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September 29, 2022
E-59796

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

Subject: Application for Amendment 4 to NUHOMS® EOS Certificate of Compliance No. 1042, Revision 0 (Docket 72-1042)

In accordance with 10 CFR 72.244, TN Americas LLC herewith submits its application to amend Certificate of Compliance (CoC) No. 1042 for the NUHOMS® EOS System. The scope of Amendment 4 is described in Enclosure 2. Enclosure 3 includes a markup of proposed changes to the CoC document. Enclosure 4 provides a complete revision to the Technical Specifications (TS) with proposed changes indicated by italicized text and revision bars. The proprietary version of the updated final safety analysis report (UFSAR) changed pages and drawings associated with Amendment 4 are included as Enclosure 5 with the proposed UFSAR changed and new pages indicated by gray shading, italicized text, revision bars, and a footer on each changed page annotated as “72-1042 Amendment 4, Revision 0, September 2022.” The gray shading is to distinguish Amendment 4 changes from tracked Amendment 3 and 72.48 changes. The public version of these UFSAR changed pages is provided as Enclosure 6.

Enclosure 7 provides a listing of the computer files associated with CoC 1042 Amendment 4. Enclosure 8 contains the computer files associated with this amendment submittal. The file structure of the computer files is not compatible with the NRC EIE application process and Enclosure 8 is therefore being submitted separately. Since Enclosure 8 contains entirely proprietary information, no public version is provided. Enclosure 9 provides a listing of the TS and UFSAR pages involved in Amendment 4, Revision 0. Enclosure 10 provides a proprietary version of a roadmap of where the newly designed EOS-HSM-SC is discussed in the UFSAR, and discussion of how the EOS-HSM-SC conforms to ANSI/AISC N690-18. Enclosure 11 provides a public version of Enclosure 10.

Enclosure 12 provides the proprietary EOS-HSM-SC qualification test documents referenced in Enclosure 10. Since Enclosure 12 contains entirely proprietary information, no public version is provided.

Certain portions of this submittal include proprietary information, which may not be used for any purpose other than to support the NRC staff's review of the application. In accordance with 10 CFR 2.390, TN Americas LLC is providing an affidavit (Enclosure 1), specifically requesting that this proprietary information be withheld from public disclosure. The submittal also includes security-related information.

Based on recent experience with similar amendment scopes, with essentially no physical changes to the design, and no major appendices being added to the UFSAR, TN is hopeful that NRC review of this application will result in Amendment 4 becoming effective in July 2024.

TN Americas LLC looks forward to working with the NRC staff on this amendment application. We are prepared to meet with the staff to resolve any questions the staff might have. Should the NRC staff require additional information to support review of this application, please do not hesitate to contact Mr. Glenn Mathues at 410-910-6538, or by email at Glenn.Mathues@orano.group.

Sincerely,

A. Prakash

Prakash Narayanan
Chief Technical Officer

cc: Chris Jacobs (NRC), Senior Project Manager, Storage and Transportation Licensing Branch, Division of Fuel Management

Enclosures:

1. Affidavit Pursuant to 10 CFR 2.390
2. Description, Justification, and Evaluation of Amendment 4 Changes
3. Proposed Certificate of Compliance No. 1042 Amendment 4, Revision 0 Markup
4. Proposed Technical Specifications, CoC 1042 Amendment 4, Revision 0
5. Proposed Amendment 4, Revision 0 Changes to the NUHOMS® EOS System Updated Final Safety Analysis Report (Proprietary and Security-Related Version)
6. Proposed Amendment 4, Revision 0 Changes to the NUHOMS® EOS System Updated Final Safety Analysis Report (Public Version)
7. Listing of Computer Files Contained in Enclosure 8
8. Computer Files Associated with Certificate of Compliance 1042 Amendment 4, Revision 0 (Proprietary) (contained on one hard drive)
9. List of TS and UFSAR Pages Involved in CoC 1042 Amendment 4, Revision 0
10. UFSAR Presentation of EOS-HSM-SC Design Based on ANSI/AISC N690-18 (Proprietary Version)
11. UFSAR Presentation of EOS-HSM-SC Design Based on ANSI/AISC N690-18 (Public Version)
12. EOS-HSM-SC Qualification Test Documents (Proprietary)

AFFIDAVIT PURSUANT
TO 10 CFR 2.390

TN Americas LLC)
State of Maryland) SS.
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 that 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 contained in Enclosures 5 and 8, 10, and 12 as listed below:

- Enclosure 5 – Portions of certain updated final safety analysis report (UFSAR) chapters
- Enclosure 8 – Certain Computer Files Associated with Certificate of Compliance 1042 Amendment 4
- Enclosure 10 – Portions of UFSAR Presentation of EOS-HSM-SC Design Based on ANSI/AISC N690-18
- Enclosure 12 – EOS-HSM-SC Qualification Test Documents

These documents have 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 UFSAR, analysis computer files, and other documents related to the design of a spent fuel storage system, all related to the design of the NUHOMS® EOS System, which are owned and have 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 dry spent fuel storage systems, 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 Americas LLC's product, and avoid developing similar data and analyses in support of their processes, methods, or apparatus.

Further the deponent sayeth not.

A. Prakash

Prakash Narayanan
Chief Technical Officer, TN Americas LLC

Subscribed and sworn before me this 27 day of September 2022.

Notary Public

My Commission Expires 10 / 5 / 25

KHYNESYA TAYLOR
Notary Public
Howard County
Maryland
My Commission Expires Oct. 5, 2025

DESCRIPTION, JUSTIFICATION, AND EVALUATION OF AMENDMENT 4 CHANGES

1.0 INTRODUCTION

The scope of Amendment 4 to Certificate of Compliance (CoC) No. 1042 includes the changes described below.

Change No. 1:

For the EOS-37PTH, similar to the EOS-89BTH concept submitted under Amendment 3 (Change 7), incorporate a method to determine new loading patterns based on the maximum allowable heat load per DSC, identified as the maximum allowable heat load configuration (MHLC). The MHLC is applicable to the EOS-37PTH transferred in the EOS-TC125 and stored in the EOS-HSM. Two (2) new heat load zone configurations (HLZCs) are applicable to this MHLC.

Change No. 2:

Introduce a steel plate composite option for the EOS-HSM. The steel plate composite option allows for the HSM components to be constructed from concrete-filled integrated steel wall forms. The walls are tied together with tie bars and studs are welded to the inside of the walls to provide concrete reinforcement. When used without distinction, EOS-HSM-SC refers to both the segmented and one-piece base. The EOS-HSM-SC is used only with the flat plate support structure.

Change No. 3:

Introduce the use of MAVRIC software for a confirmatory run of the HSM-MX dose rates.

Change No. 4:

Technical Specification (TS) changes for consistency among DSC types and terminology clarification.

Change No. 5:

Various updated final safety analysis report (UFSAR) editorial corrections for consistency and clarification.

Change No. 6:

Measured exposures from past loading campaigns are added to highlight that measured exposures are significantly less than calculated exposures.

2.0 DESCRIPTION OF THE CHANGES

2.1 Changes to the CoC 1042 NUHOMS® EOS System CoC

The table below provides proposed changes to the CoC pages, a brief description of the subject and/or change, and a reference to the scope item from Section 1.0 that relates to the change or changes.

CoC page	CoC Section Number	Description	Change No.
1	N/A	Amendment number changed to 4 and Amendment effective Date changed to “tbd”.	none
2	N/A	Amendment number changed to 4.	none
3	N/A	Amendment number changed to 4.	none
4	N/A	Amendment number changed to 4 and Amendment effective Date changed to “tbd”.	none

Note: The proposed changes to the CoC are contained in Enclosure 3.

2.2 Changes to the NUHOMS® EOS System CoC 1042 Technical Specifications

The table below provides proposed changes to the TS pages with a brief description of the subject and/or change, and a reference to the scope item from Section 1.0 that relates to the change or changes.

TS page	TS Number	Description	Change No.
Cover Page	N/A	Amendment number changed to 4.	none
TOC/LOT/LOF	N/A	Table of Contents, etc. automated updates.	none
2-1	2.1	In the PHYSICAL PARAMETERS row, “Fuel” was added for clarity. In the DAMAGED FUEL ASSEMBLIES row, “slots” was changed to “cells” for consistency. In the FAILED FUEL row, “slots” was changed to 'cells' for consistency.	4
2-1	2.1	In the DAMAGED FUEL ASSEMBLIES row, “and 13” was added, referring to the added Figure 13.	1
2-1	2.1	In the FAILED FUEL row, “and 13” was added, referring to the added Figure 13.	1
2-1	2-1	The RECONSTITUTED FUEL ASSEMBLIES section has been completely revised.	1
2-2	2.2	In the THERMAL PARAMETERS row, "Heat Load Zone" was changed to "Maximum Heat Load," "(MHLC)" was added, and several paragraphs were added.	1
2-4	2.1	In the RADIOLOGICAL PARAMETERS section, the discussion regarding “Minimum Cooling Time” has been completely revised.	1
2-5	2.2	In the Fuel to be Stored in the 89BTH DSC Section, in the sub-section titled “NUMBER OF INTACT FUEL ASSEMBLIES,” the word “Fuel” was added for clarification.	4

TS page	TS Number	Description	Change No.
2-8	2.3	In the Fuel to be Stored in the 61BTH Type 2 DSC Section, in the sub-section titled “NUMBER OF INTACT FUEL ASSEMBLIES,” the word “Fuel” was added for clarification. In the DAMAGED FUEL ASSEMBLIES row, “slots” is changed to “cells” for consistency. In the FAILED FUEL row, “slots” was changed to “cells” for consistency.	4
3-7	3.1.3	In the Table on this page, a few changes were made in the "APPLICABLE HLZC" column. Note numbers were added to a few rows in the "TIME LIMITS" column, a new Note 2 was added, and the previous Note 2 is now Note 3.	1
4-1	4.2.2	In Section 4.2.2, Storage Pad, discussion regarding the EOS-HSM construction, specifically for the EOS-HSM-RC and the EOS-HSM-SC, was added.	2
4-3	4.4.1	In the HORIZONTAL STORAGE MODULE (HSM) section, discussion regarding the construction of the steel composite HSM (EOS-HSM-SC) components (steel and concrete), was added.	2
4-13	4.4.4	In the Code alternatives for the HSM concrete specifications section, a code alternative to ANSI/AISC N9.1.1(a) and to N9.1.1(d) was added.	2
5-6	5.1.3.2.b.i	An instance of “HSM” was changed to “HSM-MX” for consistency.	4
5-8	5.3	In the Concrete Testing section, the word “accident” was added for clarification.	4
5-9	5.5	In the first paragraph, “12, or 13” was added, referring to the added HLCZ 12 and HLZC 13.	1

TS page	TS Number	Description	Change No.
T-1	Table 3	Table 3 has been revised, adding two columns, one for the “Transfer in the EOS-TC108 OR storage in the HSM-MX,” and one for the “Transfer in the EOS-TC125/135 AND storage in the EOS-HSM.”	1
T-7	Table 7B	In the title, "for Storage in the HSM-MX" was added for clarification.	1
T-8	Table 7C	Added Table 7C: EOS-37PTH DSC Fuel Qualification Table for Storage in the EOS-HSM, All Fuel.	1
T-25	Table 24	Added Table 24: EOS-37PTH DSC Reconstituted Fuel Limits for Transfer in the EOS-TC125/135 AND Storage in the EOS-HSM.	1
T-26	Table 25	Added Table 25: EOS-37PTH DSC Reconstituted Fuel Limits for Transfer in the EOS-TC108.	1
F-2	Figure 1B	In the title, “Transferred in the EOS-TC108” was added for clarification.	1
F-3	Figure 1C	In the title, “Transferred in the EOS-TC108” was added for clarification.	1
F-4	Figure 1D	In the title, “Transferred in the EOS-TC108” was added for clarification.	1
F-5	Figure 1E	In the title, “Transferred in the EOS-TC108” was added for clarification.	1
F-6	Figure 1F	In the title, “Transferred in the EOS-TC108” was added for clarification.	1
F-7	Figure 1G	In the title, “Stored in the HSM-M, or Transferred in the EOS-TC108” was added for clarification.	1
F-8	Figure 1H	In the title, “Stored in the HSM-M, or Transferred in the EOS-TC108” was added for clarification.	1

TS page	TS Number	Description	Change No.
F-9	Figure 1I	In the title, "Stored in the HSM-M, or Transferred in the EOS-TC108" was added for clarification.	1
F-11	Figure 1K	In the title, "Stored in the HSM-M" was added for clarification.	1
F-31	Figure 12	Added Figure 12: Maximum Heat Load Configuration 1 for EOS-37PTH DSC (MHLC-37-1) Transferred in the EOS-TC125/135 and Stored in the EOS-HSM.	1
F-32	Figure 13	Added Figure 13: Damaged and Failed Fuel Configurations for the EOS-37PTH DSC.	1
F-33	Figure 14	Added Figure 14: EOS-37PTH DSC Allowed Reconstituted Fuel Locations for Transfer in the EOS-TC108.	1

2.3 Changes to the NUHOMS® EOS System CoC 1042 UFSAR

Enclosure 5 (Proprietary version) and Enclosure 6 (Public version) provide proposed Amendment 4 changed pages and drawings for the NUHOMS® EOS System UFSAR. Amendment 4 proposed UFSAR changes are tracked by gray shading, italicized text and revision bars.

The following paragraphs discuss the changed UFSAR areas, based on the changes described in Section 1 above. Editorial changes to correct spelling, grammar, etc. are also made to the changed UFSAR pages where appropriate.

In support of Change 1, changes were made to UFSAR Chapters 1, 2, 4, 6, 7, 8, 9, 10, 11, new Chapter 4 Appendix 4.9.9, as well as a revision to drawing EOS01-1010-SAR.

In support of Change 2, changes were made to UFSAR Chapters 1, 2, 3, 3.9.4, 3.9.7, 3.9.8 (new), 4, 6, 8, 10, A.10, as well as drawing EOS01-3300-SAR (new).

In support of Change 3, changes were made to UFSAR Chapter A.6.

In support of Change 6, changes were made to UFSAR Chapters 11 and A.11

3.0 JUSTIFICATION OF THE NEED FOR THESE CHANGES

Change 1 introduces the ability for the EOS-37PTH, incorporating a method to determine new loading patterns based on the maximum allowable heat load per DSC, identified as the maximum allowable heat load configuration (MHLC).

Change 2 introduces a steel plate composite option for the EOS-HSM.

Change 3 introduces a comparison of the MCNP runs for the HSM-MX dose rates to new MAVRIC software runs to demonstrate the MAVRIC software capability.

Change 4 introduces improvements to the quality and consistency of the TS.

Change 5 introduces improvements to the quality and consistency of the UFSAR.

Change 6 introduces information from past loading campaigns to highlight that the actual measured exposures are significantly less than calculated exposures.

4.0 EVALUATION OF CHANGES

TN has evaluated the changes described above for structural, thermal, shielding, confinement and criticality adequacy, as applicable, and has concluded that these changes to the NUHOMS® EOS System have no significant effect on safety.

The evaluations for the changes are included in Enclosure 5 (Proprietary version) and Enclosure 6 (Public version) of this submittal.

NRC FORM 651
(10-2004)
10 CFR 72

U.S. NUCLEAR REGULATORY COMMISSION

CERTIFICATE OF COMPLIANCE FOR SPENT FUEL STORAGE CASKS

Page 1 of 4

The U.S. Nuclear Regulatory Commission is issuing this Certificate of Compliance pursuant to Title 10 of the *Code of Federal Regulations*, Part 72, "Licensing Requirements for Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor-related Greater than Class C Waste" (10 CFR Part 72). This certificate is issued in accordance with 10 CFR 72.238, certifying that the storage design and contents described below meet the applicable safety standards set forth in 10 CFR Part 72, Subpart L, and on the basis of the final safety analysis report (FSAR) of the cask design. This certificate is conditional upon fulfilling the requirements of 10 CFR Part 72, as applicable, and the conditions specified below.

Certificate No.	Effective Date	Expiration Date	Docket No.	Amendment No.	Amendment Effective Date	Package Identification No.
1042	6/7/2017	6/7/2037	72-1042	~~2~~ 4	~~10/26/2021~~ tbd	USA/72-1042

Issued To: (Name/Address)

TN Americas LLC
7160 Riverwood Drive, Suite 200
Columbia, Maryland 21046

Safety Analysis Report Title

TN Americas LLC, "Safety Analysis Report for the NUHOMS® EOS Horizontal Modular Storage System for Irradiated Nuclear Fuel"

CONDITIONS

This certificate is conditioned upon fulfilling the requirements of 10 CFR Part 72, as applicable, the attached Appendix A (Technical Specifications), and the conditions specified below:

1. CASK:

   a. Model Nos. NUHOMS® EOS-37PTH, -89BTH, and 61BTH Type 2 DSCs

   The two digits refer to the maximum number of fuel assemblies stored in the dry shielded canister (DSC), the character P for pressurized water reactor (PWR) or B for boiling water reactor (BWR) is to designate the type of fuel stored, and T is to designate that the DSC is intended for transportation in a 10 CFR Part 71 approved package. The character H refers to designs that are also qualified for fuel with burnup greater than 45 GWd/MTU.

   b. Description

   The NUHOMS® EOS System is certified as described in the safety analysis report (SAR) and in the NRC's safety evaluation report (SER). The NUHOMS® EOS System is a horizontal canister system composed of a steel dry shielded canister (DSC), a reinforced concrete horizontal storage module (HSM), and a transfer cask (TC). The welded DSC provides confinement and criticality control for the storage and transfer of irradiated fuel. The concrete module provides radiation shielding while allowing cooling of the DSC and fuel by natural convection during storage. The TC is used for transferring the DSC from/to the spent fuel pool area to/from the HSM and provides radiation shielding during these operations.

The principal component subassemblies of the DSC are the shell with bottom cover plates and bottom shield plug, or bottom forging assembly, ram/grapple ring, top shield plug, top cover plates, and basket assembly. The shell is a welded stainless or duplex steel sealed container with a length that is fuel-specific. The internal basket assembly for the EOS-37PTH and EOS-89BTH DSCs is composed of interlocking slotted plates to form an egg-crate like structure that forms a grid of fuel compartments to house the fuel assemblies. The grid structure is composed of one or more of the following: a steel plate, an aluminum plate and a neutron absorber plate. Basket transition rails, made of aluminum, provide the interface between the rectangular basket structure and the cylindrical DSC shell. The DSC is designed to hold either 37 PWR or 89 BWR fuel assemblies.

The 61BTH Type 2 DSC consists of the DSC shell assembly (cylindrical shell, canister bottom and top cover plates and shield plug assemblies) and a basket assembly. Top grid assemblies have been provided to accommodate hoist ring designs. The transition rails support the fuel assemblies and transfer mechanical loads to the DSC shell. The DSC is designated to hold up to 61 BWR fuel assemblies.

Different DSC basket configurations are provided for the EOS-37PTH DSC, with poison plates containing a borated metal matrix composite (MMC) at differing B-10 concentrations. The EOS-89BTH DSC has basket configurations that differ in the material used for the poison plates, either borated MMC or Boral®, and the concentration of B-10 used.

The 61BTH Type 2 DSC is designated to use one of three types of poison materials in the basket: Borated Aluminum alloy, Boron Carbide/Aluminum MMC or Boral®.

The basket assembly aids in the insertion of the fuel assemblies, enhances subcriticality during loading operations, and provides structural support during a hypothetical drop accident. The DSC is designed to slide from the transfer cask into the HSM and back.

The HSM is a reinforced concrete unit and is designed to store DSCs with up to 50.0 kW decay heat. The HSM has variable lengths to accommodate the range of DSC lengths. There are multiple versions of the HSM, the NUHOMS® EOS-HSM (EOS-HSM) and the NUHOMS® MATRIX HSM (HSM-MX). When used without distinction, the term HSM refers to the EOS-HSM as well as the HSM-MX. Because they are geometrically the same design overall, the term EOS-HSM refers to a single module for storage of a single DSC as a single unit (EOS-HSM) or as a split base unit (EOS-HSMS). Only the fabrication details differ. The HSM-MX is an alternate design with a two-tiered, staggered, high-density module, which contains multiple compartments to accommodate multiple DSCs.

The TC is designed and fabricated as a lifting device to meet NUREG-0612 and ANSI N14.6 requirements. It is used for transfer operations within the spent fuel pool area and for transfer operations to/from the HSM. The TC is a multi-walled cylindrical vessel, comprised of a gamma shield and neutron shield layers with a bottom end closure assembly and a bolted top cover plate. There are multiple versions of the TC. The EOS-TC system consists of the EOS-TC135 cask, the EOS-TC125 cask, and the EOS-TC108 cask. The EOS-TC108 is designed with a removable neutron shield for use at nuclear plant sites with space limitations and/or crane capacity limits. Two upper lifting trunnions are located near the top of the cask for downending/uprighting and lifting of the cask in the spent fuel pool area. The lower trunnions, located near the base of the cask, serve as the axis of rotation during downending/uprighting operations and as supports during transfer to/from the independent spent fuel storage installation (ISFSI).

The OS197 transfer cask is used to transfer the 61BTH Type 2 DSC to the HSM-MX. The OS197 includes the OS197H and OS197FC-B variants as described in the TS. The maximum loaded weight for the OS197 TCs and OS197H TCs is 110 tons and 125 tons, respectively.

With the exception of the TC, fuel transfer and auxiliary equipment necessary for ISFSI operations are not included as part of the NUHOMS® EOS System referenced in this certificate of compliance (CoC). Such site-specific equipment may include, but is not limited to, special lifting devices, the transfer trailer, and the skid positioning system.

c. Drawings

The drawings for the NUHOMS® EOS System are contained in Section 1.3, Section A.1.3, and Section B.1.3 of the SAR.

d. Principal Components

The principal components of the NUHOMS® EOS System that are important to safety are the DSC, HSM, and TC. These components are described in Section 2.1, Section A.2.1, and Section B.2.1 of the SAR.

2. OPERATING PROCEDURES

Written operating procedures shall be prepared for handling, loading, movement, surveillance and maintenance. The user's site-specific written operating procedures shall be consistent with the technical basis described in Chapter 9, Chapter A.9, and Chapter B.9 of the SAR.

3. ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

Written cask acceptance tests and maintenance program shall be prepared consistent with the technical basis described in Chapter 10, Chapter A.10, and Chapter B.10 of the SAR.

4. QUALITY ASSURANCE

Activities in the areas of design, purchase, fabrication, assembly, inspection, testing, operation, maintenance, repair, modification of structures, systems and components, and decommissioning shall be conducted in accordance with a quality assurance program that satisfies the applicable requirements of 10 CFR Part 72, Subpart G, and that is established, maintained, and executed with regard to the cask system.

5. HEAVY LOADS REQUIREMENTS

Each lift of a DSC and TC must be made in accordance with the existing heavy loads requirements and procedures of the licensed facility at which the lift is made. A plant-specific safety review (under 10 CFR 50.59 or 10 CFR 72.48, if applicable) is required to show operational compliance with NUREG-0612 and or existing plant-specific heavy loads requirements.

If a single failure proof crane is not used, the licensee must evaluate the accidental drop of the shielding components of the TC under 10 CFR 50.59, 10 CFR 72.48, and 10 CFR 72.212, and evaluate the consequences of the accident drops.

6. APPROVED CONTENTS

Contents of the NUHOMS® EOS System must meet the fuel specifications in Appendix A (Technical Specifications).

7. DESIGN FEATURES

Features or characteristics for the site, or cask system must be in accordance with Appendix A (Technical Specifications).

8. CHANGES TO THE CERTIFICATE OF COMPLIANCE

The holder of this certificate who desires to change the certificate or technical specifications shall submit an application for amendment of the certificate or technical specifications.

9. PRE-OPERATIONAL TESTING AND TRAINING EXERCISE

A dry run training exercise of the loading, closure, handling, unloading and transfer of the NUHOMS® EOS System shall be conducted by each licensee prior to the first use of the system to load spent nuclear fuel assemblies. The training exercise shall not be conducted with spent nuclear fuel in the canister. The dry run may be performed in an alternate step sequence from the actual procedural guidelines in Chapter 9, Chapter A.9, and Chapter B.9 of the SAR. The dry run shall include, but need not be limited to the following:

Loading Operations

a. Fuel loading
b. DSC sealing, drying and backfilling operations
c. TC downending and transfer to the ISFSI
d. DSC transfer to the HSM

Unloading Operations
e. DSC retrieval from the HSM
f. Opening of the DSC
g. Flooding of the DSC

Any of the above steps can be omitted if the site has already successfully loaded a NUHOMS® EOS System or another NUHOMS® system.

10. AUTHORIZATION

The NUHOMS® EOS System, which is authorized by this certificate, is hereby approved for general use by holders of 10 CFR Part 50 licenses for nuclear reactors at reactor sites under the general license issued pursuant to 10 CFR 72.210, subject to the conditions specified by 10 CFR 72.212, this certificate, and the attached Appendix A.

FOR THE NUCLEAR REGULATORY COMMISSION

John B. McKirgan

Digitally signed by John B. McKirgan
Date: 2021.09.15 15:38:07 -04'00'

John McKirgan, Chief
Storage and Transportation Licensing Branch
Division of Fuel Management
Office of Nuclear Material Safety
and Safeguards

Attachment: Appendix A. Technical Specifications
Dated: Sep~~tember 15, 2021~~ tbd

Enclosure 4 to E-59796

Proposed Technical Specifications, CoC 1042

Amendment 4, Revision 0

Revision 0 to Amendment 4 Proposed Technical Specifications

CoC 1042

APPENDIX A

NUHOMS® EOS SYSTEM GENERIC TECHNICAL SPECIFICATIONS

Amendment 4

List of Tables

List of Figures

1.0 USE AND APPLICATION

1.1 Definitions

-- NOTE --

The defined terms of this section appear in capitalized type and are applicable throughout these Technical Specifications and Bases.

Term	Definition
ACTIONS	ACTIONS shall be that part of a Specification that prescribes Required Actions to be taken under designated Conditions within specified Completion Times.
BLEU FUEL	Blended Low Enriched Uranium (BLEU) FUEL material is generated by down-blending high enriched uranium (HEU). Because the feedstock contains both unirradiated and irradiated HEU, fresh BLEU fuel has elevated concentrations of U-232, U-234, and U-236.
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), Flux Suppression Inserts (FSIs), Burnable Absorber Assemblies (BAAs), Neutron Source Assemblies (NSAs) and Neutron Sources. CCs not explicitly listed are also authorized as long as external materials are limited to zirconium alloys, nickel alloys, and stainless steels. 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.

(continued)

1.1 Definitions (continued)

DAMAGED FUEL	DAMAGED FUEL assemblies are fuel assemblies containing 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 so that a fuel assembly maintains its configuration for normal and off-normal conditions. The extent of cladding damage is also limited so that no release of pellet material is observed during inspection and handling operations in the pool prior to loading operations. DAMAGED FUEL assemblies shall also contain top and bottom end fittings. DAMAGED FUEL assemblies may also contain missing or partial fuel rods.
DRY SHIELDED CANISTER (DSC)	An EOS-37PTH DSC, EOS-89BTH DSC, and 61BTH Type 2 DSC are sealed containers that provide confinement of fuel in an inert atmosphere.
FAILED FUEL	FAILED FUEL is defined as ruptured fuel rods, severed fuel rods, loose fuel pellets, fuel fragments, or fuel assemblies that may not maintain configuration for normal or off-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 or off-normal conditions. FAILED FUEL shall be stored in a failed fuel canister (FFC).
FUEL BUILDING	The FUEL BUILDING is the site-specific area or facility where the LOADING OPERATIONS take place.
FUEL CLASS	A FUEL CLASS includes fuel assemblies of the same array size for a particular type of fuel design. For example, WEV 17x17, WEO 17x17, and ANP Advanced MK BW 17x17 fuel assemblies are part of a WE 17x17 FUEL CLASS.

(continued)

1.1 Definitions (continued)

HORIZONTAL STORAGE MODULE (HSM)	An HSM is a reinforced concrete structure for storage of a loaded DSC at a spent fuel storage installation. Where the term “HSM” is used without distinction, this term shall apply to both the EOS-HSM and HSM-MX. The term EOS-HSM refers to the base unit for storage of a single DSC as a single piece (EOS-HSM) or as a split base (EOS-HSMS). The term MATRIX (HSM-MX) refers to the two-tiered staggered structure for storage of the DSCs.
INDEPENDENT SPENT FUEL STORAGE INSTALLATION (ISFSI)	The facility within a perimeter fence licensed for storage of spent fuel within HSMs.
INTACT FUEL	Fuel assembly with no known or suspected cladding defects in excess of pinhole leaks or hairline cracks, and with no missing rods.
LOADING OPERATIONS	LOADING OPERATIONS include all licensed activities on a DSC in a TC while it is being loaded with fuel assemblies. LOADING OPERATIONS begin when the first fuel assembly is placed in the DSC and end when the TC is ready for TRANSFER OPERATIONS (i.e., when the cask is in a horizontal position on the transfer trailer.) LOADING OPERATIONS do not include DSC transfer between the TC and the HSM.
LOW-ENRICHED OUTLIER FUEL (LEOF)	LOW-ENRICHED OUTLIER FUEL is PWR and BWR fuel with enrichments below the minimum enrichment specified in Table 7A and Table 18, respectively.
RECONSTITUTED FUEL ASSEMBLY	A RECONSTITUTED FUEL ASSEMBLY is a fuel assembly where one or more fuel rods are replaced by low enriched uranium or natural uranium fuel rods or non-fuel rods.

(continued)

1.1 Definitions (continued)

STORAGE OPERATIONS	STORAGE OPERATIONS include all licensed activities that are performed at the ISFSI, while a DSC containing fuel assemblies is located in an HSM on the storage pad within the ISFSI perimeter. STORAGE OPERATIONS do not include DSC transfer between the TC and the HSM.
TRANSFER CASK (TC)	A TRANSFER CASK (TC) (EOS-TC108, EOS-TC125, EOS-TC135, and OS197/OS197H/OS197FC-B/OS197HFC-B) consists of a licensed NUHOMS® System TC. When used without distinction, the term EOS-TC includes the EOS-TC108, EOS-TC125, and EOS-TC135. The term OS197 includes the OS197/OS197H/OS197FC-B/OS197HFC-B. The TC is placed on a transfer trailer for movement of a DSC to the HSM.
TRANSFER OPERATIONS	TRANSFER OPERATIONS include all licensed activities involving the movement of a TC loaded with a DSC containing fuel assemblies. TRANSFER OPERATIONS begin after the TC has been placed horizontal on the transfer trailer ready for TRANSFER OPERATIONS and end when the DSC is at its destination and/or no longer horizontal on the transfer trailer. TRANSFER OPERATIONS include DSC transfer between the TC and the HSM.
UNLOADING OPERATIONS	UNLOADING OPERATIONS include all licensed activities on a DSC to unload fuel assemblies. UNLOADING OPERATIONS begin when the DSC is no longer horizontal on the transfer trailer and end when the last fuel assembly has been removed from the DSC. UNLOADING OPERATIONS do not include DSC transfer between the HSM and the TC.

1.0 USE AND APPLICATION

1.2 Logical Connectors

PURPOSE

The purpose of this section is to explain the meaning of logical connectors.

Logical connectors are used in Technical Specifications (TS) to discriminate between, and yet connect, discrete Conditions, Required Actions, Completion Times, Surveillances, and Frequencies. The only logical connectors that appear in TS are <u>AND</u> and <u>OR</u>. The physical arrangement of these connectors constitutes logical conventions with specific meanings.

BACKGROUND

Several levels of logic may be used to state Required Actions. These levels are identified by the placement (or nesting) of the logical connectors and by the number assigned to each Required Action. The first level of logic is identified by the first digit of the number assigned to a Required Action and the placement of the logical connector in the first level of nesting (i.e., left justified with the number of the Required Action). The successive levels of logic are identified by additional digits of the Required Action number and by successive indentions of the logical connectors.

When logical connectors are used to state a Condition, Completion Time, Surveillance, or Frequency, only the first level of logic is used, and the logical connector is left justified with the statement of the Condition, Completion Time, Surveillance, or Frequency.

EXAMPLES

The following examples illustrate the use of logical connectors:

<u>EXAMPLE 1.2-1</u>

ACTIONS:

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. LCO (Limiting Condition for Operation) not met.	A.1 Verify… <u>AND</u> A.2 Restore…	

In this example the logical connector <u>AND</u> is used to indicate that when in Condition A, both Required Actions A.1 and A.2 must be completed.

(continued)

1.2 Logical Connectors (continued)

EXAMPLES (continued)

EXAMPLE 1.2-2

ACTIONS:

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. LCO not met.	A.1 Stop… OR A.2 A.2.1 Verify… AND A.2.2 A.2.2.1 Reduce… OR A.2.2.2 Perform… OR A.3 Remove…	

This example represents a more complicated use of logical connectors. Required Actions A.1, A.2, and A.3 are alternative choices, only one of which must be performed as indicated by the use of the logical connector OR and the left justified placement. Any one of these three Actions may be chosen. If A.2 is chosen, then both A.2.1 and A.2.2 must be performed as indicated by the logical connector AND. Required Action A.2.2 is met by performing A.2.2.1 or A.2.2.2. The indented position of the logical connector OR indicates that A.2.2.1 and A.2.2.2 are alternative choices, only one of which must be performed.

1.0 USE AND APPLICATION

1.3 Completion Times

PURPOSE

The purpose of this section is to establish the Completion Time convention and to provide guidance for its use.

BACKGROUND

Limiting Conditions for Operation (LCOs) specify the lowest functional capability or performance levels of equipment required for safe operation of the facility. The ACTIONS associated with an LCO state Conditions that typically describe the ways in which the requirements of the LCO are not met. Specified with each stated Condition are Required Action(s) and Completion Times(s).

DESCRIPTION

The Completion Time is the amount of time allowed for completing a Required Action. It is referenced to the time of discovery of a situation (e.g., equipment or variable not within limits) that requires entering an ACTIONS Condition unless otherwise specified, providing the facility is in a specified condition stated in the Applicability of the LCO. Required Actions must be completed prior to the expiration of the specified Completion Time. An ACTIONS Condition remains in effect and the Required Actions apply until the Condition no longer exists or the facility is not within the LCO Applicability.

Once a Condition has been entered, subsequent subsystems, components, or variables expressed in the Condition, discovered to be not within limits, will <u>not</u> result in separate entry into the Condition unless specifically stated. The Required Actions of the Condition continue to apply to each additional failure, with Completion Times based on initial entry into the Condition.

EXAMPLES

The following examples illustrate the use of Completion Times with different types of Conditions and Changing Conditions.

<u>EXAMPLE 1.3-1</u>

ACTIONS

CONDITION	REQUIRED ACTION	COMPLETION TIME
B. Required Action and associated Completion Time not met.	B.1 Perform Action B.1 <u>AND</u> B.2 Perform Action B.2	12 hours 36 hours

(continued)

1.3 Completion Times (continued)

EXAMPLES (continued)

Condition B has two Required Actions. Each Required Action has its own separate Completion Time. Each Completion Time is referenced to the time that Condition B is entered.

The Required Actions of Condition B are to complete action B.1 within 12 hours AND complete action B.2 within 36 hours. A total of 12 hours is allowed for completing action B.1 and a total of 36 hours (not 48 hours) is allowed for completing action B.2 from the time that Condition B was entered. If action B.1 is completed within 6 hours, the time allowed for completing action B.2 is the next 30 hours because the total time allowed for completing action B.2 is 36 hours.

EXAMPLES

EXAMPLE 1.3-2

ACTIONS

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. One system not within limit.	A.1 Restore system to within limit.	7 days
B. Required Action and associated Completion Time not met.	B.1 Perform Action B.1.	12 hours
	AND	
	B.2 Perform Action B.2.	36 hours

When a system is determined to not meet the LCO, Condition A is entered. If the system is not restored within 7 days, Condition B is also entered and the Completion Time clocks for Required Actions B.1 and B.2 start. If the system is restored after Condition B is entered, Condition A and B are exited, and therefore, the Required Actions of Condition B may be terminated.

(continued)

1.3 Completion Times (continued)

EXAMPLES (continued)

EXAMPLE 1.3-3

ACTIONS

---NOTE---

Separate Condition entry is allowed for each component.

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. LCO not met.	A.1 Restore compliance with LCO.	4 hours
B. Required Action and associated Completion Time not met.	B.1 Perform Action B.1.	6 hours
	AND	
	B.2 Perform Action B.2.	12 hours

The Note above the ACTIONS Table is a method of modifying how the Completion Time is tracked. If this method of modifying how the Completion Time is tracked was applicable only to a specific Condition, the Note would appear in that Condition rather than at the top of the ACTIONS Table.

The Note allows Condition A to be entered separately for each component, and Completion Times tracked on a per component basis. When a component is determined to not meet the LCO, Condition A is entered and its Completion Time starts. If subsequent components are determined to not meet the LCO, Condition A is entered for each component and separate Completion Times start and are tracked for each component.

IMMEDIATE COMPLETION TIME

When “Immediately” is used as a Completion Time, the Required Action should be pursued without delay and in a controlled manner.

1.0 USE AND APPLICATION

1.4 Frequency

PURPOSE

The purpose of this section is to define the proper use and application of Frequency requirements

DESCRIPTION

Each Surveillance Requirement (SR) has a specified Frequency in which the Surveillance must be met in order to meet the associated Limiting Condition for Operation (LCO). An understanding of the correct application of the specified Frequency is necessary for compliance with the SR.

The "specified Frequency" is referred to throughout this section and each of the Specifications of Section 3.0, Limiting Condition for Operation (LCO) and Surveillance Requirement (SR) Applicability. The "specified Frequency" consists of the requirements of the Frequency column of each SR, as well as certain Notes in the Surveillance column that modify performance requirements.

Situations where a Surveillance could be required (i.e., its Frequency could expire), but where it is not possible or not desired that it be performed until sometime after the associated LCO is within its Applicability, represent potential SR 3.0.4 conflicts. To avoid these conflicts, the SR (i.e., the Surveillance or the Frequency) is stated such that it is only "required" when it can be and should be performed. With a SR satisfied, SR 3.0.4 imposes no restriction.

(continued)

1.4 Frequency (continued)

EXAMPLES

The following examples illustrate the various ways that Frequencies are specified:

EXAMPLE 1.4-1

SURVEILLANCE REQUIREMENTS

SURVEILLANCE	FREQUENCY
Verify pressure within limit.	12 hours

Example 1.4-1 contains the type of SR most often encountered in the Technical Specifications (TS). The Frequency specifies an interval (12 hours) during which the associated Surveillance must be performed at least one time. Performance of the Surveillance initiates the subsequent interval. Although the Frequency is stated as 12 hours, an extension of the time interval to 1.25 times the stated Frequency is allowed by SR 3.0.2 for operational flexibility. The measurement of this interval continues at all times, even when the SR is not required to be met per SR 3.0.1 (such as when the equipment is determined to not meet the LCO, a variable is outside specified limits, or the unit is outside the Applicability of the LCO). If the interval specified by SR 3.0.2 is exceeded while the facility is in a condition specified in the Applicability of the LCO, the LCO is not met in accordance with SR 3.0.1.

If the interval as specified by SR 3.0.2 is exceeded while the facility is not in a condition specified in the Applicability of the LCO for which performance of the SR is required, the Surveillance must be performed within the Frequency requirements of SR 3.0.2 prior to entry into the specified condition. Failure to do so would result in a violation of SR 3.0.4.

(continued)

1.4 Frequency (continued)

EXAMPLES (continued)

EXAMPLE 1.4-2

SURVEILLANCE REQUIREMENTS

SURVEILLANCE	FREQUENCY
Verify flow is within limits.	Once within 12 hours prior to starting activity AND 24 hours thereafter

Example 1.4-2 has two Frequencies. The first is a one-time performance Frequency, and the second is of the type shown in Example 1.4-1. The logical connector "AND" indicates that both Frequency requirements must be met. Each time the example activity is to be performed, the Surveillance must be performed prior to starting the activity.

The use of "once" indicates a single performance will satisfy the specified Frequency (assuming no other Frequencies are connected by "AND"). This type of Frequency does not qualify for the 25% extension allowed by SR 3.0.2.

"Thereafter" indicates future performances must be established per SR 3.0.2, but only after a specified condition is first met (i.e., the "once" performance in this example). If the specified activity is canceled or not performed, the measurement of both intervals stops. New intervals start upon preparing to restart the specified activity.

(continued)

1.4 Frequency (continued)

EXAMPLES (continued)

EXAMPLE 1.4-3

SURVEILLANCE REQUIREMENTS

SURVEILLANCE	FREQUENCY
------------------- NOTE-------------------- Not required to be met until 96 hours after verifying the helium leak rate is within limit. --	
Verify EOS DSC vacuum drying pressure is within limit.	Once after verifying the helium leak rate is within limit.

As the Note modifies the required performance of the Surveillance, it is construed to be part of the "specified Frequency." Should the vacuum drying pressure not be met immediately following verification of the helium leak rate while in LOADING OPERATIONS, this Note allows 96 hours to perform the Surveillance. The Surveillance is still considered to be performed within the "specified Frequency."

Once the helium leak rate has been verified to be acceptable, 96 hours, plus the extension allowed by SR 3.0.2, would be allowed for completing the Surveillance for the vacuum drying pressure. If the Surveillance was not performed within this 96 hour interval, there would then be a failure to perform the Surveillance within the specified Frequency, and the provisions of SR 3.0.3 would apply.

2.0 FUNCTIONAL AND OPERATING LIMITS

2.1 Fuel to be Stored in the EOS-37PTH DSC

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.
Number of FUEL ASSEMBLIES with CCs	≤ 37
Maximum *Fuel* Assembly plus CC Weight	1900 lbs
DAMAGED FUEL ASSEMBLIES:	
Number and Location of DAMAGED FUEL Assemblies	Maximum of 8 DAMAGED FUEL Assemblies. Balance may be INTACT FUEL, empty *cells*, or dummy assemblies. Number and Location of DAMAGED FUEL assemblies are shown in Figures 1F, 1H, and 1K*, and 13*. The DSC basket cells which store DAMAGED FUEL assemblies are provided with top and bottom end caps.
FAILED FUEL:	
Number and Location of FAILED FUEL	Maximum of 4 FAILED FUEL locations. Balance may be INTACT FUEL assemblies, empty *cells*, or dummy assemblies. Number and Location of FAILED FUEL assemblies are shown in Figures 1F, 1H, and 1K*, and 13*. FAILED FUEL shall be stored in a failed fuel canister (FFC).
Maximum Uranium Loadings per FFC for FAILED FUEL	Per Table 2
RECONSTITUTED FUEL ASSEMBLIES:	
• *Limits for transfer in the EOS-TC125/135 AND storage in the EOS-HSM*	*Per Table 24*
• *Limits for transfer in the EOS-TC125/135 AND storage in the HSM-MX*	*≤ 37 RECONSTITUTED FUEL ASSEMBLIES per DSC with a minimum cooling time of 2 years*
• *Limits for transfer in the EOS-TC108*	*Per Table 25*

(continued)

Item 4

Item 1

Item 4

Item 1

2.1 Fuel to be Stored in the EOS-37PTH DSC (continued)

BLENDED LOW ENRICHED URANIUM (BLEU) FUEL Assemblies: - Number of BLEU FUEL Assemblies per DSC	 ≤ 37
THERMAL PARAMETERS: *Maximum Heat Load Configuration (MHLC)* and Decay Heat Calculations	*Per Figures 1B, 1C, 1D, 1E AND 1F for transfer in the EOS-TC108 and storage in EOS-HSM.* *Per Figures 1G, 1H AND 1I for transfer in the EOS-TC108 /TC125/TC135 and storage in HSM-MX.* *Per Figure 1K for transfer in the EOS-TC108 and storage in HSM-MX.* *Per Figure 12, which specifies maximum allowable heat loads in a six-zone configuration, for transfer in the EOS-TC125/TC135 and storage in the EOS-HSM.* *Heat load zoning configurations (HLZCs) enveloped by the MHLC in Figure 12 are allowed for transfer in the EOS-TC125/TC135 and storage in the EOS-HSM. Chapter 2, Section 2.4.3.2 of the UFSAR provides the specific HLZCs.* The maximum allowable heat loads may be reduced based on the thermal analysis methodology in the UFSAR. However, the maximum decay heat for each FA shall not exceed the values specified in the aforementioned figures. The licensee is responsible for ensuring that uncertainties in fuel enrichment and burnup are correctly accounted for in the decay heat calculations.

(continued)

2.1 Fuel to be Stored in the EOS-37PTH DSC (continued)

THERMAL PARAMETERS (continued)	For FAs with active fuel length shorter than 144 inches, reduce the maximum heat load per FA in each loading zone of the HLZCs using a scaling factor (SF) as shown below. $q_{Short\ FA} = q_{Bounding\ FA} \cdot SF,$ $SF = \frac{L_{a,Short\ FA}}{L_{a,Bounding\ FA}} \cdot \frac{k_{eff,Short\ FA}}{k_{eff,Bounding\ FA}}.$ Where, k_{eff}= Effective conductivity for FA, q = Decay heat load per assembly defined for each loading zone, L_a= Active fuel length, SF= Scaling factor (SF) for short FAs. The effective conductivity for the shorter FA should be determined using the same methodology documented in the UFSAR. For FAs with active fuel length greater than 144 inches, no scaling is required and the maximum heat loads listed for each HLZC are applicable.
Decay Heat per DSC	≤ 50.0 kW and as specified for the applicable heat load zone configuration

(continued)

2.1 Fuel to be Stored in the EOS-37PTH DSC (continued)

RADIOLOGICAL PARAMETERS:	
Maximum Assembly Average Burnup	62 GWd/MTU
Minimum Cooling Time	*For all fuel to be stored in the HSM-MX, minimum cooling time as a function of burnup and enrichment per Table 7B.* *For all fuel to be stored in the EOS-HSM, minimum cooling time as a function of burnup and enrichment per Table 7C.* *1 year for the EOS-TC125/135* *2 years for the EOS-TC108*
Minimum Assembly Average Initial Fuel Enrichment	As specified in Table 7A as a function of assembly average burnup.
Maximum Planar Average Initial Fuel Enrichment	As specified in Table 4 as a function of minimum soluble boron concentration
Minimum B-10 Concentration in Poison Plates	As specified in Table 5
Number and location of LOW-ENRICHED OUTLIER FUEL (LEOF)	≤ 4 LEOF in the peripheral locations. A minimum of three non-LEOFs shall circumferentially separate LEOFs within the peripheral locations. No limitation for LEOF in the inner locations. The peripheral and inner locations are defined in Figure 3.
CONTROL COMPONENTS (CCs)	
Maximum Co-60 equivalent activity for the CCs.	As specified in Table 3

2.0 FUNCTIONAL AND OPERATING LIMITS

2.2 Fuel to be Stored in the EOS-89BTH DSC

PHYSICAL PARAMETERS: FUEL CLASS	INTACT unconsolidated 7x7, 8x8, 9x9, 10x10, and 11x11 FUEL CLASS BWR assemblies (with or without channels) that are enveloped by the fuel assembly design characteristics listed in Table 6.
NUMBER OF INTACT FUEL ASSEMBLIES	≤ 89
Channel Hardware	Channeled fuel may be stored with or without associated channel hardware.
Maximum Uranium Loading	198 kg/assembly
Maximum *Fuel* Assembly Weight with a Channel	705 lb
RECONSTITUTED FUEL ASSEMBLIES:	
• Limits for transfer in the EOS-TC125	Per Table 22
• Limits for transfer in the EOS-TC108	Per Table 23
BLENDED LOW ENRICHED URANIUM (BLEU) FUEL ASSEMBLIES:	
• Number of BLEU FUEL Assemblies per DSC	≤ 89

(continued)

2.2 Fuel to be Stored in the EOS-89BTH DSC (continued)

THERMAL PARAMETERS:	
Maximum Heat Load Configuration (MHLC) and Decay Heat Calculations	Per Figure 2 for transfer in the EOS-TC108. Per Figure 11, which specifies maximum allowable heat loads in a six-zone configuration, for transfer in the EOS-TC125. Heat load zoning configurations (HLZCs) enveloped by the MHLC in Figure 11 are allowed for transfer in the EOS-TC125 and storage in the EOS-HSM or HSM-MX. Chapter 2, Section 2.4.3.2 of the UFSAR provides the specific HLZCs. The maximum allowable heat loads may be reduced based on the thermal analysis methodology in the UFSAR. However, the maximum decay heat for each FA shall not exceed the values specified in Figure 11. The licensee is responsible for ensuring that uncertainties in fuel enrichment and burnup are correctly accounted for in the decay heat calculations. For FAs with active fuel length shorter than 144 inches, reduce the maximum decay heat for each FA in each loading zone of the HLZCs using a scaling factor (SF) as shown below. $q_{Short\ FA} = q_{Bounding\ FA} \cdot SF,$ $SF = \frac{L_{a,Short\ FA}}{L_{a,Bounding\ FA}} \cdot \frac{k_{eff,Short\ FA}}{k_{eff,Bounding\ FA}}.$ Where, k_{eff} = Effective conductivity for FA, q = Decay heat load per assembly defined for each loading zone, L_a = Active fuel length, SF = Scaling factor for short FAs. The effective conductivity for the shorter FA should be determined using the same methodology documented in the UFSAR. For FAs with active fuel length greater than 144 inches, no scaling is required and the maximum heat loads listed for each HLZC are applicable.
Decay Heat per DSC	≤ 48.2 kW for EOS-TC125 ≤ 41.6 kW for EOS-TC108

(continued)

2.2 Fuel to be Stored in the EOS-89BTH DSC continued)

RADIOLOGICAL PARAMETERS:	
Maximum Assembly Average Burnup	62 GWd/MTU
Minimum Cooling Time	As specified as a function of burnup and enrichment per Table 21. 1.0 year for EOS-TC125 3.0 years for EOS-TC108; See Figure 2 for additional cooling times for HLZC 2 and 3 transferred in the EOS-TC108.
Maximum Lattice Average Initial Fuel Enrichment	Per Table 8
Minimum B-10 Concentration in Poison Plates	Per Table 8
Minimum Assembly Average Initial Fuel Enrichment	As specified in Table 18 as a function of assembly average burnup.
Number and location of LOW-ENRICHED OUTLIER FUEL (LEOF)	≤ 4 LEOF in the peripheral locations. A minimum of six non-LEOFs shall circumferentially separate LEOFs within the peripheral locations. No limitation for LEOF in the inner locations. The peripheral and inner locations are defined in Figure 8.

2.0 FUNCTIONAL AND OPERATING LIMITS

2.3 Fuel to be stored in the 61BTH Type 2 DSC

PHYSICAL PARAMETERS:	
FUEL CLASS	INTACT or DAMAGED or FAILED 7x7, 8x8, 9x9, 10x10 or 11x11 BWR assemblies (with or without channels) that are enveloped by the fuel assembly design characteristics listed in Table 13
Number of INTACT FUEL ASSEMBLIES	≤ 61
Channel Hardware	Chaneled fuel may be stored with or without associated channel hardware.
Maximum Uranium Loading	198 kg/ assembly
Maximum *Fuel* Assembly Weight with a Channel	705 lbs
DAMAGED FUEL ASSEMBLIES:	
Number and Location of DAMAGED FUEL Assemblies	Maximum of 61 DAMAGED FUEL assemblies as shown in Figure 5. Balance may be INTACT FUEL, empty *cells*, or dummy assemblies. The DSC basket cells which store DAMAGED FUEL assemblies are provided with top and bottom end caps.
FAILED FUEL:	
Number and Location of FAILED FUEL	Maximum of 4 FAILED FUEL locations as shown in Figure 5 Balance may be INTACT FUEL assemblies, empty *cells*, or dummy assemblies. FAILED FUEL shall be stored in a failed fuel canister (FFC)
Maximum Uranium Loadings per FFC for FAILED FUEL	Table 14
RECONSTITUTED FUEL ASSEMBLIES:	
• Number of RECONSTITUTED FUEL ASSEMBLIES per DSC	≤ 61
• Maximum number of irradiated stainless steel rods per DSC	120

(continued)

• Maximum number of irradiated stainless steel rods per RECONSTITUTED FUEL ASSEMBLY	10
• Loading restrictions for locations within the basket	Inner and peripheral loading locations are defined in Figure 6. Inner Loading Locations: • RECONSTITUTED FUEL ASSEMBLIES may be loaded in any compartment within the inner locations. Peripheral Loading Locations: • RECONSTITUTED FUEL ASSEMBLIES with ≤ 5 irradiated stainless steel rods per fuel assembly may be loaded into all peripheral locations (i.e., not restricted). • RECONSTITUTED FUEL ASSEMBLIES with > 5 and ≤ 10 irradiated stainless steel rods per fuel assembly shall have at least one fuel assembly that does not contain irradiated stainless steel rods on each peripherally adjacent location (see Figure 7).
<u>BLENDED LOW ENRICHED URANIUM (BLEU) FUEL Assemblies:</u>	
• Number of BLEU FUEL Assemblies per DSC	≤ 61
THERMAL/RADIOLOGICAL PARAMETERS:	
Heat Load Zone Configuration and Fuel Qualification	Limitations on decay heats are presented in the respective HLZC tables in Figures 4A through 4J.
Maximum Assembly Average Burnup	62 GWd/MTU
Minimum Cooling Time	For all fuel, minimum cooling time as a function of burnup and enrichment per Table 19. For the peripheral fuel of HLZC 2, 4, 5, 6, 7, and 8 only, minimum cooling time as a function of burnup and enrichment per Table 20. The peripheral and inner locations are defined in Figure 6.

(continued)

Minimum Assembly Average Initial Fuel Enrichment	As specified in Table 18 as a function of assembly average burnup.
Decay Heat per DSC	≤ 31.2 kW
Maximum Lattice Average Initial Enrichment	Per Table 9, Table 10, Table 11 or Table 12
Minimum B-10 Concentration in Poison Plates	Per Table 9, Table 10, Table 11 or Table 12
Number and location of LOW-ENRICHED OUTLIER FUEL (LEOF)	≤ 4 LEOF in the peripheral locations. A minimum of five non-LEOFs shall circumferentially separate LEOFs within the peripheral locations. No limitation for LEOF in the inner locations. The peripheral and inner locations are defined in Figure 6.

2.0 FUNCTIONAL OPERATING LIMITS

2.4 Functional and Operating Limits Violations

If any Functional and Operating Limit of 2.1 or 2.2 or 2.3 is violated, the following ACTIONS shall be completed:

2.4.1 The affected fuel assemblies shall be placed in a safe condition.

2.4.2 Within 24 hours, notify the NRC Operations Center.

2.4.3 Within 60 days, submit a special report which describes the cause of the violation and the ACTIONS taken to restore compliance and prevent recurrence.

3.0 LIMITING CONDITION FOR OPERATION (LCO) AND SURVEILLANCE REQUIREMENT (SR) APPLICABILITY

LIMITING CONDITION FOR OPERATION

LCO 3.0.1	LCOs shall be met during specified conditions in the Applicability, except as provided in LCO 3.0.2.
LCO 3.0.2	Upon discovery of a failure to meet an LCO, the Required Actions of the associated Conditions shall be met, except as provided in LCO 3.0.5. If the LCO is met or is no longer applicable prior to expiration of the specified Completion Time(s), completion of the Required Action(s) is not required, unless otherwise stated.
LCO 3.0.3	Not applicable to a spent fuel storage cask.
LCO 3.0.4	When an LCO is not met, entry into a specified condition in the Applicability shall not be made except when the associated ACTIONS to be entered permit continued operation in the specified condition in the Applicability for an unlimited period of time. This Specification shall not prevent changes in specified conditions in the Applicability that are required to comply with ACTIONS, or that are related to the unloading of a DSC. Exceptions to this Specification are stated in the individual Specifications. These exceptions allow entry into specified conditions in the Applicability when the associated ACTIONS to be entered allow operation in the specified condition in the Applicability only for a limited period of time.
LCO 3.0.5	Equipment removed from service or not in service in compliance with ACTIONS may be returned to service under administrative control solely to perform testing required to demonstrate it meets the LCO or that other equipment meets the LCO. This is an exception to LCO 3.0.2 for the system returned to service under administrative control to perform the testing required to demonstrate that the LCO is met.
LCO 3.0.6	Not applicable to a spent fuel storage cask.
LCO 3.0.7	Not applicable to a spent fuel storage cask.

(continued)

SURVEILLANCE REQUIREMENTS

SR 3.0.1

SRs shall be met during the specified conditions in the Applicability for individual LCOs, unless otherwise stated in the SR. Failure to meet a Surveillance, whether such failure is experienced during the performance of the Surveillance or between performances of the Surveillance, shall be failure to meet the LCO. Failure to perform a Surveillance within the specified Frequency shall be failure to meet the LCO except as provided in SR 3.0.3. Surveillances do not have to be performed on equipment or variables outside specified limits.

SR 3.0.2

The specified Frequency for each SR is met if the Surveillance is performed within 1.25 times the interval specified in the Frequency, as measured from the previous performance or as measured from the time a specified condition of the Frequency is met.

For Frequencies specified as “once,” the above interval extension does not apply. If a Completion Time requires periodic performance on a “once per . . .” basis, the above Frequency extension applies to each performance after the initial performance.

Exceptions to this Specification are stated in the individual Specifications.

SR 3.0.3

If it is discovered that a Surveillance was not performed within its specified Frequency, then compliance with the requirement to declare the LCO not met may be delayed, from the time of discovery, up to 24 hours or up to the limit of the specified Frequency, whichever is less. This delay period is permitted to allow performance of the Surveillance.

If the Surveillance is not performed within the delay period, the LCO must immediately be declared not met, and the applicable Condition(s) must be entered.

When the Surveillance is performed within the delay period and the Surveillance is not met, the LCO must immediately be declared not met, and the applicable Condition(s) must be entered.

SR 3.0.4

Entry into a specified condition in the Applicability of an LCO shall not be made unless the LCO's Surveillances have been met within their specified Frequency. This provision shall not prevent entry into specified conditions in the Applicability that are required to comply with ACTIONS or that are related to the unloading of a DSC.

3.1 DSC Fuel Integrity

3.1.1 Fuel Integrity during Drying

LCO 3.1.1 Medium:

Helium shall be used for cover gas during drainage of bulk water (blowdown or draindown) from the DSC.

Pressure:

The DSC vacuum drying pressure shall be sustained at or below 3 Torr (3 mm Hg) absolute for a period of at least 30 minutes following evacuation.

APPLICABILITY: During LOADING OPERATIONS but before TRANSFER OPERATIONS.

ACTIONS:

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. If the required vacuum drying pressure cannot be obtained.	A.1	30 days
	A.1.1 Confirm that the vacuum drying system is properly installed. Check and repair the vacuum drying system as necessary. <u>OR</u>	
	A.1.2 Establish helium pressure of at least 0.5 atm and no greater than 15 psig in the DSC. <u>OR</u>	
	A.2 Flood the DSC with spent fuel pool water or water meeting the requirements of LCO 3.2.1, if applicable, submerging all fuel assemblies.	30 days

(continued)

3.1 DSC Fuel Integrity (continued)

SURVEILLANCE REQUIREMENTS

SURVEILLANCE		FREQUENCY
SR 3.1.1	Verify that the DSC vacuum drying pressure is less than or equal to 3 Torr (3 mm Hg) absolute for at least 30 minutes following evacuation.	Once per DSC, after an acceptable NDE of the inner top cover plate to DSC shell weld.

(continued)

3.1 DSC Fuel Integrity (continued)

3.1.2 DSC Helium Backfill Pressure

LCO 3.1.2 DSC helium backfill pressure shall be 2.5 ± 1 psig (stable for 30 minutes after filling) after completion of vacuum drying.

APPLICABILITY: During LOADING OPERATIONS but before TRANSFER OPERATIONS.

ACTIONS:

CONDITION	REQUIRED ACTION	COMPLETION TIME
-----------------NOTE----------------- Not applicable until SR 3.1.2 is performed. --- A. The required backfill pressure cannot be obtained or stabilized.	A.1 A.1.1 Maintain helium atmosphere in the DSC cavity. <u>AND</u> A.1.2 Confirm, check and repair or replace as necessary the vacuum drying system, helium source and pressure gauge. <u>AND</u> A.1.3 Check and repair, as necessary, the seal weld between the inner top cover plate and the DSC shell.	30 days
	<u>OR</u> A.2 Establish the DSC helium backfill pressure to within the limit. If pressure exceeds the criterion, release a sufficient quantity of helium to lower the DSC cavity pressure within the limit. <u>OR</u>	30 days

(continued)

3.1 DSC Fuel Integrity (continued)

CONDITION	REQUIRED ACTION		COMPLETION TIME
	A.3	Flood the DSC with spent fuel pool water or water meeting the requirements of LCO 3.2.1, if applicable, submerging all fuel assemblies.	30 days

SURVEILLANCE REQUIREMENTS

SURVEILLANCE		FREQUENCY
SR 3.1.2	Verify that the DSC helium backfill pressure is 2.5 ± 1 psig stable for 30 minutes after filling.	Once per DSC, after the completion of SR 3.1.1 requirement.

(continued)

3.1 DSC Fuel Integrity (continued)

3.1.3 Time Limit for Completion of DSC Transfer

LCO 3.1.3 The time to transfer the DSC to the HSM shall be within the limits.

Additionally, if the DSC and HLZC combination result in a time limit for completion of transfer from the table below, the air circulation system shall be assembled and be verified to be operable within 7 days before commencing the TRANSFER OPERATIONS of the loaded DSC.

DSC MODEL	APPLICABLE HLZC	TIME LIMITS (HOURS)
EOS-37PTH	*HLZCs qualified per Figure 12*	8(1)
EOS-37PTH	HLZC 3	No Limit
EOS-37PTH	HLZC *1, 2, or* 4-11	8(1) *(2)*
EOS-89BTH	HLZCs qualified per Figure 11	8(1)
EOS-89BTH	HLZC 2	10(1)*(3)*
EOS-89BTH	HLZC 3	No Limit*(3)*
61BTH Type 2	HLZC 1, 2, 3, 4, or 9	No limit
61BTH Type 2	5, 6, or 8	23
61BTH Type 2	7 or 10	10

NOTE

1. The time limit for completion of a DSC transfer is defined as the time elapsed in hours after the initiation of draining of TC/DSC annulus water until the completion of insertion of the DSC into the HSM. For transfer of an EOS-DSC, the time limit for transfer operations is determined based on the EOS-37PTH DSC in EOS-TC125 with the maximum allowable heat load of 50 kW or EOS-89BTH DSC in EOS-TC125 with the maximum allowable heat load of 48.2 kW. If the maximum heat load of a DSC is less than 50 kW for EOS-37PTH DSC or 48.2 kW for the EOS-89BTH DSC, a new time limit can be determined to provide additional time for transfer operations. The calculated time limit shall not be less than the time limit specified in LCO 3.1.3. The calculation should be performed using the same methodology documented in the UFSAR.
2. *HLZC 2, 4-6 (shown in Figures 1B, 1D-1F) time limits apply for the EOS-37PTH DSC transferred in the EOS-TC108 only. HLZC 7-9 time limits apply for storage in the HSM-MX. If transferring the EOS-37PTH with HLZC 2, 4-6, or 11 in the EOS-TC125 and storing in the EOS-HSM, the limits for Figure 12 apply. Time limits also apply for HLZC 1, 2, and 4-11 when storing WE 14 x 14.*
3. HLZC 2 and 3 (shown in Figure 2) time limits apply for the EOS-89BTH transferred in the EOS-TC108 only. If transferring the EOS-89BTH with HLZC 2 or 3 in the EOS-TC125, the limits for Figure 11 apply.

(continued)

3.1 DSC Fuel Integrity (continued)

APPLICABILITY: During LOADING OPERATIONS AND TRANSFER OPERATIONS.

ACTIONS:

CONDITION	REQUIRED ACTION		COMPLETION TIME
------------------- NOTE ------------------- Not applicable until SR 3.1.3 is performed. -- A. The required time limit for completion of a DSC transfer not met.	A.1	If the TC is in the cask handling area in a vertical orientation, remove the TC top cover plate and fill the TC/DSC annulus with clean water. <u>OR</u>	2 hours
	A.2	If the TC is in a horizontal orientation on the transfer skid, initiate air circulation in the TC/DSC annulus by starting one of the redundant blowers. <u>OR</u>	1 hour (1) (2)
	A.3	Return the TC to the cask handling area and follow required action A.1 above.	5 hours (1) (2)

1. For EOS-37PTH and EOS-89BTH DSCs: If Required Action A.2 is initiated, run the blower for a minimum of 8 hours. After the blower is turned off, the time limit for completion of DSC transfer is 4 hours. If Required Action A.2 fails to complete within one hour, follow Required Action A.3 for the time remaining in the original Required Action A.3 completion time of 5 hours. The minimum duration of 8 hours to run the blower and the time limit of 4 hours after the blower is turned off for completion of the transfer operations are determined based on the EOS-37PTH DSC in EOS-TC125 with the maximum allowable heat load of 50 kW or EOS-89BTH DSC in EOS-TC125 with the maximum allowable heat load of 48.2 kW. If the maximum heat load of a DSC is less than 50 kW for EOS-37PTH DSC or 48.2 kW for the EOS-89BTH DSC, new time limits can be determined to provide additional time for these transfer operations. The calculated time limits shall not be less than 4 hours for completion of transfer operation after the blower is turned off. The calculation should be performed using the same methodology documented in the UFSAR.
2. For 61BTH Type 2 DSC: If Required Action A.2 is initiated, run the blower for a minimum of 8 hours. After the blower is turned off, the time limit for completion of DSC transfer is 4 hours. If Required Action A.2 fails to complete within one hour, follow Required Action A.3 for the time remaining in the original Required Action A.3 completion time of 5 hours. The minimum duration of 8 hours to run the blower and the time limit of 4 hours after the blower is turned off for completion of the transfer operations are determined based on the 61BTH Type 2 DSC in OS197FC-B TC with the maximum allowable heat load of 31.2 kW. If the maximum heat load of a DSC is less than 31.2 kW, new time limits can be determined to provide additional time for these transfer operations. The calculated time limits shall not be less than 4 hours for completion of transfer operation after the blower is turned off. The calculation should be performed using the same methodology documented in the UFSAR.

(continued)

3.1 DSC Fuel Integrity (continued)

SURVEILLANCE REQUIREMENTS

SURVEILLANCE		FREQUENCY
SR 3.1.3	Verify that the time limit for completion of DSC transfer is met.	Once per DSC, after the initiation of draining of TC/DSC annulus water.

3.2 Cask Criticality Control

3.2.1 Soluble Boron Concentration

LCO 3.2.1 The boron concentration of the spent fuel pool water and the water added to the cavity of a loaded EOS-37PTH DSC shall be at least the boron concentration shown in Table 4 for the basket type and fuel enrichment selected.

APPLICABILITY: During LOADING and UNLOADING OPERATIONS with fuel and liquid water in the EOS-37PTH DSC cavity.

ACTIONS:

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. Soluble boron concentration limit not met.	A.1 Suspend loading of fuel assemblies into DSC. AND	Immediately
	A.2	
	A.2.1 Add boron and re-sample, and test the concentration until the boron concentration is shown to be at least that required. OR	Immediately
	A.2.2 Remove all fuel assemblies from DSC.	Immediately

SURVEILLANCE REQUIREMENTS

SURVEILLANCE		FREQUENCY
SR 3.2.1.1	Verify soluble boron concentration limit in spent fuel pool water and water to be added to the DSC cavity is met using two independent measurements (two samples analyzed by different individuals) for LOADING OPERATIONS.	Within 4 hours before insertion of the first fuel assembly into the DSC. <u>AND</u> Every 48 hours thereafter while the DSC is in the spent fuel pool or until the fuel has been removed from the DSC.
SR 3.2.1.2	Verify soluble boron concentration limit in spent fuel pool water and water to be added to the DSC cavity is met using two independent measurements (two samples analyzed by different individuals) for UNLOADING OPERATIONS.	Once within 4 hours prior to flooding DSC during UNLOADING OPERATIONS. <u>AND</u> Every 48 hours thereafter while the DSC is in the spent fuel pool or until the fuel has been removed from the DSC.

3.3 Radiation Protection

3.3.1 DSC and TRANSFER CASK (TC) Surface Contamination

LCO 3.3.1 Removable surface contamination on the outer top 1 foot surface of the DSC AND the exterior surfaces of the TC shall not exceed:

a. 2,200 dpm/100 cm^2 from beta and gamma sources; and
b. 220 dpm/100 cm^2 from alpha sources.

APPLICABILITY: During LOADING OPERATIONS

ACTIONS:

--- NOTE ---
Separate condition entry is allowed for each DSC and TC.

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. Top 1 foot exterior surface of the DSC removable surface contamination limits not met.	A.1 Decontaminate the DSC to bring the removable contamination to within limits.	Prior to TRANSFER OPERATIONS
B. TC removable surface contamination limits not met.	B.1 Decontaminate the TC to bring the removable contamination to within limits	Prior to TRANSFER OPERATIONS

SURVEILLANCE REQUIREMENTS

SURVEILLANCE		FREQUENCY
SR 3.3.1.1	Verify that the removable contamination on the top 1 foot exterior surface of the DSC is within limits.	Once, prior to TRANSFER OPERATIONS.
SR 3.3.1.2	Verify by either direct or indirect methods that the removable contamination on the exterior surfaces of the TC is within limits.	Once, prior to TRANSFER OPERATIONS.

4.0 DESIGN FEATURES

The specifications in this section include the design characteristics of special importance to each of the physical barriers and to the maintenance of safety margins in the NUHOMS® EOS System design.

4.1 Site

4.1.1 Site Location

Because this UFSAR is prepared for a general license, a discussion of a site-specific ISFSI location is not applicable.

4.2 Storage System Features

4.2.1 Storage Capacity

The total storage capacity of the ISFSI is governed by the plant-specific license conditions.

4.2.2 Storage Pad

For sites for which soil-structure interaction is considered important, the licensee is to perform site-specific analysis considering the effects of soil-structure interaction. Amplified seismic spectra at the location of the HSM center of gravity (CG) is to be developed based on the soil-structure interaction (SSI) responses. EOS-HSM seismic analysis *for the reinforced concrete EOS-HSM (EOS-HSM-RC)* information is provided in UFSAR Appendix 3.9.4, Section 3.9.4.9.2. *The steel-plate composite EOS-HSM (EOS-HSM-SC) seismic analysis information is provided in UFSAR Appendix 3.9.8, Section 3.9.8.9.* HSM-MX seismic analysis information is provided in UFSAR Appendix A.3.9.4, Section A.3.9.4.9.2.

The storage pad location shall have no potential for liquefaction at the site-specific safe shutdown earthquake (SSE) level.

Additional requirements for the pad configuration are provided in Technical Specification 4.5.2.

4.3 Canister Criticality Control

The NUHOMS® EOS-37PTH DSC is designed for the storage of PWR fuel assemblies with a maximum planar average initial enrichment of less than or equal to 5.0 wt. % U-235 taking credit for soluble boron during LOADING OPERATIONS and the boron content in the poison plates of the DSC basket. The EOS-37PTH DSC uses a boron carbide/aluminum metal matrix composite (MMC) poison plate material. The EOS-37PTH DSC has two different neutron poison loading options, A and B, based on the boron content in the poison plates as listed in Table 5. Table 4 also defines the requirements for boron concentration in the DSC cavity water as a function of the DSC basket type for the various FUEL CLASSES authorized for storage in the EOS-37PTH DSC.

The NUHOMS® EOS-89BTH DSC is designed for the storage of BWR fuel assemblies with a maximum lattice average initial enrichment of less than or equal to 5.00 wt. % U-235 taking credit for the boron content in the poison plates of the DSC basket. There are three neutron poison loading options specified for the EOS-89BTH DSC depending on the type of poison material and the B-10 areal density in the plates, as specified in Table 8.

(continued)

All Indicated Changes are Scope Item 2.

4.0 Design Features (continued)

The 61BTH Type 2 DSC is designed for the storage of BWR fuel assemblies with a maximum lattice average initial enrichment of less than or equal to 5.0 wt. % U-235 taking credit for the boron content in the poison plates of the DSC basket. The 61BTH Type 2 DSC has multiple basket configurations based on the absorber material type (borated aluminum alloy, metal matrix composite (MMC), or Boral®) and boron content in the absorber plates as listed in Table 9 through Table 12.

4.3.1 Neutron Absorber Tests

The neutron absorber used for criticality control in the DSC baskets may be one of the following materials:

- Boron carbide/MMC
- BORAL® (EOS-89BTH or 61BTH Type 2 DSCs only)
- Borated aluminum (61BTH Type 2 DSC only)

Acceptance Testing (MMC, BORAL®, and borated aluminum)

B-10 areal density is verified by neutron attenuation testing or by chemical analysis of coupons taken adjacent to finished panels, and isotopic analysis of the boron carbide powder. The minimum B-10 areal density requirements are specified in Table 5 for EOS-37PTH, Table 8 for EOS-89BTH, and Table 9 through Table 12 for 61BTH Type 2 DSCs.

Finished panels are subject to visual and dimensional inspection.

Qualification Testing (MMC only)

MMCs are qualified for use in the NUHOMS® EOS System by verification of the following characteristics.

- The chemical composition is boron carbide particles in an aluminum alloy matrix.
- The form is with or without an aluminum skin.
- The median boron carbide particle size by volume is ≤ 80 microns with no more than 10% over 100 microns.
- The boron carbide content is ≤ 50% by volume.
- The porosity is ≤ 3%.

4.3.2 High Strength Low Alloy Steel for Basket Structure for EOS-37PTH and EOS-89BTH DSCs.

The basket structural material shall be a high strength low alloy (HSLA) steel meeting one of the following requirements A, B, or C:

A. ASTM A829 Gr 4130 or AMS 6345 SAE 4130, quenched and tempered at not less than 1050°F, 103.6 ksi minimum yield strength and 123.1 ksi minimum ultimate strength at room temperature.

B. ASME SA-517 Gr A, B, E, F, or P.

(continued)

4.0 Design Features (continued)

C. Other HSLA steel, with the specified heat treatment, meeting these qualification and acceptance criteria:

  i. If quenched and tempered, the tempering temperature shall be at no less than 1000 °F,

  ii. Qualified prior to first use by testing at least two lots and demonstrating that the fracture toughness value $K_{JIc} \geq 150$ ksi $\sqrt{in}$ at ≤ -40 °F with 95% confidence.

  iii. Qualified prior to first use by testing at least two lots and demonstrating that the 95% lower tolerance limit of yield strength and ultimate strength ≥ the values in UFSAR Table 8-10.

  iv. Meet production acceptance criteria based on the 95% lower tolerance limit of yield strength and ultimate strength at room temperature as determined by qualification testing described in Section 4.3.2.C.iii.

The basket structural material shall also meet one of the following production acceptance criteria for impact testing at ≤ -40 °F:

  a. Charpy testing per ASTM A370, minimum absorbed energy 25 ft-lb average, 20 ft-lb lowest of three (for sub-size specimens, reduce these criteria per ASTM A370-17 Table 9), or

  b. Dynamic tear testing per ASTM E604 with acceptance criterion minimum 80% shear fracture appearance.

4.4 Codes and Standards

4.4.1 HORIZONTAL STORAGE MODULE (HSM)

The reinforced concrete HSM is designed in accordance with the provisions of ACI 349-06. *The steel-plate composite HSM steel is designed in accordance with the provisions of ANSI/AISC N690-18. The steel-plate composite HSM concrete is designed and constructed in accordance with ACI 318-08.* Code alternatives are discussed in Technical Specification 4.4.4. Load combinations specified in ANSI 57.9-1984, Section 6.17.3.1 are used for combining normal operating, off-normal, and accident loads for the HSM.

(continued)

4.0 Design Features (continued)

4.4.2 DRY SHIELDED CANISTER (DSC) (EOS-37PTH, EOS-89BTH, and 61BTH Type 2)

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, Subsection NB, NF, and NG, for Class 1 components. The ASME code edition years and any addenda for the various DSC types and relevant subsections are provided in the table below. Code alternatives are discussed in Technical Specification 4.4.4.

DSC Type	Applicable Code	Edition/Year
EOS-37PTH, EOS-89BTH	ASME B&PV Code, Section III, Division 1, Subsection NB	2010 Edition with Addenda through 2011
61BTH Type 2	ASME B&PV Code, Section III, Division 1, Subsections NB, NG and NF	1998 Edition with Addenda through 2000

4.4.3 TRANSFER CASK

The EOS-TC design stress analysis and OS197 design stress analysis and fabrication, exclusive of the trunnions and the neutron shield enclosures, is performed in accordance with applicable codes as provided in the table below. The stress allowables for the upper trunnions for the EOS-TCs and the upper and lower trunnions for the OS197 conform to ANSI N14.6-1993 for single-failure-proof lifting.

TC	Applicable Code	Edition/Year
EOS-TC	ASME B&PV Code, Section III, Division 1, Subsection NF for Class 1 supports	2010 Edition with Addenda through 2011
OS197	ASME B&PV Code, Section III, Division 1, Subsection NC for Class 2 vessels	1983 Edition with Winter 1985 Addenda

4.4.4 Alternatives to Codes and Standards

ASME Code alternatives for the EOS-37PTH, EOS-89BTH DSC, and 61BTH Type 2 DSC are listed below:

(continued)

4.0 Design Features (continued)

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 NB-4121	Material must be supplied by ASME approved material suppliers Material Certification by Certificate Holder	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-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.

(continued)

4.0 Design Features (continued)

EOS-37PTH and EOS-89BTH DSC ASME Code Alternatives, Subsection NB

(continued)

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 plate (OTCP) weld, the shell to the inner top cover weld, and the drain port cover and vent port plug welds are all partial penetration welds. The cover-to-shell welds are designed to meet the guidance provided in NUREG-1536, Revision 1 for the stress reduction factor. Nondestructive examination (NDE) is done by qualified personnel, in accordance with Section V and the acceptance standards of Section III, Subsection NB-5000, except as noted for OTCP weld option 2 ultrasonic examination. As an alternative to the 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 OTCP weld. <u>OTCP weld option 1</u> The shell to OTCP 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. <u>OTCP weld option 2</u> The shell to the outer top cover plate weld will be examined by UT.
NB-5330	Ultrasonic Acceptance Standards	The UT acceptance criteria for OTCP weld option 2 are: 1. Rounded flaws are evaluated by the acceptance criteria of NB-5331(a). 2. Planar flaws are allowable up to the limit (W – Σhi) ≥ D at any location, where Σhi is the sum of the depth of aligned planar defects, W is the measured weld thickness, and D is the minimum weld depth required by NB-3000. 3. Planar flaws that penetrate the surface of the weld are not allowable.
NB-5520	NDE Personnel must be qualified to the 2006 edition of SNT-TC-1A	Permit use of the Recommended Practice SNT-TC-1A up to the edition as cited in Table NCA-7000-1 of the latest ASME Code edition listed in 10 CFR 50.55a at the time of construction.

(continued)

EOS-37PTH and EOS-89BTH DSC ASME Code Alternatives, Subsection NB

(continued)

REFERENCE ASME CODE SECTION/ARTICLE	CODE REQUIREMENT	JUSTIFICATION AND COMPENSATORY MEASURES
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 when using the three plate bottom assembly. If using a single piece bottom forging, the fabrication pressure test may be waived although the helium leak test requirement remains in place. The low test pressure test does not stress a single piece bottom and bottom-to-shell weld sufficiently to cause pre-existing defects to propagate into leaks. For the purpose of finding leaks, the helium leak test is far more sensitive than the pressure test. 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.
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.

(continued)

EOS-37PTH and EOS-89BTH DSC ASME Code Alternatives, Subsection NB

(continued)

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.

(continued)

4.0 Design Features (continued)

61BTH Type 2 DSC ASME Code Alternatives for the 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 4.4.2 may be used for construction, but in no case earlier than 3 years before that specified in the Section 4.4.2 table. Materials produced and certified in accordance with ASME Section II material specification from Code Editions and Addenda other than those specified in Section 4.4.2 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	
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 weld, the siphon and vent cover plate 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 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. All of these welds will be designed to meet the guidance provided in NUREG-1536 Revision 1 for stress reduction factor.

(continued)

4.0 Design Features (continued)

61BTH Type 2 DSC ASME Code Alternatives for the Confinement Boundary

REFERENCE ASME CODE SECTION/ ARTICLE	CODE REQUIREMENT	ALTERNATIVES, JUSTIFICATION & COMPENSATORY MEASURES
NB-6100 and 6200	All completed pressure retaining systems shall be pressure tested.	The 61BTH Type 2 DSC is not a complete or “installed” pressure vessel until the top closure is welded following placement of Fuel Assemblies with 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 shell bottom (including all longitudinal and circumferential welds) is pressure tested and examined at the fabrication facility. The shell to the inner top cover closure weld are 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 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.
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.
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.

