS-304) OR (cm)	0.55880

Table 6.8.2-28
Design Input for the Burnable Poison Rod in the WE 17x17 Fuel Class

BP Material	B_2O_3-SiO_2	
Boron Loading	12.5 wt. % B_2O_3, 0.00624 g B-10/cm	
BP Density (g/cc)	2.299	
BPR Clad Material	SS-304	
BPR Inner Clad IR (cm)	0.21400	Air
BPR Inner Clad OR (cm)	0.23051	SS-304
BP Inner Radius (cm)	0.24130	Air
BP Outer Radius (cm)	0.42672	B_2O_3-SiO_2
BPR Outer Clad IR (cm)	0.43688	Air
BPR Outer Clad OR (cm)	0.48387	SS-304

Note: The B_2O_3-SiO_2 absorber material is smeared between the inner and outer clad regions by adjusting its density by the ratio of the actual area and smeared area. B_2O_3-SiO_2 absorber material density of 2.067 g/cc is used in T-DEPL models.

Table 6.8.2-29
Design Input for the Control Rod Fingers in the WE 17x17 Fuel Class

Absorber Material	Natural B_4C*/Ag-In-Cd
B_4C Pellet Radius (cm)	0.42418
B_4C Pellet Axial Height (cm)	259.08
Ag-In-Cd Radius (cm)	0.43307
Ag-In-Cd Axial Height (cm)	101.60
Cladding Material	SS-304
Cladding IR (cm)	0.43688
Cladding OR (cm)	0.48387

* B_4C is not used in T-DEPL model as it is not possible to implement axial variation in T-DEPL 2-D model to account for the B_4C and Ag-In-Cd regions

Table 6.8.2-30
Operational Conditions Employed in T-DEPL Calculation

Parameters	Value
Average Fuel Temperature (K)	1100
Average Moderator Density (g/cc)	0.63
Average Moderator Temperature (K)	610
Average Clad Temperature (K)	640
Soluble Boron Concentration (ppm)	1000
Specific Power (MW/MTU)	40
Down Time (Days)	0

Table 6.8.2-31
Comparison of Global Parameters – Maximum Enrichment

Burnup (GWd/MTU)	GBC-32	TN Eagle with EOS-37PTH
	Enrichment (wt.% U-235)	Enrichment (wt.% U-235)
10	2.300	2.347
20	3.023	3.088
30	3.754	3.848
40	4.662	4.770
50	5.000	5.000
60	5.000	5.000

Table 6.8.2-32
Comparison of Global Parameters – Criticality

Burnup (GWd/MTU)	GBC-32			TN Eagle with EOS-37PTH		
	k_{keno}	σ	k_{eff}	k_{keno}	σ	k_{eff}
10	0.9394	0.0004	0.9403	0.9417	0.0005	0.9427
20	0.9408	0.0004	0.9416	0.9403	0.0005	0.9412
30	0.9390	0.0005	0.9400	0.9403	0.0005	0.9413
40	0.9399	0.0005	0.9409	0.9399	0.0005	0.9408
50	0.9204	0.0005	0.9214	0.9126	0.0005	0.9136
60	0.8845	0.0004	0.8854	0.8783	0.0005	0.8792

Table 6.8.2-33
Comparison of Global Parameters – Energy of EALF

Burnup (GWd/MTU)	GBC-32		TN Eagle with EOS-37PTH	
	EALF	σ	EALF	σ
10	0.2034	0.0004	0.2016	0.00032
20	0.2395	0.0004	0.2386	0.00039
30	0.2688	0.0004	0.2684	0.00043
40	0.2999	0.0005	0.3000	0.00044
50	0.3161	0.0005	0.3140	0.00042
60	0.3261	0.0005	0.3251	0.00055

Table 6.8.2-34
Comparison of Global Parameters – Average Fission Energy Group

Burnup (GWd/MTU)	GBC-32		TN Eagle with EOS-37PTH	
	AEG	σ	AEG	σ
10	200.732	0.0190	200.852	0.0161
20	199.022	0.0172	199.087	0.0175
30	197.725	0.0170	197.774	0.0171
40	196.437	0.0187	196.478	0.0167
50	195.879	0.0166	196.037	0.0147
60	195.658	0.0174	195.777	0.0176

Table 6.8.2-35
Comparison of Global Parameters – H/X Ratio

Burnup (GWd/MTU)	GBC-32	TN Eagle with EOS-37PTH
	H/X Ratio	H/X Ratio
10	282	276
20	259	253
30	243	236
40	220	214
50	235	235
60	272	272

Table 6.8.2-36
Similarity Analysis – c_k Parameter Results

Burnup (GWd/MTU)	Correlation Coefficient	
	c_k	σ
10	0.9936	0.001
20	0.9987	0.0005
30	0.9959	0.0007
40	0.9988	0.0005
50	0.9989	0.0005
60	0.9968	0.0004

Table 6.8.2-37
Misload Analysis – Inventory Analysis –DSC results applied to PWR Inventory Data

Poison Configuration	Cooling Time (years)	Multiple Misload Percentage of PWR Inventory Qualified to Load (Goal is ~100%)	Single Misload Percentage of PWR Inventory Qualified to Load (Goal is ~100%)
A	[ ]	[ ]	[ ]
B	[ ]	[ ]	[ ]

Proprietary Information on Pages 6.8.2-63 and 6.8.2-64
Withheld Pursuant to 10 CFR 2.390

Table 6.8.2-42
Acceptable Average Initial Enrichment / Burnup Combinations for BW 15x15 Fuel Class Intact FAs Loaded in EOS-37PTH DSC Type A Placed in TN Eagle Cask

Fresh Fuel		Enrichment (wt. %)	k_{KENO}	σ_{KENO}	k_{eff}	
		1.90	**0.9361**	**0.0004**	**0.9369**	
Cooling Time (Years)	**Burnup (GWd/MTU)**	**Enrichment (wt. %)**	k_{KENO}	σ_{KENO}	k_{KENO} + $2\sigma_{KENO}$	$k_{eff} + (\beta_i+\Delta k_i) + \Delta k_x$
5	5	1.99	0.9238	0.0005	0.9247	0.9397
	10	2.21	0.9244	0.0004	0.9252	0.9400
	15	2.40	0.9232	0.0005	0.9242	0.9399
	20	2.96	0.9232	0.0004	0.9241	0.9395
	25	3.26	0.9236	0.0004	0.9244	0.9398
	30	**3.56**	**0.9235**	**0.0004**	**0.9244**	**0.9405**
	35	4.09	0.9229	0.0005	0.9238	0.9401
	40	4.69	0.9233	0.0004	0.9242	0.9405
	45	4.99	0.9183	0.0004	0.9192	0.9397
	50	5.00	0.9003	0.0004	0.9012	0.9231
10	5	2.02	0.9244	0.0004	0.9252	0.9402
	10	2.23	0.9238	0.0005	0.9248	0.9396
	15	2.44	0.9235	0.0004	0.9244	0.9401
	20	3.06	0.9239	0.0005	0.9249	0.9403
	25	3.39	0.9238	0.0005	0.9248	0.9402
	30	3.71	0.9228	0.0005	0.9237	0.9398
	35	4.28	0.9231	0.0005	0.9241	0.9404
	40	4.93	0.9223	0.0005	0.9233	0.9396
	45	5.00	0.9038	0.0004	0.9047	0.9252
15	5	2.03	0.9238	0.0005	0.9247	0.9397
	10	2.26	0.9246	0.0004	0.9254	0.9402
	15	2.47	0.9232	0.0005	0.9242	0.9399
	20	3.14	0.9241	0.0005	0.9250	0.9404
	25	3.47	0.9234	0.0005	0.9244	0.9398
	30	3.81	0.9223	0.0004	0.9232	0.9393
	35	4.40	0.9229	0.0004	0.9237	0.9400
	40	5.00	0.9177	0.0005	0.9187	0.9350
20	5	2.03	0.9234	0.0005	0.9244	0.9394
	10	2.27	0.9239	0.0005	0.9249	0.9397
	15	2.50	0.9230	0.0005	0.9240	0.9397
	20	3.18	0.9238	0.0005	0.9247	0.9401
	25	3.53	0.9235	0.0005	0.9245	0.9399
	30	3.87	0.9230	0.0005	0.9240	0.9401
	35	4.51	0.9231	0.0005	0.9240	0.9403
	40	5.00	0.9120	0.0004	0.9128	0.9291

Table 6.8.2-43
Acceptable Average Initial Enrichment / Burnup Combinations for BW 15x15 Fuel Class Intact FAs Loaded in EOS-37PTH DSC Type B Placed in TN Eagle Cask

Fresh Fuel		Enrichment (wt. %)	k_{KENO}	σ_{KENO}	k_{eff}	
		1.95	**0.9356**	**0.0004**	**0.9364**	
Cooling Time (Years)	**Burnup (GWd/MTU)**	**Enrichment (wt. %)**	k_{KENO}	σ_{KENO}	$k_{KENO} + 2\sigma_{KENO}$	$k_{eff} + (\beta_i+\Delta k_i) + \Delta k_x$
5	5	2.06	0.9243	0.0004	0.9252	0.9402
	10	2.29	0.9244	0.0005	0.9253	0.9401
	15	2.48	0.9230	0.0005	0.9240	0.9397
	20	3.06	0.9239	0.0004	0.9247	0.9401
	25	3.38	0.9237	0.0004	0.9245	0.9399
	30	3.68	0.9228	0.0005	0.9238	0.9399
	35	4.22	0.9229	0.0005	0.9238	0.9401
	40	4.85	0.9223	0.0004	0.9231	0.9394
	45	5.00	0.9109	0.0004	0.9118	0.9323
10	5	2.08	0.9234	0.0005	0.9244	0.9394
	10	2.32	0.9246	0.0005	0.9255	0.9403
	15	2.53	0.9229	0.0005	0.9239	0.9396
	20	3.16	0.9242	0.0004	0.9251	0.9405
	25	3.51	0.9232	0.0005	0.9241	0.9395
	30	3.84	0.9235	0.0005	0.9244	0.9405
	35	4.43	0.9231	0.0005	0.9241	0.9404
	40	5.00	0.9185	0.0005	0.9194	0.9357
15	5	2.09	0.9236	0.0005	0.9246	0.9396
	10	2.34	0.9243	0.0005	0.9253	0.9401
	15	2.56	0.9236	0.0005	0.9246	0.9403
	20	3.24	0.9239	0.0004	0.9248	0.9402
	25	3.60	0.9233	0.0005	0.9243	0.9397
	30	3.94	0.9232	0.0005	0.9241	0.9402
	35	4.56	0.9231	0.0005	0.9241	0.9404
	40	5.00	0.9097	0.0005	0.9107	0.9270
20	5	2.11	0.9241	0.0004	0.9250	0.9400
	10	2.35	0.9237	0.0005	0.9246	0.9394
	15	2.59	0.9236	0.0005	0.9245	0.9402
	20	3.29	0.9238	0.0005	0.9248	0.9402
	25	3.65	0.9242	0.0005	0.9252	0.9406
	30	4.01	0.9231	0.0005	0.9241	0.9402
	35	4.66	0.9225	0.0005	0.9235	0.9398
	40	5.00	0.9032	0.0005	0.9042	0.9205

Table 6.8.2-44
Acceptable Average Initial Enrichment / Burnup Combinations for WE 17x17 Fuel Class Intact FAs Loaded in EOS-37PTH DSC Type A Placed in TN Eagle Cask

Fresh Fuel		Enrichment (wt. %)	k_{KENO}	σ_{KENO}	k_{eff}	
		1.95	**0.9344**	**0.0005**	**0.9354**	
Cooling Time (Years)	**Burnup (GWd/MTU)**	**Enrichment (wt. %)**	**k_{KENO}**	**σ_{KENO}**	**k_{KENO} + $2\sigma_{KENO}$**	**k_{eff} + (β_i+Δk_i) + Δk_x**
5	5	2.05	0.9240	0.0005	0.9250	0.9400
	10	2.26	0.9237	0.0005	0.9246	0.9394
	15	2.45	0.9235	0.0005	0.9244	0.9401
	20	3.03	0.9240	0.0004	0.9249	0.9403
	25	3.33	0.9236	0.0005	0.9245	0.9399
	30	3.62	0.9232	0.0005	0.9242	0.9403
	35	4.13	0.9223	0.0005	0.9233	0.9396
	40	4.74	0.9228	0.0005	0.9237	0.9400
	45	5.00	0.9166	0.0005	0.9176	0.9381
10	5	2.07	0.9242	0.0005	0.9251	0.9401
	10	2.30	0.9242	0.0005	0.9252	0.9400
	15	2.50	0.9237	0.0004	0.9244	0.9401
	20	3.13	0.9233	0.0005	0.9243	0.9397
	25	3.45	0.9232	0.0005	0.9241	0.9395
	30	3.77	0.9227	0.0005	0.9236	0.9397
	35	**4.33**	**0.9235**	**0.0005**	**0.9245**	**0.9408**
	40	5.00	0.9237	0.0004	0.9245	0.9408
15	5	2.07	0.9234	0.0005	0.9244	0.9394
	10	2.31	0.9243	0.0005	0.9252	0.9400
	15	2.53	0.9227	0.0004	0.9236	0.9393
	20	3.19	0.9235	0.0005	0.9245	0.9399
	25	3.54	0.9234	0.0005	0.9244	0.9398
	30	3.88	0.9226	0.0005	0.9236	0.9397
	35	4.48	0.9228	0.0005	0.9238	0.9401
	40	5.00	0.9148	0.0005	0.9158	0.9321
20	5	2.08	0.9238	0.0005	0.9248	0.9398
	10	2.32	0.9240	0.0004	0.9248	0.9396
	15	2.56	0.9236	0.0005	0.9245	0.9402
	20	3.23	0.9235	0.0005	0.9244	0.9398
	25	3.60	0.9236	0.0005	0.9245	0.9399
	30	3.94	0.9231	0.0005	0.9241	0.9402
	35	4.56	0.9229	0.0005	0.9238	0.9401
	40	5.00	0.9076	0.0005	0.9085	0.9248

Table 6.8.2-45
Acceptable Average Initial Enrichment / Burnup Combinations for WE 17x17 Fuel Class Intact FAs Loaded in EOS-37PTH DSC Type B Placed in TN Eagle Cask

Fresh Fuel		Enrichment (wt. %)	k_{KENO}	σ_{KENO}	k_{eff}	
		2.00	**0.9347**	**0.0004**	**0.9355**	
Cooling Time (Years)	**Burnup (GWd/MTU)**	**Enrichment (wt. %)**	k_{KENO}	σ_{KENO}	k_{KENO} + $2\sigma_{KENO}$	$k_{eff} + (\beta_i+\Delta k_i) + \Delta k_x$
5	5	2.12	0.9236	0.0005	0.9246	0.9396
	10	2.35	0.9246	0.0005	0.9255	0.9403
	15	2.55	0.9235	0.0005	0.9244	0.9401
	20	3.13	0.9236	0.0005	0.9246	0.9400
	25	3.44	0.9239	0.0005	0.9249	0.9403
	30	3.75	0.9232	0.0004	0.9240	0.9401
	35	4.29	0.9228	0.0005	0.9237	0.9400
	40	4.90	0.9233	0.0004	0.9241	0.9404
	45	5.00	0.9071	0.0004	0.9080	0.9285
10	5	2.14	0.9242	0.0005	0.9252	0.9402
	10	2.37	0.9240	0.0005	0.9250	0.9398
	15	2.59	0.9227	0.0005	0.9237	0.9394
	20	3.24	0.9240	0.0005	0.9249	0.9403
	25	3.57	0.9238	0.0005	0.9248	0.9402
	30	3.90	0.9230	0.0005	0.9240	0.9401
	35	4.50	0.9224	0.0005	0.9234	0.9397
	40	5.00	0.9145	0.0005	0.9155	0.9318
15	5	2.15	0.9240	0.0005	0.9249	0.9399
	10	2.38	0.9236	0.0004	0.9245	0.9393
	15	2.63	0.9229	0.0005	0.9239	0.9396
	20	3.30	0.9241	0.0004	0.9249	0.9403
	25	3.67	0.9239	0.0005	0.9249	0.9403
	30	4.01	0.9229	0.0005	0.9238	0.9399
	35	4.63	0.9228	0.0005	0.9238	0.9401
	40	5.00	0.9057	0.0004	0.9065	0.9228
20	5	2.15	0.9238	0.0004	0.9247	0.9397
	10	2.40	0.9241	0.0005	0.9251	0.9399
	15	2.65	0.9227	0.0005	0.9236	0.9393
	20	3.36	0.9240	0.0005	0.9249	0.9403
	25	3.71	0.9236	0.0005	0.9246	0.9400
	30	4.08	0.9233	0.0005	0.9242	0.9403
	35	4.71	0.9229	0.0005	0.9239	0.9402
	40	5.00	0.8994	0.0004	0.9003	0.9166

Table 6.8.2-46
Acceptable Average Initial Enrichment / Burnup Combinations for WE 14x14 Fuel Class Intact FAs Loaded in EOS-37PTH DSC Type A Placed in TN Eagle Cask

Fresh Fuel		Enrichment (wt. %)	k_{KENO}	σ_{KENO}	k_{eff}	
		2.25	**0.9367**	**0.0004**	**0.9375**	
Cooling Time (Years)	**Burnup (GWd/MTU)**	**Enrichment (wt. %)**	k_{KENO}	σ_{KENO}	$k_{KENO} + 2\sigma_{KENO}$	$k_{eff} + (\beta_i+\Delta k_i) + \Delta k_x$
5	5	2.42	0.9242	0.0004	0.9250	0.9400
	10	2.68	0.9244	0.0005	0.9254	0.9402
	15	2.90	0.9234	0.0005	0.9243	0.9400
	20	3.58	0.9235	0.0005	0.9245	0.9399
	25	3.91	0.9237	0.0005	0.9247	0.9401
	30	4.27	0.9223	0.0005	0.9233	0.9394
	35	4.89	0.9230	0.0005	0.9239	0.9402
	40	5.00	0.8989	0.0005	0.8999	0.9162
10	5	2.44	0.9241	0.0005	0.9251	0.9401
	10	2.70	0.9240	0.0005	0.9249	0.9397
	15	2.95	0.9230	0.0005	0.9239	0.9396
	20	**3.68**	**0.9242**	**0.0003**	**0.9249**	**0.9403**
	25	4.06	0.9236	0.0005	0.9246	0.9400
	30	4.42	0.9224	0.0005	0.9234	0.9395
	35	5.00	0.9195	0.0005	0.9205	0.9368
15	5	2.44	0.9237	0.0004	0.9245	0.9395
	10	2.73	0.9245	0.0005	0.9254	0.9402
	15	2.99	0.9231	0.0005	0.9241	0.9398
	20	3.75	0.9236	0.0005	0.9245	0.9399
	25	4.15	0.9232	0.0004	0.9240	0.9394
	30	4.53	0.9224	0.0005	0.9234	0.9395
	35	5.00	0.9117	0.0004	0.9125	0.9288
20	5	2.45	0.9242	0.0005	0.9252	0.9402
	10	2.75	0.9240	0.0005	0.9249	0.9397
	15	3.01	0.9235	0.0005	0.9244	0.9401
	20	3.81	0.9238	0.0004	0.9245	0.9399
	25	4.21	0.9238	0.0005	0.9247	0.9401
	30	4.61	0.9228	0.0004	0.9237	0.9398
	35	5.00	0.9082	0.0005	0.9092	0.9255

Table 6.8.2-47
Acceptable Average Initial Enrichment / Burnup Combinations for WE 14x14 Fuel Class Intact FAs Loaded in EOS-37PTH DSC Type B Placed in TN Eagle Cask

Fresh Fuel		**Enrichment (wt. %)**	**k_{KENO}**	**σ_{KENO}**	**k_{eff}**	
		2.30	**0.9352**	**0.0005**	**0.9362**	
Cooling Time (Years)	**Burnup (GWd/MTU)**	**Enrichment (wt. %)**	**k_{KENO}**	**σ_{KENO}**	**k_{KENO} + $2\sigma_{KENO}$**	**$k_{eff} + (\beta_i+\Delta k_i) + \Delta k_x$**
5	5	2.51	0.9241	0.0005	0.9251	0.9401
	10	2.78	0.9238	0.0005	0.9247	0.9395
	15	3.02	0.9234	0.0005	0.9244	0.9401
	20	3.72	0.9237	0.0005	0.9247	0.9401
	25	**4.09**	**0.9239**	**0.0005**	**0.9249**	**0.9403**
	30	4.44	0.9228	0.0005	0.9238	0.9399
	35	5.00	0.9215	0.0005	0.9225	0.9388
10	5	2.52	0.9240	0.0005	0.9250	0.9400
	10	2.81	0.9241	0.0005	0.9251	0.9399
	15	3.07	0.9230	0.0005	0.9240	0.9397
	20	3.81	0.9234	0.0004	0.9243	0.9397
	25	4.20	0.9233	0.0004	0.9241	0.9395
	30	4.59	0.9231	0.0005	0.9241	0.9402
	35	5.00	0.9114	0.0005	0.9123	0.9286
15	5	2.53	0.9239	0.0005	0.9248	0.9398
	10	2.83	0.9236	0.0005	0.9246	0.9394
	15	3.10	0.9234	0.0005	0.9243	0.9400
	20	3.88	0.9241	0.0004	0.9249	0.9403
	25	4.29	0.9237	0.0005	0.9247	0.9401
	30	4.66	0.9225	0.0005	0.9234	0.9395
	35	5.00	0.9049	0.0005	0.9058	0.9221
20	5	2.53	0.9235	0.0005	0.9245	0.9395
	10	2.84	0.9237	0.0005	0.9246	0.9394
	15	3.12	0.9228	0.0005	0.9238	0.9395
	20	3.93	0.9233	0.0005	0.9243	0.9397
	25	4.36	0.9238	0.0005	0.9248	0.9402
	30	4.77	0.9226	0.0005	0.9236	0.9397
	35	5.00	0.9001	0.0005	0.9010	0.9173

Table 6.8.2-48
Acceptable Average Initial Enrichment / Burnup Combinations for BW 15x15 Fuel Class Failed FAs Loaded in EOS-37PTH DSC Type A Placed in TN Eagle Cask
2 Pages

Fresh Fuel		Enrichment (wt. %)		k_{KENO}	σ_{KENO}	k_{eff}	
		25 IFAs	12 FFAs				
		1.90	**1.70**	**0.9362**	**0.0004**	**0.9372**	
Cooling Time (Yrs.)	**Burnup (GWd/MTU)**	**Enrichment (wt. %)**		k_{KENO}	σ_{KENO}	k_{KENO} + $2\sigma_{KENO}$	k_{eff} + (β_i+Δk_i) + Δk_x
		25 IFAs	**12 FFAs**				
5	5	1.99	1.60	0.9209	0.0005	0.9219	0.9369
	10	2.21	1.80	0.9225	0.0005	0.9235	0.9383
	15	2.40	1.95	0.9230	0.0005	0.9240	0.9397
	20	2.96	2.45	0.9246	0.0005	0.9256	0.9410
	25	3.26	2.55	0.9217	0.0005	0.9227	0.9381
	30	3.56	2.80	0.9228	0.0005	0.9237	0.9398
	35	4.09	3.20	0.9216	0.0005	0.9226	0.9389
	40	4.69	3.65	0.9224	0.0005	0.9233	0.9396
	45	4.99	4.00	0.9182	0.0005	0.9192	0.9397
	50	5.00	4.95	0.9170	0.0005	0.9179	0.9398
	55	5.00	5.00	0.9001	0.0005	0.9011	0.9311
10	5	2.02	1.70	0.9233	0.0005	0.9243	0.9393
	10	2.23	1.80	0.9210	0.0005	0.9220	0.9368
	15	2.44	2.00	0.9222	0.0004	0.9230	0.9387
	20	3.06	2.40	0.9205	0.0005	0.9214	0.9368
	25	3.39	2.70	0.9224	0.0004	0.9232	0.9386
	30	3.71	2.95	0.9207	0.0005	0.9216	0.9377
	35	4.28	3.40	0.9216	0.0005	0.9225	0.9388
	40	4.93	3.85	0.9206	0.0004	0.9214	0.9377
	45	5.00	4.80	0.9176	0.0005	0.9186	0.9391
	50	5.00	5.00	0.9018	0.0005	0.9028	0.9247
15	5	2.03	1.65	0.9213	0.0005	0.9222	0.9372
	10	2.26	1.85	0.9231	0.0005	0.9240	0.9388
	15	2.47	2.05	0.9231	0.0005	0.9241	0.9398
	20	3.14	2.55	0.9241	0.0004	0.9248	0.9402
	25	3.47	2.80	0.9235	0.0005	0.9244	0.9398
	30	3.81	3.05	0.9227	0.0005	0.9237	0.9398
	35	4.40	3.55	0.9222	0.0005	0.9232	0.9395
	40	5.00	4.35	0.9233	0.0005	0.9243	0.9406
	45	5.00	5.00	0.9126	0.0005	0.9136	0.9341

Table 6.8.2-48
Acceptable Average Initial Enrichment / Burnup Combinations for BW 15x15 Fuel Class Failed FAs Loaded in EOS-37PTH DSC Type A Placed in TN Eagle Cask
2 Pages

Fresh Fuel		Enrichment (wt. %)		k_{KENO}	σ_{KENO}	k_{eff}	
		25 IFAs	12 FFAs				
		1.90	**1.70**	**0.9362**	**0.0004**	**0.9372**	
Cooling Time (Yrs.)	**Burnup (GWd/MTU)**	**Enrichment (wt. %)**		**k_{KENO}**	**σ_{KENO}**	**k_{KENO} + $2\sigma_{KENO}$**	**$k_{eff} + (\beta_i+\Delta k_i) + \Delta k_x$**
		25 IFAs	**12 FFAs**				
20	5	2.03	1.70	0.9244	0.0005	0.9254	0.9404
	10	2.27	1.90	0.9240	0.0004	0.9249	0.9397
	15	2.50	2.00	0.9206	0.0005	0.9215	0.9372
	20	3.18	2.50	0.9199	0.0005	0.9209	0.9363
	25	3.53	2.85	0.9224	0.0004	0.9232	0.9386
	30	3.87	3.10	0.9205	0.0005	0.9214	0.9375
	35	4.51	3.60	0.9206	0.0004	0.9215	0.9378
	40	5.00	4.70	0.9226	0.0004	0.9234	0.9397
	45	5.00	5.00	0.9053	0.0005	0.9062	0.9267

Table 6.8.2-49
Acceptable Average Initial Enrichment / Burnup Combinations for BW 15x15 Fuel Class Failed FAs Loaded in EOS-37PTH DSC Type B Placed in TN Eagle Cask

Fresh Fuel		Enrichment (wt. %)		k_{KENO}	σ_{KENO}	k_{eff}	
		25 IFAs	12 FFAs				
		1.90	1.70	0.9377	0.0005	0.9387	
Cooling Time (Yrs.)	Burnup (GWd/MTU)	Enrichment (wt. %)		k_{KENO}	σ_{KENO}	k_{KENO} + $2\sigma_{KENO}$	k_{eff} + (β_i+Δk_i) + Δk_x
		25 IFAs	12 FFAs				
5	5	2.06	1.70	0.9224	0.0004	0.9232	0.9382
	10	2.29	1.80	0.9218	0.0005	0.9228	0.9376
	15	2.48	1.95	0.9207	0.0005	0.9216	0.9373
	20	3.06	2.45	0.9224	0.0005	0.9234	0.9388
	25	3.38	2.65	0.9215	0.0005	0.9225	0.9379
	30	3.68	2.85	0.9220	0.0005	0.9230	0.9391
	35	4.22	3.35	0.9220	0.0005	0.9230	0.9393
	40	4.85	3.80	0.9240	0.0005	0.9250	0.9413
	45	5.00	4.45	0.9190	0.0004	0.9199	0.9404
	50	5.00	5.00	0.9109	0.0005	0.9119	0.9338
10	5	2.08	1.70	0.9218	0.0005	0.9227	0.9377
	10	2.32	1.85	0.9218	0.0005	0.9227	0.9375
	15	2.53	2.00	0.9215	0.0005	0.9225	0.9382
	20	3.16	2.50	0.9214	0.0005	0.9224	0.9378
	25	3.51	2.70	0.9209	0.0005	0.9219	0.9373
	30	3.84	3.05	0.9224	0.0004	0.9232	0.9393
	35	4.43	3.45	0.9207	0.0004	0.9215	0.9378
	40	5.00	4.25	0.9232	0.0004	0.9240	0.9403
	45	5.00	5.00	0.9148	0.0004	0.9157	0.9362
15	5	2.09	1.75	0.9227	0.0004	0.9236	0.9386
	10	2.34	1.85	0.9207	0.0005	0.9217	0.9365
	15	2.56	2.05	0.9214	0.0004	0.9222	0.9379
	20	3.24	2.60	0.9230	0.0004	0.9238	0.9392
	25	3.60	2.90	0.9233	0.0005	0.9242	0.9396
	30	3.94	3.10	0.9210	0.0005	0.9220	0.9381
	35	4.56	3.65	0.9221	0.0005	0.9230	0.9393
	40	5.00	4.75	0.9225	0.0005	0.9234	0.9397
	45	5.00	5.00	0.9050	0.0004	0.9059	0.9264
20	5	2.11	1.75	0.9234	0.0005	0.9243	0.9393
	10	2.35	1.95	0.9247	0.0005	0.9257	0.9405
	15	2.59	2.10	0.9221	0.0005	0.9230	0.9387
	20	3.29	2.65	0.9229	0.0005	0.9239	0.9393
	25	3.65	2.95	0.9225	0.0005	0.9234	0.9388
	30	4.01	3.20	0.9217	0.0005	0.9226	0.9387
	35	4.66	3.70	0.9204	0.0005	0.9214	0.9377
	40	5.00	5.00	0.9208	0.0004	0.9217	0.9380

Table 6.8.2-50
Acceptable Average Initial Enrichment / Burnup Combinations for WE 17x17 Fuel Class Failed FAs Loaded in EOS-37PTH DSC Type A Placed in TN Eagle Cask
2 Pages

Fresh Fuel		Enrichment (wt. %)		k_{KENO}	σ_{KENO}	k_{eff}	
		25 IFAs	12 FFAs				
		1.95	**1.75**	**0.9391**	**0.0005**	**0.9401**	
Cooling Time (Yrs.)	**Burnup (GWd/MTU)**	**Enrichment (wt. %)**		**k_{KENO}**	**σ_{KENO}**	**k_{KENO} + $2\sigma_{KENO}$**	**k_{eff} + $(\beta_i+\Delta k_i)$ + Δk_x**
		25 IFAs	**12 FFAs**				
5	5	2.05	1.65	0.9230	0.0005	0.9239	0.9389
	10	2.26	1.75	0.9028	0.0005	0.9038	0.9186
	15	2.45	1.85	0.9194	0.0004	0.9203	0.9360
	20	3.03	2.30	0.9221	0.0004	0.9228	0.9382
	25	3.33	2.45	0.9200	0.0005	0.9210	0.9364
	30	3.62	2.80	0.9226	0.0005	0.9236	0.9397
	35	4.13	3.15	0.9208	0.0005	0.9217	0.9380
	40	4.74	3.65	0.9218	0.0005	0.9227	0.9390
	45	5.00	4.05	0.9188	0.0005	0.9198	0.9403
	50	5.00	5.00	0.9177	0.0005	0.9186	0.9405
10	5	2.07	1.65	0.9241	0.0005	0.9251	0.9401
	10	2.30	1.85	0.9251	0.0004	0.9260	0.9408
	15	2.50	1.95	0.9225	0.0005	0.9234	0.9391
	20	3.13	2.40	0.9232	0.0003	0.9238	0.9392
	25	3.45	2.70	0.9236	0.0005	0.9246	0.9400
	30	3.77	2.90	0.9209	0.0004	0.9218	0.9379
	35	4.33	3.40	0.9001	0.0005	0.9011	0.9174
	40	5.00	4.00	0.9229	0.0005	0.9238	0.9401
	45	5.00	4.90	0.9186	0.0005	0.9196	0.9401
	50	5.00	5.00	0.9018	0.0005	0.9028	0.9247
15	5	2.07	1.65	0.9031	0.0005	0.9041	0.9191
	10	2.31	1.80	0.9220	0.0005	0.9229	0.9377
	15	2.53	2.00	0.9020	0.0005	0.9030	0.9187
	20	3.19	2.45	0.9218	0.0005	0.9228	0.9382
	25	3.54	2.75	0.9230	0.0005	0.9239	0.9393
	30	3.88	3.00	0.9223	0.0005	0.9233	0.9394
	35	4.48	3.55	0.9215	0.0005	0.9224	0.9387
	40	5.00	4.50	0.9220	0.0005	0.9229	0.9392
	45	5.00	5.00	0.9105	0.0005	0.9115	0.9320

Table 6.8.2-50
Acceptable Average Initial Enrichment / Burnup Combinations for WE 17x17 Fuel Class Failed FAs Loaded in EOS-37PTH DSC Type A Placed in TN Eagle Cask
2 Pages

Fresh Fuel		Enrichment (wt. %)		k_{KENO}	σ_{KENO}	k_{eff}	
		25 IFAs	12 FFAs				
		1.95	1.75	0.9391	0.0005	0.9401	
Cooling Time (Yrs.)	Burnup (GWd/MTU)	Enrichment (wt. %)		k_{KENO}	σ_{KENO}	k_{KENO} + $2\sigma_{KENO}$	$k_{eff} + (\beta_i + \Delta k_i) + \Delta k_x$
		25 IFAs	12 FFAs				
20	5	2.08	1.65	0.9217	0.0004	0.9225	0.9375
	10	2.32	1.85	0.9034	0.0005	0.9044	0.9192
	15	2.56	2.00	0.9212	0.0005	0.9222	0.9379
	20	3.23	2.55	0.9232	0.0004	0.9241	0.9395
	25	3.60	2.80	0.9212	0.0005	0.9221	0.9375
	30	3.94	3.05	0.9205	0.0005	0.9215	0.9376
	35	4.56	3.60	0.9215	0.0005	0.9225	0.9388
	40	5.00	4.85	0.9226	0.0004	0.9234	0.9397
	45	5.00	5.00	0.9035	0.0005	0.9045	0.9250

Table 6.8.2-51
Acceptable Average Initial Enrichment / Burnup Combinations for WE 17x17 Fuel Class Failed FAs Loaded in EOS-37PTH DSC Type B Placed in TN Eagle Cask

Fresh Fuel		Enrichment (wt. %)		k_{KENO}	σ_{KENO}	k_{eff}	
		25 IFAs	12 FFAs				
		2.00	**1.65**	**0.9392**	**0.0004**	**0.9400**	
Cooling Time (Yrs.)	**Burnup (GWd/MTU)**	**Enrichment (wt. %)**		k_{KENO}	σ_{KENO}	k_{KENO} + $2\sigma_{KENO}$	k_{eff} + (β_i+Δk_i) + Δk_x
		25 IFAs	**12 FFAs**				
5	5	2.12	1.65	0.9217	0.0005	0.9226	0.9376
	10	2.35	1.80	0.9042	0.0005	0.9052	0.9200
	15	2.55	1.95	0.9024	0.0005	0.9034	0.9191
	20	3.13	2.40	0.9224	0.0005	0.9234	0.9388
	25	3.44	2.60	0.9223	0.0004	0.9231	0.9385
	30	3.75	2.80	0.9214	0.0005	0.9223	0.9384
	35	4.29	3.25	0.9219	0.0005	0.9228	0.9391
	40	4.90	3.65	0.9202	0.0005	0.9211	0.9374
	45	5.00	4.50	0.9184	0.0004	0.9193	0.9398
	50	5.00	5.00	0.9095	0.0005	0.9105	0.9324
10	5	2.14	1.70	0.9226	0.0005	0.9236	0.9386
	10	2.37	1.90	0.9246	0.0004	0.9254	0.9402
	15	2.59	2.00	0.9018	0.0005	0.9027	0.9184
	20	3.24	2.45	0.9222	0.0005	0.9232	0.9386
	25	3.57	2.75	0.9230	0.0005	0.9239	0.9393
	30	3.90	3.05	0.9226	0.0004	0.9234	0.9395
	35	4.50	3.45	0.9026	0.0005	0.9035	0.9198
	40	5.00	4.40	0.9235	0.0004	0.9243	0.9406
	45	5.00	5.00	0.9131	0.0005	0.9140	0.9345
15	5	2.15	1.70	0.9229	0.0004	0.9237	0.9387
	10	2.38	1.90	0.9017	0.0005	0.9027	0.9175
	15	2.63	2.00	0.9027	0.0004	0.9035	0.9192
	20	3.30	2.50	0.9212	0.0004	0.9219	0.9373
	25	3.67	2.85	0.9233	0.0005	0.9242	0.9396
	30	4.01	3.10	0.9219	0.0005	0.9229	0.9390
	35	4.63	3.60	0.9217	0.0005	0.9227	0.9390
	40	5.00	4.85	0.9224	0.0005	0.9234	0.9397
	45	5.00	5.00	0.9045	0.0005	0.9054	0.9259
20	5	2.15	1.70	0.9017	0.0005	0.9026	0.9176
	10	2.40	1.90	0.9025	0.0005	0.9035	0.9183
	15	2.65	2.00	0.9203	0.0004	0.9212	0.9369
	20	3.36	2.55	0.9213	0.0004	0.9220	0.9374
	25	3.71	2.90	0.9225	0.0005	0.9235	0.9389
	30	4.08	3.25	0.9015	0.0005	0.9024	0.9185
	35	4.71	3.75	0.9210	0.0005	0.9220	0.9383
	40	5.00	5.00	0.9201	0.0004	0.9209	0.9372

Table 6.8.2-52
Acceptable Average Initial Enrichment / Burnup Combinations for WE 14x14 Fuel Class Failed FAs Loaded in EOS-37PTH DSC Type A Placed in TN Eagle Cask

Fresh Fuel		Enrichment (wt. %)		k_{KENO}	σ_{KENO}	k_{eff}	
		25 IFAs	12 FFAs				
		2.20	**1.95**	**0.9388**	**0.0005**	**0.9398**	
Cooling Time (Yrs.)	**Burnup (GWd/MTU)**	**Enrichment (wt. %)**		**k_{KENO}**	**σ_{KENO}**	**k_{KENO} + $2\sigma_{KENO}$**	**k_{eff} + $(\beta_i+\Delta k_i)$ + Δk_x**
		25 IFAs	**12 FFAs**				
5	5	2.42	1.75	0.9231	0.0005	0.9241	0.9391
	10	2.68	1.85	0.9217	0.0005	0.9227	0.9375
	15	2.90	1.95	0.9204	0.0005	0.9213	0.9370
	20	3.58	2.40	0.9213	0.0005	0.9223	0.9377
	25	3.91	2.50	0.9185	0.0005	0.9195	0.9349
	30	4.27	2.80	0.9217	0.0005	0.9227	0.9388
	35	4.89	3.20	0.9216	0.0004	0.9225	0.9388
	40	5.00	4.60	0.9225	0.0005	0.9234	0.9397
	45	5.00	5.00	0.9134	0.0005	0.9144	0.9349
10	5	2.44	1.75	0.9231	0.0005	0.9241	0.9391
	10	2.70	1.90	0.9216	0.0005	0.9226	0.9374
	15	2.95	2.05	0.9073	0.0005	0.9083	0.9240
	20	3.68	2.45	0.9218	0.0004	0.9226	0.9380
	25	4.06	2.75	0.9222	0.0004	0.9231	0.9385
	30	4.42	3.05	0.9214	0.0005	0.9224	0.9385
	35	5.00	3.65	0.9231	0.0004	0.9239	0.9402
	40	5.00	5.00	0.9180	0.0004	0.9189	0.9352
15	5	2.44	1.75	0.9213	0.0005	0.9223	0.9373
	10	2.73	1.85	0.9204	0.0005	0.9213	0.9361
	15	2.99	2.10	0.9075	0.0005	0.9085	0.9242
	20	3.75	2.60	0.9222	0.0005	0.9232	0.9386
	25	4.15	2.85	0.9234	0.0005	0.9244	0.9398
	30	4.53	3.05	0.9207	0.0005	0.9217	0.9378
	35	**5.00**	**4.00**	**0.9236**	**0.0004**	**0.9244**	**0.9407**
	40	5.00	5.00	0.9097	0.0005	0.9107	0.9270
20	5	2.45	1.75	0.9228	0.0005	0.9238	0.9388
	10	2.75	1.90	0.9096	0.0005	0.9106	0.9254
	15	3.01	2.10	0.9081	0.0005	0.9091	0.9248
	20	3.81	2.55	0.9228	0.0004	0.9236	0.9390
	25	4.21	2.85	0.9226	0.0005	0.9235	0.9389
	30	4.61	3.20	0.9230	0.0005	0.9240	0.9401
	35	5.00	4.25	0.9229	0.0005	0.9239	0.9402
	40	5.00	5.00	0.9038	0.0004	0.9046	0.9209

Table 6.8.2-53
Acceptable Average Initial Enrichment / Burnup Combinations for WE 14x14 Fuel Class Failed FAs Loaded in EOS-37PTH DSC Type B Placed in TN Eagle Cask

Fresh Fuel		Enrichment (wt. %)		k_{KENO}	σ_{KENO}	k_{eff}	
		25 IFAs	12 FFAs				
		2.30	**1.90**	**0.9382**	**0.0004**	**0.9390**	
Cooling Time (Yrs.)	**Burnup (GWd/MTU)**	**Enrichment (wt. %)**		**k_{KENO}**	**σ_{KENO}**	**k_{KENO} + $2\sigma_{KENO}$**	**k_{eff} + (β_i+Δk_i) + Δk_x**
		25 IFAs	**12 FFAs**				
5	5	2.51	1.75	0.9215	0.0004	0.9224	0.9374
	10	2.78	1.95	0.9237	0.0005	0.9247	0.9395
	15	3.02	2.00	0.9082	0.0005	0.9091	0.9248
	20	3.72	2.40	0.9224	0.0005	0.9233	0.9387
	25	4.09	2.65	0.9226	0.0005	0.9236	0.9390
	30	4.44	2.85	0.9217	0.0005	0.9227	0.9388
	35	5.00	3.45	0.9226	0.0005	0.9235	0.9398
	40	5.00	4.90	0.9213	0.0005	0.9222	0.9385
	45	5.00	5.00	0.9068	0.0005	0.9077	0.9282
10	5	2.52	1.80	0.9226	0.0005	0.9236	0.9386
	10	2.81	2.00	0.9245	0.0005	0.9254	0.9402
	15	3.07	2.10	0.9228	0.0005	0.9237	0.9394
	20	3.81	2.50	0.9211	0.0005	0.9221	0.9375
	25	4.20	2.80	0.9223	0.0004	0.9230	0.9384
	30	4.59	3.05	0.9221	0.0004	0.9230	0.9391
	35	5.00	4.00	0.9219	0.0005	0.9228	0.9391
	40	5.00	5.00	0.9117	0.0005	0.9126	0.9289
15	5	2.53	1.85	0.9242	0.0004	0.9251	0.9401
	10	2.83	1.95	0.9218	0.0005	0.9227	0.9375
	15	3.10	2.10	0.9079	0.0005	0.9089	0.9246
	20	3.88	2.60	0.9220	0.0004	0.9227	0.9381
	25	4.29	2.90	0.9219	0.0004	0.9227	0.9381
	30	4.66	3.15	0.9213	0.0005	0.9222	0.9383
	35	**5.00**	**4.35**	**0.9231**	**0.0005**	**0.9241**	**0.9404**
	40	5.00	5.00	0.9049	0.0004	0.9057	0.9220
20	5	2.53	1.80	0.9218	0.0005	0.9227	0.9377
	10	2.84	1.95	0.9226	0.0005	0.9236	0.9384
	15	3.12	2.15	0.9217	0.0005	0.9227	0.9384
	20	3.93	2.65	0.9219	0.0005	0.9228	0.9382
	25	4.36	2.90	0.9213	0.0005	0.9223	0.9377
	30	4.77	3.15	0.9212	0.0005	0.9222	0.9383
	35	5.00	4.55	0.9226	0.0005	0.9236	0.9399
	40	5.00	5.00	0.8950	0.0005	0.8960	0.9123

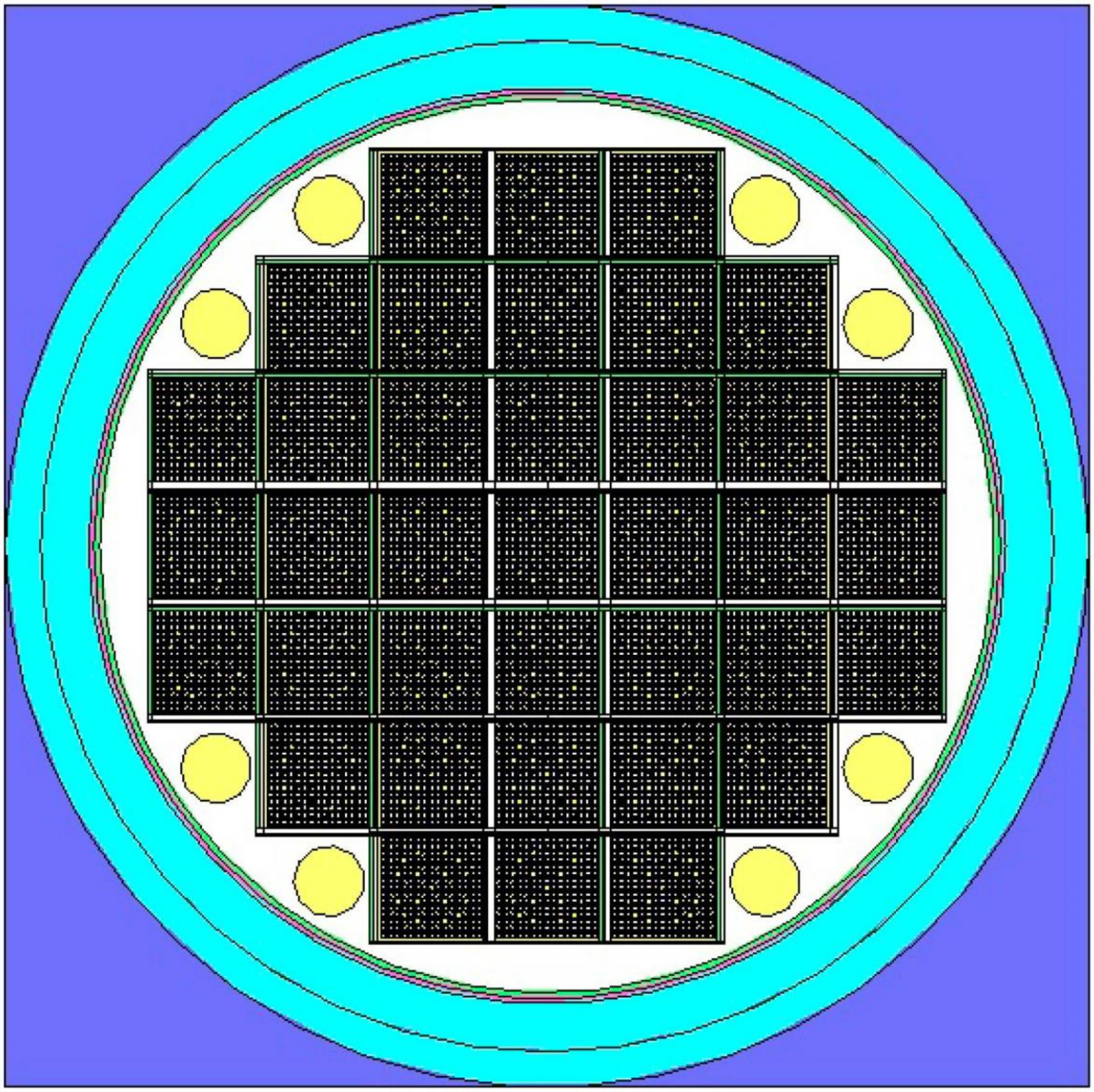

Figure 6.8.2-1
KENO Model – EOS-37PTH DSC

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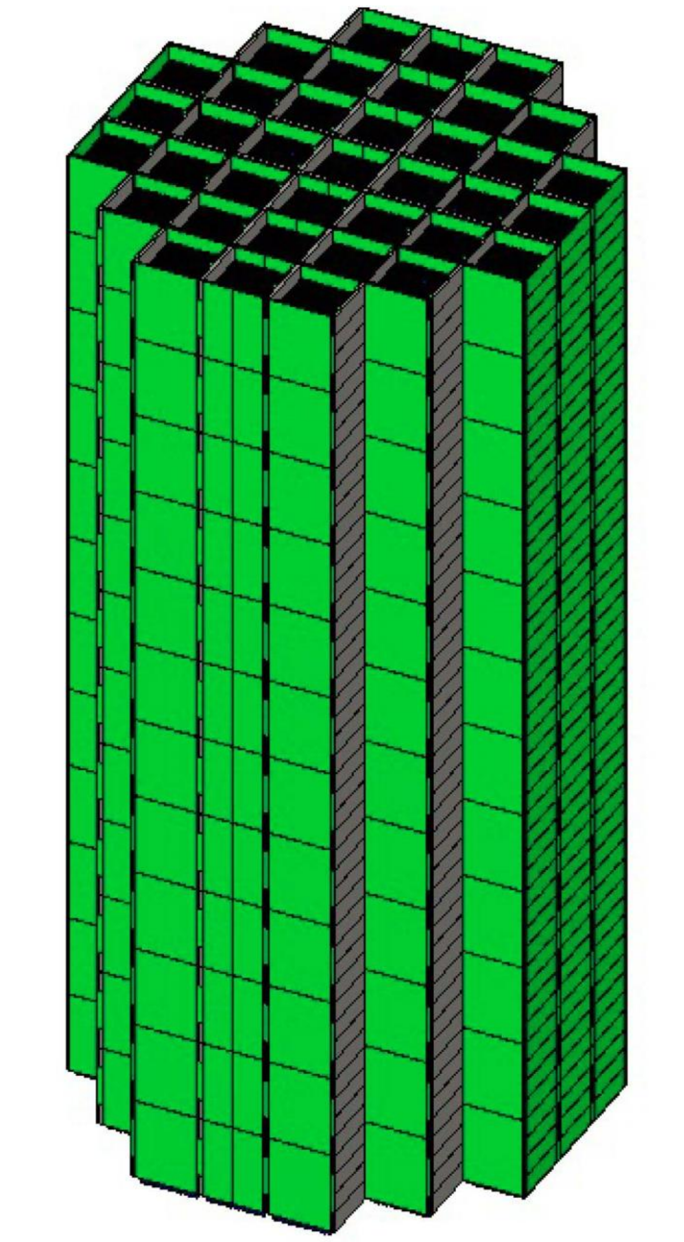

Figure 6.8.2-3
EOS-37PTH DSC Full-Length Axial Basket Structure with FAs

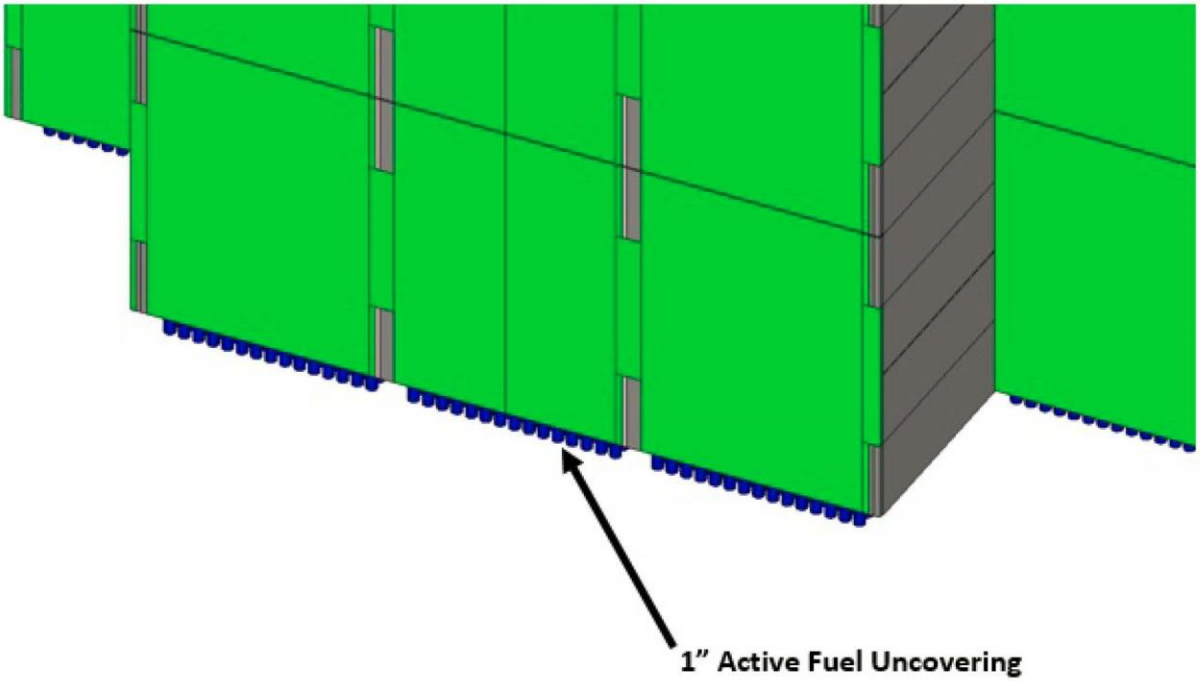

Figure 6.8.2-4
Active Fuel Uncovering Region in the EOS-37PTH DSC

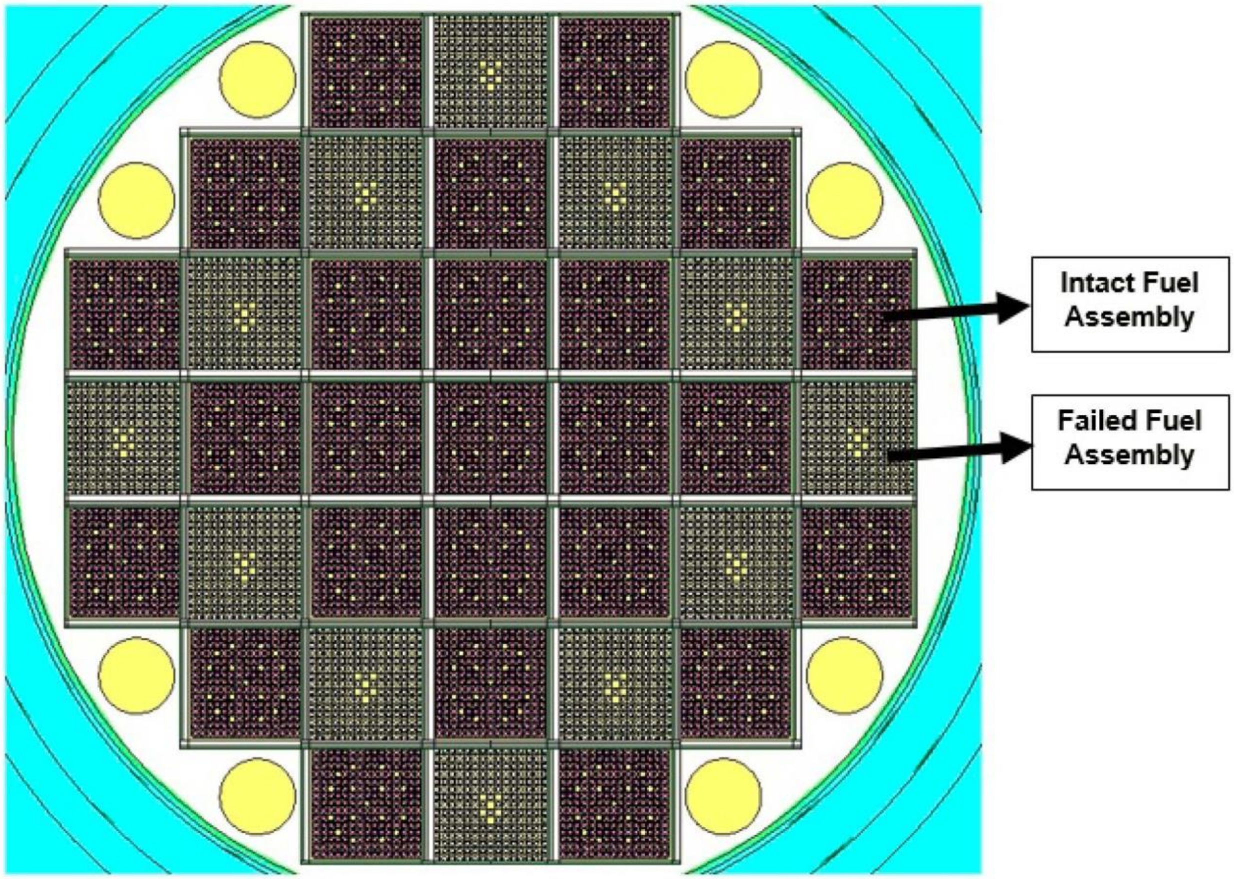

Figure 6.8.2-5
Locations of 12 Failed FAs loaded in EOS-37PTH DSC

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Withheld Pursuant to 10 CFR 2.390

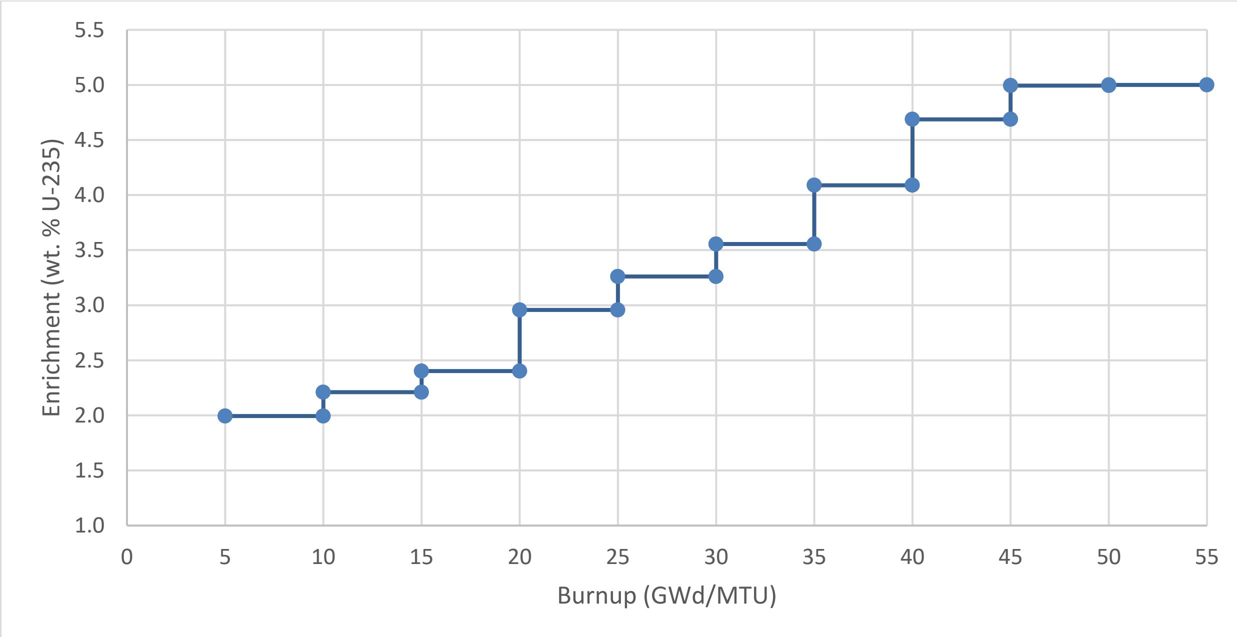


Figure 6.8.2-8
Loading Curve for Intact B&W 15x15 FAs Loaded in EOS-37PTH DSC Type A – 5 Years CT

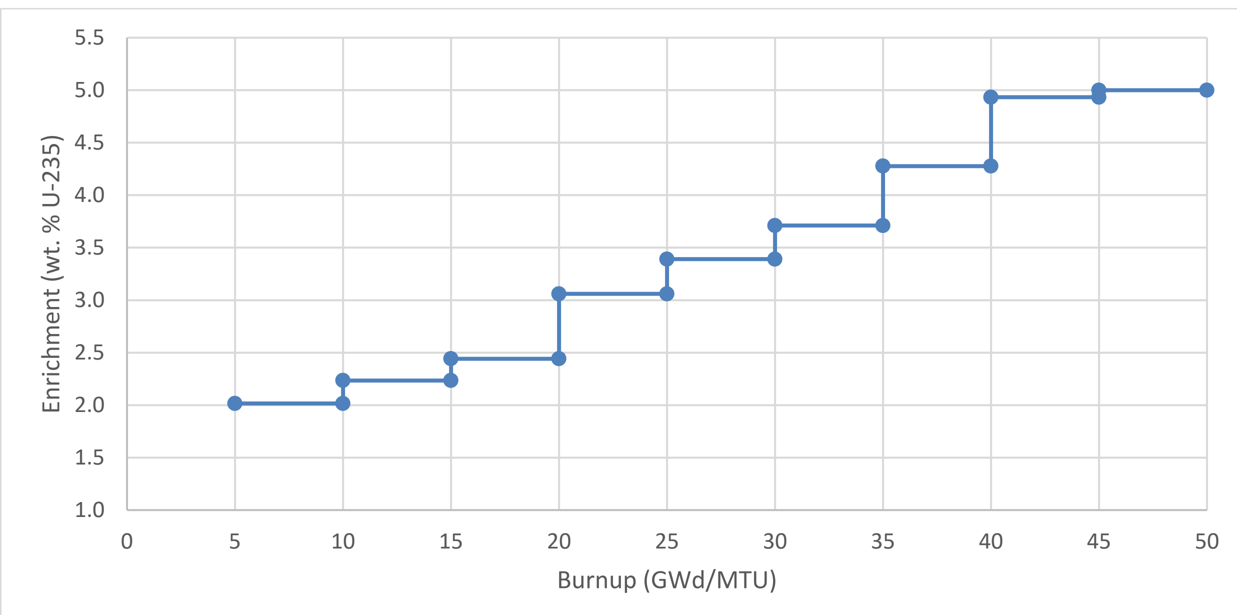


Figure 6.8.2-9
Loading Curve for Intact B&W 15x15 FAs Loaded in EOS-37PTH DSC Type A – 10 Years CT

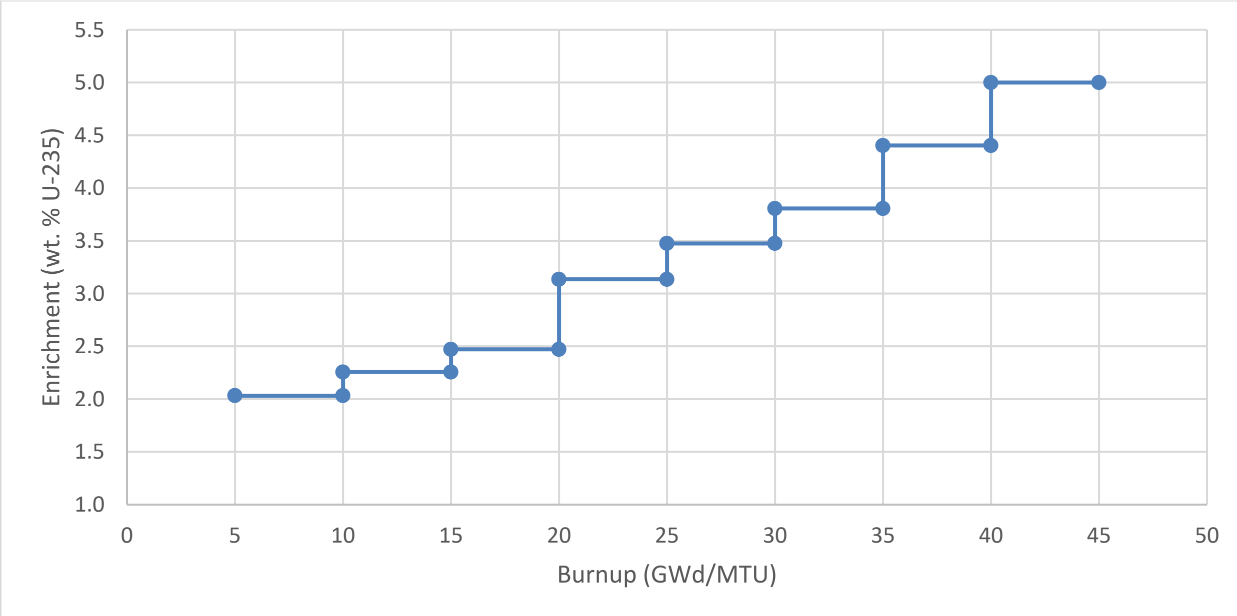


Figure 6.8.2-10
Loading Curve for Intact B&W 15x15 FAs Loaded in EOS-37PTH DSC Type A – 15 Years CT

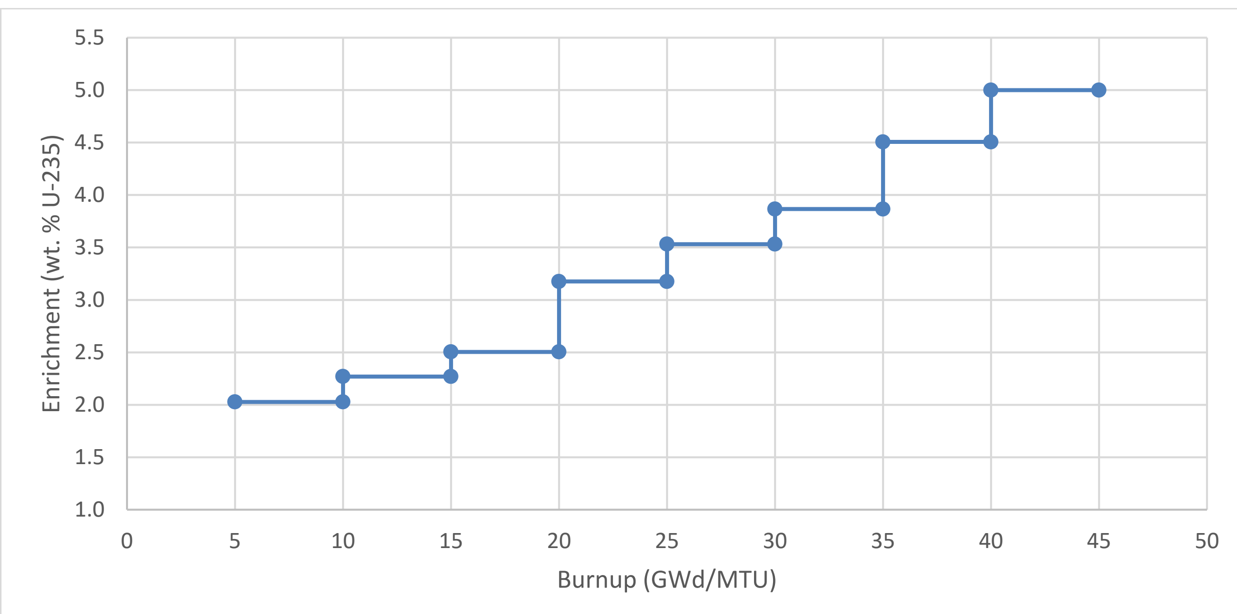


Figure 6.8.2-11
Loading Curve for Intact B&W 15x15 FAs Loaded in EOS-37PTH DSC Type A – 20 Years CT

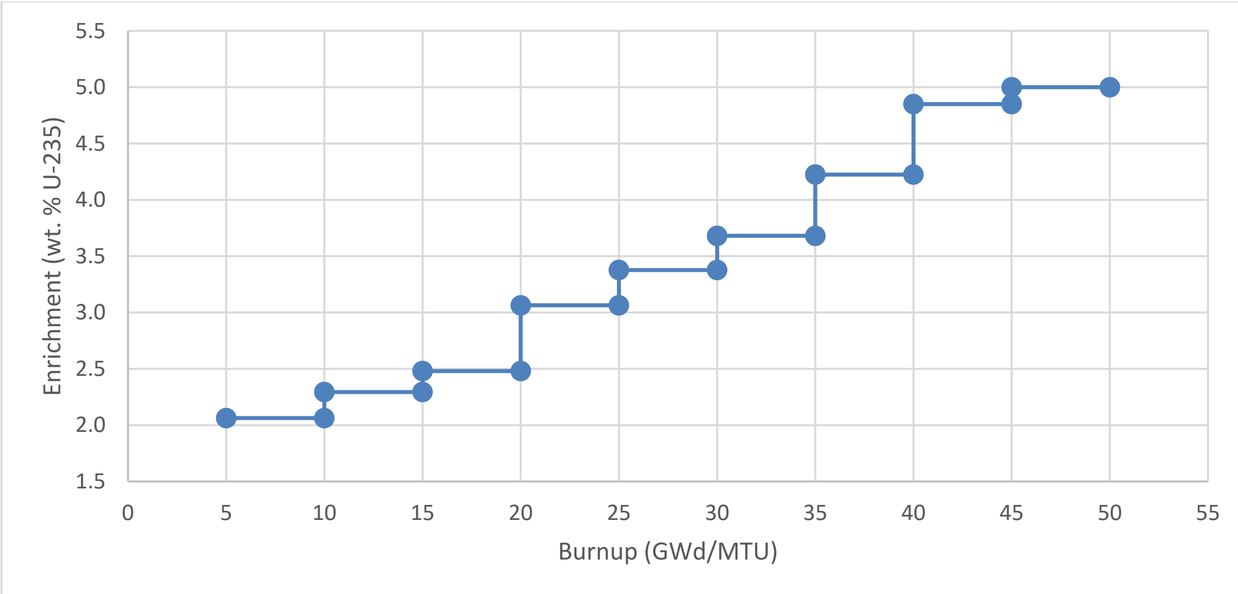


Figure 6.8.2-12
Loading Curve for Intact B&W 15x15 FAs Loaded in EOS-37PTH DSC Type B – 5 Years CT

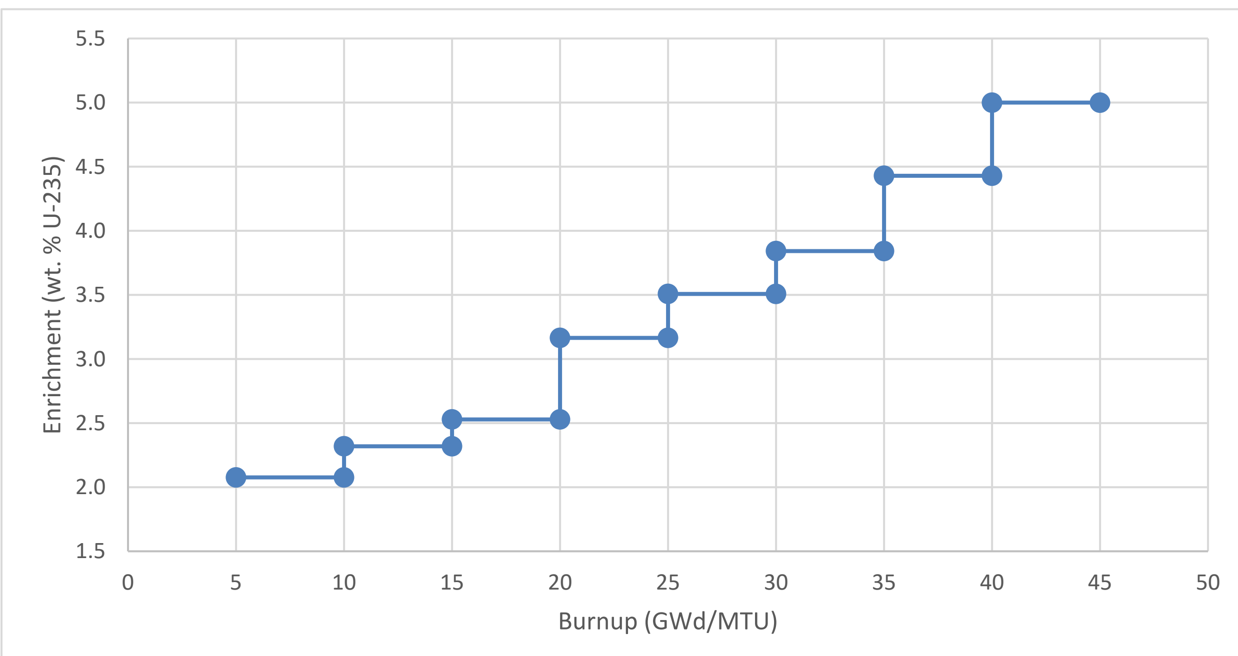


Figure 6.8.2-13
Loading Curve for Intact B&W 15x15 FAs Loaded in EOS-37PTH DSC Type B – 10 Years CT

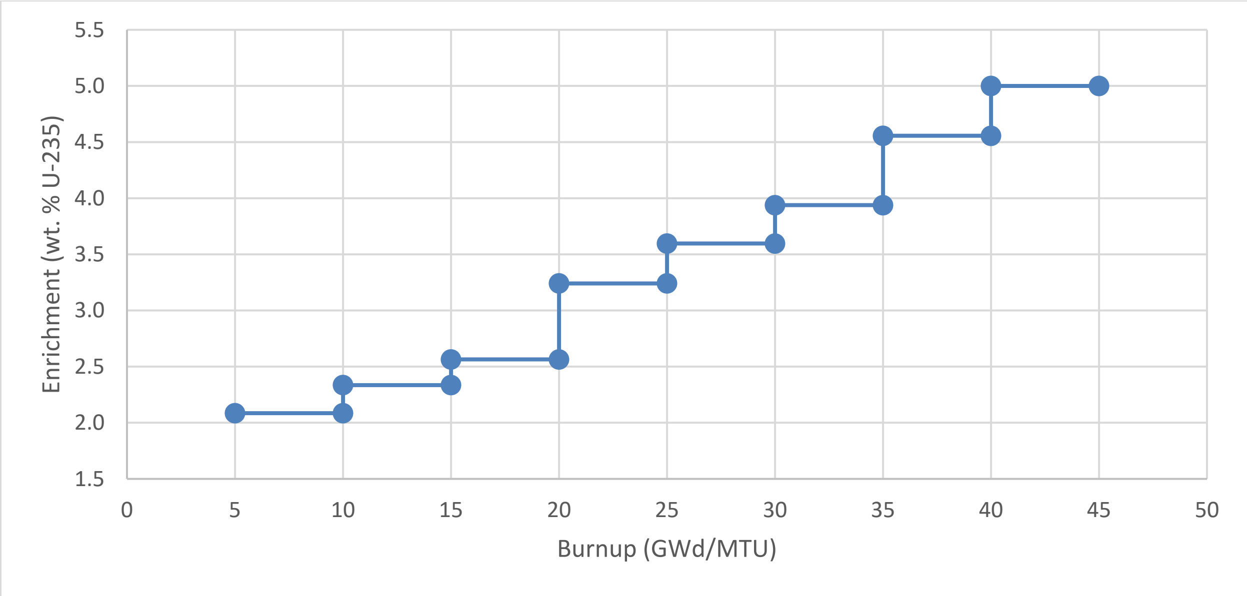


Figure 6.8.2-14
Loading Curve for Intact B&W 15x15 FAs Loaded in EOS-37PTH DSC Type B – 15 Years CT

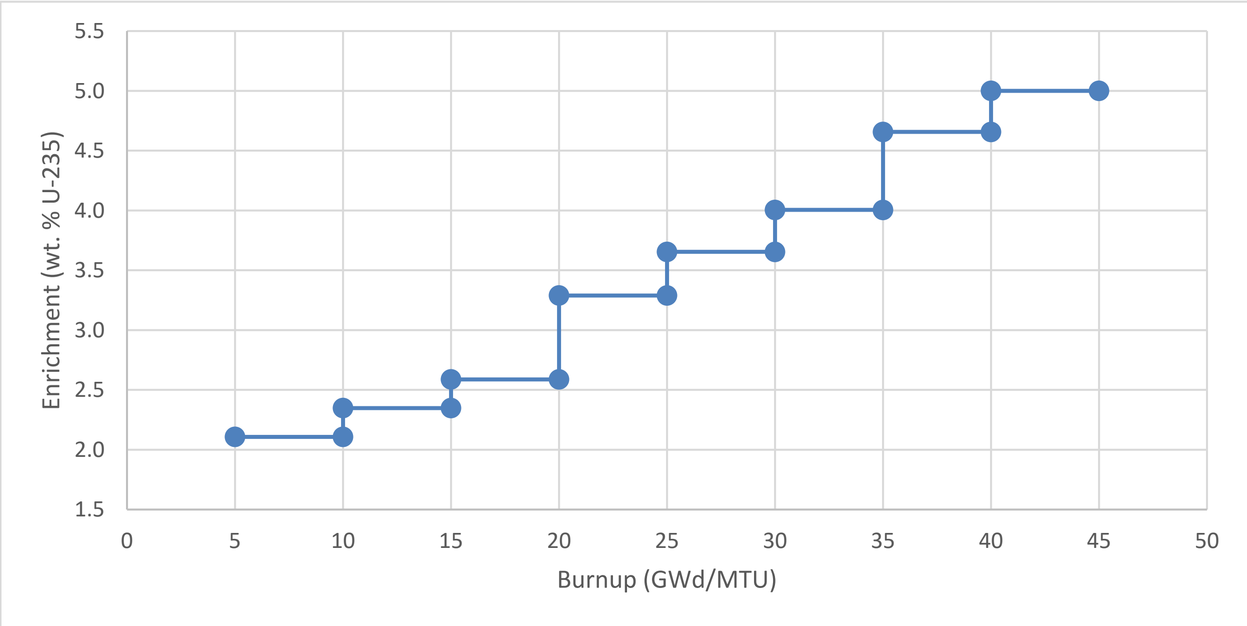


Figure 6.8.2-15
Loading Curve for Intact B&W 15x15 FAs Loaded in EOS-37PTH DSC Type B – 20 Years CT

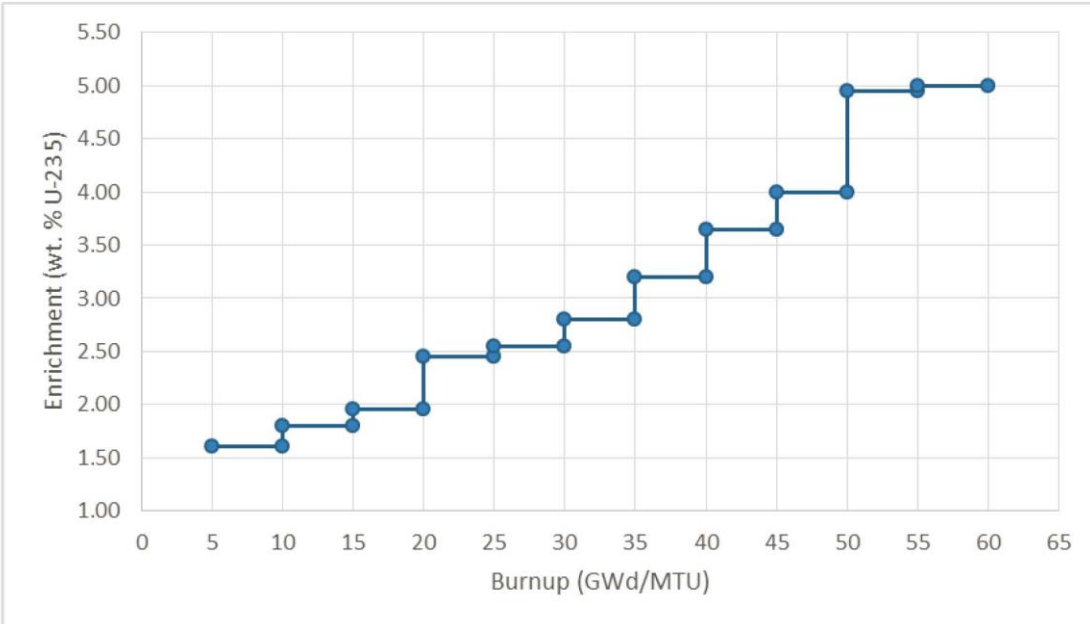


Figure 6.8.2-16
Loading Curve for Failed B&W 15x15 FAs Loaded in EOS-37PTH DSC Type A – 5 Years CT

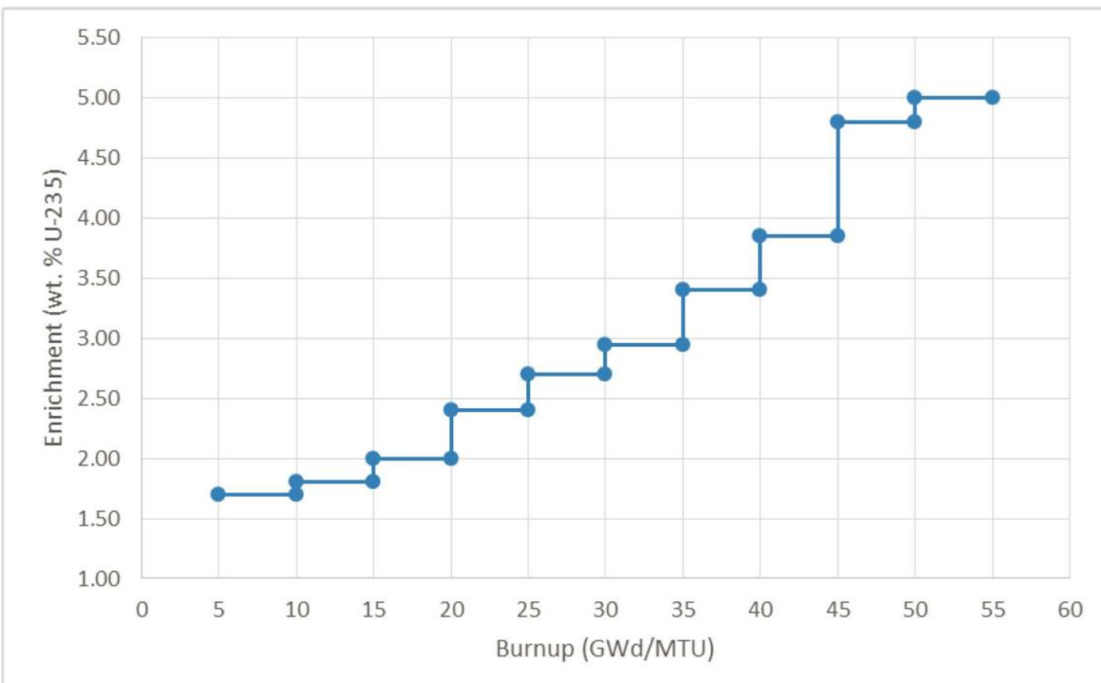


Figure 6.8.2-17
Loading Curve for Failed B&W 15x15 FAs Loaded in EOS-37PTH DSC Type A – 10 Years CT

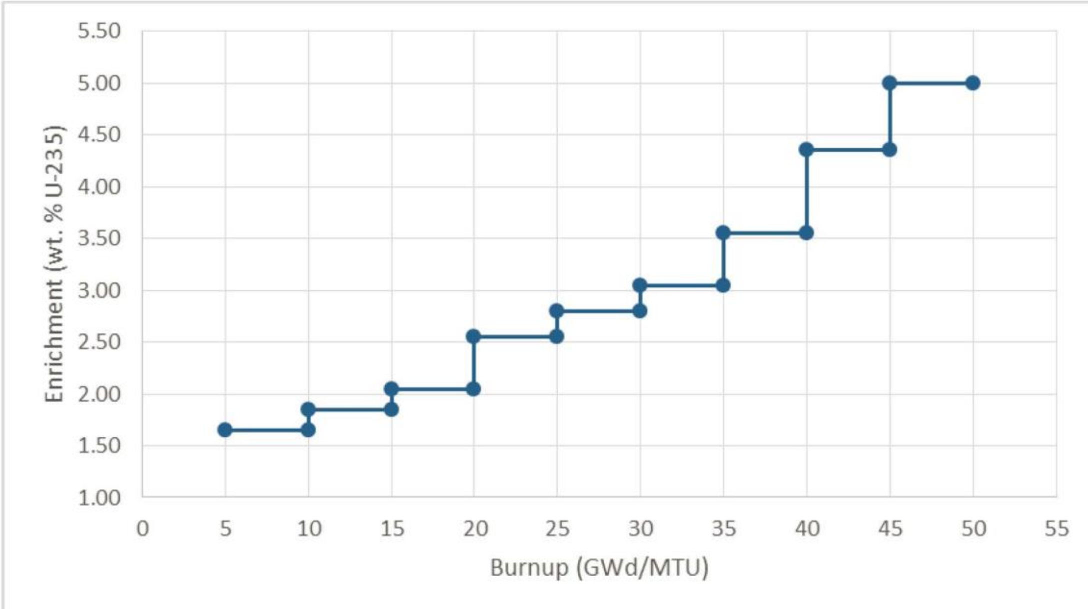


Figure 6.8.2-18
Loading Curve for Failed B&W 15x15 FAs Loaded in EOS-37PTH DSC Type A – 15 Years CT

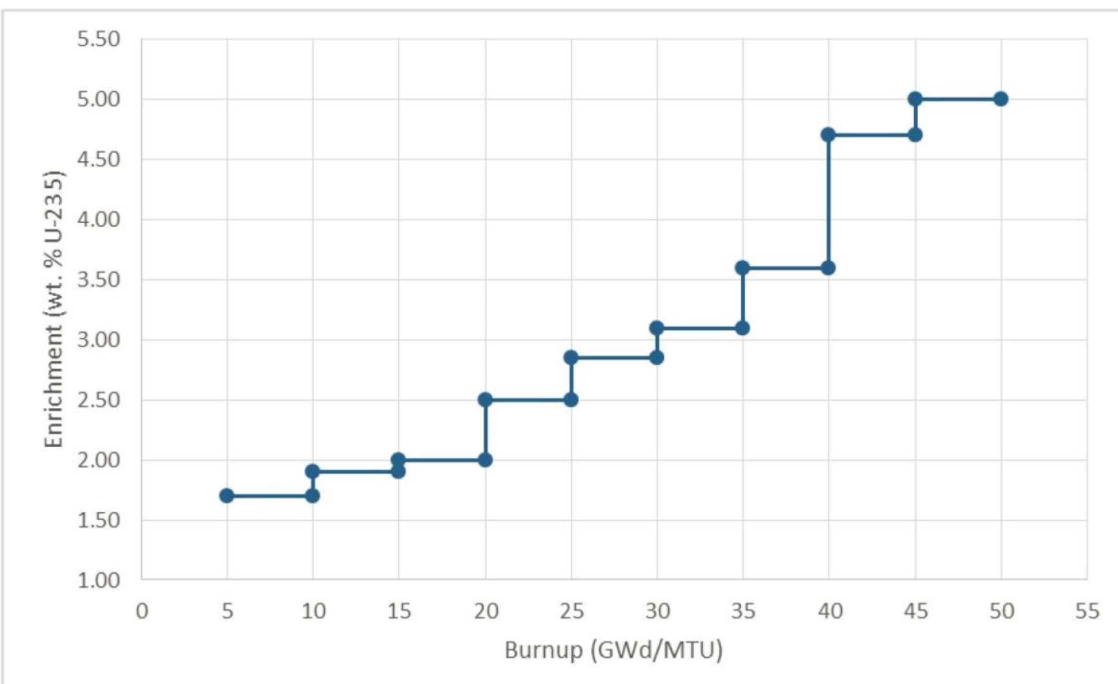


Figure 6.8.2-19
Loading Curve for Failed B&W 15x15 FAs Loaded in EOS-37PTH DSC Type A – 20 Years CT

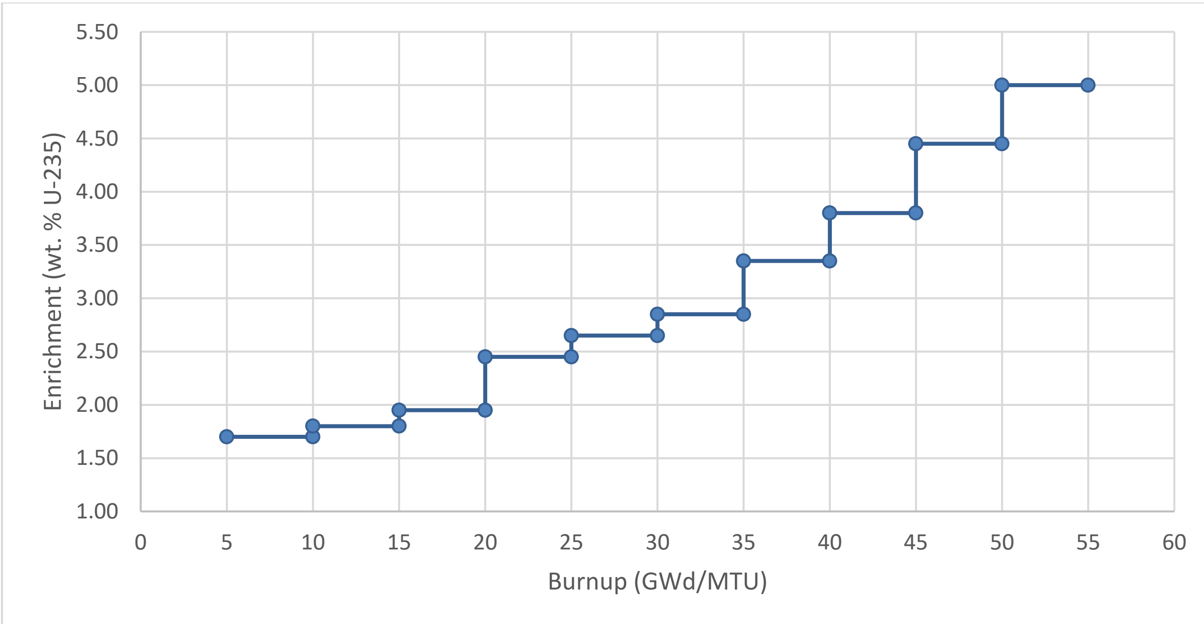


Figure 6.8.2-20
Loading Curve for Failed B&W 15x15 FAs Loaded in EOS-37PTH DSC Type B – 5 Years CT

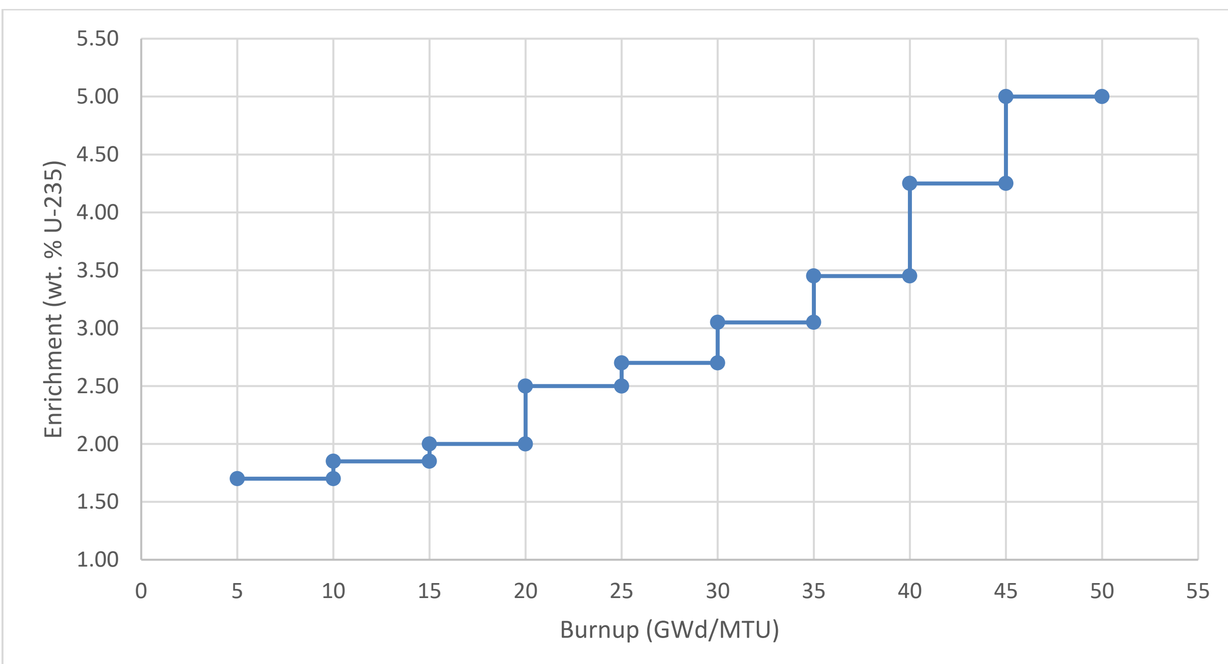


Figure 6.8.2-21
Loading Curve for Failed B&W 15x15 FAs Loaded in EOS-37PTH DSC Type B – 10 Years CT

