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**Date:** Mon, Oct 17, 2005 10:27 AM
**Subject:** Submittal of revision 4 SAR pages for NUHOMS HD storage system (7 2-1030)

Dear Sebrosky,

The attached PDF files contain the revision 4 SAR pages for the NUHOMS-HD System. Please give me a call at 410-910-6890 or U. B. Chopra at 510-744-6053 if you need additional information.

Sincerely,

Peter Shih

Transnuclear Inc.

410-910-6890

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| **Creation Date:** | Mon, Oct 17, 2005 10:25 AM |
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|---|---|
| **Expiration Date:** | None |

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| **Priority:** | Standard |
| **Reply Requested:** | No |
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| **Concealed Subject:** | No |
| **Security:** | Standard |

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AN AREVA COMPANY

October 17, 2005
E-22910

Mr Joe Sebrosky
Spent Fuel Project Office, NMSS
U S Nuclear Regulatory Commission
11555 Rockville Pike MIS 0-6-F-18
Rockville, MD 20852

Subject: Submittal of Revision 4 of SAR for NUHOMS® HD Storage System Docket No 72-1030 (TAC No L23738).

Dear Mr. Sebrosky:

Transnuclear, Inc. (TN) herewith submits replacement pages for revision 4 of the SAR for NUHOMS® HD Storage System Docket No 72-1030 Please replace the following SAR pages with the revision 4 pages included herewith.

List of Changed Pages:

| | | | | | | |
|---|---|---|---|---|---|---|
| 1-10 | 1-11 | 1-12 | 2-1 | 2-2 | 2-3 | 2-13 |
| 2-14 | Table 2-1 | Table 2-2 | Table 2-2 concluded | Table 2-3 | Figure 2-1 | 3-ii |
| 3-iii | 3-iv | 3-7 | 3-8 | 3-10 | 3-13 | 3-27 |
| 3-29 | 3-36 | 3-54 | 3-56 | 3-58 | 3-59 | 3-60 |
| Table 3-12 | Table 3-13 | Figure 3-2 | Figure 3-3 | Figure 3-4 | Figure 3-5 | Figure 3-6 |
| Figure 3-7 | 3.9.6-ii | 3.9.7-ii | 3.9.8-2 | 3.9.8-16 | 3.9.8-17 | 3.9.8-18 |
| 3.9.8-19 | Tbl 3.9.8-1 | Tbl 3.9.8-2 | Tbl 3.9.8-3 | Tbl 3.9.8-4 | Tbl 3.9.8-5 | Tbl 3.9.8-6 |
| Tbl 3.9.8-7 | Tbl 3.9.8-8 | 3.9.10-15 | 4-2 | 4-18 | 4-29 | 4-30 |
| 4-31 | 4-32 | 4-33 | 5-3 | 5-4 | 5-5 | Table 6-1 |
| Table 6-3<br>Table 6-4 | Table 6-7 | 8-1 | 8-3 | 8-4 | 8-5 | 9-4 |
| 10-1 | 10-7 | 10-8 | 11-9 | 11-26 | Chapter 12 (Entire Chapter) | B12-9 |
| B12-11 | | | | | | |

Should you or your staff require additional information to support review of this application, please do not hesitate to contact me at 410-910-6881 or Mr. U B Chopra at 510.744.6053.

Sincerely,

Jayant Bondre, PhD
Director of Engineering and Licensing

Docket 72-1030

Enclosures: 1. Seven Copies of Replacement Pages (Listed Above) of Revision 4 of SAR for NUHOMS® HD Storage System Docket No 72-1030

16. Move Loaded Transfer Cask to HSM-H

17. Transfer Cask/HSM-H Preparation and Alignment

18. Insertion of 32PTH DSC into HSM-H

19. HSM-H Closure

These operations are described in the following paragraphs. The descriptions are intended to be generic and are described in greater detail in Chapter 8. Plant specific requirements may affect these operations and are to be addressed by the licensee.

Transfer Cask Preparation: 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.

