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NUHOMS® EOS System
Safety Analysis Report

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Acronym List
(3 pages)

Acronym	Definition
3D	Three-Dimensional
AEG	Average Energy Group Causing Fission
ALARA	As Low As Reasonably Achievable
APSRA	Axial Power Shaping Rod Assembly
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
AWS	*Automated Welding System*
B&W	Babcock and Wilcox
BLEU	Blended Low-Enriched Uranium
BPRA	Burnable Poison Rod Assembly
BRC	Below Regulatory Concern
BWR	Boiling Water Reactor
CC	Control Component
CE	Combustion Engineering
CEA	Control Element Assembly
CFD	Computational Fluid Dynamics
CISCC	Chloride-Induced Stress Corrosion Cracking
CoC	Certificate of Compliance
COR	Coefficient of Restitution
CRA	Control Rod Assembly
CTE	Coefficient of Thermal Expansion
DBT	Design Basis Tornado
DO	Discrete Ordinates
DOE	Department of Energy
DOF	Degrees of Freedom
DRL	Dose Rate Location
DSC	Dry Shielded Canister
DW	Dead Weight
EALF	Energy of Average Lethargy of Fission
FA	Fuel Assembly
FE	Finite Element
FEM	Finite Element Model
GCI	Grid Convergence Index
GTAW	Gas Tungsten Arc Welding

Acronym List
(3 pages)

Acronym	Definition
HLZC	Heat Load Zone Configuration
HSM	Horizontal Storage Module
IBCP	Inner Bottom Cover Plates
IBS	Inner Bottom Shield
IFBA	Integral Fuel Burnable Absorber
IMD	Internal Moderator Density
ISFSI	Independent Spent Fuel Storage Installation
ITCP	Inner Top Cover Plate
LWR	Light Water Reactor
MCNP	Monte Carlo N-Particle
MMC	Metal Matrix Composite
MRF	Most Reactive Fuel
MRC	Most Reactive Configuration
MRS	Monitored Retrievable Storage
NDE	Non-Destructive Examination
NDRC	National Defense Research Committee
NFAH	Non-Fuel Assembly Hardware
NRC	U.S. Nuclear Regulatory Commission
NSA	Neutron Source Assembly
OBCP	Outer Bottom Cover Plate
ORA	Orifice Rod Assembly
ORNL	Oak Ridge National Laboratory
OTCP	Outer Top Cover Plate
PPSS	Peripheral Power Suppression Assemblies
ppm	Parts Per Million
PT	Liquid Penetrant Testing
PWR	Pressurized Water Reactor
QA	Quality Assurance
RCCA	Rod Cluster Control Assembly
SAR	Safety Analysis Report
SFA	Spent Fuel Assembly
TC	Transfer Cask
TD	Theoretical Density
TPA	Thimble Plug Assembly

Acronym List
(3 pages)

Acronym	Definition
TSP	Top Shield Plug
UDF	User Defined Function
USL	Upper Subcritical Limit
VDS	Vacuum Drying System
VSI	Vibration Suppression Insert
WABA	Wet Annular Burnable Absorber
WE	Westinghouse
ZPA	Zero Period Acceleration

CHAPTER 1
GENERAL INFORMATION

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1. GENERAL INFORMATION

This Safety Analysis Report (SAR) describes the design and forms the licensing basis for 10 CFR 72 [1-1], Subpart L certification of the NUHOMS® EOS dry spent fuel storage system. The NUHOMS® EOS System provides for the horizontal storage of high burnup spent pressurized water reactor (PWR) and boiling water reactor (BWR) fuel assemblies (FAs) in dry shielded canisters (DSCs) that are placed in an EOS horizontal storage module (EOS-HSM) utilizing an EOS transfer cask (EOS-TC). The NUHOMS® EOS System is designed to be installed in an independent spent fuel storage installation (ISFSI) at power reactor sites under the provision of a general license in accordance with 10 CFR 72, Subpart K. This system has been specifically optimized for high thermal loads, limited space, and needs for superior radiation shielding performance.

The quality assurance (QA) program applicable to this design satisfies the requirements of 10 CFR 72, Subpart G and is described in Chapter 14. To facilitate U.S. Nuclear Regulatory Commission (NRC) review of this application, this SAR has been prepared in compliance with the information and methods defined in Revision 1 to NRC NUREG-1536 [1-2].

The NUHOMS® EOS System is an improved version of the NUHOMS® HD System described in Certificate of Compliance (CoC) No. 1030 [1-3]. The EOS-DSCs included in this application are similar to the DSCs licensed in the NUHOMS® HD Horizontal Modular Storage System For Irradiated Nuclear Fuel Updated Final Safety Analysis Report (UFSAR), Revision 4 [1-4]. The EOS-HSMs are similar to the previously licensed HSM-H. The EOS-TCs are similar to the previously licensed TCs, but with a larger diameter.

The NUHOMS® EOS System is designed for enhanced heat rejection capabilities, and to permit storage of intact PWR spent fuel assemblies (SFAs) with or without control components (CCs), and BWR SFAs with or without channels. Protection afforded to the public is similar to the HSM-H designs described in the NUHOMS® HD System UFSAR. Details of the system design, analyses, operation, and margins are provided in the remainder of this SAR.

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-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 new 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).
- Two new DSC basket designs. In addition, depending on the boron content and neutron poison material in the basket poison plates, each basket type is designated as follows for the EOS-37PTH basket: Type A (low B-10) or Type B (high B-10), and for the EOS-89BTH: Type M1-A (low B-10), M1-B (moderate B-10) and M2-A (high B-10).
- A new 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 new 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 a 108-ton cask (EOS-TC108).

The EOS-37PTH DSC is designed for a maximum heat load of 50 kW when transferred in the EOS-TC125/135, and a maximum heat load of 41.8 kW when transferred in the EOS-TC108. The EOS-89BTH DSC is designed for a maximum heat load of 43.6 kW when transferred in the EOS-TC125/135, 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 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.

Approval of the NUHOMS® EOS System components described above is sought under the provisions of 10 CFR 72, Subpart L for use under the general license provisions of 10 CFR 72, Subpart K. 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 SAR. 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 SAR 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 EOS-HSM. The storage system components consist of a reinforced concrete 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 SAR 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 Specification. 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-Z, where XXX typically identifies the site for which the EOS-37PTH DSC was fabricated, Z designates the basket type, and YYY is a sequential number corresponding to a specific DSC. The basket types are described in SAR drawing no. EOS01-1010-SAR. Similarly, each BWR DSC is identified by a Model Number, XXX-EOS-89BTH-YYY-Z. The basket types are described in SAR 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.

1.2.1 NUHOMS® EOS System Characteristics

1.2.1.1 EOS-37PTH DSC

The key design parameters of the EOS-37PTH DSC are listed in Table 1-1. The primary confinement boundary for the EOS-37PTH DSC consists of the cylindrical shell, the top and bottom inner cover plates, the drain port cover plate, vent plug, and the associated welds. The outer top and bottom cover plates, test port plug, and associated welds form the redundant confinement boundary. The top and bottom shield plugs provide shielding for the EOS-37PTH DSC so that occupational doses at the ends are minimized during drying, sealing, handling, and transfer operations.

The cylindrical shell and inner bottom cover plate confinement boundary welds are fully compliant with Subsection NB of the ASME Code and are made during fabrication. The confinement boundary weld between the shell and the inner top cover (including drain port cover plate and vent plug welds), and the structural attachment weld between the shell and the outer top cover plate (including the test port weld) are in accordance with Alternatives to the ASME code as described in Section 4.4.4 of the Technical Specifications [1-7].

Both drain port cover plate and vent plug welds are made after drying operations are completed. There are no credible accidents that could breach the confinement boundary of the EOS-37PTH DSC, as documented in Chapters 3 and 12.

The EOS-37PTH DSC basket structure, shown schematically in Figure 1-2, consists of interlocking slotted plates to form an egg-crate type structure. The egg-crate structure forms a grid of 37 fuel compartments that house the PWR SFAs. The egg-crate grid structure is composed of one or more of the following: a steel plate, an aluminum plate and a neutron absorber plate. The steel plates are fabricated from ASTM A506 Gr 4130 (AISI 4130) steel, hot rolled to meet SAE/AMS-6345C, heat-treated and tempered per AMS-H-6875 at 1,050 °F, and provide structural support for the FAs. The poison plates are made of borated metal matrix composites (MMCs) and provide the necessary criticality control. The aluminum plates, together with the poison plates, provide a heat conduction path from the FAs to the DSC rails and shell.

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

The EOS-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 poison material and boron loading, two basket types are provided, as shown on drawing EOS01-1010-SAR and described in Chapter 10.

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

1.2.1.2 EOS-89BTH DSC

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

The cylindrical shell and inner bottom cover plate confinement boundary welds are fully compliant with Subsection NB of the ASME Code and are made during fabrication. The confinement boundary weld between the shell and the inner top cover (including drain port cover plate and vent plug welds), and structural attachment weld between the shell and the outer top cover plate (including the test plug weld) are in accordance with Alternatives to the ASME code as described in Section 4.4.4 of the Technical Specifications [1-7].

Both drain port cover plate and vent plug welds are made after drying operations are complete. There are no credible accidents that could breach the confinement boundary of the EOS-89BTH DSC as documented in Chapters 3 and 12.

The EOS-89BTH DSC basket structure, shown schematically in Figure 1-4, consists of interlocking slotted plates to form an egg-crate-type structure. The egg-crate structure forms a grid of 89 fuel compartments that house the BWR SFAs. The egg-crate grid structure is composed of one or more of the following: a steel plate, an aluminum plate, and a neutron absorber plate. The steel plates are fabricated from ASTM A506 Gr 4130 (AISI 4130) steel, hot rolled to meet SAE/AMS-6345C, heat-treated and tempered per AMS-H-6875 at 1,050 °F, and provide structural support for the FAs. The poison plates are made of borated MMCs or BORAL® and provide the necessary criticality control. The aluminum plates, together with the poison plates, provide a heat conduction path from the FAs to the DSC rails and shell.

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

The EOS-89BTH DSC is designed for a maximum heat load of 43.6 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, three basket types are provided, as shown on drawing EOS01-1020-SAR and described 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 SAR are nominal dimensions for general system description purposes. Actual design dimensions are contained in the drawings in Section 1.3.2 of this SAR. 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 SAR, 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 thick concrete roof and walls 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 four feet 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.

The EOS-HSM provides a means of removing spent fuel decay heat by a combination of radiation, conduction and convection. Ambient air enters the EOS-HSM through ventilation inlet openings located on both sides of the lower front wall of the EOS-HSM and circulates around the DSC and the heat shields. Air exits through air outlet openings located on each side of the top of the EOS-HSM. The EOS-HSM is designed to remove up to 50.0 kW of decay heat from the bounding EOS-37PTH DSC.

Decay heat is rejected from the DSC to the EOS-HSM air space by convection and then removed from the EOS-HSM by natural circulation air flow. Heat is also radiated from the DSC surface to the heat shields and EOS-HSM walls and roof, where the natural convection air flow and conduction through the walls and roof aid in the removal of the decay heat. The passive cooling system for the EOS-HSM is designed to preserve fuel cladding integrity by maintaining SFA peak cladding temperatures below acceptable limits during long-term storage.

The EOS-HSMs are installed on a load bearing foundation, which consists of a reinforced concrete basemat on a subgrade suitable to support the loads. The EOS-HSMs are not tied to the basemat.

Dimensions of the EOS-HSM components described in the text and provided in figures and tables of this SAR are, in general, nominal dimensions for general system description purposes. Actual design dimensions are contained in the drawings in Section 1.3.3.

1.2.1.4 Transfer Casks

The EOS-TCs are designed to provide shielding and protection from potential hazards during DSC loading and closure operations and transfer to the EOS-HSM. The key design parameters of the TC are listed in Table 1-1. The EOS-TCs included in this SAR are limited to onsite use under 10 CFR 72. The EOS-TCs are non-pressure-retaining, except the neutron shield tanks, atmospheric cylindrical vessels with welded bottom assemblies, and bolted top cover plates, and they are designed to ASME Division III Subsection NF Class 1 criteria. The neutron shield tanks retain pressure and are designed to ASME III Subsection ND criteria. The primary function of the EOS-TC is to provide onsite transport of loaded DSCs between the plant's spent fuel pool and the plant's onsite ISFSI. The TC provides the principal biological shielding and heat rejection mechanism for the EOS-DSC and SFAs during handling in the fuel or reactor building, EOS-DSC closure operations, transfer to the ISFSI, and placement in the EOS-HSM.

The TC is designed to provide sufficient shielding to provide reasonable assurance that dose rates are ALARA. 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 a removable 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. 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 SAR are in general nominal dimensions for general system description purposes. Actual design dimensions are contained in the drawings in Section 1.3.4.

1.2.2 Transfer Equipment

Transfer Trailer:

The typical transfer trailer for the NUHOMS® EOS System consists of a heavy industrial trailer used to transfer the empty cask, support skid and the loaded transfer cask between the plant's fuel or reactor building and the ISFSI. The trailer is designed to ride as low to the ground as possible to minimize the overall EOS-HSM height and the transfer cask height during DSC transfer operations. The trailer is equipped with leveling jacks to provide vertical alignment of the cask with the EOS-HSM. The trailer is self-powered or towed by a conventional heavy-haul truck tractor or other suitable prime mover. A typical transfer trailer is depicted in Figure 1-9.

Cask Support Skid:

A typical cask support skid for the NUHOMS® EOS System is shown in Figure 1-10, and is similar to the cask support skids described in the NUHOMS® HD System UFSAR. Key design features are:

- The skid is mounted on a surface with sliding support bearings and hydraulic positioners to provide alignment of the cask with the EOS-HSM. A mechanism is provided to prevent movement during trailer towing.
- A hydraulic or mechanical ram is mounted on the skid to insert or retrieve the DSC from the EOS-HSM.
- The cask support skid is mounted on a low profile heavy-haul or self-powered industrial trailer.

The plant's fuel or reactor building crane or other suitable lifting device is used to lower the cask onto the support skid, which is secured to the transfer trailer. Specific details of this operation and the plant-specific building arrangement are covered by the provisions of the 10 CFR 50 operating license for the plant.

Ram:

A hydraulic or mechanical ram system consists of a hydraulic cylinder or mechanical frame with a capacity and a reach sufficient for DSC insertion into and retrieval from the EOS-HSM. The design of the ram support system provides a direct load path for the ram reaction forces during DSC insertion and retrieval. The system uses a rear ram support for alignment of the ram to the DSC. The design provides positive alignment of the major components during DSC insertion and retrieval.

1.2.3 Operational Features

This section provides a discussion of the sequence of operations involving the NUHOMS® EOS System components.

1.2.3.1 Spent Fuel Assembly Loading Operations

The primary operations (in sequence of occurrence) for the NUHOMS® EOS System with the EOS-TC125 or EOS-TC135 are:

1. Prepare TC
2. Prepare DSC
3. Place DSC in TC
4. Fill TC/DSC Annulus with clean water and seal
5. Fill DSC cavity with water (may be accomplished in step 6)
6. Lift TC and place in fuel pool
7. Load spent fuel
8. Place top shield plug
9. Lift TC from pool (DSC water may be drained and replaced with helium during draindown)
10. Seal inner top cover
11. Vacuum Dry and Backfill
12. Pressure test
13. Leak test
14. Seal outer top cover plate
15. Drain TC/DSC annulus and place TC top cover plate
16. Place loaded TC on transfer skid/trailer
17. Move loaded TC to EOS-HSM
18. Prepare and align TC/EOS-HSM
19. Insert DSC into EOS-HSM
20. Close EOS-HSM

For operations (in sequence of occurrence) for the NUHOMS® EOS System with the EOS-TC108 the following additional steps may be used to meet crane limits.

- Concurrent with Step 1 the TC108 neutron shield tank may be removed from the cask and positioned for installation onto the cask once it is loaded and removed from the fuel pool.
- Between Step 9 and Step 10, the neutron shield tank is reinstalled and filled with water.

These operations are described in the following paragraphs. The descriptions are intended to be generic and are described in greater detail in Chapter 9. Plant specific requirements may affect these operations and are to be addressed by the licensee.

Prepare TC:

Transfer cask preparation includes exterior washdown and interior decontamination. These operations are performed on the decontamination pad/pit outside the fuel pool area. The operations are similar to those for a shipping cask, which are performed by plant personnel using existing procedures. For the TC108, this includes removing the neutron shield tank if required to meet crane capacity limits or cask loading space considerations.

Prepare DSC:

The internals and externals of the DSC are inspected and cleaned if necessary. This ensures that the DSC will meet plant cleanliness requirements for placement in the spent fuel pool. If the neutron shield tank is removed from the TC108, position the tank such that it can be installed onto the cask once the cask is loaded and removed from the fuel pool.

Place DSC in TC:

The empty DSC is inserted into the TC.

Fill TC/DSC annulus with clean water and seal:

The TC/DSC annulus is filled with uncontaminated water and is then sealed prior to placement in the pool. This prevents contamination of the DSC outer surface and the transfer cask inner surface by the pool water.

Fill DSC cavity with water:

The DSC cavity is filled with pool water to prevent an in-rush of water as the transfer cask is lowered into the pool.

Lift TC and place in fuel pool:

The TC, with the water-filled DSC inside, is then lowered into the fuel pool. The TC125 and TC135 liquid neutron shield may be left unfilled to meet hook weight limitations.

Load spent fuel:

Spent fuel assemblies are placed into the DSC. This operation is identical to that presently used at plants for shipping cask loading.

Place top shield plug:

This operation consists of placing the top shield plug into the DSC using the plant's crane or other suitable lifting device.

Lift TC from pool:

The loaded TC is lifted out of the pool and placed (in the vertical position) on the drying pad in the decontamination pit. This operation is similar to that used for shipping cask handling operations. If the neutron shield for the EOS-TC125 and EOS-TC135 is not filled, fill tank at this time. If using the EOS-TC108 without the neutron shield tank installed, install the neutron shield tank and fill with water.

Seal inner top cover:

The water contained in the space above the shield plug is drained. The inner top cover plate is installed and welded to the shell. This weld provides the top (confinement) seal for the DSC.

Vacuum dry and backfill:

The initial draining of the DSC is accomplished by pumping from the DSC cavity through the drain port while backfilling the cavity with helium through the the vent port. The water in the cavity is pumped out through the siphon tube and routed back to the fuel pool or to the plant's liquid radwaste processing system via appropriate size flexible hose or pipe, as appropriate. The DSC is then evacuated to remove the residual liquid water and water vapor, and helium in the cavity. When the system pressure has stabilized, the DSC is backfilled with helium.

Pressure test:A pressure test of inner top cover weld is performed by backfilling the DSC cavity with helium. After the pressure test, remove the helium lines. Then, the drain port cover plate and vent plug are installed and welded to the inner top cover.

Leak test:

A leak test of the inner top cover to the DSC shell weld, drain port cover plate and vent plug welds is performed using a temporary test head or after the root pass on the outer top cover plate through the test port or any other alternative means.

Seal outer top cover plate:

After helium backfilling, the DSC outer top cover plate is installed by using a partial penetration weld between the outer top cover plate and the DSC shell.

The outer cover plate to shell weld and inner top cover plate weld provide redundant seals at the upper end of the DSC.

Drain TC/DSC annulus and place TC top cover plate:

The TC/DSC annulus is drained. A swipe is then taken over the DSC exterior at the top cover plate and the upper portion of the shell. Demineralized water is flushed through the TC/DSC annulus, as required, to remove any contamination left on the DSC exterior. The TC top cover plate is installed, using the plant's crane or other suitable lifting device, and bolted closed.

Place Loaded Transfer Cask on Transfer Skid/Trailer:

The TC is lifted onto the TC support skid and downended onto the transfer trailer from the vertical to horizontal position.

Move Loaded Transfer Cask to EOS-HSM:

The transfer trailer is moved to the ISFSI along a predetermined route on a prepared road surface. Upon entering the ISFSI, the cask is positioned and aligned with the designated EOS-HSM into which the DSC is to be transferred.

Prepare and align TC/EOS-HSM:

At the ISFSI with the TC positioned in front of the EOS-HSM, the TC top cover plate is removed. The EOS-HSM door is removed and the transfer trailer is then backed into close proximity with the EOS-HSM. The skid positioning system is then used for the final alignment and docking of the TC with the EOS-HSM and the cask restraint installed.

Insert DSC into EOS-HSM:

After final alignment of the TC, EOS-HSM, and ram, the DSC is pushed into the EOS-HSM by the ram.

Close EOS-HSM:

Install DSC axial retainer and install EOS-HSM door.