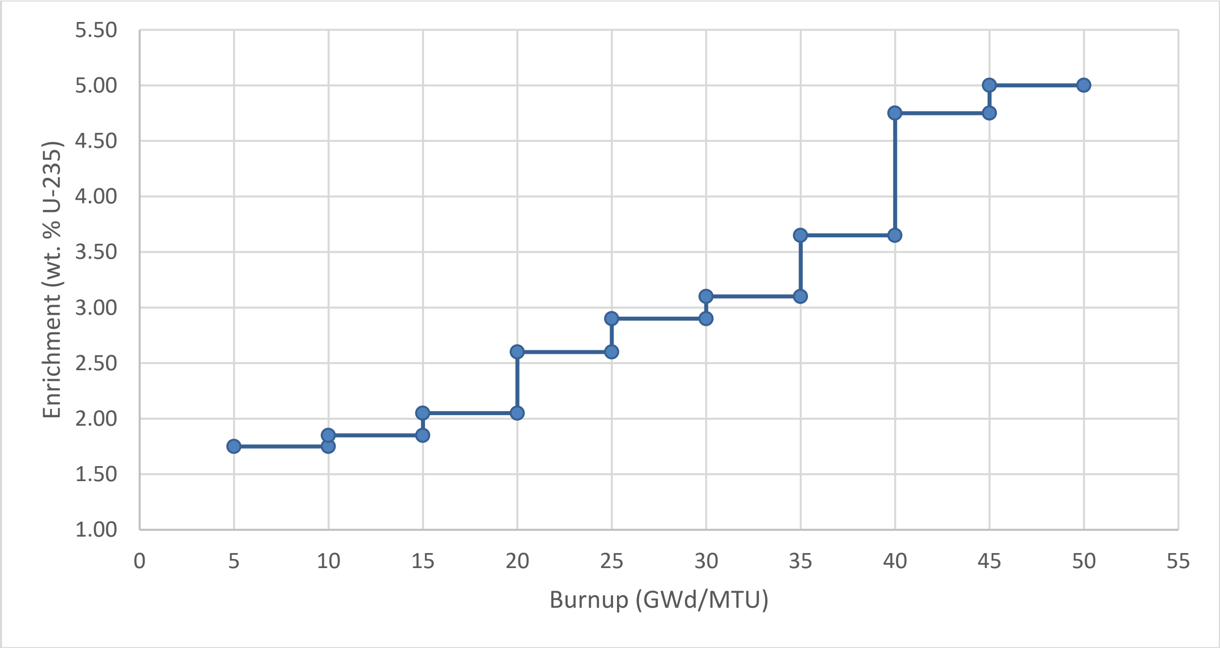


Figure 6.8.2-22
Loading Curve for Failed B&W 15x15 FAs Loaded in EOS-37PTH DSC Type B – 15 Years CT

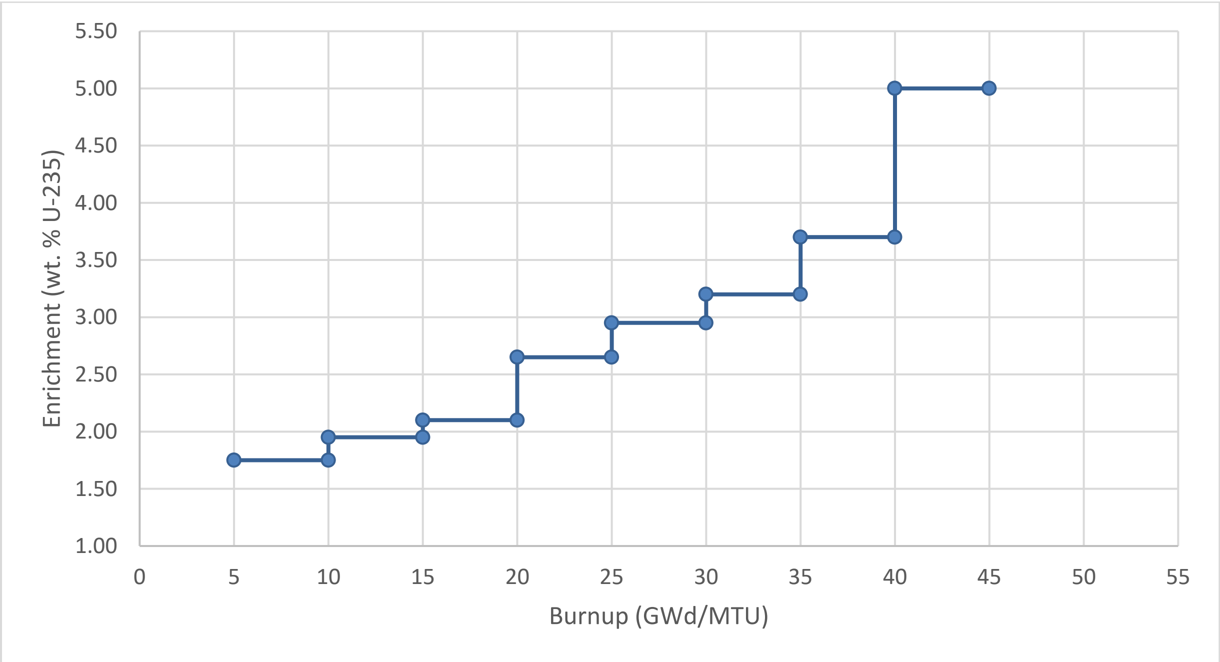


Figure 6.8.2-23
Loading Curve for Failed B&W 15x15 FAs Loaded in EOS-37PTH DSC Type B – 20 Years CT

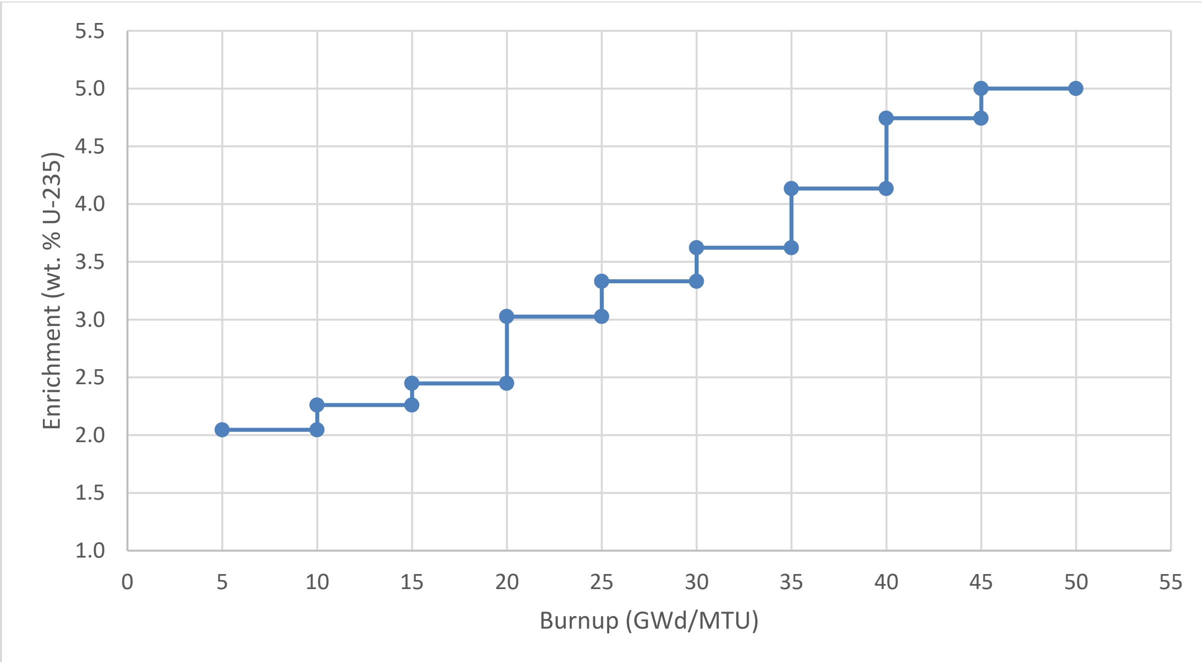


Figure 6.8.2-24
Loading Curve for Intact WE 17x17 FAs Loaded in EOS-37PTH DSC Type A – 5 Years CT

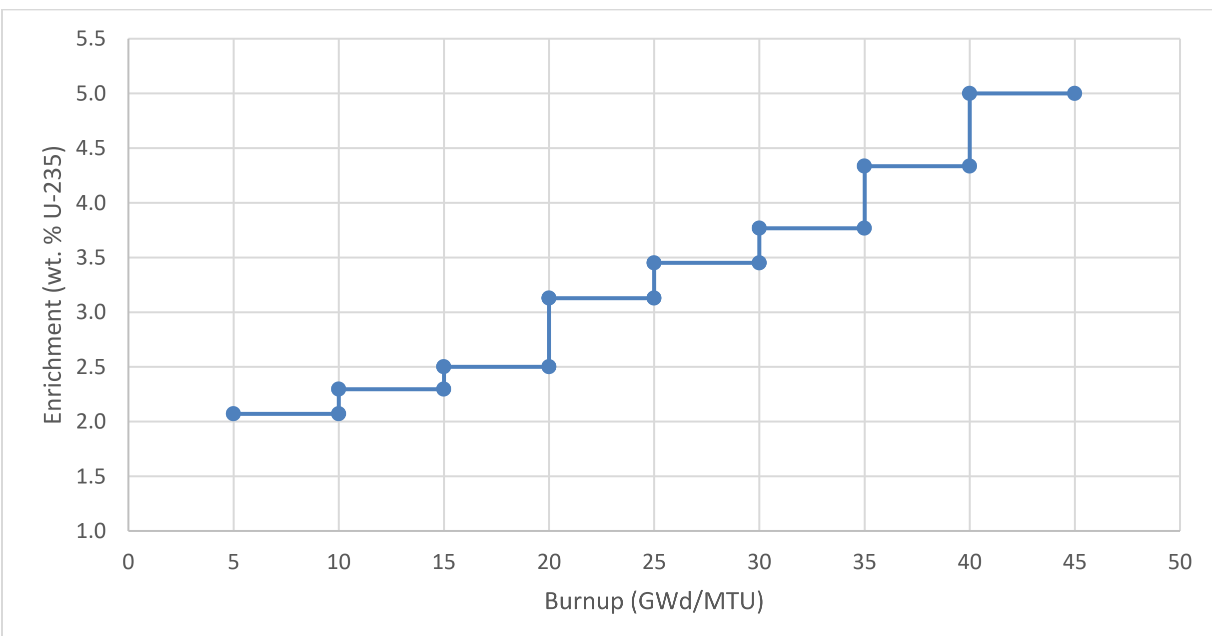


Figure 6.8.2-25
Loading Curve for Intact WE 17x17 FAs Loaded in EOS-37PTH DSC Type A – 10 Years CT

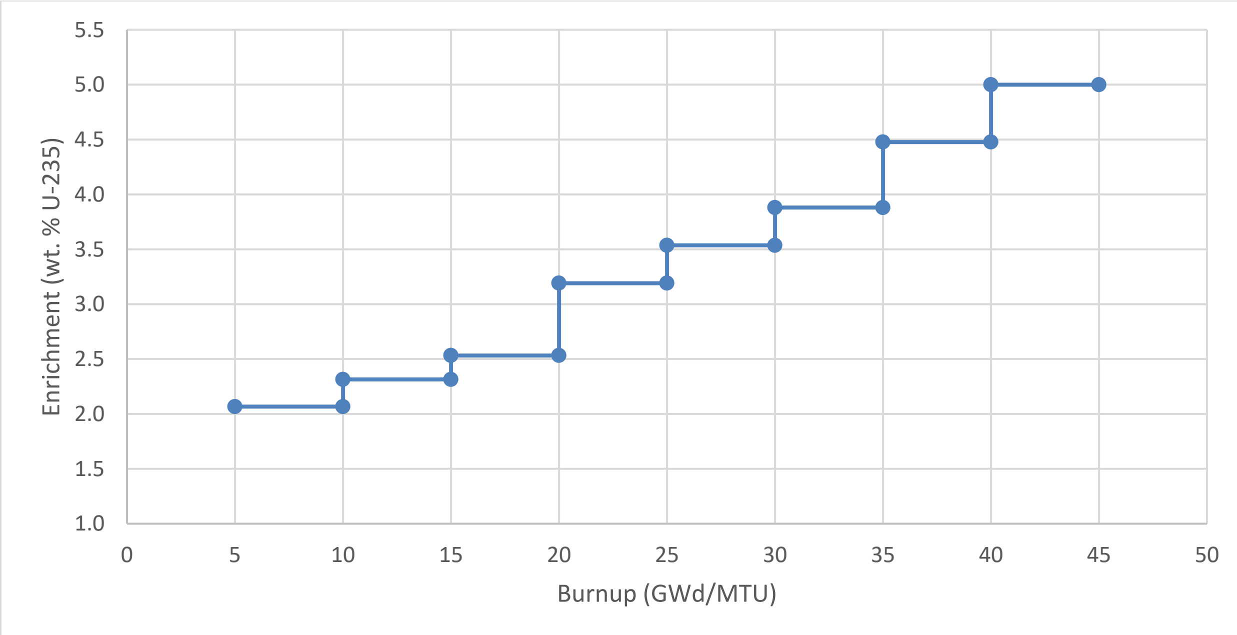


Figure 6.8.2-26
Loading Curve for Intact WE 17x17 FAs Loaded in EOS-37PTH DSC Type A – 15 Years CT

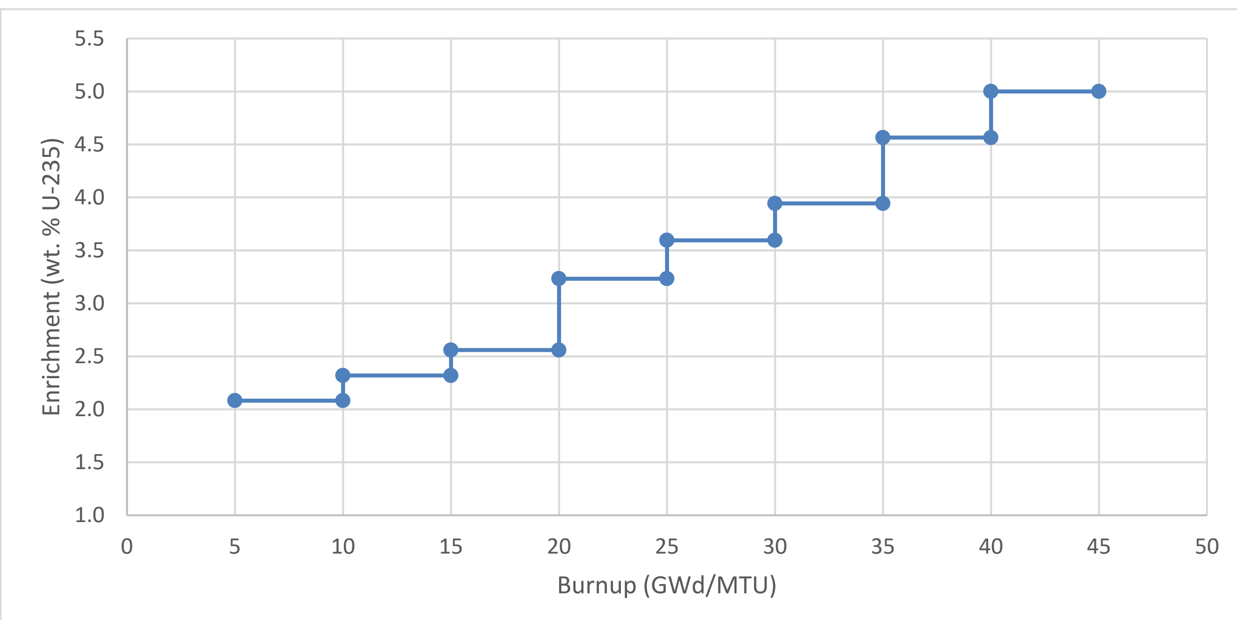


Figure 6.8.2-27
Loading Curve for Intact WE 17x17 FAs Loaded in EOS-37PTH DSC Type A – 20 Years CT

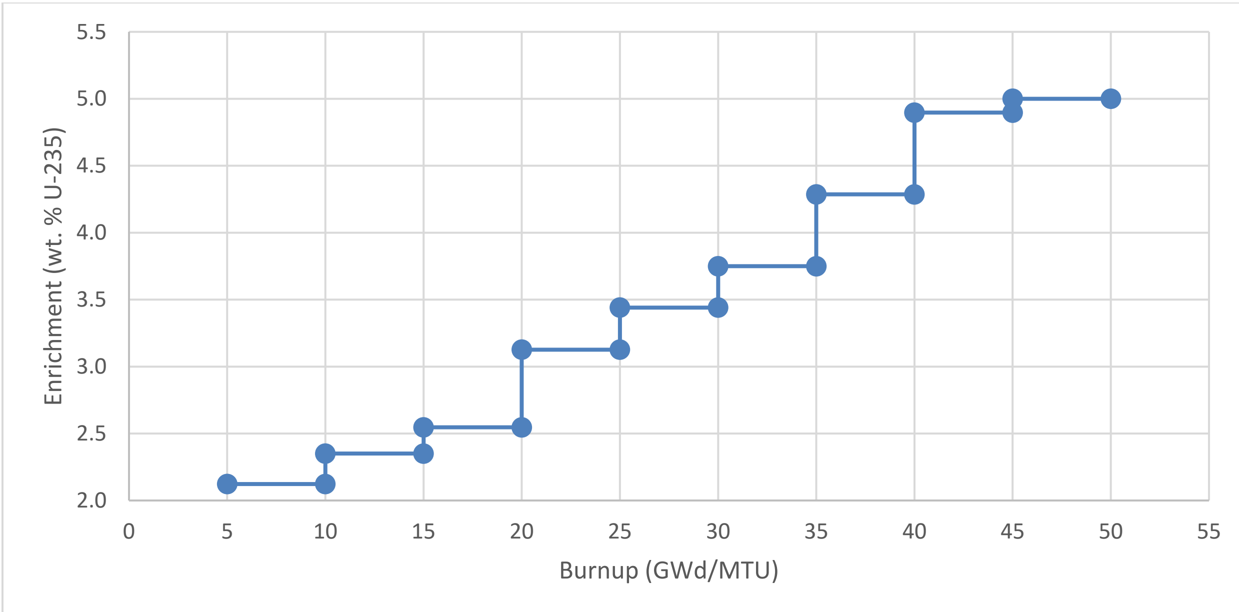


Figure 6.8.2-28
Loading Curve for Intact WE 17x17 FAs Loaded in EOS-37PTH DSC Type B – 5 Years CT

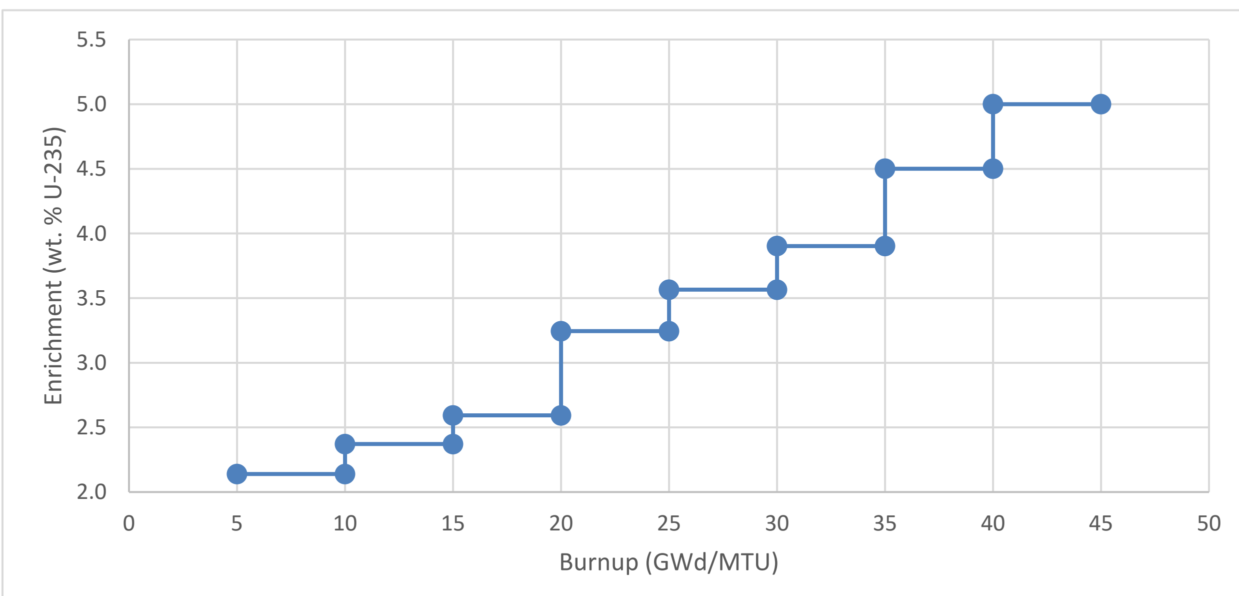


Figure 6.8.2-29
Loading Curve for Intact WE 17x17 FAs Loaded in EOS-37PTH DSC Type B – 10 Years CT

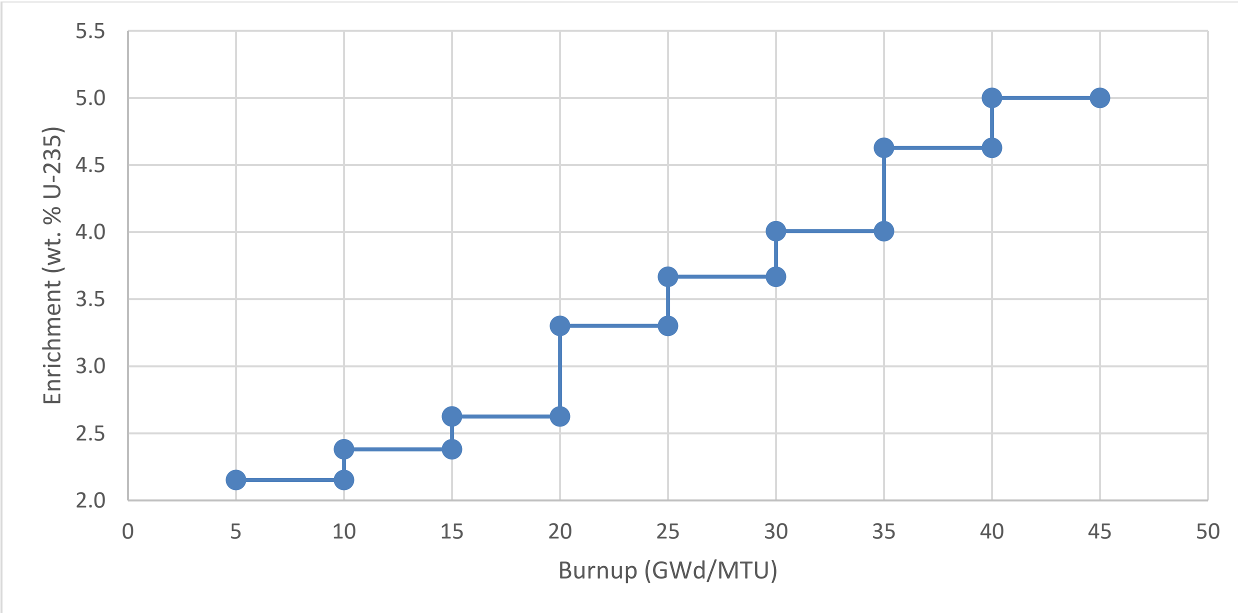


Figure 6.8.2-30
Loading Curve for Intact WE 17x17 FAs Loaded in EOS-37PTH DSC Type B – 15 Years CT

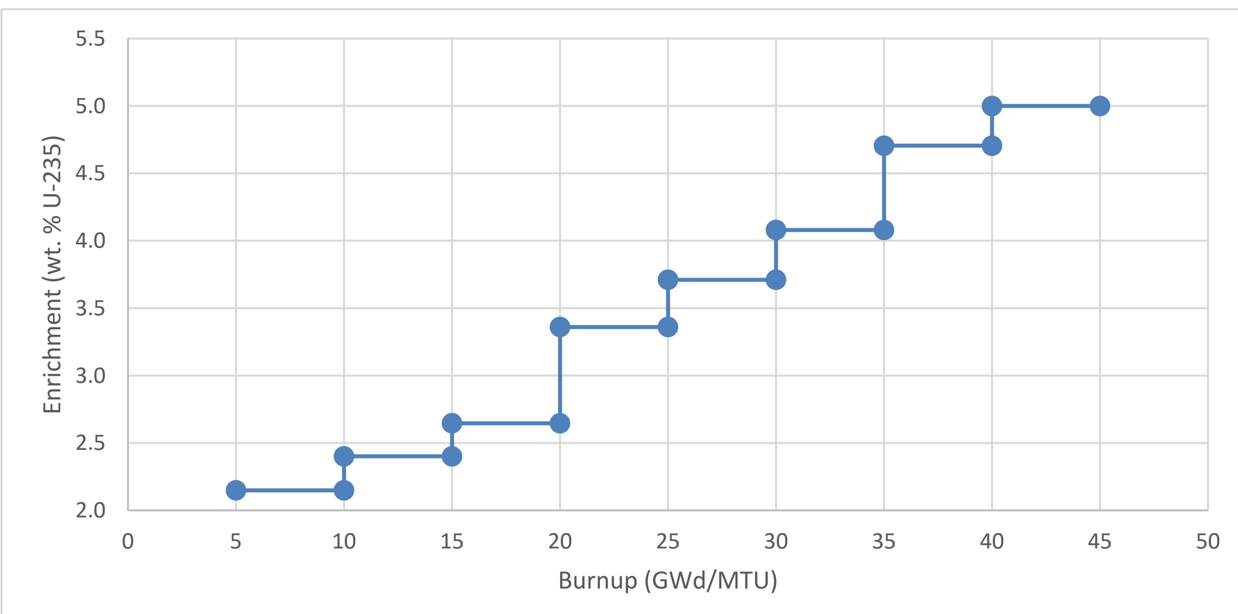


Figure 6.8.2-31
Loading Curve for Intact WE 17x17 FAs Loaded in EOS-37PTH DSC Type B – 20 Years CT

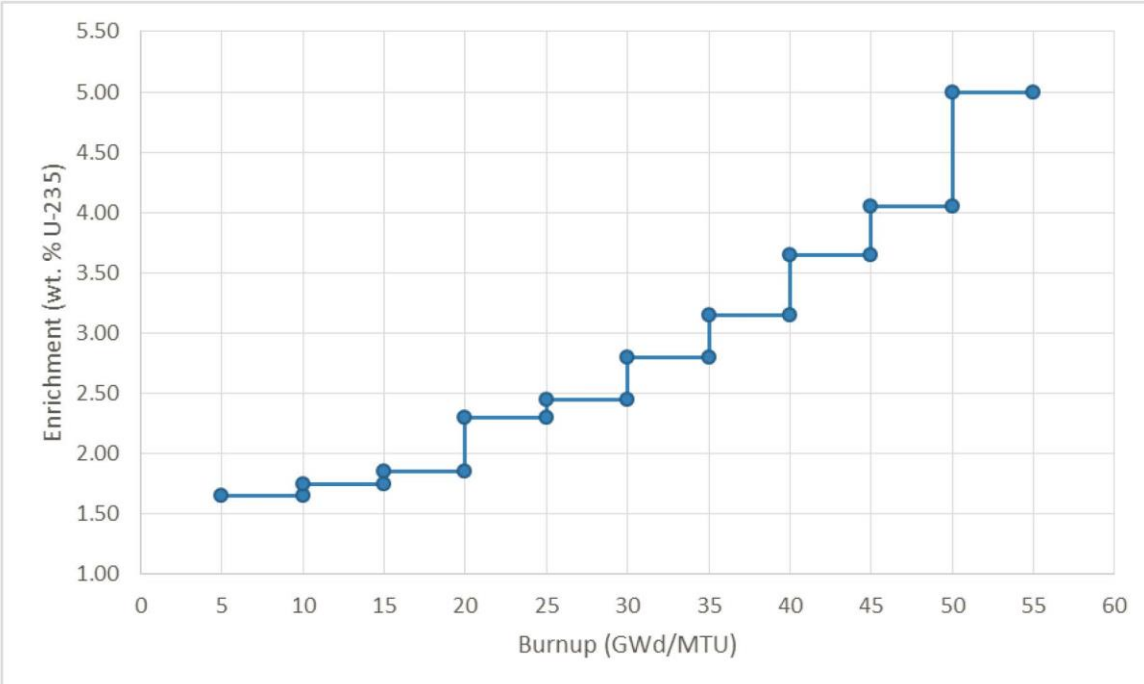


Figure 6.8.2-32
Loading Curve for Failed WE 17x17 FAs Loaded in EOS-37PTH DSC Type A – 5 Years CT

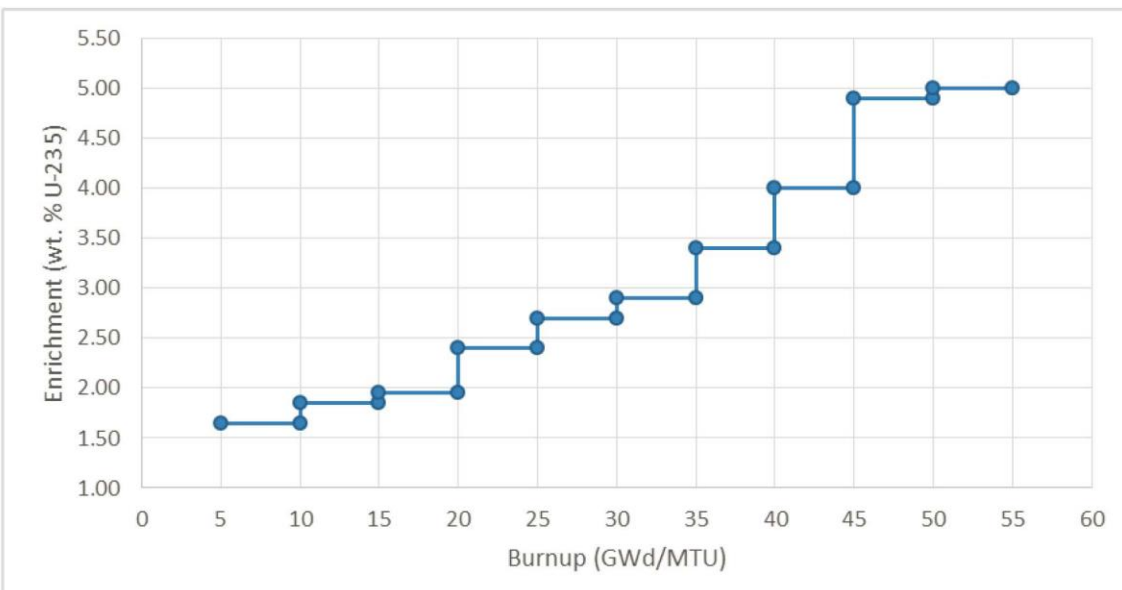


Figure 6.8.2-33
Loading Curve for Failed WE 17x17 FAs Loaded in EOS-37PTH DSC Type A – 10 Years CT

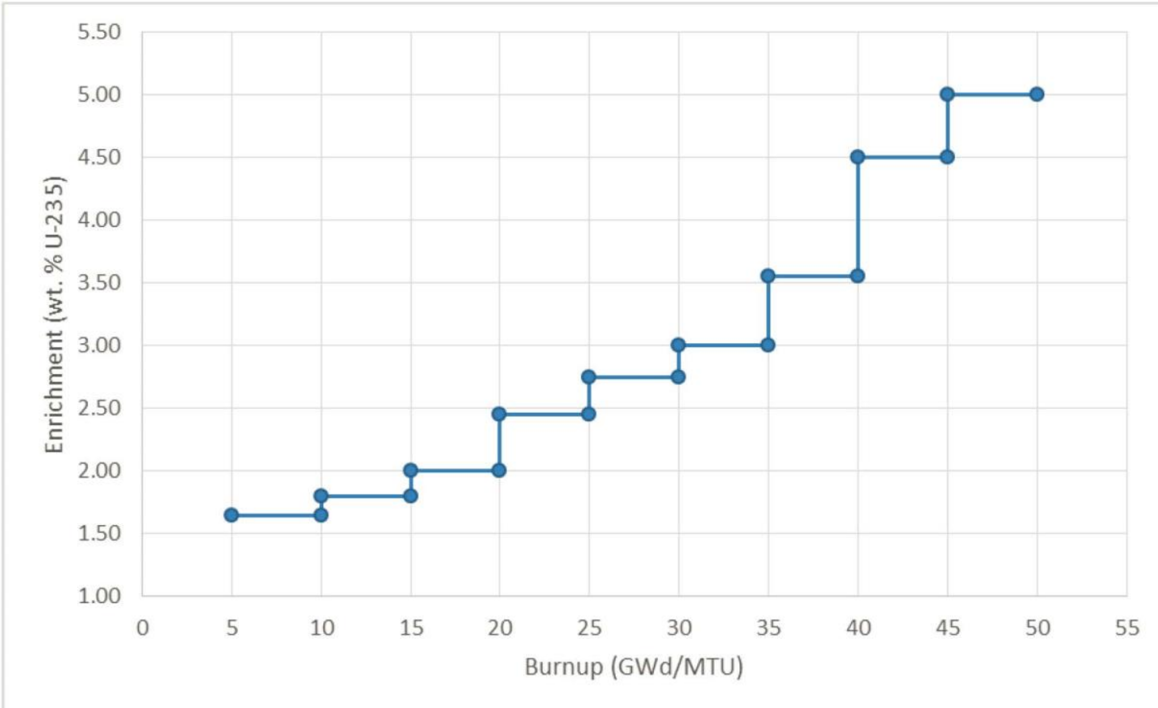


Figure 6.8.2-34
Loading Curve for Failed WE 17x17 FAs Loaded in EOS-37PTH DSC Type A – 15 Years CT

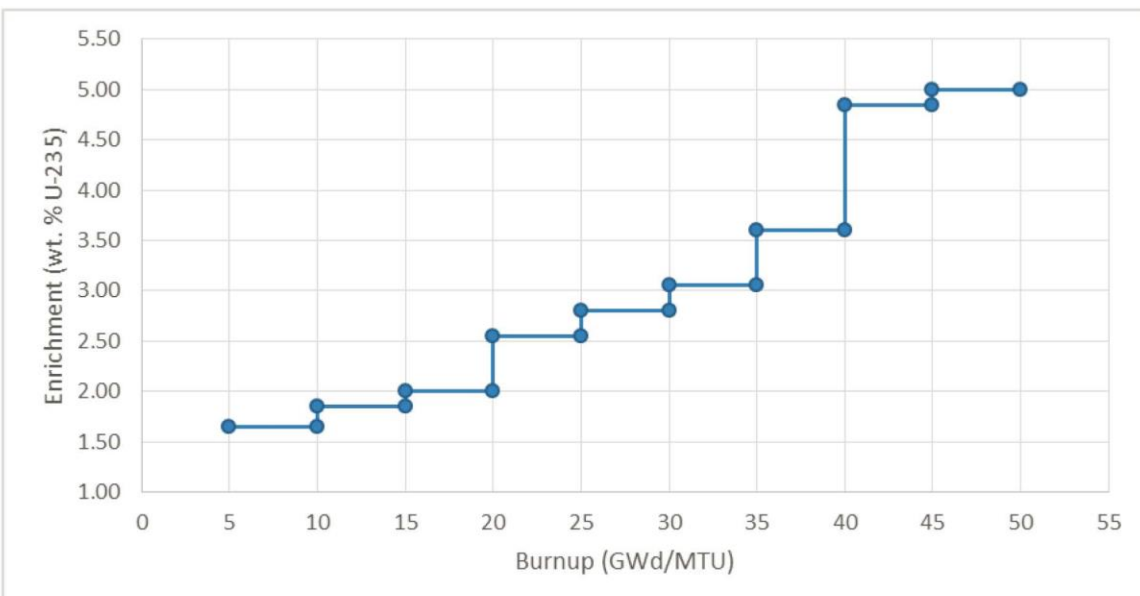


Figure 6.8.2-35
Loading Curve for Failed WE 17x17 FAs Loaded in EOS-37PTH DSC Type A – 20 Years CT

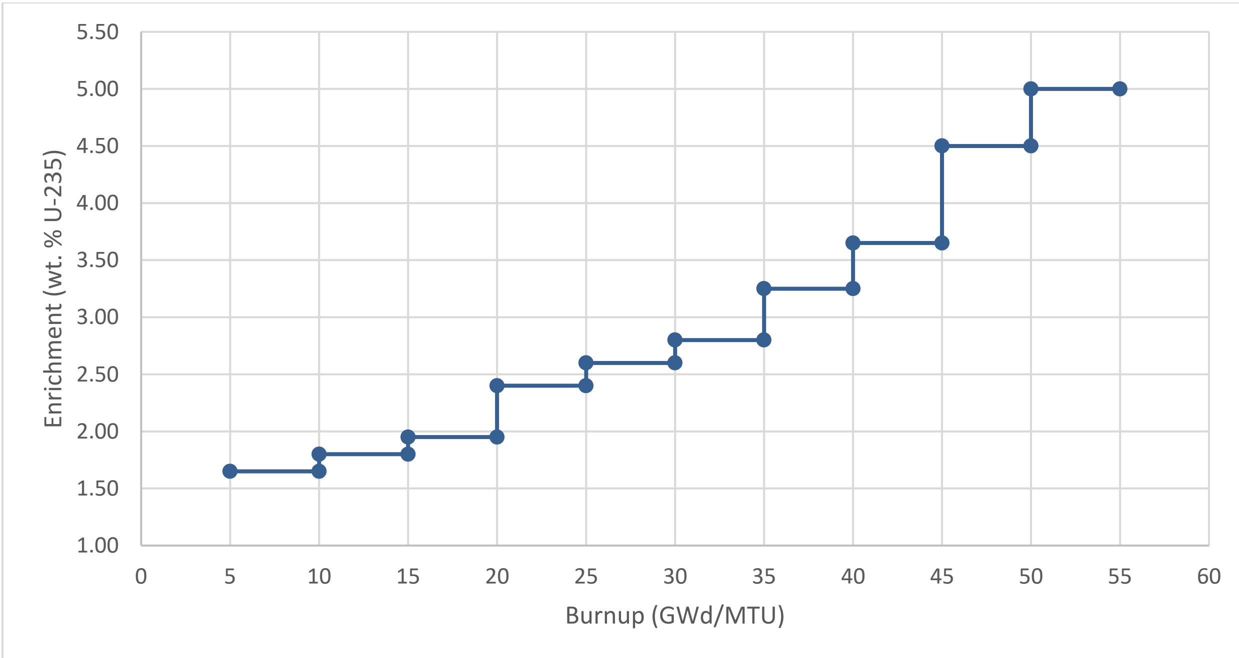


Figure 6.8.2-36
Loading Curve for Failed WE 17x17 FAs Loaded in EOS-37PTH DSC Type B – 5 Years CT

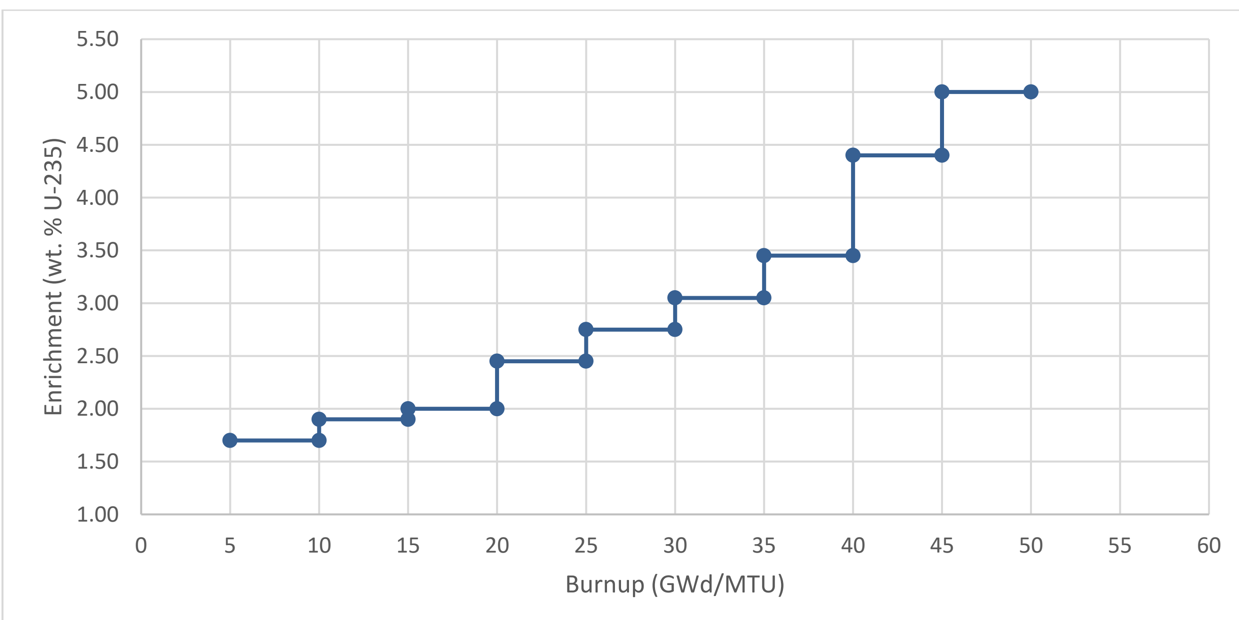


Figure 6.8.2-37
Loading Curve for Failed WE 17x17 FAs Loaded in EOS-37PTH DSC Type B – 10 Years CT

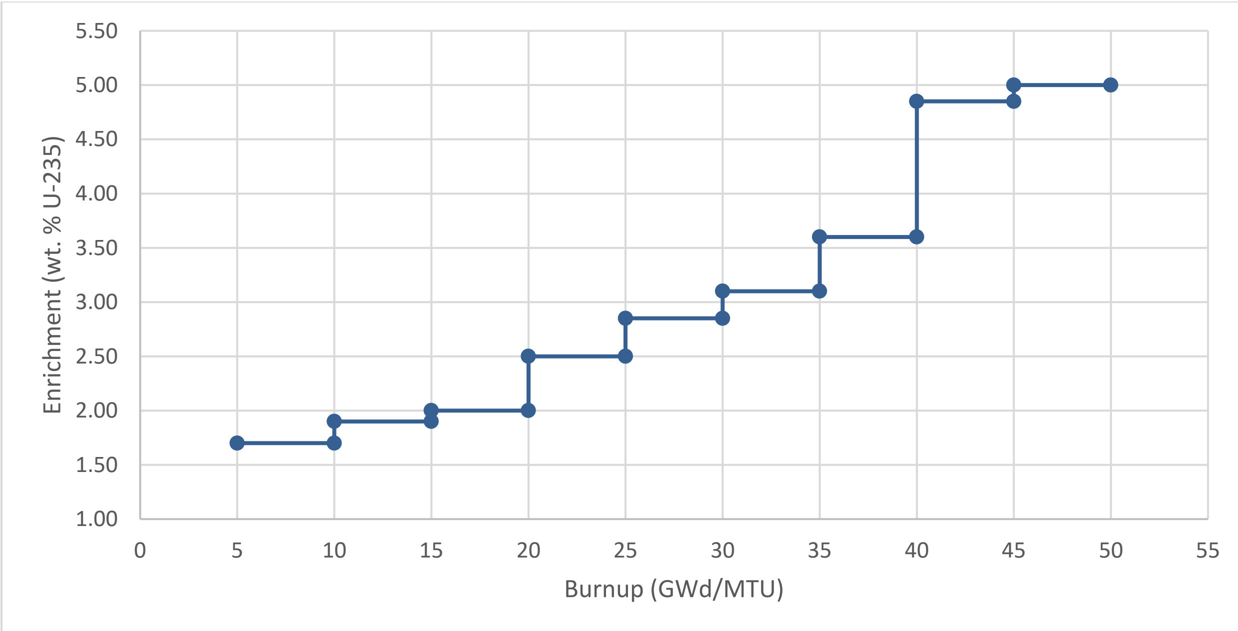


Figure 6.8.2-38
Loading Curve for Failed WE 17x17 FAs Loaded in EOS-37PTH DSC Type B – 15 Years CT

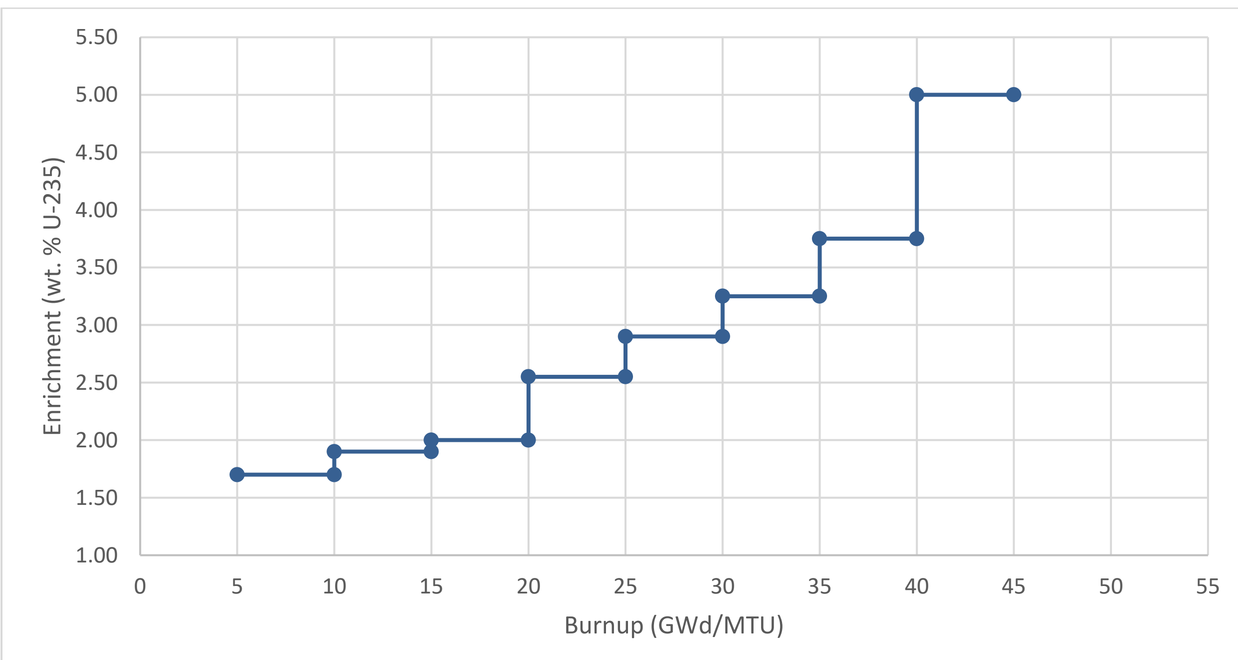


Figure 6.8.2-39
Loading Curve for Failed WE 17x17 FAs Loaded in EOS-37PTH DSC Type B – 20 Years CT

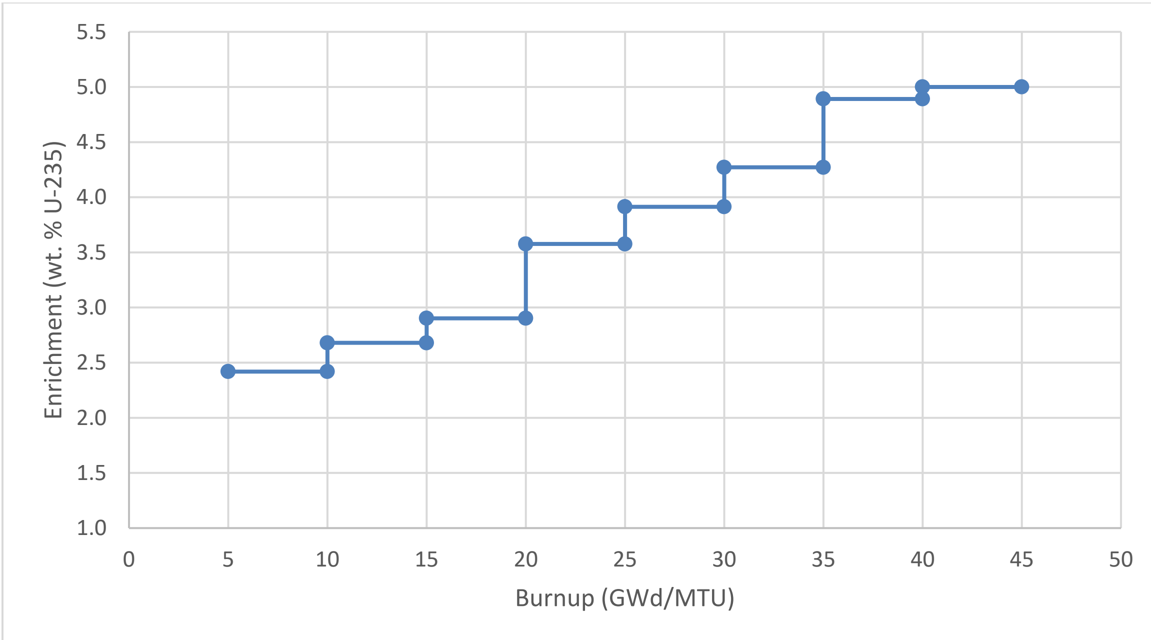


Figure 6.8.2-40
Loading Curve for Intact WE 14x14 FAs Loaded in EOS-37PTH DSC Type A – 5 Years CT

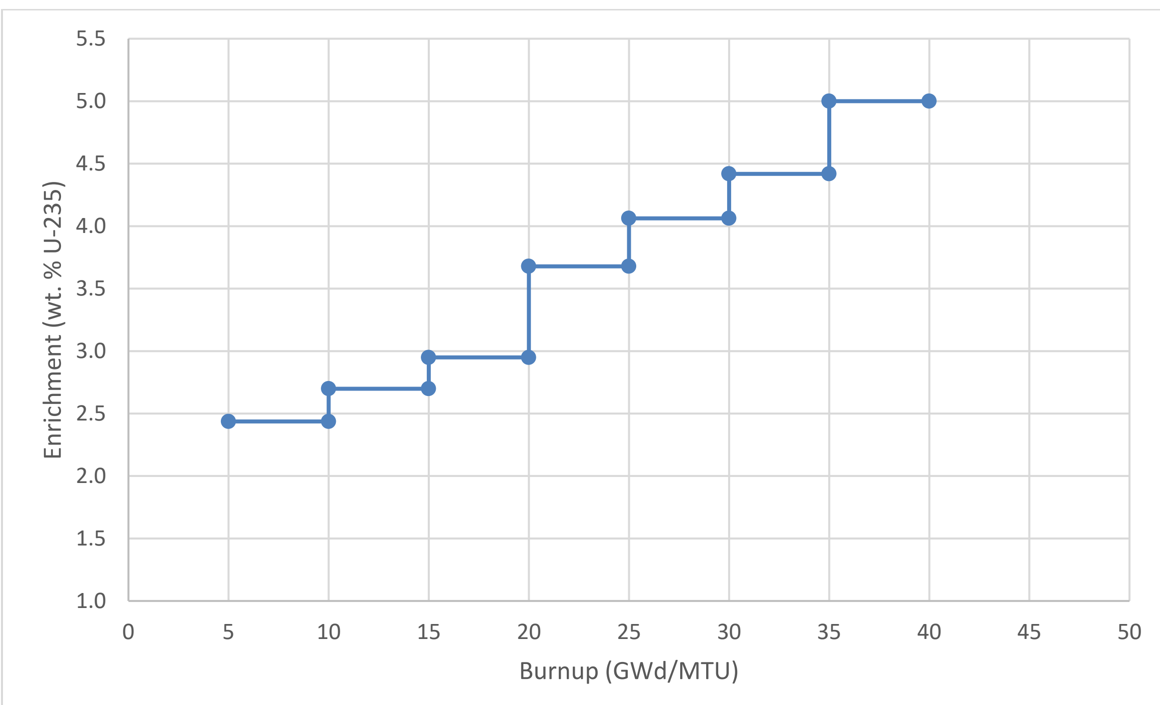


Figure 6.8.2-41
Loading Curve for Intact WE 14x14 FAs Loaded in EOS-37PTH DSC Type A – 10 Years CT

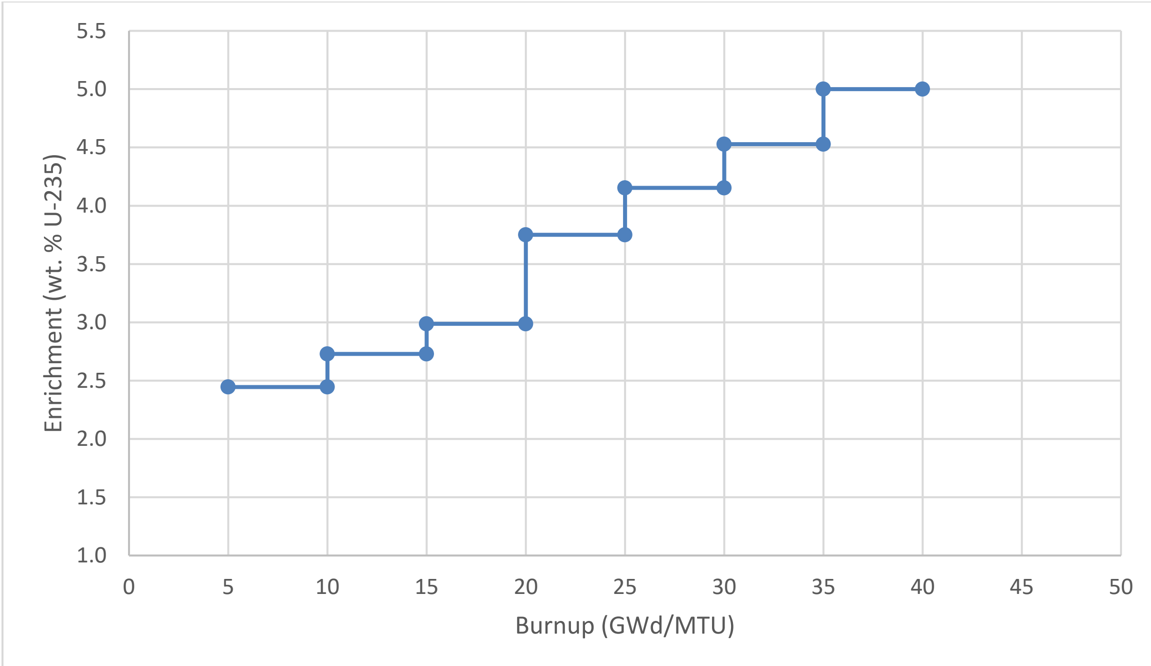


Figure 6.8.2-42
Loading Curve for Intact WE 14x14 FAs Loaded in EOS-37PTH DSC Type A – 15 Years CT

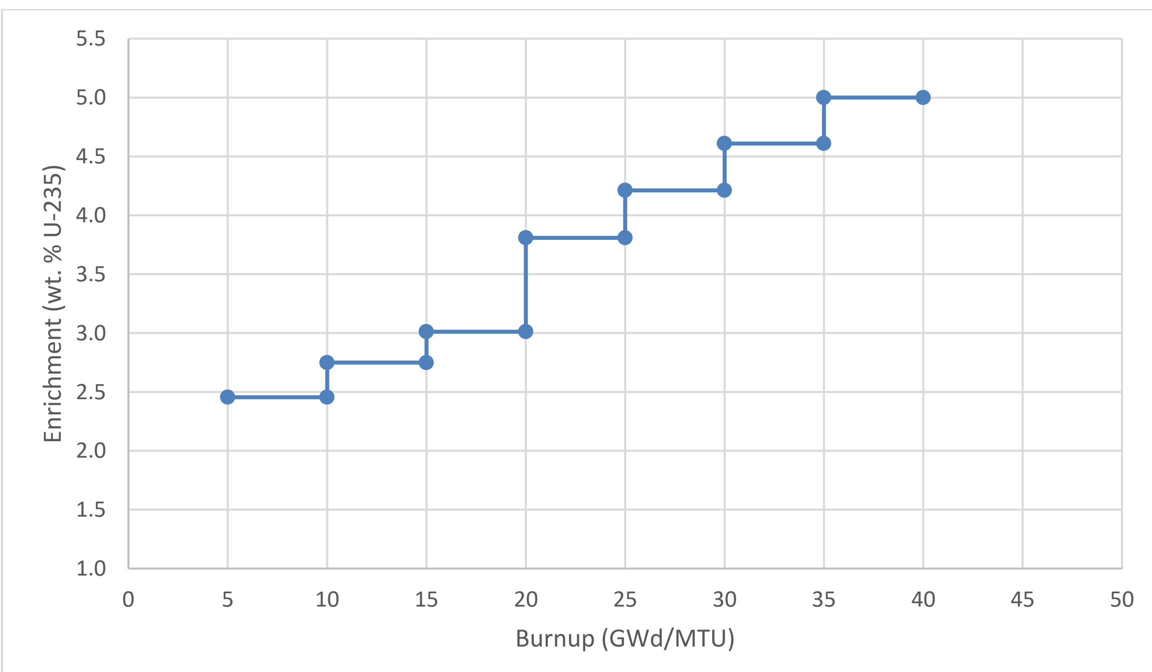


Figure 6.8.2-43
Loading Curve for Intact WE 14x14 FAs Loaded in EOS-37PTH DSC Type A – 20 Years CT

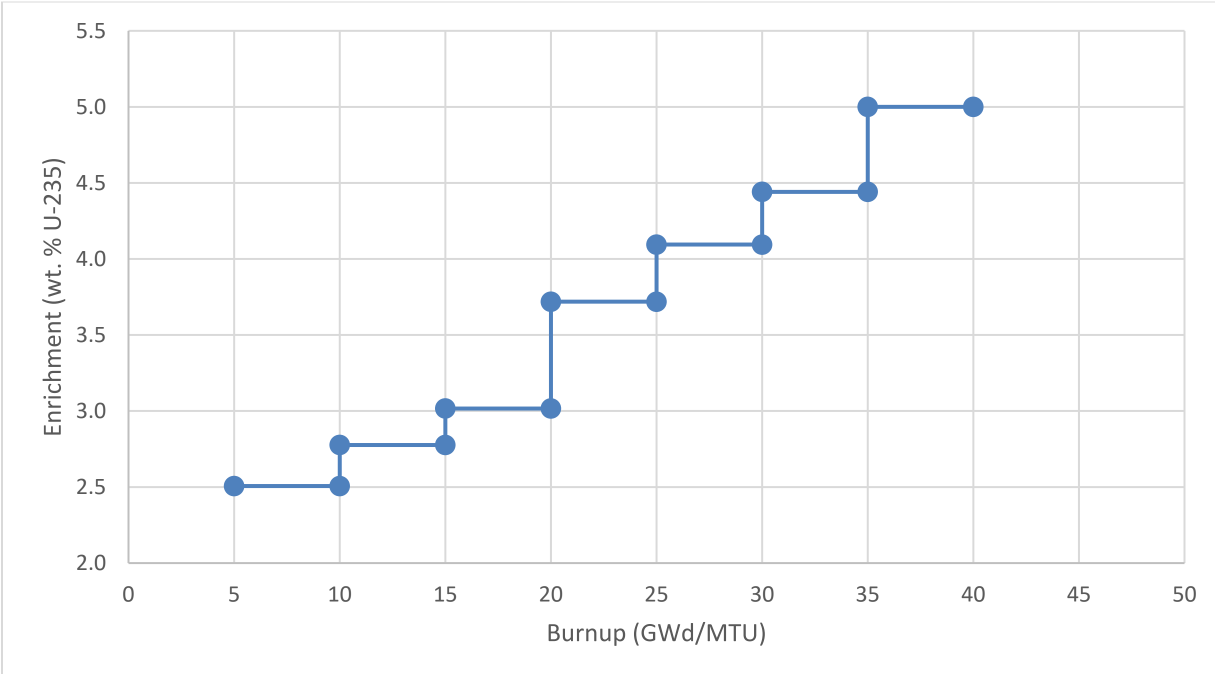


Figure 6.8.2-44
Loading Curve for Intact WE 14x14 FAs Loaded in EOS-37PTH DSC Type B – 5 Years CT

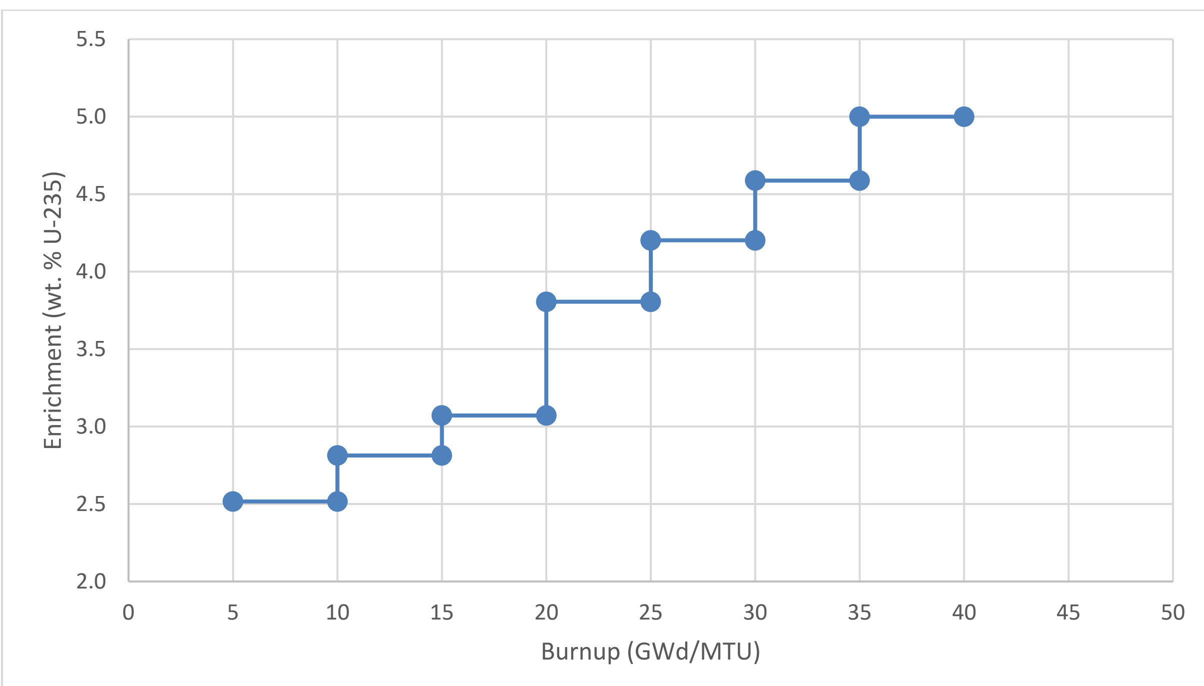


Figure 6.8.2-45
Loading Curve for Intact WE 14x14 FAs Loaded in EOS-37PTH DSC Type B – 10 Years CT

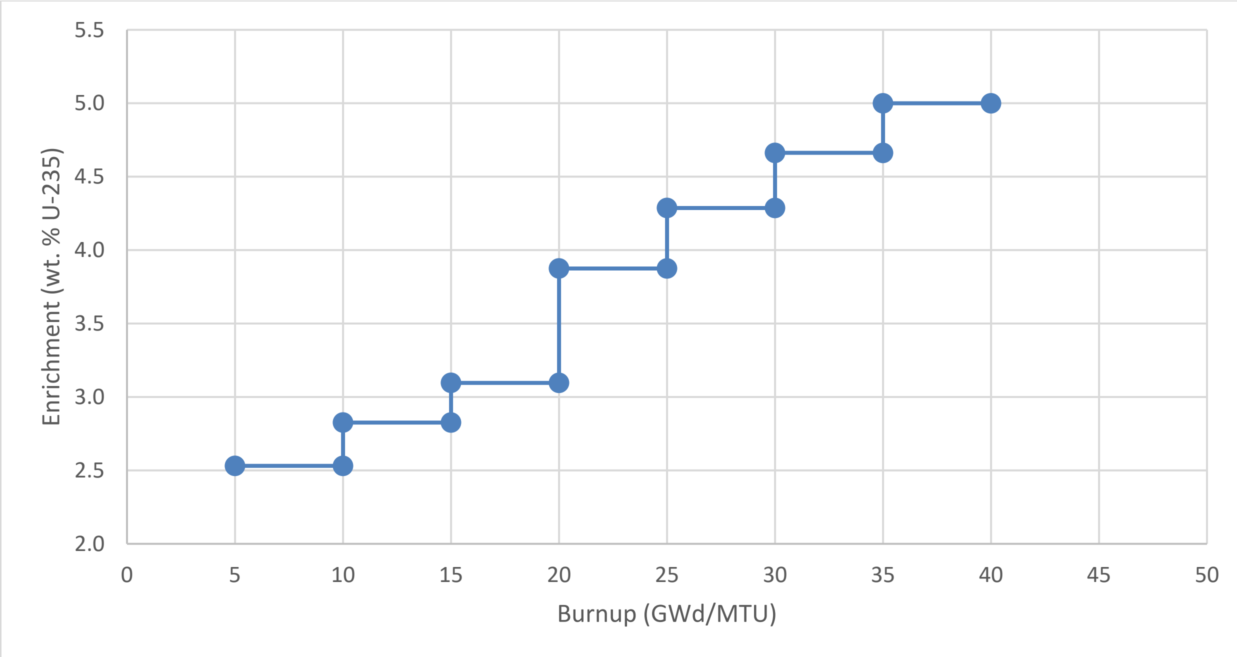


Figure 6.8.2-46
Loading Curve for Intact WE 14x14 FAs Loaded in EOS-37PTH DSC Type B – 15 Years CT

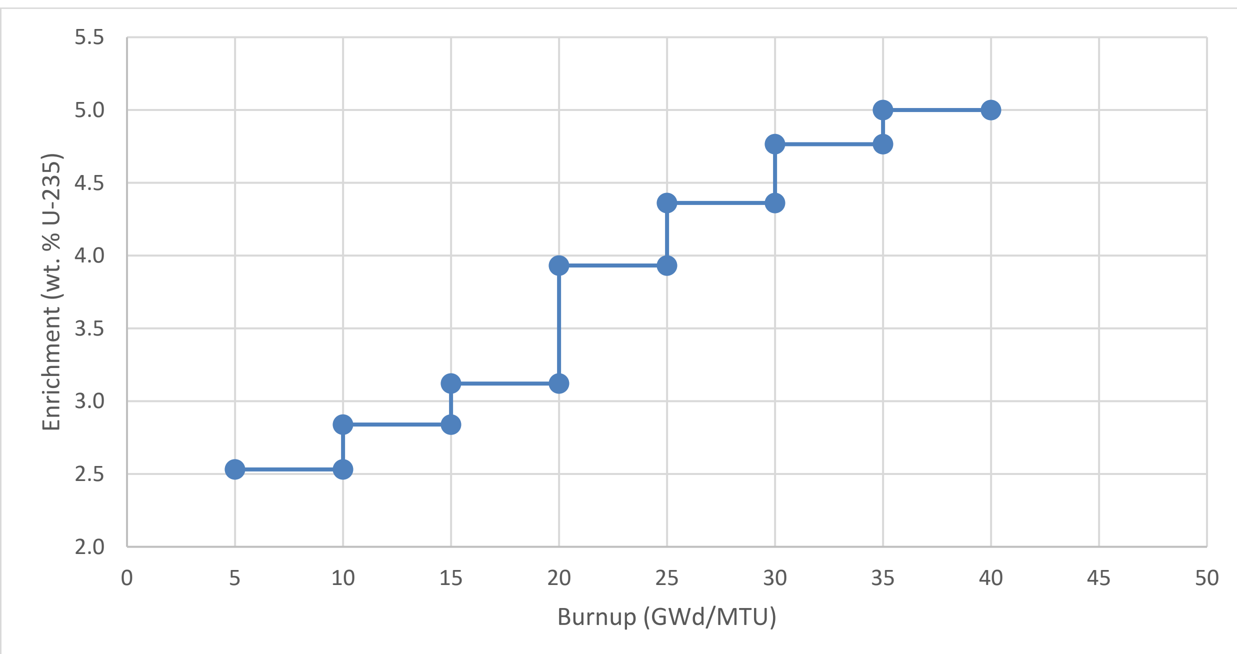


Figure 6.8.2-47
Loading Curve for Intact WE 14x14 FAs Loaded in EOS-37PTH DSC Type B – 20 Years CT

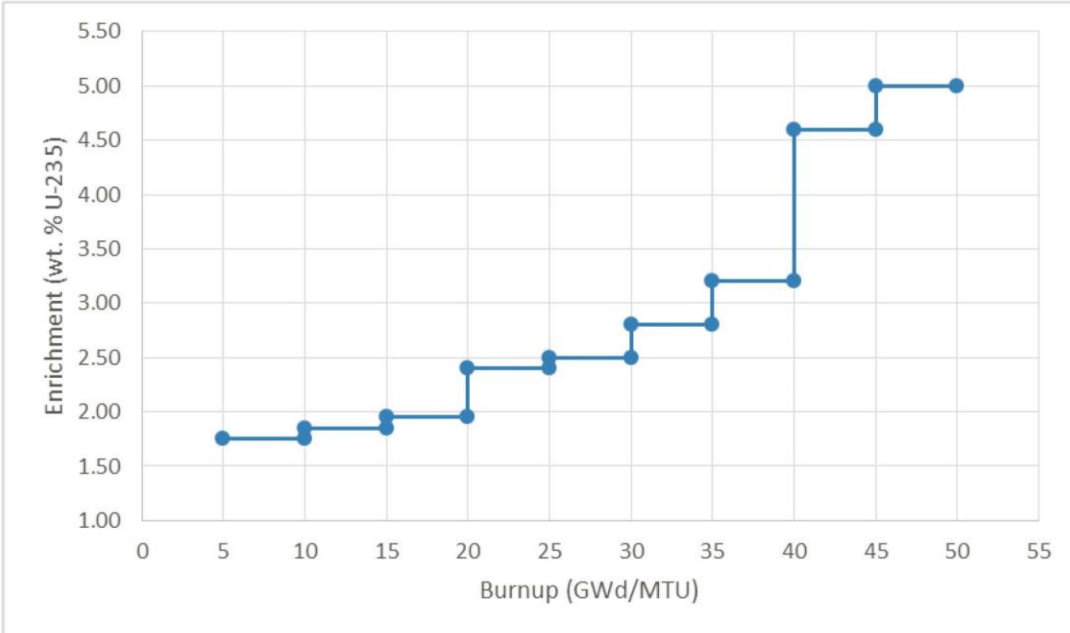


Figure 6.8.2-48
Loading Curve for Failed WE 14x14 FAs Loaded in EOS-37PTH DSC Type A – 5 Years CT

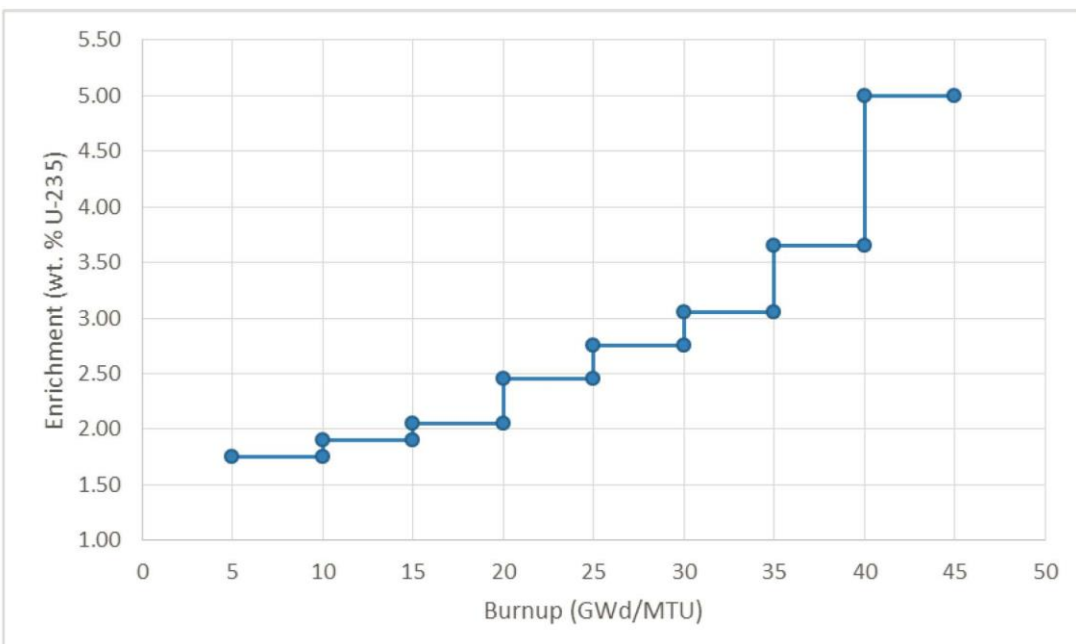


Figure 6.8.2-49
Loading Curve for Failed WE 14x14 FAs Loaded in EOS-37PTH DSC Type A – 10 Years CT

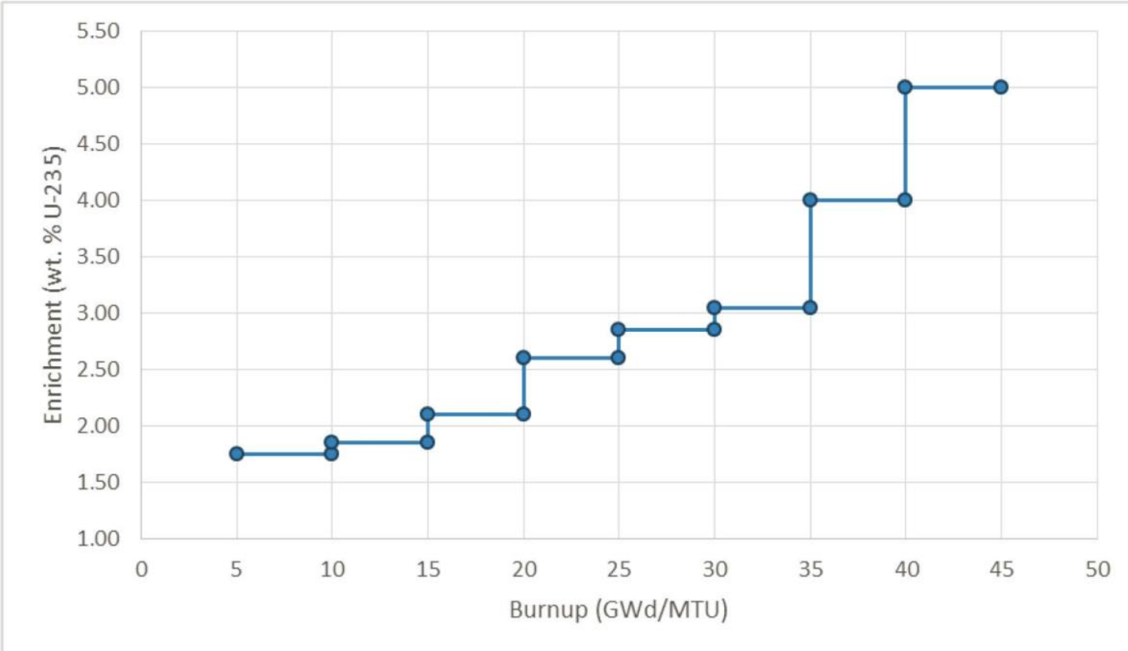


Figure 6.8.2-50
Loading Curve for Failed WE 14x14 FAs Loaded in EOS-37PTH DSC Type A – 15 Years CT

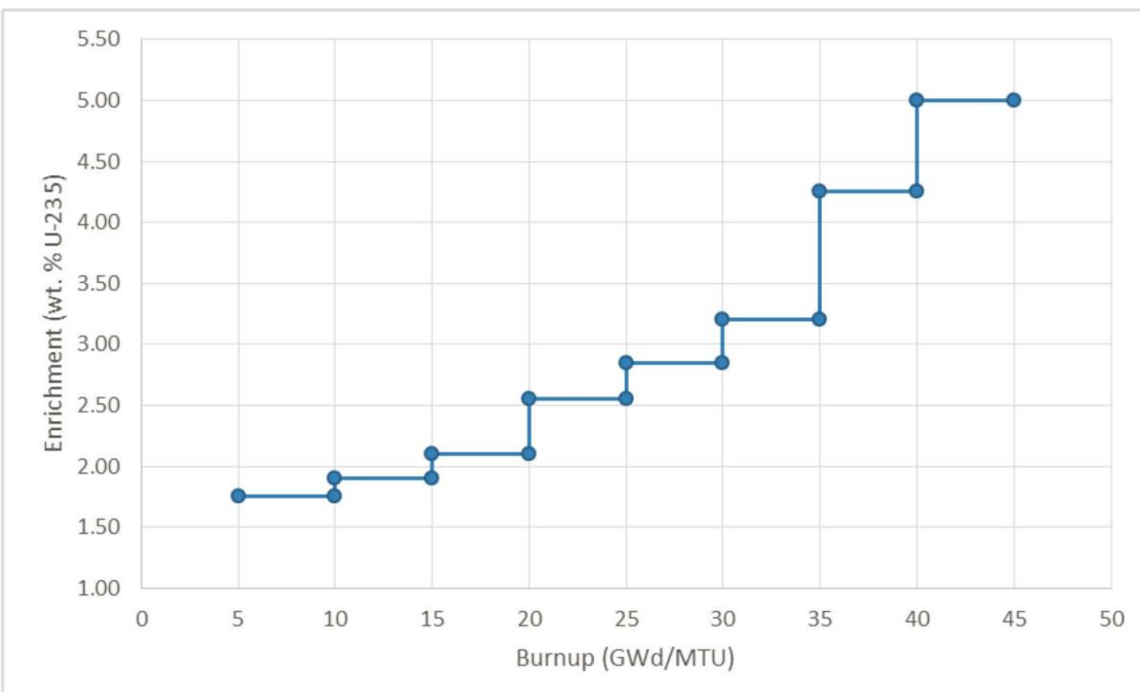


Figure 6.8.2-51
Loading Curve for Failed WE 14x14 FAs Loaded in EOS-37PTH DSC Type A – 20 Years CT

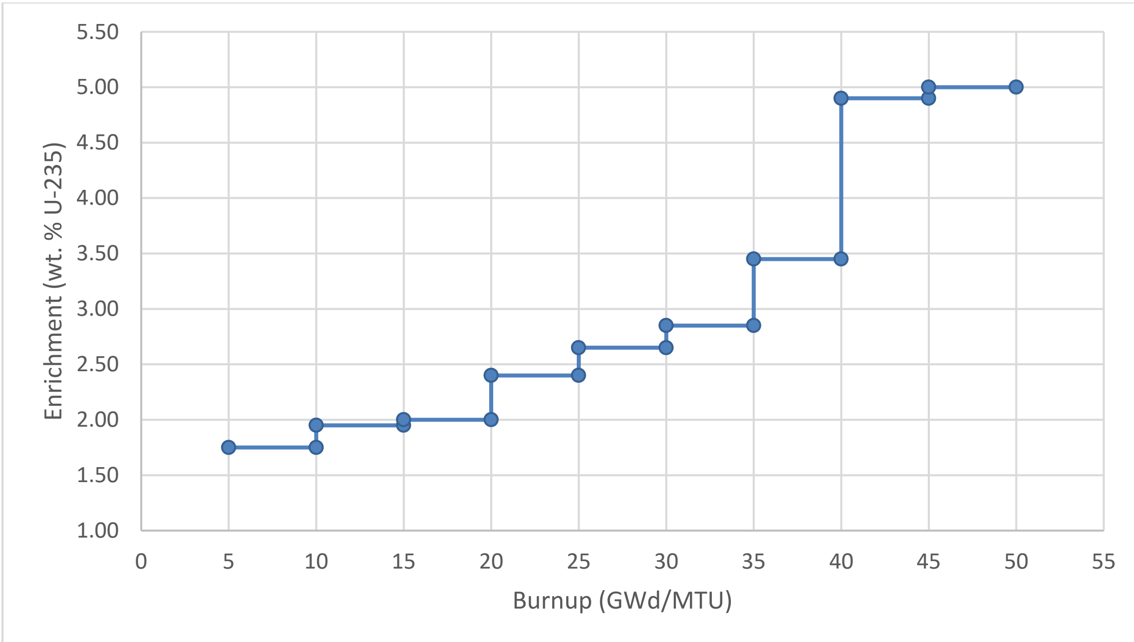
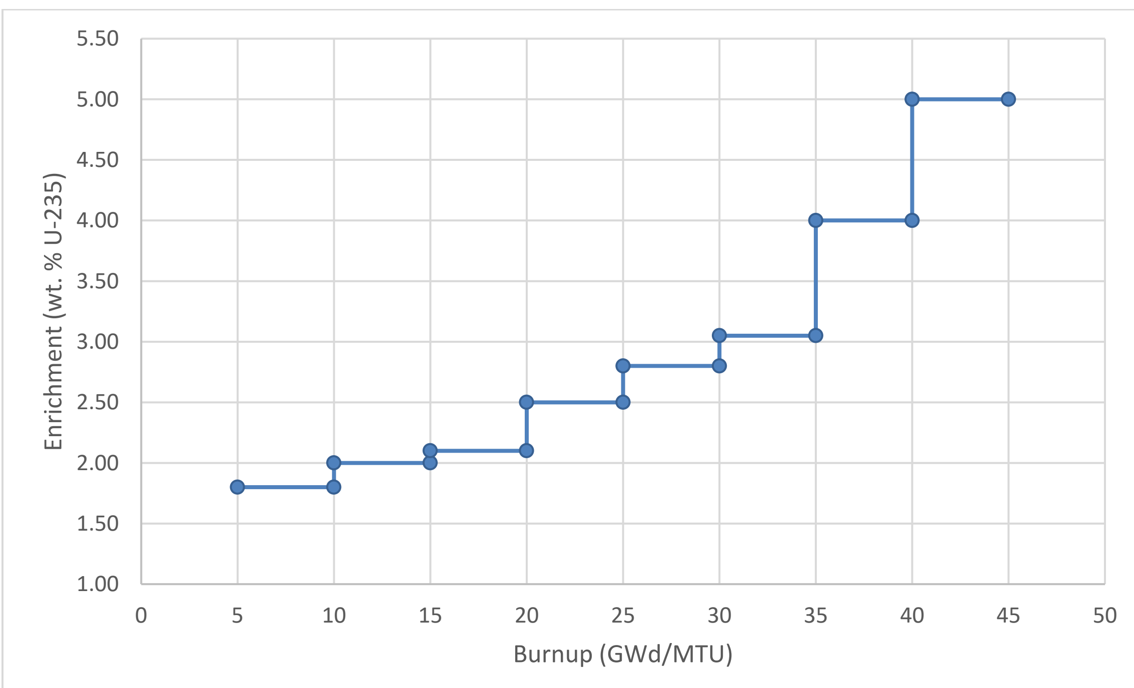


Figure 6.8.2-52
Loading Curve for Failed WE 14x14 FAs Loaded in EOS-37PTH DSC Type B – 5 Years CT



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Loading Curve for Failed WE 14x14 FAs Loaded in EOS-37PTH DSC Type B – 10 Years CT

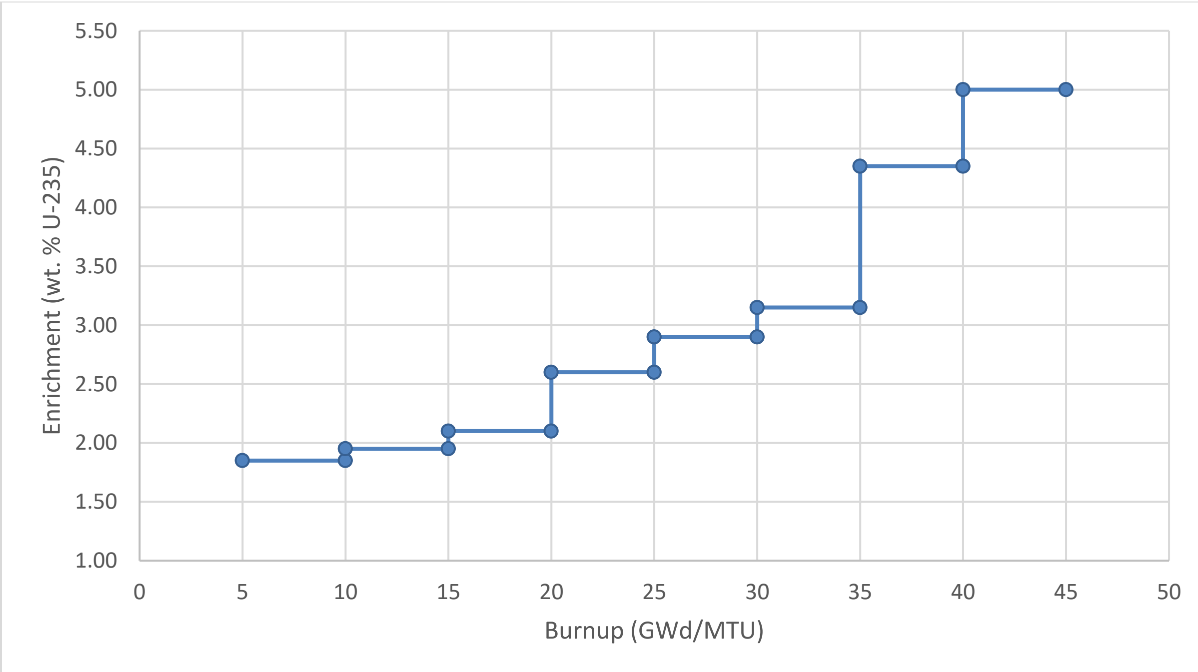

Figure 6.8.2-54
Loading Curve for Failed WE 14x14 FAs Loaded in EOS-37PTH DSC Type B – 15 Years CT

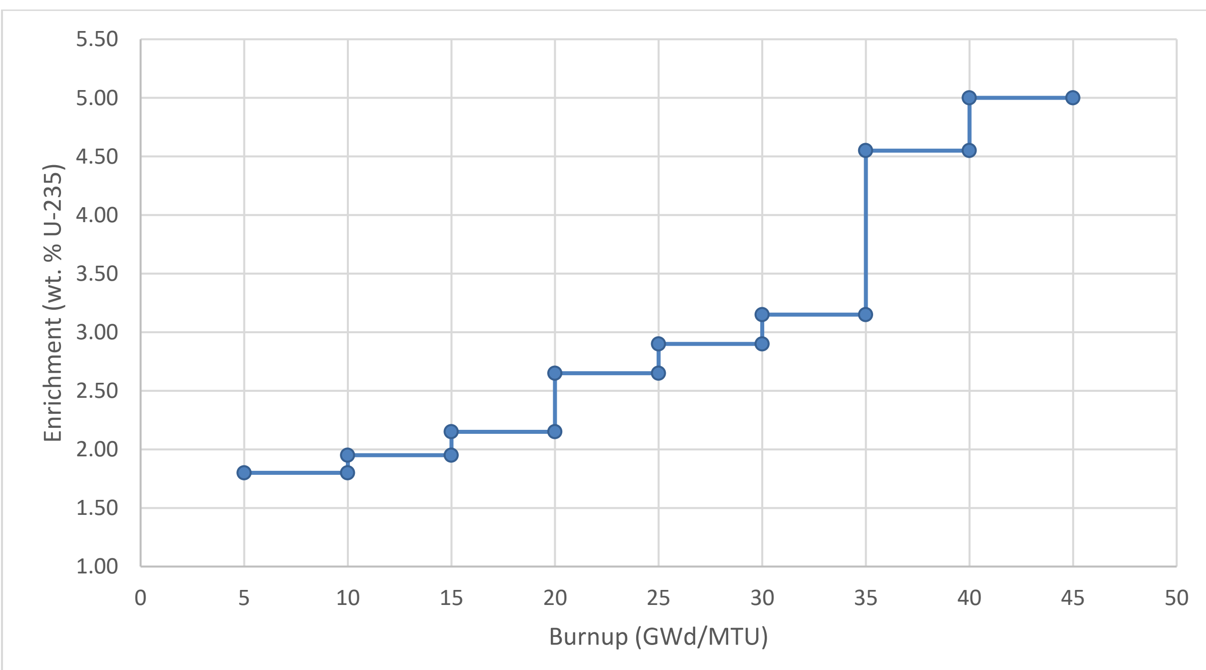

Figure 6.8.2-55
Loading Curve for Failed WE 14x14 FAs Loaded in EOS-37PTH DSC Type B – 20 Years CT

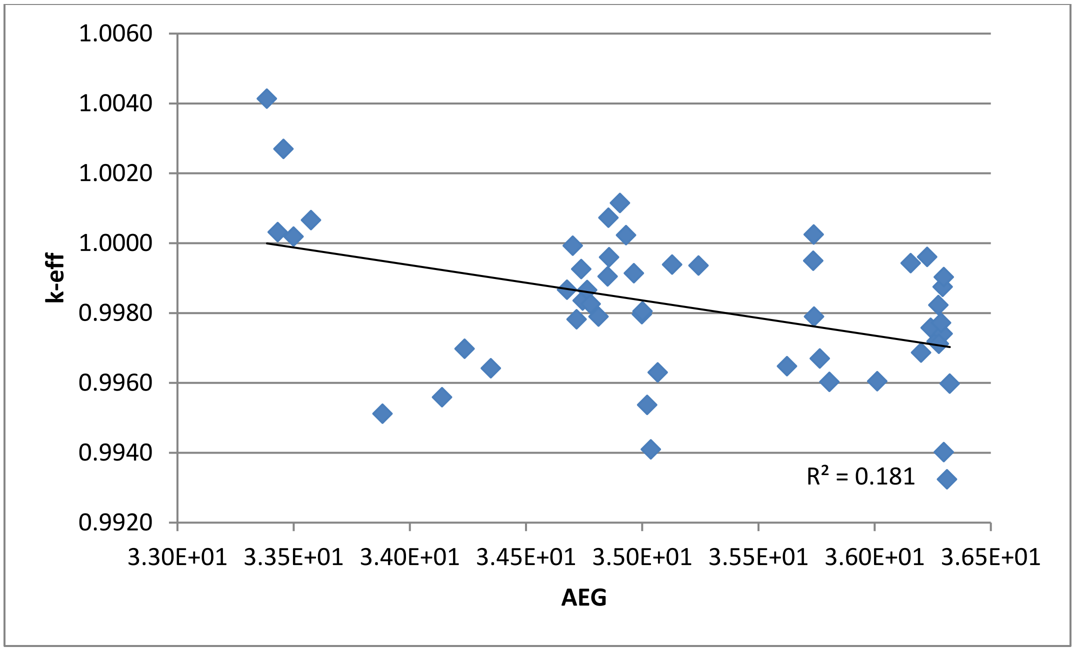

Figure 6.8.2-56
k_{eff} Plotted against AEG Values for Critical Experiments with Fresh Fuel Assumptions