32PTH DSC Preparation: The internals and externals of the 32PTH DSC are inspected and cleaned if necessary. This ensures that the 32PTH DSC will meet plant cleanliness requirements for placement in the spent fuel pool.

Place 32PTH DSC in Transfer Cask: The empty 32PTH DSC is inserted into the transfer cask.

Fill Transfer Cask/32PTH DSC Annulus with Water and Seal: The transfer cask/32PTH DSC annulus is filled with uncontaminated water and is then sealed prior to placement in the pool. This prevents contamination of the 32PTH DSC outer surface and the transfer cask inner surface by the pool water.

Fill 32PTH DSC Cavity with Water: The 32PTH DSC cavity is filled with pool water to prevent an in-rush of water as the transfer cask is lowered into the pool.

Lift Transfer Cask and Place in Fuel Pool: The transfer cask, with the water-filled 32PTH DSC inside, is then lowered into the fuel pool. The transfer cask liquid neutron shield, if provided, may be left unfilled to meet hook weight limitations.

Spent Fuel Loading: Spent fuel assemblies are placed into the 32PTH DSC. This operation is identical to that presently used at plants for shipping cask loading.

Top Shield Plug Placement: This operation consists of placing the top shield plug into the 32PTH DSC using the plant's crane or other suitable lifting device.

Lifting Transfer Cask from Pool: The loaded transfer cask is lifted out of the pool and placed (in the vertical position) on the drying pad in the decon pit. This operation is similar to that used for shipping cask handling operations.

Top Shield Plug Sealing: The water contained in the space above the top shield plug is drained. The top shield plug is welded to the shell. This weld provides the inner (confinement) seal for the 32PTH DSC.

Vacuum Drying and Backfilling: The initial blowdown of the 32PTH DSC is accomplished by pressurizing the vent port with nitrogen or helium. The remaining liquid water in the cavity is forced out of 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 cavity water may also be removed by pumping out the water using the siphon port/tube and replaced by helium or nitrogen. Nitrogen or helium is used to assist removal of water. The 32PTH DSC is then evacuated to remove the residual liquid water and water vapor, nitrogen or helium in the cavity. When the system pressure has stabilized, the 32PTH DSC is backfilled with helium and re-evacuated. After the second evacuation, the 32PTH DSC is again backfilled with helium and slightly pressurized.

The helium lines removed, and the siphon and vent port penetrations are closed. The vent and siphon cover plates are installed and welded to the shield plug

Top Cover Plate Sealing: After helium backfilling, the 32PTH DSC outer top cover plate is installed by using a partial penetration weld between the outer top cover plate and the shell

The outer cover plate or shell weld and shield plug weld provide redundant seals at the upper end of the 32PTH DSC.

Transfer Cask/32PTH DSC Annulus Draining and Transfer Cask Top Cover Plate Placement: The transfer cask/32PTH DSC annulus is drained. A swipe is then taken over the 32PTH DSC exterior at the top cover plate and the upper portion of the shell. Demineralized water is flushed through the transfer cask/32PTH DSC annulus, as required, to remove any contamination left on the 32PTH DSC exterior. The transfer cask top cover plate is installed, using the plant's crane or other suitable lifting device, and bolted closed.

Backfill Transfer Cask Cavity with Helium: The TC cavity is evacuated and the cavity/annulus is backfilled to a positive pressure with helium.

Place Loaded Transfer Cask on Transfer Skid/Trailer: The transfer cask is lifted onto the transfer cask support skid and downended onto the transfer trailer from the vertical to horizontal position. The transfer cask is secured to the skid.

Move Loaded Transfer Cask to HSM: Once loaded and secured, the transfer trailer is towed 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 HSM-H into which the 32PTH DSC is to be transferred

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

Insertion of 32PTH DSC into HSM: After final alignment of the transfer cask, HSM-H, and hydraulic ram, the 32PTH DSC is pushed into the HSM-H by the hydraulic ram.

HSM Closure: Install 32PTH DSC axial retainer and install HSM-H door.