1.3 Drawings

1.3.1 NUHOMS® EOS-37PTH DSC

EOS01-1000-SAR	NUHOMS® EOS System Transportable Canister 37PTH DSC Main Assembly (6 sheets)
EOS01-1001-SAR	NUHOMS® EOS System Transportable Canister 37PTH DSC Shell Assembly (2 sheets)
EOS01-1010-SAR	NUHOMS® EOS System Transportable Canister 37PTH Basket Assembly (8 sheets)
EOS01-1011-SAR	NUHOMS® EOS System Transportable Canister 37PTH Basket Transition Rails (6 sheets)

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SAFETY ANALYSIS REPORT
NUHOMS® EOS SYSTEM
TRANSPORTABLE CANISTER 37PTH DSC
MAIN ASSEMBLY

DRAWING NO.	SCALE	SHEET
EOS01-1000-SAR	NONE	1 OF 6

DRAWING NO. EOS01-1000-SAR SHEET 1 OF 6

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EOS01-1000-SAR	2 OF 6	0A

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NUHOMS® EOS SYSTEM
TRANSPORTABLE CANISTER 37PTH DSC
SHELL ASSEMBLY

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EOS01-1001-SAR	NONE	1 OF 2

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SAFETY ANALYSIS REPORT
NUHOMS® EOS SYSTEM
TRANSPORTABLE CANISTER 37PTH
BASKET ASSEMBLY

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SAFETY ANALYSIS REPORT
NUHOMS® EOS SYSTEM
TRANSPORTABLE CANISTER 37PTH
BASKET TRANSITION RAILS

DRAWING NO.	SCALE	SHEET
EOS01-1011-SAR	NONE	1 OF 6

DRAWING NO. EOS01-1011-SAR SHEET 1 OF 6

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1.3.2 NUHOMS® EOS-89BTH DSC

EOS01-1005-SAR	NUHOMS® EOS System Transportable Canister 89BTH DSC Main Assembly (6 sheets)
EOS01-1006-SAR	NUHOMS® EOS System Transportable Canister 89BTH DSC Shell Assembly (2 sheets)
EOS01-1020-SAR	NUHOMS® EOS System Transportable Canister 89BTH Basket Assembly (9 sheets)
EOS01-1021-SAR	NUHOMS® EOS System Transportable Canister 89BTH Basket Transition Rails (7 sheets)

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NUHOMS® EOS SYSTEM
TRANSPORTABLE CANISTER 89BTH DSC
MAIN ASSEMBLY

DRAWING NO.	SCALE	SHEET
E0S01-1005-SAR	NONE	1 OF 6

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NUHOMS® EOS SYSTEM
TRANSPORTABLE CANISTER 89BTH DSC
SHELL ASSEMBLY

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EOS01-1006-SAR	NONE	1 OF 2

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SAFETY ANALYSIS REPORT
NUHOMS® EOS SYSTEM
TRANSPORTABLE CANISTER 89BTH
BASKET ASSEMBLY

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SAFETY ANALYSIS REPORT
NUHOMS® EOS SYSTEM
TRANSPORTABLE CANISTER 89BTH
BASKET TRANSITION RAILS

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1.3.3 NUHOMS® EOS-HSM/EOS-HSMS

EOS01-3000-SAR NUHOMS® EOS System Horizontal Storage Module (EOS-HSM) Main Assembly (18 sheets)

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SAFETY ANALYSIS REPORT
NUHOMS® EOS SYSTEM
HORIZONTAL STORAGE MODULE (EOS-HSM)
MAIN ASSEMBLY

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1.3.4 NUHOMS® EOS-TCs (EOS-TC108 and EOS-TC-125/135)

EOS01-2000-SAR	NUHOMS® EOS System Onsite Transfer Cask EOS-TC108 Main Assembly (5 sheets)
EOS01-2001-SAR	NUHOMS® EOS System Onsite Transfer Cask EOS-TC108 Inner and Outer Shells (7 sheets)
EOS01-2002-SAR	NUHOMS® EOS System Onsite Transfer Cask EOS-TC108 Shielding and Rails Details (4 sheets)
EOS01-2003-SAR	NUHOMS® EOS System Onsite Transfer Cask EOS-TC108 Removable Neutron Shield (7 sheets)
EOS01-2010-SAR	NUHOMS® EOS System Onsite Transfer Cask EOS-TC125/TC135 Main Assembly (5 sheets)
EOS01-2011-SAR	NUHOMS® EOS System Onsite Transfer Cask EOS-TC125/TC135 Inner and Outer Shells (7 sheets)
EOS01-2012-SAR	NUHOMS® EOS System Onsite Transfer Cask E EOS-TC125/TC135 Shielding and Rails Details (4 sheets)

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NUHOMS® EOS SYSTEM
ONSITE TRANSFER CASK EOS-TC108
MAIN ASSEMBLY

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ONSITE TRANSFER CASK EOS-TC108
INNER AND OUTER SHELLS

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EOS01-2001-SAR	NONE	1 OF 7

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SAFETY ANALYSIS REPORT
NUHOMS® EOS SYSTEM
ONSITE TRANSFER CASK EOS-TC108
SHIELDING AND RAILS DETAILS

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SAFETY ANALYSIS REPORT
NUHOMS® EOS SYSTEM
ONSITE TRANSFER CASK EOS-TC108
REMOVABLE NEUTRON SHIELD

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EOS01-2003-SAR	NONE	1 OF 7

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SAFETY ANALYSIS REPORT
NUHOMS® EOS SYSTEM
ONSITE TRANSFER CASK EOS-TC125/TC135
MAIN ASSEMBLY

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SAFETY ANALYSIS REPORT
NUHOMS® EOS SYSTEM
ONSITE TRANSFER CASK EOS-TC125/TC135
INNER AND OUTER SHELLS

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SECURITY RELATED INFORMATION
WITHHELD UNDER 10 CFR 2.390

DRAWING NO.	SHEET	REVISION
EOS01–2011–SAR	6 OF 7	0A

EOS01-2011-SAR 7 OF 7

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

DRAWING NO. EOS01-2011-SAR SHEET 7 OF 7 REVISION 0A

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

REVISION	DESCRIPTION	DATE
0A	FIRST ISSUE	12/17/14

AREVA

SAFETY ANALYSIS REPORT
NUHOMS® EOS SYSTEM
ONSITE TRANSFER CASK EOS-TC125/TC135
SHIELDING AND RAILS DETAILS

DRAWING NO.	SCALE	SHEET
EOS01-2012-SAR	NONE	1 OF 4

DRAWING NO. EOS01-2012-SAR SHEET 1 OF 4

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

DRAWING NO.	SHEET	REVISION
E0S01-2012-SAR	3 OF 4	0A

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

DRAWING NO.	SHEET	REVISION
EOS01-2012-SAR	4 OF 4	0A

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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.

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 up to five replacement irradiated stainless steel rods per assembly or an unlimited number of low enriched or natural uranium fuel rods or non-fuel rods are acceptable for storage in an EOS-37PTH DSC as intact FAs.

The EOS-37PTH DSC is also authorized to store FAs containing blended low enriched uranium (BLEU) fuel material. Limitations for storing BLEU fuel are provided in Chapter 2.

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 weight % 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 Figure 1 of 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 quantity and type of radionuclides 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.

The EOS-89BTH DSC is qualified for storage of 7x7, 8x8, 9x9, and 10x10 class BWR FAs of initial design or equivalent reload FAs as described in Chapter 2.

Reconstituted assemblies containing up to five replacement irradiated stainless steel rods per assembly or an unlimited number of low enriched or natural uranium fuel rods or non-fuel rods are acceptable for storage in an EOS-89BTH DSC as intact FAs.

The EOS-89BTH DSC is also authorized to store FAs containing BLEU fuel material. Limitations for storing BLEU fuel are provided in Chapter 2.

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

The maximum allowable lattice average initial enrichment of the fuel to be stored is 4.80 weight % U-235 and the maximum assembly average burnup is 62,000 MWd/MTU. The FAs (with or without channels) must be cooled to meet the decay heat limits specified in Figure 2 of the Technical Specifications [1-7] prior to storage.

The criticality control features of the EOS-89BTH 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 quantity and type of radionuclides in the SFAs are described and tabulated in Chapter 6. Chapter 7 covers the criticality safety of the EOS-89BTH DSC and its parameters. These parameters include rod pitch, rod outside diameter, material densities, moderator ratios, and geometric configurations. The maximum pressure buildup in the EOS-89BTH DSC cavity is addressed in Chapter 4.

1.5 Qualification of AREVA Inc. (Applicant)

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

The design activities for the NUHOMS® EOS Safety Analysis Report were performed by AREVA TN Americas and subcontractors, in accordance with AREVA TN Americas QA program requirements. AREVA 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.

1.6 Quality Assurance

AREVA TN Americas' (an operating division of AREVA Inc.) QA program has been established in accordance with the requirements of 10 CFR 72, Subpart G [1-1]. The QA program applies to the design, purchase, fabrication, handling, shipping, storing, cleaning, assembly, inspection, testing, operation, maintenance, repair, and modification of the NUHOMS® EOS System and components identified as "important to safety" and "safety-related." These components and systems are defined in Chapter 2.

The complete description and specific commitments of the AREVA Inc. QA program are contained in the AREVA Inc. QA Program Description Manual [1-6]. This manual has been approved by the NRC for performing 10 CFR Part 72-related activities.

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 AREVA Transnuclear, Updated Final Safety Analysis Report, "NUHOMS® HD Horizontal Modular Storage System for Irradiated Nuclear Fuel," Revision 4, U.S. Nuclear Regulatory Commission Docket No. 72-1030, September 2013.

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

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

1-7 Proposed CoC 1042 Appendix A, NUHOMS® EOS System Generic Technical Specifications, Amendment 0.

1.8 Supplemental Data

1.8.1 Generic Cask Arrays

The DSC containing the SFAs is transferred to, and stored in, an EOS-HSM in the horizontal position. Multiple EOS-HSMs are grouped together to form arrays whose size is determined to meet plant-specific needs. Arrays of EOS-HSMs are arranged within the ISFSI site on a concrete basemat(s) with the entire area enclosed by a security fence. Individual EOS-HSMs are arranged adjacent to each other. The decay heat for each EOS-HSM is primarily removed by internal natural circulation flow and conduction through the EOS-HSM walls. Figure 1-11, Figure 1-12 and Figure 1-13 show typical layouts for NUHOMS® EOS System ISFSIs, which are capable of modular expansion to any capacity. These are typical layouts only and do not represent limitations in number of modules, number of rows, and orientation of modules in rows. Two empty modules are required at the end of an array to allow for future expansion until an end shield wall is used adjacent to a final loaded module. Back-to-back module configurations require expansion in sets of pairs. Expansion can be accomplished, as necessary, by the licensee provided the criteria of 10 CFR 72.104, 10 CFR 72.106 and Chapter 14 are met. The parameters of interest in planning the installation layout are the configuration of the EOS-HSM array and an area in front of each EOS-HSM to provide adequate space for backing and aligning the transfer trailer.

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

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

Horizontal Storage Module (EOS-HSM/EOS-HSMS):	
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"
Total Weight not including DSC (lbs.)	311,000 EOS-Short
	334,000 EOS-Medium
	351,000 EOS-Long
Materials of Construction	Reinforced concrete and structural steel
Heat Removal	Conduction, convection, and radiation
OnSite Transfer Cask (EOS-TC)	
Overall Length (in)	206.76 EOS-TC108
	208.01 EOS-TC125
	228.59 EOS-TC135
Outside Diameter (in)	90.61 EOS-TC108 w/ NS tank
	88.50 EOS-TC108 w/o NS tank
	95.38 EOS-TC125
	95.38 EOS-TC125
Cavity Length (in)	199.17 EOS-TC108
	199.25 EOS-TC125
	219.75 EOS-TC135
Lead Thickness (in)	2.50 EOS-TC108
	3.63 EOS-TC125
	3.63 EOS-TC135
Gross Weight (with neutron shield and steel lid and no payload) (tons)	46.5 EOS-TC108
	62.1 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