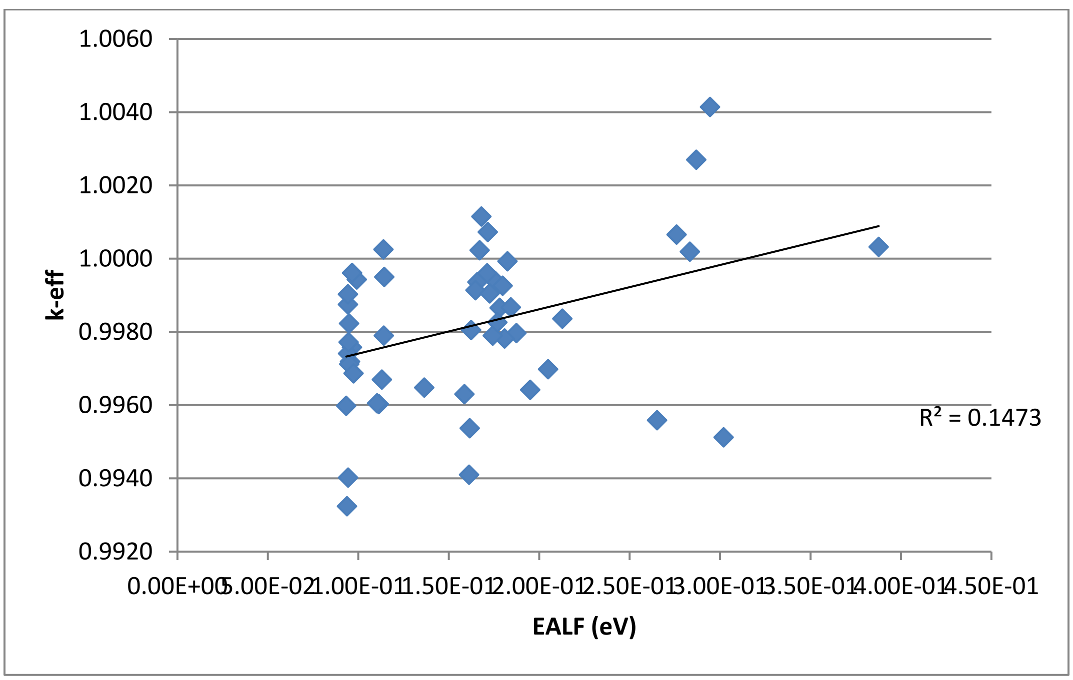

Figure 6.8.2-57
k_{eff} Plotted against EALF Values for Critical Experiments with Fresh Fuel Assumptions

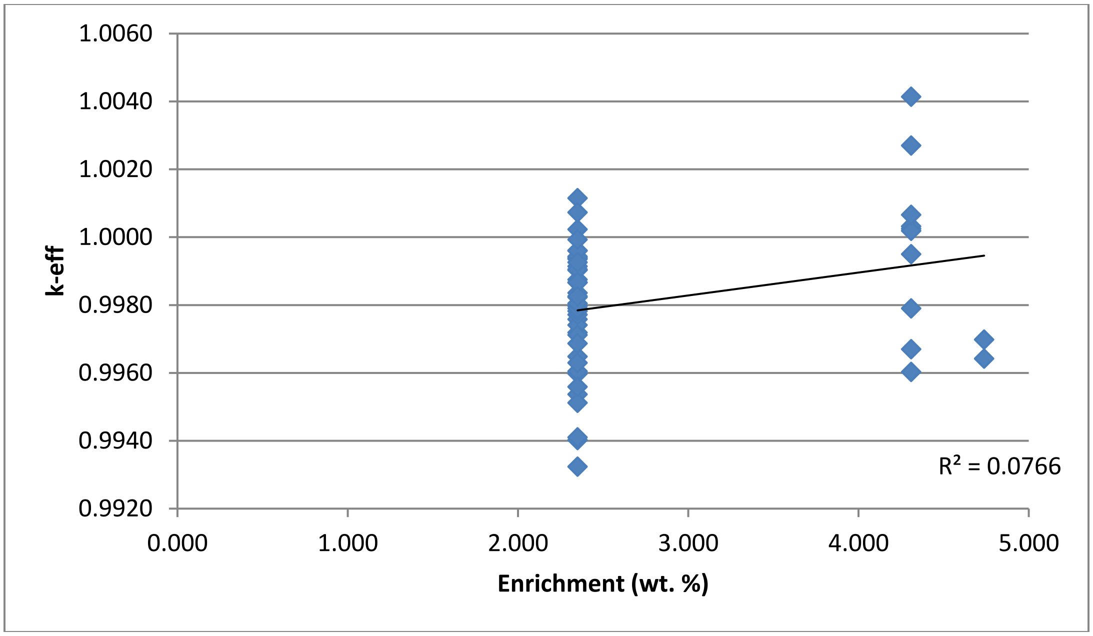

Figure 6.8.2-58
k_{eff} Plotted against Enrichment Values for Critical Experiments with Fresh Fuel Assumptions

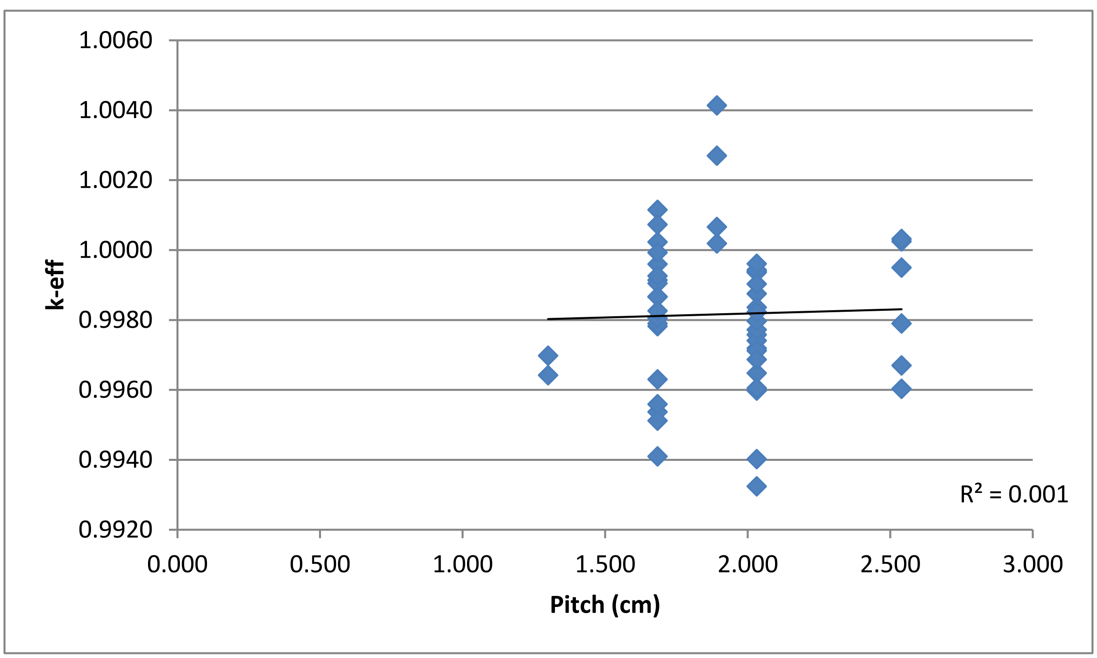

Figure 6.8.2-59
k_{eff} Plotted against Pitch Values for Critical Experiments with Fresh Fuel Assumptions

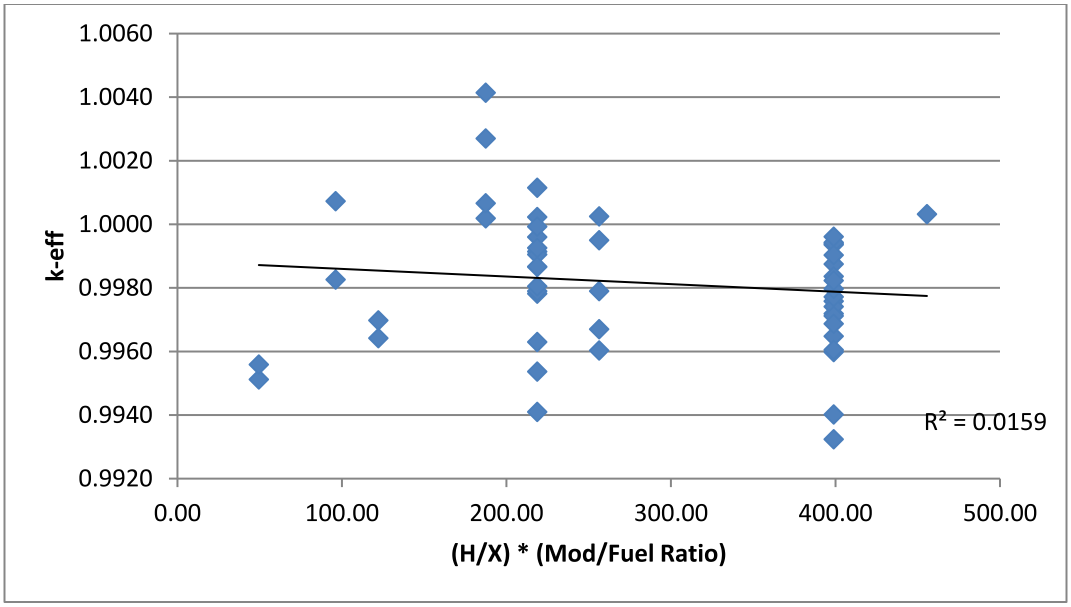

Figure 6.8.2-60
k_{eff} Plotted against (H/X) * (Mod/Fuel Ratio) Values for Critical Experiments with Fresh Fuel Assumptions

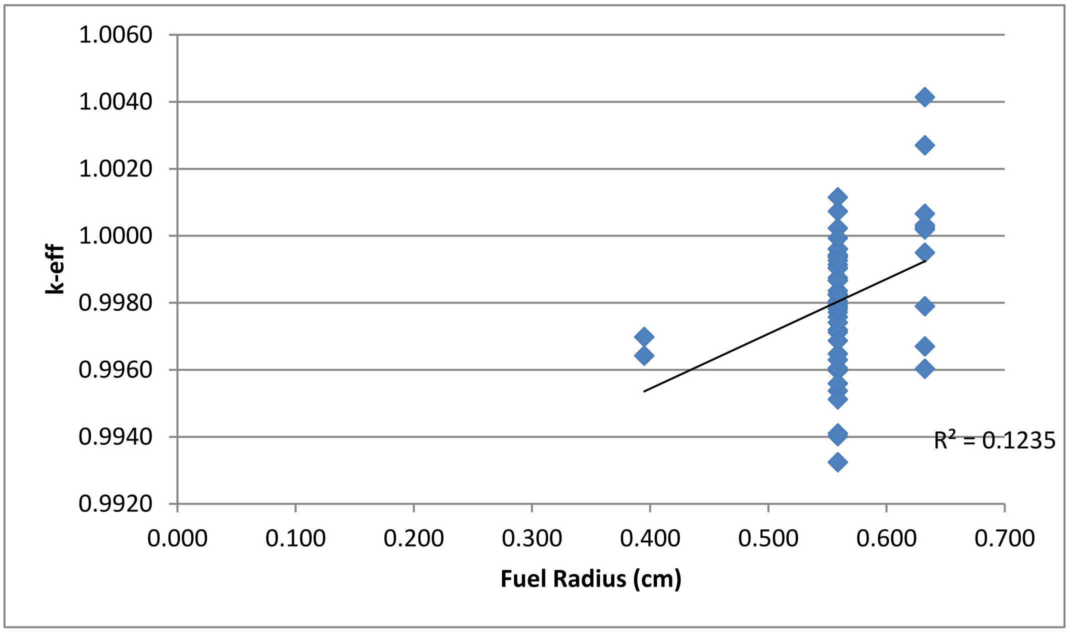

Figure 6.8.2-61
k_{eff} Plotted against Fuel Rod Radius Values for Critical Experiments with Fresh Fuel Assumptions

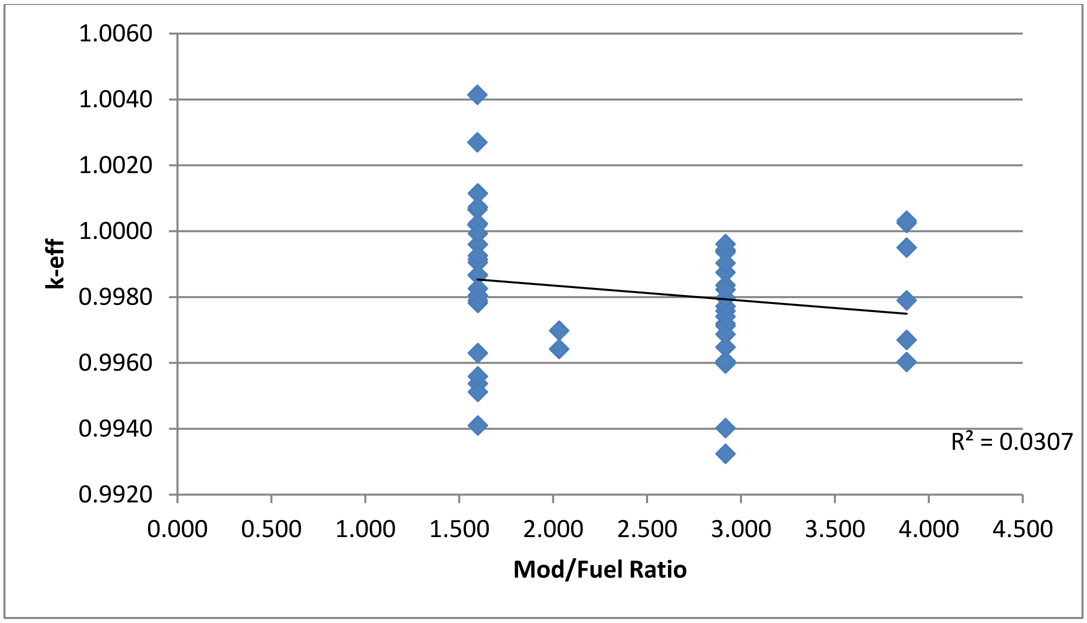

Figure 6.8.2-62
k_{eff} Plotted against Mod/Fuel Ratio Values for Critical Experiments with Fresh Fuel Assumptions

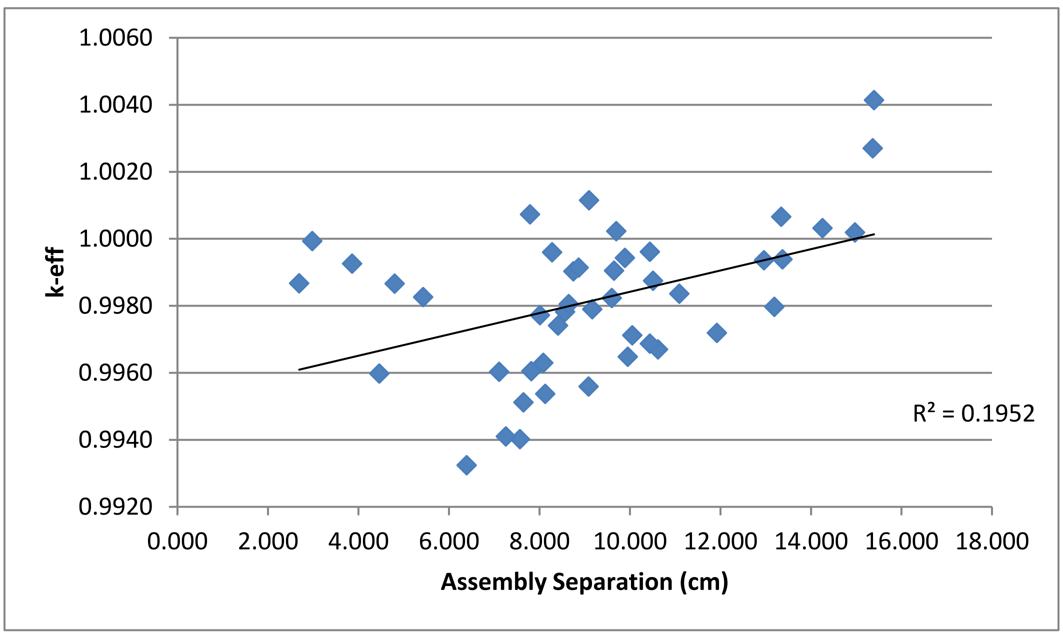

Figure 6.8.2-63
k_{eff} Plotted against Assembly Separation Values for Critical Experiments with Fresh Fuel Assumptions

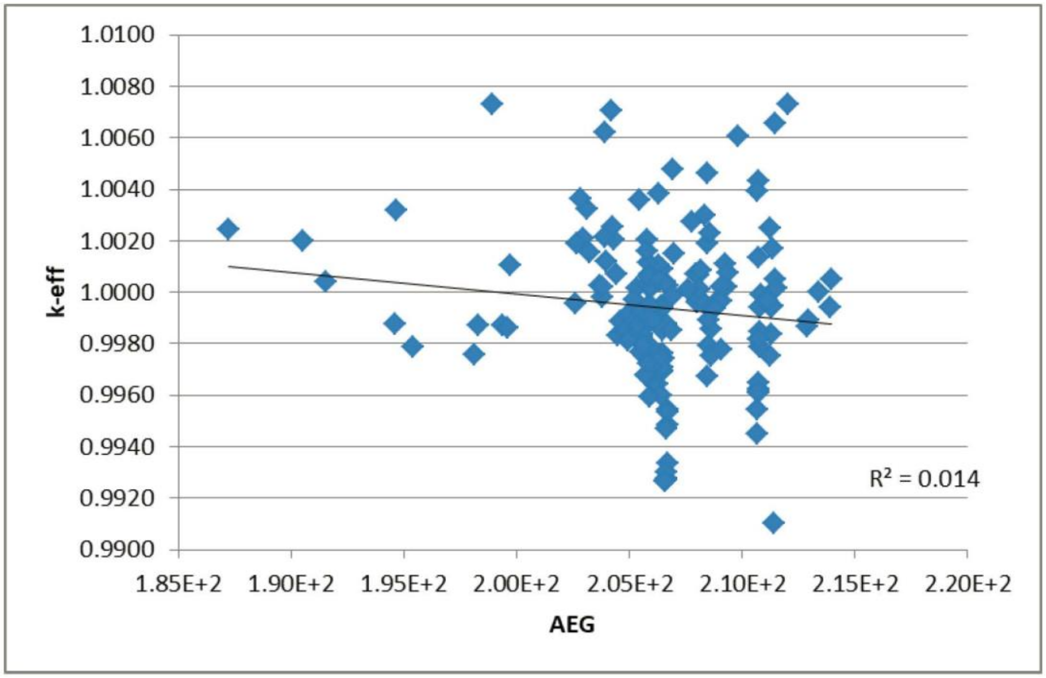

Figure 6.8.2-64
k_{eff} Plotted against AEG Values for Critical Experiments with PWR Burnup Credit Assumptions

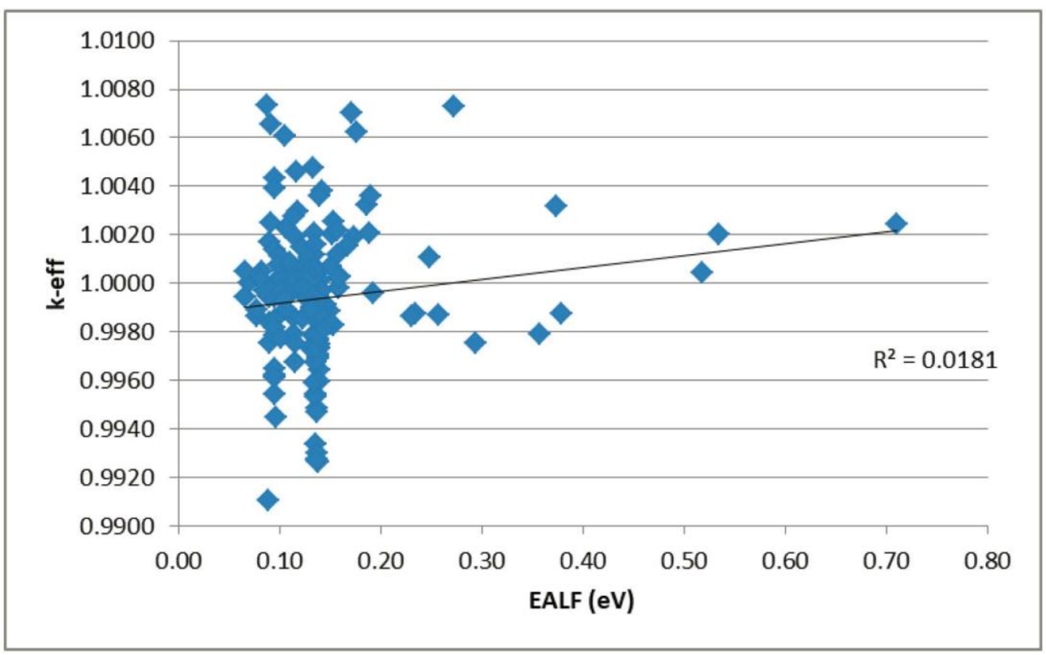

Figure 6.8.2-65
k_{eff} Plotted against EALF Values for Critical Experiments with PWR Burnup Credit Assumptions

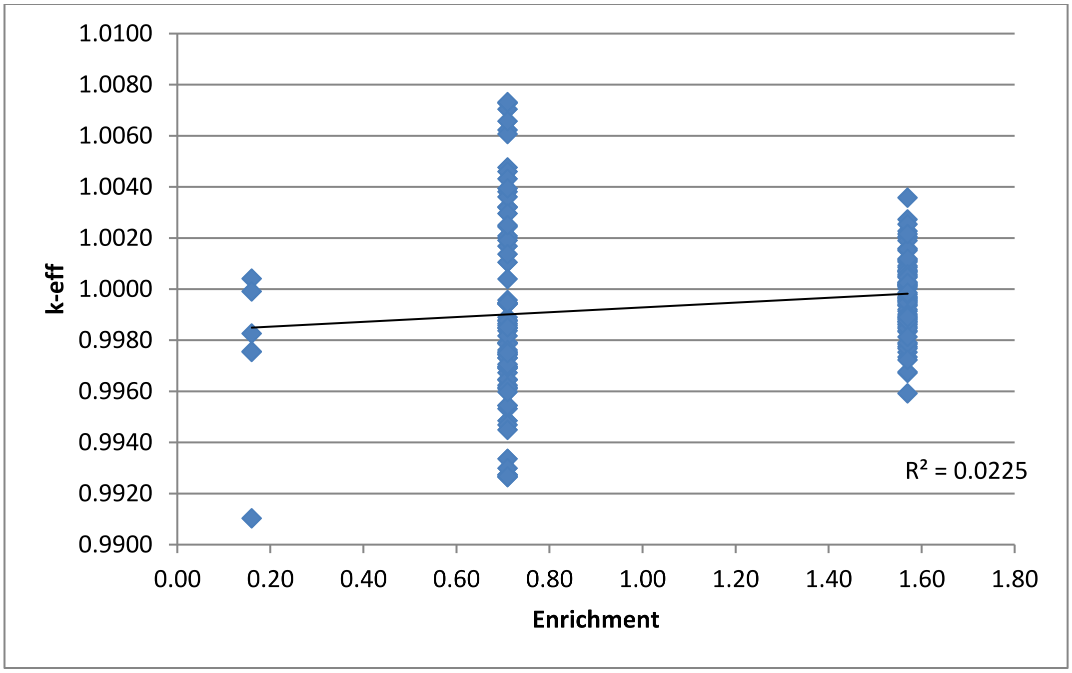

Figure 6.8.2-66
k_{eff} Plotted against Enrichment Values for Critical Experiments with PWR Burnup Credit Assumptions

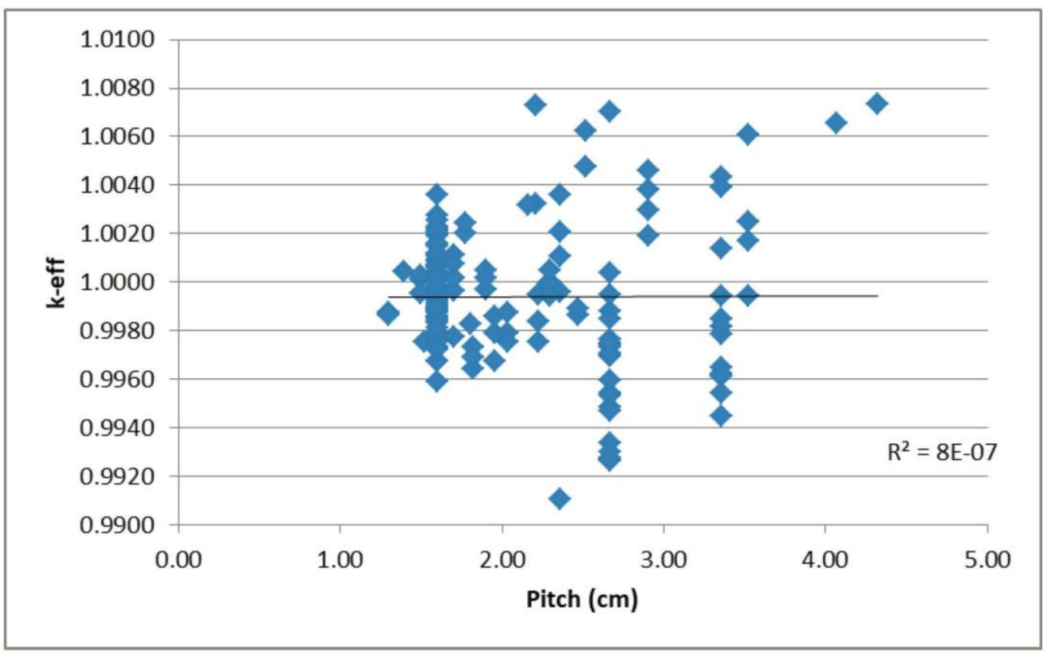

Figure 6.8.2-67
k_{eff} Plotted against Pitch Values for Critical Experiments with PWR Burnup Credit Assumptions

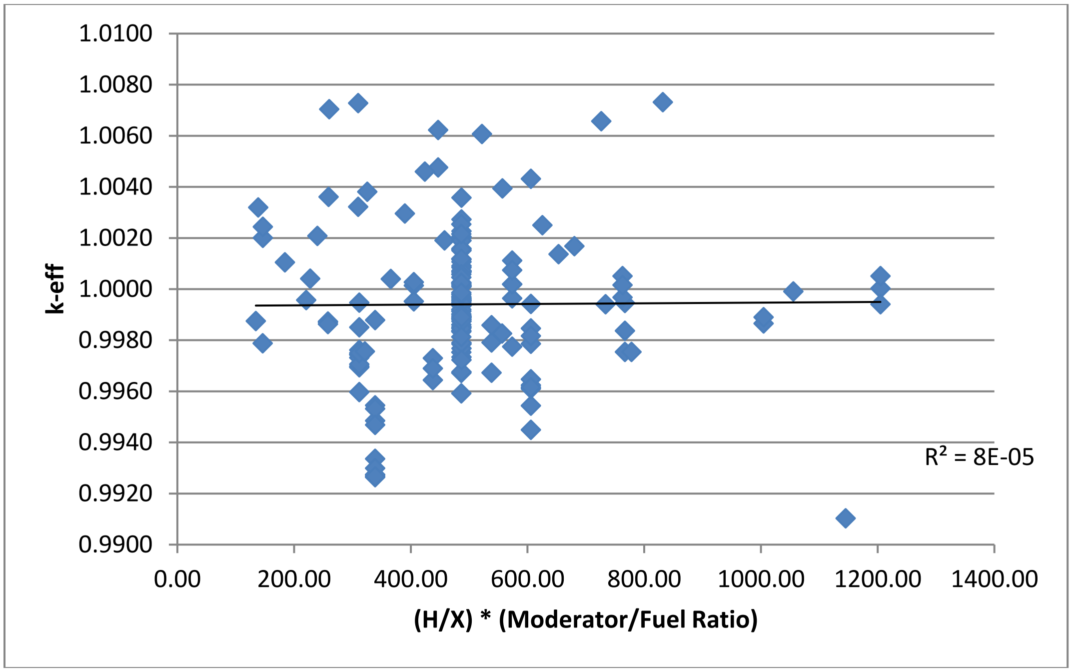

Figure 6.8.2-68
k_{eff} Plotted against (H/X) * (Mod/Fuel Ratio) Values for Critical Experiments with PWR Burnup Credit Assumptions

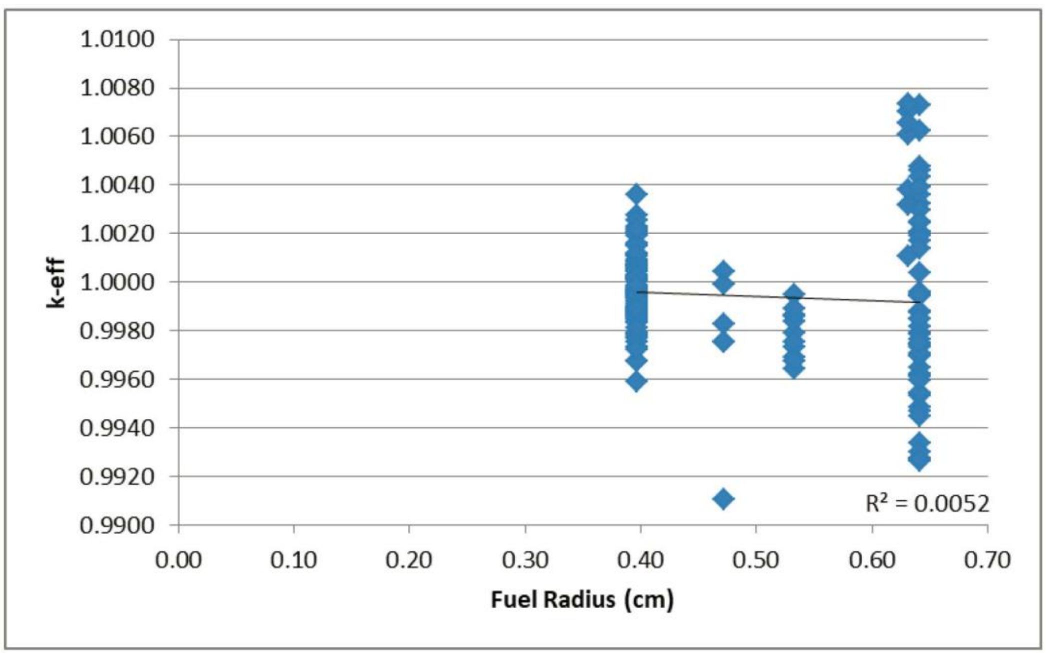

Figure 6.8.2-69
k_{eff} Plotted against Fuel Radius Values for Critical Experiments with PWR Burnup Credit Assumptions

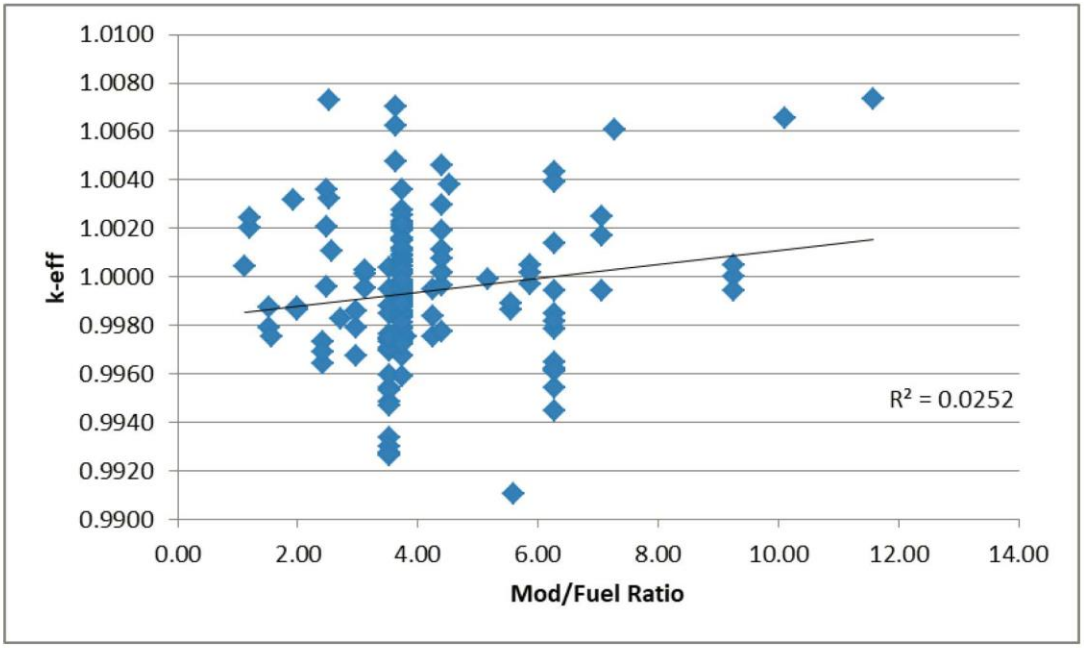

Figure 6.8.2-70
k_{eff} Plotted against Mod/Fuel Values for Critical Experiments with PWR Burnup Credit Assumptions

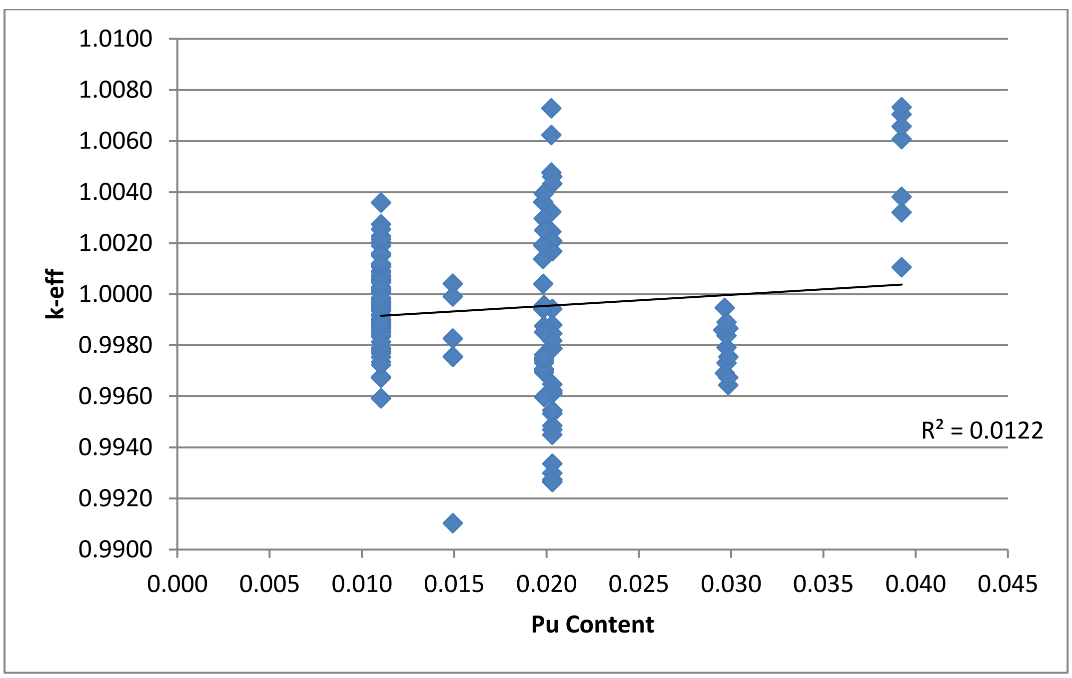

Figure 6.8.2-71
k_{eff} Plotted against Pu/Pu+U Values for Critical Experiments with PWR Burnup Credit Assumptions

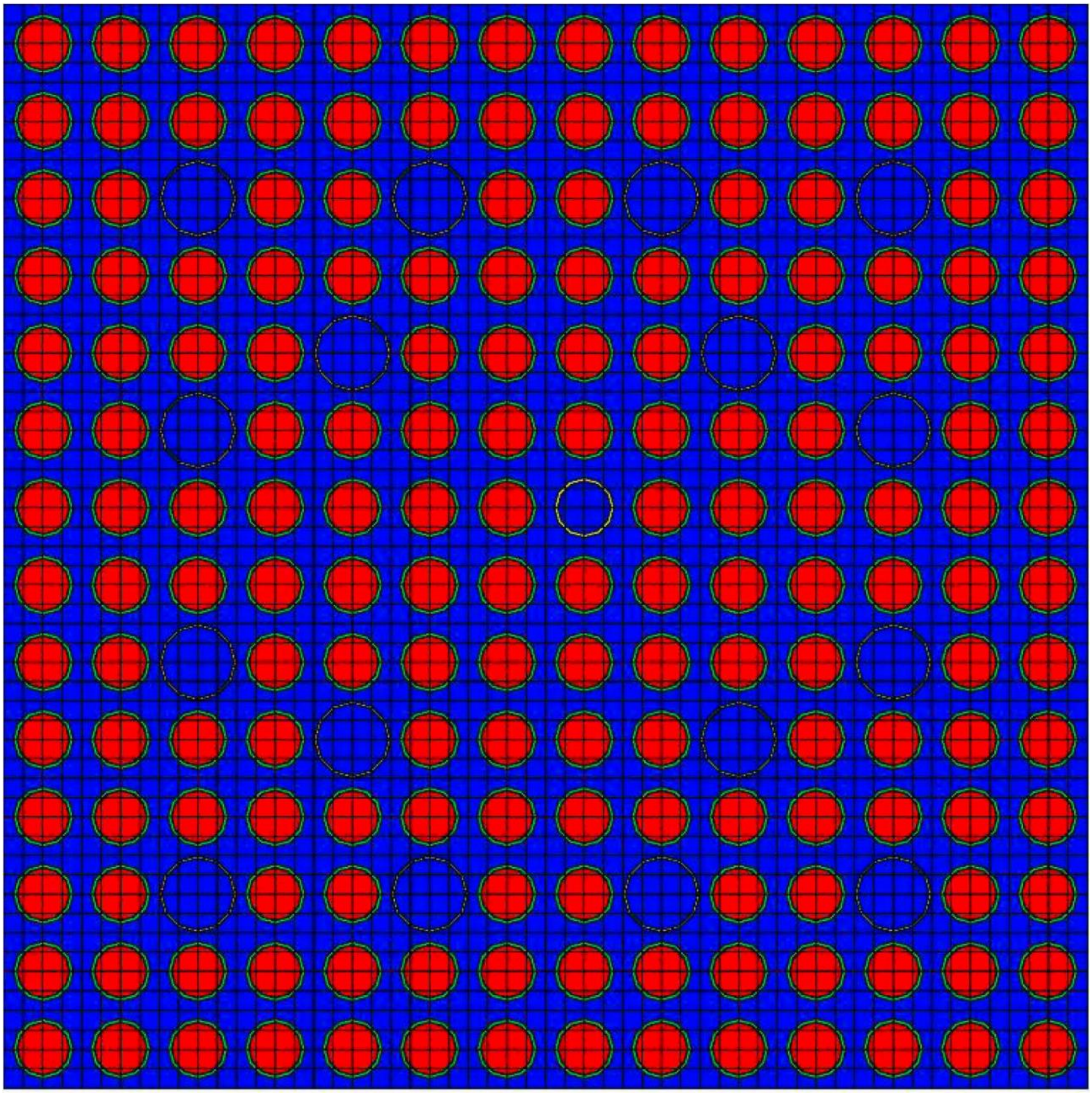

Figure 6.8.2-72
T-DEPL Model for the WE 14x14 Fuel Class

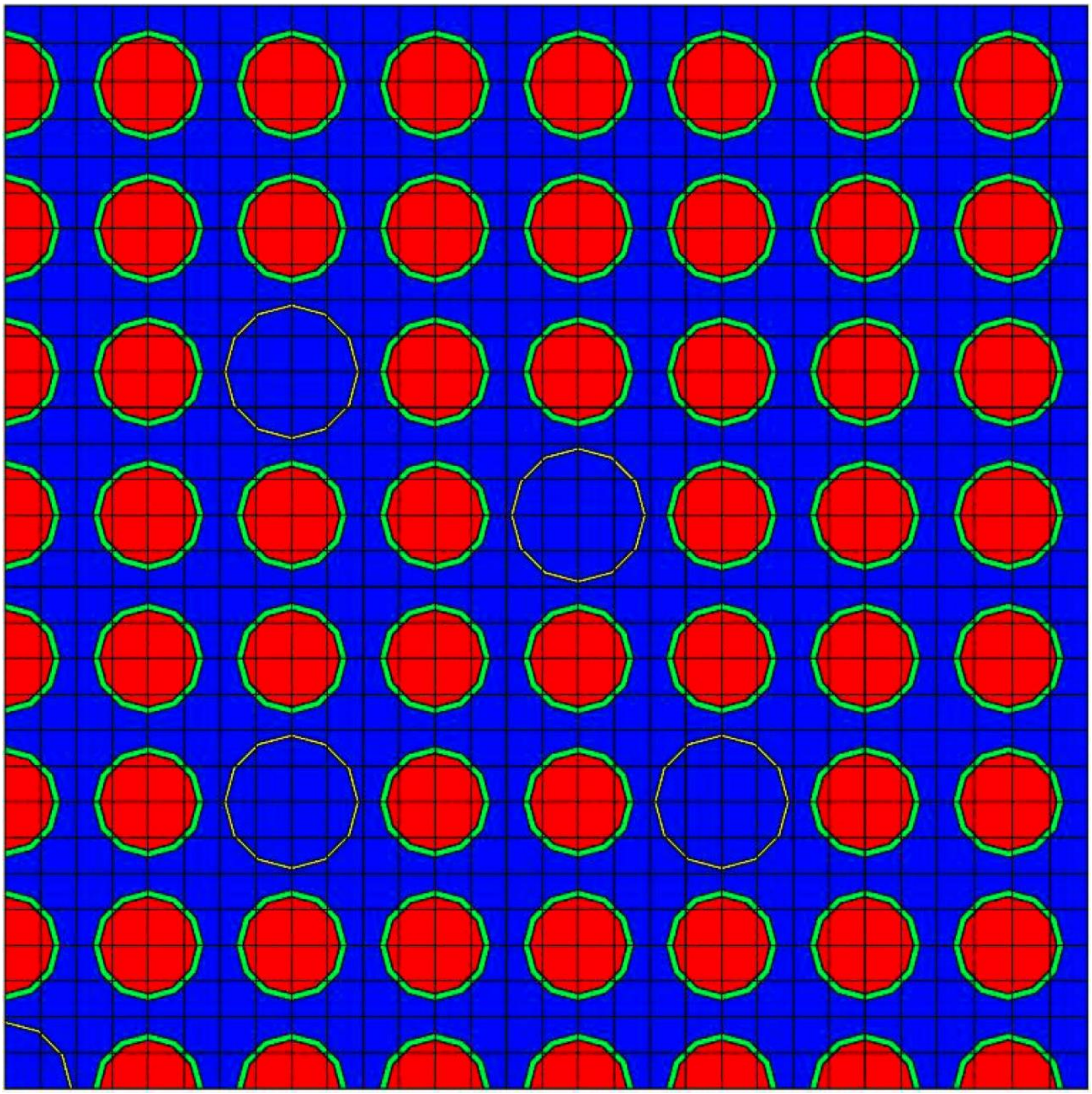

Figure 6.8.2-73
T-DEPL Model for the BW 15x15 Fuel Class

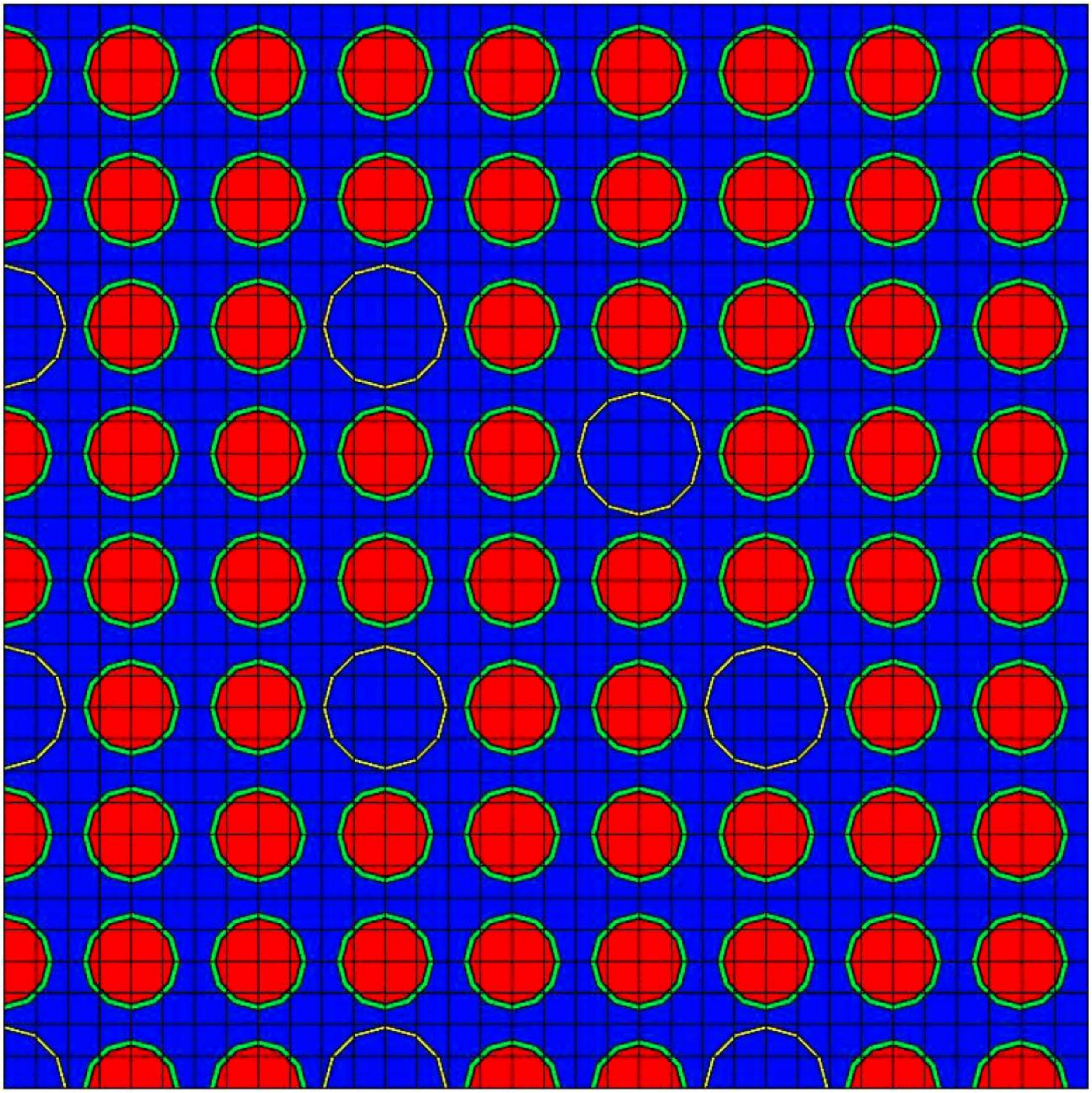

Figure 6.8.2-74
T-DEPL Model of the WE 17x17 Fuel Class

Proprietary Information on Pages 6.8.2-121 and 6.8.2-122
Withheld Pursuant to 10 CFR 2.390

Appendix 6.8.3
FO, FC, FF and 24PT1 DSCs Criticality Evaluation

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6.8.3 FO, FC, FF and 24PT1 DSCs Criticality Evaluation

NOTE: References in this Appendix are shown as [1], [2], etc. and refer to the reference list in Section 6.8.3.4.

This Appendix 6.8.3 to Chapter 6 demonstrates that the TN Eagle Cask when loaded with the FO or FC or FF or 24PT1 DSC meets the criticality requirements specified in the Sections 71.55 and 71.59 of 10 CFR Part 71 [1].

6.8.3.1 Fissile Material Contents

The design basis fuel for the FO/FC and FF dry shielded cansiters (DSCs) is Babcock and Wilcox (B&W) 15x15 Mark B fuel with a maximum fuel enrichment of 3.43 wt% U-235.

The design basis fuels for the 24PT1 DSC are Westinghouse (WE) 14x14 stainless steel clad uranium dioxide fuel assembly (FA), WE 14x14 SS, and WE 14x14 zirconium clad mixed oxide FA, WE 14x14 MOX.

6.8.3.2 General Consideration

The FO DSC is composed of four axially oriented support rods and twenty-six spacer discs. The basket is designed to accommodate up to 24 FAs. Fixed neutron absorbers composed of boron carbide and alloy aluminum are used for criticality control.

The FC DSC is designed with a longer internal cavity length to accommodate fuel control. The FC DSC is similar to the FO DSC regarding criticality analysis as no credit is taken for the presence of control hardware.

The FF DSC is designed to accommodate up to 13 failed fuels. The maximum failed rods in FF DSC are 15 rods per FA.

The 24PT1 DSC is similar to the FO DSC with capability to accommodate fuel control component, no credit is taken for the presence of control hardware in the criticality analysis. The 24PT1 DSC can also accommodate a screened failed fuel can to contain damaged FAs and portions of damaged fuel pins.

6.8.3.3 Discussion and Results

The methodology employed to ensure the subcriticality of the FO/FC and FF DSCs is based on a “fresh fuel” representation of the spent FAs. For these DSCs, the design basis FA is modeled with fresh (unirradiated) fuel.

The criticality analysis for the FO/FC and FF DSCs with B&W 15x15 Mark B design basis FA type was performed in Chapter 6 of the NUHOMS®-187 multipurpose cask SAR, [2], considering:

- Water leak in or out the canister.

- Criticality analyses performed with consideration for the most reactive credible configuration consistent with the chemical and physical form of the material, moderation by water to the most reactive credible extent and close full reflection by water on all sides or such greater reflection of the containment system as may additionally be provided by the surrounding material of the packaging.
- Any number of undamaged or damaged packages will remain subcritical in any arrangement with close full water reflection and optimum interspersed hydrogenous moderation. Therefore, the criticality safety index (CSI), transport index for the package, is zero.

As such the criticality analysis for the FO/FC and FF DSCs in Chapter 6 of the NUHOMS®-187 Multipurpose Cask SAR, [2], for compliance with the criticality requirements specified in Sections 71.55 and 71.59 of 10 CFR Part 71 is applicable to the TN Eagle Cask. The fuel loading parameters related to criticality are summarized in Table 6.8.3-1. The design properties of the design basis fuel for FO/FC and FF DSCs are given in Table 6.8.3-2.

The methodology employed to ensure the subcriticality of the 24PT1 DSC is based on a “fresh fuel” representation of the spent FAs. For this DSC, the design basis fuel assemblies are modeled with fresh (unirradiated) fuel.

The criticality analysis for the 24PT1 DSCs with the 2 WE 14x14 design basis fuel assembly types was performed in Chapter A6 of [2], considering:

- Water leak in or out the canister.
- Criticality analyses performed with consideration for the most reactive credible configuration consistent with the chemical and physical form of the material, moderation by water to the most reactive credible extent and close full reflection by water on all sides or such greater reflection of the containment system as may additionally be provided by the surrounding material of the packaging.
- Any number of undamaged or damaged packages will remain subcritical in any arrangement with close full water reflection and optimum interspersed hydrogenous moderation. Therefore, the CSI, transport index for the package, is zero.

As such the criticality analysis for the 24PT1 DSC in Chapter A6 of [2], for compliance with the criticality requirements specified in Sections 71.55 and 71.59 of 10 CFR Part 71 is applicable to the TN Eagle Cask. [

] The fuel loading parameters related to criticality are summarized in Table 6.8.3-3. The design properties of the design basis fuels for the 24PT1 DSC are given in Table 6.8.3-4.

6.8.3.4 Reference

1. 10 CFR 71, Packaging and Transportation of Radioactive Materials.

2. TN Americas LLC, NUHOMS®-MP187 Multi-Purpose Cask Transportation Package Safety Analysis Report, Docket Number 71-9255, NUH-05-151 Revision 17.

Table 6.8.3-1
Maximum Fuel Loading Parameters - FO/FC and FF DSC

Parameter	Value
Number of Assemblies, FO/FC-DSCs	≤ 24
Number of Assemblies, FF-DSC	≤ 13
Enrichment, w/o U-235	≤ 3.43%
Design Basis Fuel	B&W 15x15
Maximum Number of Failed Rods (FF-DSC only)	15/assy

Table 6.8.3-2
BW 15x15 Design Basis Fuel Parameters for Criticality Analysis - FO/FC and FF DSC

Parameter	Value
Fuel Pellet Outside Diameter	0.3686 in.
Fuel Clad Thickness	0.0265 in.
Fuel Clad Outside Diameter	0.43 in.
Fuel Rod Pitch	0.568 in.
Active Fuel Height	141.8 in.
Enrichment, w/o U-235	3.43%
UO_2 Density, %Theoretical Dens.	95.0%
Rod Array (NxN Rods)	15
Fueled Rod Locations	208

Table 6.8.3-3
Maximum Fuel Loading Parameters – 24PT1 DSC

Parameter	Value
Number of Assemblies, 24PT1 DSC	≤ 24
Number of fuel assemblies in Failed Fuel Cans in 24PT1-DSC	≤ 4 WE 14x14 SC or ≤ 1 WE 14x14 .80.
Enrichment, wt. % U-235	WE 14x14 SC: ≤ 4.05 WE 14x14 MOX: ≤ 0.71
Maximum Fissile Pu Enrichment in WE 14x14 MOX fuel assemblies, wt. %	64 rods – 2.84 wt. % 92 rods – 3.10 wt. % 24 rods – 3.31 wt. %
Design Basis Fuel	WE 14x14 SC and WE 14x14 MOX
Maximum Number of Failed Rods (in Failed Fuel Cans)	14/assy

Table 6.8.3-4
Design Basis Fuel Parameters for Criticality Analysis – 24PT1 DSC

Parameter	WE 14x14 SC Fuel	WE 14x14 MOX Fuel
Fuel Pellet Outside Diameter, in.	0.3835	0.3659
Fuel Clad Thickness (nominal), in.	0.0165	0.0243
Fuel Clad Outside Diameter (nominal), in.	0.422	0.422
Fuel Rod Pitch, in.	0.556	0.556
Active Fuel Height, in.	120	120
Maximum Initial Enrichment, wt. %	U-235: 4.05	U-235: 0.71 Fissile Pu: 64 rods – 2.84 92 rods – 3.10 24 rods – 3.31
Pellet Density, %Theoretical Dens.	95	91
Rod Array (NxN Rods)	14	14
Fueled Rod Locations	180	180

Appendix 6.8.4
24PT4, 32PTH1 DSCs Criticality Evaluation

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6.8.4 24PT4, 32PTH1 DSCs Criticality Evaluation

NOTE: References in this Appendix are shown as [1], [2], etc. and refer to the reference list in Section 6.8.4.4.

This Appendix 6.8.4 to Chapter 6 demonstrates that the TN Eagle cask when loaded with the 24PT4 or 32PTH1 DSC meets the criticality requirements specified in Sections 71.55 and 71.59 of 10 CFR Part 71 [1].

6.8.4.1 Fissile Material Contents

The allowable contents for the 24PT4 DSC, intact and damaged CE 16x16 fuel type, are listed in Chapter 1, Appendix 1.6.3.

The allowable contents for the 32PTH1 DSC are listed in Chapter 1, Appendix 1.6.5.

6.8.4.2 General Consideration

6.8.4.2.1 24PT4 DSC

The 24PT4 DSC is designed to accommodate up to 12 damaged fuel assemblies in lieu of intact. The required placement of the damaged fuel assemblies is in the twelve outermost fuel assembly locations as specified in Figure 1.6.3-1 (Zones A and/or B only). Damaged fuel includes assemblies with known or suspected cladding defects greater than hairline cracks or pinhole leaks or an assembly with partial and/or missing rods (i.e., extra water holes). Damaged fuel assemblies shall be placed in failed fuel canisters, which will replace basket guide sleeves. Loose rods can be loaded in rod storage baskets and are considered as part of failed fuel contents. Criticality control in the 24PT4 DSC is provided by the basket structural components that maintain the relative position of the spent fuel assemblies under all normal and hypothetical accident conditions (HAC) and by fixed neutron absorbers. The fixed neutron absorbers are present in the form of BORAL® poison plates provided around the DSC guide sleeves and poison rodlets which are inserted in the guide tubes of certain assemblies in the basket.

6.8.4.2.2 32PTH1 DSC

The 32PTH1 DSC stainless steel basket consists of an “egg-crate” plate design. The fuel assemblies are housed in 32 stainless steel fuel compartment tubes. The basket structure, including the fuel compartment tubes, is held together with stainless steel insert plates and the poison and aluminum plates that form the “egg-crate” structure. The basket compartment structure is connected to perimeter transition rail assemblies, portions of it comprised of aluminum interface.

6.8.4.3 Discussion and Results

6.8.4.3.1 24PT4 DSC

The criticality analysis for the 24PT4 DSCs for the allowable contents, intact and damaged CE 16x16 fuel assembly type, was performed based on fresh fuel assumption in Appendix A.6.5.3 of the MP197HB transportation cask SAR, [2].

The 24PT4 DSC in the MP197HB transportation cask is shown to be subcritical for an infinite array of flooded undamaged casks and for an infinite array of damaged casks after being subjected to hypothetical accident conditions. “N” is equal to ∞. The cask is shown to be subcritical for five times “N” or an infinite number of undamaged packages with close full reflection between packages and no inleakage of water as required by 10 CFR Part 71.59(a)(1). In addition, as required by 10 CFR Part 71.59(a)(2), two times “N” or an infinite array of packages is shown to be subcritical with the fissile material in its most reactive configuration, optimum water moderation, and close full water reflection consistent with its damaged condition. A CSI of 0 (less than 50) ensures that, per 10 CFR Part 71.59 (c)(1), the package may be shipped by a carrier in a nonexclusive conveyance.

The fuel loading parameters related to criticality are summarized in Table 6.8.4-1. The summary of the limiting criticality results for 24PT4 loaded with the CE 16x16 fuel assembly type is given in Table 6.8.4-2.

6.8.4.3.2 32PTH1 DSC

The criticality analysis for the 32PTH1 DSCs for the allowable contents listed in Table 1.6.5-4 of Chapter 1, Appendix 1.6.5 was performed based on burnup credit in Appendix A.6.5.4 of the MP197HB transportation cask SAR [2].

The 32PTH1 DSC in the MP197HB transportation cask is shown to be subcritical for an infinite array of flooded undamaged casks and for an infinite array of damaged casks after being subjected to hypothetical accident conditions. “N” is equal to ∞. The cask is shown to be subcritical for five times “N” or an infinite number of undamaged packages with close full reflection between packages and no inleakage of water as required by 10 CFR Part 71.59(a)(1). In addition, as required by 10 CFR Part 71.59(a)(2), two times “N” or an infinite array of packages is shown to be subcritical with the fissile material in its most reactive configuration, optimum water moderation, and close full water reflection consistent with its damaged condition. CSI is 0.

[ ]

Table 6.8.4-3 lists the fuel assemblies considered as authorized contents of the 32PTH1 DSC.

The fuel loading parameters related to criticality are summarized in Table 6.8.4-4. The criticality analysis is performed using two fuel assembly classes: Westinghouse (WE) 17x17 and WE 14x14 classes. The results of the WE 17x17 class bound those of the WE 15x15, Babcock and Wilcox (B&W) 15x15, Combustion Engineering (CE) 14x14, CE 16x16, and CE 15x15 classes. The minimum required burnup as a function of initial enrichment and fixed poison plate boron-10 bounding loading and cooling time for both intact and damaged fuel assemblies is shown in Table 1.6.5-7 and Table 1.6.5-8.

6.8.4.4 References

1. 10 CFR 71, Packaging and Transportation of Radioactive Materials.

2. TN Americas LLC, NUHOMS®-MP197 Transportation Packaging Safety Analysis Report, Docket Number 71-9302, NUH09-0101 Revision 20.

Table 6.8.4-1
Fuel Parameters for Criticality Analysis of the CE 16x16 Fuel Assemblies – 24PT4 DSC

Maximum Initial Enrichment	4.85 weight % U-235
Number of Rods	236 fuel rods
Number of Guide Tubes	5 guide tubes
Fuel Rod Material (sintered pellet)	UO_2
Pellet Diameter (nominal, inches)	0.3255
Pellet Density (% theoretical)	97
Clad Material	Zircaloy-4
Clad OD (nominal, inches)	0.382
Clad Thickness (nominal, inches)	0.025
Active Fuel Length (inches)	150
Rod Pitch (inches)	0.506
Guide Tube ID (in)	0.90
Guide Tube OD (in)	0.98

Table 6.8.4-2
Summary of Limiting Criticality Evaluations for the CE 16x16 Fuel Assembly – 24PT4 DSC (1)

.025 g/cm^2 B-10 Configuration	Maximum Initial Enrichment U-235
0.025 g/cm^2 B-10, 24 intact assemblies	4.10 wt. %
0.025 g/cm^2 B-10, 4 damaged assemblies + 20 intact assemblies, no poison rodlets	4.10 wt. %
0.025 g/cm^2 B-10, 12 damaged assemblies + 12 intact assemblies, no poison rodlets	3.70 wt. % damaged assys; 4.1 wt. % intact assys
0.025 g/cm^2 B-10, 12 damaged assemblies + 12 intact assemblies, 1 poison rodlet per undamaged fuel assembly	4.10 wt. %

0.068 g/cm^2 B-10 Configuration	Maximum Initial Enrichment U-235
0.068 g/cm^2 B-10, 24 intact assemblies	4.85 wt. %
0.068 g/cm^2 B-10, 4 damaged assemblies + 20 intact assemblies, no poison rodlets	4.85 wt. %
0.068 g/cm^2 B-10, 12 damaged assemblies + 12 intact assemblies, no poison rodlets	4.10 wt. % damaged assys; 4.85 wt. % intact assys
0.068 g/cm^2 B-10, 12 damaged assemblies + 12 intact assemblies, 5 poison rodlets per undamaged fuel assembly	4.85 wt. %

(1) SeeFigure 1.6.3-1 for location of damaged fuel assemblies and poison rodlets within the 24PT4 DSC.

Table 6.8.4-3
Authorized Contents for 32PTH1 System

Assembly Type[(1)]	Array	Assembly Class
Westinghouse 17x17 LOPAR/Standard	17x17	WE 17x17
Westinghouse 17x17 OFA/Vantage 5[(2)]	17x17	WE 17x17
Framatome 17x17 MK BW	17x17	WE 17x17
Westinghouse 17x17 RFA	17x17	WE 17x17
CE 16x16 System 80	16x16	CE 16x16
CE 16x16 Standard	16x16	CE 16x16
B&W 15x15 Mark B (through B11)[(3)]	15x15	BW 15x15
B&W 17x17 Mark C	17x17	BW 15x15
CE 15x15 Palisades[(3)]	15x15	CE 15x15
Exxon/ANF (ANP) 15x15 CE[(3)]	15x15	CE 15x15
Exxon/ANF (ANP) 15x15 WE[(3)]	15x15	WE 15x15
Westinghouse 15x15 Standard/ZC	15x15	WE 15x15
Westinghouse 15x15 LOPAR/OFA/ DRFA/Vantage 5	15x15	WE 15x15
CE 14x14 Standard/Generic	14x14	CE 14x14
CE 14x14 Fort Calhoun	14x14	CE 14x14
Framatome-ANP 14x14 CE	14x14	CE 14x14
Exxon/ANF (ANP) 14x14 WE[(3)]	14x14	WE 14x14
Exxon/ANF (ANP) 14x14 Toprod[(3)]	14x14	WE 14x14
Westinghouse 14x14[(3)] Standard/LOPAR/ZCA/ZCB	14x14	WE 14x14
Westinghouse 14x14 OFA[(3)]	14x14	WE 14x14

Notes:
(1) Reload fuel from other manufacturers with these parameters are also acceptable.
(2) Includes all Vantage versions (5, +, ++, 5H, etc.).
(3) B&W 15x15 class, CE 15x15 class, and WE 14x14 class fuel assemblies are not authorized for loading in the 32PTH/32PTH Type 1 DSC.

Table 6.8.4-4
Fuel Parameters for Criticality Analysis – 32PTH1 DSC
(Part 1 of 2)

Manufacturer(1)	Array	Version	Active Fuel Length (in)	Number Fuel Rods per Assembly	Pitch (in)	Fuel Pellet OD (in)
WE	17x17	LOPAR	144	264	0.496	0.3225
WE	17x17	OFA/Van 5	144	264	0.496	0.3088
Framatome	17x17	MK BW	144	264	0.496	0.3195
WE	17x17	RFA	144	264	0.496	0.3225
CE	16x16	System 80	150	236	0.506	0.3255
CE	16x16	Standard	150	236	0.506	0.3255
B&W	15x15	Mark B2 – B8	141.8	208	0.568	0.3686
B&W	15x15	Mark B9	140.6	208	0.568	0.3700
B&W	15x15	Mark B10	142.3	208	0.568	0.3735
B&W	15x15	Mark B11	142.3	208	0.568	0.3615
B&W	17x17	Mark C	144	265	0.502	0.3232
CE	15x15	Palisades	132	216	0.550	0.3600(2)
Exxon/ANF (ANP)	15x15	CE	131.4	216	0.550	0.3565
Exxon/ANF (ANP)	15x15	WE	144	204	0.563	0.3565
WE	15x15	Std/ZC	144	204	0.563	0.3659
WE	15x15	LOPAR/OFA/DRFA/Van 5	144	204	0.563	0.3659
CE	14x14	Std/Gen	136.7	176	0.580	0.3765
CE	14x14	Ft. Calhoun	128	176	0.580	0.3815
Framatome	14x14	CE	136.7	176	0.580	0.3805
Exxon/ANF (ANP)	14x14	WE	142	179	0.556	0.3505
Exxon/ANF (ANP)	14x14	Toprod	142	179	0.556	0.3505
WE	14x14	Std/LOPAR/ZCA/ZCB	144	179	0.556	0.3674
WE	14x14	OFA	144	179	0.556	0.3444

Table 6.8.4-4
Fuel Parameters for Criticality Analysis – 32PTH1 DSC
(Part 2 of 2)

Manufacturer[1]	Array	Version	Clad Thickness (in)	Clad OD (in)	Water Hole OD (in)	Water Hole ID (in)
WE	17x17	LOPAR	0.0225	0.374	24@0.474 1@0.480	24@0.422 1@0.450
WE	17x17	OFA/Van 5	0.0225	0.360	24@0.482 1@0.476	24@0.450 1@0.460
Framatome	17x17	MK BW	0.0225	0.374	25@0.482	25@0.450
WE	17x17	RFA	0.0225	0.374	24@0.474 1@0.480	24@0.422 1@0.450
CE	16x16	System 80	0.0230	0.382	5@0.768	5@0.687
CE	16x16	Standard	0.0250	0.382	5@0.768	5@0.687
B&W	15x15	Mark B2 – B8	0.0265	0.430	16@0.530 1@0.493	16@0.498 1@441
B&W	15x15	Mark B9	0.0265	0.430	16@0.530 1@0.493	16@0.498 1@441
B&W	15x15	Mark B10	0.0250	0.430	16@0.530 1@0.493	16@0.498 1@441
B&W	15x15	Mark B11	0.0240	0.416	16@0.530 1@0.493	16@0.498 1@441
B&W	17x17	Mark C	0.0240	0.379	24@0.482 1@0.442	24@0.430 1@0.390
CE	15x15	Palisades	0.0260[3]	0.418[4]	8@0.4135	8@0.3655
Exxon/ANF (ANP)	15x15	CE	0.0300	0.417	8Guide Bars[5] 1@0.417	1@0.363
Exxon/ANF (ANP)	15x15	WE	0.0300	0.424	21@0.544	2@0.510
WE	15x15	Std/ZC	0.0242	0.422	20@0.546 1@0.546	20@0.512 1@0.516[6]
WE	15x15	LOPAR/OFA/D RFA/Van 5	0.0280	0.440	21@0.546	21@0.5166
CE	14x14	Std/Gen	0.0280	0.440	5@1.115	5@1.035
CE	14x14	Ft. Calhoun	0.0280	0.440	5@1.115	5@1.035
Framatome	14x14	CE	0.0260	0.440	5@1.115	5@1.035
Exxon/ANF (ANP)	14x14	WE	0.0300	0.424	16@0.541 1@0.480	16@0.507 1@0.448
Exxon/ANF (ANP)	14x14	Toprod	0.0295	0.0295	16@0.541 1@0.424	16@0.507 1@0.370
WE	14x14	Std/LOPAR/ ZCA/ZCB	0.0225	0.422	16@0.539 1@0.422	16@0.505 1@0.392
WE	14x14	OFA	0.0243	0.400	16@0.526 1@0.400	16@0.492 1@0.353

Notes:
(1) Reload fuel assemblies from other manufacturers with these parameters are also acceptable.
(2) Pellet OD ranges from 0.3510 to 0.3600 inches.
(3) Clad thickness ranges from 0.0240 to 0.0295 inches.
(4) Clad OD ranges from 0.4135 to 0.4175 inches.
(5) Guide bars are solid Zircaloy-4 approximately 0.40 inches x 0.45 inches.
(6) Instrument tube is 0.015 thick, however modeled as 0.017 thick.
(7) All dimensions shown are nominal.

Appendix 6.8.5
32PT DSC Criticality Evaluation

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6.8.5 32PT DSC Criticality Evaluation

NOTE: References in this Appendix are shown as [1], [2], etc., and refer to the reference list in Section 6.8.5.8.

This Appendix 6.8.5 to Chapter 6 demonstrates that the TN Eagle Cask when loaded with the NUHOMS® 32PT Dry Shielded Canister (DSC) payload meets the criticality requirements specified in the Sections 71.55 and 71.59 of 10 CFR Part 71 [1]. This is done by ensuring that the effective multiplication factor (k_{eff}) of the most reactive configuration of the system stays below the upper subcritical limit (USL). The USL includes a confidence band with an administrative safety margin of 0.05. The design has a criticality safety index (CSI), given in 10 CFR 71.59(b) as CSI = 50/"N" of 0 because "N" is infinity (∞). The number "N" is based on all of the following conditions being satisfied, assuming packages are stacked together in any arrangement and with close full reflection on all sides of the stack by water:

1. Five times "N" undamaged packages with nothing between the packages are subcritical;
2. Two times "N" damaged packages, if each package is subjected to the tests specified in 10 CFR 71.73 hypothetical accident condition (HAC) is subcritical with optimum interspersed hydrogenous moderation; and
3. The value of "N" cannot be less than 0.5.

Burnup credit is employed in the criticality analysis to demonstrate compliance with the sub-criticality requirements of 10 CFR 71.55 (b). The criticality analysis of the NUHOMS® 32PT DSC loaded with CE14x14 fuel class in the 24 poison plates configuration (24PP) follows the burnup credit approach for pressurized water reactor (PWR) fuels described in ISG 08 [4] and incorporated in NUREG-2216 [5]. The criticality analysis of the NUHOMS® 32PT DSC loaded with the allowable PWR intact fuels except the Combustion Engineering (CE) 14x14 in 24PP configuration was performed, based on burnup credit, in Appendix A.6.5.6 of the NUHOMS®-MP197HB Transportation Cask Safety Analysis Report (SAR), [3].

[ ]

6.8.5.1 Fissile Material Contents

The allowable contents for the 32PT DSC are listed in Chapter 1, Appendix 1.6.4, Table 1.6.4-3.

The 32PT DSC is designed to transport 32 intact fuel assemblies (FAs) and/or damaged and/or failed PWR FAs with or without control components (CCs). Note that only the Combustion Engineering (CE) 14x14 fuel class is allowed for transportation with intact and/or damaged and/or failed FAs.

6.8.5.2 General Consideration

The basket uses an aluminum/B_4C metal matrix composite (MMC) as its neutron poison material. The minimum required B-10 loading is 0.070 g/cm^2 (90% credit is taken in the criticality analysis or 0.063 g/cm^2). In addition to the fixed neutron poison in the basket, “poison rod assemblies” (PRAs) are required for the center zero, four, eight or sixteen assemblies depending on fuel assembly design and initial enrichment. The minimum required B_4C content of the PRAs is 40% theoretical density (TD) (75% credit is taken in the criticality analysis or 30% TD). The minimum required B_4C content of the PRAs is only 30% (in the KENO input).

Two different basket types are applicable to the 32PT DSC depending on the number and orientation of the L-shaped poison/aluminum inserts:

- 16-plate configuration (16PP) containing fixed poison in 16 compartments. FAs containing PRAs are not authorized in this configuration
- 24-plate configuration (24PP) containing fixed poison in 24 compartments. FAs containing 0, 4, 8 or 16 PRAs are authorized in this configuration.

The arrangements of poison/aluminum plates in the fuel compartments of the basket for these two configurations are shown in Figure 6.8.5-4 and Figure 6.8.5-5. The mandatory location of the PRAs for the 4, 8 or 16 PRA configurations is shown in Figure 6.8.5-1 through Figure 6.8.5-3.

6.8.5.3 Discussion and Results

Table 6.8.5-1 lists the FAs considered as authorized contents of the 32PT DSC.

The criticality analysis for the 32PT DSCs for the allowable PWR intact fuel contents listed in Chapter 1, Appendix 1.6.4, Table 1.6.4-3, was performed based on burnup credit in Appendix A.6.5.6 of [3], CE 14x14 in the 24PP configuration.

The 32PT DSC in the NUHOMS®-MP197HB transportation cask is shown to be subcritical for an infinite array undamaged casks and for an infinite array of damaged casks after being subjected to hypothetical accident conditions. “N” is equal to ∞. The cask is shown to be subcritical for five times “N” or an infinite number of undamaged packages with close full reflection between packages and no inleakage of water as required by 10 CFR 71.59(a)(1). In addition, as required by 10 CFR 71.59(a)(2), two times “N” or an infinite array of packages is shown to be subcritical with the fissile material in its most reactive configuration, optimum water moderation and close full water reflection consistent with its damaged condition. CSI is 0.

The minimum required burnup as a function of initial enrichment, cooling time and basket/poison type for the two bounding fuel assembly classes, Westinghouse (WE) 17x17, and WE 14x14 are shown in Table 1.6.4-6. The results of the WE 17X17 class bound those of the WE 15x15, the Babcock and Wilcox (B&W) 15x15, the CE 14x14 (except the 24PP configuration), and CE 15x15 classes.

Additional analysis for the CE 14x14 is performed considering intact, damaged and failed fuels in the 32PT DSC with the 24-PP configuration. A maximum of 8 failed or up to 28 damaged CE 14x14 FAs are authorized to store along with intact fuel assemblies in the 32PT DSC. The additional criticality analysis follows the burnup credit approach for PWR fuels described in ISG-08 [4], incorporated in NUREG-2216 [5] and applied to the TN Eagle cask in Appendix 6.8.2 for the EOS 37PTH. The minimum required burnup as a function of initial enrichment, cooling time for the CE 14x14 in the 24PP configuration are shown in Table 1.6.4-7 through Table 1.6.4-9.

The control components (CCs) are also authorized for storage in the 32PT DSCs. The authorized CCs are burnable poison rod assemblies (BPRAs), control rod assemblies (CRAs), thimble plug assemblies (TPAs), axial power shaping rod assemblies (APSRAs), control element assemblies (CEAs), vibration suppressor inserts (VSIs), orifice rod assemblies (ORAs), neutron source assemblies (NSAs), and Neutron Sources.

The results of the evaluation demonstrate that the maximum k_{eff}, including statistical uncertainty, is less than the USL determined from a statistical analysis of benchmark criticality experiments. The statistical analysis procedure includes a confidence band with an administrative safety margin of 0.05.

6.8.5.4 Package Fuel Loading

The 32PT DSC is capable of storing and transporting a maximum of 32 intact PWR FAs. In addition, a maximum of 8 failed and up to 28 damaged and remaining intact (for a total of 32) PWR FAs can also be transported within the 32PT DSC for CE 14x14 fuel class.

Reconstituted FAs, where the fuel pins are replaced by lower enriched fuel pins or non-fuel pins that displace an equal to or greater than the amount of water in the active fuel region of the FA, are considered intact FAs in the criticality evaluation.

For all the FA classes, CCs are also included as authorized contents. The only change to the package fuel loading to evaluate the addition of these CCs is replacing the water in the guide tubes/water holes with $^{11}B_4C$. Since these CCs displace moderator in the assembly guide and or instrument tubes, an evaluation is not needed to determine the potential impact of storage of CCs that extend into the active fuel region on the system reactivity. The presence of these CCs such as CRAs, CEAs and BPRAs will result in a reduction in the reactivity of the fuel assemblies. CCs that do not extend into the active fuel region of the assembly do not have any effect on the reactivity of the system as evaluated because only the active fuel region is modeled in this evaluation with periodic boundary conditions making the model infinite in the axial direction. Additionally, the presences of non-multiplying sources like the NSAs have no impact on criticality calculations.

Therefore, any CC that is inserted into the FA in such a way that it does or does not extend into the active fuel region is considered as authorized for transportation without adjustment to the burnup or initial enrichment as required for CCs. No credit is taken for the presence of any residual absorber remaining in the CC nor is any credit taken for the displacement of fresh water from within the guide tube of theFAs containing CCs.

6.8.5.5 Model Specification

The following section is related to the criticality analysis for the CE 14x14 with intact, damaged and failed fuels in the 32PT DSC with the 24-PP configuration.

The evaluations are performed using SCALE 6.1.3 [2] and ENDF/B-VII nuclear data. The SCALE 6.1.3 capabilities used include automated sequences to produce problem-dependent multi-group cross-section data and analysis sequences for Monte Carlo neutron transport (CSAS5) and burnup-credit criticality safety (STARBUCS). The 238-group cross-section library based on the ENDF/B-VII nuclear data, 44-group cross section library based on the ENDF/B-V nuclear data and the resonance cross-section methodology employing CENTRM are used.

The STARBUCS sequence is used to determine U-235 wt. % enrichment values for various burnup and cooling times. STARBUCS enables modelling of the phenomena important to burnup credit and allows analysts to investigate the impact on criticality safety of various assumptions related to the burnup credit calculation methodology. The STARBUCS sequence provides a burnup credit loading curve search capability in addition to its initial capability of performing criticality safety analyses employing burnup credit. This capability may be used to determine the combination of assembly initial enrichment and discharge burnup values that result in a user-specified k_{eff} values. STARBUCS uses the ORIGEN-ARP method to rapidly generate fuel compositions as a function of fuel mixture initial enrichment, burnup and cooling time. ORIGEN-ARP libraries for the STARBUCS calculations are obtained by performing TRITON depletion calculations for the PWR assembly types used in the safety analysis models and for a range of fuel initial enrichment and assembly average burnup values.

The following subsections describe the physical models and materials of the 32PT DSC within the TN Eagle Cask used for the input to the STARBUCS or CSAS5 module of SCALE 6.1.3 [2] to perform the criticality evaluations.

6.8.5.5.1 Description of the Calculational Models

The basic calculational KENO model employed in Appendix A.6.5.6 of [3], for the 32PT DSC with 24PP configuration is used for the analysis. The fixed poison modeled in the calculation is based on a poison plate thickness of 0.050 inches consistent with that specified for borated aluminum. The important parameter is the minimum B-10 areal density; therefore, the modeled thickness of the poison plate does not affect the results of the calculation.

The key basket dimensions utilized in the calculation are shown in Table 6.8.5-5.

The basket structure is connected to the DSC shell by perimeter transition rail assemblies. The transition rail material is “solid” aluminum that provides a structural function as well as provides a heat conduction path from the basket to the DSC shell. The rails are modeled as solid aluminum between the outside of the basket and the inner diameter (ID) of the DSC shell.

For criticality analysis, only the cask body and the inner shielding ring layer of the TN Eagle cask are modelled.

A list of all the geometry units used in this KENO model is shown in Table 6.8.5-6.

<u>Intact Fuel Assemblies Model</u>

The most reactive configuration determined in Appendix A.6.5.6 of [3], is utilized to determine the k_{eff} of the 32PT for the CE 14x14 fuel class in the 24PP configuration.

<u>Damaged Fuel Assemblies Model</u>

[ ]

<u>Failed Fuel Assemblies Model</u>

[ ]

6.8.5.5.2 Package Regional Densities

The Oak Ridge National Laboratory (ORNL) SCALE 6.1.3 code package [2] contains a standard material data library for common elements, compounds, and mixtures. All the materials used for the cask and canister analyses are available in this data library. The DSC model does not include the top shell or closure lid, the bottom shell or the resin shielding rings. The gap between the casks contains unborated water. For the transfer cask, the neutron skin and shield are assumed to have vanished under accident loading conditions.

A list of the relevant materials used for the criticality evaluation is provided in Table 6.8.5-4. The poison plate material specifications are modeled considering a 90% B-10 credit for the B-10 loading.

6.8.5.6 Criticality Calculations

The following section is related to the criticality analysis for the CE 14x14 with intact, damaged and failed fuels in the 32PT DSC with the 24PP configuration.

This section describes the models used for the criticality analysis. The analyses are performed with the STARBUCS and the CSAS5 modules of the SCALE 6.1.3 computer package [2]. The USL is calculated for the TN Eagle system based on the critical experiments benchmarked with fresh fuel and burnup credit assumptions in Section 6.8.2.4.2.1.

6.8.5.6.1 Calculational Model

Criticality Calculations with Fresh Fuel

The fresh fuel criticality analysis is performed using the CSAS5 module of SCALE 6.1.3. The maximum allowable fresh fuel enrichment is determined for the CE 14x14 fuel class intact, damaged and failed fuels in the 24PP configuration. The USL determined using fresh fuel assumptions in Section 6.8.2.4.2.1 is applicable.

Criticality Calculations with Burnup Credit

This section describes the analysis methodology utilized for the criticality analysis by taking credit for depletion of fissile material in FAs loaded in the EOS-32PT DSC. The loading curves in terms of initial fuel enrichment as a function of average burnup and cooling times for the CE 14x14 fuel class intact, damaged and failed fuels in the 24PP configuration are determined based on the most reactive assembly in the most reactive DSC configuration. The criticality model includes the full active fuel length of the FA for the purpose of burnup credit. The criticality safety analysis for the TN Eagle cask loaded with the 32PT DSC is performed with pure water flooding the entire cavity.

A total of 28 isotopes are included in the material description of the burned fuel assembly, which includes 12 actinides and 16 fission products, listed Table 6.8.5-5. Loading curves show the acceptable combinations of average burnup and initial fuel enrichment for any cooling period after FA discharge. The acceptable combinations of average burnups and initial fuel enrichments for intact and failed fuel are developed using the STARBUCS module with ORIGEN-ARP libraries generated using TRITON simulations. The ORIGEN-ARP library for CE 14x14 fuel class is developed in Section 6.8.5.6.2.8, which is used in the STARBUCS models. The loading curves are developed for cooling periods of 5, 10, 15 and 20 years. The maximum initial fuel enrichment is determined for burnups 5, 10, 15, 20, 25, 30, 35, 40, 45 and 50 GWd/MTU. For each assembly type, the averaged burnup value, and the initial enrichment value satisfying the USL and all applicable biases and bias uncertainties associated with burnup credit are determined. The USL and all applicable biases and bias uncertainties are discussed in Section 6.8.5.6.2.1 and Section 6.8.5.6.2.2.

The damaged fuel loading curve is developed for the 32PT DSC loaded with 28 damaged FAs along with 4 intact FAs.

The failed fuel loading curve is developed for the 32PT DSC loaded with 8 FAs in failed fuel configuration along with 24 intact FAs.

The material compositions of discharged intact, damaged and failed for specific enrichment/burnup/cooling time are obtained from STARBUCS simulations.

Computer Codes

The evaluations are performed using SCALE 6.1.3 [2] and the ENDF/B-VII nuclear data. The burnup credit criticality analysis for intact fuel is performed using the STARBUCS module, the burnup credit criticality analysis for failed fuel is performed using CSAS5 module (material composition using STARBUCS) and the fresh fuel criticality analysis is performed using CSAS5 control module of SCALE 6.1.3 [2].

The STARBUCS sequence provides a burnup credit loading curve search capability in addition to its initial capability of performing criticality safety analysis employing burnup credit. STARBUCS uses ORIGEN-ARP sequence to deplete the fuel assembly with given irradiation history and assigned ORIGEN-ARP libraries. The spent fuel compositions obtained after depletions are applied in the given KENO V.a models for criticality safety calculations.

The CSAS5 control module is used to calculate the effective neutron multiplication factor (k_{eff}) of the fuel in the TN Eagle cask. The CSAS5 control module allows simplified data input to the functional modules BONAMI, CENTRM and KENO V.a. These modules process the required cross sections and calculate the k_{eff} of the system. BONAMI performs resonance self-shielding calculations for nuclides that have Bondarenko data associated with their cross sections. CENTRM provides the neutron spectra for processing self-shielded multigroup cross sections. Finally, KENO V.a calculates the k_{eff} of a three-dimensional system. A sufficiently large number of neutron histories are run so that the standard deviation is below 0.0005 for all evaluations.

Physical and Nuclear Data

The criticality analysis uses the 238 group ENDF/B-VII cross-section library and 44-group ENDF/B-V cross-section library. The material definitions for fuel, cladding, 32PT DSC and TN Eagle cask structural material are available in the SCALE 6.1.3, [2], standard composition library. Details of materials of fuel and component design are included in Table 6.8.5-4.

Bases and Assumptions

The analytical results reported in Chapter A.2, Appendix A.2.13.1, demonstrate that the cask containment boundary and canister basket structure do not experience any significant distortion under hypothetical accident conditions. The maximum local plastic deformation calculated in Chapter A.2, Appendix A.2.13.8, is less than 0.1 inches and is well below the precision of the KENO V.a models.

To demonstrate compliance with the requirements specified in 10 CFR 71.55(b), the FAs are modeled in the appropriate conditions (moderation and configurations) for intact, damaged and failed fuels.

Since the FAs are modeled using an axial burnup distribution with the ends of the FAs modeled with a burnup that is approximately 50% lower than that in the middle, the reactivity of the burned fuel assemblies is dominated by that at the axial ends.

Therefore, for both NCT and HAC, the basket, DSC and cask geometry is identical except for the neutron shield and skin. As discussed above, the neutron shield and skin are conservatively modeled as air (void).

The cask was modeled with KENO V.a using the permissible geometry options. These options allow a model to be constructed with regular geometric shapes and define the material boundaries. No cases have been made to model the FAs with burnable absorbers, or axial blankets. This results in a significant margin of conservatism in the calculated k_{eff}.

The fixed neutron poison spans the entire basket height for the 32PT DSC. The poison plate coverage begins at a height of 2.5 inches from the bottom of the basket, thereby allowing for a height of approximately 2.5 inches, to include the bottom nozzle and bottom spacer/plenum regions of the FA. For PWR FA designs, the active fuel begins at a height of approximately 4 inches from the bottom of the FA thereby ensuring that the axial positioning of the poison provides adequate coverage.

The following assumptions were also incorporated into the criticality evaluations:

1. Omission of grid plates, spacers, and hardware in the FA.
2. No credit is taken for burnable absorbers.
3. Fuel pins are modeled assuming 18 axial burnup zones, Table 6.8.5-6. Natural uranium blankets, gadolinia, integral fuel burnable absorber (IFBA), erbia or any other burnable absorber rods and axial or radial enrichment zones are modeled as uniform everywhere.
4. All fuel rods are assumed to be filled with 100% pure water in the fuel/cladding gap to account for the possibility of water being entrained in the fuel pin and because it has a slight positive effect on reactivity.
5. Water density at full internal and optimum external moderator density.
6. Only the active fuel length of each assembly type is explicitly modeled. The presence of the plenum, end fittings, channels above and below the active fuel reduce the k_{eff} of the system; therefore; these regions are modeled as water or the reflective boundary conditions. For the cases with reflective boundary condition, the model is effectively infinitely long. This is valid due to the basket specific evaluation discussed above.
7. For all of the transportation HAC cases the neutron shield and stainless steel skin of the cask assumed to be replaced with external moderator.
8. The least material condition (LMC) is assumed for the fuel compartment, poison plates and wrappers. This minimizes neutron absorption in the steel sheets and poison plates.
9. Impact limiters on the cask ends are not included because they have negligible effect on the k_{eff} of the system.
10. Temperature at 20 °C (293K).

11. All zirconium based materials in the fuel are modeled as Zircalloy-4. The small differences in the composition of the various clad / tube / channel materials have no effect on the results of the evaluation.
12. Void is considered in the DSC/cask gap and for external cask.

Determination of k_{eff}

The criticality calculations are performed with STARBUCS and CSAS5 modules in SCALE 6.1.3. The Monte Carlo calculations performed use a flat neutron starting distribution. The total number of histories traced for each calculation is at least 1,000,000. This number of histories is sufficient to achieve source convergence and produce standard deviations of less than 0.0005. The maximum k_{eff} for the calculation is determined with the following formula:

$$k_{eff} = k_{KENO} + 2\sigma_{KENO}$$

6.8.5.6.2 Fuel Loading Optimization

6.8.5.6.2.1 Calculation of USL

The SCALE 6.1.3 criticality code benchmarking using criticality experiments for fresh fuel assumption and burnup credit analysis is provided in Section 6.8.2.5.

The USL with fresh fuel assumptions determined in Section 6.8.2.4.2.1 is 0.94173.

The USL for burnup credit analysis determined in Section 6.8.2.4.2.1 is 0.94236.

6.8.5.6.2.2 Biases and Biases Uncertainties for Burnup Credit Analysis

Additional bias and bias uncertainty due to minor actinide and fission products associated with the code validation for k_{eff} determination and bias and bias uncertainty associated to the code validation for isotopic depletion should be addressed and added to the calculated package k_{eff}.

Section 6.4.7.4 of [5] regarding minor actinide and fission product states that it is acceptable to credit the minor actinide and fission product nuclides listed in Table 6-2 of [5] provided that the bias and bias uncertainty associated with the major actinides is determined as performed in Section 6.8.2.4.2.1.Additionally, the bias from these minor actinides and fission products is conservatively covered by 1.5 percent of the minor actinides and fission products worth provided per Table 6.6 of [5]:

- SCALE code package with ENDF/B-VII cross-section library are used,
- The similarity between the current design and the virtual GBC-32 cask is shown,
- and the credited minor actinide and fission product worth is < 0.1 in k_{eff} are shown – Table 6.6 of [5].

No additional uncertainty in the bias is needed. The bias due to minor actinide and fission products (Δk_x) is to be added to the calculated package k_{eff} ($k_{KENO} + 2\sigma_{KENO}$).

The minor actinide and fission product worth is shown in Section 6.8.5.6.2.7.

Section 6.4.7.3 of [5] regarding the code validation for isotopic depletion states that, instead of an explicit benchmarking analysis, it is acceptable to use the bias (βi) and bias uncertainty (Δki) values shown in Tables 6-3 of [5] provided:

- SCALE/TRITON and ENDF/B-VII cross-section library are used
- And the similarity between the current design and the virtual GBC-32 cask is shown

The burnup-dependent bias and bias uncertainty due to isotopic depletion code validation is to be added to the calculated package k_{eff} ($k_{KENO} + 2\sigma_{KENO}$). The similarity between the current design and the virtual GBC-32 cask is shown in Section 6.8.5.6.2.9.