(continued)

61BTH Type 2 DSC ASME Code Alternatives for the Basket

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 4.4.2 may be used for construction, but in no case earlier than 3 years before that specified in the Section 4.4.2 table. Materials produced and certified in accordance with ASME Section II material specification from Code Editions and Addenda other than those specified in Section 4.4.2 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/NF-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/NF-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.
NG/NF-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/NF-2130 is not possible. Material traceability and certification are maintained in accordance with TN’s NRC approved QA program.
NG/NF-4121	Material Certification by Certificate Holder	
NG-3352	Table NG-3352-1 lists the permissible welded joints and quality factors.	The fuel compartment tubes may be fabricated from sheet with full penetration seam weldments. Per Table NG-3352-1, a joint efficiency (quality) factor of 0.5 is to be used for full penetration weldments examined in accordance with ASME Section V visual examination (VT). A joint efficiency (quality) factor of 1.0 is utilized for the fuel compartment longitudinal seam welds (if present) with VT examination. This is justified because the compartment seam weld is thin and the weldment is made in one pass; and both surfaces of the weldment (inside and outside) receive 100% VT examination. The 0.5 quality factor, applicable to each surface of the weldment, results is a quality factor of 1.0 since both surfaces are 100% examined. In addition, the fuel compartments have no pressure retaining function and the stainless steel material that comprises the fuel compartment tubes is very ductile.
NG/NF-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/NF-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.

(continued)

4.0 Design Features (continued)

Code alternatives for the HSM concrete specifications are listed below:

REFERENCE ACI349-06 SECTION/ARTICLE	CODE REQUIREMENT	ALTERNATIVES, JUSTIFICATION AND COMPENSATORY MEASURES
Appendix E, Section E.4-Concrete Temperatures, Paragraph E.4.3	Paragraph E.4.3 requires testing of concrete for temperatures higher than those given in Paragraph E.4.1.	The concrete temperature limit criteria in NUREG-1536, Section 8.4.14.2 is used for normal and off-normal conditions. Alternatively, per ACI 349-13, Code Requirements for Nuclear Safety-Related Concrete Structures and Commentary, Section RE.4, the specified compressive strength, which may be tested up to 56 days, is increased to 7,000 psi for HSM fabrication so that any losses in properties (e.g., compressive strength) resulting from long-term thermal exposure will not affect the safety margins based on the specified 5,000 psi compressive strength used in the design calculations. Additionally, also as indicated in Section RE.4, short, randomly oriented steel fibers may be used to provide increased ductility, dynamic strength, toughness, tensile strength, and improved resistance to spalling. The safety margin on compressive strength is 40% for a concrete temperature limit of 300 °F normal and off-normal conditions.

(continued)

4.0 Design Features (continued)

Code alternatives for the steel-plate composite HSM specifications are listed below:

REFERENCE ANSI/AISC N690	*CODE REQUIREMENT*	*JUSTIFICATION AND COMPENSATORY MEASURES*
N9.1.1.(a)	*For exterior SC walls, the minimum value of the section thickness, t_{sc}, shall be 18 inches (450 mm). For interior SC walls, the minimum t_{sc} shall be 12 inches (300 mm).*	*As presented in Commentary for Section N9.1.1(a) of N690, the minimum section thickness for exterior SC walls is based on Table 1 of NUREG-0800, Revision 3, Section 3.5.3, Revision 3. It requires minimum 16.9-inch thick (430mm) 4-ksi (28 MPa) reinforced concrete (RC) walls to resist a tornado missile. Conservatively, the SC wall is treated as a RC wall for missile loading. The 10.25 inch and 14.5 inch sections of the door are supported by the front wall of the EOS-HSM-SC during missile impact. Therefore, the door meets the specified minimum thickness value of 18 inches for exterior walls. The minimum thickness for interior walls is based on the maximum reinforcement ratio and minimum faceplate thickness. The specified minimum thickness value of 12 inches is conservatively rounded up from the actual minimum of 10 inches as presented in Commentary for Section N9.1.1(a) of N690. Therefore, the 10.25-inch thick section of the door and 11.38-inch section of the OVC does meet the minimum thickness requirement.*
N9.1.1.(d)	*The specified minimum yield stress of faceplates, F_y, shall not be less than 50 ksi (350 MPa) nor more than 65 ksi (450 MPa).*	*The door and OVC steel plates are constructed from ASTM A36. The margins for the door thickness to withstand local damage due to missile attack, ductile capacity for missile impact, and structural adequacy for punching shear are sufficiently large. The margins for the OVC are sufficiently large as well. Therefore, a material meeting the properties of ASTM A36 will have sufficient strength for this application.*

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Proposed alternatives to the above-specified ASME and ACI codes, other than the aforementioned alternatives, may be used when authorized by the Director of the Office of Nuclear Material Safety and Safeguards, or designee. The applicant should demonstrate that:

1. The proposed alternatives would provide an acceptable level of quality and safety, or
2. Compliance with the specified requirements of above-specified ASME and ACI codes would result in hardship or unusual difficulty without a compensating increase in the level of quality and safety.

The applicant should also submit information regarding the environmental impact of such a request to support the NRC's NEPA regulations in 10 CFR Part 51. Any proposed alternatives must be submitted and approved prior to implementation.

Requests for exceptions in accordance with this section should be submitted in accordance with 10 CFR 72.4.

(continued)

4.5 Storage Location Design Features

The following storage location design features and parameters shall be verified by the system user to assure technical agreement with the UFSAR.

4.5.1 Storage Configuration

EOS-HSMs and HSM-MXs are placed together in single rows or back to back arrays. A rear shield wall is placed on the rear of any single row loaded EOS-HSM.

4.5.2 Concrete Storage Pad Properties to Limit DSC Gravitational Loadings Due to Postulated Drops

The EOS-37PTH DSC and EOS-89BTH DSC have been evaluated for drops of up to 65 inches onto a reinforced concrete storage pad. The 61BTH Type 2 DSC has been evaluated for drops of up to 80 inches onto a reinforced concrete storage pad.

4.5.3 Site Specific Parameters and Analyses

The following parameters and analyses are applicable to all HSMs unless specifically noted and shall be verified by the system user for applicability at their specific site. Other natural phenomena events, such as lightning, tsunamis, hurricanes, and seiches, are site specific and their effects are generally bounded by other events, but they should be evaluated by the user.

1. Flood levels up to 50 ft and water velocity of 15 fps.
2. One-hundred year roof snow load of 110 psf.
3. Normal ambient temperature is based on the heat load of the DSC as follows:

   For the EOS-HSM:

   a. For the EOS-37PTH DSCs with a heat load less than or equal to 41.8 kW or for the EOS-89BTH DSCs with a heat load less than or equal to 41.6 kW, the minimum temperature is -20 °F. The maximum calculated normal average ambient temperature corresponding to a 24-hour period is 90 °F.
   b. For the EOS-37PTH DSCs with a heat load greater than 41.8 kW or for the EOS-89BTH DSCs with a heat load greater than 41.6 kW, the minimum temperature is -20 °F. The maximum calculated average yearly temperature is 70 °F.

   For the HSM-MX:

   c. The minimum temperature is -20 °F. The maximum calculated normal average ambient temperature corresponding to a 24-hour period is 90 °F.
4. Off-normal ambient temperature range of -40 °F without solar insolation to 117 °F with full solar insolation. The 117 °F off-normal ambient temperature corresponds to a 24-hour calculated average temperature of 103 °F.

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5. The response spectra at the base of the HSMs shall be compared against the response spectra defined in UFSAR Section 2.3.4 for the EOS-HSM, and Section A.2.3.4 for the HSM-MX and shown to be enveloped by the UFSAR response spectra. If it is not enveloped, stability can be demonstrated by either static or dynamic analysis.
6. The potential for fires and explosions shall be addressed, based on site-specific considerations.
7. Supplemental Shielding: In cases where engineered features (i.e., berms, shield walls) are used to ensure that the requirements of 10 CFR 72.104(a) are met, such features are to be considered important to safety and must be evaluated to determine the applicable Quality Assurance Category.
8. If an INDEPENDENT SPENT FUEL STORAGE INSTALLATION (ISFSI) site is located in a coastal salt water marine atmosphere, then any load-bearing carbon steel DSC support structure rail components for the EOS-HSM, or front and rear DSC supports for the HSM-MX shall be procured with a minimum 0.20% copper content or stainless steel shall be used for corrosion resistance. For weld filler material used with carbon steel, 1% or more nickel bearing weld material would also be acceptable in lieu of 0.20% copper content.
9. If an ISFSI site is required to evaluate blockage of air vents for durations longer than evaluated in the UFSAR, a new duration can be determined based on site-specific parameters. The evaluation should be performed using the same methodology documented in the UFSAR.

5.0 ADMINISTRATIVE CONTROLS

5.1 Programs

Each user of the NUHOMS® EOS System will implement the following programs to ensure the safe operation and maintenance of the ISFSI:

- Radiological Environmental Monitoring Program (see 5.1.1 below)
- Radiation Protection Program (see 5.1.2 below)
- HSM Thermal Monitoring Program (see 5.1.3 below)

5.1.1 Radiological Environmental Monitoring Program

a. A radiological environmental monitoring program will be implemented to ensure that the annual dose equivalent to an individual located outside the ISFSI controlled area does not exceed the annual dose limits specified in 10 CFR 72.104(a).

b. Operation of the ISFSI will not create any radioactive materials or result in any credible liquid or gaseous effluent release.

5.1.2 Radiation Protection Program

The Radiation Protection Program will establish administrative controls to limit personnel exposure to As Low As Reasonably Achievable (ALARA) levels in accordance with 10 CFR Part 20 and Part 72.

a. As part of its evaluation pursuant to 10 CFR 72.212, the licensee shall perform an analysis to confirm that the limits of 10 CFR Part 20 and 10 CFR 72.104 will be satisfied under the actual site conditions and configurations considering the planned number of DSCs to be used and the planned fuel loading conditions. This analysis is also used to qualify fuel considered for loading, as outlined below:

    1. For the DSCs considered for loading, select HLZC(s) appropriate to store the spent fuel.
    2. Compute the decay heat of the fuel assemblies considered for loading. Methods include, but are not limited to, NRC Regulatory Guide 3.54, or the methodology described in the UFSAR (i.e., ORIGEN-ARP).
    3. Compute the source term for the fuel assemblies considered for loading. The design basis source terms provided in the UFSAR may be used for site-specific shielding analysis if they are shown to bound the site-specific source terms.
    4. Demonstrate computationally that the EOS-HSM or HSM-MX to be loaded meets the dose rate requirements of TS 5.1.2(c). This evaluation may be used as the basis for the dose rate limits established in TS 5.1.2(b).
    5. Demonstrate computationally that direct radiation from the ISFSI meets the requirements of 72.104.

(continued)

5.0 ADMINISTRATIVE CONTROLS (continued)

b. On the basis of the analysis in TS 5.1.2(a), the licensee shall establish a set of HSM dose rate limits which are to be applied to DSCs used at the site. Limits shall establish dose rates for:
   i. HSM front face,
   ii. HSM door centerline, and
   iii. End shield wall exterior for the EOS-HSM or exterior side wall of the HSM-MX monolith.

c. Notwithstanding the limits established in TS 5.1.2(b), the dose rate limits may not exceed the following values as calculated for a content of design basis fuel as follows:

   For EOS-HSM:
   i. 65 mrem/hr average over the front face,
   ii. 15 mrem/hr at the door centerline, and
   iii. 5 mrem/hr average at the end shield wall exterior.

   For HSM-MX:
   i. 165 mrem/hr average over the front face,
   ii. 15 mrem/hr at the door centerline, and
   iii. 5 mrem/hr average at the exterior side wall of the HSM-MX monolith.

   If the measured dose rates do not meet the limits of TS 5.1.2(b) or TS 5.1.2(c), whichever are lower, the licensee shall take the following actions:

   - Notify the U.S. Nuclear Regulatory Commission (Director of the Office of Nuclear Material Safety and Safeguards) within 30 days,
   - Administratively verify that the correct fuel was loaded,
   - Ensure proper installation of the HSM door,
   - Ensure that the DSC is properly positioned on the DSC supports, and
   - Perform an analysis to determine that placement of the as-loaded DSC at the ISFSI will not cause the ISFSI to exceed the radiation exposure limits of 10 CFR Part 20 and 10 CFR Part 72 and/or provide additional shielding to assure exposure limits are not exceeded.

d. A monitoring program to ensure the annual dose equivalent to any real individual located outside the ISFSI controlled area does not exceed regulatory limits is incorporated as part of the environmental monitoring program in the Radiological Environmental Monitoring Program of TS 5.1.1.

(continued)

5.0 ADMINISTRATIVE CONTROLS (continued)

e. When using the EOS-TC108 with a liquid neutron shield (NS), the NS shall be verified to be filled when DSC cavity draining or TC/DSC annulus draining operations are initiated and continually monitored during the first five minutes of the draining evolution to ensure the NS remains filled. The NS shall also be verified to be filled prior to the movement of the loaded TC from the decontamination area. Observation of water level in the expansion tank or some other means can be used to verify compliance with this requirement.

f. Following completion of the DSC shell assembly at the fabricator facility, the inner bottom cover plate, canister shell and all associated welds are leak-tested to demonstrate that these welds and components meet the “leak-tight” criterion ($\leq 1.0 \times 10^{-7}$ reference cm^3/sec) as defined in “American National Standard for Radioactive Materials – Leakage Tests on Packages for Shipment”, ANSI N14.5-1997. If the leakage rate exceeds 1.0×10^{-7} reference cm^3/sec, check and repair these welds or components.

Following completion of the welding of the DSC shell to the inner top cover and drain port cover and vent plug after fuel loading, these welds and components are leak-tested to demonstrate that they meet the “leak-tight” criterion ($\leq 1.0 \times 10^{-7}$ reference cm^3/sec) as defined in “American National Standard for Radioactive Materials - Leakage Tests on Packages for Shipment”, ANSI N14.5-1997. If the leakage rate exceeds 1.0×10^{-7} reference cm^3/sec, check and repair these welds or components.

5.1.3 HSM Thermal Monitoring Program

Two separate programs for the EOS-HSM and MATRIX HSM are described in Technical Specifications 5.1.3.1 and 5.1.3.2, respectively.

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5.0 ADMINISTRATIVE CONTROLS (continued)

5.1.3.1 EOS-HSM Thermal Monitoring Program

This program provides guidance for temperature measurements that are used to monitor the thermal performance of each EOS-HSM. The intent of the program is to prevent conditions that could lead to exceeding the concrete and fuel clad temperature criteria. Each user must implement either TS 5.1.3.1(a) OR 5.1.3.1(b).

a. Daily Visual Inspection of EOS-HSM Inlets and Outlets (Front Wall and Roof Birdscreens) and Wind Deflectors

  i. The user shall develop and implement procedures to perform visual inspection of EOS-HSM inlets and outlets on a daily basis.

  Perform a daily visual inspection of the air vents to ensure that EOS-HSM air vents are not blocked for more than 40 hours. If visual inspection indicates blockage, clear air vents and replace or repair birdscreens if damaged. If the air vents are blocked or could have been blocked for more than 40 hours, evaluate existing conditions in accordance with the site corrective action program to confirm that conditions adversely affecting the concrete or fuel cladding do not exist.

  ii. Daily Visual Inspection of Wind Deflectors

  If wind deflectors are required per TS 5.5, the user shall develop and implement procedures to perform visual inspection of the wind deflectors on a daily basis.

  There is a possibility that the wind deflectors could become damaged or lost by extreme winds, tornados, or other accidents. The condition caused by a damaged or lost wind deflector is bounded by the air vent blockage postulated and analyzed in the UFSAR accident analyses. The procedures shall ensure that the duration of a damaged or lost wind deflector will not exceed periods longer than 40 hours as assumed in the UFSAR analyses for vent blockage. If visual inspection indicates a damaged or lost wind deflector, replace or repair the wind deflector. If the wind deflectors are damaged or could have been damaged for more than 40 hours, evaluate existing conditions in accordance with the site corrective action program to confirm that conditions adversely affecting the concrete or fuel cladding do not exist.

b. Daily EOS-HSM Temperature Measurement Program

  i. The user shall develop a daily temperature measurement program to verify the thermal performance of each NUHOMS® EOS System. The user shall establish administrative temperature limits to (1) detect off-normal and accident blockage conditions before the EOS- HSM components and fuel cladding temperatures would exceed temperature design limits and (2) ensure the EOS-HSM air vents are not blocked for more than 40 hours. The daily temperature measurements shall include one of the following options:

    1. direct measurement of the EOS-HSM concrete temperature
    2. direct measurement of inlet and outlet air temperatures

(continued)

5.0 ADMINISTRATIVE CONTROLS (continued)

If the direct measurement of the inlet and outlet air temperatures (option 2) is performed, the measured temperature differences of the inlet and outlet vents of each individual EOS-HSM must be compared to the predicted temperature differences for each individual EOS-HSM during normal operations. The measured temperature difference between the inlet and outlet vents shall not exceed 138 °F.

ii. The user shall establish in the program, measurement locations in the EOS-HSM that are representative of the EOS-HSM thermal performance and directly correlated to the predicted fuel cladding temperatures, air mass flow rates, and NUHOMS® EOS System temperature distributions that would occur with the off-normal and accident blockage conditions, as analyzed in the UFSAR. The administrative temperature limits shall employ appropriate safety margins that ensure temperatures would not exceed design basis temperature limits in the UFSAR, and be based on the UFSAR methodologies used to predict thermal performance of the NUHOMS® EOS System. If the direct measurement of the inlet and outlet air temperatures (option 2) is performed, the user must develop procedures to measure air temperatures that are representative of inlet and outlet air temperatures, as analyzed in the UFSAR. The user must also consider site-specific environmental conditions, loaded decay heat patterns, and the proximity of adjacent EOS-HSM modules in the daily air temperature measurement program. The user must ensure that measured air temperatures reflect only the thermal performance of each individual module, and not the combined performance of adjacent modules.

iii. The user shall establish in the program the appropriate actions to be taken if administrative temperature criteria are exceeded. If an administrative temperature limit is exceeded during a daily measurement, the user shall inspect the vents, wind deflectors if installed, and implement TS 5.1.3.1(a) for the affected system, until the cause of the excursion is determined and necessary corrective actions are completed under the site corrective action program.

iv. If measurements or other evidence indicate that the EOS-HSM concrete temperatures have exceeded the concrete accident temperature limit of 500 °F for more than 40 hours, the user shall perform an analysis and/or tests of the concrete in accordance with TS 5.3. The user shall demonstrate that the structural strength of the EOS-HSM has an adequate margin of safety and take appropriate actions to return the EOS-HSM to normal operating conditions.

v. If measurements or other evidence indicate that off-normal or accident temperature limits for fuel cladding have been exceeded, verify that canister confinement is maintained and assess analytically the condition of the fuel. Additionally, within 30 days, take appropriate actions to restore the spent fuel to a safe configuration.

(continued)

5.0 ADMINISTRATIVE CONTROLS (continued)

5.1.3.2 HSM-MX Thermal Monitoring Program

This program provides guidance for temperature measurements that are used to monitor the thermal performance of each HSM-MX. There are no credible scenarios that could block both the inlet and outlet vents. Therefore, only blockage of inlet vent is considered in the UFSAR. The intent of the program is to prevent conditions that could lead to exceeding the concrete and fuel clad temperature criteria. Each user must implement either TS 5.1.3.2(a) OR 5.1.3.2(b).

a. Daily Visual Inspection of HSM-MX Inlets and Outlets (Front Wall and Roof Birdscreens)

The user shall develop and implement procedures to perform visual inspection of HSM-MX inlets and outlets on a daily basis.

Perform a daily visual inspection of the air vents to ensure that HSM-MX air vents are not blocked for more than 32 hours. If visual inspection indicates blockage, clear air vents and replace or repair birdscreens if damaged. If the air vents are blocked or could have been blocked for more than 32 hours, evaluate existing conditions in accordance with the site corrective action program to confirm that conditions adversely affecting the concrete or fuel cladding do not exist.

b. Daily HSM-MX Temperature Measurement Program

i. The user shall develop a daily temperature measurement program to verify the thermal performance of each HSM-MX System through direct measure of the HSM-MX concrete temperature. The user shall establish administrative temperature limits to (1) detect off-normal and accident blockage conditions before the HSM*-MX* components and fuel cladding temperatures would exceed temperature design limits and (2) ensure the HSM-MX air vents are not blocked for more than 32 hours.

ii. The user shall establish in the program measurement locations in the HSM-MX that are representative of the HSM-MX thermal performance and directly correlated to the predicted fuel cladding temperatures, air mass flow rates, and NUHOMS® MATRIX System temperature distributions that would occur with the off-normal and accident blockage conditions, as analyzed in the UFSAR. The administrative temperature limits shall employ appropriate safety margins that ensure temperatures would not exceed design basis temperature limits in the UFSAR, and be based on the UFSAR methodologies used to predict thermal performance of the NUHOMS® MATRIX System.

iii. The user shall establish in the program the appropriate actions to be taken if administrative temperature criteria are exceeded. If an administrative temperature limit is exceeded during a daily measurement, the user shall inspect the vents and implement TS 5.1.3.2(a) for the affected system, until the cause of the excursion is determined and necessary corrective actions are completed under the site corrective action program.

(continued)

5.0 ADMINISTRATIVE CONTROLS (continued)

iv. If measurements or other evidence indicate that the HSM-MX concrete temperatures have exceeded the concrete accident temperature limit of 500 °F for more than 32 hours, the user shall perform an analysis and/or tests of the concrete in accordance with TS 5.3. The user shall demonstrate that the structural strength of the HSM-MX has an adequate margin of safety and take appropriate actions to return the HSM-MX to normal operating conditions.

v. If measurements or other evidence indicate that off-normal or accident temperature limits for fuel cladding have been exceeded, verify that canister confinement is maintained and assess analytically the condition of the fuel. Additionally, within 30 days, take appropriate actions to restore the spent fuel to a safe configuration.

5.2 Lifting Controls

5.2.1 TC/DSC Lifting Height and Temperature Limits

The requirements of 10 CFR 72 apply to TC/DSC lifting/handling height limits outside the FUEL BUILDING. The requirements of 10 CFR Part 50 apply to TC/DSC lifting/handling height limits inside the FUEL BUILDING. Confirm the surface temperature of the TC before TRANSFER OPERATIONS of the loaded TC/DSC.

The lifting height of a loaded TC/ DSC is limited as a function of low temperature and the type of lifting/handling device, as follows:

- No lifts or handling of the TC/DSC at any height are permissible at TC surface temperatures below 0 °F
- The maximum lift height of the TC/DSC shall be 65 inches for the EOS-DSCs or 80 inches for the 61BTH Type 2 DSC if the surface temperature of the TC is above 0 °F and a non-single-failure-proof lifting/handling device is used.
- No lift height restriction is imposed on the TC/DSC if the TC surface temperature is higher than 0 °F, and a single-failure-proof lifting/handling system is used.

The requirements of 10 CFR Part 72 apply when the TC/DSC is in a horizontal orientation on the transfer trailer. The requirements of 10 CFR Part 50 apply when the TC/DSC is being lifted/handled using the cask handling crane/hoist. (This distinction is valid only with respect to lifting/handling height limits.)

5.2.2 Cask Drop

Inspection Requirement

The TC will be inspected for damage and the DSC will be evaluated after any TC with a loaded DSC side drop of 15 inches or greater.

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5.0 ADMINISTRATIVE CONTROLS (continued)

Background

TC/DSC handling and loading activities are controlled under the 10 CFR Part 50 license until a loaded TC/DSC is placed on the transporter, at which time fuel handling activities are controlled under the 10 CFR Part 72 license.

Safety Analysis

The analysis of bounding drop scenarios shows that the TC will maintain the structural integrity of the DSC confinement boundary from an analyzed side drop height of 65 inches for the EOS-DSCs and 80 inches for the 61BTH Type 2 DSC. This 65-inch/80-inch drop height envelopes the maximum height from the bottom of the TC when secured to the transfer trailer while en route to the ISFSI.

Although analyses performed for cask drop accidents at various orientations indicate much greater resistance to damage, requiring the inspection of the DSC after a side drop of 15 inches or greater ensures that:

1. The DSC will continue to provide confinement.
2. The TC can continue to perform its design function regarding DSC transfer and shielding.

5.3 Concrete Testing

HSM concrete shall be tested during the fabrication process for elevated temperatures to verify that there are no significant signs of spalling or cracking and that the concrete compressive strength is greater than that assumed in the structural analysis. Tests shall be performed at or above the calculated peak *accident* temperature and for a period no less than the permissible duration as specified in Technical Specification 5.1.3.

HSM concrete temperature testing shall be performed whenever:

- There is a change in the supplier of the cement, or
- There is a change in the source of the aggregate, or
- The water-cement ratio changes by more than 0.04.

(continued)

5.0 ADMINISTRATIVE CONTROLS (continued)

5.4 Hydrogen Gas Monitoring

For DSCs, while welding the inner top cover during LOADING OPERATIONS, and while cutting the inner top cover to DSC shell weld when the DSC cavity is wet during UNLOADING OPERATIONS, hydrogen monitoring of the space under the top shield plug in the DSC cavity is required, to ensure that the combustible mixture concentration remains below the flammability limit of 4%. If this limit is exceeded, all welding operations shall be stopped and the DSC cavity purged with helium to reduce hydrogen concentration safely below the limit before welding or cutting operations can be resumed.

5.5 EOS-HSM Wind Deflectors

If the heat load of an EOS-37PTH DSC during STORAGE OPERATIONS is greater than 41.8 kW, wind deflectors shall be installed on the EOS-HSM.

If the heat load of a fuel assembly loaded per HLZC 5 in the EOS-37PTH DSC during STORAGE OPERATIONS is greater than 1.625 kW, wind deflectors shall be installed on the EOS-HSM.

If the heat load of an EOS-89BTH DSC during STORAGE OPERATIONS is greater than 41.6 kW, wind deflectors shall be installed on the EOS-HSM.

Table 1
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 2
Maximum Uranium Loading per FFC for Failed PWR Fuel

Fuel Assembly Class	**Maximum Uranium Loading (MTU)**
WE 17x17	0.550
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 3
Co-60 Equivalent Activity for CCs Stored in the EOS-37PTH DSC

Fuel Region	***Maximum Co-60 Equivalent Activity per DSC (Curies/DSC)(2)***		
	Transfer in the EOS-TC108 AND (storage in the EOS-HSM OR HSM-MX)	***Transfer in the EOS-TC125/135 AND storage in the HSM-MX***	***Transfer in the EOS-TC125/135 AND storage in the EOS-HSM***
Active Fuel	32,656		*37,259*
Plenum/Top Region	6,671		*7,607*

Notes:

1. Not Used.
2. NSAs and Neutron Sources shall only be stored in the inner zone of the basket. Figure 3 defines the compartments categorized as the Inner and Peripheral Zones.

Table 4
Maximum Planar Average Initial Enrichment for EOS-37PTH

(2 Pages)

PWR Fuel Class	Minimum Soluble Boron (ppm)	Maximum Planar Average Initial Enrichment (wt. % U-235) as a Function of Soluble Boron Concentration and Basket Type (Fixed Poison Loading) With and Without CCs							
		Basket Type							
		A1/A2/A3/A4H/A4L/A5				B1/B2/B3/B4H/B4L/B5			
		w/o CCs		w/ CCs		w/o CCs		w/ CCs	
		INTACT FUEL	DAMAGED/ FAILED FUEL(2)	INTACT FUEL	DAMAGED/ FAILED FUEL(2)	INTACT FUEL	DAMAGED/ FAILED FUEL(3)	INTACT FUEL	DAMAGED/ FAILED FUEL(3)
WE 17x17 Class	2000	4.35	4.20	4.35	4.15	4.50	4.15	4.45	4.25
	2100	4.50	4.20	4.45	4.20	4.65	4.25	4.60	4.40
	2200	4.60	4.40	4.55	4.35	4.75	4.45	4.70	4.55
	2300	4.70	4.45	4.65	4.50	4.85	4.65	4.85	4.60
	2400	4.85	4.45	4.80	4.60	5.00	4.65	4.95	4.75
	2500	4.95	4.65	4.90	4.70	5.00	5.00	5.00	4.95
CE 16x16 Class	2000	5.00	4.75	5.00	4.70	5.00	5.00	5.00	5.00
	2100	5.00	5.00	5.00	5.00	-	-	-	-
	2200	-	-	-	-	-	-	-	-
	2300	-	-	-	-	-	-	-	-
	2400	-	-	-	-	-	-	-	-
	2500	-	-	-	-	-	-	-	-
BW 15x15 Class	2000	4.25	4.05	4.20	4.00	4.40	4.10	4.35	4.15
	2100	4.40	4.10	4.30	4.15	4.55	4.20	4.45	4.25
	2200	4.50	4.25	4.45	4.15	4.65	4.35	4.60	4.30
	2300	4.60	4.35	4.55	4.30	4.80	4.40	4.70	4.50
	2400	4.75	4.40	4.65	4.45	4.90	4.55	4.85	4.50
	2500	4.85	4.55	4.75	4.65	5.00	4.75	4.90	4.75
	2600	(1)	(1)	(1)	(1)	5.00	5.00	(1)	(1)
WE 15x15	2000	4.45	4.10	4.40	4.10	4.55	4.30	4.55	4.25
	2100	4.60	4.15	4.55	4.15	4.65	4.50	4.65	4.35
	2200	4.70	4.25	4.65	4.35	4.80	4.55	4.80	4.45
	2300	4.85	4.35	4.75	4.45	5.00	4.50	4.95	4.50
	2400	4.95	4.50	4.90	4.50	5.00	4.90	5.00	4.80
	2500	5.00	4.75	5.00	4.65	5.00	5.00	5.00	5.00
CE 15x15 Assembly Class	2000	4.60	4.25	4.55	4.20	4.75	4.35	4.70	4.30
	2100	4.70	4.45	4.65	4.40	4.85	4.50	4.85	4.35
	2200	4.85	4.50	4.80	4.45	5.00	4.60	4.95	4.60
	2300	5.00	4.55	4.90	4.65	5.00	5.00	5.00	4.80
	2400	5.00	5.00	5.00	4.85	5.00	5.00	5.00	5.00
	2500	-	-	5.00	5.00	-	-	-	-
CE 14x14 Assembly Class	2000	5.00	5.00	5.00	4.50	5.00	5.00	5.00	4.95
	2100	-	-	5.00	4.95	-	-	5.00	5.00
	2200	-	-	5.00	5.00	-	-	-	-
	2300	-	-	-	-	-	-	-	-
	2400	-	-	-	-	-	-	-	-
	2500	-	-	-	-	-	-	-	-

Table 4
Maximum Planar Average Initial Enrichment for EOS-37PTH

(2 Pages)

PWR Fuel Class	**Maximum Planar Average Initial Enrichment (wt. % U-235) as a Function of Soluble Boron Concentration and Basket Type (Fixed Poison Loading) With and Without CCs**								
	Minimum Soluble Boron (ppm)	**Basket Type**							
		A1/A2/A3/A4H/A4L/A5				**B1/B2/B3/B4H/B4L/B5**			
		w/o CCs		**w/ CCs**		**w/o CCs**		**w/ CCs**	
		INTACT FUEL	**DAMAGED/ FAILED FUEL(2)**	**INTACT FUEL**	**DAMAGED/ FAILED FUEL(2)**	**INTACT FUEL**	**DAMAGED/ FAILED FUEL(3)**	**INTACT FUEL**	**DAMAGED/ FAILED FUEL(3)**
WE 14x14 Class	2000	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
	2100	-	-	-	-	-	-	-	-
	2200	-	-	-	-	-	-	-	-
	2300	-	-	-	-	-	-	-	-
	2400	-	-	-	-	-	-	-	-
	2500	-	-	-	-	-	-	-	-

Notes:

1. Not analyzed.
2. May only be stored in basket types A4H and A4L
3. May only be stored in basket types B4H and B4L

Table 5
Minimum B-10 Content in the Neutron Poison Plates of the EOS-37PTH DSC

Basket Type	**Minimum B-10 Content (areal density) for MMC (mg/cm^2)**
A1/A2/A3/A4H/A4L/A5	28.0
B1/B2/B3/B4H/B4L/B5	35.0

Table 6
Fuel Assembly Design Characteristics for the EOS-89BTH DSC

BWR FUEL CLASS	BWR Fuel ID	Example Fuel Designs (1)(2)
7 x 7	ENC-7-A	ENC-IIIA
7 x 7	ENC-7-B	ENC-III ENC-IIIE ENC-IIIF
7 x 7	GE-7-A	GE-1, GE-2, GE-3
8 x 8	ENC-8-A	ENC Va and Vb
8 x 8	ABB-8-A	SVEA-64
8 x 8	ABB-8-B	SVEA-64
8 x 8	FANP-8-A	FANP 8x8-2
8 x 8	GE-8-A	GE-4, XXX-RCN
8 x 8	GE-8-B	GE-5, GE-Pres GE-Barrier GE-8 Type 1
8 x 8	GE-8-C	GE-8 Type II
8 x 8	GE-8-D	GE-9, GE-10
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
9 x 9	GE-9-A	GE-11, GE-13
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
10 x 10	FANP-10-A	ATRIUM 10 ATRIUM 10XM
10 x 10	GE-10-A	GE-12, GE-14
10 x 10	GE-10-B	GNF2
11 x 11	FANP-11-A	ATRIUM 11

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 7A
PWR Minimum Enrichments as a Function of Burnup

Burnup Range (GWd/MTU)	Minimum Enrichment (wt. % U-235)
1-6	0.7
7-16	1.3
17-30	1.8
31-62	Burnup/16(1)

Notes:

(1) Round enrichment down to the nearest 0.1%. Example: for 62 GWd/MTU, 62/16 = 3.875%, round down to 3.8%.

(2) Fuel below the minimum enrichment defined in this table is classified as LOW-ENRICHED OUTLIER FUEL. Number and location are specified in Section 2.1.

Table 7B
EOS-37PTH DSC Fuel Qualification Table ***for Storage in the HSM-MX***, All Fuel

(Minimum required years of cooling time after reactor core discharge)

Burnup (GWd/FA)	Fuel Assembly Average Initial U-235 Enrichment (wt.%)												
	0.7	1.3	1.8	2.0	2.5	2.8	3.1	3.4	3.7	3.8	4.0	4.5	5.0
2.95	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
4.92		2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
9.84			2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
14.76			2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
19.68					2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
22.14						2.16	2.12	2.09	2.05	2.04	2.02	2.00	2.00
24.60							2.35	2.31	2.28	2.26	2.24	2.18	2.14
27.06								2.55	2.51	2.49	2.47	2.41	2.35
29.52									2.76	2.75	2.71	2.64	2.58
30.50										2.85	2.82	2.74	2.67
34.10										3.22	3.20	3.11	3.03

Notes:

(1) The minimum cooling time is 2.0 years.

(2) The burnup in GWd/FA is the assembly average burnup in GWd/MTU multiplied by the MTU of the fuel assembly.

(3) Linear interpolation is allowed to obtain a cooling time within the specified range of burnup and enrichment values.

(4) Extrapolation is allowed to obtain a cooling time in the gray-shaded region.

Table 7C
EOS-37PTH DSC Fuel Qualification Table for Storage in the EOS-HSM, All Fuel

(Minimum required years of cooling time after reactor core discharge)

Burnup (GWd/FA)	*Fuel Assembly Average Initial U-235 Enrichment (wt.%)*												
	0.7	*1.3*	*1.8*	*2.0*	*2.5*	*2.8*	*3.1*	*3.4*	*3.7*	*3.8*	*4.0*	*4.5*	*5.0*
2.95	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*
3.44		*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*
7.87		*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*
8.36			*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*
9.84			*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*
14.76			*1.08*	*1.07*	*1.03*	*1.01*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*
19.68					*1.35*	*1.32*	*1.30*	*1.27*	*1.25*	*1.24*	*1.23*	*1.20*	*1.17*
22.14						*1.48*	*1.46*	*1.43*	*1.40*	*1.39*	*1.38*	*1.34*	*1.31*
24.60							*1.62*	*1.59*	*1.56*	*1.55*	*1.53*	*1.49*	*1.45*
27.06								*1.75*	*1.72*	*1.71*	*1.69*	*1.65*	*1.60*
29.52									*1.89*	*1.88*	*1.85*	*1.80*	*1.76*
30.50										*1.94*	*1.92*	*1.87*	*1.82*
34.10										*2.19*	*2.17*	*2.11*	*2.06*

Notes:

(1) The minimum cooling time is 1 year. For fuel transferred in the EOS-TC108, the minimum cooling time is 2.0 years.

(2) The burnup in GWd/FA is the assembly average burnup in GWd/MTU multiplied by the MTU of the fuel assembly.

(3) Linear interpolation is allowed to obtain a cooling time within the specified range of burnup and enrichment values.

(4) Extrapolation is allowed to obtain a cooling time in the gray-shaded region.

Table 8
Maximum Lattice Average Initial Enrichment and Minimum B-10 Areal Density for the EOS-89BTH DSC

Basket Type	**Loading Configuration - Number of Fuel Assemblies** (1)	**Maximum Lattice Average Initial Enrichment (wt. % U-235)**			**Minimum B-10 Areal Density (mg/cm^2)**	
		All fuel Except ABB-10-C and ATRIUM 11	**ABB-10-C Fuel**	**ATRIUM 11 Fuel**	**MMC**	**BORAL®**
A1/A2/A3 (2)	89	4.20	4.05	4.05	32.7	39.2
	88	4.45	4.25	4.25		
	87	4.60	4.40	4.35		
	84	5.00	4.90	4.80		
B1/B2/B3 (2)	89	4.55	4.35	4.30	41.3	49.6
	88	4.80	4.60	4.50		
	87	4.95	4.70	4.65		
	84	5.00	5.00	5.00		
C1/C2/C3 (2)	89	4.85	4.60	(3)	Not Allowed	60.0

Note:

1. See Figure 10 for 88-FA, 87-FA and 84-FA loading configurations.
2. Mixing fuel types in the same DSC is permissible based on the calculated enrichments for each fuel type for a given basket type and loading configuration. For example, when mixing GNF2 and ATRIUM 11 fuels in basket type A1/A2/A3 and 88-fuel-assembly loading configuration, the maximum enrichment for GNF2 fuels is 4.45wt% and the maximum enrichment for ATRIUM 11 fuels is 4.25wt%.
3. ATRIUM 11 fuel is not an allowed content for basket type C1/C2/C3.

Table 9
Maximum Lattice Average Initial Enrichment and Minimum B-10 Areal Density for the 61BTH Type 2 DSC (Intact Fuel)

Basket Type	Maximum Lattice Average Initial Enrichment (wt. % U-235)(1)	Minimum B-10 Areal Density, (mg/cm^2)	
		Borated Aluminum/MMC	Boral®
A	3.7	22	27
B	4.1	32	38
C	4.4	42	50
D	4.6	48	58
E	4.8	55	66
F	5.0(1)	62	75

Note:

1) For ATRIUM 11 fuel assemblies, the U-235 wt. % enrichment is reduced by 0.55%. The ATRIUM 11 fuel assemblies are authorized for storage in the Type F basket only.

Table 10
Maximum Lattice Average Initial Enrichment and Minimum B-10 Areal Density for the 61BTH Type 2 DSC (Damaged Fuel)

Basket Type	**Maximum Lattice Average Initial Enrichment (wt. % U-235)**		**Minimum B-10 Areal Density, (mg/cm^2)**	
	Up to 4 Damaged Assemblies(1)	**Five or More Damaged Assemblies(1) (16 Maximum)**	**Borated Aluminum/MMC**	**Boral®**
A	3.7	2.80	22	27
B	4.1	3.10	32	38
C	4.4	3.20	42	50
D	4.6	3.40	48	58
E	4.8	3.50	55	66
F	5.0(2, 3)	3.60	62	75

Notes:

1) See Figure 5 for the location of damaged fuel assemblies within the 61BTH Type 2 DSC.
2) ATRIUM 11 fuel assemblies are authorized for storage only in the Type F basket only with a maximum of 4 damaged fuel assemblies.
3) For ATRIUM 11 fuel assemblies, the U-235 wt. % enrichment is reduced by 0.55%.

Table 11
Maximum Lattice Average Initial Enrichment and Minimum B-10 Areal Density for the 61BTH Type 2 DSC (Failed and Damaged Fuel)

Basket Type	Maximum Lattice Average Initial Enrichment (wt. % U-235)		Minimum B-10 Areal Density (mg/cm^2)	
	Up to 4 Failed Assemblies (Corner Locations)$^{(1, 2)}$	Up to 4 Failed Assemblies (Corner Locations) and up to 12 Damaged Assemblies (Interior Locations)$^{(1, 2)}$	Borated Aluminum/MMC	Boral®
A	3.7	2.8	22	27
B	4.0	3.1	32	38
C	4.4	3.2	42	50
D	4.6	3.4	48	58
E	4.8	3.4	55	66
F	5.0	3.5	62	75

Notes:

1) See Figure 5 for the locations of the failed and damaged assemblies within the 61BTH Type 2 DSC.
2) Failed ATRIUM 11 fuel assemblies are not authorized for storage in the 61BTH Type 2 DSC.

Table 12
Maximum Lattice Average Initial Enrichments and Minimum B-10 Areal Density for the 61BTH Type 2 DSC for > 16 Damaged Fuel Assemblies

Basket Type	Up to 57 Damaged Fuel at 3.30 wt. % U-235		Minimum B-10 Areal Density (mg/cm^2)	
	Remaining Four Intact Assemblies (1)	Remaining Four Damaged Assemblies (1)	Borated Aluminum/MMC	Boral®
A	-	-	-	-
B	-	-	-	-
C	-	-	-	-
D	5.00	4.20	48	58
E	5.00	4.20	55	66
F	5.00	4.20	62	75

Note:
1) See Figure 5 for the locations of the damaged assemblies within the 61BTH Type 2 DSC

Table 13
BWR Fuel Assembly Design Characteristics for the 61BTH Type 2 DSC

BWR FUEL CLASS	Initial Design or Reload Fuel Designation(1) (3)
7x7-49/0	GE1 GE2 GE3
8x8-63/1	GE4
8x8-62/2	GE-5 GE-Pres GE-Barrier GE8 Type I
8x8-60/4	GE8 Type II
8x8-60/1	GE9 GE10
9x9-74/2	GE11 GE13
10x10-92/2	GE12 GE14 GNF2
7x7-49/0	ENC-IIIA
7x7-48/1Z	ENC-III(2)
8x8-60/4Z	ENC Va ENC Vb
8x8-62/2	FANP 8x8-2
9x9-79/2	FANP9 9x9-2
Siemens QFA	9x9
10x10-91/1	ATRIUM-10 ATRIUM-10XM
11x11	ATRIUM-11

Notes:

(1) Any fuel channel average thickness up to 0.120 inch is acceptable on any of the fuel designs.

(2) Includes ENC-IIIE and ENC-IIIF.

(3) Initial designs or reload fuel designations belonging to a listed fuel class, but not listed herein may be qualified for storage using the same methodology as documented in the UFSAR.

Table 14
Maximum Uranium Loading per FFC for Failed 61BTH Type 2 Fuel

Fuel Assembly Class	Maximum MTU/Assembly
7x7	0.198
8x8	0.188
9x9	0.180
10x10	0.187

Table 15

Deleted

Table 16
Deleted

Table 17
System Configurations for 61BTH Type 2 HLZCs

HLZC	Storage Module	Transfer Cask
1	HSM-MX	OS197/OS197H/ OS197FC-B/OS197HFC-B
2	HSM-MX	OS197/OS197H/ OS197FC-B/OS197HFC-B
3	HSM-MX	OS197/OS197H/ OS197FC-B/OS197HFC-B
4	HSM-MX	OS197/OS197H/ OS197FC-B/OS197HFC-B
5	HSM-MX	OS197FC-B/OS197HFC-B
6	HSM-MX	OS197FC-B/OS197HFC-B
7	HSM-MX	OS197FC-B/OS197HFC-B
8	HSM-MX	OS197FC-B/OS197HFC-B
9	HSM-MX	OS197/OS197H/ OS197FC-B/OS197HFC-B
10	HSM-MX	OS197FC-B/OS197HFC-B

Table 18
BWR Minimum Enrichments as a Function of Burnup (EOS-89BTH DSC and 61BTH Type 2 DSC)

Burnup Range (GWd/MTU)	**Minimum Enrichment (wt. %)**
1-6	0.7
7-19	0.9
20-35	Burnup/20(1)
36-62	Burnup/16(1)

Notes:

1) Round down to the nearest 0.1%. Example: for 62 GWd/MTU, 62/16 = 3.875%, round down to 3.8%.
2) Fuel below the minimum enrichment defined in this table is classified as LOW-ENRICHED OUTLIER FUEL. Number and location are specified in Section 2.2 for the EOS-89BTH DSC and in Section 2.3 for the 61BTH Type 2 DSC.

Table 19
61BTH Type 2 DSC Fuel Qualification Table, All Fuel

(Minimum required years of cooling time after reactor core discharge)

Burnup (GWd/FA)	Fuel Assembly Average Initial U-235 Enrichment (wt.%)														
	0.7	0.9	1.0	1.5	1.7	2.2	2.5	2.8	3.1	3.4	3.7	3.8	4.0	4.5	5.0
1.19	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
1.39		2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
2.97		2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
3.76		2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
3.96			2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
5.94				2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
6.93					2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
7.13						2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
7.92							2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
8.91								2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
9.90									2.11	2.06	2.01	2.00	2.00	2.00	2.00
10.89										2.29	2.24	2.22	2.19	2.11	2.05
11.88											2.48	2.46	2.43	2.34	2.27
12.28												2.57	2.53	2.44	2.36

Notes:

1) The minimum cooling time is 2.0 years.
2) The burnup in GWd/FA is the assembly average burnup in GWd/MTU multiplied by the MTU of the fuel assembly.
3) Linear interpolation is allowed to obtain a cooling time within the specified range of burnup and enrichment values.
4) Extrapolation is allowed to obtain a cooling time in the gray-shaded region.

Table 20
61BTH Type 2 DSC Fuel Qualification Table, HLZC 2, 4, 5, 6, 7, and 8, Peripheral Locations

(Minimum required years of cooling time after reactor core discharge)

Burnup (GWd/FA)	Fuel Assembly Average Initial U-235 Enrichment (wt.%)														
	0.7	0.9	1.0	1.5	1.7	2.2	2.5	2.8	3.1	3.4	3.7	3.8	4.0	4.5	5.0
1.19	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
1.39		2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
2.97		2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
3.76		2.35	2.33	2.23	2.20	2.12	2.09	2.06	2.03	2.01	2.00	2.00	2.00	2.00	2.00
3.96			2.41	2.31	2.28	2.20	2.16	2.13	2.10	2.08	2.06	2.05	2.04	2.02	2.00
5.94				3.13	3.09	2.98	2.93	2.88	2.83	2.79	2.75	2.74	2.72	2.67	2.63
6.93					3.55	3.43	3.36	3.29	3.24	3.18	3.14	3.12	3.10	3.03	2.98
7.13						3.52	3.45	3.39	3.33	3.27	3.22	3.21	3.18	3.11	3.06
7.92							3.87	3.79	3.71	3.64	3.58	3.57	3.53	3.45	3.38
8.91								4.39	4.29	4.20	4.12	4.10	4.05	3.94	3.85
9.90									5.03	4.91	4.80	4.77	4.70	4.56	4.43
10.89										5.86	5.70	5.65	5.56	5.35	5.18
11.88											6.97	6.89	6.75	6.45	6.19
12.28												7.53	7.36	7.00	6.70

Notes:

1) The minimum cooling time is 2.0 years.
2) The burnup in GWd/FA is the assembly average burnup in GWd/MTU multiplied by the MTU of the fuel assembly.
3) Linear interpolation is allowed to obtain a cooling time within the specified range of burnup and enrichment values.
4) Extrapolation is allowed to obtain a cooling time in the gray-shaded region.
5) The peripheral locations are defined in Figure 6.

Table 21
EOS-89BTH DSC Fuel Qualification Table, All Fuel

(Minimum required years of cooling time after reactor core discharge)

Burnup (GWd/FA)	Fuel Assembly Average Initial U-235 Enrichment (wt.%)														
	0.7	0.9	1.0	1.5	1.7	2.2	2.5	2.8	3.1	3.4	3.7	3.8	4.0	4.5	5.0
1.19	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1.39		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2.97		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
3.76		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
3.96			1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
5.94				1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
6.93					1.11	1.06	1.03	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
7.13						1.09	1.06	1.03	1.00	1.00	1.00	1.00	1.00	1.00	1.00
7.92							1.17	1.14	1.11	1.08	1.06	1.05	1.04	1.00	1.00
8.91								1.28	1.25	1.22	1.19	1.18	1.16	1.12	1.09
9.90									1.40	1.36	1.33	1.32	1.30	1.25	1.21
10.89										1.51	1.48	1.46	1.44	1.39	1.34
11.88											1.63	1.62	1.59	1.53	1.48
12.28												1.68	1.66	1.60	1.54

Notes:

1) The minimum cooling time is 1.0 year.
2) The burnup in GWd/FA is the assembly average burnup in GWd/MTU multiplied by the MTU of the fuel assembly.
3) Linear interpolation is allowed to obtain a cooling time within the specified range of burnup and enrichment values.
4) Extrapolation is allowed to obtain a cooling time in the gray-shaded region.
5) For fuel transferred in the EOS-TC108, additional cooling time restrictions are specified in Figure 2.

Table 22

EOS-89BTH DSC Reconstituted Fuel Limits for Transfer in the EOS-TC125

Parameter	Limit
Number of RECONSTITUTED FUEL ASSEMBLIES per DSC	≤ 89
Maximum number of irradiated stainless steel rods per RECONSTITUTED FUEL ASSEMBLY	Per table below
Minimum cooling time	Per table below

Number of Irradiated Stainless Steel Rods per Fuel Assembly										Minimum Cooling Time (years)
7x7 Class		8x8 Class		9x9 Class		10x10 Class		11x11 Class		
Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	
0	5	0	6	0	7	0	9	0	11	Per Table 21
6	15	7	18	8	22	10	26	12	34	2.00
16	20	19	24	23	29	27	34	35	46	2.25
21	25	25	30	30	37	35	43	47	57	2.50
26	30	31	36	38	44	44	51	58	69	2.75
31	35	37	42	45	51	52	60	70	80	3.00
36	49	43	64	52	81	61	100	81	112	3.25

Table 23
EOS-89BTH DSC Reconstituted Fuel Limits for Transfer in the EOS-TC108

Parameter	Limit
Number of RECONSTITUTED FUEL ASSEMBLIES per DSC	• ≤ 89 (all types) • ≤ 49 containing irradiated stainless steel rods
Maximum number of irradiated stainless steel rods per DSC	• 100 for 7x7 Class • 120 for 8x8 Class • 140 for 9x9 Class • 180 for 10x10 Class • 220 for 11x11 Class
Maximum number of irradiated stainless steel rods per RECONSTITUTED FUEL ASSEMBLY	• 5 for 7x7 Class • 6 for 8x8 Class • 7 for 9x9 Class • 9 for 10x10 Class • 11 for 11x11 Class
Loading restrictions for locations within the basket	Per Figure 9
Minimum cooling time	Per Table 21

Table 24
EOS-37PTH DSC Reconstituted Fuel Limits for Transfer in the EOS-TC125/135 AND Storage in the EOS-HSM

Parameter	*Limit*
Number of RECONSTITUTED FUEL ASSEMBLIES per DSC	*≤ 37*
Maximum number of irradiated stainless steel rods per RECONSTITUTED FUEL ASSEMBLY	*Per table below*
Minimum cooling time	*Per table below*

Number of Irradiated Stainless Steel Rods per Fuel Assembly								*Minimum Cooling Time (years)*
14x14 Class		*15x15 Class*		*16x16 Class*		*17x17 Class*		
Min.	*Max.*	*Min.*	*Max.*	*Min.*	*Max.*	*Min.*	*Max.*	
0	*8*	*0*	*10*	*0*	*11*	*0*	*13*	*Per Table 7C*
9	*17*	*11*	*20*	*12*	*23*	*14*	*25*	*3.00*
18	*34*	*21*	*40*	*24*	*45*	*26*	*51*	*4.00*
35	*51*	*41*	*60*	*46*	*68*	*52*	*76*	*4.50*
52	*68*	*61*	*80*	*69*	*91*	*77*	*102*	*5.00*
69	*85*	*81*	*100*	*92*	*113*	*103*	*127*	*5.25*
86	*102*	*101*	*120*	*114*	*136*	*128*	*152*	*5.50*
103	*118*	*121*	*140*	*137*	*159*	*153*	*178*	*5.75*
119	*135*	*141*	*160*	*160*	*182*	*179*	*203*	*6.00*
136	*179*	*161*	*216*	*183*	*236*	*204*	*264*	*6.25*

Table 25
EOS-37PTH DSC Reconstituted Fuel Limits for Transfer in the EOS-TC108

Number of RECONSTITUTED FUEL ASSEMBLIES per DSC	- *≤ 37 (all types)* - *≤ 21 containing irradiated stainless steel rods*
Maximum number of irradiated stainless steel rods per DSC	- *32 for 14x14 Class* - *40 for 15x15 Class* - *48 for 16x16 and 17x17 Classes*
Maximum number of irradiated stainless steel rods per RECONSTITUTED FUEL ASSEMBLY	- *4 for 14x14 Class* - *5 for 15x15 Class* - *6 for 16x16 and 17x17 Classes*
Loading restrictions for locations within the basket	*Per Figure 14*
Minimum cooling time	*2 years*

Figure 1A

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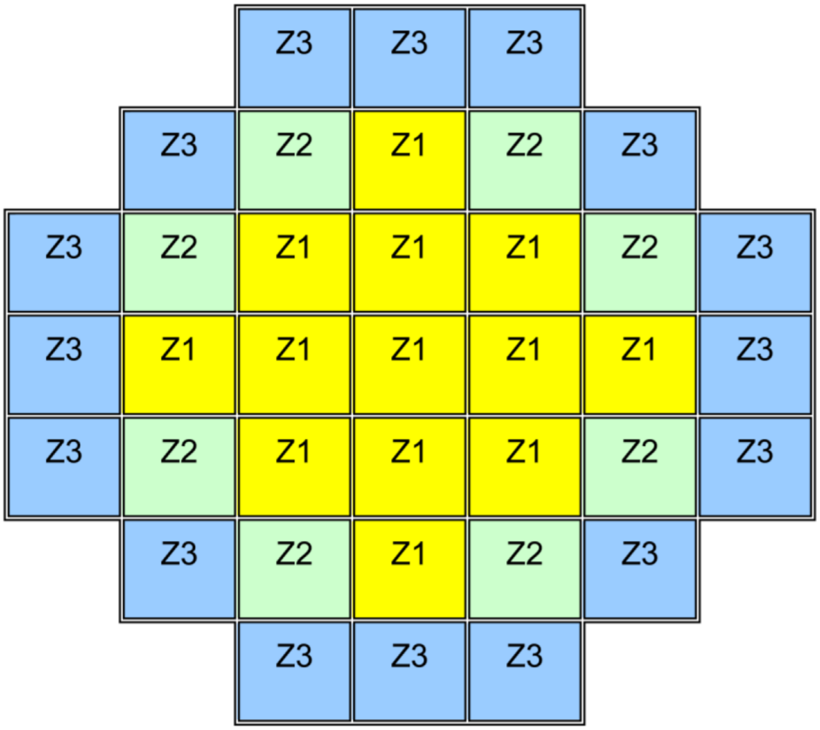
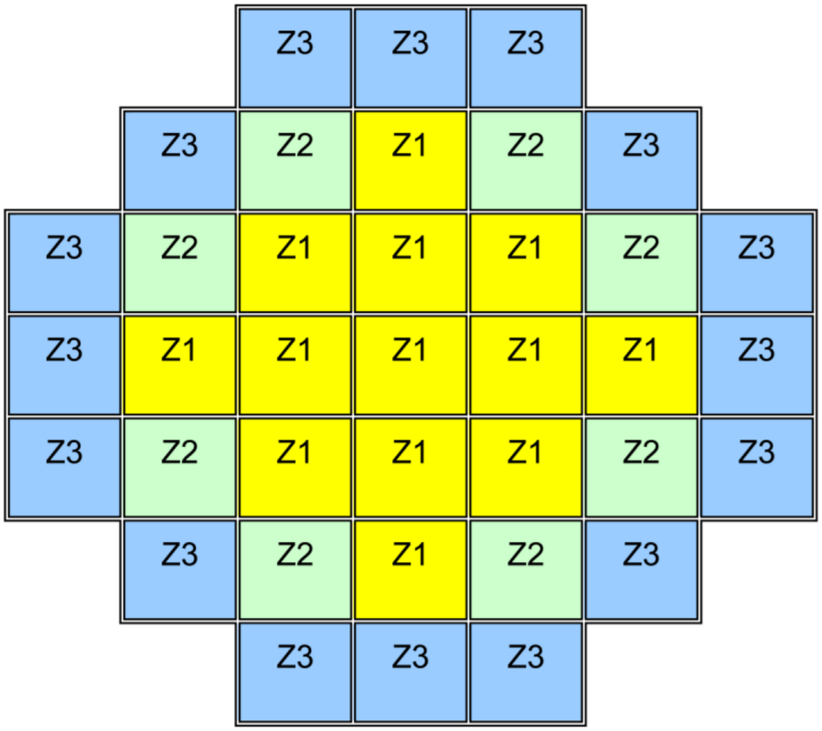


		Z3	Z3	Z3		
	Z3	Z2	Z1	Z2	Z3	
Z3	Z2	Z1	Z1	Z1	Z2	Z3
Z3	Z1	Z1	Z1	Z1	Z1	Z3
Z3	Z2	Z1	Z1	Z1	Z2	Z3
	Z3	Z2	Z1	Z2	Z3	
		Z3	Z3	Z3		

Zone Number	1	2	3
Maximum Decay Heat, (H), (kW/FA plus CCs, if included)	1.0	1.5	1.05
Maximum Number of Fuel Assemblies	13	8	16
Maximum Decay Heat per DSC (kW)	41.8		

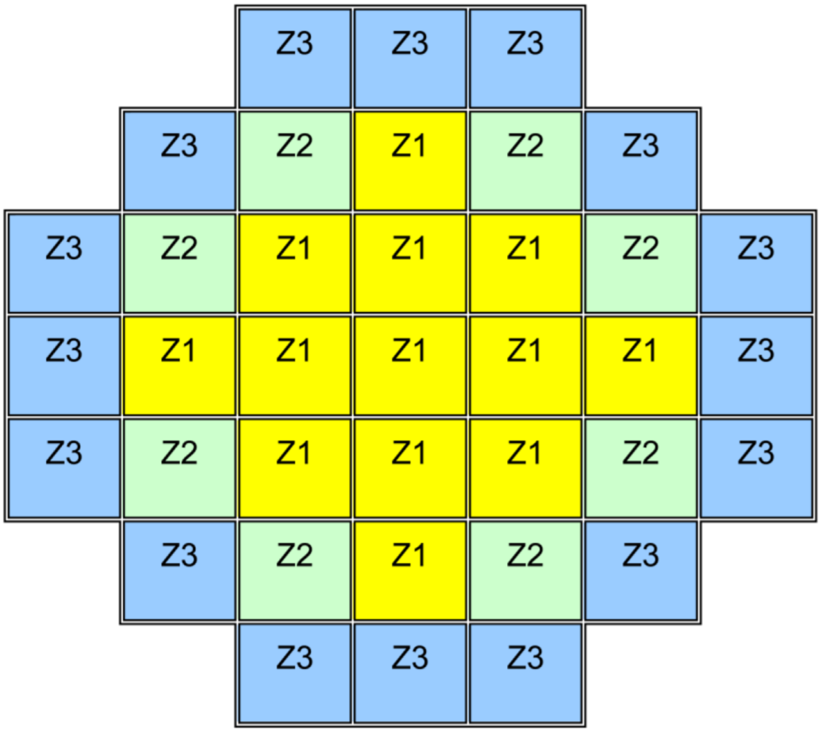
Figure 1B
Heat Load Zone Configuration 2 for the EOS-37PTH DSC



		Z3	Z3	Z3		
	Z3	Z2	Z1	Z2	Z3	
Z3	Z2	Z1	Z1	Z1	Z2	Z3
Z3	Z1	Z1	Z1	Z1	Z1	Z3
Z3	Z2	Z1	Z1	Z1	Z2	Z3
	Z3	Z2	Z1	Z2	Z3	
		Z3	Z3	Z3		

Zone Number	1	2	3
Maximum Decay Heat (kW/FA plus CCs, if included)	0.95	1.0	1.0
Maximum Number of Fuel Assemblies	13	8	16
Maximum Decay Heat per DSC (kW)	36.35		

Figure 1C
Heat Load Zone Configuration 3 for the EOS-37PTH DSC

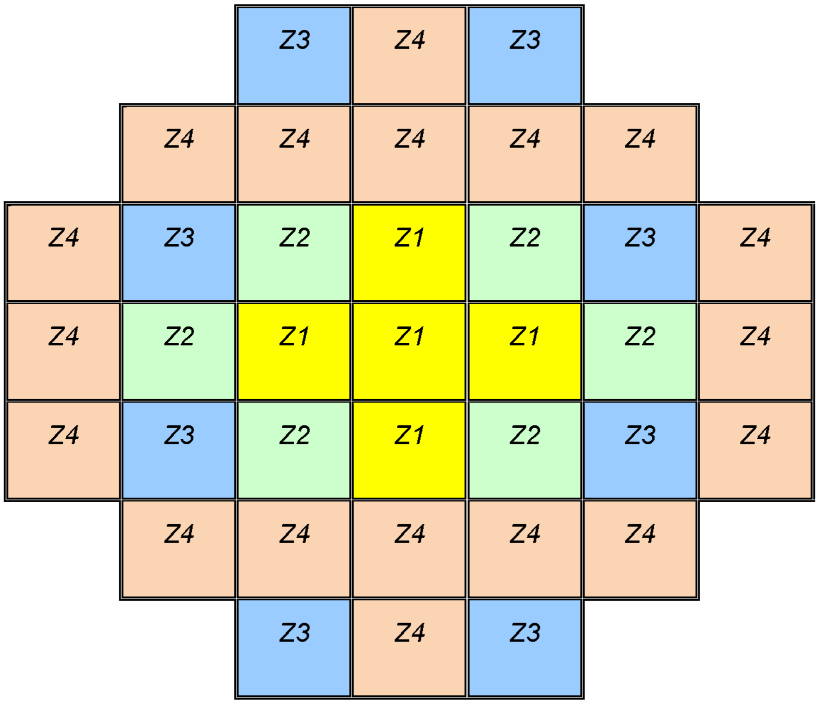


Zone Number	1	2	3
Maximum Decay Heat (kW/FA plus CCs, if included)	1.0	1.625	1.6
Maximum Number of Fuel Assemblies	13	8	16
Maximum Decay Heat per DSC (kW)	50.0(1)		

Notes:

1. Adjust payload to maintain total canister heat load within the specified limit.

Figure 1D
Heat Load Zone Configuration 4 for the EOS-37PTH DSC



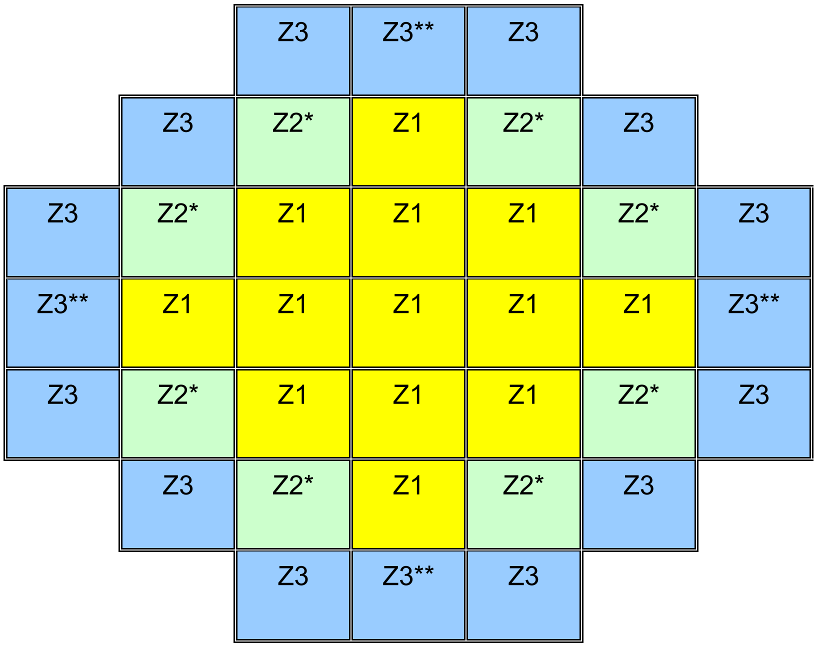
		Z3	Z4	Z3		
	Z4	Z4	Z4	Z4	Z4	
Z4	Z3	Z2	Z1	Z2	Z3	Z4
Z4	Z2	Z1	Z1	Z1	Z2	Z4
Z4	Z3	Z2	Z1	Z2	Z3	Z4
	Z4	Z4	Z4	Z4	Z4	
		Z3	Z4	Z3		

Zone Number	1	2	3	4
Maximum Decay Heat (kW/FA plus CCs, if included)	0.7	0.5	2.4	0.85
Maximum Number of Fuel Assemblies	5	6	8	18
Maximum Decay Heat per DSC (kW)	41.0			

Notes:

1. Adjust payload to maintain total canister heat load within the specified limit.

Figure 1E
Heat Load Zone Configuration 5 for the EOS-37PTH DSC



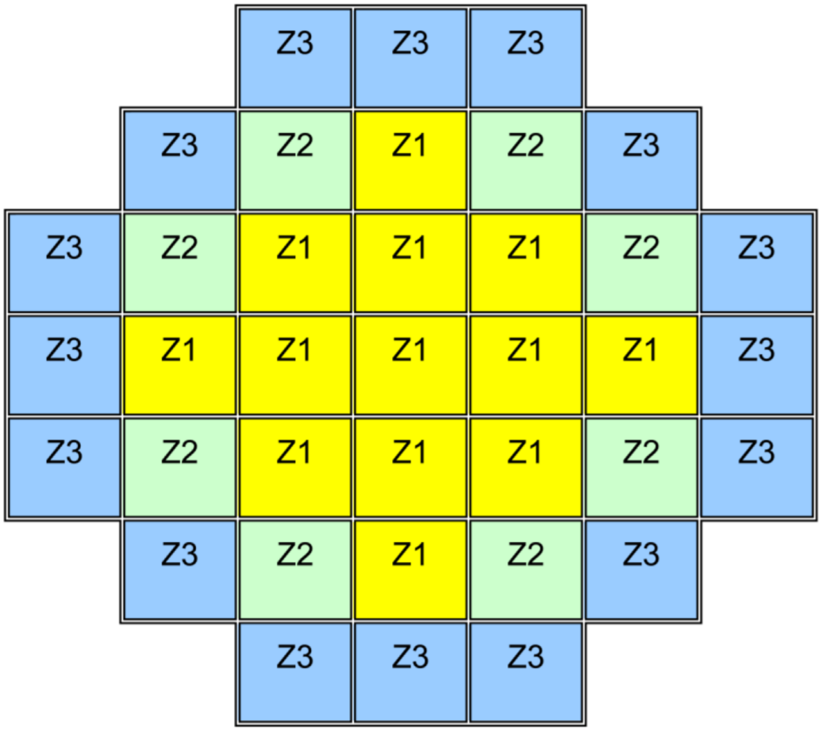
		Z3	Z3**	Z3		
	Z3	Z2*	Z1	Z2*	Z3	
Z3	Z2*	Z1	Z1	Z1	Z2*	Z3
Z3**	Z1	Z1	Z1	Z1	Z1	Z3**
Z3	Z2*	Z1	Z1	Z1	Z2*	Z3
	Z3	Z2*	Z1	Z2*	Z3	
		Z3	Z3**	Z3		

(*) 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)	1.0	1.5	1.3125(2)
Maximum Number of Fuel Assemblies	13	8	16
Maximum Decay Heat per DSC (kW)	46.00		

1. DAMAGED FUEL and FAILED FUEL shall not be loaded in the same DSC.
2. The maximum allowable heat load per FAILED FUEL compartment is 0.8 kW.

Figure 1F
Heat Load Zone Configuration 6 for the EOS-37PTH DSC



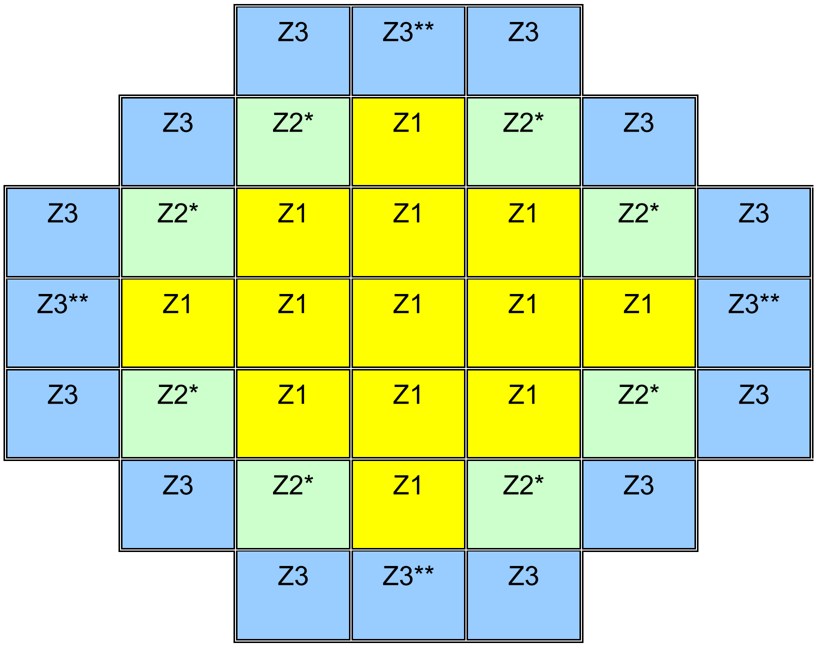
		Z3	Z3	Z3		
	Z3	Z2	Z1	Z2	Z3	
Z3	Z2	Z1	Z1	Z1	Z2	Z3
Z3	Z1	Z1	Z1	Z1	Z1	Z3
Z3	Z2	Z1	Z1	Z1	Z2	Z3
	Z3	Z2	Z1	Z2	Z3	
		Z3	Z3	Z3		

Zone Number	1	2	3
Maximum Number of Fuel Assemblies	13	8	16
Upper Compartment			
Maximum Decay Heat (kW/FA plus CCs, if included)	1.0	1.60	1.3125
Maximum Decay Heat per DSC (kW)	41.8(1)		
Lower Compartment			
Maximum Decay Heat (kW/FA plus CCs, if included)	0.9	1.60	1.60
Maximum Decay Heat per DSC (kW)	50.0(1)		

Notes:

1. Adjust payload to maintain total canister heat load within the specified limit.

Figure 1G
Heat Load Zone Configuration 7 for the EOS-37PTH DSC



		Z3	Z3**	Z3		
	Z3	Z2*	Z1	Z2*	Z3	
Z3	Z2*	Z1	Z1	Z1	Z2*	Z3
Z3**	Z1	Z1	Z1	Z1	Z1	Z3**
Z3	Z2*	Z1	Z1	Z1	Z2*	Z3
	Z3	Z2*	Z1	Z2*	Z3	
		Z3	Z3**	Z3		

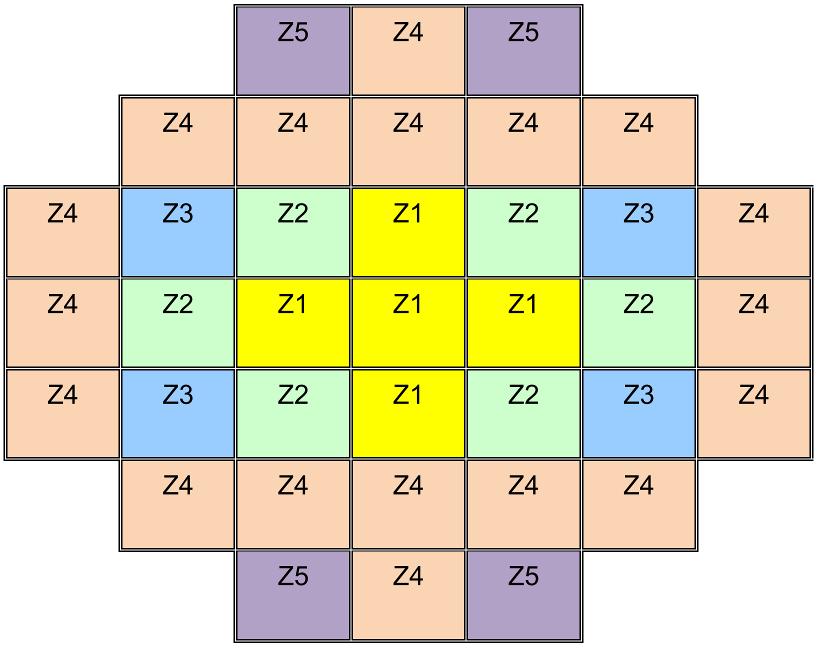
(*) denotes location where INTACT or DAMAGED FUEL can be stored.
(**) denotes location where INTACT or FAILED FUEL can be stored.

Zone Number	1	2(2)	3(2)(3)
Maximum Number of Fuel Assemblies	13	8	16
Upper Compartment			
Maximum Decay Heat (kW/FA plus CCs, if included)	0.8	1.50	1.50
Maximum Decay Heat per DSC (kW)	41.8(1)(4)		
Lower Compartment			
Maximum Decay Heat (kW/FA plus CCs, if included)	0.8	1.50	1.50
Maximum Decay Heat per DSC (kW)	46.4(1)		

Notes:

1. The maximum decay heat per DSC is limited to 41.8 kW when DAMAGED or FAILED FUEL is loaded.
2. DAMAGED FUEL and FAILED FUEL shall not be loaded in the same DSC.
3. The maximum allowable heat load per FAILED FUEL is 0.8 kW.
4. Adjust payload to maintain total canister heat load within the specified limit.

Figure 1H
Heat Load Zone Configuration 8 for the EOS-37PTH DSC



		Z5	Z4	Z5		
	Z4	Z4	Z4	Z4	Z4	
Z4	Z3	Z2	Z1	Z2	Z3	Z4
Z4	Z2	Z1	Z1	Z1	Z2	Z4
Z4	Z3	Z2	Z1	Z2	Z3	Z4
	Z4	Z4	Z4	Z4	Z4	
		Z5	Z4	Z5		

Zone Number	1	2	3	4	5
Maximum Decay Heat (kW/FA plus CCs, if included)	0.50	0.70	2.0	0.75	2.4
Maximum Number of Fuel Assemblies	5	6	4	18	4
Maximum Decay Heat per DSC (kW)	37.80				

Figure 1I
Heat Load Zone Configuration 9 for the EOS-37PTH DSC

Figure 1J
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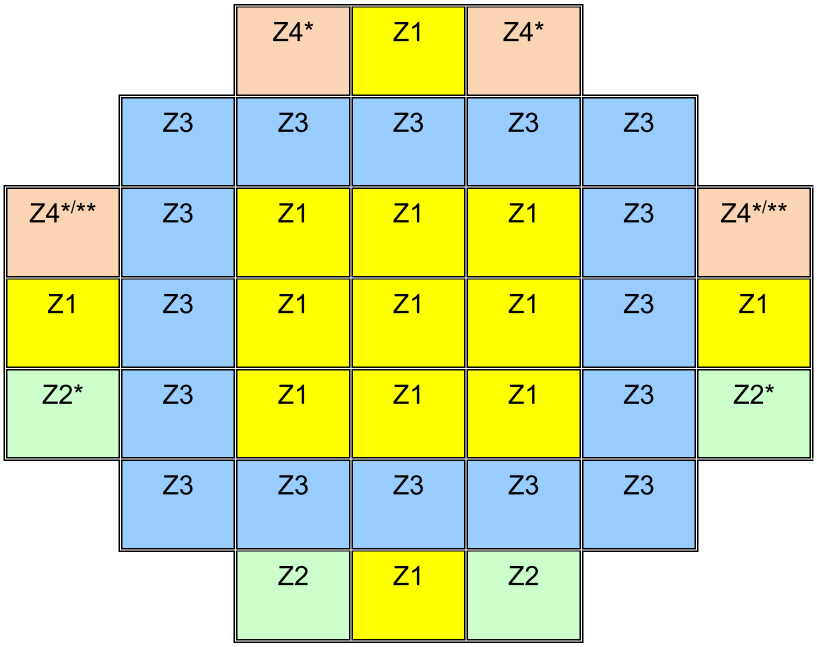


		Z4*	Z1	Z4*		
	Z3	Z3	Z3	Z3	Z3	
Z4$^{*/**}$	Z3	Z1	Z1	Z1	Z3	Z4$^{*/**}$
Z1	Z3	Z1	Z1	Z1	Z3	Z1
Z2*	Z3	Z1	Z1	Z1	Z3	Z2*
	Z3	Z3	Z3	Z3	Z3	
		Z2	Z1	Z2		

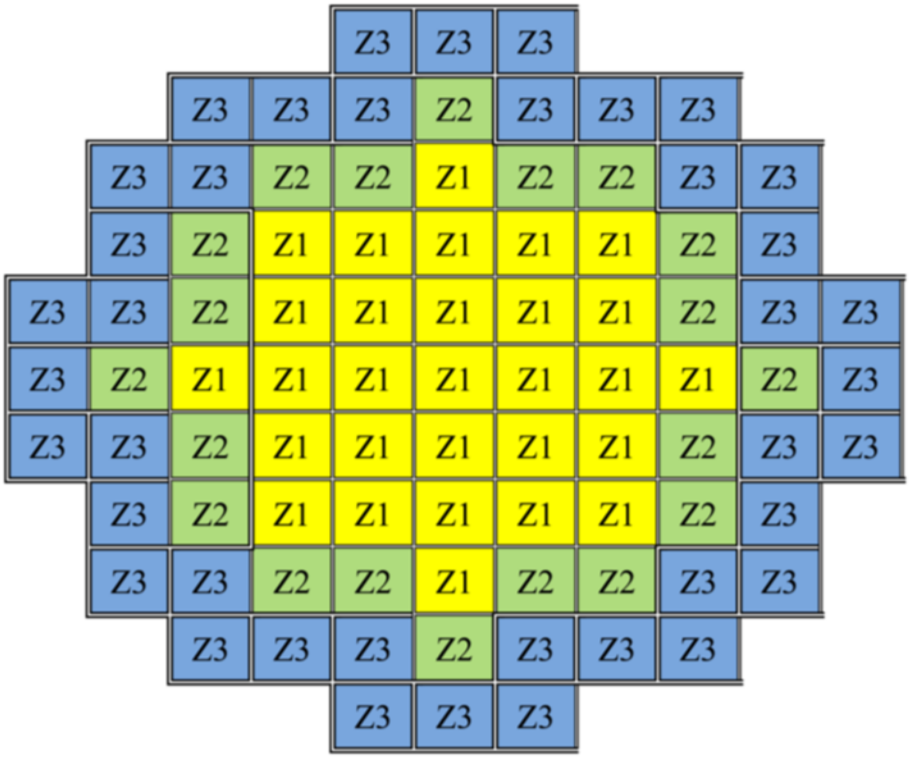
(*) denotes location where INTACT or DAMAGED FUEL ASSEMBLY can be stored.
(**) denotes location where INTACT or FAILED FUEL can be stored.

Zone Number	1	2(1)	3	4(1)
Maximum Number of Fuel Assemblies	13	4	16	4
Upper Compartment				
Maximum Decay Heat (kW/FA plus CCs, if included)	0.5	3.0	0.7	3.0(2)
Maximum Decay Heat per DSC (kW)	41.8			
Lower Compartment				
Maximum Decay Heat (kW/FA plus CCs, if included)	0.5	3.5	0.7	3.2(2)
Maximum Decay Heat per DSC (kW)	44.5			

Notes:

1. DAMAGED FUEL and FAILED FUEL shall not be loaded in the same DSC.
2. The maximum allowable heat load per FAILED FUEL is 0.8 kW.