1.2.2.3 Identification of Subjects for Safety and Reliability Analysis

1.2.2.3.1 Criticality Prevention

Criticality is controlled by utilizing the fixed borated neutron absorbing material in the 32PTH DSC basket and the pool water boron loading. During storage, with the cavity dry and sealed from the environment, criticality control measures within the installation are not necessary because water cannot enter the canister during storage.

1.2.2.3.2 Chemical Safety

There are no chemical safety hazards associated with operations of the NUHOMS® HD System. The coating materials used in the design of the 32PTH DSC are chosen to minimize hydrogen generation. Hydrogen monitoring is required during sealing operations to ensure hydrogen concentration levels remain within acceptable limits.

1.2.2.3.3 Operation Shutdown Modes

The NUHOMS® HD System is a totally passive system so that consideration of operation shutdown modes is unnecessary.

1.2.2.3.4 Instrumentation

The NUHOMS® HD System is a totally passive system. No safety-related instrumentation is necessary. The maximum temperatures and pressures are conservatively bounded by analyses. Therefore, there is no need for monitoring the internal cavity of the 32PTH DSC for pressure or temperature during normal operations. The 32PTH DSC is conservatively designed to perform its confinement function during all worst case normal, off-normal, and accident conditions.

1.2.2.3.5 Maintenance and Surveillance

All maintenance and surveillance tasks are described in Chapter 9.

1.2.3 32PTH DSC Contents

The 32PTH DSC is designed to store up to 32 intact PWR Westinghouse 15x15 (WE 15x15), Westinghouse 17x17 (WE 17x17), and/or Framatome ANP Advanced MK BW 17x17 fuel assemblies (Fr 17x17) with or without NFAHs likeVibration Suppressor Inserts (VSI), Burnable Poison Rod Assemblies (BPRAs), or Thimble Plug Assemblies (TPAs). The 32PTH DSC is also designed for storage of up to 16 damaged fuel assemblies, and remaining intact assemblies, utilizing top and bottom end caps. A description of the fuel assemblies including the damaged fuel assemblies is provided in Chapter 2.

The maximum allowable assembly average initial enrichment of the fuel to be stored is 5.00 weight % U-235 and the maximum assembly average burnup is 60,000 MWd/MTU. The fuel must be cooled at least 5 years prior to storage.

The criticality control features of the NUHOMS® HD System 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 5. Chapter 6 covers the criticality safety of the NUHOMS® HD System and its parameters. These parameters include rod pitch, rod outside diameter, material densities, moderator ratios, and geometric configurations. The maximum pressure buildup in the 32PTH DSC cavity is addressed in Chapter 4.

# 2. PRINCIPAL DESIGN CRITERIA

## 2.1 Spent Fuel to be Stored

The NUHOMS® HD System components have currently been designed for the storage of 32 intact and or up to 16 damaged with remaining intact, Westinghouse 15x15 (WE 15x15), Westinghouse 17x17 (WE 17x17), Framatome ANP Advanced 17x17 MK BW (FR 17x17), and/or Combustion Engineering 14x14 (CE 14x14) PWR fuel assemblies. Equivalent reload fuel assemblies that are enveloped by the fuel assembly design characteristics listed in Table 2-1 for a given assembly class are also acceptable Additional payloads may be defined in future amendments to this application.

The thermal and radiological characteristics for the PWR spent fuel were generated using the SCALE computer code package [1]. The physical characteristics for the PWR fuel assembly types are shown in Table 2-1. Free volume in the 32PTH DSC cavity is addressed in Chapter 4. Specific gamma and neutron source spectra are given in Chapter 5.

Although analyses in this SAR are performed only for the design basis fuel, any other intact or damaged PWR fuel which falls within the geometric, thermal, and nuclear limits established for the design basis fuel can be stored in the 32PTH DSC.

### 2.1.1 Detailed Payload Description

This payload consists of 32 PWR $UO_2$ fuel assemblies with or without Non-Fuel Assembly Hardware (NFAH) which includes Burnable Poison Rod Assemblies, (BPRAs), Vibration Suppression Inserts (VSI) or Thimble Plug Assemblies (TPAs) Each 32PTH DSC can accommodate a maximum of sixteen damaged fuel assemblies, with the remaining assemblies intact. The fuel to be stored in the 32PTH DSC is limited to fuel with a maximum assembly average initial enrichment of 5.00 weight % U-235 The maximum allowable burnup is given as a function of initial fuel enrichment but does not exceed 60,000 MWd/MTU. The minimum cooling time is five years.