In summary, for burnup credit analysis, the criterion for subcriticality is that:

$$k_{eff} + (\beta_i + \Delta k_i) + \Delta k_x < USL$$

$$k_{KENO} + 2\sigma_{KENO} + (\beta_i + \Delta k_i) + \Delta k_x < k_{limit} - (\beta + \Delta k_\beta) - \Delta k_m$$

6.8.5.6.2.3 Most Reactive Damaged and Failed Fuel Configuration

Damaged FAs are defined as those assemblies containing missing or partial fuel rods, or fuel rods with known or suspected cladding defects greater than hairline cracks or pinhole leaks. Defect cladding and/or crack size in the fuel pins is to be limited such that a fuel pellet is not able to pass through the gap created by the cladding opening during handling and fuel assembly retrievability is assured following normal and off-normal conditions. The fuel compartments housing the damaged FAs are enclosed with end caps at the top and the bottom such that the damaged assembly is encapsulated within the compartment for normal and off-normal conditions of storage and transfer.

There are several mechanisms by which an FA can be damaged, either within the reactor core, in the spent fuel pool, or in interim dry storage. The mechanisms include rod pitch variation which simulates cases in which the fuel rods may get bent inwards or bowed outwards, where the fuel is intact but not at its nominal pitch value. In this scenario, fuel rod pitches are varied uniformly throughout the entire fuel matrix to determine the optimum pitch.

Failed fuels are modeled with de-cladded fuel rods at optimum pitch and each guide tube houses a fuel rod.

Additional sensitivity analysis is performed for various rods removal configurations using the burnup/enrichment/cooling time of 50 GWd/MTU / 4.90wt% / 5 years cooling time for the 8 failed fuels, remaining fuels are intact fuels of 50 GWd/MTU / 5.00wt% / 5 years cooling time. Table 6.8.5-9A shows that 24-rod removal is the most reactive configuration for failed fuels which is then employed for developing the loading curve in Table 6.8.5-13.

6.8.5.6.2.4 Determination of Maximum Initial Enrichment

The most reactive 32PT DSC 24PP configuration from Appendix A.6.5.6 of [3], and the most reactive configuration for the CE 14x14 intact, damaged and failed fuels are employed to develop the loading curves considering water moderation to the most reactive credible extent, maximum initial enrichment as a function of burnup and cooling time, for intact, damaged and failed fuels loading. Water boundary conditions are applicable on all sides. The radial layout of the 32PT DSC in the TN Eagle is presented in Figure 6.8.5-6.

The STARBUCS control module of SCALE 6.1.3 [2] is used to perform the burnup credit criticality analysis for the 32PT DSC loaded with CE 14x14 in 24PP configuration. The loading curves are determined by ensuring that the maximum expected k_{eff} and applicable biases and biases uncertainties are less than the USL.

Nuclides of Importance

Based on the results presented in [6], the nuclides listed in Table 6.8.5-5 are the actinides and fission products important to burnup credit criticality analysis. Note that these are the credited isotopes of the fuel composition in the criticality analysis. During depletion, ISG-8 [4] states that the code must ensure that all the transmutation and decay chains during burnup must be tracked. This is due to the fact that the burnup-dependent cross-sections generated for the next cycle burnup depend on the neutron spectrum, which is impacted by the actinide and fission product content at current cycle. The burnup credit may be taken by using actinide-only depletion or actinide and fission product depletion. Since there are sufficient data to validate the use of both actinides and fission products, the TN Eagle criticality evaluation is evaluated by taking credit for isotopes listed in Table 6.8.5-5.

Burnup and Enrichment Limits

ISG-8 [4] states that the available radio-chemical assay data support assembly-average burnups of up to 60 GWd/MTU and enrichments of up to 5 wt. % U-235. The local burnups for the assembly may be higher but the assembly-average burnup shall not exceed 60 GWd/MTU.

Horizontal Burnup Profiles

The effect on FAs discharged from the periphery of the reactor core where differences in neutron flux in this region relative to the rest of the core may result in significant variations in horizontal burnup after a cycle of operation. The discussion in [4] indicates that for large systems such as the 32PT DSC, horizontal loading bias has little impact on burnup credit evaluations and therefore zero horizontal bias is assigned for the burnup credit analysis.

Axial Burnup Profiles

ISG-8 [4] points to [9], where axial burnup profiles are presented based on an evaluation of 4% of fuel assemblies discharged through 1994 (~45,000 FAs) and uses as SCALE 6.1.3 built-in burnup dependent axial profiles. These data are used in [7] to state that:

- The survey of fuel assemblies in [9] provides a representative sampling of discharged assemblies. This conclusion is reached in [7] based on:
  - Fuel vendor/reactor design,
  - Type of operation (i.e., first cycles, out-in fuel management, and low-leakage fuel management),
  - Burnup and enrichment ranges,
  - Use of burnable absorbers (including different absorber types), and
  - Exposure to control rods (CRs) (including axial power shaping rods (APSRs)).
- Although limited data exist for burnup values greater than 40 GWd/MTU and initial enrichments greater than 4 wt. % U-235, the profiles resulting in the highest reactivity at intermediate burnup values will yield the highest reactivity at higher burnups.

In addition to the SCALE 6.1.3 built-in burnup-dependent axial profiles, the evaluations herein employ an additional axial profile for burnups greater than 38 GWd/MTU using 38 to 42 GWd/MTU range from [2]. Note that the SCALE 6.1.3 built-in axial profiles are also from the same reference and this evaluation adds one more profile to use more representative axial profiles for higher burnup fuel. The 18-section burnup-dependent axial correction factors are shown in Table 6.8.5-6.

<u>Loading Curves</u>

Loading curves present the acceptable combinations of assembly average burnup, and initial enrichment for loading FAs. The STARBUCS control module is used with ORIGEN-ARP to develop loading curves for various BECTs for 32PT DSC loaded with intact FAs. The CSAS5 module is used to develop loading curves for various BECTs for 32PT DSC loaded with failed fuel assemblies. The STARBUCS control module is used to obtain the depleted fuel composition of failed fuel to be used in KENO V.a models for failed fuel burnup credit criticality analysis. The run time is determined by the uncertainty cutoff of 0.0005. The burnup is used as an input to determine the maximum allowable initial enrichment that satisfies the USL. The cooling times considered are 5, 10, 15 and 20 years. In addition, maximum allowable initial enrichment for fresh fuel that satisfies the USL is also evaluated.

6.8.5.6.2.5 Criticality Results

The burnup criticality analyses is performed to develop loading curves for the CE 14x14 intact and failed FAs loaded in 32PT DSC 24PP configuration placed inside TN Eagle. The initial U-235 enrichment is calculated for burnups ranging from 5 GWd/MTU to 60 GWd/MTU. The loading curves are developed for 5, 10, 15 and 20 years of cooling time.

The loading curves for the 32PT DSC 24PP loaded with CE 14x14 fuel class intact FAs are summarized and provided in Table 1.6.4-7.

The loading curves for the 32PT DSC 24PP loaded with CE 14x14 fuel class damaged FAs are summarized and provided in Table 1.6.4-8.

The results for the loading curves calculations are shown in Table 6.8.5-10 through Table 6.8.5-13.

The loading curves for the 32PT DSC 24PP loaded with CE 14x14 fuel class failed FAs are summarized and provided in Table 1.6.4-9.

The criterion for subcriticality is that:

$$k_{eff} + (\beta_i + \Delta k_i) + \Delta k_x < USL$$

where USL is the upper subcriticality limit established by an analysis of benchmark criticality experiments,

Δk_x is the code bias due to minor actinides and fission products, 0.1 x 0.015 = 0.0015,

And $(\beta_i + \Delta k_i)$ is the burnup-dependent bias and bias uncertainty for isotopics validation shown in Table 6-3 of [5].

$$k_{KENO} + 2\sigma_{KENO} + (\beta_i + \Delta k_i) + 0.0015 < 0.94236$$

6.8.5.6.2.6 Critical Benchmark Experiments and applicable biases

The criticality benchmark for fresh fuel and burnup credit are provided in Section 6.8.2.5.1 through Section 6.8.2.5.5.

6.8.5.6.2.7 Minor Actinides and Fission Products Worth

The code bias and bias uncertainty due to minor actinides and fission products may be computed as 1.5% of the worth provided the credited minor actinides and fission products worth not greater than 0.1 in k_{eff}.

To demonstrate that the minor actinides and fission product worth is less than 0.1, criticality simulations are performed using STARBUCS for a range of burnups and cooling time combinations, at a fixed fuel enrichment (5.00 wt. % U-235). For each BECT combination, two cases are run, one including only major actinides in the calculation, and other including major actinides, minor actinides and fission products, selected in accordance with Table 6.8.5-8. The differences in k_{eff} from both cases give the minor actinide and fission product worth. The code bias due to minor actinides and fission products is calculated based on the results presented in Table 6.8.5-7. The highest value of minor actinide and fission product worth (Δk_{eff}) is 0.09557, which satisfy the condition. Therefore, the bias and bias uncertainty of the criticality code associated with minor actinides and fission products, 0.0015 (=1.5%x0.1) is used.

6.8.5.6.2.8 ORIGEN-ARP Cross-Section Libraries

[ ]

6.8.5.6.2.9 Code Validation – Isotopic depletion

According to ISG-8, [4], the purpose of the validation of the depletion analysis code is to:

- Determine if the code is capable of modelling the depletion environment of FAs by performing depletion of FAs from which measurement has been obtained through radiochemical assay,
- Quantify bias and bias uncertainty of the isotopic depletion calculation code against the depletion parameters, fuel assembly design characteristics, initial enrichment, and cooling time.

ISG-8, [4], states that, if it can be shown that the system considered is similar to the GBC-32, a virtual generic 32-PWR compartment cask that is used in the NUREGs to generate bias and bias uncertainties, after which the NUREG-generated bias and bias uncertainties can be used. This similarity approach is used in this evaluation.

ISG-8, [4], presents a list of burnup-dependent bias and bias uncertainties of the isotopic depletion calculation that may be used, provided the following conditions are met:

- The applicant uses the same depletion code and cross-section library as was used in NUREG/CR-7108 [8] (SCALE/TRITON and the ENDF/B-V or -VII cross-section library),
- The applicant can justify that its design is similar to the hypothetical GBC-32 system design used as the basis for the NUREG/CR-7108 [8] isotopic depletion validation, and credit is limited to the specific nuclides listed in Table 6.8.5-5.

A similarity analysis is performed in Section 6.8.2.7 for the TN Eagle cask loaded with the EOS-37PTH DSC. The evaluation demonstrates similarity by comparing the global parameters, as well as by determining the sensitivity and uncertainty. The c_k parameters generated from the sensitivity and uncertainty calculation, which indicate high degree of similarity between the EOS-37PTH and the GBC-32, are provided in Table 6.8.2-48.

One notable structural difference between the EOS-37PTH DSC and the 32PT DSC are the poison plate specifications. For 32PT DSC, the poison plate is made of borated aluminum while EOS-37PTH utilizes an MMC. The B-10 areal density in the poison plates used in the models for 32PT DCS 24PP configuration is 13.5 mg B-10/cm^2 while it is 25.2 mg B-10/cm^2 for the EOS-37PTH Type A. These differences are expected to have minimum effects on the c_k parameters; the 32PT DCS 24PP configuration is expected to high degree of similarity with the GBC-32; therefore, it is acceptable to use the isotopic bias and bias uncertainties from Table 6A.3 of [5] when the preparing system-specific loading requirements with burnup credit.

6.8.5.6.2.10 Misload Analysis

The misload analysis for the 32PT DSC is performed in Appendix A.6.5.13 of [3].

6.8.5.7 Evaluations under NCT and HAC

This section describes the evaluations under HAC and NCT performed for the TN Eagle transport package with the 32PT DSC.

6.8.5.7.1 Package Arrays under Hypothetical Accident Conditions

6.8.5.7.2 Package Arrays under Normal Conditions of Transport

6.8.5.7.3 Single package

6.8.5.8 Reference

1. 10 CFR 71, Packaging and Transportation of Radioactive Materials.

2. Oak Ridge National Laboratory, RSIC Computer Code Collection, “SCALE: A Comprehensive Modeling and Simulation Suite for Nuclear Safety Analysis and Design,” ORNL/TM-2005/39, Version 6.1, June 2011.

3. TN Americas LLC, NUHOMS®-MP197 Transportation Packaging Safety Analysis Report, Docket Number 71-9302, NUH09-0101 Revision 20.

4. US NRC, Interim Staff Guidance (ISG) – 8 Revision 3, “Burnup Credit in the Criticality Safety Analyses of PWR Spent Fuel in Transportation and Storage Casks,” U.S. Nuclear Regulatory Commission, Spent Fuel Project Office.

5. US NRC, NUREG-2216, “Standard Review Plan for Transportation Packages for Spent Fuel and Radioactive Material,” August 2020.

6. US NRC, NUREG/CR-7203, “A quantitative Impact Assessment of Hypothetical Spent Fuel Reconfiguration in Spent Fuel Storage Casks and Transportation Packages,” September 2015.

7. US NRC, NUREG/CR-6801, “Recommendations for Addressing Axial Burnup in PWR Burnup Credit Analysis,” March 2003.

8. US NRC, NUREG/CR-7108, “An Approach for Validating Actinide and Fission Product Burnup Credit Criticality Safety Analyses-Isotopic Composition Predictions,” April 2012.

9. YAEC 1937, “Axial Burnup Profile Database for Pressurized Water Reactors,” R.J. Cacciaputi, Van S. Volkinburg, May 1997.

Table 6.8.5-1
Authorized Contents for NUHOMS®-32PT System

Assembly Type[1]	Array	Assembly Class
Westinghouse 17x17 LOPAR/Standard	17x17	WE 17x17
Westinghouse 17x17 OFA/Vantage 5[2]	17x17	WE 17x17
Framatome 17x17 MK BW	17x17	WE 17x17
Westinghouse 17x17 RFA	17x17	WE 17x17
B&W 15x15 Mark B (through B11)	15x15	BW 15x15
B&W 17x17 Mark C	17x17	BW 15x15
CE 15x15 Palisades	15x15	CE 15x15
Exxon/ANF (ANP) 15x15 CE	15x15	CE 15x15
Exxon/ANF (ANP) 15x15 WE	15x15	WE 15x15
Westinghouse 15x15 Standard/ZC	15x15	WE 15x15
Westinghouse 15x15 LOPAR/OFA/ DRFA/Vantage 5	15x15	WE 15x15
CE 14x14 Standard/Generic	14x14	CE 14x14
CE 14x14 Fort Calhoun	14x14	CE 14x14
Framatome-ANP 14x14 CE	14x14	CE 14x14
Exxon/ANF (ANP) 14x14 WE	14x14	WE 14x14
Exxon/ANF (ANP) 14x14 Toprod	14x14	WE 14x14
Westinghouse 14x14 Standard/LOPAR/ZCA/ZCB	14x14	WE 14x14
Westinghouse 14x14 OFA	14x14	WE 14x14

Notes:
(1) Reload fuel from other manufacturers with these parameters are also acceptable.
(2) Includes all Vantage versions (5, +, ++, 5H, etc.).

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Table 6.8.5-3
Description of the Basic KENO Model Units

Geometry Units	Description
1	Fuel rod
2	Guide tube
3	Instrument tube
4	Top horizontal poison plate
5	Bottom horizontal poison plate
6	Right vertical poison plate
7	Left vertical poison plate
8	Horizontal aluminum plate
9	Vertical aluminum plate
10	FA low left poison South East Quadrant
11	FA low right poison South West Quadrant
12	FA low left poison North East Quadrant
13	FA low left poison North West Quadrant
20	FA low right Aluminum South East Quadrant
21	FA low right Aluminum South West Quadrant
22	FA Assembly low left Aluminum North East Quadrant
23	FA low right Aluminum North West Quadrant
29	Top row of 4 FAs positions 231, 232, 233, 234
30	Left row of 4 FAs positions 225, 226, 227, 228
31	Bottom row of 4 FAs positions 221, 222, 223, 224
32	Right row of 4 FAs positions 235, 236, 237, 238
33	Global Unit - array of FAs positions 201, 202, 203, 204, 205, 206, 207, 207, 208, 211, 212, 213, 214, 215, 216, 217, 218

Table 6.8.5-4
Material Property Data

Material	ID	Density g/cm^3	Element	Weight %	Atom Density (atoms/b-cm)
Zircaloy-4	2	6.56	Zr	98.23	4.2541E-02
			Sn	1.45	4.8254E-04
			Fe	0.21	1.4856E-04
			Cr	0.10	7.5978E-05
			Hf	0.01	2.2133E-06
Water (Pellet Clad Gap)	3	0.998	H	11.1	6.6769E-02
			O	88.9	3.3385E-02
Stainless Steel (SS304)	5	7.94	C	0.080	3.1877E-04
			Si	1.000	1.7025E-03
			P	0.045	6.9468E-05
			Cr	19.000	1.7473E-02
			Mn	2.000	1.7407E-03
			Fe	68.375	5.8545E-02
			Ni	9.500	7.7402E-03
$^{11}B_4C$ in CC	8	2.555	B11	78.56	1.0988E-01
			C	21.44	2.7470E-02
Aluminum	6	2.702	Al	100.0	6.0307E-02
Aluminum - Boron Poison Plate (13.5 mg B-10/cm^2)	7	2.693	B-10	2.63	4.26230E-03
			B11	0.29	4.3073E-04
			Al	97.08	5.8349E-02
Water	9	0.998	H	11.1	6.6769E-02
			O	88.9	3.3385E-02

Table 6.8.5-5
List of Isotopes used for Burnup Credit Calculations

Nuclides for Major Actinide-Only Burnup Credit				
^{234}U	^{235}U	^{238}U	^{238}Pu	^{239}Pu
^{240}Pu	^{241}Pu	^{242}Pu	^{241}Am	
Additional Nuclides for Minor Actinide and Fission Product Burnup Credit				
^{95}Mo	^{99}Tc	^{101}Ru	^{103}Rh	^{109}Ag
^{133}Cs	^{147}Sm	^{149}Sm	^{150}Sm	^{151}Sm
^{152}Sm	^{143}Nd	^{145}Nd	^{151}Eu	^{153}Eu
^{155}Gd	^{236}U	^{243}Am	^{237}Np	

Table 6.8.5-6
Burnup-Dependent Axial Correction Factors for 18 Axial Zones

Axial Zone No.	Fraction of Core Height	Source: STARBUCS			Source: Ref. [7]
		< 18 GWd/MTU	18 - 30 GWd/MTU	30 - 38 GWd/MTU	Burnup ≥ 38 GWd/MTU
		1	2	3	4
1	0.0278	0.649	0.668	0.652	0.660
2	0.0833	1.044	1.034	0.967	0.936
3	0.1389	1.208	1.150	1.074	1.045
4	0.1944	1.215	1.094	1.103	1.080
5	0.2500	1.214	1.053	1.108	1.091
6	0.3056	1.208	1.048	1.106	1.093
7	0.3611	1.197	1.064	1.102	1.092
8	0.4167	1.189	1.095	1.097	1.090
9	0.4722	1.188	1.121	1.094	1.089
10	0.5278	1.192	1.135	1.094	1.088
11	0.5833	1.195	1.140	1.095	1.088
12	0.6389	1.190	1.138	1.096	1.086
13	0.6944	1.156	1.130	1.095	1.084
14	0.7500	1.022	1.106	1.086	1.077
15	0.8056	0.756	1.049	1.059	1.057
16	0.8611	0.614	0.933	0.971	0.996
17	0.9167	0.481	0.669	0.738	0.823
18	0.9722	0.284	0.373	0.462	0.525

Table 6.8.5-7
Calculation of Minor Actinide and Fission Product Worth

Cooling Time (years)	Burnup (GWD/MTU)	Major Actinides Only			Including Minor Actinides and Fission Products			Minor Actinides and Fission Products Worth
		K_{KENO}	σ	k_{eff}	K_{KENO}	σ	k_{eff}	
5	10	1.16369	0.00049	1.16467	1.1294	0.00049	1.13038	0.03429
	15	1.14616	0.00045	1.14706	1.10529	0.00045	1.10619	0.04087
	20	1.1098	0.00047	1.11074	1.05046	0.00046	1.05138	0.05936
	30	1.06081	0.00041	1.06163	0.98919	0.00045	0.99009	0.07154
	40	1.01027	0.00048	1.01123	0.92252	0.00047	0.92346	0.08777
	50	**0.96756**	**0.00049**	**0.96854**	**0.87199**	**0.00049**	**0.87297**	**0.09557**
10	10	1.16286	0.00049	1.16384	1.12905	0.00043	1.12991	0.03393
	15	1.14314	0.00045	1.14404	1.10386	0.00044	1.10474	0.0393
	20	1.10633	0.00049	1.10731	1.04862	0.00042	1.04946	0.05785
	30	1.05348	0.00049	1.05446	0.98106	0.00049	0.98204	0.07242
	40	0.99817	0.00041	0.99899	0.91117	0.00046	0.91209	0.0869
	50	0.95222	0.00049	0.9532	0.85868	0.00048	0.85964	0.09356
15	10	1.1636	0.00039	1.16438	1.12816	0.00049	1.12914	0.03524
	15	1.1417	0.00049	1.14268	1.10276	0.00046	1.10368	0.039
	20	1.10091	0.00049	1.10189	1.04538	0.00043	1.04624	0.05565
	30	1.04924	0.00049	1.05022	0.97615	0.00043	0.97701	0.07321
	40	0.98994	0.00047	0.99088	0.90424	0.0004	0.90504	0.08584
	50	0.94223	0.00048	0.94319	0.84926	0.00049	0.85024	0.09295
20	10	1.16255	0.00049	1.16353	1.12798	0.00048	1.12894	0.03459
	15	1.14157	0.00049	1.14255	1.10267	0.00047	1.10361	0.03894
	20	1.09875	0.00049	1.09973	1.04416	0.00038	1.04492	0.05481
	30	1.04227	0.00049	1.04325	0.97318	0.00049	0.97416	0.06909
	40	0.98255	0.00047	0.98349	0.8984	0.00042	0.89924	0.08425
	50	0.93373	0.00049	0.93471	0.84338	0.00044	0.84426	0.09045

Table 6.8.5-8
Bounding Depletion Parameters used in T-DEPL Calculations

Parameter	Value
Average Fuel Temperature	1100 K
Average Moderator Density	0.63 g/cm^3
Average Moderator Temperature	610 K
Average Clad Temperature	640 K
Soluble Boron Concentration	1000 ppm
Specific Power	40 MW/MTU
Down Time	0 Days

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Table 6.8.5-9a
Rod Removal Study of Failed Fuel Assemblies

Rods Removed	k-keno	σ	k-keno+2σ
0	0.9160	0.0005	0.9170
1	0.9168	0.0004	0.9176
2	0.9169	0.0005	0.9179
4	0.9164	0.0005	0.9174
6	0.9160	0.0004	0.9168
8	0.9172	0.0004	0.9180
10	0.9174	0.0005	0.9184
12	0.9160	0.0005	0.9170
14	0.9168	0.0005	0.9178
16	0.9166	0.0004	0.9174
18	0.9160	0.0005	0.9170
20	0.9174	0.0005	0.9184
22	0.9177	0.0004	0.9185
24	**0.9177**	**0.0005**	**0.9187**
26	0.9167	0.0004	0.9175
28	0.9169	0.0005	0.9179
32	0.9170	0.0005	0.9180
36	0.9176	0.0005	0.9186
40	0.9162	0.0004	0.9170
44	0.9159	0.0005	0.9169

Table 6.8.5-10
Acceptable Initial Enrichment / Burnup Combinations for CE 14x14 Fuel Class Intact FAs – 24PP No PRA

Cooling Time	Burnup	Enrichment	k_{keno}	σ_{keno}	k_{keno}+2 σ_{keno}	k_{eff} + (β_i+Δk_i) + Δk_x
0 years (Fresh Fuel)	0	1.80	0.9343	0.0005	0.9353	-
5 years	5	1.78	0.9240	0.0004	0.9249	0.9414
	10*	1.91	0.9240	0.0004	0.9249	0.9412
	15	2.06	0.9241	0.0004	0.9248	0.9420
	20	2.44	0.9243	0.0004	0.9252	0.9421
	25	2.83	0.9243	0.0005	0.9252	0.9421
	30	3.29	0.9231	0.0005	0.9240	0.9416
	35	3.69	0.9234	0.0004	0.9243	0.9421
	40*	4.29	0.9228	0.0005	0.9238	0.9416
	45	4.64	0.9194	0.0004	0.9202	0.9422
	50	5.00	0.9148	0.0005	0.9157	0.9391
	55	5.00	0.8957	0.0005	0.8967	0.9282
10 years	5	1.80	0.9240	0.0005	0.9250	0.9415
	10	1.97	0.9250	0.0005	0.9259	0.9422
	15	2.12	0.9239	0.0005	0.9249	0.9421
	20	2.61	0.9244	0.0005	0.9253	0.9422
	25	2.98	0.9243	0.0005	0.9252	0.9421
	30	3.48	0.9232	0.0005	0.9241	0.9417
	35	3.89	0.9230	0.0005	0.9240	0.9418
	40	4.58	0.9228	0.0005	0.9237	0.9415
	45	4.92	0.9184	0.0005	0.9194	0.9414
	50	5.00	0.9004	0.0005	0.9014	0.9248
	55	5.00	0.8785	0.0005	0.8794	0.9109
15 years	5	1.82	0.9248	0.0004	0.9257	0.9422
	10	2.01	0.9247	0.0005	0.9257	0.9420
	15	**2.17**	**0.9241**	**0.0005**	**0.9251**	**0.9423**
	20	2.69	0.9242	0.0004	0.9251	0.9420
	25	3.07	0.9236	0.0004	0.9245	0.9414
	30	3.60	0.9233	0.0005	0.9242	0.9418
	35	4.03	0.9231	0.0005	0.9240	0.9418
	40	4.76	0.9232	0.0004	0.9241	0.9419
	45	5.00	0.9122	0.0004	0.9131	0.9351
	50	5.00	0.8906	0.0005	0.8915	0.9149
	55	5.00	0.8676	0.0005	0.8686	0.9001
20 years	5	1.82	0.9245	0.0004	0.9254	0.9419
	10	2.03	0.9247	0.0005	0.9257	0.9420
	15	2.20	0.9240	0.0004	0.9249	0.9421
	20	2.75	0.9243	0.0005	0.9253	0.9422
	25	3.14	0.9232	0.0004	0.9241	0.9410
	30	3.69	0.9229	0.0005	0.9238	0.9414
	35	4.13	0.9232	0.0005	0.9242	0.9420
	40	4.87	0.9233	0.0005	0.9242	0.9420
	45	5.00	0.9058	0.0004	0.9067	0.9287
	50	5.00	0.8823	0.0004	0.8832	0.9066
	55	5.00	0.8586	0.0005	0.8596	0.8911

Note: Reported enrichments are rounded down to 2 decimal digits.

Table 6.8.5-11
Acceptable Initial Enrichment / Burnup Combinations for 4 CE 14x14 Fuel Class Damaged FAs – 24PP No PRA

Cooling Time	Burnup	Enrichment	k_{keno}	σ_{keno}	k_{keno}+2 σ_{keno}	k_{eff} + (β_i+Δk_i) + Δk_x
0 years (Fresh Fuel)	0	1.75	0.9375	0.0005	0.9385	-
5 years	5	1.55	0.9221	0.0005	0.9230	0.9395
	10	1.65	0.9214	0.0004	0.9222	0.9385
	15	1.75	0.9223	0.0005	0.9233	0.9405
	20	2.10	0.9210	0.0005	0.9219	0.9388
	25	2.30	0.9227	0.0004	0.9235	0.9404
	30	2.80	0.9212	0.0005	0.9221	0.9397
	35	3.15	0.9219	0.0005	0.9228	0.9406
	40	3.80	0.9202	0.0005	0.9211	0.9389
	45	4.05	0.9165	0.0005	0.9175	0.9395
	50	4.50	0.9149	0.0004	0.9157	0.9391
	55	5.00	0.8996	0.0005	0.9005	0.9320
10 years	5	**1.60**	**0.9233**	**0.0005**	**0.9242**	**0.9407**
	10	1.70	0.9224	0.0005	0.9233	0.9396
	15	1.85	0.9219	0.0005	0.9229	0.9401
	20	2.20	0.9227	0.0005	0.9237	0.9406
	25	2.40	0.9205	0.0005	0.9215	0.9384
	30	3.05	0.9222	0.0005	0.9231	0.9407
	35	3.35	0.9214	0.0005	0.9223	0.9401
	40	3.85	0.9212	0.0004	0.9220	0.9398
	45	4.25	0.9176	0.0005	0.9185	0.9405
	50	5.00	0.9051	0.0004	0.9059	0.9293
	55	5.00	0.8830	0.0004	0.8838	0.9153
15 years	5	1.55	0.9220	0.0004	0.9229	0.9394
	10	1.70	0.9233	0.0005	0.9242	0.9405
	15	1.85	0.9212	0.0005	0.9221	0.9393
	20	2.30	0.9221	0.0004	0.9230	0.9399
	25	2.60	0.9221	0.0005	0.9230	0.9399
	30	3.15	0.9216	0.0005	0.9225	0.9401
	35	3.50	0.9212	0.0005	0.9221	0.9399
	40	4.00	0.9216	0.0005	0.9225	0.9403
	45	5.00	0.9178	0.0005	0.9187	0.9407
	50	5.00	0.8944	0.0005	0.8954	0.9188
	55	5.00	0.8717	0.0005	0.8727	0.9042
20 years	5	1.60	0.9227	0.0004	0.9236	0.9401
	10	1.70	0.9232	0.0005	0.9241	0.9404
	15	1.90	0.9225	0.0005	0.9235	0.9407
	20	2.40	0.9220	0.0005	0.9229	0.9398
	25	2.70	0.9223	0.0005	0.9232	0.9401
	30	3.20	0.9216	0.0005	0.9226	0.9402
	35	3.55	0.9205	0.0005	0.9215	0.9393
	40	4.25	0.9214	0.0004	0.9222	0.9400
	45	5.00	0.9101	0.0005	0.9110	0.9330
	50	5.00	0.8858	0.0005	0.8867	0.9101
	55	5.00	0.8623	0.0004	0.8632	0.8947

Note: The burnup/enrichment combinations shown in this table apply only to damaged fuel assemblies while the burnup/enrichment combinations for balance intact fuels are at the values provided in Table 6.8.5-10.

Table 6.8.5-12
Acceptable Initial Enrichment / Burnup Combinations for 28 CE 14x14 Fuel Class Damaged FAs – 24PP No PRA

Cooling Time	Burnup	Enrichment	k_{keno}	σ_{keno}	k_{keno}+2 σ_{keno}	k_{eff} + (β_i+Δk_i) + Δk_x
0 years (Fresh Fuel)	0	1.70	0.9343	0.0005	0.9353	-
5 years	5	1.60	0.9222	0.0005	0.9232	0.9397
	10	1.70	0.9232	0.0004	0.9240	0.9403
	20	2.15	0.9215	0.0005	0.9225	0.9394
	25	2.45	0.9233	0.0004	0.9241	0.9410
	30	2.85	0.9231	0.0005	0.9241	0.9417
	35	3.15	0.9230	0.0004	0.9238	0.9416
	40	**3.75**	**0.9231**	**0.0005**	**0.9241**	**0.9419**
	45	4.05	0.9189	0.0004	0.9197	0.9417
	50	4.35	0.9161	0.0004	0.9169	0.9403
	55	4.70	0.9095	0.0004	0.9103	0.9418
10 years	5	1.60	0.9203	0.0004	0.9211	0.9376
	10	1.75	0.9240	0.0005	0.9250	0.9413
	20	2.25	0.9207	0.0005	0.9216	0.9385
	25	2.55	0.9219	0.0005	0.9229	0.9398
	30	3.05	0.9233	0.0004	0.9242	0.9418
	35	3.35	0.9209	0.0004	0.9217	0.9395
	40	3.95	0.9227	0.0005	0.9236	0.9414
	45	4.30	0.9185	0.0005	0.9195	0.9415
	50	4.75	0.9169	0.0005	0.9178	0.9412
	55	5.00	0.9061	0.0005	0.9071	0.9386
15 years	5	1.65	0.9235	0.0005	0.9245	0.9410
	10	1.80	0.9240	0.0004	0.9248	0.9411
	20	2.35	0.9235	0.0005	0.9244	0.9413
	25	2.65	0.9219	0.0005	0.9228	0.9397
	30	3.15	0.9226	0.0005	0.9235	0.9411
	35	3.50	0.9224	0.0005	0.9233	0.9411
	40	4.10	0.9212	0.0005	0.9222	0.9400
	45	4.50	0.9179	0.0004	0.9188	0.9408
	50	5.00	0.9152	0.0005	0.9162	0.9396
	55	5.00	0.8932	0.0005	0.8941	0.9256
20 years	5	1.65	0.9233	0.0005	0.9242	0.9407
	10	1.80	0.9223	0.0004	0.9231	0.9394
	20	2.40	0.9221	0.0005	0.9230	0.9399
	25	2.70	0.9210	0.0005	0.9220	0.9389
	30	3.20	0.9201	0.0005	0.9211	0.9387
	35	3.60	0.9226	0.0005	0.9236	0.9414
	40	4.20	0.9206	0.0005	0.9216	0.9394
	45	4.70	0.9183	0.0004	0.9192	0.9412
	50	5.00	0.9087	0.0005	0.9097	0.9331
	55	5.00	0.8849	0.0005	0.8858	0.9173

Note: The burnup/enrichment combinations shown in this table apply only to damaged fuel assemblies while the burnup/enrichment combinations for balance intact fuels are at the values provided in Table 6.8.5-10.

Table 6.8.5-13
Acceptable Initial Enrichment / Burnup Combinations for 8 CE 14x14 Fuel Class Failed FAs – 24PP No PRA

Cooling Time	Burnup	Enrichment	k-keno	σ	k-keno+2σ	k-keno+2σ+Δk$_x$+Δk$_i$
0 years (Fresh Fuel)	0	1.65	0.9313	0.0006	0.9325	-
5 years	5	1.55	0.9228	0.0005	0.9238	0.9403
	10	1.70	0.9227	0.0005	0.9237	0.9400
	15	**1.80**	**0.9237**	**0.0005**	**0.9247**	**0.9419**
	20	2.15	0.9229	0.0005	0.9239	0.9408
	25	2.30	0.9235	0.0005	0.9245	0.9414
	30	2.80	0.9211	0.0004	0.9219	0.9395
	35	3.10	0.9208	0.0005	0.9218	0.9396
	40	3.65	0.9200	0.0005	0.9210	0.9388
	45	4.05	0.9187	0.0005	0.9197	0.9417
	50	4.85	0.9170	0.0004	0.9178	0.9412
	55	5.00	0.8968	0.0005	0.8978	0.9293
10 years	5	1.60	0.9215	0.0005	0.9225	0.9390
	10	1.70	0.9225	0.0005	0.9235	0.9398
	15	1.85	0.9217	0.0004	0.9225	0.9397
	20	2.10	0.9224	0.0005	0.9234	0.9403
	25	2.35	0.9233	0.0005	0.9243	0.9412
	30	3.05	0.9224	0.0005	0.9234	0.9410
	35	3.25	0.9218	0.0005	0.9228	0.9406
	40	3.80	0.9231	0.0004	0.9239	0.9417
	45	4.15	0.9169	0.0004	0.9177	0.9397
	50	5.00	0.9030	0.0004	0.9038	0.9272
15 years	5	1.45	0.9220	0.0005	0.9230	0.9395
	10	1.70	0.9221	0.0005	0.9231	0.9394
	15	1.85	0.9224	0.0005	0.9234	0.9406
	20	2.25	0.9221	0.0004	0.9229	0.9398
	25	2.65	0.9228	0.0005	0.9238	0.9407
	30	3.10	0.9225	0.0005	0.9235	0.9411
	35	3.45	0.9219	0.0005	0.9229	0.9407
	40	4.10	0.9217	0.0005	0.9227	0.9405
	45	5.00	0.9139	0.0005	0.9149	0.9369
20 years	5	1.65	0.9227	0.0005	0.9237	0.9402
	10	1.70	0.9233	0.0005	0.9243	0.9406
	15	1.90	0.9226	0.0005	0.9236	0.9408
	20	2.35	0.9212	0.0005	0.9222	0.9391
	25	2.65	0.9227	0.0005	0.9237	0.9406
	30	3.05	0.9206	0.0005	0.9216	0.9392
	35	3.35	0.9210	0.0005	0.9220	0.9398
	40	4.30	0.9223	0.0005	0.9233	0.9411
	45	5.00	0.9070	0.0005	0.9080	0.9300

Note: The burnup/enrichment combinations shown in this table apply only to failed fuel assemblies while the burnup/enrichment combinations for balance intact fuels are at the values provided in Table 6.8.5-10.

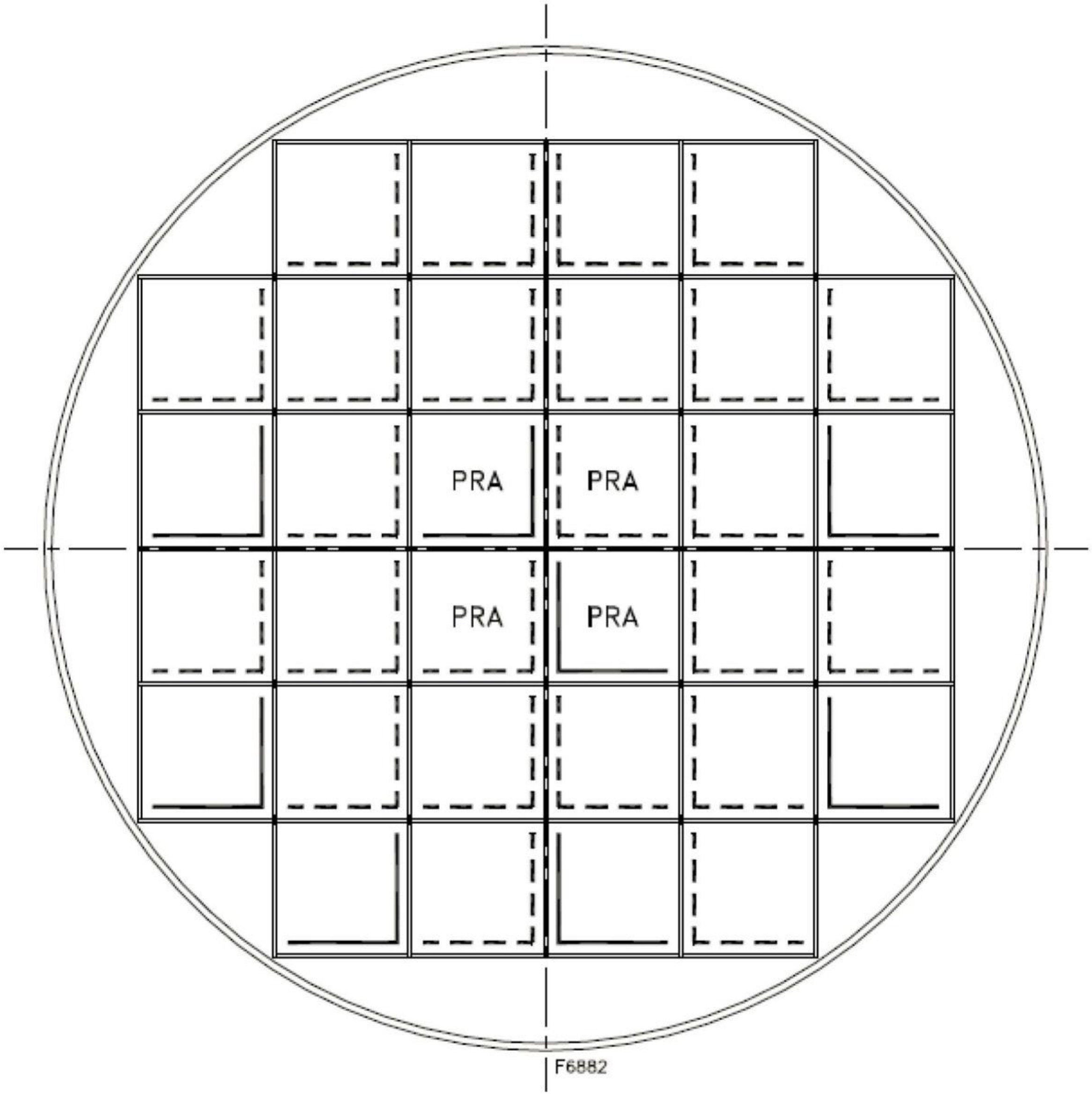

Figure 6.8.5-1
Required PRA Locations for Configurations with Four PRAs – 32PT DSC

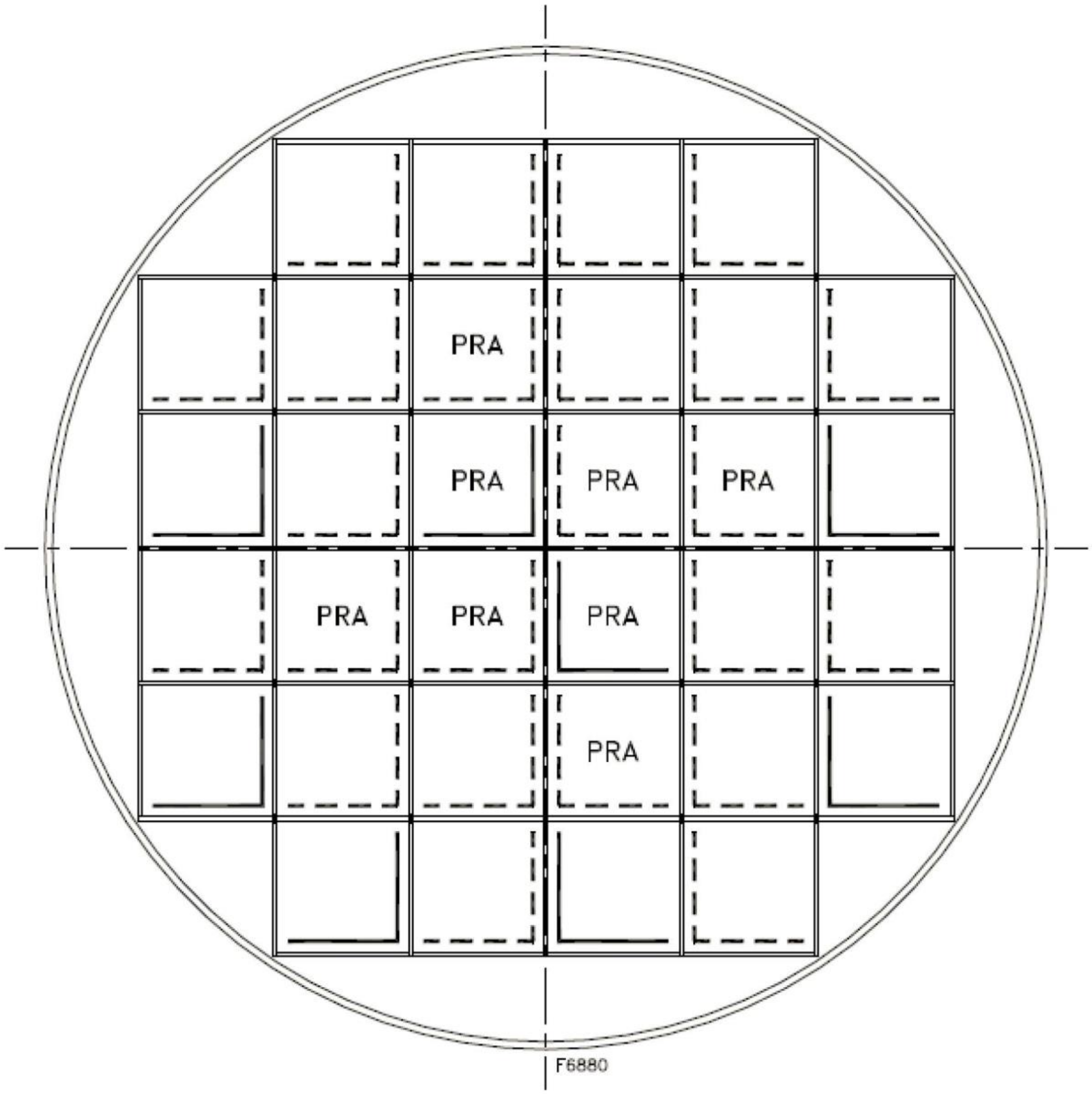

Figure 6.8.5-2
Required PRA Locations for Configurations with Eight PRAs – 32PT DSC
(Part 1 of 2)

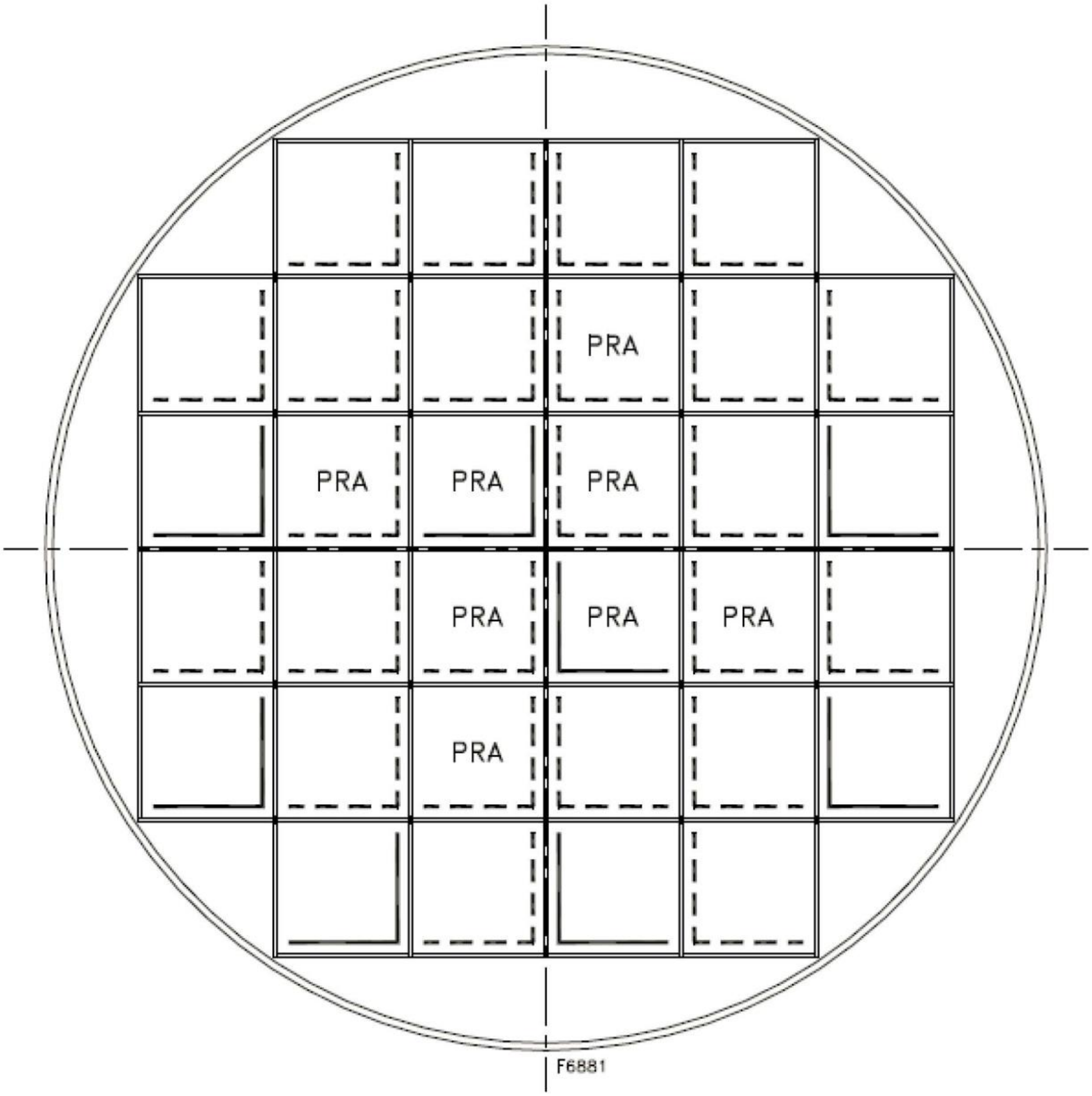

Figure 6.8.5-2
Required PRA Locations for Configurations with Eight PRAs – 32PT DSC
(Part 2 of 2)

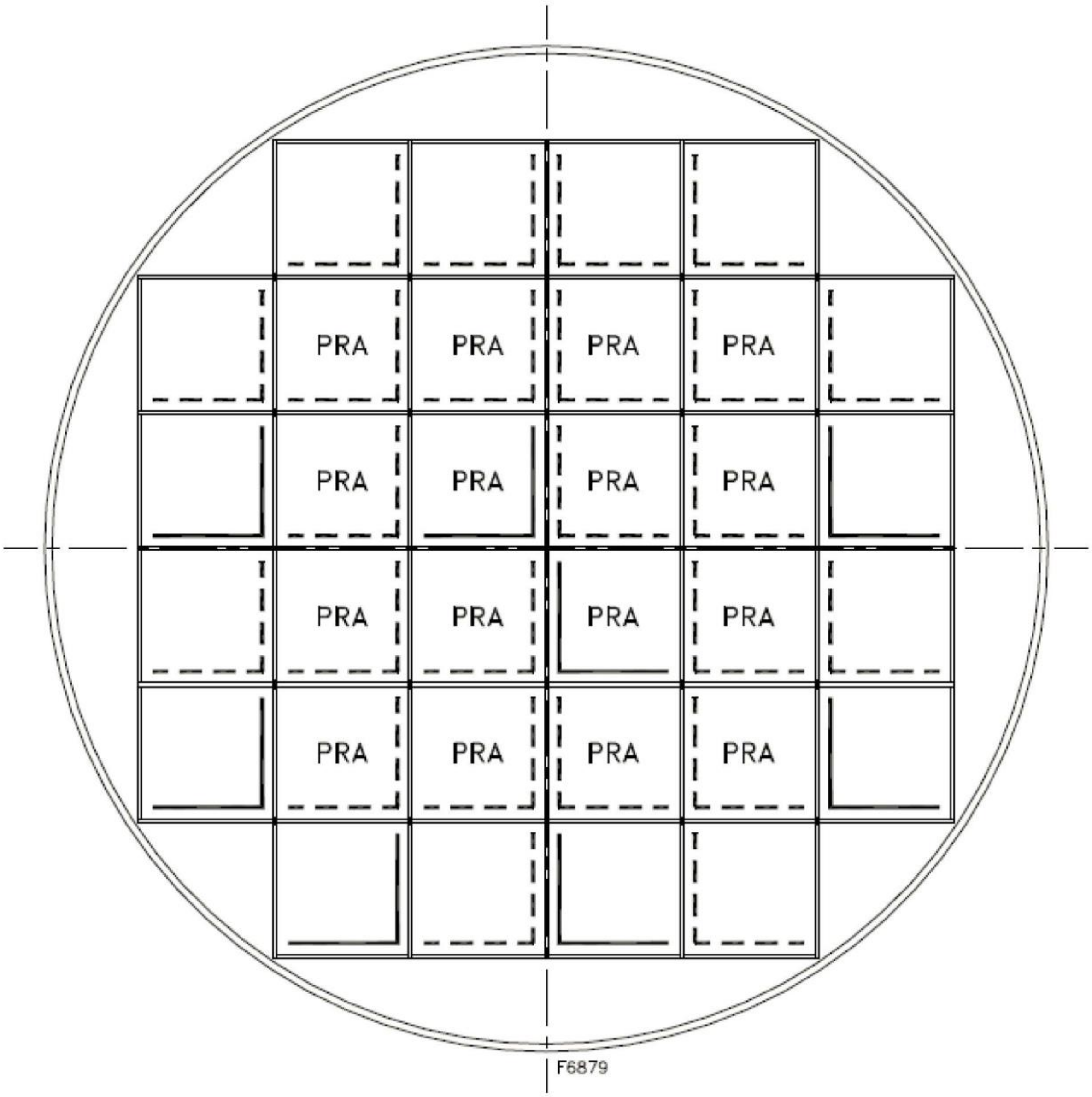

Figure 6.8.5-3
Required PRA Locations for Configurations with Sixteen PRAs – 32PT DSC

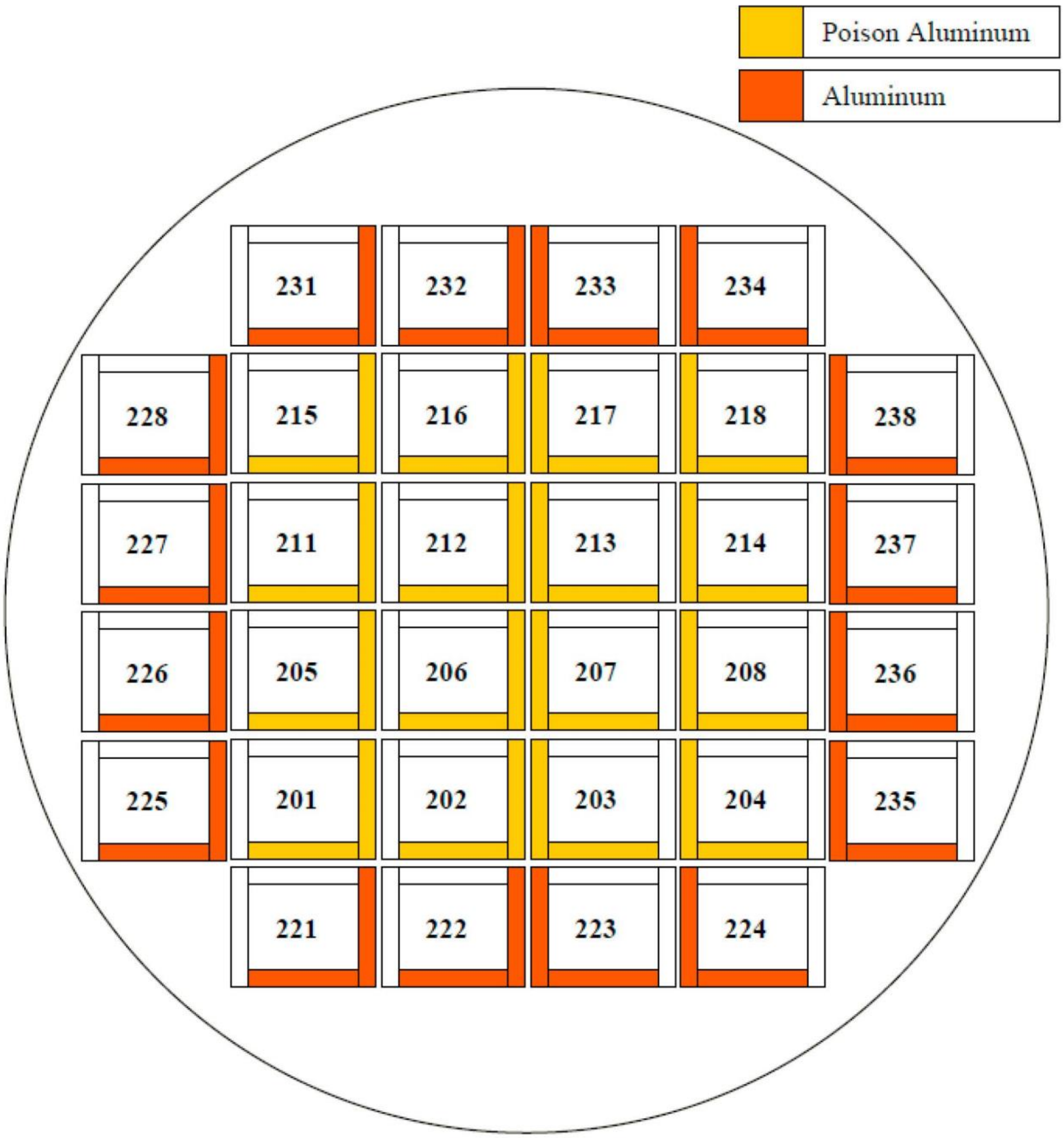

Figure 6.8.5-4
Fuel Positions and Poison Locations - 16PP Model – 32PT DSC

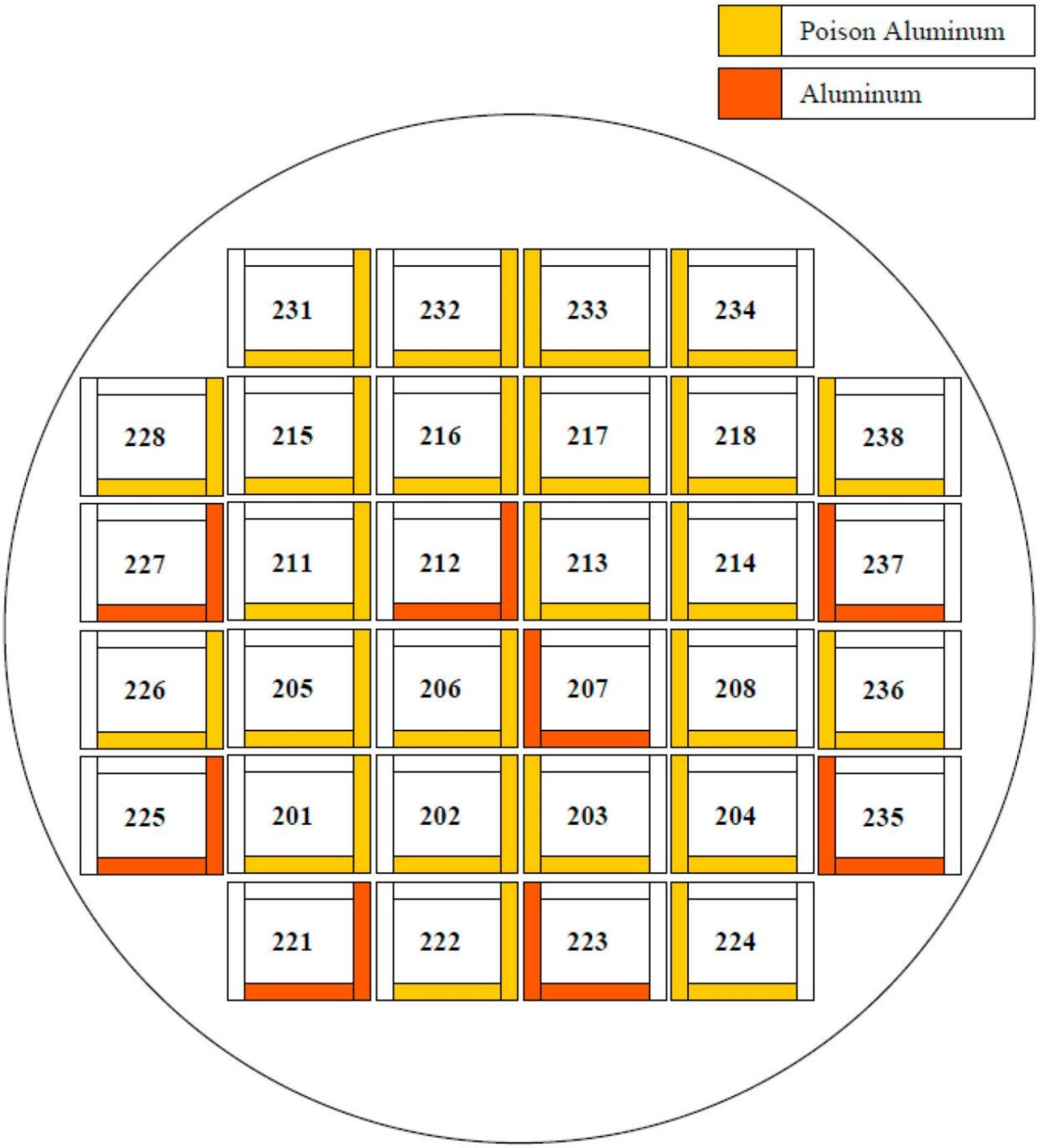

Figure 6.8.5-5
Fuel Positions and Poison Locations - 24PP Model – 32PT DSC

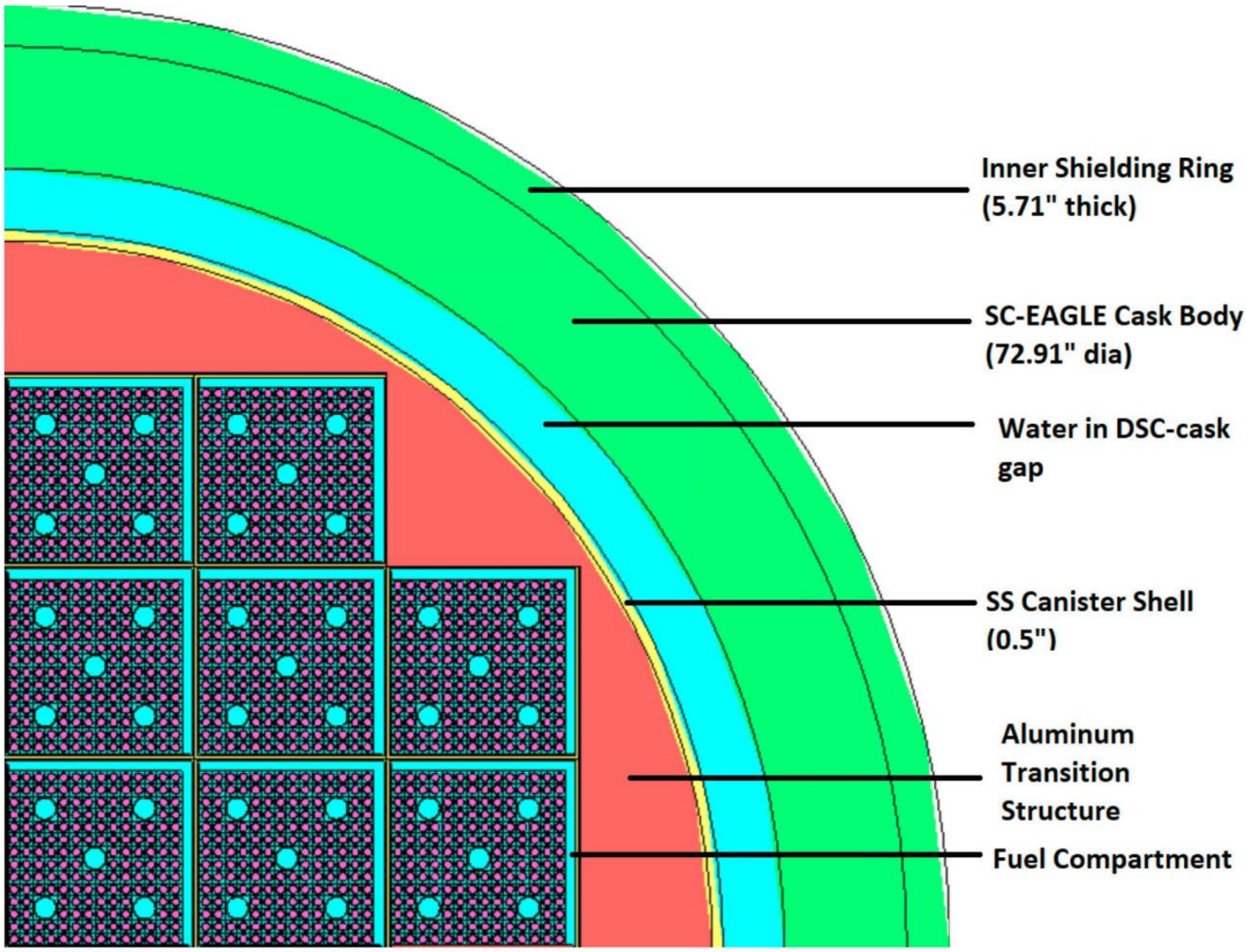

Figure 6.8.5-6
Radial Layout of the 32PT DSC in TN Eagle

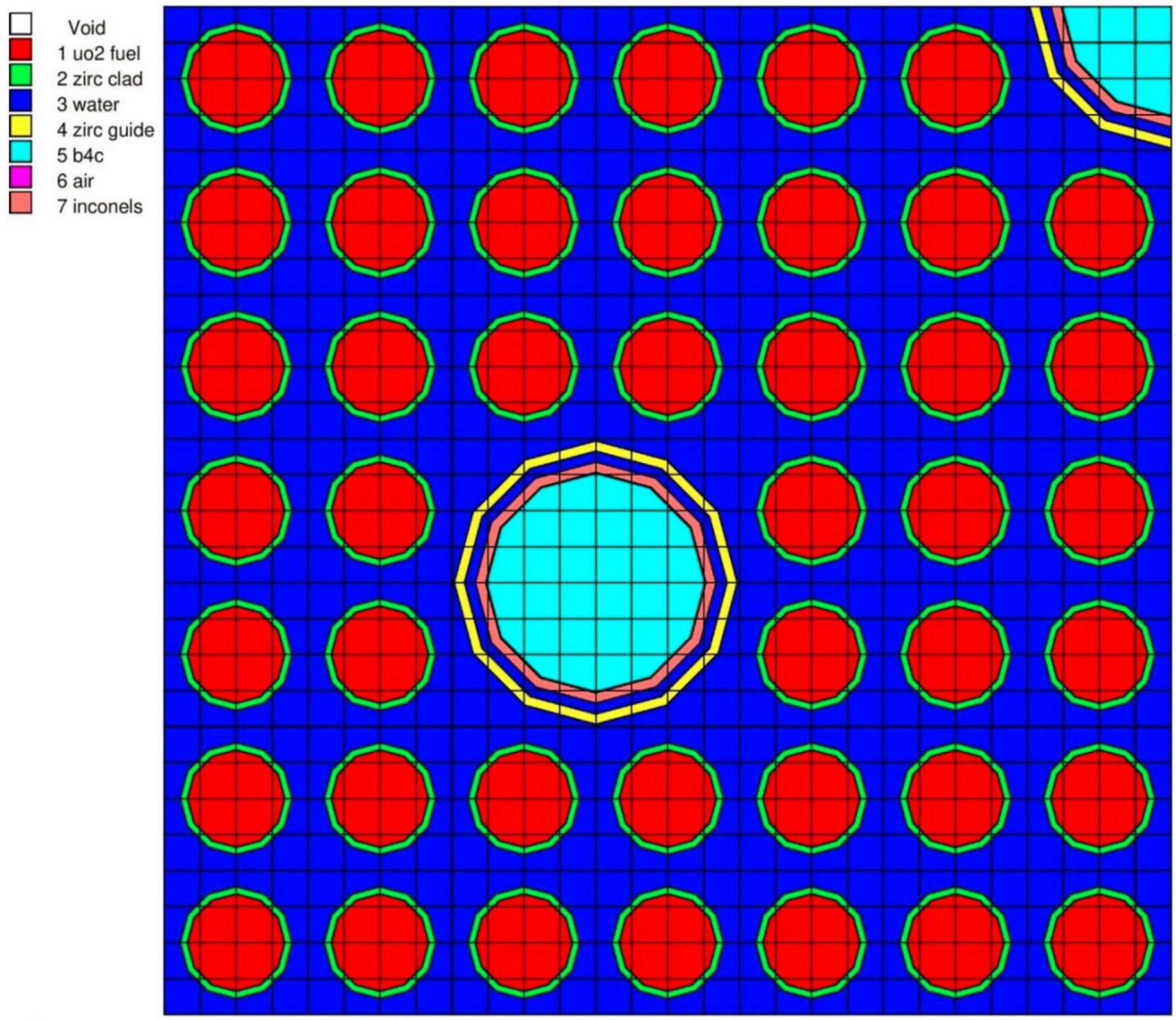

Figure 6.8.5-7
T-DEPL Model for the CE 14x14 Fuel Assembly

Chapter 7
Material Evaluation

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Chapter 7
Material Evaluation

7.1 Drawings

The drawings for the TN Eagle and DSCs are provided in Chapter 1, Section 1.5. The materials specification, governing code, and quality category are specified in the parts list for each component.

7.2 Codes and Standards

7.2.1 Usage and Endorsement

The containment boundary of the TN Eagle is designed and constructed in accordance with ASME Boiler and Pressure Vessel Code, 2017 edition [1] as described in Section 7.2.2.

7.2.2 American Society of Mechanical Engineers (ASME) Code Component

The TN Eagle containment boundary is designed and fabricated as a Class 1 component in accordance to the ASME Code, Section III, Division 1, subsection NB and the alternative provisions to the ASME Codes as described in Chapter 1. The affected parts are identified as NB in the code criteria column of the drawing parts list.

Attachments to the containtainment boundary with a pressure retaining function, or in the support load path for the cask body are identified as NF on the drawing parts list. The stress analysis rules of NF are used for these parts, and either ASME or ASTM materials may be used.

7.2.3 Code Case Use/Acceptability

The TN Eagle transport cask is designed and constructed without code case usage.

7.2.4 Non-ASME Code Components

Parts that do not meet the criteria in Section 7.2.2 for designation as ASME NB or NF are designated as non-code on the drawing parts list. These include the impact limiters, neutron shielding, and non-pressure retaining plates. Materials for these parts are as specified on the drawing parts list.

7.3 Weld Design and Inspection

Welders and weld procedures are qualified per ASME Section IX. Weld inspections use the criteria of NB-5000 for containment boundary parts, and either NB-5000 or NF-5000 for all other components.

7.3.1 Moderator Exclusion for Commercial Spent Nuclear Fuel Packages Under Hypothetical Accident Conditions.

The forged cask body results from a “monobloc” fabrication with no welding except for the stainless steel overlay at the flange sealing surface, and welds to attach the rails to the inside surface. The package body and closure design assures that the in-leakage of water is not credible after HAC drop events.

7.4 Mechanical Properties

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7.4.1 Tensile Properties

The material properties are described in the tables at the end of this chapter. The sources for the tensile properties are identied in those tables.

7.4.2 Fracture Resistance

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7.4.3 Tensile Properties and Creep of Aluminum Alloys at Elevated Temperatures

Not applicable for TN Eagle; there are no aluminum parts other than the honeycomb of the impact limiters and the bottom spacer plate. The honeycomb is subject to neither high temperature nor tensile loads in NCT, and the spacer plate is replaceable dunnage.

7.4.4 Impact Limiters

[

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7.5 Thermal Properties of Materials

The thermal properties are described in the tables at the end of this chapter.

7.6 Radiation Shielding

7.6.1 Neutron-Shielding Materials

The neutron shielding is provided by the proprietary VYAL-B blocks inserted in the shielding rings and in the top of the impact limiters. VYAL-B is described in Table 7-7). [

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7.6.2 Gamma-Shielding Materials

The gamma shielding is provided by the forged cask body (low alloy steel described in Table 7-1), the primary lid, the RACP, the top handling ring (material described in Table 7-4), and the metalic parts of the shielding rings (materials described in Table 7-6A to Table 7-6C).

7.7 Criticality Control

Not applicable to the TN Eagle. Criticality control is addressed by materials that are part of the authorized content (DSCs). The TN Eagle packaging itself has no criticality control components.

7.7.1 Neutron-Absorbing (Poison) Material Specification

Not applicable to the TN Eagle. Neutron absorbing material is addressed by materials that are part of the authorized content (DSCs).

7.7.2 Computation of Percent Credit for Boron-Based Neutron Absorbers

Not applicable to the TN Eagle. Boron based neutron absorbers are addressed by materials that are part of the authorized content (DSCs).

7.7.3 Qualifying Properties Not Associated with Attenuation

Not applicable to the TN Eagle. Neutron absorbers for criticality control are part of the authorized content (DSCs), and testing for properties other than neutron attenuation is addressed in the storage licenses for those DSCs.

7.8 Corrosion Resistance

Carbon and low-alloy steel components are coated to prevent corrosion as described in Section 7.8. There is silicone sealant between the shielding rings, top handling ring, bottom ring, bottom closure plate, and forged cask body to prevent water ingress to unpainted carbon steel surfaces. The primary lid, RACP, and the impact limiters' structure are made of stainless steel, which is sufficiently corrosion-resistant for the environment described in Section 7.7.5. The main containment boundary seals are elastomeric, not metallic, and therefore not subject to corrosion. Orifice cover plate seal item G6 is the only metallic containment boundary seal. The lid orifice cover plate and the lid port plug metallic seals will be replaced prior to each transport, eliminating corrosion concerns.

The possibility of corrosion damage to the DSC containment boundary during its storage period is addressed by inspections performed during storage prior to transport in the TN Eagle.

7.8.1 Environment

The TN Eagle is designed for dry loading DSCs from and to the HSM, so there is no water immersion under normal operations. Its environment is limited to rain and snow. Some exposure to road salts is possible during transfer from the HSM to a rail car or during transport.

The DSCs that form the TN Eagle contents are protected from direct exposure to precipitation, and are exposed only to the humidity and aerosols in the cooling air that flows through the HSM during their storage period. The internal environment of the DSCs is dry helium. During transport in the TN Eagle, there is no further corrosive environment for the contents.

7.8.2 Carbon and Low Allow Steels

All exposed surfaces of carbon and low-alloy steels are coated to prevent corrosion.

7.8.3 Austenitic Stainless Steel

The only austenitic stainless parts of the TN Eagle containment are the weld overlay (note: it also could be a corrosion protection coating as described in Chapter 1) on the forged cask body top flange and the RACP port sealing surfaces . The weld overlay will have little exposure to chloride aerosols because it is covered by the impact limiter during transport. Stress corrosion cracking or pitting of the weld overlay would not affect its design function performance unless a defect crossed the seal area; continued performance of the design function is verified by pre-shipment and periodic leak testing. The ITS category C lid port plug and various NITS spacers, pins, washers, DSC rails, etc., are made of austenitic stainless steel.

The top handling ring item 131, the primary lid item 201, the lid orifice cover plate item 220 and the ram access cover plate item 910 are SA-182 TYPE F6NM, which is a martensitic stainless steel without welding, and therefore these parts are not susceptible to stress corrosion cracking.

The shell of the impact limiters is welded stainless steel and could be subject to pitting or stress corrosion cracking due to environmental chlorides. The shells will be visually inspected periodically and indications of corrosion can be examined in more detail. Any defect that penetrates the shell can be found by periodic leak testing of the impact limiters.

7.9 Protective Coatings

7.9.1 Review Guidance

A silicone-acrylic paint will be used on the exposed carbon and low alloy steel on the outside surface of the TN Eagle Package, and a zinc/aluminum thermal spray on the inside.

7.9.2 Scope of Coating Application

Manufacturer’s recommendations are followed for surface preparation, primer coat selection, and coating application.

7.9.3 Coating Selection

The zinc-aluminum thermal spray and the silicone-acrylic paint chosen for the TN Eagle are in compliance with ISO 2063-1 and -2 [19 and 20] and ISO 12944-5 [18], respectively. Alloy steel bolts are coated with bi-chromatic zinc.

7.9.4 Coating Qualification Testing

Zinc-aluminum thermal spray has been successfully used to coat the interior of TN-32 and TN-40 storage casks, which are immersed in a PWR spent fuel pool for loading. In addition, zinc-aluminum thermal spray has been qualified successfully for such utilization (according to RAP-11-00033156 Revision 0 [17]). This coating is more than adequate for the dry loading environment of the TN Eagle interior.

Silicone-acrylic paints have been qualified successfully for such utilization (According to NTE-20-031053-000 Rev.1 – International system coating qualification). Visual inspection and repair of the paint will be included in periodic maintenance per Chapter 8.

7.10 Content Reactions

7.10.1 Flammable and Explosive Reactions

Not applicable. The TN Eagle will be dry loaded and the TN Eagle cavity will be back filled with helium before each transport.

7.10.2 Content Chemical Reactions, Outgassing, and Corrosion

Not applicable for the TN Eagle. The content DSCs were vacuum-dried and backfilled with helium before storage.

7.11 Radiation Effects

At the center of the content DSCs, the neutron fluence is on the order of 10^{15} n/cm^2 after 20 years. The fluence experienced by the metal part of the TN Eagle will be much lower. Because neutron embrittlement only begins at around 10^{17} n/cm^2, there will be no effect of neutron irradiation on the metal parts of the TN Eagle. Metals are not affected by gamma irradition.

The organic materials that could be affected by gamma irradiation are the neutron shielding resin, the closure o-rings, and the silicone-acrylic exterior coating.

The maximum total gamma energy deposit rates are 7.33E-05 [rad/s] for the resin and 6.65E-05 [rad/s] for the PTFE. Given the maximum total gamma energy deposit rate, the maximum gamma exposures in 40 years are 9.25E+04 [rad] for the resin and 8.40E+04 [rad] for the PTFE. Note that the PTFE is used to approximate the FLUOROCARBON of the seals, and the gamma energy deposit rate of the PTFE is estimated under a conservative assumption that the PTFE is located at the cask side with much higher gamma flux, instead of the actual locations at the cask ends.

7.12 Package Contents

The TN Eagle cask contents are described in Chapter 1, Section 1.2.3 and Appendix 1.6.1 to Appendix 1.6.7.

7.13 Fresh (Unirradiated) Fuel Cladding

Not applicable.

7.14 Spent Nuclear Fuel

7.14.1 Spent Fuel Classification

The mechanical properties of spent nuclear fuel are documented and analyzed in Chapter 2. The SNF to be transported is classified under various storage CoCs. Those CoCs state different classifications such as damaged fuel, intact fuel, failed fuel, etc., that are also documented in Appendix 1.6.1 to Appendix 1.6.7.

7.14.2 Uncanned Spent Fuel

Fuel authorized for transport in the TN Eagle is only fuel that is contained in one of the authorized DSCs. These DSCs contain uncanned, undamaged fuel and may also contain damaged fuel that is confined within its fuel compartment by damaged fuel end caps.

7.14.3 Canned Spent Fuel

Some of the authorized DSCs may contain failed fuel enclosed in a failed fuel canister as described in Chapter 1 appendices.

7.15 Bolting Material

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7.16 Seals

7.16.1 Metallic Seals

The primary lid has a lid port hole closed by a plug with a non-containment boundary metallic seal and a containment double ring metallic seal (item G6) on the port cover. The metallic seals have a minimum and maximum temperature rating of -40 °C (-40 °F) and 300 °C (572 °F), respectively. The maximum metallic seal temperatures under HAC are 217 °C (422 °F) for intact fuel and 224 °C (435 °F) for HBU fuel (the maximum temperature of primary lid is conservatively reported as the maximum seal temperature), all well below the temperature limit.

7.16.2 Elastomeric Seals

The primary lid and ram access cover plate are both equipped with two elastomeric seals. The cask body sealing surfaces are protected with a stainless-steel cladding or a corrosion protection coating as described in Chapter 1.

Other non-containment elastomeric seals are at the lid alignment pin and test ports.

The fluorocarbon seals have a minimum and maximum temperature rating of -40 °C (-40 °F) and 204 °C (400 °F), respectively. The maximum seal temperatures under HAC are 169 °C (336 °F) for intact fuel and 179 °C (354 °F) for HBU fuel (the maximum temperature of primary lid seal is conservatively reported as the maximum fluorocarbon seal temperature), all well below the temperature limit.

RACP seals temperatures are bounded by primary lid seal temperatures.

7.17 References

1. ASME Boiler and Pressure Vessel Code, Section III, Division 1, Subsection NB, 2017 Edition.

2. U.S. Nuclear Regulatory Commission, Regulatory Guide 7.11, “Fracture Toughness Criteria of Base Metal for Ferritic Steel Shipping Cask Containment Vessels with a Maximum Wall Thickness of 4 Inches (0.1m),” June 1991.

3. VYAL-B Resin Safety Analysis Report Reference Values, TN International Report No. DI/RI-A-1-5-02 Rev 1, 2006.

4. ASME Boiler and Pressure Vessel Code, Section II, Part D, “Properties,” 2017 Edition.

5. ASME Boiler and Pressure Vessel Code, Section III, Division 1, Subsection NF, 2017 Edition.

6. Validation de l’applicabilite d’une correlation resilience/tenacite a la demontration du non risque a la rupture fragile de l’acier A350 LF5, TN International Report No. NTC-11-00032796 Rev. 1, 2011.

7. Note technique sur la qualification du systeme de peinture International, TN International Report No. NTE-20-031053-000 Rev.1, 2020.

8. Spécification pour essais complémentaires de caractérisation de l’acier A350 grade LF5, TN International Report No. SPI-06-00038221 Rev. 01.

9. SA-350 LF5 Class 2 Enhanced Mechanical Properties at 180°C, TN International Report No. DI-83016-009, 2020.

10. Rupture Brutale: Capitalisation des essais de caracterisation de l’acier inoxidable martensitique SA182 F6NM, TN International Report No. NTE-20-031928-000 Rev.1, 2020.

11. Note on the Fire Resistance of the VYAL-B Resin, TN International Report No. DI-83016-007, 2020.

12. Aluminum Honeycomb Material Properties, TN International Report No. DI-83016-008, 2020.

13. Benchmarking of the Constitutive Model of Biaxial Aluminum Honeycomb, TN International/TN Americas Report No. TR-1004453, 2020.

14. Aluminum Honeycomb fire test results, CSTB Report No. RA20-0290.

15. Quasi-Static Tensile Tests on Part of Shell Ring in A350 Grade LF5 Class 2 Material, TN International Report No. SPI-16-00177304 Revision 02.