Figure 1K
Heat Load Zone Configuration 11 for the EOS-37PTH DSC



Z3 Z3 Z3
Z3 Z3 Z3 Z2 Z3 Z3 Z3
Z3 Z3 Z2 Z2 Z1 Z2 Z2 Z3 Z3
Z3 Z2 Z1 Z1 Z1 Z1 Z1 Z2 Z3
Z3 Z3 Z2 Z1 Z1 Z1 Z1 Z1 Z2 Z3 Z3
Z3 Z2 Z1 Z1 Z1 Z1 Z1 Z1 Z1 Z2 Z3
Z3 Z3 Z2 Z1 Z1 Z1 Z1 Z1 Z2 Z3 Z3
Z3 Z2 Z1 Z1 Z1 Z1 Z1 Z2 Z3
Z3 Z3 Z2 Z2 Z1 Z2 Z2 Z3 Z3
Z3 Z3 Z3 Z2 Z3 Z3 Z3
Z3 Z3 Z3

Heat Load Zone Configuration 2

Zone Number	1	2	3(1)
Maximum Decay Heat (kW/FA plus channel, if included)	0.4	0.5	0.5
Maximum Number of Fuel Assemblies	29	20	40
Maximum Decay Heat per DSC (kW)	41.6		

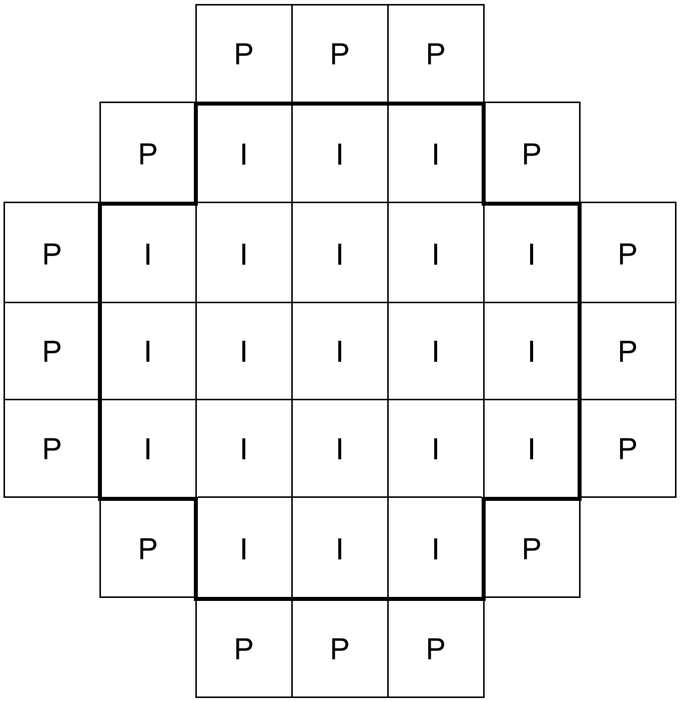
Heat Load Zone Configuration 3

Zone Number	1	2	3(2)
Maximum Decay Heat (kW/FA plus channel, if included)	0.36	0.4	0.4
Maximum Number of Fuel Assemblies	29	20	40
Maximum Decay Heat per DSC (kW)	34.44		

Notes:

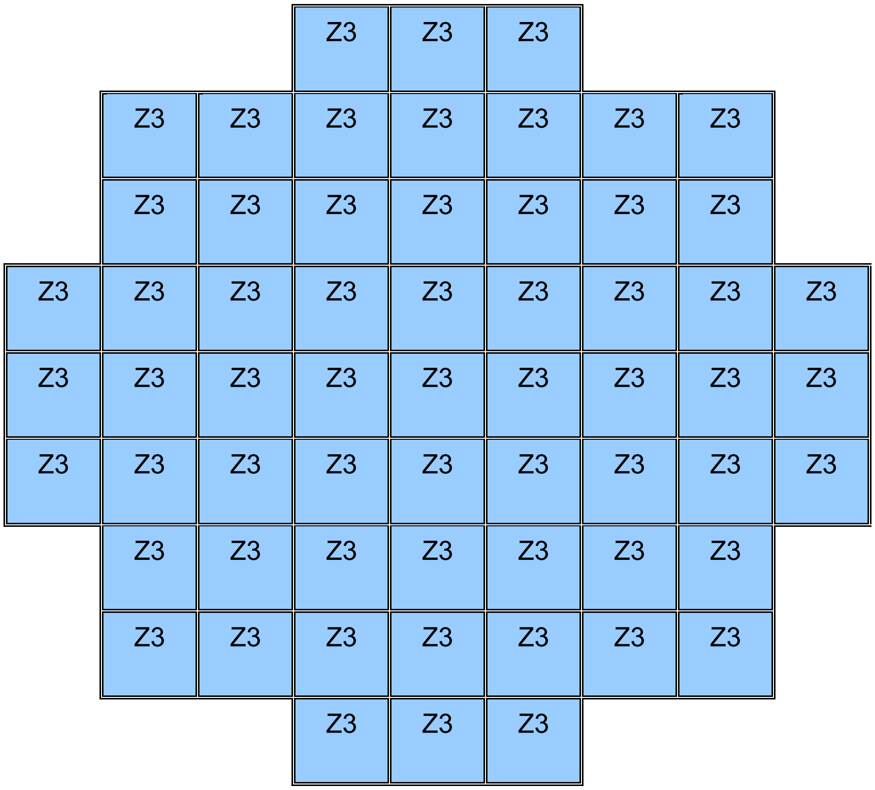
1. The minimum cooling time for HLZC 2 Zone 3 in the EOS-TC108 is 9.7 years.
2. The minimum cooling time for HLZC 3 Zone 3 in the EOS-TC108 is 9.0 years.

Figure 2
EOS-89BTH DSC Heat Load Zone Configurations for transfer in the EOS-TC108



		P	P	P		
	P	I	I	I	P	
P	I	I	I	I	I	P
P	I	I	I	I	I	P
P	I	I	I	I	I	P
	P	I	I	I	P	
		P	P	P		

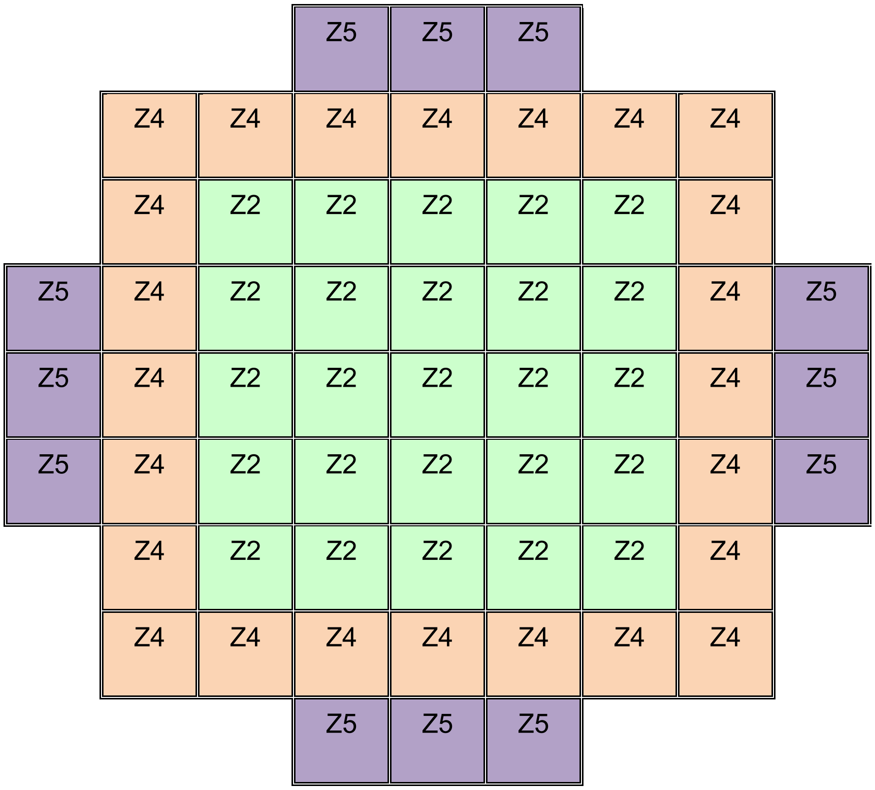
Figure 3
Peripheral (P) and Inner (I) Fuel Locations for the EOS-37PTH DSC



Z3 Z3 Z3
Z3 Z3 Z3 Z3 Z3 Z3 Z3
Z3 Z3 Z3 Z3 Z3 Z3 Z3
Z3 Z3 Z3 Z3 Z3 Z3 Z3 Z3 Z3
Z3 Z3 Z3 Z3 Z3 Z3 Z3 Z3 Z3
Z3 Z3 Z3 Z3 Z3 Z3 Z3 Z3 Z3
Z3 Z3 Z3 Z3 Z3 Z3 Z3
Z3 Z3 Z3 Z3 Z3 Z3 Z3
Z3 Z3 Z3

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Maximum Decay Heat (kW/FA)	NA	NA	0.393	NA	NA	NA
Maximum Decay Heat per Zone (kW)	NA	NA	22.0	NA	NA	NA
Maximum Decay Heat per DSC (kW)	22.0					

Figure 4A
Heat Load Zone Configuration 1 for the 61BTH Type 2 DSC

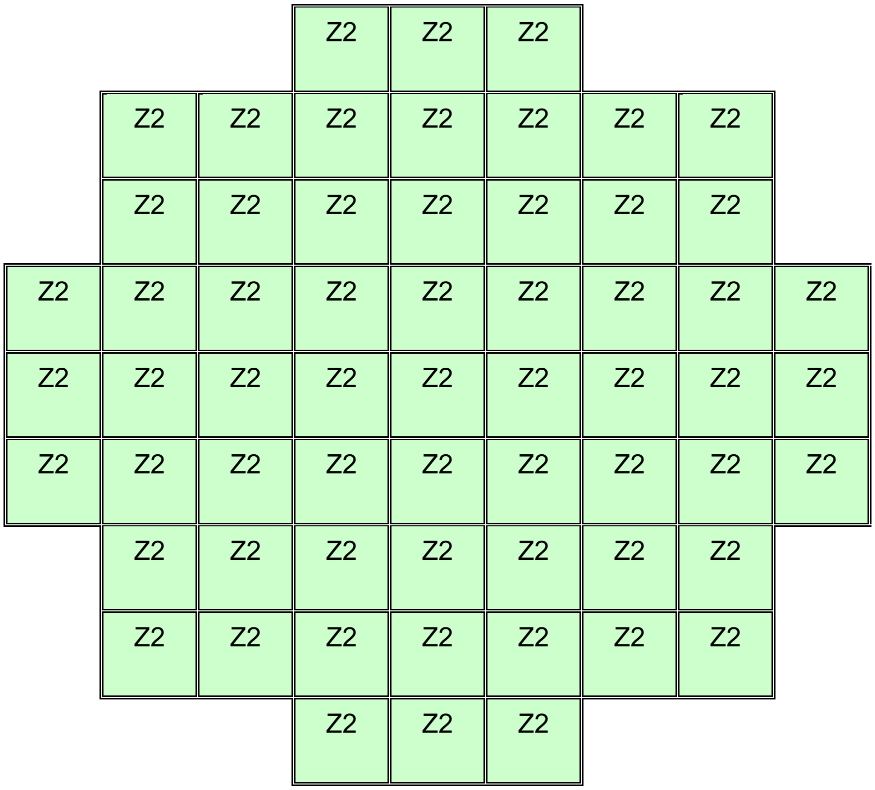


			Z5	Z5	Z5			
	Z4	Z4	Z4	Z4	Z4	Z4	Z4	
	Z4	Z2	Z2	Z2	Z2	Z2	Z4	
Z5	Z4	Z2	Z2	Z2	Z2	Z2	Z4	Z5
Z5	Z4	Z2	Z2	Z2	Z2	Z2	Z4	Z5
Z5	Z4	Z2	Z2	Z2	Z2	Z2	Z4	Z5
	Z4	Z2	Z2	Z2	Z2	Z2	Z4	
	Z4	Z4	Z4	Z4	Z4	Z4	Z4	
			Z5	Z5	Z5			

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Maximum Decay Heat (kW/FA)	NA	0.35	NA	0.48	0.54	NA
Maximum Decay Heat per Zone (kW)	NA	8.75	NA	11.52	6.48	NA
Maximum Decay Heat per DSC (kW)	22.0(1)					

(1) Adjust payload to maintain total DSC heat load within the specified limit

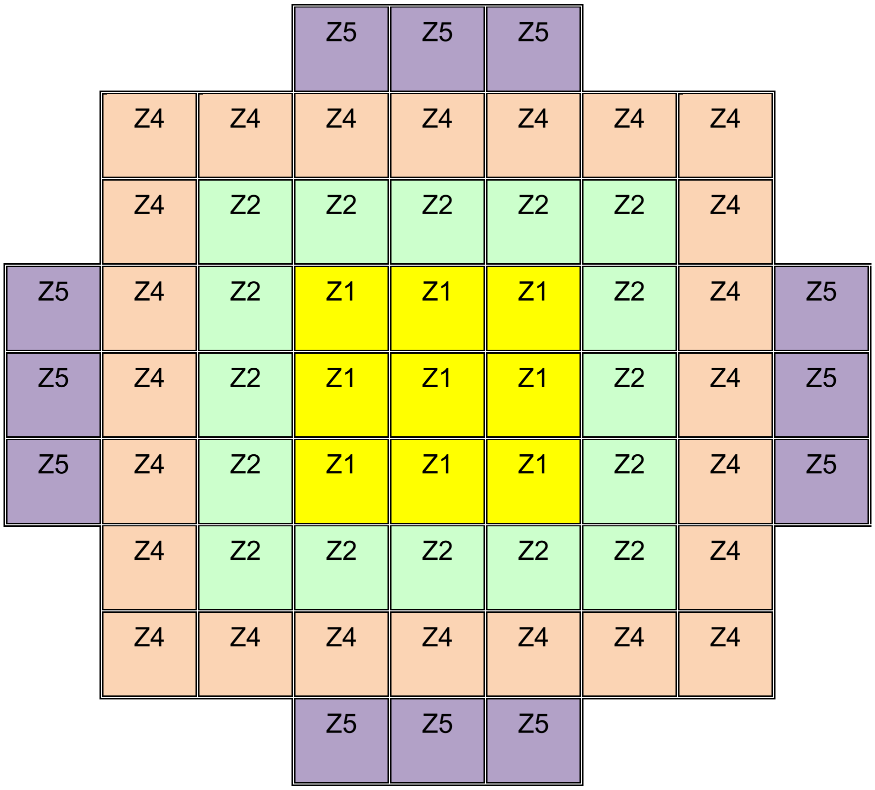
Figure 4B
Heat Load Zone Configuration 2 for the 61BTH Type 2 DSC



			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	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			

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Maximum Decay Heat (kW/FA)	NA	0.35	NA	NA	NA	NA
Maximum Decay Heat per Zone (kW)	NA	19.4	NA	NA	NA	NA
Maximum Decay Heat per DSC (kW)	19.4					

Figure 4C
Heat Load Zone Configuration 3 for the 61BTH Type 2 DSC

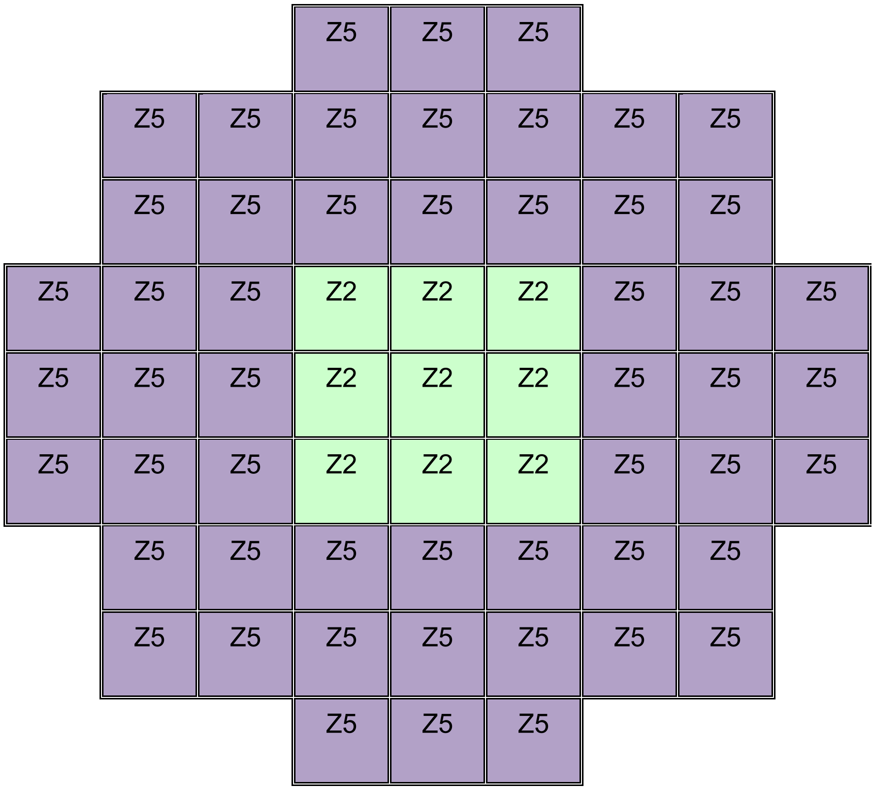


			Z5	Z5	Z5			
	Z4	Z4	Z4	Z4	Z4	Z4	Z4	
	Z4	Z2	Z2	Z2	Z2	Z2	Z4	
Z5	Z4	Z2	Z1	Z1	Z1	Z2	Z4	Z5
Z5	Z4	Z2	Z1	Z1	Z1	Z2	Z4	Z5
Z5	Z4	Z2	Z1	Z1	Z1	Z2	Z4	Z5
	Z4	Z2	Z2	Z2	Z2	Z2	Z4	
	Z4	Z4	Z4	Z4	Z4	Z4	Z4	
			Z5	Z5	Z5			

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Maximum Decay Heat (kW/FA)	0.22	0.35	NA	0.48	0.54	NA
Maximum Decay Heat per Zone (kW)	1.98	5.60	NA	11.52	6.48	NA
Maximum Decay Heat per DSC (kW)	19.4(1)					

(1) Adjust payload to maintain total DSC heat load within the specified limit.

Figure 4D
Heat Load Zone Configuration 4 for the 61BTH Type 2 DSC

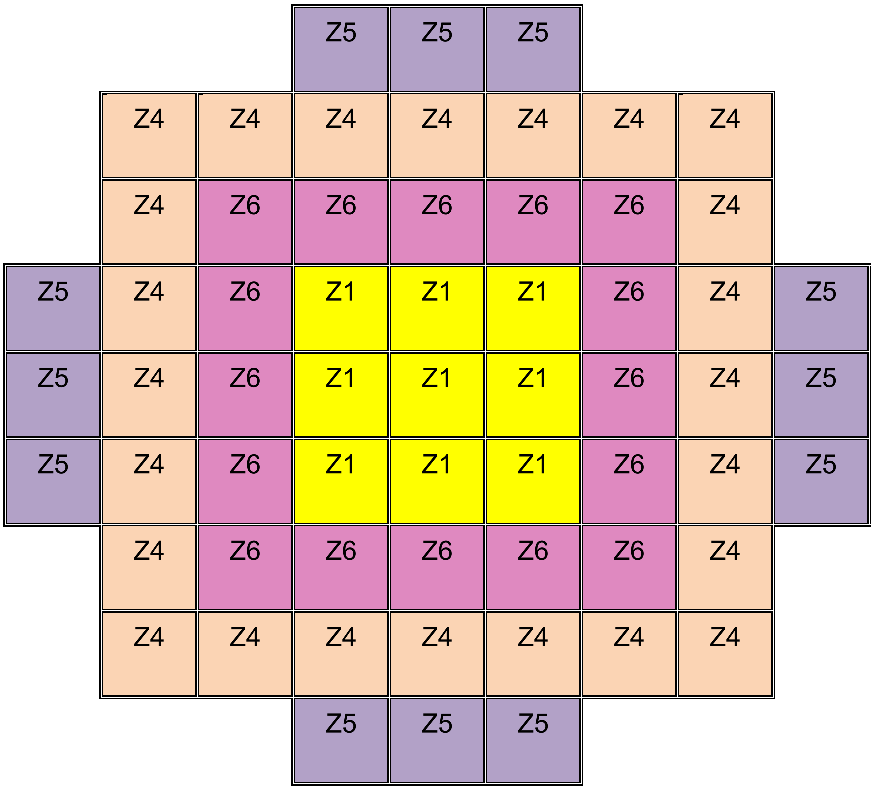


			Z5	Z5	Z5			
	Z5	Z5	Z5	Z5	Z5	Z5	Z5	
	Z5	Z5	Z5	Z5	Z5	Z5	Z5	
Z5	Z5	Z5	Z2	Z2	Z2	Z5	Z5	Z5
Z5	Z5	Z5	Z2	Z2	Z2	Z5	Z5	Z5
Z5	Z5	Z5	Z2	Z2	Z2	Z5	Z5	Z5
	Z5	Z5	Z5	Z5	Z5	Z5	Z5	
	Z5	Z5	Z5	Z5	Z5	Z5	Z5	
			Z5	Z5	Z5			

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Maximum Decay Heat (kW/FA)	NA	0.35	NA	NA	0.54	NA
Maximum Decay Heat per Zone (kW)	NA	3.15	NA	NA	28.08	NA
Maximum Decay Heat per DSC (kW)	31.2(1)					

(1) Adjust payload to maintain total DSC heat load within the specified limit.

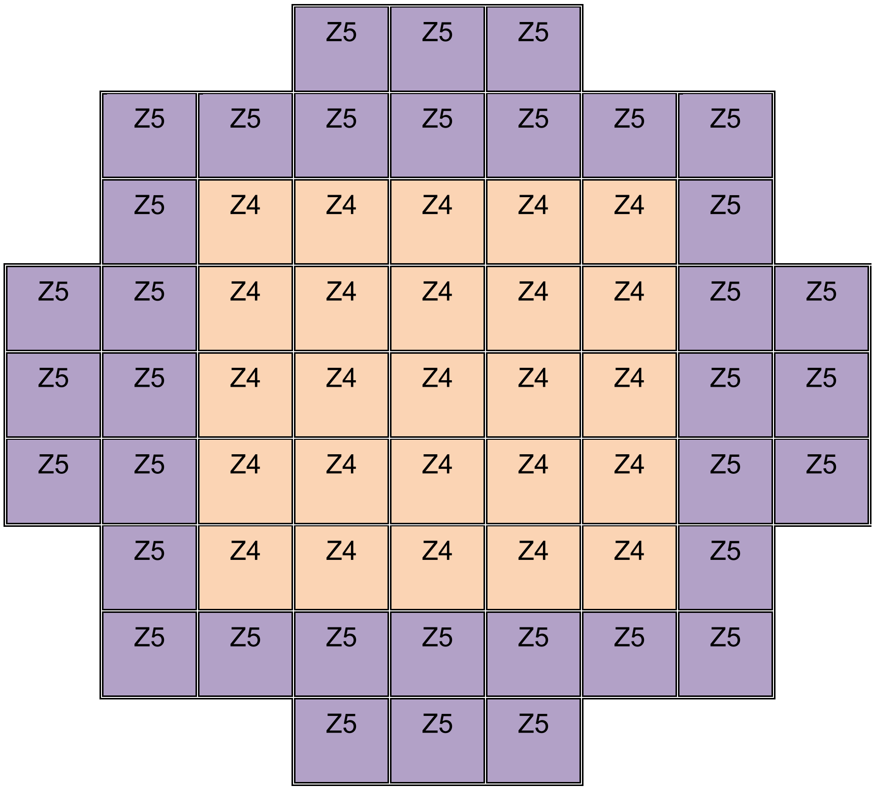
Figure 4E
Heat Load Zone Configuration 5 for the 61BTH Type 2 DSC



			Z5	Z5	Z5			
	Z4	Z4	Z4	Z4	Z4	Z4	Z4	
	Z4	Z6	Z6	Z6	Z6	Z6	Z4	
Z5	Z4	Z6	Z1	Z1	Z1	Z6	Z4	Z5
Z5	Z4	Z6	Z1	Z1	Z1	Z6	Z4	Z5
Z5	Z4	Z6	Z1	Z1	Z1	Z6	Z4	Z5
	Z4	Z6	Z6	Z6	Z6	Z6	Z4	
	Z4	Z4	Z4	Z4	Z4	Z4	Z4	
			Z5	Z5	Z5			

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Maximum Decay Heat (kW/FA)	0.22	NA	NA	0.48	0.54	0.70
Maximum Decay Heat per Zone (kW)	1.98	NA	NA	11.52	6.48	11.20
Maximum Decay Heat per DSC (kW)	31.2					

Figure 4F
Heat Load Zone Configuration 6 for the 61BTH Type 2 DSC

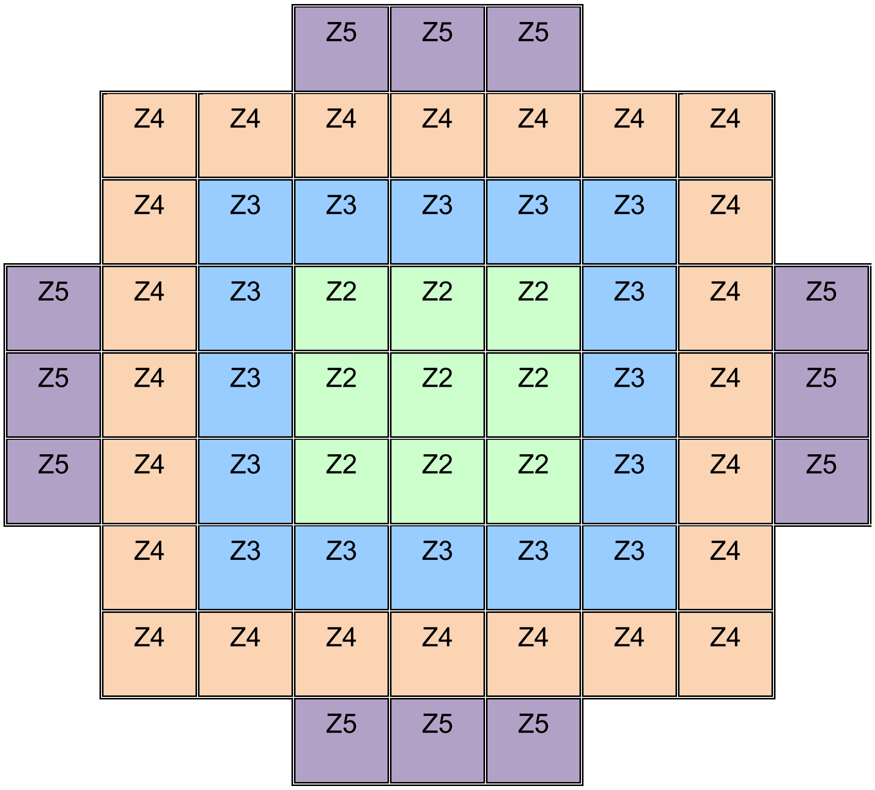


			Z5	Z5	Z5			
	Z5	Z5	Z5	Z5	Z5	Z5	Z5	
	Z5	Z4	Z4	Z4	Z4	Z4	Z5	
Z5	Z5	Z4	Z4	Z4	Z4	Z4	Z5	Z5
Z5	Z5	Z4	Z4	Z4	Z4	Z4	Z5	Z5
Z5	Z5	Z4	Z4	Z4	Z4	Z4	Z5	Z5
	Z5	Z4	Z4	Z4	Z4	Z4	Z5	
	Z5	Z5	Z5	Z5	Z5	Z5	Z5	
			Z5	Z5	Z5			

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Maximum Decay Heat (kW/FA)	NA	NA	NA	0.48	0.54	NA
Maximum Decay Heat per Zone (kW)	NA	NA	NA	12.00	19.44	NA
Maximum Decay Heat per DSC (kW)	31.2(1)					

(1) Adjust payload to maintain total DSC heat load within the specified limit.

Figure 4G
Heat Load Zone Configuration 7 for the 61BTH Type 2 DSC

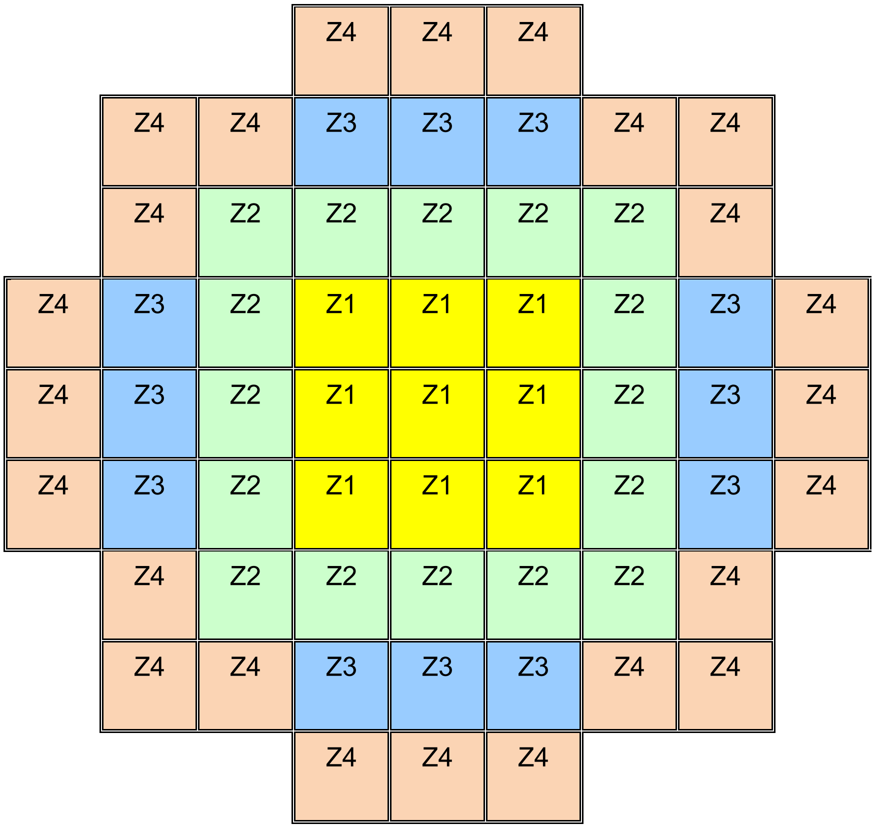


			Z5	Z5	Z5			
	Z4	Z4	Z4	Z4	Z4	Z4	Z4	
	Z4	Z3	Z3	Z3	Z3	Z3	Z4	
Z5	Z4	Z3	Z2	Z2	Z2	Z3	Z4	Z5
Z5	Z4	Z3	Z2	Z2	Z2	Z3	Z4	Z5
Z5	Z4	Z3	Z2	Z2	Z2	Z3	Z4	Z5
	Z4	Z3	Z3	Z3	Z3	Z3	Z4	
	Z4	Z4	Z4	Z4	Z4	Z4	Z4	
			Z5	Z5	Z5			

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Maximum Decay Heat (kW/FA)	NA	0.35	0.393	0.48	0.54	NA
Maximum Decay Heat per Zone (kW)	NA	3.15	6.288	11.52	6.48	NA
Maximum Decay Heat per DSC (kW)	27.4(1)					

(1) Adjust payload to maintain total DSC heat load within the specified limit.

Figure 4H
Heat Load Zone Configuration 8 for the 61BTH Type 2 DSC

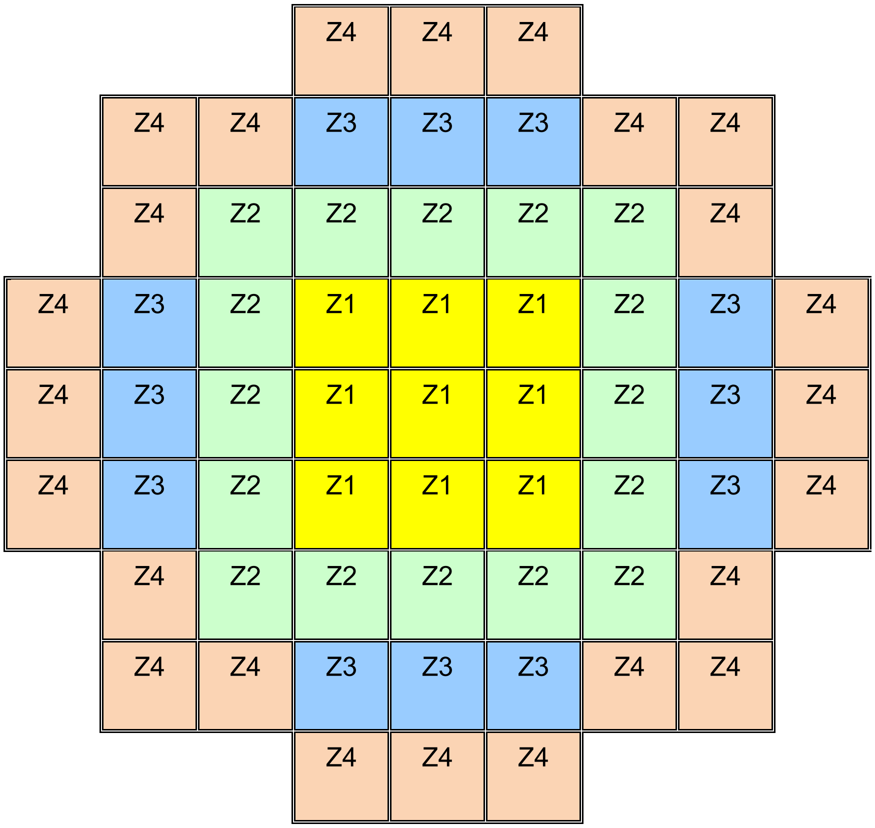


			Z4	Z4	Z4			
	Z4	Z4	Z3	Z3	Z3	Z4	Z4	
	Z4	Z2	Z2	Z2	Z2	Z2	Z4	
Z4	Z3	Z2	Z1	Z1	Z1	Z2	Z3	Z4
Z4	Z3	Z2	Z1	Z1	Z1	Z2	Z3	Z4
Z4	Z3	Z2	Z1	Z1	Z1	Z2	Z3	Z4
	Z4	Z2	Z2	Z2	Z2	Z2	Z4	
	Z4	Z4	Z3	Z3	Z3	Z4	Z4	
			Z4	Z4	Z4			

	Zone 1	Zone 2	Zone 3	Zone 4
Maximum Decay Heat (kW/FA)	0.393	0.48	0.35	0.35
Maximum Decay Heat per Zone (kW)	3.54	7.68	4.2	8.4
Maximum Decay Heat per DSC (kW)	22.0(1)			

Note 1: Adjust payload to maintain total canister heat load within the specified limit.

Figure 4I
Heat Load Zone Configuration 9 for the 61BTH Type 2 DSC



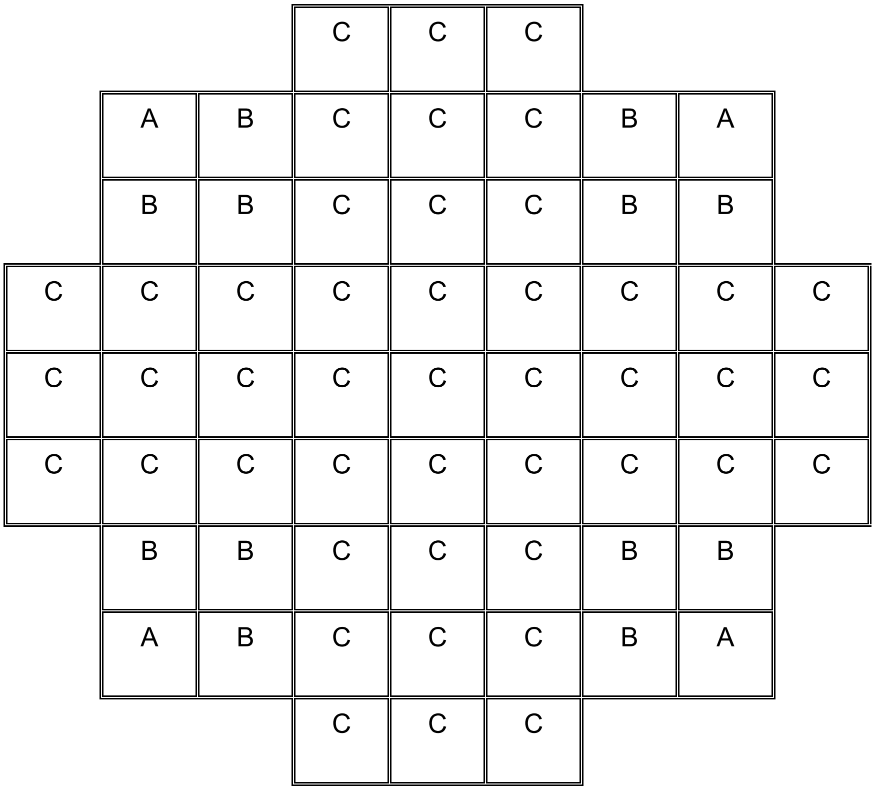
			Z4	Z4	Z4			
	Z4	Z4	Z3	Z3	Z3	Z4	Z4	
	Z4	Z2	Z2	Z2	Z2	Z2	Z4	
Z4	Z3	Z2	Z1	Z1	Z1	Z2	Z3	Z4
Z4	Z3	Z2	Z1	Z1	Z1	Z2	Z3	Z4
Z4	Z3	Z2	Z1	Z1	Z1	Z2	Z3	Z4
	Z4	Z2	Z2	Z2	Z2	Z2	Z4	
	Z4	Z4	Z3	Z3	Z3	Z4	Z4	
			Z4	Z4	Z4			

	Zone 1	Zone 2	Zone 3	Zone 4
Maximum Decay Heat (kW/FA)	0.393	0.48$^{(2)}$	1.20$^{(2)}$	0.48$^{(2)}$
Maximum Decay Heat per Zone (kW)	3.54	7.68	14.4	11.52
Maximum Decay Heat per DSC (kW)	31.2$^{(1)}$			

Note 1: Adjust payload to maintain total canister heat load within the specified limit.

Note 2: If the maximum decay heat per FA in Zone 3 is greater than 0.9 kW, the maximum decay heat per FA in Zone 2 and Zone 4 shall be less than or equal to 0.393 kW.

Figure 4J
Heat Load Zone Configuration 10 for the 61BTH Type 2 DSC



			C	C	C			
	A	B	C	C	C	B	A	
	B	B	C	C	C	B	B	
C	C	C	C	C	C	C	C	C
C	C	C	C	C	C	C	C	C
C	C	C	C	C	C	C	C	C
	B	B	C	C	C	B	B	
	A	B	C	C	C	B	A	
			C	C	C			

A	Corner Locations See Note 1
C	Interior/Edge Locations See Note 3

B	Interior Locations See Note 2

Note 1: When loading up to 4 damaged or 4 failed assemblies, these must be placed in corner “A” locations, and the remaining locations “B” and “C” shall be loaded with intact fuel. If fewer than 4 damaged or 4 failed assemblies are to be stored, the remaining “A” locations may be loaded with intact fuel provided they meet the respective damaged or failed enrichment limits of Table 10 or Table 11. Damaged and failed fuel shall not be mixed, i.e., up to four damaged assemblies may be stored, or up to four failed assemblies may be stored in “A” locations.

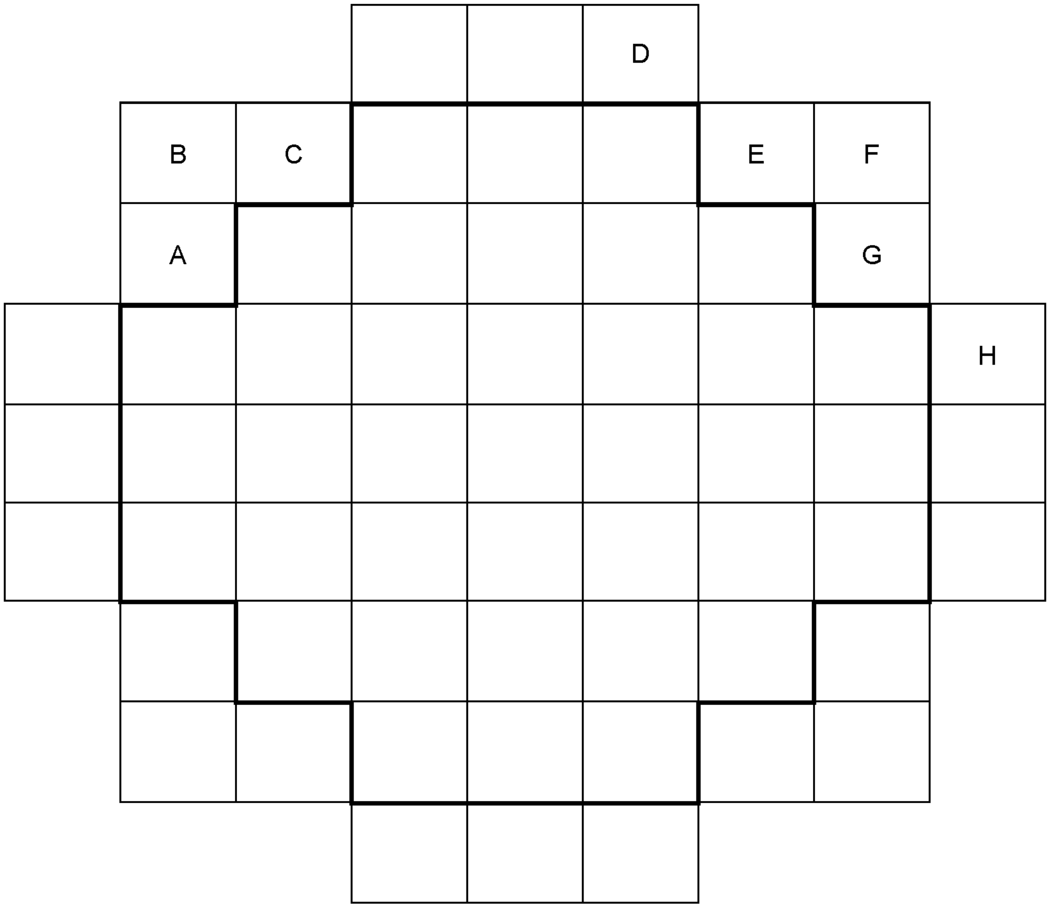
Note 2: If loading more than four damaged assemblies, place first four damaged assemblies in the corner “A” locations per Note 1, and up to 12 additional damaged assemblies in these interior “B” locations, with the remaining intact in a 61BTH Type 2 Basket. The maximum lattice average initial enrichment of assemblies (damaged or intact stored in the 2x2 cells) is limited to the “Five or More Damaged Assemblies” column of Table 10. For the 61BTH Type 2 DSC containing both damaged and failed fuel assemblies, this enrichment is limited to the “and up to 12 Damaged Assemblies” column of Table 11.

Note 3: If loading more than 16 damaged assemblies, place the first 57 damaged assemblies in the interior/edge "C" and the interior “B” locations. Place the remaining four intact or damaged assemblies in the corner "A" locations. The maximum lattice average initial enrichments of assemblies is limited to the “Remaining Four Intact Assemblies” or “Remaining Four Damaged Assemblies” column of Table 12.

Figure 5
Location of Damaged and Failed Fuel Assemblies inside the 61BTH Type 2 DSC

			P	P	P			
	P	P	I	I	I	P	P	
	P	I	I	I	I	I	P	
P	I	I	I	I	I	I	I	P
P	I	I	I	I	I	I	I	P
P	I	I	I	I	I	I	I	P
	P	I	I	I	I	I	P	
	P	P	I	I	I	P	P	
			P	P	P			

Figure 6
Peripheral (P) and Inner (I) Fuel Locations for the 61BTH Type 2 DSC

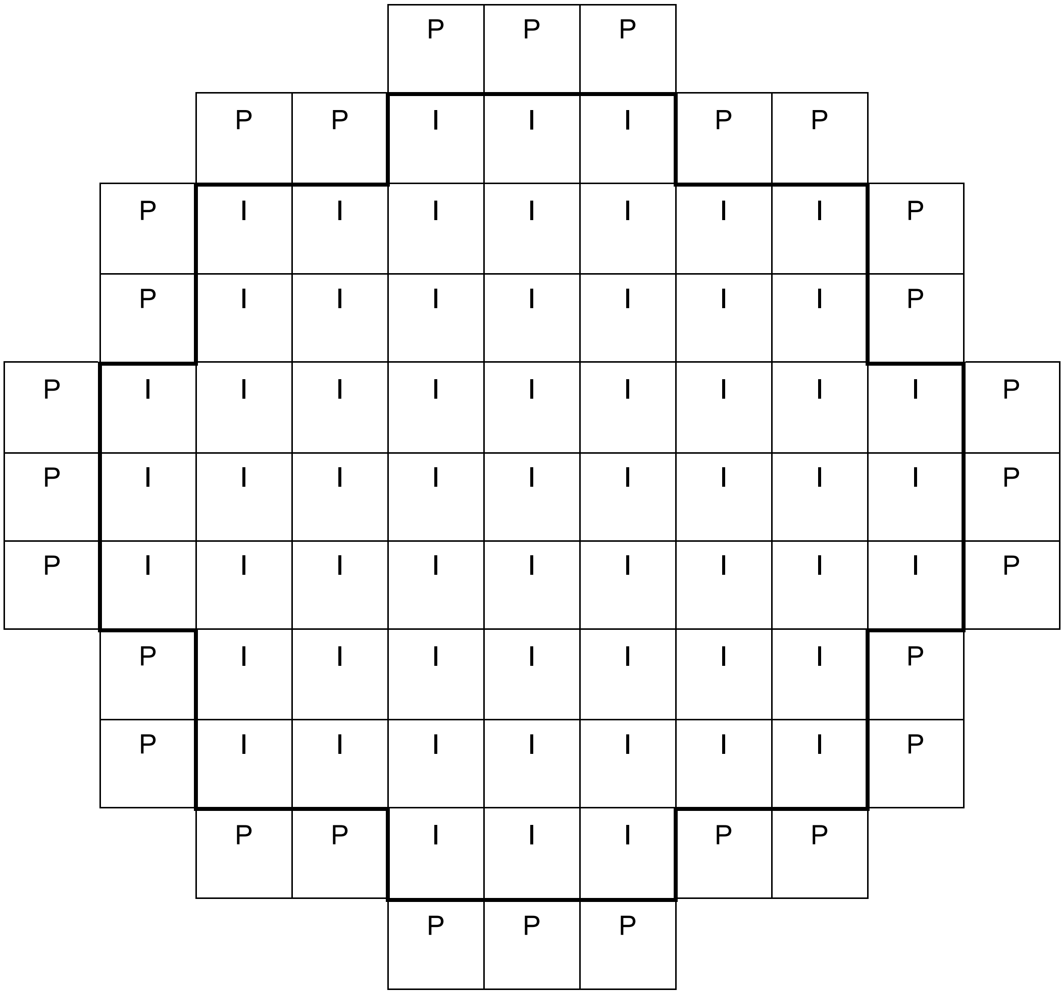


RECONSTITUTED FUEL ASSEMBLIES with ≤ 5 irradiated stainless steel rods may be loaded into all peripheral locations (i.e., not restricted). See Figure 6 for peripheral locations.

A RECONSTITUTED FUEL ASSEMBLY with > 5 and ≤ 10 irradiated stainless steel rods may be loaded in any peripheral location, with additional restrictions in accordance with Section 2.3. Examples:

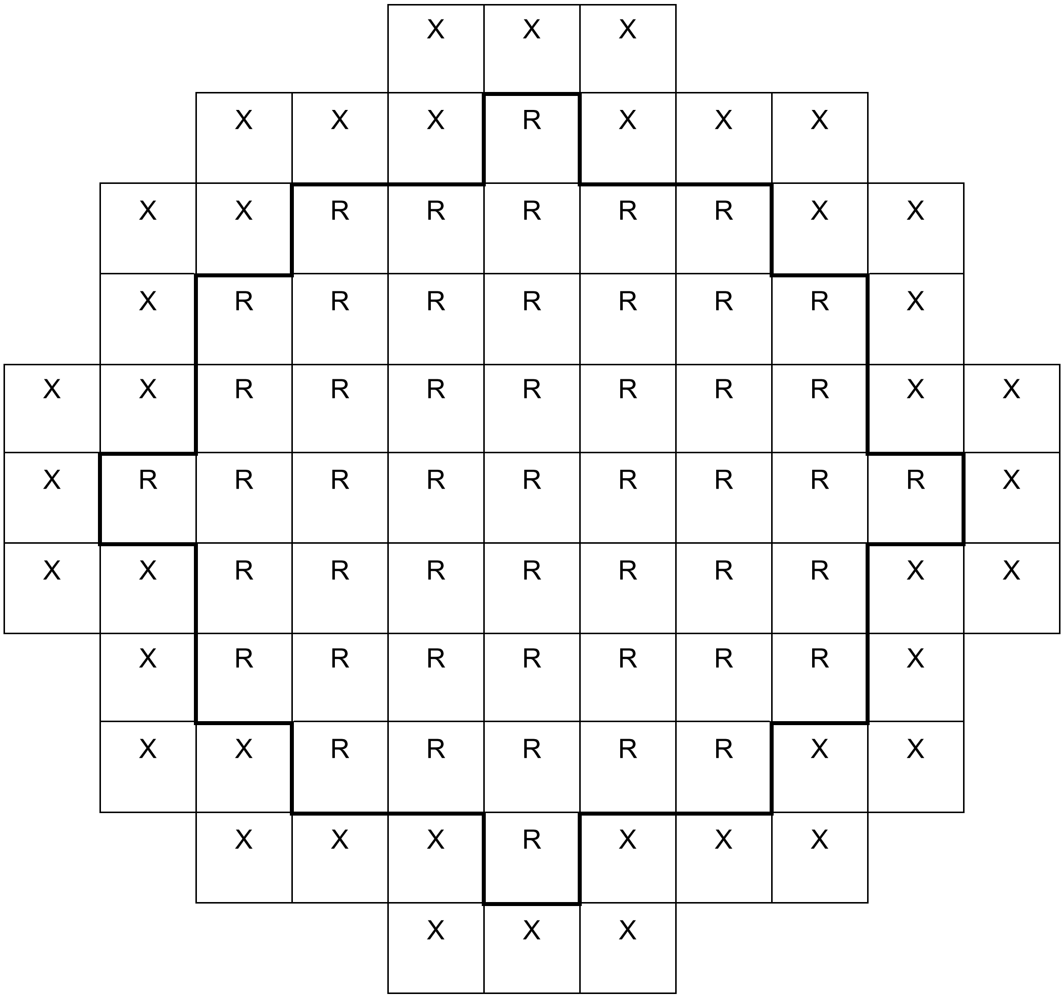
- If Location B contains a RECONSTITUTED FUEL ASSEMBLY with > 5 irradiated stainless steel rods, peripherally adjacent Locations A and C shall contain fuel assemblies that do not contain irradiated stainless steel rods.
- If Locations E and G contain RECONSTITUTED FUEL ASSEMBLIES with > 5 irradiated stainless steel rods, peripherally adjacent Locations D, F, and H shall contain fuel assemblies that do not contain irradiated stainless steel rods.

Figure 7
Peripheral Location Restrictions for Reconstituted Fuel with Irradiated Stainless Steel Rods for the 61BTH Type 2 DSC



				P	P	P				
		P	P	I	I	I	P	P		
	P	I	I	I	I	I	I	I	P	
	P	I	I	I	I	I	I	I	P	
P	I	I	I	I	I	I	I	I	I	P
P	I	I	I	I	I	I	I	I	I	P
P	I	I	I	I	I	I	I	I	I	P
	P	I	I	I	I	I	I	I	P	
	P	I	I	I	I	I	I	I	P	
		P	P	I	I	I	P	P		
				P	P	P				

Figure 8
Peripheral (P) and Inner (I) Fuel Locations for the EOS-89BTH DSC



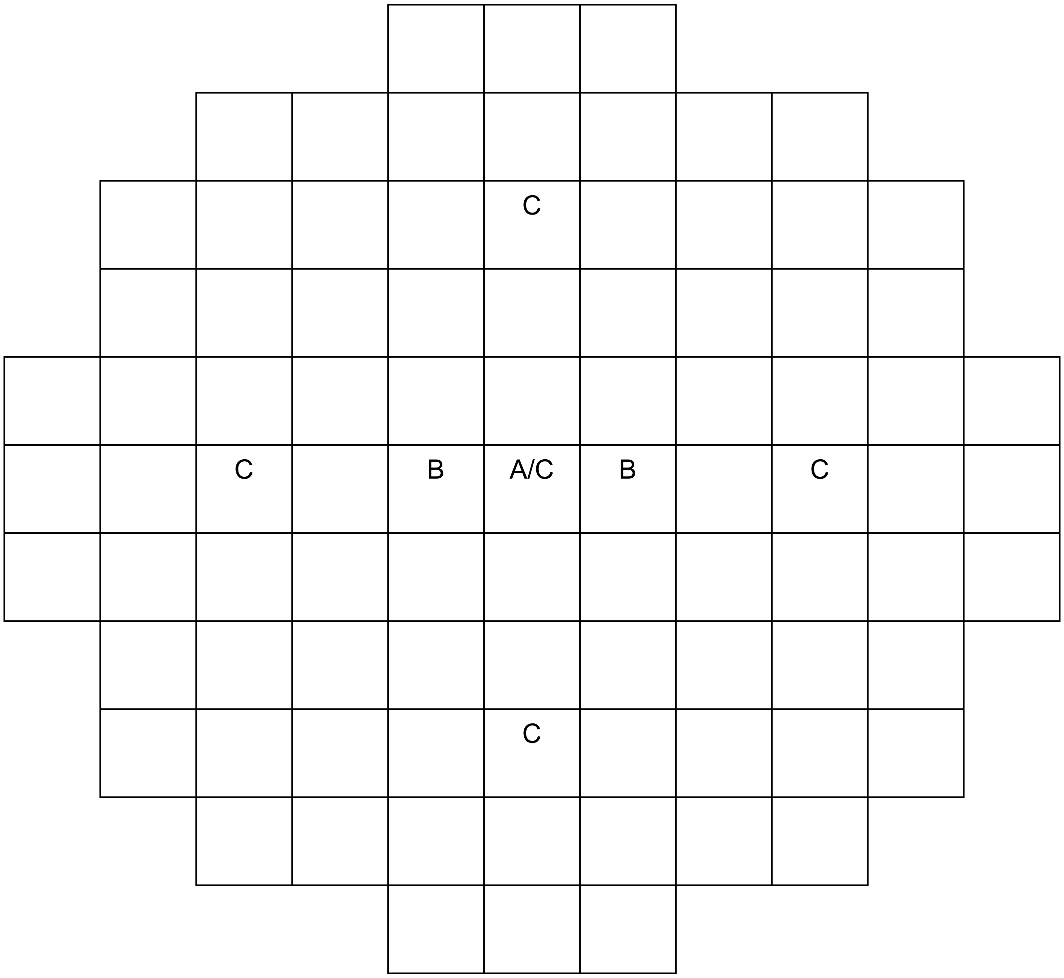
				X	X	X				
		X	X	X	R	X	X	X		
	X	X	R	R	R	R	R	X	X	
	X	R	R	R	R	R	R	R	X	
X	X	R	R	R	R	R	R	R	X	X
X	R	R	R	R	R	R	R	R	R	X
X	X	R	R	R	R	R	R	R	X	X
	X	R	R	R	R	R	R	R	X	
	X	X	R	R	R	R	R	X	X	
		X	X	X	R	X	X	X		
				X	X	X				

R = RECONSTITUTED FUEL ASSEMBLIES with irradiated stainless steel rods allowed at these locations.

X = RECONSTITUTED FUEL ASSEMBLIES with irradiated stainless steel rods not allowed at these locations.

Note: No restrictions on location for RECONSTITUTED FUEL ASSEMBLIES that do not contain irradiated stainless steel rods.

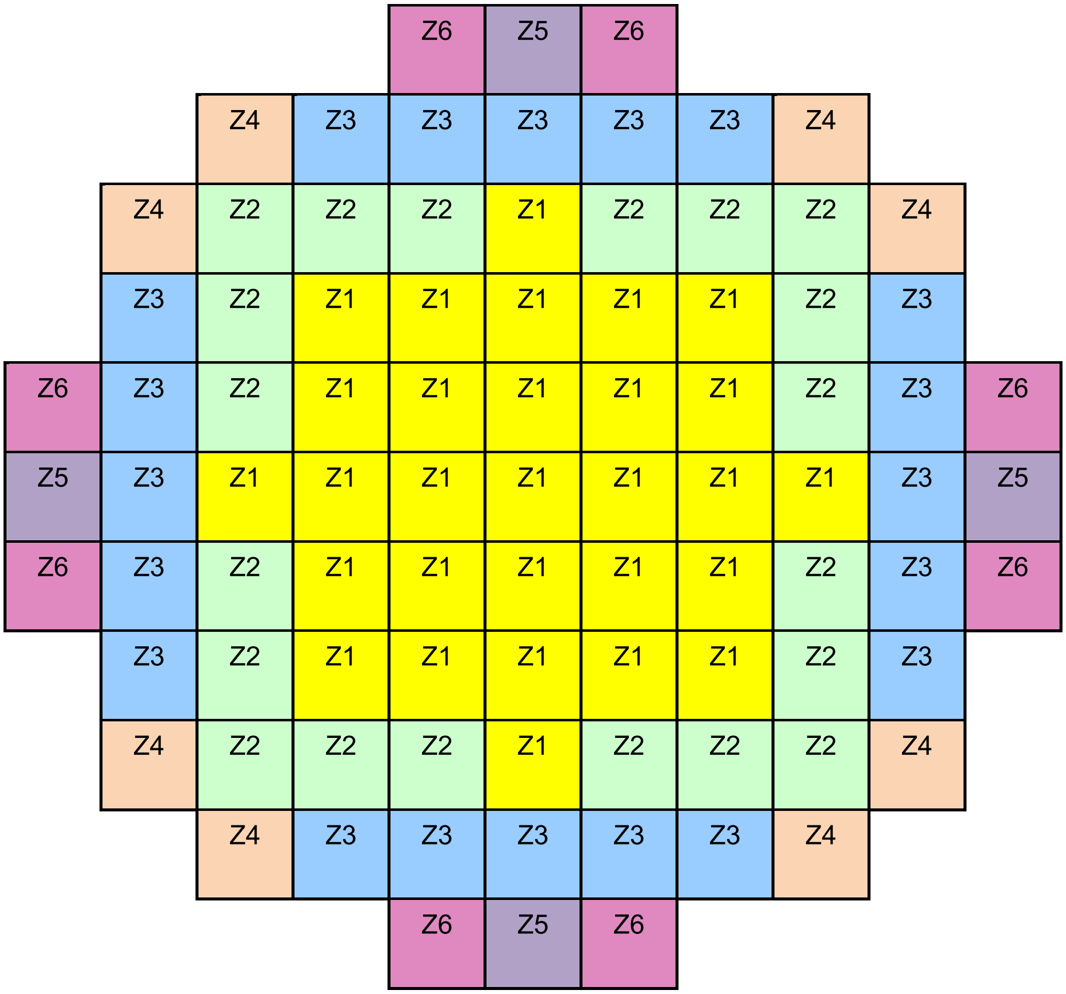
Figure 9
EOS-89BTH DSC Allowed Reconstituted Fuel Locations for Transfer in the EOS-TC108



Note:

1. Location identified as “A” is for empty placement in 88-FA Loading
2. Locations identified as “B” are for empty placements in 87-FA Loading
3. Locations identified as “C” are for empty placements in 84-FA Loading

Figure 10
Empty Locations in Short-Loading Configurations for the EOS-89BTH DSC



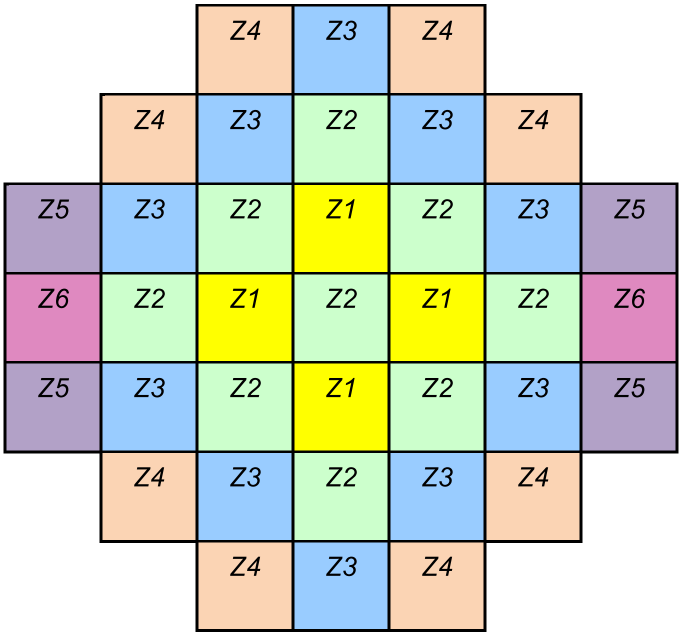
				Z6	Z5	Z6				
		Z4	Z3	Z3	Z3	Z3	Z3	Z4		
	Z4	Z2	Z2	Z2	Z1	Z2	Z2	Z2	Z4	
	Z3	Z2	Z1	Z1	Z1	Z1	Z1	Z2	Z3	
Z6	Z3	Z2	Z1	Z1	Z1	Z1	Z1	Z2	Z3	Z6
Z5	Z3	Z1	Z1	Z1	Z1	Z1	Z1	Z1	Z3	Z5
Z6	Z3	Z2	Z1	Z1	Z1	Z1	Z1	Z2	Z3	Z6
	Z3	Z2	Z1	Z1	Z1	Z1	Z1	Z2	Z3	
	Z4	Z2	Z2	Z2	Z1	Z2	Z2	Z2	Z4	
		Z4	Z3	Z3	Z3	Z3	Z3	Z4		
				Z6	Z5	Z6				

Zone No.	Z1	Z2	Z3	Z4	Z5	Z6
Max. Decay Heat per SFA (kW)	0.40	0.60	1.30	1.70	1.30	1.70
No. of Fuel Assemblies	29	20	20	8	4	8
Heat Load Per Zone	11.6	12.0	26.0	13.6	5.2	13.6
Max. Decay Heat per DSC (kW)	See Note 1 for EOS-HSM and Note 2 for HSM-MX					

Notes:

1. Maximum heat load for EOS-89BTH DSC during Storage is 48.2 kW in EOS-HSM.
2. Maximum heat load for EOS-89BTH DSC during Storage is 48.2 kW in lower compartment of HSM-MX and 41.8 kW in upper compartment of HSM-MX.

Figure 11
Maximum Heat Load Configuration 1 for EOS-89BTH DSC (MHLC-89-1) Transferred in the EOS-TC125



		Z4	Z3	Z4		
	Z4	Z3	Z2	Z3	Z4	
Z5	Z3	Z2	Z1	Z2	Z3	Z5
Z6	Z2	Z1	Z2	Z1	Z2	Z6
Z5	Z3	Z2	Z1	Z2	Z3	Z5
	Z4	Z3	Z2	Z3	Z4	
		Z4	Z3	Z4		

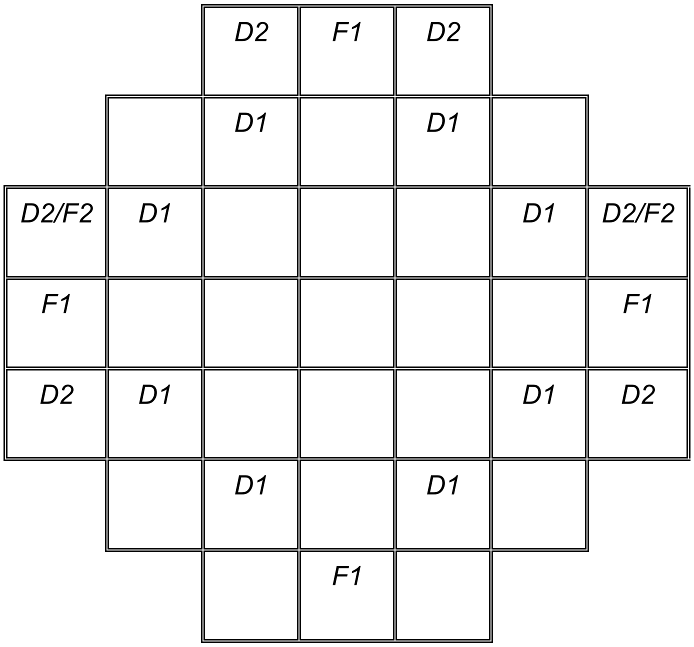
Zone No.	*Z1*	*Z2*	*Z3*	*Z4*	*Z5*	*Z6*
Max. Decay Heat per SFA (kW)	*1.5*	*1.0*	*2.4*	*3.5*	*4.3*	*1.6*
No. of Fuel Assemblies	*4*	*9*	*10*	*8*	*4*	*2*
Heat Load Per Zone	*6.0*	*9.0*	*24.0*	*28.0*	*17.2*	*3.2*
Max. Decay Heat per DSC (kW)	*See Note 1 (87.4 kW total)*					

Notes:

1. *Maximum heat load for EOS-37PTH DSC during Storage is 50.0 kW in the EOS-HSM.*
2. *See Figure 13 for Damaged/failed fuel locations.*
3. *The MHLC is not applicable to the storage in the HSM-MX or transfer in the EOS-TC108 or EOS-TC125/135 with reduced lead thickness unless further qualified. It is also not qualified for transfer or storage of WE 14 x 14 and CE 15 x 15 fuels.*

Figure 12

Maximum Heat Load Configuration 1 for EOS-37PTH DSC (MHLC-37-1) Transferred in the EOS-TC125/135 AND Stored in the EOS-HSM



		D2	*F1*	*D2*		
		D1		*D1*		
D2/F2	*D1*				*D1*	*D2/F2*
F1						*F1*
D2	*D1*				*D1*	*D2*
		D1		*D1*		
			F1			

Notes:

1. *The damaged fuel locations are marked with a "D1" for configuration 1, and "D2" for configuration 2. Only one configuration may be loaded in each DSC.*
2. *The Failed fuel locations are marked with an "F1" for configuration 1, and "F2" for configuration 2. Only one configuration may be loaded in each DSC. Failed fuel in all configurations is limited to 0.8 kW.*
3. *Damaged and failed fuel shall not be loaded in the same DSC.*

Figure 13
Damaged and Failed Fuel Configurations for the EOS-37PTH DSC

		X	*X*	*X*		
	X	*R*	*R*	*R*	*X*	
X	*R*	*R*	*R*	*R*	*R*	*X*
X	*R*	*R*	*R*	*R*	*R*	*X*
X	*R*	*R*	*R*	*R*	*R*	*X*
	X	*R*	*R*	*R*	*X*	
		X	*X*	*X*		

R = RECONSTITUTED FUEL ASSEMBLIES with irradiated stainless steel rods allowed at these locations.

X = RECONSTITUTED FUEL ASSEMBLIES with irradiated stainless steel rods not allowed at these locations.

Note: No restrictions on location for RECONSTITUTED FUEL ASSEMBLIES that do not contain irradiated stainless steel rods.

Figure 14
EOS-37PTH DSC Allowed Reconstituted Fuel Locations for Transfer in the EOS-TC108

Enclosure 5 to E-59796

Proposed Amendment 4, Revision 0 Changes to the NUHOMS® EOS System Updated Final Safety Analysis Report

Withheld Pursuant to 10 CFR 2.390

Enclosure 6 to E-59796

Proposed Amendment 4, Revision 0 Changes to the NUHOMS® EOS System Updated Final Safety Analysis Report

(Public Version)

Item 1

Amendment 4 adds a maximum heat load configuration (MHLC) for the EOS-37PTH as shown in the Technical Specifications, Figure 12 [1-7], similar to that added for the EOS-89BTH in Amendment 3. Any HLZCs that fall within the bounds of the MHLC that are transferred in the EOS-TC125 and stored in any variation of the EOS-HSM may be qualified for use in the UFSAR. Amendment 4 also adds HLZC 12 and 13 for the EOS-37PTH.

Amendment 4 also adds a new EOS-HSM option to fabricate the components using a steel-plate composite (SC) design, EOS-HSM-SC. A comparison of MCNP to MAVRIC software analyses is performed to demonstrate MAVRIC software capability for use in dose rate analyses. Additionally, measured exposures from past loading campaigns are added to highlight that measured exposures are significantly less than calculated exposures.

Items 2, 3 and 6

1.1 Introduction

The type of fuel to be stored in the NUHOMS® EOS System is light water reactor (LWR) fuel of the PWR and BWR type. The EOS-37PTH DSC is designed to accommodate up to 37 intact PWR FAs with uranium dioxide (UO_2) fuel, zirconium alloy cladding, and with or without control components (CCs). The EOS-37PTH DSC is also designed to accommodate up to eight damaged FAs or up to four failed fuel canisters (FFCs) with the balance intact FAs. The EOS-89BTH DSC is designed to accommodate up to 89 intact BWR FAs with uranium dioxide (UO_2) fuel, zirconium alloy cladding, and with or without fuel channels. The physical and radiological characteristics of these payloads are provided in Chapter 2.

The NUHOMS® EOS System consists of the following components as shown in Figure 1-1 through Figure 1-7:

- Two dual-purpose (storage and transportation) DSCs that provide confinement in an inert environment, structural support and criticality control for the FAs; the EOS-37PTH DSC and the EOS-89BTH DSC. The DSC shells are welded stainless or duplex steel pressure vessels that includes thick shield plugs at either end to maintain occupational exposures as low as reasonably achievable (ALARA).
- *Three* EOS-37PTH DSC basket designs*, see the table below. Basket Type 1 has non-staggered basket plates as shown in EOS01-1010-SAR for storage of intact fuel only.* Basket Type 4 incorporates a plate configuration that offsets the aluminum plates to allow for damaged/failed fuel storage in the EOS-37PTH DSC. The Type 4 basket has two options. The Type 4H basket is fabricated from a coated steel plate for higher emissivity and higher conductivity poison plate, while the Type 4L basket has a low emissivity coated steel plate and a low conductivity poison plate. These requirements are further detailed in the material and design limits discussed in Section 4.2 and Section 10.1. *The 4HA basket type is a subset of the 4H basket where the aluminum basket plates are anodized. This anodizing is required when HLZCs with decay heats greater than 3.5 kW are stored in the basket. When used without distinction, 4H includes both basket types 4H and 4HA.* The Type 5 basket is similar to the Type *1* basket in configuration, but also incorporates the low emissivity coated steel plates and low conductivity poison plate. The maximum heat loads and the allowable HLZCs for Basket Types 4 and 5 are listed in Table 1-2. Each of these basket types also allows for two levels of boron loading in the poison plates (A and B). Each basket type is designated as follows:

EOS-37PTH Basket Types

Neutron Poison Loading Option	**TYPE 1** ***(Non-staggered basket high K, high ϵ)***	**TYPE 4 (Damaged/Failed Fuel)**	**TYPE 5 (*****Non-staggered,*** **Low K, Low ϵ)**
A (Low B-10)	A1	A4H/*A4HA*/A4L	A5
B (High B-10)	B1	B4H/*B4HA*/B4L	B5

- Three EOS-89BTH DSC basket designs. Basket Types 1 through 3 correlate with the respective HLZC 1 through 3 (*Figure 2-2a through Figure 2-2c of Chapter 2*). Each of these basket types also allows for three levels of boron loading in the poison plates (Low, Moderate, and High). *Basket Type 1 also considers HLZCs 4, 5, and 6. Figure 2-2d through Figure 2-2f of Chapter 2 present HLZCs 4-6. In addition, Basket Type 1 can also be used to qualify additional HLZCs as noted per Figure 11 of the Technical Specification [1-7].*

EOS 89BTH Basket Types

Neutron Poison Loading Option	**Type 1 (HLZC 1,*4,5,6* max. *48.2* kW)**	**Type 2 (HLZC 2 max. 41.6 kW)**	**Type 3 (HLZC 3 max. 34.44 kW)**
M1-A (Low B-10)	A1	A2	A3
M1-B (Moderate B-10)	B1	B2	B3
M2-A (High B-10)	C1	C2	C3

The criticality evaluations in Chapter 7 refer to the basket types based on the boron content in the poison plates. In Chapter 7, the references to the basket types differ from the above table. The correlations between the basket types used in Chapter 7 and basket types identified in the above table are clarified below:

- EOS-37PTH basket types A1, A4H, *A4HA,* A4L, and/or A5 are identified as EOS-37PTH basket type A in Chapter 7
- EOS-37PTH basket types B1, B4H, *B4HA,* B4L, and/or B5 are identified as EOS-37PTH basket type B in Chapter 7
- EOS-89BTH basket type A1 *is* identified as EOS-89BTH basket type M1-A in Chapter 7
- EOS-89BTH basket type B1 *is* identified as EOS-89BTH basket type M1-B in Chapter 7
- EOS-89BTH basket type C1 *is* identified as EOS-89BTH basket type M2-A in Chapter 7

The thermal evaluation in Chapter 4 refers directly to the HLZC instead of using the basket types.

Provisions have been made for storage of up to eight damaged fuel assemblies in lieu of an equal number of intact assemblies placed in cells located in the EOS-37PTH basket. Damaged fuel assemblies are defined in Section 1.1 of the Technical Specifications [1-7].

The EOS-37PTH DSC is also designed to accommodate up to a maximum of four FFCs, placed in cells located at the outer edge of the DSC. Failed fuel is defined in Section 1.1 of the Technical Specifications [1-7].

All Indicated Changes are Scope Item 1.

The damaged/failed fuel *(staggered)* basket*s are* identical to the intact fuel basket with the exception that the aluminum in the composite basket plates has been offset vertically in order to prevent debris from the damaged fuel from migrating between basket plates to adjacent compartments. The offset is accomplished by lengthening the aluminum plates in the bottom section by [ ] and subsequently shortening the top-most aluminum plates by that same [ ] The middle sections of aluminum plates remain the same height as the intact basket. The damaged/failed basket configuration is shown in Figure 1-2a. Damaged fuel assemblies must contain end fittings or nozzles or tie plates at the top and bottom.

- An HSM design, designated as either the EOS-HSM or the EOS-HSMS, is equipped with special design features for enhanced shielding and heat rejection capabilities. The HSM base has two alternatives, a single piece or a split base. The HSM with the split base is designated as the EOS-HSMS. Finally, the EOS-HSM and EOS-HSMS can be fabricated with three lengths to accommodate the range of DSC lengths, provided in the table below.

NUHOMS® Module	**DSC Length without Grapple Ring (in.)**		**Total EOS-HSM Length (in.)**
	Minimum (in.)	**Maximum (in.)**	
EOS-Short	165.5	179.5	228
EOS-Medium	185.5	199.5	248
EOS-Long	205.5	219.5	268

- EOS-HSM and EOS-HSMS modules are arranged in arrays to minimize space and maximize self-shielding. The DSCs are longitudinally restrained to prevent movement during seismic events. Arrays are fully expandable to permit modular expansion in support of operating power plants.
- The EOS-HSM and EOS-HSMS provides the bulk of the radiation shielding for the DSCs. The EOS-HSM/EOS-HSMS can be arranged in either a single-row or a back-to-back arrangement. Thick concrete supplemental shield walls are used at either end of an EOS-HSM and EOS-HSMS array and along the back wall of single-row arrays to minimize radiation dose rates both onsite and offsite. Two or more empty modules can be substituted for the end walls until the array is fully built.
- A horizontal storage module (HSM), designated as the HSM-MX, is a two-tiered, staggered reinforced monolithic structure, consisting of massive reinforced concrete compartments to accommodate EOS-DSCs. This system is further detailed in Appendix A, where relevant chapters are preceded with an A, i.e., A.1. Where the term "HSM" is used without distinction, this term applies to both the EOS-HSM and HSM-MX.

- An EOS-TC system is provided with a top cover plate that allows air circulation through the TC/DSC annulus during transfer operations at certain heat loads when time limits for transfer operations cannot be satisfied. The EOS-TC system consists of a 135-ton cask (EOS-TC135), a 125-ton cask (EOS-TC125), and the EOS-TC108 Cask.

The EOS-37PTH DSC is designed for a maximum heat load of 50 kW when transferred in the EOS-TC125/135 or EOS-TC108. The EOS-89BTH DSC is designed for a maximum heat load of *48.2* kW when transferred in the EOS-TC125, and a maximum heat load of 41.6 kW when transferred in the EOS-TC108. The EOS-37PTH DSC can be transferred in any EOS-TC with a maximum heat load of 36.35 kW without air circulation available and, similarly, the EOS-89BTH with a maximum heat load of 34.4 kW.

The NUHOMS® EOS System is designed to be compatible with removal of the stored DSC for transportation and ultimate disposal by the Department of Energy, in accordance with 10 CFR *72.*236(m). However, this application only addresses the storage of the spent fuel in the NUHOMS® EOS System.

The cavity length of the DSCs is adjustable to match the length of the fuel to be stored. This eliminates or reduces the need for fuel spacers to address secondary impact of the fuel on the lids during transportation accident scenarios.

The NUHOMS® EOS System provides structural integrity, confinement, shielding, criticality control, and passive heat removal independent of any other facility structures or components.

The EOS-HSMs and DSCs are intended for outdoor or sheltered storage on a reinforced concrete pad at a nuclear power plant. In addition to these components, the system requires use of an onsite TC, transfer trailer, and other auxiliary equipment that are described in this UFSAR. Similar equipment was previously licensed under NUHOMS® HD System UFSAR, Revision 4. Sufficient information for the transfer system and auxiliary equipment is included in this UFSAR to demonstrate that means for safe operation of the system are provided.

1.2 General Description and Operational Features of the NUHOMS® EOS System

The NUHOMS® EOS System provides for the horizontal, dry storage of canisterized SFAs in a concrete *or steel-plate composite (SC)* EOS-HSM. The storage system components consist of a reinforced concrete *or SC* EOS-HSM and a stainless or duplex steel DSC confinement vessel that houses the SFAs. The general arrangement of the NUHOMS® EOS System components is shown in Figure 1-8. The confinement boundary is defined in Section 5.1 and shown in Figure 5-1. This UFSAR addresses the design and analysis of the storage system components, including the EOS-37PTH DSC, the EOS-89BTH DSC, the TC135, the TC125, the TC108, the EOS-HSM, and the EOS-HSMS, which are important to safety in accordance with 10 CFR 72.

In addition to these storage system components, the NUHOMS® EOS System also utilizes transfer equipment to move the DSCs from the plant's fuel or reactor building, where they are loaded with SFAs and prepared for storage in the EOS-HSM where they are stored. This transfer system consists of a TC, a lifting yoke, a ram system, a prime mover, a transfer trailer, a cask support skid, and a skid positioning system. This transfer system interfaces with the existing plant fuel pool, the cask handling crane, the site infrastructure (i.e., roadways and topography) and other site-specific conditions and procedural requirements. Auxiliary equipment, such as a TC/DSC annulus seal, a vacuum drying system, and a welding system, are also used to facilitate DSC loading, draining, drying, inerting, and sealing operations. Similar transfer system and auxiliary equipment has been previously licensed under the NUHOMS® HD System.

During dry storage of the spent fuel, no active systems are required for the removal and dissipation of the decay heat from the fuel. The NUHOMS® EOS System is designed to transfer the decay heat from the fuel to the DSC and from the DSC to the surrounding air by conduction, radiation and natural convection. The NUHOMS® EOS System ISFSI can also be housed in enclosed buildings provided the ISFSI with the building design is bounded by the design criteria described in Chapter 2 and the Technical Specifications [1-7]. No credit is taken for the building in the Safety Analysis of the NUHOMS® EOS System.

Each PWR DSC is identified by a Model Number, XXX-EOS-37PTH-YYY-*ZZZ*, where XXX typically identifies the site for which the EOS-37PTH DSC was fabricated, *ZZZ* designates the basket type, and YYY is a sequential number corresponding to a specific DSC. The basket types are defined by both the HLZC and neutron poison loading and are described in UFSAR drawing no. EOS01-1010-SAR for the intact and damaged/failed fuel basket. Similarly, each BWR DSC is identified by a Model Number, XXX-EOS-89BTH-YYY-*ZZ*. The basket types are described in UFSAR drawing no. EOS01-1020-SAR.

The NUHOMS® EOS System components do not include receptacles, valves, sampling ports, impact limiters, protrusions, or pressure relief systems, except for the neutron shield tanks on the EOS-TCs, which include pressure relief valves.

The EOS-37PTH damaged/failed fuel basket configuration is also used in conjunction with failed fuel canisters 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. The FFC geometry and the materials used for its fabrication are shown on Drawing EOS01-1010-SAR.

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 for a maximum heat load of 50.0 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 analysis also takes credit for soluble boron during loading operations. Sub-criticality during wet loading/unloading, drying, sealing, transfer, and storage operations is maintained through the geometric separation of the FAs by the basket assembly, the boron loading of the pool water, 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, *ten* basket configurations are provided, as shown on drawing EOS01-1010-SAR for the intact and damaged/failed fuel basket. Poison material and boron loading requirements as well as basket plate coating requirements are discussed in Chapter 10. *The aluminum basket plates may be anodized to allow for storage of fuels with decay heats greater than 3.5 kW. Requirements are discussed in Section 4.9.9.*

In general, the dimensions of the EOS-37PTH DSC components described in the text and provided in figures and tables of this UFSAR are nominal dimensions for general system description purposes. Actual design dimensions are contained in the drawings in Section 1.3.1 of this UFSAR. See Sections 1.4.1 and 2.2.1 for a discussion of the contents authorized to be stored in this DSC.