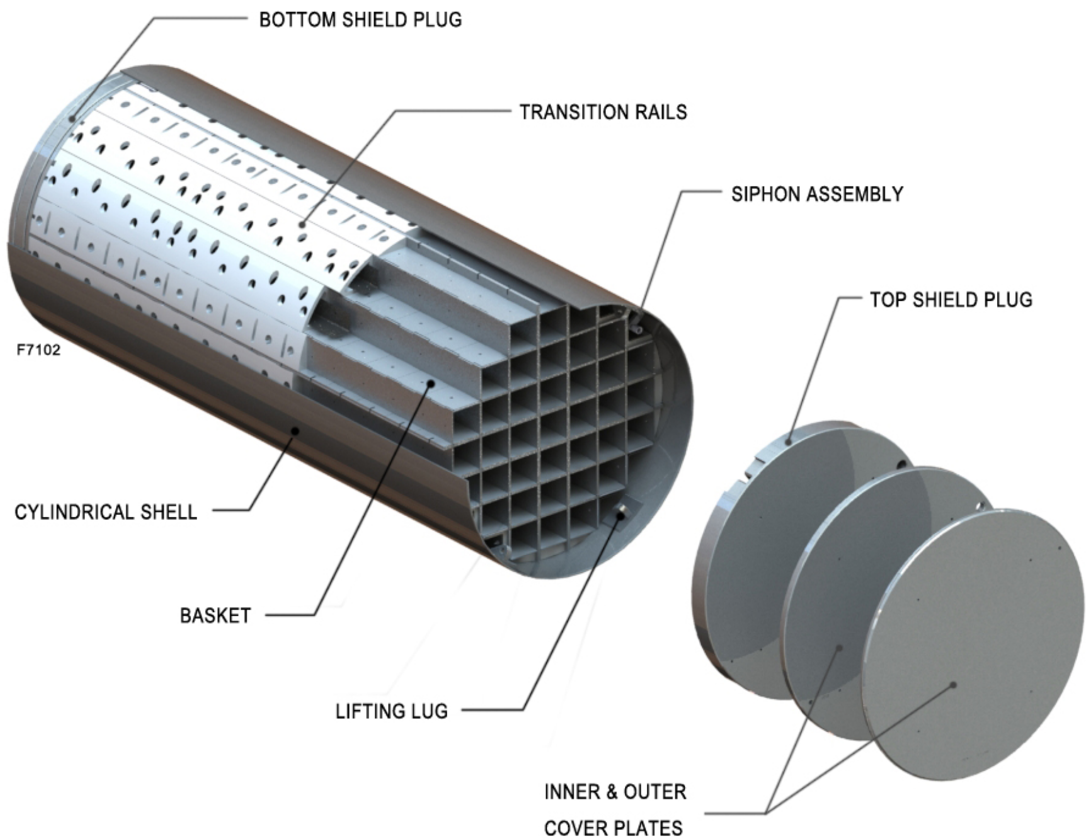


Figure 1-1
EOS-37PTH DSC

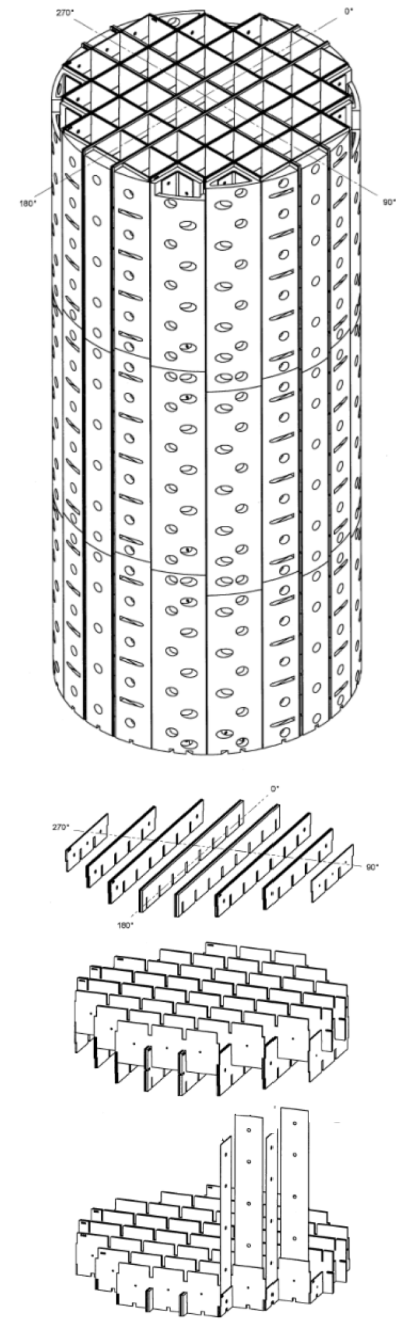


Figure 1-2
EOS-37PTH Basket

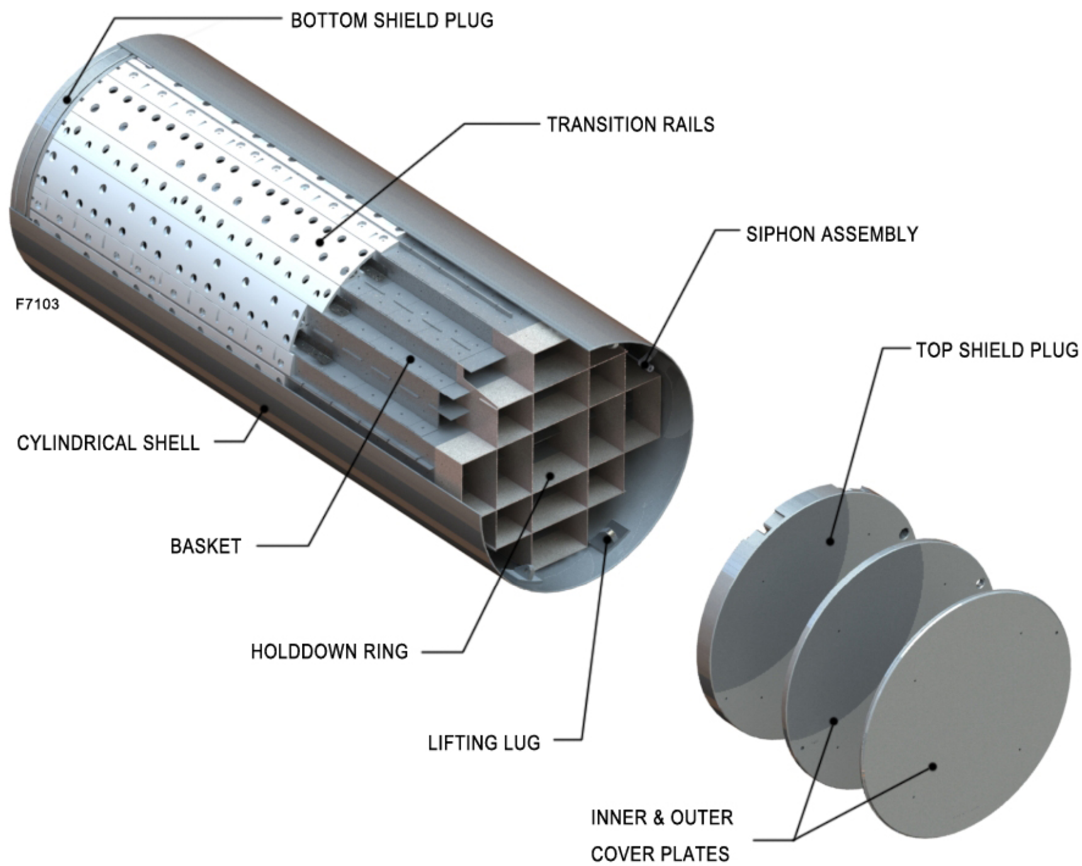


Figure 1-3
EOS-89BTH DSC

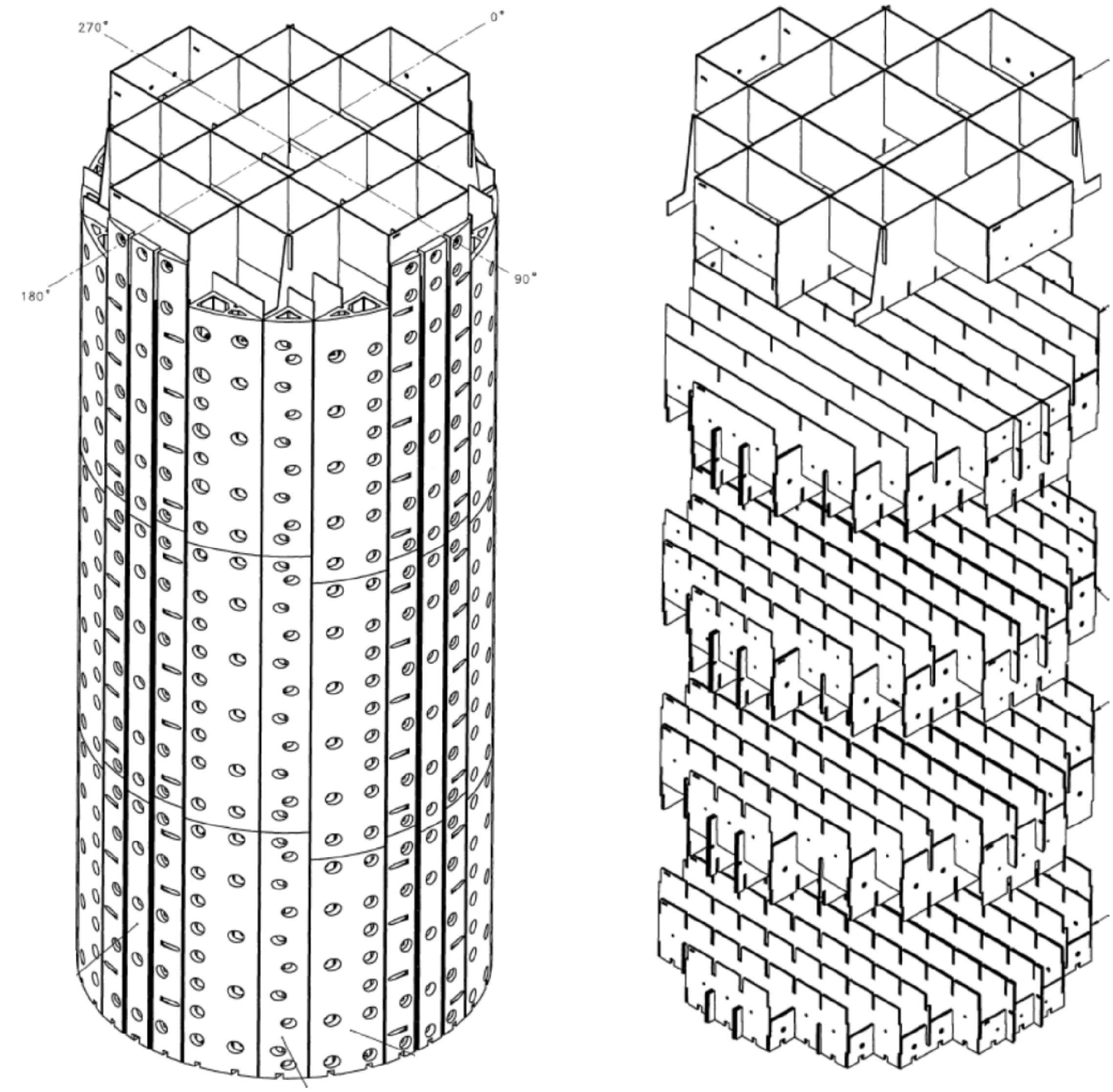


Figure 1-4
EOS-89BTH Basket

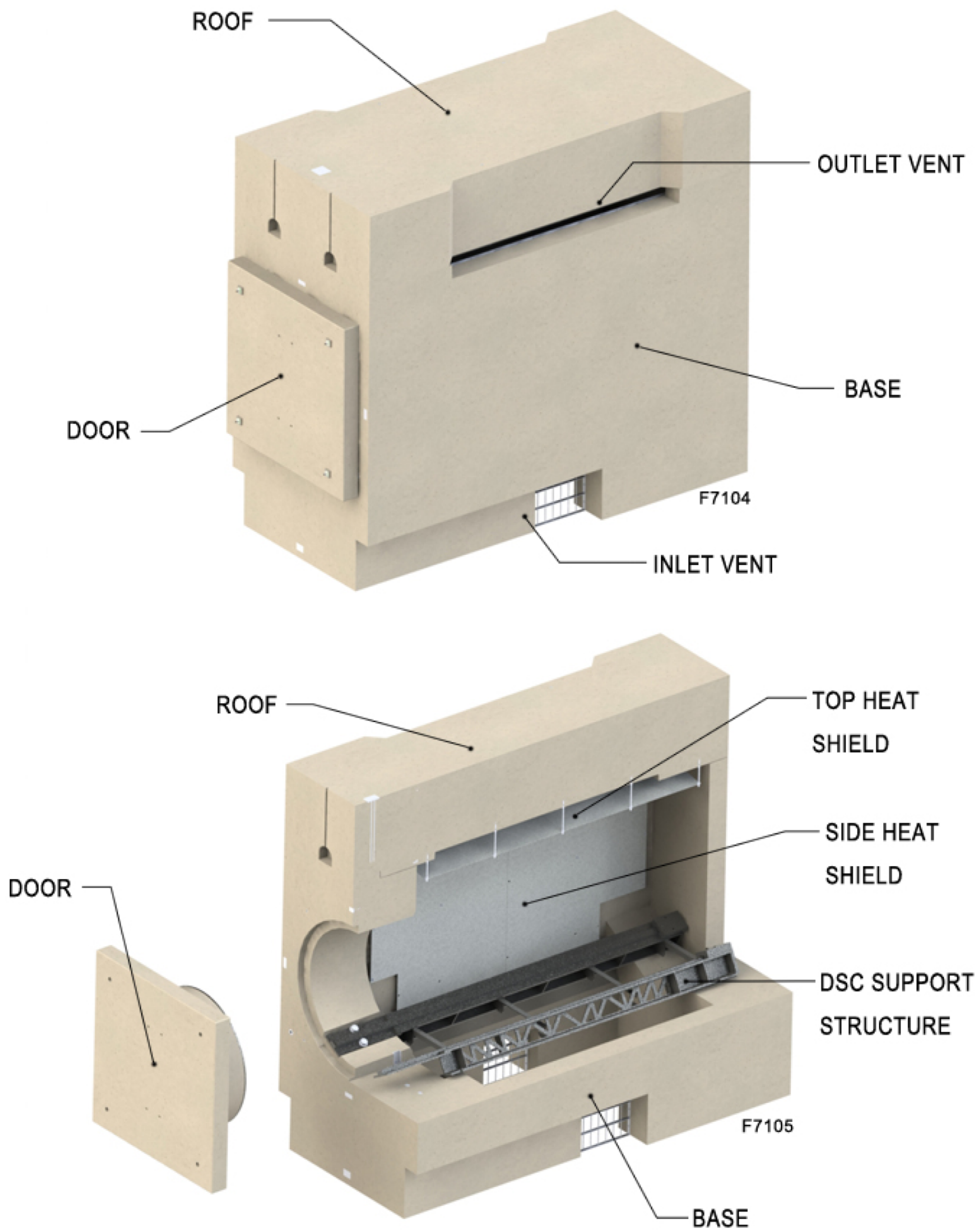


Figure 1-5
EOS-HSM

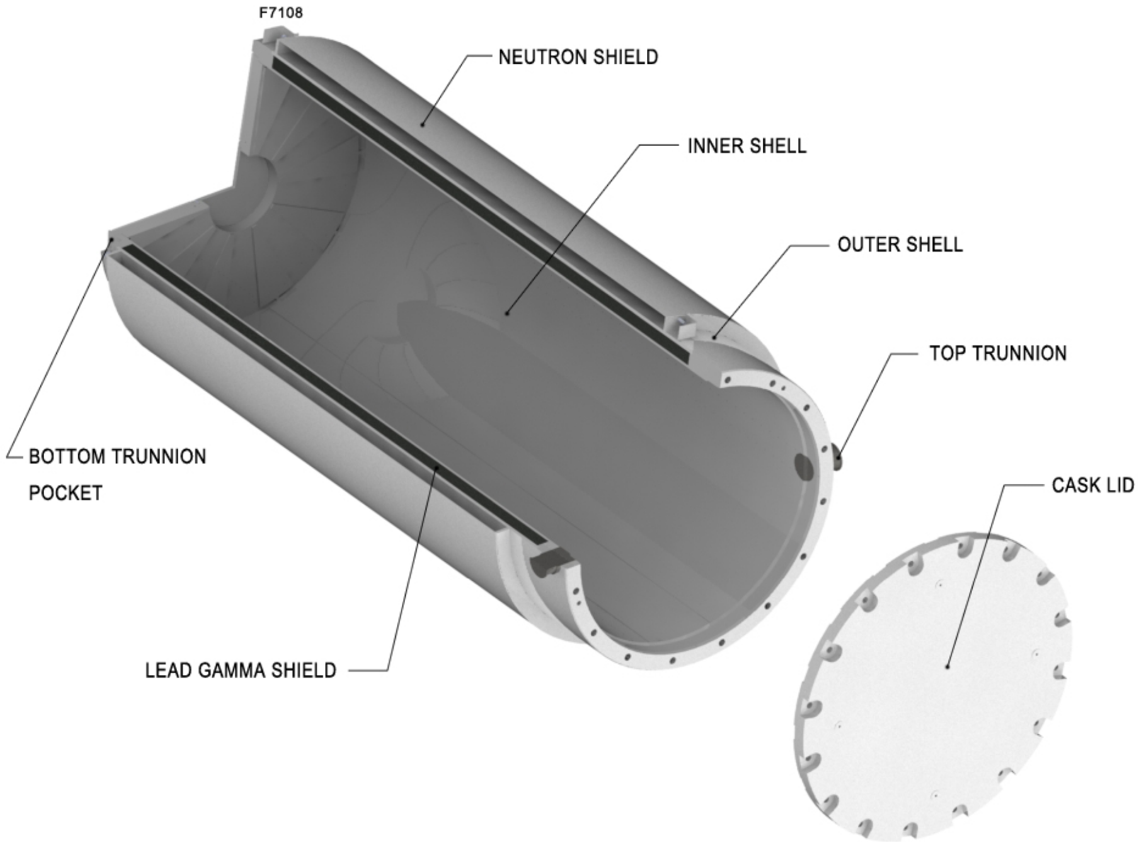


Figure 1-6
TC125/135 Transfer Cask

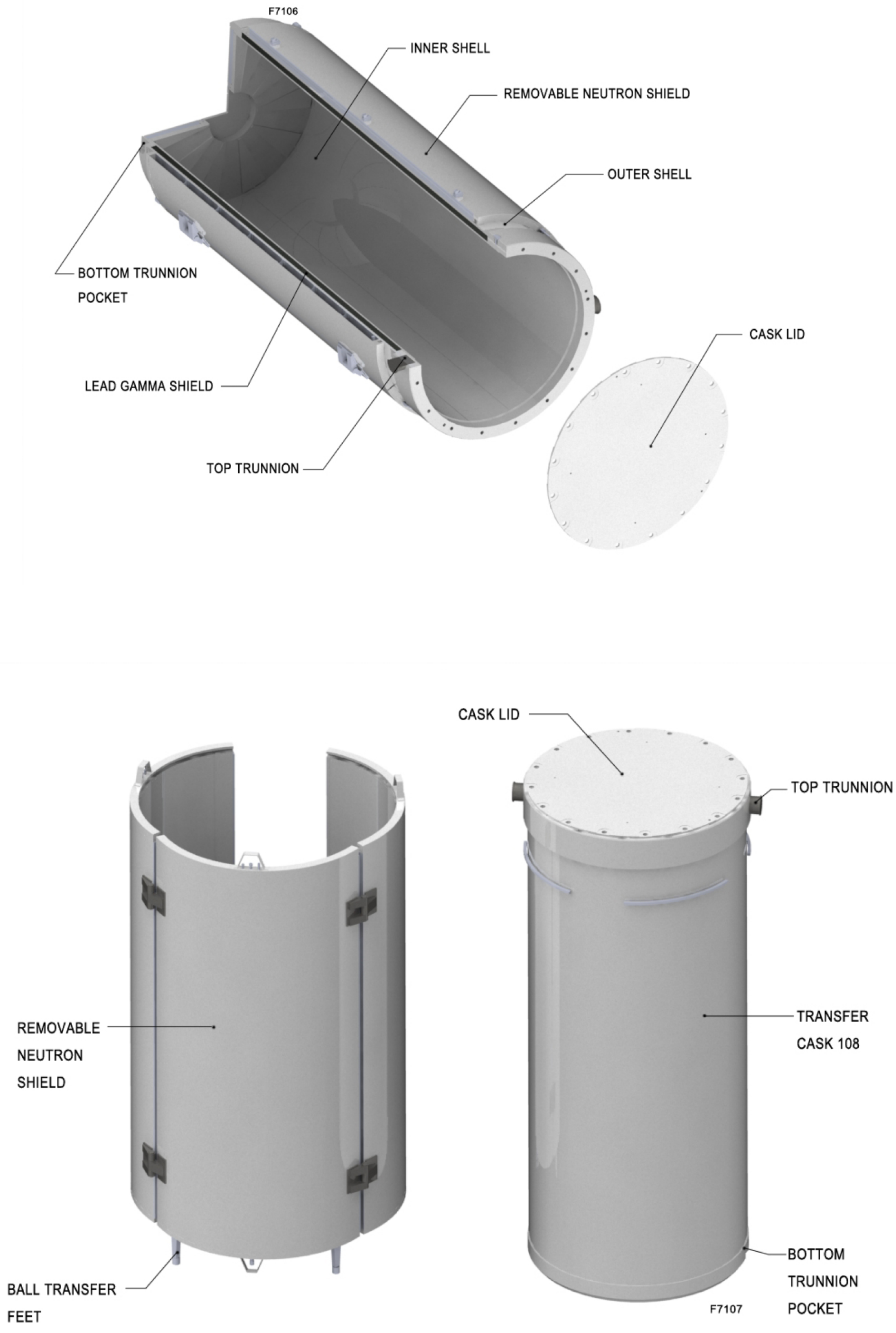


Figure 1-7
TC108 Transfer Cask

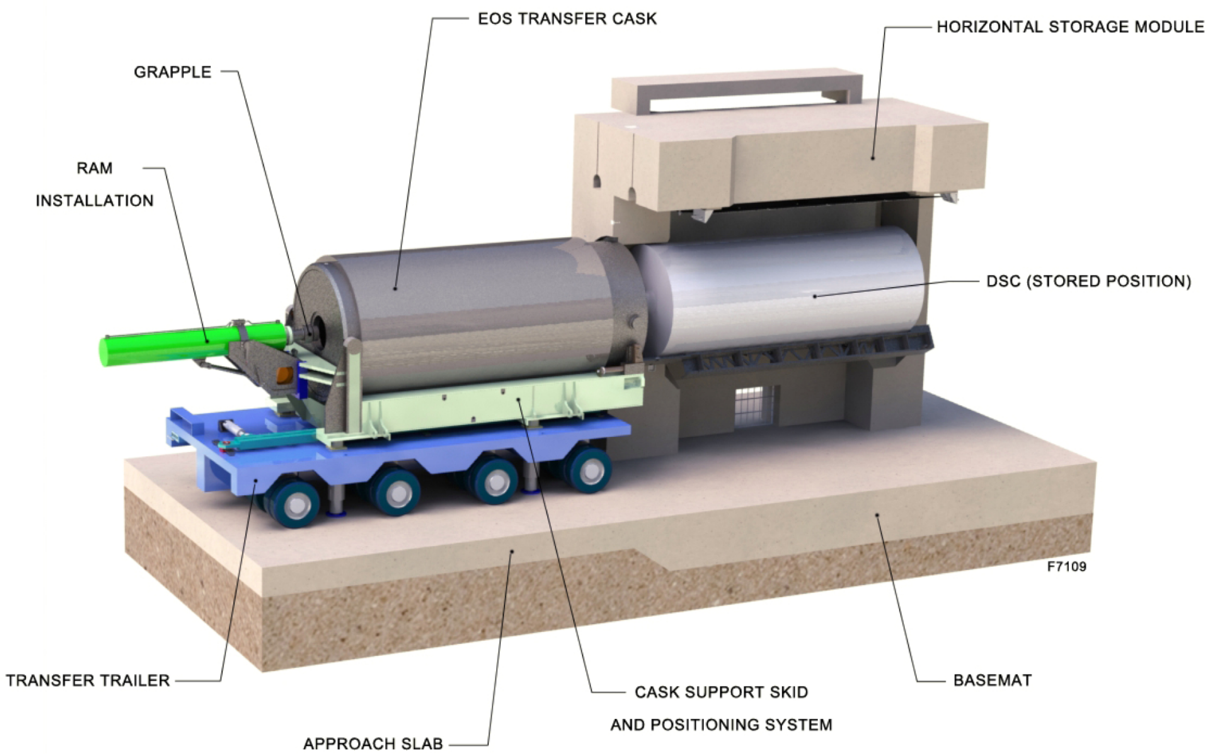


Figure 1-8
NUHOMS® EOS System Components, Structures, and Transfer Equipment

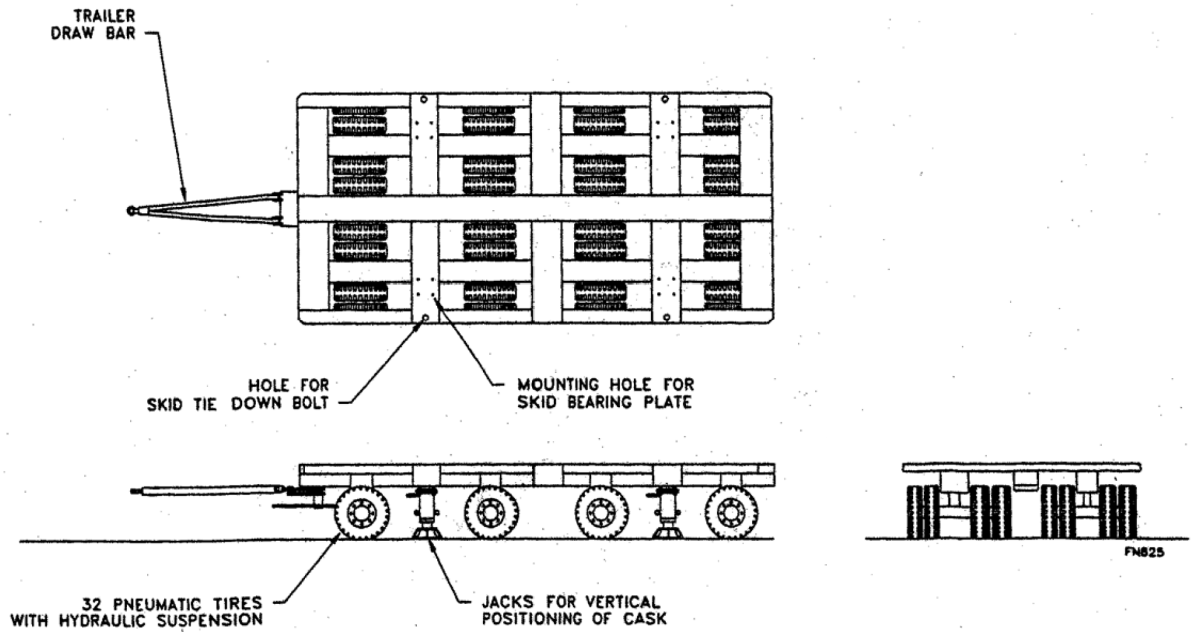


Figure 1-9
Typical Transfer Trailer

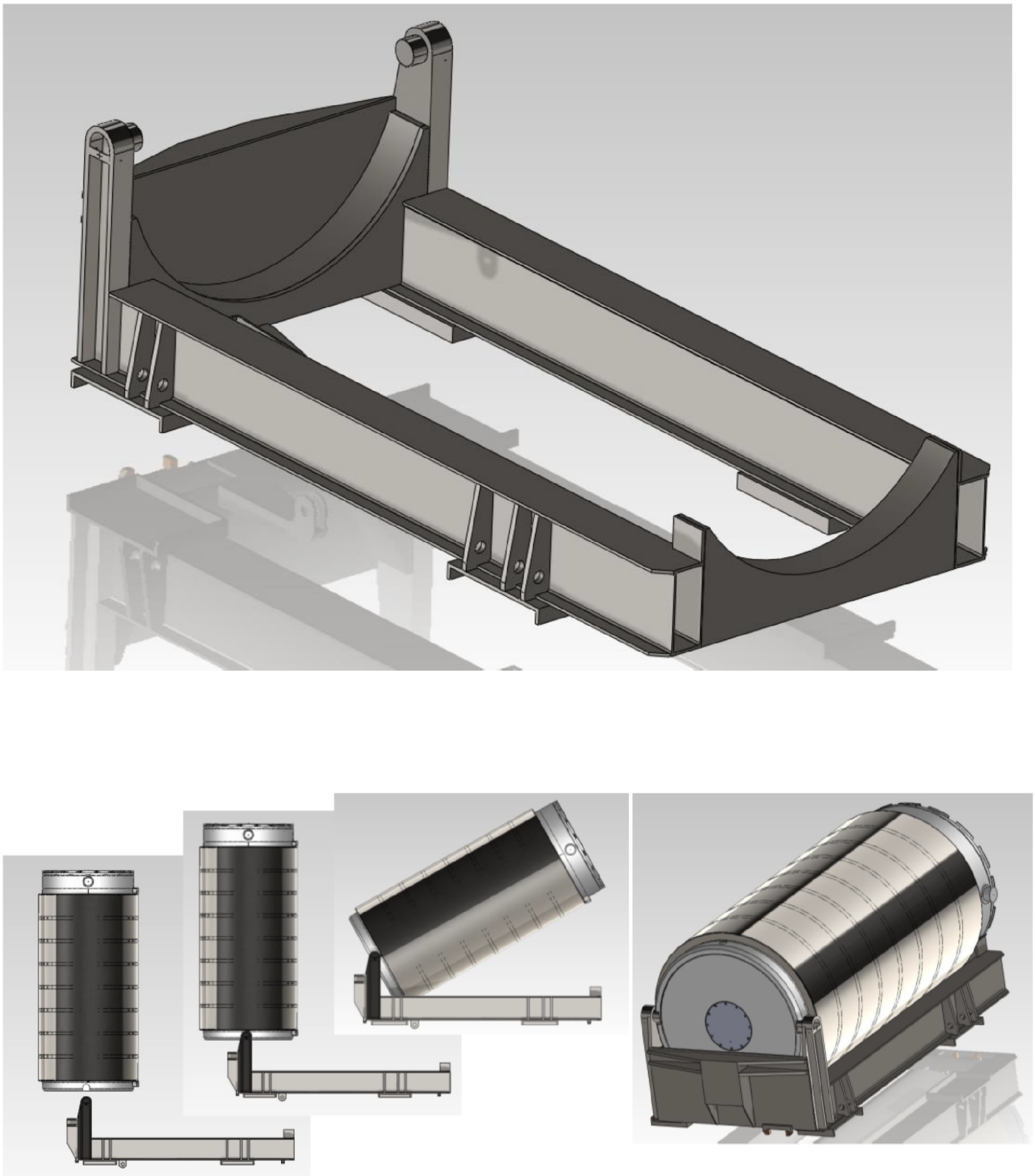
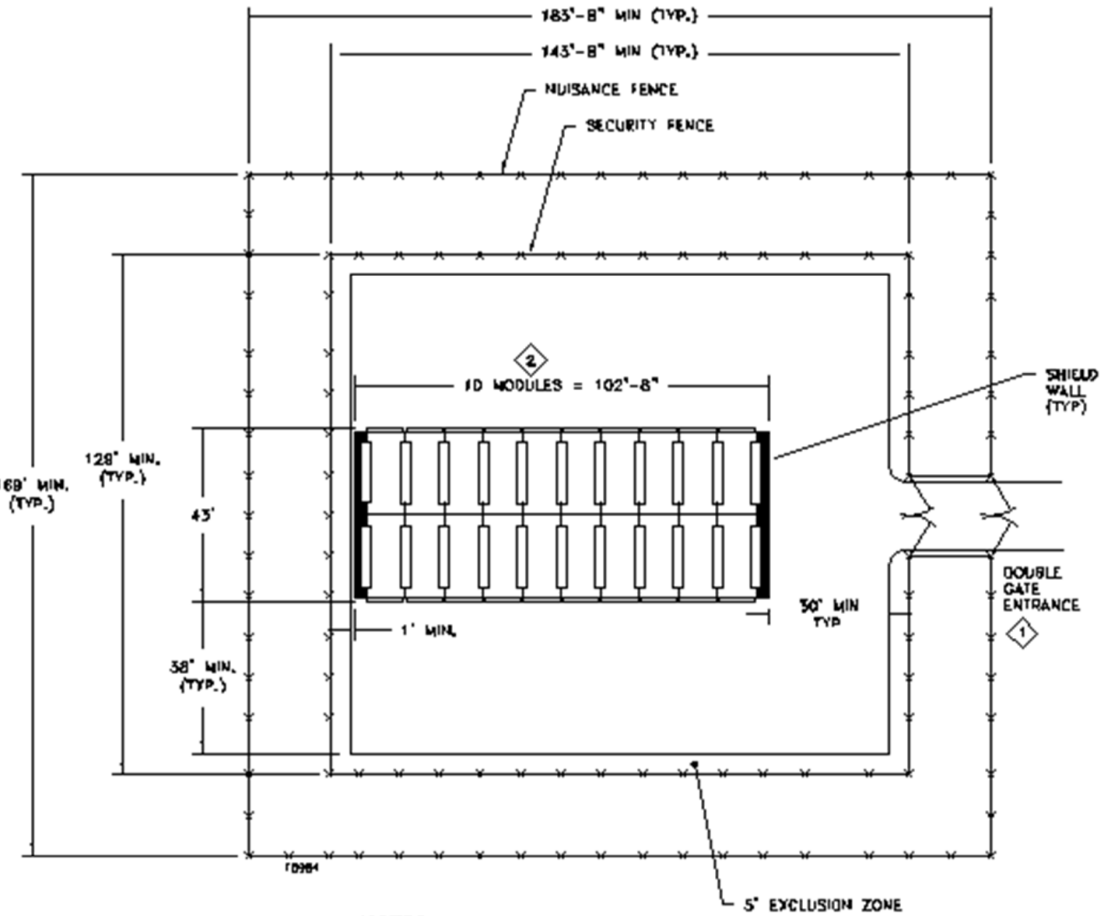


Figure 1-10
Typical Cask Support Skid



NOTES:

1. LOCATION OF ENTRANCE TO ISFSI TO BE COMPATIBLE WITH PLANT SITE ROADS.
2. NUMBER OF MODULES DETERMINED BY USER BASED ON PLANT DISCHARGE RATES AND DRY STORAGE NEEDS.
3. HSM ARRAYS CAN BE EXPANDED BY ADDING ADDITIONAL HSM UNITS. THIS CAN BE DONE WITH OR WITHOUT RELOCATING END SHIELD WALLS.

Figure 1-11
Typical Double Module Row ISFSI Layout with EOS-Medium Modules

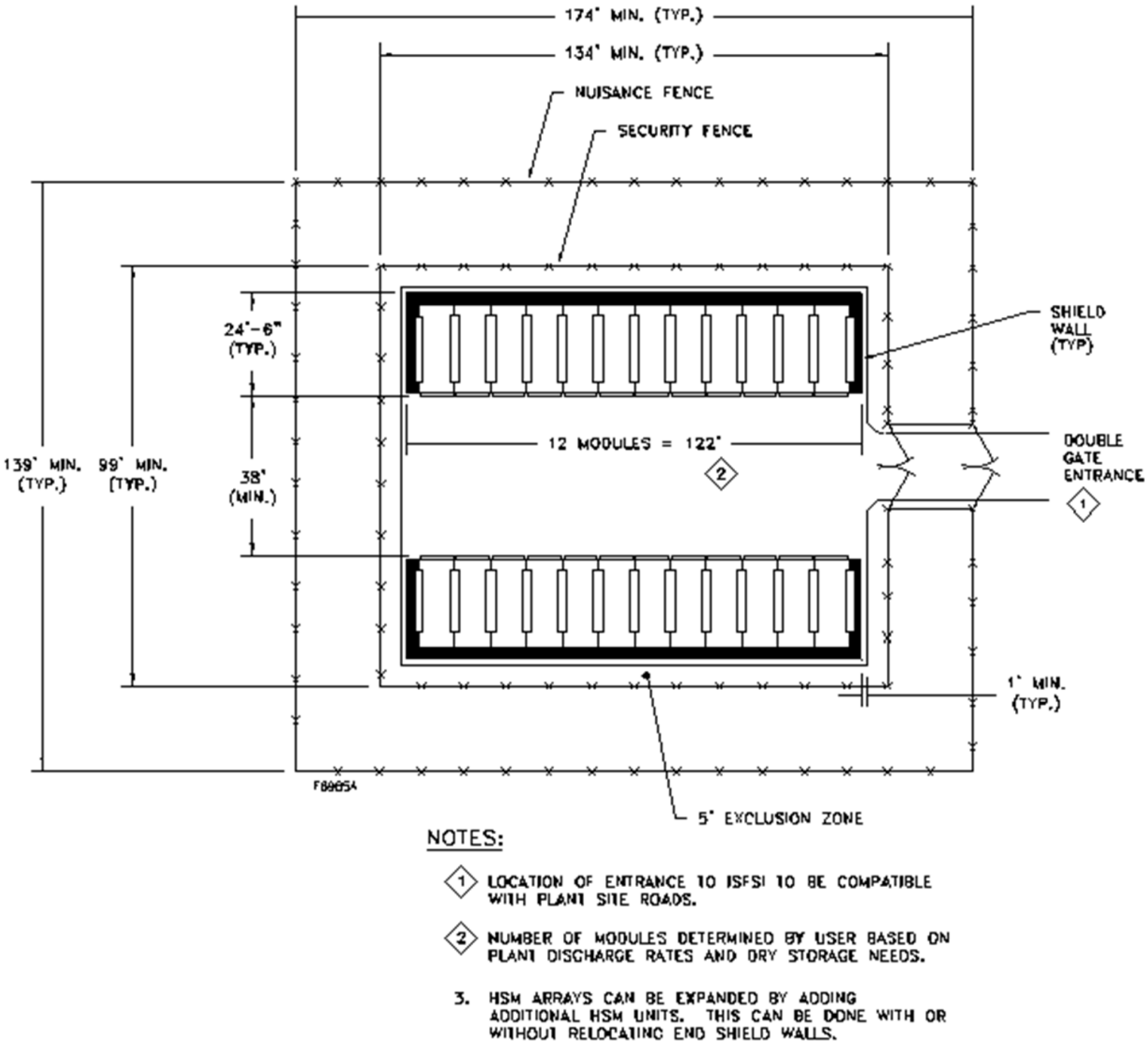
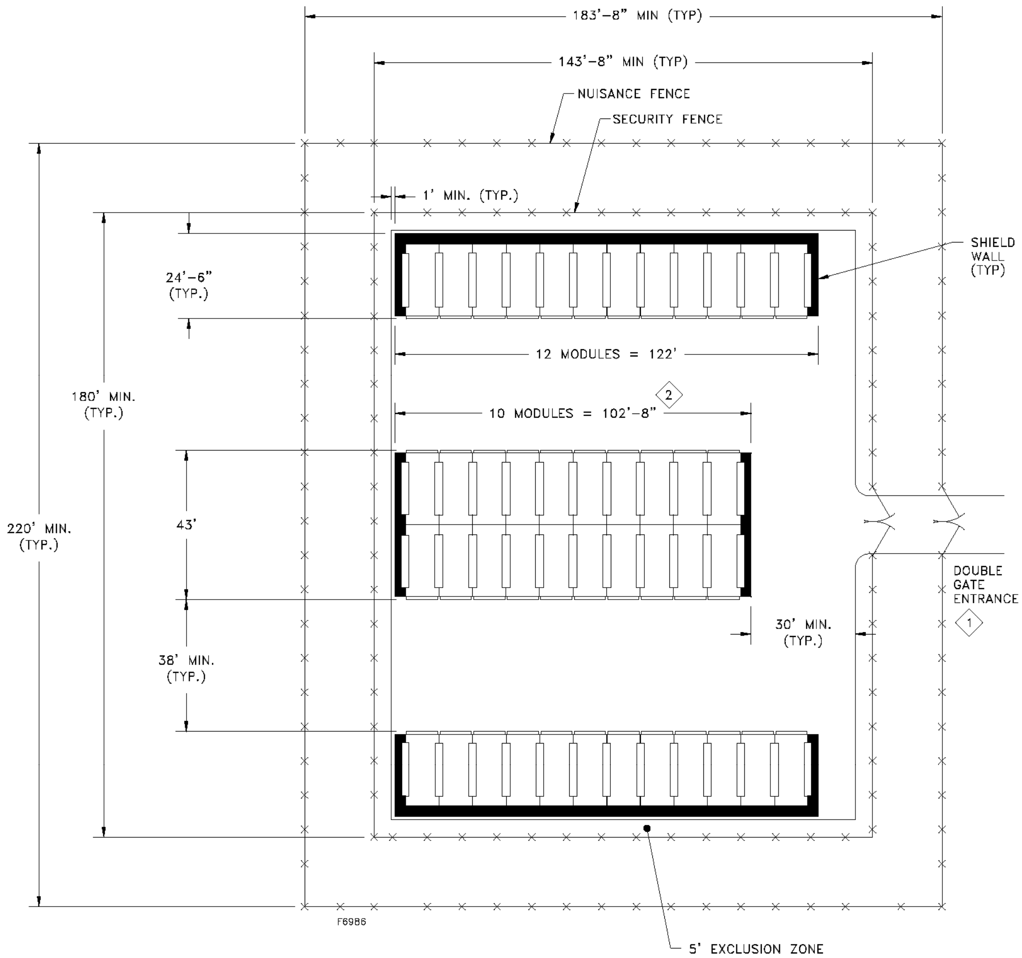


Figure 1-12
Typical Single Module Row ISFSI Layout with EOS-Medium Modules



NOTES:

1. LOCATION OF ENTRANCE TO ISFSI TO BE COMPATIBLE WITH PLANT SITE ROADS.
2. NUMBER OF MODULES DETERMINED BY USER BASED ON PLANT DISCHARGE RATES AND DRY STORAGE NEEDS.
3. HSM ARRAYS CAN BE EXPANDED BY ADDING ADDITIONAL HSM UNITS. THIS CAN BE DONE WITH OR WITHOUT RELOCATING END SHIELD WALLS.

Figure 1-13
Typical Combined Single and Double Module Row ISFSI Layout with EOS-Medium Modules

CHAPTER 2
PRINCIPAL DESIGN CRITERIA

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2. PRINCIPAL DESIGN CRITERIA

This section provides the principal design criteria for the NUHOMS® EOS System described in Chapter 1. Section 2.1 identifies the structures, systems, and components (SSCs) important-to-safety (ITS) for the NUHOMS® EOS System design. Section 2.2 presents a general description of the spent fuel to be stored. Section 2.3 provides the design criteria for environmental conditions and natural phenomena. Section 2.4 discusses safety protection systems.

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 Chapters 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 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).

2.1.3 ISFSI Basemat and Approach Slabs

The ISFSI basemat and approach slabs and buildings for indoor storage are considered NITS and are designed, constructed, maintained, and tested as commercial-grade items.

Licensees are required to perform an assessment to confirm that the license seismic criteria described in Section 2.3.4 are met.

2.1.4 Transfer Equipment

2.1.4.1 Transfer Cask and Yoke

The transfer casks (EOS-TCs) are ITS since they protect the DSC during handling and are part of the primary load path used while handling the DSCs in the fuel/reactor building. An accidental drop of a loaded transfer cask (TC) (weighing up to 135 tons) has the potential for creating conditions in the plant that must be evaluated. These possible drop conditions are evaluated with respect to the impact on the DSC in Chapters 3 and 12. Therefore, the EOS-TCs are designed, constructed, and tested in accordance with a 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.

A lifting yoke is used for handling the TC within the fuel/reactor building and it is used by the licensee (utility) under their 10 CFR Part 50 [2-5] program requirements.

Due to site-unique requirements, rigid or sling lifting members can be used to augment the lifting yoke. These members shall be designed, fabricated and tested in accordance with the same requirements as the cask lifting yoke.

2.1.4.2 Other Transfer Equipment

The NUHOMS® EOS System transfer equipment (i.e., ram, skid, transfer trailer) are necessary for the successful loading of the DSCs into the EOS-HSM. However, these items are not required 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. Therefore, these components are considered NITS and need not comply with the requirements of 10 CFR Part 72. These components are designed, constructed, and tested in accordance with good industry practices.

2.1.5 Auxiliary Equipment

The vacuum drying system and the automated welding system are NITS. Performance of these items is not required 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. Failure of any part of these systems may result in a delay of operations, but will not result in a hazard to the public or operating personnel. These components are designed, constructed, and tested in accordance with good industry practices.

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 and 10x10 array designs) fuel types and reload assemblies 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-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.

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.

The maximum allowable assembly average burnup is limited to 62 GWd/MTU and the minimum cooling time is three years. Dummy FAs, reconstituted FAs are also included in the EOS-37PTH DSC and EOS-89BTH DSC payloads. Reconstituted assemblies containing up to five replacement irradiated stainless steel rods per assembly or an unlimited number of low enriched or natural uranium fuel rods or non-fuel rods are acceptable for storage in an EOS-37PTH DSC and ESO-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.