16. Apave Materials Laboratory Test Report No. 16.6467-1.

Proprietary Information on Pages 7-9 and 7-10
Withheld Pursuant to 10 CFR 2.390

Table 7-4
ASME SA-182 Type F6NM
Nominal Composition: 13Cr – 4Ni

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Temp (°C)	$E^{(a)}$ (10^3 MPa)	$S_m^{(a)}$ (MPa)	$S_y^{(a)}$ (MPa)	$S_u^{(a)}$ (MPa)	$\alpha_{AVG}^{(a)}$ (10^{-6} °C^{-1})	ρ (kg/m^3)	$K^{(a)}$ (W/m·°C)	$C_p^{(a)(b)}$ (J/kg·°C)
20	-	-	≥ 620	≥ 790	10.6	7750	24.6	446
25	201	-	-	-	-		-	-
40	-	264	621	793	-		-	-
50	-	-	-	-	10.9		24.7	460
75	-	-	-	-	11.0		24.7	469
100	195	264	595	793	11.1		24.8	478
125	-	264	589	-	11.3		24.9	488
150	192	264	583	793	11.4		24.9	496
175	-	-	578	-	11.4		25.0	506
200	189	262	572	785	11.5		25.0	515
225	-	-	566	-	11.6		25.1	527
250	186	254	560	761	11.6		25.1	538
275	-	-	553	-	11.7		25.2	551
300	182	244	546	733	11.7		25.2	563
325	-	240	538	719	11.8		25.2	576
350	178	235	530	705	11.8		25.3	590
375	-	229	520	689	11.9		25.3	603
400	173	-	-	672	11.9		25.3	617
425	-	-	-	654	12.0		25.4	633
450	166	-	-	634	12.0		25.4	646
475	-	-	-	613	12.1		25.4	662
500	157	-	-	-	12.1		25.4	677
ASME	Table TM-1 Group F p.835	Table 2A p. 300 Line 32	Table Y-1 p. 654-655 Line 27	Table U p. 535 Line 20	Table TE-1, group 1-B p. 805	Table PRD p. 841	Calculated based on Table TCD p. 822, Group G	

(1) Rupture Elongation: ≥ 14% @ 20 °C
(2) Poisson's Ratio: 0.30 from Table PRD p. 841
(3) Minimum impact test value: ≥ 60 J @ -40 °C
(4) Dynamic Toughness: ≥ 341 MPa.√m @ -40 °C [According to NTE-20-031928-000 Rev.1]
(5) Emissivity: ≥ 0.46

Notes:
(a) Linear interpolation at intermediate temperatures is possible in safety studies
(b) The specific heat C_p is obtained using thermal diffusivity α and conductivity λ tabulated in ASME II-D, density ρ and equation:

$$\alpha = \frac{\lambda}{\rho \cdot C_p} \Rightarrow C_p = \frac{\lambda}{\rho \cdot \alpha}$$

Table 7-5
ASME SA-240/SA-479 gr. 304L
Nominal Composition: 18 Cr – 8 Ni

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Temp (°C)	$E^{(a)}$ (10^3 MPa)	$S_m^{(a)}$ (MPa)	$S_y^{(a)}$ (MPa)	$S_u^{(a)}$ (MPa)	$\alpha_{AVG}^{(a)}$ (10^{-6} °C^{-1})	ρ (kg/m^3)	$K^{(a)}$ (W/m·°C)	$C_p^{(a)(b)}$ (J/kg·°C)
20	-	-	≥ 170	≥ 485	15.3		14.8	473
25	195	-	-	-	-		-	-
40	-	115	172	483	-		-	-
50	-	-	-	-	15.6		15.3	484
65	-	-	157	-	-		-	-
75	-	-	-	-	15.9		15.8	493
100	189	115	146	452	16.2		16.2	499
125	-	115	138	-	16.4		16.6	507
150	186	115	132	421	16.6		17.0	511
175	-	-	126	-	16.8		17.5	520
200	183	110	121	406	17.0		17.9	526
225	-	-	117	-	17.2	8030	18.3	530
250	179	103	114	398	17.4		18.6	532
275	-	-	111	-	17.5		19.0	537
300	176	97.7	108	393	17.7		19.4	542
325	-	95.8	106	392	17.8		19.8	546
350	172	94.1	104	391	17.9		20.1	548
375	-	92.9	103	389	18.0		20.5	551
400	169	91.6	101	386	18.1		20.8	552
425	-	89.7	100	382	18.2		21.2	557
450	165	88.4	98.9	377	18.3		21.5	558
475	-	-	97.1	372	18.4		21.9	562
500	160	-	95.2	364	18.4		22.2	563
ASME	Table TM-1 Group G p. 835	Table 2A p. 324 Line 6	Table Y-1 p. 686-687 Line 39	Table U p. 551 Line 18	Table TE-1 p. 806 Group 3	Table PRD p. 841	Calculated based on Table TCD p. 822, Group J	

(1) Rupture Elongation: ≥ 40% @ 20 °C
(2) Poisson's Ratio: 0.31 from Table PRD p. 841

Notes:
(a) Linear interpolation at intermediate temperatures is possible in safety studies
(b) The specific heat C_p is obtained using thermal diffusivity α and conductivity λ tabulated in ASME II-D, density ρ and equation:

$$\alpha = \frac{\lambda}{\rho \cdot C_p} \Rightarrow C_p = \frac{\lambda}{\rho \cdot \alpha}$$

(3) Impact Limiter outer surface (painting):
- Emissivity: ≥ 0.86 [According to NTE 20-031053-000 Revision 1]
- Absorptivity: ≤ 0.613

Table 7-6A
ASME SA-350/SA-350M LF2 Class 1
Nominal Composition: Carbon Steel

[ ]

Temp (°C)	$E^{(a)}$ (10^3 MPa)	$S_m^{(a)}$ (MPa)	$S_y^{(a)}$ (MPa)	$S_u^{(a)}$ (MPa)	$\alpha_{AVG}^{(a)}$ (10^{-6} °C^{-1})	ρ (kg/m³)	$K^{(a)}$ (W/m·°C)	$C_p^{(a)(b)}$ (J/kg·°C)
20	-	-	≥ 250	≥ 485	11.5		60.4	431
25	202	-	-	-	-		-	-
40	-	161	248	483	-		-	-
50	-	-	-	-	11.8		59.8	453
65	-	156	233	-	-		-	-
75	-	-	-	-	11.9		58.9	467
100	198	151	227	483	12.1		58.0	480
125	-	148	223	-	12.3		57.0	490
150	195	146	219	483	12.4		55.9	500
175	-	-	216	-	12.6		54.7	508
200	192	142	213	483	12.7		53.6	516
225	-	-	209	-	12.9	7750	52.5	525
250	189	136	204	483	13.0		51.4	534
275	-	-	199	-	13.2		50.3	543
300	185	129	194	483	13.3		49.2	553
325	-	125	188	483	13.4		48.1	564
350	179	122	183	483	13.6		47.0	575
375	-	118	177	483	13.7		45.9	585
400	171	-	171	476	13.8		44.9	600
425	-	-	166	446	14.0		43.8	614
450	162	-	162	411	14.1		42.7	628
475	-	-	158	372	14.2		41.6	644
500	151	-	154	332	14.4		40.5	660
ASME	Table TM-1 Carbon Steel with C ≤ 0.3% p.835	Table 2A p. 280 Line 30	Table Y-1 p. 668-669 Line 16	Table U p. 620 Line 10	Table TE-1 p. 803 Group 1	Table PRD p. 841	Calculated based on Table TCD p. 821, Group A	

(1) Rupture Elongation: ≥ 22% @ 20 °C
(2) Poisson's Ratio: 0.30 from Table PRD p. 841
(3) Impact test according to Table NF-2331 (a)-1 of [5]
(4) Outer shell surface (painting):

- Emissivity: ≥ 0.86 [According to NTE-20-031053-000 Rev.1]
- Absorptivity: ≤ 0.613

Notes:
(a) Linear interpolation at intermediate temperatures is possible in safety studies
(b) The specific heat C_p is obtained using thermal diffusivity α and conductivity λ tabulated in ASME II-D, density ρ and equation:

$$\alpha = \frac{\lambda}{\rho \cdot C_p} \Rightarrow C_p = \frac{\lambda}{\rho \cdot \alpha}$$

Table 7-6B
ASME SA-516 gr. 70
Nominal Composition: Carbon Steel

[ ]

Temp (°C)	$E^{(a)}$ (10^3 MPa)	$S_m^{(a)}$ (MPa)	$S_y^{(a)}$ (MPa)	$S_u^{(a)}$ (MPa)	$\alpha_{AVG}^{(a)}$ (10^{-6} °C^{-1})	ρ (kg/m^3)	$K^{(a)}$ (W/m·°C)	$C_p^{(a)(b)}$ (J/kg·°C)
20	-	-	≥ 260	≥ 485	11.5		60.4	425
25	202	-	-	-	-		-	-
40	-	161	262	483	-		-	-
50	-	-	-	-	11.8		59.8	453
65		161	246	-	-		-	-
75	-	-	-	-	11.9		58.9	467
100	198	160	239	483	12.1		58.0	480
125	-	157	235	-	12.3		57.0	490
150	195	154	232	483	12.4		55.9	500
175	-	-	228	-	12.6		54.7	508
200	192	149	225	483	12.7		53.6	516
225	-	-	221	-	12.9	7750	52.5	525
250	189	143	216	483	13.0		51.4	534
275	-	-	210	-	13.2		50.3	543
300	185	136	204	483	13.3		49.2	553
325	-	132	199	483	13.4		48.1	564
350	179	129	193	483	13.6		47.0	575
375	-	124	187	483	13.7		45.9	585
400	171	-	181	476	13.8		44.9	600
425	-	-	176	446	14.0		43.8	614
450	162	-	171	411	14.1		42.7	628
475	-	-	167	372	14.2		41.6	644
500	151	-	162	332	14.4		40.5	660
ASME	Table TM-1 Carbon Steel with C ≤ 0.3% p.835	Table 2A p. 280 Line 38	Table Y-1 p. 622-623 Line 18	Table U p. 519 Line 2	Table TE-1 p. 803 Group 1	Table PRD p. 841	Calculated based on Table TCD p. 821, Group A	

(1) Rupture Elongation: ≥ 22% @ 20 °C
(2) Poisson's Ratio: 0.30 from Table PRD p. 841
(3) Impact test according to Table NF-2331 (a)-1 of [5]
(4) Outer shell surface (painting):

- Emissivity: ≥ 0.86 [According to NTE-20-031053-000 Rev.1]
- Absorptivity: ≤ 0.613

Notes:
(a) Linear interpolation at intermediate temperatures is possible in safety studies
(b) The specific heat C_p is obtained using thermal diffusivity α and conductivity λ tabulated in ASME II-D, density ρ and equation:

$$\alpha = \frac{\lambda}{\rho \cdot C_p} \Rightarrow C_p = \frac{\lambda}{\rho \cdot \alpha}$$

Table 7-6C
Cast iron EN-GJS 400-18 LT
Nominal Composition: Ductile Cast Iron
[ ]

Temp (°C)	$E^{(a)}$ (10^3 MPa)	$S_m^{(a)}$ (MPa)	$S_y^{(a)}$ (MPa)	$S_u^{(a)}$ (MPa)	$\alpha_{AVG}^{(a)}$ (10^{-6} °C^{-1})	ρ (kg/m^3)	$K^{(a)}$ (W/m·°C)	$C_p^{(a)(b)}$ (J/kg·°C)
20	161	-	≥ 220	≥ 360	10.3		37.5	455
25	161	-	-	-	-		-	-
40	-	-	200	300	-		-	-
50	-	-	-	-	10.5		38.5	-
65	-	-	182	-	-		-	-
75	-	-	-	-	10.7		39.18	-
100	155	-	174	297	10.9		39.73	479
125	-	-	-	-	11.1		40.15	-
150	151	-	166	285	11.3		40.45	495
175	-	-	-	-	11.6		40.64	-
200	147	-	162	276	11.8		40.73	508
225	-	-	-	-	12.0	7200	40.73	-
250	142	-	160	270	12.2		40.64	521
275	-	-	-	-	12.4		40.47	-
300	138	-	157	267	12.5		40.23	-
325	-	-	154	263	12.6		39.93	-
350	134	-	151	257	12.8		-	-
375	-	-	-	-	12.9		-	-
400	-	-	-	-	13.0		-	-
425	-	-	-	-	13.1		-	-
450	-	-	-	-	13.2		-	-
475	-	-	-	-	13.2		-	-
500	-	-	-	-	13.3		-	-
ASME	Table TM-1 Ductile Cast Iron p.835	-	Table Y-1 p. 630-631 Line 16	Table U p. 523 Line 34	Table TE-1 p. 806 Ductile Cast Iron	Table PRD p. 841	Calculated from Table TCD p. 822, Ductile Cast Iron	

(1) Rupture Elongation: ≥ 12% @ 20 °C
(2) Poisson's Ratio: 0.29 from Table PRD p. 841
(3) Minimum impact test value ≥ 10J @ -40 °C
(4) Outer shell surface (painting):

- Emissivity: ≥ 0.86 [According to NTE-20-031053-000 Rev.1]
- Absorptivity: ≤ 0.613

Notes:
(a) Linear interpolation at intermediate temperatures is possible in safety studies
(b) The specific heat C_p is obtained using thermal diffusivity α and conductivity λ tabulated in ASME II-D, density ρ and equation:

$$\alpha = \frac{\lambda}{\rho \cdot C_p} \Rightarrow C_p = \frac{\lambda}{\rho \cdot \alpha}$$

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Table 7-8
ASME SA-540/540M B24/B23 Class 2
Nominal Composition: 2Ni – ¾ Cr – 1/3Mo

[

]

Temp (°C)	$E^{(a)}$ (10^3 MPa)	S_m[(a)] (MPa)	S_y[(a)] (MPa)	S_u[(a)] (MPa)	α_{AVG}[(a)] (10^{-6} °C^{-1})	ρ (kg/m^3)	K[(a)] (W/m·°C)	C_p[(a)(b)] (J/kg·°C)
20	-	-	≥ 965	≥ 1070	11.5		36.3	445
25	191	-	-	-	-		-	-
40	-	322	-	-	-		-	-
50	-	-	-	-	11.8		36.5	460
75	-	-	-	-	11.9	7750	36.7	472
100	187	306	-	-	12.1		36.9	483
125	-	-	-	-	12.3		37.0	492
150	184	297	830[(c)]	940[(c)]	12.4		37.1	501
200	181	-	790[(c)]	890[(c)]	-		-	-
ASME	Table TM-1 Group B p.835	Table 4 p. 418 Lines 3 & 10	Table Y-1 p. 668 Lines 5 & 11	Table U p. 540 Lines 34 & 40	Table TE-1 p. 803 Group 1	Table PRD p. 841	Calculated from Table TCD p. 821, Group D	

(1) Rupture Elongation: ≥ 11% @ 20 °C
(2) Poisson's Ratio: 0.30 from Table PRD p. 841
(3) Acceptance criteria is that the material exhibit at least 0.64 mm (25 mils) lateral expansion (Table NB-2333-1)

Notes:

(a) Linear interpolation at intermediate temperatures is possible in safety studies
(b) The specific heat C_p is obtained using thermal diffusivity α and conductivity λ tabulated in ASME II-D, density ρ and equation:

$$\alpha = \frac{\lambda}{\rho \cdot C_p} \Rightarrow C_p = \frac{\lambda}{\rho \cdot \alpha}$$

(c) Values chosen below ASME minimum for conservative inspection purposes

Table 7-8A
Grade 1.6580 according to EN10269 (Alloy steel EN 10269 30CrNIMo8)
[

]

Temp (°C)	$E^{(a)}$ (10^3 MPa)	S_y (a) (MPa)	S_u (a) (MPa)	α_{AVG} (a) (10^{-6} °C^{-1})	ρ (kg/m^3)	K (a) (W/m·°C)	C_p (a)(b) (J/kg·°C)
20	191-	≥ 940	≥ 1040	11.5	7750	36.3	445
25	-	-	-	-		-	-
40	-	-	-	-		-	-
50	-	-	-	-		-	-
75	-	-	-	-		-	-
100	187	-	-	12.1		36.9	484
125	-	-	-	-		-	-
150	184	850	941	12.4		37.1	503
200	181	815	902	-		-	-
Per reference from Note (b) for all properties							

(1) Rupture Elongation: ≥ 9% @ 20 °C
(2) Poisson's Ratio: 0.30 from DI-RI-A-1-05 Revision 0
(3) Acceptance criteria is that the material exhibit at least 0.64 mm (25 mils) lateral expansion (Table NB-2333-1)

Notes:
(a) Linear interpolation at intermediate temperatures is possible in safety studies
(b) Properties as per DI-RI-A-1-05 Revision 0

Table 7-9
Not Used

Table 7-10
ASME SA-320 L43
Nominal Composition: 1 ¾ Ni– ¾ Cr– ¼ Mo
[ ]

Temp (°C)	$E^{(a)}$ (10^3 MPa)	$S_m^{(a)}$ (MPa)	$S_y^{(a)}$ (MPa)	$S_u^{(a)}$ (MPa)	$\alpha_{AVG}^{(a)}$ (10^{-6} °C^{-1})	ρ (kg/m^3)	$K^{(a)}$ (W/m·°C)	$C_p^{(a)(b)}$ (J/kg·°C)
20	-	-	≥ 725	≥ 860	11.5		36.3	445
25	191	-	-	-	-		-	-
40	-	241	724	-	-		-	-
50	-	-	-	-	11.8		36.5	460
65	-	-	702	-	-		-	-
75	-	-	-	-	11.9	7750	36.7	472
100	187	226	679	-	12.1		36.9	483
125	-	-	669	-	12.3		37.0	492
150	184	220	659	≥ 783	12.4		37.1	501
175	-	-	647	-	12.6		37.2	510
200	181	212	635	-	12.7		37.2	519
ASME	Table TM-1 Group B p.835	Table 4 p. 416 Line 28	Table Y-1 p. 666-667 Line 43	(1)	Table TE-1 Group 1 p.803	Table PRD p. 841	Calculated from Table TCD, Group D p.821	

(1) Values chosen below ASME minimum for conservative inspection purposes
(2) Rupture Elongation: ≥ 16% @ 20 °C
(3) Poisson's Ratio: 0.30 from Table PRD p. 841
(4) Acceptance criteria is that the material exhibit at least 0.64 mm (25 mils) lateral expansion (Table NB-2333-1)

Notes:
(a) Linear interpolation at intermediate temperatures is possible in safety studies
(b) The specific heat C_p is obtained using thermal diffusivity α and conductivity λ tabulated in ASME II-D, density ρ and equation:

$$\alpha = \frac{\lambda}{\rho \cdot C_p} \Rightarrow C_p = \frac{\lambda}{\rho \cdot \alpha}$$

Table 7-11
ASME SA-540/540M B24/B23 Class 2
Nominal Composition: 2Ni – ¾ Cr – 1/3Mo
[ ]

Temp (°C)	**$E^{(a)}$ (10^3 MPa)**	**$S_m^{(a)}$ (MPa)**	**$S_y^{(a)}$ (MPa)**	**$S_u^{(a)}$ (MPa)**	**$\alpha_{AVG}^{(a)}$ (10^{-6} °C^{-1})**	**ρ (kg/m³)**	**$K^{(a)}$ (W/m·°C)**	**$C_p^{(a)(b)}$ (J/kg·°C)**
20	-	-	≥ 965	≥ 1070	11.5		36.3	445
25	191	-	-	-	-		-	-
40	-	322	-	-	-		-	-
50	-	-	-	-	11.8		36.5	460
75	-	-	-	-	11.9	7750	36.7	472
100	187	306	-	-	12.1		36.9	483
125	-	-	-	-	12.3		37.0	492
150	184	297	903	1070	12.4		37.1	501
200	181	-	888	1070	-		-	-
ASME	Table TM-1 Group B p.835	Table 4 p. 418 Lines 3 & 10	Table Y-1 p. 668 Lines 5 & 11	Table U p.540 Lines 34 & 40	Table TE-1 p. 803 Group 1	Table PRD p. 841	Calculated from Table TCD p. 821, Group D	

(1) Rupture Elongation: ≥ 11% @ 20 °C
(2) Poisson's Ratio: 0.30 from Table PRD p. 841

Notes:
(a) Linear interpolation at intermediate temperatures is possible in safety studies
(b) The specific heat C_p is obtained using thermal diffusivity α and conductivity λ tabulated in ASME II-D, density ρ and equation:

$$\alpha = \frac{\lambda}{\rho \cdot C_p} \Rightarrow C_p = \frac{\lambda}{\rho \cdot \alpha}$$

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Table 7-19
ASME SA-240 UNS S31803
Nominal Composition: 22Cr–5Ni–3Mo–N
[ ]

Temp (°C)	$E^{(a)}$ (10^3 MPa)	$S_m^{(a)}$ (MPa)	$S_y^{(a)}$ (MPa)	$S_u^{(a)}$ (MPa)	$\alpha_{AVG}^{(a)}$ (10^{-6} °C^{-1})	ρ (kg/m³)	$K^{(a)}$ (W/m·°C)	$C_p^{(a)(b)}$ (J/kg·°C)
20	-	-	≥ 450	≥ 655	12.6		14.1	506
25	200	-	-	-	-		-	-
40	-	207	448	655	-		-	-
50	-	-	-	-	12.8		14.6	514
65	-	207	418	-	-		-	-
75	-	-	-	-	13.0		15.0	520
100	194	207	395	655	13.1		15.4	526
125	-	204	381	-	13.2		15.7	529
150	190	199	370	631	13.4		16.1	534
175	-	-	361	-	13.5		16.5	539
200	186	193	354	610	13.6		16.8	540
225	-	-	349	-	13.7	7800	17.2	544
250	183	188	344	596	13.8		17.6	549
275	-	-	339	-	13.9		17.9	551
300	180	186	334	588	14.0		18.3	555
325	-	185	328	587	14.1		18.7	559
350	177		322	586	14.2		19.0	562
375	-	-	-	-	14.3		19.4	566
400	174	-	-	-	14.4		19.7	568
425	-	-	-	-	14.5		20.1	572
450	172	-	-	-	14.6		20.5	577
475	-	-	-	-	14.6		20.8	578
500	-	-	-	-	14.7		21.2	583
ASME	Table TM-1 for group H p.835	Table 2A p. 348 Line 8	Table Y-1 p. 714-715 Line 34	Table U p. 562 Line 31	Table TE-1 for p. 803 group 2	Table PRD p. 841	Table TCD for group K p.823	

(1) Rupture Elongation: ≥ 25% @ 20 °C
(2) Poisson's Ratio: 0.31 from Table PRD p. 841
(3) Dynamic toughness

Notes:
(a) Linear interpolation at intermediate temperatures is possible in safety studies
(b) The specific heat C_p is obtained using thermal diffusivity α and conductivity λ tabulated in ASME II-D, density ρ and equation:

$$\alpha = \frac{\lambda}{\rho \cdot C_p} \Rightarrow C_p = \frac{\lambda}{\rho \cdot \alpha}$$

(3) Impact Limiter outer surface (painting):
- Emissivity: ≥ 0.86 [According to NTE 20-031053-000 Revision 1]
- Absorptivity: ≤ 0.613

Table 7-20
ASTM A240 UNS S21800
Nominal Composition: 18Cr – 8Ni – 4Si - N
[ ]

Temp (°C)	$E^{(a)(b)}$ (10^3 MPa)	$S_m^{(a)}$ (MPa)	$S_y^{(a)(b)}$ (MPa)	$S_u^{(a)(b)}$ (MPa)	$\alpha_{AVG}^{(a)}$ (10^{-6} °C^{-1})	ρ (kg/m³)	$K^{(a)(b)}$ (W/m·°C)	$C_p^{(a)(b)(c)}$ (J/kg·°C)
20	-	-	≥345	≥655	15.3	7600	14.8	473
25	178	-	-	-	-		-	-
40	-	219	345	655	-		-	-
50	-	-	-	-	15.6		15.3	484
75	-	-	-	-	15.9		15.8	493
100	173	175	262	644	16.2		16.2	499
125	-	162	243	-	16.4		16.6	507
150	170	152	228	599	16.6		17.0	511
175	-	-	216	-	16.8		17.5	520
200	167	138	206	568	17.0		17.9	526
225	-	-	198	-	17.2		18.3	530
250	163	128	192	550	17.4		18.6	532
275	-	-	188	-	17.5		19.0	537
300	160	123	184	539	17.7		19.4	542
325	-	121	181	536	17.8		19.8	546
350	157	119	178	534	17.9		20.1	548
375	-	118	176	531	18.0		20.5	551
400	154	116	175	529	18.1		20.8	552
425	-	116	174	526	18.2		21.2	557
450	151	115	173	521	18.3		21.5	558
475	-	-	172	517	18.4		21.9	562
500	148	-	172	510	18.4		22.2	563
ASME	Table TM-1 Group I p.835	Table 2A p. 332 Line 29	Table Y-1 p. 698-699 Line 15	Table U p. 554 Line 36	Table TE-1 p. 806 Group 3	Table PRD p. 841	Calculated based on Table TCD p. 822, Group J	

(1) Poisson's Ratio: 0.31 from Table PRD p. 841

Notes:
(a) Thermal values of gr. 304L
(b) Linear interpolation at intermediate temperatures is possible in safety studies
(c) The specific heat C_p is obtained using thermal diffusivity α and conductivity λ tabulated in ASME II-D, density ρ and equation:

$$\alpha = \frac{\lambda}{\rho \cdot C_p} \Rightarrow C_p = \frac{\lambda}{\rho \cdot \alpha}$$

Chapter 8
Operating Procedures

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LIST OF FIGURES

Chapter 8
Operating Procedures

NOTE: References in this chapter are shown as [1], [2], etc., and refer to the reference list in Section 8.6. A glossary of terms used in this chapter is provided in Section 8.5.

This chapter contains cask loading and unloading procedures that are intended to show the general approach to cask operational activities, which are limited to the horizontal dry loading and unloading of content from the cask. The content is limited to the dry shielded canisters (DSCs) listed in Chapter 1 that were previously loaded in accordance with 10 CFR Part 72. Unless noted otherwise, the procedures in this chapter pertain to all cask models listed in Chapter 1. The procedures for loading and unloading of contents from the DSC are controlled by the licensed users of the DSCs.

Cask operational activities are to be performed at 10 CFR Part 50 or 10 CFR Part 72 licensed facilities, as applicable. As such, specific procedures for these activities are bound by the requirements of their applicable license and are not considered part of the scope for this 10 CFR Part 71 application.

The procedures in this chapter are intended to show the types of operations that will be performed and are not intended to be limiting. Site specific conditions and requirements may require the use of different equipment and ordering of steps to accomplish the same objectives or acceptance criteria which must be met to ensure the integrity of the package. Deviations to the provided procedures are acceptable if justified by the applicable Licensee or Certificate Holder in their QA program to maintain equal or better package effectiveness and continued compliance with the applicable 10 CFR 71 requirements.

8.1 Package Loading

8.1.1 Preparation for Loading

Procedures provided in this section are for preparing the empty cask for use after receipt at the loading site and verification that the DSC and previously loaded content is acceptable for shipment. These steps are written assuming the empty cask recently arrived on site and is in its transportation configuration.

1. Prior to arrival on site, if necessary, the appropriate internal sleeve will be installed in the cask and secured in place.
2. Inspect the cask, transport frame, and conveyance for any evidence of damage sustained during the shipment that may reduce the effectiveness of the cask.
3. Remove the transport frame personnel barrier.
4. Remove the impact limiters from the cask.
5. Remove the transport frame tie-down straps.
6. Using an appropriately sized lift beam and rigging, engage the outer ends of the cask body with slings in a basket configuration.

7. Lift the cask out of the transport frame and place it in the transfer skid on the transfer trailer.
8. Remove the test port plugs from the primary lid and ram access cover plate.
9. Remove the lid port cover plate.
10. Remove the lid port plug tightening nut and the lid port plug.
11. As required by the site program, sample the cask cavity atmosphere through the lid port.
12. Remove the primary lid from the cask.
13. Remove the ram access cover plate from the cask.
14. Inspect the cask cavity for foreign material and remove as necessary.
15. Inspect the accessible surfaces of the cask and related components, including the impact limiters, for any evidence of damage that may reduce the effectiveness of the cask. If necessary, inspect the internal sleeve to ensure that there is no damage and that it remains secured in place.
16. Inspect the lid bolts, ram access cover plate bolts, impact limiter bolts, lid orifice cover plate bolts, as well as all mating threaded holes, for any damage or degradation. Components shall be reworked or replaced if they show signs of bending, cracking, thread deformation, or corrosion.
17. Inspect the inner elastomer O-rings, located in the primary lid and ram access cover plate, and associated sealing surfaces for any damage or degradation. O-rings shall be replaced if they have been installed for more than 12 months or show signs of damage such as cuts, cracking, or hard areas.
18. Verify the bottom closure plate bolts are torqued as specified in the applicable drawings for package approval. If necessary, re-torque following the torque pattern shown in Figure 8-1.
19. Inspect the neutron shielding ring pressure relief valves for any damage or evidence of reduced performance.
20. Remove and discard the lid port plug and lid orifice cover plate metal seals.
21. Install a new lid port plug and lid orifice cover plate metal seals after inspecting the associated sealing surfaces for any damage or degradation.
22. As necessary, install appropriate axial spacers in the cask cavity to ensure the nominal axial gap between the cask and the DSC will be between 0.25″ and 0.75″ for EOS canisters for normal conditions of transport at room temperature. The spacers may be either above or below the DSC.
23. Verify that the cask maintenance activities required in Section 9.2 have been performed and are up to date. If maintenance expires during transport, then cask maintenance must be performed before subsequent cask loading operations.
24. Verify that the DSC to be transported was evaluated in accordance with Section 8.4.1.

8.1.2 Loading of Contents

Procedures provided in this section are for transferring the DSC from a horizontal storage module (HSM) to the cask, closure of the cask, and performing the required leak testing of the cask containment boundary. These steps are written assuming the procedures in Section 8.1.1 have recently been completed.

1. Move the transfer trailer and the cask to the HSM containing the DSC to be transported.
2. Remove the HSM door and the DSC seismic restraint assembly, if installed, from the HSM.
3. Align and dock the cask with the HSM.
4. Install the cask/HSM restraints.
5. Install and align the hydraulic ram cylinder.
6. Extend the hydraulic ram cylinder and engage the DSC grapple ring.
7. Retract the hydraulic ram cylinder until the DSC is fully retracted into the cask.
8. Disengage the hydraulic ram from the grapple ring and remove from the cask ram access opening.
9. Install the ram access cover plate onto the cask and torque the bolts as specified in the applicable drawings for package approval following the torque pattern shown in Figure 8-1.
10. Remove the cask/HSM restraints.
11. Undock the cask from the HSM.
12. As necessary, install appropriate axial spacers in the cask cavity to ensure the nominal axial gap between the cask and the DSC will be between 0.25″ and 0.75″ for EOS canisters for normal conditions of transport at room temperature. The spacers may be either above or below the DSC.
13. Install the primary lid and torque the bolts as specified in the applicable drawings for package approval following the torque pattern shown in Figure 8-1.
14. Evacuate the cask cavity and backfill with helium to a pressure of 2.5±1 psig.
15. Install the lid port plug and the lid port plug tightening nut, torqueing the nut as specified in the applicable drawings for package approval.
16. Install lid orifice cover plate and torque bolts as specified in the applicable drawings for package approval following the torque pattern shown in Figure 8-1.
17. Perform the pre-shipment leakage tests of the cask containment boundary following the procedure given in Section 8.4.3. These tests must be performed within 12 months prior to releasing the loaded cask for shipment.

8.1.3 Preparation for Transport

Procedures provided in this section are for transfer and securement of the loaded cask onto the transportation vehicle, installation of the impact limiters, performance of requirement radiation, contamination, and thermal surveys, preparation of the shipment paperwork, and release of the loaded cask for shipment. Note that, based on the shielding system design, the loaded cask shall be transported in accordance with Exclusive Use regulations. These steps are written assuming the procedures in Sections 8.1.1 and 8.1.2 have recently been completed.

1. Verify that the cask surface removable contamination levels meet the requirements of 49 CFR 173.443 [2]. If measured contamination levels exceed expected values, decontaminate the surface.
2. If the packaging contains high burnup fuel assemblies, perform a radiation survey (both neutron and gamma) of the cask loaded with the contents to evaluate the axial radiation distributions prior to transportation.
   a) These surveys shall be performed using the same quality assurance requirements to comply with 10 CFR 71.43 [3] and 10 CFR 71.47 [3] in accordance with Regulatory Guide 1.21 [5].
   b) A record of the survey results showing the location of the survey points, type and model of the instruments shall be prepared for delivery to the packaging recipient.
   c) The location of the survey points should be labeled legibly on the cask outer surface for recipient use. An example showing survey points on a Type B cask for transportation of non-fuel bearing solid material is provided in Figure 8-2.

CAUTION

Cask lifts without impact limiters installed shall only be performed in compliance with requirements for movement of heavy loads at an NRC licensed nuclear facility.

3. Using an appropriately sized lift beam and rigging, engage the outer ends of the cask body with slings in a basket configuration.
4. Lift the cask out of the transfer skid and place it in the transport frame on the conveyance.
5. Install the transport frame tie-down straps.
6. Install the impact limiters on the cask and torque the bolts as specified in the applicable drawings for package approval following the torque pattern shown in Figure 8-1.
7. Render the impact limiter lifting points inoperable.
8. Install tamperproof seals at each end of the cask.
9. Install the transport frame personnel barrier.

10. Perform a final radiation survey to verify compliance with 49 CFR 173.441 [2] and 10 CFR 71.47 [3]. If measured radiation levels exceed expected values, ensure that the package is properly loaded and investigate other possible sources of the discrepancy.
11. If the measured dose rate in the normally occupied spaces exceeds 2 mr/hr, the location of the package shall be changed or supplementary shielding added as necessary to reduce the dose to an acceptable level. Supplementary shielding may be added to the conveyance (e.g., attached to the sides of the trailer or truck cab) to reduce the external radiation levels, but shall not be attached to the package without prior NRC approval. Alternatively, the carrier may implement the radiation dosimetry requirements of 49 CFR 173.441(b)(4) [2] and 10 CFR 71.47(b)(4) [3].
12. Perform a temperature survey to verify compliance with 10 CFR 71.43(g) [3].
13. Verify the carrier has been provided with written instructions and a list of contacts for notification in case of accident or delays.
14. Verify the carrier has been provided with written instructions for maintenance of the Exclusive Use shipment controls in accordance with 10 CFR 71.47 [3].
15. In accordance with 49 CFR 173 [2], prepare the final shipping documentation, ensure the package is properly marked and labeled, and release the loaded cask for shipment.

8.2 Package Unloading

8.2.1 Receipt of Package from Carrier

Procedures provided in this section are for receiving the loaded cask, removing the impact limiters, and transferring the cask from the transportation vehicle. These steps are written assuming the loaded cask recently arrived on site and is in its transportation configuration.

1. Inspect the cask, transport frame, and conveyance for any evidence of damage sustained during the shipment that may reduce the effectiveness of the cask.
2. Verify that the tamperproof seals are intact, and then remove the seals.
3. Remove the transport frame personnel barrier.
4. Remove the impact limiters from the cask.
5. Remove the transport frame tie-down straps.

CAUTION

Contamination levels higher than those measure during preparation for transport may indicate that the package is leaking or may have leaked during shipment. ALARA and good radiation safety practices should be used at all times.

6. Verify that the cask surface removable contamination levels meet the requirements of 49 CFR 173.443 [2]. If measured containment levels exceed expected values, assess the extent of contamination, determine the cause for the increase contamination, and decontaminate the package external surface.

CAUTION

Radiation levels higher than expected may indicate damage to the package or contents have shifted. ALARA and good radiation safety practices should be used at all times.

7. Perform a radiation survey of the cask to verify compliance with 10 CFR 71.47 [3]. If the survey indicates radiation levels exceeding those allowed for transportation, perform detailed measurements on the surface and 1 meter (3.3 ft) from the surface. Plot radiation levels as isodose curves and record the degree of accuracy of the measurements. Provide results to the shipper and the NRC as soon as available so that dosage calculations can be made.

CAUTION

Cask lifts without impact limiters installed shall only be performed in compliance with requirements for movement of heavy loads at an NRC licensed nuclear facility.

8. Using an appropriately sized lift beam and rigging, engage the outer ends of the cask body with slings in a basket configuration.
9. Lift the cask out of the transport frame and place it in the transfer skid on the transfer trailer.

8.2.2 Preparation for Unloading

Procedures provided in this section are for performing radiation, thermal, and cavity gas surveys. These steps are written assuming the procedures in Section 8.2.1 have recently been completed.

1. If the cask contains high burnup fuel assemblies, perform a radiation survey (both neutron and gamma) of the cask loaded with the contents to evaluate the axial radiation source distributions.
   a) These surveys shall be performed on the survey locations identified in Section 8.1.3 using the same quality assurance requirements. It is recommended to use the same type and model of instruments that were used in the surveys prior to transportation.
   b) Compare the results of the above surveys to the results of the surveys performed prior to transportation required in Section 8.1.3. Shifts of the peak dose rates, particularly the neutron dose rate, toward the cask ends are the criteria to indicate that potentially a fuel reconfiguration occurred during transport.
   c) The information obtained from these inspections can be employed as indicators to determine the ALARA requirements of the unloading operations.
2. If the cask contains high burnup fuel assemblies, perform the operations contained in Section 8.4.2.
3. As required by the site program, sample the cask cavity atmosphere through the lid port.

8.2.3 Removal of Contents

Procedures provided in this section are for transferring the DSC from the cask to an HSM. These steps are written assuming the procedures in Section 8.2.1 and Section 8.2.2 have recently been completed.

1. Remove the HSM door and the DSC seismic restraint assembly, if installed, from the HSM.
2. Inspect the HSM cavity for foreign material and remove as necessary.
3. Align the cask with the HSM.
4. Remove the primary lid.
5. As necessary, remove the top axial spacer, if previously installed.
6. Dock the cask with the HSM.
7. Install the cask/HSM restraints.
8. Remove the cask ram access cover plate.
9. Install and align the hydraulic ram cylinder.
10. Extend the hydraulic ram cylinder and engage the DSC grapple ring.
11. Extend the hydraulic ram cylinder until the DSC is fully inserted into the HSM.
12. Disengage the hydraulic ram from the grapple ring, retract the hydraulic ram cylinder, and remove from the cask ram access opening.
13. Remove the cask/HSM restraints.
14. Undock the cask from the HSM.
15. Install the HSM door and seismic restraint, as applicable.
16. Install the primary lid.
17. Install the ram access cover plate.

8.3 Preparation of Empty Package for Transport

Procedures provided in this section are for preparing the empty cask for shipment. These steps are written assuming the cask has been emptied of its radioactive contents in accordance with the steps in Section 8.2.

1. Verify that the cask is empty to the extent practical.
2. Determine the amount and form of residual internal activity within the interior of the empty cask.
3. Inspect and securely close the empty cask.
   a) All seals may be reused if they are inspected and found to be free of damage.
   b) Install the primary lid and torque the bolts to between 20% and 50% of the maximum value specified in the applicable drawings for package approval following the torque pattern shown in Figure 8-1.

c) Install the ram access cover plate and torque the bolts to at least 20% of the maximum value specified in the applicable drawings for package approval following the torque pattern shown in Figure 8-1.

d) Install the lid port plug and the lid port plug tightening nut, torqueing the nut to at least 20% of the value specified in the applicable drawings for package approval.

e) Install the lid orifice cover plate and torque the bolts to at least 20% of the value specified in the applicable drawings for package approval following the torque pattern shown in Figure 8-1.

f) If the impact limiters are re-installed, torque the bolts to at least 20% of the maximum value specified in the applicable drawings for package approval following the torque pattern shown in Figure 8-1.

g) Install the lid port cover plate.

h) Install the test port plugs into the primary lid and ram access cover plate.

4. Prepare the empty cask for shipment using the package requirements specified in the Hazardous Material Regulations [2] which are appropriate for the amount and form of the residual activity and contamination.

8.4 Other Procedures

8.4.1 DSC Evaluation for Transport

To ensure the DSCs, previously loaded under a 10 CFR 72 program, are acceptable for transportation, the following verifications need to be performed prior to shipment. These verifications shall be performed in accordance with written procedures with the results being documented and retained.

1. The DSCs were fabricated and maintained in compliance with the applicable drawings for package approval. Verify there is no evidence that degradation of DSC components, including but not limited to the neutron absorbers and basket materials, has occurred to the extent they would no longer comply with the applicable materials and dimensions, as specified on the applicable drawings for package approval.
2. The DSCs were loaded with contents in accordance with the applicable fuel specification requirements in Appendix 1.6 and the applicable fuel qualification tables in Appendix 8.7, including type, form, quantity, burnup, enrichment, decay heat, cooling time, and loading location of the contents. An independent check of this verification is also required. This shall include a review of the original loading plan and confirmation that the loading plan was independently verified to match the as-loaded condition of the DSC.
3. For 32PT (except when loaded with CE 14x14 fuel) and 32PTH1 DSCs, the content evaluation shall also include a comparison of the irradiation parameters of the loaded contents against the following to ensure compliance with the isotopic depletion analysis.

   Fuel Temperature = 1,010 K

   Clad Temperature = 640 K

   Reactor Operating Pressure = 158 Kg/cm2

   Specific Power = 37.5 MW/MTU

   Number of Irradiation Cycles = 1

   Moderator Temperature = 615 K

   Soluble Boron Concentration = 1,000 ppm.
4. For 32PT (except when loaded with CE 14x14 fuel) and 32PTH1 DSCs, the content evaluation shall also include a comparison of the irradiation parameters of the loaded contents against the following to ensure compliance with the isotopic depletion analysis.

   Average Fuel Temperature = 1,100 K

   Average Moderator Density = 0.63 g/cc

   Average Moderator Temperature = 610 K

   Average Clad Temperature = 640 K

   Soluble Boron Concentration = 1,000 ppm

   Specific Power = 40 MW/MTU

   Down Time = 0 days.

5. The DSCs were loaded, closed, handled, stored, and maintained in accordance with the applicable 10 CFR 72 requirements:
   a) FO, FC, FF DSCs in accordance with Part 72 license SNM-2510
   b) 24PT1 and 24PT4 DSCs in accordance with Part 72 CoC 1029
   c) 32PT and 32PTH1 DSCs in accordance with Part 72 CoC 1004
   d) EOS 37PTH and EOS 89BTH DSCs in accordance with Part 72 CoC 1042.
6. For DSCs being stored under the initial 10 CFR 72 licensed period, the loading reports were reviewed to ensure the DSC was not damaged during the insertion or extraction process and that, if necessary, appropriate evaluations were performed to verify the performance of the DSC shell to the original design requirements for safety functions.
7. For DSCs being stored under a renewed 10 CFR 72 licensed period, the requirements of any Aging Management Program associated with the applicable 10 CFR 72 CoC, and previously submitted to the NRC, have been satisfied throughout the storage period.
8. For 32PT, 32PTH1, and EOS 37PTH DSCs, the fuel loading plans included the following requirements (required since burnup credit is employed for demonstration of criticality safety):
   a) A requirement for no fresh fuel in pool at time of loading, or verification that fuel being loaded into the canister is not fresh, either visually or by qualitative measurement.
   b) A full pool audit within one year prior to loading, including visual verification of assembly identification numbers.
   c) Identification of highly underburned and high reactivity fuel assemblies in the pool both prior to and after loading. Alternatively, the licensee can perform a misload evaluation to identify these highly underburned and high reactivity fuel assemblies. This evaluation will be subject to NRC review and approval.
   d) A minimum required soluble boron concentration of 1800 ppm (based on minimum value from the 10 CFR 72 CoC 1004 UFSAR [8]) in the pool for both loading and unloading.
   e) A requirement that assemblies without visible identification number must have a quantitative confirmatory measurement prior to loading.
9. For EOS 37PTH DSCs, the cooling time of the fuel at time of shipment will be at least five years for criticality control.
10. For the 24PT1 DSCs, bottom fuel spacers were placed in each fuel assembly location and top fuel spacers were installed between loading the fuel and installation of the top shield plug. No top fuel spacer is required for failed fuel canisters.
11. For the 24PT4 DSCs with damaged/failed fuel loaded and for 32PT, 32PTH1, and EOS 37PTH DSCs with damaged fuel loaded, a bottom end cap was placed into the associated cell locations prior to loading the fuel and a top end cap was placed over each damaged fuel assembly after loading.

12. For the 24PT4, 32PT, and 32PTH1 DSCs, fuel and basket spacers were installed such that the average gap between a fuel assembly and the DSC is less than 1.5″ and the gap between the basket and the DSC is less than 0.815″, both under normal transport conditions where thermal and irradiation growth of the components is accounted for. The fuel and basket spacers may be combined into one spacer.
13. For 24PT4 DSCs, the failed fuel canisters, required for loading damaged/failed fuel assemblies, if used, had the guide sleeves replaced at the locations specified for the specific configurations of the 24PT4 DSC.
14. The DSC top shield plug was installed into the DSC after loading the fuel assemblies.
15. Water was removed from above the top shield plug.
16. The DSC inner top cover plate was installed and welded.
    a) The welds were performed and inspected in accordance with the applicable drawings for package approval.
17. The DSC cavity was drained of water.
    a) For EOS 37PTH, EOS 89BTH, 24PT4, 32PT, and 32PTH1 DSCs, the cavity was backfilled with 1 psig to 3 psig of helium as any water was being removed.
18. The DSC cavity was vacuum dried.
    a) For the EOS 37PTH, EOS 89BTH, 24PT4, 32PT, and 32PTH1 DSCs, steps were taken, such as a step-wise pressure reduction, to minimize the likelihood of freezing water in the cavity during the drying process.
    b) A vacuum dryness test was satisfactorily performed where a vacuum of 3 torr or less was held for a minimum time of 30 minutes in the DSC cavity.
19. For the 24PT4 DSC, a satisfactory helium leak test was performed on the top shield plug assembly and vent/siphon block. Acceptance criterion for this test is a detected leak rate of ≤ 1E-4 ref-cm^3/sec.
20. The DSC cavity was backfilled with helium to within the following stable pressure range:
    a) 0 psig to 2.5 psig for FO, FC, and FF DSCs
    b) 0 psig to 3 psig for 24PT1 DSCs
    c) 6.0 psig to 7.0 psig for 24PT4 DSCs
    d) 1.5 psig to 3.5 psig for EOS 37PTH, EOS 89BTH, 32PT, and 32PTH1 DSCs.
21. The DSC vent and siphon port cover plates were installed and welded.
    a) For EOS 37PTH, EOS 89BTH, 24PT4, 32PT, and 32PTH1 DSCs, helium was injected under the plates before weld completion.
    b) The welds were performed and inspected in accordance with the applicable drawings for package approval.

22. The DSC outer top cover plate was installed and welded.
    a) The welds were performed and inspected in accordance with the applicable drawings for package approval.
    b) For 24PT1, FO, FC, and FF DSCs, the outer top cover plate weld was satisfactorily inspected by either volumetric or multiplayer penetrant test (PT) examination. If PT was used, at a minimum, it must have included the root, each successive ¼ inch weld thickness, and the final layer. The inspection of the weld must have been performed by qualified personnel and shall have met the acceptance requirements of the 1992 Edition (with 1993 Addenda) ASME B&PVC Section III, NB-5350 [7]. The inspection process, including findings (indications) shall have been made a permanent part of the licensee's records by video, photographic, or other means providing an equivalent retrievable record of weld integrity.
23. For the EOS 37PTH, EOS 89BTH, 32PT, and 32PTH1 DSCs, a helium leak test of the inner top cover plate and vent/siphon port plate welds was performed using the test port in the outer top cover plate. The acceptance criterion was leak-tight and the personnel performing the test were qualified in accordance with SNT-TC-1A [4]. Alternatively, this test could have been performed with a test head before installing the outer top cover plate.
24. For the EOS 37PTH, EOS 89BTH, 24PT1, 32PT, and 32PTH1 DSCs, the outer top cover plate test port plug was installed (when applicable) and welded.
    a) The welds were performed and inspected in accordance with the applicable drawings for package approval.
    b) For the EOS 37PTH, EOS 89BTH, 32PT, and 32PTH1 DSCs, a dye penetrant weld examination was performed on the competed welds.

8.4.2 Cask Cavity Gas Sampling

The following procedure shall be implemented during unloading of a DSC from a cask that was loaded with high burnup fuel assemblies. In the event that a breach and/or reconfiguration of fuel are confirmed during unloading of high burnup fuel assemblies, a written report should be generated in accordance with 10 CFR 71.95. The report shall include the required corrective action(s). The corrective action(s) shall be implemented prior to resumption of transports.

1. Prior to opening the cask lid, sample the cask/DSC annulus gas for presence of airborne radioactive particles.
    a) If airborne radioactive particles are found in the cask/DSC annulus gas sample, assume that the DSC is breached, leave the DSC in the cask and institute special procedures to recover the DSC from the cask.
    b) If no airborne radioactive particles are found in the cask/DSC annulus gas sample then transfer the DSC to an HSM.

8.4.3 Pre-shipment Leakage Testing of the Cask Containment Boundary

The procedure for pre-shipment leakage testing of the cask containment boundary is given in this section. This testing shall be performed in accordance with written procedures and conform to the requirements of ANSI N14.5 [1]. Personnel performing the tests shall be qualified and certified in leakage testing in accordance with SNT-TC-1A [4].

If the seal being tested was not replaced, then the acceptance criterion for pre-shipment leakage rate testing shall be no detected leakage when tested to a sensitivity of at least 1E-3 ref-cm^3/sec. If the seal was replaced, then the maintenance leakage test as described in Section 9.2 shall be performed.

This procedure is written assuming the cask has been prepared, loaded, and closed in accordance with the steps in Sections 8.1.1 and 8.1.2. The following steps present one method of performing the pre-shipment verification leakage testing. If more than one leakage detector is available, then more than one seal may be tested at a time. Alternate methods and order of testing are acceptable as long as the above criteria are satisfied for the cask containment boundary seals.

1. Utilizing the test ports on the primary lid, connect an appropriate leak test system to the cask.
2. Evacuate the volume between the primary lid O-rings and perform the pre-shipment leak test of the inner O-ring. If the inner O-ring was replaced, the maintenance leak test in Section 9.2 shall be performed.
3. After meeting the leak test criteria, disconnect the leak test system and install the test port plugs.
4. Utilizing the test ports on the ram access cover plate, connect an appropriate leak test system to the cask.
5. Evacuate the volume between the ram access cover plate O-rings and perform the pre-shipment leak test of the inner O-ring. If the inner O-ring was replaced, the maintenance leak test in Section 9.2 shall be performed.
6. After meeting the leak test criteria, disconnect the leak test system and install the test port plugs.
7. Utilizing the test port on the lid orifice cover plate, connect an appropriate leak test system to the cover plate.
8. Evacuate the volume outside of the closed lid orifice cover plate seal and perform the pre-shipment leak test. If the lid orifice cover plate seal was replaced, the maintenance leak test in Section 9.2 shall be performed.
9. After meeting the leak test criteria, disconnect the leak test system and install the lid port cover plate test port plug.

8.5 Glossary

bottom closure plate: The outer-most plate on the bottom of the cask that prevents the shielding rings and top handling ring from moving axially along the cask.

cask/HSM restraints: Provides the load path between the cask and HSM during DSC transfer operation.

conveyance: Any suitable conveyance such as a railcar, heavy haul trailer, barge, ship, etc.

horizontal storage module: Concrete shielded structure used for onsite storage of DSCs. HSM references herein refer to all models of HSM (e.g., HSM Model 80, Model 102, Model 152, Model 202, HSM-H, HSM-HS, AHSM, etc.). HSM also includes any other overpack, interim transfer station, or other DSC supporting device that is authorized to accept a DSC via a horizontal transfer.

hydraulic ram cylinder: Hydraulic cylinder with a grapple at one end that is used to insert/withdraw DSCs to/from HSMs.

lid port: A threaded hole in the primary lid that provides access from the exterior of the cask to the interior cask cavity.

lid orifice cover plate: A plate attached to the cask lid that has a double ring metallic seal to provide closure of the lid port plug orifice.

lid port plug: A slip plug that contains a metal seal and that fits into the lid port to provide closure of the port as well as shielding.

lid port plug tightening nut: An externally threaded nut that secures the lid port plug in place.

ram access closure plate: A plate at the bottom of the cask that has elastomer O-ring seals and that fits into the bottom cask opening to provide closure as well as shielding.

skid positioning system: Hydraulically operated alignment system that provides the interface between the transfer trailer and the transfer skid. It is used to align the skid (and cask) with the HSM prior to transfer.

test port: A threaded hole that provides access from the exterior of the cask to the annular space between the concentric O-ring seals found on the primary lid or the ram access cover plate.

test port plug: A threaded plug that contains an elastomer O-ring seal and is used to close the two test ports on the primary lid and the two test ports on the ram access cover plate.

transfer skid: Skid present on the transfer trailer used to support the cask during onsite movements.

transfer trailer: A specialized trailer used for onsite movements of the cask.

transport frame: Skid present on the conveyance used to support the cask during off site transport.

8.6 References

1. ANSI N14.5-2014, “American National Standard for Radioactive Materials – Leakage Tests on Packages for Shipment,” American National Standards Institute, Inc., New York, 2014.

2. Title 49, Code of Federal Regulations, Subtitle B, Chapter 1, Parts 171 through 180.

3. Title 10, Code of Federal Regulations, Part 71 (10 CFR 71), “Packaging and Transportation of Radioactive Material.”

4. SNT-TC-1A, “American Society for Nondestructive Testing, Personnel Qualification and Certification in Nondestructive Testing.”

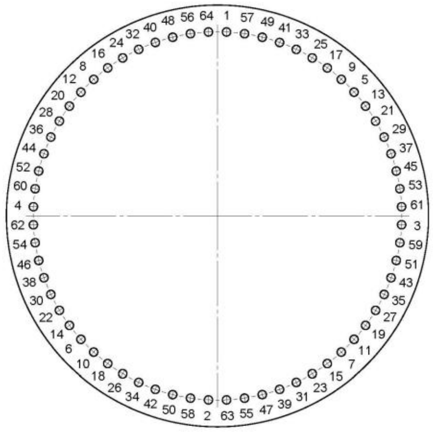
5. Regulatory Guide 1.21, Revision 2, June 2009, “Measuring, Evaluation, and Reporting Radioactive Material in Liquid Gaseous Effluents and Solid Waste,” United States Nuclear Regulatory Commission.

6. NUREG-2216, “Standard Review Plan for Transportation Packages for Spent Fuel and Radioactive Material Final Report,” August 2020.

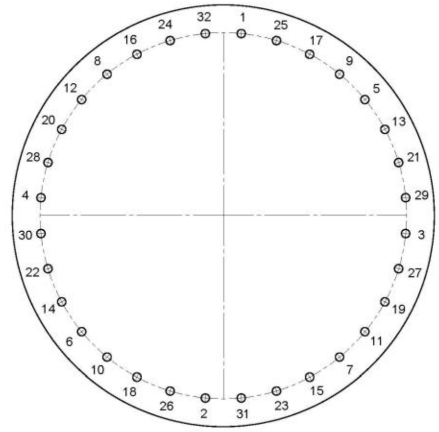
7. ASME Boiler and Pressure Vessel Codes, 1992 Edition with 1993 Addenda.

8. NUH003.0103, “Updated Final Safety Analysis Report for the Standardized NUHOMS Horizontal Modular Storage System for Irradiated Nuclear Fuel,” (for CoC 1004) Revision 12.

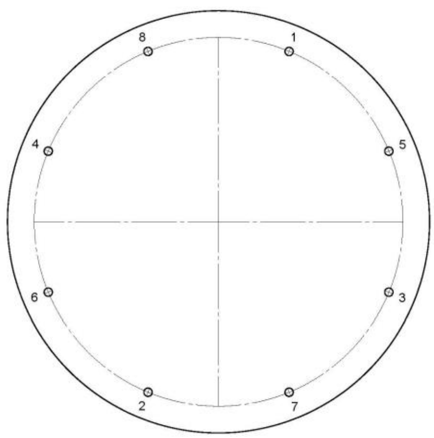
9. ASME PCC-1, “Guidelines for Pressure Boundary Bolted Flange Joint Assembly,” American Society of Mechanical Engineers, New York, 2019.



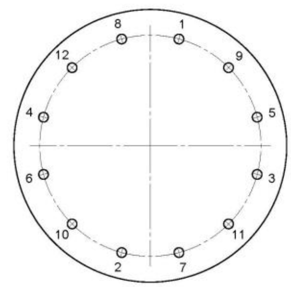
Cask Lid Bolts



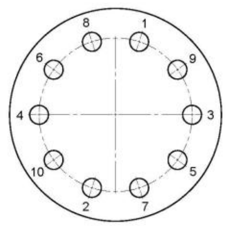
Bottom Cover Plate Bolts



Impact Limiter Bolts



Ram Access Cover Plate Bolts



Lid Orifice Cover Plate Bolts

Bolts shall be installed for each component in the following steps [9]:

1) Install all bolts hand tight.
2) Tighten bolts to 20-30% of final torque value in the pattern shown.
3) Tighten bolts to 50-70% of final torque value in the pattern shown.
4) Tighten bolts to 100% of final torque value in the pattern shown
5) Continue tightening to 100% of final torque value in a circular clockwise pattern until no further bolt movement is observed.

Figure 8-1
Cask Bolt Torque Patterns

Proprietary Information on This Page
Withheld Pursuant to 10 CFR 2.390

8.7 APPENDICES

8.7.1 EOS-37PTH FQTs

8.7.2 EOS-89BTH FQTs

8.7.3 24PT4/32PT/32PTH1/FO-FC-FF/24PT1 FQTs

Appendix 8.7.1
EOS-37PTH FQTs

LIST OF TABLES

8.7.1 EOS-37PTH FQTs

Table 8.7.1-1
FQTs for EOS-37PTH DSCs inside TN Eagle LC

<table>
<tr><th>DSC</th><th>HLZC #</th><th>Plan #</th><th>FQTs</th></tr>
<tr><td rowspan="4">EOS-37PTH</td><td>1</td><td>1</td><td>For uranium loading up to 492 kgU, refer to Table 8.7.1-2 through Table 8.7.1-4, for standard FQTs (Table 8.7.1-24 through Table 8.7.1-26 for FQT exceptions, and Table 8.7.1-27 through Table 8.7.1-29 for FQT exception-counterparts);
For uranium loading up to 450 kgU, refer to Table 8.7.1-21 through Table 8.7.1-23; and
For uranium loading up to 400 kgU, refer to Table 8.7.1-18 through Table 8.7.1-20</td></tr>
<tr><td>1</td><td>2</td><td>For uranium loading up to 492 kgU, refer to Table 8.7.1-5 through Table 8.7.1-7</td></tr>
<tr><td>2</td><td>1</td><td>For uranium loading up to 492 kgU, refer to Table 8.7.1-8 through Table 8.7.1-13</td></tr>
<tr><td>2</td><td>2</td><td>For uranium loading up to 492 kgU, refer to Table 8.7.1-8, Table 8.7.1-9, and Table 8.7.1-14 through Table 8.7.1-17</td></tr>
</table>

Table 8.7.1-2
Fuel Qualification Table for EOS-37PTH, 492kgU, HLZC1, Plan1, Zone 1
(Minimum required years of cooling time after reactor core discharge)

BU (GWD/MTU)	Fuel Assembly Average Initial U-235 Enrichment (wt.%)																																											
	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5
6	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
7								3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
10								3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
16								3.3	3.3	3.3	3.3	3.3	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
17												3.4	3.4	3.4	3.4	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.1	3.1	3.1	3.1	3.1	3.1	3.1
20												3.8	3.8	3.8	3.8	3.8	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
25												4.6	4.6	4.6	4.5	4.5	4.5	4.5	4.5	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2
28												5.2	5.2	5.1	5.1	5.1	5.1	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.6
30												5.7	5.7	5.6	5.6	5.5	5.5	5.5	5.4	5.4	5.4	5.3	5.3	5.3	5.3	5.3	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.1	5.1	5.1	5.1	5.1	5.1	5.0	5.0	5.0	5.0
31													5.9	5.8	5.8	5.8	5.7	5.7	5.7	5.7	5.7	5.6	5.6	5.6	5.5	5.5	5.5	5.5	5.4	5.4	5.4	5.4	5.3	5.3	5.3	5.3	5.3	5.3	5.2	5.2	5.2	5.2	5.2	5.2
32														6.1	6.1	6.1	6.0	6.0	5.9	5.9	5.9	5.8	5.8	5.8	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.6	5.6	5.6	5.6	5.6	5.5	5.5	5.5	5.5	5.5	5.4	5.4	5.4
34															6.7	6.6	6.6	6.6	6.5	6.5	6.4	6.4	6.4	6.3	6.3	6.3	6.2	6.2	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.0	6.0	6.0	6.0	6.0	5.9	5.9	5.9	5.9
36																7.4	7.3	7.3	7.2	7.1	7.1	7.0	7.0	7.0	7.0	7.0	6.9	6.8	6.8	6.8	6.7	6.7	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.5	6.5	6.5	6.5	6.4
38																	8.3	8.3	8.1	8.0	7.9	7.9	7.9	7.8	7.7	7.7	7.6	7.6	7.6	7.5	7.5	7.5	7.4	7.4	7.3	7.3	7.3	7.2	7.2	7.2	7.1	7.1	7.1	7.0
39																		8.7	8.6	8.5	8.4	8.3	8.3	8.3	8.3	8.3	8.1	8.0	7.9	7.9	7.9	7.9	7.8	7.8	7.7	7.7	7.6	7.6	7.6	7.6	7.6	7.6	7.5	7.5
40																			9.2	9.1	9.0	8.9	8.9	8.9	8.7	8.7	8.6	8.5	8.4	8.4	8.3	8.3	8.3	8.3	8.3	8.3	8.1	8.0	8.0	8.0	7.9	7.9	7.9	7.9
41																			9.9	9.7	9.7	9.6	9.6	9.6	9.3	9.2	9.2	9.1	9.0	8.9	8.9	8.9	8.9	8.9	8.7	8.7	8.6	8.5	8.5	8.4	8.4	8.4	8.3	8.3
42																				10.5	10.4	10.3	10.2	10.2	10.0	9.9	9.8	9.7	9.7	9.6	9.6	9.6	9.6	9.3	9.2	9.2	9.2	9.1	9.1	9.0	9.0	8.9	8.9	8.9
43																				11.5	11.2	11.0	11.0	10.9	10.9	10.9	10.6	10.5	10.4	10.2	10.2	10.2	10.2	10.2	9.9	9.8	9.8	9.7	9.7	9.7	9.6	9.6	9.6	9.6
44																					12.2	12.2	11.9	11.7	11.5	11.5	11.5	11.5	11.1	11.0	11.0	10.9	10.9	10.9	10.9	10.6	10.5	10.4	10.4	10.3	10.2	10.2	10.2	10.2
45																						12.9	12.8	12.8	12.8	12.3	12.3	12.2	12.2	12.2	11.8	11.7	11.6	11.5	11.5	11.5	11.5	11.2	11.1	11.0	11.0	11.0	10.9	10.9
46																						14.1	14.1	13.7	13.6	13.5	13.5	13.5	13.0	12.8	12.8	12.8	12.8	12.4	12.3	12.3	12.2	12.2	12.2	12.2	11.9	11.8	11.7	11.6
47																							15.0	14.8	14.8	14.8	14.3	14.1	14.1	14.1	14.1	13.7	13.5	13.5	13.5	13.5	13.5	13.0	12.9	12.8	12.8	12.8	12.8	12.8
48																								16.1	16.1	16.1	15.4	15.4	15.4	15.4	14.9	14.8	14.8	14.8	14.8	14.2	14.1	14.1	14.1	14.1	14.1	13.7	13.6	13.5
49																								17.4	17.4	16.8	16.8	16.8	16.8	16.2	16.1	16.1	16.1	16.1	15.4	15.4	15.4	15.4	15.4	14.9	14.8	14.8	14.8	14.8
50																									18.7	18.1	18.1	18.1	18.1	17.4	17.4	17.4	17.4	16.8	16.8	16.8	16.8	16.8	16.1	16.1	16.1	16.1	16.1	16.1
51																									20.0	19.4	19.4	19.4	18.8	18.7	18.7	18.7	18.7	18.1	18.1	18.1	18.1	17.5	17.4	17.4	17.4	17.4	17.4	16.8
52																										20.7	20.7	20.7	20.0	20.0	20.0	20.0	19.4	19.4	19.4	19.4	19.4	18.7	18.7	18.7	18.7	18.7	18.1	18.1
53																											22.0	22.0	21.3	21.3	21.3	21.3	20.7	20.7	20.7	20.7	20.1	20.0	20.0	20.0	20.0	19.4	19.4	19.4
54																											23.3	23.3	22.6	22.6	22.6	22.6	22.0	22.0	22.0	22.0	21.3	21.3	21.3	21.3	21.3	20.7	20.7	20.7
55																												24.0	23.9	23.9	23.9	23.3	23.3	23.3	23.3	23.3	22.6	22.6	22.6	22.6	22.0	22.0	22.0	22.0
56																													25.2	25.2	25.2	24.6	24.6	24.6	24.6	23.9	23.9	23.9	23.9	23.9	23.3	23.3	23.3	23.3
57																													26.5	26.5	25.9	25.9	25.9	25.9	25.9	25.2	25.2	25.2	25.2	24.6	24.6	24.6	24.6	24.6
58																														27.9	27.2	27.2	27.2	27.2	26.5	26.5	26.5	26.5	26.5	25.9	25.9	25.9	25.9	25.9
59																														28.5	28.5	28.5	28.5	27.9	27.9	27.9	27.9	27.9	27.2	27.2	27.2	27.2	27.2	26.5
60																															29.8	29.8	29.8	29.2	29.2	29.2	29.2	29.2	28.5	28.5	28.5	28.5	27.9	27.9
61																																30.5	30.5	30.5	30.5	30.5	29.8	29.8	29.8	29.8	29.8	29.2	29.2	29.2
62																																31.8	31.8	31.8	31.8	31.1	31.1	31.1	31.1	31.1	30.5	30.5	30.5	30.5

Table 8.7.1-3
Fuel Qualification Table for EOS-37PTH, 492kgU, HLZC1, Plan1, Zone 2
(Minimum required years of cooling time after reactor core discharge)

BU (GWD/MTU)	Fuel Assembly Average Initial U-235 Enrichment (wt.%)																																											
	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5
6	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
7								3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
10								3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
16								3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
17												3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
20												3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
25												3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
28												3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
30												3.2	3.2	3.1	3.1	3.1	3.1	3.1	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
31													3.2	3.2	3.2	3.2	3.2	3.2	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
32														3.3	3.3	3.3	3.3	3.2	3.2	3.2	3.2	3.2	3.2	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
34															3.5	3.5	3.4	3.4	3.4	3.4	3.4	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
36																3.6	3.6	3.6	3.6	3.6	3.5	3.5	3.5	3.5	3.5	3.5	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.2	3.2
38																	3.8	3.8	3.8	3.7	3.7	3.7	3.7	3.7	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.4	3.4	3.4	3.4	3.4
39																		3.9	3.9	3.8	3.8	3.8	3.8	3.8	3.7	3.7	3.7	3.7	3.7	3.7	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.5	3.5	3.5	3.5	3.5	3.5	3.5
40																			4.0	3.9	3.9	3.9	3.9	3.9	3.8	3.8	3.8	3.8	3.8	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
41																			4.1	4.0	4.0	4.0	4.0	4.0	3.9	3.9	3.9	3.9	3.9	3.9	3.8	3.8	3.8	3.8	3.8	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.6
42																				4.2	4.1	4.1	4.1	4.1	4.0	4.0	4.0	4.0	4.0	3.9	3.9	3.9	3.9	3.9	3.9	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.7	3.7
43																				4.3	4.2	4.2	4.2	4.2	4.1	4.1	4.1	4.1	4.1	4.0	4.0	4.0	4.0	4.0	4.0	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.8	3.8
44																					4.4	4.4	4.3	4.3	4.3	4.2	4.2	4.2	4.2	4.1	4.1	4.1	4.1	4.1	4.1	4.0	4.0	4.0	4.0	4.0	4.0	3.9	3.9	3.9
45																						4.5	4.4	4.4	4.4	4.4	4.3	4.3	4.3	4.3	4.2	4.2	4.2	4.2	4.2	4.1	4.1	4.1	4.1	4.1	4.1	4.0	4.0	4.0
46																						4.6	4.5	4.5	4.5	4.5	4.4	4.4	4.4	4.4	4.4	4.3	4.3	4.3	4.3	4.2	4.2	4.2	4.2	4.2	4.2	4.1	4.1	4.1
47																							4.7	4.6	4.6	4.6	4.6	4.5	4.5	4.5	4.5	4.4	4.4	4.4	4.4	4.4	4.4	4.3	4.3	4.3	4.3	4.2	4.2	4.2
48																								4.8	4.8	4.7	4.7	4.7	4.6	4.6	4.6	4.6	4.5	4.5	4.5	4.5	4.5	4.4	4.4	4.4	4.4	4.4	4.4	4.3
49																								4.9	4.9	4.9	4.8	4.8	4.8	4.8	4.7	4.7	4.7	4.6	4.6	4.6	4.6	4.5	4.5	4.5	4.5	4.5	4.5	4.4
50																									5.0	5.0	5.0	4.9	4.9	4.9	4.8	4.8	4.8	4.8	4.8	4.7	4.7	4.7	4.6	4.6	4.6	4.6	4.6	4.5
51																									5.2	5.2	5.1	5.1	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.8	4.8	4.8	4.8	4.7	4.7	4.7	4.7
52																										5.3	5.3	5.2	5.2	5.2	5.1	5.1	5.1	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.8	4.8	4.8
53																											5.4	5.4	5.4	5.3	5.3	5.2	5.2	5.2	5.2	5.1	5.1	5.1	5.0	5.0	5.0	5.0	4.9	4.9
54																											5.6	5.6	5.5	5.5	5.4	5.4	5.4	5.3	5.3	5.3	5.2	5.2	5.2	5.2	5.1	5.1	5.1	5.1
55																												5.7	5.7	5.7	5.6	5.6	5.5	5.5	5.5	5.4	5.4	5.4	5.3	5.3	5.3	5.3	5.2	5.2
56																													5.9	5.8	5.8	5.7	5.7	5.7	5.7	5.6	5.6	5.5	5.5	5.5	5.4	5.4	5.4	5.4
57																													6.1	6.1	6.0	5.9	5.9	5.8	5.8	5.8	5.7	5.7	5.7	5.7	5.6	5.6	5.6	5.5
58																														6.2	6.2	6.1	6.1	6.1	6.0	6.0	5.9	5.9	5.8	5.8	5.8	5.7	5.7	5.7
59																														6.5	6.4	6.4	6.3	6.2	6.2	6.2	6.1	6.1	6.1	6.0	6.0	5.9	5.9	5.9
60																															6.6	6.6	6.6	6.5	6.4	6.4	6.3	6.3	6.2	6.2	6.2	6.1	6.1	6.1
61																																6.8	6.8	6.7	6.6	6.6	6.6	6.5	6.5	6.4	6.4	6.3	6.3	6.2
62																																7.1	7.0	7.0	6.9	6.9	6.8	6.7	6.7	6.6	6.6	6.6	6.5	6.5

Table 8.7.1-4
Fuel Qualification Table for EOS-37PTH, 492kgU, HLZC1, Plan1, Zone 3
(Minimum required years of cooling time after reactor core discharge)

BU (GWD/MTU)	Fuel Assembly Average Initial U-235 Enrichment (wt.%)																																											
	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5
6	3.8	3.8	3.8	3.7	3.7	3.7	3.7	3.7	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.4	3.4
7								3.9	3.9	3.9	3.9	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.6	3.6	3.6	3.6
10								4.6	4.5	4.5	4.5	4.5	4.4	4.4	4.4	4.4	4.4	4.4	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.1	4.1	4.1	4.1
16								5.8	5.8	5.7	5.7	5.6	5.6	5.6	5.5	5.5	5.5	5.4	5.4	5.4	5.3	5.3	5.3	5.3	5.2	5.2	5.2	5.2	5.2	5.2	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.0	5.0	5.0	5.0	5.0	5.0	5.0
17												5.8	5.8	5.8	5.7	5.7	5.6	5.6	5.6	5.5	5.5	5.5	5.5	5.4	5.4	5.4	5.4	5.4	5.3	5.3	5.3	5.3	5.3	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.1	5.1	5.1
20												6.5	6.4	6.4	6.3	6.3	6.2	6.2	6.2	6.1	6.1	6.0	6.0	6.0	6.0	5.9	5.9	5.9	5.8	5.8	5.8	5.8	5.8	5.7	5.7	5.7	5.7	5.7	5.6	5.6	5.6	5.6	5.6	5.6
25												7.9	7.8	7.7	7.6	7.5	7.5	7.4	7.3	7.3	7.2	7.2	7.1	7.1	7.0	7.0	6.9	6.9	6.9	6.8	6.8	6.7	6.7	6.7	6.6	6.6	6.6	6.6	6.5	6.5	6.5	6.5	6.4	6.4
28												8.9	8.8	8.7	8.6	8.5	8.4	8.3	8.2	8.1	8.0	8.0	7.9	7.8	7.8	7.7	7.7	7.6	7.6	7.5	7.5	7.4	7.4	7.3	7.3	7.3	7.2	7.2	7.2	7.1	7.1	7.1	7.0	7.0
30												9.7	9.5	9.4	9.3	9.2	9.1	9.0	8.9	8.8	8.7	8.6	8.5	8.5	8.4	8.3	8.2	8.2	8.1	8.1	8.0	8.0	7.9	7.9	7.8	7.8	7.7	7.7	7.6	7.6	7.6	7.5	7.5	7.4
31													9.9	9.8	9.7	9.5	9.4	9.3	9.2	9.1	9.0	8.9	8.8	8.8	8.7	8.6	8.5	8.5	8.4	8.3	8.3	8.2	8.2	8.1	8.1	8.0	8.0	7.9	7.9	7.8	7.8	7.8	7.7	7.7
32														10.2	10.1	9.9	9.8	9.7	9.6	9.5	9.3	9.2	9.2	9.1	9.0	8.9	8.8	8.8	8.7	8.6	8.6	8.5	8.4	8.4	8.3	8.3	8.2	8.2	8.1	8.1	8.1	8.0	8.0	7.9
34															10.9	10.7	10.6	10.5	10.3	10.2	10.1	10.0	9.9	9.8	9.7	9.6	9.5	9.4	9.3	9.2	9.2	9.1	9.0	9.0	8.9	8.9	8.8	8.7	8.7	8.6	8.6	8.5	8.5	8.4
36																11.7	11.5	11.3	11.2	11.0	10.9	10.8	10.6	10.5	10.4	10.3	10.2	10.1	10.0	9.9	9.8	9.8	9.7	9.6	9.5	9.5	9.4	9.3	9.3	9.2	9.2	9.1	9.0	9.0
38																	12.4	12.2	12.1	11.9	11.8	11.6	11.5	11.3	11.2	11.1	11.0	10.9	10.8	10.7	10.6	10.5	10.4	10.3	10.2	10.1	10.1	10.0	9.9	9.8	9.8	9.7	9.7	9.6
39																		12.6	12.5	12.3	12.2	12.0	11.9	11.7	11.6	11.4	11.3	11.2	11.1	11.0	10.9	10.8	10.7	10.6	10.5	10.5	10.4	10.3	10.2	10.2	10.1	10.0	10.0	9.9
40																			13.0	12.8	12.6	12.5	12.3	12.2	12.0	11.9	11.7	11.6	11.5	11.4	11.3	11.2	11.1	11.0	10.9	10.8	10.7	10.7	10.6	10.5	10.4	10.4	10.3	10.2
41																			13.5	13.3	13.1	12.9	12.7	12.6	12.4	12.3	12.2	12.0	11.9	11.8	11.7	11.6	11.5	11.4	11.3	11.2	11.1	11.0	10.9	10.9	10.8	10.7	10.6	10.6
42																				13.8	13.6	13.4	13.3	13.1	12.9	12.7	12.6	12.5	12.4	12.2	12.1	12.0	11.9	11.8	11.7	11.6	11.5	11.4	11.3	11.2	11.1	11.1	11.0	10.9
43																				14.4	14.1	13.9	13.8	13.5	13.4	13.2	13.1	12.9	12.8	12.6	12.5	12.4	12.3	12.2	12.1	12.0	11.9	11.8	11.7	11.6	11.5	11.4	11.3	11.3
44																					14.7	14.5	14.3	14.1	13.9	13.7	13.5	13.4	13.2	13.1	13.0	12.8	12.7	12.6	12.5	12.4	12.2	12.2	12.0	12.0	11.9	11.8	11.7	11.6
45																						15.0	14.8	14.6	14.4	14.2	14.0	13.9	13.7	13.6	13.4	13.3	13.1	13.0	12.9	12.8	12.7	12.6	12.5	12.4	12.3	12.2	12.1	12.0
46																						15.6	15.3	15.2	14.9	14.8	14.6	14.4	14.2	14.0	13.9	13.7	13.6	13.5	13.3	13.2	13.1	13.0	12.9	12.8	12.7	12.6	12.5	12.4
47																							15.9	15.7	15.5	15.3	15.1	14.9	14.7	14.5	14.4	14.2	14.1	13.9	13.8	13.7	13.6	13.4	13.3	13.2	13.1	13.0	12.9	12.8
48																								16.2	16.1	15.8	15.6	15.4	15.2	15.0	14.9	14.7	14.5	14.4	14.2	14.1	14.0	13.9	13.7	13.6	13.5	13.4	13.3	13.2
49																								16.9	16.6	16.4	16.1	16.0	15.8	15.6	15.4	15.2	15.1	14.9	14.7	14.6	14.5	14.3	14.2	14.1	13.9	13.8	13.7	13.6
50																									17.3	17.0	16.7	16.5	16.3	16.1	15.9	15.7	15.6	15.4	15.2	15.1	14.9	14.8	14.7	14.5	14.4	14.3	14.2	14.0
51																									17.8	17.6	17.3	17.1	16.9	16.7	16.5	16.3	16.1	15.9	15.8	15.6	15.4	15.3	15.1	15.0	14.8	14.7	14.6	14.5
52																										18.2	17.9	17.7	17.5	17.2	17.1	16.8	16.6	16.5	16.2	16.1	15.9	15.8	15.6	15.5	15.3	15.2	15.1	15.0
53																											18.6	18.3	18.1	17.8	17.6	17.4	17.2	17.0	16.8	16.6	16.4	16.3	16.1	15.9	15.8	15.7	15.5	15.4
54																											19.2	18.9	18.6	18.5	18.2	18.0	17.7	17.5	17.3	17.1	17.0	16.8	16.7	16.4	16.3	16.1	16.0	15.9
55																												19.6	19.3	19.1	18.8	18.5	18.4	18.1	17.9	17.7	17.6	17.3	17.1	17.0	16.8	16.7	16.5	16.4
56																													20.0	19.6	19.4	19.2	19.0	18.7	18.5	18.3	18.1	17.9	17.7	17.6	17.3	17.2	17.0	16.9
57																													20.6	20.3	20.1	19.8	19.5	19.3	19.1	18.9	18.6	18.5	18.3	18.1	17.9	17.7	17.6	17.4
58																														20.9	20.8	20.4	20.1	20.0	19.7	19.5	19.3	19.0	18.9	18.6	18.5	18.3	18.1	17.9
59																														21.6	21.3	21.1	20.8	20.6	20.3	20.0	19.9	19.6	19.4	19.2	19.0	18.8	18.6	18.5
60																															22.0	21.8	21.5	21.2	20.9	20.7	20.5	20.2	19.9	19.8	19.5	19.4	19.2	19.0
61																																22.3	22.1	21.8	21.6	21.3	21.0	20.8	20.7	20.7	20.7	20.0	20.0	20.0
62																																23.0	22.8	22.6	22.6	22.1	22.0	22.0	22.0	21.4	21.3	21.3	21.3	21.3

Table 8.7.1-5
Fuel Qualification Table for EOS-37PTH, 492kgU, HLZC1, Plan2, Zone 1
(Minimum required years of cooling time after reactor core discharge)

BU (GWD/MTU)	Fuel Assembly Average Initial U-235 Enrichment (wt.%)																																										
	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5
6	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
7								3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
10								3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
16								3.3	3.3	3.3	3.3	3.3	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
17												3.4	3.4	3.4	3.4	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.1	3.1	3.1	3.1	3.1	3.1	3.1
20												3.8	3.8	3.8	3.8	3.8	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
25												4.6	4.6	4.6	4.5	4.5	4.5	4.5	4.5	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2
28												5.2	5.2	5.1	5.1	5.1	5.1	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.6
30												5.7	5.7	5.6	5.6	5.5	5.5	5.5	5.4	5.4	5.4	5.3	5.3	5.3	5.3	5.3	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.1	5.1	5.1	5.1	5.1	5.1	5.0	5.0	5.0	5.0
31													5.9	5.8	5.8	5.8	5.7	5.7	5.7	5.7	5.7	5.6	5.6	5.6	5.5	5.5	5.5	5.5	5.4	5.4	5.4	5.4	5.3	5.3	5.3	5.3	5.3	5.3	5.2	5.2	5.2	5.2	5.2	5.2
32														6.1	6.1	6.1	6.0	6.0	5.9	5.9	5.9	5.8	5.8	5.8	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.6	5.6	5.6	5.6	5.6	5.5	5.5	5.5	5.5	5.5	5.4	5.4	5.4
34															6.7	6.6	6.6	6.6	6.5	6.5	6.4	6.4	6.4	6.3	6.3	6.3	6.2	6.2	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.0	6.0	6.0	6.0	6.0	5.9	5.9	5.9	5.9
36																8.6	7.3	7.3	7.2	7.1	7.1	7.0	7.0	7.0	7.0	7.0	6.9	6.8	6.8	6.8	6.7	6.7	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.5	6.5	6.5	6.5	6.4
38																	11.5	10.2	9.4	8.0	7.9	7.9	7.9	7.8	7.7	7.7	7.6	7.6	7.6	7.5	7.5	7.5	7.4	7.4	7.3	7.3	7.3	7.2	7.2	7.2	7.1	7.1	7.1	7.0
39																		11.7	11.5	10.1	8.5	8.3	8.3	8.3	8.3	8.3	8.1	8.0	7.9	7.9	7.9	7.9	7.8	7.8	7.7	7.7	7.6	7.6	7.6	7.6	7.6	7.6	7.5	7.5
40																			12.7	12.4	10.8	9.6	8.9	8.9	8.7	8.7	8.6	8.5	8.4	8.4	8.3	8.3	8.3	8.3	8.3	8.3	8.1	8.0	8.0	8.0	7.9	7.9	7.9	7.9
41																			15.6	13.8	13.3	11.5	10.9	9.6	9.3	9.2	9.2	9.1	9.0	8.9	8.9	8.9	8.9	8.9	8.7	8.7	8.6	8.5	8.5	8.4	8.4	8.4	8.3	8.3
42																				16.8	14.5	14.3	12.8	11.5	11.5	9.9	9.8	9.7	9.7	9.6	9.6	9.6	9.6	9.3	9.2	9.2	9.2	9.1	9.1	9.0	9.0	8.9	8.9	8.9
43																				18.2	18.0	15.4	15.2	13.5	12.8	11.5	10.6	10.5	10.4	10.2	10.2	10.2	10.2	10.2	9.9	9.8	9.8	9.7	9.7	9.7	9.6	9.6	9.6	9.6
44																					19.0	17.8	16.7	16.0	15.3	13.5	12.2	11.5	11.1	11.0	11.0	10.9	10.9	10.9	10.9	10.6	10.5	10.4	10.4	10.3	10.2	10.2	10.2	10.2
45																						20.8	18.6	17.8	17.5	16.7	14.6	13.5	12.8	12.2	11.8	11.7	11.6	11.5	11.5	11.5	11.5	11.2	11.1	11.0	11.0	11.0	10.9	10.9
46																						21.7	21.3	19.7	18.8	18.7	16.8	16.1	15.3	13.5	12.8	12.8	12.8	12.4	12.3	12.3	12.2	12.2	12.2	12.2	11.9	11.8	11.7	11.6
47																							23.9	21.7	21.2	19.3	19.3	17.4	16.8	15.4	14.8	13.7	13.5	13.5	13.5	13.5	13.5	13.0	12.9	12.8	12.8	12.8	12.8	12.8
48																								24.5	22.5	21.3	21.2	19.3	18.1	17.4	17.5	15.4	14.8	14.8	14.8	14.2	14.1	14.1	14.1	14.1	14.1	13.7	13.6	13.5
49																								25.3	24.8	23.1	22.1	21.4	21.2	19.5	18.7	17.4	16.8	16.1	15.4	15.4	15.4	15.4	15.4	14.9	14.8	14.8	14.8	14.8
50																									26.5	25.3	24.7	24.5	22.1	21.3	21.2	19.0	18.7	17.4	16.8	16.8	16.8	16.8	16.1	16.1	16.1	16.1	16.1	16.1
51																									27.8	27.3	27.1	24.7	25.4	23.9	22.6	21.3	20.7	19.3	18.7	18.1	18.1	17.5	17.4	17.4	17.4	17.4	17.4	16.8
52																										28.8	27.8	27.2	27.1	24.7	23.9	23.3	22.0	21.3	20.0	19.4	19.4	18.7	18.7	18.7	18.7	18.7	18.1	18.1
53																											29.4	28.3	27.8	27.2	25.5	24.7	23.9	23.3	22.0	21.3	20.2	20.0	20.0	20.0	20.0	19.4	19.4	19.4
54																											31.7	31.4	28.9	28.3	27.3	27.2	25.5	24.3	23.9	22.6	22.0	21.3	21.3	21.3	21.3	20.7	20.7	20.7
55																												32.5	31.1	30.5	29.2	27.8	27.3	27.2	25.5	24.7	23.9	23.3	22.6	22.6	22.0	22.0	22.0	22.0
56																													33.2	31.6	30.6	29.6	29.2	27.9	27.2	26.5	25.2	24.6	23.9	23.9	23.3	23.3	23.3	23.3
57																													34.4	33.3	33.2	31.6	30.6	29.6	29.2	28.5	27.2	26.5	25.9	24.6	24.6	24.6	24.6	24.6
58																														34.5	33.9	33.3	33.1	31.6	30.6	29.6	29.2	27.9	27.2	26.5	25.9	25.9	25.9	25.9
59																														36.5	35.2	34.5	33.9	33.3	33.1	31.1	30.6	29.6	29.2	27.9	27.2	27.2	27.2	26.5
60																															37.2	36.6	35.5	34.4	34.4	33.1	32.4	31.1	30.1	29.6	28.5	28.5	27.9	27.9
61																																37.3	36.7	36.0	35.5	34.4	33.7	33.1	31.8	31.1	30.5	29.2	29.2	29.2
62																																39.2	39.1	37.3	36.6	36.0	34.9	34.4	33.7	32.4	31.8	31.1	30.5	30.5

Table 8.7.1-6
Fuel Qualification Table for EOS-37PTH, 492kgU, HLZC1, Plan2, Zone 2
(Minimum required years of cooling time after reactor core discharge)

BU (GWD/MTU)	Fuel Assembly Average Initial U-235 Enrichment (wt.%)																																											
	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5
6	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
7								3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
10								3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
16								3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
17												3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
20												3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
25												3.5	3.5	3.4	3.4	3.4	3.3	3.3	3.2	3.2	3.2	3.2	3.2	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
28												3.9	3.9	3.8	3.8	3.7	3.6	3.6	3.5	3.5	3.5	3.5	3.5	3.4	3.4	3.4	3.3	3.3	3.3	3.3	3.3	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.1	3.1	3.1	3.1	3.1	3.1
30												4.4	4.2	4.2	4.1	4.0	3.9	3.9	3.8	3.8	3.7	3.7	3.6	3.6	3.6	3.5	3.5	3.5	3.5	3.5	3.5	3.4	3.4	3.4	3.4	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.2	3.2
31													4.5	4.3	4.2	4.2	4.1	4.0	4.0	3.9	3.8	3.8	3.8	3.7	3.7	3.6	3.6	3.6	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.4	3.4	3.4	3.4	3.4	3.3	3.3	3.3	3.3
32														4.6	4.4	4.4	4.3	4.2	4.1	4.1	4.0	3.9	3.9	3.8	3.8	3.8	3.7	3.7	3.7	3.6	3.6	3.6	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.4	3.4	3.4	3.4	3.4
34															5.0	4.8	4.7	4.6	4.5	4.4	4.4	4.3	4.2	4.1	4.0	4.0	3.9	3.9	3.9	3.8	3.8	3.8	3.7	3.7	3.7	3.7	3.7	3.6	3.6	3.5	3.6	3.6	3.5	3.5
36																5.6	5.4	5.2	5.0	4.9	4.8	4.7	4.6	4.5	4.4	4.4	4.3	4.2	4.1	4.1	4.1	4.0	4.0	3.9	3.9	3.8	3.8	3.8	3.8	3.7	3.7	3.7	3.7	3.7
38																	6.3	6.0	5.8	5.7	5.4	5.2	5.1	4.9	4.9	4.8	4.7	4.6	4.5	4.4	4.3	4.3	4.3	4.2	4.2	4.1	4.1	4.0	4.0	3.9	3.9	3.9	3.9	3.9
39																		6.6	6.2	5.9	5.8	5.5	5.4	5.2	5.0	5.0	4.9	4.8	4.7	4.6	4.5	4.4	4.4	4.3	4.3	4.2	4.2	4.1	4.1	4.1	4.0	4.0	4.0	4.0
40																			6.9	6.5	6.2	6.0	5.8	5.7	5.3	5.2	5.1	5.0	4.9	4.8	4.7	4.6	4.5	4.5	4.4	4.4	4.4	4.3	4.2	4.2	4.1	4.1	4.1	4.0
41																			7.5	7.2	6.7	6.5	6.1	6.0	5.8	5.5	5.4	5.2	5.1	5.0	5.0	4.8	4.8	4.7	4.6	4.5	4.5	4.5	4.4	4.4	4.3	4.2	4.2	4.1
42																				8.1	7.4	7.4	7.0	6.4	6.2	6.0	5.8	5.6	5.5	5.3	5.2	5.1	5.0	4.9	4.8	4.7	4.6	4.6	4.5	4.5	4.4	4.4	4.3	4.3
43																				9.3	8.4	8.2	7.5	7.3	6.8	6.5	6.5	6.1	5.9	5.7	5.5	5.4	5.3	5.2	5.1	5.0	4.9	4.8	4.7	4.6	4.6	4.5	4.5	4.4
44																					9.6	8.8	8.4	8.2	7.4	7.3	6.7	6.5	6.5	6.3	5.9	5.8	5.7	5.5	5.4	5.2	5.1	5.0	4.9	4.8	4.7	4.7	4.6	4.6
45																						10.1	9.6	8.9	8.5	8.3	7.4	7.3	6.9	6.6	6.4	6.4	5.9	5.8	5.7	5.5	5.5	5.3	5.1	5.1	5.0	4.9	4.9	4.8
46																						11.4	11.1	10.1	9.8	8.9	8.7	8.0	7.5	7.1	7.0	6.6	6.5	6.2	6.1	5.9	5.7	5.6	5.5	5.3	5.2	5.1	5.0	5.0
47																							12.2	11.4	10.6	9.8	9.8	8.9	8.5	8.0	7.7	7.2	7.0	6.7	6.6	6.3	6.3	5.9	5.8	5.7	5.7	5.4	5.3	5.2
48																								12.5	12.1	11.2	11.1	9.9	9.3	9.0	8.5	8.0	7.8	7.5	7.0	6.8	6.7	6.5	6.1	6.0	5.9	5.7	5.7	5.5
49																								14.0	13.5	12.6	12.1	11.6	10.5	10.0	9.4	9.0	8.5	8.1	7.9	7.5	7.1	6.9	6.8	6.5	6.2	6.1	5.9	5.8
50																									15.0	14.4	13.6	12.6	12.1	11.0	10.8	9.8	9.4	9.3	8.5	8.2	8.0	7.5	7.3	7.0	7.0	6.5	6.3	6.1
51																									16.1	16.0	14.7	14.1	13.2	12.5	12.4	11.1	10.8	10.0	9.6	9.5	8.5	8.3	7.9	7.6	7.3	7.1	7.0	6.6
52																										17.0	16.2	15.2	14.8	14.1	13.6	12.5	11.6	11.3	10.5	10.1	9.7	9.2	8.7	8.4	8.3	7.7	7.5	7.2
53																											17.7	16.7	16.0	15.2	14.9	14.1	13.0	12.9	11.8	11.3	10.9	10.3	9.9	9.2	8.8	8.5	8.5	7.7
54																											19.2	18.2	17.4	16.7	15.7	15.8	14.3	13.5	13.0	12.3	12.4	11.2	10.8	10.2	9.9	9.8	9.1	8.6
55																												19.7	18.8	18.1	17.2	16.3	16.0	15.1	14.5	13.8	13.2	12.5	11.8	11.4	10.7	10.4	9.8	9.6
56																													20.2	19.3	19.0	18.0	17.2	16.8	15.6	15.6	14.3	13.8	13.5	12.6	12.3	11.6	11.0	10.6
57																													21.8	21.0	20.2	19.3	18.9	17.9	17.0	16.6	16.2	15.2	14.6	13.8	13.3	12.6	12.4	12.0
58																														22.2	21.8	20.8	19.9	19.3	18.6	17.9	17.2	16.4	16.5	15.1	14.6	13.9	14.0	12.8
59																														23.6	23.0	22.2	21.3	20.7	20.1	19.2	19.0	18.3	17.2	16.5	16.2	15.2	14.4	14.3
60																															24.4	23.6	22.8	21.9	21.4	20.5	19.9	19.2	18.7	17.8	17.0	16.6	15.8	15.1
61																																24.8	24.3	23.2	22.9	21.9	21.1	20.5	19.7	19.7	18.9	17.6	17.2	16.4
62																																26.1	25.6	25.0	24.0	23.5	22.6	22.0	21.1	20.2	19.8	19.2	19.3	17.8

Table 8.7.1-7
Fuel Qualification Table for EOS-37PTH, 492kgU, HLZC1, Plan2, Zone 3
(Minimum required years of cooling time after reactor core discharge)

BU (GWD/MTU)	Fuel Assembly Average Initial U-235 Enrichment (wt.%)																																										
	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5
6	3.6	3.6	3.6	3.5	3.5	3.5	3.5	3.5	3.5	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3
7								3.7	3.7	3.7	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
10								4.3	4.3	4.3	4.2	4.2	4.2	4.2	4.2	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.9	3.9	3.9	3.9
16								5.5	5.4	5.4	5.3	5.3	5.3	5.2	5.2	5.2	5.1	5.1	5.1	5.1	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.7	4.7	4.7	4.7
17												5.5	5.4	5.4	5.4	5.3	5.3	5.3	5.2	5.2	5.2	5.2	5.1	5.1	5.1	5.1	5.1	5.1	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9
20												6.1	6.0	6.0	5.9	5.9	5.8	5.8	5.8	5.7	5.7	5.7	5.6	5.6	5.6	5.6	5.5	5.5	5.5	5.5	5.4	5.4	5.4	5.4	5.4	5.4	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.2
25												7.2	7.2	7.1	7.0	6.9	6.9	6.8	6.8	6.7	6.7	6.6	6.6	6.5	6.5	6.5	6.4	6.4	6.4	6.3	6.3	6.3	6.2	6.2	6.2	6.2	6.1	6.1	6.1	6.1	6.0	6.0	6.0	6.0
28												8.1	8.0	7.9	7.8	7.7	7.6	7.6	7.5	7.4	7.4	7.3	7.3	7.2	7.1	7.1	7.1	7.0	7.0	6.9	6.9	6.8	6.8	6.8	6.7	6.7	6.7	6.6	6.6	6.6	6.6	6.5	6.5	6.5
30												8.8	8.6	8.5	8.4	8.3	8.2	8.2	8.1	8.0	7.9	7.8	7.8	7.7	7.7	7.6	7.5	7.5	7.4	7.4	7.3	7.3	7.2	7.2	7.2	7.1	7.1	7.1	7.0	7.0	7.0	6.9	6.9	6.9
31													8.9	8.8	8.7	8.6	8.5	8.4	8.3	8.3	8.2	8.1	8.0	8.0	7.9	7.8	7.8	7.7	7.7	7.6	7.6	7.5	7.5	7.4	7.4	7.3	7.3	7.3	7.2	7.2	7.2	7.1	7.1	7.1
32														9.2	9.1	8.9	8.8	8.7	8.7	8.6	8.5	8.4	8.3	8.2	8.2	8.1	8.0	8.0	7.9	7.9	7.8	7.8	7.7	7.7	7.6	7.6	7.5	7.5	7.4	7.4	7.4	7.3	7.3	7.3
34															9.8	9.6	9.5	9.4	9.3	9.2	9.1	9.0	8.9	8.8	8.7	8.7	8.6	8.5	8.5	8.4	8.3	8.3	8.2	8.2	8.1	8.1	8.0	8.0	7.9	7.9	7.8	7.8	7.7	7.7
36																10.4	10.3	10.1	10.0	9.9	9.8	9.7	9.6	9.5	9.4	9.3	9.2	9.1	9.0	9.0	8.9	8.8	8.8	8.7	8.6	8.6	8.5	8.5	8.4	8.4	8.3	8.3	8.2	8.2
38																	11.1	10.9	10.8	10.6	10.5	10.4	10.3	10.1	10.0	9.9	9.8	9.8	9.7	9.6	9.5	9.4	9.3	9.3	9.2	9.1	9.1	9.0	9.0	8.9	8.8	8.8	8.7	8.7
39																		11.3	11.1	11.0	10.9	10.7	10.6	10.5	10.3	10.3	10.1	10.1	10.0	9.9	9.8	9.7	9.6	9.6	9.5	9.4	9.3	9.3	9.2	9.2	9.1	9.1	9.0	8.9
40																			11.6	11.4	11.2	11.1	11.0	10.9	10.7	10.6	10.5	10.4	10.3	10.2	10.1	10.0	10.0	9.9	9.8	9.7	9.7	9.6	9.5	9.4	9.4	9.3	9.3	9.2
41																			12.0	11.8	11.7	11.5	11.4	11.2	11.1	11.0	10.9	10.7	10.6	10.6	10.5	10.4	10.3	10.2	10.1	10.0	10.0	9.9	9.8	9.7	9.7	9.6	9.6	9.5
42																				12.3	12.1	11.9	11.8	11.6	11.5	11.4	11.3	11.1	11.0	10.9	10.8	10.7	10.6	10.5	10.4	10.3	10.3	10.2	10.1	10.1	10.0	9.9	9.9	9.8
43																				12.7	12.5	12.4	12.2	12.0	11.9	11.8	11.7	11.5	11.4	11.3	11.2	11.1	11.0	10.9	10.8	10.7	10.6	10.5	10.5	10.4	10.3	10.2	10.2	10.1
44																					13.0	12.8	12.7	12.5	12.3	12.2	12.0	11.9	11.8	11.7	11.5	11.4	11.3	11.2	11.1	11.0	10.9	10.9	10.8	10.7	10.6	10.5	10.5	10.4
45																						13.3	13.1	12.9	12.8	12.6	12.4	12.3	12.2	12.1	11.9	11.8	11.7	11.6	11.5	11.4	11.3	11.2	11.1	11.1	11.0	10.9	10.8	10.7
46																						13.8	13.6	13.4	13.2	13.1	12.9	12.8	12.6	12.5	12.4	12.2	12.1	12.0	11.9	11.8	11.7	11.6	11.5	11.4	11.3	11.2	11.1	11.0
47																							14.1	13.9	13.7	13.5	13.4	13.2	13.1	12.9	12.8	12.6	12.5	12.4	12.3	12.1	12.1	11.9	11.8	11.7	11.7	11.6	11.5	11.4
48																								14.4	14.2	14.0	13.8	13.7	13.5	13.3	13.2	13.0	12.9	12.8	12.6	12.6	12.4	12.3	12.2	12.1	12.0	11.9	11.8	11.7
49																								14.9	14.7	14.5	14.3	14.1	13.9	13.8	13.6	13.5	13.3	13.2	13.1	13.0	12.8	12.7	12.6	12.5	12.4	12.3	12.2	12.1
50																									15.2	15.0	14.8	14.6	14.4	14.2	14.1	13.9	13.8	13.6	13.5	13.4	13.2	13.1	13.0	12.9	12.8	12.7	12.6	12.5
51																									15.7	15.5	15.3	15.1	14.9	14.7	14.6	14.4	14.3	14.1	14.0	13.8	13.6	13.5	13.4	13.3	13.2	13.1	12.9	12.9
52																										16.1	15.9	15.6	15.4	15.2	15.1	14.9	14.7	14.6	14.4	14.3	14.1	14.0	13.8	13.7	13.6	13.5	13.3	13.3
53																											16.4	16.1	16.0	15.7	15.5	15.4	15.2	15.0	14.8	14.7	14.6	14.4	14.3	14.1	14.0	13.9	13.8	13.6
54																											17.0	16.7	16.4	16.3	16.1	15.9	15.7	15.5	15.4	15.1	15.0	14.8	14.7	14.6	14.5	14.3	14.2	14.1
55																												17.3	17.0	16.9	16.6	16.4	16.2	16.0	15.9	15.6	15.5	15.3	15.1	15.0	14.9	14.8	14.6	14.5
56																													17.6	17.3	17.2	16.9	16.8	16.5	16.3	16.2	15.9	15.8	15.6	15.5	15.3	15.2	15.0	15.0
57																													18.2	18.1	17.7	17.5	17.4	17.1	16.8	16.8	16.8	16.8	16.2	16.1	16.1	16.1	15.7	15.5
58																														18.7	18.7	18.7	18.2	18.1	18.1	18.1	17.6	17.4	17.4	17.4	17.4	16.8	16.8	16.8
59																														20.0	20.0	19.4	19.4	19.4	19.4	18.8	18.7	18.7	18.7	18.2	18.1	18.1	18.1	18.1
60																															20.8	20.7	20.7	20.7	20.0	20.0	20.0	20.0	19.4	19.4	19.4	19.4	18.8	18.7
61																																22.0	21.5	21.3	21.3	21.3	20.8	20.7	20.7	20.7	20.7	20.0	20.0	20.0
62																																22.7	22.6	22.6	22.6	22.1	22.0	22.0	22.0	21.4	21.3	21.3	21.3	21.3

Table 8.7.1-8
Fuel Qualification Table for EOS-37PTH, 492kgU, HLZC2, Plan1&Plan2, Zone 1
(Minimum required years of cooling time after reactor core discharge)