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 for a maximum heat load of *48.2* 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. Sub-criticality during wet loading/unloading, drying, sealing, transfer, and storage operations 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, as shown on drawing EOS01-1020-SAR. Poison material and boron loading requirements are discussed in Chapter 10.

In general, the dimensions of the EOS-89BTH DSC components described in the text and provided in figures and tables of this UFSAR are nominal dimensions for general system description purposes. Actual design dimensions are contained in the drawings in Section 1.3.2 of this UFSAR. See Sections 1.4.2 and 2.2.2 for a discussion of the contents authorized to be stored in this DSC.

1.2.1.3 Horizontal Storage Module

Each EOS-HSM or EOS-HSMS provides a self-contained modular structure for storage of spent fuel canisterized in an EOS-37PTH or EOS-89BTH DSC. The EOS-HSMS is essentially identical to the EOS-HSM except that the base is split into two sections (upper and lower), which are tied together via shear keys and six grouted tie rods. Henceforth in this UFSAR, EOS-HSM is used interchangeably for both the EOS-HSM and EOS-HSMS. The EOS-HSM is constructed from reinforced concrete and structural steel.

The EOS-HSM may be constructed from reinforced concrete and steel, termed EOS-HSM-RC, or alternatively, the components may be constructed from a steel-plate composite. The steel-plate composite EOS-HSM is termed the EOS-HSM-SC, and is included when generically referring to the EOS-HSM. See clarification table below.

EOS-HSM			
EOS-HSM-RC		*EOS-HSM-SC*	
EOS-HSM-RC	*EOS-HSMS-RC*	*EOS-HSM-SC*	*EOS-HSMS- SC*
EOS-HSM-FPS-RC	*EOS-HSMS-FPS-RC*	*EOS-HSM-FPS-SC*	*EOS-HSMS-FPS-SC*

The thick roof and walls *of the EOS-HSM* provide substantial neutron and gamma shielding. Contact doses for the EOS-HSM are designed to be ALARA. The key design parameters of the EOS-HSM are listed in Table 1-1.

The nominal thickness of the EOS-HSM roof is *44 inches* for biological shielding. Separate shield walls at the end of a module row in conjunction with the module base wall, provide a minimum total thickness of four feet for shielding. Similarly, an additional shield wall is used at the rear of the module if the ISFSI is configured as single module arrays to provide a minimum total thickness of four feet of shielding with the module base rear wall. Sufficient shielding is provided by thick concrete side walls between EOS-HSMs in an array to minimize doses in adjacent EOS-HSMs during loading and retrieval operations.

The EOS-HSMs provide an independent, passive system with substantial structural capacity to ensure the safe dry storage of SFAs. To this end, the EOS-HSMs are designed to ensure that normal transfer operations and postulated accidents or natural phenomena do not impair the DSC or pose a hazard to the public or plant personnel.

Table 1-3 provides a listing of known fabricated NUHOMS® Transfer Casks that have design compatibility with the TC design basis models indicated on this table.

The TC is designed to provide sufficient shielding to provide reasonable assurance that dose rates are ALARA. *The EOS-TC125 lead gamma shielding thickness may vary between 3.12 and 3.56 inches when transferring the EOS-89BTH for a weight reduction of up to 11,210 pounds. This change is made to allow for use of the EOS-TC125 at sites with lower crane capacities to minimize/eliminate the need for limiting the allowable contents or use weight management techniques such as draining water or switching out a lighter aluminum lid.* Two top-lifting trunnions are provided for handling the TC using a lifting yoke and overhead crane. Lower pocket trunnions are provided for rotating the cask from/to the vertical and horizontal positions on the support skid/transport trailer.

The EOS-TC108 is designed with the capability to remove the neutron shield for use at nuclear plant sites with space limitations and/or crane capacity limits and, therefore, cannot use one of the other EOS-TCs. Provided that the EOS-TC108 is designed to be used in situations of limited space or crane capacity, the EOS-TC108 can be modified to allow alternative configurations necessary to fit the loading environment restrictions. A schematic sketch of the EOS-TC125/135 is shown in Figure 1-6, and of the EOS-TC108 with removable neutron shield is shown in Figure 1-7.

A cask spacer is required in the bottom of the EOS-TC to provide the correct interface at the top of the EOS-TC during loading, drying, and sealing operations for DSCs that are shorter than the cavity length. All EOS-TCs utilize a bottom cover incorporating wedges and top cover assembly that allows for air circulation. This mechanism enables cooling air to travel through the annular space between the EOS-DSC and the TC inner diameter through the entire cask length and to exit through the vent passages in the modified top cover assembly of the cask.

Dimensions of the EOS-TC components described in the text and provided in figures and tables of this UFSAR are in general nominal dimensions for general system description purposes. Actual design dimensions are contained in the drawings in Section 1.3.4.

1.2.1.5 System Configurations

As discussed in Sections 1.2.1.1 through 1.2.1.4, the various system configurations are determined based on basket type, heat load, fuel type, storage module, transfer cask, etc. *Nine* alternate system configurations for the EOS-37PTH DSC, and *four* system configurations for the EOS-89BTH, are summarized in Table 1-2.

All Indicated Changes are Scope Item 1.

Proprietary and Security Related Information
for Drawing EOS01-1010-SAR, Rev. 5A
Withheld Pursuant to 10 CFR 2.390

1.3.3 NUHOMS® EOS-HSM/EOS-HSMS

EOS01-3000-SAR	NUHOMS® EOS System Horizontal Storage Module (EOS-HSM) Main Assembly
EOS01-3016-SAR	NUHOMS® EOS System Wind Deflector Assembly
EOS01-3017-SAR	NUHOMS® EOS System Horizontal Storage Module Optional Outlet Vent Dose Reduction Hardware
EOS01-3300-SAR	*NUHOMS® EOS System Horizontal Storage Module-Steel-Plate Composite (EOS-HSM-SC) Main Assembly*

All Indicated Changes are Scope Item 2.

Proprietary and Security Related Information for Drawing EOS01-3300-SAR, Rev. 0A Withheld Pursuant to 10 CFR 2.390

1.4 NUHOMS® EOS System Contents

1.4.1 EOS-37PTH DSC Contents

The EOS-37PTH DSC is designed to store up to 37 intact PWR FAs (with or without CCs), up to eight damaged FAs, or up to four compartments with failed fuel may be stored in lieu of intact fuel as described in the Technical Specifications [1-7].

The EOS-37PTH DSC is qualified for storage of Babcock and Wilcox (B&W) 15 x 15 class, Combustion Engineering (CE) 14 x 14 class, CE 15 x 15 class, CE 16 x 16 class, Westinghouse (WE) 14 x 14 class, WE 15 x 15 class, and WE 17x17 class PWR FA designs, as described in Chapter 2.

The EOS-37PTH DSC payload may include CCs that are contained within the FA, such as described in Chapter 2.

Reconstituted assemblies containing an unlimited number of low enriched or natural uranium fuel rods or unirradiated non-fuel rods are acceptable for storage in an EOS-37PTH DSC as intact FAs. *Restrictions on the maximum number of irradiated stainless steel rods per fuel assembly differ between transfer in the EOS-TC125/135 and EOS-TC108. These restrictions are provided in the Technical Specifications, Tables 24 and 25 [1-7].*

The EOS-37PTH DSC is also authorized to store FAs containing blended low enriched uranium (BLEU) fuel material.

The contents of the DSC are stored in an inert atmosphere of helium.

The maximum allowable planar average initial enrichment of the fuel to be stored is 5.00 wt. % U-235, and the maximum assembly average burnup is 62,000 MWd/MTU. The FAs (with or without CCs) must be cooled to meet the decay heat limits specified in the Technical Specifications [1-7] prior to storage.

The criticality control features of the EOS-37PTH DSC are designed to maintain the neutron multiplication factor k-effective (including uncertainties and calculational bias) at less than 0.95 under normal, off-normal, and accident conditions.

The gamma and neutron source terms in the SFAs are described and tabulated in Chapter 6. Chapter 7 covers the criticality safety of the EOS-37PTH DSC and its parameters. These parameters include rod pitch, rod outside diameter, material densities, moderator ratios, soluble boron content and geometric configurations. The maximum pressure buildup in the EOS-37PTH DSC cavity is addressed in Chapter 4.

1.4.2 EOS-89BTH DSC Contents

The EOS-89BTH DSC is designed to store up to 89 intact BWR FAs with or without channels.

1.5 Qualification of TN Americas LLC (Applicant)

The prime contractor for design and procurement of the NUHOMS® EOS System components is TN Americas LLC (TN). TN will subcontract the fabrication, testing, onsite construction, and QA services, as necessary, to qualified firms on a project-specific basis, in accordance with TN's QA program requirements.

The design activities for the NUHOMS® EOS Safety Analysis Report were performed by TN and subcontractors, in accordance with TN's QA program requirements. TN Americas is responsible for the design and analysis of the EOS-37PTH DSC, the EOS-89BTH DSC, the EOS-HSMs, the onsite EOS-TCs, and the associated transfer equipment.

Closure activities associated with welding the top cover plates on the DSCs following fuel loading are typically performed by the licensee under the licensee's NRC approved QA program.

1.7 References

1-1 Title 10, Code of Federal Regulations, Part 72, "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor-Related Greater Than Class C Waste."

1-2 NUREG-1536, "Standard Review Plan for Spent Fuel Dry Storage Systems at a General License Facility," Revision 1, U.S. Nuclear Regulatory Commission, Office of Nuclear Material Safety and Safeguards, July 2010.

1-3 U.S. Nuclear Regulatory Commission, "Certificate of Compliance 72-1030, NUHOMS® HD Horizontal Modular Storage System for Irradiated Nuclear Fuel," Amendment No. 2, October 14, 2014.

1-4 TN Americas LLC, Updated Final Safety Analysis Report, "NUHOMS® HD Horizontal Modular Storage System for Irradiated Nuclear Fuel," Revision 6, U.S. Nuclear Regulatory Commission Docket No. 72-1030, September 2017.

1-5 Title 10, Code of Federal Regulations, Part 50, "Domestic Licensing of Production and Utilization Facilities."

1-6 TN Americas LLC, "TN Americas LLC Quality Assurance Program Description Manual for 10 CFR Part 71, Subpart H and 10 CFR Part 72, Subpart G," current revision.

1-7 CoC 1042 Appendix A, NUHOMS® EOS System Generic Technical Specifications, Amendment *4*.

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

EOS-37PTH DSC	
Overall Length (in.)	219.12 (max for TC135)
	197.65 (max for TC125 and TC108)
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.)	135,000 (max for TC135)
	124,000 (max for TC125 and TC108)
Materials of Construction	Stainless steel or duplex shell assembly and carbon steel internals, carbon steel shield plugs, aluminum
Neutron Absorbing Material	MMC as specified in Chapter 10
Internal Atmosphere	Helium
EOS-89BTH DSC	
Overall Length (in.)	197.65 (max. for TC125 and TC108)
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.)	124,000 (max for TC125 and TC108)
Materials of Construction	Stainless steel or duplex shell assembly and carbon steel internals, carbon steel shield plugs, aluminum
Neutron Absorbing Material	BORAL™, MMC, as specified in Chapter 10
Internal Atmosphere	Helium
Horizontal Storage Module (*EOS-HSM-RC/ EOS-HSM-SC*):	
Overall length (without back shield wall)	19’ EOS-Short
	20’ 8” EOS-Medium
	22’ 4” EOS-Long
Overall width (without end shield walls)	9’-8”
Overall height (without vent covers)	18’ 6”

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

EOS-HSM-RC Total Weight not including DSC (lbs.)	311,000 EOS-Short
	334,000 EOS-Medium(1)
	351,000 EOS-Long
EOS-HSM-SC Total Weight not including DSC (lbs.)	*362,000*
Materials of Construction *(EOS-HSM-RC)*	Reinforced concrete and structural steel
Materials of Construction (EOS-HSM-SC)	*Concrete, structural steel for faceplates, and carbon/alloy/bolt steels for studs and tie bars*
Heat Removal	Conduction, convection, and radiation
OnSite Transfer Cask (EOS-TC)	
Overall Length (in)	206.76 EOS-TC108
	208.21 EOS-TC125
	228.71 EOS-TC135
Outside Diameter (in)	90.61 EOS-TC108 w/ NS tank
	88.50 EOS-TC108 w/o NS tank
	95.38 *maximum* EOS-TC125
	95.38 EOS-*TC135*
Cavity Length (in)	199.17 EOS-TC108
	199.25 EOS-TC125
	219.75 EOS-TC135
Lead Thickness (in)	2.50 EOS-TC108
	3.12-3.56 EOS-TC125
	3.56 EOS-TC135
Gross Weight (with neutron shield and steel lid and no payload) (tons)	46.5 EOS-TC108
	62.1 *maximum* EOS-TC125
	67.9 EOS-TC135
Materials of Construction	Carbon steel shell assemblies and closures with lead shielding, aluminum and carbon steel lids and aluminum neutron shield tank for the TC108
Internal Atmosphere	Air

Note 1: Without the optional outlet vent dose reduction hardware presented in Item 2, Section 1.2.1.3.

Table 1-2
System Configurations for the NUHOMS® EOS System and NUHOMS® MATRIX System

(2 Pages)

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DSC	System Configuration	Basket Design	Basket Type	Emissivity/ Poison	Storage Module	Wind Deflector	HLZC	Intact	Damaged/ Failed	Transfer Cask
EOS-37PTH	S1	Non-Staggered	1	High	EOS-HSM	Yes(1)	1	Yes	No	EOS-TC125/135
	S2	Non-Staggered	*1*	High	EOS-HSM	No	2	Yes	No	EOS-TC108/125/135
		Non-Staggered	*1*	High	EOS-HSM	No	3	Yes	No	EOS-TC108/125/135
	S3	Staggered	4L	Low	EOS-HSM	Yes	4	Yes	No	EOS-TC125/135
		Staggered	4L	Low	EOS-HSM	Yes*(2)*	5	Yes	No	EOS-TC125/135
		Staggered	4L	Low	EOS-HSM	Yes	6	Yes	Yes	EOS-TC125/135
	S3a	Staggered	4H	High	EOS-HSM	Yes(1)	1	Yes	No	EOS-TC125/135
		Staggered	4H	High	EOS-HSM	Yes(1)	4	Yes	No	EOS-TC108/125/135
		Staggered	4H	High	EOS-HSM	Yes*(2)*	5	Yes	No	EOS-TC108/125/135
		Staggered	4H	High	EOS-HSM	Yes(1)	6	Yes	Yes	EOS-TC108/125/135
		Staggered	4H	High	EOS-HSM	Yes(1)	10	Yes	Yes	EOS-TC125/135
		Staggered	4H	High	EOS-HSM	Yes(1)	11	Yes	Yes	EOS-TC125/135
	S3b	*Staggered*	*4HA*	*High*	*EOS-HSM*	*Yes(3)*	*12*	*Yes*	*Yes*	*EOS-TC125/135*
		Staggered	*4HA*	*High*	*EOS-HSM*	*Yes(3)*	*13*	*Yes*	*Yes*	*EOS-TC125/135*
	S4	Non-staggered	5	Low	EOS-HSM	Yes	4	Yes	No	EOS-TC125/135
		Non-staggered	5	Low	EOS-HSM	Yes*(2)*	5	Yes	No	EOS-TC125/135
	S5	Staggered	4H	High	HSM-MX	N/A	7	Yes	No	EOS-TC108/125/135
		Staggered	4H	High	HSM-MX	N/A	8	Yes	Yes	EOS-TC108/125/135
		Staggered	4H	High	HSM-MX	N/A	9	Yes	No	EOS-TC108/125/135
		Staggered	4H	High	HSM-MX	N/A	11	Yes	Yes	EOS-TC125/135
	S6	Staggered	4L	Low	HSM-MX	N/A	8	Yes	Yes	EOS-TC125/135
		Staggered	4L.	Low	HSM-MX	N/A	9	Yes	No	EOS-TC125/135
	S7	Non-staggered	5	Low	HSM-MX	N/A	8	Yes	No	EOS-TC125/135
		Non-staggered	5	Low	HSM-MX	N/A	9	Yes	No	EOS-TC125/135

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Table 1-2
System Configurations for the NUHOMS® EOS System and NUHOMS® MATRIX System
(2 Pages)

DSC	System Configuration	Basket Design	Basket Type	Emissivity/ Poison	Storage Module	Wind Deflector	HLZC	Intact	Damaged/ Failed	Transfer Cask
EOS-89BTH	S8	Non-Staggered	1	High	EOS-HSM	Yes	1	Yes	No	EOS-TC125
		Non-Staggered	*1*	*High*	*EOS-HSM*	*Yes*	*4*	*Yes*	*No*	*EOS-TC125*
		Non-Staggered	*1*	*High*	*EOS-HSM*	*Yes*	*5*	*Yes*	*No*	*EOS-TC125*
		Non-Staggered	*1*	*High*	*EOS-HSM*	*Yes*	*6*	*Yes*	*No*	*EOS-TC125*
	S9	Non-Staggered	2	High	EOS-HSM	No	2	Yes	No	EOS-TC108/125
		Non-Staggered	3	High	EOS-HSM	No	3	Yes	No	EOS-TC108/125
	S10	Non-Staggered	3	High	HSM-MX	N/A	3	Yes	No	EOS-TC108/125
	S11	*Non-Staggered*	*1*	*High*	*HSM-MX*	*N/A*	*4*	*Yes*	*No*	*EOS-TC125*
		Non-Staggered	*1*	*High*	*HSM-MX*	*N/A*	*5*	*Yes*	*No*	*EOS-TC125*
		Non-Staggered	*1*	*High*	*HSM-MX*	*N/A*	*6*	*Yes*	*No*	*EOS-TC125*

Notes:

1. Wind deflectors are needed only if the heat load is greater than 41.8 kW.
2. For HLZC 5, wind deflectors are needed only if the heat load of a single fuel assembly is greater than 1.625 kW.
3. *Basket Type 4HA with anodized aluminum plates is required for HLZCs storing fuels with decay heats higher than 3.5 kW. Basket Type 4HA capabilities bound basket types 4L and 4H and may be used in lieu of any 4L and 4H basket.*

2.1 SSCs Important to Safety

Table 2-1 provides a list of major NUHOMS® EOS System independent spent fuel storage installation (ISFSI) components and their classification. Table 2-1 identifies all SSCss that are ITS. Components are classified in accordance with the criteria of 10 CFR Part 72. Structures, systems, and components classified as ITS are defined in 10 CFR 72.3 as the features of the ISFSI whose function is:

- To maintain the conditions required to store spent fuel safely.
- To prevent damage to the spent fuel container during handling and storage.
- To provide reasonable assurance that spent fuel can be received, handled, packaged, stored, and retrieved without undue risk to the health and safety of the public.

These criteria are applied to the NUHOMS® EOS System components in determining their classification in the paragraphs that follow.

2.1.1 Dry Shielded Canisters

The EOS-37PTH dry shielded canister (DSC) and EOS-89BTH DSC provide the fuel assembly (FA) support required to maintain the fuel geometry for criticality control. Accidental criticality inside a DSC could lead to offsite doses comparable with the limits in 10 CFR Part 100 [2-1], which must be prevented. The DSCs also provide the confinement boundary for radioactive materials. Therefore, the DSCs are designed to maintain structural integrity under all accident conditions identified in Chapter 12 without losing its function to provide confinement of the spent fuel assemblies (SFAs). The DSCs are designed, constructed, and tested in accordance with a quality assurance (QA) program incorporating a graded quality approach for ITS requirements as defined by 10 CFR Part 72, Subpart G, paragraph 72.140(b) and described in Chapter 14.

2.1.2 Horizontal Storage Module (EOS-HSM/EOS-HSMS)

The EOS horizontal storage module (HSM) and EOS-HSMS are essentially identical except the EOS-HSMS base is split into two parts. EOS-HSM is used herein for both the EOS-HSM and EOS-HSMS. The EOS-HSMs are considered ITS since these provide physical protection and shielding for the DSC during storage. The reinforced concrete HSM is designed in accordance with American Concrete Institute (ACI) 349-06 [2-3] and constructed to ACI-318-08 [2-4]. *The steel-plate composite (EOS-HSM-SC) is designed in accordance with ANSI/AISC N690-18 [2-21].* The level of testing, inspection, and documentation provided during construction and maintenance is in accordance with the quality assurance requirements as defined in 10 CFR Part 72, Subpart G and as described in Chapter 14. Thermal instrumentation for monitoring EOS-HSM concrete temperatures is considered "not important-to-safety" (NITS).

2.2 Spent Fuel to Be Stored

The NUHOMS® EOS System is designed to accommodate pressurized water reactor (PWR) (14x14, 15x15, 16x16 and 17x17 array designs) and boiling water reactor (BWR) (7x7, 8x8, 9x9, 10x10*, and 11x11* array designs) fuel types that are available for storage. As described in Chapter 1, there are two DSC designs for the NUHOMS® EOS System: the EOS-37PTH DSC for PWR fuel and EOS-89BTH DSC for BWR fuel. The EOS-37PTH DSC is designed to accommodate up to 37 intact PWR FAs with uranium dioxide (UO_2) fuel, zirconium-alloy cladding, and with or without control components. The EOS-37PTH DSC is also designed to accommodate up to eight damaged FAs or up to four failed fuel canisters (FFCs), with the balance being intact FAs. The EOS-89BTH DSC is designed to accommodate up to 89 intact BWR FAs with UO_2 fuel, zirconium-alloy cladding, and with or without fuel channels. Specifications for the fuel to be stored in the NUHOMS® EOS System are provided in Technical Specifications (TS) Sections 2.1 and 2.2.

The cavity length of the DSC is determined for a specific site to match the FA length used at that site, including control components (CCs), as applicable. Both DSCs store intact, including reconstituted and blended low enriched uranium (BLEU), FAs as specified in Table 2-2, Table 2-3 and Table 2-4. Any FA that has fuel characteristics within the range of Table 2-2, Table 2-3 and Table 2-4 and meets the other limits specified for initial enrichment, burnup and heat loads is acceptable for storage in the NUHOMS® EOS System. Equivalent fuels manufactured by other vendors are also acceptable.

Damaged and failed fuel from the FA classes detailed in Table 2-2 and PWR fuels in Table 2-4 are also acceptable for storage in the EOS-37PTH DSC in the appropriate compartments. The potential for fuel reconfiguration for intact, damaged, and failed fuel under normal, off-normal, and accident conditions is summarized in Table 2-4a.

All fuel categorized as failed shall be placed in a failed fuel canister (FFC). Failed fuel may include FAs, fuel rods, segments of fuel rods, fuel pellets, and debris. FFCs are not required for damaged FAs, because damaged FAs maintain their geometry under normal and off-normal conditions.

The failed fuel content of each FFC is limited to the maximum metric tons of uranium (MTU) of an intact fuel assembly for each class. These limits are summarized in *Table 2 of the Technical Specifications [2-18]*. Failed CCs may also be stored inside an FFC. *Failed CCs are defined as CCs that may not maintain configuration for normal or off-normal conditions and thus could impact the safety function of the basket, degrade the fuel cladding, or result in an unanalyzed condition. Disassembled CCs are considered failed. A CC with missing rods or components that is otherwise structurally sound is considered intact.* The maximum Co-60 content for failed CCs is the same as intact CCs.

All Indicated Changes are Scope Item 1.

The maximum allowable assembly average burnup is limited to 62 GWd/MTU and the minimum cooling time is *1 year for both the EOS-37PTH DSC and 1 year for the EOS-89BTH DSC*. Dummy FAs and reconstituted FAs are also included in the EOS-37PTH DSC and EOS-89BTH DSC payloads. Low enriched or natural uranium fuel rods or unirradiated non-fuel rods are acceptable for storage in an EOS-37PTH DSC and EOS-89BTH DSC as intact FAs.

Fuel assemblies that contain fixed integral non-fuel rods are also considered as intact FAs. These FAs are different than reconstituted assemblies because fuel rods are not "replaced" by non-fuel rods, rather the non-fuel rods are part of the initial fuel design. The non-fuel rods displace the same amount of moderator, with zirconium-alloy (or aluminum) cladding and typically contain burnable absorber (or other non-fuel) material. The radiation and thermal source terms for the non-fuel rods are significantly lower than those of the fuel rods since there is no significant radioactive decay source. The internal pressure of the non-fuel rods after irradiation is lower than those of the fuel rods since there is no fission gas generation. The reactivity of the fuel rods (from a criticality standpoint) is significantly higher than that of non-fuel rods. In summary, the mechanical, thermal, shielding, and criticality evaluations for these rods are bounded by those of the regular fuel rods. Therefore, no further evaluations are required for the qualification of these FAs.

Reconstituted assemblies containing an unlimited number of low enriched or natural uranium fuel rods or unirradiated non-fuel rods are acceptable for storage. Reconstituted fuel assemblies with irradiated stainless steel rods are allowed, with additional restrictions. These restrictions vary between the EOS-37PTH DSC and EOS-89BTH DSC and are defined in the Technical Specifications, Table 22 through Table 25 [2-18].

The EOS-37PTH DSC may contain less than 37 FAs and the EOS-89BTH DSC may contain less than 89 FAs. In both DSCs, the basket slots not loaded with FAs may have empty slots or be loaded with dummy FAs. The dummy FAs approximate the weight and center of gravity of an FA.

The NUHOMS® EOS-37PTH DSC can also accommodate up to eight damaged FAs placed in the DSC. Damaged PWR FAs are defined in Section 1.1 of the Technical Specifications [2-18]. *Locations for damaged fuel storage are shown in Figure 13 of the Technical Specifications [2-18].*

The NUHOMS® EOS-37PTH DSCs can also accommodate up to a maximum of four FFCs, placed in cells located on the outer edge of the DSC. Failed fuel is defined in Section 1.1 of the Technical Specifications [2-18]. *Locations for failed fuel storage are shown in Figure 13 of the Technical Specifications [2-18].*

Following loading, each DSC is evacuated and then backfilled with an inert gas, helium, to preclude detrimental chemical reaction between the fuel and the DSC interior atmosphere during storage. Multilayer, *confinement boundary* welds at each end of the DSC and multi-layer circumferential and longitudinal DSC shell welds ensure retention of the helium atmosphere for the full storage period.

2.2.1 EOS-37PTH DSC

The EOS-37PTH DSC stores up to 37 PWR FAs with up to eight damaged FAs or four FFCs with characteristics as described in Table 2-2 and the PWR FAs listed in Table 2-4. One or more PWR fuel designs are grouped under a “PWR class”. EOS-37PTH DSC payloads may also contain CCs, such as identified below, with radiological characteristics as listed in Table 3 and *Figure 2-3a through Figure 2-3m*:

Burnable Poison Rod Assemblies

- Burnable poison rod assemblies (BPRAs),
- Burnable absorber assemblies (BAAs),
- Wet annular burnable absorbers (WABAs),
- Vibration suppression inserts (VSIs),

Thimble Plug Assemblies

- Thimble plug assemblies (TPAs),
- Control spiders,
- Orifice rod assemblies (ORAs),

Control Element Assemblies

- Control rod assemblies (CRAs),
- Rod cluster control assemblies (RCCAs),
- Control element assemblies (CEAs),
- Axial power shaping rod assemblies (APSRAs),
- Peripheral power suppression assemblies (PPSAs),
- Flux suppression inserts (FSIs),

Neutron Sources

- Neutron sources,
- Neutron source assemblies (NSAs).

Damaged fuel containing control components may be stored in the designated damaged fuel compartments. Similarly, failed control component debris may be stored in the FFCs.

Control components not explicitly listed herein are also authorized within the DSC, as long as they meet the following criteria:

1. External materials are limited to zirconium alloys, nickel alloys, and stainless steels,
2. Radiological limits listed in Table 3 and *Figure 2-3a through Figure 2-3m*, and
3. They fit within the weight limits and dimensional limits of the DSC.

10 CFR 72.236(a) requires the maximum heat designed to be dissipated and the maximum spent fuel loading limit to be specified in the TS. For the EOS-37PTH DSC transferred in the EOS-TC125/135 and stored in the EOS-HSM, Figure 12 of the TS provides this required information, wherein the maximum heat load of the DSC is limited to 50 kW. It also provides limits on the maximum allowable heat loads in each fuel compartment and zone.

The limits on the total decay heat load of the DSC and the maximum heat load in each fuel compartment and zone in Figure 12 of the Technical Specification [2-18] are used to qualify the various HLZCs and to also verify the corresponding radiation source term is consistent with the shielding analysis presented in Chapter 6. The maximum weight of a FA plus CC, if applicable, is 1,900 lbs.

Furthermore, since TS Figure 12 [2-18] presents only the maximum heat loads, there can be a multitude of ways that the heat loads in each fuel compartment and zone can be adjusted to meet the total heat load limit of the DSC. To ensure this adjustment meets all the design criteria, the various HLZCs that are developed based on Figure 12 of TS [2-18] must be evaluated and pre-qualified. It should be noted that the pre-qualification is limited to thermal and structural design functions, since the shielding evaluation in Chapter 6 considers a bounding evaluation that encompasses the maximum heat loads in Figure 12 of TS [2-18].

UFSAR Figure 2-3a through Figure 2-3f and Figure 2-3j through Figure 2-3m present examples for EOS-37PTH wherein HLZCs 1 to 6 and 10 to 13 are qualified based on the limitations and constraints of TS Figure 12. Chapter 4, Sections 4.4 and 4.5 present the evaluations of HLZCs 1 through 3, Appendix 4.9.6 provides the evaluations of HLZCs 4 through 6, Appendix 4.9.7 provides the evaluations of HLZCs 10 and 11, and Appendix 4.9.9 provides the evaluation of HLZCs 12 and 13 in the EOS-HSM and EOS-TC125/135.

In addition, LCO 3.1.3 of the TS [2-18] notes that a minimum duration of 13 hours shall be allowed for transfer operations (8 hours for the transfer and 5 hours for recovery as allowed by the action statements). Table 2-10 presents the minimum transfer time limits for the various HLZCs. It should be noted that these time limits are the minimum required time limits for transfer operations based on the maximum allowable heat loads for each HLZC and a new time limit may be determined to allow for longer time limits if the DSC is loaded to less than the maximum allowable limit.

The evaluations presented for storage in EOS-HSM and EOS-TC125/135 in Chapter 4 present the methodology to evaluate and pre-qualify additional HLZCs.

Section2.4.3.1 presents the detailed methodology to evaluate and pre-qualify additional HLZCs based on these evaluations.

For EOS-37PTH DSCs transferred in the EOS-TC108 and stored in EOS-HSM or HSM-MX and for those transferred in EOS-TC125/TC135 and stored in the HSM-MX, Figures 1B through 1I and Figure 1K of the Technical Specifications [2-18] apply. These figures define the maximum decay heat, failed/damaged fuel locations, and other parameters for PWR fuel assemblies, with or without CCs, authorized for storage. These tables are used to ensure that the decay heat load of the FA to be stored is less than that as specified in each table, and that the corresponding radiation source term is consistent with the shielding analysis presented in Chapter 6. *The parameters of Section 2.1 of the TS [2-18] apply.*

The heat loads listed in *Figure 2-3a through Figure 2-3m* [2-18] are the maximum allowable heat loads for each FA and the maximum allowable heat load per DSC. These heat loads can be reduced to ensure adequate heat removal capability is maintained to accommodate site-specific conditions. Some examples of the site-specific conditions are a higher ambient temperature, different blocked vent duration, a requirement to use a different neutron absorber plate or a requirement for a specific coating on the basket steel plates. Each of these changes could result in a change to the inputs of the thermal evaluation utilized in the UFSAR. To ensure that adequate heat removal is maintained with these modified inputs, the bounding evaluations for storage and transfer operations should be re-evaluated. The maximum fuel cladding temperature based on the modified inputs shall be lower than the maximum fuel cladding temperatures listed in the Chapter 4 and Chapter A.4 for the same bounding evaluations.

As limited by their definition, damaged FAs maintain their geometric configuration for normal and off-normal conditions and are confined to their respective compartments by means of top and bottom end caps. Damaged FAs do not contain missing major sub-components like top and bottom nozzles that impact their ability to maintain their geometric configuration for normal and off-normal conditions during loading.

From the standpoint of NUREG-1536 Revision 1, the damaged FAs for the EOS System are more similar to the undamaged FAs, where their geometry is still in the form of intact bundles. For completeness, failed fuel for the EOS System is more similar to the damaged FAs per NUREG-1536 Revision 1 and will require FFCs.

The fuel compartment and the top and bottom end cap together form the "acceptable alternative," per NUREG-1536 Revision 1 for confinement of damaged fuel. If fuel particles are released from the damaged assembly, the top and bottom end caps provide for the confinement of gross fuel particles to a known volume. Similarly, the FFC provides confinement of the FFC contents to a known volume, and has lifting features to allow the ability to unload the FFC. Additionally, consistent with ISG-2, Revision 2, ready retrieval of the damaged and failed fuel *as well as intact fuel* is based on the ability to remove a canister from the HSM.

The structural analysis for damaged fuel cladding described in Chapter 3 demonstrates that the cladding does not undergo additional degradation under normal and off-normal conditions of storage. The structural analyses performed for FFCs are provided in Section 3.9.2.1A. The criticality analysis described in Chapter 7 is based on damaged and failed fuel in the most limiting credible geometry and material reconfigurations under normal, off-normal, and accident conditions. The maximum enrichment values for damaged and/or failed fuel are reduced to account for fuel reconfiguration. The thermal analysis described in Chapter 4 limits the maximum allowable heat load per DSC storing damaged or failed fuel to be less than that for when storing only intact FAs. The shielding analysis described in Chapter 6 demonstrates that damaged or failed fuel reconfiguration has a negligible effect on dose rates compared to intact fuel.

Calculations were performed to determine the FA type that was most limiting for each of the analyses including shielding, criticality, thermal and confinement. These evaluations are performed in Chapter 6, 7, 4 and 5, respectively.

2.2.2 EOS-89BTH DSC

The EOS-89BTH DSC design accommodates up to 89 intact BWR FAs with characteristics as described in Table 2-3, and the BWR FAs listed in Table 2-4. One or more BWR FA designs are grouped under a "BWR Fuel ID". The EOS-89BTH accommodates:

- Fuel assemblies with and without channels,
- Fuel assemblies with and without channel fasteners.

For localized damage of the HSM resulting from DBT missile impact, the four postulated missiles are used in the evaluation of concrete penetration, scabbing, and perforation thickness. The modified National Defense Research Committee (NDRC) empirical formula is used for this evaluation as recommended in NUREG-0800, Section 3.5.3, Revision 3 [2-11].

2.3.2 Tornado Wind and Tornado Missiles for EOS-TC

The EOS-TC is evaluated for the tornado characteristics as specified in NRC Regulatory Guide 1.76, Revision 1 [2-8] and the missiles spectrum of NUREG-0800, Revision 3, Section 3.5.1.4 [2-10] with missile velocity for Region I. The evaluation is performed for an EOS-TC secured horizontally to the cask support skid/transport trailer. Both overall stability and maximum cask stresses are evaluated.

2.3.2.1 Tornado Wind Design Parameters

The DBT wind intensities used for the EOS-TC designs are obtained from NRC Regulatory Guide 1.76, Revision 1 [2-8]. Region I intensities are utilized since they result in the most severe loading parameters. For this region, the maximum wind speed is 230 mph, the rotational speed is 184 mph and the maximum translational speed is 46 mph. The radius of the maximum rotational speed is 150 feet, the pressure drop across the tornado is 1.2 psi and the rate of pressure drop is 0.5 psi per second.

2.3.2.2 Tornado Missiles

The tornado missiles specified in NRC Regulatory Guide 1.76, Revision 1 [2-8] are used to evaluate the EOS-TC. As specified in NUREG-0800, Revision 3, Section 3.5.1.4 [2-10], the postulated missiles include at least (1) a massive high-kinetic-energy missile that deforms on impact, (2) a rigid missile to test penetration resistance, and (3) a small rigid missile of a size sufficient to just pass through any openings in protective barriers. The DBT missiles used in the evaluation of EOS-TC are listed below:

Missile Type	Schedule 40 Pipe	Automobile	Solid Steel Sphere
Dimensions	6.625 in. dia x 15 ft long	16.4 ft x 6.6 ft x 4.3 ft	1 in. dia
Mass	287 lb	4000 lb	0.147 lb
C_DA/m	0.0212 ft^2/lb	0.0343 ft^2/lb	0.0166 ft^2/lb
V_{Mh}^{max}	135 ft/s	135 ft/s	26 ft/s

Barrier design should be evaluated assuming a normal impact to the surface for the Schedule 40 pipe and automobile missiles. The automobile missile is considered to impact at all altitudes less than 30 feet above grade level.

All Indicated Changes are Scope Item 5.

2.3.3 Water Level (Flood) Design

EOS-HSM inlet vents are blocked when the depth of flooding is greater than 0.76 m (2 ft-6 in.) above the level of the ISFSI basemat. The DSC is wetted when flooding exceeds a depth of 1.7 m (5 ft-8 in.) above ISFSI basemat. Greater flood heights result in submersion of the DSC and blockage of the EOS-HSM outlet vents.

The DSC and EOS-HSM are conservatively designed for an enveloping design basis flood. The flood is postulated to result from natural phenomena such as tsunamis and seiches as specified by 10 CFR 72.122(b) [2-6]. A bounding assumption of a 15-meter (50-foot) flood height and water velocity of 4.6 m/sec (15 fps) is used for the flood evaluation. The EOS-HSM is evaluated for the effects of the 4.6 m/sec (15 fps) water current impinging upon the side of the submerged EOS-HSM. The DSC is subjected to an external pressure equivalent to a 15-meter (50-foot) head of water. These evaluations are presented in Chapter 3 and Section 12.3.5. The effects of water reflection on DSC criticality safety are addressed in Chapter 7. Due to its short term infrequent use, the onsite EOS-TC is not explicitly evaluated for flood effects. ISFSI procedures should ensure that the EOS-TC is not used for DSC transfer during flood conditions.

The plant-specific design basis flood (if the possibility for flooding exists at a particular ISFSI site) should be evaluated by the licensee and shown to be enveloped by the flooding conditions used for this generic evaluation of the NUHOMS® EOS System.

2.3.4 Seismic Design

The seismic design criteria for the EOS-HSM are based on the NRC Regulatory Guide 1.60 [2-13] response spectra anchored at a zero period acceleration (ZPA) of 0.45g in the horizontal direction and 0.30g in the vertical direction and enhanced frequency content above 9 Hz. The horizontal and vertical components of the design response spectra correspond to a maximum horizontal ground acceleration of 1.0g are shown in Figure 2-1. The seismic structural evaluations consider both stability evaluation and stress qualification of the EOS-HSM. The structural stress qualifications of the HSM *concrete, steel, and SC* components are conservatively based on the spectra shown in Figure 2-1 anchored at 0.50g in the horizontal direction and 0.33g in the vertical direction. The stability criteria for seismic loading are based on the stability response of a single, freestanding EOS-HSM with and without an end shield wall.

The EOS-HSMs in the array have no anchorage to the concrete basemat and there are no positive structural connections between EOS-HSMs. The stability analyses consider the effects of sliding and rocking motions, and determine the maximum possible sliding of a single module with and without an end shield wall. The EOS-HSM will neither slide nor overturn at design ZPA of 0.45g in the horizontal direction and 0.30g in the vertical direction.

The licensee shall determine if, based on ISFSI-specific site investigations, a soil structure interaction (SSI) analyses ought to be performed to assess potential site-specific amplifications. The SSI evaluations are based on ISFSI site-specific parameters (free-field accelerations, strain-dependent soil properties, EOS-HSM array configurations, etc.). The SSI response spectra at the base of the EOS-HSMs are to be bounded by the EOS-HSM design basis seismic criteria response spectra, i.e., the Regulatory Guide 1.60 response spectra shape, with enhanced spectral accelerations above 9 Hz, and anchored at 0.45g horizontal and 0.30g vertical directions. The licensee shall reconcile spectral accelerations from the SSI analysis response spectra that exceed the seismic criteria spectra (if any); 5% damped response spectra may be used in making these determinations.

Note: For dynamic analysis, the stability evaluation shall be performed using the methodology in CoC 1029 [2-19].

Since the DSC can be considered to act as a large diameter pipe for the purpose of evaluating seismic effects, the "Equipment and Large Diameter Piping System" category in NRC Regulatory Guide 1.61, Table 1 [2-16] is applicable. Therefore, a damping value of 3% of critical damping for the design bases safe shutdown earthquake is used. Similarly, from the same Regulatory Guide table, a damping value of 7% of critical damping is used for the reinforced concrete structural components of the EOS-HSM. *A damping value of 5% of critical damping prescribed by [2-21] is used for the SC components of the EOS-HSM.*

2.3.5 Snow and Ice Loading

Snow and ice loads for the HSM are derived from ASCE 7-10 [2-12]. The maximum 100-year roof snow load, specified for most areas of the continental United States for an unheated structure, of 110 psf is assumed.

Snow and ice loads for the onsite TC with a loaded DSC are not evaluated because these are negligible due to the smooth curved surface of the cask, the heat rejection of the SFAs, and the infrequent short term use of the cask.

2.3.6 Tsunami

Specific analyses including analysis for tip-over are not done for tsunamis as they are typically bounded by the tornado wind and flooding load conditions. The licensee should evaluate site-specific impacts of a tsunami.

2.3.7 Lightning

A lightning strike will not cause a significant thermal effect on the EOS-HSM or stored DSC. The effects on the EOS-HSM resulting from a lightning strike are discussed in Section 12.3.7.

All Indicated Changes are Scope Item 2.

2.4.2 Structural

2.4.2.1 EOS-DSC Design Criteria

The principal design criteria for the DSCs are presented in Table 2-5 and Table 2-6. The EOS-37PTH DSC is designed to store intact PWR FAs with or without CCs, damaged fuel and failed fuel canisters. The EOS-89BTH DSC is designed to store intact BWR FAs with or without fuel channels. The maximum total heat generation rate of the stored fuel is limited to 50 kW per DSC for the EOS-37PTH DSC and *48.2* kW per DSC for the EOS-89BTH DSC, in order to keep the maximum fuel cladding temperature below the limit necessary to ensure cladding integrity. The maximum heat load for any single assembly is 3.5 kW for the EOS-37PTH DSC and *1.7* kW for the EOS-89BTH DSC. The fuel cladding integrity is assured by limiting fuel cladding temperature and maintaining a nonoxidizing environment in the DSC cavity as described in Chapter 4.

2.4.2.2 EOS-HSM Design Criteria

The principal design criteria for the EOS-HSM/EOS-HSMS, both the module and DSC support structure, are presented in Table 2-7.

The EOS reinforced concrete EOS-HSM is designed to meet the requirements of ACI 349-06 [2-3]. The ultimate strength method of analysis is utilized with the appropriate strength reduction factors as described in Appendix 3.9.4. *The steel-plate composite EOS-HSM (EOS-HSM-SC) is designed to meet the requirements of ANSI/AISC N690-18 [2-21] with exceptions as noted in Section 4.4.4 of the TS [2-18]. The load and resistance factor design (LRFD) method of ANSI/AISC N690-18 is used as described in Appendix 3.9.8.* The load combinations specified in Section 6.17.3.1 of ANSI 57.9-1984 are used for combining normal operating, off-normal, and accident loads for the EOS-HSM. All seven load combinations specified are considered and the governing combinations are selected for detailed design and analysis. The resulting EOS-HSM load combinations and the appropriate load factors are presented in Appendix 3.9.4. The effects of duty cycle on the EOS-HSM are considered and found to have negligible effect on the design.

2.4.2.3 EOS-TC Design Criteria

The EOS-TCs are designed in accordance with the applicable portions of the ASME Code, Section III, Division 1, Subsection NF for Class 1 vessels, except for the neutron shield tank, which is designed to ASME Code, Section III, Division 1, Subsection ND, since it will see pressure greater than 15 psig. The load combinations considered for the TC normal, off-normal, and postulated accident loadings are shown in Table 2-8. Service Levels A and B allowables are used for all normal operating and off-normal loadings. Service Levels C and D allowables are used for load combinations that include postulated accident loadings. The maximum shear stress theory is used to calculate principal stresses in the cask structural shell. Allowable stress limits for the lifting trunnions conservatively meet the requirements of ANSI N14.6- 1993 [2-14] for critical loads.

2.4.3 Thermal

The NUHOMS® EOS System relies on natural convection through the air space in the EOS-HSM to cool the DSC. This passive convective ventilation system is driven by the pressure difference due to the stack effect (ΔP_s) provided by the height difference between the bottom of the DSC and the EOS-HSM air outlet. This pressure difference is greater than the flow pressure drop (ΔP_f) at the design air inlet and outlet temperatures. The details of the ventilation system design are provided in Chapter 4.

Thermal analysis is based on FAs with decay heat up to 50.0 kW per DSC for the EOS-37PTH and up to *48.2* kW per DSC for the EOS-89BTH. Zoning is used to accommodate high per assembly heat loads. *For the EOS-37PTH DSC stored in the HSM-MX or transferred in the EOS-TC108, t*he heat load zoning configurations (HLZCs) for the DSCs are shown in Figures *1B* through *1I and Figure* 1K of the Technical Specifications [2-18]. *Based on the discussion in Section 2.2.1, for the EOS-37PTH DSC stored in the EOS-HSM and transferred in the EOS-TC125/135, Figure 12 in the TS [2-18] presents the maximum heat load configuration (MHLC) while the individual HLZCs are presented in UFSAR Section 2.4.3.2. For the EOS-89BTH DSC based on the discussion in Section 2.2.2, Figure 11 presents the maximum allowable heat loads in the Technical Specifications while the individual HLZCs are presented in Section 2.4.3.2.* As noted in Section 2.1 of Technical Specification [2-18], the maximum allowable heat loads may be reduced based on the methodology presented in Chapter 4 or Chapter A.4 for each FA type allowed in either the EOS-37PTH DSC or the EOS-89BTH DSC. *The* thermal properties for the various FA types should be determined based on the methodology presented in Chapter 4, Appendix 4.9.1.

The thermal analyses is performed for the environmental conditions listed in Table 2-9.

Peak clad temperature of the fuel at the beginning of the long-term storage does not exceed 400 °C for normal conditions of storage, and for short-term operations, including DSC drying and backfilling. Fuel cladding temperature shall be maintained below 570 °C (1058 °F) for accident conditions involving fire or off-normal storage conditions.

For onsite transfer in the EOS-TC, air circulation may be used, as a recovery action, to facilitate transfer operations when the heat loads in the EOS-37PTH DSC are above 36.35 kW and 34.4 kW in the EOS-89BTH DSC as described in the Technical Specifications [2-18].

Wind deflectors are installed on the EOS-HSM to eliminate the effect of sustained winds for DSCs *as required* in Section 5.5 of the Technical Specifications [2-18].

2.4.3.1 *Methodology for Evaluating Additional HLZCs in EOS-37PTH DSC and EOS-89BTH DSC*

This section provides the detailed methodology to qualify a new HLZC for EOS-37PTH DSC and EOS-89BTH DSC.

Each new HLZC qualified per Figure 12 of the TS [2-18] will be evaluated for the Basket Type 4H or 4HA if the HLZC contains fuel assembly decay heats higher than 3.5 kW for the EOS-37PTH DSC, which includes the coated steel plate for high emissivity as indicated in Section 4.9.1.2, high conductivity poison plate as indicated in Section 4.2.2, and anodized aluminum plate as indicated in Section 4.2.1 Item 13. HLZCs evaluated for use with the EOS-37PTH shall follow the same methodology as described in Chapter 4, Section 4.9.9.3 for the EOS-HSM. Similarly, the methodology laid out in Chapter 4, Section 4.9.9.2 shall be followed to ensure that the various design criteria for transfer operations are satisfied.

Each new HLZC qualified per Figure 11 of the TS will be evaluated for the Basket Type 1 of the EOS-89BTH DSC, which includes the coated steel plate for high emissivity, as indicated in Section 4.9.1.2, and high conductivity poison plate, as indicated in Section 4.2.2. HLZCs evaluated for use with the EOS-89BTH shall follow the same methodology as described in Chapter 4, Section 4.9.8.2 for EOS-HSM and/or Appendix A.4, Section A.4.5.6 for HSM-MX depending on the storage module. Similarly, the methodology laid out in Chapter 4, Section 4.9.8.3 shall be followed to ensure that the various design criteria for transfer operations are satisfied.

The following steps present the methodology to qualify new HLZCs for EOS-37PTH DSC and EOS-89BTH DSC:

1. *HLZCs shall satisfy the maximum per DSC and per zone/compartment heat loads listed in Figure 11 and Figure 12 of the TS.*
   a) *EOS-37PTH DSC: Similar to HLZCs 12 and 13, a HLZC may require the total decay heat load per EOS-37PTH DSC to be adjusted to meet the requirements specified in Figure 12 of the TS. For these types of HLZCs, the same approach as presented in Section 4.9.9.1 for HLZCs 12 and 13 shall be utilized to ensure the bounding temperatures and maximum internal pressure are determined.*
   EOS-89BTH: Similar to HLZC 5 and 6, a HLZC may require the total decay heat load per EOS-89BTH DSC to be adjusted to meet the requirements specified in Figure 11 of the TS. For these types of HLZCs, the same approach as presented in Section 4.9.8.1 and Appendix A.4 for HLZCs 5 and 6 shall be utilized to ensure the bounding temperatures and maximum internal pressure are determined.

2. *Thermal evaluations based on the storage and transfer configuration described above shall be performed for each new HLZC to demonstrate that:*
    a) *Thermal design criteria specified in Section 4.2, Chapter 4 are satisfied.*
    b) *The calculated duration for the blocked vent accident condition is equal to or greater than the durations specified in Section 5.1.3.1 of the TS for EOS-HSM and Section 5.1.3.2 of the TS for HSM-MX, applicable to the EOS-89BTH only.*
    The calculated duration should only be used to confirm that the new HLZCs are compliant with the TS for temperature monitoring. It cannot be used to reduce or increase the durations for blocked vent accident condition specified in the TS for temperature monitoring.
    c) *The calculated "Total Time for Transfer," as defined in Section 4.9.9.2.3 for EOS-37PTH DSC and Section 4.9.8.3.4 for EOS-89BTH DSC, at the maximum allowable heat load for each HLZC qualified per Figure 11 and Figure 12 of the TS shall not be less than the sum of the transfer time limit (8 hours) and the duration for recovery actions (5 hours) listed in LCO 3.1.3 of the TS. This requirement also applies to a "Total Time for Transfer" calculated with less than the maximum allowable heat load allowed per each HLZC.*

3. *The thermal evaluations for the storage or transfer configurations as described in Step 2 represent the fuel assemblies as homogenized regions. The bounding effective properties for homogenized regions for the various fuel assembly classes listed in Section 2.2 of the TS are listed in Chapter 4, Appendix 4.9.1. If the thermal properties for the homogenized regions are updated, they shall be calculated based on the same methodology as presented in Section 4.9.1.1 or 4.9.1.2 for the EOS-37PTH and EOS-89BTH DSCs, respectively.*

4. *If design changes of the system result in updating the thermal evaluations of the storage or transfer configuration as described in Step 2, the impact of these design changes shall be evaluated separately, and then as necessary, collectively. The design changes can be evaluated either based on the 10 CFR 72.48 process, or through a CoC No. 1042 amendment submitted to NRC for review and approval.*

Design changes (i.e., individual and collective) cannot result in an alteration of the thermal physics, correlations, and submodels of the thermal model being outside of their applicable ranges from the baseline analyses in Chapter 4, Appendix 4.9.8, Appendix 4.9.9 and Appendix A.4, Section A.4.5.6.

5. *Based on the thermal evaluation in Step 2 through Step 4 (if applicable), the impact of temperature changes on structural design functions shall be considered based on the methodology in Chapter 3.*

2.4.3.2 HLZCs for EOS-37PTH DSC and EOS-89BTH DSC

HLZCs 1 through 6 and 10 through 13 that are qualified for use with the EOS-37PTH DSC based on the methodology presented in Section 2.4.3.1 are presented in Figure 2-3a through Figure 2-3f and Figure 2-3j through Figure 2-3m. In addition to these HLZCs, additional HLZCs may be qualified based on the methodology presented in Section 2.4.3.1. Note that HLZCs 1-3, 4-6, and 7-11 were previously approved by the NRC in Amendment 0, 1, and 2, respectively.

HLZCs 1 through 6 that are qualified for use with the EOS-89BTH DSC based on the methodology presented in Section 2.4.3.1 are presented in Figure 2-2a through Figure 2-2f. In addition to these HLZCs, additional HLZCs may be qualified based on the methodology presented in Section 2.4.3.1. Note that HLZCs 1-3 were previously approved by the NRC in Amendment 0.

2.4.4 Shielding/Confinement/Radiation Protection

As described earlier, the DSC shells are a welded stainless or duplex steel pressure vessel that includes thick shield plugs at both ends to maintain occupational exposures as low as reasonably achievable (ALARA). The top end of the DSC has nominally 10 inches of steel shielding and the bottom eight inches of steel shielding. The confinement boundary is designed, fabricated, and tested to ensure that it is leaktight in accordance with [2-15]. Section 2.4.2.1 provides a summary of the features of the DSCs that ensure confinement of the contents.

The EOS-HSM/EOS-HSMS provides the bulk of the radiation shielding for the DSCs. The EOS-HSM designs can be arranged in either a single-row or a back-to-back arrangement. Thick concrete *or SC* supplemental shield walls are used at either end of an EOS-HSM array and along the back wall of single-row arrays to minimize radiation dose rates both onsite and offsite. The nominal thickness of the EOS-HSM roof is 44 inches for biological shielding. Separate shield walls at the end of a module row, in conjunction with the module wall, provide a minimum thickness of four feet for shielding. Similarly, an additional shield wall is used at the rear of the module if the ISFSI is configured as single module arrays. Sufficient shielding is provided by thick concrete *or SC* side walls between EOS-HSMs in an array to minimize doses in adjacent EOS-HSMs during loading and retrieval operations. Section 11.3 provides a summary of the offsite dose calculations for representative arrays of design basis EOS-HSMs providing assurance that the limits in 10 CFR 72.104 and 10 CFR 72.106(b) are not exceeded. Dose rates reported do not include the effect of any optional dose reduction hardware.

The EOS-TCs are designed to provide sufficient shielding to ensure dose rates are ALARA. The EOS-TCs are constructed of steel and lead gamma shielding with high-density polyethylene neutron shielding at the bottom and water neutron shielding jackets/tanks. The dose rates on and around the EOS-TCs are provided in Chapter 6 and the occupational exposures associated with a loading campaign are provided in Section 11.2. Off-normal and accident doses and dose rates are provided in Chapters 6 and 12.

There are no radioactive releases of effluents during normal and off-normal storage operations. Also, there are no credible accidents that cause significant releases of radioactive effluents from the DSC. Therefore, there are no off-gas or monitoring systems required for the EOS-HSM. An off-gas system is required only during DSC drying operations. During this operation, the spent fuel pool or plant's radwaste system is used to process the air and helium exchanges required to establish a DSC interior inert atmosphere.

All Indicated Changes are Scope Item 2.

2.4.6 Material Selection

Materials are selected based on their corrosion resistance, susceptibility to stress corrosion cracking, embrittlement properties, and the environment in which they operate during normal off-normal and accident conditions. The confinement boundary for the DSC materials meet the requirements of ASME Boiler and Pressure Vessel Code, Section III, Article NB-2000 and the specification requirements of Section II, Part D, with code alternatives provided in Section 4.4.4 of the Technical Specifications [2-18]. The DSC and TC materials are resistant to corrosion and are not susceptible to other galvanic reactions. Studies under severe marine environments have demonstrated that the shell materials used in the DSC shells are expected to demonstrate minimal corrosion during a 80-year exposure. The DSC internals are enveloped in a dry, helium-inerted environment and are designed for all postulated environmental conditions. The HSM is a reinforced concrete *or steel-plate composite* component with an internal DSC support structure (EOS-HSM) or front and rear DSC supports (HSM-MX) that is fabricated to ACI and AISC Code requirements with code alternatives provided in Section 4.4.4 of the Technical Specifications [2-18], respectively; both have durability well beyond their design life of 80 years. Chapter 8 and Chapter A.8 provide additional discussion related to the materials used for the NUHOMS® EOS System.

2.4.7 Operating Procedures

The sequence of operations are outlined for the NUHOMS® EOS System in Chapter 9 for loading of fuel, closure of the DSC, transfer to the ISFSI using the TC, insertion into the HSM, monitoring operations, and retrieval and unloading. Throughout Chapter 9, CAUTION statements are provided at the step where special notice is needed to maintain ALARA, protect the contents of the DSC, protect the public and/or ITS components of the NUHOMS® EOS System.

2.4.8 Acceptance Tests and Maintenance

Chapter 10 specifies the acceptance testing and maintenance program for important to safety components of the NUHOMS® EOS System (DSC, EOS-HSM and EOS-TCs).

2.4.9 Decommissioning

The DSC is designed to interface with a transportation system for the eventual offsite transport of stored canisters by the Department of Energy (DOE) to either a monitored retrievable storage (MRS) facility or a permanent geologic repository. Decommissioning of the ISFSI will be performed in a manner consistent with the decommissioning of the plant itself since all NUHOMS® EOS System components are constructed of materials similar to those found in existing plants.

If the fuel is to be removed from the DSC at the plant prior to shipment, the DSC will likely be contaminated internally by crud from the spent fuel, and may be slightly activated by neutron emissions from the spent fuel. The DSC internals can be cleaned to remove surface contamination and the DSC disposed of as low-level waste. Alternatively, if the contamination and activation levels of the DSC are small enough (to be determined on a case-by-case basis), it may be possible to decontaminate the DSC and dispose of it as commercial scrap pending NRC rulings on below regulatory concern (BRC) waste disposal issues.

While the intent for the NUHOMS® EOS System includes the eventual disposal of each DSC following fuel removal, current closure weld designs do not preclude future development of a non-destructive closure removal technique that allows for reuse of the DSC shell/basket assembly. Economic and technical conditions existing at the time of fuel removal would be assessed prior to making a decision to reuse the DSC.

The exact decommissioning plan for the ISFSI will be dependent on the DOE's fuel transportation system capability and requirements for a specific plant. Because of the minimal contamination of the outer surface of the DSC, no contamination is expected on the internal passages of the EOS-HSM. It is anticipated that the EOS-HSMs can be dismantled and disposed of using commercial demolition and disposal techniques. Alternatively, the EOS-HSMs may be refurbished and reused at another site, or at the MRS for storage of intact DSCs transported from the plant.

2-18 CoC 1042 Appendix A, NUHOMS® EOS System Generic Technical Specifications, Amendment *4*.

2-19 Updated Final Safety Analysis Report For The Standardized Advanced NUHOMS® Horizontal Modular Storage System For Irradiated Nuclear Fuel, 72-1029, Revision 6

2-20 DOE/RW-0184 Volume 1 of 6, "Characteristics of Spent Fuel, High-Level Waste, and Other Radioactive Wastes Which May Require Long-Term Isolation," December 1987, U.S. Department of Energy, Office of Civilian Radioactive Waste Management.

2-21 American National Standards Institute/American Institute of Steel Construction, ANSI/AISC N690-18, "Specification for Safety-Related Steel Structures for Nuclear Facilities."

Table 2-1
NUHOMS® EOS System Major Components and Safety Classification

Component	10 CFR 72 Classification(1)
Dry Shielded Canister (EOS-37PTH DSC and EOS-89BTH DSC)	
Basket Steel Plate	ITS
Poison Plate	ITS
Basket Aluminum Plate	ITS
Transition Rails	ITS
Transition Rail Tie Rod and Nuts	ITS
Transition Rail Angle Plates	ITS
Transition Rail Screw, Washer and Nut	ITS
Shell	ITS
Outer Top Cover Plate	ITS
Top Shield Plug	ITS
Inner Top Cover Plate	ITS
Inner Bottom Cover Plate	ITS
Bottom Shield Plug	ITS
Outer Bottom Cover Plate	ITS
Alternate 1-Bottom Forging	ITS
Lifting Lug Plate	ITS
DSC Lifting Lug	NITS
Drain Port Assembly	NITS
Drain Port Cover and Vent Port Plug	ITS
Test Port Plug	ITS
Grapple Ring and Grapple Support	ITS
Basket Key	ITS
Weld Filler Metal	ITS
Top and Bottom End Caps	ITS
Failed Fuel Canisters	ITS
Horizontal Storage Module (EOS-HSM/EOS-HSMS)	
Reinforced Concrete/*Steel-plate Composite Structure*	ITS
DSC Support Structure	ITS
Thermal Instrumentation (if used)	NITS
ISFSI Basemat and Approach Slabs	NITS
Transfer Equipment	
EOS-TC (TC135/TC125/TC108)	ITS
Cask Lifting Yoke	See Note 2
Transfer Trailer/Skid	NITS
Ram Assembly	NITS
Dry Film Lubricant	NITS
Auxiliary Equipment	
Vacuum Drying System	NITS
Automated Welding System	NITS
TC/DSC Annulus Seal	NITS

Notes:

1. SSCs ITS are defined in 10 CFR 72.3 as those features of the ISFSI whose function is (1) to maintain the conditions required to store spent fuel safely, (2) to prevent damage to the spent fuel container during handling and storage, or (3) to provide reasonable assurance that spent fuel can be received, handled, packaged, stored, and retrieved without undue risk to the health and safety of the public.
2. Safety classification shall be per existing plant-specific requirements under the user's 10 CFR 50 heavy loads program.

All Indicated Changes are Scope Item 2.

Table 2-4a
Potential for Fuel Reconfiguration

Fuel Category	Normal	Off-Normal	Accident
Intact	No	No	No
Damaged	No	No	Yes
Failed	Yes	Yes	Yes

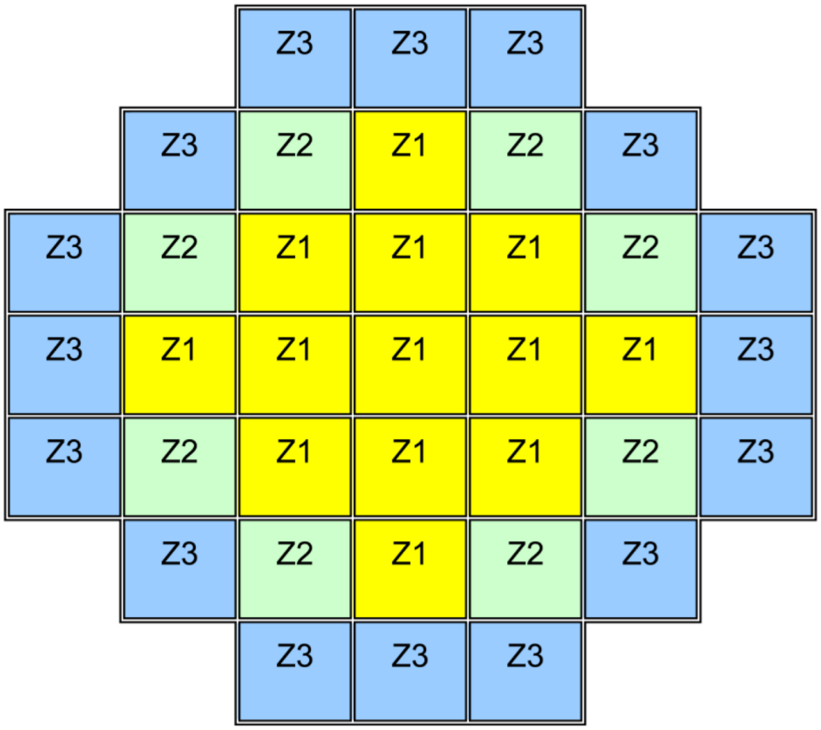
Table 2-4b
Deleted

Table 2-7
HSM Design Criteria

Number	Load Combination	Event
Concrete *and Steel-Plate Composite* Structures		
1	$U > 1.4\,D + 1.7\,(L + R_o)$	Normal
2	$U > 1.05\,D + 1.275\,(L + T_o + W)$	Off-Normal – Wind
3	$U > 1.05\,D + 1.275\,(L + T_o + R_a)$	Off-Normal – Handling
4	$U > D + L + T_o + E$	Accident – Earthquake
5	$U > D + L + T_o + W_t$	Accident – Tornado
6	$U > D + L + T_o + FL$	Accident – Flood
7	$U > D + L + T_a$	Accident – Thermal
Steel Structures Allowable Stress Design		
1	$S > D + L + R_o$	Normal
2	$1.3\,S > D + L + W$	Off-Normal – Wind
3	$1.3\,S > D + L + T_o + R_a$	Off-Normal – Handling
4	$(1.5\,S \text{ or } 1.4\,S_v) > D + L + T_o + W$	Off-Normal – Wind with Thermal
5	$(1.6\,S \text{ or } 1.4\,S_v) > D + L + T_o + E$	Accident – Earthquake
6	$(1.6\,S \text{ or } 1.4\,S_v) > D + L + T_o + W_t$	Accident – Tornado
7	$(1.6\,S \text{ or } 1.4\,S_v) > D + L + T_o + FL$	Accident – Flood
8	$(1.7\,S \text{ or } 1.4\,S_v) > D + L + T_a$	Accident – Thermal
Steel Structures Plastic Strength Design		
1	$U_s > 1.7\,(D + L)$	Normal
2	$U_s > 1.3\,(D + L + W)$	Off-Normal – Wind
3	$U_s > 1.3\,(D + L + R_a)$	Off-Normal – Handling
4	$U_s > 1.3\,(D + L + T_o + W)$	Off-Normal – Wind with Thermal
5	$U_s > 1.1\,(D + L + T_o + E)$	Accident – Earthquake
6	$U_s > 1.1\,(D + L + T_o + W_t)$	Accident – Tornado
7	$U_s > 1.1\,(D + L + T_o + FL)$	Accident – Flood
8	$U_s > 1.1\,(D + L + T_a)$	Accident – Thermal

Table 2-10
Time Limits for Transfer by HLZC

DSC Model	***Applicable HLZC***	***Time Limits (Hours)***
EOS-37PTH	*HLZC 1, 2, 4-13*	*8*
EOS-37PTH	*HLZC 3*	*No Limit*
EOS-89BTH	*HLZC 1 or 2*	*10*
EOS-89BTH	*HLZC 3*	*No Limit*
EOS-89BTH	*HLZC 4-6*	*8*

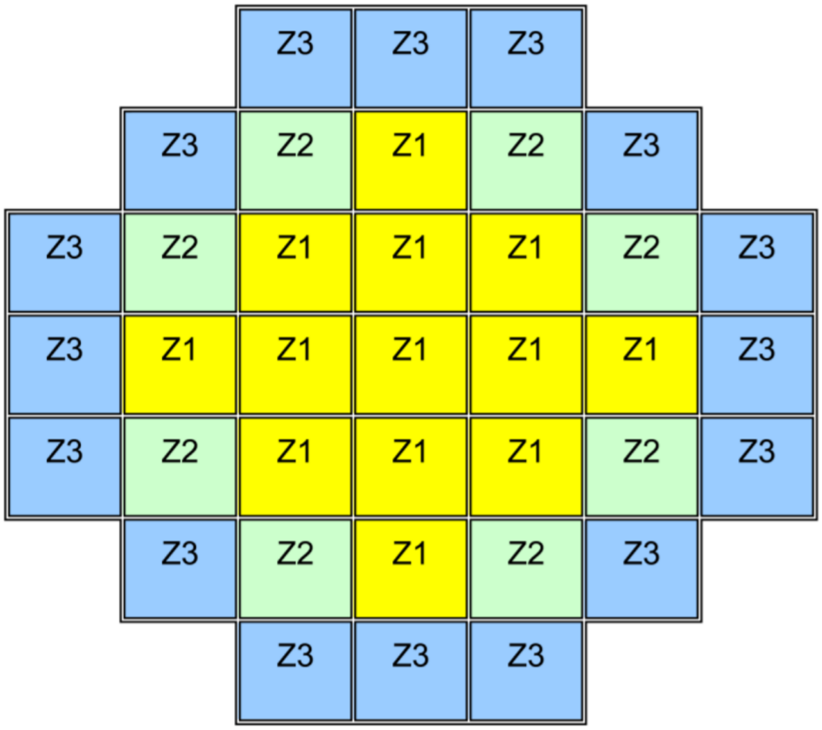


		Z3	Z3	Z3		
	Z3	Z2	Z1	Z2	Z3	
Z3	Z2	Z1	Z1	Z1	Z2	Z3
Z3	Z1	Z1	Z1	Z1	Z1	Z3
Z3	Z2	Z1	Z1	Z1	Z2	Z3
	Z3	Z2	Z1	Z2	Z3	
		Z3	Z3	Z3		

Zone Number	*1*	*2*	*3*
Maximum Decay Heat (kW/FA plus CCs, if included)	*1.0*	*2.0*	*1.3125*
Maximum Number of Fuel Assemblies	*13*	*8*	*16*
Maximum Decay Heat per DSC (kW)	*50.0*		

1. *See UFSAR Table 1-2 or TS Section 2.1 for applicable system configurations.*

Figure 2-3a
Heat Load Zone Configuration 1 for the EOS-37PTH DSC

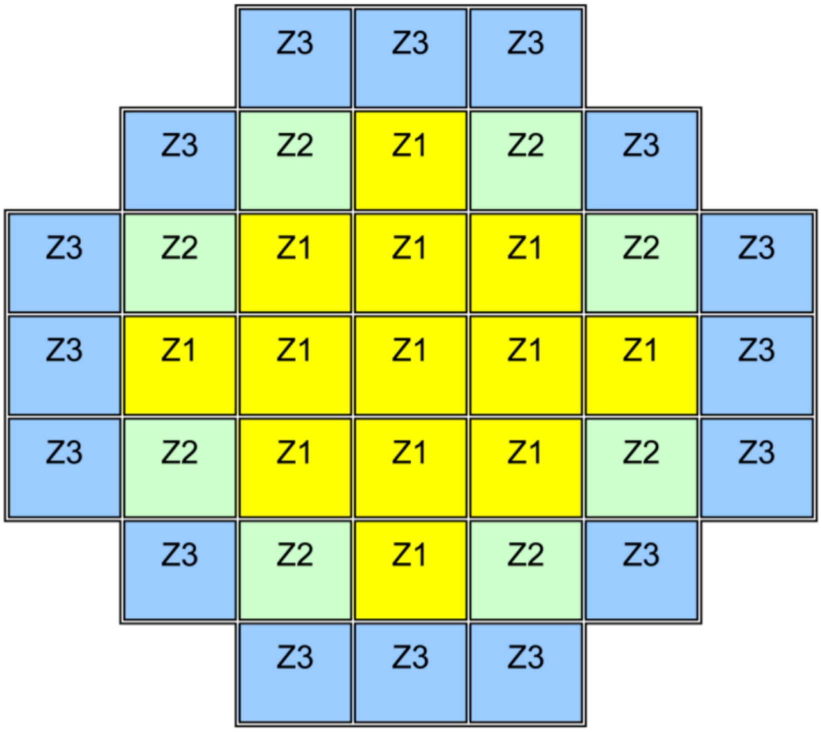


		Z3	Z3	Z3		
	Z3	Z2	Z1	Z2	Z3	
Z3	Z2	Z1	Z1	Z1	Z2	Z3
Z3	Z1	Z1	Z1	Z1	Z1	Z3
Z3	Z2	Z1	Z1	Z1	Z2	Z3
	Z3	Z2	Z1	Z2	Z3	
		Z3	Z3	Z3		

Zone Number	*1*	*2*	*3*
Maximum Decay Heat, (H), (kW/FA plus CCs, if included)	*1.0*	*1.5*	*1.05*
Maximum Number of Fuel Assemblies	*13*	*8*	*16*
Maximum Decay Heat per DSC (kW)	*41.8*		

1. *See UFSAR Table 1-2 or TS Section 2.1 for applicable system configurations.*

Figure 2-3b
Heat Load Zone Configuration 2 for the EOS-37PTH DSC

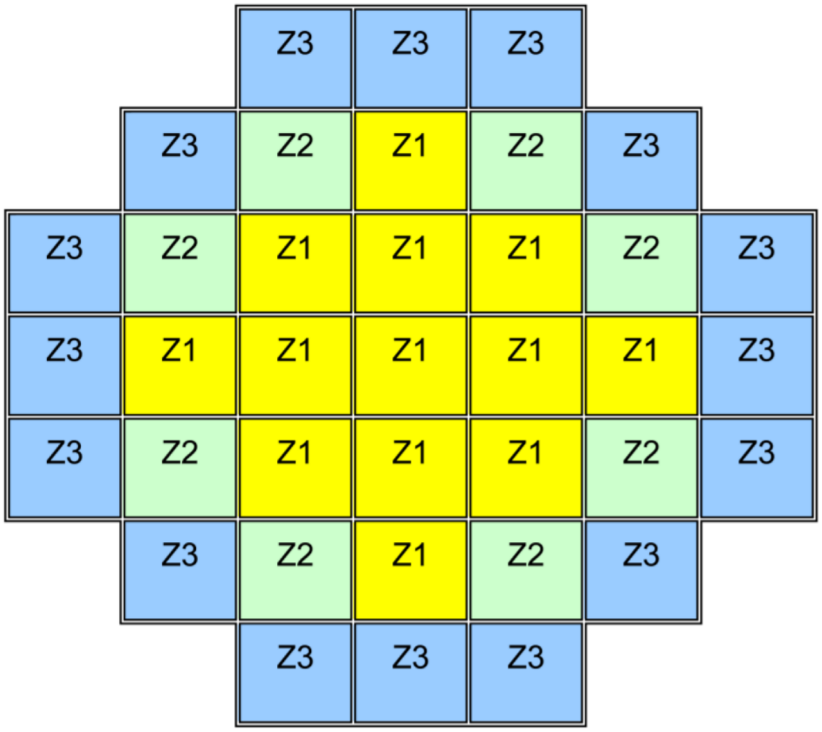


		Z3	Z3	Z3		
	Z3	Z2	Z1	Z2	Z3	
Z3	Z2	Z1	Z1	Z1	Z2	Z3
Z3	Z1	Z1	Z1	Z1	Z1	Z3
Z3	Z2	Z1	Z1	Z1	Z2	Z3
	Z3	Z2	Z1	Z2	Z3	
		Z3	Z3	Z3		

Zone Number	*1*	*2*	*3*
Maximum Decay Heat (kW/FA plus CCs, if included)	*0.95*	*1.0*	*1.0*
Maximum Number of Fuel Assemblies	*13*	*8*	*16*
Maximum Decay Heat per DSC (kW)	*36.35*		

1. *See UFSAR Table 1-2 or TS Section 2.1 for applicable system configurations.*

Figure 2-3c
Heat Load Zone Configuration 3 for the EOS-37PTH DSC



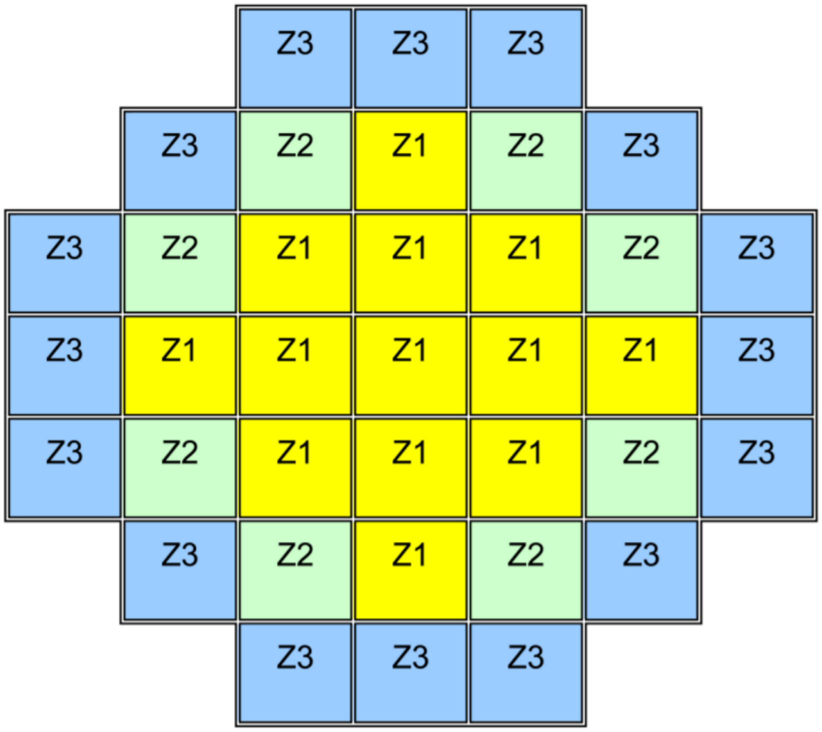
		Z3	Z3	Z3		
	Z3	Z2	Z1	Z2	Z3	
Z3	Z2	Z1	Z1	Z1	Z2	Z3
Z3	Z1	Z1	Z1	Z1	Z1	Z3
Z3	Z2	Z1	Z1	Z1	Z2	Z3
	Z3	Z2	Z1	Z2	Z3	
		Z3	Z3	Z3		

Zone Number	*1*	*2*	*3*
Maximum Decay Heat (kW/FA plus CCs, if included)	*1.0*	*1.625*	*1.6*
Maximum Number of Fuel Assemblies	*13*	*8*	*16*
Maximum Decay Heat per DSC (kW)	*50.0(1)*		

Notes:

1. *Adjust payload to maintain total canister heat load within the specified limit.*
2. *See UFSAR Table 1-2 or TS Section 2.1 for applicable system configurations.*

Figure 2-3d
Heat Load Zone Configuration 4 for the EOS-37PTH DSC



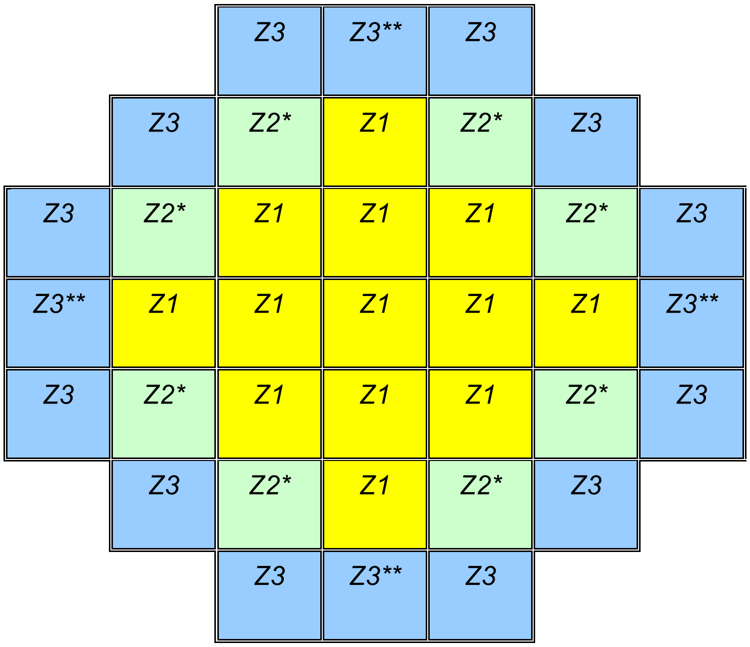
		Z3	Z3	Z3		
	Z3	Z2	Z1	Z2	Z3	
Z3	Z2	Z1	Z1	Z1	Z2	Z3
Z3	Z1	Z1	Z1	Z1	Z1	Z3
Z3	Z2	Z1	Z1	Z1	Z2	Z3
	Z3	Z2	Z1	Z2	Z3	
		Z3	Z3	Z3		

Zone Number	*1*	*2*	*3*
Maximum Decay Heat (kW/FA plus CCs, if included)	*1.0*	*1.625*	*1.6*
Maximum Number of Fuel Assemblies	*13*	*8*	*16*
Maximum Decay Heat per DSC (kW)	*50.0(1)*		

Notes:

1. *Adjust payload to maintain total canister heat load within the specified limit.*
2. *See UFSAR Table 1-2 or TS Section 2.1 for applicable system configurations.*

Figure 2-3e
Heat Load Zone Configuration 5 for the EOS-37PTH DSC



		Z3	Z3**	Z3		
	Z3	Z2*	Z1	Z2*	Z3	
Z3	Z2*	Z1	Z1	Z1	Z2*	Z3
Z3**	Z1	Z1	Z1	Z1	Z1	Z3**
Z3	Z2*	Z1	Z1	Z1	Z2*	Z3
	Z3	Z2*	Z1	Z2*	Z3	
		Z3	Z3**	Z3		

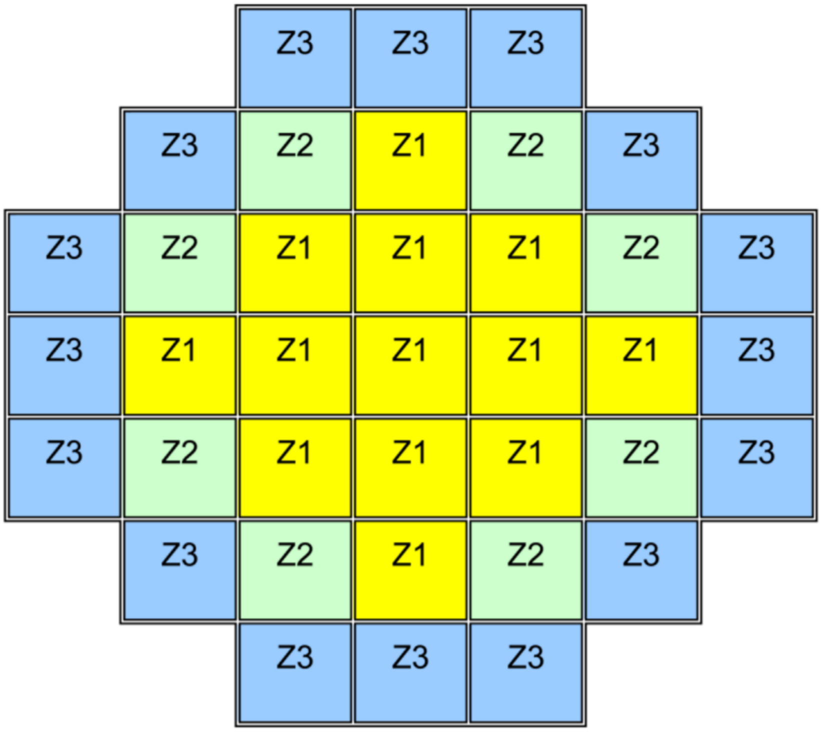
(*) denotes location where INTACT or DAMAGED FUEL can be stored.
(**) denotes location where INTACT or FAILED FUEL can be stored.