For FAs with up to five irradiated stainless steel rods the minimum cooling time is 15 years or the cooling time to meet the decay heat limit for the location it is to be stored in the DSC basket, whichever is longer. The stainless steel rods are assumed to have two-thirds the irradiation time as the remaining fuel rods of the assembly. The reconstituted UO_2 rods are assumed to have the same irradiation history as the entire FA. The reconstituted rods can be at any location in the FAs.

There is no limit on the number of reconstituted FAs per DSC. For BLEU fuel the Co-60 activity in the BLEU fuel must be limited to the values shown in Tables 2 and 7 of the Technical Specifications [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 shall be loaded with dummy FAs. The dummy FAs approximate the weight and center of gravity of an FA.

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, double seal 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 intact PWR FAs 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 Control Components (CCs), such as identified below, with thermal and radiological characteristics as listed in Table 3 and Figure 1 of the Technical Specifications [2-18]:

- Control spiders,
- Burnable poison rod assemblies (BPRAs),
- Neutron source assemblies (NSAs),
- Thimble plug assemblies (TPAs),
- Control rod assemblies (CRAs),
- Axial power shaping rod assemblies (APSRAs),
- Orifice rod assemblies (ORAs),
- Integral fuel burnable absorber assemblies (IFBAs),
- Peripheral power suppression assemblies (PPSAs),
- Rod cluster control assemblies (RCCAs),
- Wet annular burnable absorbers (WABAs),
- Vibration suppression inserts (VSIs),
- Neutron sources and,

- Control element assemblies (CEAs)

Furthermore, non-fuel hardware that is positioned within the fuel assembly after the fuel assembly is discharged from the core such as guide tube or instrument tube tie rods or anchors, guide tube inserts, BPRA spacer plates or devices that are positioned and operated within the FA during reactor operation such as those listed above are also considered as CCs.

Figure 1 of the Technical Specifications [2-18] defines the maximum decay heat 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 maximum weight of a FA plus CC, if applicable, is 1,900 lbs.

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.

Figure 2 of the Technical Specifications [2-18] define the maximum decay heat and other parameters for BWR fuel assemblies authorized for storage. These tables are used to ensure that the decay heat load of the fuel assembly 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 maximum weight of an FA plus channel, if applicable, is 705 lbs.

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.

2.3 Design Criteria for Environmental Conditions and Natural Phenomena

The NUHOMS® EOS System ITS SSCs described in Section 2.1 are designed consistent with the 10 CFR Part 72 [2-6] §122(b) requirement for protection against environmental conditions and natural phenomena. The criterion used in the design of the NUHOMS® EOS System ensures that exposure to credible site hazards does not impair their safety functions.

2.3.1 Tornado Wind and Tornado Missiles for EOS-HSM

The EOS-HSM is designed to safely withstand 10 CFR 72.122 (b)(2) tornado missiles. To ensure that the EOS-HSM design covers existing plants designed to earlier U.S. Nuclear Regulatory Commission (NRC) criteria, the EOS-HSM is designed to resist the bounding most severe tornado characteristics. The tornado characteristics as specified in NRC Regulatory Guide 1.76, Revision 0 [2-7] are used to qualify the EOS-HSM and the missiles spectrum of NUREG-0800, Revision 2, Section 3.5.1.4 [2-9] with missile velocity for Region I is used to qualify the EOS-HSM.

Extreme wind effects are much less severe than the specified design basis tornado (DBT) wind forces. The design basis extreme wind for the EOS-HSM is calculated per [2-12].

2.3.1.1 Tornado Wind Design Parameters

The design basis tornado wind intensities used for the EOS-HSM design are obtained from NRC Regulatory Guide 1.76, Revision 0 [2-7]. Region I intensities are utilized since they result in the most severe loading parameters. For this region, the maximum wind speed is 360 mph, the rotational speed is 290 mph and the maximum translational speed is 70 mph. The radius of the maximum rotational speed is 150 feet, the pressure drop across the tornado is 3 psi and the rate of pressure drop is 2 psi per second.

2.3.1.2 Determination of Forces on Structures

Tornado loads result from three separate loading phenomena and these loading effects are combined in accordance with Section 3.3.2 of NUREG-0800, Revision 3 [2-10]:

- Pressure or suction forces created by drag as air impinges on and flows past the EOS-HSM. These pressure or suction forces are due to tornado-generated wind with maximum wind speed of 360 mph.
- Pressure or suction forces created by tornado generated pressure drop or differential pressure load of 3 psi.
- Impact forces created by tornado-generated missiles striking the EOS-HSM.

The determination of the DBT velocity pressure is in accordance with the requirements of American Society of Civil Engineers (ASCE) 7-10 [2-12]. The resistance to overturning and sliding of the EOS-HSM under these design pressures is determined considering the bounding condition of a single EOS-HSM with end shield walls.