BU (GWD/MTU)	Fuel Assembly Average Initial U-235 Enrichment (wt.%)																																											
	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5
6	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
7								3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
10								3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
16								3.6	3.6	3.6	3.6	3.6	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3
17												3.7	3.7	3.7	3.7	3.7	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
20												4.2	4.2	4.2	4.2	4.1	4.1	4.1	4.1	4.1	4.1	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9
25												5.2	5.2	5.1	5.1	5.1	5.1	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.7	4.7	4.7	4.7
28												5.9	5.9	5.8	5.8	5.8	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.6	5.6	5.6	5.6	5.5	5.5	5.5	5.5	5.5	5.4	5.4	5.4	5.4	5.4	5.4	5.3	5.3	5.3	5.3	5.3	5.3
30												6.6	6.6	6.5	6.5	6.4	6.4	6.3	6.3	6.3	6.3	6.2	6.2	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.0	6.0	6.0	6.0	5.9	5.9	5.9	5.9	5.9	5.8	5.8	5.8	5.8	5.8
31													7.0	6.9	6.8	6.8	6.7	6.7	6.6	6.6	6.6	6.6	6.5	6.5	6.5	6.4	6.4	6.4	6.3	6.3	6.3	6.3	6.3	6.3	6.2	6.2	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1
32														7.3	7.2	7.1	7.1	7.0	7.0	7.0	7.0	7.0	6.9	6.8	6.8	6.8	6.7	6.7	6.7	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.5	6.5	6.5	6.5	6.4	6.4	6.4	6.4
34															8.3	8.1	8.0	7.9	7.9	7.9	7.8	7.8	7.7	7.6	7.6	7.6	7.6	7.6	7.5	7.5	7.4	7.4	7.4	7.3	7.3	7.3	7.2	7.2	7.2	7.1	7.1	7.1	7.1	7.0
36																9.3	9.2	9.2	9.1	9.0	8.9	8.9	8.9	8.9	8.7	8.6	8.5	8.5	8.4	8.4	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.0	8.0	8.0	7.9	7.9
38																	10.9	10.9	10.9	10.5	10.4	10.3	10.2	10.2	10.2	10.2	9.9	9.8	9.7	9.7	9.7	9.6	9.6	9.6	9.6	9.6	9.6	9.2	9.2	9.2	9.2	9.2	9.1	9.1
39																		11.6	11.5	11.5	11.5	11.1	11.0	11.0	10.9	10.9	10.9	10.9	10.6	10.5	10.4	10.3	10.2	10.2	10.2	10.2	10.2	10.2	10.2	9.9	9.8	9.8	9.7	9.7
40																			12.8	12.8	12.3	12.2	12.2	12.2	12.2	11.7	11.6	11.5	11.5	11.5	11.5	11.5	11.1	11.0	11.0	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.5
41																			14.1	13.6	13.5	13.5	13.5	13.0	12.8	12.8	12.8	12.8	12.8	12.3	12.2	12.2	12.2	12.2	12.2	12.2	11.8	11.7	11.6	11.5	11.5	11.5	11.5	11.5
42																				14.8	14.8	14.8	14.8	14.1	14.1	14.1	14.1	14.1	13.5	13.5	13.5	13.5	13.5	13.5	12.9	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.3	12.3
43																				16.1	16.1	16.1	16.1	15.4	15.4	15.4	15.4	14.9	14.8	14.8	14.8	14.8	14.8	14.1	14.1	14.1	14.1	14.1	14.1	13.6	13.5	13.5	13.5	13.5
44																					17.4	17.4	17.4	16.8	16.8	16.8	16.8	16.1	16.1	16.1	16.1	16.1	15.4	15.4	15.4	15.4	15.4	15.4	15.4	14.8	14.8	14.8	14.8	14.8
45																						18.7	18.7	18.7	18.1	18.1	18.1	18.1	17.4	17.4	17.4	17.4	16.8	16.8	16.8	16.8	16.8	16.8	16.1	16.1	16.1	16.1	16.1	16.1
46																						20.0	20.0	20.0	19.4	19.4	19.4	19.4	18.7	18.7	18.7	18.7	18.7	18.1	18.1	18.1	18.1	18.1	17.4	17.4	17.4	17.4	17.4	17.4
47																							21.3	21.3	21.3	20.7	20.7	20.7	20.7	20.0	20.0	20.0	20.0	19.4	19.4	19.4	19.4	19.4	19.4	18.7	18.7	18.7	18.7	18.7
48																								22.6	22.6	22.0	22.0	22.0	22.0	21.3	21.3	21.3	21.3	21.3	20.7	20.7	20.7	20.7	20.7	20.0	20.0	20.0	20.0	20.0
49																								23.9	23.9	23.9	23.9	23.3	23.3	23.3	22.6	22.6	22.6	22.6	22.6	22.0	22.0	22.0	22.0	22.0	21.3	21.3	21.3	21.3
50																									25.2	25.2	24.6	24.6	24.6	24.6	24.6	23.9	23.9	23.9	23.9	23.9	23.3	23.3	23.3	23.3	22.6	22.6	22.6	22.6
51																									26.5	26.5	26.5	25.9	25.9	25.9	25.9	25.2	25.2	25.2	25.2	25.2	24.6	24.6	24.6	24.6	24.6	23.9	23.9	23.9
52																										27.9	27.9	27.2	27.2	27.2	27.2	26.5	26.5	26.5	26.5	26.5	25.9	25.9	25.9	25.9	25.9	25.2	25.2	25.2
53																											29.2	29.2	28.5	28.5	28.5	28.5	27.9	27.9	27.9	27.9	27.2	27.2	27.2	27.2	27.2	27.2	26.5	26.5
54																											30.5	29.8	29.8	29.8	29.8	29.8	29.2	29.2	29.2	29.2	29.2	29.2	28.5	28.5	28.5	28.5	27.9	27.9
55																												31.1	31.1	31.1	31.1	31.1	30.5	30.5	30.5	30.5	30.5	29.8	29.8	29.8	29.8	29.8	29.2	29.2
56																													32.4	32.4	32.4	32.4	31.8	31.8	31.8	31.8	31.8	31.1	31.1	31.1	31.1	31.1	30.5	30.5
57																													33.7	33.7	33.7	33.1	33.1	33.1	33.1	33.1	33.1	32.4	32.4	32.4	32.4	32.4	31.8	31.8
58																														35.0	35.0	34.4	34.4	34.4	34.4	34.4	34.4	34.4	33.7	33.7	33.7	33.7	33.1	33.1
59																														36.3	35.7	35.7	35.7	35.7	35.7	35.7	35.0	35.0	35.0	35.0	35.0	34.4	34.4	34.4
60																															37.0	37.0	37.0	37.0	37.0	36.3	36.3	36.3	36.3	36.3	36.3	35.7	35.7	35.7
61																																38.3	38.3	38.3	37.6	37.6	37.6	37.6	37.6	37.6	37.0	37.0	37.0	37.0
62																																39.6	39.6	39.6	39.6	38.9	38.9	38.9	38.9	38.3	38.3	38.3	38.3	38.3

Table 8.7.1-9
Fuel Qualification Table for EOS-37PTH, 492kgU, HLZC2, Plan1&Plan2, Zone 2
(Minimum required years of cooling time after reactor core discharge)

BU (GWD/MTU)	Fuel Assembly Average Initial U-235 Enrichment (wt.%)																																											
	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5
6	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
7								3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
10								3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
16								3.6	3.6	3.6	3.6	3.6	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3
17												3.7	3.7	3.7	3.7	3.7	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
20												4.2	4.2	4.2	4.2	4.1	4.1	4.1	4.1	4.1	4.1	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9
25												5.2	5.2	5.1	5.1	5.1	5.1	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.7	4.7	4.7	4.7
28												5.9	5.9	5.8	5.8	5.8	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.6	5.6	5.6	5.6	5.5	5.5	5.5	5.5	5.5	5.4	5.4	5.4	5.4	5.4	5.4	5.3	5.3	5.3	5.3	5.3	5.3
30												6.6	6.6	6.5	6.5	6.4	6.4	6.3	6.3	6.3	6.3	6.2	6.2	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.0	6.0	6.0	6.0	5.9	5.9	5.9	5.9	5.9	5.8	5.8	5.8	5.8	5.8
31													7.0	6.9	6.8	6.8	6.7	6.7	6.6	6.6	6.6	6.6	6.5	6.5	6.5	6.4	6.4	6.4	6.3	6.3	6.3	6.3	6.3	6.3	6.2	6.2	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1
32														7.3	7.2	7.1	7.1	7.0	7.0	7.0	7.0	7.0	6.9	6.8	6.8	6.8	6.7	6.7	6.7	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.5	6.5	6.5	6.5	6.4	6.4	6.4	6.4
34															8.3	8.1	8.0	7.9	7.9	7.9	7.8	7.8	7.7	7.6	7.6	7.6	7.6	7.6	7.5	7.5	7.4	7.4	7.4	7.3	7.3	7.3	7.2	7.2	7.2	7.1	7.1	7.1	7.1	7.0
36																9.3	9.2	9.2	9.1	9.0	8.9	8.9	8.9	8.9	8.7	8.6	8.5	8.5	8.4	8.4	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.0	8.0	8.0	7.9	7.9
38																	10.9	10.9	10.9	10.5	10.4	10.3	10.2	10.2	10.2	10.2	9.9	9.8	9.7	9.7	9.7	9.6	9.6	9.6	9.6	9.6	9.6	9.2	9.2	9.2	9.2	9.2	9.1	9.1
39																		11.6	11.5	11.5	11.5	11.1	11.0	11.0	10.9	10.9	10.9	10.9	10.6	10.5	10.4	10.3	10.2	10.2	10.2	10.2	10.2	10.2	10.2	9.9	9.8	9.8	9.7	9.7
40																			12.8	12.8	12.3	12.2	12.2	12.2	12.2	11.7	11.6	11.5	11.5	11.5	11.5	11.5	11.1	11.0	11.0	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.5
41																			14.1	13.6	13.5	13.5	13.5	13.0	12.8	12.8	12.8	12.8	12.8	12.3	12.2	12.2	12.2	12.2	12.2	12.2	11.8	11.7	11.6	11.5	11.5	11.5	11.5	11.5
42																				14.8	14.8	14.8	14.8	14.1	14.1	14.1	14.1	14.1	13.5	13.5	13.5	13.5	13.5	13.5	12.9	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.3	12.3
43																				17.4	16.1	16.1	16.1	15.4	15.4	15.4	15.4	14.9	14.8	14.8	14.8	14.8	14.8	14.1	14.1	14.1	14.1	14.1	14.1	14.1	13.6	13.5	13.5	13.5
44																					18.1	17.4	17.4	16.8	16.8	16.8	16.8	16.1	16.1	16.1	16.1	16.1	15.4	15.4	15.4	15.4	15.4	15.4	15.4	14.8	14.8	14.8	14.8	14.8
45																						18.7	18.7	18.7	18.1	18.1	18.1	18.1	17.4	17.4	17.4	17.4	16.8	16.8	16.8	16.8	16.8	16.8	16.1	16.1	16.1	16.1	16.1	16.1
46																						20.7	20.0	20.0	19.4	19.4	19.4	19.4	18.7	18.7	18.7	18.7	18.7	18.1	18.1	18.1	18.1	18.1	17.4	17.4	17.4	17.4	17.4	17.4
47																							22.0	21.3	21.3	20.7	20.7	20.7	20.7	20.0	20.0	20.0	20.0	19.4	19.4	19.4	19.4	19.4	19.4	18.7	18.7	18.7	18.7	18.7
48																								22.6	22.6	22.0	22.0	22.0	22.0	21.3	21.3	21.3	21.3	21.3	20.7	20.7	20.7	20.7	20.7	20.0	20.0	20.0	20.0	20.0
49																								24.6	23.9	23.9	23.9	23.3	23.3	23.3	22.6	22.6	22.6	22.6	22.6	22.0	22.0	22.0	22.0	22.0	21.3	21.3	21.3	21.3
50																									25.2	25.2	24.6	24.6	24.6	24.6	24.6	23.9	23.9	23.9	23.9	23.9	23.3	23.3	23.3	23.3	22.6	22.6	22.6	22.6
51																									27.2	26.5	26.5	25.9	25.9	25.9	25.9	25.2	25.2	25.2	25.2	25.2	24.6	24.6	24.6	24.6	24.6	23.9	23.9	23.9
52																										27.9	27.9	27.2	27.2	27.2	27.2	26.5	26.5	26.5	26.5	26.5	25.9	25.9	25.9	25.9	25.9	25.2	25.2	25.2
53																											29.2	29.2	28.5	28.5	28.5	28.5	27.9	27.9	27.9	27.9	27.2	27.2	27.2	27.2	27.2	27.2	26.5	26.5
54																											30.5	29.8	29.8	29.8	29.8	29.8	29.2	29.2	29.2	29.2	29.2	29.2	28.5	28.5	28.5	28.5	27.9	27.9
55																												31.1	31.1	31.1	31.1	31.1	30.5	30.5	30.5	30.5	30.5	29.8	29.8	29.8	29.8	29.8	29.2	29.2
56																													32.4	32.4	32.4	32.4	31.8	31.8	31.8	31.8	31.8	31.1	31.1	31.1	31.1	31.1	30.5	30.5
57																													33.7	33.7	33.7	33.1	33.1	33.1	33.1	33.1	33.1	32.4	32.4	32.4	32.4	32.4	31.8	31.8
58																														35.0	35.0	34.4	34.4	34.4	34.4	34.4	34.4	34.4	33.7	33.7	33.7	33.7	33.1	33.1
59																														36.3	35.7	35.7	35.7	35.7	35.7	35.7	35.0	35.0	35.0	35.0	35.0	34.4	34.4	34.4
60																															37.0	37.0	37.0	37.0	37.0	36.3	36.3	36.3	36.3	36.3	36.3	35.7	35.7	35.7
61																																38.3	38.3	38.3	37.6	37.6	37.6	37.6	37.6	37.6	37.0	37.0	37.0	37.0
62																																39.6	39.6	39.6	39.6	38.9	38.9	38.9	38.9	38.3	38.3	38.3	38.3	38.3

Table 8.7.1-10
Fuel Qualification Table for EOS-37PTH, 492kgU, HLZC2, Plan1, Zone 3
(Minimum required years of cooling time after reactor core discharge)

BU (GWD/MTU)	Fuel Assembly Average Initial U-235 Enrichment (wt.%)																																										
	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5
6	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
7								3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
10								3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
16								3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
17												3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
20												3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
25												3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
28												3.1	3.1	3.1	3.1	3.1	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
30												3.3	3.3	3.3	3.3	3.3	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
31													3.4	3.4	3.4	3.4	3.3	3.3	3.3	3.3	3.3	3.3	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.0	3.0	3.0	3.0	3.0
32														3.5	3.5	3.5	3.4	3.4	3.4	3.4	3.4	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.1	3.1	3.1	3.1	3.1	3.1	3.1
34															3.7	3.6	3.6	3.6	3.6	3.6	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.4	3.4	3.4	3.4	3.4	3.4	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.2
36																3.8	3.8	3.8	3.8	3.7	3.7	3.7	3.7	3.7	3.7	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.4	3.4	3.4
38																	4.0	4.0	4.0	4.0	3.9	3.9	3.9	3.9	3.9	3.8	3.8	3.8	3.8	3.8	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.6	3.6	3.6	3.6	3.6	3.6	3.6
39																		4.1	4.1	4.1	4.0	4.0	4.0	4.0	4.0	3.9	3.9	3.9	3.9	3.9	3.9	3.8	3.8	3.8	3.8	3.8	3.8	3.7	3.7	3.7	3.7	3.7	3.7	3.7
40																			4.2	4.2	4.1	4.1	4.1	4.1	4.1	4.0	4.0	4.0	4.0	4.0	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.8	3.8	3.8	3.8	3.8	3.8	3.8
41																			4.3	4.3	4.3	4.2	4.2	4.2	4.2	4.1	4.1	4.1	4.1	4.1	4.1	4.0	4.0	4.0	4.0	4.0	4.0	3.9	3.9	3.9	3.9	3.9	3.9	3.9
42																				4.4	4.4	4.4	4.4	4.3	4.3	4.3	4.2	4.2	4.2	4.2	4.2	4.1	4.1	4.1	4.1	4.1	4.1	4.0	4.0	4.0	4.0	4.0	4.0	4.0
43																				4.5	4.5	4.5	4.5	4.4	4.4	4.4	4.4	4.4	4.3	4.3	4.3	4.3	4.2	4.2	4.2	4.2	4.2	4.1	4.1	4.1	4.1	4.1	4.1	4.1
44																					4.6	4.6	4.6	4.6	4.5	4.5	4.5	4.5	4.4	4.4	4.4	4.4	4.4	4.3	4.3	4.3	4.3	4.3	4.2	4.2	4.2	4.2	4.2	4.2
45																						4.8	4.7	4.7	4.7	4.6	4.6	4.6	4.6	4.5	4.5	4.5	4.5	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.3	4.3	4.3	4.3
46																						4.9	4.9	4.8	4.8	4.8	4.8	4.7	4.7	4.7	4.6	4.6	4.6	4.6	4.5	4.5	4.5	4.5	4.5	4.4	4.4	4.4	4.4	4.4
47																							5.0	5.0	4.9	4.9	4.9	4.8	4.8	4.8	4.8	4.8	4.7	4.7	4.7	4.6	4.6	4.6	4.6	4.6	4.5	4.5	4.5	4.5
48																								5.1	5.1	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.8	4.8	4.8	4.8	4.7	4.7	4.7	4.7	4.6	4.6	4.6
49																								5.3	5.2	5.2	5.2	5.2	5.1	5.1	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.8	4.8	4.8	4.8	4.8	4.8
50																									5.4	5.4	5.3	5.3	5.3	5.2	5.2	5.2	5.2	5.1	5.1	5.1	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9
51																									5.6	5.6	5.5	5.5	5.4	5.4	5.4	5.3	5.3	5.3	5.2	5.2	5.2	5.2	5.1	5.1	5.1	5.1	5.0	5.0
52																										5.7	5.7	5.7	5.6	5.6	5.5	5.5	5.5	5.4	5.4	5.4	5.3	5.3	5.3	5.2	5.2	5.2	5.2	5.2
53																											5.9	5.8	5.8	5.7	5.7	5.7	5.7	5.6	5.6	5.5	5.5	5.5	5.4	5.4	5.4	5.4	5.3	5.3
54																											6.1	6.1	6.0	6.0	5.9	5.8	5.8	5.8	5.7	5.7	5.7	5.7	5.6	5.6	5.6	5.5	5.5	5.5
55																												6.2	6.2	6.1	6.1	6.1	6.0	6.0	5.9	5.9	5.9	5.8	5.8	5.8	5.7	5.7	5.7	5.7
56																													6.4	6.4	6.3	6.3	6.2	6.2	6.1	6.1	6.1	6.1	6.0	6.0	5.9	5.9	5.8	5.8
57																													6.6	6.6	6.6	6.5	6.5	6.4	6.4	6.3	6.3	6.2	6.2	6.1	6.1	6.1	6.1	6.0
58																														6.9	6.8	6.7	6.7	6.6	6.6	6.6	6.5	6.5	6.4	6.4	6.3	6.3	6.2	6.2
59																														7.1	7.0	7.0	7.0	6.9	6.9	6.8	6.7	6.7	6.6	6.6	6.6	6.6	6.5	6.5
60																															7.4	7.3	7.2	7.2	7.1	7.0	7.0	7.0	6.9	6.9	6.8	6.7	6.7	6.6
61																																7.6	7.5	7.5	7.4	7.4	7.3	7.2	7.2	7.1	7.0	7.0	7.0	6.9
62																																7.9	7.9	7.8	7.7	7.6	7.6	7.5	7.5	7.4	7.4	7.3	7.2	7.2

Table 8.7.1-11
Fuel Qualification Table for EOS-37PTH, 492kgU, HLZC2, Plan1, Zone 4
(Minimum required years of cooling time after reactor core discharge)

BU (GWD/MTU)	Fuel Assembly Average Initial U-235 Enrichment (wt.%)																																											
	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5
6	3.2	3.2	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
7								3.3	3.3	3.3	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
10								3.9	3.8	3.8	3.8	3.8	3.8	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.5	3.5	3.5
16								4.8	4.8	4.8	4.7	4.7	4.7	4.7	4.6	4.6	4.6	4.6	4.5	4.5	4.5	4.5	4.5	4.5	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.2
17												4.9	4.8	4.8	4.8	4.7	4.7	4.7	4.7	4.7	4.6	4.6	4.6	4.6	4.6	4.6	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4
20												5.3	5.3	5.3	5.2	5.2	5.2	5.1	5.1	5.1	5.1	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.8	4.8	4.8	4.8	4.8	4.8	4.7	4.7	4.7	4.7	4.7	4.7
25												6.2	6.2	6.1	6.1	6.0	6.0	5.9	5.9	5.9	5.8	5.8	5.8	5.7	5.7	5.7	5.6	5.6	5.6	5.6	5.5	5.5	5.5	5.5	5.5	5.4	5.4	5.4	5.4	5.4	5.3	5.3	5.3	5.3
28												6.8	6.8	6.7	6.6	6.6	6.5	6.5	6.4	6.4	6.3	6.3	6.3	6.2	6.2	6.2	6.1	6.1	6.1	6.0	6.0	6.0	5.9	5.9	5.9	5.9	5.8	5.8	5.8	5.8	5.7	5.7	5.7	5.7
30												7.3	7.2	7.2	7.1	7.0	7.0	6.9	6.8	6.8	6.7	6.7	6.7	6.6	6.6	6.5	6.5	6.4	6.4	6.4	6.3	6.3	6.3	6.2	6.2	6.2	6.2	6.1	6.1	6.1	6.1	6.0	6.0	6.0
31													7.5	7.4	7.3	7.2	7.2	7.1	7.1	7.0	6.9	6.9	6.8	6.8	6.7	6.7	6.7	6.6	6.6	6.5	6.5	6.5	6.4	6.4	6.4	6.3	6.3	6.3	6.3	6.2	6.2	6.2	6.2	6.1
32														7.6	7.5	7.5	7.4	7.3	7.3	7.2	7.1	7.1	7.0	7.0	6.9	6.9	6.9	6.8	6.8	6.7	6.7	6.6	6.6	6.6	6.5	6.5	6.5	6.4	6.4	6.4	6.4	6.3	6.3	6.3
34															8.0	7.9	7.9	7.8	7.7	7.7	7.6	7.5	7.5	7.4	7.3	7.3	7.3	7.2	7.1	7.1	7.1	7.0	7.0	6.9	6.9	6.9	6.8	6.8	6.8	6.7	6.7	6.7	6.6	6.6
36																8.5	8.4	8.3	8.2	8.1	8.0	8.0	7.9	7.9	7.8	7.7	7.7	7.6	7.6	7.5	7.5	7.4	7.4	7.3	7.3	7.3	7.2	7.2	7.1	7.1	7.1	7.0	7.0	7.0
38																	8.9	8.8	8.7	8.6	8.6	8.5	8.4	8.3	8.3	8.2	8.1	8.1	8.0	8.0	7.9	7.8	7.8	7.7	7.7	7.7	7.6	7.6	7.5	7.5	7.4	7.4	7.4	7.3
39																		9.1	9.0	8.9	8.8	8.7	8.6	8.5	8.5	8.4	8.3	8.3	8.2	8.2	8.1	8.1	8.0	8.0	7.9	7.8	7.8	7.8	7.7	7.7	7.6	7.6	7.6	7.5
40																			9.3	9.2	9.1	9.0	8.9	8.8	8.7	8.7	8.6	8.5	8.5	8.4	8.3	8.3	8.2	8.2	8.1	8.1	8.0	8.0	7.9	7.9	7.8	7.8	7.8	7.7
41																			9.5	9.4	9.3	9.2	9.1	9.1	9.0	8.9	8.8	8.8	8.7	8.6	8.6	8.5	8.5	8.4	8.3	8.3	8.2	8.2	8.1	8.1	8.0	8.0	8.0	7.9
42																				9.7	9.6	9.5	9.4	9.3	9.3	9.2	9.1	9.0	9.0	8.9	8.8	8.7	8.7	8.6	8.6	8.5	8.5	8.4	8.4	8.3	8.3	8.2	8.2	8.1
43																				10.0	9.9	9.8	9.7	9.6	9.5	9.4	9.4	9.3	9.2	9.1	9.1	9.0	8.9	8.9	8.8	8.7	8.7	8.6	8.6	8.5	8.5	8.4	8.4	8.3
44																					10.2	10.1	10.0	9.9	9.8	9.7	9.6	9.5	9.5	9.4	9.3	9.3	9.2	9.1	9.1	9.0	8.9	8.9	8.8	8.8	8.7	8.7	8.6	8.6
45																						10.4	10.3	10.2	10.1	10.0	9.9	9.8	9.7	9.7	9.6	9.5	9.4	9.4	9.3	9.2	9.2	9.1	9.1	9.0	8.9	8.9	8.8	8.8
46																						10.7	10.6	10.5	10.4	10.3	10.2	10.1	10.0	9.9	9.9	9.8	9.7	9.6	9.6	9.5	9.4	9.4	9.3	9.2	9.2	9.1	9.1	9.0
47																							10.9	10.8	10.7	10.6	10.5	10.4	10.3	10.2	10.1	10.1	10.0	9.9	9.8	9.8	9.7	9.6	9.6	9.5	9.4	9.4	9.3	9.3
48																								11.1	11.0	10.9	10.8	10.7	10.6	10.5	10.4	10.3	10.3	10.2	10.1	10.0	9.9	9.9	9.8	9.8	9.7	9.6	9.6	9.5
49																								11.5	11.4	11.2	11.1	11.0	10.9	10.8	10.7	10.6	10.5	10.5	10.4	10.3	10.2	10.2	10.1	10.0	9.9	9.9	9.8	9.8
50																									11.7	11.6	11.4	11.4	11.2	11.1	11.0	10.9	10.8	10.7	10.7	10.6	10.5	10.4	10.4	10.3	10.2	10.1	10.1	10.0
51																									12.0	11.9	11.8	11.7	11.6	11.4	11.4	11.2	11.2	11.0	11.0	10.9	10.8	10.7	10.6	10.5	10.5	10.4	10.3	10.3
52																										12.3	12.1	12.0	11.9	11.8	11.7	11.5	11.4	11.4	11.2	11.2	11.1	11.0	10.9	10.8	10.7	10.7	10.6	10.6
53																											12.5	12.4	12.2	12.1	12.0	11.9	11.8	11.7	11.6	11.5	11.4	11.3	11.2	11.1	11.0	11.0	10.9	10.8
54																											12.9	12.7	12.6	12.5	12.3	12.2	12.1	12.0	11.9	11.8	11.7	11.6	11.5	11.4	11.3	11.3	11.2	11.1
55																												13.1	12.9	12.8	12.7	12.5	12.4	12.3	12.2	12.1	12.0	11.9	11.8	11.7	11.6	11.5	11.4	11.4
56																													13.3	13.1	13.1	12.9	12.8	12.6	12.5	12.4	12.3	12.2	12.1	12.0	11.9	11.9	11.8	11.7
57																													13.7	13.5	13.4	13.3	13.1	13.0	12.9	12.8	12.7	12.6	12.4	12.3	12.3	12.1	12.1	12.0
58																														13.9	13.8	13.7	13.5	13.4	13.2	13.1	13.0	12.9	12.8	12.7	12.6	12.5	12.4	12.3
59																														14.3	14.2	14.0	13.9	13.8	13.6	13.5	13.4	13.2	13.1	13.0	12.9	12.8	12.7	12.6
60																															14.6	14.4	14.3	14.1	14.0	13.8	13.7	13.6	13.5	13.4	13.2	13.2	13.0	12.9
61																																14.8	14.7	14.5	14.4	14.2	14.1	14.0	13.8	13.7	13.6	13.5	13.4	13.3
62																																15.3	15.1	14.9	14.7	14.6	14.4	14.3	14.2	14.1	13.9	13.8	13.7	13.6

Table 8.7.1-12
Fuel Qualification Table for EOS-37PTH, 492kgU, HLZC2, Plan1, Zone 5
(Minimum required years of cooling time after reactor core discharge)

BU (GWD/MTU)	Fuel Assembly Average Initial U-235 Enrichment (wt.%)																																											
	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5
6	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
7								3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
10								3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
16								3.5	3.5	3.5	3.4	3.4	3.4	3.4	3.4	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.1	3.1	3.1	3.1
17												3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3
20												4.0	4.0	4.0	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7
25												4.9	4.8	4.8	4.8	4.8	4.8	4.8	4.7	4.7	4.7	4.7	4.7	4.6	4.6	4.6	4.6	4.6	4.6	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.4	4.4	4.4	4.4	4.4	4.4	4.4
28												5.5	5.5	5.5	5.4	5.4	5.4	5.3	5.3	5.3	5.3	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.1	5.1	5.1	5.1	5.1	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9
30												6.1	6.1	6.0	6.0	5.9	5.9	5.9	5.8	5.8	5.8	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.6	5.6	5.6	5.6	5.5	5.5	5.5	5.5	5.5	5.4	5.4	5.4	5.4	5.4	5.4	5.3
31													6.3	6.3	6.3	6.2	6.1	6.1	6.1	6.1	6.1	6.0	6.0	6.0	5.9	5.9	5.9	5.9	5.8	5.8	5.8	5.8	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.6	5.6
32														6.6	6.6	6.6	6.5	6.5	6.4	6.4	6.3	6.3	6.3	6.2	6.2	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.0	6.0	6.0	6.0	6.0	5.9	5.9	5.9	5.9	5.9	5.8	5.8
34															7.3	7.3	7.2	7.1	7.1	7.0	7.0	7.0	7.0	7.0	6.9	6.8	6.8	6.8	6.7	6.7	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.5	6.5	6.5	6.5	6.4	6.4	6.4
36																8.3	8.1	8.0	7.9	7.9	7.9	7.8	7.8	7.7	7.6	7.6	7.6	7.6	7.5	7.5	7.5	7.4	7.4	7.3	7.3	7.3	7.2	7.2	7.2	7.1	7.1	7.1	7.0	7.0
38																	9.3	9.2	9.1	9.0	8.9	8.9	8.9	8.9	8.7	8.6	8.5	8.5	8.4	8.4	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.1	8.0	8.0	7.9	7.9	7.9	7.9
39																		9.9	9.8	9.7	9.6	9.6	9.6	9.6	9.2	9.2	9.2	9.1	9.0	8.9	8.9	8.9	8.9	8.9	8.7	8.7	8.6	8.6	8.5	8.5	8.5	8.4	8.4	8.3
40																			10.6	10.5	10.4	10.2	10.2	10.2	10.2	9.9	9.8	9.7	9.7	9.6	9.6	9.6	9.6	9.6	9.3	9.2	9.2	9.2	9.2	9.1	9.1	9.0	9.0	8.9
41																			11.5	11.5	11.5	11.0	11.0	10.9	10.9	10.9	10.9	10.5	10.4	10.3	10.2	10.2	10.2	10.2	10.2	9.9	9.9	9.8	9.7	9.7	9.7	9.7	9.6	9.6
42																				12.3	12.2	12.2	12.2	11.8	11.6	11.5	11.5	11.5	11.5	11.1	11.0	11.0	10.9	10.9	10.9	10.9	10.9	10.9	10.5	10.5	10.4	10.3	10.3	10.2
43																				14.1	13.5	13.1	12.9	12.8	12.8	12.8	12.4	12.3	12.2	12.2	12.2	12.2	11.8	11.7	11.6	11.5	11.5	11.5	11.5	11.5	11.5	11.1	11.0	11.0
44																					14.8	14.1	14.1	14.1	14.1	13.6	13.5	13.5	13.5	13.5	13.0	12.8	12.8	12.8	12.8	12.8	12.4	12.3	12.3	12.2	12.2	12.2	12.2	12.2
45																						15.4	15.4	15.4	14.9	14.8	14.8	14.8	14.8	14.1	14.1	14.1	14.1	14.1	13.7	13.5	13.5	13.5	13.5	13.5	13.5	13.0	12.9	12.8
46																						16.8	16.8	16.8	16.1	16.1	16.1	16.1	15.5	15.4	15.4	15.4	15.4	14.9	14.8	14.8	14.8	14.8	14.8	14.2	14.1	14.1	14.1	14.1
47																							18.1	18.1	17.4	17.4	17.4	17.4	16.8	16.8	16.8	16.8	16.8	16.1	16.1	16.1	16.1	16.1	15.4	15.4	15.4	15.4	15.4	15.4
48																								19.4	18.7	18.7	18.7	18.7	18.1	18.1	18.1	18.1	17.5	17.4	17.4	17.4	17.4	17.4	16.8	16.8	16.8	16.8	16.8	16.8
49																								20.7	20.0	20.0	20.0	20.0	19.4	19.4	19.4	19.4	18.7	18.7	18.7	18.7	18.7	18.1	18.1	18.1	18.1	18.1	18.1	17.4
50																									22.0	21.3	21.3	21.3	20.7	20.7	20.7	20.7	20.7	20.0	20.0	20.0	20.0	19.4	19.4	19.4	19.4	19.4	19.4	18.7
51																									23.3	22.6	22.6	22.6	22.0	22.0	22.0	22.0	22.0	21.3	21.3	21.3	21.3	20.7	20.7	20.7	20.7	20.7	20.0	20.0
52																										23.9	23.9	23.9	23.9	23.3	23.3	23.3	23.3	22.6	22.6	22.6	22.6	22.0	22.0	22.0	22.0	22.0	21.3	21.3
53																											25.2	25.2	25.2	24.6	24.6	24.6	24.6	23.9	23.9	23.9	23.9	23.9	23.3	23.3	23.3	23.3	22.6	22.6
54																											26.5	26.5	25.9	25.9	25.9	25.9	25.9	25.2	25.2	25.2	25.2	24.6	24.6	24.6	24.6	24.6	23.9	23.9
55																												27.9	27.2	27.2	27.2	27.2	27.2	26.5	26.5	26.5	26.5	25.9	25.9	25.9	25.9	25.9	25.2	25.2
56																													28.5	28.5	28.5	28.5	27.9	27.9	27.9	27.9	27.9	27.2	27.2	27.2	27.2	27.2	26.5	26.5
57																													29.8	29.8	29.8	29.8	29.2	29.2	29.2	29.2	29.2	28.5	28.5	28.5	28.5	28.5	27.9	27.9
58																														31.1	31.1	30.5	30.5	30.5	30.5	30.5	29.8	29.8	29.8	29.8	29.8	29.2	29.2	29.2
59																														32.4	32.4	31.8	31.8	31.8	31.8	31.8	31.1	31.1	31.1	31.1	31.1	30.5	30.5	30.5
60																															33.1	33.1	33.1	33.1	33.1	32.4	32.4	32.4	32.4	32.4	31.8	31.8	31.8	31.8
61																																34.4	34.4	34.4	34.4	33.7	33.7	33.7	33.7	33.1	33.1	33.1	33.1	33.1
62																																35.7	35.0	35.0	35.0	35.0	35.0	35.0	34.4	34.4	34.4	34.4	34.4	34.4

Table 8.7.1-13
Fuel Qualification Table for EOS-37PTH, 492kgU, HLZC2, Plan1, Zone 6
(Minimum required years of cooling time after reactor core discharge)

BU (GWD/MTU)	Fuel Assembly Average Initial U-235 Enrichment (wt.%)																																										
	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5
6	4.9	4.9	4.8	4.8	4.8	4.7	4.7	4.7	4.6	4.6	4.6	4.6	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3
7								5.0	4.9	4.9	4.9	4.8	4.8	4.8	4.8	4.8	4.8	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.5	4.5	4.5	4.5	4.5	4.5
10								5.8	5.8	5.7	5.7	5.7	5.7	5.6	5.6	5.5	5.5	5.5	5.5	5.4	5.4	5.4	5.4	5.4	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.1	5.1
16								8.0	7.9	7.8	7.7	7.6	7.5	7.4	7.4	7.3	7.2	7.2	7.1	7.1	7.0	7.0	6.9	6.9	6.9	6.8	6.8	6.7	6.7	6.7	6.6	6.6	6.6	6.6	6.5	6.5	6.5	6.5	6.4	6.4	6.4	6.4	6.4	6.3
17												8.0	7.9	7.8	7.8	7.6	7.6	7.5	7.4	7.4	7.3	7.3	7.2	7.2	7.1	7.1	7.1	7.0	7.0	6.9	6.9	6.9	6.8	6.8	6.8	6.8	6.7	6.7	6.7	6.7	6.6	6.6	6.6	6.6
20												9.3	9.2	9.1	8.9	8.8	8.8	8.6	8.6	8.5	8.4	8.4	8.2	8.2	8.2	8.1	8.0	8.0	7.9	7.9	7.8	7.7	7.7	7.7	7.6	7.6	7.6	7.5	7.5	7.5	7.5	7.4	7.4	7.3
25												12.3	12.1	11.9	11.7	11.6	11.4	11.2	11.0	11.0	10.8	10.6	10.6	10.4	10.4	10.3	10.1	10.1	10.0	9.9	9.8	9.7	9.7	9.5	9.5	9.4	9.4	9.3	9.2	9.2	9.2	9.1	9.1	9.0
28												14.6	14.2	14.0	13.8	13.6	13.4	13.0	12.9	12.7	12.6	12.5	12.3	12.1	12.0	11.9	11.7	11.6	11.5	11.3	11.2	11.2	11.0	11.0	10.9	10.8	10.8	10.6	10.6	10.5	10.4	10.4	10.3	10.3
30												16.3	16.1	15.8	15.4	15.2	14.8	14.6	14.3	14.1	13.9	13.7	13.5	13.5	13.3	13.0	13.0	12.8	12.7	12.5	12.5	12.3	12.2	12.1	11.9	11.9	11.7	11.7	11.6	11.5	11.4	11.4	11.2	11.2
31													16.8	16.5	16.2	15.9	15.6	15.4	15.0	14.9	14.6	14.5	14.2	14.1	13.9	13.7	13.5	13.3	13.3	13.1	13.0	12.9	12.7	12.7	12.5	12.4	12.4	12.2	12.1	12.0	11.9	11.8	11.7	11.7
32														17.4	17.1	16.7	16.4	16.2	15.9	15.5	15.4	15.2	14.9	14.8	14.5	14.3	14.1	14.1	13.9	13.7	13.7	13.5	13.3	13.1	13.1	13.0	12.9	12.8	12.7	12.5	12.5	12.3	12.3	12.2
34															18.9	18.5	18.3	17.9	17.7	17.2	16.9	16.7	16.5	16.2	15.9	15.7	15.7	15.5	15.2	15.0	14.9	14.8	14.5	14.5	14.3	14.1	14.0	13.9	13.8	13.6	13.6	13.4	13.4	13.4
36																20.4	20.1	19.8	19.4	19.1	18.6	18.3	18.2	18.0	17.6	17.3	17.0	16.8	16.6	16.5	16.3	16.1	16.0	15.8	15.6	15.5	15.3	15.1	15.1	14.8	14.8	14.6	14.5	14.4
38																	22.0	21.5	21.4	20.8	20.6	20.2	19.8	19.5	19.4	18.9	18.8	18.5	18.2	17.9	17.8	17.5	17.4	17.1	16.9	16.8	16.6	16.5	16.2	16.2	16.0	15.9	15.9	15.6
39																		22.4	22.0	21.6	21.4	21.0	20.6	20.2	20.0	19.7	19.3	19.2	19.0	18.7	18.4	18.1	18.0	17.7	17.6	17.5	17.2	17.0	17.0	16.9	16.6	16.6	16.3	16.3
40																			23.1	22.7	22.2	21.8	21.4	21.1	21.0	20.7	20.4	20.1	19.6	19.5	19.1	19.1	18.7	18.5	18.3	18.3	18.0	17.7	17.7	17.4	17.3	17.1	17.0	16.8
41																			24.1	23.6	23.2	22.8	22.6	22.2	21.8	21.4	21.0	20.9	20.6	20.3	20.2	19.8	19.5	19.4	19.1	18.9	18.6	18.6	18.3	18.3	18.0	18.0	17.7	17.5
42																				24.6	24.1	24.0	23.6	22.9	22.7	22.3	22.2	21.8	21.4	21.3	20.9	20.5	20.5	20.2	19.8	19.8	19.5	19.2	19.1	19.0	18.7	18.6	18.3	18.4
43																				25.9	25.2	24.7	24.6	24.1	23.6	23.2	23.0	22.7	22.3	22.0	21.8	21.4	21.4	20.9	20.9	20.6	20.2	20.2	19.8	19.8	19.5	19.3	19.2	18.9
44																					26.2	25.8	25.6	25.2	24.7	24.2	23.9	23.5	23.3	22.9	22.6	22.3	22.0	21.8	21.4	21.4	21.2	20.9	20.5	20.6	20.2	20.2	19.8	19.8
45																						26.8	26.3	26.2	25.5	25.2	24.8	24.7	24.2	23.8	23.4	23.3	22.9	22.5	22.3	22.1	22.0	21.6	21.3	21.3	20.9	20.8	20.5	20.5
46																						27.9	27.4	27.2	26.7	26.2	25.8	25.6	25.2	24.7	24.4	24.2	23.8	23.4	23.3	22.9	22.9	22.5	22.2	21.9	21.7	21.7	21.4	21.1
47																							28.5	28.3	27.8	27.2	26.8	26.4	26.2	25.7	25.3	25.2	24.7	24.3	24.2	23.8	23.8	23.3	23.0	22.9	22.6	22.5	22.1	22.1
48																								29.0	28.7	28.2	27.9	27.4	26.9	26.7	26.2	26.1	25.5	25.3	25.1	24.7	24.3	24.2	23.8	23.8	23.4	23.3	22.9	22.9
49																								30.1	29.9	29.4	28.8	28.4	27.9	27.8	27.3	26.9	26.5	26.2	25.9	25.6	25.2	25.2	24.7	24.7	24.2	23.9	23.8	23.4
50																									31.0	30.5	29.9	29.5	29.0	28.4	28.3	27.8	27.4	27.3	26.8	26.4	26.4	25.9	25.6	25.5	25.1	24.8	24.7	24.3
51																									31.7	31.6	31.0	30.5	30.0	29.5	29.4	28.8	28.4	28.3	27.8	27.4	27.0	26.8	26.4	26.4	25.9	25.6	25.5	25.1
52																										32.4	31.9	31.4	31.1	30.5	30.4	29.9	29.4	29.0	28.8	28.3	27.9	27.8	27.3	27.3	26.8	26.5	26.4	26.0
53																											33.3	32.7	32.2	31.6	31.1	30.8	30.6	30.1	29.8	29.3	29.2	28.7	28.3	27.9	27.8	27.3	27.3	26.8
54																											34.0	33.5	33.3	32.7	32.2	31.8	31.6	31.1	30.6	30.2	30.1	29.6	29.2	28.8	28.6	28.3	28.0	27.9
55																												34.6	34.0	33.9	33.3	32.7	32.4	32.1	31.6	31.1	31.1	30.6	30.1	29.7	29.6	29.2	28.7	28.6
56																													35.1	34.6	34.5	33.9	33.4	32.9	32.7	32.2	31.7	31.6	31.1	30.7	30.6	30.1	29.7	29.6
57																													36.2	35.6	35.5	34.9	34.4	33.9	33.7	33.2	32.7	32.7	32.1	31.6	31.3	31.1	30.6	30.2
58																														36.7	36.6	36.1	35.5	34.9	34.4	34.4	33.7	33.2	33.1	32.5	32.4	31.8	31.8	31.2
59																														37.9	37.3	36.9	36.3	36.1	35.5	35.0	34.9	34.4	33.9	33.7	33.1	33.1	32.4	32.4
60																															38.5	37.9	37.4	36.8	36.7	36.1	35.7	35.5	34.9	34.4	34.1	33.7	33.3	33.1
61																																38.9	38.4	37.9	37.6	37.3	36.7	36.2	35.7	35.5	35.0	34.5	34.4	33.9
62																																39.8	39.6	38.9	38.4	38.3	37.6	37.2	37.0	36.3	36.0	35.7	35.3	35.0

Table 8.7.1-14
Fuel Qualification Table for EOS-37PTH, 492kgU, HLZC2, Plan2, Zone 3
(Minimum required years of cooling time after reactor core discharge)

BU (GWD/MTU)	Fuel Assembly Average Initial U-235 Enrichment (wt.%)																																											
	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5
6	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
7								3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
10								3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
16								3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
17												3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
20												3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
25												3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
28												3.1	3.1	3.1	3.1	3.1	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
30												3.3	3.3	3.3	3.3	3.3	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
31													3.4	3.4	3.4	3.4	3.3	3.3	3.3	3.3	3.3	3.3	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.0	3.0	3.0	3.0	3.0
32														3.5	3.5	3.5	3.4	3.4	3.4	3.4	3.4	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.1	3.1	3.1	3.1	3.1	3.1	3.1
34															3.7	3.6	3.6	3.6	3.6	3.6	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.2
36																3.8	3.8	3.8	3.8	3.7	3.7	3.7	3.7	3.7	3.7	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.4	3.4	3.4
38																	4.0	4.0	4.0	4.0	3.9	3.9	3.9	3.9	3.9	3.8	3.8	3.8	3.8	3.8	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.6	3.6	3.6	3.6	3.6	3.6
39																		4.1	4.1	4.1	4.0	4.0	4.0	4.0	4.0	3.9	3.9	3.9	3.9	3.9	3.9	3.8	3.8	3.8	3.8	3.8	3.8	3.7	3.7	3.7	3.7	3.7	3.7	3.7
40																			4.2	4.2	4.1	4.1	4.1	4.1	4.1	4.0	4.0	4.0	4.0	4.0	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.8	3.8	3.8	3.8	3.8	3.8	3.8
41																			4.3	4.3	4.3	4.2	4.2	4.2	4.2	4.1	4.1	4.1	4.1	4.1	4.1	4.0	4.0	4.0	4.0	4.0	4.0	3.9	3.9	3.9	3.9	3.9	3.9	3.9
42																				4.4	4.4	4.4	4.4	4.3	4.3	4.3	4.2	4.2	4.2	4.2	4.2	4.1	4.1	4.1	4.1	4.1	4.1	4.0	4.0	4.0	4.0	4.0	4.0	4.0
43																				4.5	4.5	4.5	4.5	4.4	4.4	4.4	4.4	4.4	4.3	4.3	4.3	4.3	4.2	4.2	4.2	4.2	4.2	4.1	4.1	4.1	4.1	4.1	4.1	4.1
44																					4.6	4.6	4.6	4.6	4.5	4.5	4.5	4.5	4.4	4.4	4.4	4.4	4.4	4.3	4.3	4.3	4.3	4.3	4.2	4.2	4.2	4.2	4.2	4.2
45																						4.8	4.7	4.7	4.7	4.6	4.6	4.6	4.6	4.5	4.5	4.5	4.5	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.3	4.3	4.3	4.3
46																						5.5	4.9	4.8	4.8	4.8	4.8	4.7	4.7	4.7	4.6	4.6	4.6	4.6	4.5	4.5	4.5	4.5	4.5	4.4	4.4	4.4	4.4	4.4
47																							5.7	5.6	4.9	4.9	4.9	4.8	4.8	4.8	4.8	4.8	4.7	4.7	4.7	4.6	4.6	4.6	4.6	4.6	4.5	4.5	4.5	4.5
48																								5.8	5.3	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.8	4.8	4.8	4.8	4.7	4.7	4.7	4.7	4.6	4.6	4.6
49																								6.9	6.4	5.9	5.2	5.2	5.1	5.1	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.8	4.8	4.8	4.8	4.8	4.8
50																									7.3	6.9	6.4	5.6	5.3	5.2	5.2	5.2	5.2	5.1	5.1	5.1	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9
51																									8.3	7.4	7.1	6.4	6.2	5.5	5.4	5.3	5.3	5.3	5.2	5.2	5.2	5.2	5.1	5.1	5.1	5.1	5.0	5.0
52																										8.3	7.5	7.0	7.3	6.4	6.3	5.5	5.5	5.4	5.4	5.4	5.3	5.3	5.3	5.2	5.2	5.2	5.2	5.2
53																											9.3	8.7	8.1	7.5	7.1	6.5	6.3	5.6	5.6	5.5	5.5	5.5	5.4	5.4	5.4	5.4	5.3	5.3
54																											10.0	9.5	9.3	8.2	8.1	7.6	7.1	6.1	5.8	5.7	5.7	5.7	5.6	5.6	5.6	5.5	5.5	5.5
55																												10.7	9.6	9.5	9.0	8.2	7.9	7.2	6.8	6.1	5.9	5.8	5.8	5.8	5.7	5.7	5.7	5.7
56																													11.3	10.5	10.6	9.4	9.3	8.1	7.2	7.0	7.1	6.2	6.0	6.0	5.9	5.9	5.8	5.8
57																													12.2	11.9	12.0	11.1	10.3	9.1	9.0	8.3	7.6	7.2	7.1	6.1	6.1	6.1	6.1	6.0
58																														12.8	12.5	12.2	10.6	10.5	10.3	9.1	8.5	7.9	7.4	6.9	7.2	6.3	6.2	6.2
59																														15.4	13.5	13.6	12.5	11.9	10.6	10.4	10.3	9.1	9.0	7.9	7.9	7.0	6.6	6.5
60																															15.6	15.3	13.8	13.4	11.8	11.5	10.7	10.7	10.3	9.1	9.0	8.7	7.9	7.6
61																																15.1	14.5	13.6	13.4	13.4	11.7	11.6	11.3	10.0	9.9	8.7	9.3	7.9
62																																17.5	17.1	15.0	14.6	14.6	14.3	13.4	11.7	11.5	11.4	10.0	9.9	9.8

Table 8.7.1-15
Fuel Qualification Table for EOS-37PTH, 492kgU, HLZC2, Plan2, Zone 4
(Minimum required years of cooling time after reactor core discharge)

BU (GWD/MTU)	Fuel Assembly Average Initial U-235 Enrichment (wt.%)																																										
	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5
6	3.2	3.2	3.2	3.2	3.2	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
7								3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
10								3.9	3.9	3.9	3.9	3.8	3.8	3.8	3.8	3.8	3.8	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
16								4.9	4.9	4.9	4.8	4.8	4.8	4.7	4.7	4.7	4.7	4.6	4.6	4.6	4.6	4.6	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.3	4.3	4.3	4.3	4.3
17												4.9	4.9	4.9	4.9	4.8	4.8	4.8	4.8	4.7	4.7	4.7	4.7	4.7	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.4	4.4	4.4
20												5.4	5.4	5.4	5.3	5.3	5.2	5.2	5.2	5.2	5.1	5.1	5.1	5.1	5.1	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.8	4.8	4.8	4.8	4.8	4.8	4.8
25												6.3	6.3	6.2	6.2	6.1	6.1	6.1	6.0	6.0	5.9	5.9	5.9	5.8	5.8	5.8	5.7	5.7	5.7	5.7	5.6	5.6	5.6	5.6	5.5	5.5	5.5	5.5	5.5	5.5	5.4	5.4	5.4	5.4
28												7.0	6.9	6.9	6.8	6.7	6.7	6.6	6.6	6.5	6.5	6.4	6.4	6.3	6.3	6.3	6.2	6.2	6.2	6.1	6.1	6.1	6.1	6.0	6.0	6.0	6.0	5.9	5.9	5.9	5.9	5.8	5.8	5.8
30												7.5	7.4	7.3	7.2	7.2	7.1	7.1	7.0	6.9	6.9	6.8	6.8	6.7	6.7	6.7	6.6	6.6	6.5	6.5	6.5	6.4	6.4	6.4	6.3	6.3	6.3	6.2	6.2	6.2	6.2	6.1	6.1	6.1
31													7.6	7.6	7.5	7.4	7.3	7.3	7.2	7.2	7.1	7.0	7.0	6.9	6.9	6.8	6.8	6.8	6.7	6.7	6.6	6.6	6.6	6.5	6.5	6.5	6.4	6.4	6.4	6.4	6.3	6.3	6.3	6.3
32														7.8	7.7	7.6	7.6	7.5	7.4	7.4	7.3	7.2	7.2	7.1	7.1	7.0	7.0	7.0	6.9	6.9	6.8	6.8	6.8	6.7	6.7	6.6	6.6	6.6	6.5	6.5	6.5	6.5	6.4	6.4
34															8.2	8.1	8.1	8.0	7.9	7.8	7.8	7.7	7.6	7.6	7.5	7.5	7.4	7.4	7.3	7.3	7.2	7.2	7.1	7.1	7.1	7.0	7.0	6.9	6.9	6.9	6.8	6.8	6.8	6.8
36																8.7	8.6	8.5	8.4	8.3	8.2	8.2	8.1	8.0	8.0	7.9	7.9	7.8	7.7	7.7	7.6	7.6	7.5	7.5	7.5	7.4	7.4	7.3	7.3	7.3	7.2	7.2	7.2	7.1
38																	9.2	9.0	9.0	8.9	8.8	8.7	8.6	8.5	8.5	8.4	8.3	8.3	8.2	8.2	8.1	8.0	8.0	7.9	7.9	7.8	7.8	7.8	7.7	7.7	7.6	7.6	7.5	7.5
39																		9.3	9.2	9.1	9.0	8.9	8.9	8.8	8.7	8.6	8.6	8.5	8.4	8.4	8.3	8.2	8.2	8.1	8.1	8.0	8.0	7.9	7.9	7.9	7.8	7.8	7.7	7.7
40																			9.5	9.4	9.3	9.2	9.1	9.0	9.0	8.9	8.8	8.7	8.7	8.6	8.5	8.5	8.4	8.4	8.3	8.3	8.2	8.2	8.1	8.1	8.0	8.0	7.9	7.9
41																			9.8	9.7	9.6	9.5	9.4	9.3	9.2	9.1	9.1	9.0	8.9	8.9	8.8	8.7	8.7	8.6	8.5	8.5	8.4	8.4	8.3	8.3	8.2	8.2	8.2	8.1
42																				10.0	9.9	9.8	9.7	9.6	9.5	9.4	9.3	9.3	9.2	9.1	9.1	9.0	8.9	8.9	8.8	8.7	8.7	8.6	8.6	8.5	8.5	8.4	8.4	8.3
43																				10.3	10.2	10.1	10.0	9.9	9.8	9.7	9.6	9.5	9.5	9.4	9.3	9.2	9.2	9.1	9.0	9.0	8.9	8.9	8.8	8.8	8.7	8.7	8.6	8.6
44																					10.5	10.4	10.3	10.2	10.1	10.0	9.9	9.8	9.7	9.7	9.6	9.5	9.4	9.4	9.3	9.2	9.2	9.1	9.0	9.0	8.9	8.9	8.9	8.8
45																						10.7	10.6	10.5	10.4	10.3	10.2	10.1	10.0	10.0	9.8	9.8	9.7	9.6	9.6	9.5	9.4	9.4	9.3	9.3	9.2	9.1	9.1	9.0
46																						11.1	10.9	10.8	10.7	10.6	10.5	10.4	10.3	10.2	10.2	10.0	10.0	9.9	9.8	9.7	9.7	9.6	9.6	9.5	9.4	9.4	9.3	9.3
47																							11.3	11.2	11.0	10.9	10.8	10.7	10.6	10.5	10.4	10.3	10.3	10.2	10.1	10.0	10.0	9.9	9.8	9.8	9.7	9.6	9.6	9.5
48																								11.5	11.4	11.3	11.1	11.0	10.9	10.8	10.7	10.6	10.5	10.5	10.4	10.3	10.2	10.2	10.1	10.0	9.9	9.9	9.8	9.8
49																								11.8	11.7	11.6	11.5	11.4	11.2	11.1	11.1	10.9	10.8	10.8	10.7	10.6	10.5	10.4	10.4	10.3	10.2	10.1	10.1	10.0
50																									12.1	11.9	11.8	11.7	11.6	11.4	11.4	11.2	11.2	11.0	11.0	10.9	10.8	10.7	10.7	10.6	10.5	10.4	10.4	10.3
51																									12.4	12.3	12.2	12.0	11.9	11.8	11.7	11.6	11.5	11.4	11.3	11.2	11.1	11.0	10.9	10.9	10.8	10.7	10.6	10.6
52																										12.7	12.5	12.4	12.3	12.1	12.0	11.9	11.8	11.7	11.6	11.5	11.4	11.3	11.2	11.2	11.1	11.0	10.9	10.8
53																											12.9	12.7	12.6	12.5	12.4	12.3	12.1	12.1	11.9	11.8	11.7	11.7	11.5	11.4	11.4	11.3	11.2	11.1
54																											13.3	13.1	13.0	12.9	12.7	12.6	12.5	12.4	12.2	12.1	12.0	11.9	11.9	11.8	11.7	11.6	11.5	11.4
55																												13.5	13.4	13.2	13.1	12.9	12.9	12.7	12.6	12.5	12.4	12.3	12.2	12.1	12.0	11.9	11.8	11.7
56																													13.7	13.6	13.5	13.3	13.2	13.1	12.9	12.8	12.7	12.6	12.5	12.4	12.3	12.2	12.1	12.1
57																													14.2	14.0	13.9	13.7	13.5	13.4	13.3	13.2	13.1	13.0	12.8	12.7	12.6	12.5	12.5	12.3
58																														14.4	14.3	14.1	13.9	13.8	13.7	13.6	13.4	13.3	13.2	13.1	13.0	12.9	12.8	12.7
59																														14.8	14.6	14.5	14.3	14.2	14.0	13.9	13.8	13.7	13.6	13.4	13.3	13.2	13.1	13.0
60																															15.0	14.9	14.7	14.6	14.4	14.3	14.2	14.0	13.9	13.8	13.7	13.6	13.4	13.3
61																																15.3	15.2	15.0	14.8	14.7	14.5	14.4	14.3	14.2	14.0	13.9	13.8	13.7
62																																15.7	15.6	15.4	15.2	15.1	14.9	14.8	14.7	14.5	14.4	14.3	14.2	14.0

Table 8.7.1-16
Fuel Qualification Table for EOS-37PTH, 492kgU, HLZC2, Plan2, Zone 5
(Minimum required years of cooling time after reactor core discharge)

BU (GWD/MTU)	Fuel Assembly Average Initial U-235 Enrichment (wt.%)																																											
	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5
6	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
7								3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
10								3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
16								3.5	3.5	3.5	3.4	3.4	3.4	3.4	3.4	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.1	3.1	3.1	3.1
17												3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3
20												4.0	4.0	4.0	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7
25												4.9	4.8	4.8	4.8	4.8	4.8	4.8	4.7	4.7	4.7	4.7	4.7	4.6	4.6	4.6	4.6	4.6	4.6	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.4	4.4	4.4	4.4	4.4	4.4	4.4
28												5.5	5.5	5.5	5.4	5.4	5.4	5.3	5.3	5.3	5.3	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.1	5.1	5.1	5.1	5.1	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9
30												6.2	6.1	6.0	6.0	5.9	5.9	5.9	5.8	5.8	5.8	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.6	5.6	5.6	5.6	5.5	5.5	5.5	5.5	5.5	5.4	5.4	5.4	5.4	5.4	5.4	5.3
31													6.5	6.3	6.3	6.2	6.1	6.1	6.1	6.1	6.1	6.0	6.0	6.0	5.9	5.9	5.9	5.9	5.8	5.8	5.8	5.8	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.6	5.6
32														6.9	6.6	6.6	6.5	6.5	6.4	6.4	6.3	6.3	6.3	6.2	6.2	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.0	6.0	6.0	6.0	6.0	5.9	5.9	5.9	5.9	5.9	5.8	5.8
34															8.6	7.7	7.3	7.1	7.1	7.0	7.0	7.0	7.0	7.0	6.9	6.8	6.8	6.8	6.7	6.7	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.5	6.5	6.5	6.5	6.4	6.4	6.4
36																10.2	9.4	9.4	8.2	7.9	7.9	7.8	7.8	7.7	7.6	7.6	7.6	7.6	7.5	7.5	7.5	7.4	7.4	7.3	7.3	7.3	7.2	7.2	7.2	7.1	7.1	7.1	7.0	7.0
38																	12.6	12.4	10.9	10.0	9.6	8.9	8.9	8.9	8.7	8.6	8.5	8.5	8.4	8.4	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.1	8.0	8.0	7.9	7.9	7.9	7.9
39																		13.3	12.1	11.6	10.9	10.2	9.6	9.6	9.2	9.2	9.2	9.1	9.0	8.9	8.9	8.9	8.9	8.9	8.7	8.7	8.6	8.6	8.5	8.5	8.5	8.4	8.4	8.3
40																			14.3	12.9	12.3	11.5	10.9	10.2	10.2	9.9	9.8	9.7	9.7	9.6	9.6	9.6	9.6	9.6	9.3	9.2	9.2	9.2	9.2	9.1	9.1	9.0	9.0	8.9
41																			15.4	15.3	13.5	13.1	11.9	11.5	10.9	10.9	10.9	10.5	10.4	10.3	10.2	10.2	10.2	10.2	10.2	9.9	9.9	9.8	9.7	9.7	9.7	9.7	9.6	9.6
42																				16.9	15.4	15.3	13.7	12.6	11.9	11.5	11.5	11.5	11.5	11.1	11.0	11.0	10.9	10.9	10.9	10.9	10.9	10.9	10.5	10.5	10.4	10.3	10.3	10.2
43																				18.7	17.4	16.3	15.4	15.3	13.7	12.8	12.4	12.3	12.2	12.2	12.2	12.2	11.8	11.7	11.6	11.5	11.5	11.5	11.5	11.5	11.5	11.1	11.0	11.0
44																					19.0	18.1	17.4	16.1	15.4	14.4	13.5	13.5	13.5	13.5	13.0	12.8	12.8	12.8	12.8	12.8	12.4	12.3	12.3	12.2	12.2	12.2	12.2	12.2
45																						19.9	18.7	18.1	17.5	16.8	15.4	14.8	14.8	14.1	14.1	14.1	14.1	14.1	13.7	13.5	13.5	13.5	13.5	13.5	13.5	13.0	12.9	12.8
46																						21.7	21.3	19.9	18.7	18.1	17.4	16.8	15.5	15.4	15.4	15.4	15.4	14.9	14.8	14.8	14.8	14.8	14.8	14.2	14.1	14.1	14.1	14.1
47																							22.5	21.7	21.3	19.6	18.7	18.1	17.4	16.8	16.8	16.8	16.8	16.1	16.1	16.1	16.1	16.1	15.4	15.4	15.4	15.4	15.4	15.4
48																								23.3	22.6	21.3	20.7	20.0	18.7	18.1	18.1	18.1	17.5	17.4	17.4	17.4	17.4	17.4	16.8	16.8	16.8	16.8	16.8	16.8
49																								25.1	24.3	23.3	22.0	21.3	20.7	20.0	19.4	19.4	18.7	18.7	18.7	18.7	18.7	18.1	18.1	18.1	18.1	18.1	18.1	17.4
50																									25.9	25.1	23.9	23.3	22.0	21.3	20.7	20.7	20.7	20.0	20.0	20.0	20.0	19.4	19.4	19.4	19.4	19.4	19.4	18.7
51																									27.3	27.2	25.5	24.7	23.9	23.3	22.6	22.0	22.0	21.3	21.3	21.3	21.3	20.7	20.7	20.7	20.7	20.7	20.0	20.0
52																										29.2	27.2	26.5	25.9	24.7	23.9	23.3	23.3	22.6	22.6	22.6	22.6	22.0	22.0	22.0	22.0	22.0	21.3	21.3
53																											29.2	27.9	27.2	26.5	25.2	24.6	24.6	23.9	23.9	23.9	23.9	23.9	23.3	23.3	23.3	23.3	22.6	22.6
54																											30.6	29.6	28.5	27.9	27.2	26.5	25.9	25.2	25.2	25.2	25.2	24.6	24.6	24.6	24.6	24.6	23.9	23.9
55																												31.1	30.1	29.6	28.5	27.9	27.2	26.5	26.5	26.5	26.5	25.9	25.9	25.9	25.9	25.9	25.2	25.2
56																													32.1	31.1	30.1	29.2	28.5	27.9	27.9	27.9	27.9	27.2	27.2	27.2	27.2	27.2	26.5	26.5
57																													33.7	32.4	31.8	31.1	29.8	29.2	29.2	29.2	29.2	28.5	28.5	28.5	28.5	28.5	27.9	27.9
58																														34.4	33.7	32.4	31.8	31.1	30.5	30.5	29.8	29.8	29.8	29.8	29.8	29.2	29.2	29.2
59																														35.5	34.9	34.4	33.1	32.4	31.8	31.8	31.1	31.1	31.1	31.1	31.1	30.5	30.5	30.5
60																															36.1	35.5	34.9	33.7	33.1	32.4	32.4	32.4	32.4	32.4	31.8	31.8	31.8	31.8
61																																37.0	36.3	35.0	35.0	33.7	33.7	33.7	33.7	33.1	33.1	33.1	33.1	33.1
62																																38.3	37.6	37.0	35.7	35.0	35.0	35.0	34.4	34.4	34.4	34.4	34.4	34.4

Table 8.7.1-17
Fuel Qualification Table for EOS-37PTH, 492kgU, HLZC2, Plan2, Zone 6
(Minimum required years of cooling time after reactor core discharge)

BU (GWD/MTU)	Fuel Assembly Average Initial U-235 Enrichment (wt.%)																																											
	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5
6	4.4	4.4	4.4	4.3	4.3	4.3	4.2	4.2	4.2	4.2	4.2	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.9	3.9	3.9	3.9	3.9
7								4.5	4.5	4.4	4.4	4.4	4.4	4.4	4.4	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.1	4.1
10								5.2	5.2	5.2	5.1	5.1	5.1	5.1	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7
16								6.9	6.8	6.7	6.7	6.6	6.5	6.5	6.5	6.4	6.3	6.3	6.3	6.2	6.2	6.1	6.1	6.1	6.0	6.0	6.0	6.0	6.0	5.9	5.9	5.9	5.9	5.9	5.8	5.8	5.8	5.8	5.8	5.8	5.7	5.7	5.7	5.7
17												6.9	6.8	6.8	6.7	6.7	6.6	6.6	6.5	6.5	6.4	6.4	6.4	6.3	6.3	6.2	6.2	6.2	6.2	6.1	6.1	6.1	6.1	6.0	6.0	6.0	6.0	6.0	6.0	5.9	5.9	5.9	5.9	5.9
20												7.9	7.8	7.7	7.6	7.5	7.5	7.4	7.3	7.3	7.2	7.2	7.1	7.0	7.0	7.0	6.9	6.9	6.8	6.8	6.8	6.7	6.7	6.7	6.7	6.6	6.6	6.6	6.6	6.6	6.5	6.5	6.5	6.4
25												10.1	9.9	9.7	9.6	9.4	9.3	9.2	9.1	9.0	8.9	8.8	8.7	8.7	8.6	8.5	8.4	8.4	8.3	8.3	8.2	8.1	8.1	8.0	8.0	7.9	7.9	7.9	7.8	7.8	7.7	7.7	7.7	7.6
28												11.7	11.4	11.3	11.1	10.9	10.7	10.6	10.4	10.3	10.2	10.1	10.0	9.9	9.7	9.6	9.6	9.5	9.4	9.4	9.3	9.2	9.1	9.1	9.0	9.0	8.8	8.8	8.7	8.7	8.7	8.6	8.5	8.5
30												13.1	12.8	12.5	12.3	12.1	12.0	11.8	11.6	11.4	11.2	11.1	11.0	10.8	10.7	10.6	10.5	10.4	10.3	10.2	10.1	10.0	9.9	9.8	9.7	9.7	9.6	9.6	9.5	9.4	9.4	9.3	9.2	9.2
31													13.5	13.3	12.9	12.7	12.5	12.3	12.1	11.9	11.8	11.6	11.4	11.4	11.2	11.0	10.9	10.8	10.7	10.6	10.5	10.4	10.3	10.3	10.1	10.1	10.0	9.9	9.9	9.8	9.7	9.6	9.6	9.6
32														13.9	13.7	13.3	13.1	12.9	12.7	12.5	12.4	12.2	12.0	11.8	11.8	11.6	11.4	11.3	11.2	11.0	11.0	10.8	10.7	10.7	10.6	10.5	10.5	10.3	10.3	10.2	10.1	10.0	10.0	9.9
34															15.1	14.8	14.5	14.2	14.0	13.7	13.5	13.3	13.1	12.9	12.8	12.6	12.5	12.4	12.2	12.0	12.0	11.8	11.7	11.6	11.5	11.4	11.3	11.2	11.2	11.0	11.0	10.8	10.8	10.7
36																16.3	16.0	15.7	15.4	15.2	14.9	14.7	14.4	14.2	14.0	13.8	13.6	13.5	13.3	13.2	13.0	12.8	12.7	12.6	12.5	12.3	12.3	12.1	12.1	11.9	11.9	11.7	11.7	11.6
38																	17.6	17.2	17.0	16.6	16.3	16.0	15.9	15.6	15.3	15.1	15.0	14.7	14.5	14.3	14.2	14.0	13.8	13.7	13.6	13.5	13.3	13.2	13.0	13.0	12.8	12.7	12.6	12.5
39																		18.0	17.7	17.3	17.1	16.8	16.5	16.2	15.9	15.7	15.4	15.3	15.1	14.9	14.7	14.5	14.4	14.2	14.0	13.9	13.8	13.7	13.5	13.5	13.3	13.2	13.0	13.0
40																			18.4	18.1	17.7	17.4	17.1	16.9	16.6	16.4	16.1	15.9	15.8	15.5	15.4	15.1	14.9	14.9	14.6	14.5	14.3	14.2	14.1	14.0	13.8	13.7	13.6	13.5
41																			19.2	18.9	18.5	18.2	17.9	17.7	17.4	17.1	16.8	16.6	16.4	16.2	15.9	15.7	15.6	15.4	15.2	15.1	14.9	14.8	14.7	14.5	14.4	14.2	14.1	14.0
42																				19.8	19.5	19.1	18.8	18.5	18.2	17.8	17.7	17.4	17.1	16.8	16.8	16.4	16.2	16.0	15.9	15.7	15.6	15.4	15.2	15.1	14.9	14.9	14.6	14.6
43																				20.7	20.3	20.0	19.7	19.2	19.1	18.7	18.3	18.1	17.8	17.5	17.4	17.1	16.9	16.8	16.5	16.3	16.2	16.0	15.9	15.6	15.6	15.3	15.2	15.1
44																					21.3	20.7	20.4	20.0	19.7	19.5	19.1	18.9	18.5	18.3	18.1	17.8	17.7	17.4	17.1	17.1	16.9	16.6	16.4	16.2	16.2	15.9	15.9	15.7
45																						21.7	21.3	21.0	20.5	20.3	19.9	19.6	19.3	19.1	18.8	18.7	18.3	18.1	17.8	17.7	17.5	17.4	17.1	16.9	16.8	16.6	16.4	16.3
46																						22.6	22.1	21.8	21.4	21.1	20.7	20.6	20.2	19.9	19.6	19.3	19.0	18.9	18.7	18.3	18.1	18.1	17.7	17.5	17.4	17.2	17.1	16.8
47																							23.1	22.9	22.3	21.9	21.7	21.3	21.0	20.6	20.4	20.1	19.9	19.6	19.4	19.0	19.0	18.7	18.5	18.2	18.1	17.9	17.7	17.5
48																								23.5	23.3	22.8	22.6	22.1	21.7	21.5	21.1	21.0	20.6	20.3	20.0	19.9	19.6	19.4	19.1	19.0	18.7	18.5	18.3	18.2
49																								24.5	24.3	23.8	23.3	23.0	22.6	22.4	22.0	21.7	21.4	21.2	20.8	20.7	20.3	20.3	19.9	19.7	19.4	19.3	19.0	18.8
50																									25.1	24.7	24.3	23.9	23.5	23.1	22.9	22.6	22.2	22.0	21.6	21.3	21.2	20.8	20.7	20.3	20.2	20.0	19.8	19.5
51																									26.0	25.6	25.2	24.7	24.4	24.0	23.7	23.4	23.1	22.7	22.6	22.1	22.0	21.6	21.3	21.1	20.8	20.7	20.4	20.3
52																										26.6	26.1	25.6	25.3	24.9	24.7	24.3	23.9	23.6	23.3	23.0	22.6	22.4	22.1	22.0	22.0	22.0	21.3	21.3
53																											27.2	26.5	26.3	25.9	25.4	25.2	24.7	24.6	24.1	23.9	23.9	23.9	23.3	23.3	23.3	23.3	22.6	22.6
54																											28.0	27.5	27.2	26.8	26.3	26.1	25.9	25.2	25.2	25.2	25.2	24.6	24.6	24.6	24.6	24.6	23.9	23.9
55																												28.5	28.0	27.9	27.2	27.2	27.2	26.5	26.5	26.5	26.5	25.9	25.9	25.9	25.9	25.9	25.2	25.2
56																													29.2	28.5	28.5	28.5	27.9	27.9	27.9	27.9	27.9	27.2	27.2	27.2	27.2	27.2	26.5	26.5
57																													30.0	29.8	29.8	29.8	29.2	29.2	29.2	29.2	29.2	28.5	28.5	28.5	28.5	28.5	27.9	27.9
58																														31.1	31.1	30.5	30.5	30.5	30.5	30.5	29.8	29.8	29.8	29.8	29.8	29.2	29.2	29.2
59																														32.4	32.4	31.8	31.8	31.8	31.8	31.8	31.1	31.1	31.1	31.1	31.1	30.5	30.5	30.5
60																															33.1	33.1	33.1	33.1	33.1	32.4	32.4	32.4	32.4	32.4	31.8	31.8	31.8	31.8
61																																34.4	34.4	34.4	34.4	33.7	33.7	33.7	33.7	33.1	33.1	33.1	33.1	33.1
62																																35.7	35.0	35.0	35.0	35.0	35.0	35.0	34.4	34.4	34.4	34.4	34.4	34.4

Table 8.7.1-18
Fuel Qualification Table for EOS-37PTH, 400kgU, HLZC1, Plan1, Zone 1
(Minimum required years of cooling time after reactor core discharge)

BU (GWD/MTU)	Fuel Assembly Average Initial U-235 Enrichment (wt.%)																																											
	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5
6	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
7								3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
10								3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
16								3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
17												3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
20												3.3	3.3	3.3	3.3	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
25												3.9	3.9	3.9	3.9	3.9	3.9	3.8	3.8	3.8	3.8	3.8	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.5	3.5
28												4.4	4.4	4.3	4.3	4.3	4.2	4.2	4.2	4.2	4.2	4.1	4.1	4.1	4.1	4.1	4.1	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9
30												4.7	4.7	4.6	4.6	4.6	4.5	4.5	4.5	4.5	4.5	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.3	4.3	4.3	4.3	4.3	4.3	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.1	4.1
31													4.8	4.8	4.8	4.8	4.7	4.7	4.7	4.6	4.6	4.6	4.6	4.5	4.5	4.5	4.5	4.5	4.5	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.3	4.3	4.3	4.3	4.3
32														4.9	4.9	4.9	4.9	4.8	4.8	4.8	4.8	4.8	4.8	4.7	4.7	4.7	4.7	4.6	4.6	4.6	4.6	4.6	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.4	4.4	4.4	4.4	4.4
34															5.3	5.2	5.2	5.2	5.2	5.2	5.1	5.1	5.1	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.7	4.7	4.7
36																5.7	5.7	5.7	5.6	5.6	5.5	5.5	5.4	5.4	5.4	5.3	5.3	5.3	5.3	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.1	5.1	5.1	5.1	5.1	5.0	5.0
38																	6.1	6.1	6.1	6.0	6.0	5.9	5.9	5.8	5.8	5.8	5.7	5.7	5.7	5.7	5.7	5.7	5.6	5.6	5.6	5.6	5.5	5.5	5.5	5.5	5.4	5.4	5.4	5.4
39																		6.3	6.3	6.3	6.2	6.1	6.1	6.1	6.1	6.1	6.0	6.0	5.9	5.9	5.9	5.8	5.8	5.8	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.6	5.6
40																			6.6	6.6	6.5	6.5	6.4	6.4	6.3	6.3	6.2	6.2	6.1	6.1	6.1	6.1	6.1	6.1	6.0	6.0	6.0	5.9	5.9	5.9	5.8	5.8	5.8	5.8
41																			7.0	6.8	6.8	6.7	6.7	6.6	6.6	6.6	6.5	6.5	6.5	6.4	6.4	6.3	6.3	6.3	6.2	6.2	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.0
42																				7.1	7.1	7.0	7.0	7.0	7.0	6.9	6.8	6.8	6.7	6.7	6.6	6.6	6.6	6.6	6.5	6.5	6.5	6.4	6.4	6.4	6.3	6.3	6.3	6.3
43																				7.6	7.5	7.4	7.4	7.3	7.2	7.2	7.1	7.0	7.0	7.0	7.0	7.0	6.9	6.8	6.8	6.7	6.7	6.7	6.6	6.6	6.6	6.6	6.6	6.6
44																					7.9	7.8	7.7	7.6	7.6	7.6	7.5	7.5	7.4	7.3	7.3	7.2	7.2	7.1	7.1	7.0	7.0	7.0	7.0	7.0	7.0	6.9	6.8	6.8
45																						8.3	8.3	8.0	8.0	7.9	7.9	7.8	7.8	7.7	7.6	7.6	7.6	7.5	7.5	7.4	7.4	7.3	7.3	7.2	7.2	7.2	7.1	7.1
46																						8.8	8.6	8.5	8.4	8.3	8.3	8.3	8.3	8.1	8.0	7.9	7.9	7.9	7.8	7.8	7.7	7.7	7.6	7.6	7.6	7.6	7.5	7.5
47																							9.4	9.0	8.9	8.9	8.9	8.7	8.6	8.5	8.5	8.4	8.3	8.3	8.3	8.3	8.3	8.1	8.0	7.9	7.9	7.9	7.9	7.8
48																								10.2	9.6	9.6	9.3	9.2	9.1	9.0	8.9	8.9	8.9	8.9	8.7	8.6	8.6	8.5	8.4	8.4	8.3	8.3	8.3	8.3
49																								12.2	11.5	10.0	9.9	9.7	9.7	9.6	9.6	9.6	9.3	9.2	9.2	9.1	9.1	9.0	8.9	8.9	8.9	8.9	8.7	8.7
50																									12.8	12.2	10.7	10.4	10.3	10.2	10.2	10.2	9.9	9.8	9.7	9.7	9.6	9.6	9.6	9.6	9.3	9.2	9.2	9.2
51																									15.3	13.5	13.1	11.7	11.0	10.9	10.9	10.9	10.6	10.5	10.4	10.3	10.2	10.2	10.2	10.0	9.9	9.8	9.7	9.7
52																										15.4	14.1	13.5	12.4	11.6	11.5	11.5	11.5	11.1	11.0	11.0	10.9	10.9	10.9	10.6	10.5	10.4	10.4	10.3
53																											15.9	15.3	14.1	13.0	12.3	12.2	12.2	12.2	11.8	11.7	11.5	11.5	11.5	11.5	11.2	11.1	11.0	11.0
54																											17.5	16.5	15.4	14.8	14.1	13.1	12.8	12.8	12.8	12.8	12.3	12.3	12.2	12.2	12.2	11.9	11.7	11.6
55																												18.1	17.2	16.8	15.4	14.8	13.7	13.6	13.5	13.5	13.5	13.1	12.9	12.8	12.8	12.8	12.8	12.4
56																													18.7	18.1	17.6	16.1	15.4	14.8	14.8	14.2	14.1	14.1	14.1	13.7	13.6	13.5	13.5	13.5
57																													21.2	19.3	18.7	18.1	16.8	16.1	15.4	15.4	15.4	14.9	14.8	14.8	14.8	14.8	14.2	14.1
58																														21.3	21.2	19.8	18.7	18.1	16.8	16.2	16.1	16.1	16.1	15.6	15.4	15.4	15.4	15.4
59																														22.6	21.4	21.3	19.9	18.9	18.7	17.4	17.4	16.9	16.8	16.8	16.8	16.8	16.2	16.1
60																															23.3	22.6	21.3	20.7	20.0	19.4	18.7	18.1	18.1	18.1	17.5	17.4	17.4	17.4
61																																23.9	23.3	22.0	21.3	20.7	20.0	19.4	18.8	18.7	18.7	18.7	18.7	18.1
62																																25.1	24.3	23.9	22.6	22.0	21.3	20.7	20.0	20.0	20.0	19.4	19.4	19.4

Table 8.7.1-19
Fuel Qualification Table for EOS-37PTH, 400kgU, HLZC1, Plan1, Zone 2
(Minimum required years of cooling time after reactor core discharge)

BU (GWD/MTU)	Fuel Assembly Average Initial U-235 Enrichment (wt.%)																																											
	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5
6	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
7								3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
10								3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
16								3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
17												3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
20												3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
25												3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
28												3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
30												3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
31													3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
32														3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
34															3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
36																3.1	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
38																	3.2	3.2	3.2	3.2	3.1	3.1	3.1	3.1	3.1	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
39																		3.3	3.2	3.2	3.2	3.2	3.2	3.2	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
40																			3.3	3.3	3.3	3.3	3.3	3.2	3.2	3.2	3.2	3.2	3.2	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0
41																			3.4	3.4	3.4	3.4	3.3	3.3	3.3	3.3	3.3	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
42																				3.5	3.5	3.4	3.4	3.4	3.4	3.4	3.3	3.3	3.3	3.3	3.3	3.3	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.1	3.1	3.1
43																				3.6	3.5	3.5	3.5	3.5	3.5	3.4	3.4	3.4	3.4	3.4	3.4	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.2	3.2	3.2	3.2	3.2	3.2
44																					3.6	3.6	3.6	3.6	3.5	3.5	3.5	3.5	3.5	3.5	3.4	3.4	3.4	3.4	3.4	3.4	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3
45																						3.7	3.7	3.6	3.6	3.6	3.6	3.6	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.3	3.3
46																						3.8	3.7	3.7	3.7	3.7	3.7	3.6	3.6	3.6	3.6	3.6	3.6	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.4	3.4	3.4
47																							3.8	3.8	3.8	3.8	3.7	3.7	3.7	3.7	3.7	3.7	3.6	3.6	3.6	3.6	3.6	3.6	3.5	3.5	3.5	3.5	3.5	3.5
48																								3.9	3.9	3.9	3.8	3.8	3.8	3.8	3.8	3.7	3.7	3.7	3.7	3.7	3.7	3.6	3.6	3.6	3.6	3.6	3.6	3.6
49																								4.0	4.0	4.0	3.9	3.9	3.9	3.9	3.9	3.8	3.8	3.8	3.8	3.8	3.7	3.7	3.7	3.7	3.7	3.7	3.6	3.6
50																									4.1	4.0	4.0	4.0	4.0	4.0	3.9	3.9	3.9	3.9	3.9	3.9	3.8	3.8	3.8	3.8	3.8	3.7	3.7	3.7
51																									4.2	4.1	4.1	4.1	4.1	4.1	4.0	4.0	4.0	4.0	4.0	3.9	3.9	3.9	3.9	3.9	3.9	3.8	3.8	3.8
52																										4.3	4.2	4.2	4.2	4.2	4.1	4.1	4.1	4.1	4.0	4.0	4.0	4.0	4.0	4.0	3.9	3.9	3.9	3.9
53																											4.4	4.3	4.3	4.3	4.2	4.2	4.2	4.2	4.1	4.1	4.1	4.1	4.1	4.0	4.0	4.0	4.0	4.0
54																											4.4	4.4	4.4	4.4	4.4	4.3	4.3	4.3	4.2	4.2	4.2	4.2	4.2	4.1	4.1	4.1	4.1	4.1
55																												4.5	4.5	4.5	4.4	4.4	4.4	4.4	4.4	4.3	4.3	4.3	4.3	4.2	4.2	4.2	4.2	4.2
56																													4.6	4.6	4.6	4.5	4.5	4.5	4.5	4.4	4.4	4.4	4.4	4.4	4.3	4.3	4.3	4.3
57																													4.7	4.7	4.7	4.6	4.6	4.6	4.6	4.5	4.5	4.5	4.5	4.4	4.4	4.4	4.4	4.4
58																														4.8	4.8	4.8	4.8	4.7	4.7	4.7	4.6	4.6	4.6	4.6	4.5	4.5	4.5	4.5
59																														5.0	4.9	4.9	4.9	4.8	4.8	4.8	4.8	4.7	4.7	4.7	4.6	4.6	4.6	4.6
60																															5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.8	4.8	4.8	4.8	4.8	4.7	4.7
61																																5.2	5.1	5.1	5.1	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.8	4.8
62																																5.3	5.3	5.2	5.2	5.2	5.1	5.1	5.1	5.0	5.0	5.0	5.0	4.9

Table 8.7.1-20
Fuel Qualification Table for EOS-37PTH, 400kgU, HLZC1, Plan1, Zone 3
(Minimum required years of cooling time after reactor core discharge)

BU (GWD/MTU)	Fuel Assembly Average Initial U-235 Enrichment (wt.%)																																											
	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5
6	3.6	3.5	3.5	3.5	3.5	3.4	3.4	3.4	3.4	3.4	3.4	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2
7								3.6	3.6	3.6	3.6	3.6	3.6	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4
10								4.2	4.2	4.2	4.2	4.1	4.1	4.1	4.1	4.1	4.1	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9
16								5.4	5.3	5.3	5.3	5.2	5.2	5.1	5.1	5.1	5.1	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.8	4.8	4.8	4.8	4.8	4.8	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.6	4.6	4.6
17												5.4	5.4	5.3	5.3	5.3	5.2	5.2	5.2	5.1	5.1	5.1	5.1	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8
20												6.0	5.9	5.9	5.8	5.8	5.7	5.7	5.7	5.6	5.6	5.6	5.5	5.5	5.5	5.5	5.4	5.4	5.4	5.4	5.4	5.3	5.3	5.3	5.3	5.3	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.1
25												7.1	7.0	7.0	6.9	6.8	6.8	6.7	6.7	6.6	6.6	6.5	6.5	6.4	6.4	6.4	6.3	6.3	6.2	6.2	6.2	6.1	6.1	6.1	6.1	6.0	6.0	6.0	6.0	5.9	5.9	5.9	5.9	5.9
28												7.9	7.8	7.7	7.7	7.6	7.5	7.4	7.4	7.3	7.2	7.2	7.1	7.1	7.0	7.0	6.9	6.9	6.8	6.8	6.8	6.7	6.7	6.6	6.6	6.6	6.5	6.5	6.5	6.4	6.4	6.4	6.4	6.4
30												8.6	8.5	8.4	8.3	8.2	8.1	8.0	7.9	7.8	7.8	7.7	7.6	7.6	7.5	7.4	7.4	7.3	7.3	7.2	7.2	7.1	7.1	7.1	7.0	7.0	6.9	6.9	6.9	6.8	6.8	6.8	6.7	6.7
31													8.8	8.7	8.6	8.5	8.4	8.3	8.2	8.1	8.0	8.0	7.9	7.8	7.7	7.7	7.6	7.6	7.5	7.5	7.4	7.4	7.3	7.3	7.2	7.2	7.1	7.1	7.1	7.0	7.0	7.0	6.9	6.9
32														9.0	8.9	8.8	8.7	8.6	8.5	8.4	8.3	8.2	8.1	8.1	8.0	7.9	7.9	7.8	7.8	7.7	7.6	7.6	7.6	7.5	7.4	7.4	7.4	7.3	7.3	7.2	7.2	7.2	7.1	7.1
34															9.6	9.4	9.3	9.2	9.1	9.0	8.9	8.8	8.7	8.6	8.6	8.5	8.4	8.3	8.3	8.2	8.1	8.1	8.0	8.0	7.9	7.9	7.8	7.8	7.7	7.7	7.6	7.6	7.6	7.5
36																10.2	10.0	9.9	9.8	9.6	9.5	9.4	9.3	9.2	9.1	9.1	9.0	8.9	8.8	8.7	8.7	8.6	8.5	8.5	8.4	8.4	8.3	8.2	8.2	8.2	8.1	8.1	8.0	8.0
38																	10.8	10.6	10.5	10.3	10.2	10.1	10.0	9.9	9.8	9.7	9.6	9.5	9.4	9.3	9.2	9.2	9.1	9.0	9.0	8.9	8.8	8.8	8.7	8.7	8.6	8.5	8.5	8.5
39																		10.9	10.8	10.7	10.5	10.4	10.3	10.2	10.1	10.0	9.9	9.8	9.7	9.6	9.5	9.4	9.4	9.3	9.2	9.2	9.1	9.0	9.0	8.9	8.9	8.8	8.7	8.7
40																			11.2	11.0	10.9	10.8	10.6	10.5	10.4	10.3	10.2	10.1	10.0	9.9	9.8	9.7	9.7	9.6	9.5	9.4	9.4	9.3	9.2	9.2	9.1	9.1	9.0	8.9
41																			11.6	11.5	11.3	11.2	11.0	10.9	10.8	10.6	10.5	10.4	10.3	10.2	10.2	10.0	10.0	9.9	9.8	9.7	9.7	9.6	9.5	9.5	9.4	9.3	9.3	9.2
42																				11.9	11.7	11.5	11.4	11.3	11.1	11.0	10.9	10.8	10.7	10.6	10.5	10.4	10.3	10.2	10.1	10.0	10.0	9.9	9.8	9.7	9.7	9.6	9.5	9.5
43																				12.3	12.1	11.9	11.8	11.6	11.5	11.4	11.3	11.2	11.0	10.9	10.8	10.7	10.6	10.5	10.5	10.4	10.3	10.2	10.1	10.0	10.0	9.9	9.8	9.8
44																					12.6	12.4	12.2	12.1	11.9	11.8	11.6	11.5	11.4	11.3	11.2	11.1	11.0	10.9	10.8	10.7	10.6	10.5	10.4	10.4	10.3	10.2	10.1	10.1
45																						12.8	12.6	12.5	12.3	12.2	12.0	11.9	11.8	11.7	11.5	11.4	11.3	11.2	11.1	11.0	10.9	10.8	10.8	10.7	10.6	10.5	10.4	10.4
46																						13.3	13.0	12.9	12.8	12.6	12.4	12.3	12.2	12.0	11.9	11.8	11.7	11.6	11.5	11.4	11.3	11.2	11.1	11.0	10.9	10.8	10.8	10.7
47																							13.5	13.4	13.2	13.0	12.9	12.7	12.6	12.4	12.3	12.2	12.1	11.9	11.8	11.7	11.6	11.5	11.4	11.3	11.3	11.2	11.1	11.0
48																								13.8	13.6	13.4	13.3	13.1	13.0	12.8	12.7	12.6	12.4	12.3	12.2	12.1	12.0	11.9	11.8	11.7	11.6	11.5	11.4	11.3
49																								14.3	14.1	13.9	13.7	13.6	13.4	13.3	13.1	13.0	12.8	12.7	12.6	12.4	12.3	12.2	12.1	12.0	11.9	11.8	11.7	11.7
50																									14.6	14.4	14.2	14.0	13.8	13.6	13.5	13.4	13.2	13.1	13.0	12.8	12.7	12.6	12.5	12.4	12.3	12.2	12.1	12.0
51																									15.0	14.9	14.7	14.5	14.3	14.1	14.0	13.8	13.7	13.5	13.4	13.2	13.1	13.0	12.9	12.8	12.6	12.5	12.4	12.4
52																										15.4	15.1	14.9	14.8	14.6	14.4	14.2	14.1	13.9	13.8	13.7	13.5	13.4	13.3	13.2	13.0	12.9	12.8	12.7
53																											15.7	15.4	15.3	15.0	14.9	14.7	14.5	14.4	14.2	14.0	13.9	13.8	13.7	13.5	13.4	13.3	13.2	13.1
54																											16.2	16.0	15.7	15.5	15.3	15.2	15.0	14.8	14.7	14.5	14.4	14.2	14.1	13.9	13.8	13.7	13.6	13.5
55																												16.5	16.2	16.1	15.8	15.6	15.5	15.3	15.1	14.9	14.8	14.6	14.5	14.4	14.2	14.1	14.0	13.9
56																													16.8	16.6	16.3	16.1	16.0	15.8	15.5	15.4	15.2	15.1	14.9	14.8	14.6	14.6	14.4	14.2
57																													17.3	17.1	16.9	16.6	16.4	16.2	16.0	15.9	15.7	15.6	15.4	15.2	15.1	14.9	14.8	14.7
58																														17.6	17.4	17.1	16.9	16.8	16.5	16.3	16.2	16.0	15.9	15.7	15.6	15.4	15.3	15.1
59																														18.2	17.9	17.7	17.5	17.2	17.1	16.8	16.7	16.5	16.3	16.2	16.0	15.8	15.6	15.6
60																															18.5	18.3	18.0	17.7	17.6	17.4	17.2	17.0	16.8	16.7	16.5	16.3	16.1	16.0
61																																18.7	18.5	18.3	18.1	17.9	17.7	17.5	17.3	17.1	16.9	16.7	16.6	16.4
62																																19.3	19.1	18.9	18.6	18.4	18.2	18.0	17.8	17.6	17.4	17.2	17.1	16.9