The 32PTH DSC may store up to 32 PWR fuel assemblies arranged in accordance with a heat load zoning configuration as shown in Figure 2-1, with a maximum decay heat of 1.5 kW per assembly and a maximum heat load of 34.8 kW per DSC, (33.8 kW per DSC for CE 14x14).

The 32PTH DSC can accommodate up to 16 structurally intact damaged fuel assemblies. A fuel assembly that is damaged in such a manner as to impair its structural integrity, has missing or displaced structural components such as grid spacers, or cannot be handled using normal handling methods can not be considered a candidate for storage in the 32 PTH DSC. Neither can fuel that is no longer in the form of an intact fuel bundle and consists of, or contains, debris such as loose fuel pellets, rod segments, etc. Damaged fuel assemblies shall be placed into the sixteen inner most basket fuel compartments, as shown in Figure 2-2, which contain top and bottom end caps that confine any loose material and gross fuel particles to a known, sub-critical volume during normal, off-normal and accident conditions and to facilitate handling and retrievability. Reactor records, visual/videotape records, fuel sipping, ultrasonic examination, and radio chemistry are examples of techniques utilized by utilities to identify damaged fuel.

The end caps are sized to fit inside the fuel compartment (see drawing 10494-72-30). The bottom end cap is slid into the fuel compartment before loading the fuel, utilizing a special tool.

After fuel loading, a top end cap is placed into the fuel compartment. The end caps are not "attached" to the basket, but are a slip/friction fit into the basket compartment. The fuel assembly is thus enclosed/confined by the fuel compartment walls and the end caps. The DSC inner top cover prevents any significant movement of the top end cap. The damaged fuel assemblies can be retrieved simply by removing the top end cap and grappling the fuel assembly by normal means.

The NUHOMS®-32PTH DSC basket is designed with three alternate poison materials: Borated Aluminum alloy, Boron Carbide/Aluminum Metal Matrix Composite (MMC) and Boral®

The NUHOMS®-32PTH DSC basket is analyzed for seven alternate basket configurations, depending on the boron loadings and poison materials.

A summary of the alternate poison loadings considered for each poison material as a function of basket types is presented below:

| **NUHOMS®-32PTH DSC Basket Type** | **Minimum B10 Areal Density, g/cm²** | |
|---|---|---|
| | Natural or Enriched Boron Aluminum Alloy / Metal Matrix Composite (MMC) (Type I) | Boral® (Type II) |
| A | 0.007 | 0.009 |
| B | 0.015 | 0.019 |
| C | 0.020 | 0.025 |
| D | 0.032 | N/A |
| E | 0.050 | N/A |

Note: Information on the material composition of the absorbers is provided in Table 9-1 New neutron absorbers or changes to existing absorbers will be qualified as per the information provided in chapter 9

Table 2-2 shows a parametric equation that can be utilized to qualify spent fuel assemblies for the defined decay heat load zones. The decay heat load can be calculated based on a fuel assembly's burnup, cool time, and initial enrichment parameters. This table ensures that the fuel assembly decay heat load is within the appropriate zone. The development of this equation is provided in Appendix 4.16.2.

The maximum fuel cladding temperature limit of 400°C (752°F) is applicable to normal conditions of storage and all short term operations from spent fuel pool to ISFSI pad including vacuum drying and helium backfilling of the NUHOMS®-32PTH DSC per Interim Staff Guidance (ISG) No. 11, Revision 2 [15] In addition, ISG-11 restricts the change in fuel cladding temperature to less than 65°C (117°F) and limits the numbers of cycles to less than 10 during DSC drying, backfilling and transfer operations

The maximum fuel cladding temperature limit of 570°C (1058°F) is applicable to accidents or off-normal thermal transients [15].