2.3.1.3 Tornado Missiles

The four missiles listed below envelope the missile spectrum of NUREG-0800, Revision 2, Section 3.5.1.4 [2-9]. These missiles also bound the missile spectrum of NRC Regulatory Guide 1.76, Revision 1 [2-8] and NUREG-0800, Revision 3, Section 3.5.1.4 [2-10]. Evaluation for the effects of small diameter solid spherical missiles is not required because there are no openings in the EOS-HSM leading directly to the DSC through which such missiles could pass.

- Utility wooden pole, 13.5" diameter, 35' long, 1,124 lbs, traveling 180 fps.
- Armor piercing artillery shell, 8" diameter, 276 lbs, traveling 185 fps.
- Steel pipe, 12" diameter, schedule 40, 15 ft. long, 750 lbs, traveling 154 fps.
- Deformable massive missile simulated by a 4,000-pound automobile traveling through the air not more than 25 feet above the ground level with a contact area of 20 ft^2, impacting at normal incidence with a horizontal velocity of 195 fps.

In determining the overall effects of a DBT missile impact, overturning, and sliding of the EOS-HSM, the force due to the missile impact is applied to the structure at the most adverse location. For hand calculations, conservation of momentum is used to demonstrate that sliding and/or tipping of a single module does not result in an unstable condition for the module. The coefficient of restitution is conservatively assumed as zero so that 100% of the missile energy is transferred to the EOS-HSM. The missile energy transferred to the EOS-HSM dissipates by sliding friction and/or an increase in potential energy by raising the EOS-HSM center of gravity. The calculations assume the missile impact force as evenly distributed over the impact area, and use a 0.6 coefficient of friction for concrete on concrete surfaces.

For localized damage of the EOS-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 evaluated 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.

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 0.5g in the horizontal direction and 0.333g 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 stability criteria for seismic loading are based on the stability response of a single, freestanding EOS-HSM with and without an end shield wall.

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.

Reference [2-13] also states that, for sites with acceleration values different from maximum horizontal ground acceleration of 1.0g, the response spectra used for design should be linearly scaled in proportion to the maximum specified horizontal ground acceleration. The maximum horizontal ground acceleration component selected for design of the NUHOMS® EOS-HSM is 0.5g. The maximum vertical acceleration component selected is two-thirds of the horizontal component, which is 0.333g.

The EOS-HSMs in the array have no anchorage to the concrete basemat and there are no structural ties between 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 0.5g in the horizontal direction and 0.333g in the vertical direction. It is recommended to provide shims under the end and rear shield walls when the concrete pad surface is uneven.

For sites having higher peak ground acceleration than the design ZPA, more than one module may need to be tied together to prevent significant sliding or to prevent the modules from banging into each other causing unacceptable damage. The reinforcement requirement may also need to be reviewed and additional rebar may be added for such sites. The methodology, as documented in COC 1029 [2-19], may be used for higher seismic load cases.

2.3.5 Snow and Ice Loading

Snow and ice loads for the EOS-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.

2.4 Safety Protection Systems

2.4.1 General

The NUHOMS® EOS System is designed to provide long-term storage of spent fuel. The DSC materials are selected for degradation to not be expected during the storage period. The DSC shell and bottom end assembly confinement boundary weld is made during fabrication of the DSC in accordance with the subsection NB of the ASME code. The top and bottom shield plugs and covers provide shielding for the DSC so that occupational doses are minimized during drying, sealing, and handling operations. The confinement boundary weld between the DSC shell and inner top cover (including drain port cover and vent plug welds) and structural attachment weld between the DSC shell and outer top cover plate are in accordance with alternatives to the ASME code as described in Section 4.4.4 of the Technical Specifications [2-18].

The radioactive material stored in the NUHOMS® EOS System is the SFAs and the associated contaminated or activated materials.

During fuel loading operations, the radioactive material in the plant's fuel pool is prevented from contacting the DSC exterior by filling the TC/DSC annulus with uncontaminated, demineralized water prior to placing the cask and DSC in the fuel pool. In addition, the TC\DSC annulus opening at the top of the EOS-TC is sealed using an inflatable seal to prevent pool water from entering the annulus. This procedure minimizes the likelihood of contaminating the DSC exterior surface. The combination of the above operations ensures that the DSC surface loose contamination levels are within those required for shipping cask externals. Compliance with these contamination limits is ensured by taking surface swipes of the upper end of the DSC before transferring the cask from the fuel building.

Once inside the DSC, the contents are confined by the DSC confinement boundary. The fuel cladding integrity is ensured by maintaining the storage cladding temperatures below levels that are known to cause degradation of the cladding. In addition, the SFAs are stored in an inert atmosphere to prevent degradation of the cladding, specifically cladding rupture due to oxidation and its resulting volumetric expansion of the fuel. Thus, a helium atmosphere for the DSC is incorporated into the design to protect the fuel cladding integrity by inhibiting the ingress of oxygen into the cavity.

Helium is known to leak through valves, mechanical seals, and escape through very small passages because it has a small atomic diameter, is an inert element, and exists in a monatomic species. Helium will not, to any practical extent, diffuse through stainless or duplex steel. For this reason, the DSC has been designed as a welded confinement pressure vessel with no mechanical or electrical penetrations and meets the leak-tight criteria as described in Chapter 10. See Chapter 5 for a detailed discussion of the confinement boundary design.

The DSC itself has a series of barriers to ensure the confinement of radioactive materials. The cylindrical shell is fabricated from rolled ASME stainless steel plate or duplex steel, which is joined with full penetration welds that are 100% inspected by non-destructive examination. All top and bottom end closure welds are multiple-layer welds. This effectively eliminates any pinhole leaks that might occur in a single pass weld, since the chance of pinholes being in alignment on successive weld passes is not credible. Furthermore, the cover plates are sealed by separate, redundant closure welds. Pressure boundary welds and welders are qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code and inspected according to the appropriate articles of Section III, Division 1, Subsection NB including alternatives to ASME Code as specified in Section 4.4.4 of the Technical Specifications [2-18]. These criteria ensure that the as-deposited weld filler metal is as sound as the parent metal of the pressure vessel.

Pressure monitoring instrumentation is not used since penetration of the pressure boundary would be required. The penetration itself would then become a potential leakage path and by its presence compromise the integrity of the DSC design. The shell and welded cover plates provide total confinement of radioactive materials. Once the DSC is sealed, there are no credible events, as discussed in Chapter 12, which could fail the cylindrical shell or the closure plates that form the confinement boundary.

The NUHOMS® EOS System provides safe and long-term dry storage of SFAs. The key elements of the NUHOMS® EOS System, and its operation requiring special design consideration, are:

A. Minimizing contamination of the DSC exterior by fuel pool water.

B. Double-closure seal welds on the DSC shell to form a pressure retaining containment boundary, and to maintain the DSC interior helium atmosphere.

C. Minimizing personnel radiation exposure during DSC loading, closure, and transfer operations.

D. Maintaining EOS-TC and DSC ITS features under postulated accident conditions.

E. Passive ventilation of the EOS-HSM providing effective decay heat removal thereby maintaining fuel cladding temperature below the maximum limit.

F. DSC basket assembly to ensure that the SFAs are maintained in a subcritical configuration.

Components of the NUHOMS® EOS System that are ITS and NITS are listed in Table 2-1.

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. 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 43.6 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 2 kW for the EOS-37PTH DSC and 0.6 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 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 43.6 kW per DSC for the EOS-89BTH. Zoning is used to accommodate high per assembly heat loads. The heat load zoning configurations (HLZCs) for the DSCs are shown in Figures 1 and 2 of the Technical Specifications [2-18].

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 34.3 kW in the EOS-89BTH DSC as described in the Technical Specifications [2-18].

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 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 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.

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.

2.4.5 Criticality

The criticality analyses are performed with the CSAS5 module of the SCALE system [2-17]. For the EOS-37PTH DSC a combination of soluble boron in the fuel pool, the fixed poison in the basket and geometry are relied on to maintain criticality control. The structural analysis shows that there is no deformation of the basket under accident conditions that would increase reactivity. The EOS-37PTH basket is fabricated with one of two neutron poison loading options as shown in Table 5 of the Technical Specifications [2-18].

These two basket types allow flexibility to accommodate the payload fuel types and initial enrichments, with and without CCs, and credit for soluble boron (2000 – 2500 ppm) in the fuel pool during loading and unloading operations. Table 4 of the Technical Specifications [2-18] and Chapter 7 documents the minimum soluble boron required as a function of basket type and FA design/initial enrichment to be stored. Pressurized water reactor FAs with maximum planar average enrichments up to 5.0 wt.% U-235 can be stored.

For the EOS-89BTH DSC, a combination of fixed poison in the basket and geometry are relied on to maintain criticality control. The structural analysis shows that there is no deformation of the basket under accident conditions that would increase reactivity. The EOS-89BTH basket is fabricated with one of three neutron poison loading options as shown in Table 8 of the Technical Specifications [2-18].

These three basket types allow flexibility to accommodate the payload fuel types and initial enrichments, with and without channels during loading and unloading operations. Table 8 of the Technical Specifications [2-18] and Chapter 7 documents the allowed fuel assembly design/initial enrichment as a function of basket type allowed to be stored. Fuel assemblies with maximum lattice average enrichments up to 4.8 wt. % U-235 can be stored in the M2-A basket type.

The criticality analysis in Chapter 7 takes 90% credit for the B-10 content of the metal matrix composite (MMC) material and 75% credit for the B-10 content of the BORAL® material. Chapter 10 provides the testing requirements to justify the B-10 credit used in the criticality analysis.

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 EOS-HSM is a reinforced concrete component with an internal DSC support structure 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 provides an 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 prefabricated 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.

2.5 References

2-1 Title 10, Code of Federal Regulations, Part 100, "Reactor Site Criteria."

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

2-3 ACI 349-06, "Code Requirements for Nuclear Safety Related Concrete Structures," American Concrete Institute.

2-4 ACI 318-08, "Building Code Requirements for Structural Concrete and Commentary," American Concrete Institute.

2-5 Title 10, Code of Federal Regulations, Part 50, "Domestic Licensing of Production and Utilization Facilities."

2-6 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."

2-7 NRC Regulatory Guide 1.76, "Design Basis Tornado for Nuclear Power Plants," Rev. 0, April 1974.

2-8 U.S. Nuclear Regulatory Commission, Regulatory Guide 1.76, "Design Basis Tornado and Tornado Missiles for Nuclear Power Plants," Rev. 1, March 2007.

2-9 NUREG-0800, Standard Review Plan, Section 3.5.1.4 "Missiles Generated by Natural Phenomena," Rev. 2, July 1981.

2-10 NUREG-0800, Standard Review Plan, Section 3.3.1 "Wind Loading", Section 3.3.2 "Tornado Loads", and Section 3.5.1.4 "Missiles Generated by Tornado and Extreme Winds," Rev. 3, March 2007.

2-11 NUREG-0800, Standard Review Plan, Section 3.5.3 "Barrier Design Procedures," Rev. 3, March 2007.

2-12 American Society of Civil Engineers, ASCE 7-10, "Minimum Design Loads for Buildings and Other Structures," (formerly ANSI A58.1).

2-13 NRC Regulatory Guide 1.60, "Design Response Spectra for Seismic Design of Nuclear Power Plants" Rev. 1, December 1973.

2-14 ANSI N14.6, "American National Standard for Special Lifting Device for Shipping Containers Weighing 10,000 lbs. or More for Nuclear Materials," American National Standards Institute, Inc., 1993.

2-15 ANSI N14.5, "Leakage Tests on Packages for Shipment of Radioactive Materials," American National Standards Institute, Inc., 1997.

2-16 U.S. Nuclear Regulatory Commission, Regulatory Guide 1.61, "Damping Values for Seismic Design of Nuclear Power Plants," Rev 1, March 2007.

2-17 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.

2-18 Proposed CoC 1042 Appendix A, NUHOMS® EOS System Generic Technical Specifications, Amendment 0.

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

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
DSC Lifting Lug	NITS
Siphon Assembly	NITS
Drain Port Cover and Vent Plug	ITS
Test Port Plug	ITS
Grapple Ring and Grapple Support	ITS
Basket Key	ITS
Weld Filler Metal	ITS
Horizontal Storage Module (EOS-HSM/EOS-HSMS)	
Reinforced Concrete	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
Automatic 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.

Table 2-2
PWR Fuel Assembly Design Characteristics
3 Pages

Fuel Class	**B&W 15x15**				**WE 17x17**
Assembly Type	**Mark B2 - B8**	**Mark B9**	**Mark B10**	**Mark B11**	**BW 17x17 Mark C**
Fuel Parameters					
Number of Rods	208	208	208	208	264
Active Fuel Length (in.)	≤150	≤150	≤150	≤150	≤150
Pellet Diameter (in.)	0.3686	0.37	0.3735	0.3615	0.3232
Fuel Rod Pitch (in.)	0.568	0.568	0.568	0.568	0.502
Clad Outer Diameter (OD) (in.)	0.43	0.43	0.43	0.416	0.379
Clad Thickness (in.)	0.0265	0.0265	0.025	0.024	0.024
Guide and Instrument Tubes					
Number of Guide/Instrument Tubes	17	17	17	17	17
Guide/Instrument Tube Thickness (in.)	≥0.016	≥0.016	≥0.016	≥0.016	≥0.026

Fuel Class	**WE 14 x 14**			
Assembly Type	**Std/LOPAR/ ZCA/ZCB**	**OFA**	**Exxon/ANF (ANP) WE**	**Exxon/ANF (ANP) Top rod**
Fuel Parameters				
Number of Rods	179	179	179	179
Active Fuel Length (in.)	≤150	≤150	≤150	≤150
Pellet Diameter (in.)	0.364-0.3674	0.364-0.3674	0.3505	0.3505
Fuel Rod Pitch (in.)	0.556	0.556	0.556	0.556
Clad OD (in.)	0.422	0.400	0.424	0.417
Clad Thickness (in.)	0.0225-0.030	0.0243-0.034	0.024-0.030	0.024-0.0295
Guide and Instrument Tubes				
Number of Guide/Instrument Tubes	17	17	17	17
Guide/Instrument Tube Thickness (in.)	≥0.015	≥0.015	≥0.016	≥0.019

Fuel Class	**WE 17x17**			
Assembly Type	**LOPAR**	**OFA/ Van 5**	**Framatome 17x17 STD/Van 5H/RFA**	**Framatome 17x17 MK BW**
Fuel Parameters				
Number of Rods	264	264	264	264
Active Fuel Length (in.)	≤150	≤150	≤150	≤150
Pellet Diameter (in.)	0.3225	0.3088	0.3225	0.3195
Fuel Rod Pitch (in.)	0.496	0.496	0.496	0.496
Clad OD (in.)	0.374	0.360	0.374	0.374
Clad Thickness (in.)	0.0225	0.0225	0.0225	0.0240
Guide and Instrument Tubes				
Number of Guide/Instrument Tubes	25	25	25	25
Guide/Instrument Tube Thickness (in.)	≥0.015	≥0.015	≥0.015	≥0.016

Table 2-2
PWR Fuel Assembly Design Characteristics
3 Pages

Fuel Class	**CE 14 x 14**		
Assembly Type	**Std/Gen/St. Lucie**	**Fort Calhoun**	**Framatome CE**
Fuel Parameters			
Number of Rods	176	168	176
Active Fuel Length (in.)	≤150	≤150	≤150
Pellet Diameter (in.)	0.370 – 0.3805	0.3765	0.3805
Fuel Rod Pitch (in.)	0.58	0.580	0.580
Clad OD (in.)	0.44	0.440	0.440
Clad Thickness (in.)	0.026 – 0.031	0.0280	0.0280
Guide and Instrument Tubes			
Number of Guide/Instrument Tubes	5	5	5
Guide/Instrument Tube Thickness (in.)	≥0.040	≥0.040	≥0.040

Fuel Class	**WE 15 x 15**			**CE 15x15**	
Assembly Type	**LOPAR/ OFA DRFA/ Van5**	**Std/ZC**	**Exxon ANF (ANP) WE**	**CE 15x15 Palisades**	**CE 15x15 Exxon/ ANF (ANP)**
Fuel Parameters					
Number of Rods	204	204	204	216	216
Active Fuel Length (in.)	≤150	≤150	≤150	≤150	≤150
Pellet Diameter (in.)	0.3659	0.3559	0.3565	0.3150 - 0.3600	0.3565
Fuel Rod Pitch (in.)	0.563	0.563	0.563	0.550	0.550
Clad OD (in.)	0.422	0.422	0.424	0.4138 - 0.4180	0.417
Clad Thickness (in.)	0.0280	0.0242	0.0300	0.024 – 0.0295	0.0300
Guide and Instrument Tubes					
Number of Guide/Instrument Tubes	21	21	21	8	Note 3
Guide/Instrument Tube Thickness (in.)	≥0.015	≥0.015	≥0.017	≥0.024	≥0.027

Table 2-2
PWR Fuel Assembly Design Characteristics
3 Pages

Fuel Class	**CE 16x16**			
Assembly Type	**Standard**	**System 80**	**CE 16 x 16 SCE U2/3 Westinghouse Designs**	**CE 16 x 16 SCE U2/3 AREVA Designs**
Fuel Parameters				
Number of Rods	236	236	236	236
Active Fuel Length (in.)	≤150	≤150	≤150	≤150
Pellet Diameter (in.)	0.3250	0.3250	0.3255	0.3255
Fuel Rod Pitch (in.)	0.506	0.506	0.506	0.506
Clad OD (in.)	0.382	0.382	0.382	0.382
Clad Thickness (in.)	0.025	0.023	0.025	0.025
Guide and Instrument Tubes				
Number of Guide/Instrument Tubes	5	5	5	5
Guide/Instrument Tube Thickness (in.)	≥0.041	≥0.041	≥0.040	≥0.040

Notes:

1. All dimensions shown are nominal.
2. Reload FAs from other manufacturers with these parameters are also acceptable.
3. One instrument tube and eight guide bars (solid Zr).