Zone Number	*1*	*2[(1)]*	*3[(1)]*
Maximum Decay Heat (kW/FA plus CCs, if included)	*1.0*	*1.5*	*1.3125[(2)]*
Maximum Number of Fuel Assemblies	*13*	*8*	*16*
Maximum Decay Heat per DSC (kW)	*46.00*		

1. *DAMAGED FUEL and FAILED FUEL shall not be loaded in the same DSC.*
2. *The maximum allowable heat load per FAILED FUEL compartment is 0.8 kW.*
3. *See UFSAR Table 1-2 or TS Section 2.1 for applicable system configurations.*

Figure 2-3f
Heat Load Zone Configuration 6 for the EOS-37PTH DSC

All Indicated Changes are Scope Item 1.



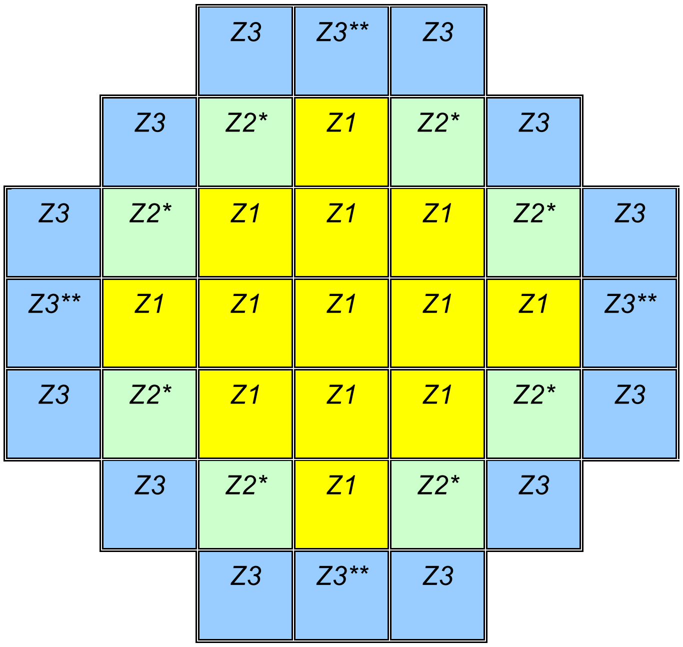
		Z3	Z3	Z3		
	Z3	Z2	Z1	Z2	Z3	
Z3	Z2	Z1	Z1	Z1	Z2	Z3
Z3	Z1	Z1	Z1	Z1	Z1	Z3
Z3	Z2	Z1	Z1	Z1	Z2	Z3
	Z3	Z2	Z1	Z2	Z3	
		Z3	Z3	Z3		

Zone Number	*1*	*2*	*3*
Maximum Number of Fuel Assemblies	*13*	*8*	*16*
Upper Compartment			
Maximum Decay Heat (kW/FA plus CCs, if included)	*1.0*	*1.60*	*1.3125*
Maximum Decay Heat per DSC (kW)	*41.8*(1)		
Lower Compartment			
Maximum Decay Heat (kW/FA plus CCs, if included)	*0.9*	*1.60*	*1.60*
Maximum Decay Heat per DSC (kW)	*50.0*(1)		

Notes:

1. *Adjust payload to maintain total canister heat load within the specified limit.*
2. *See UFSAR Table 1-2 or TS Section 2.1 for applicable system configurations.*

Figure 2-3g
Heat Load Zone Configuration 7 for the EOS-37PTH DSC



		Z3	Z3**	Z3		
	Z3	Z2*	Z1	Z2*	Z3	
Z3	Z2*	Z1	Z1	Z1	Z2*	Z3
Z3**	Z1	Z1	Z1	Z1	Z1	Z3**
Z3	Z2*	Z1	Z1	Z1	Z2*	Z3
	Z3	Z2*	Z1	Z2*	Z3	
		Z3	Z3**	Z3		

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

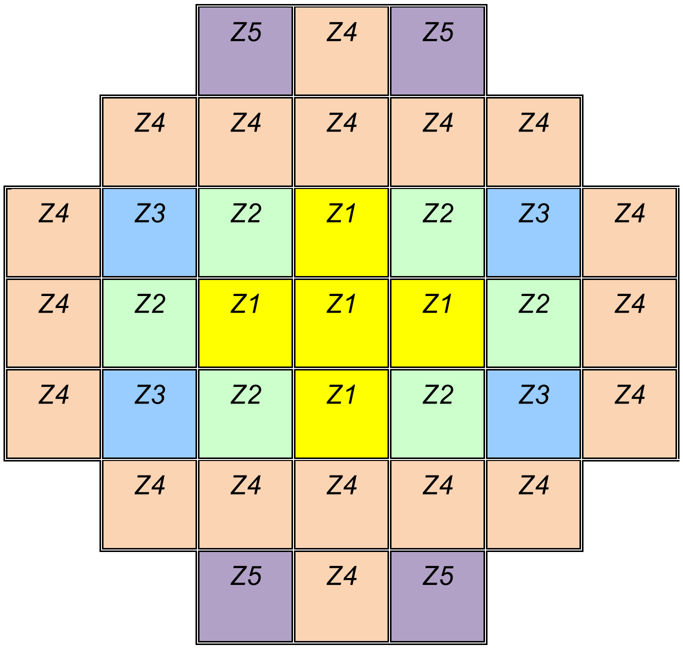
(**) denotes location where INTACT or FAILED FUEL can be stored.

Zone Number	*1*	*2[2]*	*3[2][3]*
Maximum Number of Fuel Assemblies	*13*	*8*	*16*
Upper Compartment			
Maximum Decay Heat (kW/FA plus CCs, if included)	*0.8*	*1.50*	*1.50*
Maximum Decay Heat per DSC (kW)	*41.8[1][4]*		
Lower Compartment			
Maximum Decay Heat (kW/FA plus CCs, if included)	*0.8*	*1.50*	*1.50*
Maximum Decay Heat per DSC (kW)	*46.4[1]*		

Notes:

1. *The maximum decay heat per DSC is limited to 41.8 kW when DAMAGED or FAILED FUEL is loaded.*
2. *DAMAGED FUEL and FAILED FUEL shall not be loaded in the same DSC.*
3. *The maximum allowable heat load per FAILED FUEL is 0.8 kW.*
4. *Adjust payload to maintain total canister heat load within the specified limit.*
5. *See UFSAR Table 1-2 or TS Section 2.1 for applicable system configurations.*

Figure 2-3h
Heat Load Zone Configuration 8 for the EOS-37PTH DSC

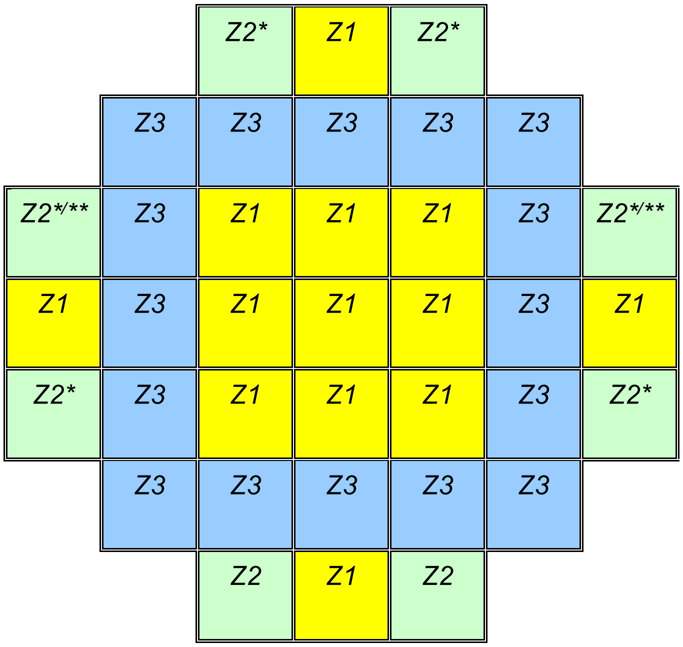


		Z5	Z4	Z5		
	Z4	Z4	Z4	Z4	Z4	
Z4	Z3	Z2	Z1	Z2	Z3	Z4
Z4	Z2	Z1	Z1	Z1	Z2	Z4
Z4	Z3	Z2	Z1	Z2	Z3	Z4
	Z4	Z4	Z4	Z4	Z4	
		Z5	Z4	Z5		

Zone Number	*1*	*2*	*3*	*4*	*5*
Maximum Decay Heat (kW/FA plus CCs, if included)	*0.50*	*0.70*	*2.0*	*0.75*	*2.4*
Maximum Number of Fuel Assemblies	*5*	*6*	*4*	*18*	*4*
Maximum Decay Heat per DSC (kW)	*37.80*				

1. *See UFSAR Table 1-2 or TS Section 2.1 for applicable system configurations.*

Figure 2-3i
Heat Load Zone Configuration 9 for the EOS-37PTH DSC



		Z2*	Z1	Z2*		
	Z3	Z3	Z3	Z3	Z3	
Z2*/**	Z3	Z1	Z1	Z1	Z3	Z2*/**
Z1	Z3	Z1	Z1	Z1	Z3	Z1
Z2*	Z3	Z1	Z1	Z1	Z3	Z2*
	Z3	Z3	Z3	Z3	Z3	
		Z2	Z1	Z2		

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

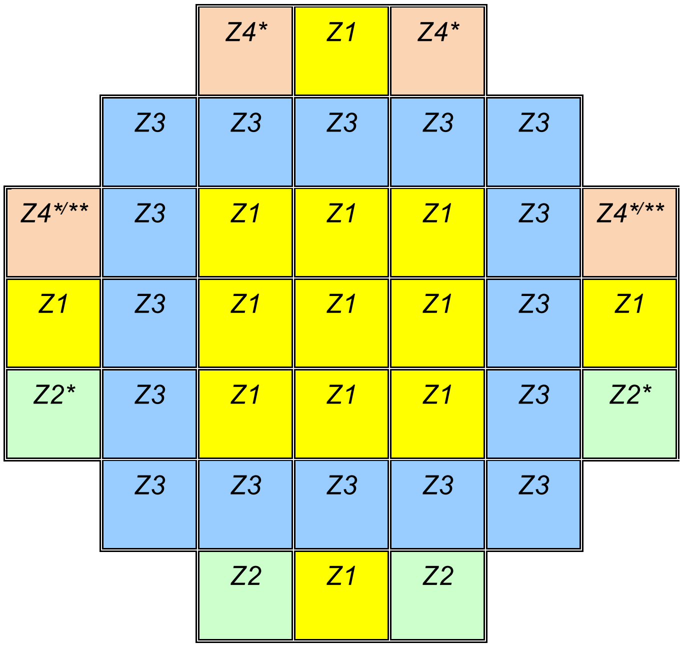
(**) denotes location where INTACT or FAILED FUEL can be stored.

Zone Number	*1*	*2(1)*	*3*
Max Decay Heat (kW/ plus CCs, if included)	*0.5*	*3.5(2)*	*0.7*
Maximum Number of Fuel Assemblies	*13*	*8*	*16*
Maximum Decay Heat per DSC (kW)	*45.7*		

Notes:

1. *DAMAGED FUEL and FAILED FUEL shall not be loaded in the same DSC.*
2. *The maximum allowable heat load per FAILED FUEL is 0.8 kW.*
3. *See UFSAR Table 1-2 or TS Section 2.1 for applicable system configurations.*

Figure 2-3j
Heat Load Zone Configuration 10 for the EOS-37PTH DSC



		Z4*	Z1	Z4*		
	Z3	Z3	Z3	Z3	Z3	
Z4*/**	Z3	Z1	Z1	Z1	Z3	Z4*/**
Z1	Z3	Z1	Z1	Z1	Z3	Z1
Z2*	Z3	Z1	Z1	Z1	Z3	Z2*
	Z3	Z3	Z3	Z3	Z3	
		Z2	Z1	Z2		

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

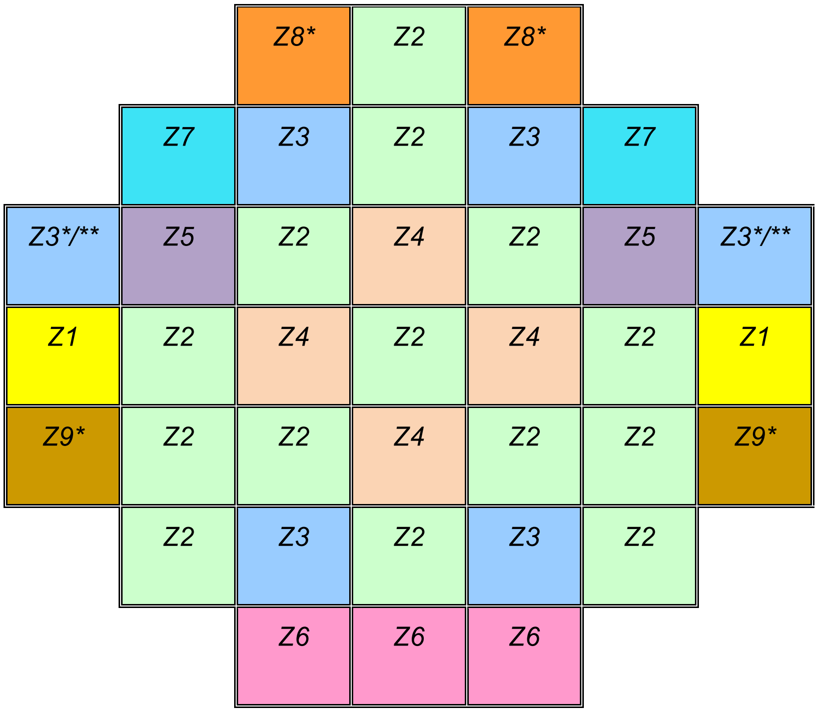
(**) denotes location where INTACT or FAILED FUEL can be stored.

Zone Number	1	$2^{(1)}$	3	$4^{(1)}$
Maximum Number of Fuel Assemblies	13	4	16	4
Upper Compartment				
Maximum Decay Heat (kW/FA plus CCs, if included)	0.5	3.0	0.7	$3.0^{(2)}$
Maximum Decay Heat per DSC (kW)	41.8			
Lower Compartment				
Maximum Decay Heat (kW/FA plus CCs, if included)	0.5	3.5	0.7	$3.2^{(2)}$
Maximum Decay Heat per DSC (kW)	44.5			

Notes:

1. DAMAGED FUEL and FAILED FUEL shall not be loaded in the same DSC.
2. The maximum allowable heat load per FAILED FUEL is 0.8 kW.
3. See UFSAR Table 1-2 or TS Section 2.1 for applicable system configurations.

Figure 2-3k
Heat Load Zone Configuration 11 for the EOS-37PTH DSC



		Z8*	Z2	Z8*		
	Z7	Z3	Z2	Z3	Z7	
Z3*/**	Z5	Z2	Z4	Z2	Z5	Z3*/**
Z1	Z2	Z4	Z2	Z4	Z2	Z1
Z9*	Z2	Z2	Z4	Z2	Z2	Z9*
	Z2	Z3	Z2	Z3	Z2	
		Z6	Z6	Z6		

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

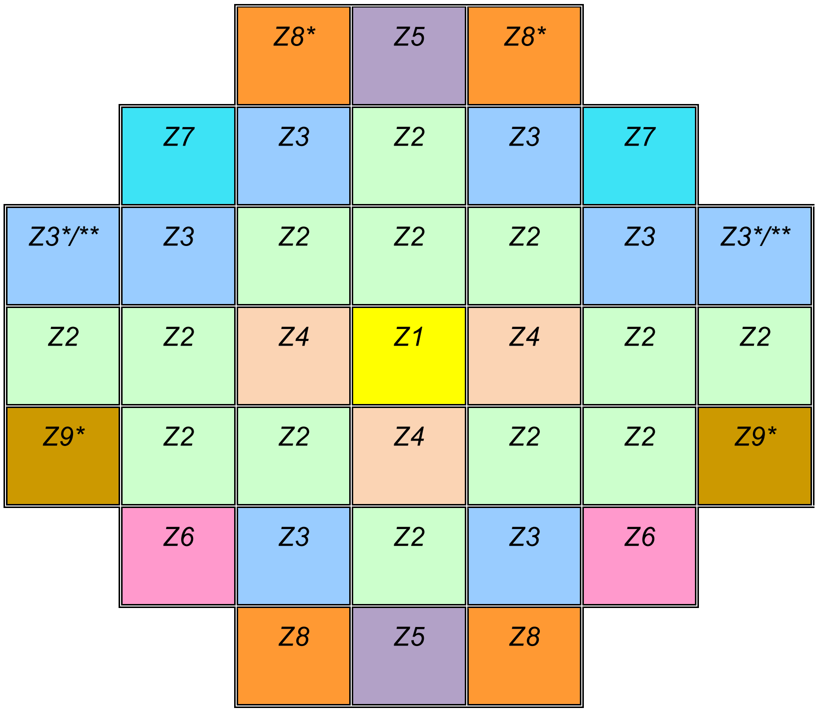
(**) denotes location where INTACT or FAILED FUEL can be stored. Damaged and failed fuels cannot be loaded in the same DSC.

Zone No.	*Z1*	*Z2*	*Z3*	*Z4*	*Z5*	*Z6*	*Z7*	*Z8*	*Z9*
Max. Decay Heat per SFA (kW)	*0.5*	*0.8*	*1.0*	*1.25*	*1.5*	*2.0*	*2.9*	*3.5*	*4.3*
No. of Fuel Assemblies	*2*	*14*	*6*	*4*	*2*	*3*	*2*	*2*	*2*
Heat Load Per Zone	*1*	*11.2*	*6*	*5*	*3*	*6*	*5.8*	*7*	*8.6*
Max Decay Heat per DSC	*Note 1 (53.6 kW)*								

Notes:

1. *Maximum heat load for EOS-37PTH DSC during Storage is 50.0 kW in the EOS-HSM.*
2. *This HLZC is not applicable for:*
   A. *Transfer in EOS-TC108 transfer cask and storage in either EOS-HSM or HSM-MX storage module, or*
   B. *Transfer in EOS-TC125 or EOS-TC135 transfer cask and storage in HSM-MX storage module.*
3. *This HLZC is not applicable for storage of WE 14x14 class FAs.*
4. *See UFSAR Table 1-2 or TS Section 2.1 for applicable system configurations.*

Figure 2-3l
Heat Load Zone Configuration 12 for the EOS-37PTH DSC



		Z8*	Z5	Z8*		
	Z7	Z3	Z2	Z3	Z7	
Z3*/**	Z3	Z2	Z2	Z2	Z3	Z3*/**
Z2	Z2	Z4	Z1	Z4	Z2	Z2
Z9*	Z2	Z2	Z4	Z2	Z2	Z9*
	Z6	Z3	Z2	Z3	Z6	
		Z8	Z5	Z8		

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

(**) denotes location where INTACT or FAILED FUEL can be stored. Damaged and failed fuels cannot be loaded in the same DSC.

Zone No.	Z1	Z2	Z3	Z4	Z5	Z6	Z7	Z8	Z9
Max. Decay Heat per SFA (kW)	0.5	0.8	1.0	1.25	1.5	2.0	2.2	2.9	4.2
No. of Fuel Assemblies	1	13	8	3	2	2	2	4	2
Heat Load Per Zone	0.5	10.4	8.0	3.75	3.0	4.0	4.4	11.6	8.4
Max Decay Heat per DSC	Note 1 (54.05 kW total)								

Notes:

1. *Maximum heat load for EOS-37PTH DSC during Storage is 50.0 kW in the EOS-HSM.*
2. *This HLZC is not applicable for:*
   - *A. Transfer in EOS-TC108 transfer cask and storage in either EOS-HSM or HSM-MX storage module, or*
   - *B. Transfer in EOS-TC125 or EOS-TC135 transfer cask and storage in HSM-MX storage module.*
3. *This HLZC in not applicable for storage of WE 14x14 class FAs.*
4. *See UFSAR Table 1-2 or TS Section 2.1 for applicable system configurations.*

Figure 2-3m
Heat Load Zone Configuration 13 for the EOS-37PTH DSC

3. STRUCTURAL EVALUATION

This chapter and its appendices describe the structural evaluation of the NUHOMS® EOS System, described in Chapter 1, under normal and off-normal conditions, accident conditions, and natural phenomena events. Structural evaluations are performed for the important-to-safety components, which are the EOS-37PTH dry shielded canister (DSC), the EOS-89BTH DSC, the NUH 61BTH Type 2 DSC, the EOS horizontal storage module (EOS-HSM), NUHOMS® MATRIX (HSM-MX), and the EOS transfer casks (EOS-TCs) and the OS197 TC. The DSC functions as the confinement boundary, and restrains and positions the fuel assemblies (FAs) in the DSC.

Within Chapter 3, unless specified otherwise, the term EOS-HSM refers to both the reinforced concrete EOS-HSM (EOS-HSM-RC) and steel-plate composite EOS-HSM (EOS-HSM-SC). Either the EOS-HSM-RC or EOS-HSM-SC will be specified explicitly if the discussion pertains to only one of the two types and not both.

3.1 Structural Design

The NUHOMS® EOS System provides for the horizontal, dry storage of canisterized spent fuel assemblies (SFAs) in a concrete *or steel-plate composite (SC)* EOS horizontal storage module (HSM). The storage system components consist of a reinforced concrete *or SC* EOS-HSM, HSM-MX, and a stainless or duplex steel DSC confinement vessel that houses the SFAs. A general description and operational features of the NUHOMS® EOS System is provided in Chapter 1, and the confinement boundary is defined in Chapter 5. This chapter addresses the structural design and analysis of the storage system components, including the EOS-37PTH DSC, the EOS-89BTH DSC, the TC135, the TC125, TC108, the EOS-HSM, and the EOS-HSMS, which are important-to-safety in accordance with 10 CFR Part 72 [3-13]. The structural analysis of the NUHOMS® 37PTH Type 4L and 4H baskets (Type 4), as detailed in Chapter 2, is provided in this chapter. The structural design and analysis of the HSM-MX are provided in Chapter A.3. The structural design and analysis of the NUHOMS® NUH61BTH Type 2 DSC and the OS197 TC are provided in Chapter B.3.

3.1.1 Design Criteria

3.1.1.1 EOS-37PTH DSC/EOS-89BTH DSC Design Criteria

The EOS-37PTH DSC/EOS-89BTH DSC are designed using the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel (B&PV) Code, Section III, Division 1, Subsections NB, NG, NF, ND and NCA [3-2] criteria with the code Alternatives as described in Section 8.2.1.

3.1.1.1.1 Stress Criteria

EOS-37PTH DSC/EOS-89BTH DSC Shell Assembly Stress Limits

The stress limits for the DSC shell are taken from the ASME B&PV Code, Section III, Subsection NB, Article NB-3200 for Level A and B Service Limits [3-2]. In accordance with NB-3225, Appendix F is used for accident condition loads (Level D). Service Level A and B stress limits apply to normal and off-normal conditions, respectively, and Service Level D stress limits apply to accident conditions. Elastic system analysis is used for calculation of stresses for normal, off-normal, and accident conditions, except that plastic analysis is used for side drop accident conditions.

Stress limits for Level A, B and D service loading conditions are summarized in Table 3-1. The stress due to each load type is identified as to the type of stress induced, such as membrane or membrane plus bending, and classified accordingly as primary, secondary, peak, etc. Local yielding is permitted at the point of contact where Level D load is applied. In accordance with NB-3222, the plastic analysis provisions of NB-3228 may be used if the Level A Service Limits for local membrane stress intensity and/or primary membrane plus primary bending stress intensity are not satisfied.

Finite element, non-linear analysis models, or hand calculations using actual material properties, are used to calculate the critical buckling load of the DSC shell.

The allowable stress intensity value, S_m, as defined by the Code, is based on the calculated (or a bounding) temperature for each service load condition.

The DSC closure welds are designed in accordance with the guidance of NUREG-1536 [3-1], using a stress reduction factor of 0.8 on weld strength. Weld inspection interval requirements are based on calculation of critical flaw depth using ASME Section XI. See Section 8.4.7.4 of NUREG-1536.

EOS-37PTH/EOS-89BTH Basket Stress/Strain Limits

The basis for the steel basket stress allowables is the ASME Code, Section III, Subsection NG [3-2]. Stress limits for Level A through D service loading conditions are summarized in Table 3-2. The design stress intensity, S_m, is defined as the lower of $2/3S_y$ or $1/3\ S_u$ (Appendix 2 of ASME B&PV, Section II [3-3]).

The hypothetical impact accidents are evaluated as short duration Level D conditions. Secondary and peak stresses are not required to be evaluated for Level D events, but should be evaluated to ensure that they are not a source of uncontrolled crack initiation. Appendix 3.9.2 classifies the rails as "non-code," and does not perform any stress analysis of the rail aluminum or steel plates. The membrane equivalent plastic strain in the steel grid plate is limited to 1%. Membrane + bending equivalent plastic strain is limited to 3% and peak equivalent plastic strain is limited to 10%. This ensures that displacement and permanent deformation of the steel grid is small and within failure limits for high-strength low-alloy steel such as American Iron and Steel Institute (AISI) 4130 material.

3.1.1.1.2 Stability Criteria

Stability of the EOS-37PTH DSC/EOS-89BTH DSC shell assembly is addressed for load conditions in which the DSC is under external hydrostatic pressure (such as vacuum drying and external flood load cases) and/or axial compression, (e.g., loading the shell due to the shield plug's dead weight). Stability criteria are from ASME Section III, NB-3133.3 and NB-3133.6 [3-2].

3.1.1.2 EOS-HSM Design Criteria

The *EOS-HSM-RC* concrete and steel components are designed to the requirements of American Concrete Institute (ACI) 349-06 [3-4] and the American Institute of Steel Construction (AISC) Manual of Steel Construction [3-5], respectively, meeting the load combinations in accordance with the requirements of ANSI 57.9 [3-6]. *The SC components of the EOS-HSM-SC are designed to the requirements of ANSI/AISC N690 specification [3-15].* The load combination and design criteria for *EOS-HSM-RC* concrete and support structure components are described in Appendix 3.9.4. *The design criteria for EOS-HSM-SC components are described in Appendix 3.9.8.*

All Indicated Changes are Scope Item 2.

3.6 Normal Conditions of Storage and Transfer

This section presents the structural analyses of the EOS-37PTH DSC/ EOS-89BTH DSC, the EOS-HSM and the EOS-TC subjected to normal conditions of storage and transfer. The analyses performed evaluate these three major NUHOMS® EOS System components for the design criteria described in Section 3.1.1.

The EOS-37PTH DSC/EOS-89BTH DSC are subjected to both storage and transfer loading conditions, while the EOS-HSM is only subjected to storage loading conditions and the EOS-TC is only subjected to transfer loading conditions.

Numerical analyses have been performed for the normal and accident conditions, as well as for the lifting loads. In general, numerical analyses have been performed for the regulatory events. These analyses are summarized in this section, and described in detail in Appendix 3.9.1 through 3.9.*8*.

The detailed structural analysis of the NUHOMS® EOS System is included in the following appendices:

Appendix 3.9.1	DSC Shell Structural Analysis
Appendix 3.9.2	EOS-37PTH and EOS-89BTH Basket Structural Analysis
Appendix 3.9.3	NUHOMS® EOS System Accident Drop Evaluation
Appendix 3.9.4	EOS-HSM Structural Analysis
Appendix 3.9.5	NUHOMS® EOS-TC Body Structural Analysis
Appendix 3.9.6	NUHOMS® EOS Fuel Cladding Evaluation
Appendix 3.9.7	NUHOMS® EOS System Stability Analysis
Appendix 3.9.8	*EOS-HSM-SC Structural Analysis*

The detailed structural analysis of the NUHOMS® MATRIX is included in Appendices A.3.9.1 through A.3.9.7.

The detailed structural analysis for the NUHOMS® NUH61BTH Type 2 DSC and OS197 TC are included in Appendices B.3.9.1 through B.3.9.7.

3.6.1 EOS-37PTH DSC/89BTH DSC

The basket and DSC shell are analyzed independently. Details of the structural analyses of the EOS-37PTH DSC and EOS-89BTH DSC shell assemblies are provided in Appendix 3.9.1, while the structural analyses for the basket assemblies are provided in Appendix 3.9.2.

3.6.1.1 EOS-37PTH DSC/89BTH DSC Shell Normal Condition Structural Evaluation

This section summarizes the evaluation of the structural adequacy of the EOS-37PTH DSC and EOS-89BTH DSC under all applied normal condition loads. Detailed evaluation of the stresses generated in the DSC is presented in Appendix 3.9.1. The DSC shell buckling evaluation is presented in Appendix 3.9.1.

An enveloping technique of combining various individual loads in a single analysis is used in this evaluation for several load combinations. This approach greatly reduces the number of computer runs while remains conservative. For some load combinations, the stress intensities under individual loads are added to obtain resultant stress intensities for the specified combined loads. This stress addition at the stress intensity level for the combined loads, instead of at the component stress level, is also a conservative way to reduce the number of analysis runs.

Elastic and elastic-plastic analyses are performed to calculate the stresses in the EOS-37PTH DSC under the transfer and storage loads. These detailed load cases are summarized in Appendix 3.9.1.

Based on the results of these analyses, the design of the EOS-37PTH DSC/EOS-89BTH DSC canister is structurally adequate with respect to both transfer and storage loads under normal conditions.

3.6.1.2 EOS-37PTH DSC/89BTH DSC/37PTH Type 4 Basket Normal Condition Structural Evaluation

The fuel basket stress analysis is performed for normal conditions loads during fuel transfer and storage. The detailed stress analysis is presented in Appendix 3.9.2. A summary of the fuel basket load cases is provided in Appendix 3.9.2. The basket stress analysis is performed using a finite element method for the transfer handling, storage dead weight, and both transfer and storage thermal load cases. The finite element model (FEM) is described in detail in Appendix 3.9.2.

Basket component stress results for normal condition dead weight + handling loads are listed in Appendix 3.9.2. Thermal stress analysis results are listed in Appendix 3.9.2. Combined results with controlling stress ratios are listed in Appendix 3.9.2.

Based on the results of these analyses, the design of the EOS-37PTH DSC/ EOS-89BTH DSC basket is structurally adequate with respect to both transfer and storage loads under normal conditions.

3.6.2 EOS-HSM

The *EOS-HSM-RC* design has variable lengths to accommodate DSC lengths. For the structural evaluation, *EOS-HSM-RC* Long bounds the three sizes. The following table shows how the bounding loads are used for structural evaluation of the *EOS-HSM-RC*.

Component	Weight (kips)	Thermal Heat Load
EOS-37PTH DSC (Loaded Weight)	134	50 kW
EOS-89BTH DSC (Loaded Weight)	120	*48.2 kW*
Bounding *EOS-HSM-RC*	135 (2)	50 kW (1)

Notes:

1. The thermal loading condition of the *EOS-HSM-RC* is based on the most conservative thermal loading configuration.
2. For stability evaluation, several different combinations of DSC and HSM bounding weights are considered.

Detailed geometry descriptions, material properties, loadings, and structural evaluation for the *EOS-HSM-RC* is presented in Appendix 3.9.4.

For the EOS-HSM-SC, only the medium length model is evaluated using the bounding DSC weight of 135 kips and bounding thermal heat load of 50 kW. Detailed geometry descriptions, material properties, loadings, and structural evaluation for the EOS-HSM-SC are presented in Appendix 3.9.8.

3.6.3 EOS-TC

Details of the structural analysis of the EOS-TC are provided in Appendices 3.9.3 and 3.9.5.

The details of the structural analyses of the EOS-TC body, including the cylindrical shell assembly and bottom assembly, the top cover, and the local stresses at the trunnion/cask body interface are presented in Appendix 3.9.5. The specific methods, models and assumptions used to analyze the cask body for the various individual loading conditions specified in 10 CFR Part 72 [3-13] are described in that appendix.

The EOS-TC body structural analyses use static or quasistatic linear elastic methods. The stresses and deformations due to the applied loads are determined using the ANSYS [3-12] computer program.

Appendix 3.9.5 presents the evaluation of the trunnion stresses in the EOS-TC due to all applied loads during fuel loading and transfer operations.

Based on the loading and transfer scenario, the top trunnions are analyzed per ANSI N14.6 [3-7] for vertical lifting loads.

The evaluations summarized in Appendix 3.9.5 show that all calculated trunnion stresses are less than their corresponding allowable stresses. Therefore, the EOS-TC top and bottom trunnions are structurally adequate to withstand loads during lifting and transfer operations.

3.7.2 EOS-HSM

This section summarizes the evaluation of the structural adequacy of the EOS-HSM under all applied off-normal and accident condition loads. Detailed evaluation of the geometry descriptions, material properties, loadings, and structural evaluation for the *EOS-HSM-RC and EOS-HSM-SC* is presented in Appendix 3.9.4 *and 3.9.8, respectively*.

3.7.3 EOS-TC

The main accident condition for the EOS-TC is the drop load combination, which is analyzed via a LS-DYNA analysis. The details of the analysis is presented in Appendix 3.9.3. All other off-normal and accident load cases that are not bounded by the normal condition analyses are presented in Appendix 3.9.5.

3.8 References

3-1 NUREG-1536, Revision 1, "Standard Review Plan for Spent Fuel Dry Cask Storage Systems at a General License Facility," July 2010.

3-2 American Society of Mechanical Engineers, "ASME Boiler and Pressure Vessel Code," Section III, Division 1, Subsections NB, NG, NF, ND and NCA, 2010 Edition through 2011 Addenda.

3-3 American Society of Mechanical Engineers, "ASME Boiler and Pressure Vessel Code," Section II, Materials Specifications, Parts A, B, C and D, 2010 Edition through 2011 Addenda.

3-4 ACI 349-06, "Code Requirements for Nuclear Safety Related Concrete Structures," American Concrete Institute, November 2006.

3-5 American Institute of Steel Construction, "AISC Manual of Steel Construction," 13th Edition or later.

3-6 ANSI/ANS 57.9-1984, "Design Criteria for an Independent Spent Fuel Storage Installation (Dry Storage Type)," American National Standards Institute.

3-7 ANSI N14.6-1993, "American National Standard for Special Lifting Device for Shipping Containers Weighing 10,000 lbs. or More for Nuclear Materials," American National Standards Institute.

3-8 U.S. Nuclear Regulatory Commission, Regulatory Guide 1.124, "Service Limits and Loading Combination for Class 1 Linear-Type Supports," February 2007.

3-9 NUREG/CR-7024, "Material Property Correlations: Comparisons between FRAPCON-3.4, FRAPTRAN 1.4, and MATPRO," U.S. Nuclear Regulatory Commission, August 2010.

3-10 Nuclear Assurance Corporation, "Domestic Light Water Reactor Fuel Design Evolution," Volume III, 1981.

3-11 U.S. Nuclear Regulatory Commission Interim Staff Guidance No. 11, Revision 3, "Cladding Considerations for the Transportation and Storage of Spent Fuel," November 17, 2003.

3-12 "ANSYS Computer Code and User's Manual", Release 14.0.3 and Release 17.1.

3-13 Title 10, Code of Federal Regulations, Part 72, "Licensing Requirements for the Storage of Spent Fuel in the Independent Spent Fuel Storage Installation," U.S. Nuclear Regulatory Commission, August 3, 1988.

3-14 NUREG/CR–6007, "Stress Analysis of Closure Bolts for Shipping Casks," U.S. Nuclear Regulatory Commission, 1993.

3-15 ANSI/ANSI N690-18, "Specification for Safety-Related Steel Structures for Nuclear Facilities."

All Indicated Changes are Scope Item 2.

Table 3-7
Summary of EOS-89BTH DSC Component Weights

Component Description	Weight (lb)
DSC Shell	17,000
Basket Assembly	27,400
Dry/Unloaded/Open DSC	**44,400**
89 Fuel Assemblies	62,800
DSC Top Shield Plug	7,340
Flooding Water in Loaded DSC	15,900
Flooded/Loaded Open DSC	**131,000**
DSC Top Cover Plates	5060
Sealed/Loaded DSC Weight	**120,000**

Table 3-8
Summary of EOS-HSM Weight and Center of Gravity

Component	Description	Value
Empty *EOS-HSM-RC* Long	Total Weight (lb)	350,000
	Center of Gravity from Bottom in Vertical Direction	126.5 inches
EOS-HSM-RC Long Loaded with EOS-37PTH DSC	Maximum Weight (lb)	484,000
	Center of Gravity from Bottom in Vertical Direction	120.8 inches
Empty EOS-HSM-SC	*Total Weight (lb)*	*362,000*
	Center of Gravity from Bottom in Vertical Direction	*125.6 inches*
EOS-HSM-SC Loaded with EOS-37PTH DSC	*Maximum Weight (lb)*	*482,000*
	Center of Gravity from Bottom in Vertical Direction	*120.7 inches*

Notes:

1. The weight and center of gravity values listed in the table are corresponding to the maximum concrete density of 160 pcf.

3.9.2.3A NUHOMS® EOS-37PTH Type 4 Basket Evaluation

The NUHOMS® EOS-37PTH Type 4 (staggered plate) basket can accommodate up to a maximum of eight damaged fuel assemblies and up to a maximum of four loaded FFCs in designated basket compartments. The detailed description to the Type 4 Basket is discussed in Chapter 1.

3.9.2.3A.1 General Description

The primary design change to EOS-37PTH Type 4 Basket is a modification to stagger the alignment of the steel, aluminum, and poison basket plates to ensure no continuous gaps across the compartments. With the addition of end caps for damaged fuel and a top lid for FFCs, the EOS-37PTH Type 4 Fuel Basket ensures that fuel is confined within the fuel compartment.

3.9.2.3A.2 Dimensions and Materials

The change to the NUHOMS® EOS-37PTH Type 4 Basket is accomplished by using aluminum plates that are [ ] *longer* than the steel/poison basket plates at the bottom of the basket assembly. The overall length, thickness or dimensions used in the structural evaluations (Section 3.9.2.1 and Section 3.9.2.3) remains same for the Type 4 Basket.

Similarly, the materials in the EOS-37PTH Type 4 Basket are consistent with the structural analysis in Section 3.9.2.1 and Section 3.9.2.3.

The key basket dimensions and materials are per Drawing EOS01-1010-SAR, as provided in Section 1.3.1.

3.9.2.3A.3 Temperature

Thermal analyses to support the EOS-37PTH Type 4 Basket design are provided in Chapter 4, Appendix 4.9.6. The maximum bounding temperature for Type 4 Basket is 671 °F for the bounding HLZC 4 under the normal conditions (Chapter 4, Figure 4.9.6-4). The temperatures on the EOS-37PTH Type 4 basket is lower compared to the temperature of 798 °F (Figure 3.9.2-10) used in the structural analyses. The thermal analyses in Section 3.9.2.1 utilized a bounding steeper gradient and therefore envelop the EOS-37PTH Type 4 Basket thermal results.

3.9.2.3A.4 Fuel Weight

The damaged or failed fuel weights are considered to be less than or equal to intact fuel weight for the pressurized water reactor PWR FA. Therefore, it is considered to be bounded.

All Indicated Changes are Scope Item 5.

3.9.4 EOS-HSM STRUCTURAL ANALYSIS

Within Appendix 3.9.4, the term EOS-HSM refers to the reinforced concrete EOS-HSM (EOS-HSM-RC), which includes the EOS-HSM-RC, EOS-HSMS-RC, EOS-HSM-FPS-RC, and EOS-HSMS-FPS-RC.

The purpose of this appendix is to present the structural evaluation of the EOS-HSM due to all applied loads during storage, loading and unloading operation. The NUHOMS® EOS System consists of the dual-purpose (transportation and storage) EOS-37PTH and EOS-89BTH dry shielded canister (DSC), a horizontal storage module (EOS-HSM), an onsite transfer cask (EOS-TC), and associated ancillary equipment.

3.9.4.1 General Description

General description and operational features for the NUHOMS® EOS System is provided in Chapter 1. The EOS-HSM is a freestanding, reinforced concrete structure, designed to provide environmental protection and radiological shielding for the EOS-37PTH DSC or EOS-89BTH DSC. The drawings of the EOS-HSM, showing different components and overall dimensions, are provided in Chapter 1.

The EOS-HSM consists of a base unit and a roof unit. The roof unit rests mainly on the front and rear walls, and partly on the side walls of the base unit. The roof and the base are connected by bolts/embedments to form a single module via four steel brackets located at each of the interior upper corners of base unit.

Alternate designs of horizontal storage modules may be used in lieu of EOS-HSM as part of NUHOMS® EOS System. The EOS-HSMS is a multi-segment design of horizontal storage module which consists of two segments of the base unit and a roof unit. The two segments of the base unit of EOS-HSMS are connected by grouted, high-strength, threaded bars/embedments, and the base and roof are connected in a similar way to that of EOS-HSM.

An alternate Flat Plate Support (FPS) Rail design of horizontal storage module, the EOS-HSM-FPS, may also be used in lieu of EOS-HSM as a part of the NUHOMS® EOS System. EOS-HSM-FPS is modified from the EOS-HSM to support the FPS DSC Support Structure with concrete pedestals spaced along the length of the DSC Support Structure.

For dynamic analysis, the stability evaluation shall be performed using the analysis methodology described in CoC 1029 [3.9.4-21]. *The response spectra of the time histories used in the dynamic analysis shall envelope the site-specific response spectra at the top of the ISFSI basemat. The licensee shall determine if, based on ISFSI-specific site investigations, a soil structure interaction (SSI) analyses ought to be performed to assess potential site-specific amplifications. The SSI evaluations are based on ISFSI site-specific parameters (free-field accelerations, strain-dependent soil properties, EOS-HSM array configurations, etc.).*

Seismic analysis of the EOS-HSM heat shields consists of a modal time-history analysis of the EOS-HSM for obtaining the ISRS at heat shields support locations and an equivalent static analysis of the EOS-HSM heat shields using the seismic acceleration load corresponding to the ISRS obtained in the first step. The earthquake time histories compatible with the RG 1.60 spectra are used as seismic input motion. The acceleration, velocity, and displacement time histories and corresponding spectra of the motion in the two horizontal and vertical directions, all with 1.0g ZPA, are shown in Figure 3.9.4-10 through Figure 3.9.4-15. Modal frequencies and mass participation factors of the EOS-HSMS are shown in Table 3.9.4-23 for EOS-HSMS and in Table 3.9.4-23a for EOS-HSMS-FPS for the minimum length DSC (governing configuration). Modal frequencies and mass participation factors of the EOS-HSMS-FPS-OVVP are shown in Table 3.9.4-23b. From the modal time-history analysis, the ISRS with a damping value of four percent are obtained at the support locations of the heat shields for the EOS-HSMS as shown in Figure 3.9.4-16 through Figure 3.9.4-21. Modal participations factors for the EOS-HSM roof heat shield and side heat shield are shown in Table 3.9.4-24 and Table 3.9.4-25, respectively. Similarly, EOS-HSM-FPS modal participations factors for the roof heat shield and side heat shield are shown in Table 3.9.4-24 and Table 3.9.4-25a, respectively. The ISRS for the head heat shields is conservatively determined using ground motion based on the RG 1.60 spectra anchored at 0.50g and 0.33g in the horizontal and vertical directions, respectively.

3.9.4.9.3 Flood Load (FL) Analysis

Since the source of flooding is site specific, the exact source, or quantity of flood water, should be established by the licensee. However, for this generic evaluation of the EOS-HSM, bounding flooding conditions are specified that envelope those that are postulated for most plant sites. As described in Section 2.3.3, the design basis flooding load is specified as a 50-foot static head of water and a maximum flow velocity of 15 feet per second. Each licensee should confirm that this represents a bounding design basis for their specific ISFSI site.

Since the EOS-HSM is open to the atmosphere, static differential pressure due to flooding is not a design load.

All Indicated Changes are Scope Item 5.

3.9.4-10 ANSI/ANS 57.9-1984, “Design Criteria for an Independent Spent Fuel Storage Installation (Dry Storage Type),” American National Standards Institute, American Nuclear Society.

3.9.4-11 ACI-318-08, “Building Code Requirement for Structural Concrete,” American Concrete Institute.

3.9.4-12 ACI 349-06, “Code Requirements for Nuclear Safety Related Concrete Structures,” American Concrete Institute.

3.9.4-13 American Society of Civil Engineers, “Structural Analysis and Design of Nuclear Plant Facilities,” ASCE Publication No. 58.

3.9.4-14 American Institute of Steel Construction, AISC Manual of Steel Construction, 13th Edition *or Later*.

3.9.4-15 American Society of Civil Engineers, “Minimum Design Loads for Buildings and Other Structures,” ASCE 7-10 (formerly ANSI A58.1).

3.9.4-16 AREVA Inc., “Updated Final Safety Analysis Report for the Standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel,” Revision 17, USNRC Docket Number 72-1004, March 2018.

3.9.4-17 Bechtel Power Corporation, “Design of Structures for Missile Impact,” Topical Report BCTOP-9A, Revision 2, San Francisco, California.

3.9.4-18 Bechtel Corporation, “Design Guide Number C-2.45 for Design of Structures for Tornado Missile Impact,” Rev. 0, April 1982.

3.9.4-19 “ANSYS Computer Code and User’s Manual”, Release 14.0.3 and Release 17.1.

3.9.4-20 Binder, Raymond C., “Fluid Mechanics,” 3rd Edition, Prentice-Hall, Inc, 1973.

3.9.4-21 AREVA Inc., “Updated Final Safety Analysis Report For The Standardized Advanced NUHOMS® Horizontal Modular Storage System For Irradiated Nuclear Fuel,” Revision 7, US NRC Docket Number 72-1029, April 2016.

3.9.4-22 U.S. Nuclear Regulatory Commission, Regulatory Guide 1.76, “Design Basis Tornado for Nuclear Power Plants,” Revision 1, March 2007.

3.9.7 NUHOMS® EOS SYSTEM STABILITY ANALYSIS

Within Appendix 3.9.7, the term EOS-HSM refers to the reinforced concrete EOS-HSM (EOS-HSM-RC), which includes the EOS-HSM-RC, EOS-HSMS-RC, EOS-HSM-FPS-RC, and EOS-HSMS-FPS-RC.

3.9.7.1 EOS-HSM Stability Evaluation

The sliding and overturning stability analyses due to design basis wind, flood, seismic, and massive missile impact loads are performed using hand calculations. The NUHOMS® EOS System consists of a reinforced concrete horizontal storage module (EOS-HSM) loaded with a dry shielded canister (DSC) (EOS-37PTH or EOS-89BTH).

3.9.7.1.1 General Description

The system consists of the dual-purpose (transport/storage) EOS-37PTH and EOS-89BTH DSCs, the EOS-HSM, and the onsite transfer cask (EOS-TC) with associated ancillary equipment. Each EOS-HSM is designed to store a DSC containing up to either 37 pressurized water reactor (PWR) or 89 boiling water reactor (BWR) spent fuel assemblies (SFAs).

The EOS-HSM storage modules can be arranged in both single-row or back-to-back-row arrays, with thick shield walls connected to the EOS-HSM at the ends of the arrays (end shield walls) and at the back end of the module (rear shield walls), if single-row arrays are used.

In the standard configuration, the EOS-HSM consists of two main segments: a base and a roof. The roof is installed on top of the base and is connected to it by bolts/embedments via four stiffened steel brackets located at each of the interior upper corners of the module's cavity. Alternate designs of horizontal storage modules may be used in lieu of EOS-HSM as part of the NUHOMS® EOS System.

All Indicated Changes are Scope Item 2.

APPENDIX 3.9.8
EOS-HSM-SC STRUCTURAL ANALYSIS

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3.9.8 EOS-HSM-SC STRUCTURAL ANALYSIS

The purpose of this appendix is to present the structural evaluation of the EOS-HSM-SC due to all applied loads during storage, and loading and unloading operations. The EOS-HSM-SC is an alternate horizontal storage module option that may be used in lieu of the EOS-HSM-RC as part of the NUHOMS® EOS System.

3.9.8.1 General Description

A general description and operational features for the NUHOMS® EOS System are provided in Chapter 1. Similar to the EOS-HSM-RC, the EOS-HSM-SC is a freestanding structure, designed to provide environmental protection and radiological shielding for the EOS-37PTH DSC or EOS-89BTH dry shielded canister (DSC). In contrast to the EOS-HSM-RC, the EOS-HSM-SC is a steel-plate composite (SC) structure consisting of two steel plates (faceplates) with structural concrete between them, with the faceplates attached to the concrete using steel-headed stud anchors, and connected to each other using steel tie bars. Different components and overall dimensions of the EOS-HSM-SC are shown in Drawing EOS01-3300-SAR, which is provided in Chapter 1.

As with any EOS-HSM option in the NUHOMS® EOS System, the EOS-HSM-SC consists of a base unit and a roof unit. The EOS-HSM-SC is a multi-segment design, which consists of two segments of the base unit like the EOS-HSMS-RC and the EOS-HSMS-FPS-RC. The EOS-37PTH DSC or the EOS-89BTH DSC are supported inside the EOS-HSM-SC by the flat plate support (FPS) DSC support structure, which is supported by pedestals spaced along the length of the DSC support structure. The configuration of the EOS-HSM-SC, in terms of component dimensions and thicknesses, is essentially the same as that of the EOS-HSMS-FPS-RC. The configuration of the DSC support structure of the EOS-HSM-SC is identical to that of the FPS DSC support structure for the EOS-HSMS-FPS-RC. As such, only the medium length option is evaluated for the EOS-HSM-SC.

Like the EOS-HSM-RC, the EOS-HSM-SC storage modules can be arranged in either a single-row array, or back-to-back double-row arrays. The front wall of the EOS-HSM-SC has a round access door opening provided for transferring the EOS-37PTH DSC or EOS-89BTH DSC into the module or for retrieving it from the module. The door opening is closed by a shield door after the DSC insertion. The EOS-HSM-SC shield door is also an SC component and provides environmental protection, including missile and shielding protection.

End shield walls are installed at each end of a module array to provide the required missile and shielding protection. Similarly, a rear shield wall is installed at the rear of each module of the single-row module array for the same purpose. Both the end shield wall and rear shield wall are also SC components.

For thermal protection of the EOS-HSM-SC components, thin stainless steel heat shields are installed inside the EOS-HSM-SC. The configurations of the roof and side heat shields for the EOS-HSM-SC are identical with those for the EOS-HSMS-FPS-RC.

The EOS-HSM-SC is also provided with cask restraint embedments in the front wall to secure the EOS-TC during DSC insertion and retrieval operations.

3.9.8.2 Material Properties

The material properties used in the analysis and design of the EOS-HSM-SC and its components are discussed in detail in Chapter 8.

3.9.8.3 Design Criteria

The SC components, FPS DSC support structure, heat shields, and axial retainer are important-to-safety components of the EOS-HSM-SC. Consequently, they are designed and analyzed to perform their intended functions under the extreme environmental and natural phenomena specified in 10 CFR 72.122 [3.9.8-1] and American National Standards Institute (ANSI) 57.9 [3.9.8-2], which are the same criteria used for the EOS-HSM-RC in Appendix 3.9.4.

The SC components are designed to the requirements of American Institute of Steel Construction (AISC) N690-18 [3.9.8-3], using the load combinations prescribed by ANSI 57.9 [3.9.8-2]. N690-18 is compatible with ANSI/AISC 360-16 [3.9.8-6], provisions of which are applicable as well unless stated otherwise. Guidelines of the U.S. NRC Regulatory Guide 1.243 [3.9.8-4] are also considered. The FPS DSC support structure, heat shields, and axial retainer are designed to the requirements of the AISC Manual of Steel Construction [3.9.8-5] as in Appendix 3.9.4.

The load and resistance factor design (LRFD) method of N690-18 [3.9.8-3] is used for the design of the EOS-HSM-SC components. The faceplate and ties are provided to meet the minimum flexural and shear requirement of N690-18 and to ensure that the provided design strength exceeds the required strength. The steel headed stud anchors, or studs, are provided to ensure composite action of the steel faceplates and concrete.

The provisions of N690-18 [3.9.8-3] are primarily intended for the thick walls of nuclear power plant structures that provide radiation shielding and resistance to severe and extreme loads. Modified provisions of N690-18, based on nonlinear inelastic finite element analyses and physical test results, are used for the rear wall, middle/front pedestal, lower side wall bottom (14 inches), and upper side wall, which are thin walls of the EOS-HSM-SC.

3.9.8.4 Load Cases

The design load cases for EOS-HSM-SC component evaluation are the same as the load cases for EOS-HSM-RC concrete component evaluation provided in Table 3.9.4-4 except for the earthquake load, which depends on the frequencies and damping value for the EOS-HSM-SC as described in Section 3.9.8.9. The EOS-HSM-SC dead load also includes the self-weight of the faceplate based on the sheet weight density of 490 lb/ft^3. The design load cases for the FPS DSC support structure, heat shields, and axial retainer of the EOS-HSM-SC are also the same as the load cases for the EOS-HSM-RC except for the earthquake load.

3.9.8.5 Load Combination

The load combinations used in the structural analysis of the EOS-HSM-SC are the same as the combinations for the EOS-HSM-RC provided in Table 3.9.4-5. The load combinations used for the FPS DSC support structure, heat shields, and axial retainer of the EOS-HSM-SC are also the same as the combinations used for the EOS-HSM-RC.

3.9.8.6 Finite Element Models

Finite element models (FEMs) for the EOS-HSM-SC and heat shields are described in this section. The FPS DSC support structure and axial retainer are evaluated by hand calculation methodologies.

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3.9.8.7 Normal Operation Structural Analysis

The same normal operating loads described in Section 3.9.4.7 for the EOS-HSM-RC are used to evaluate the EOS-HSM-SC. The same thermal load for the EOS-HSM-FPS is applicable to the EOS-HSM-SC because, as discussed in Section 4.4.12, the SC construction does not impact the thermal performance of the horizontal storage module.

3.9.8.8 Off-Normal Operation Structural Analysis

The same off-normal operating loads described in Section 3.9.4.8 for the EOS-HSM-RC are applicable to the EOS-HSM-SC.

3.9.8.9 Accident Condition Structural Analysis

The same accident condition loads described in Section 3.9.4.9 for the EOS-HSM-RC, except for the seismic load, are used to evaluate the EOS-HSM-SC.

The design basis seismic load used for analysis of the EOS-HSM-SC components is as discussed in Section 2.3.4. Based on N690-18 [3.9.8-3], a damping value of five percent is used for seismic analysis of SC components of the EOS-HSM-SC. An evaluation of the frequency content of the loaded EOS-HSM-SC is performed to determine the amplified accelerations associated with the design basis seismic response spectra for the EOS-HSM-SC. Modal frequencies and mass participation factors of the EOS-HSM-SC are shown in Table 3.9.8-1. The results of the frequency analysis yield a lowest frequency of 18.29 Hz in the transverse direction and 30.12 Hz in the longitudinal direction. Because the lowest vertical frequency exceeds 45 Hz, the spectral acceleration is not amplified in the vertical direction. Therefore, based on the Regulatory Guide 1.60 response spectra amplifications, and conservatively using zero period acceleration (ZPA) accelerations of 0.50g and 0.33g in the horizontal and vertical directions, respectively, the corresponding seismic accelerations used for the design of the EOS-HSM-SC are 1.073g and 0.703g in the transverse and longitudinal directions, respectively, and 0.333g in the vertical direction. The resulting amplified accelerations are given in Table 3.9.8-2.

Like the EOS-HSM-RC, for sites where the response spectra at the base of the HSM are larger than analyzed, more than one module may need to tie together to prevent significant sliding or to prevent the modules from banging into each other causing unacceptable damage. The requirements on the faceplate, stud, and tie may also need to be reviewed, and the faceplate thickness and tie size may be increased for such sites. The tie and stud spacing may be adjusted as well.

The stability evaluation of the EOS-HSM-SC due to a 0.45g Horizontal/0.30g Vertical seismic load is discussed in Section 3.9.8.11. The stability evaluation by dynamic analysis shall be performed using the analysis methodology described in CoC 1029 [3.9.8-10].

Seismic analysis of the EOS-HSM-SC heat shields consists of a modal time-history analysis of the EOS-HSM-SC for obtaining four percent damped in-structure response spectra (ISRS) at heat shields support locations. The earthquake time histories compatible with the RG 1.60 spectra, described in Section 3.9.4.9.2 for the EOS-HSM-RC, are used as seismic input motion. The ISRS for the head heat shields is conservatively determined using ground motion based on the RG 1.60 spectra anchored at 0.50g and 0.33g in the horizontal and vertical directions, respectively. The modal frequencies and mass participation factors and the results of the equivalent static analysis of the heat shields, described in Section 3.9.4.9.2 for the EOS-HSM-RC, are applicable to the EOS-HSM-SC.

3.9.8.10 Structural Evaluation

The load combination results of the EOS-HSM-SC components are presented in this section.

3.9.8.10.1 EOS-HSM-SC SC Components

[ ]

The maximum demand-to-capacity ratios and governing load combinations for each of the SC components of the EOS-HSM-SC are presented in Table 3.9.8-3. The demand-to-capacity ratios for all component categories are less than one for all strength categories.

3.9.8.10.2 FPS DSC Support Structure

The FPS DSC support structure of the EOS-HSM-SC is identical with the support structure for the EOS-HSM-FPS-RC, and the load combination results for the FPS DSC support structure provided in Table 3.9.4-17a, Table 3.9.4-21a, and Table 3.9.4-22a are applicable to the FPS DSC support structure of the EOS-HSM-SC except for the results for the stop plate, which are affected by load combination C4. The demand-to-capacity ratio for the stop plate of the EOS-HSM-SC is 0.98. Therefore, the DSC support structure is adequate to resist the foreseeable loads applied to it.

3.9.8.10.3 EOS-HSM-SC Shield Door

The shield door is free to grow in the radial direction when subjected to thermal loads. Therefore, there are no stresses in the door due to thermal growth. The dead weight, tornado wind, differential pressure, and flood loads cause insignificant stresses in the door compared to stresses due to missile impact load. The evaluation of the door for the missile impact load is presented in Section 3.9.8.10.6.2. For the door anchorage, the controlling load due to tornado-generated differential pressure drop load, calculated for the EOS-HSM-RC in Section 3.9.4.10.3, is applicable.

3.9.8.10.4 Heat Shield

The heat shield design of the EOS-HSM-SC is identical with the heat shield design for the EOS-HSM-FPS-RC described in Section 3.9.4.10.4.

For the roof heat shield, the maximum interaction ratio for combined axial and bending stress in the connection bolts is 0.509, which is less than 1.0. The maximum bending moment in the roof heat shield panel is 26.2 in-lb/in, which is also less than the panel moment capacity of 59.59 in-lb/in.

For the side heat shield, the maximum interaction ratio for combined axial and bending stress in connection bolts is 0.272, which is less than 1.0. The maximum bending moment in side heat shield panel is 27.2 in-lb/in, which is also less than the panel moment capacity of 59.59 in-lb/in.

The thermal expansion evaluation of the heat shields for the EOS-HSM-RC is also applicable to the EOS-HSM-SC and, therefore, neither the roof heat shield panel and side wall heat shield panel is subjected to thermal stress.

3.9.8.10.5 DSC Axial Restraint

The DSC axial retainer of the EOS-HSM-SC is identical with the axial retainer for the EOS-HSM-RC described in Section 3.9.4.10.5. The maximum seismically induced shear load in the retainer is 140.2 kips, and the allowable shear strength of the axial retainer is 196.0 kips. The maximum seismically induced moment in the retainer is 280.4 in-kips, taking a moment arm of 2 inches, conservatively. The allowable flexural strength of axial retainer is 344.9 in-kips. Hence, the DSC axial retainer design is adequate to perform its intended function.

3.9.8.10.6 Evaluation of SC Components for Missile Loading

Missile impact effects are assessed in terms of local damage and overall structural response. As per [3.9.8-11], the local failure modes of SC components subjected to missile impact differ from those for reinforced concrete components in that SC components may experience penetration, bulging, splitting and perforation sequentially. Generally, scabbing is prevented by steel plates and perforation is considered to be the governing local failure mode for SC components. Evaluation of local effects is essential to ensure that protected items (the DSC and fuel) would not be damaged by a missile perforating a protective barrier. Evaluation of overall structural response is essential to ensure that protected items are not damaged or functionally impaired by deformation or collapse of the impacted structure.

The tornado-generated missiles are conservatively assumed to strike normal to the surface with the long axis of the missile parallel to the line of flight to maximize the local effects. Plastic deformation to absorb the energy input by the tornado-generated missile load is desirable and acceptable, provided that the overall integrity of the structure is not impaired. Due to complex physical processes associated with missile impact effects, the EOS-HSM-SC structure is primarily evaluated conservatively by application of empirical formulae.

3.9.8.10.6.1 Local Damage Evaluation

The required thickness for concrete targets to prevent perforation is 18.5 inches, as calculated in Section 3.9.4.10.6.1. Since the minimum concrete thickness of the SC components is greater, perforation of the SC components of the EOS-HSM-SC do not occur due to missile impact.

3.9.8.10.6.2 Global Structural Response

The overall structural response of each SC component is determined by single DOF analysis using the response charts solution method of [3.9.8-12] as described in Section 3.9.4.10.6.2 for the EOS-HSM-RC considering the same enveloping missiles.

The end wall, rear wall, base front wall, roof, and door of the EOS-HSM-SC are evaluated for global response, since these components may interface with missile loading. The rear wall and door are idealized as simply supported plates while the end wall, base front wall and roof are idealized as simply supported beams for structural response. The yield resistance and fundamental period of vibration of SC components are then determined based on the assumed idealized boundary condition. The calculated value of yield resistance, R_y, and fundamental period of vibration, T_n, are tabulated below.

Component	R_y (kip)	T_n (sec)
End Wall	1624	0.0300
Rear Wall	4680	0.00626
Base Front Wall	3174	0.00471
Roof	1648	0.0264
Door	1257	0.00168

The maximum value of ductility ratio of all five components is found to be less than 1.0, which is less than the allowable ductility ratio of 1.3 for shear-controlled SC components with shear reinforcement spaced more than half the section thickness as per N690-18 [3.9.8-3]. Therefore, the global response of the EOS-HSM-SC is within the deformation limit meeting the ductility requirement. Per [3.9.8-11], punching shear as a failure mode is inherently prevented by an SC wall designed to resist local failure. Therefore, no additional evaluation of the EOS-HSM-SC is required for punching shear.

3.9.8.11 Stability Evaluation

The sliding and overturning stability analyses of the EOS-HSM-SC due to design basis wind, flood, seismic, and massive missile impact loads are performed using hand calculations.

3.9.8.11.1 General Description

The stability of the EOS-HSM-SC unit is evaluated for the same four load cases that are considered for the EOS-HSM-RC in Appendix 3.9.7, namely, tornado-generated wind loads, massive missile impact loads, flood loads, and seismic loads. The weight of an empty EOS-HSM-SC is between 307.6 kips minimum and 361.6 kips maximum. As in the stability evaluation of the EOS-HSM-RC, bounding upper and lower values of concrete density are considered; a concrete-to-concrete friction coefficient of 0.6 is used; the stability analysis considers rigid body motions; and the differential pressure load caused by the tornado pressure drop is ignored. Consideration is also given to partial steel-to-concrete friction at the base of the HSM resulting in an effective friction coefficient of 0.576. The stability is evaluated using the same methodologies described in Appendix 3.9.7.

3.9.8.11.2 Design Basis Tornado (Wind and Missile)

The tornado wind speed and resulting wind pressures on the module considered in the stability analysis are described in Section 3.9.7.1.8.1. Results of stability evaluations for the design basis tornado are summarized below.

- Static Overturning Analysis due to Tornado Wind: The safety factor against overturning computed for the EOS-HSM-SC due to tornado wind is 1.61.
- Dynamic Overturning Analysis of Tornado Wind Concurrent with Massive Missile Impact Loading: The evaluation for the EOS-HSM-RC presented in Section 3.9.7.1.8.1.2 is bounding for the EOS-HSM-SC.
- Time-Dependent Overturning Analysis of Tornado Wind Concurrent with Massive Missile Impact Loading: The evaluation for the EOS-HSM-RC presented in Section 3.9.7.1.8.1.3 is bounding for the EOS-HSM-SC.
- Sliding Analysis for Tornado Wind Concurrent with Massive Missile Impact loading: The sliding distance of the EOS-HSM-SC is calculated to be 1.09 inches.
- Time-Dependent Sliding Analysis for Tornado Wind Concurrent with Massive Impact Loading: The governing sliding displacement is 1.10 inch.

3.9.8.11.3 Flood Loads

The flood load on the module considered in the stability analysis is described in Section 3.9.7.1.8.2. Results of stability evaluations for the flood loads are summarized below.

- Overturning Analysis: The factor of safety against overturning for a single, freestanding EOS-HSM-SC due to the postulated design basis flood water velocity is 1.15.
- Sliding Analysis: The factor of safety against sliding for a single, freestanding EOS-HSM-SC due to the postulated design basis flood water velocity is 1.37.

3.9.8.11.4 Seismic Load

The seismic load on the module considered in the stability analysis is described in Section 3.9.7.1.8.3. Results of stability evaluations for the seismic load are summarized below.

- Static Overturning Analysis of the EOS-HSM-SC due to Seismic Load: The safety factor against overturning is 1.02 and is greater than 1. The maximum acceptable acceleration values before tipping occurs are 0.45g horizontal and 0.30g vertical.
- Static Sliding Analysis of the EOS-HSM-SC due to Seismic Load: The safety factor against sliding is 1.02 and is greater than 1. The maximum acceptable acceleration values before sliding occurs are 0.45g horizontal and 0.30g vertical.
- Seismic Stability of the DSC on DSC Support Structure inside the EOS-HSM-SC: The safety factor against DSC lift off from the DSC support is 1.01. The maximum acceptable acceleration values before any uplift occurs are 0.455g horizontal and 0.303g vertical.

3.9.8.11.5 Interaction of EOS-HSM-SC with Adjacent Modules

When interaction of the EOS-HSM-SC with adjacent modulus is considered, the maximum displacement obtained in this section is conservative and bounding and this conservatism also applies to overturning, as described in Section 3.9.7.1.8.4 for the EOS-HSM-RC.

3.9.8.11.6 Results

For the maximum seismic acceleration of 0.45g horizontal and 0.30g vertical, no sliding will occur. Also, there will be no overturning at this set of seismic accelerations.

For flood, wind, and missile impact, it is also determined that the uplift values are small and so the DSC remains stable on the support rails. For seismic loading, it is also determined that there is no uplift of the DSC.

Table 3.9.8-4 shows a summary of the bounding results from the analyses in this section. Therefore, a maximum horizontal acceleration of 0.45g and a vertical acceleration of 0.30g can be exerted on the EOS-HSM-SC before any uplift or sliding occurs. Additionally, there is no DSC lift-off due to this seismic loading.

3.9.8.12 References

3.9.8-1 Code of Federal Regulation Title 10, Part 72 (10CFR Part 72), "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor-Related Greater than Class C Waste."

3.9.8-2 ANSI/ANS 57.9-1984, "Design Criteria for an Independent Spent Fuel Storage Installation (Dry Storage Type)," American National Standards Institute, American Nuclear Society.

3.9.8-3 AISC (2018), Specification for Safety-Related Steel Structures for Nuclear Facilities, ANSI/AISC N690-18, American Institute of Steel Construction.

3.9.8-4 U.S. Nuclear Regulatory Commission, Regulatory Guide 1.243, "Safety-Related Steel Structures and Steel-plate Composite Walls for other than Reactor Vessels and Containments," Rev. 0, August 2021.

3.9.8-5 American Institute of Steel Construction, AISC Manual of Steel Construction, 13th Edition or Later.

3.9.8-6 AISC (2016), Specification for Structural Steel Buildings, ANSI/AISC 360-16, American Institute of Steel Construction.

3.9.8-7 Not used.

3.9.8-8 Not used.

3.9.8-9 "ANSYS Computer Code and User's Manual," Release 17.1.

3.9.8-10 AREVA Inc., "Updated Final Safety Analysis Report for The Standardized Advanced NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel," Revision 11, US NRC Docket Number 72-1029, November 2021.

3.9.8-11 J. M. Kim, J. Bruhl, and A. Varma, "Design of SC Walls Subjected to Impactive Loading for Local and Global Demands," 23rd Conference on Structural Mechanics in Reactor Technology, 2015.

3.9.8-12 Bechtel Corporation, "Design Guide Number C-2.45 for Design of Structures for Tornado Missile Impact," Revision 0, April 1982.

All Indicated Changes are Scope Item 2.

Table 3.9.8-1
Modal Frequencies and Mass Participation of EOS-HSM-SC

Mode	Frequency (Hz)	X-Direction		Y-Direction		Z-Direction	
		Mass (kip-s^2/in)	%	Mass (kip-s^2/in)	%	Mass (kip-s^2/in)	%
1	18.29	0.685	54.7	0.000	0.0	0.000	0.0
2	30.12	0.000	0.0	0.000	0.0	0.822	65.6
3	30.74	0.000	0.0	0.000	0.0	0.019	1.5
4	32.97	0.001	0.1	0.000	0.0	0.000	0.0
5	35.62	0.003	0.2	0.000	0.0	0.000	0.0
6	42.26	0.000	0.0	0.002	0.1	0.173	13.8
7	45.74	0.350	28.0	0.000	0.0	0.000	0.0
8	48.61	0.000	0.0	0.002	0.1	0.000	0.0
9	48.69	0.003	0.2	0.000	0.0	0.000	0.0
10	56.29	0.000	0.0	0.366	29.2	0.000	0.0
11	70.28	0.000	0.0	0.000	0.0	0.000	0.0
12	71.36	0.002	0.2	0.000	0.0	0.000	0.0
13	78.53	0.000	0.0	0.001	0.0	0.003	0.2
14	81.43	0.000	0.0	0.279	22.3	0.007	0.6
15	81.53	0.000	0.0	0.000	0.0	0.000	0.0
16	94.03	0.000	0.0	0.065	5.2	0.006	0.4
17	95.40	0.000	0.0	0.000	0.0	0.000	0.0

Table 3.9.8-2
Spectral Acceleration Applicable to Different Components of EOS-HSM-SC for Seismic Analysis

Direction	**Frequency (Hz)**	**Spectral Acceleration (g) Corresponding to Design ZPA**		
		At 3% Damping (for DSC)	**At 4% Damping (Steel Structures)**	**At 5% Damping (for SC Components)**
X (Transverse)	18.29	1.257	1.154	1.073
Y (Vertical)	56.29	0.333	0.333	0.333
Z (Longitudinal)	30.12	0.754	0.726	0.703

Table 3.9.8-3
Maximum Demand-to-Capacity Ratios and Governing Load Combinations for SC Component Design

Component Category	Tension		Compression		Out-of-Plane Flexure		In-Plane Shear	
Rear Wall Pedestal	0.10	C4	0.03	C4	0.06	C7	0.09	C4
Rear Wall	0.35	C4	0.19	C4	0.13	C7	0.15	C4
Middle / Front Pedestal	0.12	C4	0.12	C4	0.06	C1	0.10	C4
Front Wall	0.33	C4	0.11	C4	0.23	C2	0.22	C4
Lower Side Wall Bottom	0.54	C3	0.04	C4	0.23	C7	0.09	C7
Lower Side Wall Bottom (14″)	0.21	C7	0.04	C4	0.08	C3	0.10	C5
Lower Side Wall Middle	0.19	C7	0.10	C2	0.44	C7	0.18	C7
Lower Side Wall Top	0.18	C4	0.38	C5	0.19	C7	0.25	C5
Upper Side Wall	0.35	C5	0.57	C7	0.15	C7	0.25	C5
Roof	0.25	C2	0.06	C5	0.26	C2	0.08	C5

Component Category	Out-of-Plane Shear		Out-of-Plane Shear Interaction		Membrane Force and Out-of-Plane Moment Interaction		Maximum	
Rear Wall Pedestal	0.67	C3	0.83	C1	0.15	C4	0.83	C1
Rear Wall	0.46	C5	0.92	C5	0.41	C4	0.92	C5
Middle / Front Pedestal	0.31	C3	0.38	C1	0.14	C4	0.38	C1
Front Wall	0.38	C2	0.33	C2	0.57	C4	0.57	C4
Lower Side Wall Bottom	0.36	C7	0.37	C7	0.62	C7	0.62	C7
Lower Side Wall Bottom (14″)	0.36	C7	0.90	C7	0.26	C7	0.90	C7
Lower Side Wall Middle	0.43	C7	0.41	C7	0.58	C7	0.58	C7
Lower Side Wall Top	0.39	C7	0.47	C7	0.36	C5	0.47	C7
Upper Side Wall	0.41	C5	0.89	C4	0.49	C7	0.89	C4
Roof	0.89	C5	0.89	C5	0.44	C2	0.89	C5

Note: Calculation of out-of-plane shear interaction is per modified equation described in Section 3.9.8.3 for the rear wall, middle/front pedestal, lower side wall bottom (14″), and upper side wall.

Table 3.9.8-4
Summary of EOS-HSM-SC Stability Results

Loading	Result	EOS-HSM-SC
Tornado Wind + Missile	Maximum Sliding Distance (in)	1.10
	Maximum Rocking Uplift Angle(1) (°)	2.8
Flood	Safety Factor against Sliding	1.37
	Safety Factor against Tipping	1.15
Seismic for Loaded EOS-HSM-SC with End Shield Wall	Maximum Acceleration before Sliding (horiz / vert) (g)	0.45 / 0.30
	Maximum Acceleration before Tipping (horiz / vert) (g)	0.45 / 0.30

Note:

(1) A 1.1 required factor is included in the angles.

Proprietary Information on Pages 3.9.8-18 through 3.9.8-21
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4. THERMAL EVALUATION

NOTE: For *the EOS-89BTH DSC with* HLZCs 1 through 3, the basket types directly correlate to the Heat Load Zone Configurations (HLZCs), throughout this chapter, basket types are directly referred to by the HLZC. For *the EOS-37PTH DSC and HLZCs 4 through 6 for EOS-89BTH DSC*, the basket types do not directly correlate to the HLZC. A description of the various basket assembly types is presented in Chapter 1, Section 1.1.

The thermal evaluation described in this chapter is applicable to the NUHOMS® EOS System that includes an EOS-37PTH or EOS-89BTH dry shielded canisters (DSCs) loaded inside the EOS-TC108, EOS-TC125 or EOS-TC135 transfer cask (TC) and the EOS horizontal storage module (HSM) or EOS-HSMS. With respect to thermal evaluations, the EOS-HSM and EOS-HSMS are identical; therefore, when the EOS-HSM is referred to in this chapter, the analysis is applicable to both the EOS-HSM and EOS-HSMS. A flat plate support structure (FPS) is an option for the medium length EOS-HSM/HSMS, which allows a DSC support structure to be built up from a flat plate. This option is referred to as the EOS-HSM-FPS or EOS-HSMS-FPS.

A summary of the EOS-37PTH and EOS-89BTH DSC configurations analyzed in this chapter and Chapter A.4 is shown in Chapter 1, Table 1-2.

Descriptions of the detailed analyses performed for normal, off-normal, and hypothetical accident conditions are provided in Section 4.4 for storage operations in the EOS-HSM, Section 4.5 for transfer operations in the EOS-TC125/EOS-TC135, and Section 4.6 for transfer operations in the EOS-TC108 up to a maximum heat load of 41.8 kW in EOS-37PTH DSC and 41.6 kW in EOS-89BTH DSC. The thermal analyses performed for the loading and unloading conditions are described in Section 4.5.11. DSC internal pressures are discussed in Section 4.7. The thermal performance of the FPS option of the EOS-HSM is discussed in Appendix 4.9.5.

Appendix 4.9.6 and Chapter A.4 present the thermal evaluation of the EOS-37PTH DSC with HLZCs 4 through 6 and HLZCs 7 through 9, respectively for storage operations. Thermal evaluation of the EOS-37PTH DSC with HLZCs 4 through 9 is presented in Appendix 4.9.6 for transfer operations. Appendix 4.9.6 also includes the thermal evaluation of transfer operations for EOS-TC108 with EOS-37PTH DSC and heat loads greater than 41.8 kW. Appendix 4.9.7 presents the thermal evaluation of the EOS-37PTH DSC with HLZCs 10 and 11 for storage operations in the EOS-HSM and transfer operations in the EOS-TC125/EOS-TC135. Section A.4.6 in Chapter A.4 presents the thermal storage evaluation of the EOS-37PTH DSC with HLZC 11 in the HSM-MX. Thermal evaluation of the EOS-89BTH DSC with *HLZCs 3 though 6* during storage operations in the HSM-MX is presented in Chapter A.4.

Appendix 4.9.8 presents the thermal evaluation of the EOS-89BTH DSC with HLZCs 4 though 6 for storage operations in the EOS-HSM and transfer operations in the EOS-TC125.

Appendix 4.9.9 presents the thermal evaluation of the EOS-37PTH DSC with HLZCs 12 and 13 for storage operations in the EOS-HSM and transfer operations in the EOS-TC125/TC135.

As discussed in Appendix 4.9.6.1.1, EOS-37PTH Type 4H basket has the same emissivity of steel plates and conductivity of poison material as those of the EOS-37PTH Type 1 basket. Therefore, all the thermal evaluations for EOS-37PTH Type 1 baskets for storage conditions in Section 4.4 and transfer conditions in Section 4.5 are also applicable for EOS-37PTH Type 4H basket.

In addition, since Type 4H basket assembly has higher emissivity steel plates and higher conductivity poison plates, they are more efficient in terms of thermal performance compared to Type 4L/5 baskets. Therefore, all the thermal evaluations for EOS-37PTH Type 4L/5 baskets for storage and transfer conditions in Appendix 4.9.6, Sections A.4.4.4 and A.4.5.5 in Appendix A.4 are also applicable for EOS-37PTH Type 4H basket.

4.1 Discussion of Decay Heat Removal System

The EOS-37PTH and EOS-89BTH DSCs are designed to passively reject decay heat during storage and transfer for normal, off-normal, and hypothetical accident conditions while maintaining temperatures and pressures within specified limits. Objectives of the thermal analyses performed for this evaluation include:

- Determination of maximum and minimum temperatures with respect to material limits to ensure components perform their intended safety functions,
- Determination of temperature distributions to support the calculation of thermal stresses,
- Determination of maximum DSC internal pressures for normal, off-normal, and hypothetical accident conditions, and
- Determination of the maximum fuel cladding temperature, and to confirm that this temperature will remain sufficiently low to prevent unacceptable degradation of the fuel during storage.