Calculations were performed to determine the fuel assembly type which was most limiting for each of the analyses including shielding, criticality, thermal and confinement. These evaluations are performed in Chapters 5 and 6. The fuel assembly classes considered are listed in Table 2-1 It was determined that the Framatome 17x17 is the enveloping fuel design for the shielding, thermal and confinement source term calculation because of its total assembly weight and highest initial heavy metal loading. The bounding source term for shielding analysis is given in Table 2-3. Table 2-4 presents the thermal and radiological source terms for the Non-Fuel Assembly Hardware (NFAH).

These values are consistent with the cumulative exposures and cooling times of the fuel assemblies. The gamma spectra for the bounding fuel assembly and NFAH are presented in Chapter 5.

The shielding evaluation is performed assuming 32 fuel assemblies with the parameters (1 5kW) shown in Table 2-3. Any fuel assembly that is thermally qualified by Table 2-2 is also acceptable from a shielding perspective since the maximum decay heat load is 1.5 kW and only eight (8) are allowed in the 32PTH DSC. The shielding analysis assumes 32, 1.5 kW assemblies are in the 32PTH DSC. Minimum initial enrichments are defined for each of the zones to assure the shielding evaluation is bounding.

For criticality safety, the WE 17x17 standard assembly is the most reactive assembly type for a given enrichment. This assembly is used to determine the most reactive configuration in the DSC. Using this most reactive configuration, criticality analysis for all other fuel assembly classes is performed to determine the maximum enrichment allowed as a function of the soluble boron concentration and fixed poison plate loading. The analyses results are presented in Chapter 6.

For calculating the maximum internal pressure in the NUHOMS®-32PTH DSC, it is assumed that 1% of the fuel rods are damaged for normal conditions, up to 10% of the fuel rods are damaged for off normal conditions, and 100% of the fuel rods will be damaged following a design basis accident event. A minimum of 100% of the fill gas and 30% of the fission gases within the ruptured fuel rods are assumed to be available for release into the DSC cavity, consistent with NUREG-1536 [17].

The maximum internal pressures used in the structural analysis for the NUHOMS®-32PTH DSC are 15, 20, and 120 psig for normal, off-normal and accident conditions, respectively, during storage and transfer operations and 70 psig during storage accident conditions.

The structural integrity of the fuel cladding due to the side drop is analyzed in Section 3 5.3 The end and corner drops are not considered credible during storage and transfer. The structural integrity of the fuel cladding due to these loads will be addressed by the users under their site license (10CFR50)

## 2.2 Design Criteria for Environmental Conditions and Natural Phenomena

The 32PTH DSC and HSM-H form a self-contained, independent, passive system, which does not rely on any other systems or components for its operation. The criterion used in the design of the 32PTH DSC and HSM-H ensures that their exposure to credible site hazards does not impair their safety functions.

The design criteria satisfy the requirements of 10CFR Part 72 [2]. They include the effects of normal operation, natural phenomena and postulated man-made accidents. The criteria are defined in terms of loading conditions imposed on the 32PTH DSC. The loading conditions are evaluated to determine the type and magnitude of loads induced on the 32PTH DSC. The combinations of these loads are then established based on the conditions that can be superimposed. The load combinations are classified by Service Level consistent with Section III of the ASME Boiler and Pressure Vessel Code [3]. The stresses resulting from the application of these loads are then evaluated based on the rules for a Class I nuclear component prescribed by Subsection NB of the Code for the 32PTH DSC Shell Assembly important to safety components. Subsections NG and NF of the Code apply to the 32PTH DSC Basket Assembly. The HSM-H loads and load combinations are developed in accordance with the requirements of ANSI 57.9 [4] and ASCE 7-95 [5]. The HSM-H component stresses are evaluated based on the applicable ACI and AISC standards specified.