Table 2-3
BWR Fuel Assembly Design Characteristics
4 Pages

BWR Fuel ID	**GE-7-A**	**GE-8-A**	**GE-8-B**	**GE-8-C**	**GE-8-D**	**GE-9-A**	**GE-10-A**	**GE-10-B**	**ENC-7-B**
FA Design	**7 x 7-49/0**	**8 x 8-63/1**	**8 x 8-62/2**	**8 x 8-60/4**	**8 x 8-60/1**	**9 x 9-74/2**	**10x10-92/2**	**10x10**	**7 x 7-48/0**
Reload Fuel Designation[(1)(2)]	GE1 GE2 GE3	GE4	GE-5 GE-Pres GE-Barrier GE8 Type I	GE8 Type II	GE9 GE10	GE11 GE13	GE12 GE14	GNF2	ENC-III [(11)]
Rod Pitch (in.)	0.738	0.640	0.640	0.640	0.640	0.566	0.510	0.510	0.738
No of Fueled Rods	49	63	62	60	60	66 full 8 partial	78 full 14 partial	78 full 14 partial	48
Maximum Active Fuel Length (in.)	≤150	≤150	≤150	≤150	≤150	146” full 90” partial 108” partial GE13	150” full 93” partial 84” partial GE14	150.3” full 110.81” partial 59.4” partial	≤150
Fuel Rod OD (in.)	0.563	0.493	0.483	0.483	0.483	0.440	0.404	0.404	0.570
Clad Thickness (in.)	0.032 0.037	0.034	0.032	0.032	0.032	0.028	0.026	0.0236	≥0.0355
Fuel Pellet OD (in.)	0.491 0.477	0.416	0.410 0.411	0.410 0.411	0.411	0.376	0.345	0.350	0.468 - 0.491
No of Water Rods	0	1	2	4	1	2	2	2	1 (Note 3)
Water Rod OD (in.)	---	0.493	0.591	2 @ 0.591 2 @ 0.483	1.340	0.980	0.980	0.98	0.572[(3)]
Water Rod Inner Diameter ID (in.)	---	0.425	0.531	2 @ 0.531 2 @ 0.419	1.260	0.920	0.920	0.92	Note 3

Table 2-3
BWR Fuel Assembly Design Characteristics
4 Pages

BWR Fuel ID	**ENC-7-A**	**ENC-8-A**	**FANP-8-A**	**FANP-9-A**	**FANP-9-B**	**FANP-10-A**	**GE-8-A**	**GE-8-A**	**FANP-9-A**
FA Design	**7 x 7-49/0**	**8 x 8-60/4**	**8 x 8-62/2**	**9 x 9-79/2**	**9 x 9**	**10x10-91/1**	**8 x 8-59/5**	**8 x 8-63/1**	**9 x 9-81**
Reload Fuel Designation[(1)(2)]	ENC-IIIA	ENC Va and Vb	FANP 8X8-2	FANP 9X9-2	Siemens QFA 9X9 ATRIUM 9	ATRIUM-10 ATRIUM-10XM	XXX-RCN	STD GE-4 w/ higher exposure	FANP 9X9
Rod Pitch (in.)	0.738	0.642	0.641	0.572	0.569	0.510	0.640	0.640	0.572
No of Fueled Rods	49	60	62	79	72	83 full 8 partial	59 to 64	63	72, 80, 81
Maximum Active Fuel Length (in.)	≤150	≤150	≤150	≤150	≤150	149.54” full 149.45”full 90” partial	150	146	150
Fuel Rod OD (in.)	0.570	0.5015	0.484	0.424	0.433	0.3957	0.493	0.493	0.424
Clad Thickness (in.)	≥0.0355	0.036	0.035	0.030	0.0262	0.0239	0.034	0.034	0.030
Fuel Pellet OD (in.)	0.468- 0.488	0.4195	0.4045 - 0.4055	0.3565	0.3737	0.3413	0.416	0.416	0.3565
No of Water Rods	0	4[(3)]	2	2	1 (9 pins)	1	5	1	2 max.
Water Rod OD (in.)	---	0.5015[(3)]	0.484	0.425 - 0.424	1.516 square	1.378 square	0.493	0.493	0.425 -0.424
Water Rod ID (in.)	---	Note 3	0.414	0.364	1.458 square	1.321 square	0.425	0.425	0.364

Table 2-3
BWR Fuel Assembly Design Characteristics
4 Pages

BWR Fuel ID	**ABB-8-A**	**ABB-8-B**	**ABB-10-A**	**ABB-10-B**	**ABB-10-B**	**ABB-10-B**	**ABB-10-A**	**ABB-10-B**
FA Design	**4x(4 x 4)**	**4x(4 x 4)**	**4x(5x5-2)**	**4x(5x5-2)**	**4x(5x5-1)**	**4x(5x5-1)**	**4x(5x5)**	**4x(5x5)**
Reload Fuel Designation(1)(2)	SVEA-64	SVEA-64	SVEA-92	SVEA-92	SVEA-96(5)	SVEA-96(5)	SVEA-100	SVEA-100
Rod Pitch (in.)	0.610	0.622	0.500	0.500	0.496	0.488	0.500	0.496
No. of Fueled Rods	64	64	96	96	96	96	100	100
Maximum Active Fuel Length (in.)	150.59	150.59	150.59	150.59	150.59	150.59	151	151
Fuel Rod OD (in.)	0.461	0.483	0.387	0.378	0.387	0.378	0.443	0.387
Clad Thickness (in.)	0.027	0.031	0.0243	0.0243	0.0243	0.0243	0.028	0.0243
Fuel Pellet OD (in.)	0.3940	0.4110	0.3350	0.3224	0.3350	0.3224	0.3745	0.3350
No. of Water Rods	0	0	0	0	0	0	0	0
Water Rod OD (in.)	---	---	---	---	---	---	---	---
Water Rod ID (in.)	---	---	---	---	---	---	---	---

Table 2-3
BWR Fuel Assembly Design Characteristics
4 Pages

BWR Fuel ID	**ABB-10-A**	**ABB-10-C**
FA Design	**4x(5x5-3) 4x(5x5-1) Optima**	**4x(5x5-4) 4x(5x5-2) 4x(5x5-1) Optima2**
Reload Fuel Designation[(1)(2)]	SVEA-96Opt[(4)(5)]	SVEA-96Op2[(4)(5)]
Rod Pitch (in.)	0.496 - 0.500	0.484 - 0.512
No of Fueled Rods	96	96
Maximum Active Fuel Length (in.)	150.42	150.42
Fuel Rod OD (in.)	0.379-0.406	0.387
Clad Thickness (in.)	0.0248 -0.0268	0.0238
Fuel Pellet OD (in.)	0.323-0.346	0.334
No of Water Rods	0	0
Water Rod OD (in.)	---	---
Water Rod ID (in.)	---	---

Notes:

1. All dimensions shown are nominal.
2. Reload FAs from other manufacturers with these parameters are also acceptable.
3. Solid Zircaloy rod(s).
4. Fuel bundles designated as ABB or SVEA are typically assembled from four sub-assemblies. There is a cruciform internal water channel between the sub-assemblies. The thickness of the water channel is 0.8 mm, the inner width of the channel is 4 mm for most ABB or SVEA bundles, except 2.4 mm for SVEA-Optima 1 and SVEA-Optima 2.
5. There is one rod that occupies the four central fuel rod locations and four water bars/channels that divide the FA into four quadrants.

Table 2-4
Additional PWR and BWR Fuel Assembly Design Characteristics
2 Pages

Fuel Class	**WE 14x14**	**WE17x17**	**WE17x17**	**WE15x15**	**WE17x17**	**WE17x17**
FA Design	**Doel 1&2 14x14**	**Doel 3 17x17**	**Doel 4 17x17**	**Tihange 1 15x15**	**Tihange 2 17x17**	**Tihange 3 17x17**
Fuel Parameters						
No. of Rods	179	264	264	204	264	264
Active Fuel Length (in.)	96	145	169	145	145	169
Pellet Diameter (in.)	0.368	0.322	0.323	0.368	0.323	0.323
Fuel Rod Pitch (in.)	0.556	0.496	0.496	0.563	0.496	0.496
Clad OD (in.)	0.424	0.376	0.376	0.426	0.376	0.376
Clad Thickness (in.)	0.0225-0.030	0.0225	0.0225	0.0242	0.0225	0.0225
Guide and Instrument Tubes						
No. of Guide/Instrument Tubes	17	25	25	21	25	25
Guide/Instrument Tube Thickness (in.)	≥0.015	≥0.015	≥0.015	≥0.015	≥0.015	≥0.015

Fuel Class / BWR Fuel ID	**WE 14x14**	**WE 15x15**	**WE 17x17**	**GE-8-C**	**WE 17x17**	**WE 17x17**
FA Design (1) (2)	**Kansai 14x14 Step I Type A**	**Kansai 15x15 Step I Type A**	**Kansai 17x17 Step II**	**8x8 Step II**	**17x17**	**17x17**
Fuel Parameters						
No. of Rods	179	204	264	60	264	264
Active Fuel Length (in.)	143	143	144	146	144	165
Pellet Diameter (in.)	0.366	0.366	0.317	0.409	0.322	0.322
Fuel Rod Pitch (in.)	0.555	0.563	0.496	0.642	0.496	0.496
Clad OD (in.)	0.422	0.422	0.374	0.484	0.36	0.372
Clad Thickness (in.)	0.0225-0.030	0.0242	0.0225	0.036	0.0225	0.0225
Guide and Instrument Tubes						
No. of Guide/Instrument Tubes	17	21	25	4 (Note 3)	25	25
Guide/Instrument Tube Thickness (in.)	≥0.015	≥0.015	≥0.015	0.5015(3)	≥0.015	≥0.015

Table 2-4
Additional PWR and BWR Fuel Assembly Design Characteristics
2 Pages

BWR Fuel ID	**GE-8-C**	**GE-9-A**	**GE-10-A**	**ABB-8-A**	**ABB-10-B**	**ABB-10-A**	**ABB-10-C**
	BWR 1/4	**BWR 2/5/8**	**BWR 3/9/12/13**	**BWR 6**	**BWR 7/14**	**BWR 10/15**	**BWR 11/16**
FA Design	**KKL 8x8**	**KKL 9x9**	**KKL 10x10**	**KKL 4x4x4**	**KKL 4x(5x5-1)**	**KKL 4x(5x5-3)/ 4x(5x5-1)**	**KKL 4x(5x5-4)/ 4x(5x5-2)/ 4x(5x5-1)**
Fuel Parameters							
Number of Rods	62	74	92	64	96	88-96	84-96
Active Fuel Length (in.)	150	146	148	151	151	151	151
Pellet Diameter (in.)	0.413	0.378	0.35	0.394	0.323	0.323 - 0.346	0.334 - 0.335
Fuel Rod Pitch (in.)	0.64	0.566	0.51	0.61	0.488	0.496 - 0.502	0.512
Clad OD (in.)	0.483	0.441	0.431	0.461	0.369 - 0.378	0.379 - 0.406	0.369 - 0.387
Clad Thickness (in.)	0.036	0.028	0.026	0.027	0.0228	0.023	0.024
Number of Water Rods	4 (Note 3)	2	2	0	0	0	0
Water Rod OD	0.5015(3)	0.98	0.98	---	---	---	---
Water Rod ID	Note 3	0.92	0.92	---	---	---	---

Notes:

1. All dimensions shown are nominal.
2. Reload fuel assemblies from other manufacturers with these parameters are also acceptable.
3. Solid Zirc rod(s).

Table 2-5
EOS-37PTH/EOS-89BTH DSC Shell Assembly Loads and Load Combinations

Loading Type	DSC Orientation	Load for Analysis	Load Combination	Service Level	Load Combination No.
Dead weight (DW)	Vertical[1]	1g down (axial)	DW + Normal Pressure + Normal Thermal[2]	A	1
Blowdown/Pressure Test		20 psig internal pressure			
Thermal		Normal vertical orientation thermal			
Dead weight	Horizontal[3]	1g down	DW + H + Pressure + Thermal (117 °F)	A	2
Thermal – Off-Normal Hot		Off-Normal –Hot (117 °F)			
Thermal – Off-Normal Cold		Off-Normal Cold (-40 °F)			
Internal Pressure – Off-Normal		30 psig[4]	DW + H + Pressure + Thermal (-40 °F)		3
Handling (H) in TC [16]		H = ± ½ g axial ± ½ g trans. ± ½ g vertical and 1g vertical, 1g trans., 1g axial applied individually			
Dead weight	Horizontal[3]	1g down	DW + Hydraulic Ram (135 kips insertion) + Pressure + Thermal	A/B[7]	4
Hydraulic Ram Loads (push/pull)		135 kips (push)[5]			
		80 kips (pull)[6]			
Internal pressure-Off-Normal		30 psig[4][9]	DW + Hydraulic Ram (80 kips, retrieval) + Pressure + Thermal		5
Thermal — Off-Normal		Thermal –Off Normal[8]			
Dead weight	Horizontal[3]	1g down	DW + Hydraulic Ram (135 kips retrieval) + Pressure	D	6
Hydraulic Ram Loads (pull)		135 kips[6]			
Internal pressure – Off-Normal		30 psig[4][9]			
Dead Weight	Horizontal	1g down	DW + Pressure + 65 inch Accident Drop	D	7
Internal pressure – Off-Normal		30 psig[4][9]			
Accident Side/corner drop[17]		65 inch drop			
Dead Weight	Horizontal	1g down	DW + Accident Pressure	D	8
Internal pressure – Accident		130 psig[3][9][10]			
Dead Weight	Horizontal[11]	1g down	DW + Pressure + Thermal	A	9
Internal Pressure – Off-Normal		30 psig[4]			
Thermal – Off-Normal		Thermal-Off Normal			
Dead Weight	Horizontal[11]	1 g down	DW + Pressure + Seismic (S)	D	10
Internal Pressure – Off-Normal		30 psig[4]			
Seismic (S)		S = ± 3g (axial) ± 3g (transverse ± 3g (vertical)			
Test Pressure at fabricator – 18 psig[12]	Vertical	18 psig internal pressure	18 psig internal pressure	Test	11
External pressure	Horizontal	See Note 14		D	12

Notes

1. DSC in EOS-TC in vertical orientation. Only inner top cover is installed.
2. Bounding thermal case for normal operations of TC in vertical orientation.
3. DSC in EOS-TC; EOS-TC is in horizontal orientation and supported at the trunnion and saddle locations.
4. Conservatively, 30 psig internal pressure is used for structural evaluation of the DSC.
5. The hydraulic push loads are applied at the canister bottom surface within the grapple ring support.
6. The hydraulic pull loads are applied at the inner surface of the grapple ring.
7. Level B evaluations may take credit for 10% increase in allowable per NB-3223(a).
8. Controlling thermal off-normal case.
9. Load combination results to bound cases with and without internal pressure. Level B is used for the case with internal pressure. Level A is used for the case without internal pressure.
10. Bounding pressure of EOS-HSM blocked vent accident or TC accident fire conditions.
11. DSC in EOS-HSM supported on the steel rails.
12. Conservatively used 18 psig as the test pressure; test configuration is circular shell and inner bottom welded to shell; a top end lid with a 155 kips clamping force used to seal the test assembly.
13. (General) Material properties at temperature.
14. The maximum accident condition external pressure before DSC collapse/buckling is determined.
15. (General) In addition to the Part 72 loads, postulated end, corner, and side drops associated with 10 CFR Part 71 are evaluated to ensure that the DSC can be licensed as a transportable system.
16. These handling loads in conjunction with Level A limits bounds case of EOS-TC in fuel building under seismic loads (Level D accident condition).
17. The top end drop and bottom end drop are not credible events under 10 CFR Part 72; therefore these drop analyses are not required. However, consideration of end drops (for 10 CFR Part 71 conditions) and the 65-inch side drop conservatively envelope the effects of a corner drop.

Table 2-6
EOS-37PTH/EOS-89BTH DSC Basket Assembly Load Combinations

Loading	Canister w/Transfer Cask Orientation	Load for Analysis	Load Combinations	Service Level	Notes
Dead Weight Thermal	Vertical	1 g down (axial) Thermal	DW + Thermal	A	Note 1
Dead Weight Handling Thermal	Horizontal	1g down H = + ½ g axial + ½ g trans.+ ½ g vertical and 1g vertical, 1g trans., 1g axial applied individually Thermal Off Normal hot and cold	DW + H + Thermal (117 °F) DW + H + Thermal (-40 °F)	A	Notes 2
Dead Weight Side Drop	Horizontal	65-inch side drop	65” side drop	D	Notes 3
Dead Weight Corner Drop	30 Degrees from Horizontal	65-inch corner drop	1g down+65” side drop	D	Notes 5

Notes:

1. Basket and FAs are supported at the bottom of the DSC. No mechanical loads other than basket self-weight. Due to its egg-crate, segmental, and non-welded construction, basket deformations due to thermal expansion/gradients are not expected to be significant. Not a bounding case.
2. Basket cells deformations due to FA inertia. Bounding case for Normal/Off-Normal conditions.
3. Seismic loads bounded by Dead Weight Side Drop load.
4. Not used
5. The top end drop and bottom end drop are not credible events under 10 CFR Part 72; therefore these drop analyses are not required. However, consideration of end drops (for 10 CFR Part 71 conditions) and the 65-inch side drop to conservatively envelope the effects of a corner drop.

Table 2-7
EOS-HSM Design Criteria

Number	Load Combination	Event
Concrete 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 2-8
EOS-TC Load Combinations and Service Levels

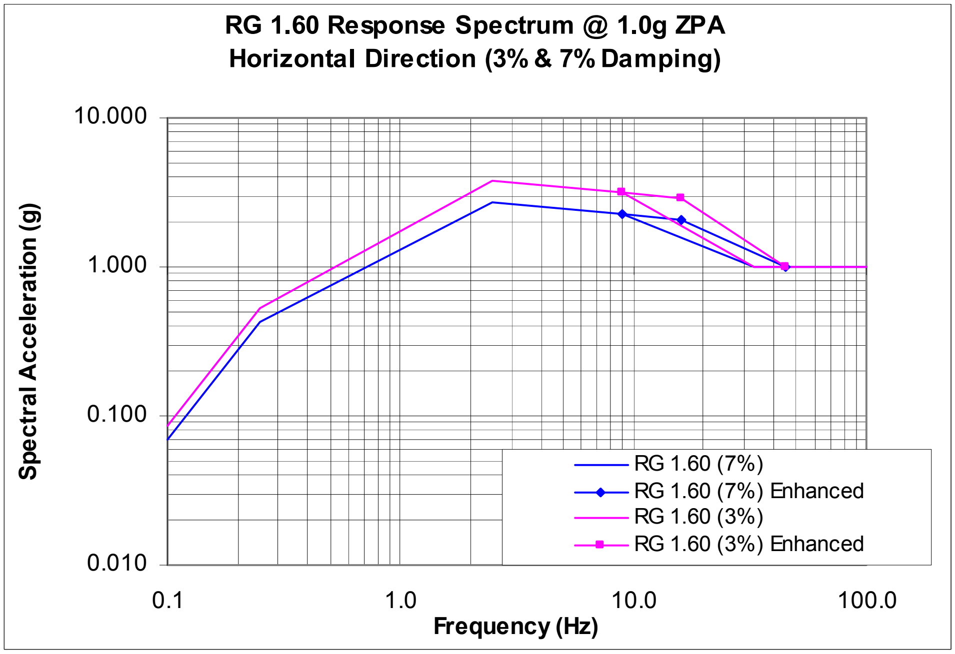
Load Case		Normal Conditions			Off-Normal			Accident Conditions			
		1	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**1**	**2**
Dead Load / Live Load		X		X		X		X			
Thermal w/EOS-DSC	Normal	X	X	X							
	Off-normal				X	X					
Handling Loads (Critical Lifts)	Vertical	X									
	Downending	X									
	Horizontal	X									
Load Test	300% of Design Load						X				
Transfer Handling Loads	±1g Ax. + DW		X		X						
	±1g Tran. + DW		X		X						
	±1g Vert + DW		X		X						
	± ½g Ax.± ½g Tran. ± ½g Vert + DW		X		X						
HSM Loading/ EOS-DSC Transfer	Normal (135k) Insertion			X		X					
	Normal (80k) Retrieval			X		X					
	"Accident" (135k) Insertion							X			
	"Accident" (135k) Retrieval							X			
Seismic	± 0.5g Ax. ± 0.5g Tran. ± 0.33g Vert +DW								X		
Drop Loads	65" Side Drop									X	
	65"End Drop										X
ASME Code Service Level		A	A	A	B	B	B	C	C	D	D
Load Combination Number		A1	A2	A3	B1	B2	B3	C1	C2	D1	D2

Table 2-9
Thermal Conditions for NUHOMS® EOS System Analyses

Operating Conditions	EOS-37PTH/EOS-89BTH DSC Location	Minimum Ambient Temperature	Maximum Ambient Temperature
Normal	Transfer Cask (Refuel Floor)	0 °F	120 °F
	Transfer Cask	0 °F	100 °F
	EOS-HSM/EOS-HSMS	-20 °F	100 °F
	Transportation Cask(1)	-20 °F	100 °F
Off-Normal	Transfer Cask	0 °F	117 °F
	EOS-HSM/EOS-HSMS	-40 °F	117 °F
	Transportation Cask	n/a	n/a
Accident	Transfer Cask (2)	n/a	117 °F
	EOS-HSM/EOS-HSMS (Blocked inlet and outlet vents) (3)	n/a	117 °F
	Transportation Cask(1)	-40 °F	100 °F

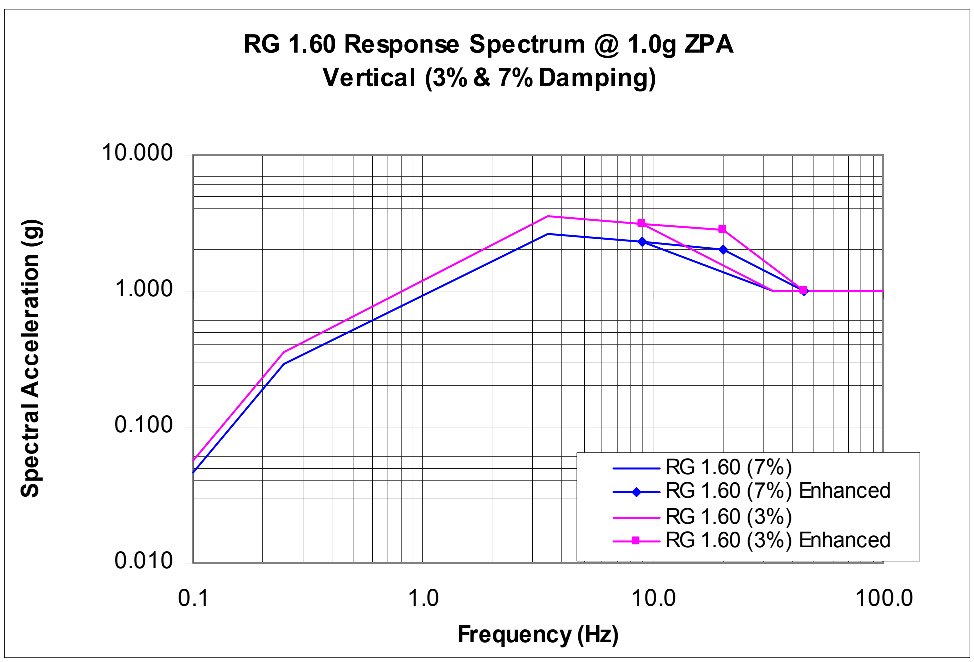
Notes:

1. For information only.
2. Loss of forced air, loss of neutron shield, ambient at 117 °F.
3. 10% rod rupture is considered for this blocked vent accident condition for DSC internal pressure calculation.
4. Assume pool water temperature = 125 °F.