Table 8.7.1-21
Fuel Qualification Table for EOS-37PTH, 450kgU, HLZC1, Plan1, Zone 1
(Minimum required years of cooling time after reactor core discharge)

BU (GWD/MTU)	Fuel Assembly Average Initial U-235 Enrichment (wt.%)																																										
	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5
6	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
7								3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
10								3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
16								3.1	3.1	3.1	3.1	3.1	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
17												3.2	3.2	3.2	3.2	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
20												3.6	3.6	3.6	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3
25												4.3	4.3	4.3	4.2	4.2	4.2	4.2	4.2	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9
28												4.8	4.8	4.8	4.7	4.7	4.7	4.7	4.6	4.6	4.6	4.6	4.5	4.5	4.5	4.5	4.5	4.5	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.3	4.3	4.3	4.3
30												5.2	5.2	5.2	5.1	5.1	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.7	4.7	4.7	4.7	4.7	4.7	4.6	4.6	4.6	4.6	4.6
31													5.4	5.3	5.3	5.2	5.2	5.2	5.2	5.2	5.2	5.1	5.1	5.1	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8
32														5.6	5.5	5.5	5.5	5.4	5.4	5.3	5.3	5.3	5.3	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.1	5.1	5.1	5.1	5.1	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9
34															6.0	6.0	5.9	5.9	5.8	5.8	5.8	5.7	5.7	5.7	5.7	5.7	5.7	5.6	5.6	5.6	5.5	5.5	5.5	5.5	5.4	5.4	5.4	5.4	5.4	5.3	5.3	5.3	5.3	5.3
36																6.6	6.5	6.5	6.4	6.3	6.3	6.3	6.2	6.2	6.1	6.1	6.1	6.1	6.1	6.0	6.0	6.0	6.0	5.9	5.9	5.9	5.8	5.8	5.8	5.8	5.8	5.7	5.7	5.7
38																	7.1	7.1	7.0	7.0	7.0	6.9	6.8	6.8	6.7	6.7	6.6	6.6	6.6	6.6	6.6	6.5	6.5	6.5	6.4	6.4	6.4	6.3	6.3	6.3	6.3	6.3	6.2	6.2
39																		7.5	7.4	7.4	7.3	7.2	7.2	7.1	7.1	7.0	7.0	7.0	7.0	7.0	6.9	6.8	6.8	6.7	6.7	6.7	6.6	6.6	6.6	6.6	6.6	6.6	6.5	6.5
40																			7.9	7.8	7.7	7.6	7.6	7.6	7.5	7.4	7.4	7.3	7.3	7.2	7.2	7.1	7.1	7.0	7.0	7.0	7.0	7.0	7.0	7.0	6.9	6.8	6.8	6.8
41																			8.3	8.3	8.3	8.0	8.0	7.9	7.9	7.8	7.8	7.7	7.6	7.6	7.6	7.6	7.5	7.5	7.4	7.4	7.3	7.3	7.3	7.2	7.2	7.2	7.1	7.1
42																				8.8	8.6	8.5	8.5	8.4	8.3	8.3	8.3	8.3	8.1	8.0	7.9	7.9	7.9	7.9	7.8	7.8	7.7	7.7	7.6	7.6	7.6	7.6	7.6	7.5
43																				9.3	9.2	9.1	9.0	8.9	8.9	8.9	8.7	8.6	8.6	8.5	8.4	8.4	8.3	8.3	8.3	8.3	8.3	8.1	8.0	8.0	7.9	7.9	7.9	7.9
44																					9.8	9.7	9.6	9.6	9.6	9.3	9.2	9.2	9.1	9.0	9.0	8.9	8.9	8.9	8.8	8.7	8.6	8.6	8.5	8.5	8.4	8.4	8.3	8.3
45																						10.4	10.3	10.2	10.2	10.0	9.9	9.8	9.7	9.7	9.6	9.6	9.6	9.3	9.2	9.2	9.2	9.1	9.0	9.0	8.9	8.9	8.9	8.9
46																						11.7	11.0	10.9	10.9	10.9	10.6	10.5	10.4	10.3	10.2	10.2	10.2	10.0	9.9	9.8	9.7	9.7	9.7	9.6	9.6	9.6	9.6	9.3
47																							12.8	11.7	11.6	11.5	11.5	11.5	11.1	11.0	10.9	10.9	10.9	10.9	10.6	10.5	10.4	10.3	10.2	10.2	10.2	10.2	10.2	10.0
48																								13.5	12.8	12.3	12.2	12.2	12.2	11.9	11.7	11.6	11.5	11.5	11.5	11.5	11.1	11.0	11.0	10.9	10.9	10.9	10.9	10.9
49																								14.8	14.1	13.5	13.5	13.0	12.8	12.8	12.8	12.8	12.3	12.3	12.2	12.2	12.2	12.2	11.8	11.7	11.6	11.5	11.5	11.5
50																									16.1	14.7	14.1	14.1	14.1	13.7	13.6	13.5	13.5	13.5	13.0	12.9	12.8	12.8	12.8	12.8	12.4	12.3	12.3	12.2
51																									18.3	16.8	15.4	15.4	14.9	14.8	14.8	14.8	14.3	14.1	14.1	14.1	14.1	13.7	13.6	13.5	13.5	13.5	13.5	13.1
52																										18.7	17.4	16.1	16.1	16.1	16.1	15.4	15.4	15.4	15.4	14.9	14.8	14.8	14.8	14.8	14.3	14.2	14.1	14.1
53																											19.0	18.1	17.4	17.4	16.8	16.8	16.8	16.8	16.1	16.1	16.1	16.1	15.6	15.4	15.4	15.4	15.4	15.4
54																											20.7	20.0	18.7	18.1	18.1	18.1	18.1	17.4	17.4	17.4	17.4	16.8	16.8	16.8	16.8	16.8	16.2	16.1
55																												21.3	20.7	20.0	19.4	19.4	18.7	18.7	18.7	18.7	18.1	18.1	18.1	18.1	18.1	17.4	17.4	17.4
56																													22.0	21.3	20.7	20.0	20.0	20.0	20.0	19.4	19.4	19.4	19.4	19.4	18.7	18.7	18.7	18.7
57																													23.9	22.6	22.0	21.3	21.3	21.3	20.7	20.7	20.7	20.7	20.7	20.0	20.0	20.0	20.0	19.4
58																														24.3	23.9	22.6	22.6	22.1	22.0	22.0	22.0	22.0	21.3	21.3	21.3	21.3	20.7	20.7
59																														25.9	24.6	23.9	23.9	23.3	23.3	23.3	23.3	22.6	22.6	22.6	22.6	22.0	22.0	22.0
60																															26.5	25.9	24.6	24.6	24.6	24.6	23.9	23.9	23.9	23.9	23.3	23.3	23.3	23.3
61																																27.2	26.5	25.9	25.9	25.2	25.2	25.2	25.2	24.6	24.6	24.6	24.6	24.6
62																																28.5	27.9	27.2	26.5	26.5	26.5	26.5	25.9	25.9	25.9	25.9	25.9	25.2

Table 8.7.1-22
Fuel Qualification Table for EOS-37PTH, 450kgU, HLZC1, Plan1, Zone 2
(Minimum required years of cooling time after reactor core discharge)

BU (GWD/MTU)	Fuel Assembly Average Initial U-235 Enrichment (wt.%)																																											
	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5
6	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
7								3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
10								3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
16								3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
17												3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
20												3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
25												3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
28												3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
30												3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
31													3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
32														3.1	3.1	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
34															3.2	3.2	3.2	3.2	3.2	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
36																3.4	3.4	3.3	3.3	3.3	3.3	3.3	3.3	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.0	3.0	3.0	3.0	3.0
38																	3.5	3.5	3.5	3.5	3.5	3.5	3.4	3.4	3.4	3.4	3.4	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.1
39																		3.6	3.6	3.6	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.4	3.4	3.4	3.4	3.4	3.4	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.2	3.2	3.2
40																			3.7	3.7	3.6	3.6	3.6	3.6	3.6	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.3	3.3	3.3	3.3	3.3
41																			3.8	3.7	3.7	3.7	3.7	3.7	3.6	3.6	3.6	3.6	3.6	3.6	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.4	3.4	3.4	3.4	3.4	3.4
42																				3.8	3.8	3.8	3.8	3.8	3.7	3.7	3.7	3.7	3.7	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
43																				3.9	3.9	3.9	3.9	3.9	3.8	3.8	3.8	3.8	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.5	3.5
44																					4.0	4.0	4.0	3.9	3.9	3.9	3.9	3.9	3.9	3.8	3.8	3.8	3.8	3.8	3.7	3.7	3.7	3.7	3.7	3.7	3.6	3.6	3.6	3.6
45																						4.1	4.1	4.0	4.0	4.0	4.0	4.0	3.9	3.9	3.9	3.9	3.9	3.9	3.8	3.8	3.8	3.8	3.8	3.7	3.7	3.7	3.7	3.7
46																						4.2	4.2	4.1	4.1	4.1	4.1	4.1	4.0	4.0	4.0	4.0	4.0	3.9	3.9	3.9	3.9	3.9	3.9	3.8	3.8	3.8	3.8	3.8
47																							4.3	4.3	4.2	4.2	4.2	4.2	4.1	4.1	4.1	4.1	4.1	4.0	4.0	4.0	4.0	4.0	4.0	3.9	3.9	3.9	3.9	3.9
48																								4.4	4.4	4.3	4.3	4.3	4.2	4.2	4.2	4.2	4.2	4.1	4.1	4.1	4.1	4.1	4.0	4.0	4.0	4.0	4.0	4.0
49																								4.5	4.5	4.4	4.4	4.4	4.4	4.4	4.3	4.3	4.3	4.2	4.2	4.2	4.2	4.2	4.1	4.1	4.1	4.1	4.1	4.1
50																									4.6	4.5	4.5	4.5	4.5	4.4	4.4	4.4	4.4	4.4	4.3	4.3	4.3	4.3	4.2	4.2	4.2	4.2	4.2	4.2
51																									4.7	4.7	4.6	4.6	4.6	4.6	4.5	4.5	4.5	4.5	4.4	4.4	4.4	4.4	4.4	4.4	4.3	4.3	4.3	4.3
52																										4.8	4.8	4.8	4.7	4.7	4.7	4.6	4.6	4.6	4.6	4.5	4.5	4.5	4.5	4.4	4.4	4.4	4.4	4.4
53																											4.9	4.9	4.8	4.8	4.8	4.8	4.7	4.7	4.7	4.6	4.6	4.6	4.6	4.6	4.5	4.5	4.5	4.5
54																											5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.8	4.8	4.8	4.8	4.7	4.7	4.7	4.7	4.6	4.6	4.6
55																												5.2	5.1	5.1	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.8	4.8	4.8	4.8	4.7	4.7
56																													5.3	5.2	5.2	5.2	5.1	5.1	5.1	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.8
57																													5.4	5.4	5.3	5.3	5.3	5.2	5.2	5.2	5.2	5.1	5.1	5.1	5.0	5.0	5.0	5.0
58																														5.6	5.5	5.5	5.4	5.4	5.4	5.3	5.3	5.3	5.2	5.2	5.2	5.2	5.1	5.1
59																														5.7	5.7	5.7	5.6	5.6	5.5	5.5	5.4	5.4	5.4	5.4	5.3	5.3	5.3	5.2
60																															5.8	5.8	5.8	5.7	5.7	5.7	5.6	5.6	5.6	5.5	5.5	5.4	5.4	5.4
61																																6.0	6.0	5.9	5.9	5.8	5.8	5.7	5.7	5.7	5.7	5.6	5.6	5.5
62																																6.2	6.1	6.1	6.1	6.0	6.0	5.9	5.9	5.8	5.8	5.8	5.7	5.7

Table 8.7.1-23
Fuel Qualification Table for EOS-37PTH, 450kgU, HLZC1, Plan1, Zone 3
(Minimum required years of cooling time after reactor core discharge)

BU (GWD/MTU)	Fuel Assembly Average Initial U-235 Enrichment (wt.%)																						
	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9
6	3.7	3.7	3.7	3.6	3.6	3.6	3.6	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.4	3.4	3.4	3.4	3.4	3.4	3.4
7								3.8	3.8	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.6	3.6	3.6	3.6	3.6	3.6
10								4.4	4.4	4.4	4.3	4.3	4.3	4.3	4.3	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2
16								5.6	5.6	5.5	5.5	5.4	5.4	5.4	5.3	5.3	5.3	5.2	5.2	5.2	5.2	5.1	5.1
17												5.6	5.6	5.6	5.5	5.5	5.5	5.4	5.4	5.4	5.3	5.3	5.3
20												6.3	6.2	6.2	6.1	6.1	6.0	6.0	5.9	5.9	5.9	5.8	5.8
25												7.5	7.4	7.4	7.3	7.2	7.2	7.1	7.0	7.0	6.9	6.9	6.8
28												8.4	8.3	8.2	8.2	8.1	8.0	7.9	7.8	7.7	7.7	7.6	7.5
30												9.2	9.1	8.9	8.8	8.7	8.6	8.5	8.4	8.4	8.3	8.2	8.1
31													9.4	9.3	9.2	9.0	8.9	8.8	8.7	8.7	8.6	8.5	8.4
32														9.6	9.5	9.4	9.3	9.2	9.1	9.0	8.9	8.8	8.7
34															10.3	10.1	10.0	9.9	9.8	9.6	9.5	9.4	9.3
36																11.0	10.8	10.7	10.5	10.4	10.3	10.2	10.0
38																	11.7	11.5	11.3	11.2	11.1	10.9	10.8
39																		11.9	11.7	11.6	11.4	11.3	11.1
40																			12.2	12.0	11.8	11.7	11.5
41																			12.6	12.4	12.3	12.1	12.0
42																				12.9	12.7	12.6	12.4
43																				13.4	13.2	13.0	12.9
44																					13.7	13.5	13.3
45																						14.0	13.8
46																						14.5	14.3
47																							14.8
48																							
49																							
50																							
51																							
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61																							
62																							

BU (GWD/MTU)	Fuel Assembly Average Initial U-235 Enrichment (wt.%)																				
	3	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5
6	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.3	3.3	3.3	3.3	3.3	3.3
7	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
10	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
16	5.1	5.1	5.1	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.8	4.8
17	5.3	5.2	5.2	5.2	5.2	5.2	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
20	5.8	5.7	5.7	5.7	5.7	5.6	5.6	5.6	5.6	5.6	5.5	5.5	5.5	5.5	5.5	5.5	5.4	5.4	5.4	5.4	5.4
25	6.8	6.7	6.7	6.7	6.6	6.6	6.5	6.5	6.5	6.4	6.4	6.4	6.4	6.3	6.3	6.3	6.2	6.2	6.2	6.2	6.2
28	7.5	7.4	7.4	7.3	7.3	7.2	7.2	7.1	7.1	7.1	7.0	7.0	7.0	6.9	6.9	6.9	6.8	6.8	6.8	6.7	6.7
30	8.0	8.0	7.9	7.9	7.8	7.7	7.7	7.6	7.6	7.5	7.5	7.4	7.4	7.4	7.3	7.3	7.3	7.2	7.2	7.1	7.1
31	8.3	8.2	8.2	8.1	8.0	8.0	7.9	7.9	7.8	7.8	7.7	7.7	7.6	7.6	7.5	7.5	7.5	7.4	7.4	7.4	7.3
32	8.6	8.5	8.5	8.4	8.3	8.3	8.2	8.1	8.1	8.0	8.0	7.9	7.9	7.8	7.8	7.7	7.7	7.7	7.6	7.6	7.5
34	9.2	9.2	9.1	9.0	8.9	8.8	8.8	8.7	8.6	8.6	8.5	8.5	8.4	8.4	8.3	8.2	8.2	8.1	8.1	8.1	8.0
36	9.9	9.8	9.7	9.6	9.6	9.5	9.4	9.3	9.2	9.2	9.1	9.0	9.0	8.9	8.8	8.8	8.7	8.7	8.6	8.6	8.5
38	10.7	10.6	10.4	10.3	10.2	10.1	10.0	10.0	9.9	9.8	9.7	9.6	9.6	9.5	9.4	9.4	9.3	9.2	9.2	9.1	9.1
39	11.0	10.9	10.8	10.6	10.6	10.4	10.4	10.3	10.2	10.1	10.0	9.9	9.8	9.8	9.7	9.7	9.6	9.5	9.5	9.4	9.3
40	11.4	11.3	11.2	11.0	10.9	10.8	10.7	10.6	10.5	10.4	10.3	10.3	10.2	10.1	10.0	10.0	9.9	9.8	9.8	9.7	9.6
41	11.8	11.7	11.6	11.4	11.3	11.2	11.1	11.0	10.9	10.8	10.7	10.6	10.5	10.4	10.4	10.3	10.2	10.1	10.1	10.0	9.9
42	12.2	12.1	11.9	11.8	11.7	11.6	11.4	11.4	11.2	11.2	11.0	11.0	10.9	10.8	10.7	10.6	10.5	10.5	10.4	10.3	10.3
43	12.7	12.5	12.4	12.2	12.1	12.0	11.9	11.7	11.6	11.5	11.4	11.3	11.2	11.1	11.0	11.0	10.9	10.8	10.7	10.7	10.6
44	13.1	13.0	12.8	12.7	12.5	12.4	12.3	12.1	12.0	11.9	11.8	11.7	11.6	11.5	11.4	11.3	11.2	11.1	11.1	11.0	10.9
45	13.6	13.4	13.3	13.1	13.0	12.8	12.7	12.6	12.4	12.3	12.2	12.1	12.0	11.9	11.8	11.7	11.6	11.5	11.4	11.3	11.3
46	14.1	13.9	13.8	13.6	13.4	13.3	13.1	13.0	12.8	12.7	12.6	12.5	12.4	12.3	12.2	12.0	11.9	11.9	11.8	11.7	11.6
47	14.6	14.4	14.2	14.1	13.9	13.7	13.5	13.4	13.3	13.2	13.0	12.9	12.8	12.6	12.5	12.5	12.3	12.2	12.1	12.1	12.0
48	15.1	15.0	14.7	14.6	14.3	14.2	14.0	13.8	13.7	13.6	13.5	13.3	13.2	13.0	12.9	12.8	12.7	12.6	12.5	12.4	12.3
49	15.7	15.5	15.3	15.0	14.9	14.7	14.5	14.3	14.2	14.0	13.9	13.7	13.6	13.5	13.4	13.2	13.1	13.0	12.9	12.8	12.7
50		16.0	15.8	15.5	15.4	15.2	15.0	14.8	14.6	14.5	14.3	14.2	14.0	13.9	13.8	13.7	13.5	13.4	13.3	13.2	13.1
51		16.5	16.4	16.1	15.9	15.7	15.5	15.3	15.1	15.0	14.8	14.7	14.5	14.4	14.2	14.1	14.0	13.8	13.7	13.6	13.5
52			16.9	16.7	16.4	16.2	16.0	15.9	15.6	15.4	15.3	15.1	15.0	14.8	14.7	14.5	14.4	14.3	14.2	14.0	13.9
53				17.2	17.0	16.8	16.6	16.3	16.2	15.9	15.8	15.6	15.5	15.3	15.2	15.0	14.8	14.7	14.6	14.5	14.3
54				17.8	17.5	17.3	17.1	16.9	16.7	16.5	16.3	16.1	15.9	15.8	15.6	15.5	15.3	15.2	15.0	14.9	14.8
55					18.2	17.9	17.7	17.5	17.2	17.0	16.8	16.7	16.4	16.3	16.1	15.9	15.8	15.6	15.5	15.3	15.2
56						18.5	18.2	18.0	17.7	17.6	17.3	17.1	17.0	16.8	16.6	16.4	16.3	16.1	16.0	15.8	15.7
57						19.1	18.8	18.6	18.3	18.2	17.9	17.7	17.5	17.3	17.1	16.9	16.7	16.6	16.4	16.3	16.1
58							19.4	19.2	18.9	18.7	18.5	18.2	18.0	17.8	17.6	17.5	17.3	17.2	16.9	16.8	16.6
59							20.0	19.8	19.6	19.3	19.0	18.8	18.6	18.4	18.2	18.1	17.8	17.6	17.5	17.2	17.2
60								20.4	20.2	19.9	19.6	19.4	19.2	18.9	18.7	18.5	18.4	18.1	18.0	17.8	17.7
61									20.7	20.5	20.2	20.0	19.8	19.5	19.3	19.1	18.9	18.7	18.5	18.3	18.1
62									21.3	21.2	20.8	20.5	20.4	20.1	19.8	19.7	19.4	19.3	19.0	18.9	18.6

Table 8.7.1-24
Fuel Qualification Table of Exceptions for EOS-37PTH, 492kgU, HLZC1, Plan1, Zone 1
(Minimum required years of cooling time after reactor core discharge)

BU (GWD/MTU)	Fuel Assembly Average Initial U-235 Enrichment (wt.%)																																											
	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5
6	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
7								3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
10								3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
16								3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
17												3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
20												3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
25												3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
28												3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
30												3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
31													3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
32														3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
34															3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
36																3.3	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
38																	3.9	3.7	3.5	3.3	3.2	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
39																		3.9	3.8	3.5	3.4	3.2	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
40																			4.4	3.9	3.7	3.5	3.4	3.3	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
41																			5.0	4.5	4.4	3.9	3.7	3.7	3.4	3.2	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
42																				5.7	5.0	4.5	4.4	3.9	3.8	3.5	3.5	3.3	3.2	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
43																				6.4	5.7	5.1	5.0	4.4	4.4	3.9	3.8	3.7	3.5	3.3	3.2	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
44																					7.0	6.3	5.7	5.1	4.7	4.4	4.4	3.9	3.8	3.7	3.5	3.4	3.2	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
45																						7.6	7.0	6.3	5.7	5.2	5.0	4.4	4.4	4.0	3.8	3.7	3.5	3.4	3.3	3.2	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0
46																						9.6	8.3	7.6	7.0	6.3	5.7	5.2	5.0	4.4	4.4	3.9	3.9	3.7	3.5	3.4	3.3	3.2	3.1	3.0	3.0	3.0	3.0	3.0
47																							10.2	9.6	8.3	7.6	7.0	6.3	5.7	5.1	5.0	4.5	4.4	4.0	3.9	3.7	3.7	3.5	3.4	3.3	3.2	3.1	3.0	3.0
48																								10.9	10.2	8.9	8.3	7.6	7.0	6.3	5.7	5.2	5.0	4.5	4.4	4.1	3.9	3.8	3.7	3.5	3.4	3.3	3.2	3.1
49																								12.2	11.5	10.9	9.6	8.9	8.3	7.6	7.0	6.3	5.7	5.2	5.0	4.6	4.4	4.4	3.9	3.9	3.7	3.5	3.5	3.4
50																									13.5	12.2	11.5	10.9	9.6	8.9	8.3	7.6	7.0	6.3	5.7	5.2	5.0	4.6	4.4	4.4	4.0	3.9	3.8	3.7
51																									14.8	14.1	13.5	12.2	11.5	10.2	9.6	8.9	8.3	7.6	7.0	6.3	5.7	5.7	5.0	4.7	4.4	4.4	4.0	3.9
52																										16.1	14.8	13.5	13.5	12.2	11.5	10.2	9.6	8.9	8.3	7.6	7.0	6.3	5.7	5.7	5.0	5.0	4.5	4.4
53																											16.8	15.4	14.8	13.5	12.8	12.2	10.9	10.2	9.6	8.9	8.3	7.6	7.0	6.3	6.3	5.7	5.2	5.0
54																											18.7	17.4	16.1	15.4	14.1	13.5	12.8	11.5	10.9	10.2	9.6	8.9	8.3	7.6	7.0	6.3	6.3	5.7
55																												18.7	17.4	16.8	16.1	14.8	14.1	13.5	12.8	12.2	11.5	10.2	9.6	8.9	8.3	7.6	7.0	7.0
56																													19.4	18.7	17.4	16.8	16.1	14.8	14.1	13.5	12.8	12.2	10.9	10.9	9.6	8.9	8.3	8.3
57																													21.2	19.7	19.7	18.7	17.4	16.8	15.4	15.4	14.1	13.5	12.8	11.5	11.5	10.2	10.2	8.9
58																														21.3	21.0	19.7	19.2	18.9	17.1	16.8	16.1	14.8	14.1	13.5	12.8	12.2	11.5	10.9
59																														23.0	22.7	21.8	20.4	19.8	19.4	17.8	17.1	16.3	16.0	14.8	14.1	13.5	12.8	12.2
60																															23.5	23.5	22.1	21.3	20.8	19.5	18.8	17.8	16.9	16.3	15.8	15.4	14.0	13.5
61																																24.0	23.9	22.9	22.3	21.5	20.0	19.4	18.5	18.0	17.1	16.1	15.7	15.2
62																																26.0	25.4	24.5	23.2	22.8	21.5	21.0	19.9	19.2	19.3	17.8	17.1	16.9

Table 8.7.1-25
Fuel Qualification Table of Exceptions for EOS-37PTH, 492kgU, HLZC1, Plan1, Zone 2
(Minimum required years of cooling time after reactor core discharge)

BU (GWD/MTU)	Fuel Assembly Average Initial U-235 Enrichment (wt.%)																																										
	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5
6	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
7								3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
10								3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
16								3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
17												3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
20												3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
25												3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
28												3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
30												3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
31													3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
32														3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
34															3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
36																3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
38																	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
39																		3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
40																			3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
41																			3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
42																				3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
43																				3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
44																					3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
45																						3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
46																						3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
47																							3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
48																								3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
49																								3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
50																									3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
51																									3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
52																										3.2	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
53																											3.2	3.1	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
54																											3.4	3.3	3.2	3.2	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
55																												3.5	3.4	3.3	3.2	3.1	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
56																													3.5	3.4	3.4	3.3	3.2	3.2	3.1	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
57																													3.7	3.6	3.5	3.4	3.3	3.3	3.2	3.2	3.1	3.1	3.0	3.0	3.0	3.0	3.0	3.0
58																														3.7	3.7	3.6	3.5	3.4	3.3	3.3	3.2	3.2	3.1	3.1	3.0	3.0	3.0	3.0
59																														4.0	3.9	3.8	3.7	3.6	3.5	3.4	3.4	3.3	3.2	3.2	3.1	3.1	3.0	3.0
60																															4.0	4.0	3.8	3.7	3.7	3.6	3.5	3.5	3.3	3.3	3.2	3.2	3.1	3.1
61																																4.1	4.1	3.9	3.9	3.7	3.6	3.6	3.5	3.4	3.4	3.3	3.3	3.2
62																																4.4	4.3	4.2	4.0	3.9	3.8	3.8	3.6	3.6	3.5	3.4	3.4	3.3

Table 8.7.1-26
Fuel Qualification Table of Exceptions for EOS-37PTH, 492kgU, HLZC1, Plan1, Zone 3
(Minimum required years of cooling time after reactor core discharge)

BU (GWD/MTU)	Fuel Assembly Average Initial U-235 Enrichment (wt.%)																																											
	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5
6	3.7	3.7	3.7	3.6	3.6	3.6	3.6	3.6	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4
7								3.8	3.8	3.8	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.5	3.5	3.5
10								4.4	4.4	4.4	4.4	4.3	4.3	4.3	4.3	4.3	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.0	4.0	4.0	4.0	4.0
16								5.6	5.6	5.5	5.5	5.4	5.4	5.4	5.3	5.3	5.3	5.2	5.2	5.2	5.2	5.1	5.1	5.1	5.1	5.1	5.1	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.8
17												5.6	5.6	5.6	5.5	5.5	5.5	5.4	5.4	5.4	5.3	5.3	5.3	5.3	5.2	5.2	5.2	5.2	5.2	5.2	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.0	5.0	5.0	5.0	5.0	5.0	5.0
20												6.3	6.2	6.2	6.1	6.1	6.0	6.0	5.9	5.9	5.9	5.8	5.8	5.8	5.7	5.7	5.7	5.7	5.6	5.6	5.6	5.6	5.6	5.5	5.5	5.5	5.5	5.5	5.5	5.4	5.4	5.4	5.4	5.4
25												7.5	7.4	7.4	7.3	7.2	7.1	7.1	7.0	7.0	6.9	6.9	6.8	6.8	6.7	6.7	6.7	6.6	6.6	6.5	6.5	6.5	6.4	6.4	6.4	6.4	6.3	6.3	6.3	6.3	6.2	6.2	6.2	6.2
28												8.4	8.3	8.2	8.1	8.0	8.0	7.9	7.8	7.7	7.7	7.6	7.5	7.5	7.4	7.4	7.3	7.3	7.2	7.2	7.1	7.1	7.1	7.0	7.0	7.0	6.9	6.9	6.9	6.8	6.8	6.8	6.7	6.7
30												9.2	9.0	8.9	8.8	8.7	8.6	8.5	8.4	8.3	8.3	8.2	8.1	8.0	8.0	7.9	7.9	7.8	7.7	7.7	7.6	7.6	7.5	7.5	7.5	7.4	7.4	7.3	7.3	7.3	7.2	7.2	7.2	7.1
31													9.4	9.3	9.1	9.0	8.9	8.8	8.7	8.6	8.6	8.5	8.4	8.3	8.2	8.2	8.1	8.1	8.0	7.9	7.9	7.8	7.8	7.7	7.7	7.6	7.6	7.6	7.5	7.5	7.4	7.4	7.4	7.3
32														9.7	9.5	9.4	9.3	9.2	9.1	9.0	8.9	8.8	8.7	8.6	8.5	8.5	8.4	8.3	8.3	8.2	8.2	8.1	8.0	8.0	7.9	7.9	7.8	7.8	7.8	7.7	7.7	7.6	7.6	7.6
34															10.3	10.1	10.0	9.9	9.8	9.7	9.5	9.4	9.3	9.2	9.2	9.1	9.0	8.9	8.8	8.8	8.7	8.6	8.6	8.5	8.5	8.4	8.4	8.3	8.3	8.2	8.2	8.1	8.1	8.0
36																11.0	10.8	10.7	10.5	10.4	10.3	10.2	10.0	9.9	9.8	9.7	9.7	9.6	9.5	9.4	9.3	9.2	9.2	9.1	9.0	9.0	8.9	8.9	8.8	8.7	8.7	8.6	8.6	8.5
38																	11.7	11.5	11.4	11.2	11.1	10.9	10.8	10.7	10.6	10.4	10.3	10.2	10.2	10.1	10.0	9.9	9.8	9.7	9.7	9.6	9.5	9.5	9.4	9.3	9.3	9.2	9.1	9.1
39																		11.9	11.7	11.6	11.4	11.3	11.2	11.0	10.9	10.8	10.7	10.6	10.5	10.4	10.3	10.2	10.1	10.0	10.0	9.9	9.8	9.7	9.7	9.6	9.5	9.5	9.4	9.4
40																			12.2	12.0	11.9	11.7	11.6	11.4	11.3	11.2	11.1	11.0	10.8	10.7	10.6	10.6	10.4	10.4	10.3	10.2	10.1	10.1	10.0	9.9	9.9	9.8	9.7	9.7
41																			12.6	12.5	12.3	12.2	12.0	11.9	11.7	11.6	11.4	11.3	11.2	11.1	11.0	10.9	10.8	10.7	10.6	10.6	10.5	10.4	10.3	10.2	10.2	10.1	10.0	10.0
42																				13.0	12.8	12.6	12.4	12.3	12.1	12.0	11.9	11.7	11.6	11.5	11.4	11.3	11.2	11.1	11.0	10.9	10.8	10.7	10.6	10.6	10.5	10.4	10.3	10.3
43																				13.5	13.3	13.1	12.9	12.7	12.6	12.4	12.3	12.1	12.0	11.9	11.8	11.7	11.6	11.4	11.4	11.3	11.2	11.1	11.0	10.9	10.8	10.7	10.7	10.6
44																					13.8	13.6	13.4	13.2	13.0	12.9	12.7	12.6	12.4	12.3	12.2	12.1	11.9	11.9	11.7	11.6	11.5	11.4	11.3	11.3	11.2	11.1	11.0	11.0
45																						14.1	13.8	13.7	13.5	13.3	13.2	13.0	12.9	12.8	12.6	12.5	12.3	12.2	12.1	12.0	11.9	11.8	11.7	11.6	11.5	11.5	11.4	11.3
46																						14.6	14.4	14.2	14.0	13.8	13.7	13.5	13.3	13.2	13.0	12.9	12.8	12.6	12.5	12.4	12.3	12.2	12.1	12.0	11.9	11.8	11.7	11.6
47																							14.9	14.7	14.5	14.3	14.1	13.9	13.8	13.6	13.5	13.3	13.2	13.1	13.0	12.8	12.7	12.6	12.5	12.4	12.3	12.2	12.1	12.0
48																								15.2	15.0	14.8	14.6	14.5	14.2	14.1	13.9	13.8	13.7	13.5	13.4	13.3	13.1	13.0	12.9	12.8	12.7	12.6	12.5	12.4
49																								15.8	15.6	15.4	15.1	15.0	14.7	14.6	14.4	14.3	14.1	14.0	13.8	13.7	13.6	13.4	13.3	13.2	13.1	13.0	12.9	12.8
50																									16.2	15.9	15.7	15.5	15.3	15.1	14.9	14.7	14.6	14.4	14.3	14.1	14.0	13.8	13.7	13.6	13.5	13.4	13.3	13.2
51																									16.7	16.5	16.2	16.0	15.8	15.6	15.4	15.2	15.1	14.9	14.8	14.6	14.4	14.3	14.2	14.1	13.9	13.8	13.7	13.6
52																										17.1	16.8	16.5	16.4	16.1	16.0	15.8	15.5	15.4	15.2	15.1	14.9	14.8	14.6	14.5	14.4	14.3	14.1	14.0
53																											17.4	17.1	16.9	16.7	16.4	16.3	16.1	15.9	15.7	15.6	15.4	15.3	15.1	15.0	14.8	14.7	14.6	14.4
54																											18.0	17.7	17.4	17.3	17.0	16.9	16.6	16.4	16.3	16.0	15.9	15.7	15.6	15.4	15.3	15.1	15.0	14.9
55																												18.3	18.1	17.9	17.6	17.3	17.2	16.9	16.8	16.6	16.4	16.3	16.0	15.9	15.7	15.6	15.4	15.4
56																													18.7	18.4	18.2	17.9	17.8	17.5	17.3	17.1	16.9	16.8	16.6	16.4	16.3	16.1	15.9	15.9
57																													19.3	19.0	18.8	18.5	18.3	18.1	17.8	17.7	17.5	17.3	17.1	16.9	16.8	16.6	16.4	16.3
58																														19.6	19.4	19.2	18.9	18.7	18.4	18.3	18.1	17.8	17.7	17.4	17.3	17.1	17.0	16.8
59																														20.3	20.0	19.8	19.5	19.3	19.0	18.8	18.6	18.4	18.2	18.0	17.8	17.7	17.4	17.3
60																															20.6	20.4	20.1	19.8	19.6	19.4	19.2	18.9	18.7	18.5	18.3	18.2	17.9	17.7
61																																20.9	20.8	20.4	20.2	20.0	19.7	19.5	19.3	19.1	18.9	18.6	18.5	18.3
62																																21.6	21.4	21.1	20.8	20.6	20.3	20.2	19.9	19.6	19.5	19.2	19.1	18.9

Table 8.7.1-27
Fuel Qualification Table of Exception-counterparts for EOS-37PTH, 492kgU, HLZC1, Plan1, Zone 1
(Minimum required years of cooling time after reactor core discharge)

BU (GWD/MTU)	Fuel Assembly Average Initial U-235 Enrichment (wt.%)																																											
	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5
6	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
7								3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
10								3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
16								3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
17												3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
20												3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
25												3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
28												3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
30												3.9	3.7	3.5	3.4	3.2	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
31													4.0	3.8	3.7	3.5	3.4	3.2	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
32														4.4	4.0	3.8	3.7	3.5	3.4	3.3	3.2	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
34															5.7	5.0	4.6	4.4	4.0	3.9	3.7	3.7	3.5	3.4	3.2	3.1	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
36																7.6	6.3	6.3	5.7	5.0	4.5	4.4	4.4	3.9	3.8	3.7	3.5	3.5	3.4	3.3	3.2	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
38																	10.2	8.9	8.3	7.0	6.3	6.3	5.7	5.0	5.0	4.4	4.4	4.0	3.9	3.8	3.7	3.5	3.5	3.4	3.3	3.2	3.2	3.1	3.0	3.0	3.0	3.0	3.0	3.0
39																		10.2	9.6	8.3	8.3	7.0	6.3	5.7	5.1	5.0	4.5	4.4	4.4	4.0	3.9	3.7	3.7	3.5	3.5	3.4	3.3	3.2	3.2	3.1	3.0	3.0	3.0	3.0
40																			11.5	10.2	9.6	8.3	7.6	7.0	6.3	5.7	5.7	5.0	4.6	4.4	4.4	4.1	3.9	3.8	3.7	3.7	3.5	3.5	3.4	3.3	3.3	3.2	3.1	3.0
41																			13.5	13.5	11.5	10.2	9.6	8.3	8.3	7.0	6.3	5.7	5.7	5.0	5.0	4.4	4.4	4.4	4.0	3.9	3.8	3.7	3.7	3.5	3.5	3.4	3.3	3.2
42																				14.8	13.5	13.5	11.5	10.2	9.6	8.3	8.3	7.0	6.3	5.7	5.7	5.0	5.0	4.5	4.4	4.4	4.1	3.9	3.9	3.8	3.7	3.7	3.5	3.5
43																				16.8	15.4	14.1	13.5	12.2	11.5	10.2	9.6	8.3	8.3	7.0	6.3	6.3	5.7	5.2	5.0	5.0	4.5	4.4	4.4	4.0	3.9	3.8	3.7	3.7
44																					18.7	16.1	15.4	14.1	13.5	12.2	10.9	10.2	9.6	8.9	8.3	7.6	7.0	6.3	5.7	5.7	5.0	5.0	4.5	4.4	4.4	4.4	4.0	3.9
45																						18.7	17.4	16.1	15.4	14.1	13.5	12.2	11.5	10.2	9.6	8.9	8.3	7.0	7.0	6.3	6.3	5.7	5.1	5.0	5.0	4.5	4.4	4.4
46																						20.7	19.4	18.7	17.4	16.1	15.4	14.1	13.5	12.2	11.5	10.2	9.6	8.9	8.3	7.6	7.0	6.3	6.3	5.7	5.7	5.0	5.0	4.6
47																							21.3	20.7	19.4	18.7	17.4	16.1	15.4	14.1	13.5	12.2	11.5	10.9	10.2	8.9	8.3	8.3	7.6	7.0	6.3	5.7	5.7	5.2
48																								22.0	21.3	20.0	19.4	18.7	16.8	16.1	14.8	14.1	13.5	13.5	11.5	10.9	10.2	9.6	8.3	8.3	7.6	7.0	6.3	6.3
49																								23.9	23.9	22.0	20.7	20.0	18.7	18.7	16.8	16.1	15.4	14.8	13.5	13.5	11.5	10.9	10.2	9.6	8.9	8.3	8.3	7.0
50																									24.6	23.9	22.6	22.0	20.7	19.4	18.7	18.7	17.4	16.1	15.4	14.1	13.5	13.5	12.2	10.9	10.9	9.6	8.9	8.3
51																									26.5	25.9	24.6	23.9	22.6	21.3	20.7	20.0	18.7	18.7	17.4	16.1	15.4	14.8	13.5	13.5	12.2	11.5	10.9	10.2
52																										27.2	26.5	25.2	24.6	23.9	22.6	21.3	20.7	20.0	18.7	18.7	17.4	16.8	15.4	14.8	14.1	13.5	12.2	11.5
53																											29.2	27.2	26.5	25.2	23.9	23.9	22.6	22.0	20.7	20.0	18.7	18.7	17.4	16.1	15.4	14.8	14.1	13.5
54																											29.8	29.2	27.9	27.2	25.9	25.2	23.9	23.9	22.6	21.3	20.7	20.0	19.4	18.7	18.7	16.8	16.1	15.4
55																												30.5	29.2	29.2	27.9	26.5	25.9	24.6	23.9	23.9	22.6	21.3	20.7	20.0	18.7	18.7	17.4	16.8
56																													31.1	29.8	29.2	29.2	27.9	26.5	25.9	25.2	23.9	23.9	22.6	22.0	20.7	20.0	19.4	18.7
57																													33.3	32.5	31.4	29.8	29.2	29.2	27.2	26.5	25.9	25.2	23.9	23.9	22.6	21.3	21.3	20.0
58																														33.2	33.1	32.5	30.7	30.3	29.4	29.2	27.2	26.5	25.9	24.6	24.6	23.9	23.9	22.0
59																														35.6	33.6	34.1	32.1	32.4	30.9	30.4	29.4	28.2	27.3	26.5	25.9	25.2	23.9	23.9
60																															35.6	34.7	34.1	33.4	32.8	32.3	31.4	30.4	29.4	28.6	27.0	26.5	25.6	24.6
61																																36.5	35.3	35.4	34.8	33.7	32.6	31.1	31.3	30.2	29.3	29.0	27.2	26.4
62																																37.7	37.0	35.9	35.1	35.4	33.5	32.8	31.8	31.8	30.9	29.3	28.7	27.9

Table 8.7.1-28
Fuel Qualification Table of Exception-counterparts for EOS-37PTH, 492kgU, HLZC1, Plan1, Zone 2
(Minimum required years of cooling time after reactor core discharge)

BU (GWD/MTU)	Fuel Assembly Average Initial U-235 Enrichment (wt.%)																																											
	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5
6	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
7								3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
10								3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
16								3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
17												3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
20												3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
25												3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
28												3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
30												3.2	3.1	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
31													3.2	3.2	3.1	3.1	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
32														3.3	3.3	3.2	3.2	3.1	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
34															3.5	3.5	3.4	3.4	3.3	3.2	3.2	3.2	3.1	3.1	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
36																3.8	3.7	3.6	3.5	3.5	3.5	3.4	3.4	3.3	3.3	3.2	3.2	3.2	3.1	3.1	3.1	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
38																	4.0	3.9	3.9	3.8	3.7	3.6	3.6	3.5	3.5	3.5	3.4	3.4	3.3	3.3	3.2	3.2	3.2	3.2	3.1	3.1	3.1	3.1	3.0	3.0	3.0	3.0	3.0	3.0
39																		4.1	4.0	3.9	3.9	3.8	3.7	3.6	3.6	3.5	3.5	3.5	3.4	3.4	3.3	3.3	3.3	3.2	3.2	3.2	3.2	3.1	3.1	3.1	3.1	3.1	3.0	3.0
40																			4.3	4.1	4.0	3.9	3.9	3.8	3.7	3.7	3.6	3.6	3.5	3.5	3.5	3.4	3.4	3.3	3.3	3.3	3.2	3.2	3.2	3.2	3.1	3.1	3.1	3.1
41																			4.4	4.4	4.2	4.1	4.0	3.9	3.9	3.8	3.8	3.7	3.6	3.6	3.5	3.5	3.5	3.5	3.4	3.4	3.3	3.3	3.3	3.2	3.2	3.2	3.2	3.1
42																				4.6	4.4	4.4	4.3	4.1	4.0	3.9	3.9	3.9	3.8	3.7	3.7	3.6	3.6	3.5	3.5	3.5	3.5	3.4	3.4	3.3	3.3	3.3	3.2	3.2
43																				4.9	4.7	4.6	4.4	4.4	4.3	4.2	4.1	4.0	3.9	3.9	3.8	3.8	3.7	3.6	3.6	3.5	3.5	3.5	3.5	3.4	3.4	3.4	3.3	3.3
44																					5.0	4.8	4.8	4.6	4.4	4.4	4.3	4.2	4.1	4.0	3.9	3.9	3.8	3.8	3.7	3.7	3.6	3.6	3.5	3.5	3.5	3.5	3.5	3.4
45																						5.2	5.0	4.8	4.7	4.6	4.5	4.4	4.3	4.2	4.1	4.0	4.0	3.9	3.9	3.8	3.8	3.7	3.7	3.6	3.6	3.5	3.5	3.5
46																						5.7	5.3	5.2	5.0	4.8	4.8	4.6	4.5	4.4	4.4	4.2	4.2	4.0	4.0	3.9	3.9	3.9	3.8	3.7	3.7	3.6	3.6	3.6
47																							5.7	5.7	5.3	5.2	5.0	4.8	4.8	4.6	4.5	4.4	4.4	4.3	4.2	4.1	4.0	4.0	3.9	3.9	3.9	3.8	3.7	3.7
48																								6.0	5.7	5.5	5.3	5.2	5.0	4.9	4.8	4.7	4.5	4.4	4.4	4.3	4.2	4.1	4.0	4.0	3.9	3.9	3.9	3.8
49																								6.6	6.3	6.0	5.7	5.6	5.3	5.2	5.0	4.9	4.8	4.7	4.6	4.5	4.4	4.4	4.3	4.2	4.1	4.0	4.0	3.9
50																									7.0	6.6	6.3	6.0	5.7	5.5	5.3	5.2	5.1	4.9	4.8	4.7	4.6	4.5	4.4	4.4	4.3	4.2	4.2	4.1
51																									7.6	7.2	7.0	6.5	6.3	5.9	5.7	5.6	5.4	5.2	5.1	5.0	4.8	4.8	4.6	4.5	4.4	4.4	4.3	4.3
52																										8.3	7.6	7.0	7.0	6.5	6.3	6.0	5.7	5.7	5.4	5.2	5.1	5.0	4.8	4.8	4.7	4.6	4.5	4.4
53																											8.3	7.9	7.6	7.1	6.7	6.5	6.3	6.0	5.7	5.7	5.4	5.3	5.2	5.0	4.9	4.8	4.8	4.6
54																											9.6	8.9	8.3	7.9	7.6	7.1	6.7	6.4	6.3	6.0	5.8	5.7	5.5	5.3	5.2	5.1	5.0	4.8
55																												9.7	9.1	8.9	8.3	7.7	7.6	7.0	7.0	6.5	6.3	6.1	5.8	5.7	5.5	5.4	5.2	5.1
56																													10.2	9.6	9.1	8.6	8.3	7.8	7.4	7.1	6.7	6.6	6.3	6.1	5.9	5.7	5.6	5.4
57																													11.4	10.6	10.1	9.6	8.9	8.6	8.3	7.8	7.6	7.1	7.0	6.5	6.3	6.1	6.0	5.7
58																														11.7	11.4	10.6	10.0	9.8	8.9	8.9	8.3	7.7	7.6	7.1	7.0	6.6	6.4	6.1
59																														13.1	12.3	12.1	11.0	10.6	10.2	9.4	9.1	8.5	8.2	7.8	7.6	7.2	7.0	6.6
60																															13.7	13.0	12.3	11.5	11.0	10.6	10.2	9.5	8.9	8.6	8.1	7.9	7.5	7.1
61																																14.2	13.4	12.7	12.4	11.6	10.8	10.8	9.8	9.6	9.0	8.5	8.3	7.8
62																																15.2	14.7	13.9	13.2	12.7	11.9	11.5	11.0	10.3	10.0	9.4	9.2	8.6

Table 8.7.1-29
Fuel Qualification Table of Exception-counterparts for EOS-37PTH, 492kgU, HLZC1, Plan1, Zone 3
(Minimum required years of cooling time after reactor core discharge)

BU (GWD/MTU)	Fuel Assembly Average Initial U-235 Enrichment (wt.%)																																										
	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5
6	4.0	3.9	3.9	3.9	3.9	3.8	3.8	3.8	3.8	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.5
7								4.0	4.0	4.0	4.0	4.0	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.7	3.7	3.7
10								4.7	4.7	4.6	4.6	4.6	4.6	4.6	4.5	4.5	4.5	4.5	4.5	4.5	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3
16								6.0	6.0	5.9	5.9	5.8	5.8	5.8	5.7	5.7	5.6	5.6	5.6	5.6	5.5	5.5	5.5	5.4	5.4	5.4	5.4	5.4	5.3	5.3	5.3	5.3	5.3	5.3	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.1	5.1
17												6.1	6.0	6.0	5.9	5.9	5.8	5.8	5.8	5.7	5.7	5.7	5.7	5.6	5.6	5.6	5.6	5.5	5.5	5.5	5.5	5.5	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.3	5.3	5.3	5.3	5.3
20												6.8	6.7	6.7	6.6	6.6	6.5	6.5	6.4	6.4	6.3	6.3	6.2	6.2	6.2	6.1	6.1	6.1	6.1	6.0	6.0	6.0	6.0	5.9	5.9	5.9	5.9	5.9	5.8	5.8	5.8	5.8	5.8	5.8
25												8.3	8.2	8.1	8.0	7.9	7.8	7.8	7.7	7.6	7.6	7.5	7.5	7.4	7.3	7.3	7.2	7.2	7.2	7.1	7.1	7.0	7.0	7.0	6.9	6.9	6.9	6.8	6.8	6.8	6.7	6.7	6.7	6.7
28												9.4	9.3	9.2	9.0	8.9	8.8	8.7	8.6	8.6	8.5	8.4	8.3	8.3	8.2	8.1	8.1	8.0	8.0	7.9	7.8	7.8	7.7	7.7	7.7	7.6	7.6	7.5	7.5	7.5	7.4	7.4	7.3	7.3
30												10.3	10.1	10.0	9.9	9.7	9.6	9.5	9.4	9.3	9.2	9.1	9.0	8.9	8.8	8.8	8.7	8.6	8.6	8.5	8.4	8.4	8.3	8.3	8.2	8.2	8.1	8.1	8.0	8.0	7.9	7.9	7.9	7.8
31													10.6	10.4	10.3	10.1	10.0	9.9	9.7	9.7	9.5	9.4	9.3	9.3	9.2	9.1	9.0	8.9	8.9	8.8	8.7	8.7	8.6	8.6	8.5	8.4	8.4	8.3	8.3	8.2	8.2	8.2	8.1	8.1
32														10.9	10.7	10.6	10.4	10.3	10.1	10.0	9.9	9.8	9.7	9.6	9.5	9.4	9.3	9.3	9.2	9.1	9.1	9.0	8.9	8.8	8.8	8.7	8.7	8.6	8.6	8.5	8.5	8.4	8.4	8.3
34															11.6	11.4	11.3	11.1	11.0	10.8	10.7	10.6	10.5	10.4	10.3	10.2	10.1	10.0	9.9	9.8	9.7	9.7	9.6	9.5	9.4	9.4	9.3	9.2	9.2	9.1	9.1	9.0	9.0	8.9
36																12.4	12.3	12.1	11.9	11.8	11.6	11.5	11.3	11.2	11.1	11.0	10.8	10.7	10.6	10.6	10.4	10.4	10.3	10.2	10.1	10.1	10.0	9.9	9.8	9.8	9.7	9.7	9.6	9.5
38																	13.3	13.1	12.9	12.7	12.6	12.4	12.2	12.1	11.9	11.8	11.7	11.6	11.4	11.3	11.2	11.1	11.0	11.0	10.9	10.8	10.7	10.6	10.6	10.5	10.4	10.3	10.2	10.2
39																		13.5	13.3	13.2	13.0	12.8	12.7	12.5	12.3	12.2	12.1	11.9	11.9	11.7	11.6	11.5	11.4	11.3	11.2	11.1	11.0	11.0	10.9	10.8	10.7	10.7	10.6	10.5
40																			13.9	13.7	13.5	13.3	13.1	13.0	12.8	12.7	12.5	12.4	12.3	12.1	12.0	11.9	11.8	11.7	11.6	11.5	11.4	11.3	11.3	11.2	11.1	11.0	11.0	10.9
41																			14.4	14.2	14.0	13.8	13.7	13.5	13.3	13.1	13.0	12.8	12.7	12.6	12.5	12.3	12.2	12.1	12.0	11.9	11.8	11.7	11.6	11.6	11.5	11.4	11.3	11.2
42																				14.8	14.6	14.4	14.2	14.0	13.8	13.7	13.5	13.3	13.2	13.0	12.9	12.8	12.7	12.5	12.4	12.3	12.2	12.1	12.0	12.0	11.9	11.8	11.7	11.6
43																				15.4	15.1	14.9	14.7	14.5	14.3	14.1	14.0	13.8	13.7	13.5	13.4	13.2	13.1	13.0	12.9	12.8	12.7	12.5	12.5	12.3	12.3	12.2	12.1	12.0
44																					15.8	15.5	15.3	15.1	14.8	14.7	14.5	14.3	14.1	14.0	13.8	13.7	13.6	13.5	13.3	13.2	13.1	13.0	12.9	12.8	12.7	12.6	12.5	12.4
45																						16.1	15.9	15.6	15.4	15.2	15.0	14.9	14.7	14.6	14.3	14.2	14.1	13.9	13.8	13.7	13.5	13.4	13.3	13.2	13.1	13.0	12.9	12.8
46																						16.8	16.4	16.3	16.0	15.8	15.6	15.4	15.2	15.0	14.9	14.7	14.6	14.4	14.3	14.1	14.0	13.9	13.8	13.7	13.5	13.4	13.3	13.2
47																							17.1	16.9	16.6	16.3	16.2	15.9	15.8	15.6	15.4	15.2	15.1	14.9	14.8	14.6	14.5	14.3	14.2	14.1	14.0	13.9	13.8	13.7
48																								17.4	17.2	16.9	16.8	16.5	16.3	16.1	15.9	15.8	15.6	15.4	15.2	15.1	15.0	14.8	14.7	14.6	14.4	14.3	14.2	14.1
49																								18.1	17.9	17.6	17.3	17.2	16.9	16.8	16.5	16.3	16.1	16.0	15.8	15.7	15.5	15.4	15.2	15.1	14.9	14.8	14.7	14.6
50																									18.5	18.2	18.0	17.7	17.5	17.2	17.1	16.8	16.7	16.5	16.3	16.1	16.0	15.9	15.7	15.5	15.4	15.3	15.2	15.0
51																									19.1	18.9	18.6	18.3	18.1	17.8	17.7	17.4	17.3	17.1	16.9	16.7	16.5	16.4	16.2	16.0	15.9	15.8	15.6	15.5
52																										19.6	19.3	19.0	18.8	18.5	18.3	18.1	17.8	17.7	17.4	17.3	17.1	16.9	16.8	16.6	16.4	16.3	16.1	16.0
53																											19.9	19.6	19.4	19.1	18.9	18.7	18.4	18.2	18.0	17.8	17.7	17.5	17.3	17.1	16.9	16.8	16.7	16.5
54																											20.7	20.3	20.0	19.8	19.5	19.3	19.0	18.8	18.6	18.4	18.2	18.0	17.8	17.7	17.5	17.3	17.2	17.0
55																												21.0	20.7	20.4	20.2	19.9	19.7	19.4	19.2	19.0	18.8	18.6	18.4	18.2	18.0	17.9	17.7	17.6
56																													21.4	21.1	20.8	20.5	20.3	20.0	19.8	19.6	19.4	19.2	19.0	18.8	18.6	18.5	18.2	18.1
57																													22.1	21.7	21.5	21.2	20.9	20.8	20.4	20.3	20.0	19.9	19.6	19.4	19.2	19.0	18.8	18.6
58																														22.4	22.2	21.9	21.6	21.4	21.1	20.9	20.7	20.3	20.2	19.9	19.8	19.5	19.4	19.2
59																														23.2	22.8	22.6	22.2	22.1	21.8	21.4	21.3	21.0	20.8	20.6	20.3	20.2	19.9	19.8
60																															23.5	23.3	23.0	22.6	22.4	22.1	22.0	21.7	21.4	21.2	21.0	20.8	20.5	20.3
61																																23.9	23.7	23.3	23.1	22.8	22.5	22.3	22.0	21.9	21.6	21.3	21.2	20.9
62																																24.7	24.4	24.0	23.7	23.5	23.2	23.0	22.7	22.4	22.3	22.0	21.8	21.5

Table 8.7.1-30
Additional Cooling Time for FAs with CCs (year)

Ratio to CC DBS (1)	Zone3, HLZC1, Plan1	Zone3, HLZC1, Plan2
1	6.6	4.8
0.75	4.6	3.4
0.5	2.9	2.2
0.25	1.4	1.1
0.1	0.6	0.5
0	0.0	0.0
Ratio to CC DBS	**Zone4, HLZC2, Plan1**	**Zone4, HLZC2, Plan2**
1	3.1	3.3
0.75	2.2	2.4
0.5	1.4	1.5
0.25	0.7	0.8
0.1	0.3	0.3
0	0.0	0.0
Ratio to CC DBS	**Zone6, HLZC2, Plan1**	**Zone6, HLZC2, Plan2**
1	18.7	11.5
0.75	12.7	8.0
0.5	7.6	5.1
0.25	3.6	2.3
0.1	1.6	1.0
0	0.0	0.0

Note: (1) ratio of as loaded CC equivalent Co-60 activity to the CC DBS equivalent Co-60 activity in Table 1.6.1-17.

Notes: Table 8.7.1-2 through Table 8.7.1-30

Note A: General Notes

- BU = Assembly average burnup.
- For the fuel assembly (FA) with axial blankets that are large (>5% active fuel length at each end), BU = Maximum burnup.
- Use burnup and enrichment to look up minimum cooling time in years. Licensee is responsible for ensuring that uncertainties in fuel enrichment and burnup are correctly accounted for during fuel qualification.
- Round burnup UP to next higher entry; round enrichments DOWN to next lower entry.
- Fuel with an assembly average initial enrichment less than 0.6 wt.% U-235 or greater than 5.0 wt.% U-235 is unacceptable for transport.
- Fuel with a burnup greater than 62 GWd/MTU is unacceptable for transport.
- Fuel with a burnup less than 6 GWd/MTU is acceptable for transport after 5.0 years cooling.
- The cooling times for failed, damaged, and intact assemblies are identical.
- Decay heat of damaged and fail fuel has to be verified against the heat load zone configurations (HLZCs).
- For HBU FAs that have been in dry storage for more than 20 years, add 5.0 years of additional cooling time.
- For FAs in EOS-37PTH DSCs in HLZC 1, tables are provided for uranium loadings of 400 kgU, 450 kgU, and 492 kgU. Use an FQT with a uranium loading that exceeds the fuel assembly uranium loading. Optionally, cooling times may be interpolated between tables based on the fuel assembly uranium loading, as described in Note B below.
- Requirements for reconstituted FAs are described in Note C below.
- Applications of FQT exceptions are described in Note D below.
- Requirements for FAs with control components in the EOS-37PTH DSC are described in Note E below.
- For old fuel with higher cobalt impurity in materials (Stainless Steel 304, Inconel-718, and Inconel X-750) than shown in Table 5-5, add 13.0 years of additional cooling time.

Example: An FA with 488 kgU is to be loaded into the EOS-37PTH DSC, HLZC 1, Plan 1, and Zone 1. The FA has an initial enrichment of 3.65 wt.% U-235 and a burnup of 41.5 GWd/MTU. Because 488 kgU is larger than 450 kgU, the 492 kgU FQT applies. This assembly is acceptable for transport after 9.6 years as defined by 3.6% (rounding down) and 42 GWd/MTU (rounding up) per the 492 kgU/FA section of FQT Table 8.7.1-3.

Note B: Interpolation of Cooling Times based on Uranium Loading

If the FA uranium loading kgUnew falls within the range kgUlow < kgUnew < kgUhigh, where kgUlow and kgUhigh represent the uranium loadings of the FQTs, cooling times may be interpolated between fuel qualification tables (FQTs) using the following equation:

$$\text{CTnew} = \frac{\mathbf{CThigh} * \ln(\mathbf{kgUnew}/\mathbf{kgUlow}) + \mathbf{CTlow} * [\ln(\mathbf{kgUhigh}/\mathbf{kgUlow}) - \ln(\mathbf{kgUnew}/\mathbf{kgUlow})]}{\ln(\mathbf{kgUhigh}/\mathbf{kgUlow})}$$

In this equation, CTlow and CThigh correspond to the cooling times in the FQTs for the low and high uranium loadings.

Because FQTs are available for 400 kgU, 450 kgU, and 492 kgU, interpolation may be performed either between the 400 kgU and 450 kgU tables or between the 450 kgU and 492 kgU tables. The fitting equation solution shall be rounded up to the nearest 0.1 years.

Note C: Requirements for Reconstituted Fuel Assemblies

- For reconstituted FAs with UO_2 rods and/or Zr rods or Zr pellets and/or stainless steel rods, use the assembly average equivalent enrichment to determine the minimum cooling time.
- For irradiated stainless steel rods, the number of irradiated stainless steel rods ≤ 5 rods, no additional cooling time is needed when reconstituted fuel is loaded in the inner zone shown in Figure 1.6.1-3, and an additional cooling time of 2 years is needed when reconstituted fuel is loaded in the peripheral zone shown in Figure 1.6.1-3.

Note D: Application of FQT Exceptions

When an FA has a cooling time shorter than the minimum required cooling time listed in the standard FQTs of EOS-37PTH HLZC1 Plan 1 (Table 8.7.1-2 through Table 8.7.1-4) there are exceptions that may be applied to qualify this FA to be loaded. The exceptions are applied with three conditions/steps:

- Condition 1: the total decay heat of this FA is verified against the heat load zone configurations (HLZCs).
- Condition 2: this FA has a cooling time longer than the minimum cooling time listed in the FQT exceptions for EOS-37PTH HLZC 1 Plan 1 (Table 8.7.1-25 through Table 8.7.1-27)
- Condition 3: at least two adjacent FAs in the same zone as this FA have a cooling time longer than the minimum cooling time listed in the FQT exception-counterparts for EOS-37PTH HLZC 1 Plan 1 Table 8.7.1-28 through Table 8.7.1-30.

- Example: Three FAs, FA 1, FA 2, FA 3, with a fuel loading of 488 kgU, are to be loaded into the EOS-37PTH DSC, HLZC 1, Plan 1, and Zone 3. The FAs have an initial enrichment of 3.6 wt.% U-235 and a burnup of 42 GWd/MTU. Because 488 kgU is larger than 450 kgU and less than 492 kgU, the 492 kgU FQT can be applied. The cooling times are 11.9, 13.2, and 13.5 years for FA 1, FA 2, and FA 3, respectively. Even though the decay heat from each of the three FAs is lower than the decay heat limit for the EOS-37PTH DSC, HLZC1, Plan 1, and Zone 3, checked by other means, FA 1 still cannot be qualified according to the standard FQT of the EOS-37PTH DSC, HLZC 1, Plan 1, and Zone 3 (Table 8.7.1-4), which shows a minimum cooling time of 12.2 years. However, the cooling time of FA 1 is longer than 11.5 years, the minimum cooling time listed in the FQT of exceptions for the EOS-37PTH DSC, HLZC 1, Plan 1, and Zone 3 (Table 8.7.1-26), and the cooling times of FA 2 and FA 3 are both longer than 13.0 years, the minimum cooling time listed in the FQT of exception-counterparts for the EOS-37PTH DSC, HLZC 1, Plan 1, and Zone 3 (Table 8.7.1-29). Therefore, FA 1 can be loaded into the EOS-37PTH DSC, HLZC 1, Plan 1, and Zone 3, as long as FA 2 and FA 3 are loaded adjacent to FA 1 in the same zone.

<u>Note E: Requirements for FAs with control components (CCs):</u>

The maximum Co-60 equivalent activity for the CCs stored in the EOS-37PTH DSC is specified in Table 1.6.1-17.

- For an FA with control components are loaded in the inner zones of the EOS-37PTH DSC shown in Figure 1.6.1-3, no additional cooling time is needed for the FA.
- For an FA with control components are loaded in the peripheral zones of the EOS-37PTH DSC shown in Figure 1.6.1-3, additional cooling time is added to the minimum cooling time in the FQTs for the FA according to Table 8.7.1-30.
- Example: A CC is going to be loaded in the EOS-37PTH DSC, HLZC 1, Plan1, Zone 3, and the CC has equivalent Co-60 activities of 200, 7, and 4 Ci, from the active fuel, plenum, and top nozzle regions, respectively. The maximum ratio of 0.65 can be obtained from ratios of 0.65 (=200/308) from the active fuel region, 0.47 (=7/14.8), and 0.42 (=4/9.5) from the active fuel, plenum, and top nozzle regions, respectively, compared to the equalent Co-60 activity limits in Table 1.6.1-6. The maximum ratio of 0.65 is between 0.5 and 0.75; therefore, the ratio of 0.75 is applied and an additional cooling time of 4.6 years is required for the host FA, according to Table 8.7.1-30.

The following procedure is used to compute Co-60 equivalent activity:

1. A CC source must be known. This procedure is necessary only if the CC contains silver, hafnium, or other element with significant activation sources in comparison to Co-60.

2. Using the peripheral zone response functions (Table 5-55 for EOS-37PTH in HLZC 1, Zone 3, Table 5-59 for EOS-37PTH in HLZC 2, Zone 4, or Table 5-61 for EOS-37PTH in HLZC 2, Zone 6), and using the CC source, compute response function dose rates and choose the maximum response function dose rate D_{CC} from segments 4 to 32.

3. Repeat step 2 but using the CC design basis source (DBS) in Table 5-32, compute response function dose rates and choose the maximum response function dose rate D_{DBS} from segments 4 to 32.

4. Co-60 equivalent activity for the CC source is: $Co_{CC} = (Co_{DBS})(D_{CC}/D_{DBS})$. Co_{DBS} is the Co-60 equivalent activity provided in Table 1.6.1-17.

Appendix 8.7.2
EOS-89BTH FQTs

LIST OF TABLES

8.7.2 EOS-89BTH FQTs

Table 8.7.2-1
FQTs for EOS-89BTH DSCs inside TN Eagle LC

DSC	HLZC #	Plan #	FQTs
EOS-89BTH	1	1	For uranium loading up to 198 kgU, refer to Table 8.7.2-2 through Table 8.7.2-4 for standard FQTs (Table 8.7.2-5 through Table 8.7.2-7 for FQT exceptions, and Table 8.7.2-8 through Table 8.7.2-10 for FQT exception-counterparts)

Table 8.7.2-2
Fuel Qualification Table for EOS-89BTH, 198kgU, HLZC1, Plan1, Zone 1
(Minimum required years of cooling time after reactor core discharge)

BU (GWD/MTU)	Fuel Assembly Average Initial U-235 Enrichment (wt.%)																																										
	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5
6	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
7			3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
10			3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
15			3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
19			3.6	3.6	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.4	3.4	3.4	3.4	3.4	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
20				3.7	3.7	3.7	3.6	3.6	3.6	3.6	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.2	3.2	3.2
25						4.4	4.4	4.4	4.3	4.3	4.3	4.2	4.2	4.2	4.2	4.1	4.1	4.1	4.1	4.1	4.0	4.0	4.0	4.0	4.0	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.8
28								4.8	4.8	4.8	4.7	4.7	4.7	4.6	4.6	4.6	4.5	4.5	4.5	4.5	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.3	4.3	4.3	4.3	4.3	4.3	4.2	4.2	4.2	4.2	4.2
30									5.2	5.1	5.1	5.0	5.0	5.0	5.0	5.0	4.9	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.7	4.7	4.7	4.7	4.7	4.6	4.6	4.6	4.6	4.6	4.6	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.4
32										5.5	5.4	5.4	5.4	5.3	5.3	5.2	5.2	5.2	5.2	5.2	5.2	5.1	5.1	5.1	5.1	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8
35											6.1	6.1	6.1	6.0	6.0	5.9	5.9	5.8	5.8	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.5	5.5	5.5	5.4	5.4	5.4	5.4	5.4	5.3	5.3	5.3	5.3	5.3	5.2	5.2
36																6.3	6.1	6.1	6.1	6.0	6.0	5.9	5.9	5.9	5.8	5.8	5.8	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.5	5.5	5.5	5.5
38																	6.6	6.6	6.6	6.6	6.5	6.5	6.4	6.4	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.1	6.1	6.1	6.1	6.0	6.0	6.0	6.0	5.9	5.9	5.9	5.9
39																		7.0	7.0	7.0	7.0	6.7	6.7	6.6	6.6	6.6	6.6	6.5	6.5	6.5	6.4	6.4	6.4	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3
40																			7.2	7.1	7.1	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	6.7	6.7	6.6	6.6	6.6	6.6	6.6	6.6	6.5	6.5	6.5	6.4	6.4	6.4	6.4
41																			7.6	7.6	7.6	7.6	7.6	7.3	7.2	7.2	7.1	7.1	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	6.7	6.7	6.6	6.6
42																				7.9	7.9	7.8	7.7	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.3	7.2	7.2	7.2	7.1	7.1	7.0	7.0	7.0	7.0	7.0	7.0	7.0
43																				8.3	8.3	8.3	8.3	8.3	8.3	8.3	7.9	7.8	7.8	7.7	7.7	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.3	7.3
44																					8.9	8.9	8.9	8.5	8.4	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	7.9	7.9	7.8	7.8	7.7	7.7	7.6	7.6	7.6
45																						9.6	9.1	9.0	8.9	8.9	8.9	8.9	8.9	8.9	8.9	8.4	8.4	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3
46																						10.2	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.1	9.0	8.9	8.9	8.9	8.9	8.9	8.9	8.9	8.9	8.9	8.9	8.9	8.4	8.4
47																							10.2	10.2	10.2	10.2	10.2	10.2	10.2	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.0	9.0	8.9	8.9	8.9
48																								10.9	10.9	10.9	10.9	10.9	10.2	10.2	10.2	10.2	10.2	10.2	10.2	10.2	10.2	10.2	9.6	9.6	9.6	9.6	9.6	9.6
49																								11.5	11.5	11.5	11.5	11.5	11.5	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.2	10.2	10.2	10.2	10.2	10.2	10.2
50																									12.2	12.2	12.2	12.2	12.2	11.5	11.5	11.5	11.5	11.5	11.5	11.5	11.5	10.9	10.9	10.9	10.9	10.9	10.9	10.9
51																									13.5	13.5	13.5	12.8	12.8	12.8	12.2	12.2	12.2	12.2	12.2	12.2	12.2	11.5	11.5	11.5	11.5	11.5	11.5	11.5
52																										14.1	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	12.8	12.8	12.8	12.8	12.2	12.2	12.2	12.2	12.2	12.2
53																											14.8	14.8	14.1	14.1	14.1	14.1	14.1	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5
54																											15.4	15.4	15.4	15.4	14.8	14.8	14.8	14.8	14.8	14.1	14.1	14.1	14.1	14.1	14.1	14.1	13.5	13.5
55																												16.1	16.1	16.1	16.1	16.1	15.4	15.4	15.4	15.4	15.4	14.8	14.8	14.8	14.8	14.8	14.8	14.8
56																													17.4	16.8	16.8	16.8	16.8	16.8	16.1	16.1	16.1	16.1	16.1	16.1	15.4	15.4	15.4	15.4
57																													18.7	18.7	18.7	18.1	17.4	17.4	17.4	17.4	16.8	16.8	16.8	16.8	16.8	16.8	16.1	16.1
58																														18.7	18.7	18.7	18.7	18.7	18.7	18.7	18.7	18.7	18.7	17.4	17.4	17.4	17.4	17.4
59																														20.0	20.0	20.0	19.4	19.4	19.4	19.4	18.7	18.7	18.7	18.7	18.7	18.7	18.7	18.7
60																															20.7	20.7	20.7	20.7	20.0	20.0	20.0	20.0	20.0	19.4	19.4	19.4	19.4	19.4
61																																22.0	21.3	21.3	21.3	21.3	20.7	20.7	20.7	20.7	20.7	20.0	20.0	20.0
62																																23.3	22.6	22.6	22.0	22.0	22.0	22.0	22.0	21.3	21.3	21.3	21.3	21.3

Table 8.7.2-3
Fuel Qualification Table for EOS-89BTH, 198kgU, HLZC1, Plan1, Zone 2
(Minimum required years of cooling time after reactor core discharge)

BU (GWD/MTU)	Fuel Assembly Average Initial U-235 Enrichment (wt.%)																																										
	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5
6	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
7			3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
10			3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
15			3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
19			3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
20				3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
25						3.4	3.4	3.3	3.3	3.3	3.2	3.2	3.2	3.2	3.2	3.2	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
28								3.6	3.6	3.6	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.4	3.4	3.4	3.4	3.4	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.1	3.1	3.1	3.1
30									3.9	3.8	3.8	3.8	3.7	3.7	3.7	3.7	3.6	3.6	3.6	3.6	3.6	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.3	3.3	3.3
32										4.0	4.0	4.0	3.9	3.9	3.9	3.9	3.9	3.9	3.8	3.8	3.8	3.8	3.8	3.7	3.7	3.7	3.7	3.7	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
35											4.4	4.4	4.4	4.3	4.3	4.3	4.2	4.2	4.2	4.1	4.1	4.1	4.1	4.0	4.0	4.0	4.0	4.0	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.8	3.8	3.8	3.8	3.8	3.8
36																4.4	4.4	4.3	4.3	4.3	4.3	4.2	4.2	4.2	4.1	4.1	4.1	4.1	4.1	4.0	4.0	4.0	4.0	4.0	4.0	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9
38																	4.6	4.6	4.5	4.5	4.5	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.3	4.3	4.3	4.3	4.2	4.2	4.2	4.2	4.2	4.2	4.1	4.1	4.1	4.1	4.1	4.1
39																		4.7	4.7	4.7	4.6	4.6	4.6	4.5	4.5	4.5	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.3	4.3	4.3	4.3	4.3	4.2	4.2	4.2	4.2
40																			4.8	4.8	4.8	4.7	4.7	4.7	4.7	4.6	4.6	4.6	4.5	4.5	4.5	4.5	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.3	4.3
41																			5.0	4.9	4.9	4.8	4.8	4.8	4.8	4.8	4.8	4.7	4.7	4.7	4.6	4.6	4.6	4.6	4.5	4.5	4.5	4.5	4.5	4.4	4.4	4.4	4.4	4.4
42																				5.1	5.0	5.0	5.0	4.9	4.9	4.9	4.8	4.8	4.8	4.8	4.8	4.8	4.7	4.7	4.7	4.7	4.7	4.6	4.6	4.6	4.6	4.6	4.5	4.5
43																				5.2	5.2	5.2	5.1	5.1	5.1	5.0	5.0	5.0	5.0	4.9	4.9	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.7	4.7	4.7	4.7	4.7
44																					5.3	5.3	5.2	5.2	5.2	5.2	5.2	5.1	5.1	5.1	5.0	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.8	4.8	4.8	4.8	4.8	4.8
45																						5.5	5.4	5.4	5.4	5.3	5.3	5.2	5.2	5.2	5.2	5.2	5.2	5.1	5.1	5.1	5.1	5.0	5.0	5.0	5.0	5.0	4.9	4.9
46																						5.7	5.7	5.7	5.6	5.5	5.5	5.4	5.4	5.4	5.3	5.3	5.3	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.1	5.1	5.1	5.1
47																							5.8	5.7	5.7	5.7	5.7	5.7	5.7	5.6	5.5	5.5	5.5	5.4	5.4	5.4	5.3	5.3	5.3	5.2	5.2	5.2	5.2	5.2
48																								6.0	5.9	5.9	5.8	5.8	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.6	5.5	5.5	5.5	5.4	5.4	5.4	5.4	5.3
49																								6.1	6.1	6.1	6.1	6.0	6.0	5.9	5.9	5.8	5.8	5.8	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.6	5.5
50																									6.4	6.3	6.3	6.3	6.1	6.1	6.1	6.1	6.0	6.0	6.0	5.9	5.9	5.8	5.8	5.8	5.7	5.7	5.7	5.7
51																									6.6	6.6	6.5	6.5	6.4	6.3	6.3	6.3	6.3	6.1	6.1	6.1	6.1	6.1	6.0	6.0	6.0	5.9	5.9	5.9
52																										6.8	6.7	6.6	6.6	6.6	6.6	6.5	6.5	6.4	6.4	6.3	6.3	6.3	6.3	6.3	6.1	6.1	6.1	6.1
53																											7.0	7.0	7.0	7.0	6.8	6.7	6.6	6.6	6.6	6.6	6.5	6.5	6.4	6.4	6.4	6.3	6.3	6.3
54																											7.3	7.2	7.1	7.1	7.0	7.0	7.0	7.0	7.0	6.8	6.7	6.7	6.6	6.6	6.6	6.6	6.6	6.5
55																												7.6	7.6	7.4	7.3	7.3	7.2	7.1	7.1	7.0	7.0	7.0	7.0	7.0	7.0	6.8	6.7	6.7
56																													7.8	7.7	7.6	7.6	7.6	7.6	7.4	7.3	7.3	7.2	7.2	7.1	7.0	7.0	7.0	7.0
57																													8.3	8.0	7.9	7.9	7.8	7.7	7.7	7.6	7.6	7.6	7.6	7.6	7.4	7.3	7.3	7.2
58																														8.3	8.3	8.3	8.3	8.3	8.0	7.9	7.9	7.8	7.8	7.7	7.6	7.6	7.6	7.6
59																														8.9	8.9	8.6	8.5	8.4	8.3	8.3	8.3	8.3	8.3	8.3	7.9	7.9	7.9	7.8
60																															9.1	9.0	8.9	8.9	8.9	8.9	8.6	8.5	8.4	8.3	8.3	8.3	8.3	8.3
61																																9.6	9.6	9.2	9.1	9.0	8.9	8.9	8.9	8.9	8.9	8.6	8.5	8.5
62																																10.3	9.7	9.7	9.6	9.6	9.6	9.6	9.2	9.2	9.1	9.0	8.9	8.9

Table 8.7.2-4
Fuel Qualification Table for EOS-89BTH, 198kgU, HLZC1, Plan1, Zone 3
(Minimum required years of cooling time after reactor core discharge)

BU (GWD/MTU)	Fuel Assembly Average Initial U-235 Enrichment (wt.%)																																											
	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5
6	4.3	4.3	4.2	4.2	4.1	4.1	4.1	4.1	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8
7			4.5	4.5	4.4	4.4	4.4	4.3	4.3	4.3	4.3	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
10			5.4	5.3	5.2	5.2	5.1	5.1	5.1	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.8	4.8	4.8	4.8	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.5	4.5
15			6.9	6.8	6.7	6.6	6.5	6.4	6.3	6.3	6.2	6.2	6.1	6.0	6.0	6.0	5.9	5.9	5.8	5.8	5.8	5.7	5.7	5.7	5.7	5.6	5.6	5.6	5.6	5.6	5.5	5.5	5.5	5.5	5.5	5.5	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4
19			8.3	8.2	8.0	7.9	7.8	7.7	7.6	7.5	7.4	7.3	7.2	7.1	7.1	7.0	6.9	6.9	6.8	6.8	6.7	6.7	6.6	6.6	6.5	6.5	6.5	6.4	6.4	6.4	6.3	6.3	6.3	6.3	6.2	6.2	6.2	6.2	6.2	6.1	6.1	6.1	6.1	6.1
20				8.6	8.4	8.3	8.2	8.0	7.9	7.8	7.7	7.6	7.5	7.4	7.3	7.3	7.2	7.1	7.1	7.0	7.0	6.9	6.9	6.8	6.8	6.7	6.7	6.7	6.6	6.6	6.6	6.5	6.5	6.5	6.5	6.4	6.4	6.4	6.3	6.3	6.3	6.3	6.3	6.2
25						10.5	10.3	10.1	10.0	9.8	9.6	9.5	9.3	9.2	9.1	9.0	8.9	8.8	8.7	8.6	8.5	8.4	8.4	8.3	8.2	8.2	8.1	8.0	8.0	7.9	7.9	7.8	7.8	7.7	7.7	7.6	7.6	7.6	7.5	7.5	7.5	7.4	7.4	7.4
28								11.6	11.4	11.2	11.0	10.8	10.6	10.5	10.3	10.2	10.1	9.9	9.8	9.7	9.6	9.5	9.4	9.3	9.2	9.2	9.1	9.0	8.9	8.9	8.8	8.7	8.7	8.6	8.6	8.5	8.5	8.4	8.4	8.3	8.3	8.2	8.2	8.2
30									12.6	12.3	12.1	11.9	11.7	11.5	11.3	11.1	11.0	10.8	10.7	10.6	10.4	10.3	10.2	10.1	10.0	9.9	9.8	9.7	9.7	9.6	9.5	9.4	9.4	9.3	9.2	9.2	9.1	9.1	9.0	9.0	8.9	8.9	8.8	8.8
32										13.2	12.9	12.7	12.5	12.3	12.1	11.9	11.8	11.6	11.5	11.3	11.2	11.1	10.9	10.8	10.7	10.6	10.5	10.4	10.4	10.3	10.2	10.1	10.0	10.0	9.9	9.8	9.8	9.7	9.6	9.6	9.5	9.5	9.4	9.4
35											14.6	14.4	14.1	13.8	13.6	13.4	13.2	13.1	12.9	12.7	12.5	12.4	12.3	12.1	12.0	11.9	11.7	11.6	11.5	11.4	11.4	11.2	11.2	11.1	11.0	10.9	10.8	10.8	10.7	10.6	10.6	10.5	10.4	10.4
36																14.0	13.7	13.5	13.4	13.2	13.0	12.9	12.7	12.6	12.4	12.3	12.2	12.1	11.9	11.8	11.7	11.6	11.6	11.5	11.4	11.3	11.2	11.1	11.1	11.0	10.9	10.9	10.8	10.7
38																	14.8	14.6	14.4	14.2	14.0	13.9	13.7	13.5	13.4	13.2	13.1	12.9	12.8	12.7	12.6	12.5	12.4	12.3	12.2	12.1	12.0	11.9	11.8	11.8	11.7	11.6	11.5	11.5
39																		15.2	15.0	14.8	14.5	14.3	14.2	14.0	13.8	13.7	13.5	13.4	13.3	13.2	13.0	12.9	12.8	12.7	12.6	12.5	12.4	12.3	12.2	12.2	12.1	12.0	11.9	11.9
40																			15.5	15.3	15.1	14.9	14.7	14.5	14.3	14.2	14.0	13.9	13.7	13.6	13.5	13.4	13.2	13.1	13.0	12.9	12.8	12.7	12.7	12.6	12.5	12.4	12.3	12.2
41																			16.2	15.9	15.7	15.4	15.2	15.0	14.9	14.7	14.5	14.4	14.2	14.0	13.9	13.8	13.7	13.6	13.5	13.3	13.2	13.1	13.1	13.0	12.9	12.8	12.7	12.6
42																				16.5	16.2	16.0	15.8	15.6	15.4	15.2	15.0	14.9	14.7	14.5	14.4	14.3	14.1	14.0	13.9	13.8	13.7	13.6	13.5	13.4	13.3	13.2	13.1	13.0
43																				17.1	16.8	16.6	16.3	16.1	16.0	15.7	15.5	15.4	15.2	15.0	14.9	14.8	14.6	14.5	14.4	14.2	14.1	14.0	13.9	13.8	13.7	13.7	13.5	13.5
44																					17.4	17.2	17.0	16.7	16.5	16.3	16.1	15.9	15.7	15.5	15.4	15.3	15.1	15.0	14.8	14.7	14.6	14.5	14.4	14.3	14.2	14.1	14.0	13.9
45																						17.8	17.6	17.3	17.1	16.9	16.6	16.4	16.3	16.1	15.9	15.8	15.6	15.4	15.3	15.2	15.0	14.9	14.8	14.7	14.6	14.5	14.4	14.3
46																						18.4	18.1	18.0	17.7	17.4	17.2	17.0	16.8	16.6	16.4	16.3	16.1	16.0	15.8	15.7	15.5	15.4	15.3	15.2	15.1	14.9	14.8	14.7
47																							18.8	18.6	18.3	18.0	17.8	17.6	17.4	17.2	17.0	16.8	16.6	16.4	16.3	16.1	16.0	15.9	15.8	15.7	15.5	15.4	15.3	15.2
48																								19.2	18.9	18.7	18.4	18.2	17.9	17.7	17.6	17.3	17.2	17.0	16.9	16.7	16.5	16.4	16.2	16.1	16.0	15.9	15.8	15.7
49																								19.9	19.6	19.3	19.0	18.8	18.5	18.3	18.1	17.9	17.7	17.5	17.4	17.2	17.0	16.9	16.8	16.6	16.5	16.3	16.2	16.1
50																									20.2	20.0	19.7	19.4	19.2	18.9	18.7	18.5	18.3	18.1	17.9	17.7	17.6	17.4	17.3	17.1	17.0	16.8	16.8	16.6
51																									20.8	20.6	20.2	19.9	19.7	19.4	19.2	19.0	18.8	18.5	18.4	18.2	18.1	17.9	17.7	17.6	17.4	17.3	17.2	17.0
52																										21.1	20.9	20.6	20.3	20.1	19.8	19.6	19.4	19.2	18.9	18.8	18.6	18.4	18.2	18.1	17.9	17.8	17.7	17.5
53																											21.6	21.3	20.9	20.7	20.4	20.2	19.9	19.8	19.5	19.3	19.1	18.9	18.8	18.6	18.5	18.3	18.2	18.1
54																											22.2	21.9	21.6	21.3	21.1	20.8	20.6	20.4	20.1	19.9	19.7	19.5	19.4	19.2	19.0	18.9	18.7	18.6
55																												22.7	22.3	22.0	21.7	21.5	21.2	20.9	20.7	20.5	20.3	20.1	19.9	19.7	19.5	19.4	19.2	19.1
56																													23.0	22.7	22.4	22.2	21.9	21.6	21.4	21.1	20.9	20.7	20.5	20.3	20.1	19.9	19.8	19.6
57																													23.6	23.4	23.1	22.8	22.5	22.2	22.0	21.7	21.5	21.2	21.1	20.8	20.7	20.5	20.3	20.2
58																														24.1	23.8	23.5	23.1	22.9	22.6	22.3	22.2	21.9	21.6	21.4	21.2	21.1	20.9	20.7
59																														24.7	24.5	24.1	23.8	23.6	23.3	23.0	22.8	22.5	22.3	22.1	21.8	21.6	21.4	21.2
60																															25.2	24.8	24.5	24.2	23.9	23.6	23.3	23.1	22.9	22.6	22.4	22.2	22.0	21.8
61																																25.6	25.2	24.9	24.6	24.3	24.0	23.8	23.5	23.3	23.1	22.8	22.6	22.4
62																																26.3	25.9	25.6	25.3	25.0	24.7	24.4	24.2	23.9	23.6	23.4	23.2	23.0

Table 8.7.2-5
Fuel Qualification Table of Exceptions for EOS-89BTH, 198kgU, HLZC1, Plan1, Zone 1
(Minimum required years of cooling time after reactor core discharge)

BU (GWD/MTU)	Fuel Assembly Average Initial U-235 Enrichment (wt.%)																																											
	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5
6	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
7			3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
10			3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
15			3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
19			3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
20				3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
25						3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
28								3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
30									3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
32										3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
35											3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
36																3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
38																	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
39																		3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
40																			3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
41																			3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
42																				3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
43																				3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
44																					3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
45																						3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
46																						3.7	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
47																							4.4	3.7	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
48																								5.0	3.9	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
49																								6.4	5.7	4.4	3.7	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
50																									7.0	6.3	5.0	4.4	3.4	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
51																									8.3	7.6	6.3	5.1	4.4	3.7	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
52																										9.0	8.3	7.0	5.7	5.0	3.9	3.2	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
53																											10.2	8.9	7.6	6.3	5.7	4.5	3.7	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
54																											11.5	10.9	9.6	8.3	7.6	6.3	5.1	4.4	3.7	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
55																												12.8	11.5	10.2	8.9	8.3	7.0	5.7	5.0	4.4	3.7	3.0	3.0	3.0	3.0	3.0	3.0	3.0
56																													12.8	12.2	10.9	9.7	8.9	7.6	7.0	5.7	5.0	4.4	3.3	3.0	3.0	3.0	3.0	3.0
57																													14.8	13.5	12.3	11.5	10.3	9.6	8.3	7.6	6.3	5.2	4.5	3.8	3.3	3.0	3.0	3.0
58																														15.4	14.1	12.8	12.2	10.9	10.2	8.9	8.3	7.0	5.8	5.2	4.4	3.8	3.1	3.0
59																														16.8	16.1	14.8	13.5	12.8	11.5	10.9	9.7	8.9	7.6	7.0	5.7	5.0	4.4	3.7
60																															17.4	16.8	15.4	14.1	13.5	12.2	11.5	10.2	9.6	8.3	7.6	6.4	5.7	5.0
61																																18.1	16.8	16.1	14.9	14.1	12.8	11.6	10.9	10.2	9.6	8.3	7.0	6.4
62																																20.0	18.7	17.4	16.8	15.4	14.8	13.5	12.8	11.5	10.9	10.2	8.9	7.7

Table 8.7.2-6
Fuel Qualification Table of Exceptions for EOS-89BTH, 198kgU, HLZC1, Plan1, Zone 2
(Minimum required years of cooling time after reactor core discharge)