The EOS-37PTH DSC is analyzed based on a maximum heat load of 50.0 kW from 37 pressurized water reactor (PWR) fuel assemblies (FAs) with a maximum heat load of *4.3* kW per assembly. The EOS-89BTH DSC is analyzed based on a maximum heat load of *48.2* kW from 89 boiling water reactor (BWR) fuel assemblies (FAs) with a maximum heat load of *1.7* kW per assembly. The authorized HLZC*s* for *the EOS-37PTH DSC* are provided in Figure 1 of the Technical Specification [4-24] *if transferred using an EOS-TC108 transfer cask and stored in either EOS-HSM or HSM-MX, or transferred using EOS-TC125 or EOS-TC135 transfer cask and stored in HSM-MX*. *For EOS-37PTH DSCs transferred in EOS-TC125 or EOS-TC135 and stored in EOS-HSM, the authorized HLZCs are shown in* Figure *2-3a through Figure 2-3m of Chapter 2*. *The authorized HLZCs for the EOS-89BTH DSC are provided in Figure 2-2a through Figure 2-2f in Chapter 2 for transfer in the EOS-TC125 and Figure 2 of the TS [4-24] for the EOS-89BTH when transferred in the EOS-TC108.*

Fuel assemblies are considered as homogenized materials in the fuel compartments. The effective thermal conductivity of the FAs used in the thermal analysis is based on the conservative assumption that heat transfer within the fuel region occurs only by conduction and radiation where any convection heat transfer is neglected. The lowest effective properties among the applicable FAs are selected to perform the thermal analysis. Evaluations of heat transfer from the FAs to the basket assembly credits conduction through the basket assembly materials (steel/metal matrix composite/aluminum) and helium fill gas within the DSC. Convection and radiation heat transfer within the basket assembly are conservatively ignored.

13. Surface Properties

Material	Emissivity (ε)	Solar Absorptivity (α)	References
Zircaloy based Fuel Cladding	0.8	--	Figure 3.4-1 from [4-16]
Aluminum	0.09	--	[4-17]
Stainless steel	0.46 (1)	--	[4-19], Appendix U, Section U.4.2
	0.587 (2)	--	[4-18]
Carbon steel	0.55	--	[4-19], Appendix U, Section U.4.2
Concrete	0.9 (3)	1.0	[4-17]

Notes:

1. For machined or flat stainless steel surfaces
2. For rolled surfaces of the DSC cylindrical shell
3. Emissivity of 0.8 is conservatively used in the analyses

For the EOS-37PTH Basket Types 4L and 5, an emissivity of 0.07 is considered based on emissivity of electroless nickel coating [4-28].

Emissivity of rolled stainless steel plates is 0.587 as considered in [4-18]. The emissivity for rolled steel sheets is 0.657 as reported in Table 10-17 of [4-2]. An emissivity of 0.587 is assumed for the exterior surfaces of the DSC.

All exposed internal and external surfaces of the transfer cask are painted. Based on the emissivities listed in Table B-1 of [4-17], it is observed that all paints have an emissivity between 0.92-0.96. Therefore, an emissivity of 0.9 is used for all painted surfaces of the TC.

4.4 Thermal Evaluation for Storage

This section provides an evaluation of the thermal performance of the EOS-HSM loaded with the EOS-37PTH DSC with a maximum heat load of 50 kW and the EOS-89BTH DSC with a maximum heat load of 43.6 kW for normal, off-normal, and hypothetical accident conditions. ANSYS FLUENT CFD models are used to demonstrate that the maximum temperatures of key components such as fuel cladding, concrete, heat shields, etc. are below maximum temperature limits. This section also provides the average temperature of cavity gas for pressure calculation, and the average temperatures of basket plates and DSC shells for thermal expansion calculations.

To evaluate the thermal performance of the EOS-HSM loaded with the EOS-37PTH and EOS-89BTH DSCs, a three-dimensional (3D), half-symmetrical, CFD and thermal model in ANSYS FLUENT [4-5] is developed for each DSC. Due to the complexity of the geometries, it is impractical to generate a single conformal mesh for the whole model. Instead, the EOS-37PTH, EOS-89BTH basket assemblies and the EOS-HSM are separately meshed and combined in ANSYS FLUENT.

Section 4.4.1 and Section 4.4.2 present a description of the loading cases and the CFD model used for the thermal evaluation of the EOS-37PTH during storage in EOS-HSM, respectively. Sections 4.4.3, 4.4.4, and 4.4.5 present the results of the thermal evaluation for normal, off-normal, and hypothetical accident conditions of storage for the EOS-37PTH DSC.

Section 4.4.6 and Section 4.4.7 present a description of the loading cases and the CFD model used for the thermal evaluation of the EOS-89BTH during storage in EOS-HSM, respectively. Sections 4.4.9, 4.4.10, and 4.4.11 present the results of the thermal evaluation for normal, off-normal, and hypothetical accident conditions of storage for the EOS-89BTH DSC.

The thermal performance of the FPS option of the EOS-HSM is discussed in Appendix 4.9.5.

Section 4.4.12 discusses the thermal performance of the steel composite variant of the EOS-HSM storage module.

4.4.1 EOS-37PTH DSC - Description of Loading Cases for Storage

To determine the thermal performance of the EOS-HSM loaded with the EOS-37PTH DSC, the load combinations (load cases) listed in Table 4-1 are evaluated for normal, off-normal, and accident conditions using the CFD model described in Section 4.4.2.3.

The HLZCs are described in *Figure 2-3a through Figure 2-3m in Chapter 2* for the EOS-37PTH DSC. As shown in *Figure 2-3a through Figure 2-3c in Chapter 2*, HLZCs 1, 2 and 3 have identical zoning with different allowable heat loads. Since HLZC 1 has the maximum total heat load and the maximum heat load per FA in each zone, it is the bounding HLZC among all HLZCs. Therefore, load cases for normal, off-normal, and accident conditions will be evaluated with HLZC 1. No thermal evaluation is performed for HLZCs 2 and 3 for all storage conditions.

Among the various load cases shown in Table 4-1, Load Case 1a with HLZC 1 for the EOS-37PTH DSC is the bounding case for normal hot storage conditions among all EOS-37PTH HLZCs (Load Cases 1a-1c). Load Case 2 is the normal cold storage condition with -20 ºF ambient temperature. Its maximum temperatures are bounded by Load Case 1a and temperature gradients are bounded by Load Case 4. Load Case 3 evaluates the off-normal hot storage condition with 117 °F ambient temperature. Load Case 4 analyzes the off-normal cold storage condition with -40 °F ambient temperature, and provides the bounding thermal gradients for structural analysis. Insolation is conservatively neglected for load cases with cold ambient temperatures of -20 °F and -40 °F.

Since the EOS-HSM is located outdoors, there is a remote probability that the air inlet or outlet openings will be blocked by debris from events such as flooding, high wind, and tornados. The perimeter security fence around independent spent fuel storage installation (ISFSI) and the location of the air inlet and outlet openings reduce the probability of such an accident. A complete blockage of all air inlets and outlets simultaneously is not a credible event. However, to bound this scenario, Load Case 5 performs a transient analysis assuming complete blockage of the inlet and outlet vents with 117 °F ambient temperature. Initial temperatures are taken from steady-state results of off-normal hot storage condition (Load Case 3). Blocked vents accident transient conditions are considered for up to 40 hours. The test requirements for concrete at elevated temperatures are described in Section 8.2.1.3.

4.4.12 Thermal Evaluation of EOS-HSM-SC

As discussed in Chapter 1, Section 1.2.1.3, the EOS-HSM may be constructed of reinforced concrete and steel, or alternatively, the components may be constructed from a steel-plate composite. The steel-plate composite EOS-HSM is termed the EOS-HSM-SC. Within this variant, there are no changes to the inlet or outlet air vents or the internal cavity.

[

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Since the vent sizes along with the HSM cavity remain unchanged, the heat dissipation from natural convection will remain the same. For the small amount of heat (~2.9 kW out of 50 kW as seen from Appendix 4.9.4, Section 4.9.4.8.2) dissipated through the outer surfaces of the EOS-HSM, replacing the concrete with steel will increase this amount of heat dissipation since steel will enhance the thermal performance due to higher thermal conductivities. In addition, the steel composite variant also includes ties between the inner and outer face plates and stud anchors on each face plate as shown in Table 1 of Drawing EOS01-3300-SAR in Chapter 1, Section 1.3.3, which will also enhance the heat dissipation. The following table presents a comparison of effective thermal conductivity for the steel-plate composite variant without crediting the ties to the current reinforced concrete option for the 42-inch thick front wall. The presence of studs closely spaced throughout the structure ensures a good contact between the steel and concrete. As shown in the table, the effective conductivities in both the across and parallel directions are higher for the steel-plate composite variant compared to the current design with reinforced concrete. This compassion shows that the steel-plate composite variant of the HSM does not impact the thermal performance.

Proprietary Information on Pages 4-77 and 4-78
Withheld Pursuant to 10 CFR 2.390

The methodology to determine the axial conductivity is described in Section P.4.8.1.3 of the Standardized NUHOMS® System UFSAR [4.9.1-2] and is used in this evaluation based on the bounding FA and the properties described above. Similarly, the effective density and specific heat are determined based on the methodology presented in Section P.4.8.2 of the Standardized NUHOMS® System UFSAR, using the bounding FA and the properties described above.

Using the methodology presented in Appendix P, Section P.4.8.1.4 of the Standardized NUHOMS® System [4.9.1-2], a two-dimensional (2D) finite element model (FEM) of WE14x14 OFA FA is developed in ANSYS [4.9.1-3] to determine the transverse effective conductivity. The outer surfaces, representing the fuel compartment walls, are held at a constant temperature, and heat generating boundary condition is applied to the fuel pellets within the model. The models were run with a series of isothermal boundary conditions applied to the nodes representing the fuel compartment walls. The FEMs of WE14x14 OFA FA is shown in Figure 4.9.1-1. Figure 4.9.1-2 shows the heat generation rate and temperature boundary conditions.

The computed FA transverse and axial effective conductivities as functions of temperature for irradiated WE14x14 FA are listed in Table 4.9.1-3 and also summarized in Section 4.2.1. The effective specific heat and density for irradiated WE14x14 FA is shown is listed in Table 4.9.1-4 and also summarized in Section 4.2.1. The effective thermal conductivities for the FAs are also applicable for vacuum drying conditions since helium is used for water blowdown from the DSC.

As shown in Figure P.4-46 of [4.9.1-2], WE 17x17 FAs have the bounding transverse effective thermal conductivity among all FAs except for WE 14x14 FAs. Based on the same methodology in Section P.4.8 of [4.9.1-2], the effective thermal properties for WE 17x17 FA are recomputed and listed in Table 4.9.1-10 and Table 4.9.1-11. These effective thermal properties are used to bound the effective thermal properties for all fuel types except WE14x14 FAs.

4.9.1.2 Effective Thermal Properties for BWR Spent Fuel Assemblies in EOS-89BTH DSC

The FAs considered for storage in the EOS-89BTH DSC including the design data for each FA, are listed in Table 2-3 and Table 2-4. The FAs listed in Table 2-3 are previously studied in Section T.4.8 and Section Y.4.9 of the Standardized NUHOMS® System UFSAR [4.9.1-2], except for the GNF2 FA. However, the dimensions of GNF2 FA listed in Table 2-3 are very similar to the previously evaluated GE12/GE14 FAs from Section T.4.8 and Section Y.4.9 of the Standardized NUHOMS® System UFSAR. Therefore, the thermal properties for the GE12/GE14 FAs are also applicable to the GNF2 FA.

Table 4.9.1-10
Transverse and Axial Effective Thermal Conductivities of WE 17x17 Fuel Assemblies in EOS-37PTH DSC (Basket Assembly Type 4HA)

T	**k_{eff}**	**T**	**k_{axl}**
(°F)	**Btu/(hr-in-°F)**	**(°F)**	**Btu/(hr-in-°F)**
147	1.877E-02	200	5.956E-02
239	2.238E-02	300	6.274E-02
333	2.645E-02	400	6.574E-02
428	3.174E-02	500	6.875E-02
524	3.714E-02	600	7.156E-02
620	4.476E-02	800	7.738E-02
717	5.134E-02		
815	6.019E-02		
913	6.982E-02		
1011	7.934E-02		
1110	9.187E-02		
SI UNITS			
T	**k_{eff}**	**T**	**k_{axl}**
(°C)	**W/(m-K)**	**(°C)**	**W/(m-K)**
64	3.898E-01	93	1.236
115	4.648E-01	149	1.302
167	5.493E-01	204	1.365
220	6.592E-01	260	1.427
273	7.714E-01	316	1.485
326	9.296E-01	427	1.606
381	1.066E+00		
435	1.250E+00		
489	1.450E+00		
544	1.648E+00		
599	1.908E+00		

Table 4.9.1-11
Effective Specific Heat and Density of WE 17x17 Fuel Assemblies in EOS-37PTH DSC (Basket Assembly Type 4HA)

T	$C_{p\ eff}$	ρ_{eff}
(°F)	Btu/(lb_m-°F)	(lb_m/in^3)
80	0.0578	0.1249
260	0.0648	
692	0.0720	
1502	0.0782	
SI units		
T	$C_{p\ eff}$	ρ_{eff}
(°C)	J/(kg-K)	(kg/m^3)
27	241.9	3456
127	271.2	
367	301.5	
817	327.3	

APPENDIX 4.9.9
THERMAL EVALUATION OF EOS-37PTH DSC FOR HLZCS 12 AND 13

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4.9.9 THERMAL EVALUATION OF EOS-37PTH DSC FOR HLZCS 12 AND 13

This appendix evaluates the thermal performance of the EOS-37PTH Dry Shielded Canister (DSC) for normal, off-normal, and accident conditions with intact fuel assemblies (FAs), damaged FAs, and failed fuel canisters (FFCs) in Basket Assembly Type 4HA with heat load zone configurations (HLZCs) 12 and 13. The Type 4HA basket is a subset of the Type 4H basket [ ]

The geometry dimensions of Type 4HA basket are the same as Type 4H baskets. The EOS-37PTH Basket Assembly Type 4HA with HLZCs 12 and 13 can be stored in the EOS-HSM and transferred in the EOS-TC125/TC135. There are no changes to the confinement boundary (DSC shell).

A summary of the EOS-37PTH DSC configurations analyzed in this section is shown below.

DSC Type	Basket Assembly Type	Heat Load Zone Configuration (HLZC)	Max. Heat Load (kW)	Transfer Cask	Storage Module (1)
EOS-37PTH	4HA	12	50	EOS-TC125/ EOS-TC135	EOS-HSM/ EOS-HSMS/ EOS-HSM-FPS/ EOS-HSMS-FPS/
	4HA	13	50		

Note:

1. EOS-HSM and EOS-HSMS are identical in thermal performance, and EOS-HSM-FPS and EOS-HSMS-FPS are identical in thermal performance, as discussed in Chapter 4.

Section 4.9.9.1 presents the descriptions of HLZCs 12 and 13 for EOS-37PTH DSC. Section 4.9.9.2 presents the transfer evaluation of the EOS-37PTH DSC with intact fuels with HLZCs 12 and 13 in EOS-TC125/TC135. Section 4.9.9.3 presents the storage evaluation of the EOS-37PTH DSC with intact fuels with HLZCs 12 and 13 in the EOS-HSM. Section 4.9.9.4 evaluates the damaged and failed FAs in HLZCs 12 and 13.

In addition, Section 4.9.9.5 evaluates the full models that include the whole EOS-37PTH DSC basket for storage in EOS-HSM and transfer in EOS-TC125.

4.9.9.1 Description of HLZCs 12 and 13

HLZCs 12 and 13 are shown in Chapter 2, Figure 2-3l and Figure 2-3m, respectively. As discussed in Section 2.4.3, the total heat load per DSC is limited to 50 kW when loaded in the EOS-HSM per HLZC 12 and HLZC 13.

HLZCs 12 and 13 can accommodate up to six damaged FAs, or up to two failed FAs, along with the remaining intact FAs. The maximum allowable heat load per failed FA is reduced to 0.8 kW. It should be noted that damaged FAs and failed FAs shall not be stored in the same DSC.

As shown in Figure 2-3l and Figure 2-3m in Chapter 2 for HLZC 12 and HLZC 13, Zone 1 through Zone 9 are arranged from the lowest to the highest heat loads per fuel assembly (FA). Zone 9 in HLZC 12 has a maximum heat load per FA of 4.3 kW, which is the highest heat load per FA among all the HLZCs that can be used in the EOS-37PTH DSC. Zone 6 through Zone 8 all have heat loads per FA above 2.0 kW in HLZCs 12 and 13. These high payload FAs are conveniently placed in the outermost compartments of the DSC. [

]

HLZC #	Zone	No. of FAs	Heat Load / FA (kW)	Heat Load / Zone (kW)
12-1	**1**	2	0.5	1
	2	14	0.8	11.2
	3	6	1	6
	4	4	1.25	5
	5	2	1.5	3
	6	1	2.4	2.4
	7	2	2.9	5.8
	8	2	3.5	7
	9	2	4.3	8.6
	Total Heat Load / DSC (kW)			50
12-2	**1**	2	0.5	1
	2	14	0.8	11.2
	3	6	1	6
	4	4	1.25	5
	5	2	1.5	3
	6	3	2	6
	7	2	2.9	5.8
	8	2	1.7	3.4
	9	2	4.3	8.6
	Total Heat Load / DSC (kW)			50
13-1	**1**	1	0.5	0.5
	2	13	0.8	10.4
	3	8	1	8
	4	3	1.25	3.75
	5	2	1.5	3
	6	2	2	4
	7	2	2.2	4.4
	8	4	1.89	7.56
	9	2	4.2	8.4
	Total Heat Load / DSC (kW)			50.01
13-2	**1**	1	0.5	0.5
	2	13	0.8	10.4
	3	8	1	8
	4	3	1.25	3.75
	5	2	1.5	3
	6	2	2	4
	7	2	2.2	4.4
	8	2	2.9	5.8
	8a	2	0.88	1.76
	9	2	4.2	8.4
	Total Heat Load / DSC (kW)			50.01

4.9.9.2 Transfer Evaluation of Intact Fuels in HLZCs 12 and 13

This section evaluates the thermal performance of the EOS-37PTH DSC with Basket Type 4HA loaded with intact FAs in the EOS-TC125/TC135 during transfer operations for normal, off-normal, and accident conditions, based on HLZCs 12 and 13.

4.9.9.2.1 Description of Load Cases

There are ten load cases (LCs) discussed in Table 4-23, out of which the bounding transfer cases are LC 1 for normal transfer in vertical orientation, LC 3 for off-normal transfer in horizontal orientation, and LC 5 for accident condition. These LCs are chosen to be re-evaluated for HLZCs 12 and 13.

To determine the thermal performance of the EOS-TC125 loaded with the EOS-37PTH DSC for HLZCs 12 and 13, the LCs listed in Table 4.9.9-1 are evaluated. The LCs listed in Table 4.9.9-1 are identical to the LCs listed in Table 4-23 except for the HLZC.

If the maximum temperatures from the above transient analyses and the accident evaluation are less than those previously approved for HLZC 1, the maximum temperatures for all other LCs (LCs 2, 6a, 6b and 7) evaluated for transfer operations of HLZC 1 in Table 4-23 will also remain bounded and no further evaluations are necessary for HLZCs 12 and 13.

4.9.9.2.2 Computational Fluid Dynamics Modeling

4.9.9.2.3 Results and Conclusions

This section evaluates the thermal performance of the EOS-TC125/135 loaded with the EOS-37PTH DSC for HLZCs 12 and 13 with intact FAs during normal, off-normal, and accident conditions.

4.9.9.2.3.1 Transfer Time Limits

Based on the discussion in Section 4.5.4, the time limit to complete normal/off-normal transfer operations of an EOS-37PTH DSC loaded per HLZC 1 is 10 hours. If transfer operations cannot be completed within the time limit, an additional duration of 5 hours is available to complete one of the recovery actions as described in Section 4.5.4.

For the EOS-37PTH DSC with HLZCs 12 and 13, the time limit for normal/off-normal transfer operations is reduced from 10 hours to 8 hours based on the comparisons of temperatures for HLZCs 12 and 13 to HLZC 1 as shown in Table 4.9.9-2 and Table 4.9.9-3. This is to ensure that the maximum fuel cladding temperatures for HLZCs 12 and 13 remain below the design basis temperature determined in Section 4.5.4 for HLZC 1. The duration available to complete the recovery actions if transfer operations cannot be completed within the time limit remains unchanged at 5 hours.

Therefore, the total duration for transfer operations is 13 hours (8 hour transfer time limit plus 5 hour recovery time) for EOS-37PTH DSC with HLZCs 12 and 13 compared to 15 hours for design basis evaluation with HLZC 1 in Section 4.5.4.

4.9.9.2.3.2 Components Temperatures

A. Normal/Off-Normal Transfer Conditions without Air Circulation

Table 4.9.9-2 and Table 4.9.9-3 present the maximum temperatures of the fuel cladding and the various components within the EOS-37PTH DSC and the EOS-TC125 for the bounding normal and off-normal conditions, respectively, at 13 hours for HLZCs 12 and 13. As shown in Table 4.9.9-2 and Table 4.9.9-3, the bounding maximum fuel cladding temperatures at 13 hours for normal and off-normal transfer conditions are 738 °F and 736 °F for HLZCs 12 and 13, respectively, remaining below the allowable temperature limit of 752 °F. Figure 4.9.9-1 and Figure 4.9.9-2 present the temperature profiles for the bounding HLZC 12 for normal and off-normal conditions at 13 hours.

The design basis evaluations for HLZC 1 are also included in Table 4.9.9-2 and Table 4.9.9-3 to provide a comparison with the design basis temperatures. As shown in Table 4.9.9-2 and Table 4.9.9-3, the maximum fuel cladding temperatures for normal and off-normal conditions remain bounded by the design basis evaluation for the EOS37PTH DSC with HLZC 1 in Section 4.5. Since the fuel cladding temperatures are lower compared to HLZC 1, the remaining time limits listed in Table 4-31 of Section 4.5 for insertion of DSC into the EOS-HSM or restarting of air circulation after its inactivation also remain applicable. The time limits for transfer operations of the EOS-37PTH DSC with HLZCs 12 and 13 are listed in Table 4.9.9-5.

In addition, as shown in Table 4.9.9-2, the maximum temperatures for all the other key components from HLZC 12-1 bound HLZCs 13-1 and 13-2. Therefore HLZC 12-1 and HLZC 12-2 are the bounding HLZCs for HLZC 12 and HLZC 13. For off-normal and accident transfer conditions, the thermal performance with HLZC 13 will be bounded by HLZC 12.

B. Accident Transfer Condition

The accident condition with loss in neutron shield and with loss of air circulation is performed using the bounding heat load configuration HLZC 12-1 and HLZC 12-2 identified from normal condition of transfer operation (LC 1). As shown in Table 4.9.9-4, the maximum fuel cladding temperature is 918 °F and is 17 °F below design basis value of 935 °F for HLZC 1 in Section 4.5 for the EOS-37PTH DSC. In addition, the maximum component temperatures are all below the allowable limits. Therefore, there is no impact on the fuel cladding integrity. Figure 4.9.9-3 presents the temperature profiles for the bounding HLZC 12 during accident conditions.

4.9.9.2.3.3 Internal Pressure

The internal pressure calculation follows the same methodology and computation as in Section 4.7. As shown in Table 4.9.9-6, the average helium temperatures for bounding normal, off-normal, and accident storage conditions remain below the design basis values listed in Table 4-45 of Section 4.7. Therefore, the maximum internal pressures calculated in Table 4-45 remain bounding for normal, off normal, and accident transfer conditions.

Based on the above discussion, all the temperature criteria along with the internal pressure criteria are satisfied for transfer of the EOS-37PTH DSC with Basket Type 4HA in an EOS-TC125/TC135 with intact FAs for HLZC 12 or 13.

4.9.9.3 Storage Evaluation of Intact Fuels in HLZCs 12 and 13

This section evaluates the thermal performance of the EOS-HSM loaded with the EOS-37PTH DSC for HLZCs 12 and 13 with intact FAs during normal, off-normal, and accident conditions.

4.9.9.3.1 Description of Load Cases

To identify the bounding LC for this evaluation, a review of the thermal evaluations presented in Section 4.4, Section 4.9.4, and Section 4.9.5 for normal, off normal, and accident conditions was performed. This review identified that the normal storage condition evaluation for HLZC 1 (50 kW) [ ] and wind deflector in Section 4.9.5 (See LC 1 in Table 4.9.5-1 and Table 4.9.5-2) resulted in a maximum fuel cladding temperature of 716 °F and has the lowest margin to the maximum fuel cladding temperature limit of 752 °F. Therefore, this LC is selected as the bounding LC to evaluate the thermal performance of the EOS-37PTH DSC with HLZCs 12 and 13 during storage operations in the EOS-HSM.

According to the results shown in Table 4.9.9-2, HLZC 12 bounds HLZC 13 in transfer evaluation and is used to evaluate the thermal performance of EOS-HSM loaded with the EOS-37PTH DSC.

To determine the thermal performance of the EOS-HSM loaded with the EOS-37PTH DSC, the LCs listed in Table 4.9.9-7 are evaluated.

- LC 1 evaluates the thermal performance of EOS-37PTH DSC in EOS-HSM with HLZC 12-1 as discussed in Section 4.9.9.1, up to the maximum allowable heat loads of 50 kW during storage operations.
- LC 2 evaluates the thermal performance of EOS-37PTH DSC in EOS-HSM with HLZC 12-2 as discussed in Section 4.9.9.1, up to the maximum allowable heat loads of 50 kW during storage operations.

Ambient temperatures for the EOS-37PTH DSC with HLZCs 12 and 13 are identical to those in Section 4.3.

In addition to the ambient temperature, normal thermal evaluation for EOS-HSM considers impact of wind on the maximum fuel cladding temperature. Based on the evaluations presented in Section 4.9.4, wind deflectors are implemented on top of the EOS-HSM and next to the outlet as shown in Figure 4.9.4-7.

4.9.9.3.2 Computational Fluid Dynamics Modeling

To evaluate the thermal performance of the EOS-37PTH DSC with HLZC 12, the base mesh thermal model for the bounding side wind evaluation from Section 4.9.5.2 for LC 1 is modified. The modifications to simulate the LCs are limited to changes in heat generation rates based on the HLZC 12 and homogenized fuel assembly properties are updated based on the WE 17x17 FAs [ ] as discussed in Section 4.9.9.2.2. No changes are considered to the mesh.

Convergence Criteria

The convergence criteria described in Section 4.9.5.2.3.2.B is also applicable to this evaluation.

4.9.9.3.3 Results and Conclusions

4.9.9.3.3.1 Component Temperatures

Table 4.9.9-8 presents the maximum temperatures for the EOS-37PTH DSC with the bounding HLZC 12 during storage operations with LC 1 and LC 2, and compares them with the design basis temperatures from LC 1 from Table 4.9.5-2, respectively. Figure 4.9.9-4 and Figure 4.9.9-5 present the temperature profiles for LCs 1 and 2, respectively.

As shown in Table 4.9.9-8, the maximum fuel cladding temperature for LC 1 and LC 2 are either lower by 7 °F or the same when compared to LC 1 from Table 4.9.5-2. Including the [ ] described in Section 4.9.7.2.1.3, the fuel cladding temperature remains below the allowable temperature limit of 752 °F and is bounded by the design basis load case (LC 1) from Section 4.9.5.

As shown in Table 4.9.9-8, the maximum concrete temperatures for both LCs are lower as compared to their design basis temperatures (LC 1 from Table 4.9.5-2) previously evaluated for the EOS-HSM. Therefore, there is no impact on the concrete temperatures.

As the key component temperatures for EOS-37PTH DSC with HLZC 12 during storage operations in EOS-HSM during normal conditions are lower compared to previous evaluations from Section 4.9.5 with HLZC 1, the off-normal and accident conditions evaluated in Section 4.9.5 with HLZC 1 will remain bounding. Therefore, no evaluation is needed for off-normal and accident storage conditions with HLZCs 12 and 13.

4.9.9.3.3.2 Internal Pressure

The internal pressure calculation follows the same methodology and computation as in Section 4.7. As shown in Table 4.9.9-9, the average helium gas temperature within the DSC cavity of 529 K remains below the design basis value of 565 K listed in Table 4-45 of Section 4.7. Therefore, the maximum internal pressures in Table 4-45 remain bounding for HLZCs 12 and 13 under normal, off-normal, and accident storage.

Based on this discussion, no further evaluations of internal pressure are required for the EOS-HSM loaded with the EOS-37PTH DSC with HLZCs 12 and 13.

Based on this discussion, all the temperature criteria are satisfied for HLZCs 12 and 13 with intact FAs in the EOS-37PTH DSC with Basket Type 4HA in the EOS-HSM for normal, off-normal, and accident storage conditions.

4.9.9.4 Evaluation of Damaged and Failed FAs in HLZCs 12 and 13

HLZCs 12 and 13 can accommodate a combination of intact FAs along with damaged FAs, or intact FAs along with failed FAs. HLZCs 12 and 13 can be loaded with up to six damaged FAs or up to two failed FAs, but not both, as noted in Figure 2-3l and Figure 2-3m, respectively. This section presents the thermal evaluation of the EOS-37PTH DSC with Basket Type 4HA for HLZCs 12 and 13 with damaged FAs along with intact FAs or failed FAs along with intact FAs during storage and transfer conditions.

4.9.9.4.1 Damaged FAs

The damaged FAs considered for storage in the EOS-37PTH DSC ensure that the fuel pellet cannot pass through the cladding opening during normal and off-normal conditions. Additionally, the damaged FAs maintain their structural integrity during normal and off-normal conditions of storage and onsite transfer as noted in Chapter 3, Section 3.9.6.7. This ensures that there is no reconfiguration of the heat generating regions during normal/off-normal conditions. Additionally, the effective thermal conductivity of the FAs determined in Section 4.9.1.4 depends on the physical configuration of the fuel assembly. Since the damaged FAs maintain the overall physical configuration similar to that of the intact FAs during normal and off-normal conditions, the minimum effective thermal conductivity values determined in Section 4.9.1.4 remain valid for the damaged FAs during normal and off-normal conditions. Therefore, the thermal evaluations presented in Sections 4.9.9.2.3 and 4.9.9.3.3 are acceptable for the normal and off-normal transfer and storage conditions, respectively, wherein up to six damaged FAs are stored in the EOS-37PTH DSC.

During the accident condition, the thermal evaluations presented in Sections 4.9.9.2.3 and 4.9.9.3.3 remain applicable to the damaged FAs if they maintain their physical configuration during the postulated drop accident. However, the cladding of high burnup damaged FAs can experience further damages during postulated drop accidents. In the event that they experience further damage, the worst possible scenario is the damaged FAs turning into rubble at the bottom of the DSC. There are no credible accident scenarios that would alter the physical configuration of the damaged FAs during storage operations.

Similar to HLZC 10, HLZCs 12 and 13 allow for intact, damaged or failed fuels in the same locations in the EOS-37PTH DSC. The thermal evaluations for intact and damaged fuels in HLZC 10 are documented in Section 4.9.7.2 and 4.9.7.3, respectively. A comparison in Table 4.9.7-5 and Table 4.9.7-7 shows that when HLZC 10 allows for six damaged fuels, the maximum fuel cladding temperature for the accident transfer load case (LC 5) only increases 7 °F. The same increase is expected for HLZC 12 and HLZC 13 when loaded with six damaged fuels. Table 4.9.9-4 shows that the maximum fuel cladding temperature for the bounding HLZC 12 with intact fuels is 17 °F below the design basis accident transfer condition LC 5 in Table 4-29. Therefore, with the 7 °F increase, the maximum fuel cladding temperature for the bounding HLZC 12 with six damaged fuels will remain below the design basis accident transfer condition. The thermal evaluation for the accident transfer case presented in Section 4.9.9.2.3 remains applicable to the EOS-37PTH DSC loaded with HLZCs 12 and 13.

Since the temperature criteria along with the internal pressure criteria are satisfied, no further evaluations are required to load damaged FAs in the EOS-37PTH DSC with HLZCs 12 and 13.

4.9.9.4.2 Failed FAs

Heat load zone configurations 12 and 13 can accommodate a combination of intact FAs along with failed FAs. It can be loaded with up to a two failed FAs as per Figure 2-3l and Figure 2-3m, which is similar to HLZCs 10 and 11 as describes in Appendix 4.9.7. The thermal performance evaluated in Appendix 4.9.7 of the EOS-37PTH DSC with Basket Type 4H with HLZCs 10 and 11 loaded with intact and failed FAs during storage and transfer is also applicable to the evaluation with HLZCs 12 and 13.

Similar to HLZC 10, HLZCs 12 and 13 allow for intact, damaged or failed fuels in the same locations in the EOS-37PTH DSC. The thermal evaluations for intact and failed fuels in HLZC 10 are documented in Sections 4.9.7.2 and 4.9.7.4, respectively. The comparison in Table 4.9.7-8 shows that when HLZC 10 allows for two failed fuels, the maximum fuel cladding temperature for the normal transfer load case decreases by 9 °F. The same decrease is expected for HLZCs 12 and 13 when loaded with two failed fuels. Therefore, the thermal evaluation of EOS-37PTH DSC transferring in EOS-TC125 with HLZCs 12 and 13 with intact FAs bounds the evaluation with two failed FAs.

Review of thermal evaluations presented in Section 4.9.9.3.3 for storage and in Section 4.9.9.2.3 for transfer normal, off-normal, and accident conditions for HLZCs 12 and 13 identifies that transfer operation bounds the storage operation similar to HLZC 10. Since the thermal evaluation of EOS-37PTH DSC transferring in EOS-TC125 with HLZCs 12 and 13 with intact FAs bound the evaluation with failed FAs. Similarly, for storage condition the thermal evaluation with intact FAs in Section 4.9.9.2.3 will bound the evaluation with two failed FAs for HLZCs 12 and 13.

Based on this discussion, all the temperature criteria along with the internal pressure criteria are satisfied for storage of the EOS-37PTH DSC with HLZCs 10 or 11 with intact FAs and failed FAs.

4.9.9.5 Evaluation of Full Model with Whole EOS-37PTH DSC

Asymmetric HLZCs are permitted in the EOS-37PTH DSC about the X axis (90° to 270° in Figure 1-2) and Y axis (0° to 180° in Figure 1-2). Full models that include the whole EOS-37PTH DSC basket for storage in EOS-HSM and transfer in EOS-TC125 are evaluated in this section for use in evaluating asymmetric heat load patterns. Maximum and average temperatures of fuel cladding, EOS-HSM, EOS-TC125 and EOS-37PTH DSC components are compared between the full model and the symmetrical basis models used in Section 4.9.5.2 for storage and Section 4.5.2 for transfer.

4.9.9.5.1 Storage Evaluation in EOS-HSM

[

]

4.9.9.5.2 Transfer Evaluation in EOS-TC125

[

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All Indicated Changes are Scope Item 1.

4.9.9.6 References

4.9.9-1 J.M. Cuta, U.P. Jenquin, and M.A. McKinnon, "Evaluation of Effect of Fuel Assembly Loading Patterns on Thermal and Shielding Performance of a Spent Fuel Storage/Transportation Cask," PNNL-13583, Pacific Northwest National Laboratory, November 2001.

Table 4.9.9-1
Design Load Cases for EOS-TC125/TC135 Loaded with EOS-37PTH DSC

Load Case	HLZC	Operation Condition	EOS-TC125 Orientation	Description	Ambient Temperature (°F)	Solar Insolation	Notes
1	12	Normal	Vertical	Normal, hot, indoor, Transient, No air circulation	120	No	(1), (2)
	13						
3	12	Off-Normal	Horizontal	Off-normal, hot, outdoor, Transient, No air circulation	117	Yes	(1), (2)
	13						
5	12	Accident	Horizontal	Accident, hot, outdoor, loss of liquid in neutron shield, Steady state, No air circulation	117	Yes	(1)
	13						

Notes:

(1) Daily average temperatures as noted in Section 4.3 are used for normal and off-normal transfer conditions outside the fuel building. No averaging is used for the temperature inside the fuel building and the maximum temperature of 120 °F is used in the thermal evaluation.

(2) Initial steady-state conditions are calculated assuming water in the TC/DSC annulus is at 223 °F and an ambient temperature of 120 °F.

Table 4.9.9-2
Maximum Temperatures of EOS-TC125 Loaded with EOS-37PTH DSC with HLZCs 12 and 13 for the Bounding Normal Conditions

	Normal, Hot, Indoor, Vertical, No Air Circulation (LC 1)					
HLZC	**HLZC 1 Design Basis (Table 4-29)**	**HLZC 12-1**	**HLZC 12-2**	**HLZC 13-1**	**HLZC 13-2**	**Temperature Limit (°F)**
Component Name	**Temperature (°F)**					
Fuel Cladding	742 (2)	733	738	735	733	752
Basket Plates	680	653	636	630	630	
DSC Shell	484	504	473	479	487	-
Transition Rail	553	583	544	552	557	
Inner Shell	316	328	310	312	320	-
Gamma Shield	315	326	308	310	318	620
Structural Shell	228	233	224	225	229	-
Neutron Shield (1) Avg.	212	209	209	209	209	259
Neutron Shield Outer Skin	222	227	218	219	223	-
Solid Neutron Shield Avg.	223	221	221	221	221	262
Closure Lid	179	180	178	178	179	-
Top Ring	200	202	197	198	200	-
Bottom Ring	220	220	220	220	220	-

Notes:

(1) Bulk average temperature of water in the neutron shield is limited by the 20 psig pressure relief valves on the shield. The equivalent steam saturation temperature at this pressure is approximately 259 °F.

(2) Maximum fuel cladding temperature is reported at 15 hours based on the discussion in Section 4.5.4.

Table 4.9.9-3
Maximum Temperatures of EOS-TC125 Loaded with EOS-37PTH DSC with HLZCs 12 and 13 for the Bounding Off-normal Conditions

	Off-normal, Hot, Outdoor, Horizontal, No Air Circulation (LC 3)			
HLZC	**HLZC 1 Design Basis (Table 4-29)**	**HLZC 12-1**	**HLZC 12-2**	**Temperature Limit (°F)**
Component Name	**Temperature (°F)**			
Fuel Cladding	740 (2)	736	729	752
Basket Plates	670	652	628	
DSC Shell	483	509	475	-
Transition Rail	552	586	542	
Inner Shell	347	322	342	-
Gamma Shield	344	320	338	620
Structural Shell	236	230	232	-
Neutron Shield (1) Avg.	203	201	200	259
Neutron Shield Outer Skin	224	219	221	-
Solid Neutron Shield Avg.	172	165	164	262
Closure Lid	185	180	183	-
Top Ring	217	207	214	-
Bottom Ring	194	188	192	-

Notes:

(1) Bulk average temperature of water in the neutron shield is limited by the 20 psig pressure relief valves on the shield. The equivalent steam saturation temperature at this pressure is approximately 259 °F.

(2) Maximum fuel cladding temperature is reported at 15 hours based on the discussion in Section 4.5.4.

Table 4.9.9-4
Maximum Temperatures of EOS-TC125 with EOS-37PTH DSC at 50 kW, Accident Loss of Neutron Shield with Loss of Air Circulation Accident Condition

	Accident, Hot, Outdoor, Loss of Liquid in Neutron Shield, No Air Circulation (LC 5)			
HLZC	**HLZC 1 Design Basis (Table 4-29)**	**HLZC 12-1**	**HLZC 12-2**	**Temperature Limit (°F)**
Component Name	**Temperature (°F)**			
Fuel Cladding	935	918	904	1058
Basket Plates	902	887	873	
DSC Shell	674	707	674	-
Transition Rail	750	792	750	
Inner Shell	583	581	585	-
Gamma Shield	579	578	581	620
Structural Shell	478	484	479	-
Neutron Shield Avg.	296	303	296	N/A (1)
Neutron Shield Outer Skin	257	241	240	-
Solid Neutron Shield Avg.	255	251	255	N/A (1)
Closure Lid	316	307	316	-
Top Ring	304	296	304	-
Bottom Ring	935	918	904	-

Notes:

(1) For accident conditions, it is assumed that all neutron shielding materials including the bottom neutron shield are lost as discussed in Section 6.3.2. Therefore, the temperature limit of 262 °F is not applicable to the neutron shield for the accident case (LC 5).

Table 4.9.9-5
Time Limit for Transfer Operations for HLZCs 12 and 13

Operating Conditions (2)	**Heat Load Zoning Configuration**	**Heat Load (kW)**	**Time Limit (hrs)**
Normal/ Off-normal Transfer	HLZC 12 or 13 (LC 1)	50	8
	HLZC 12 or 13 (LC 2, 3, and 4)	50	8
	HLZC 12 or 13 (LC 6b)	50	No Time Limit (1)
Insertion of EOS-37PTH DSC into the EOS-HSM or restart of air circulation after its inactivation	HLZC 12 or 13 (LC 7)	50	4
Loss of Neutron Shield with Loss of Air Circulation, Accident Condition	HLZC 12 or 13 (LC 5)	50	No Time Limit

Notes

(1) If air circulation is initiated as a recovery option, it must be maintained for a minimum duration of 8 hours per LC 6a, before it is turned off as explained in Section 4.5.4.

(2) Description of design LCs is listed in Table 4-23.

Table 4.9.9-6
Average Temperatures of Helium Gas in EOS-37PTH DSC Cavity in Transfer Conditions with Bounding HLZCs 12 and 13

Load Cases (1)	**Condition**	**Average Temperature of Helium Gas in DSC Cavity (K)**		**Temperature Difference (K)**
		Bounding Design Basis [See Table 4-45]	**HLZC 12 in EOS-TC125**	
1	Normal	565	542	-23
3	Off-Normal	565	536	-29
5	Accident	653	645	-8

Notes:

(1) Description of design LCs is listed in Table 4.9.9-1.

Table 4.9.9-7
Design Load Cases for EOS-HSM Loaded with EOS-37PTH DSC Basket Assembly Type 4HA with HLZC 12

Load Case	**Description**	**Ambient Temperature (°F) (1)**	**Insolation**	**HLZC**
1	[ ]	70	Yes	12-1
2	[ ]	70	Yes	12-2

Notes:

(1) See Section 4.9.9.3.1 for discussion on ambient temperatures and wind deflectors.

Table 4.9.9-8
Maximum Component Temperatures of the EOS-HSM loaded with EOS-37PTH DSC (HLZC 12)

	Maximum Temperatures (°F)		
	Fuel Cladding	**Concrete**	**DSC Shell**
Design Basis LC 1 (1) (HLZC 1, 50.0 kW)	716	234	414
LC 1 (HLZC 12-1, 50 kW)	709	227	428
LC 2 (HLZC 12-2, 50 kW)	716	232	412
$\Delta T = T_{LC\ 1} - T_{LC\ 1\ (design\ basis)}$	-7	-7	14
$\Delta T = T_{LC\ 2} - T_{LC\ 1\ (design\ basis)}$	0	-2	-2

Notes:

(1) Maximum temperatures are from Table 4.9.5-2 for LC 1.

Table 4.9.9-9
Average Temperatures of Helium Gas in EOS-37PTH DSC Cavity

LC (1)	**Average Temperature of Helium in DSC (K)**		**Temperature Difference (K)**
	Bounding Design Basis [See Table 4-45]	**HLZC 12 in EOS-HSM**	
1	565	527	-38
2		529	-36

Notes:

(1) Description of design LCs is listed in Table 4.9.9-7.

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6. SHIELDING EVALUATION

Item 2

The EOS system is designed to store intact, damaged, or failed pressurized water reactor (PWR) and intact boiling water reactor (BWR) fuel assemblies (FAs) within the EOS-37PTH dry shielded canister (DSC) and EOS-89BTH DSC, respectively. Failed PWR fuel shall be stored in a failed fuel canister (FFC). The transfer casks (TCs) EOS-TC108 and EOS-TC125/135 are used to transfer the EOS-DSC to the EOS horizontal storage module (EOS-HSM). *Within this chapter, the term EOS-HSM refers to the reinforced concrete EOS-HSM (EOS-HSM-RC), which includes the EOS-HSM-RC, EOS-HSMS-RC, EOS-HSM-FPS-RC, and EOS-HSMS-FPS-RC.* Normal and off-normal condition, near-field dose rates are presented in this chapter for the EOS-TC and EOS-HSM. Detailed three-dimensional dose rate calculations are performed to determine the dose rate fields around the EOS-TCs during loading, decontamination, welding, drying, and transfer operations. Detailed three-dimensional dose rate calculations are also performed to determine the dose rate fields around an EOS-HSM. These near-field dose rates are used as input to the dose assessment documented in Chapter 11, Radiation Protection.

The methodology, source terms, and dose rates presented in this chapter are developed to be reasonably bounding for general licensee implementation of the EOS System. Justification of the reasonably bounding source term methodology is provided in Section 6.2.8. These results may be used in lieu of near-field calculations by the general licensee, although the inputs utilized in this chapter should be evaluated for applicability by each site. Site-specific EOS-TC and EOS-HSM near-field calculations may be performed by the general licensee to modify key input parameters.

Compliance with 10 CFR 72.106 is demonstrated in this chapter for a loss of neutron shield accident for a single EOS-TC. Further, site dose calculations for an array of EOS-HSMs under normal, off-normal, and accident conditions are documented in Chapter 11, based on the near-field EOS-HSM results presented in this chapter. Because the number and arrangement of EOS-HSMs and the distance to the site boundary is site-specific, compliance with 10 CFR 72.104 and 10 CFR 72.106 for an array of EOS-HSMs can only be demonstrated using a site-specific calculation. Inputs for the site dose calculations developed in the current chapter may be directly used as input to a site-specific dose calculation by the general licensee.

The shielding evaluation for the NUHOMS® MATRIX *(HSM-MX)* is documented in Appendix A.6*, although HSM-MX source terms are developed in Chapter 6.*

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The shielding evaluation for the 61BTH DSC is documented in Appendix B.6.

6.1 Discussions and Results

The following is a summary of the methodology and results of the shielding analysis of the EOS system. More detailed information is presented in the body of the chapter.

The EOS-37PTH DSC stores up to 37 PWR FAs, while the EOS-89BTH stores up to 89 BWR FAs. Each EOS-DSC is configured into heat load zones in order to optimize the system performance for both thermal and shielding considerations. *Thirteen* heat load *zone* configurations (HLZCs) are available for the EOS-37PTH DSC, and *six* HLZCs are available for the EOS-89BTH DSC. The HLZCs are defined in *either* the Technical Specifications (TS) [6-11] *or Chapter 2*. Fuel to be stored is limited by the decay heat and minimum cooling times defined in the Technical Specifications.

The EOS-37PTH DSC is authorized to store up to eight damaged FAs or four FFCs using HLZC 6*, 8, 12, or 13*. The EOS-37PTH DSC is also authorized to store up to six damaged FAs or two FFCs using HLZC 10 or 11. Damaged and failed fuel shall not be present in the same DSC.

Source Terms

The ORIGEN-ARP module of the Oak Ridge National Laboratory (ORNL) SCALE6.0 code package [6-1] is used to develop reasonably bounding gamma and neutron source terms. **[**

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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. The CC source term used in the analysis is provided in Table 6-37. Co-60 equivalent activity limits per zone are provided in TS Table 3 [6-11].

BWR fuel does not include CCs other than the fuel channel, which is conservatively included in the source term. The BWR fuel channel is fabricated from zirconium alloy and does not require a Co-60 limit because the contribution to the source term from the fuel channel is negligible.

Item 1

Item 5

Dose Rates

The Monte Carlo transport code, MCNP5 [6-5], is used to compute dose fields around the EOS-TCs and EOS-HSM using detailed three-dimensional models for the following normal configurations:

- EOS-37PTH DSC inside the EOS-TC108
- EOS-37PTH DSC inside the EOS-TC125/135 *(maximum lead thickness design)*
- EOS-37PTH DSC inside the EOS-HSM-Short
- EOS-89BTH DSC inside the EOS-TC108
- EOS-89BTH DSC inside the EOS-TC125 *(minimum lead thickness design)*
- EOS-89BTH DSC inside the EOS-HSM-Medium

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All EOS-HSM dose rates presented in this chapter are for the reinforced concrete design, EOS-HSM-RC. The steel-clad EOS-HSM-SC design results in significantly lower dose rates than the EOS-HSM design based on a sensitivity study using EOS-89BTH DSC sources (approximately 50% lower dose rates on the front and approximately 75% lower dose rates on the roof). In this sensitivity study, the corrosion allowance of 1/8 inch utilized in the Chapter 3 structural evaluation is not applied because any corrosion would occur only after the source term has decayed significantly.

The computed EOS-HSM dose rates are used to establish TS dose rate limits and support compliance with 72.104 and 72.106 requirements. EOS-TC accident dose rates are used to support compliance with 72.106 requirements. However, normal condition EOS-TC dose rates are used as input to an exposure evaluation but are not used to support compliance with either 72.104 or 72.106 requirements. Therefore, the conservative EOS-TC source terms provided in this chapter may be used directly to compute normal condition EOS-TC dose rates when evaluating modifications to the EOS-TC design.

The EOS-TC125 and EOS-TC135 provide equivalent shielding but accommodate different DSC lengths. The EOS-TC135 is used only with the EOS-37PTH DSC. The EOS-TC125 and EOS-TC135 designs are bounded by the same Monte Carlo N-particle (MCNP) model and are referred to in this chapter as EOS-TC125/135. The EOS-TC108 offers less shielding than the EOS-TC125/135 and features a removable neutron shield. The neutron shield is removed for fuel loading and attached subsequent to fuel loading. The neutron shield for the EOS-TC125/135 is integral to the cask and cannot be removed.

The EOS-37PTH and EOS-89BTH DSCs are custom-built for the fuel to be stored and, therefore, do not have a standard length. BWR fuel is typically longer than PWR fuel, so the EOS-89BTH DSC is longer than the EOS-37PTH DSC in the MCNP models. To accommodate the various DSC lengths, three versions of the EOS-HSM are available: short, medium, and long. In the EOS-HSM models, the EOS-37PTH DSC is paired with the EOS-HSM-Short, while the EOS-89BTH DSC is paired with the EOS-HSM-Medium, as these are the smallest EOS-HSMs that can accommodate the modeled EOS-DSCs.

All EOS-37PTH DSC calculations conservatively include both the FA and CC sources. BWR fuel does not include CC, other than the fuel channel, which is conservatively included in the source term.

Based on the near-field dose rates calculated for the EOS-TCs, a dose assessment is performed for the EOS-TC loading operation. This dose assessment is documented in Chapter 11.

The shielding effectiveness of the EOS-TC and EOS-HSM is not impacted by any off-normal events. Two accident events have been identified:

- Loss of neutron shielding for the EOS-TCs
- Loss of EOS-HSM outlet vent covers due to a tornado or missile event

Separate source terms are developed in this chapter for both transfer and storage operations. As these source terms were developed over multiple Amendments, key input parameters or methodologies may be different for the different source terms presented. A high-level summary of the key input parameters and methodologies used to develop the various source terms are summarized in Table 6-1. The information summarized in Table 6-1 is explained in detail in this chapter.

6.2.1 Computer Programs

Source terms are generated using the ORIGEN-ARP module of SCALE6.0. 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 are developed in TRITON using the FA design data in Chapter 2. The ENDF/B-VII 238-group cross section library (v7-238) is utilized in the TRITON input files. TRITON is used to generate ORIGEN-ARP data libraries as a function of burnup and enrichment. These libraries are used by ORIGEN-ARP to compute the source terms. *For the EOS-89BTH DSC source terms developed for the EOS-TC125 and EOS-HSM analyses, the default GE 7x7 ORIGEN-ARP library provided with SCALE 6.0 is used.*

ORIGEN-ARP uses interpolated cross section libraries to generate source terms that are essentially equivalent to the detailed TRITON runs. TRITON has been benchmarked against experimentally measured isotopes and results in excellent agreement with the measured data in ORNL/TM-2010 SCALE 5.1 [6-2]. As part of the code validation, the TRITON benchmark cases from SCALE 5.1 are rerun using the ENDF/B-VII 238-group cross section library. The isotopes important for shielding for which benchmark data are available include Cs-137/Ba-137m, Cs-134, Eu-154, Ce-144/Pr-144, Ru-106/Rh-106, Sr-90/Y-90, and Cm-244. The average ratio of the measured to calculated concentration for these nuclides is close to unity, indicating that TRITON/ORIGEN-ARP is an acceptable program for source term generation.

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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

6.2.2.1 Bounding HLZCs

The EOS-DSC baskets are zoned by heat load. Heat load zoning allows hotter FAs, which generally have larger neutron and gamma source terms, to be placed in the inner zones and be shielded by FAs in the outer zone. The EOS-TC108 and EOS-TC125/135 have different heat load zone configurations because the EOS-TC125/135 is more heavily shielded than the EOS-TC108 and can therefore be loaded with stronger sources.

Thirteen HLZCs are available for the EOS-37PTH DSC and *six* HLZCs are available for the EOS-89BTH DSC. *The EOS-37PTH DSC and EOS-89BTH DSC also have maximum heat load configurations (MHLC) that bound the HLZCs. The MHLCs are provided in the TS [6-11], although the individual HLZCs may be provided in either the TS or Chapter 2. When source terms are developed based on an MHLC rather than individual HLZCs, all HLZCs bounded by the MHLC are also bounded by the shielding analysis. Systems for which the MHLC concept has been employed in source term development are summarized in Table 6-1.*

All PWR HLZCs may be transferred in the EOS-TC125/135, while the EOS-TC108 is limited to HLZCs 2 through 9. All BWR HLZCs may be transferred in the EOS-TC125/135, while the EOS-TC108 is limited to BWR HLZC 2 and 3. The EOS-HSM may store PWR HLZCs 1 through 6, 10, 11*, 12, 13* and all BWR HLZCs.

The bounding HLZCs are used for dose rate analysis. For each zone within a DSC, higher heat loads result in stronger source terms and larger dose rates if the minimum cooling time is the same.

EOS-89BTH DSC

The bounding HLZCs used in the EOS-89BTH DSC analyses are:

- *EOS-89BTH DSC transferred in the EOS-TC125 and stored in the EOS-HSM: “Shielding HLZC” that bounds HLZC 1 through 6, as described below.*
- *EOS-89BTH DSC transferred in the EOS-TC108: HLZC 2*

Rather than justify which HLZC is bounding, an EOS-89BTH DSC "shielding HLZC" is developed to bound HLZC 1 through 6 when transferred in the EOS-TC125 and stored in the EOS-HSM. Each basket location in the shielding HLZC bounds the corresponding heat load at that location allowed in HLZC 1 through 6. The shielding HLZC is provided in Figure 6-18 and is identical to the MHLC, Figure 11 of the TS [6-11]. The shielding HLZC is highly conservative for dose rate analysis, as the shielding HLZC features 42.8 kW on the periphery and 82.8 kW within the entire DSC. The peripheral fuel assemblies are defined in TS Figure 8 [6-11]. The minimum cooling time associated with the shielding HLZC is 1.0 year.

Only the EOS-89BTH DSC HLZC 2 and 3 may be transferred in the EOS-TC108. The minimum cooling time of 3 years is applicable to zones 1 and 2. HLZC 2 has larger heat loads in each zone compared to HLZC 3. When HLZC 2 or 3 is used with the EOS-TC108, the minimum cooling time in zone 3 is 9.7 years and 9.0 years, respectively. While the EOS-89BTH DSC HLZC 2 zone 3 has a slightly longer minimum cooling time than HLZC 3 zone 3, the minimum cooling time difference (0.7 years) is small compared to the large difference in decay heat (0.1 kW/FA). Therefore, EOS-89BTH DSC HLZC 2 is bounding for EOS-TC108 analysis.

<u>EOS-37PTH DSC</u>

The HLZCs used in the EOS-37PTH DSC analyses are:

- *EOS-37PTH DSC transferred in the EOS-TC125/135 and stored in the EOS-HSM: HLZCs 4 and 10*
- *EOS-37PTH DSC transferred in the EOS-TC125/135 and stored in the EOS-HSM: "Shielding HLZC" that bounds the MHLC, as described below.*
- *EOS-37PTH DSC transferred in the EOS-TC108: HLZCs 4 and 5*

Rather than justify which HLZC is bounding, an EOS-37PTH DSC "shielding HLZC" is developed when transferred in the EOS-TC125/135 and stored in the EOS-HSM. The shielding HLZC is provided in Figure 6-19 and bounds the MHLC, Figure 12 of the TS [6-11]. Therefore, the shielding HLZC also bounds HLZC 1 through 13.

In the shielding HLZC, the hottest fuel is distributed evenly around the periphery to ensure EOS-HSM inlet and outlet vent dose rates are maximized. The heat load of the bounding fuel assembly is also increased to 5.0 kW/FA rather than the MHLC maximum of 4.3 kW/FA. The shielding HLZC is highly conservative for dose rate analysis, as the shielding HLZC features 63.6 kW on the periphery and 98.3 kW within the entire DSC. The peripheral fuel assembly locations are defined in TS Figure 3 [6-11]. The minimum cooling time associated with the shielding HLZC is 1.0 year.

The PWR MHLC has not been incorporated into the HSM-MX source term development methodology. Therefore, HSM-MX HLZC 10 source terms are maintained to support the HSM-MX dose rate analysis provided in Chapter A.6. HLZC 10 features eight 3.5 kW FAs in the peripheral region. HLZC 10 is bounding for the *HSM-MX* because vent dose rates are dominated by gamma radiation emitted from the peripheral region. *In addition, EOS-TC125/135 source terms for HLZC 4 and 10 are maintained to support the damaged/failed fuel reconfiguration analysis, which has not been updated using shielding HLZC source terms. HLZC 4 and 10 source terms are developed based on a minimum cooling time of 2 years.*

Only HLZC 2 through 9 may be transferred in the EOS-TC108, and both HLZC 4 and 5 are analyzed for the EOS-TC108 and bound the remaining HLZCs. HLZC 5 features eight 2.4 kW fuel assemblies.

Note that up to eight damaged PWR fuel assemblies or up to four FFCs are authorized for HLZC 6 and HLZC 8. Source terms are also developed for a damaged/failed fuel HLZC that bounds both HLZC 6 and 8. These source terms are derived for 1.0 kW/FA in Zone 1, 1.5 kW/FA in Zone 2, 1.5 kW/FA for intact fuel in Zone 3, and 0.85 kW/FA for failed fuel in Zone 3. The EOS-37PTH DSC is also authorized for storage of up to six damaged FAs or two FFCs using HLZC 10 or 11. For failed fuel analysis using HLZC 10, the same 0.85 kW/FA source terms used in the HLZC 6/8 analysis are utilized. The ORIGEN-ARP methodology for developing damaged/failed fuel source terms is the same as used for developing intact fuel source terms. Reconfiguration of damaged/failed fuel source terms is addressed in Section 6.3.2. *While damaged and failed fuel are also authorized in HLZC 12 and 13, the analysis in Section 6.3.2 is not updated with shielding HLZC source terms because it is demonstrated in Section 6.3.2 that damaged/failed fuel reconfiguration has a negligible effect on dose rates.*

6.2.2.2 Source Term Generation for Limited Burnup, Enrichment, and Cooling Time Combinations (Method 1)

Using only a limited number of burnup, enrichment, and cooling time (BECT) combinations in source term development is referred to as "Method 1." A limited number of BECT combinations (typically 3 to 5) are used to select bounding BECT combinations for each zone.

Source term generation outlined in this section is applicable to source terms generated for the EOS-37PTH DSC and the EOS-89BTH DSC transferred within the EOS-TC108. EOS-37PTH DSC source terms are also generated for HLZC 10 for HSM-MX analysis, and various EOS-37PTH DSC source terms are generated to support the damaged/failed fuel reconfiguration analysis.

Source terms for the EOS-89BTH DSC transferred within the EOS-TC125 and stored in the EOS-HSM using "Method 2" are developed in Section 6.2.2.3. Source terms for the EOS-37PTH DSC transferred within the EOS-TC125/135 and stored in the EOS-HSM using "Method 2" are developed in Section 6.2.2.4.

Because the FAs are zoned by heat load, it is necessary to develop source terms for each zone. Candidate sources are developed for high burnup (62 GWd/MTU), medium burnup (50 GWd/MTU) and lower burnup (40 GWd/MTU) fuel. Cooling time is selected so that the decay heat meets or exceeds the heat load limit for each zone. Because the cooling time required at these burnups is generally much larger than the minimum allowed cooling time for each zone, the burnup that results in a cooling time that matches the minimum cooling time for each zone is also determined. From these four candidate burnup/cooling time combinations, a bounding source for each zone is selected.

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In these tables, the "raw" neutron source computed by ORIGEN-ARP is provided, as well as neutron sources that include neutron peaking factors and subcritical neutron multiplication. These factors are derived in Section 6.2.3. 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. For example, for the 62 GWd/MTU, 10.25 year cooled PWR source, 95% of the neutron source is due to spontaneous fission of Cm-244. Cm-244 is also the dominant neutron source for shorter cooling times. For instance, for a 36.178 GWd/MTU, three-year cooled PWR source, Cm-244 represents 97% of the total neutron source. The effect on the neutron spectrum of neutron source isotopes with shorter half-lives, such as Cm-242 and Cf-252, is negligible.

6.2.2.3 *EOS-89BTH DSC Source Term Generation for Comprehensive Burnup, Enrichment, and Cooling Time Combinations (Method 2)*

Source term generation outlined in this section is applicable to source terms generated for the EOS-89BTH DSC transferred within the EOS-TC125 and stored in the EOS-HSM. The overall methodology is the same as the methodology outlined in Section 6.2.2.2, with minor changes as noted below.

1. *Candidate source terms over a range of BECT combinations are generated to match the decay heat of each zone of the EOS-89BTH DSC shielding HLZC provided in Figure 6-18. The ORIGEN-ARP module of SCALE 6.0 is used in the analysis. However, while only a limited number of BECT combinations are considered in Section 6.2.2.2, a comprehensive set of 142 burnup and enrichment combinations are considered for the EOS-89BTH DSC shielding HLZC. The burnup and enrichment combinations considered correspond to the fuel qualification table (FQT) provided in TS Table 21 [6-11].*

2. *Using MCNP, response functions are generated for the side of the EOS-TC125 and outlet vent opening of the EOS-HSM (the vent cover is not modeled). The response functions when multiplied by a source term generate a dose rate. These dose rates are used to rank the source terms and select bounding BECT combinations in the active fuel region.*

3. *The source in the bottom nozzle, plenum, and top nozzle are due almost entirely to Co-60. As an added conservatism, the bounding BECT of the hardware regions is selected to optimize Co-60 activation and may differ from the bounding BECT of the active fuel region.*

4. *Using the bounding BECT combinations developed in steps 2 and 3, design basis source terms are generated for each zone. Separate bounding source terms are generated for EOS-TC125 and EOS-HSM analysis.*

A constant specific power of 25 MW/MTU is used for all calculations. This specific power is also used in the 61BTH Type 2 DSC analysis documented in Chapter B.6.

Source terms are developed based on the bounding BECTs listed above. EOS-TC125 source terms are provided in Table 6-23 through Table 6-26, and EOS-HSM source terms are provided in Table 6-27 through Table 6-29a.

As noted in Section 6.2.2.2, EOS-TC125 accident cases should use maximum neutron sources because the loss of the neutron shield increases neutron dose rates more than gamma dose rates. To minimize the number of sources generated, the accident cases conservatively use the gamma sources generated for reconstituted fuel, which has a much larger Co-60 component. However, the accident neutron sources are the maximum values over all BECT combinations for both standard and reconstituted fuel, as standard fuel typically has a larger neutron source than reconstituted fuel. The accident neutron sources are provided in the last row of Table 6-23 through Table 6-26.

6.2.2.4 EOS-37PTH DSC Source Term Generation for Comprehensive Burnup, Enrichment, and Cooling Time Combinations (Method 2)

Source term generation outlined in this section is applicable to source terms generated for the EOS-37PTH DSC transferred within the EOS-TC125/135 and stored in the EOS-HSM. The overall methodology is the same as the methodology outlined in Section 6.2.2.2 except that approximately 100 burnup/enrichment combinations are considered rather than only 3 to 5 burnup/enrichment combinations. Using a comprehensive set of burnup/enrichment combinations is referred to as "Method 2." Also, fuel assemblies reconstituted with 10 stainless steel rods are addressed in the baseline analysis. The methodology used to develop the shielding HLZC source terms is provided below.

1. *Candidate source terms over a range of BECT combinations are generated to match the decay heat of each zone of the EOS-37PTH DSC shielding HLZC provided in Figure 6-19. The ORIGEN-ARP module of SCALE 6.0 is used in the analysis. However, while only a limited number of BECT combinations are considered in Section 6.2.2.2, a comprehensive set of approximately 100 burnup/enrichment combinations are considered for the EOS-37PTH DSC shielding HLZC. The burnup and enrichment combinations considered correspond to the fuel qualification table (FQT) provided in TS Table 7C [6-11].*
2. *Using MCNP, response functions are generated for the side of the EOS-TC125/135 and outlet vent opening of the EOS-HSM (the vent cover is not modeled). The response functions when multiplied by a source term generate a dose rate. These dose rates are used to rank the source terms and select bounding BECT combinations in the active fuel region. The EOS-HSM response function is for 37 fuel assemblies (i.e., not developed per zone) and is the same response function that is used in Section 6.2.2.2.*

3. *The source in the bottom nozzle, plenum, and top nozzle are due almost entirely to Co-60. As an added conservatism, the bounding BECT of the hardware regions is selected to optimize Co-60 activation and may differ from the bounding BECT of the active fuel region.*

4. *Using the bounding BECT combinations developed in steps 2 and 3, design basis source terms are generated for each zone. Separate bounding source terms are generated for EOS-TC125/135 and EOS-HSM analysis.*

Because reconstituted fuel with irradiated stainless steel rods is an allowed content, candidate source terms are generated for both standard fuel (i.e., without irradiated stainless steel rods) and reconstituted fuel (i.e., with 10 irradiated stainless steel rods). Standard fuel light element inputs are provided in Table 6-5. Reconstituted fuel light element inputs are developed in Section 6.2.6 for 5 stainless steel rods, and the same methodology is used to develop the light element inputs for 10 stainless steel rods.

Response functions for EOS-HSM and EOS-TC125/135 analysis are provided in Table 6-65 and Table 6-66, respectively. The nominal lead thickness for the EOS-TC125/135 design varies from 3.12 inches to 3.56 inches. The EOS-TC125/135 response functions are based on the maximum lead thickness design, modeled at the minimum tolerance of 3.51 inches. The bounding BECT combinations, response function results, Co-60 activities, and neutron sources are summarized in Table 6-8a and Table 6-8b for standard and reconstituted fuel, respectively. The following observations are made based on these results:

- *EOS-HSM vent dose rates are approximately 1-3% larger for peripheral zones 3, 4, and 5 for reconstituted fuel.*
- *EOS-TC125/135 side dose rates are approximately 2-5% larger for peripheral zones 3, 4, and 5 for reconstituted fuel.*
- *Maximum neutron sources for standard fuel are typically 3-5% larger than for reconstituted fuel.*

Based on the response function dose rates, the gamma source is conservatively developed based on reconstituted fuel. However, the neutron source is conservatively based on the maximum neutron source, which typically occurs for standard fuel. As noted in Section 6.2.2.2, EOS-TC125/135 accident cases use maximum neutron sources because the loss of the neutron shield increases neutron dose rates more than gamma dose rates. Because the neutron source is maximized in all normal condition source terms, these source terms are also applicable for use in accident analysis.

*Because modeling all fuel as reconstituted results in higher dose rates than modeling all fuel as standard, all reported EOS-37PTH DSC source terms for EOS-HSM and EOS-TC125/135 analysis include 10 irradiated steel rods, or 37*10 = 370 irradiated stainless steel rods per DSC. The bounding BECT combinations are:*

Hardware (i.e., bottom nozzle, plenum, top nozzle)

- *Zone 1: BU = 30 GWd/MTU, E = 1.8 wt.% U-235, CT = 3.18 years*
- *Zone 2: BU = 30 GWd/MTU, E = 1.8 wt.% U-235, CT = 4.40 years*
- *Zone 3: BU = 55 GWd/MTU, E = 3.4 wt.% U-235, CT = 3.50 years*
- *Zone 4: BU = 62 GWd/MTU, E = 3.8 wt.% U-235, CT = 2.70 years*
- *Zone 5: BU = 62 GWd/MTU, E = 3.8 wt.% U-235, CT = 1.85 years*

EOS-HSM (active fuel)

- *Zone 1: BU = 50 GWd/MTU, E = 5.0 wt.% U-235, CT = 4.60 years*
- *Zone 2: BU = 30 GWd/MTU, E = 1.8 wt.% U-235, CT = 4.40 years*
- *Zone 3: BU = 62 GWd/MTU, E = 5.0 wt.% U-235, CT = 3.73 years*
- *Zone 4: BU = 62 GWd/MTU, E = 4.0 wt.% U-235, CT = 2.67 years*
- *Zone 5: BU = 62 GWd/MTU, E = 3.8 wt.% U-235, CT = 1.85 years*

EOS-TC125 (active fuel)

- *Zone 1: BU = 62 GWd/MTU, E = 3.8 wt.% U-235, CT = 7.25 years*
- *Zone 2: BU = 62 GWd/MTU, E = 3.8 wt.% U-235, CT = 17.94 years*
- *Zone 3: BU = 62 GWd/MTU, E = 3.8 wt.% U-235, CT = 3.98 years*
- *Zone 4: BU = 62 GWd/MTU, E = 3.8 wt.% U-235, CT = 2.70 years*
- *Zone 5: BU = 62 GWd/MTU, E = 3.8 wt.% U-235, CT = 1.85 years*

Maximum Neutron Source

- *Zone 1: BU = 62 GWd/MTU, E = 3.8 wt.% U-235, CT = 7.82 years, standard fuel*
- *Zone 2: BU = 62 GWd/MTU, E = 3.8 wt.% U-235, CT = 17.94 years, reconstituted fuel*
- *Zone 3: BU = 62 GWd/MTU, E = 3.8 wt.% U-235, CT = 4.17 years, standard fuel*
- *Zone 4: BU = 62 GWd/MTU, E = 3.8 wt.% U-235, CT = 2.83 years, standard fuel*
- *Zone 5: BU = 62 GWd/MTU, E = 3.8 wt.% U-235, CT = 1.94 years, standard fuel*

Source terms are developed based on the bounding BECTs listed above. EOS-TC125/135 source terms are provided in Table 6-67 through Table 6-71, and EOS-HSM source terms are provided in Table 6-72 through Table 6-76. These source terms include a 1 year cooled control component source, which is derived in Section 6.2.4.

6.2.3 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 fuel assembly 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 [6-6] for fuel in the burnup range 26-30 GWd/MTU and is provided in Table 6-30. 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 [6-7]. 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 is 1.215, as shown in Table 6-30. 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 factor 1.215 to account for the burnup profile.

For clarity, both the gamma and neutron axial source distributions are renormalized to sum to 1.0, as shown in Table 6-30. When normalized in this manner, the source distribution is the fraction of the source in each axial segment. For example, the fraction of the neutron source in axial segment 10 is 0.0781, or 7.81%.

The BWR axial burnup profile is taken from [6-8] for fuel with a burnup of 40.2 GWd/MTU and is provided in Table 6-31. This distribution is highly peaked and is conservative. The BWR gamma and neutron source distributions are derived using the same method used for the PWR source distributions. The average value of the BWR neutron source distribution is 1.232, and the “raw” neutron sources computed by ORIGEN-ARP are increased by this factor to account for the burnup profile.

ORIGEN-ARP does not account for subcritical neutron multiplication. Subcritical neutron multiplication is taken into account by multiplying the neutron source by 1/(1-k), where k is the multiplication factor for the system. When the system is dry, k is low due to the lack of moderation as well as burnup of the fuel. For dry analysis, k is assumed to be 0.40. When the system is wet, such as during decontamination of the EOS-TC, k is larger. For wet analysis, k is assumed to be 0.65. This value of k is reasonable for shielding calculations because the fuel is burned and heavily poisoned. Fresh or lightly burned fuel would have a higher value for k, but fresh or lightly burned FAs have a small neutron source. Because the neutron source increases proportional to the 4.2 power of the burnup, large neutron sources occur only at high burnups, and for such burnups a k of 0.65 is reasonable.

The effect on the neutron source of both the axial source distribution and subcritical neutron multiplication are combined, as shown in the source term tables (Table 6-10 and Table 6-29). For PWR sources, the “raw” ORIGEN-ARP neutron sources are scaled by 1.215/(1-0.40) = 2.025 for dry analysis and 1.215/(1-0.65) = 3.471 for wet analysis. For BWR sources, the “raw” ORIGEN-ARP neutron sources are scaled by 1.232/(1-0.40) = 2.053 for dry analysis and 1.232/(1-0.65) = 3.520 for wet analysis.

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

6.2.4 Control Components

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

Any other CC type is acceptable if it can be demonstrated that the source term is below the CC activity limits provided in TS Table 3 [6-11]. Also, the total as-loaded decay heat of the system, including CCs, must be less that the heat load *zone* configurations defined in *either* the TS [6-11] *or Chapter 2*.

Any other CC type is acceptable if it can be demonstrated that the source term is below the CC activity limits provided in TS Table 3 [6-11]. The BPRA is used as a representative CC for category (1) and the TPA is used as a representative CC for category (2). The objective is to use these representative CC types to develop Co-60 activity limits for CCs.

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

A neutron source may be included in CCs, such as an NSA. Typically, the neutron source from an NSA is negligible compared to the neutron source from spent fuel. However, some neutron sources could have comparable source strength relative to the FAs. For this purpose, the loading of neutron sources is limited to the interior locations of the EOS-37PTH basket to maximize self shielding. The inner locations are defined in *TS Figure 3 [6-11]*.

Representative BPRA hardware masses are available for three BPRA types:

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

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

Representative TPA hardware masses are available for three TPA hardware types:

- Westinghouse 17x17
- Westinghouse 14x14 Type 1 and 2

The TPA hardware masses are provided in Table 6-33.

Elemental compositions for Zircaloy-4, Inconel-718, Inconel X-750, and 304 stainless steel are provided in Table 6-3. Note that the source term and dose rate are driven by Co-60, which arises primarily from Co-59 activation and to a much lesser extent from Ni-60 activation via an (n,p) reaction. The remaining light elements have little effect on the source term at the decay times of interest.

The poison is assumed to be Pyrex® (borosilicate glass). The choice of poison material has little effect on the source term or decay heat and is included for completeness. The elemental composition is obtained from [6-9] and is reproduced in Table 6-34.

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 6-4.

The source term and decay heat for the decay times of interest are dominated by Co-60. Co-60 primarily arises through activation of the Co-59 impurity present in the metal. Therefore, the BPRA and TPA hardware that has the largest Co-59 mass in each region is used to prepare the light element inputs. For the BPRA, B&W 15x15 is used for the top and WE 17x17 Pyrex is used for the plenum and active fuel regions. For the TPA, the WE 17x17 is used for all regions.

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.

For the BPRA, the host FA is burned to 50 GWd/MTU in two cycles. The minimum enrichment is 3.1% based on Table 6-7. The FA loading is 0.492 MTU. The assembly power is 19.68 MW, the irradiation time per cycle is 625 days, and the down time between cycles is 30 days. Decay heat, Co-60 activity, and the gamma source term is requested for decay *times* of *1 year and* 2 years.

To account for the reduced flux in the plenum and top regions, the BPRA input masses are scaled by the appropriate flux scaling factor. The ORIGEN-ARP inputs for the three BPRA regions are summarized in Table 6-35.

The methodology for TPAs is slightly different than for BPRAs. The reason is that a TPA may reside in several host FAs for a total host fuel assembly burnup of 300 GWd/MTU. ORIGEN-ARP cannot burn a single FA to such a high burnup. Therefore, rather than apply the flux scaling factors to the input masses, the true masses are input and the flux scaling factors are applied to the FA burnup. The TPA input masses are summarized in Table 6-33. These masses do not include flux scaling factors and are therefore larger than the BPRA input masses.

For the TPA plenum, the effective burnup is 300*0.2 = 60 GWd/MTU, while for the TPA top the effective burnup is 300*0.1 = 30 GWd/MTU. This reduces the cumulative burnup in each region to a value within the bounds of a typical ORIGEN-ARP model.

The TPA irradiation time is input to match the true irradiation time to properly credit Co-60 decay during the irradiation. Assuming a reactor assembly power of 19.68 MW and fuel loading of 0.492 MTU, the irradiation time to achieve a cumulative fuel assembly burnup of 300,000 GWd/MTU is 7,500 days. Because the irradiation time is fixed at 7,500 days, the FA power is selected to give the desired effective burnup in the plenum and top regions. For the top, the assembly power is 1.968 MW to achieve an effective burnup of 30 GWd/MTU. For the plenum, the assembly power is 3.936 MW to achieve an effective burnup of 60 GWd/MTU.

For simplicity of input preparation in the TPA calculation, no credit is taken for down time between cycles (typically assumed to be 30 days). Using approximately 12 cycles to achieve a burnup of 300 GWd/MTU, the conservatism of this assumption is 11*30 = 330 days of uncredited decay time.

Results for Co-60 activity and decay heat for both the BPRA and TPA are summarized in Table 6-36 for cooling *times* of *1 year and* 2 years. It is observed that the BPRA source may be used in the active fuel region, as the TPA does not extend into this region. However, the TPA has a larger source than the BPRA in the plenum and top regions due to the high TPA burnup. Decay heat for both is small compared to SFA but must be accounted for during loading. The CC source used in the detailed PWR dose rate calculations is a hybrid CC source that combines the active fuel source of the BPRA with the top/plenum source of the TPA. This source is provided in Table 6-37. The CC source significantly impacts the peak dose rates on the side of the EOS-TC, due to the reduced lead thickness near the top nozzle.

The CC source terms provided in Table 6-37 are included in all EOS-37PTH DSC MCNP models utilized in this chapter. The 1 year cooled CC sources are added to the fuel assembly sources developed in Section 6.2.2.4 (i.e., EOS-TC125/135 and EOS-HSM). The 2 year cooled CC sources are added to the fuel assembly sources developed in Section 6.2.2.2 (i.e., EOS-HSM, EOS-TC108, and EOS-TC125/135 sources used in the damaged/failed fuel reconfiguration analysis).

TS Table 3 [6-11] is expressed in terms of "Co-60 equivalent" because some CC designs feature dose rate producing isotopes in addition to Co-60 (e.g., control rods containing silver or hafnium). For these CC types, it is convenient to convert the active fuel region CC sources to the equivalent activity of Co-60 that results in the same dose rate. This approach provides a common baseline for comparison against TS Table 3 [6-11]. For the top/plenum regions, Co-60 equivalent is simply the Co-60 activity because the top/plenum regions are always dominated by Co-60. Also, for CCs that contain primarily Co-60 in the active region (e.g., BPRAs), the Co-60 equivalent is simply the Co-60 activity.

The Co-60 equivalence methodology is generally applicable only for control rods containing silver or hafnium. The fuel assembly source terms developed in Section 6.2.2 are selected using simplified MCNP models (i.e., response functions) to estimate the dose rate on the side of the transfer cask or EOS-HSM roof vent (without vent covers). **[**

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Item 1

6.2.5 Blended Low Enriched Uranium Fuel

Item 5

6.2.6 Reconstituted Fuel

6.2.6.1 EOS-37PTH DSC (EOS-TC125/135 and EOS-TC108) and EOS-89BTH DSC (EOS-TC108 Only)

The dose rate effect of reconstituted fuel assemblies containing irradiated stainless steel rods is addressed in this section for the EOS-37PTH DSC when transferred in either the EOS-TC125/135 (Method 1 sources) or EOS-TC108 and the EOS-89BTH DSC when transferred in the EOS-TC108. For the EOS-89BTH DSC transferred in the EOS-TC125, the dose rate effect of reconstituted fuel assemblies containing irradiated stainless steel rods is addressed in Section 6.2.6.2. The EOS-TC125/135 results presented in this section are maintained to support transfer to the HSM-MX. For the EOS-37PTH DSC transferred in the EOS-TC125/135 to the EOS-HSM using shielding HLZC source terms, the dose rate effect of reconstituted fuel assemblies containing irradiated stainless steel rods is addressed in Section 6.2.6.3.

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The maximum number of irradiated stainless steel rods per fuel assembly for different fuel classes is N_{SS}*, where* $N_{SS} = 5/49*N_F$*. The maximum number of irradiated stainless steel rods per DSC is* N_{DSC}*, where* $N_{DSC} = 20*N_{SS}$*, based on the 20 reconstituted fuel assemblies modeled in the EOS-89BTH DSC analysis. Values of* N_{SS} *and* N_{DSC} *as a function of BWR fuel assembly class are provided in TS Table 23 [6-11].*

A similar approach is used for the EOS-37PTH DSC when transferred in the EOS-TC108. The B&W 15x15 fuel with 208 fuel rods is used as the design basis. Other PWR fuel classes (i.e., 14x14, 16x16, and 17x17) have smaller or larger numbers of fuel rods per fuel assembly. For instance, 5 steel rods in the B&W 15x15 represents ≈2.5% of the fuel assembly, while 6 steel rods in a 17x17 would also represent ≈2.5% of the fuel assembly. Therefore, limits on the number of irradiated stainless steel rods per fuel assembly are developed for each class of PWR fuel to maintain the same ~2.5% fraction as B&W 15x15 fuel. The number of stainless steel rods is rounded to the nearest whole number.