RG 1.60 (3%, Horiz. Enhanced)	
Freq (Hz)	**Acc. (g)**
0.10	0.085
0.25	0.529
2.5	3.755
9.0	3.130
16.0	2.885
45.0	1.000
100.0	1.000
RG 1.60 (7%, Horiz. Enhanced)	
Freq (Hz)	**Acc. (g)**
0.10	0.069
0.25	0.432
2.5	2.720
9.0	2.270
16.0	2.093
45.0	1.000
100.0	1.000

HORIZONTAL



RG 1.60 (3%, Vert. Enhanced)	
Freq (Hz)	**Acc. (g)**
0.10	0.056
0.25	0.353
3.5	3.577
9.0	3.130
20.0	2.797
45.0	1.000
100.0	1.000
RG 1.60 (7%, Vert. Enhanced)	
Freq (Hz)	**Acc. (g)**
0.10	0.046
0.25	0.287
3.5	2.590
9.0	2.270
20.0	2.030
45.0	1.000
100.0	1.000

VERTICAL

Figure 2-1
RG 1.60 Response Spectra with Enhancement in Frequencies above 9.0 Hz

CHAPTER 3
STRUCTURAL EVALUATION

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List of Tables

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 EOS horizontal storage module (EOS-HSM), and the EOS transfer casks (EOS-TCs). The DSC functions as the confinement boundary, and restrains and positions the fuel assemblies (FAs) in the DSC.

3.1 Structural Design

The NUHOMS® EOS System provides for the horizontal, dry storage of canisterized spent fuel assemblies (SFAs) in a concrete EOS horizontal storage module (HSM). The storage system components consist of a reinforced concrete EOS-HSM 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].

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 3.9.3 classifies the rails as ”non-code,” and does not perform any stress analysis of the rail aluminum or steel plates. The membrane plastic strain in the steel grid plate is limited to 1%. Membrane + bending plastic strain is limited to 3% and peak plastic strains is limited to 10%. This ensures that displacement and permanent deformation of the steel grid is small and within failure limits of 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 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 load combination and design criteria for concrete and support structure components are described in Appendix 3.9.4.

3.1.1.3 EOS-TC Design Criteria

The onsite TC is a non-pressure retaining component, which is conservatively designed by analysis to meet the stress allowables of the ASME Code [3-2] Subsection NF Class 1 criteria. 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. Stress limits for Level A, B, C and D service loading conditions are summarized in Table 3-3. The stress due to each load type is identified as to the type of stress induced and classified accordingly. Allowable stress limits for the upper lifting trunnions and lower trunnion sleeves are conservatively developed to meet the requirements of ANSI N14.6- 1993 [3-7] for a non-redundant lifting device for all cask movements within the fuel/reactor building.

The TC structural design criteria are summarized in Table 3-3, Table 3-4 and Table 3-5.

3.2 Weight and Centers of Gravity

Table 3-6 through Table 3-9 summarize the bounding weights of the various components in the NUHOMS® EOS system. The dead weights of the components are determined based on nominal dimensions.

3.3 Mechanical Properties of Materials

3.3.1 EOS-37PTH DSC/EOS-89BTH DSC

Material properties for EOS-37PTH DSC and EOS-89BTH DSC are summarized in Chapter 8.

The analyses are performed based on the least favorable set of properties to ensure that the analysis results are conservative. For example, for stress analysis it is conservative to use the minimum stress intensity allowables.

3.3.2 EOS-HSM

The material properties for the EOS-HSMs are summarized in Chapter 8.

3.3.3 EOS-TC

The material properties for EOS-TCs are summarized in Chapter 8, and are taken from the ASME B&PV Code, Section II, Part D [3-3].

3.4 General Standards for EOS System

3.4.1 Chemical and Galvanic Reaction

Chemical and galvanic reactions for the NUHOMS® EOS System are presented in Chapter 8.

3.4.2 Positive Closure

Positive closure is provided by the the presence of redundant closure welds in the DSC, which precludes unintentional opening.

3.4.3 Lifting Devices

There are no permanent lifting devices used for lifting a loaded DSC. The loaded DSC is inside a TC during handling.

The evaluation of upper trunnions is performed in the EOS -TC body analysis (see Appendix 3.9.5).

3.4.4 Heat

3.4.4.1 Summary of Pressures and Temperatures

Temperatures and pressures for the NUHOMS® EOS System are described in Chapter 4. The thermal evaluations for storage and transfer conditions are performed in Chapter 4 for normal, off-normal, and accident conditions. The internal pressure evaluation is performed in Chapter 4, Section 4.7.

Maximum temperatures for the various components of the EOS-HSM, loaded with EOS-37PTH DSC and EOS-89BTH DSC under normal, off-normal and accident conditions are summarized in Table 4-5, Table 4-6, Table 4-17 and Table 4-18.

These temperatures are used for the structural evaluations documented in Appendices 3.9.1 through 3.9.6. Stress allowables for the components are a function of component temperature. The temperatures used to perform the structural analyses are based on actual calculated temperatures or conservatively selected higher temperatures.

3.4.4.2 Differential Thermal Expansion

Clearances are provided between the various components of the DSC to accommodate differential thermal expansion and to minimize thermal stress. The radial direction clearance is provided between the basket outer diameter and DSC shell inside diameter, and between the poison/aluminum plates and the interfacing basket components. In the axial direction, clearances are provided between the DSC cavity and all the basket parts. Additionally, the connections between the transition rails and the fuel support structure are designed to permit relative axial growth.

The thermal analyses of the basket for handling/transfer conditions are described in Chapter 4. The thermal analyses are performed to determine the basket/DSC temperatures and thermal expansion for -40 °F ambient, 0 ºF ambient, 117 ºF ambient, and vacuum drying conditions. The temperatures are used to evaluate the effects of axial and radial thermal expansion in the basket/DSC components

To verify that adequate clearance exists, the thermal expansion of different components are calculated in the following sections.

3.4.4.2.1 Minimum Gaps within the Interlocking Slots

EOS-37PTH DSC

The EOS-37PTH DSC basket assembly is made up of interlocking slotted plates to form an egg-crate type structure. To avoid interference between the perpendicular plates, the width of the slots is varied between the various basket assembly plates. This section presents the thermal expansion evaluation to demonstrate that the aluminum/metal matrix composite (MMC) plates do no extend past the steel plates at the interlocking slot location.

To avoid any interference between the perpendicular basket assembly plates, the location of slots within the aluminum/MMC plates should not extend past the location of the slots within the steel plates. The thermal expansion of the basket assembly plates is calculated as:

$$L_{Hot,i} = L_{Cold,i} + [L_{Cold,i} \times \alpha_i \,(T_{avg,B} - T_{ref})]$$

Where,

$L_{Hot,i}$ = Hot length of the steel plates ($L_{Hot,St}$) and the aluminum plates ($L_{Hot,Al}$)

$L_{Cold,i}$ = Cold length of the steel plates ($L_{Cold,St}$) and the aluminum plates ($L_{Cold,Al}$)

α_i = Thermal expansion coefficient of the steel (α_{St}) and aluminum plates (α_{Al}) at $T_{avg,B}$

$T_{avg,B}$ = Average temperature of the basket assembly plates based at hottest cross section

T_{ref} = Reference ambient temperature

The minimum gap between each location of the slots within the steel plates and the location of the slots within the aluminum/MMC plates is is calculated as:

$$\Delta_{St\text{-}Al} = L_{Hot,St} - L_{Hot,Al}$$

The minimum gap between the slots of the steel plates with aluminum/MMC plates is 0.01 inch. Therefore, the slots within the aluminum/MMC plates provide sufficient space to accommodate any differential thermal growth.

EOS-89BTH DSC

Similar to the EOS-37PTH DSC design, the minimum gaps between the slots of the steel plates with aluminum/MMC plates is calculated to be 0.02 inch. Therefore, the slots within the aluminum/MMC plates provide sufficient space to accommodate any differential thermal growth.

3.4.4.2.2 Axial Gaps between the Basket Assembly Plates

EOS-37PTH DSC

To accommodate the axial thermal growth between the various basket assembly plates, the aluminum/MMC plates are designed to be smaller than the paired steel plates. Each aluminum/MMC plate and the steel plates have a nominal cold gap of 0.06 inch.

Similar to Section 3.4.4.2.1, the hot gap between the steel and aluminum/MMC plates due to the axial thermal expansion of the basket assembly plates is 0.015 inch. There is sufficient clearance for the thermal growth of aluminum/MMC plates.

EOS-89BTH DSC

Similar to the EOS-37PTH DSC design, the minimum gaps between the steel and aluminum/MMC plates due to the axial thermal expansion of the basket assembly plates is 0.015 inch. Therefore, the slots within the aluminum/MMC plates provide sufficient space to accommodate any differential thermal growth.

3.4.4.2.3 Radial Gap between the Basket Assembly and the DSC Shell

EOS-37PTH DSC

The nominal diametrical cold gap between the basket rails and the EOS-37PTH DSC shell is 0.40 inches. The hot diametrical gap is calculated as:

$$ID_1 = ID_{SHELL} \cdot \left[1 + \alpha_{SHELL}\left(T_{avg,\,SHELL} - 70\right)\right] - \sum_{n=1}^{N} L_n \left[1 + \alpha_n \cdot \left(T_{avg,\,n} - 70\right)\right]$$

Where,

ID_{SHELL} is the DSC shell inner diameter

$T_{avg,\,SHELL}$ is the DSC shell volumetric average temperature

n represents a basket component rail

N is total number of components considered

L_n is the nominal length of basket component n in the radial direction

$T_{avg,\ n}$ is the volumetric average temperature of basket component n

α_n is the expansion coefficient of basket component n at T_n

Hot Radial Gap = ID_1 / 2

Using the above-formula and bounding conditions, the minimum hot radial gap (clearance) is calculated as 0.065 inch. Therefore, there is no interference between the basket and the DSC shell.

EOS-89BTH DSC

Similar to EOS-37PTH DSC, the minimum hot radial gap (clearance) for the EOS-89BTH DSC is calculated as 0.067 inch. Therefore, there is no interference between the basket and the DSC shell.

3.4.4.2.4 Axial Gaps between Fuel Assemblies and the DSC Cavity

EOS-37PTH DSC

To accommodate this variation in the axial length, and also due to the effect of various parameters such as burnup or irradiation growth on the FA, this evaluation considers one approach to determine the minimum gap and is repeated for each type of FA and the DSC size.

The DSC cavity length is chosen to ensure a minimum of 1-inch cold gap exists as a starting point and is verified to ensure that no interference exists as described below. Furthermore, if available, the methodology presented below to determine the irradiation growth can be replaced with an appropriate methodology from the license.

A bounding average temperature is used in determining the thermal expansion for the fuel assemblies. The hot length of the fuel assemblies within the EOS-37PTH DSC is calculated as:

$$L_{Fuel,Total,Hot} = L_{Fuel,Hot} + L_{Fuel,Irrad}$$

Where,

$L_{Fuel,Hot}$ = Total hot length of un-irradiated FA

$L_{Fuel,Irrad}$ = Net irradiation growth of the FA

The total hot length of the FA without irradiation growth is:

$$L_{Fuel,Hot} = L_{Fuel,Cold} + \alpha_{Zr} \cdot L_{Fuel,Cold}$$

Where,

α_{Zr} = Zircaloy axial thermal expansion

T_{Zr} = Average temperature of Zircaloy (FA)

$L_{Fuel,Cold}$ = Maximum cold length of the un-irradiated FA

The irradiation growth model presented in equation 3.7-2 of [3-9] for a PWR fuel rod is:

ax = $2.18x10^{-21} \times \Phi^{0.845}$

Where,

ax = irradiation growth (m/m) or (in/in)

Φ = fast neutron fluence (n/cm^2) (E > 1.0 MeV).

However, FA designs include gaps to accommodate a portion of the irradiation growth without increasing the overall length.

$$L_{Fuel,Irrad} = L_{Fuel,Irrad,Total} - L_{Fuel,Gap}$$

The total hot length of the fuel, including the net irradiation growth is:

$$L_{Fuel,Total,Hot} = L_{Fuel,Hot} + L_{Fuel,Irrad}$$

The length of the DSC cavity is calculated as:

$$L_{DSC,Cav,Hot} = L_{DSC,Cav} \cdot [1 + \alpha_{DSC} \cdot (T_{DSC} - 70)]$$

Where,

α_{DSC} = Coefficient of thermal expansion for DSC shell

T_{DSC} = Average temperature of DSC shell

$L_{DSC,Cav}$ = Cold length of the DSC Cavity

The bounding gap between the irradiated fuel assemblies and the DSC cavity is calculated as:

$$\Delta_{FA-DSC\,Cav} = L_{DSC,Cav,Hot} - L_{Fuel,Total,Hot}$$

Using the approach presented above, it would be ensured that a positive gap exists to avoid any interference between the FAs and the DSC cavity.

EOS-89BTH DSC

Similar to EOS-37PTH DSC, the minimum axial gap (clearance) between the FAs and the DSC cavity is calculated.

3.4.4.2.5 Axial Gap between the Basket Assembly and the DSC Cavity

EOS-37PTH DSC

The following steps present the methodology to determine a bounding cold gap between the basket assembly and the DSC cavity that will encompass any variations due to the different FAs.

1. The maximum hot lengths of the basket assembly are calculated for a nominal cold length and a maximum cold length

$$L_{BSK,Nom,Hot} = L_{BSK,Nom} \cdot [1 + \alpha_{Bsk} \cdot (T_{Bsk} - 70)]$$
$$L_{BSK,Long,Hot} = L_{BSK,Long} \cdot [(1 + \alpha_{Bsk} \cdot (T_{Bsk} - 70)]$$

Where,

α_{Bsk}, = Coefficient of thermal expansion of basket assembly

T_{Bsk} = Average temperature of basket assembly

$L_{Bsk,Nom}$ = Nominal cold length of the basket assembly

$L_{Bsk,Long}$ = Maximum cold length of the basket assembly

2. Assuming a zero gap under hot conditions, the maximum hot length of the DSC cavity is assumed to be equal to the hot length of the basket assembly.

$$L_{BSK,Nom,Hot} = L_{DSC,Nom,Hot}$$
$$L_{BSK,Long,Hot} = L_{DSC,Long,Hot}$$

Where,

$L_{DSC,Nom,Hot}$ = Nominal hot length of the DSC cavity

$L_{DSC,Long,Hot}$ = Maximum hot length of the DSC cavity

3. Using the hot length of the DSC cavity, the cold lengths of the DSC cavity are determined as:

$$L_{DSC,Nom} = \frac{L_{DSC,Nom,Hot}}{1+\alpha_{DSC}\cdot(T_{DSC}-70)}$$

$$L_{DSC,Long} = \frac{L_{DSC,Long,Hot}}{1+\alpha_{DSC}\cdot(T_{DSC}-70)}$$

Where,

$L_{DSC,Nom}$ = Nominal Cold length of the DSC cavity

$L_{DSC,Long}$ = Maximum Cold length of the DSC cavity

4. The net gap at cold conditions between the DSC cavity and the basket assembly is determined.

$$\Delta_{DSC-Bsk,Nom} = L_{DSC,Nom} - L_{Bsk,Nom}$$

$$\Delta_{DSC-Bsk,Long} = L_{DSC,Long} - L_{Bsk,Long}$$

5. As long as the cold gap calculated in Step 4 is maintained, there will be no interference under hot conditions.

To bound any uncertainties a minimum axial cold gap of 0.6 inch is recommended between the DSC cavity and the basket assembly.

EOS-89BTH DSC

Similar to EOS-37PTH DSC, the minimum axial cold gap of 0.6 inch is recommended between the DSC cavity and the basket assembly.

3.4.4.2.6 Axial Gap between the Transition Rails and the DSC Cavity

EOS-37PTH DSC

To determine the bounding cold gap to avoid interference between the transition rails and the EOS-37PTH DSC cavity, the steps outlined in Section 3.4.4.2.5 are repeated for the transition rails.

To bound any uncertainties a minimum axial cold gap of 1.2 inches is recommended between the DSC cavity and the transition rails.

EOS-89BTH DSC

Similar to EOS-37PTH DSC, the minimum axial cold gap of 1.2 inches is recommended between the DSC cavity and the transition rails.

3.4.4.2.7 Axial Gap between the TC125/TC135 Cavity and the DSC Shell

EOS-37PTH DSC

To determine the bounding cold gap to avoid interference between the EOS-TC and the EOS-37PTH DSC cavity, the steps outlined in Section 3.4.4.2.5 are repeated for the EOS-TC cold gap.

To bound any uncertainties, a minimum axial cold gap of 0.6 inch in is recommended between the TC cavity and the DSC shell, including the cask spacer.

EOS-89BTH DSC

Similar to EOS-37PTH DSC, the minimum axial cold gap of 0.6 inch is recommended between the TC cavity and the DSC shell including the cask spacer.

3.4.4.2.8 Axial Gap between the EOS-HSM Support Structure and the EOS-HSM Cavity

EOS-37PTH DSC/EOS-89BTH DSC

A 1-inch gap is provided between the EOS-HSM support structure and the EOS-HSM cavity to accommodate any thermal growth. This section verifies that there is no interference between the EOS-HSM cavity and the support structure.

The maximum support structure temperature ($T_{EOS\text{-}HSM,SS}$) and is selected to determine the maximum length of support structure within EOS-HSM long cavity. The maximum support structure temperature is conservatively applied as the average temperature as it maximizes the thermal expansion.

The thermal growth of the support structure is determined as:

$$\Delta L_{EOS-HSM,SS,Hot} = L_{EOS-HSM,SS,Cold} \times \alpha_{EOS-HSM,SS} \times (T_{EOS-HSM,SS} - 70)$$

Where,

$L_{EOS\text{-}HSM,SS,Cold}$ = Cold length of the EOS-HSM long support structure ,

$\alpha_{EOS\text{-}HSM,SS}$ = Thermal expansion coefficient for EOS-HSM support structure

$T_{EOS\text{-}HSM,SS}$ = Maximum EOS-HSM support structure temperature.

The maximum thermal growth of the EOS-HSM support structure is 0.46 inch and is less than the 1-inch gap. Therefore, sufficient clearance exists within the EOS-HSM cavity for free thermal expansion of the support structure.

3.4.5 Cold

Impact on material properties of cold ambient temperatures is discussed in Chapter 8. Structural analyses performed for all components account for both hot and cold ambient conditions.

3.5 Fuel Rods General Standards for NUHOMS® EOS System

This section provides the temperature criteria used in the EOS-37PTH DSC and EOS-89BTH DSC thermal evaluation for the safe storage and handling of SFAs in accordance with the requirements of 10 CFR Part 72 [3-13]. This section also contains the analysis of the thermal and irradiation growth of the FAs to ensure adequate space exists within the EOS-37PTH DSC and EOS-89BTH DSC cavity for the FAs to grow thermally under all conditions. In addition, this section provides an evaluation of the fuel rod stresses due to accident drop loads.

3.5.1 Fuel Rod Temperature Limits

The fuel rod temperature limits during transfer operation and storage are defined by Interim Staff Guidance, ISG-11, Revision 3 [3-11]. The temperature limits are summarized in the following table.

Transfer		Storage	
Normal/Off-Normal	**Accident**	**Normal**	**Off-Normal / Accident**
752 °F	1058 °F	752 °F	1058 °F

3.5.2 Fuel Assembly Thermal and Irradiation Growth

The thermal and irradiation growth of the FAs were calculated to ensure that there is adequate space for the FAs to grow within the cavity of the EOS-37PTH DSC and EOS-89BTH DSC. Detailed thermal expansion evaluations of the DSC cavity versus lengths of the basket and the FA, the DSC internal diameter (ID) versus the basket outer diameter (OD), the DSC OD versus the TC ID, and the overall length of the DSC versus the TC cavity length are included in Section 3.4.4.2.

3.5.3 Fuel Rod Integrity during Drop Scenarios

The fuel rod integrity is demonstrated in Appendix 3.9.6.

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 3.9.7.

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

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

Component	Weight (kips)	Thermal Heat Load
EOS-37PTH DSC (Loaded Weight)	134	50 kW
EOS-89BTH DSC (Loaded Weight)	120	43.6 kW
Bounding EOS-HSM	135 (2)	50 kW (1)

Notes:
1. The thermal loading condition of the EOS-HSM 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 is presented in Appendix 3.9.4.

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.

Appendix 3.9.5 presents the evaluation of the stresses in the EOS-TC neutron shield shell due to all applied loads during fuel loading and transfer operations. An FEM was built for the structural analysis of the neutron shield shell, end closure, central plates and structural shell. These structural components were modeled with ANSYS shell elements.