BU (GWD/MTU)	Fuel Assembly Average Initial U-235 Enrichment (wt.%)																																										
	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5
6	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
7			3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
10			3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
15			3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
19			3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
20				3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
25						3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
28								3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
30									3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
32										3.1	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
35											3.3	3.3	3.2	3.2	3.1	3.1	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
36																3.2	3.1	3.1	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
38																	3.3	3.3	3.2	3.2	3.1	3.1	3.1	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
39																		3.4	3.3	3.3	3.2	3.2	3.2	3.1	3.1	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
40																			3.4	3.4	3.3	3.3	3.2	3.2	3.2	3.1	3.1	3.1	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
41																			3.5	3.5	3.4	3.4	3.3	3.3	3.2	3.2	3.2	3.1	3.1	3.1	3.1	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
42																				3.5	3.5	3.5	3.4	3.4	3.3	3.3	3.2	3.2	3.2	3.2	3.1	3.1	3.1	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
43																				3.7	3.6	3.5	3.5	3.5	3.4	3.4	3.3	3.3	3.2	3.2	3.2	3.2	3.1	3.1	3.1	3.1	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0
44																					3.7	3.6	3.6	3.5	3.5	3.5	3.4	3.4	3.3	3.3	3.3	3.2	3.2	3.2	3.2	3.1	3.1	3.1	3.1	3.1	3.0	3.0	3.0	3.0
45																						3.8	3.7	3.6	3.6	3.5	3.5	3.5	3.4	3.4	3.3	3.3	3.3	3.2	3.2	3.2	3.2	3.1	3.1	3.1	3.1	3.1	3.1	3.0
46																						3.9	3.8	3.8	3.7	3.6	3.6	3.5	3.5	3.5	3.4	3.4	3.3	3.3	3.3	3.3	3.2	3.2	3.2	3.2	3.1	3.1	3.1	3.1
47																							4.0	3.9	3.8	3.7	3.7	3.6	3.6	3.5	3.5	3.5	3.4	3.4	3.4	3.3	3.3	3.3	3.2	3.2	3.2	3.2	3.2	3.1
48																								4.0	3.9	3.9	3.8	3.7	3.7	3.6	3.6	3.5	3.5	3.5	3.4	3.4	3.4	3.3	3.3	3.3	3.2	3.2	3.2	3.2
49																								4.2	4.1	4.0	3.9	3.9	3.8	3.7	3.7	3.6	3.6	3.5	3.5	3.5	3.4	3.4	3.4	3.3	3.3	3.3	3.3	3.2
50																									4.2	4.1	4.1	4.0	3.9	3.9	3.8	3.7	3.7	3.6	3.6	3.5	3.5	3.5	3.5	3.4	3.4	3.4	3.3	3.3
51																									4.4	4.3	4.2	4.1	4.0	3.9	3.9	3.8	3.8	3.7	3.7	3.6	3.6	3.5	3.5	3.5	3.4	3.4	3.4	3.4
52																										4.4	4.4	4.3	4.1	4.1	4.0	3.9	3.9	3.8	3.8	3.7	3.7	3.6	3.6	3.6	3.5	3.5	3.5	3.4
53																											4.5	4.4	4.3	4.2	4.1	4.1	4.0	3.9	3.9	3.8	3.8	3.7	3.7	3.6	3.6	3.6	3.5	3.5
54																											4.7	4.6	4.5	4.4	4.3	4.2	4.1	4.1	4.0	3.9	3.9	3.8	3.8	3.7	3.7	3.6	3.6	3.6
55																												4.8	4.7	4.6	4.5	4.4	4.3	4.2	4.1	4.0	4.0	3.9	3.9	3.8	3.8	3.7	3.7	3.6
56																													4.9	4.8	4.7	4.6	4.4	4.4	4.3	4.2	4.1	4.0	4.0	3.9	3.9	3.8	3.8	3.7
57																													5.2	5.0	4.9	4.8	4.6	4.5	4.4	4.4	4.3	4.2	4.1	4.0	4.0	3.9	3.9	3.8
58																														5.3	5.1	5.0	4.8	4.7	4.6	4.5	4.4	4.3	4.2	4.2	4.1	4.0	4.0	3.9
59																														5.6	5.4	5.2	5.1	4.9	4.8	4.7	4.6	4.5	4.4	4.3	4.2	4.2	4.1	4.0
60																															5.7	5.6	5.3	5.2	5.0	4.9	4.8	4.7	4.6	4.5	4.4	4.3	4.3	4.2
61																																5.9	5.7	5.4	5.3	5.2	5.0	4.8	4.8	4.6	4.6	4.5	4.4	4.3
62																																6.3	6.1	5.8	5.6	5.4	5.2	5.1	5.0	4.8	4.7	4.6	4.5	4.4

Table 8.7.2-7
Fuel Qualification Table of Exceptions for EOS-89BTH, 198kgU, HLZC1, Plan1, Zone 3
(Minimum required years of cooling time after reactor core discharge)

BU (GWD/MTU)	Fuel Assembly Average Initial U-235 Enrichment (wt.%)																																											
	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5
6	4.2	4.1	4.1	4.1	4.0	4.0	4.0	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7
7			4.4	4.3	4.3	4.3	4.2	4.2	4.2	4.2	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9
10			5.2	5.1	5.1	5.0	5.0	4.9	4.9	4.9	4.8	4.8	4.8	4.7	4.7	4.7	4.7	4.7	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.4	4.4	4.4	4.4	4.4	4.4
15			6.6	6.5	6.4	6.3	6.2	6.2	6.1	6.0	6.0	5.9	5.9	5.8	5.8	5.7	5.7	5.7	5.6	5.6	5.6	5.6	5.5	5.5	5.5	5.5	5.4	5.4	5.4	5.4	5.4	5.4	5.3	5.3	5.3	5.3	5.3	5.3	5.2	5.2	5.2	5.2	5.2	5.2
19			7.9	7.8	7.7	7.5	7.4	7.3	7.2	7.1	7.1	7.0	6.9	6.8	6.8	6.7	6.6	6.6	6.5	6.5	6.5	6.4	6.4	6.3	6.3	6.3	6.2	6.2	6.2	6.1	6.1	6.1	6.1	6.0	6.0	6.0	6.0	6.0	5.9	5.9	5.9	5.9	5.9	5.8
20				8.2	8.0	7.9	7.8	7.6	7.5	7.4	7.3	7.3	7.2	7.1	7.0	7.0	6.9	6.8	6.8	6.7	6.7	6.6	6.6	6.6	6.5	6.5	6.5	6.4	6.4	6.3	6.3	6.3	6.3	6.2	6.2	6.2	6.2	6.1	6.1	6.1	6.1	6.1	6.0	6.0
25						9.9	9.7	9.6	9.4	9.3	9.1	9.0	8.8	8.7	8.6	8.5	8.4	8.3	8.2	8.2	8.1	8.0	8.0	7.9	7.8	7.8	7.7	7.7	7.6	7.6	7.5	7.5	7.4	7.4	7.3	7.3	7.3	7.2	7.2	7.2	7.1	7.1	7.1	7.0
28								10.9	10.7	10.5	10.3	10.2	10.0	9.9	9.8	9.6	9.5	9.4	9.3	9.2	9.1	9.0	8.9	8.8	8.8	8.7	8.6	8.5	8.5	8.4	8.3	8.3	8.2	8.2	8.1	8.1	8.1	8.0	8.0	7.9	7.9	7.8	7.8	7.8
30									11.8	11.6	11.4	11.2	11.0	10.8	10.6	10.5	10.3	10.2	10.1	10.0	9.8	9.7	9.7	9.6	9.5	9.4	9.3	9.2	9.1	9.1	9.0	8.9	8.9	8.8	8.8	8.7	8.6	8.6	8.5	8.5	8.4	8.4	8.4	8.3
32										12.4	12.1	11.9	11.7	11.6	11.4	11.2	11.1	10.9	10.8	10.7	10.6	10.4	10.3	10.2	10.1	10.0	9.9	9.8	9.8	9.7	9.6	9.5	9.5	9.4	9.3	9.3	9.2	9.2	9.1	9.1	9.0	9.0	8.9	8.9
35											13.7	13.5	13.2	13.0	12.8	12.6	12.4	12.3	12.1	11.9	11.8	11.6	11.5	11.4	11.3	11.2	11.1	11.0	10.9	10.8	10.7	10.6	10.5	10.4	10.4	10.3	10.2	10.1	10.1	10.0	10.0	9.9	9.8	9.8
36																13.1	12.9	12.7	12.6	12.4	12.2	12.1	11.9	11.8	11.7	11.6	11.4	11.3	11.2	11.1	11.0	11.0	10.9	10.8	10.7	10.6	10.6	10.5	10.4	10.4	10.3	10.2	10.2	10.1
38																	13.9	13.7	13.5	13.3	13.2	13.0	12.8	12.7	12.5	12.4	12.3	12.1	12.0	11.9	11.8	11.7	11.6	11.5	11.4	11.4	11.3	11.2	11.1	11.1	11.0	10.9	10.9	10.8
39																		14.2	14.0	13.8	13.7	13.4	13.3	13.1	13.0	12.8	12.7	12.6	12.4	12.3	12.2	12.1	12.0	11.9	11.8	11.7	11.7	11.6	11.5	11.4	11.3	11.3	11.2	11.1
40																			14.6	14.3	14.1	13.9	13.8	13.6	13.4	13.3	13.2	13.0	12.9	12.8	12.6	12.5	12.4	12.3	12.2	12.1	12.0	12.0	11.9	11.8	11.7	11.6	11.6	11.5
41																			15.1	14.9	14.7	14.5	14.3	14.1	13.9	13.7	13.6	13.4	13.3	13.2	13.1	12.9	12.8	12.7	12.6	12.5	12.4	12.3	12.3	12.2	12.1	12.0	11.9	11.9
42																				15.4	15.2	15.0	14.8	14.6	14.4	14.2	14.1	13.9	13.8	13.7	13.5	13.4	13.3	13.2	13.0	12.9	12.8	12.8	12.6	12.6	12.5	12.4	12.3	12.2
43																				16.0	15.7	15.5	15.3	15.1	14.9	14.7	14.6	14.4	14.2	14.1	13.9	13.8	13.7	13.6	13.5	13.4	13.2	13.1	13.1	12.9	12.9	12.8	12.7	12.6
44																					16.3	16.1	15.9	15.6	15.4	15.2	15.0	14.9	14.7	14.6	14.4	14.3	14.1	14.0	13.9	13.8	13.7	13.6	13.5	13.4	13.3	13.2	13.1	13.0
45																						16.7	16.4	16.2	16.0	15.8	15.6	15.4	15.2	15.0	14.9	14.7	14.6	14.5	14.3	14.2	14.1	14.0	13.9	13.8	13.7	13.6	13.5	13.4
46																						17.2	17.0	16.8	16.5	16.3	16.1	15.9	15.8	15.5	15.4	15.2	15.1	15.0	14.8	14.7	14.6	14.4	14.3	14.2	14.1	14.0	13.9	13.8
47																							17.6	17.4	17.1	16.9	16.7	16.4	16.3	16.1	15.9	15.7	15.6	15.4	15.3	15.1	15.0	14.9	14.8	14.6	14.6	14.4	14.3	14.2
48																								17.9	17.7	17.4	17.2	17.0	16.8	16.6	16.4	16.2	16.1	15.9	15.8	15.6	15.4	15.4	15.2	15.1	15.0	14.9	14.7	14.7
49																								18.5	18.3	18.1	17.8	17.6	17.3	17.2	17.0	16.8	16.6	16.4	16.3	16.1	15.9	15.8	15.7	15.5	15.4	15.3	15.2	15.1
50																									18.9	18.7	18.4	18.1	17.9	17.7	17.5	17.3	17.1	16.9	16.8	16.6	16.4	16.3	16.2	16.0	15.9	15.8	15.7	15.5
51																									19.4	19.2	18.9	18.6	18.4	18.2	18.0	17.8	17.6	17.3	17.2	17.0	16.9	16.8	16.5	16.4	16.3	16.2	16.0	15.9
52																										19.8	19.5	19.3	19.0	18.8	18.5	18.3	18.1	17.9	17.7	17.6	17.4	17.2	17.1	16.9	16.8	16.6	16.5	16.4
53																											20.2	19.9	19.6	19.4	19.1	18.9	18.6	18.5	18.2	18.1	17.9	17.7	17.6	17.4	17.3	17.1	17.0	16.8
54																											20.8	20.5	20.3	19.9	19.8	19.5	19.2	19.0	18.8	18.6	18.5	18.2	18.1	17.9	17.7	17.6	17.4	17.3
55																												21.2	20.9	20.6	20.3	20.1	19.9	19.6	19.4	19.2	19.0	18.8	18.6	18.5	18.3	18.1	18.0	17.8
56																													21.6	21.2	20.9	20.8	20.4	20.2	20.0	19.8	19.5	19.4	19.1	19.0	18.8	18.6	18.5	18.3
57																													22.1	21.9	21.6	21.3	21.1	20.8	20.5	20.3	20.1	19.9	19.7	19.5	19.4	19.1	19.0	18.8
58																														22.6	22.2	22.0	21.6	21.4	21.2	20.9	20.7	20.4	20.3	20.1	19.9	19.7	19.5	19.4
59																														23.2	23.0	22.6	22.3	22.1	21.8	21.5	21.3	21.1	20.8	20.7	20.4	20.2	20.0	19.9
60																															23.6	23.3	23.0	22.6	22.5	22.1	21.9	21.7	21.4	21.2	21.0	20.8	20.7	20.4
61																																24.0	23.6	23.3	23.1	22.8	22.5	22.2	22.1	21.8	21.6	21.4	21.2	21.0
62																																24.7	24.3	24.0	23.7	23.4	23.1	22.9	22.6	22.4	22.1	22.0	21.7	21.5

Table 8.7.2-8
Fuel Qualification Table of Exception-counterparts for EOS-89BTH, 198kgU, HLZC1, Plan1, Zone 1
(Minimum required years of cooling time after reactor core discharge)

BU (GWD/MTU)	Fuel Assembly Average Initial U-235 Enrichment (wt.%)																																											
	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5
6	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
7			3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
10			3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
15			3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
19			3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
20				3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
25						3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
28								3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
30									3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
32										3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
35											3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
36																3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
38																	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
39																		3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
40																			3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
41																			3.7	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
42																				4.4	3.3	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
43																				6.3	5.0	4.4	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
44																					7.0	5.7	5.0	3.7	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
45																						7.6	7.0	5.7	4.4	3.7	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
46																						9.6	8.3	7.6	6.3	5.0	4.4	3.2	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
47																							10.2	9.6	8.3	7.0	5.7	5.0	3.7	3.2	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
48																								11.5	10.2	8.9	7.6	6.3	5.7	4.4	3.7	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
49																								13.5	12.2	10.9	9.6	8.9	7.6	6.3	5.7	4.4	3.7	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
50																									14.1	12.8	11.5	10.2	9.6	8.3	7.0	6.3	5.0	4.4	3.7	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
51																									15.4	14.1	13.5	11.5	10.2	9.6	8.3	7.6	6.3	5.0	4.4	3.7	3.2	3.0	3.0	3.0	3.0	3.0	3.0	3.0
52																										16.1	14.8	13.5	12.2	11.5	10.2	8.9	8.3	7.0	5.7	5.0	4.4	3.7	3.0	3.0	3.0	3.0	3.0	3.0
53																											16.8	15.4	14.1	13.5	12.2	10.9	9.6	8.9	7.6	7.0	5.7	5.0	4.4	3.7	3.1	3.0	3.0	3.0
54																											18.7	17.4	16.1	14.8	14.1	12.8	11.5	10.9	9.6	8.3	7.6	6.3	5.7	5.0	4.4	3.7	3.0	3.0
55																												19.4	18.1	16.8	15.4	14.8	13.5	12.2	11.5	10.2	9.6	8.3	7.6	7.0	5.7	5.0	4.4	3.7
56																													20.0	18.7	17.4	16.8	15.4	14.1	13.5	12.2	10.9	10.2	8.9	8.3	7.6	6.3	5.7	5.0
57																													21.3	20.7	19.4	18.1	17.4	16.1	14.8	14.1	12.8	12.2	10.9	10.2	8.9	8.3	7.0	6.3
58																														22.0	21.3	20.0	18.7	18.1	16.8	15.4	14.8	13.5	12.8	11.5	10.9	10.2	8.9	8.3
59																														23.9	22.6	22.0	20.7	20.0	18.7	17.4	16.8	15.4	14.1	13.5	12.8	11.5	10.9	9.6
60																															24.6	23.3	22.0	21.3	20.0	19.4	18.1	17.4	16.1	14.8	14.1	13.5	12.8	11.5
61																																25.2	23.9	22.6	22.0	20.7	20.0	18.7	18.1	16.8	16.1	14.8	14.1	13.5
62																																26.5	25.9	24.6	23.3	22.6	21.3	20.7	19.4	18.7	17.4	16.8	15.4	14.8

Table 8.7.2-9
Fuel Qualification Table of Exception-counterparts for EOS-89BTH, 198kgU, HLZC1, Plan1, Zone 2
(Minimum required years of cooling time after reactor core discharge)

BU (GWD/MTU)	Fuel Assembly Average Initial U-235 Enrichment (wt.%)																																											
	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5
6	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
7			3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
10			3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
15			3.1	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
19			3.5	3.5	3.5	3.4	3.4	3.3	3.3	3.3	3.3	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
20				3.6	3.5	3.5	3.5	3.5	3.4	3.4	3.4	3.3	3.3	3.3	3.3	3.3	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
25						4.1	4.1	4.0	3.9	3.9	3.9	3.8	3.8	3.7	3.7	3.6	3.6	3.6	3.6	3.6	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.3	3.3	3.3	3.3	3.3	3.3
28								4.5	4.4	4.3	4.2	4.2	4.1	4.0	4.0	3.9	3.9	3.9	3.9	3.8	3.8	3.7	3.7	3.7	3.7	3.7	3.6	3.6	3.6	3.6	3.6	3.6	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
30									4.9	4.8	4.6	4.5	4.4	4.4	4.3	4.2	4.1	4.1	4.0	4.0	4.0	3.9	3.9	3.9	3.9	3.8	3.8	3.8	3.7	3.7	3.7	3.7	3.7	3.7	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
32										5.1	4.9	4.8	4.7	4.6	4.5	4.4	4.4	4.3	4.2	4.2	4.1	4.1	4.0	4.0	4.0	3.9	3.9	3.9	3.9	3.9	3.8	3.8	3.8	3.8	3.8	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.6	3.6
35											5.8	5.6	5.4	5.2	5.1	4.9	4.8	4.8	4.7	4.6	4.5	4.4	4.4	4.3	4.3	4.2	4.2	4.1	4.1	4.1	4.0	4.0	4.0	4.0	4.0	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.8	3.8
36																5.2	5.1	4.9	4.8	4.8	4.7	4.6	4.5	4.4	4.4	4.4	4.3	4.3	4.2	4.2	4.1	4.1	4.1	4.0	4.0	4.0	4.0	4.0	3.9	3.9	3.9	3.9	3.9	3.9
38																	5.7	5.4	5.2	5.2	5.0	4.9	4.8	4.8	4.7	4.6	4.5	4.5	4.4	4.4	4.4	4.3	4.3	4.2	4.2	4.2	4.1	4.1	4.1	4.1	4.0	4.0	4.0	4.0
39																		5.7	5.6	5.4	5.2	5.2	5.0	4.9	4.8	4.8	4.7	4.6	4.5	4.5	4.4	4.4	4.4	4.4	4.3	4.3	4.2	4.2	4.2	4.1	4.1	4.1	4.1	4.1
40																			5.9	5.7	5.6	5.4	5.2	5.2	5.0	4.9	4.8	4.8	4.7	4.7	4.6	4.5	4.5	4.4	4.4	4.4	4.4	4.3	4.3	4.2	4.2	4.2	4.1	4.1
41																			6.3	6.1	5.9	5.7	5.5	5.4	5.2	5.2	5.1	4.9	4.9	4.8	4.8	4.7	4.6	4.5	4.5	4.4	4.4	4.4	4.4	4.4	4.3	4.3	4.2	4.2
42																				6.5	6.2	6.0	5.8	5.7	5.5	5.3	5.2	5.2	5.1	5.0	4.9	4.8	4.8	4.7	4.6	4.6	4.5	4.5	4.4	4.4	4.4	4.4	4.3	4.3
43																				7.0	6.6	6.5	6.1	6.0	5.8	5.7	5.5	5.4	5.2	5.2	5.1	5.0	4.9	4.8	4.8	4.8	4.7	4.6	4.6	4.5	4.5	4.4	4.4	4.4
44																					7.2	7.0	6.6	6.4	6.1	6.0	5.7	5.7	5.5	5.4	5.2	5.2	5.1	5.0	4.9	4.8	4.8	4.8	4.7	4.7	4.6	4.5	4.5	4.5
45																						7.6	7.2	7.0	6.6	6.3	6.1	5.9	5.8	5.7	5.5	5.4	5.2	5.2	5.1	5.0	4.9	4.9	4.8	4.8	4.7	4.7	4.6	4.6
46																						8.3	7.8	7.4	7.0	6.7	6.6	6.3	6.1	5.9	5.7	5.7	5.5	5.4	5.3	5.2	5.2	5.1	5.0	4.9	4.8	4.8	4.8	4.7
47																							8.5	8.3	7.7	7.3	7.0	6.7	6.5	6.3	6.1	6.0	5.8	5.7	5.6	5.4	5.3	5.2	5.2	5.1	5.0	4.9	4.9	4.8
48																								8.9	8.4	7.9	7.6	7.3	7.0	6.6	6.5	6.3	6.1	5.9	5.8	5.7	5.6	5.5	5.3	5.2	5.2	5.1	5.1	5.0
49																								9.9	9.6	8.9	8.3	7.9	7.6	7.1	7.0	6.6	6.4	6.3	6.1	6.0	5.8	5.7	5.6	5.5	5.4	5.3	5.2	5.2
50																									10.2	9.7	9.1	8.6	8.3	7.8	7.4	7.1	7.0	6.6	6.5	6.3	6.1	6.0	5.8	5.7	5.7	5.5	5.4	5.3
51																									11.1	10.6	9.8	9.2	8.7	8.3	7.9	7.6	7.3	7.0	6.8	6.6	6.4	6.2	6.1	5.9	5.8	5.7	5.6	5.5
52																										11.5	11.0	10.2	9.6	9.2	8.6	8.3	7.9	7.6	7.2	7.0	6.7	6.6	6.4	6.3	6.1	5.9	5.8	5.7
53																											12.2	11.5	10.9	10.2	9.6	8.9	8.4	8.3	7.8	7.6	7.2	7.0	6.7	6.6	6.4	6.3	6.1	6.0
54																											13.5	12.8	11.8	11.0	10.5	9.9	9.3	8.9	8.4	8.0	7.8	7.5	7.2	7.0	6.7	6.6	6.4	6.3
55																												14.1	13.0	12.2	11.5	10.9	10.2	9.7	9.2	8.9	8.4	8.0	7.7	7.6	7.2	7.0	6.8	6.6
56																													14.8	13.5	12.8	12.2	11.5	10.9	10.2	9.7	9.1	8.9	8.3	7.9	7.7	7.5	7.2	7.0
57																													15.5	14.8	14.1	13.5	12.8	11.8	11.0	10.9	10.2	9.6	9.1	8.7	8.3	8.0	7.7	7.6
58																														16.3	15.4	14.8	13.6	13.0	12.2	11.5	11.0	10.4	9.8	9.6	9.0	8.9	8.3	8.0
59																														17.4	16.8	16.1	14.9	14.2	13.5	12.8	12.2	11.5	10.9	10.4	9.8	9.6	9.0	8.6
60																															18.2	17.4	16.3	15.4	14.8	14.1	13.5	12.8	12.2	11.5	10.9	10.2	9.8	9.6
61																																18.7	18.1	16.8	16.1	15.4	14.8	13.6	13.1	12.3	12.2	11.5	10.9	10.2
62																																20.7	19.4	18.1	17.4	16.8	16.1	14.8	14.3	13.5	12.8	12.3	11.6	11.0

Table 8.7.2-10
Fuel Qualification Table of Exception-counterparts for EOS-89BTH, 198kgU, HLZC1, Plan1, Zone 3
(Minimum required years of cooling time after reactor core discharge)

BU (GWD/MTU)	Fuel Assembly Average Initial U-235 Enrichment (wt.%)																																											
	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5
6	4.5	4.4	4.4	4.3	4.3	4.3	4.2	4.2	4.2	4.2	4.1	4.1	4.1	4.1	4.1	4.1	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9
7			4.7	4.6	4.6	4.5	4.5	4.5	4.5	4.4	4.4	4.4	4.4	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1
10			5.6	5.5	5.4	5.4	5.3	5.3	5.2	5.2	5.2	5.1	5.1	5.1	5.0	5.0	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7
15			7.2	7.1	7.0	6.9	6.8	6.7	6.6	6.5	6.5	6.4	6.3	6.3	6.2	6.2	6.1	6.1	6.1	6.0	6.0	6.0	5.9	5.9	5.9	5.8	5.8	5.8	5.8	5.8	5.7	5.7	5.7	5.7	5.7	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.5	5.5
19			8.8	8.6	8.5	8.3	8.2	8.1	8.0	7.8	7.7	7.6	7.6	7.5	7.4	7.3	7.3	7.2	7.1	7.1	7.0	7.0	6.9	6.9	6.8	6.8	6.7	6.7	6.7	6.6	6.6	6.6	6.6	6.5	6.5	6.5	6.4	6.4	6.4	6.4	6.4	6.3	6.3	6.3
20				9.1	8.9	8.8	8.6	8.5	8.3	8.2	8.1	8.0	7.9	7.8	7.7	7.6	7.6	7.5	7.4	7.4	7.3	7.2	7.2	7.1	7.1	7.1	7.0	7.0	6.9	6.9	6.9	6.8	6.8	6.8	6.7	6.7	6.7	6.6	6.6	6.6	6.6	6.6	6.5	6.5
25						11.2	11.0	10.8	10.6	10.4	10.2	10.1	9.9	9.8	9.7	9.5	9.4	9.3	9.2	9.1	9.0	8.9	8.8	8.8	8.7	8.6	8.5	8.5	8.4	8.4	8.3	8.2	8.2	8.1	8.1	8.1	8.0	8.0	7.9	7.9	7.9	7.8	7.8	7.7
28								12.4	12.2	11.9	11.7	11.5	11.3	11.2	11.0	10.8	10.7	10.6	10.4	10.3	10.2	10.1	10.0	9.9	9.8	9.7	9.6	9.6	9.5	9.4	9.3	9.3	9.2	9.1	9.1	9.0	9.0	8.9	8.9	8.8	8.8	8.7	8.7	8.6
30									13.4	13.2	12.9	12.7	12.5	12.3	12.1	11.9	11.7	11.6	11.4	11.3	11.1	11.0	10.9	10.8	10.7	10.6	10.5	10.4	10.3	10.2	10.1	10.0	10.0	9.9	9.8	9.7	9.7	9.6	9.6	9.5	9.5	9.4	9.3	9.3
32										14.1	13.8	13.6	13.3	13.2	12.9	12.8	12.6	12.4	12.2	12.1	11.9	11.8	11.7	11.6	11.4	11.3	11.2	11.1	11.0	10.9	10.8	10.8	10.7	10.6	10.5	10.5	10.4	10.3	10.3	10.2	10.1	10.1	10.0	10.0
35											15.7	15.4	15.1	14.8	14.6	14.4	14.2	14.0	13.8	13.6	13.4	13.2	13.1	12.9	12.8	12.7	12.6	12.4	12.3	12.2	12.1	12.0	11.9	11.8	11.7	11.6	11.6	11.5	11.4	11.4	11.3	11.2	11.1	11.1
36																15.0	14.7	14.5	14.3	14.1	13.9	13.8	13.6	13.4	13.3	13.2	13.0	12.9	12.8	12.7	12.5	12.4	12.3	12.3	12.2	12.1	12.0	11.9	11.9	11.7	11.7	11.6	11.5	11.5
38																	15.9	15.7	15.4	15.2	15.0	14.8	14.6	14.5	14.3	14.1	14.0	13.8	13.7	13.6	13.5	13.3	13.2	13.2	13.0	12.9	12.8	12.8	12.7	12.6	12.5	12.4	12.3	12.3
39																		16.3	16.0	15.9	15.6	15.4	15.2	15.0	14.8	14.7	14.5	14.4	14.2	14.1	13.9	13.8	13.7	13.6	13.5	13.4	13.3	13.2	13.1	13.0	12.9	12.8	12.8	12.7
40																			16.7	16.4	16.2	16.0	15.8	15.5	15.4	15.2	15.0	14.9	14.7	14.6	14.4	14.3	14.2	14.1	14.0	13.8	13.7	13.7	13.6	13.5	13.4	13.3	13.2	13.1
41																			17.3	17.0	16.8	16.6	16.3	16.1	15.9	15.7	15.6	15.4	15.2	15.1	15.0	14.8	14.7	14.6	14.4	14.3	14.2	14.1	14.0	13.9	13.8	13.7	13.7	13.6
42																				17.7	17.4	17.2	16.9	16.7	16.5	16.3	16.1	15.9	15.8	15.6	15.4	15.3	15.2	15.0	14.9	14.8	14.7	14.6	14.5	14.4	14.3	14.2	14.1	14.0
43																				18.4	18.1	17.8	17.6	17.3	17.1	16.9	16.7	16.5	16.3	16.2	16.0	15.9	15.7	15.5	15.4	15.3	15.2	15.0	15.0	14.8	14.7	14.6	14.6	14.5
44																					18.7	18.5	18.2	18.0	17.7	17.5	17.3	17.1	16.9	16.7	16.5	16.3	16.2	16.0	15.9	15.8	15.7	15.5	15.4	15.3	15.2	15.1	15.0	14.9
45																						19.1	18.9	18.6	18.3	18.1	17.9	17.7	17.5	17.3	17.1	16.9	16.8	16.6	16.4	16.3	16.2	16.0	15.9	15.8	15.7	15.6	15.4	15.4
46																						19.8	19.5	19.3	19.0	18.7	18.5	18.3	18.1	17.8	17.7	17.5	17.3	17.2	17.0	16.8	16.7	16.5	16.4	16.3	16.2	16.0	15.9	15.9
47																							20.2	19.9	19.7	19.4	19.2	18.9	18.6	18.5	18.2	18.1	17.9	17.7	17.6	17.3	17.2	17.1	16.9	16.8	16.7	16.5	16.4	16.3
48																								20.6	20.3	20.0	19.8	19.5	19.3	19.0	18.9	18.6	18.5	18.3	18.1	17.9	17.7	17.7	17.4	17.3	17.2	17.1	16.9	16.8
49																								21.3	21.1	20.8	20.4	20.2	19.9	19.7	19.5	19.3	19.0	18.9	18.6	18.5	18.3	18.2	18.0	17.8	17.7	17.6	17.5	17.3
50																									21.7	21.5	21.2	20.8	20.6	20.3	20.1	19.9	19.6	19.5	19.3	19.0	18.9	18.7	18.6	18.4	18.3	18.1	18.0	17.8
51																									22.3	22.1	21.7	21.4	21.1	20.9	20.6	20.4	20.2	19.9	19.8	19.5	19.4	19.2	19.0	18.9	18.7	18.6	18.4	18.3
52																										22.7	22.5	22.1	21.8	21.6	21.3	21.0	20.8	20.6	20.3	20.2	19.9	19.8	19.6	19.4	19.3	19.1	19.0	18.8
53																											23.2	22.8	22.5	22.2	22.0	21.7	21.4	21.2	21.0	20.8	20.6	20.3	20.2	20.0	19.9	19.7	19.5	19.4
54																											23.9	23.5	23.2	22.9	22.6	22.4	22.1	21.9	21.6	21.4	21.2	21.0	20.8	20.6	20.4	20.3	20.1	19.9
55																												24.3	23.9	23.6	23.3	23.0	22.8	22.5	22.3	22.1	21.8	21.6	21.3	21.2	21.0	20.8	20.7	20.4
56																													24.7	24.3	24.0	23.8	23.4	23.2	23.0	22.7	22.4	22.2	22.0	21.7	21.6	21.4	21.2	21.1
57																													25.3	25.1	24.7	24.4	24.2	23.9	23.5	23.4	23.1	22.8	22.6	22.4	22.2	22.0	21.8	21.6
58																														25.8	25.5	25.2	24.8	24.6	24.3	23.9	23.8	23.5	23.2	23.0	22.8	22.6	22.4	22.2
59																														26.5	26.2	25.9	25.5	25.3	25.0	24.7	24.4	24.2	23.9	23.7	23.4	23.2	23.0	22.8
60																															27.0	26.6	26.2	25.9	25.6	25.3	25.1	24.8	24.5	24.3	24.1	23.9	23.7	23.4
61																																27.4	27.0	26.6	26.4	26.1	25.7	25.4	25.2	24.9	24.7	24.5	24.3	24.1
62																																28.2	27.8	27.4	27.0	26.8	26.5	26.1	25.9	25.6	25.3	25.2	24.9	24.7

Notes: Table 8.7.2-2 through Table 8.7.2-10

Note A: General Notes

- BU = Assembly Average burnup.
- For the fuel assembly with axial blankets that are large (>5% active fuel length at each end), BU = Maximum burnup.
- Use burnup and enrichment to look up minimum cooling time in years. The licensee is responsible for ensuring that uncertainties in fuel enrichment and burnup are correctly accounted for during fuel qualification.
- Round burnup UP to next higher entry, round enrichments DOWN to next lower entry.
- Fuel with an assembly average initial enrichment less than 0.6 wt.% U-235 or greater than 5.0 wt.% U-235 is unacceptable for transport.
- Fuel with a burnup greater than 62 GWd/MTU is unacceptable for transport.
- Fuel with a burnup less than 6 GWd/MTU is acceptable for transport after 5.0 years cooling.
- For high burnup (HBU) fuel assemblies (FAs) that have been in dry storage for more than 20 years, add 5.0 years of additional cooling time.
- Decay heat has to be verified against the heat load zone configuration (HLZC).
- Requirements for reconstituted fuel assemblies are described in Note B below.
- Applications of FQT exceptions are described in Note C below.
- For old fuel with higher cobalt impurity in materials (Stainless Steel 304, Inconel-718, and Inconel X-750) than shown in Table 5-5, add 7.5 years of additional cooling time.

Note B: Requirements for Reconstituted Fuel Assemblies

- For reconstituted fuel assemblies with UO_2 rods and/or Zr rods or Zr pellets and/or stainless steel rods, use the assembly average equivalent enrichment to determine the minimum cooling time.
- For irradiated stainless steel rods, the number of irradiated stainless steel rods ≤ 5 rods, no additional cooling time is needed when reconstituted fuel is loaded in the inner zone shown in Figure 1.6.2-2, and an additional cooling time of 6 years is needed when reconstituted fuel is loaded in the peripheral zone shown in Figure 1.6.2-2.

Note C: Application of FQT Exceptions

When an FA has a cooling time shorter than the minimum required cooling time listed in the standard fuel qualification tables (FQTs) for EOS-89BTH HLZC 1 Plan 1 (Table 8.7.2-2 through Table 8.7.2-4), there are exceptions that may be applied to qualify this FA to be loaded. The excexptions are applied with three conditions/steps:

- Condition 1: the total decay heat of this fuel assembly is verified against the heat load zone configurations (HLZCs).
- Condition 2: this FA has a cooling time longer than the minimum cooling time listed in the FQT exceptions for EOS-89BTH HLZC 1 Plan 1 (Table 8.7.2-5 through Table 8.7.2-7).
- Condition 3: at least two adjacent FAs in the same zone as this FA have a cooling time longer than the minimum cooling time listed in the FQT exception-counterparts for EOS-89BTH HLZC 1 Plan 1 (Table 8.7.2-8 through Table 8.7.2-10).

Example: Three FAs, FA 1, FA 2, FA 3, with a fuel loading of 188 kgU, are to be loaded into the EOS-89BTH Dry Shielded Canister (DSC), HLZC 1, Plan 1, and Zone 3. The FAs have an initial enrichment of 3.6 wt.% U-235 and a burnup of 42 GWd/MTU. Because 188 kgU is less than 198 kgU, the 198 kgU FQTs can be applied. The cooling times are 14.0, 16.2, and 16.5 years for FA 1, FA 2, and FA 3, respectively. Even though the decay heat from each of the three FAs is lower than the decay heat limit for the EOS-89BTH DSC, HLZC1, Plan1, and Zone 3, checked by other means, FA 1 still cannot be qualified according to the standard FQT of the EOS-89BTH DSC, HLZC 1, Plan 1, and Zone 3 (Table 8.7.2-4), which shows a minimum cooling time of 14.4 years. However, the cooling time of FA1 is longer than 13.7 years, the minimum cooling time listed in the FQT of exceptions for the EOS-89BTH DSC, HLZC 1, Plan 1, and Zone 3 (Table 8.7.2-7), and the cooling times of FA 2 and FA 3 are both longer than 15.6 years, the minimum cooling time listed in the FQT of exception-counterparts for the EOS-89BTH DSC, HLZC 1, Plan 1, and Zone 3 (Table 8.7.2-10). Therefore, FA 1 can be loaded into the EOS-89BTH DSC, HLZC 1, Plan 1, and Zone 3, as long as FA 2 and FA 3 are loaded adjacent to FA 1 in the same zone.

Appendix 8.7.3
24PT4/32PT/32PTH1/FO-FC-FF/24PT1 FQTs

LIST OF TABLES

8.7.3 24PT4/32PT/32PTH1/FO-FC-FF/24PT1 FQTs

Table 8.7.3-1
Fuel Qualification Table for DSCs inside TN Eagle SC

Maximum Burnup (GWD/MTU)	Minimum Enrichment (wt.% U235) (1)	Minimum cooling time (years)				
		32PTH1	32PT	24PT4	24PT1	FC/FO/FF
15	0.2	15	15	15	39	15
19	1.3	15	15	15	39	15
20	1.8	15	15	15	39	15
25	1.8	15	15	15	39	15
28	1.8	15	15	15	39	15
30	1.8	15	15	15	39	15
31	1.9	15	15	15	39	15
32	2.0	15	15	15	39	15
34	2.1	15	15	15	39	15 (16(10))
36	2.2	15	15	15	39	15 (17(10))
38	2.3	15	15	15	39	15 (18(10))
39	2.4	15	15	15	39	15 (19(10))
40	2.5	15	15	15	39	15 (20(10))
41	2.5	15	15	15	39	
42	2.6	15	15	15	39	
43	2.6	15	15	15	39	
44	2.7	15	15	15	39	
45	2.8	15	15	15	39	
46	2.8	15	15	15		
47	2.9	15	15	15		
48	3.0	15	15	15		
49	3.0	15	15	15		
50	3.1	15.2	15.2	15.2		
51	3.1	15.7	15.7	15.7		
52	3.2	16.1	16.1	16.1		
53	3.3	16.4	16.4	16.4		
54	3.3	17.0	17.0	17.0		
55	3.4/2.9	17.3/18.6	17.3/18.6	17.3/18.6		
56	3.5	17.6	17.6	17.6		
57	3.5	18.2	18.2	18.2		
58	3.6	18.7	18.7	18.7		
59	3.6	20.0	20.0	20.0		
60	3.7	20.8	20.8	20.8		
61	3.8	22.0	22.0			
62	3.8	22.7	22.7			

Note:

1) The minimum enrichment for UO_2 fuel in the 24PT1 DSC is 3.12 wt.% U-235 if the burnup is no more than 35 GWd/MTU; 3.36 wt.% U235 if the burnup is no more than 40 GWd/MTU; and 3.76 wt.% U-235 if the burnup is no more than 45 GWd/MTU. The maximum burnup for MOX fuel in the 24PT1 DSC is 25 GWd/MTU. The maximum enrichment (wt. %) for MOX fuel in the 24PT1 DSC is 0.71 U-235; 2.84 Fissile Pu (64 rods); 3.10 Fissile Pu (92 rods); and 3.31 Fissile Pu (24 rods). The minimum enrichment (wt. %) for MOX fuel in the 24PT1 DSC is 2.78 Fissile Pu (64 rods); 3.05 Fissile Pu (92 rods); and 3.25 Fissile Pu (24 rods).
2) BU = Assembly average burnup.
3) For the fuel assembly (FA) with axial blankets that are large (>5% active fuel length at each end), BU = Maximum burnup.
4) Use burnup and enrichment to lookup minimum cooling time in years. The licensee is responsible for ensuring that uncertainties in fuel enrichment and burnup conservatively applied in determination of actual values for these two parameters.
5) Round burnup UP to next higher entry, round enrichments DOWN to 0.1 wt.% U-235.
6) Fuel with an initial enrichment either less than 0.2 or greater than 5.0 wt.% U-235 is unacceptable for Transport.
7) Fuel with a burnup less than 15 GWd/MTU is acceptable for transport after 15-years cooling.
8) For high burnup (HBU) FAs that have been in dry storage for more than 20 years, add 5.0 years of additional cooling time.
9) Example: An assembly with an initial enrichment of 4.85 wt. % U-235 and a burnup of 38.5 GWd/MTU is acceptable for transport in all DSCs after a 15-year year cooling time as defined by 4.8 wt. % U-235 (rounding down) and 39 GWd/MTU (rounding up) on the qualification table (other considerations not withstanding).
10) Minimal cooling time required for Type II fuel.
11) Except 24PT1 DSC, for old fuel with higher cobalt impurity in materials (Stainless Steel 304, Inconel-718, and Inconel X-750) than shown in Table 5-5, add 13.0 years of additional cooling time.

Chapter 9
Acceptance Tests and Maintenance Program Evaluation

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Chapter 9
Acceptance Tests and Maintenance Program Evaluation

NOTE: References in this chapter are shown as [1], [2], etc., and refer to the reference list in Section 9.3.

9.1 Acceptance Tests

This chapter contains inspections and tests that shall be performed on the cask prior to initial transport. Many of these tests will be performed at the fabricator's facility prior to delivery of the cask for use. These tests and inspections, which are only applicable to cask components identified as quality category A, B, or C on the applicable drawings for package approval, shall be performed in accordance with written procedures with the results being documented and retained.

9.1.1 Visual Inspections and Measurements

1. Visual inspections shall be performed on all cask components for any evidence of damage or deformation such as, but not limited to, cracks, pinholes, and uncontrolled voids.
2. Surface finish inspections shall be performed on all containment boundary sealing surfaces for conformance with the applicable drawings for package approval.
3. Dimensional inspections shall be performed of the cask components to verify they conform to the applicable drawings for package approval.
4. Verify that the cask components were assembled in conformance with the applicable drawings for package approval.
5. Verify that the cask is conspicuously and durably marked with the following information:
   - Model number,
   - Serial number,
   - Gross weight, and
   - Package identification number assigned by the NRC.

9.1.2 Weld Examinations

1. Verify that the welds were performed using processes and personnel, both qualified in accordance with the applicable sections of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel (B&PV) Code [1]. Refer to the applicable drawings for package approval for code section applicability.
2. Visual weld inspections shall be performed to verify conformance with the weld type, quantity, and location of welds indicated on the applicable drawings for package approval.
3. Dimensional inspections shall be performed of the welds for conformance with the applicable drawings for package approval.

4. Nondestructive examination as indicated on the applicable drawings for package approval shall be performed with personnel qualified and certified in accordance with SNT-TC-1A [2].

9.1.3 Structural and Pressure Tests

1. There are no structural tests that need to be performed prior to first use of the cask.
2. A hydrostatic pressure test shall be performed on the containment boundary of each package fabricated to the design provided in the applicable drawings for package approval. The test pressure is between 20.0 and 25.0 psig and held for a minimum of 10 minutes. The test shall be performed in accordance with ASME B&PV Code, Section III, Subsection NB, Paragraphs NB-6100, NB-6200, and NB-6400 [1].

9.1.4 Leakage Tests

NOTE: As an alternative to leak testing the base metal of the containment boundary, a volumetric UT examination may be done over 100% of its surface area per the requirements of ASME B&PV Code, Section III, Subsection NB, Paragraph NB-2542 [1] and ASTM A388M [4]. The maximum allowed flaw dimension is 6 mm. The acceptance criteria require no recordable indications that could provide a leakage path through the thickness of the shell.

1. Leakage tests shall be performed on the cask containment boundary prior to first use. The fabrication verification leakage test can be separated into the following four tests:
   - Base metal integrity to evaluate the material of the cask body, primary lid, ram access cover plate, and the lid orifice cover plate,
   - Lid orifice cover plate seal integrity,
   - Primary lid inner seal integrity, and
   - Ram access cover plate inner seal integrity.

   a) This testing shall be performed in accordance with written procedures and conform to the requirements of ANSI N14.5 [3]. These tests are usually performed using the helium mass spectrometer method. Alternative methods are acceptable, provided they conform to ANSI N14.5 [3] and the required sensitivity is achieved.

   b) Personnel performing the tests shall be qualified and certified in leakage testing in accordance with SNT-TC-1A [2].

   c) The acceptance criterion requires each component to be individually leak tight, that is, the leakage rate must be less than 1E-7 ref-cm^3/sec with a sensitivity of 5E-8 ref-cm^3/sec, or better.

   d) The cask body test shall be performed without the bottom closure plate, bottom ring, shielding rings, top handling ring, or associated fasteners installed.

   e) The primary lid test shall be performed without the lid spacer or associated fasteners installed.

2. Leakage tests shall be performed on the impact limiters and neutron shielding rings prior to first use. This testing will involve pressuring the associated cavity with an inert gas between 2.0 to 3.0 psig and performing a bubble test of all accessible surfaces that are part of the cavity boundary. The cavity of the neutron shielding ring test, which for this test does not include the relief valves, is formed after assembling and sealing all neutron shielding rings along with the top handling ring and the closing plate.

9.1.5 Component and Material Tests

1. The base metal of structural and containment components shall be inspected and tested in accordance with the applicable sections of the ASME B&PV Code [1]. Refer to the applicable drawings for package approval for code section applicability.
2. The base metal of structural and containment components shall be chemically and physically tested to confirm that the required properties of the material specification, listed in the applicable drawings for package approval, are achieved.
3. Installation and removal of the following components shall be observed. Each component shall be checked for difficulties in installation and removal. After removal, each component shall be visually examined for damage.
   a) Impact limiters,
   b) Primary lid,
   c) Ram access cover plate,
   d) Lid port plug,
   e) Lid port plug tightening nut,
   f) Lid port cover plate,
   g) Test port plugs, and
   h) All related fasteners.

9.1.6 Neutron Absorber and Moderator Tests

The neutron absorber material is located within the DSC and fuel assemblies. The DSCs to be transported were all previously fabricated, loaded, and maintained under 10 CFR Part 72 requirements. Any neutron absorber and moderator acceptance tests required for compliance with 10 CFR Part 71 requirements were performed previously before DSC loading. Verification that previously loaded DSCs and fuel assemblies are compliant with the 10 CFR Part 71 requirements is included in Chapter 8.

9.1.7 Shielding Tests

1. The primary gamma shielding in the cask consists of thick carbon steel components that are fabricated to industry standard specifications as indicated on the applicable drawings for package approval. The acceptance testing for the gamma shielding is fulfilled by the visual and dimensional inspections described in Section 9.1.1.

2. Acceptance testing of the VYAL-B neutron shield material shall be performed to verify the following criteria are met:

   a) Resin density is 1.75 g/cm^3 or greater,

   b) Minimum Composition is as follows:

Element	Weight%
Hydrogen	4.59
Boron	0.82
Carbon	23.35
Aluminum	19.50
Zinc	1.40
Oxygen	50.34

   c) Any visible surface of resin is inspected visually according to following acceptance criteria:

   - No lack of material (void) or segregation.
   - Polymerization defects are not accepted.
   - Presence of bubbles is allowed if their diameter does not exceed 3 mm and if the sum of their area is lower than 0.35% of the surface.
   - No cracks are accepted.
   - Dimensions specified on the engineering drawings are checked with a calibrated gauge.

9.1.8 Thermal Tests

1. A thermal test shall be performed to measure the effective thermal conductivity of the assembled cask in the radial direction.
2. An analysis shall then be performed using the measured data to show that the thermal performance of the fabricated cask is equal to or exceeds the theoretical design performance.
3. The thermal test is only required on the first cask (any model) fabricated to the design provided in the applicable drawings for package approval. Any change to the design that could impact the thermal performance will require a new thermal test.

9.2 Maintenance Program

After the cask is placed into service, the following periodic inspections and tests are required to ensure the cask remains acceptable for usage. Any replacement of cask components shall be performed in accordance with written instructions and shall satisfy the applicable requirements in Section 9.1.

9.2.1 Structural and Pressure Tests

There are no periodic structural or pressure tests required.

9.2.2 Leakage Tests

NOTE: As an alternative to leak testing the base metal of the containment boundary, a volumetric UT examination may be done over 100% of its surface area per the requirements of ASME B&PV Code, Section III, Subsection NB, Paragraph NB-2542 [1] and ASTM A388M [4]. The maximum allowed flaw dimension is 6 mm. The acceptance criteria require no recordable indications that could provide a leakage path through the thickness of the shell.

1. After any maintenance or repair that could challenge the containment capability, or after replacement of the following containment boundary components, maintenance leakage testing shall be performed.
    - Primary lid inner O-ring seal,
    - Ram access cover plate inner O-ring seal,
    - Lid orifice cover plate metal seal,
    - Sealing surfaces associated with the above seals,
    - Cask body base metal,
    - Primary lid base metal,
    - Ram access cover plate base metal, and
    - Lid orifice cover plate base metal.

    a) This testing shall be performed in accordance with written procedures and conform to the requirements of ANSI N14.5 [3]. These tests are usually performed using the helium mass spectrometer method. Alternative methods are acceptable, provided they conform to ANSI N14.5 [3] and the required sensitivity is achieved.

    b) Personnel performing the tests shall be qualified and certified in leakage testing in accordance with SNT-TC-1A [2].

    c) The acceptance criterion requires each component to be individually leak tight, that is, the leakage rate must be less than 1E-7 ref-cm^3/sec with a sensitivity of 5E-8 ref-cm^3/sec or better.

    d) The cask body base metal test shall be performed without the bottom closure plate, bottom ring, shielding rings, and top handling ring installed.

    e) The primary lid base metal test shall be performed without the lid spacer installed.

2. The impact limiter leakage test described in Section 9.1 shall be performed every 5 years.

3. The neutron shielding ring leakage test described in Section 9.1 shall be performed within 12 months prior to releasing the loaded cask for shipment. This test shall also be performed after any sealing material has been replaced.

9.2.3 Component and Materials Tests

The following component inspections and replacements shall be performed within 12 months prior to releasing the loaded cask for shipment. The inspections shall be performed by personnel not directly involved in the operations of the cask during the past 12 months:

1. Inspect the accessible surfaces of the cask, including the impact limiters, for any evidence of damage or degradation that may reduce the effectiveness of the cask. Evidence of cracks, dents, gouges, deformations, corrosion, and also pitting in stainless steel surfaces shall be evaluated prior to putting the cask back into service.
2. Coatings on the exterior and interior surfaces of the cask components shall be inspected for damage or degradation. Areas that show blistering, cracking, flaking, peeling, or other similar damage that can expose the base metal shall be evaluated and repaired as necessary.
3. Inspect the lid bolts, ram access cover plate bolts, impact limiter bolts, lid orifice cover plate bolts, as well as all mating threaded holes, for any damage or degradation. Components shall be reworked or replaced if they show signs of bending, cracking, thread deformation, or corrosion.
4. Inspect the sealing material on the neutron shielding rings, top handling ring, and closing plate for any damage or degradation. The material shall be replaced in accordance with the manufacturer’s instructions, as necessary, if there is evidence of cutting, cracking, loss of material, or loss of adhesion.
5. Inspect the relief valves for any damage or evidence of reduced performance. Test the valves to verify they open at the design set point in accordance with the manufacturer’s instructions.
6. Remove and discard the inner elastomeric O-ring seals of the primary lid and ram access cover plate.
7. Inspect the sealing surfaces of the primary lid inner O-ring, ram access cover plate inner O-ring, and the lid orifice cover plate seal for any damage or degradation. Components shall be reworked or replaced if they show signs of cracking, gouging, or other deformation that may reduce sealing performance.
8. Install new inner elastomeric O-ring seals of the primary lid and ram access cover plate. Note that the lid orifice cover plate metal seal will be replaced each shipment as the loaded cask is being closed.
9. Review cask usage and determine the remaining number of shipments that can be performed. To ensure adequate fatigue strength is maintained, the cask is limited to 800 one-way shipments (empty or loaded).

9.2.4 Neutron Absorber and Moderator Tests

There are no periodic neutron absorber or moderator tests required.

9.2.5 Shielding Tests

There are no periodic shielding tests required.

9.2.6 Thermal Tests

There are no periodic thermal tests required.

9.2.7 Miscellaneous Tests

There are no additional periodic tests required.

9.3 References

1. ASME Boiler and Pressure Vessel Codes, 2017 Edition.

2. SNT-TC-1A, “American Society for Nondestructive Testing, Personnel Qualification and Certification in Nondestructive Testing.”

3. ANSI N14.5-2014, “American National Standard for Radioactive Materials – Leakage Tests on Packages for Shipment,” American National Standards Institute, Inc., New York, 2014.

4. ASTM A388/388M, “Standard Practice for Ultrasonic Examination of Steel Forgings,” 2019 Edition, September 1, 2019.

9.4 APPENDICES

9.4.1 Code Alternatives

Appendix 9.4.1
Code Alternatives

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9.4.1 Code Alternatives

9.4.1.1 TN Eagle

ASME Code Alternatives for the TN Eagle Transport Cask (TC) Containment Boundary

Reference ASME Code Section/ Article	Code Requirement	Alternative, Justification & Compensatory Measures
NCA	All	Not compliant with NCA code section. Quality assurance is provided according to 10 CFR 71 Subpart H and 10 CFR 72 Subpart G in lieu of NCA-4000.
NB-1131	The design specification shall define the boundary of a component to which other components are attached.	A code design specification is not prepared for the TN Eagle cask. A TN design criteria is prepared in accordance with TN's QA program. Additionally, boundaries are defined in the SAR.
NCA-1140	Use of code editions and addenda	Code edition and addenda other than those specified may be used for construction, but in no case earlier than 3 years before that specified. Materials produced and certified in accordance with ASME Section II material specification from code editions and addenda other than those specified may be used, so long as the materials meet all the requirements of Article 2000 of the applicable subsection of the Section III edition and addenda used for construction.
NCA-1221.1	ASTM materials are allowed if the specification is identical with the corresponding ASME specification.	ASTM A-350 is not identical to SA-350; however, all discrepancies are identified and modified to match the requirements of SAR.
NB-2121 & NB-2128	Material must be listed in Section II, Part D, Subpart 1, Tables 2A and 2B.	The lid and RAM Access closure bolts have an option for 1.6580 carbon steel. The mechanical properties of this material are analyzed in the calculations and are discussed in the SAR.
NB-2130	Material must be supplied by ASME approved material suppliers.	The material shall be obtained from a TN approved supplier with a Certified Material Test Report (CMTR). Material is certified to meet all ASME code criteria but is not eligible for certification or code stamping, if a non-ASME fabricator is used. As the fabricator is not required to be ASME certified, material certification to NB-2130 is not possible.
NB-2331	The LST shall be 60°F above RTNDT as clarified by interpretation number III-1-83-282	TN shall complete an evaluation to ensure protection against nonductile fracture in accordance with NB-3210.d. This evaluation will justify the LST relative to fracture toughness properties of this material.
NB-2410	Drop weight test for material as-welded according to NB-2331	TN Shall complete an evaluation to ensure protection against nonductile fracture in accordance with NB-3210.d. This evaluation will justify the LST relative to fracture toughness properties of this material

Reference ASME Code Section/ Article	Code Requirement	Alternative, Justification & Compensatory Measures
NB-2539.4	When the depth of the repair cavity exceeds the lesser of 3/8 in. (10 mm) or 10% of the section thickness, the repair weld shall be radiographed after repair in accordance with NB-5110 and to the acceptance standards of NB-5320.	It may not be possible to perform RT on weld repair on the inside surface of the TC, which would require examination through very thick material and other components on the outside of the TC. Alternatively, the use of UT or multi-level MT/PT may be used to provide volumetric examination of the repair.
NB-4120	Material certification by certificate holder	Material traceability & certification are maintained in accordance with TN's NRC approved QA program.
NB-5520	NDE personnel must be qualified to a specific edition of SNT-TC-1A.	Permit use of the Recommended Practice SNT-TC-1A to include up to the most recent 2016 edition.
NB-7000	Overpressure Protection	No overpressure protection is provided for the TN Eagle cask. The function of the TN Eagle cask is to contain radioactive materials under normal, off normal, and hypothetical accident conditions postulated to occur during transportation. The TN Eagle cask is designed to withstand the maximum internal pressure considering 100% fuel rod failure at maximum accident temperature.
NB-8000	Requirements for nameplates, stamping & reports per NCA-8000	The TN Eagle cask nameplate provides the information required by 10 CFR 71. Code stamping is not required for the TC. QA data packages are prepared in accordance with the requirements of 10CFR71 and TN's NRC approved QA program.
NCA-8200	Requirements for code stamping of components	The TN Eagle is designed and fabricated to the requirements of Subsection NB, to the maximum extent practical. However, the cask does not have a code stamp.

Note: ASME Code alternatives are only listed for containment boundary material and fabrication. Code alternatives of non-containment boundary ASME code material and fabrication shall be listed in the applicable specifications.

9.4.1.2 EOS-37PTH and EOS-89BTH

The DSC confinement boundary is designed, fabricated and inspected to the maximum practical extent in accordance with ASME Boiler and Pressure Vessel Code Section III, Division 1, 2010 Edition with Addenda through 2011, Subsection NB, for Class 1 components.

EOS-37PTH and EOS-89BTH DSC ASME Code Alternatives, Subsection NB

Reference ASME Code Section/Article	Code Requirement	Justification AND Compensatory Measures
NCA	All	Not compliant with NCA
NB-1100	Requirements for Code Stamping of Components	The canister shell, the inner top cover, the inner bottom cover or bottom forging assembly, the outer top cover, and the drain port cover and vent port plug are designed and fabricated in accordance with the ASME Code, Section III, Subsection NB to the maximum extent practical. However, Code Stamping is not required. As Code Stamping is not required, the fabricator is not required to hold an ASME “N” or “NPT” stamp, or to be ASME Certified.
NB-2121	Permitted Material Specifications	Type 2205 and UNS S31803 are duplex stainless steels that provide enhance resistance to chloride-induced stress corrosion cracking. They are not included in Section II, Part D, Subpart 1, Tables 2A and 2B. UNS S31803 has been accepted for Class 1 components by ASME Code Case N-635-1, endorsed by NRC Regulatory Guide 1.84. Type 2205 falls within the chemical and mechanical requirements of UNS S31803. Normal and off-normal temperatures remain below the 600 °F operating limit. Accident conditions may exceed this limit, but only for durations too short to cause embrittlement.
NB-2130	Material must be supplied by ASME approved material suppliers	Material is certified to meet all ASME Code criteria but is not eligible for certification or Code Stamping if a non-ASME fabricator is used. As the fabricator is not required to be ASME certified, material certification to NB-2130 is not possible. Material traceability and certification are maintained in accordance with the NRC approved QA program associated with CoC 1042.
NB-4121	Material Certification by Certificate Holder	
NB-2300	Fracture toughness requirements for material	Type 2205 and UNS S31803 duplex stainless steels are tested by Charpy V-notch only per NB-2300. Drop weight tests are not required. Impact testing is not required for the vent port plug.
NB-2531	Drain port cover; straight beam ultrasonic testing (UT) per SA-578 for all plates for vessel	SA-578 applies to 3/8" and thicker plate only; allow alternate UT techniques to achieve meaningful UT results.
NB- 2531 and NB-2541	Vent port plug UT and liquid penetrant testing (PT)	This plug may be made from plate or bar. Due to its small area, it has no structural function. It is leak tested along with the inner top cover plate after welding. Therefore, neither UT nor PT are required.

Reference ASME Code Section/Article	Code Requirement	Justification AND Compensatory Measures
NB-4243 and NB-5230	Category C weld joints in vessels and similar weld joints in other components shall be full penetration joints. These welds shall be examined by UT or radiographic testing (RT) and either PT or magnetic particle testing (MT).	The shell to the outer top cover weld, the shell to the inner top cover weld, and the drain port cover and vent port plug welds are all partial penetration welds. As an alternative to the non-destructive examination (NDE) requirements of NB-5230 for Category C welds, all of these closure welds will be multi-layer welds and receive a root and final PT examination, except for the shell to the outer top cover weld. The shell to the outer top cover weld will be a multi-layer weld and receive multi-level PT examination in accordance with the guidance provided in NUREG 1536 Revision 1 for NDE. The multi-level PT examination provides reasonable assurance that flaws of interest will be identified. The PT examination is done by qualified personnel, in accordance with Section V and the acceptance standards of Section III, Subsection NB-5000. The cover to shell welds are designed to meet the guidance provided in ISG-15 for stress reduction factor.
NB-5520	NDE Personnel must be qualified to the 1992 edition of SNT-TC-1A	Permit use of the Recommended Practice SNT-TC-1A up to the 2006 edition as permitted by the 2013 Code Edition.
NB-6000	All completed pressure retaining systems shall be pressure tested	The DSC is not a complete or “installed” pressure vessel until the top closure is welded following placement of fuel assemblies within the DSC. Due to the inaccessibility of the shell and lower end closure welds following fuel loading and top closure welding, as an alternative, the pressure testing of the DSC is performed in two parts. The DSC shell, shell bottom, including all longitudinal and circumferential welds, is pneumatically tested and examined at the fabrication facility. The shell to the inner top cover closure weld is pressure tested and examined for leakage in accordance with NB-6300 in the field. The drain port cover and vent port plug welds will not be pressure tested; these welds and the shell to the inner top cover closure weld are helium leak tested after the pressure test. Per NB-6324 the examination for leakage shall be done at a pressure equal to the greater of the design pressure or three-fourths of the test pressure. As an alternative, if the examination for leakage of these field welds, following the pressure test, is performed using helium leak detection techniques, the examination pressure may be reduced to 1.5 psig. This is acceptable given the significantly greater sensitivity of the helium leak detection method.

Reference ASME Code Section/Article	Code Requirement	Justification AND Compensatory Measures
NB-7000	Overpressure Protection	No overpressure protection is provided for the EOS-37PTH or EOS-89BTH DSC. The function of the DSC is to contain radioactive materials under normal, off-normal, and hypothetical accident conditions postulated to occur during transportation. The DSC is designed to withstand the maximum internal pressure considering 100% fuel rod failure at maximum accident temperature.
NB-8000	Requirements for nameplates, stamping and reports per NCA-8000	The EOS-37PTH and EOS-89BTH DSC are stamped or engraved with the information required by 10 CFR Part 72. Code stamping is not required for these DSCs. QA Data packages are prepared in accordance with requirements of the NRC approved QA program associated with CoC 1042.

9.4.1.3 32PT

ASME B&PV Code, Section III, Division 1, Subsection NB and NF, 1983 Edition with Winter 1985 Addenda

Alternatives to the ASME Code for the NUHOMS®-32PT DSC Confinement Boundary

Reference ASME Code Section/Article	Code Requirement	Alternatives, Justification & Compensatory Measures
NCA	All	Not compliant with NCA. Quality Assurance is provided according to 10 CFR Part 72 Subpart G in lieu of NCA-4000.
NCA-1140	Use of Code editions and addenda	Code edition and addenda other than those specified in Section 4.2.2 may be used for construction, but in no case earlier than 3 years before that specified in the Section 4.2.2 table. Materials produced and certified in accordance with ASME Section II material specification from Code Editions and Addenda other than those specified in Section 4.2.2 may be used, so long as the materials meet all the requirements of Article 2000 of the applicable Subsection of the Section III Edition and Addenda used for construction.
NB-1100	Requirements for Code Stamping of Components, Code reports and certificates, etc.	Code Stamping is not required. As Code Stamping is not required, the fabricator is not required to hold an ASME “N” or “NPT” stamp, or to be ASME Certified.
NB-1132	Attachments with a pressure retaining function, including stiffeners, shall be considered part of the component.	Bottom shield plug and outer bottom cover plate are outside code jurisdiction; these components together are much larger than required to provide stiffening for the inner bottom cover plate; the weld that retains the outer bottom cover plate and with it the bottom shield plug is subject to root and final PT examination.
NB-2130	Material must be supplied by ASME approved material suppliers.	Material is certified to meet all ASME Code criteria but is not eligible for certification or Code Stamping if a non-ASME fabricator is used. As the fabricator is not required to be ASME certified, material certification to NB-2130 is not possible. Material traceability and certification are maintained in accordance with TN’s NRC approved QA program.
NB-4121	Material Certification by Certificate Holder	

Reference ASME Code Section/Article	Code Requirement	Alternatives, Justification & Compensatory Measures
NB-4243 and NB-5230	Category C weld joints in vessels and similar weld joints in other components shall be full penetration joints. These welds shall be examined by UT or RT and either PT or MT.	The joints between the top outer and inner cover plates and containment shell are designed and fabricated per ASME Code Case N-595-2, which provides alternative requirements for the design and examination of spent fuel canister closures. This includes the inner top cover plate weld around the vent & siphon block and the vent and siphon block welds to the shell. The closure welds are partial penetration welds and the root and final layer are subject to PT examination (in lieu of volumetric examination) in accordance with the provisions of ASME Code Case N-595-2. The 32PT closure system employs austenitic stainless steel shell, lid materials, and welds. Because austenitic stainless steels are not subject to brittle failure at the operating temperatures of the DSC, crack propagation is not a concern. Thus, multi-level PT examination provides reasonable assurance that flaws of interest will be identified. The PT examination is done by qualified personnel, in accordance with Section V and the acceptance standards of Section III, Subsection NB-5000. This alternative does not apply to other shell confinement welds, i.e., the longitudinal and circumferential welds applied to the DSC shell, and the inner bottom cover plate-to-shell weld which comply with NB-4243 and NB-5230.
NB-6100 and 6200	All pressure retaining components and completed systems shall be pressure tested. The preferred method shall be hydrostatic test.	The NUHOMS®-32PT DSC is pressure tested in accordance with ASME Code Case N-595-2. The shield plug support ring and the vent and siphon block are not pressure tested due to the manufacturing sequence. The support ring is not a pressure-retaining item and the vent and siphon block weld is helium leak tested after fuel is loaded to the same criteria as the inner top closure plate-to-shell weld (ANSI N14.5-1997 leaktight criteria).
NB-7000	Overpressure Protection	No overpressure protection is provided for the NUHOMS® DSCs. The function of the DSC is to contain radioactive materials under normal, off-normal and hypothetical accident conditions postulated to occur during transportation and storage. The DSC is designed to withstand the maximum possible internal pressure considering 100% fuel rod failure at maximum accident temperature.
NB-8000	Requirements for nameplates, stamping & reports per NCA-8000.	The NUHOMS® DSC nameplate provides the information required by 10 CFR Part 71, 49 CFR Part 173 and 10 CFR Part 72 as appropriate. Code stamping is not required for the DSC. QA data packages are prepared in accordance with the requirements of TN's approved QA program.

Reference ASME Code Section/Article	Code Requirement	Alternatives, Justification & Compensatory Measures
NB-5520	NDE Personnel must be qualified to a specific edition of SNT-TC-1A.	Permit use of the Recommended Practice SNT-TC-1A to include up to the most recent 2011 edition.

Alternatives to the ASME Code for the NUHOMS®-32PT DSC Basket Assembly

Reference ASME Code Section/Article	Code Requirement	Alternatives, Justification & Compensatory Measures
NCA	All	Not compliant with NCA. Quality Assurance is provided according to 10 CFR Part 72 Subpart G in lieu of NCA-4000.
NCA-1140	Use of Code editions and addenda	Code edition and addenda other than those specified in Section 4.2.2 may be used for construction, but in no case earlier than 3 years before that specified in the Section 4.2.2 table. Materials produced and certified in accordance with ASME Section II material specification from Code Editions and Addenda other than those specified in Section 4.2.2 may be used, so long as the materials meet all the requirements of Article 2000 of the applicable Subsection of the Section III Edition and Addenda used for construction.
NG-1100	Requirements for Code Stamping of Components, Code reports and certificates, etc.	Code Stamping is not required. As Code Stamping is not required, the fabricator is not required to hold an ASME “N” or “NPT” stamp, or to be ASME Certified.
NG-2000	Use of ASME Material	Some baskets include neutron absorber and aluminum plates that are not ASME Code Class 1 material. They are used for criticality safety and heat transfer, and are only credited in the structural analysis with supporting their own weight and transmitting bearing loads through their thickness. Material properties in the ASME Code for Type 6061 aluminum are limited to 400 °F to preclude the potential for annealing out the hardening properties. Annealed properties (as published by the Aluminum Association and the American Society of Metals) are conservatively assumed for the solid aluminum rails for use above the Code temperature limits.
NG-2130	Material must be supplied by ASME approved material suppliers.	Material is certified to meet all ASME Code criteria but is not eligible for certification or Code Stamping if a non-ASME fabricator is used. As the fabricator is not required to be ASME certified, material certification to

Reference ASME Code Section/Article	Code Requirement	Alternatives, Justification & Compensatory Measures
NG-4121	Material Certification by Certificate Holder	NG-2130 is not possible. Material traceability and certification are maintained in accordance with TN's NRC approved QA program.
NG-8000	Requirements for nameplates, stamping & reports per NCA-8000.	The NUHOMS® DSC nameplate provides the information required by 10 CFR Part 71, 49 CFR Part 173 and 10 CFR Part 72 as appropriate. Code stamping is not required for the DSC. QA data packages are prepared in accordance with the requirements of TN's approved QA program.
NG-3000/ Section II, Part D, Table 2A	Maximum temperature limit for XM-19 plate material is 800°F.	Not compliant with ASME Section II Part D Table 2A material temperature limit for XM-19 steel for the postulated transfer accident case (117 °F, loss of sunshade, loss of neutron shield). This is a post-drop accident scenario, where the calculated maximum steady state temperature is 852 °F, the expected reduction in material strength is small (less than 1 ksi by extrapolation), and the only primary stresses in the basket grid are deadweight stresses. The recovery actions following the postulated drop accident are as described in Section 8.2.5 of the UFSAR.
NG-5520	NDE personnel must be qualified to a specific edition of SNT-TC-1A.	Permit use of the Recommended Practice SNT-TC-1A to include up to the most recent 2011 edition.

9.4.1.4 32PTH1

ASME B&PV Code, Section III, Division 1, Subsection NB,NG and NF, 1998 Edition with Addenda through 2000

Alternatives to the ASME Code for the NUHOMS® 32PTH1 DSC Confinement Boundary

Reference ASME Code Section/Article	Code Requirement	Alternatives, Justification & Compensatory Measures
NCA	All	Not compliant with NCA. Quality Assurance is provided according to 10 CFR Part 72 Subpart G in lieu of NCA-4000.
NCA-1140	Use of Code editions and addenda	Code edition and addenda other than those specified in Section 4.2.2 may be used for construction, but in no case earlier than 3 years before that specified in the Section 4.2.2 table. Materials produced and certified in accordance with ASME Section II material specification from Code Editions and Addenda other than those specified in Section 4.2.2 may be used, so long as the materials meet all the requirements of Article 2000 of the applicable Subsection of the Section III Edition and Addenda used for construction.
NB-1100	Requirements for Code Stamping of Components, Code reports and certificates, etc.	Code Stamping is not required. As Code Stamping is not required, the fabricator is not required to hold an ASME “N” or “NPT” stamp, or to be ASME Certified.
NB-2130	Material must be supplied by ASME approved material suppliers.	Material is certified to meet all ASME Code criteria but is not eligible for certification or Code Stamping if a non-ASME fabricator is used. As the fabricator is not required to be ASME certified, material certification to NB-2130 is not possible. Material traceability and certification are maintained in accordance with TN’s NRC approved QA program.
NB-4121	Material Certification by Certificate Holder	
NB-4243 and NB-5230	Category C weld joints in vessels and similar weld joints in other components shall be full penetration joints. These welds shall be examined by UT or RT and either PT or MT.	The shell to the outer top cover weld, the shell to the inner top cover/shield plug weld (including optional design configurations for the inner top cover as described in the 32PTH1 DSC drawings), the siphon/vent cover welds, and the vent and siphon block welds to the shell are all partial penetration welds. As an alternative to the NDE requirements of NB-5230, for Category C welds, all of these closure welds are multi-layer welds and receive a root and final PT examination, except for the shell to the outer top cover weld. The shell to the outer top cover weld will be a multi-layer weld and receive multi-level PT examination in accordance with the guidance provided in ISG-15 for NDE. The multi-level PT examination provides reasonable assurance that flaws of interest will be identified. The PT examination is done by qualified personnel, in accordance with Section V and the acceptance standards of Section

Reference ASME Code Section/Article	Code Requirement	Alternatives, Justification & Compensatory Measures
		III, Subsection NB-5000. All of these welds are designed to meet the guidance provided in ISG-15 for stress reduction factor.
NB-1132	Attachments with a pressure retaining function, including stiffeners, shall be considered part of the component.	Bottom shield plug and outer bottom cover plate are outside code jurisdiction; these components together are much larger than required to provide stiffening for the inner bottom cover plate; the weld that retains the outer bottom cover plate and with it the bottom shield plug is subject to root and final PT examination.
NB-6100 and 6200	All pressure retaining components and completed systems shall be pressure tested. The preferred method shall be hydrostatic test.	The NUHOMS® 32PTH1 DSC is not a complete vessel until the top closure is welded following placement of fuel assemblies within the DSC. Due to the inaccessibility of the shell and lower end closure welds following fuel loading and top closure welding, as an alternative, the pressure testing of the DSC is performed in two parts. The DSC shell and inner bottom plate/forging (including all longitudinal and circumferential welds), are pressure tested and examined at the fabrication facility. The shell to the inner top cover/shield plug closure weld (including optional design configurations for the inner top cover as described in the 32PTH1 DSC drawings) is pressure tested and examined for leakage in accordance with NB-6300 in the field. The siphon/vent cover welds are not pressure tested; these welds and the shell to the inner top cover/shield plug closure weld (including Optional design configurations for the inner top cover as described in the 32PTH1 DSC drawings) are helium leak tested after the pressure test. Per NB-6324 the examination for leakage shall be done at a pressure equal to the greater of the design pressure or three-fourths of the test pressure. As an alternative, if the examination for leakage of these field welds, following the pressure test, is performed using helium leak detection techniques, the examination pressure may be reduced to $\geq$1.5 psig. This is acceptable given the significantly greater sensitivity of the helium leak detection method.
NB-7000	Overpressure Protection	No overpressure protection is provided for the NUHOMS® DSCs. The function of the DSC is to contain radioactive materials under normal, off-normal and hypothetical accident conditions postulated to occur during transportation and storage. The DSC is designed to withstand the maximum possible internal pressure considering 100% fuel rod failure at maximum accident temperature.

Reference ASME Code Section/Article	Code Requirement	Alternatives, Justification & Compensatory Measures
NB-8000	Requirements for nameplates, stamping & reports per NCA-8000.	The NUHOMS® DSC nameplate provides the information required by 10 CFR Part 71, 49 CFR Part 173 and 10 CFR Part 72 as appropriate. Code stamping is not required for the DSC. QA data packages are prepared in accordance with the requirements of TN's approved QA program.
NB-5520	NDE Personnel must be qualified to a specific edition of SNT-TC-1A.	Permit use of the Recommended Practice SNT-TC-1A to include up to the most recent 2011 edition.

Alternatives to the ASME Code for the NUHOMS® 32PTH1 DSC Basket Assembly

Reference ASME Code Section/Article	Code Requirement	Alternatives, Justification & Compensatory Measures
NCA	All	Not compliant with NCA. Quality Assurance is provided according to 10 CFR Part 72 Subpart G in lieu of NCA-4000.
NCA-1140	Use of Code editions and addenda	Code edition and addenda other than those specified in Section 4.2.2 may be used for construction, but in no case earlier than 3 years before that specified in the Section 4.2.2 table. Materials produced and certified in accordance with ASME Section II material specification from Code Editions and Addenda other than those specified in Section 4.2.2 may be used, so long as the materials meet all the requirements of Article 2000 of the applicable Subsection of the Section III Edition and Addenda used for construction.
NG-1100	Requirements for Code Stamping of Components, Code reports and certificates, etc.	Code Stamping is not required. As Code Stamping is not required, the fabricator is not required to hold an ASME "N" or "NPT" stamp, or to be ASME Certified.
NG-2000	Use of ASME Material	Some baskets include neutron absorber and aluminum plates that are not ASME Code Class 1 material. They are used for criticality safety and heat transfer, and are only credited in the structural analysis with supporting their own weight and transmitting bearing loads through their thickness. Material properties in the ASME Code for Type 6061 aluminum are limited to 400 °F to preclude the potential for annealing out the hardening properties. Annealed properties (as published by the Aluminum Association and the American Society of Metals) are conservatively assumed for the aluminum transition rails for use above the Code temperature limits.

Reference ASME Code Section/Article	Code Requirement	Alternatives, Justification & Compensatory Measures
NG-2130	Material must be supplied by ASME approved material suppliers.	Material is certified to meet all ASME Code criteria but is not eligible for certification or Code Stamping if a non-ASME fabricator is used. As the fabricator is not required to be ASME certified, material certification to NG-2130 is not possible. Material traceability and certification are maintained in accordance with TN's NRC approved QA program.
NG-4121	Material Certification by Certificate Holder	
NG-8000	Requirements for nameplates, stamping & reports per NCA-8000.	The NUHOMS® DSC nameplate provides the information required by 10 CFR Part 71, 49 CFR Part 173 and 10 CFR Part 72 as appropriate. Code stamping is not required for the DSC. QA data packages are prepared in accordance with the requirements of TN's approved QA program.
NG-3000/ Section II, Part D, Table 2A	Maximum temperature limit for Type 304 plate material is 800 °F.	Not compliant with ASME Section II Part D Table 2A material temperature limit for Type 304 steel for the postulated transfer accident case (117 °F, loss of sunshade, loss of neutron shield) and blocked vent accident (117 °F, 40 hr). The calculated maximum steady state temperatures for transfer accident case and blocked vent accident case are less than 1000 °F. The only primary stresses in the basket grid are deadweight stresses. The ASME Code allows use of SA240 Type 304 stainless steel to temperatures up to 1000 °F, as shown in ASME Code, Section II, Part D, Table 1A. In the temperature range of interest (near 800 °F), the S_m values for SA240 Type 304 shown in ASME Code, Section II Part D, Table 2A are identical to the allowable S values for the same material shown in Section B, Part D, Table 1A. The recovery actions following these accident scenarios are as described in the UFSAR.

Reference ASME Code Section/Article	Code Requirement	Alternatives, Justification & Compensatory Measures
NG-3352	Table NG-3352-1 lists the permissible welded joints.	The fusion welds between the stainless steel insert plates and the stainless fuel compartment tube are not included in Table NG-3352-1. These welds are qualified by testing. The required minimum tested capacity of the welded connection (at each side of the tube) shall be 45 kips (at room temperature). The capacity shall be demonstrated by qualification and production testing. Testing shall be performed using, or corrected to, the lowest tensile strength of material used in the basket assembly or to minimum specified tensile strength. Testing may be performed on individual welds, or on weld patterns representative of one wall of the tube. ASME Code Section IX does not provide tests for qualification of these type of welds. Therefore, these welds are qualified using Section IX to the degree applicable together with the testing described here. The welds will be visually inspected to confirm that they are located over the insert plates, in lieu of the visual acceptance criteria of NG-5260 which are not appropriate for this type of weld.
		A joint efficiency (quality) factor of 1.0 is utilized for the fuel compartment longitudinal seam welds. Table NG-3352-1 permits a joint efficiency (quality) factor of 0.5 to be used for full penetration weld examined by ASME Section V visual examination (VT). For the 32PTH1 DSC, the compartment seam weld is thin and the weld will be made in one pass. Both surfaces of weld (inside and outside) will be fully examined by VT and therefore a factor of 2 x 0.5=1.0, will be used in the analysis. This is justified as both surfaces of the single weld pass/layer will be fully examined, and the stainless steel material that comprises the fuel compartment tubes is very ductile.
NG-5520	NDE personnel must be qualified to a specific edition of SNT-TC-1A.	Permit use of the Recommended Practice SNT-TC-1A to include up to the most recent 2011 edition.

9.4.1.5 24PT1 or 24PT4

24PT1 or 24PT4 DSC Shell Assembly Alternatives to ASME Code, Subsection NB

Reference ASME Code Section/Article	Code Requirement	Alternative, Justification & Compensatory Measures
NCA	All	Not compliant with NCA.
NB-1100	Requirements for Code Stamping of Components	The DSC shell is designed & fabricated in accordance with the ASME Code, Section III, Subsection NB to the maximum extent practical. However, Code Stamping is not required. As Code Stamping is not required, the fabricator is not required to hold an ASME “N” or “NPT” stamp, or to be ASME Certified.
NB-2130	Material must be supplied by ASME approved material suppliers	All materials designated as ASME on the UFSAR drawings are obtained from ASME approved MM or MS supplier(s) with ASME CMTR’s. Material is certified to meet all ASME Code criteria but is not eligible for certification or Code Stamping if a non-ASME fabricator is used. As the fabricator is not required to be ASME certified, material certification to NB-2130 is not possible. Material traceability & certification are maintained in accordance with TN’s NRC approved QA program.
NB-4121	Material Certification by Certificate Holder	
NB-6111	All completed pressure retaining systems shall be pressure tested	The shield plug support ring and vent and siphon block are not pressure tested due to the manufacturing sequence. The support ring is not a pressure-retaining item and the siphon block weld is helium leak tested after fuel is loaded and the inner top closure plate installed in accordance with Code Case N-595-1.
NB-7000	Overpressure Protection	No overpressure protection is provided for the DSC. The function of the DSC is to contain radioactive materials under normal, off-normal and hypothetical accident conditions postulated to occur during transportation and storage. The DSC is designed to withstand the maximum internal pressure considering 100% fuel rod failure at maximum accident temperature. The DSC is pressure tested to 120% of normal operating design pressure. An overpressure protection report is not prepared for the DSC.
NB-8000	Requirements for nameplates, stamping & reports per NCA-8000	The DSC nameplate provides the information required by 10 CFR Part 71, 49 CFR Part 173 and 10 CFR Part 72 as appropriate. Code stamping is not required for the DSC. In lieu of code stamping, QA Data packages are prepared in accordance with the requirements of 10 CFR Part 71, 10 CFR Part 72 and TN’s approved QA program.

24PT1 or 24PT4 Basket Alternatives to ASME Code, Subsection NG/NF

Reference ASME Code Section/Article	Code Requirement	Alternative, Justification & Compensatory Measures
NCA	All	Not compliant with NCA.
NG/NF-1100	Requirements for Code Stamping of Components	The DSC baskets are designed & fabricated in accordance with the ASME Code, Section III, Subsection NG/NF to the maximum extent practical as described in the UFSAR, but Code Stamping is not required. As Code Stamping is not required, the fabricator is not required to hold an ASME N or NPT stamp or be ASME Certified.
NG/NF-2130 NG/NF-4121	Material must be supplied by ASME approved material suppliers Material Certification by Certificate Holder	All materials designated as ASME on the UFSAR drawings are obtained from ASME approved MM or MS supplier with ASME CMTR's. Material is certified to meet all ASME Code criteria but is not eligible for certification or Code Stamping if a non-ASME fabricator is used. As the fabricator is not required to be ASME certified, material certification to NG/NF-2130 is not possible. Material traceability & certification are maintained in accordance with TN's NRC approved QA program.
Table NG-3352-1	Permissible Joint Efficiency Factors	Joint efficiency (quality) factor of 1 is assumed for the guidesleeve longitudinal weld. Table NG-3352-1 permits a quality factor of 0.5 for full penetration weld with visual inspection. Inspection of both faces provides n = (2*0.5) = 1. This is justified by this gauge of material (0.12 inch) with visual examination of both surfaces which ensures that any significant deficiencies would be observed and corrected.
NG/NF-8000	Requirements for nameplates, stamping & reports per NCA-8000	The DSC nameplate provides the information required by 10 CFR Part 71, 49 CFR Part 173 and 10 CFR Part 72 as appropriate. Code stamping is not required for the DSC. In lieu of code stamping, QA Data packages are prepared in accordance with the requirements of 10 CFR Part 71, 10 CFR Part 72 and TN's approved QA program.
N/A	N/A	Oversleeve to guidesleeve welds are non-code welds which meet the requirements of AWS D1.3-98, the Structural Welding Code-Sheet Steel.
NG-3000 / Section II, Part D, Table 2A	Maximum temperature limit for Type 304 plate material is 800ºF	For 24PT4-DSC only: The DSC guidesleeves, oversleeves and failed fuel cans do not comply with ASME Code limit of 800ºF for Type 304 steel for the postulated blocked vent accident for approximately 25 hours. The maximum predicted temperature of those components for this event is less than 900ºF. In accordance with Table I-14.5 of Article NH, the expected reduction in material strength is small (less than 1 ksi) and the calculated stress ratio is very small.

9.4.1.6 FO/FC/FF

FC, FO, and FF DSC Shell Code Alternatives

<table>
<tr><th>Reference ASME Code Section/Article</th><th>Code Requirement</th><th>Alernative, Justification & Compensatory Measures</th></tr>
<tr><td>NB-1100</td><td>Requirements for Code Stamping of Components</td><td>The FO, FC and FF DSC shells are designed & fabricated in accordance with the ASME Code, Section III, Subsection NV to the maximum extent practical as described in the SAR, but Code Stamping is not required. As Code Stamping is not required , the fabricator is not required to hold an ASME or NPT stamp or be ASME Certified</td></tr>
<tr><td>NB-2130</td><td>Material must be supplied by ASME approved material suppliers</td><td rowspan="2">All materials designated as ASME on the SAR drawings are obtained from AMSE approved MM or MS supplier with ASME CMTR's or from a supplier whose QA program has been audited to meet the appropriate ASME requirements. Alternately, material may be independently tested by an approved test lab to verify material. Material is certified to meet all ASME Code criteria but is not eligible for certification or Code Stamping if a non-ASME fabricator is used. As the fabricator is not required to be ASME certified, material certification to NB-2130 is not possible. Material traceability & certification are maintained in accordance with TNW's NRC approved QA program.</td></tr>
<tr><td>NB-4121</td><td>Material Certification by Certificate Holder</td></tr>
<tr><td>NB-4243 fig. NB-4243-1</td><td>Full penetration at welds are required for DSC closure welds</td><td rowspan="2"><u>DSC Inner and Outer Top Cover Closure Welds:</u>
Joint details do not comply with the requirements of fig. NB-4243-1 for a Type 1 Category C flat head closure weld. RT inspection to NB-5231 is not practical due to the presence of the loaded fuel, high radiation area, and presence of the transfer cask. The inner and outer cover plate closure welds provide the redundant closure welds required by 10CFR72.
The inner top cover plate to shell weld is a 3/16” multi-layer effective throat partial penetration weld. Examination is multi-level PT (root and final) plus surface PT, or a multi-layer (root, each ¼ “ and final) PT. redundant multi-pass welds provide assurance that imperfections will not propagate in the ductile, fracture tough stainless steel used for fabrication.</td></tr>
<tr><td>NB-5231</td><td>Weld examination shall be UT or RT with surface PT</td></tr>
</table>

Reference ASME Code Section/Article	Code Requirement	Alernative, Justification & Compensatory Measures
NB-6111	All completed pressure retaining systems shall be pressure tested	The DSC Shell and inner bottom cover are pressure tested during fabrication to the requirements of NV-6000. In addition, a helium leak test is preformed to demonstrate leakage integrity of this boundary. The outer bottom cover plate cannot be installed until after the bottom shield plug is installed. The top closure welds are not completed until the DSC is loaded with fuel and, therefore, the top cover plates are also not subject to the pressure test. Multi-pass welds are used for these joints to eliminate potential leakage paths and a helium leak test is performed after completion of the inner top cover plate to shell closure weld. PT inspections of the top closure welds are performed on the root, each ¼” of deposited metal & final layer. The DSC inner and outer closure welds have been subjected to an extensive test program to ensure the joint parameters provide satisfactory welds with over 60 similar canisters successfully welded using similar joint details and parameters. The shield plug support ring and vent and siphon block are also not pressure tested due to the manufacturing sequence. The support ring is not a pressure-retaining item and siphon block weld is helium leak tested when fuel is loaded and then covered with the outer top closure plate.
NB-6112.1	Pneumatic Test Limitations	For convenience, this may be accomplished as pneumatic test concurrent with the helium leak test.
NB-7000	Overpressure Protection	O overpressure protection is provided for the DSC. The function of the DSC is to contain radioactive materials under normal, off normal & hypothetical accident conditions postulated to occur during transportation & storage. The DSC is designed to withstand the maximum internal pressure considering 200% fuel rod failure at maximum accident temperature. The DSC is pressure tested to 125% of normal operating design pressure.
NB-8000	Requirements for nameplates, stamping & reports per NCA-8000	The DSC nameplate provides the information required by 10CFR71, 49CFR173 and 10CFR72 as appropriate. Code stamping is not required for the DSC. QA Data packages are prepared in accordance with the requirements of 10CFR71, 10CFR72 and TNW’ approved QA program.

FC, FO, and FF DSC Basket Code Alternatives

Reference ASME Code Section/Article	Code Requirement	Alternative, Justification & Compensatory Measures
NG-1100	Requirements for Code Stamping of Components	The FO, FC and FF DSC baskets are designed & fabricated in accordance with the ASME Code, Section III, Subsection NG to the maximum extent practical as described in the SAR, but Code Stamping is not required. As Code Stamping is not required , the fabricator is not required to hold an ASME N or NPT stamp or be ASME Certified.
NG-2130	Material must be supplied by ASME approved material suppliers	All materials designed as ASME on the SAR drawings are obtained from ASME approved MM or MS supplier with ASME CMTR's or from a supplier whose QA program has been audited to meet the appropriate ASME requirements. Alternately, material may be independently tested by an approved test lab to verify material. Material is certified to meet all ASME Code criterial but is not eligible for certification or Code Stamping if a non-ASME fabricator is used. As the fabricator is not required to be ASME certified, material certification to NB-2130 is not possible. Material traceability & certification are maintained in accordance with TNW's NRC approved QA program.
NG-4121	Material Certification by Certificate Holder	
NG-2400	General requirements	Support rod ends contain tack welds to provide assurance that the sleeves do not rotate. Tack welding of this material will not comply to code requirements. Due to lack of stresses on this weld, safety is not impacted.
NB-8000	Requirements for nameplates, stamping & reports NCA-8000	The DSC nameplate provides the information required by 10CFR71, 49CFR173 and 10CFR72 as appropriate. Code stamping is not required for the DSC. QA Data packages are prepared in accordance with the requirements of 10CFR71, 10CFR72 and TNW' approved QA program.

Chapter 10
QUALITY ASSURANCE

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Chapter 10
Quality Assurance

TN Americas LLC (TN) has a Quality Assurance (QA) program [1] that has been previously approved by the NRC [2]. The TN QA program has been established in accordance with the requirements of 10 CFR Parts 71 and 72, Subparts H and G, respectively. The QA program applies to the design, purchase, fabrication, handling, shipping, storing, cleaning, assembly, inspection, testing, operation, maintenance, repair, and modification of the TN Eagle package components identified as "important- to- safety".

10.1 References

1. TN Americas LLC, Quality Assurance Program Description Manual for 10 CFR Part 71, Subpart H and 10 CFR Part 72, Subpart G.

2. NRC Quality Assurance Program Approval for Radioactive Material Packages, Approval Number 0250.

AFFIDAVIT PURSUANT
TO 10 CFR 2.390

State of Maryland:
County of HOWARD:

I, Prakash Narayanan, depose and say that I am Chief Technical Officer of TN Americas LLC, duly authorized to execute this affidavit, and have reviewed or caused to have reviewed the information which is identified as proprietary and referenced in the paragraph immediately below. I am submitting this affidavit in conformance with the provisions of 10 CFR 2.390 of the Commission's regulations for withholding this information.

The information for which proprietary treatment is sought is listed below:

- Enclosure 1 - Portions of the TN Eagle System SAR (Proprietary Version)

This document has been appropriately designated as proprietary.

I have personal knowledge of the criteria and procedures utilized by TN Americas LLC in designating information as a trade secret, privileged, or as confidential commercial or financial information.

Pursuant to the provisions of paragraph (b) (4) of Section 2.390 of the Commission's regulations, the following is furnished for consideration by the Commission in determining whether the information sought to be withheld from public disclosure, included in the above referenced document, should be withheld.

1) The information sought to be withheld from public disclosure involves portions of the safety analysis report related to the design of the TN Eagle System, which is owned and has been held in confidence by TN Americas LLC.
2) The information is of a type customarily held in confidence by TN Americas LLC and not customarily disclosed to the public. TN Americas LLC has a rational basis for determining the types of information customarily held in confidence by it.
3) Public disclosure of the information is likely to cause substantial harm to the competitive position of TN Americas LLC because the information consists of descriptions of the design and analysis of a radioactive material transportation system, the application of which provide a competitive economic advantage. The availability of such information to competitors would enable them to modify their product to better compete with TN Americas LLC, take marketing or other actions to improve their product's position or impair the position of TN America LLC's product, and avoid developing similar data and analyses in support of their processes, methods or apparatus.

I declare that the statements set forth in this affidavit are true and correct to the best of my knowledge, information, and belief. I declare under penalty of perjury that the foregoing is true and correct.

Executed on: 9/20/2023

DocuSigned by:
A·Prakash
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Prakash Narayanan
Chief Technical Officer, TN Americas LLC