The number of fuel rods for each fuel assembly is defined in Chapter 2, Table 2-2 and Table 2-4. The minimum numbers of fuel rods (N_F*) for each class are:*

- *14x14:* $N_F = 176$ *fuel rods (minimum)*
- *16x16:* $N_F = 236$ *fuel rods (minimum)*
- *17x17:* $N_F = 264$ *fuel rods (minimum)*

The maximum number of irradiated stainless steel rods per fuel assembly for different fuel classes is N_{SS}*, where* $N_{SS} = 5/208*N_F$*. The maximum number of irradiated stainless steel rods per DSC is* N_{DSC}*, where* $N_{DSC} = 8*N_{SS}$*, based on the 8 reconstituted fuel assemblies modeled in the EOS-37PTH DSC analysis. Values of* N_{SS} *and* N_{DSC} *as a function of PWR fuel assembly class are provided in TS Table 25 [6-11]. For instance, for 17x17 class fuel,* $N_F = 264$ *rods, and* $N_{SS} = 5/208*264 = 6.3$*, rounded to the nearest whole number, or 6. The number of rods per EOS-37PTH DSC is then 6*8 = 48.*

6.2.6.2 *EOS-89BTH DSC Transferred in the EOS-TC125*

The methodology for addressing dose rates due to reconstituted fuel for transfer of the EOS-89BTH DSC within the EOS-TC125 is different than the EOS-TC108 methodology described in Section 6.2.6.1. Major differences are:

- *In the EOS-TC108 analysis, reconstituted fuel with irradiated stainless steel rods is not modeled on the periphery. However, the baseline source terms for EOS-TC125 and EOS-HSM analysis are developed with 5 irradiated stainless steel rods in all fuel assemblies, including peripheral fuel assemblies (see Section 6.2.2.3). Therefore, for up to 5 irradiated stainless steel rods per fuel assembly (for 7x7 class fuel), there are no additional restrictions for reconstituted fuel compared to standard fuel.*

6.2.6.3 *EOS-37PTH DSC Transferred in the EOS-TC125/135 (Shielding HLZC)*

The methodology for addressing dose rates due to reconstituted fuel for transfer of the EOS-37PTH DSC within the EOS-TC125/135 using shielding HLZC source terms is different than the methodology described in Section 6.2.6.1. Major differences are:

- *In Section 6.2.6.1, reconstituted fuel with irradiated stainless steel rods is not modeled on the periphery. However, the baseline shielding HLZC source terms for EOS-TC125/135 and EOS-HSM analysis are developed with 10 irradiated stainless steel rods in all fuel assemblies, including peripheral fuel assemblies (see Section 6.2.2.4). Therefore, for up to 10 irradiated stainless steel rods per fuel assembly (for 15x15 class fuel), there are no additional restrictions for reconstituted fuel compared to standard fuel.*
- *In Section 6.2.6.1, a maximum of 5 irradiated stainless steel rods per fuel assembly and 40 rods per DSC (for 15x15 class fuel) is defined. However, in the EOS-TC125/135 analysis using shielding HLZC source terms, > 10 irradiated stainless steel rods per fuel assembly are allowed, but with a cooling time penalty to result in comparable dose rates.*

EOS-HSM and EOS-TC125/135 response functions are described in Section 6.2.2.4 and provided in Table 6-65 and Table 6-66. These response functions are used to generate ranking dose rates for approximately 100 BECT combinations for each zone of the shielding HLZC. The approach is to allow > 10 irradiated stainless steel rods per fuel assembly but increase the minimum cooling time so that response function dose rates are comparable (i.e., negligible dose rate increase) to the baseline results with 10 irradiated stainless steel rods.

The number of irradiated stainless steel rods per fuel assembly is varied from 20 to 200 in increments of 20. Light element masses and uranium loadings are adjusted for each case, as appropriate. The bounding ranking dose rates with 10 irradiated stainless steel rods are provided in Table 6-77. The percent change of the dose rate from the base case is provided for the EOS-HSM and the EOS-TC125/135 for peripheral zones 3, 4, and 5.

The peripheral zones dominate both EOS-HSM vent dose rates and EOS-TC125/135 side dose rates, and zone 5 is the dominant peripheral zone. In all cases, the zone 5 contribution to the dose rates decreases substantially with the increase in the minimum cooling time. Small dose rate increases (i.e., ≤ 6%) are allowed for peripheral zones 3 and 4, as the net dose rate increase would be negligible due to the dominance of zone 5. Inner zones 1 and 2 response function dose rates are provided in Table 6-77 for completeness, although zones 1 and 2 contribute negligibly to EOS-HSM vent dose rates and EOS-TC125/135 side dose rates.

The minimum cooling times in Table 6-67 are used as the basis for the limits provided in TS Table 24 [6-11]. The TS limits are provided as ranges in the numbers of irradiated stainless steel rods. Numbers of irradiated steel rods between those analyzed are conservatively assigned to the next higher analyzed value. For instance, the minimum cooling time developed for 40 irradiated stainless steel rods is conservatively applied to 21 through 39 irradiated stainless steel rods.

Also, consistent with the discussion in Section 6.2.6.1, limits on the number of irradiated stainless steel rods per fuel assembly developed for B&W 15x15 fuel are adjusted for 14x14, 16x16, and 17x17 class fuel. The maximum number of irradiated stainless steel rods per fuel assembly for different fuel classes is N_{SS}*. In this analysis,* $N_{SS} = B_{SS}/208*N_F$*, where* B_{SS} *is the number of irradiated stainless steel rods in the B&W 15x15 analysis (*B_{SS} *= 20, 40, 60, etc.) and* N_F *is the minimum number of fuel rods for each fuel assembly class (as defined in Section 6.2.6.1). For instance, if* B_{SS} *= 40 rods, for 17x17 class fuel,* N_F *= 264 rods, and* $N_{SS} = 40/208*264 = 51$ *rods. These limits are summarized in TS Table 24 [6-11].*

6.2.7 Irradiation Gases

During irradiation in a reactor, a FA will generate gases due to fission, alpha decay, and light element activation. The moles of gas generated are needed for subsequent pressure calculations documented in Chapter 4, Section 4.7, and are computed using ORIGEN-ARP. The noble gases (He, Ne, Ar, Kr, Xe, and Rn) are of primary interest as these gases do not react with other elements. The elements H, N, F, and Cl generated during irradiation are conservatively assumed to be present in a gaseous state, although these elements may have formed solid compounds and may not be present as a gas. Bromine and iodine are also assumed to be present as a gas because the boiling points of these elements are low. Oxygen is not treated as a gas because it is present primarily in the compound UO_2.

The quantities of irradiation gases increase with burnup. Therefore, the quantity of gas is maximized for a burnup of 62 GWd/MTU.

Integral fuel burnable absorber rods (IFBA) are used in some Westinghouse PWR designs. IFBA contains B-10, which results in helium gas generation due to the reaction B-10 + n → Li-7 + He-4. While the design basis B&W 15x15 FA does not contain IFBA, the effect of an IFBA FA is conservatively included by considering 450 g boron.

Control components also may result in helium gas generation due to B-10 activation. No actinides or fission products are present in the CCs, so the quantity of gas is smaller than spent fuel. Because the BPRA contains boron while the TPA does not, the BPRA bounds the TPA for gas generation. BPRA data is summarized in Table 6-32. The B&W 15x15 BPRA contains poison in the form B_4C-Al_2O_3, typically up to 5% B_4C, while the WE 17x17 Pyrex design utilizes Pyrex poison. To conservatively bound these designs and potentially other designs, a boron mass of 450 g is considered for CCs.

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6.3 Model Specification

MCNP5 is used to perform detailed three-dimensional near-field dose rate calculations for EOS-TCs and EOS-HSMs. All relevant details of the EOS-37PTH DSC, EOS-89BTH DSC, EOS-TC108, EOS-TC125/135, and EOS-HSM are modeled explicitly.

Separate primary gamma and neutron models are developed. The EOS-TC and EOS-HSM neutron models are run in coupled neutron-photon mode so that the secondary gamma dose rate from (n,γ) reactions may be computed. The secondary gamma dose rate from the EOS-TC arises primarily from neutron absorption in the water neutron shield. Secondary gammas from the EOS-HSM are negligible but are computed for completeness.

The treatment of subcritical neutron multiplication is suppressed in MCNP by using the NONU card. This is done because the FAs are modeled as fresh fuel and homogenized for simplicity, which would cause inaccurate treatment of subcritical neutron multiplication by MCNP. Subcritical neutron multiplication is accounted for in the neutron source magnitude, as discussed in Section 6.2.3.

6.3.1 Material Properties

Basic materials used in the models, such as 304 stainless steel, carbon steel, and concrete, are obtained from PNNL-15870 [6-9] and are summarized in Table 6-41. Not all materials are used in every model. The density of concrete has been conservatively reduced to 2.243 g/cm^3. Simple materials consisting of one element are not listed in Table 6-41. Such materials include lead, which is modeled with a reduced density of 11.18 g/cm^3. Aluminum is used in the basket plates with a density of 2.7 g/cm^3. The metal matrix composite (MMC) poison is modeled as pure aluminum (no boron) with a reduced density of 2.56 g/cm^3.

Borated polyethylene is used at the bottom of the EOS-TC for neutron shielding. Approximately 16% boric acid by weight (B_2O_3) is added to polyethylene so that the material is 5% boron by weight. Optionally, un-borated high density polyethylene (HDPE) material may be used. For both products, the atom density of hydrogen is conservatively reduced by 15% to account for potential hydrogen loss due to aging. The composition of the borated polyethylene and un-borated HDPE materials used in the EOS-TC models is provided in Table 6-42 and Table 6-42a, respectively.

The FAs are homogenized for simplicity. Fuel assemblies are modeled as fresh with a U-235 enrichment of 3%. The enrichment used is arbitrary because fission has been suppressed with the NONU card. Separate homogenization is performed for the bottom nozzle, active fuel, plenum, and top nozzle regions of the FA for both wet and dry conditions. The masses used for the homogenization are obtained from *Table 6-1a* and Table 6-2 for PWR and BWR fuel, respectively.

Table 6-1a does not include CC masses. For PWR fuel, the CC mass is also included in the plenum and top nozzle homogenizations because the CC source is always included in the MCNP models (no CC mass is credited in the active fuel region). As discussed in Section 6.2.4, the CC source is based on the BPRA B&W 15x15, BPRA WE 17x17 Pyrex, and TPA WE 17x17. The additional CC mass to be homogenized with the fuel is the minimum masses when comparing these CC types. This results in an additional 2.468 kg SS304 and 0.358 kg Inconel-718 in the top nozzle and an additional 2.85 kg SS304 in the plenum.

For BWR fuel, the mass of the channel is conservatively ignored because the channel may not be present. In the wet models, water with a density of 0.958 g/cm^3 fills the void space within the FA. The homogenized PWR fuel compositions are provided in Table 6-43 and Table 6-44 for dry and wet analysis, respectively. The homogenized BWR fuel compositions are provided in Table 6-45 and Table 6-46 for dry and wet analysis, respectively.

Concrete used in the EOS-HSM is modeled without steel rebar at a conservatively low density of 140 pcf (2.243 g/cm^3).

6.3.2 MCNP Model Geometry for the EOS-TC

Intact Fuel, Normal and Off-Normal Conditions

Detailed EOS-TC MCNP models are developed for the following four configurations:

- EOS-TC108 with EOS-37PTH DSC
- EOS-TC108 with EOS-89BTH DSC
- EOS-TC125/135 with EOS-37PTH DSC
- EOS-TC125 with EOS-89BTH DSC

The EOS-37PTH DSC and EOS-89BTH DSC are modeled explicitly, including the steel basket structure, aluminum plates, MMC (conservatively modeled without boron), transition rails, and shield plugs. Key dimensions used to develop the DSC models are summarized in Table 6-47, and figures illustrating the basic MCNP model are provided in Figure 6-3 through Figure 6-6. The figures illustrate the EOS-TC108 with the EOS-89BTH DSC, although the other EOS-TC and EOS-DSC combinations are similar.

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The source terms used in the EOS-37PTH DSC models are the combined fuel and CC source terms. The CC source term from Table 6-37 is simply added to the applicable PWR fuel source term from Section 6.2.2. The CC source is added to every FA in the EOS-37PTH DSC. *The two-year cooled CC source is used with the EOS-TC108 sources and EOS-TC125/135 sources developed for HLZC 4, 6/8, or 10, while the one-year cooled CC source is used with the EOS-TC125/135 sources developed for the shielding HLZC. Note that the PWR source terms provided in Table 6-10 through Table 6-16i are for fuel-only (i.e., no CCs), while the shielding HLZC source terms provided in Table 6-67 through Table 6-71 include the CC source terms for convenience.*

The EOS-89BTH DSC source terms are provided in Table 6-20 through Table 6-26. Note that the source term tables provide dry and wet neutron sources. Wet neutron sources are used only in the loading/decontamination models, while dry neutron sources are used in all other models. For the active fuel regions, an axial source distribution is applied per Table 6-30 and Table 6-31 for PWR and BWR fuel, respectively. For the top nozzle, plenum, and bottom nozzle regions, the source is evenly distributed throughout the region.

For each TC/DSC combination, dose rates are calculated on the surface, 30 cm, and 100 cm from the surfaces of the EOS-TC. Dose rates are also computed 300 cm from the side surface. All side dose rates are computed in 18 axial bins. The general tally locations are shown in Figure 6-7. In addition, for the final transfer configuration, dose rates are computed on the bottom and top surface in six radial segments (see Figure 6-8 and Figure 6-9) and on the side surface in 18 radial segments and 24 angular segments (see Figure 6-10).

Damaged or Failed Fuel, Normal and Off-Normal Conditions

Damaged or failed fuel may be tranferred in the EOS-37PTH DSC and EOS-TC125/135 using HLZC 6 or 8. Up to eight damaged fuel assemblies may be loaded in Zone 2, or up to four failed fuel canisters (FFCs) in Zone 3. The EOS-37PTH DSC is also authorized to store up to six damaged FAs or two FFCs using HLZC 10 or 11. *Damaged and failed fuel is also allowed in HLZC 12 and 13.* Damaged and failed fuel may not be present in the same DSC. Damaged or failed fuel is not authorized for storage in the EOS-89BTH DSC.

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PWR source terms (without CCs) *for HLZC 4 and 10* are provided in Table 6-17 through Table 6-19c, and the *2 year cooled* CC source provided in Table 6-37 is added to these PWR source terms for all FAs. *PWR source terms computed for the shielding HLZC are provided in Table 6-72 through Table 6-76. CC source terms cooled for 1 year from Table 6-37 are included in Table 6-72 through Table 6-76 for convenience.* BWR source terms are provided in Table 6-27 through *Table 6-29a*. For the active fuel regions, an axial source distribution is applied per Table 6-30 and Table 6-31 for PWR and BWR fuel, respectively. For the top nozzle, plenum, and bottom nozzle regions, the source is evenly distributed throughout the region.

The EOS-HSMs are modeled explicitly, including the inlet (front) and outlet (roof) vents. Key dimensions used to develop the EOS-HSM models are summarized in Table 6-50, and figures illustrating the basic MCNP model are provided in Figure 6-11 through Figure 6-13. The figures illustrate the EOS-HSM-Medium with the EOS-89BTH DSC, although the geometry of the EOS-HSM-Short with the EOS-37PTH DSC is similar.

The EOS-HSM design consists of a base module that includes the door and 1-foot thick shield walls on the sides and rear. A 3-foot-8-inch thick roof block that matches the length and width of the base rests on the base module. The modules may be positioned either side-by-side in a single row or back-to-back in a double row. When positioned in a single row the rear of the base module is shielded by a 3-foot thick rear shield wall. An end (side) shield wall, which is also 3 feet thick, is placed beside the last module in the row. The end shield wall is comprised of two pieces mated with a Z-joint to prevent direct streaming through the joint. A corner shield wall is placed at the interface of the rear and end shield walls. When the modules are positioned back-to-back, no rear or corner shield walls are used.

Air inlet vents are located on the front and air outlet vents are located on the roof. Because little radiation directly penetrates the thick concrete shielding, essentially all of the dose rate is due to gamma radiation streaming from the vents. Radiation streaming through the outlet vents is mitigated by the use of vent covers. The vent covers feature a 1-inch thick steel plate and approximately 11 inches of concrete. The vent covers are 4 feet wide and are placed between adjacent EOS-HSMs or between an EOS-HSM and the end shield wall. Under normal and off-normal conditions the vent covers are always in place.

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6.5 Supplemental Information

6.5.1 Fuel Qualification

6.5.1.1 EOS-37PTH DSC

Chapter 6 presents the shielding analysis for design basis fuel. For the EOS-37PTH DSC, *the shielding* HLZC results in bounding EOS-HSM vent dose rates. *The shielding HLZC features 5.0 kW fuel in the peripheral region. HLZC 10 source terms are used in the HSM-MX shielding analysis documented in Chapter A.6.* HLZC 10 features 3.5 kW fuel in the peripheral region. The peripheral region is illustrated in TS Figure 3 [6-11].

To provide additional assurance that TS dose rate limits will be met, a relationship between decay heat, burnup, enrichment, cooling time, and source terms is developed for *5.0 kW and* 3.5 kW fuel and provided as fuel qualification *tables (FQTs). The 5.0 kW FQT is applicable for loading into the EOS-HSM, and the 3.5 kW FQT is applicable for loading into the HSM-MX.* The methodology to develop *these FQTs* is the same as used to develop the design basis source terms.

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

Separate FQTs are provided for the EOS-HSM and HSM-MX because the analyses are based on different bounding source terms. Each FQT provides a global constraint and is applied to every fuel assembly to be loaded. The HSM-MX FQT is provided as TS Table 7B, and the EOS-HSM FQT is provided as TS Table 7C.

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

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

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

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

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

1. Determine the decay heat of all fuel to be loaded in an EOS-37PTH DSC using NRC Regulatory Guide 3.54, ORIGEN-ARP, or another acceptable method. Confirm the decay heat limit is met for each basket location.

2. Determine if LEOF is present in the fuel to be loaded by application of TS Table 7A.
    a) Up to 4 LEOF are allowed in the peripheral region. A minimum of three non-LEOFs shall circumferentially separate LEOFs within the peripheral region.
    b) There are no limitations on the number and location of LEOF stored in the inner region.

3. Verify all fuel to be loaded *in the HSM-MX* meets the minimum cooling time of TS Table 7B. *Verify all fuel to be loaded in the EOS-HSM meets the minimum cooling time of TS Table 7C.* Fuel that does not meet the cooling time limitations cannot be loaded.

These FQTs provide an additional constraint to ensure compliance with the dose rate limitations in TS 5.1.2(c).

Examples

Examples to illustrate application of TS Table 7A and TS Table 7B are provided below. *Application of TS Table 7C for the EOS-HSM is similar to the examples provided below for TS Table 7B.*

Example 1 (no LEOF)

This example demonstrates how to determine if a fuel assembly is LEOF and how to determine compliance with TS Table 7B *for fuel to be loaded in the HSM-MX*.

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

- The minimum enrichment for 50 GWd/MTU, per TS Table 7A, is 50/16 = 3.125%, which is rounded down to 3.1%. As E = 3.5% > 3.1%, this fuel assembly is within the minimum enrichment bounds of TS Table 7A and is not LEOF.
- Burnup in GWd/FA is (50 GWd/MTU)(0.45 MTU) = 22.5 GWd/FA
- Linearly interpolate on enrichment (first) and burnup (second) to determine the minimum cooling time
- Linearly interpolating for E = 3.5% in the 22.14 GWd/FA row of TS Table 7B, CT = 2.08 years
- Linearly interpolating for E = 3.5% in the 24.6 GWd/FA row of TS Table 7B, CT = 2.30 years
- Linearly interpolating for BU = 22.5 GWd/FA between CT = 2.08 years and CT = 2.30 years, the minimum cooling time is CT = 2.11 years.

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

Example 2 (with LEOF)

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

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

- The minimum enrichment for 50 GWd/MTU, per TS Table 7A, is 50/16 = 3.125%, which is rounded down to 3.1%. As E = 2.9% < 3.1%, this fuel assembly is LEOF. It is assumed to be the only LEOF to be loaded in this DSC.
- Burnup in GWd/FA is (50 GWd/MTU)(0.45 MTU) = 22.5 GWd/FA
- Linearly interpolate or extrapolate on enrichment (first) and burnup (second) to determine the minimum cooling time. Because the fuel is LEOF, extrapolation on the enrichment value beyond TS Table 7B is acceptable. Extrapolating to a lower enrichment value increases the minimum cooling time, which is a conservative penalty.

6.5.2 References

6-1 Oak Ridge National Laboratory, "A Modular Code System for Performing Standardized Computer Analyses for Licensing Evaluation," ORNL/TM-2005/39, Version 6, SCALE, January 2009.

6-2 Oak Ridge National Laboratory, "Predictions of PWR Spent Nuclear Fuel Isotopic Compositions," ORNL/TM-2010/44, SCALE 5.1, March 2010.

6-3 Oak Ridge National Laboratory, "Standard- and Extended-Burnup PWR and BWR Reactor Models for the ORIGEN2 Code," ORNL/TM-11018, December 1989.

6-4 Pacific Northwest Laboratory, "Spent Fuel Assembly Hardware: Characterization and 10 CFR 61 Classification for Waste Disposal, Volume 1 – Activation Measurements and Comparison with Calculations for Spent Fuel Assembly Hardware," PNL-6906, Vol. 1, June 1989.

6-5 Oak Ridge National Laboratory, "MCNP/MCNPX – Monte Carlo N-Particle Transport Code System Including MCNP5 1.40 and MCNPX 2.5.0 and Data Libraries," CCC-730, RSICC Computer Code Collection, January 2006.

6-6 NUREG/CR-6801, "Recommendations for Addressing Axial Burnup in PWR Burnup Credit Analyses," March 2003.

6-7 NUREG-1536, Rev. 1, "Standard Review Plan for Spent Fuel Dry Storage Systems at a General License Facility," July 2010.

6-8 Design Data Document DI-81001-02, NOK Document, "Technical Specification for the Supply of Transportable Casks for the Storage of Kernkraftwerk Leibstardt (KKL) Spent Fuel in ZWILAG," TS 07/01, Rev. 1.

6-9 Pacific Northwest National Laboratory, "Compendium of Material Composition Data for Radiation Transport Modeling," PNNL-15870, Rev. 1, March 2011.

6-10 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.

6-11 CoC 1042 Appendix A, NUHOMS® EOS System Generic Technical Specifications, Amendment *4*.

6-12 NUREG/CR-6999, "Technical Basis for a Proposed Expansion of Regulatory Guide 3.54 - Decay Heat Generation in an Independent Spent Fuel Storage Installation," February 2010.

6-13 U.S. Energy Information Administration (EIA), Spent Nuclear Fuel GC-859 Database, Accessed January 20, 2019. URL: https:/www.eia.gov/nuclear/spent_fuel/

6-14 ADVANTG - An Automated Variance Reduction Parameter Generator, Oak Ridge National Laboratory, August 2015.

6-15 Interagency Agreement DE-SA09-01 SR18976/TVA No. P-01 N8A-249655-001 between the Department of Energy (DOE) and the Tennessee Valley Authority (TVA) for the Off-Specification Fuel Project, April 5, 2001.

Table 6-1
Key Source Term Input Parameters for Various Configurations

System	***EOS-37PTH DSC***	***EOS-89BTH DSC***
EOS-TC108 intact fuel (normal and accident)	*Source method 1 for HLZC 4&5* *Minimum cooling time fuel: 2 years* *Minimum cooling time CCs: 2 years* *Reconstituted fuel treatment: No irradiated stainless steel rods in the baseline cases, sensitivity cases with reconstituted fuel loaded in inner zones.*	*Source method 1 for HLZC 2* *Minimum cooling time fuel: 3 years zones 1 and 2, 9.7 years zone 3* *Minimum cooling time CCs: N/A* *Reconstituted fuel treatment: No irradiated stainless steel rods in the baseline cases, sensitivity cases with reconstituted fuel loaded in inner zones.*
EOS-TC125 intact fuel (normal and accident)	*Source method 2 for MHLC* *Minimum cooling time fuel: 1 year* *Minimum cooling time CCs: 1 year* *Cask: maximum lead thickness design (No lead thickness variability when transferring EOS-37PTH)* *Reconstituted fuel treatment: 10 irradiated stainless steel rods per FA in the baseline cases.*	*Source method 2 for MHLC* *Minimum cooling time fuel: 1 year* *Minimum cooling time CCs: N/A* *Cask: minimum lead thickness design* *Reconstituted fuel treatment: 5 irradiated stainless steel rods per FA in the baseline cases.*
EOS-TC125 damaged/failed fuel (normal and accident)	*Source method 1 for HLZC 4, 6/8, 10* *Minimum cooling time fuel: 2 years* *Minimum cooling time CCs: 2 years* *Reconstituted fuel treatment: Not included in damaged/failed sensitivity study*	*N/A*
EOS-HSM	*Source method 2 for MHLC* *Minimum cooling time fuel: 1 year* *Minimum cooling time CCs: 1 year* *Cask: maximum lead thickness design (No lead thickness variability when transferring EOS-37PTH)* *Reconstituted fuel treatment: 10 irradiated stainless steel rods per FA in the baseline cases*	*Source method 2 for MHLC* *Minimum cooling time fuel: 1 year* *Minimum cooling time CCs: N/A* *Reconstituted fuel treatment: 5 irradiated stainless steel rods per FA in the baseline cases.*
HSM-MX	*Source method 1 for HLZC 10* *Minimum cooling time fuel: 2 years* *Minimum cooling time CCs: 2 years* *Reconstituted fuel treatment: No irradiated stainless steel rods in the baseline cases.*	*Source method 2 for MHLC* *Minimum cooling time fuel: 1 year* *Minimum cooling time CCs: N/A* *Reconstituted fuel treatment: 5 irradiated stainless steel rods per FA in the baseline cases.*

Table 6-1a
PWR (BW 15x15) Hardware Characteristics

Fuel Assembly Region and Length	Fuel Assembly Part	Material	Mass (kg)
Top Nozzle, 6.23 in.	Top nozzle/misc. steel	SS304	9.180
	Hold down spring	Inconel-718	1.800
Plenum, 8.73 in.	Upper spring	Inconel-718	4.344
	Upper end cap	Zircaloy-4	1.039
	Encompassing cladding	Zircaloy-4	5.763
	Upper end grid	Inconel-718	1.067
	Encompassing guide tube	Zircaloy-4	0.004
Active Fuel, 142.29 in.	Encompassing cladding	Zircaloy-4	101.1
	Encompassing guide tube	Zircaloy-4	6.328
	Six spacer grids	Inconel-718	4.985
	Grid Supports	Zircaloy-4	0.640
Bottom Nozzle, 8.38 in.	Lower end plug	Zircaloy-4	8.877
	Encompassing guide tube	Zircaloy-4	0.140
	Lower guide tube plugs	Zircaloy-4	1.439
	Lower end fitting	SS304	8.172
	Lower end grid	Inconel-718	1.067

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Table 6-8a
Source Term Ranking for the EOS-37PTH DSC Shielding HLZC, Standard Fuel, Method 2

EOS-HSM				
Zone	***BU (GWd/MTU)***	***E (%)***	***CT (years)***	***Max RF-HSM (mrem/hr)***
1	*50*	*5.0*	*4.82*	*1.87E+04*
2	*30*	*1.8*	*4.54*	*1.22E+04*
3	*62*	*5.0*	*3.90*	*3.00E+04*
4	*62*	*4.0*	*2.80*	*4.19E+04*
5	*62*	*3.8*	*1.94*	*5.54E+04*
EOS-TC125/135				
Zone	***BU (GWd/MTU)***	***E (%)***	***CT (years)***	***Max RF-TC125 (mrem/hr)***
1	*62*	*3.8*	*7.82*	*23.1*
2	*62*	*3.8*	*20.16*	*41*
3	*62*	*3.8*	*4.17*	*315*
4	*62*	*3.8*	*2.83*	*295*
5	*62*	*3.8*	*1.94*	*1119*
Total	*-*	*-*	*-*	*1793*
Co-60 Activity				
Zone	***BU (GWd/MTU)***	***E (%)***	***CT (years)***	***Max Co-60 (Ci)***
1	*30*	*1.8*	*3.29*	*665.7*
2	*30*	*1.8*	*4.54*	*564.6*
3	*55*	*3.4*	*3.65*	*818.9*
4	*62*	*3.8*	*2.83*	*966*
5	*62*	*3.8*	*1.94*	*1085*
Maximum Neutron Source				
Zone	***BU (GWd/MTU)***	***E (%)***	***CT (years)***	***Max Neutron (n/s)***
1	*62*	*3.8*	*7.82*	*1.245E+09*
2	*62*	*3.8*	*20.16*	*7.831E+08*
3	*62*	*3.8*	*4.17*	*1.440E+09*
4	*62*	*3.8*	*2.83*	*1.526E+09*
5	*62*	*3.8*	*1.94*	*1.599E+09*

Table 6-8b
Source Term Ranking for the EOS-37PTH DSC Shielding HLZC, Reconstituted Fuel, Method 2

EOS-HSM

Zone	***BU (GWd/MTU)***	***E (%)***	***CT (years)***	***Max RF-HSM (mrem/hr)***
1	*50*	*5.0*	*4.60*	*1.94E+04*
2	*30*	*1.8*	*4.40*	*1.28E+04*
3	*62*	*5.0*	*3.73*	*3.09E+04*
4	*62*	*4.0*	*2.67*	*4.28E+04*
5	*62*	*3.8*	*1.85*	*5.63E+04*

EOS-TC125/135

Zone	***BU (GWd/MTU)***	***E (%)***	***CT (years)***	***Max RF-TC125 (mrem/hr)***
1	*62*	*3.8*	*7.25*	*22.4*
2	*62*	*3.8*	*17.94*	*42*
3	*62*	*3.8*	*3.98*	*323*
4	*62*	*3.8*	*2.70*	*310*
5	*62*	*3.8*	*1.85*	*1170*
Total	*-*	*-*	*-*	*1868*

Co-60 Activity

Zone	***BU (GWd/MTU)***	***E (%)***	***CT (years)***	***Max Co-60 (Ci)***
1	*30*	*1.8*	*3.18*	*1630*
2	*30*	*1.8*	*4.40*	*1389*
3	*55*	*3.4*	*3.50*	*1981*
4	*62*	*3.8*	*2.70*	*2316*
5	*62*	*3.8*	*1.85*	*2593*

Maximum Neutron Source

Zone	***BU (GWd/MTU)***	***E (%)***	***CT (years)***	***Max Neutron (n/s)***
1	*62*	*3.8*	*7.25*	*1.207E+09*
2	*62*	*3.8*	*17.94*	*8.061E+08*
3	*62*	*3.8*	*3.98*	*1.376E+09*
4	*62*	*3.8*	*2.70*	*1.455E+09*
5	*62*	*3.8*	*1.85*	*1.526E+09*

Table 6-9a
Source Term Ranking for the EOS-89BTH DSC Shielding HLZC, Standard Fuel

EOS-HSM				
Zone	***BU (GWd/MTU)***	***E (%)***	***CT (years)***	***Max RF-HSM (mrem/hr)***
1	*36*	*2.2*	*4.72*	*12193*
2	*50*	*3.7*	*4.22*	*18270*
3	*62*	*3.8*	*2.34*	*37757*
4	*62*	*3.8*	*1.68*	*46730*
EOS-TC125				
Zone	***BU (GWd/MTU)***	***E (%)***	***CT (years)***	***Max RF-TC125 (mrem/hr)***
1	*62*	*3.8*	*15.57*	*45*
2	*62*	*3.8*	*6.23*	*144*
3	*35*	*1.7*	*1.53*	*944*
4	*35*	*1.7*	*1.11*	*2090*
Total	*-*	*-*	*-*	*3221*
Co-60 Activity				
Zone	***BU (GWd/MTU)***	***E (%)***	***CT (years)***	***Max Co-60 (Ci)***
1	*30*	*1.5*	*4.05*	*242.7*
2	*35*	*1.7*	*3.23*	*292.0*
3	*35*	*1.7*	*1.53*	*365.1*
4	*62*	*3.8*	*1.68*	*389.3*

Table 6-9b
Source Term Ranking for the EOS-89BTH DSC Shielding HLZC, Reconstituted Fuel

EOS-HSM				
Zone	**BU (GWd/MTU)**	**E (%)**	**CT (years)**	**Max RF-HSM (mrem/hr)**
1	35	1.7	4.38	14196
2	50	3.1	4.00	20364
3	62	3.8	2.09	40225
4	62	3.8	1.48	49092
EOS-TC125				
Zone	**BU (GWd/MTU)**	**E (%)**	**CT (years)**	**Max RF-TC125 (mrem/hr)**
1	62	3.8	12.22	45
2	62	3.8	5.41	147
3	35	1.7	1.37	1115
4	35	1.7	1.00	2385
Total	-	-	-	3693
Co-60 Activity				
Zone	**BU (GWd/MTU)**	**E (%)**	**CT (years)**	**Max Co-60 (Ci)**
1	35	1.7	4.38	1137
2	35	1.7	3.00	1363
3	35	1.7	1.37	1688
4	62	3.8	1.48	1808

All Indicated Changes are Scope Item 5.

Table 6-36
CC Co-60 Activity and Decay Heat

Parameter	BPRA *(2 years cooled)*			TPA *(2 years cooled)*	
	Active Fuel	**Plenum**	**Top**	**Plenum**	**Top**
Co-60 (Ci)	882.6	42.3	27.3	126.3	54.0
Decay Heat (watts)	15.2	0.7	0.5	2.1	0.9
Parameter	***BPRA (1 year cooled)***			***TPA (1 year cooled)***	
	Active Fuel	***Plenum***	***Top***	***Plenum***	***Top***
Co-60 (Ci)	*1007.0*	*48.3*	*31.1*	*144.0*	*61.6*
Decay Heat (watts)	*19.2*	*0.9*	*0.6*	*2.5*	*1.0*

Table 6-37
CC Source Term

		EOS-TC108 and HSM-MX Analysis, EOS-TC125/135 analysis for HLZC 4, 6/8, or 10 (2 years cooled)			***EOS-TC125/135 and EOS-HSM Analysis for Shielding HLZC (1 year cooled)***		
	Co-60 (Ci) →	**882.6**	**126.3**	**54.0**	***1007.0***	***144.0***	***61.6***
E$_{min}$ (MeV)	**E$_{max}$ (MeV)**	**Active Fuel (γ/s-CC)**	**Plenum (γ/s-CC)**	**Top (γ/s-CC)**	***Active Fuel (γ/s-CC)***	***Plenum (γ/s-CC)***	***Top (γ/s-CC)***
1.00E-02	5.00E-02	8.963E+11	1.286E+11	5.652E+10	*1.053E+12*	*1.504E+11*	*6.705E+10*
5.00E-02	1.00E-01	1.784E+11	2.546E+10	1.090E+10	*2.142E+11*	*3.037E+10*	*1.340E+10*
1.00E-01	2.00E-01	4.411E+10	6.253E+09	2.680E+09	*5.987E+10*	*8.174E+09*	*3.758E+09*
2.00E-01	3.00E-01	2.198E+09	3.133E+08	1.374E+08	*4.647E+09*	*6.299E+08*	*3.576E+08*
3.00E-01	4.00E-01	2.819E+09	4.033E+08	1.745E+08	*1.008E+10*	*9.442E+08*	*4.585E+08*
4.00E-01	6.00E-01	7.511E+09	9.613E+08	7.027E+08	*2.595E+11*	*3.321E+10*	*2.453E+10*
6.00E-01	8.00E-01	7.481E+07	1.174E+07	1.500E+09	*3.415E+08*	*4.598E+07*	*1.723E+09*
8.00E-01	1.00E+00	1.029E+13	6.978E+11	2.391E+11	*2.386E+13*	*1.661E+12*	*6.036E+11*
1.00E+00	1.33E+00	5.151E+13	7.371E+12	3.151E+12	*5.880E+13*	*8.410E+12*	*3.595E+12*
1.33E+00	1.66E+00	1.455E+13	2.082E+12	8.897E+11	*1.659E+13*	*2.374E+12*	*1.015E+12*
1.66E+00	2.00E+00	1.123E+08	1.437E+07	1.062E+07	*3.990E+09*	*5.106E+08*	*3.773E+08*
2.00E+00	2.50E+00	3.481E+08	4.980E+07	2.129E+07	*3.970E+08*	*5.681E+07*	*2.428E+07*
2.50E+00	3.00E+00	2.974E+05	4.255E+04	1.819E+04	*3.392E+05*	*4.854E+04*	*2.075E+04*
3.00E+00	4.00E+00	1.564E-02	4.129E-11	1.244E-06	*1.598E-02*	*4.217E-11*	*1.271E-06*
4.00E+00	5.00E+00	0.000E+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*	*0.000E+00*
6.50E+00	8.00E+00	0.000E+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*	*0.000E+00*
	Total	7.748E+13	1.031E+13	4.352E+12	*1.009E+14*	*1.267E+13*	*5.325E+12*

All Indicated Changes are Scope Item 1.

Proprietary Information on Pages 6-128 through 6-130
Withheld Pursuant to 10 CFR 2.390

Proprietary Information on Pages 6-132 and 6-133
Withheld Pursuant to 10 CFR 2.390

Table 6-48
EOS-TC108 and EOS-TC125/135 Key As-Modeled Dimensions (Inches)

Item	**EOS-TC108**	**EOS-TC125/135**
Cask inner diameter	76.25	76.25
Carbon steel inner shell thickness	0.75	0.75
Side lead minimum thickness	2.4	3.51*(1)*
Carbon steel outer shell thickness	1.0	1.0
Neutron shield water thickness	2.5	4.0
Ram port inner diameter	22.0	22.0
Carbon steel ram plate thickness	1.25	1.25
Carbon steel bottom panel thickness	0.75	0.75
Borated polyethylene or un-borated HDPE thickness	2.13	2.13
Carbon steel bottom end plate thickness	2.0	2.0
Carbon steel bottom ring height	9.0	9.0
Carbon steel top ring height	16.25	16.25
Top ring lead height	5.65	5.65
Top ring lead minimum thickness	0.85	0.85
Top ring thickness (at top nozzle)	4.63	5.38
Top cover plate (lid) thickness	2.0 (Aluminum)	3.2 (Carbon Steel)

(1) In the EOS-37PTH DSC models, the lead thickness is modeled at the indicated value. In the EOS-89BTH DSC models, the lead thickness is modeled at 3.07 inches, which is the minimum value of the variable lead EOS-TC125/135 design.

Table 6-50
EOS-HSM Key As-Modeled Dimensions (Inches)

Item	EOS-HSM-Short	EOS-HSM-Medium
Base/roof width	116	116
Base height	178	178
Base/roof length	228	248
Base upper side wall thickness	12	12
Base upper rear wall thickness	12	12
Roof thickness	44	44
Rear/end (side) shield wall thickness	36	36
Rear/end (side)/corner shield wall height	222	222
End (side) shield wall length	117	127
Corner shield wall width (square)	36	36
Door inner steel plate thickness	1	1
Door concrete thickness (centerline)	30.5	30.5
Door outer concrete width (square)	100.375	100.375
Inlet vent height	*30.25*	*30.25*
Inlet vent width	10	10
Base outlet vent height	8	8
Base outlet vent length	128	148
Roof outlet vent opening width	8	8
Roof outlet vent opening length	132 max./116 min. (trapezoidal)	152 max./136 min. (trapezoidal)
Outlet vent cover width	48	48
Outlet vent cover length	156	176
Outlet vent cover concrete thickness	10.625	10.625
Outlet vent cover steel plate thickness	1	1
Outlet vent cover opening height	6.25	6.25
Outlet vent cover opening length	132	152
Gaps between base and shield walls	1.5	1.5

All Indicated Changes are Scope Item 1.

Proprietary Information on Pages 6-158 through 6-160
Withheld Pursuant to 10 CFR 2.390

All Indicated Changes are Scope Item 1.

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Proprietary Information on This Page
Withheld Pursuant to 10 CFR 2.390

Proprietary Information on Pages 6-170 through 6-175
Withheld Pursuant to 10 CFR 2.390

Table 6-65
EOS-HSM Response Function for the EOS-37PTH DSC Shielding HLZC

	E_{upper} (MeV)	Dose Rate (mrem/hr)
Primary Gamma	*0.05*	*0.00E+00*
	0.1	*0.00E+00*
	0.2	*0.00E+00*
	0.3	*0.00E+00*
	0.4	*0.00E+00*
	0.6	*8.74E-13*
	0.8	*3.38E-12*
	1	*6.56E-12*
	1.33	*1.15E-11*
	1.66	*2.31E-11*
	2	*3.00E-11*
	2.5	*4.43E-11*
	3	*6.59E-11*
	4	*7.45E-11*
	5	*1.03E-10*
	6.5	*1.27E-10*
	8	*1.81E-10*
	10	*2.08E-10*
Neutron	-	*4.52E-08*

All Indicated Changes are Scope Item 1.

Table 6-66
EOS-TC125 Response Functions for the EOS-37PTH DSC Shielding HLZC

		Zone 1	*Zone 2*	*Zone 3*	*Zone 4*	*Zone 5*
	E_{upper} (MeV)	*Dose Rate (mrem/hr)*	*Dose Rate (mrem/hr)*	*Dose Rate (mrem/hr)*	*Dose Rate (mrem/hr)*	*Dose Rate (mrem/hr)*
Primary Gamma	*0.05*	*0.00E+00*	*0.00E+00*	*0.00E+00*	*0.00E+00*	*0.00E+00*
	0.1	*0.00E+00*	*0.00E+00*	*0.00E+00*	*0.00E+00*	*0.00E+00*
	0.2	*0.00E+00*	*0.00E+00*	*0.00E+00*	*0.00E+00*	*0.00E+00*
	0.3	*0.00E+00*	*0.00E+00*	*0.00E+00*	*0.00E+00*	*0.00E+00*
	0.4	*0.00E+00*	*0.00E+00*	*0.00E+00*	*0.00E+00*	*0.00E+00*
	0.6	*0.00E+00*	*0.00E+00*	*3.35E-18*	*1.83E-19*	*1.55E-18*
	0.8	*0.00E+00*	*1.21E-18*	*1.95E-16*	*2.91E-16*	*9.54E-16*
	1	*1.00E-18*	*1.43E-17*	*5.61E-15*	*6.26E-15*	*2.01E-14*
	1.33	*4.83E-18*	*5.45E-16*	*7.86E-14*	*8.61E-14*	*2.58E-13*
	1.66	*1.01E-16*	*5.54E-15*	*4.71E-13*	*4.84E-13*	*1.37E-12*
	2	*7.32E-16*	*2.40E-14*	*1.39E-12*	*1.38E-12*	*3.77E-12*
	2.5	*2.48E-15*	*7.95E-14*	*3.28E-12*	*3.14E-12*	*8.30E-12*
	3	*6.79E-15*	*1.75E-13*	*6.06E-12*	*5.67E-12*	*1.45E-11*
	4	*1.67E-14*	*3.52E-13*	*1.03E-11*	*9.39E-12*	*2.34E-11*
	5	*2.87E-14*	*5.59E-13*	*1.48E-11*	*1.31E-11*	*3.19E-11*
	6.5	*4.32E-14*	*6.82E-13*	*1.81E-11*	*1.55E-11*	*3.73E-11*
	8	*3.33E-14*	*7.28E-13*	*1.96E-11*	*1.72E-11*	*4.02E-11*
	10	*3.12E-14*	*6.81E-13*	*2.08E-11*	*1.82E-11*	*4.26E-11*
Secondary Gamma	*-*	*5.92E-09*	*1.46E-08*	*3.54E-08*	*1.50E-08*	*3.43E-08*
Neutron	*-*	*3.25E-09*	*1.12E-08*	*4.11E-08*	*2.25E-08*	*5.70E-08*

Table 6-67
PWR Source Term for the EOS-TC125/135 Shielding HLZC, Zone 1, with CCs (1.5 kW/FA)

Burnup (GWd/MTU)			*30*	*62*	*30*	*30*
Enrichment (wt. % U-235)			*1.8*	*3.8*	*1.8*	*1.8*
Cooling Time (years)			*3.18*	*7.25*	*3.18*	*3.18*
Gamma Source Term, γ/(sec*FA)						
E_{min}, MeV	***to***	***E_{max}, MeV***	***Bottom Nozzle***	***In-core***	***Plenum***	***Top Nozzle***
1.00E-02	*to*	*5.00E-02*	*3.596E+11*	*1.455E+15*	*3.950E+11*	*1.279E+11*
5.00E-02	*to*	*1.00E-01*	*2.218E+10*	*3.935E+14*	*4.601E+10*	*2.527E+10*
1.00E-01	*to*	*2.00E-01*	*2.267E+10*	*3.087E+14*	*2.311E+10*	*6.676E+09*
2.00E-01	*to*	*3.00E-01*	*1.512E+09*	*8.656E+13*	*1.626E+09*	*5.007E+08*
3.00E-01	*to*	*4.00E-01*	*4.915E+09*	*5.460E+13*	*4.142E+09*	*6.441E+08*
4.00E-01	*to*	*6.00E-01*	*9.265E+10*	*6.835E+14*	*9.311E+10*	*2.456E+10*
6.00E-01	*to*	*8.00E-01*	*4.961E+10*	*3.023E+15*	*3.653E+10*	*2.611E+09*
8.00E-01	*to*	*1.00E+00*	*4.968E+11*	*3.609E+14*	*1.806E+12*	*8.755E+11*
1.00E+00	*to*	*1.33E+00*	*6.081E+12*	*2.358E+14*	*1.272E+13*	*7.029E+12*
1.33E+00	*to*	*1.66E+00*	*1.717E+12*	*6.094E+13*	*3.592E+12*	*1.985E+12*
1.66E+00	*to*	*2.00E+00*	*3.857E+05*	*4.481E+11*	*5.114E+08*	*3.776E+08*
2.00E+00	*to*	*2.50E+00*	*4.109E+07*	*4.632E+11*	*8.595E+07*	*4.749E+07*
2.50E+00	*to*	*3.00E+00*	*3.511E+04*	*2.739E+10*	*7.343E+04*	*4.058E+04*
3.00E+00	*to*	*4.00E+00*	*7.449E-06*	*2.607E+09*	*3.560E-05*	*7.410E-06*
4.00E+00	*to*	*5.00E+00*	*9.946E-14*	*4.142E+07*	*9.946E-14*	*9.947E-14*
5.00E+00	*to*	*6.50E+00*	*2.866E-14*	*1.663E+07*	*2.866E-14*	*2.866E-14*
6.50E+00	*to*	*8.00E+00*	*3.645E-15*	*3.262E+06*	*3.645E-15*	*3.645E-15*
8.00E+00	*to*	*1.00E+01*	*4.865E-16*	*6.925E+05*	*4.865E-16*	*4.865E-16*
*Total Gamma, g/(sec*FA)*			*8.849E+12*	*6.663E+15*	*1.872E+13*	*1.008E+13*
Total Neutron Source Term, n/(sec*FA)						
Raw ORIGEN-ARP source for uniform burnup, normal and accident (BU = 62 GWd/MTU, E = 3.8 wt.% U-235, CT = 7.82 years, standard fuel)						*1.245E+09*
Treated with peaking factor 1.215 and k-eff=0.4 (dry)						*2.521E+09*
Treated with peaking factor 1.215 and k-eff=0.65 (wet)						*4.322E+09*

Table 6-68
PWR Source Term for the EOS-TC125/135 Shielding HLZC, Zone 2, with CCs (1.0 kW/FA)

Burnup (GWd/MTU)			*30*	*62*	*30*	*30*
Enrichment (wt. % U-235)			*1.8*	*3.8*	*1.8*	*1.8*
Cooling Time (years)			*4.4*	*17.94*	*4.4*	*4.4*
Gamma Source Term, γ/(sec*FA)						
E_{min}, MeV	***to***	***E_{max}, MeV***	***Bottom Nozzle***	***In-core***	***Plenum***	***Top Nozzle***
1.00E-02	*to*	*5.00E-02*	*2.409E+11*	*9.629E+14*	*3.171E+11*	*1.190E+11*
5.00E-02	*to*	*1.00E-01*	*1.872E+10*	*2.701E+14*	*4.359E+10*	*2.351E+10*
1.00E-01	*to*	*2.00E-01*	*1.723E+10*	*1.841E+14*	*1.956E+10*	*6.236E+09*
2.00E-01	*to*	*3.00E-01*	*1.129E+09*	*5.466E+13*	*1.376E+09*	*4.794E+08*
3.00E-01	*to*	*4.00E-01*	*3.333E+09*	*3.516E+13*	*3.116E+09*	*6.167E+08*
4.00E-01	*to*	*6.00E-01*	*6.804E+10*	*4.692E+13*	*7.717E+10*	*2.454E+10*
6.00E-01	*to*	*8.00E-01*	*3.654E+10*	*1.841E+15*	*2.809E+10*	*2.610E+09*
8.00E-01	*to*	*1.00E+00*	*1.862E+11*	*5.685E+13*	*1.718E+12*	*7.057E+11*
1.00E+00	*to*	*1.33E+00*	*5.183E+12*	*1.149E+14*	*1.209E+13*	*6.522E+12*
1.33E+00	*to*	*1.66E+00*	*1.464E+12*	*2.470E+13*	*3.412E+12*	*1.842E+12*
1.66E+00	*to*	*2.00E+00*	*5.109E+03*	*9.517E+10*	*5.106E+08*	*3.773E+08*
2.00E+00	*to*	*2.50E+00*	*3.502E+07*	*5.314E+09*	*8.164E+07*	*4.406E+07*
2.50E+00	*to*	*3.00E+00*	*2.992E+04*	*9.056E+08*	*6.976E+04*	*3.765E+04*
3.00E+00	*to*	*4.00E+00*	*7.259E-06*	*8.369E+07*	*3.469E-05*	*7.254E-06*
4.00E+00	*to*	*5.00E+00*	*1.079E-14*	*2.767E+07*	*1.079E-14*	*1.079E-14*
5.00E+00	*to*	*6.50E+00*	*3.108E-15*	*1.111E+07*	*3.108E-15*	*3.109E-15*
6.50E+00	*to*	*8.00E+00*	*3.954E-16*	*2.179E+06*	*3.954E-16*	*3.954E-16*
8.00E+00	*to*	*1.00E+01*	*5.276E-17*	*4.626E+05*	*5.276E-17*	*5.277E-17*
*Total Gamma, g/(sec*FA)*			*7.219E+12*	*3.591E+15*	*1.771E+13*	*9.246E+12*
Total Neutron Source Term, n/(sec*FA)						
Raw ORIGEN-ARP source for uniform burnup, normal and accident (BU = 62 GWd/MTU, E = 3.8 wt.% U-235, CT = 17.94 years, reconstituted fuel)						*8.061E+08*
Treated with peaking factor 1.215 and k-eff=0.4 (dry)						*1.632E+09*
Treated with peaking factor 1.215 and k-eff=0.65 (wet)						*2.798E+09*

All Indicated Changes are Scope Item 1.

Table 6-69
PWR Source Term for the EOS-TC125/135 Shielding HLZC, Zone 3, with CCs (2.4 kW/FA)

Burnup (GWd/MTU)			*55*	*62*	*55*	*55*
Enrichment (wt. % U-235)			*3.4*	*3.8*	*3.4*	*3.4*
Cooling Time (years)			*3.5*	*3.98*	*3.5*	*3.5*
Gamma Source Term, γ/(sec*FA)						
E_{min}, MeV	***to***	***E_{max}, MeV***	***Bottom Nozzle***	***In-core***	***Plenum***	***Top Nozzle***
1.00E-02	*to*	*5.00E-02*	*4.181E+11*	*2.681E+15*	*4.414E+11*	*1.412E+11*
5.00E-02	*to*	*1.00E-01*	*2.684E+10*	*7.888E+14*	*5.013E+10*	*2.778E+10*
1.00E-01	*to*	*2.00E-01*	*2.893E+10*	*6.786E+14*	*2.743E+10*	*7.284E+09*
2.00E-01	*to*	*3.00E-01*	*1.927E+09*	*1.883E+14*	*1.908E+09*	*5.310E+08*
3.00E-01	*to*	*4.00E-01*	*5.971E+09*	*1.329E+14*	*4.841E+09*	*6.836E+08*
4.00E-01	*to*	*6.00E-01*	*1.203E+11*	*2.163E+15*	*1.109E+11*	*2.455E+10*
6.00E-01	*to*	*8.00E-01*	*6.443E+10*	*4.660E+15*	*4.856E+10*	*3.102E+09*
8.00E-01	*to*	*1.00E+00*	*4.607E+11*	*9.626E+14*	*1.798E+12*	*8.559E+11*
1.00E+00	*to*	*1.33E+00*	*7.347E+12*	*3.640E+14*	*1.386E+13*	*7.762E+12*
1.33E+00	*to*	*1.66E+00*	*2.075E+12*	*1.184E+14*	*3.912E+12*	*2.192E+12*
1.66E+00	*to*	*2.00E+00*	*1.378E+05*	*3.333E+12*	*5.109E+08*	*3.774E+08*
2.00E+00	*to*	*2.50E+00*	*4.965E+07*	*6.576E+12*	*9.361E+07*	*5.243E+07*
2.50E+00	*to*	*3.00E+00*	*4.242E+04*	*2.513E+11*	*7.998E+04*	*4.481E+04*
3.00E+00	*to*	*4.00E+00*	*1.476E-05*	*2.333E+10*	*7.056E-05*	*1.344E-05*
4.00E+00	*to*	*5.00E+00*	*5.412E-14*	*4.713E+07*	*5.412E-14*	*5.412E-14*
5.00E+00	*to*	*6.50E+00*	*1.559E-14*	*1.892E+07*	*1.559E-14*	*1.559E-14*
6.50E+00	*to*	*8.00E+00*	*1.983E-15*	*3.711E+06*	*1.983E-15*	*1.983E-15*
8.00E+00	*to*	*1.00E+01*	*2.647E-16*	*7.880E+05*	*2.647E-16*	*2.647E-16*
*Total Gamma, g/(sec*FA)*			*1.055E+13*	*1.275E+16*	*2.025E+13*	*1.101E+13*
Total Neutron Source Term, n/(sec*FA)						
Raw ORIGEN-ARP source for uniform burnup, normal and accident (BU = 62 GWd/MTU, E = 3.8 wt.% U-235, CT = 4.17 years, standard fuel)						*1.440E+09*
Treated with peaking factor 1.215 and k-eff=0.4 (dry)						*2.916E+09*
Treated with peaking factor 1.215 and k-eff=0.65 (wet)						*4.999E+09*

Table 6-70
PWR Source Term for the EOS-TC125/135 Shielding HLZC, Zone 4, with CCs (3.5 kW/FA)

Burnup (GWd/MTU)			62	62	62	62
Enrichment (wt. % U-235)			3.8	3.8	3.8	3.8
Cooling Time (years)			2.7	2.7	2.7	2.7
Gamma Source Term, γ/(sec*FA)						
E_{min}, MeV	**to**	**E_{max}, MeV**	**Bottom Nozzle**	**In-core**	**Plenum**	**Top Nozzle**
1.00E-02	to	5.00E-02	5.875E+11	4.585E+15	5.555E+11	1.536E+11
5.00E-02	to	1.00E-01	3.163E+10	1.429E+15	5.391E+10	3.022E+10
1.00E-01	to	2.00E-01	3.690E+10	1.296E+15	3.274E+10	7.887E+09
2.00E-01	to	3.00E-01	2.510E+09	3.543E+14	2.295E+09	5.610E+08
3.00E-01	to	4.00E-01	8.777E+09	2.640E+14	6.666E+09	7.220E+08
4.00E-01	to	6.00E-01	1.568E+11	3.551E+15	1.347E+11	2.465E+10
6.00E-01	to	8.00E-01	8.505E+10	6.012E+15	6.255E+10	3.236E+09
8.00E-01	to	1.00E+00	9.029E+11	1.465E+15	1.925E+12	1.098E+12
1.00E+00	to	1.33E+00	8.576E+12	4.727E+14	1.485E+13	8.464E+12
1.33E+00	to	1.66E+00	2.422E+12	1.702E+14	4.192E+12	2.390E+12
1.66E+00	to	2.00E+00	2.442E+06	8.024E+12	5.156E+08	3.789E+08
2.00E+00	to	2.50E+00	5.796E+07	1.902E+13	1.003E+08	5.718E+07
2.50E+00	to	3.00E+00	4.952E+04	6.007E+11	8.571E+04	4.886E+04
3.00E+00	to	4.00E+00	1.725E-05	5.537E+10	8.244E-05	1.549E-05
4.00E+00	to	5.00E+00	2.286E-13	4.979E+07	2.286E-13	2.286E-13
5.00E+00	to	6.50E+00	6.587E-14	1.998E+07	6.587E-14	6.588E-14
6.50E+00	to	8.00E+00	8.378E-15	3.920E+06	8.379E-15	8.379E-15
8.00E+00	to	1.00E+01	1.118E-15	8.323E+05	1.118E-15	1.118E-15
Total Gamma, g/(sec*FA)			1.281E+13	1.963E+16	2.181E+13	1.217E+13
Total Neutron Source Term, n/(sec*FA)						
Raw ORIGEN-ARP source for uniform burnup, normal and accident (BU = 62 GWd/MTU, E = 3.8 wt.% U-235, CT = 2.83 years, standard fuel)						1.526E+09
Treated with peaking factor 1.215 and k-eff=0.4 (dry)						3.090E+09
Treated with peaking factor 1.215 and k-eff=0.65 (wet)						5.297E+09

Table 6-71
PWR Source Term for the EOS-TC125/135 Shielding HLZC, Zone 5, with CCs (5.0 kW/FA)

Burnup (GWd/MTU)			*62*	*62*	*62*	*62*
Enrichment (wt. % U-235)			*3.8*	*3.8*	*3.8*	*3.8*
Cooling Time (years)			*1.85*	*1.85*	*1.85*	*1.85*
Gamma Source Term, γ/(sec*FA)						
E_{min}, MeV	***to***	***E_{max}, MeV***	***Bottom Nozzle***	***In-core***	***Plenum***	***Top Nozzle***
1.00E-02	*to*	*5.00E-02*	*8.623E+11*	*7.394E+15*	*7.356E+11*	*1.641E+11*
5.00E-02	*to*	*1.00E-01*	*3.636E+10*	*2.376E+15*	*5.750E+10*	*3.232E+10*
1.00E-01	*to*	*2.00E-01*	*4.534E+10*	*2.231E+15*	*3.839E+10*	*8.449E+09*
2.00E-01	*to*	*3.00E-01*	*3.404E+09*	*5.999E+14*	*2.915E+09*	*6.027E+08*
3.00E-01	*to*	*4.00E-01*	*1.816E+10*	*4.590E+14*	*1.275E+10*	*7.652E+08*
4.00E-01	*to*	*6.00E-01*	*1.981E+11*	*5.069E+15*	*1.660E+11*	*2.672E+10*
6.00E-01	*to*	*8.00E-01*	*1.493E+11*	*7.461E+15*	*1.040E+11*	*3.243E+09*
8.00E-01	*to*	*1.00E+00*	*1.817E+12*	*1.972E+15*	*2.200E+12*	*1.599E+12*
1.00E+00	*to*	*1.33E+00*	*9.601E+12*	*5.933E+14*	*1.562E+13*	*9.046E+12*
1.33E+00	*to*	*1.66E+00*	*2.711E+12*	*2.287E+14*	*4.409E+12*	*2.554E+12*
1.66E+00	*to*	*2.00E+00*	*5.392E+07*	*1.470E+13*	*6.197E+08*	*4.106E+08*
2.00E+00	*to*	*2.50E+00*	*6.536E+07*	*3.920E+13*	*1.058E+08*	*6.111E+07*
2.50E+00	*to*	*3.00E+00*	*5.583E+04*	*1.082E+12*	*9.040E+04*	*5.222E+04*
3.00E+00	*to*	*4.00E+00*	*1.760E-05*	*9.926E+10*	*8.410E-05*	*1.577E-05*
4.00E+00	*to*	*5.00E+00*	*1.098E-12*	*5.212E+07*	*1.098E-12*	*1.098E-12*
5.00E+00	*to*	*6.50E+00*	*3.164E-13*	*2.092E+07*	*3.164E-13*	*3.164E-13*
6.50E+00	*to*	*8.00E+00*	*4.024E-14*	*4.104E+06*	*4.024E-14*	*4.025E-14*
8.00E+00	*to*	*1.00E+01*	*5.371E-15*	*8.713E+05*	*5.371E-15*	*5.371E-15*
*Total Gamma, g/(sec*FA)*			*1.544E+13*	*2.844E+16*	*2.334E+13*	*1.344E+13*
Total Neutron Source Term, n/(sec*FA)						
Raw ORIGEN-ARP source for uniform burnup, normal and accident (BU = 62 GWd/MTU, E = 3.8 wt.% U-235, CT = 1.94 years, standard fuel)						*1.599E+09*
Treated with peaking factor 1.215 and k-eff=0.4 (dry)						*3.238E+09*
Treated with peaking factor 1.215 and k-eff=0.65 (wet)						*5.551E+09*

Table 6-72
PWR Source Term for the EOS-HSM Shielding HLZC, Zone 1, with CCs (1.5 kW/FA)

Burnup (GWd/MTU)			*30*	*50*	*30*	*30*
Enrichment (wt. % U-235)			*1.8*	*5.0*	*1.8*	*1.8*
Cooling Time (years)			*3.18*	*4.6*	*3.18*	*3.18*
Gamma Source Term, γ/(sec*FA)						
E_{min}, MeV	***to***	***E_{max}, MeV***	***Bottom Nozzle***	***In-core***	***Plenum***	***Top Nozzle***
1.00E-02	*to*	*5.00E-02*	*3.596E+11*	*1.906E+15*	*3.950E+11*	*1.279E+11*
5.00E-02	*to*	*1.00E-01*	*2.218E+10*	*5.546E+14*	*4.601E+10*	*2.527E+10*
1.00E-01	*to*	*2.00E-01*	*2.267E+10*	*4.658E+14*	*2.311E+10*	*6.676E+09*
2.00E-01	*to*	*3.00E-01*	*1.512E+09*	*1.290E+14*	*1.626E+09*	*5.007E+08*
3.00E-01	*to*	*4.00E-01*	*4.915E+09*	*8.947E+13*	*4.142E+09*	*6.441E+08*
4.00E-01	*to*	*6.00E-01*	*9.265E+10*	*1.184E+15*	*9.311E+10*	*2.456E+10*
6.00E-01	*to*	*8.00E-01*	*4.961E+10*	*3.195E+15*	*3.653E+10*	*2.611E+09*
8.00E-01	*to*	*1.00E+00*	*4.968E+11*	*5.489E+14*	*1.806E+12*	*8.755E+11*
1.00E+00	*to*	*1.33E+00*	*6.081E+12*	*2.566E+14*	*1.272E+13*	*7.029E+12*
1.33E+00	*to*	*1.66E+00*	*1.717E+12*	*7.653E+13*	*3.592E+12*	*1.985E+12*
1.66E+00	*to*	*2.00E+00*	*3.857E+05*	*1.694E+12*	*5.114E+08*	*3.776E+08*
2.00E+00	*to*	*2.50E+00*	*4.109E+07*	*3.732E+12*	*8.595E+07*	*4.749E+07*
2.50E+00	*to*	*3.00E+00*	*3.511E+04*	*1.201E+11*	*7.343E+04*	*4.058E+04*
3.00E+00	*to*	*4.00E+00*	*7.449E-06*	*1.106E+10*	*3.560E-05*	*7.410E-06*
4.00E+00	*to*	*5.00E+00*	*9.946E-14*	*1.332E+07*	*9.946E-14*	*9.947E-14*
5.00E+00	*to*	*6.50E+00*	*2.866E-14*	*5.345E+06*	*2.866E-14*	*2.866E-14*
6.50E+00	*to*	*8.00E+00*	*3.645E-15*	*1.049E+06*	*3.645E-15*	*3.645E-15*
8.00E+00	*to*	*1.00E+01*	*4.865E-16*	*2.226E+05*	*4.865E-16*	*4.865E-16*
*Total Gamma, g/(sec*FA)*			*8.849E+12*	*8.412E+15*	*1.872E+13*	*1.008E+13*
Total Neutron Source Term, n/(sec*FA)						
Raw ORIGEN-ARP source for uniform burnup, normal and accident (BU = 62 GWd/MTU, E = 3.8 wt.% U-235, CT = 7.82 years, standard fuel)						*1.245E+09*
Treated with peaking factor 1.215 and k-eff=0.4 (dry)						*2.521E+09*

Table 6-73
PWR Source Term for the EOS-HSM Shielding HLZC, Zone 2, with CCs (1.0 kW/FA)

Burnup (GWd/MTU)			*30*	*30*	*30*	*30*
Enrichment (wt. % U-235)			*1.8*	*1.8*	*1.8*	*1.8*
Cooling Time (years)			*4.4*	*4.4*	*4.4*	*4.4*
Gamma Source Term, γ/(sec*FA)						
E_{min}, MeV	***to***	***E_{max}, MeV***	***Bottom Nozzle***	***In-core***	***Plenum***	***Top Nozzle***
1.00E-02	*to*	*5.00E-02*	*2.409E+11*	*1.363E+15*	*3.171E+11*	*1.190E+11*
5.00E-02	*to*	*1.00E-01*	*1.872E+10*	*4.079E+14*	*4.359E+10*	*2.351E+10*
1.00E-01	*to*	*2.00E-01*	*1.723E+10*	*3.498E+14*	*1.956E+10*	*6.236E+09*
2.00E-01	*to*	*3.00E-01*	*1.129E+09*	*9.733E+13*	*1.376E+09*	*4.794E+08*
3.00E-01	*to*	*4.00E-01*	*3.333E+09*	*7.065E+13*	*3.116E+09*	*6.167E+08*
4.00E-01	*to*	*6.00E-01*	*6.804E+10*	*7.997E+14*	*7.717E+10*	*2.454E+10*
6.00E-01	*to*	*8.00E-01*	*3.654E+10*	*1.985E+15*	*2.809E+10*	*2.610E+09*
8.00E-01	*to*	*1.00E+00*	*1.862E+11*	*3.444E+14*	*1.718E+12*	*7.057E+11*
1.00E+00	*to*	*1.33E+00*	*5.183E+12*	*2.136E+14*	*1.209E+13*	*6.522E+12*
1.33E+00	*to*	*1.66E+00*	*1.464E+12*	*6.331E+13*	*3.412E+12*	*1.842E+12*
1.66E+00	*to*	*2.00E+00*	*5.109E+03*	*1.869E+12*	*5.106E+08*	*3.773E+08*
2.00E+00	*to*	*2.50E+00*	*3.502E+07*	*3.821E+12*	*8.164E+07*	*4.406E+07*
2.50E+00	*to*	*3.00E+00*	*2.992E+04*	*1.408E+11*	*6.976E+04*	*3.765E+04*
3.00E+00	*to*	*4.00E+00*	*7.259E-06*	*1.303E+10*	*3.469E-05*	*7.254E-06*
4.00E+00	*to*	*5.00E+00*	*1.079E-14*	*9.732E+06*	*1.079E-14*	*1.079E-14*
5.00E+00	*to*	*6.50E+00*	*3.108E-15*	*3.906E+06*	*3.108E-15*	*3.109E-15*
6.50E+00	*to*	*8.00E+00*	*3.954E-16*	*7.662E+05*	*3.954E-16*	*3.954E-16*
8.00E+00	*to*	*1.00E+01*	*5.276E-17*	*1.627E+05*	*5.276E-17*	*5.277E-17*
*Total Gamma, g/(sec*FA)*			*7.219E+12*	*5.700E+15*	*1.771E+13*	*9.246E+12*
Total Neutron Source Term, n/(sec*FA)						
Raw ORIGEN-ARP source for uniform burnup, normal and accident (BU = 62 GWd/MTU, E = 3.8 wt.% U-235, CT = 17.94 years, reconstituted fuel)						*8.061E+08*
Treated with peaking factor 1.215 and k-eff=0.4 (dry)						*1.632E+09*

Table 6-74

PWR Source Term for the EOS-HSM Shielding HLZC, Zone 3, with CCs (2.4 kW/FA)

Burnup (GWd/MTU)			*55*	*62*	*55*	*55*
Enrichment (wt. % U-235)			*3.4*	*5.0*	*3.4*	*3.4*
Cooling Time (years)			*3.5*	*3.73*	*3.5*	*3.5*
Gamma Source Term, γ/(sec*FA)						
E_{min}, MeV	***to***	***E_{max}, MeV***	***Bottom Nozzle***	***In-core***	***Plenum***	***Top Nozzle***
1.00E-02	*to*	*5.00E-02*	*4.181E+11*	*2.924E+15*	*4.414E+11*	*1.412E+11*
5.00E-02	*to*	*1.00E-01*	*2.684E+10*	*8.701E+14*	*5.013E+10*	*2.778E+10*
1.00E-01	*to*	*2.00E-01*	*2.893E+10*	*7.580E+14*	*2.743E+10*	*7.284E+09*
2.00E-01	*to*	*3.00E-01*	*1.927E+09*	*2.082E+14*	*1.908E+09*	*5.310E+08*
3.00E-01	*to*	*4.00E-01*	*5.971E+09*	*1.480E+14*	*4.841E+09*	*6.836E+08*
4.00E-01	*to*	*6.00E-01*	*1.203E+11*	*2.222E+15*	*1.109E+11*	*2.455E+10*
6.00E-01	*to*	*8.00E-01*	*6.443E+10*	*4.734E+15*	*4.856E+10*	*3.102E+09*
8.00E-01	*to*	*1.00E+00*	*4.607E+11*	*9.858E+14*	*1.798E+12*	*8.559E+11*
1.00E+00	*to*	*1.33E+00*	*7.347E+12*	*3.611E+14*	*1.386E+13*	*7.762E+12*
1.33E+00	*to*	*1.66E+00*	*2.075E+12*	*1.182E+14*	*3.912E+12*	*2.192E+12*
1.66E+00	*to*	*2.00E+00*	*1.378E+05*	*3.581E+12*	*5.109E+08*	*3.774E+08*
2.00E+00	*to*	*2.50E+00*	*4.965E+07*	*8.090E+12*	*9.361E+07*	*5.243E+07*
2.50E+00	*to*	*3.00E+00*	*4.242E+04*	*2.631E+11*	*7.998E+04*	*4.481E+04*
3.00E+00	*to*	*4.00E+00*	*1.476E-05*	*2.427E+10*	*7.056E-05*	*1.344E-05*
4.00E+00	*to*	*5.00E+00*	*5.412E-14*	*3.142E+07*	*5.412E-14*	*5.412E-14*
5.00E+00	*to*	*6.50E+00*	*1.559E-14*	*1.261E+07*	*1.559E-14*	*1.559E-14*
6.50E+00	*to*	*8.00E+00*	*1.983E-15*	*2.473E+06*	*1.983E-15*	*1.983E-15*
8.00E+00	*to*	*1.00E+01*	*2.647E-16*	*5.252E+05*	*2.647E-16*	*2.647E-16*
*Total Gamma, g/(sec*FA)*			*1.055E+13*	*1.334E+16*	*2.025E+13*	*1.101E+13*
Total Neutron Source Term, n/(sec*FA)						
Raw ORIGEN-ARP source for uniform burnup, normal and accident (BU = 62 GWd/MTU, E = 3.8 wt.% U-235, CT = 4.17 years, standard fuel)						*1.440E+09*
Treated with peaking factor 1.215 and k-eff=0.4 (dry)						*2.916E+09*

Table 6-75
PWR Source Term for the EOS-HSM Shielding HLZC, Zone 4, with CCs (3.5 kW/FA)

Burnup (GWd/MTU)			*62*	*62*	*62*	*62*
Enrichment (wt. % U-235)			*3.8*	*4.0*	*3.8*	*3.8*
Cooling Time (years)			*2.7*	*2.67*	*2.7*	*2.7*
Gamma Source Term, γ/(sec*FA)						
E_{min}, MeV	***to***	***E_{max}, MeV***	***Bottom Nozzle***	***In-core***	***Plenum***	***Top Nozzle***
1.00E-02	*to*	*5.00E-02*	*5.875E+11*	*4.650E+15*	*5.555E+11*	*1.536E+11*
5.00E-02	*to*	*1.00E-01*	*3.163E+10*	*1.450E+15*	*5.391E+10*	*3.022E+10*
1.00E-01	*to*	*2.00E-01*	*3.690E+10*	*1.319E+15*	*3.274E+10*	*7.887E+09*
2.00E-01	*to*	*3.00E-01*	*2.510E+09*	*3.594E+14*	*2.295E+09*	*5.610E+08*
3.00E-01	*to*	*4.00E-01*	*8.777E+09*	*2.680E+14*	*6.666E+09*	*7.220E+08*
4.00E-01	*to*	*6.00E-01*	*1.568E+11*	*3.557E+15*	*1.347E+11*	*2.465E+10*
6.00E-01	*to*	*8.00E-01*	*8.505E+10*	*6.021E+15*	*6.255E+10*	*3.236E+09*
8.00E-01	*to*	*1.00E+00*	*9.029E+11*	*1.467E+15*	*1.925E+12*	*1.098E+12*
1.00E+00	*to*	*1.33E+00*	*8.576E+12*	*4.714E+14*	*1.485E+13*	*8.464E+12*
1.33E+00	*to*	*1.66E+00*	*2.422E+12*	*1.700E+14*	*4.192E+12*	*2.390E+12*
1.66E+00	*to*	*2.00E+00*	*2.442E+06*	*8.076E+12*	*5.156E+08*	*3.789E+08*
2.00E+00	*to*	*2.50E+00*	*5.796E+07*	*1.957E+13*	*1.003E+08*	*5.718E+07*
2.50E+00	*to*	*3.00E+00*	*4.952E+04*	*6.017E+11*	*8.571E+04*	*4.886E+04*
3.00E+00	*to*	*4.00E+00*	*1.725E-05*	*5.541E+10*	*8.244E-05*	*1.549E-05*
4.00E+00	*to*	*5.00E+00*	*2.286E-13*	*4.648E+07*	*2.286E-13*	*2.286E-13*
5.00E+00	*to*	*6.50E+00*	*6.587E-14*	*1.865E+07*	*6.587E-14*	*6.588E-14*
6.50E+00	*to*	*8.00E+00*	*8.378E-15*	*3.659E+06*	*8.379E-15*	*8.379E-15*
8.00E+00	*to*	*1.00E+01*	*1.118E-15*	*7.770E+05*	*1.118E-15*	*1.118E-15*
*Total Gamma, g/(sec*FA)*			*1.281E+13*	*1.976E+16*	*2.181E+13*	*1.217E+13*
Total Neutron Source Term, n/(sec*FA)						
Raw ORIGEN-ARP source for uniform burnup, normal and accident (BU = 62 GWd/MTU, E = 3.8 wt.% U-235, CT = 2.83 years, standard fuel)						*1.526E+09*
Treated with peaking factor 1.215 and k-eff=0.4 (dry)						*3.090E+09*

Table 6-76
PWR Source Term for the EOS-HSM Shielding HLZC, Zone 5, with CCs (5.0 kW/FA)

Burnup (GWd/MTU)			62	62	62	62
Enrichment (wt. % U-235)			3.8	3.8	3.8	3.8
Cooling Time (years)			1.85	1.85	1.85	1.85
Gamma Source Term, γ/(sec*FA)						
E_{min}, MeV	**to**	**E_{max}, MeV**	**Bottom Nozzle**	**In-core**	**Plenum**	**Top Nozzle**
1.00E-02	to	5.00E-02	8.623E+11	7.394E+15	7.356E+11	1.641E+11
5.00E-02	to	1.00E-01	3.636E+10	2.376E+15	5.750E+10	3.232E+10
1.00E-01	to	2.00E-01	4.534E+10	2.231E+15	3.839E+10	8.449E+09
2.00E-01	to	3.00E-01	3.404E+09	5.999E+14	2.915E+09	6.027E+08
3.00E-01	to	4.00E-01	1.816E+10	4.590E+14	1.275E+10	7.652E+08
4.00E-01	to	6.00E-01	1.981E+11	5.069E+15	1.660E+11	2.672E+10
6.00E-01	to	8.00E-01	1.493E+11	7.461E+15	1.040E+11	3.243E+09
8.00E-01	to	1.00E+00	1.817E+12	1.972E+15	2.200E+12	1.599E+12
1.00E+00	to	1.33E+00	9.601E+12	5.933E+14	1.562E+13	9.046E+12
1.33E+00	to	1.66E+00	2.711E+12	2.287E+14	4.409E+12	2.554E+12
1.66E+00	to	2.00E+00	5.392E+07	1.470E+13	6.197E+08	4.106E+08
2.00E+00	to	2.50E+00	6.536E+07	3.920E+13	1.058E+08	6.111E+07
2.50E+00	to	3.00E+00	5.583E+04	1.082E+12	9.040E+04	5.222E+04
3.00E+00	to	4.00E+00	1.760E-05	9.926E+10	8.410E-05	1.577E-05
4.00E+00	to	5.00E+00	1.098E-12	5.212E+07	1.098E-12	1.098E-12
5.00E+00	to	6.50E+00	3.164E-13	2.092E+07	3.164E-13	3.164E-13
6.50E+00	to	8.00E+00	4.024E-14	4.104E+06	4.024E-14	4.025E-14
8.00E+00	to	1.00E+01	5.371E-15	8.713E+05	5.371E-15	5.371E-15
Total Gamma, g/(sec*FA)			1.544E+13	2.844E+16	2.334E+13	1.344E+13
Total Neutron Source Term, n/(sec*FA)						
Raw ORIGEN-ARP source for uniform burnup, normal and accident (BU = 62 GWd/MTU, E = 3.8 wt.% U-235, CT = 1.94 years, standard fuel)						1.599E+09
Treated with peaking factor 1.215 and k-eff=0.4 (dry)						3.238E+09

Table 6-77
EOS-37PTH DSC Reconstituted Fuel Minimum Cooling Time Results

Stainless Steel Rods →	*10 (base)*	*20*	*40*	*60*	*80*	*100*	*120*	*140*	*160*	*180*	*200*
Minimum Cooling Time (years) →	*1.00*	*3.00*	*4.00*	*4.50*	*5.00*	*5.25*	*5.50*	*5.75*	*6.00*	*6.25*	*6.25*
	Maximum HSM Response Function Dose Rate (mrem/hr)										
Zone 1	*19389*	*20774*	*23947*	*26732*	*28227*	*28402*	*27887*	*28287*	*28315*	*27539*	*22715*
Zone 2	*12838*	*13901*	*16507*	*19297*	*21901*	*25714*	*27887*	*28287*	*28315*	*27539*	*22715*
Zone 3	*30908*	*32715*	*32170*	*29702*	*28227*	*28402*	*27887*	*28287*	*28315*	*27539*	*22715*
Zone 4	*42836*	*39952*	*32170*	*29702*	*28227*	*28402*	*27887*	*28287*	*28315*	*27539*	*22715*
Zone 5	*56267*	*39952*	*32170*	*29702*	*28227*	*28402*	*27887*	*28287*	*28315*	*27539*	*22715*
Zone 3	*-*	*6%*	*4%*	*-4%*	*-9%*	*-8%*	*-10%*	*-8%*	*-8%*	*-11%*	*-27%*
Zone 4	*-*	*-7%*	*-25%*	*-31%*	*-34%*	*-34%*	*-35%*	*-34%*	*-34%*	*-36%*	*-47%*
Zone 5	*-*	*-29%*	*-43%*	*-47%*	*-50%*	*-50%*	*-50%*	*-50%*	*-50%*	*-51%*	*-60%*
	Maximum EOS-TC125/135 Response Function Dose Rate (mrem/hr)										
Zone 1	*22*	*22*	*22*	*20*	*18*	*16*	*13*	*10*	*7*	*3*	*0.4*
Zone 2	*42*	*44*	*48*	*48*	*47*	*45*	*39*	*31*	*22*	*12*	*4*
Zone 3	*323*	*341*	*343*	*329*	*322*	*328*	*323*	*328*	*327*	*316*	*261*
Zone 4	*310*	*294*	*250*	*248*	*253*	*270*	*279*	*298*	*312*	*317*	*273*
Zone 5	*1170*	*790*	*677*	*677*	*696*	*750*	*784*	*844*	*891*	*912*	*791*
Zone 3	*-*	*6%*	*6%*	*2%*	*0%*	*1%*	*0%*	*2%*	*1%*	*-2%*	*-19%*
Zone 4	*-*	*-5%*	*-19%*	*-20%*	*-19%*	*-13%*	*-10%*	*-4%*	*1%*	*2%*	*-12%*
Zone 5	*-*	*-32%*	*-42%*	*-42%*	*-40%*	*-36%*	*-33%*	*-28%*	*-24%*	*-22%*	*-32%*

Figure 6-1

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Figure 6-2

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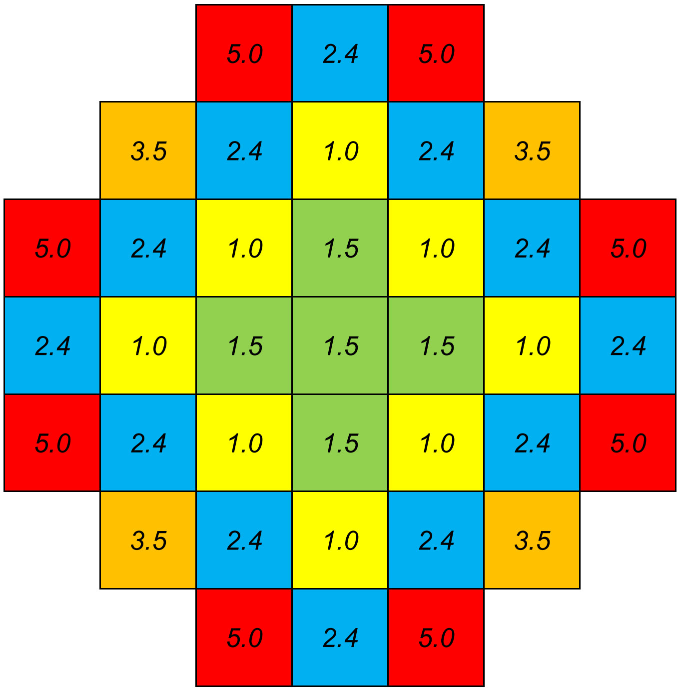

		5.0	2.4	5.0		
	3.5	2.4	1.0	2.4	3.5	
5.0	2.4	1.0	1.5	1.0	2.4	5.0
2.4	1.0	1.5	1.5	1.5	1.0	2.4
5.0	2.4	1.0	1.5	1.0	2.4	5.0
	3.5	2.4	1.0	2.4	3.5	
		5.0	2.4	5.0		

Zone	Decay Heat (kW/FA)
1	1.5
2	1.0
3	2.4
4	3.5
5	5.0

Figure 6-19
Shielding HLZC for the EOS-37PTH DSC

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7.6 References

7-1 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.