Appendix 3.9.5 summarizes the calculated stresses for the EOS-TC neutron shield shell. Based on the results of the analysis, it is concluded that the outer neutron shield shell structure is structurally adequate for the specified transfer loads.

3.7 Off–Normal and Hypothetical Accident Conditions of Storage and Transfer

This section presents the structural analyses of the EOS-37PTH DSC and EOS-89BTH DSC, the EOS-HSM and the EOS-TC subjected to off-normal and hypothetical accident conditions of storage and transfer. These analyses are summarized in this section, and described in detail in Appendices 3.9.1 through 3.9.7.

3.7.1 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. Accident drop loads are analyzed using ANSYS quasi-static analysis methods with deceleration values that bound those obtained from the LS-DYNA analyses of Appendix 3.9.3.

LS-DYNA evaluations are also performed for drop conditions. The analysis includes DSC (DSC shell and basket) and TC. The details of the analysis are presented in Appendix 3.9.3. Two scenarios are analyzed for the drop conditions: a side drop and a corner drop. The drop height is based on the 65-inch height of the transfer trailer on which the EOS-TC is transferred.

3.7.1.1 EOS-37PTH DSC/89BTH DSC Shell Off-Normal/Accident Condition Structural Evaluation

This section summarizes the evaluation of the structural adequacy of the EOS-37PTH DSC shell and EOS-89BTH DSC shell under all applied off-normal and accident condition loads.

3.7.1.1.1 Stress Analysis

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 remaining conservative. However, 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 component stress level, is also a conservative way to reduce numbers of analysis runs.

Elastic and elastic-plastic analyses are performed to calculate the stresses in the EOS-37PTH DSC/EOS-89BTH DSC under the off-normal and accident loads. These load cases are summarized in Appendix 3.9.1. All side drop loads are analyzed by elastic-plastic analyses and the rest by elastic analyses.

The calculated stresses in the DSC shell due to off-normal and accident transfer loading conditions are summarized in Appendix 3.9.1. The stresses due to accident storage loading conditions are summarized in Appendix 3.9.1.

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

3.7.1.1.2 Buckling Analysis

This section summarizes the evaluation of EOS-37PTH DSC and EOS-89BTH DSC against buckling under a vertical end drop during transfer operations. The detail of the DSC shell buckling analysis is provided in Appendix 3.9.1. A finite element plastic analysis with large displacement option is performed to monitor the occurrence of DSC shell buckling under the specified loads.

The thermal evaluation presented in Chapter 4 shows that the metal temperatures of the entire DSC are below 500 °F during the transfer operations. The material properties of the DSC at 500 °F are, therefore, conservatively used for the DSC buckling analysis.

The FEM of the DSC described in Appendix 3.9.1 for the DSC stress analysis is used for this analysis. Since the top end of the DSC is heavier than the bottom end, it is a more severe case when the DSC drops on its bottom end. A bottom end drop is therefore chosen for analysis in this calculation. The DSC shell does not buckle up to a load of 130g. For further details about the results refer Appendix 3.9.1.

3.7.1.2 EOS-37PTH DSC/89BTH DSC Basket Off-Normal/Accident Condition Structural Evaluation

This section summarizes the evaluation of the structural adequacy of the EOS-37PTH DSC and EOS-89BTH DSC baskets under all applied off-normal and accident condition loads.

The basket analyses are performed for off-normal/accident condition loads during fuel transfer and storage. The detailed analyses are presented in Appendix 3.9.2. A summary of the fuel basket load cases is provided in Appendix 3.9.2. The basket analyses are performed using a finite element method for the off-normal transfer and storage thermal load cases and for the accident side drop load cases. The finite element models (FEM) are described in detail in Appendix 3.9.2. Basket component stress and strain results for off-normal thermal and accident drop condition loads, respectively, are listed in Appendix 3.9.2. Combined results with controlling stress and strain ratios are listed in Appendix 3.9.2. Based on the results of these analyses, the EOS-37PTH DSC/ EOS-89BTH DSC basket designs are structurally adequate with respect to both off-normal and accident loads. The DSC basket buckling evaluation is also presented in Appendix 3.9.2.

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 is presented in Appendix 3.9.4.

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.

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.

Table 3-1
Summary of Stress Criteria for Subsection NB Pressure Boundary Components
Shells and Cover Plates
2 Pages

Service Level	Stress Category	References	Notes
Design (NB-3221)	$P_m \leq 1.0S_m$ $P_L \leq 1.5S_m$ $P_m\ (or\ P_L) + P_b \leq 1.5S_m$ $F_p \leq 1.0S_y or 1.5S_y$ $\sigma_1 + \sigma_2 + \sigma_3 \leq 4S_m$ External Pressure: NB-3133	NB-3221.1, NB-3221.2, NB 3221.3, NB 3227.1 and NB-3227.4	2
Level A (NB-3222)	$P_m \leq 1.0S_m$ $P_L \leq 1.5S_m$ $P_m\ (or\ P_L) + P_b \leq 1.5S_m$ $P_m\ (or\ P_L) + P_b + Q \leq 3.0S_m$ $F_p \leq 1.0S_y or 1.5S_y$ $\sigma_1 + \sigma_2 + \sigma_3 \leq 4S_m$ External Pressure: NB-3133	NB-3222, NB-3227.1, and NB-3227.4	1 and 2
Level B (NB-3223)	$P_m \leq 1.0S_m$ $P_L \leq 1.5S_m$ $P_m\ (or\ P_L) + P_b \leq 1.5S_m$ $P_m\ (or\ P_L) + P_b + Q \leq 3.0S_m$ $F_p \leq 1.0S_y or 1.5S_y$ $\sigma_1 + \sigma_2 + \sigma_3 \leq 4S_m$ External Pressure: NB-3133	NB-3223, NB-3227.1, and NB-3227.4	
Carbon Steel Components (e.g., shield plugs)			
Level D Elastic Analysis (NB-3225, App. F)	$P_m \leq 0.7S_u$ $P_m\ (or\ P_L) + P_b \leq 1.0S_u$ $P_m + P_b + Q \leq note\ 4$ $F_p \leq note\ 5$ External Pressure = 1.5 * NB-3133	NB-3225, F-1331.1, and F-1331.5(b)	Note 6

Table 3-1
Summary of Stress Criteria for Subsection NB Pressure Boundary Components
Shells and Cover Plates
2 Pages

Service Level	Stress Category	References	Notes
Level D Plastic Analysis (NB-3225, App. F)	$P_m \le 0.7S_u$ $P_m \; (\text{or } P_L) + P_b \le 0.9S_u$ $P_m + P_b + Q \le \text{note 4}$ $F_p \le \text{note 5}$ External Pressure = 1.5 * NB-3133	NB-3225, F-1341.2, and F-1331.5(b)	Note 6
Austenitic Steel Components (e.g., Shell)			
Level D Elastic Analysis (NB-3225, App. F)	$P_m \le \min(2.4S_m, 0.7S_u)$ $P_m \; (\text{or } P_L) + P_b \le \min(3.6S_m, 1.0S_u)$ $P_m + P_b + Q \le \text{note 4}$ $F_p \le \text{note 5}$ External Pressure = 1.5 * NB-3133	NB-3225, F-1331.1, and F-1331.5(b)	Note 7
Level D Plastic Analysis ([NB-3225, App. F)	$P_m \le \max(0.7S_u, S_y + (S_u - S_y)/3)$ $P_m \; (\text{or } P_L) + P_b \le 0.9S_u$ $P_m + P_b + Q \le \text{note 4}$ $F_p \le \text{note 5}$ External Pressure = 1.5 * NB-3133	NB-3225, F-1341.2, and F-1331.5(b)	Note 7

Notes:

1. The Level A limit of NB-3222.2 may be exceeded provided the criteria of NB-3228.5 are satisfied.
2. There are no specific limits on primary stresses for Level A events. However, the stresses due to primary loads during normal service must be computed and combined with the effects of other loadings in satisfying other limits. See NB-3222.1. The Code Design limits on primary stresses used for Service Level A.
3. Not used.
4. Evaluation of secondary stresses not required for Level D events.
5. Evaluation of bearing stresses not required for Level D events.
6. Criteria listed are for carbon steel components (e.g., shield plugs).
7. Criteria listed are for austenitic parts including shells, cover plates, and the grapple assembly.

Table 3-2
EOS-37PTH/EOS-89BTH Basket Assembly Stress Criteria for Subsection NG Components

Service Level	Stress Category [5]	References	Notes
Design (NG-3221)	$P_m \leq 1.0S_m$ $P_m + P_b \leq 1.5S_m$	NG-3221.1 NG-3222.2	
Level A (NG-3222)	$P_m \leq 1.0S_m$ $P_m + P_b \leq 1.5S_m$ $P_m + P_b + Q \leq 3.0S_m$ (Note 4)	NG-3222.1, NG-3221.1 NG-3222.1, NG-3221.2 NG-3222.2	Note 6
Level B (NG-3223) Note 1	$P_m \leq 1.0S_m$ $P_m + P_b \leq 1.5S_m$ $P_m + P_b + Q \leq 3.0S_m$ (Note 4)	NG-3223(a), NG-3222.1, NG-3221.1 NG-3223(a), NG-3222.1, NG-3221.2 NG-3223(a), NG-3222.2	Note 1
Level C Elastic Analysis (NG-3224)	$P_m \leq 1.5S_m$ $P_m + P_b \leq 2.25S_m$ $P_m + P_b + Q \leq$ Note 2	NG-3224.1(a)(1) NG-3224.1(a)(2) Figure NG-3224 - 1	Notes 2 and 3
Level D Elastic Analysis (NG-3225, App. F)	$P_m \leq (\max(1.2S_y, 1.5S_m), 0.7S_u)$ $P_m + P_b \leq (\max(1.8S_y, 2.2S_m), S_u)$ $P_m + P_b + Q \leq$ Note 2	NG-3225, F- 1440, F- 1332 NG-3225, F- 1440, F- 1332	
Level D Plastic Analysis (Austenitic) (NG-3225, App. F)	$P_m \leq \max(0.7S_u, S_y + 1/3(S_u - S_y))$ $P_m + P_b \leq 0.9S_u$ $P_m + P_b + Q \leq$ (Note 2)	NG-3225, F - 1440, F - 1341.2(a) NG-3225, F - 1440, F - 1341.2(b)	Note 7
Level D Plastic Analysis (Ferritic) (NG-3225, App. F)	$P_m \leq 0.7S_u$ $P_m + P_b \leq 0.9S_u$ $P_m + P_b + Q \leq$ (Note 2)	NG-3225, F-1440, F-1341.2(a) NG-3225, F-1440, F-1341.2(b)	Note 8

Notes:

1. There are no pressure loads on the basket, therefore the 10% increase permitted by NG-3223(a) for pressures exceeding the design pressure are not included.

2. Evaluation of secondary stresses not required for Level C and D events.
3. Criteria listed are for elastic analyses, other analysis methods permitted by NG-3224.1 are acceptable if performed in accordance with the appropriate paragraph of NG-3224.1.
4. This limit may be exceeded provided the requirements of NG-3228.3 are satisfied, see NG-3222.2 and NG-3228.3.
5. As appropriate, the special stress limits of NG-3227 should be applied.
6. In accordance with NG-3222 and Note 9 of Figure NG-3221-1, the Limit Analysis provisions of NG-3228 may be used.
7. Level D criteria for austenitic materials are also applicable to high-nickel alloy and copper nickel alloy materials.
8. Alternatively, the criteria in the table may be exceeded for the steel basket plates if plastic strains are within 1% for membrane, 3% for membrane plus bending and 10% for peak plastic strains.

Table 3-3
Plate and Shell Type Support for Transfer Cask Structural Shell
2 Pages

Service Level	Stress/Stress Intensity Limits	Reference	Notes
Support Component			
Design, Level A	*Membrane and Bending:* $P_m \le 1.0S_m$ $P_m + P_b \le 1.5S_m$ $P_m + P_b + Q \le 3.0S_m$ *Triaxial:* $(\sigma_t + \sigma_l + \sigma_r) \le 4\ S_m$	NF-3142, NF-3220 NF-3522, Table NF-3221.2-1, NF-3223.3	(1), (2)
Level B	*Membrane and Bending:* $P_m \le 1.0S_m$ x1.33 $P_m + P_b \le 1.5S_m$ x1.33 $P_m + P_b + Q \le 3.0S_m$ x1.33 *Triaxial*: $(\sigma_t + \sigma_l + \sigma_r) \le 4\ S_m$ x1.33		
Level C	*Membrane and Bending:* $P_m \le$ min (1.0 S_m x1.5, 0.7S_u) $P_m + P_b \le$ min(1.5 S_m x1.5, 0.7S_u) *Triaxial:* $(\sigma_t + \sigma_l + \sigma_r) \le 4\ S_m$ x1.5		
Design, Levels A, B, C	*Bearing:* *Average bearing stress* S_y	NF-3223.1	(1)(12)
Level A	*Shear:* *Average pure shear* 0.6S_m *Maximum pure shear* 0.8S_m *Primary + Secondary Shear* *Average pure shear* 1.2S_m *Maximum pure shear* 1.6S_m	NF-3223.2 Table NF-3221.2-1	
Level B	*Shear:* *Average pure shear* 0.6S_m x 1.33 *Maximum pure shear* 0.8S_m x 1.33		
Level C	*Shear:* *Average pure shear* min(0.6S_m x 1.5, 0.7S_u) *Maximum pure shear* min (0.8S_m x 1.5, 0.7S_u)		

Table 3-3
Plate and Shell Type Support for Transfer Cask Structural Shell
2 Pages

Service Level	Stress/Stress Intensity Limits	Reference	Notes
Level D (Elastic Analysis)	*Membrane and Bending:* $P_m \leq$ min (max($1.2S_y$, $1.5S_m$), $0.7S_u$) P_m+$P_b \leq$ 1.5x min (max($1.2S_y$, $1.5S_m$), $0.7S_u$) *Pure Shear:* $V_u \leq 0.42S_u$ *Bearing:* NA *Compression:* $(2/3)F_a$	F-1332.1 F-1332.4 F-1332.3 F-1331.5(a)	(3)
Level D (Plastic Analysis)	*Membrane and Bending:* $P_m \leq$ max(S_y+(S_u-S_y)/3, $0.7S_u$) P_m (or P_L)+$P_b \leq 0.9S_u$ *Primary Shear:* $0.42S_u$ *Compression:* $(2/3)F_a$	F-1342 F-1341 F-1341.8 F-1331.5a	(3),(4),(5)
Support Weld			
Design, Levels A, B	*Full Penetration Groove Weld:* Same as base metal *Partial Penetration Groove/Fillet Weld:* (i) Normal compression – same as base metal (ii) Shear stress on fillet weld, normal tension on partial pen. Groove weld, shear stress on plug/slot weld *Level A* $0.3xF_{u,\text{ weld metal}}$ $0.4xF_{y,\text{ base metal}}$ *Level B* K_v .$0.3xF_{u,\text{ weld metal}}$ K_v .$0.4xF_{y,\text{ base metal}}$	NF-3226.2 NF-3256 Table NF-3324.5(a)-1 Table NF-3523(b)-1	(8)
Level D	*Partial Penetration Groove/Fillet Weld:* Level A allowable stresses can be increased by min(2, $1.167S_u/S_y$) if $S_u > 1.2S_y$ 1.4 if $S_u \leq 1.2S_y$	F-1334	

Notes:

1. Limit Analysis may be used if stress intensity is not satisfied at a specific location per the criteria of NF-3221.4.
2. S_u is on net effective area.
3. F_a:Buckling load or stress.
4. Plastic analysis for Level D implies plastic system and component analysis.
5. P_m : General primary membrane stress intensity
   a. P_L : Local primary membrane stress intensity
   b. P_b : Primary bending stress intensity
6. For P_b , other conditions specified in NF-3322.1 must be specified.
7. Incorporates provisions of Reg. Guide 1.124 Rev2, 2007 Paragraphs C.2, C.3 and C.4 [3-8).
8. Base metal stress should be checked on appropriate shear plane.
9. Rigorous analysis of member stability may be used to determine critical bending stress for non-compact sections. A factor of safety of 1.5 is used in determining allowable bending stress.
10. Thermal load is considered even though ASME Section III Subsection NF does not require thermal stress evaluations. For Service Levels A and B, primary plus secondary stresses is limited to a range of $2S_y$ or S_u at temperature, whichever is less.
11. Primary plus secondary stresses are evaluated for critical buckling loads for all loading categories.
12. For bearing loads applied near free edges, consider shear failure. Average sheer stress is limited to 0.6 S_m in the case of primary stress and 0.5 S_y for primary stress plus secondary stress.

Table 3-4
Structural Shell Structural Stress Criteria for Transfer Cask Bolts

Stress Category	Fastener Allowable Stress		
	Normal Conditions[(1)]		Accident Conditions[(2)]
	Ferritic Steels	Austenitic Steels	
Average Tensile Stress	$\frac{S_u}{2} K_{bo}$	$\frac{S_u}{3.33} K_{bo}$	Lesser of: 0.7 S_u or S_y
Average Shear Stress	$\frac{0.625 S_u}{3} K_{bo}$	$\frac{0.625 S_u}{5} K_{bo}$	Lesser of: 0.42 S_u or 0.6 S_y
Combined Shear and Tension	$\frac{f_t^2}{f_{tb}^2}+\frac{f_v^2}{f_{vb}^2} \le 1$		$\frac{f_t^2}{f_{tb}^2}+\frac{f_v^2}{f_{vb}^2} \le 1$

Notes:

1. Stress limits are as defined in ASME Code, Section III, Subsection NF 3324.6 (a) with stress limit factors (K_{bo}) as defined in Table NF 3225.2-1. Service level A K_{bo}= 1.0, Service level B K_{bo}= 1.15, Service level C K_{bo}= 1.25.
2. Stress limits for Service Level D conditions are as defined in Appendix F.

Table 3-5
Structural Stress Criteria for Neutron Shield

Item **Shell Component**	**Stress Type**		
Stress Type	**Service Levels A**	**Service Level B**	**Service Level C**
σ_m (1)	1.0S	1.10 S	1.5 S
(σ_m or σ_L) + σ_b (1)	1.5S	1.65 S	1.8S
(σ_m or σ_L) + σ_b + Q (1, 5)	2.4S	2.4S	Note 6
Fillet Welds			
Allowable Load (P)(3, 4)	.55SA	.61 SA	.825 SA

Notes:

1. Per ASME Subsection ND Table 3321-1,
   a. σ_m : General membrane stress
   b. σ_L : Membrane stress
   c. σ_b : Bending stress
   d. Q: Stresses due to thermal gradient
2. Joint efficiency to be 1.00 for determining shell thickness/allowable pressure; analysis to provide justification for assumption.
3. ASME Subsection ND 3356.1(c)- The allowable load on fillet welds are the product of the weld area based on minimum leg dimensions , the allowable stress value in tension of the material being welded, and a joint efficiency of 0.55.
3. Per ASME Subsection ND 3356. Stress limits for components based on Table ND-3321-1. P = Allowable load, S = maximum allowable stress, A = weld area based on minimum leg dimensions.
5. Primary membrane + bending + thermal stress acceptance limits are based on Subsection NB allowables, but not to exceed the Level D limits as listed in Table ND-3321-1.
6. Evaluation of secondary membrane plus bending stresses (Q) are required for Service Level A and B loadings only per Figure NB-3222-1.

Table 3-6
Summary of EOS-37PTH DSC Component Weights

Component Description	Weight (lb)
DSC Shell (1)	17,700
Basket Assembly	33,500
Dry/Unloaded/Open DSC (5)	**51,200**
37 Fuel Assemblies	70,300
DSC Top Shield Plug	7,340
Flooding Water in Loaded DSC	15,300
Flooded/Loaded Open DSC (6)	**145,000**
DSC Top Cover Plates	5060
Sealed/Loaded DSC Weight (7)	**134,000**

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 Long	Total Weight (lb)	351,000
	Center of Gravity from Bottom in Vertical Direction	126.5 inches
EOS-HSM Long Loaded with EOS-37PTH DSC	Maximum Weight (lb)	485,000
	Center of Gravity from Bottom in Vertical Direction	120.8 inches

Notes:

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

Table 3-9
Summary of EOS-TC Component Weight

Transfer Cask Component	Calculated Weight (lb)		
	TC108	**TC125**	**TC135**
Outer Shell	13,451	13,800	15,400
Inner Shell including Rails	9,653	9,652	10,680
Lead Gamma Shielding	47,221	71,500	79,300
Top Ring	4,391	5,340	5,340
Bottom Ring	2,512	3,170	3,170
3¼" Nominal Top Cover Plate (LID)	4,692	4,790	4,790
Bottom Assembly	4,113	4,137	4,137
Neutron Shield Panel including Water	6,652	11,550	12,720
Upper Trunnion	256	256	256
Total	**92,941**	**124,195**	**135,793**