7-2 U.S. Nuclear Regulatory Commission, "Standard Review Plan for Spent Fuel Dry Storage Systems at a General License Facility," NUREG-1536, Revision 1, July 2010.

7-3 Scaglione, J.M., Mueller, D.E., Wagner, J.C., and Marshall, W.J., "An Approach for Validating Actinide and Fission Product Burnup Credit Criticality Safety Analyses – Criticality (k_{eff}) Predictions," NUREG/CR 7109, U.S. Nuclear Regulatory Commission, April 2012.

7-4 International Criticality Safety Benchmark Evaluation Project (ICSBEP), "International Handbook of Evaluated Criticality Safety Benchmark Experiments," NEA/NSC/DOC(95)03, NEA Nuclear Science Committee, September 2009, http://icsbep.inel.gov/.

7-5 USLSTATS: A Utility to Calculate Upper Subcritical Limits for Criticality Safety Applications, Version 6, Oak Ridge National Laboratory, January 26, 2009.

7-6 Dean, J.C., Tayloe Jr., R.W., "Guide for Validation of Nuclear Criticality Safety Calculational Methodology," NUREG/CR-6698, January 2001.

7-7 TN Americas LLC, "Updated Final Safety Analysis Report for the Standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel," Revision 18, USNRC Docket Number 72-1004, January 2019.

7-8 CoC 1042 Appendix A, NUHOMS® EOS System Generic Technical Specifications, Amendment *4*.

Table 7-81
EOS-37PTH - Maximum Uranium Mass per FFC, Failed Fuel Debris Analysis

Fissile Rods Diameter	Maximum Uranium Mass
10x10 array size	
0.8 inch	1104 kg
0.6 inch	621 kg
9x9 array size	
0.9 inch	1132 kg
0.6 inch	503kg
8x8 array size	
1 inch	1104 kg
0.6 inch	397 kg

Note: This table presents the as-modeled uranium masses in the failed fuel debris models. The MTU limits for an FFC containing failed fuel are defined in *Table 2 of the Technical Specifications [7-8]*.

Table 7-82
Sensitivity Analysis on ATRIUM 11 Lattices

[

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8. MATERIALS EVALUATION

8.1 General Information

8.1.1 NUHOMS® EOS System Materials

This chapter provides the materials evaluation for the NUHOMS® EOS System in accordance with the guidance outlined in NUREG-1536, Revision 1 [8-1]. Steel materials employed in the various components of the NUHOMS® EOS System, particularly those that are relied on for structural integrity, are based on American Society for Testing and Materials (ASTM) and American Society of Mechanical Engineers (ASME) specifications. Horizontal storage module (HSM) concrete is based on American Concrete Institute (ACI) specifications. Neutron and gamma shielding materials are relied on for their nuclear properties and are not credited in the structural analysis. *Note that the EOS-HSM may be constructed of reinforced concrete, termed EOS-HSM-RC, or alternatively, the components may be constructed from a steel-plate composite. The steel-plate composite EOS-HSM is termed the EOS-HSM-SC, and is included when generically referring to the EOS-HSM.*

Materials evaluation and analysis for the NUHOMS® MATRIX (HSM-MX) provided in Chapter A.8.

NOTE: Materials evaluation and analysis for the NUHOMS 61BTH Type 2 DSC and the OS197 TC are provided in Chapter B.8.

8.1.2 Environmental Conditions

The dry shielded canister (DSC) and EOS-HSM are exposed to the ambient weather conditions at the licensee site for the duration of the licensing period. Depending on the licensee local conditions, the environment may include chloride aerosols, precipitation, and freezing temperatures. The roof, front wall, door, and shield walls of the EOS-HSM concrete are directly exposed to the weather. The EOS-HSM side and rear walls, interior, and the DSC exterior surfaces are sheltered from direct effects of weather, though moisture and aerosols present in the air pass through the EOS-HSM interior via natural convention. Material temperatures of the storage system components are presented in Chapter 4.

During loading and unloading, the DSC is placed in the fuel pool, inside the EOS transfer cask (EOS-TC, hereafter identified as TC, unless otherwise noted). The annulus between the TC and DSC is filled with demineralized water and an inflatable seal is used to cover the annulus between the DSC and the cask. The exterior of the DSC is not exposed to pool water. The interior of the DSC and the exterior of the TC are exposed to either demineralized water (boiling water reactor (BWR)) or diluted boric acid (pressurized water reactor (PWR)). The TC and DSC are only kept in the spent fuel pool for a short period of time, typically less than 24 hours.

8.2 Materials Selection

This section discusses the materials used in the main NUHOMS® EOS System components (See Section A.8.2 for the HSM-MX and Section B.8.2 for the 61BTH Type 2 DSC and OS197 TC). Table 8-1 through Table 8-3 summarize the materials selected for the EOS-DSCs, -HSMs, and -TCs, respectively. Temperature-dependent mechanical and thermal properties for the materials listed in Table 8-1 through Table 8-3 are presented in Table 8-4 through Table 8-21 *and Table 8-37 through Table 8-41* for the main structural and non-structural materials, respectively. Table 8-23 and Table 8-24 present the temperature-dependent properties for reinforced concrete. The fuel cladding temperature-dependent properties are presented in Table 8-25 and Table 8-26. Properties of helium and air used in the thermal evaluations are presented in Table 8-27 and Table 8-28, respectively. Mechanical and thermal properties of the solid neutron shielding material and material compositions for the materials used in the shielding analysis Monte Carlo N-Particle (MCNP) models are shown in Table 8-29 through Table 8-31 and Table 8-31a. The material properties used for the criticality analysis, including the minimum B-10 content used in the neutron poison plates criticality evaluations, are shown in Table 8-32 through Table 8-34. Emissivity requirements for the [ ] basket plates or alternative surface treatment are provided in Table 8-35.

8.2.1 Applicable Codes and Standards and Alternatives

8.2.1.1 EOS-37PTH and EOS-89BTH DSC

The EOS-37PTH and EOS-89BTH DSC confinement boundary is designed and fabricated as a Class 1 component in accordance with the rules of the ASME Boiler and Pressure Vessel Code [8-2], Section III, Division 1, Subsection NB and the alternative provisions to the ASME Code as described in Section 4.4.4 of the Technical Specifications (TS) [8-41].

The confinement boundary materials are ASME-approved for Class 1 Components, excepting duplex stainless steels SA-240 UNS S31803 and Type 2205. The higher chromium, molybdenum and nitrogen contents give these materials significantly improved resistance to localized corrosion including intergranular, pitting and crevice corrosion, and chloride-induced stress corrosion cracking (CISCC). Therefore, these materials are used when enhanced long-term resistance to CISCC is required. ASME Code Case N-635-1 [8-3], which has been endorsed by Regulatory Guide 1.84 [8-5], is used as a basis for including duplex stainless steels as alternate DSC confinement boundary materials.

For the DSC surfaces that are exposed to the ambient atmosphere, if the standard grade Type 304 or 316 is specified, the carbon content is limited to 0.03% in order to get the tensile strength of the standard grade, with the sensitization resistance of the 304L or 316L grade material.

The primary structural material for the basket is a high-strength low-alloy (HSLA) steel, which is used for fabrication of the fuel compartments that provide structural support to the fuel assemblies (FAs). Basket component stress intensity allowables used for evaluation of normal and off-normal conditions (ASME Code Service Level A and B) are developed based on the mechanical properties (S_u and S_y) listed in Table 8-10. A strain-based criterion is used for evaluation of the basket for accident conditions (Service Level D). Thus, the basket is regarded as a non-ASME Code component. Specification and acceptance testing of the HSLA steel is included in Chapter 10 and Section 4.3.2 of the TS.

The aluminum plates in the basket perform only a heat conducting function with no credit taken for their strength *in supporting the fuel in the various loading conditions*. The aluminum 6061 peripheral transition rails are entrapped between the fuel compartment structure and the DSC shell. For normal and off-normal loading conditions the primary stresses are limited to S_y. For accident conditions, qualification of the fuel compartment demonstrates that the rails perform their structural support safety function. The transition rails are specified as ASTM B221 or B209 Alloy 6061. The important-to-safety (ITS) Cat C rail fasteners are specified as ASTM A193 Gr B7 material.

The fixed neutron absorber plates are composed of boron carbide/aluminum metal matrix composite or BORAL® (EOS-89BTH DSC only). These materials perform no structural function *in supporting the fuel in the various loading conditions*. They are subject to *TN Americas* specification and acceptance testing described in Chapter 10 and Section 4.3.1 of the TS.

8.2.1.2 EOS-TC Transfer Cask

The TC body is designed to the stress criteria of the ASME Code, Section III, Division 1, Subarticle NF-3200. The upper lifting trunnions and trunnion welds are designed in accordance with the ANSI N14.6 [8-6] stress allowables for a non-redundant lifting device. The TC neutron shields are designed to the stress criteria of Subarticle ND-3200.

The TC structural body is composed of carbon and low-alloy steel using ASME materials. The TC top cover plate (lid) may be made of ASTM aluminum or ASME carbon steel. The trunnions are ASTM martensitic stainless steel. The radial neutron shell is carbon steel for the 125 and 135 ton TCs and aluminum for the removable neutron shield on the 108-ton TC. ASTM materials are used for the neutron shield shell.

The shielding materials in the TC perform no structural function, and therefore are not subject to any design code. The gamma shield is specified as ASTM B29 lead (any grade) and the axial bottom neutron shield as 5% boron high-density polyethylene or un-borated high density polyethylene (HDPE).

All Indicated Changes are Scope Item 5.

8.2.1.3 EOS-HSM Horizontal Storage Module

The applicable codes for EOS-HSM-*RC* are:

- Concrete construction per ACI-318-08 [8-7].
- Concrete Design per ACI-349-06 [8-8].
- DSC support structure design per AISC Manual of Steel Construction [8-11].

The applicable codes for EOS-HSM-SC are:

- *Steel-plate composite design and construction per ANSI/AISC-N690-18 [8-53].*
- *Concrete construction per ACI-318-08 [8-7].*
- *DSC support structure design per AISC Manual of Steel Construction [8-11].*

Cement, aggregate, reinforcing steel, *faceplate, studs, tie bars,* and DSC support structure steel conform to ASTM specifications.

The EOS-HSM concrete *is* designed and constructed using a specified compressive strength of 5,000 psi, normal weight concrete. The specified compressive strength may be determined at 28 days or at test age designated for determination of f'c. The cement is Type II or Type III Portland cement meeting the requirements of ASTM C150. The concrete aggregate meets the specifications of ASTM C33. The reinforcing steel is ASTM A615 or A706 Gr 60 deformed bars placed vertically and horizontally at each face of the walls and roof.

For EOS-HSM-RC, the concrete surface temperature limits criteria are based on the provisions in Section 3.5.1.2 of NUREG-1536, as follows:

- If concrete temperatures in general or local areas are at or below 200 °F for normal/off-normal conditions/occurrences, no tests to prove capability at elevated temperatures or reduction of concrete strength are required.
- If concrete temperatures in general or local areas exceed 200 °F but do not exceed 300 °F, no tests to prove capability at elevated temperatures or reduction of concrete strength are required if the aggregates have a coefficient of thermal expansion (CTE) no greater than $6x10^{-6}$ in/in/°F, or are one of the following materials: limestone, dolomite, marble, basalt, granite, gabbro, or rhyolite.

The above criteria in lieu of the ACI 349-06 requirements do not extend above 300 °F for normal/off-normal conditions and do not modify the ACI 349-06 requirements for accident conditions. Per E.4.2 of ACI 349-06 [8-8], the accident conditions or short-term period (i.e., blocked vent accident transient) concrete temperatures are limited to 350 °F. Higher temperatures are allowed per E.4.3 if tests are provided to evaluate the reduction in strength and this reduction is applied to design allowables. EOS-HSM concrete compressive tests are performed on specimens heated to or above that maximum accident temperature for no less than 40 hours. EOS-HSM concrete temperature testing is performed whenever there is a significant change in the cement, aggregate, or water-cement ratio of the concrete mix design. See Section 5.3 of the Technical Specifications [8-41].

Alternatively, per the ACI 349-13 [8-26] commentary Section RE.4, the specified 28-day compressive strength can be increased to 7,000 psi for EOS-HSM fabrication, in lieu of the above aggregate types or CTE requirements, so that any losses in properties (e.g., compressive strength, modulus of elasticity) resulting from long-term thermal exposure will not affect the safety margins based on the specified 5,000 psi compressive strength used in the design calculations. Additionally, also as indicated in Section RE.4, short, randomly oriented steel fibers may be used to provide increased ductility, dynamic strength, toughness, tensile strength, and improved resistance to spalling. See Section 4.4.4 of the Technical Specification [8-41].

The EOS-HSM steel-plate composite (EOS-HSM-SC) faceplates are constructed from either ASTM A572 Gr. 60 steel or ASTM A36 steel. Steel tie bars that connect the faceplates are either ASTM A706 Gr. 60 when using rebar ties, or ASTM A449 Type 1 when using threaded rod. The steel headed stud anchors that attach the concrete to the faceplate are ASTM A29, Grades 1010-1020.

The EOS-DSC support structure is fabricated from ASTM A913 Gr 70 *or ASTM A572 Gr. 65 for the flat plate support (FPS) option. Both are* coated with an inorganic zinc-rich primer and a high build epoxy enamel finish. A corrosion allowance of 1/16 inch is used in the design calculations. Welding procedures are in accordance with ASME Code Section IX or AWS D1.1 [8-27].

At coastal sites with operational experience of corrosion due to atmospheric chlorides, the DSC support structure steel and weld filler metal have a minimum of 0.20% copper content. Weld material with 1% or more nickel is acceptable in lieu of 0.20% copper content. The copper content is equivalent to weathering steel [8-29], and nickel-bearing weld materials show equivalent corrosion resistance [8-30].

8.2.2 Material Properties

The material properties used in the NUHOMS® EOS System design analyses are listed in Table 8-4 through *Table 8-41* (See Section A.8.2 for the HSM-MX and Section B.8.2 for the 61BTH Type 2 DSC and OS197 TC). Each table cites the source for the properties. Table 8-1 to Table 8-3 tie these materials to the individual components. Emissivity values for the thermal analysis are provided in Section 4.2.1(13).

All Indicated Changes are Scope Item 2.

8.2.2.1 EOS-37PTH and EOS-89BTH DSC

The structural material used in the baskets is a high strength low-alloy (HSLA) steel. The material properties shown in Table 8-10 are used in the structural analysis. If ASTM 829 Gr 4130 is used, AREVA test report [8-24] determines the optimum tempering for the desired toughness and the corresponding minimum yield and tensile strength. The A829 Gr 4130 steel plates are heat-treated and tempered per **[**

] The requirements and acceptance criteria for HSLA steel are specified in Section 10.1.7.

The mechanical properties for the aluminum 6061 used for the basket transition rails are taken in the annealed (T0) condition to consider the effect of overaging at the service temperature near 400 °F. Therefore, the material may be supplied in any temper condition. Creep behavior of these rails is discussed in Section 8.2.6.

8.2.2.2 EOS-TC Transfer Cask

Material properties for the transfer cask body and fixed radial neutron shield shell are provided in Table 8-9 (SA-350 Gr LF3) and Table 8-11 (SA-516 Gr 70). Table 8-12 provides properties for the A182 Gr F6NM trunnion material. The mechanical properties at the welds of the EOS-TC108's removable aluminum neutron shield per Table 8-18 to account for annealing due to welding heat. The balance of the shell is analyzed and specified at the T6 condition per Table 8-17.

The lead shielding is placed in the TC as bricks or sheet. The structural properties of lead used in the drop analysis are provided in Table 8-20(a) and Table 8-20(b). The effective thermal conductivity of the layered lead brick or sheet is calculated in Chapter 4 from the thermal conductivity of lead provided in Table 8-21.

8.2.2.3 EOS-HSM Horizontal Storage Module

In accordance with ACI 349-06, Section E.4.3, the strength properties of the concrete and reinforcing steel used in the EOS-HSM*-RC* structural *analyses* are taken at the maximum calculated temperature. Temperature dependent mechanical properties of concrete and reinforcing steel are taken from [8-4] and presented in Table 8-23 and Table 8-24.

Similarly, temperature dependent material properties for the faceplates, studs, and tie bars for the EOS-HSM-SC are found in Table 8-37 through Table 8-41. The concrete used in the EOS-HSM-SC is identical to that of the EOS-HSM-RC; therefore, Table 8-23 applies.

The material properties of the ASTM A913 Gr 70 steel used for the DSC support structure are listed in Table 8-15. *The material properties for the ASTM A572 Gr. 65 steel used for the flat plate support DSC support structure are listed in Table 8-14a.* The material properties used for the Type 304 stainless steel used for the heat shields are provided in Table 8-5.

8.2.2.4 Materials Employed in the Shielding Analysis

Shielding properties of steel and concrete are obtained from [8-10] and are summarized in Table 8-30. Simple materials consisting of one element are not listed in Table 8-30. Such materials include lead, which is modeled at 11.18 g/cm^3, 98.6% of theoretical density of pure lead. Aluminum is used in the basket plates with a density of 2.7 g/cm^3. The metal matrix composite (MMC) poison is modeled as pure aluminum (no boron) with a density of 2.56 g/cm^3.

Borated polyethylene is used at the bottom of the EOS-TC for neutron shielding. Boron suppresses secondary gamma radiation from hydrogen capture of neutrons. The material is 5% boron by weight. Optionally, un-borated high density polyethylene (HDPE) material may be used. The neutron shielding performance is more sensitive to hydrogen content than boron content, so for both products, the atom density of hydrogen is reduced by 15% to account for potential hydrogen loss due to aging, although the TC components are exposed to temperature and radiation only intermittently. The composition of the borated polyethylene and un-borated HDPE materials used in the EOS-TC models is provided in Table 8-31 and Table 8-31a, respectively.

Concrete used in the EOS-HSM*-RC* is modeled without steel rebar at a density of 140 pcf (2.243 g/cm^3). *Steel plates used to model the EOS-HSM-SC use a density of 7.82 g/cm^3 to account for a reduced concrete density in the EOS-HSM-SC of 139 pcf.*

8.2.2.5 NUHOMS® EOS System Materials Employed in the Criticality Analysis

The Oak Ridge National Laboratory (ORNL) SCALE code package [8-15] contains a standard material data library for common elements, compounds, and mixtures. All materials used for the TC and canister analyses are available in this data library.

A complete list of all the relevant materials used for the criticality evaluation is provided in Table 8-33.

8.2.3 Materials for ISFSI Sites with Experience of Atmospheric Chloride Corrosion

As noted above, austenitic stainless steels for the DSC shell are procured with a maximum 0.03% carbon for reduced sensitization of the heat affected zones. Duplex stainless steels can be substituted as alternate materials when superior resistance to atmospheric chloride induced stress corrosion cracking is required. Fabrication specifications for duplex stainless steel DSCs shall use API 938-C [8-46] and API RP-582 [8-47] to establish requirements for material procurement, weld qualification, and weld process specifications in addition to those required by ASME Code Sections III and IX.

DSC support structures at sites with operational experience of corrosion caused by atmospheric chlorides are fabricated from steels equivalent to weathering steel.

All Indicated Changes are Scope Item 2.

8.2.4 Weld Design and Inspection

The primary confinement boundary consists of the DSC shell, the inner top cover plate, the inner bottom cover plate, the drain port cover and vent port plug, and the associated welds.

The confinement boundary welds made during fabrication of the DSC include the weld of the inner bottom cover plate to the shell and the circumferential and longitudinal seams of the shell. These welds are inspected (radiographic or ultrasonic inspection, and liquid penetrant inspection) in accordance with the requirements of Subsection NB of the ASME Code. The welds applied to the vent port plug and drain port covers and the inner top cover plate during closure operations define the confinement boundary at the top end of the DSC. These welds are examined by multi-level penetrant testing (PT) in accordance with NUREG 1536.

Both shop and field confinement boundary welds are pressure tested and leak tested as described in Chapter 10.

The welds of the TC structural body are designed to the stress limits for ASME Subsection NF for Class 1 supports. Weld inspections are performed by magnetic particle inspection (MT) as specified on the drawings in Chapter 1 with acceptance criteria of ASME Subarticle NF-5340.

The EOS-HSM-SC faceplates are designed in accordance with ANSI/AISC N690-18, and faceplate and corner joint welds are full penetration welds. All welds, including faceplates, studs and tie bars of the EOS-HSM-SC are made in accordance with AWS D1.1.

The DSC support structure is bolted inside the EOS-HSM. The welds of the DSC support structure are designed in accordance with the Manual of Steel Construction [8-11], and visually inspected in accordance with AWS D1.1 with acceptance criteria for statically loaded non-tubular structures.

8.2.5 Galvanic and Corrosive Reactions

Potential sources of chemical or galvanic reactions are the interaction between the aluminum, neutron absorber, and HSLA steel while the DSC is immersed in the pool.

8.2.5.1 Behavior of Aluminum and Neutron Absorbers in Water and Boric Acid

The aluminum component of the MMC and BORAL® is a ductile metal having a high resistance to corrosion. Its corrosion resistance is provided by the buildup of a protective oxide film on the metal surface when exposed to a corrosive environment. As for aluminum, once a stable film develops, the corrosion process is arrested at the surface of the metal. The film remains stable over a pH range of 4.5 to 8.5. There are no chemical, galvanic, or other reactions that could reduce the areal density of boron in the neutron poison plates with either of the poison plate materials.

The pores in the core material exposed at the edges of BORAL® can retain water, which can cause delamination of the skin from the core during drying or storage. This has been evaluated and determined to have no effect on the criticality control function of BORAL® [8-31]. Metal matrix composites are tested to verify they will not be subject to this phenomenon. *Type 4HA baskets utilize anodized aluminum, which provides improved protection against galvanic corrosion.*

The period of immersion is insufficient to cause significant localized corrosion such as pitting or crevice corrosion in the aluminum.

8.2.5.2 Behavior of Stainless Steel in Deionized Water and Weak Boric Acid

The DSC shell and cover plates are made from Type 304 or 316 or duplex stainless steels. Stainless steel does not exhibit general corrosion when immersed in deionized water. Reference [8-43] reports testing type 304 stainless steel for corrosion in saturated boric acid at 70 °F (5% boric acid, 8750 ppm boron) and 140 °F (13% boric acid, 22750 ppm boron). At 70 °F, there was no measureable corrosion, and at 140 °F, corrosion was measured at 7x10-4 inch/year (0.018 mm/year) for consumable electrode welds, and no measureable corrosion for other weld and plate conditions. Typical conditions for pool during loading of the EOS DSC would be up to 3000 ppm boron, water temperature <140 °F in the pool increasing until the time of draining, and duration usually <72 hours, including both immersion in the pool and the time until draining and drying the DSC. Considering the short time and the low boric acid concentration compared to the testing, stainless steel type 304 would show no measureable corrosion, and duplex 2205 would have less corrosion due to its higher chromium content and its molybdenum.

Under PWR reactor operating conditions, stress corrosion cracking has occurred in piping containing stagnant, high concentration boric acid, and stainless steel cladding has cracked [8-44], but the time, temperature, and concentration conditions described in the foregoing paragraph are insufficient to initiate stress corrosion cracking in the stainless steel shell during DSC loading. Galvanic corrosion could occur at contact between the basket perimeter's aluminum rails and the stainless steel DSC shell, with the aluminum corroding sacrificially, but this is mitigated by the passivity of the aluminum and the stainless steel in the short time the pool water is in the DSC. Also, the low conductivity of the pool water tends to minimize galvanic reactions.

8.2.5.3 Behavior of Low-Alloy Steel in Deionized Water and Weak Boric Acid

EPRI-1000975, Boric Acid Corrosion Guidebook, Revision 1 [8-42] provides available boric acid corrosion test data in aerated and deaerated water at various temperatures and soluble boron concentrations.

8.2.8 Protective Coatings and Surface Treatments

No coatings are applied to the DSC surface. The top shield plug of the DSCs is coated with an electroless nickel, [

] The HSLA steel plates of other 37PTH basket types have a coating or surface treatment to provide corrosion resistance for short-term pool immersion.

Anodizing is required for aluminum plates for baskets utilizing HLZCs with maximum decay heat greater than 3.5 kW per fuel assembly. Anodizing requirements for the aluminum basket plates are specified in Section [10.1.6].

Scope Item 1

The exposed carbon steel surfaces of the EOS-TCs are coated with a painting system suitable for spent fuel pool immersion, and withstanding long-term exposure to the elevated temperatures of the TC. Stainless steel surfaces, that is, trunnions, sliding rails, and the stainless steel overlay for the ram access port sealing surfaces are not coated. The removable aluminum neutron shield shell for the EOS-TC108 is painted only on the outer diameter. The following finish enamels are used on the transfer cask:

- PPG Amerishield™ enamel or Carboline Carboguard® 890, color white, is used for the EOS-TC exterior surfaces.
- PPG Amerishield™, color white, is used for coating the exterior of the removable EOS-TC108 neutron shield. This neutron shield is not immersed.
- Carboline Thermaline® 450-EP PPG or Amercoat® 91 is used for coating the EOS-TC interior surfaces, which are exposed to higher service temperatures up to 373 °F (Tables 4-26 and 4-27).

Manufacturer's recommendations are followed for surface preparation, primer coat selection, and coating application.

Alternate coatings that are accepted by licensees for spent fuel pool immersion, and whose short-term service temperature is above the normal condition TC surface temperatures may be used. For solar absorptivity, white color must be maintained where specified.

The DSC support structure in the EOS-HSM, or front and rear DSC supports on the HSM-MX, are coated with an inorganic zinc-rich primer and a high build epoxy enamel finish, for example, Carboline Carbozinc® 11 primer with Carboguard® 890 enamel. *Similarly, EOS-HSM-SC exterior faceplates are coated with either an inorganic or organic zinc-rich primer and epoxy finish coating.* Embedments and fasteners are coated, plated, or galvanized.

Scope Item 2

Coatings are not important to safety except coating or surface treatment for 89BTH and 37PTH type 1, 2, 3, or 4H steel basket plate, which is ITS quality category C.

8-48 Outokumpu, Data Sheet “Duplex Stainless Steel.”

8-49 Euronorm EN485-2, “Aluminium and aluminium alloys - Sheet, strip and plate - Part 2: Mechanical properties.”

8-50 Euronorm EN573-3, “Aluminium and aluminium alloys - Chemical composition and form of wrought products - Part 3: Chemical composition and form of products.”

8-51 “Ryerson Plastics,” Edition 26.

8-52 The Steel Construction Institute, Design Manual for Structural Stainless Steel, 4th Edition, 2017.

8-53 American National Standard, Specification for Safety-Related Steel Structures for Nuclear Facilities, ANSI/AISC-N690-18, June 28, 2018.

Table 8-2
EOS-HSM Materials
(2 Pages)

HSM Subcomponents	Material
EOS-HSM-*RC* walls, roof, floor, end shield walls, rear shield walls	Reinforced concrete with ASTM A615 or A706 Gr 60 reinforcing steel
EOS-HSM-SC walls, roof, end shield walls, rear shield walls, corner walls:	
Faceplates	*ASTM A572 Gr. 60*
Tie bars	*ASTM A706 Gr. 60 or ASTM A449 Type 1*
Studs	*ASTM A29 Gr. 1010-1020*
DSC Support Structure Assembly	ASTM A913 Gr 70 (W Beam Option), ASTM A572 (FPS Option)
Sliding Rail	Nitronic® 60 stainless steel, ASTM A240 UNS S21800
EOS-HSM-*RC* Door*:*	Reinforced concrete
Door Steel Liner Assembly	Steel
Threaded Inserts	Steel
Inspection Penetration Sleeve Door	Stainless Steel
EOS-HSM-SC Door:	
Faceplates	*ASTM A36*
Tie bars	*ASTM A706 Gr. 60 or ASTM A449 Type 1*
Studs	*ASTM A29 Gr. 1010-1020*
Axial retainer assembly:	
Bar Steel	ASTM A588 or ASTM A913 Gr. 70
Miscellaneous (top plate, plate embedment, DSC axial retainer)	Carbon steel
EOS-HSM Heat Shields	Stainless steel ASTM A240 Type 304 or 316
EOS-HSM Roof Attachment Angles and Stiffener Plates	Carbon steel
EOS-HSM-*RC* Outlet Vent Cover	Reinforced concrete
EOS-HSM-RC Outlet Vent Cover Steel Liner	ASTM A36
EOS-HSM-*RC* Inlet Vent Screen Assembly	Carbon Steel

Table 8-2
EOS-HSM Materials
(2 Pages)

HSM Subcomponents	Material
EOS-HSM-SC Outlet Vent Cover:	
Faceplates	*ASTM A36*
Tie bars	*ASTM A706 Gr. 60 or ASTM A449 Type 1*
Studs	*ASTM A29 Gr. 1010-1020*
EOS-HSM-SC Outlet Vent Cover Steel Liner	*ASTM A36*
EOS-HSM-SC Inlet Vent Screen Assembly	*Carbon Steel*
Bird Screens and Dose Reduction Hardware	Stainless steel, Carbon Steel, or Aluminum
Wind deflectors	Aluminum
Segmented EOS-HSM Connecting Hardware	ASTM A722 Gr 150
Fasteners:	
Bolts	ASTM A193 Gr B7/ A325/A563/A490/A108
Washers	ASTM A36/F436/F844/ Stainless Steel
Nuts	ASTM A194/A563/A194/ Carbon Steel
Threaded Embedments:	
Stud Bolt	ASTM A193-B8 CL 2 or ASTM A193-B8M CL 2
Sleeve Nut	ASTM A194 Gr 2H or A563 Gr A
Nut	ASTM A194 Gr 8M or A563 Gr A

All Indicated Changes are Scope Item 2.

Table 8-37
Material Properties, ASTM A-572 Gr. 60

Temp (°F)	E (10^3 ksi)	S_y (ksi)	S_u (ksi)	γ (lb/ft^3)
70	29.0	60.0	75.0	0.28
100	29.0	58.2	75.0	
200	28.4	55.2	73.5	
300	27.8	52.8	75.0	
400	27.3	51.0	75.0	
500	26.7	49.8	75.0	

Table 8-38
Material Properties, ASTM A29 Gr. 1010 through 1020

Temp (°F)	E (10^3 ksi)	S_y (ksi)	S_u (ksi)	γ (lb/ft^3)
70	29.0	51.0	65.0	0.28
100	29.0	49.5	65.0	
200	28.4	46.9	63.7	
300	27.8	44.9	65.0	
400	27.3	43.4	65.0	
500	26.7	42.3	65.0	
600	26.1	41.8	62.4	

Table 8-39
Material Properties, ASTM A706 Gr. 60

Temp (°F)	E (10^3 ksi)	S_y (ksi)	S_u (ksi)	γ (lb/ft^3)
70	29.0	60.0	80.0	0.28
100	29.0	58.2	80.0	
200	28.4	55.2	78.4	
300	27.8	52.8	80.0	
400	27.3	51.0	80.0	
500	26.7	49.8	80.0	
600	26.1	49.2	76.8	

Table 8-40
Material Properties, ASTM A449 Type 1, <1 in. dia.

Temp (°F)	E (10^3 ksi)	S_y (ksi)	S_u (ksi)	γ (lb/ft^3)
70	29.0	92.0	120.0	0.28
100	29.0	89.2	120.0	
200	28.4	84.6	117.6	
300	27.8	81.0	120.0	
400	27.3	78.2	120.0	
500	26.7	76.4	120.0	
600	26.1	75.4	115.2	

All Indicated Changes are Scope Item 2.

Table 8-41
Material Properties, ASTM A449 Type 1, diameters > 1.0 in. to 1 ½ in.

Temp (°F)	*E (10^3 ksi)*	*S_y (ksi)*	*S_u (ksi)*	*γ (lb/ft^3)*
70	29.0	81.0	105.0	0.28
100	29.0	78.6	105.0	
200	28.4	74.5	102.9	
300	27.8	71.3	105.0	
400	27.3	68.9	105.0	
500	26.7	67.2	105.0	
600	26.1	66.4	100.8	

Note: If applicable to the planned DSC heat load zone configuration per *Figure 2-2a, 2b, and 2d through 2f or Figure 2-3a, 3b, and 3d through 3m of Chapter 2*, the air circulation system shall be assembled and verified operational within 7 days prior to initiating transfer operations per Technical Specification LCO 3.1.3 [9-5].

Note: The operating procedures for the NUHOMS 61BTH Type 2 DSC and the OS197 TC are provided in Chapter B.9.

10.1.1.2 HSM

Concrete mix design, placement, and testing are performed in accordance with ACI-318 [10-2]. *For the EOS-HSM-RC, the* minimum concrete compressive strength is 5000 psi if controls are placed on the aggregate type or coefficient of thermal expansion as described in Section 8.2.1.3. If the alternative described in that Section is used, the minimum is 7000 psi. In accordance with American Concrete Institute (ACI) 349 Appendix E, paragraph E.4.3 [10-3], compressive testing of the concrete mix design for the base, roof, and doors is conducted after heating the test cylinders prior to testing. *The* testing of the specimens *is* performed at a temperature of 500 °F per Table 4-17. See Sections 4.4.4 and 5.3 of the Technical Specifications [10-32].

For the EOS-HSM-SC, the minimum concrete compressive strength is 5000 psi. The testing of the specimens are performed at a temperature of 500 °F per Table 4-17. EOS-HSM-SC faceplate, studs, and tie bar materials are procured as ASTM materials, as discussed in Section 8.2.1.3 and are, therefore, tested for their mechanical properties in accordance with their respective specifications.

The reinforcing steel *for the EOS-HSM-RC*, ITS fasteners, and steel for the door and the DSC support structure are tested for mechanical properties in accordance with the governing specifications called out on the drawings in Chapter 1.

Weld procedures and welders for the *faceplates, studs, and tie bars for the EOS-HSM-SC, and the* DSC support structure *for all EOS-HSMs* are qualified in accordance with ASME Code Section IX or American Welding Society (AWS) D1.1 [10-4].

10.1.1.3 Transfer Cask

The TC structural assembly welds are performed in accordance with ASME Code Section IX, and examined by magnetic particle examination (MT) to the acceptance standards of ASME Code Section III, Subarticle NF-5340. The upper trunnions are load tested at fabrication to three times the design load, and inspected afterwards in accordance with ANSI N14.6 [10-5].

The liquid neutron shield shell is hydrostatically tested to 1.25 times the pressure relief valve setting shown on the drawings in Chapter 1.

Transfer Cask	Test Load, Each Upper Trunnion (ton)	Neutron Shield Test Pressure (psig)
108 ton	162	35
125 ton	187.5	31.25
135 ton	202.5	31.25

All Indicated Changes are Scope Item 2.

10.1.3.2 HSM

Reinforcing steel placement *in the EOS-HSM-RC* is inspected in accordance with ACI 117 [10-9] and cured concrete is visually inspected in accordance with ACI 311.4R *for all EOS-HSMs* [10-10].

Weld inspections and inspector qualifications conform to AWS D1.1.

10.1.3.3 Transfer Cask

The load-bearing welds for the EOS-TC structural body are inspected by MT as specified on the drawings in Chapter 1, with acceptance criteria of ASME Subarticle NF-5340. Non-destructive examination personnel are qualified in accordance with SNT-TC-1A.

10.1.4 Shielding Tests

10.1.4.1 DSC

The shielding performance of the top and bottom shield plugs and cover plates of the DSC is verified by their material certifications and dimensional inspections. No further testing is required.

10.1.4.2 HSM

The HSM concrete is tested in accordance with ASTM C138 [10-11] to verify a minimum density of 140 lb/ft^3 *for the EOS-HSM-RC and 139 pcf for the EOS-HSM-SC*.

The shielding capability of the faceplates of the EOS-HSM-SC is verified by its material certifications and dimensional inspections. No further testing is required.

10.1.4.3 Transfer Cask

The TC lead shielding is installed as lead sheet or interlocking lead bricks, rather than being cast in place. The neutron shield material in the lid and bottom end is also installed as solid sheets of borated high density polyethylene. Shielding performance is verified by material certification and dimensional inspection.

The radial neutron shielding is provided by filling the neutron shield shell with water during operations. No testing is necessary.

10.1.5 Neutron Absorber Tests

The neutron absorber used for criticality control in the DSC baskets may consist of one of the following materials:

- Boron carbide/aluminum metal matrix composite (MMC)

Potential change effect	Example
Reduction of the yield or ultimate strength or the elongation	Increase in nominal boron carbide content over that previously qualified
Adverse effect on the uniformity of boron carbide distribution at the microscopic scale	Increase in the boron carbide particle size
Adverse effect on the uniformity of boron carbide distribution at the macroscopic level	Change in the blending process
Reduced density of the final product	Change in the method of billet production or thermo-mechanical processing to plate
Adverse reaction between the boron carbide and the matrix alloy under normal and off-normal service temperatures	Change in the matrix alloy
Lower corrosion resistance or higher rate of hydrogen generation	Change in the matrix alloy

Identification and Control of Key Process Changes

The manufacturer provides the Certificate Holder with a description of materials and process controls used in producing the MMC. The Certificate Holder and manufacturer prepare a written list of key process changes that cannot be made without prior approval of the Certificate Holder.

10.1.6 Thermal Acceptance

10.1.7 High-Strength Low-Alloy Steel for Basket Structure

The basket structural material shall be a High-Strength Low-Alloy (HSLA) steel meeting one of the following requirements A, B, or C:

A. ASTM A829 Gr 4130 or AMS 6345 SAE 4130, quenched and tempered at not less than 1050 °F, 103.6 ksi minimum yield strength, and 123.1 ksi minimum ultimate strength. This material is qualified as described in [10-31].

B. ASME Code edition 2010 with 2011 addenda, SA-517 Gr A, B, E, F, or P. This material is qualified by the material properties at elevated temperature in ASME Section II, Part D, which exceed the values of yield and ultimate strength in UFSAR Table 8-10.

10.3 Repair, Replacement, and Maintenance

10.3.1 Transfer Cask Repair, Replacement, and Maintenance

Typical repair, replacement, and maintenance activities include:

- Paint damage is repaired by surface preparation and application of the original paint system.
- Raised burrs from wear are removed by light abrasives, followed by paint repair as necessary.
- Wear damage that violates a design minimum dimension is corrected by weld repair, followed by paint repair as necessary.
- Bolts, screw thread inserts, quick connect fittings, and the ram access port o-ring are replaced as needed.
- TC 108 removable neutron shield latches, hinges and hinges are replaced as needed.
- Bolt threads and removable neutron shield hinges are lubricated as needed.
- Rust on unpainted wear surfaces at the upper trunnions and lower sockets can be limited by temporary coatings when not in use.
- The neutron shield is filled with potable water prior to each loading campaign, and drained afterwards.
  - **[**

    ]
- Abrasive pads such as Scotch-Brite™ should not be used to decontaminate painted surfaces. Abrasive pads degrade the paint's ease of decontamination.

10.3.2 HSM Repair, Replacement, and Maintenance

Cracking or other damage noted by visual inspection is generally entered into the licensee's corrective action program and repair or maintenance actions are developed with the help of *TN Americas.* Examples of typical exterior surface repairs *for the EOS-HSM-RC* are:

- Cracks below acceptable width – verify soundness of concrete by rebound hammer, and apply concrete sealant.
- Cracks above acceptable width – Fill crack with epoxy or cement –based grout, then apply concrete sealant.
- Damage greater than cracking (spalling, corner breaks) – repair using 5000 psi grout and bonding agent.

Examples of typical exterior surface repairs for the EOS-HSM-SC include:

- *Coating scratching or damage - Evaluate extent of damage and determine if coating repair is required. Coat affected area with coating or sealant to mitigate rusting or additional coating damage*
- *Chips or cracks in the faceplate below acceptable width - Verify soundness of faceplate and apply sealant and/or coating*
- *Chips or cracks in the faceplate above acceptable width- Repair with weld filler material and apply sealant and/or coating per ANSI/AISC N690-18 [10-33].*

It is expected that the steel faceplate is much less susceptible to environmental conditions than the reinforced concrete, and a corrosion allowance of 1/8" provides significant margin for any defects that may occur over the lifetime of the EOS-HSM-SC.

10.3.3 Maintenance of Thermal Monitoring System

In lieu of visual inspection for vent blockage, the licensee has the option to monitor the temperature by thermocouples or resistor temperature detectors inserted into wells embedded in the HSM roof. The licensee is responsible for maintenance and calibration of this temperature monitoring instrumentation and data collection.

10-17 ASTM E1461, “Standard Test Method for Thermal Diffusivity by the Flash Method,” ASTM International, West Conshohocken, PA, 2014.

10-18 USNRC SFST-ISG-23, Application of ASTM Standard Practice C1671-07 when performing technical reviews of spent fuel storage and transportation packaging licensing actions

10-19 ASTM B557, “Standard Test Methods for Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products,” ASTM International, West Conshohocken, PA, 2014.

10-20 ASTM E290-14, “Standard Test Methods for Bend Testing of Material for Ductility,” ASTM International, West Conshohocken, PA, 2014.

10-21 NUREG-0933, “Resolution of Generic Safety Issues: Issue 196: Boral Degradation, (Main Report with Supplements 1–34), U.S. Nuclear Regulatory Commission, December 2011.

10-22 ASTM A829, “Standard Specification for Alloy Structural Steel Plates,” ASTM International, West Conshohocken, PA, 2014.

10-23 **[ ]**

10-24 ASTM A370, “Standard Test Methods and Definitions for Mechanical Testing of Steel Products,” ASTM International, West Conshohocken, PA, 2014.

10-25 ASTM E604, “Standard Test Method for Dynamic Tear Testing of Metallic Materials,” ASTM International, West Conshohocken, PA, 2014.

10-26 Not used.

10-27 ACI 201.1R, “Guide for Conducting a Visual Inspection of Concrete in Service,” American Concrete Institute, 2008.

10-28 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 (0.1 m),” June 1991.

10-29 ASTM B311, “Standard Test Method for Density of Powder Metallurgy (PM) Materials Containing Less Than Two Percent Porosity,” ASTM International, West Conshohocken, PA, 2014.

10-30 ASTM B963, “Standard Test Methods for Oil Content, Oil-Impregnation Efficiency, and Surface-Connected Porosity of Sintered Powder Metallurgy (PM) Products Using Archimedes' Principle,” ASTM International, West Conshohocken, PA, 2014.

10-31 **[ ]**

10-32 CoC 1042 Appendix A, “NUHOMS® EOS System Generic Technical Specifications,” Amendment *4*.

10-33 American National Standard, Specification for Safety-Related Steel Structures for Nuclear Facilities, ANSI/AISC-N690-18, June 28, 2018.

The estimated occupational exposures to ISFSI personnel during loading, transfer, and storage operations using the EOS-TC108 (time and number of workers may vary depending on individual ISFSI practices) are provided in Table 11-2 and Table 11-3 for the EOS-37PTH DSC and EOS-89BTH DSC, respectively. Similar operations for the EOS-TC125/135 are provided in Table 11-4 and Table 11-5. The task times, number of personnel required, and total doses are listed in these tables. The total exposure results are as follows:

Item 1

- EOS-TC108 with EOS-37PTH DSC: 6504 person-mrem (6.5 person-rem)
- EOS-TC108 with EOS-89BTH DSC: 3270 person-mrem (~3.3 person-rem)
- EOS-TC125/135 with EOS-37PTH DSC: *5393* person-mrem (*5.4* person-rem)
- EOS-TC125 with EOS-89BTH DSC: *6980* person-mrem (~*7.0* person-rem)

For equivalent sources, the EOS-TC108 results in larger exposures than the EOS-TC125/135 because it is a lighter cask and provides less shielding. *T*he exposure due to *a* crane hang-up off-normal event is also considered. *The additional dose due to a crane hang-up event is provided in the footnotes of Table 11-2 through Table 11-5.*

The EOS-TC125/135 may utilize an optional aluminum top cover plate that is exchanged for a steel top cover plate after downending. For the EOS-TC135, this option is applicable only to the EOS-TC135 with the EOS-37PTH DSC, since the EOS-89BTH DSC is not an allowed content in the EOS-TC135. The exposure calculations in Table 11-4 and Table 11-5 are based on a steel top cover plate. If the aluminum top cover plate option is used, the total exposure will increase by approximately *220 person-mrem and 130 person-mrem for the EOS-37PTH DSC and EOS-89BTH DSC, respectively.*

Use of a minimum 74.0 inch diameter shield plug for the EOS-37PTH DSC *when transferred in the EOS-TC108* results in a negligible increase in occupational exposure (<5%). *The effect of the 74.0-inch diameter shield plug is included in the EOS-TC125/135 exposures provided in Table 11-4.*

The exposures provided above are bounding estimates. Measured exposures from typical NUHOMS® System loading campaigns have been *0.6 person-rem* or lower per canister for normal operations, and exposures for the NUHOMS® EOS System are expected to be similar. *Measured occupational exposure data for three EOS-HSM loading campaigns using the EOS-37PTH DSC are provided in Table 11-5a. The average measured occupational exposures range from 0.16 person-rem to 0.75 person-rem and are significantly lower than the computed value of 5.4 person-rem.*

Regulatory Guide 8.34 [11-4] is to be used to define the onsite occupational dose and monitoring requirements.

Item 6

The preceding analyses and results are intended to provide high estimates of dose rates for generic ISFSI layouts. The written evaluations performed by a general licensee for the actual ISFSI must consider the type and number of storage units, layout, characteristics of the irradiated fuel to be stored, site characteristics (e.g., berms, distance to the controlled area boundary, etc.), and reactor operations at the site in order to demonstrate compliance with 10 CFR 72.104.

11.3.2 Accident Conditions (10 CFR 72.106)

Per 10 CFR 72.106, the exposure to an individual at the site boundary due to an accident is limited to 5 rem. In an accident, the EOS-HSM outlet vent covers and wind deflectors (if required) may be lost. Only the dose rates on the roof are affected, since the front, rear, and side dose rates remain the same. As the dose rates at large distances are mostly due to skyshine from the roof, the dose rates at the site boundary are directly affected. The average EOS-HSM roof dose rates and surface fluxes in an accident are computed in Chapter 6, Tables 6-56 through 6-58 for the EOS-89BTH DSC and Tables 6-58a through 6-58c for the EOS-37PTH DSC. Under accident conditions, the roof dose rate for the EOS-89BTH DSC is larger than the roof dose rate for the EOS-37PTH DSC (*18,800* mrem/hr vs. *12,400* mrem/hr). Therefore, accident dose rates are reported only for the EOS-89BTH DSC.

Table 11-10 shows the bounding dose rate as a function of distance from a 2x10 back-to-back array of EOS-HSMs for the accident configuration described above. These dose rates are calculated assuming that the outlet vent covers and wind deflectors (if required) for the entire array are lost.

MCNP inputs for a 2x10 ISFSI accident configuration are prepared using the same method as described for the normal condition models. At a distance of 200 m and *450* m from the ISFSI, the accident dose rate is approximately *2.6* mrem/hr and 0.1 mrem/hr, respectively. It is assumed that the recovery time for this accident is five days (120 hours). Therefore, the total exposure to an individual at a distance of 200 m and *450* m is *312* mrem and 12 mrem respectively. This is significantly less than the 10 CFR 72.106 limit of 5 rem.

The EOS-TC may also be damaged in an accident during transfer operations, which would result in an offsite dose. For accident conditions, it is assumed that the neutron shield, including the steel or aluminum shell, is absent. The EOS-TC accident calculations are documented in Section 6.4.3 and the results presented in Table 6-54. Per Section 6.4.3, the estimated dose to an offsite individual is significantly below the 10 CFR 72.106 limit of 5 rem. This dose is also conservatively large because it is calculated as a distance of 100 m from the EOS-TC.

Table 11-1
Occupational Dose Rates

			Dose Rate (mrem/hr)			
			EOS-TC108		**EOS-TC125/135**	
Dose Rate Location	**Averaged Segments**	**Config.**	**EOS-37PTH DSC HLZC 4**	**EOS-89BTH DSC *HLZC 2***	**EOS-37PTH DSC *Shielding* HLZC**	**EOS-89BTH DSC *Shielding HLZC***
DRL1	A1-18, R11	Decon.	496	194	*244*	*389*
DRL2	A3-16, R10	Decon.	-	-	*735*	*1139*
		Transfer	1534	747	*671*	*1221*
DRL3	A17, R9	Decon.	-	-	*478*	*161*
		Welding	384	198	*285*	*209*
		Transfer	358	199	-	-
DRL4	A3-11, R9	Decon.	2467	1050	-	-
DRL5	A1-18, R10	Transfer	1162	586	*519*	*931*
DRL6	A17-18, R9	Transfer	183	100	*114*	*84*
DRL7	A17-18, R10	Transfer	361	189	*216*	*191*
DRL8	A2, R9	Transfer	92	165	*80*	*147*
DRL9	A19, R0	Transfer	69	137	*101*	*164*
DRL10	A1, R10	Transfer	113	121	*64*	*126*
EOS-HSM (HSM)	Front face surface average	-	25	22	*40*	*60*

Table 11-4
Occupational Exposure, EOS-TC125/135 with EOS-37PTH DSC *Shielding* HLZC
(2 Pages)

No.	Operation	Configuration	Dose Rate Location	No. of People	Duration (hr)	Dose Rate (mrem/hr)	Dose (person -mrem)	% of Total Dose
1	Drain neutron shield if necessary. Place an empty EOS-DSC into an EOS-TC and prepare the EOS-TC for placement into the spent fuel pool.	N/A	N/A	6	4	0	0	0%
2	Move the EOS-TC containing an EOS-DSC without fuel into the spent fuel pool.	N/A	N/A	6	1.5	0	0	0%
3	Remove a loaded EOS-TC from the fuel pool and place in the decontamination area. Refill neutron shield tank if necessary.	Decon.	DRL1	2	0.25	*244*	*122*	2%
4	Decontaminate the EOS-TC and prepare welds.	Decon.	DRL2	2	1.75	*735*	*2572*	*48%*
		Decon.	DRL3	2	0.5	*478*	*478*	*9%*
5	Weld inner top cover plate.	Welding	DRL3	2	0.75	*285*	*428*	8%
6	Vacuum dry and backfill with helium.	Welding	DRL3	2	0.5	*285*	*285*	*5%*
7	Weld outer top cover plate and port covers, perform non-destructive examination.	Welding	DRL3	2	0.5	*285*	*285*	*5%*
8	Drain annulus. Install EOS-TC top cover. Ready the support skid and transfer trailer.	Transfer	DRL5	1	0.5	*519*	*260*	*5%*
9	Place the EOS-TC onto the skid and trailer. Secure the EOS-TC to the skid.	Transfer	DRL2	2	0.33	*671*	*443*	*8%*
10	Ready the skid and trailer for service. Transfer the EOS-TC to ISFSI. Position the EOS-TC in close proximity with the EOS-HSM.	N/A	N/A	6	1.83	0	0	0%
11	Remove the EOS-TC top cover.	Transfer	HSM+DRL6	2	0.67	*154*	*206*	4%

Table 11-4
Occupational Exposure, EOS-TC125/135 with EOS-37PTH DSC ***Shielding*** HLZC
(2 Pages)

No.	Operation	Configuration	Dose Rate Location	No. of People	Duration (hr)	Dose Rate (mrem/hr)	Dose (person-mrem)	% of Total Dose
12	Align and dock the EOS-TC with the EOS-HSM.	Transfer	HSM+DRL7	2	0.25	*256*	*128*	2%
13	Position and align ram with EOS-TC.	Transfer	HSM+DRL8	2	0.5	*120*	*120*	2%
14	Remove ram access cover plate.	Transfer	DRL9	1	0.08	*101*	*8*	0%
15	Transfer the EOS-DSC from the EOS-TC to the EOS-HSM.	N/A	N/A	3	0.5	0	0	0%
16	Lift the ram back onto the trailer and un-dock the EOS-TC from the EOS-HSM.	Transfer	HSM+DRL10	2	0.08	*104*	*17*	0%
17	Install EOS-HSM access door.	Transfer	HSM	2	0.5	*40*	*40*	1%
						Total(1)	*5393*	

Note:

(1) Use of aluminum cask lid increases total occupational dose by approximately 4 % *(~220 person-mrem)*.

*(2) A crane hang-up off-normal event adds 976 person-mrem (DRL1/decon * 4 workers * 1 hour).*

Table 11-5a
Measured Occupational Exposures

Loading Campaign	***DSC***	***Average DSC Heat Load (kW)***	***Average Occupational Exposure (person-rem)***
1	*EOS-37PTH*	*44.7*	*0.61*
2	*EOS-37PTH*	*23.0*	*0.16*
3	*EOS-37PTH*	*39.8*	*0.75*

12.3 Postulated Accident

The design basis accident events specified by ANSI/ANS 57.9-1984 [12-2] and other postulated accidents that may affect the normal safe operation of the NUHOMS® EOS System (except as modified by the information in Appendix A Section A.10 for the HSM-MX, and Appendix B Section B.10 for the NUHOMS 61BTH Type 2 DSC and OS197 TC) are addressed in this section.

The following sections provide descriptions of the analyses performed for each accident condition. The analyses demonstrate that the requirements of 10 CFR 72.122 [12-1] are met and that adequate safety margins exist for the NUHOMS® EOS System design. The resulting accident condition stresses in the NUHOMS® EOS System components are evaluated and compared with the applicable code limits set forth in Chapter 2.

Radiological calculations are performed to confirm that on-site and off-site dose rates are within acceptable limits.

The postulated accident conditions addressed in this section include:

- EOS-TC drop
- Earthquake
- Tornado wind pressure and tornado-generated missiles
- Flood
- Blockage of EOS-HSM air inlet and outlet openings
- Lightning
- Fire/Explosion

12.3.1 EOS-TC Drop

Cause of Accident

As described in Chapter 9, handling operations involving hoisting and movement of EOS-TC loaded with the EOS-37PTH DSC or EOS-89BTH DSC is typically performed inside the plant's fuel handling building. These include utilizing the crane for placement of the empty DSC into the EOS-TC cavity, lifting the EOS-TC/DSC into and out of the plant's spent fuel pool, and placement of the EOS-TC/DSC onto the transfer skid/trailer. An analysis of the plant's lifting devices used for these operations, including the crane and lifting yoke, is needed to address a postulated drop accident for the *EOS*-TC and its contents. The postulated drop accident scenarios addressed in the plant's 10 CFR Part 50 [12-3] licensing basis are plant-specific and should be addressed by the licensee.

Corrective Actions

After a seismic event, all components are inspected for damage. Any debris is removed. An evaluation is performed to verify that the system components are still within the licensed design basis.

12.3.3 Tornado Wind and Tornado Missiles Effect on EOS-HSM

Cause of Accident

In accordance with ANSI-57.9 [12-2] and 10 CFR 72.122 [12-1], the NUHOMS® EOS System is designed for tornado effects, including tornado wind loads. In addition, the NUHOMS® EOS System is designed to withstand tornado missile effects. The NUHOMS® EOS System is designed to be located anywhere within the United States. Therefore, the most severe tornado wind and missile loadings specified by NUREG-0800 [12-7] and NRC Reg. Guide 1.76 [12-8] are selected as a design basis for this postulated accident. The determination of the tornado wind pressures and tornado missile loads acting on the NUHOMS® EOS System are detailed in Chapter 2, Section 2.3.1.

Accident Analysis

Stability and stress analyses are performed to determine the response of the EOS-HSM to tornado wind pressure loads. The stability analyses are performed using closed-form calculation methods to determine the sliding and overturning response of the EOS-HSM array. A single EOS-HSM with both the end and the rear shield walls is conservatively selected for the analyses. The stress analyses are performed using the ANSYS [12-9] finite element model of a single EOS-HSM to determine design forces and moments. These conservative generic analyses envelop the effects of wind pressures on the EOS-HSM array. These analyses are described in Appendix 3.9.7, Section 3.9.7.1. Thus, the requirements of 10 CFR 72.122 are met.

In addition, the EOS-HSM is evaluated for tornado missiles. The adequacy of the EOS-HSM to resist tornado missile loads is also addressed in Appendix 3.9.7.

Accident Dose Calculation

As shown in the above evaluations, the tornado wind and tornado missiles do not breach the EOS-HSM such that the DSC confinement boundary is *compromised*. Localized scabbing of the end shield wall of an EOS-HSM array may be possible.

The EOS-HSM outlet vent covers and wind deflectors (if required) may be lost due to a tornado or tornado missile event. Only the dose rates on the roof are affected, since the front, rear, and side dose rates remain the same. Information in Chapters 6 and 11 is used to determine that the EOS-HSM accident increases the average dose rate on the roof of the module to ~*18,800* mrem/hr.

A.6.2 Source Specification

Source term information in Section 6.2 is applicable to the HSM-MX evaluation.

A.6.2.1 Computer Programs

No change to Section 6.2.1.

A.6.2.2 PWR and BWR Source Terms

Item #5

Dose rate evaluations are performed for the HSM-MX filled with either the EOS-89BTH or EOS-37PTH DSC. EOS-89BTH DSC source terms are developed for the EOS-HSM analysis in Section 6.2. These source terms are provided in Table 6-27 through Table 6-29*a* and maximize the dose rates at the vents. These source terms are used without modification in the HSM-MX analysis in both the lower and upper compartments. *The source terms are developed for a shielding HLZC that bounds HLZC 1 through 6. This approach adds significant conservatism because the shielding HLZC features 1.3 kW/FA and 1.7 kW/FA on the basket periphery, with a total peripheral as-modeled loading of 42.8 kW. The total as-modeled loading within the basket is 82.8 kW/DSC. The maximum allowed heat load per EOS-89BTH DSC is 48.2 kW. Furthermore, each fuel assembly includes five irradiated stainless steel rods consistent with a reconstituted fuel assembly source.*

EOS-37PTH DSC HLZC 4 and 10 source terms are developed for the EOS-HSM analysis in Section 6.2, and it is demonstrated that HLZC 10 bounds HLZC 4. Therefore, HLZC 10 sources are used in HSM-MX analysis in both the upper and lower compartments. HLZC 10 sources are defined in Table 6-19a through Table 6-19c. HLZC 10 is not authorized for use in the HSM-MX but results in bounding source terms and dose rates compared to HLZC 11. HLZC 10 allows eight 3.5 kW FAs, while HLZC 11 allows only four 3.5 kW FAs and four 3.2 kW FAs in the lower compartment and allows only eight 3.0 kW FAs in the upper compartment. In addition, the same control component (CC) source is used in each basket location, as defined in Table 6-37.

A.6.2.3 Axial Source Distributions and Subcritical Neutron Multiplication

No change to Section 6.2.3.

A.6.2.4 Control Components

The control component (CC) source developed in Section 6.2.4 presented in Table 6-37 is used in the HSM-MX analysis for storage of the EOS-37PTH DSC. The CC source corresponds to a cooling time of 2 years.

Item #1

A.6.2.5 Blended Low Enriched Uranium Fuel

No change to Section 6.2.5.

A.6.2.6 Reconstituted Fuel

A.6.2.7 Irradiation Gases

No change to Section 6.2.7.

A.6.2.8 Justification for the Reasonably Bounding Source Term Methodology

No change to Section 6.2.8.

A.6.5 Supplemental Information

A.6.5.1 Fuel Qualification

No change to Section 6.5.1.

A.6.5.2 References

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

A.6-2 CoC 1042 Appendix A, NUHOMS® EOS System Generic Technical Specifications, Amendment *4*.

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

A.6-4 Oak Ridge National Laboratory, "MCNP6.1/MCNP5/MCNPX Monte Carlo N-Particle Transport Code System Including MCNP6.1, MCNP5-1.60, MCNPX-2.7.0 and Data Libraries," CCC-810, RSICC Computer Code Collection, August 2013.

A.6-5 ORNL/TM-2005/39, SCALE Code System, Version 6.2.4, Oak Ridge National Laboratory, April 2020.

A.6.5.3 HSM-MX MAVRIC Calculations

The dose rate software used in the analysis presented in this chapter is MCNP5 [A.6-1]. An alternate dose rate computational tool is the MAVRIC software, included with SCALE 6.2 [A.6-5]. Like MCNP5, MAVRIC is a Monte Carlo radiation transport program that can perform most of the functions of MCNP5. In this section, dose rates are compared between MAVRIC and MCNP5 to demonstrate the acceptability of MAVRIC as a computational tool.

The HSM-MX "triple reflection" MCNP5 dose rate results on the surface of the HSM-MX are compared to an equivalent MAVRIC calculation. The EOS-37PTH DSC is modeled. The MCNP5 model features a reflective boundary on the left, right, and rear of the module. MAVRIC cannot utilize reflective boundaries, so the MAVRIC model is an explicit 2x11 configuration, as illustrated in Figure A.6-12.

The MAVRIC source terms are input consistent with the EOS-37PTH DSC HLZC 10, as provided in Table 6-19a through Table 6-19c. As a simplification, the hardware source terms (i.e., bottom nozzle, plenum, and top nozzle) are input consistent with a Co-60 spectrum in MAVRIC since the hardware source terms are essentially due to Co-60. The control component source is also included in the MAVRIC analysis, consistent with Table 6-37.

The MAVRIC model is constructed using the same geometry and materials as the equivalent MCNP models. Front and roof dose rates are computed in separate models to optimize the importance map used to transport particles to the tallies. The tallies are computed over equivalent areas as the MCNP5 tallies. Continuous energy library ce_v7.1_endf is utilized.

The MAVRIC dose rates are provided in the upper portion of Table A.6-15, and the equivalent MCNP5 dose rates are provided in Table A.6-2a. A comparison between MCNP5 and MAVRIC is provided in the lower portion of Table A.6-15. It is observed that:

- *With the exception of the upper compartment outlet vent dose rate, the total dose rate for the two programs agree within 5%, which is excellent agreement.*
- *For the upper compartment outlet vent, the MCNP5 result is approximately 30% larger than the equivalent MAVRIC result. This difference is likely due to geometry differences in the modeling. As indicated in Figure A.6-6, reflective boundaries in the x-direction are applied in the MCNP5 models, although the HSM-MX roof is not symmetric in the x-direction. Therefore, the MCNP5 representation is approximate in the roof region. The MAVRIC representation does not include this approximation because 11 DSCs are modeled in a row, as shown in Figure A.6-12.*

- *It is concluded that MAVRIC is an acceptable radiation transport program that generates similar dose rates to MCNP5 for equivalent sources and geometry. Therefore, either MCNP5 or MAVRIC may be used for all 10 CFR Part 72 dose rate licensing actions related to the EOS system, including HSM-MX, EOS-HSM, EOS-TC125, and site dose analysis.*

Proprietary Information on Pages A.6-35 and A.6-36
Withheld Pursuant to 10 CFR 2.390

All Indicated Changes are Scope Item 3

Proprietary Information on This Page
Withheld Pursuant to 10 CFR 2.390

A.10.1 Acceptance Tests

The addition of the HSM-MX to the standardized NUHOMS® EOS system does not result in any change to the pre-operational tests described in Section 10.1, since the EOS-DSCs and EOS-TCs involved are not changed.

A.10.1.1.1 DSC

No change to Section 10.1.1.1.

A.10.1.1.2 HSM-MX

Concrete mix design, placement, and testing are performed in accordance with ACI-318 [A.10-1]. The minimum 28-day compressive strength is 5000 psi if controls are placed on the aggregate type or coefficient of thermal expansion as described in Section 8.2.1.3. If the alternative described in that section is used, the minimum is 7000 psi. In accordance with American Concrete Institute (ACI) 349 Appendix E, paragraph E.4.3 [A.10-2], compressive testing of the concrete mix design for the monolith, and doors is conducted after heating the test cylinders prior to testing. For the HSM-MX, the testing of the specimens are performed at a temperature of 500 °F per Table 4-17. See Sections 4.4.4 and 5.3 of the Technical Specifications [A.10-4].

The reinforcing steel, ITS fasteners, and steel for the door and the front and rear DSC supports are tested for mechanical properties in accordance with the governing specifications called out on the drawings in Chapter A.1.

Weld procedures and welders for the front and rear DSC supports are qualified in accordance with ASME Code Section IX or American Welding Society (AWS) D1.1 [A.10-3].

A.10.1.1.3 Transfer Cask

No change to Section 10.1.1.3.

A.10.1.2 Leak Tests

No change to Section 10.1.2.

A.10.1.3 Visual Inspection and Non-Destructive Examinations

No change to Section 10.1.3.

A.10.1.4 Shielding Tests

No change to Section 10.1.4 *for sections related to the EOS-HSM-RC System*.

A.10.1.5 Neutron Absorber Tests

No change to Section 10.1.5.

All Indicated Changes are Scope Item 2.

A.10.3 Repair, Replacement, and Maintenance

No change to Section 10.3 associated with the addition of the HSM-MX. Requirements of Section 10.3.2 for the *EOS-HSM RC* are applicable to the HSM-MX.

A.10.4 References

A.10-1 ACI 318-08, "Building Code Requirements for Structural Concrete and Commentary," American Concrete Institute, Detroit, MI.

A.10-2 ACI 349-06, "Code Requirements for Nuclear Safety Related Structures," American Concrete Institute, Detroit, MI.

A.10-3 American Welding Society, AWS D1.1/D1.1M, "Structural Welding Code – Steel."

A.10-4 CoC 1042 Appendix A, NUHOMS® EOS System Generic Technical Specifications, Amendment *4*.

All Indicated Changes are Scope Item 2.

A.11.2 Occupational Dose Assessment

This section provides estimates of occupational dose for typical EOS transfer cask (EOS-TC) and ISFSI loading operations. Assumed annual occupancy times, including the anticipated maximum total hours per year for any individual, and total person-hours per year for all personnel for each radiation area during normal operation and anticipated operational occurrences, will be evaluated by the licensee in a 10 CFR 72.212 evaluation to address the site-specific ISFSI layout, inspection, and maintenance requirements. In addition, the estimated annual collective doses associated with loading operations will be addressed by the licensee in a 10 CFR 72.212 evaluation.

A.11.2.1 EOS-DSC Loading, Transfer, and Storage Operations

The dose rates used in the occupational dose assessment are summarized in Table A.11-1. The EOS-TC loading and transfer dose rates are unchanged from the values presented in Chapter 11. The HSM-MX dose rate reported in Table A.11-1 is the average dose rate on the front surface of an HSM-MX and is obtained from Chapter A.6.

The estimated occupational exposures to ISFSI personnel during loading, transfer, and storage operations using the EOS-TC108 (time and number of workers may vary depending on individual ISFSI practices) are provided in Table A.11-1a and Table A.11-2 for the EOS-37PTH DSC and EOS-89BTH DSC, respectively. Similar operations for the EOS-TC125/135 are provided in Table A.11-3 and Table A.11-4. The task times, number of personnel required, and total doses are listed in these tables. The total exposure results are as follows:

- EOS-TC108 with EOS-37PTH DSC: 8,690 person-mrem (~8.7 person-rem)
- EOS-TC108 with EOS-89BTH DSC: 4,535 person-mrem (~4.5 person-rem)
- EOS-TC125/135 with EOS-37PTH DSC: 4,231 person-mrem (~4.2 person-rem)
- EOS-TC125 with EOS-89BTH DSC: *10,038* person-mrem (~*10.0* person-rem)

Use of a minimum 74.0 inch diameter shield plug for the EOS-37PTH DSC results in a negligible increase in occupational exposure (<5%).

The exposures provided above are bounding estimates. Measured exposures from typical NUHOMS® System loading campaigns have been *0.6 person-rem* or lower per canister for normal operations, and exposures for the HSM-MX are expected to be similar. *For an HSM-MX loading campaign using the EOS-37PTH DSC with an average DSC heat load of approximately 30 kW, the measured average occupational exposure is 0.33 person-rem. The measured exposure is significantly lower than the computed value of 4.2 person-rem*

Regulatory Guide 8.34 [A.11-4] is to be used to define the onsite occupational dose and monitoring requirements.

Table A.11-1
Occupational Dose Rates

			Dose Rate (mrem/hr)			
			EOS-TC108		**EOS-TC125/135**	
Dose Rate Location	**Averaged Segments**	**Config.**	**EOS-37PTH DSC**	**EOS-89BTH DSC**	**EOS-37PTH DSC *HLZC 10***	**EOS-89BTH DSC**
DRL1	*A1-18, R11*	*Decon.*	*(1)*	*(1)*	*142*	*(1)*
DRL2	*A3-16, R10*	*Decon.*			*431*	
		Transfer			*342*	
DRL3	*A17, R9*	*Decon.*			*339*	
		Welding			*179*	
		Transfer			*-*	
DRL4	*A3-11, R9*	*Decon.*			*-*	
DRL5	*A1-18, R10*	*Transfer*			*267*	
DRL6	*A17-18, R9*	*Transfer*			*66*	
DRL7	*A17-18, R10*	*Transfer*			*131*	
DRL8	*A2, R9*	*Transfer*			*38*	
DRL9	*A19, R0*	*Transfer*			*46*	
DRL10	*A1, R10*	*Transfer*			*31*	
HSM-MX (HMX)	Front face surface average	-	60	50	60	*160*

Note 1: Information pertaining to dose rate locations DRL1 through DRL10 is provided in Table 11-1.

Listing of Computer Files Contained in Enclosure 8

Disk ID No. (size)	Discipline	System/Component	File Series (topics)	Number of Files
Enclosure 8 One Computer Hard Drive Shielding (7.45 GB) Thermal (33.0 GB) Structural (0.28 GB)	**Shielding**	**EOS-HSM-SC / EOS-89BTH DSC**	**Section 6.1 EOS-HSM-SC Dose Rate Sensitivity** **Folder:\Shielding Files\Section 6.1 EOS-HSM-SC**	10
		EOS-TC125 / EOS-37PTH DSC	**Section 6.4.3 EOS-TC125 Dose Rates for EOS-37PTH DSC** **Folder:\Shielding\Section 6.4.3 EOS-TC125** - subfolders for decontamination, welding, transfer, and accident	22
		EOS-HSM / EOS-37PTH DSC	**Section 6.4.4 EOS-HSM Dose Rates for EOS-37PTH DSC** **Folder:\Shielding\Section 6.4.4 EOS-HSM** - subfolders for single-reflection, double-reflection, triple-reflection, and accident	40
		HSM-MX / EOS-37PTH DSC MAVRIC Analysis	**Section A.6.5.3 HSM-MX MAVRIC Calculations** **Folder:\Shielding Files\Section A.6.5.3 HSM-MX MAVRIC** - subfolders for front-gamma, front-neutron, roof-gamma, and roof-neutron	44

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-	**Thermal**	**EOS-37PTH DSC in EOS-TC125**	**Section 4.9.9.2.2 (LC 1 in Table 4.9.9-1)** **Folder: \Thermal\EOS-37PTH-EOS-TC125\LC1** Input and output files for the bounding normal transfer condition of EOS-37PTH DSC Basket Type 4HA in EOS-TC125 with Intact FAs - Subfolder HLZC-12-1: with HLZC 12-1 - Subfolder HLZC-12-2: with HLZC 12-2 (ANSYS FLUENT Evaluation)	20
			Section 4.9.9.2.2 (LC 3 in Table 4.9.9-1) **Folder: \Thermal\EOS-37PTH-EOS-TC125\LC3** Input and output files for the bounding off-normal transfer condition of EOS-37PTH DSC Basket Type 4HA in EOS-TC125 with Intact FAs - Subfolder HLZC-12-1: with HLZC 12-1 - Subfolder HLZC-12-2: with HLZC 12-2 (ANSYS FLUENT Evaluation)	24
		EOS-37PTH DSC in EOS-HSM	**Section 4.9.9.3.2 (LC 2 in Table 4.9.9-7)** **Folder: \Thermal\EOS-37PTH- EOS-HSM\LC2\HLZC-12-2** Input and output files for the bounding normal condition of EOS-37PTH DSC Basket Type 4HA in EOS-HSM with Intact FAs using HLZC 12-2. (ANSYS FLUENT Evaluation)	4
		EOS-37PTH DSC in EOS-HSM-SC	**Section 4.4.12** **Folder: \Thermal\EOS-37PTH-EOS-HSM-SC\LC1** Input and output files for the bounding normal storage condition of EOS-37PTH DSC in EOS-HSM-SC with Intact FAs using HLZC 1. (ANSYS FLUENT Evaluation)	4

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			Section 3.9.8 **Folder: \Structural\EOS-HSM-SC\design** **Design for Seismic and Accident Thermal load combination** Input and output files for design of Upper Side Wall Right (Component 20) for seismic load combination (C4); and Lower Side Wall Bottom (14”) Left (Component 13) for accident thermal load combination (C7): - Subfolder loadcomb4: Component 20 for seismic load combination - Subfolder loadcomb7: Component 13 for accident thermal load combination	197

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Computer Files Associated with Certificate of Compliance 1042 Amendment 4, Revision 0 Withheld Pursuant to 10 CFR 2.390

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11-14	11-19	11-20
11-23	12-5	12-10
A.6-4	A.6-5	A.6-12
A.6-13	A.6-14	A.6-35
A.6-36	A.6-48	A.10-2
A.10-5	A.10-6	A.11-3
A.11-11		

Enclosure 10 to E-59796

UFSAR Presentation of EOS-HSM-SC Design Based on ANSI/AISC N690-18

Withheld Pursuant to 10 CFR 2.390

UFSAR PRESENTATION OF EOS-HSM-SC DESIGN BASED ON ANSI/AISC N690-18

1.0 INTRODUCTION

The scope of Amendment 4 to Certificate of Compliance (CoC) No. 1042 includes a change that introduces the EOS-HSM-SC, a steel-plate composite (SC) option for the EOS-HSM. This change is referred to as Change No. 2 in Enclosure 2 (Description of Changes) of this submittal. This enclosure provides a roadmap for the presentation of the EOS-HSM-SC design in the UFSAR, highlighting where in the UFSAR the change is presented. In addition, this enclosure describes how the EOS-HSM-SC design conforms with ANSI/AISC N690-18 [1], which is the design code for SC components, and what modifications to the code are considered to facilitate the design. Documents supporting the justification of the modifications are also provided in this Enclosure.

2.0 UFSAR PRESENTATION OF EOS-HSM-SC DESIGN

The EOS-HSM-SC is an alternate option that may be used in lieu of the EOS-HSM-RC, which is an RC (reinforced concrete) option for the EOS-HSM and has been reviewed and approved by the NRC. The original EOS-HSM-RC design was equipped with a DSC support structure consisting of wide flange steel beams, and the later version employed a flat plate DSC support structure. The EOS-HSM-SC is an evolution of the flat plate support design, where RC components are replaced by SC components. Structural evaluations of the EOS-HSM-RC are presented in UFSAR Sections 3.9.4 and 3.9.7.1. In UFSAR Section 3.9.4 (EOS-HSM Structural Analysis), components of the EOS-HSM-RC, such as the concrete components, DSC support structure, heat shields, and axial retainer, are evaluated to demonstrate that they have sufficient strength to resist postulated loading conditions. In UFSAR Section 3.9.7.1 (EOS-HSM Stability Evaluation), stability of the overall EOS-HSM-RC structure is evaluated to demonstrate that the structure would not slide or overturn.

The evaluation of the EOS-HSM-SC is presented in UFSAR Section 3.9.8, a new section created for the EOS-HSM-SC. Section 3.9.8 contains both the structural analysis and stability analysis, and its contents are similar to those of Section 3.9.4 and 3.9.7.1. Each of the Sections 3.9.8.1 through 3.9.8.10 corresponds to that from Sections 3.9.4.1 through 3.9.4.10. Section 3.9.8.11 addresses the stability analysis and corresponds to Section 3.9.7.1. When the materials for the EOS-HSM-RC are equally applicable to the EOS-HSM-SC, it is indicated so and the materials are not repeated in the sections for the EOS-HSM-SC. The following provides a summary of what is presented in each of the subsections in UFSAR Section 3.9.8.

- 3.9.8.1 General Description: Provides a general description of the EOS-HSM-SC and highlights the similarities and differences with the EOS-HSM-RC.

- 3.9.8.2 Material Properties: Refers to UFSAR Chapter 8 for the properties of materials used for the EOS-HSM-SC.

- 3.9.8.3 Design Criteria: Identifies the design standard (ANSI/AISC N690-18 [1]) used for the SC components of the EOS-HSM-SC. States that the basis of the loading conditions (ANSI/ANS-57.9-1984 [2]) and the design code for the other components (AISC Manual of Steel Construction [3]) used for the EOS-HSM-RC are equally applicable to the EOS-HSM-SC.

- 3.9.8.4 Load Cases: States that the same load cases considered for the EOS-HSM-RC are applicable to the EOS-HSM-SC, except for the seismic load because the seismic accelerations depend on the structural frequencies and damping values.

- 3.9.8.5 Load Combination: States that the same load combinations considered for the EOS-HSM-RC are used for the EOS-HSM-SC.

- 3.9.8.6 Finite Element Models: Provides a description of the finite element model for the EOS-HSM-SC. States that the same finite element models for the heat shields are used for the EOS-HSM-SC.

- 3.9.8.7 Normal Operating Structural Analysis: States that the same normal operating loads considered for the EOS-HSM-RC are applicable to the EOS-HSM-SC.

- 3.9.8.8 Off-Normal Operation Structural Analysis: States that the same off-normal operating loads considered for the EOS-HSM-RC are applicable to the EOS-HSM-SC.

- 3.9.8.9 Accident Condition Structural Analysis: States that the same accident condition loads considered for the EOS-HSM-RC, except for the seismic load, are applicable to the EOS-HSM-SC. Provides the seismic accelerations used for analysis of the EOS-HSM-SC components.

- 3.9.8.10 Structural Evaluation: Provides the structural evaluation results for the EOS-HSM-SC SC components, DSC support structure, shield door, heat shields, and axial retainer. This section also provides the evaluation results for the SC components subjected to tornado missile loading.

- 3.9.8.11 Stability Evaluation: Provides the sliding and overturning stability analysis results for the EOS-HSM-SC. This section also states that the stability evaluation methodologies for the EOS-HSM-SC are the same as for the EOS-HSM-RC except that the weight of the EOS-HSM-SC is used.

3.0 STRUCTURAL EVALUATION OF EOS-HSM-SC BASED ON N690-18

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4.0 REFERENCES

1. American Institute of Steel Construction, “Specification for Safety-Related Steel Structures for Nuclear Facilities,” ANSI/AISC N690-18 (2018).

2. ANSI/American Nuclear Society, “Design Criteria for an Independent Spent Fuel Storage Installation (Dry Storage Type),” ANSI/ANS-57.9-1984 (1984).

3. American Institute of Steel Construction, “Manual of Steel Construction,” 13th Edition or Later.

4. U.S. Nuclear Regulatory Commission, “Safety-Related Steel Structures and Steel-plate Composite Walls for other than Reactor Vessels and Containments,” Regulatory Guide 1.243, Revision 0 (2021).

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Enclosure 12 to E-59796

EOS-HSM-SC Qualification Test Documents
Withheld Pursuant to 10 CFR 2.390