### 2.2.1 Tornado and Wind Loadings

The NUHOMS® HD System is designed to resist the most severe tornado and wind loads specified by NRC Regulatory Guide 1.76 [6] and NUREG-0800 [7]. The HSM-H is designed to safely withstand tornado missiles as defined by 10CFR 72.122(b) (2). Extreme wind effects are much less severe than the specified design basis tornado wind forces, which are used in load combinations specifying extreme wind for the design of the HSM-H

There are no credible wind loads applied to the 32PTH DSC as the HSM-H and transfer cask provide the required environmental protection. The case of the canister inside the HSM-H is evaluated in Chapter 3 for the associated pressure drop condition.

Since the NUHOMS® HD System on-site transfer cask (TC) is used infrequently and for short durations, the possibility of a tornado funnel cloud enveloping the TC/32PTH DSC during transit to the HSM-H is a low probability event. Nevertheless, the TC is designed for the effects of tornadoes, in accordance with 10CFR 72.122 which includes design for the effects of worst case tornado winds and missiles [7]. Analyses are presented in Chapter 11.

#### 2.2.1.1 Applicable Design Parameters

The design basis tornado (DBT) intensities used for the HSM-H are obtained from NRC Regulatory Guide 1.76 [6]. Region I intensities are utilized since they result in the most severe loading parameters. The maximum wind speed is 360 mph which is the sum of the rotational speed of 290 mph plus the maximum translational speed of 70 mph. The radius of the maximum rotational speed is 150 feet, the pressure drop across the tornado is 3.0 psi, and the rate of pressure drop is 2.0 psi per second.

#### 2.3.2.2 32PTH DSC Cooling

The HSM-H provides a means of removing spent fuel decay heat by a combination of radiation, conduction, and natural convection. The passive convective ventilation system is driven by the pressure difference due to the stack buoyancy effect ($\Delta P_s$) provided by the temperature difference between the 32PTH DSC and the ambient air outlet. This pressure difference is larger than the flow pressure drop ($\Delta P_f$) at the design air inlet and outlet temperatures.

There are no radioactive releases of effluents during normal and off-normal storage operations. Also, there are no credible accidents which cause releases of radioactive effluents from the 32PTH DSC. Therefore, an off-gas monitoring system is not required for the HSM-H. The only time an off-gas system is required is during 32PTH DSC drying operations. During this operation, the spent fuel pool or plant's radwaste system is used to process the nitrogen and helium evacuated from the 32PTH DSC.

During transfer of the DSC from the reactor building to the HSM, cooling of the DSC is maintained by utilizing a helium environment inside the transfer cask.

### 2.3.3 Protection by Equipment and Instrumentation Selection

#### 2.3.3.1 Equipment

The HSM-H, 32PTH DSC, and transfer cask encompass equipment which is important to safety. Other equipment important to safety associated with the NUHOMS® 32PTH System includes the equipment required for handling operations within the plant's fuel/reactor building. This equipment is regulated by the plant's 10CFR 50 [16] operating license.

#### 2.3.3.2 Instrumentation

The NUHOMS® HD System is a totally passive system. No safety-related instrumentation is necessary for monitoring the 32PTH DSC. The maximum temperatures and pressures are conservatively bounded by analyses. Therefore, there is no need for monitoring the internal cavity of the 32PTH DSC for pressure or temperature during normal operations. The 32PTH DSC is conservatively designed to perform its confinement function during all worst case normal, off-normal, and postulated accident conditions

### 2.3.4 Nuclear Criticality Safety

#### 2.3.4.1 Control Methods for Prevention of Criticality

The design criteria for criticality is that an upper sub-critical limit (USL) of 0.95 minus statistical uncertainties and bias, shall be limiting for all postulated arrangements of fuel within the canister. The 32PTH DSC incorporates borated aluminum material(s) as fixed neutron absorbing materials to provide criticality control. Criticality control is discussed in Chapter 6

The 32PTH DSC is designed to assure an ample margin of safety against criticality under the conditions of fresh fuel (fuel without burnup credit) in a canister flooded with borated pool water. The methods of criticality control are in accordance with the requirements of 10CFR 72.124 [2].

Criticality analysis is performed using the SCALE computer code package [1] which is widely used for criticality analysis of shipping casks, fuel storage pools and storage systems. Benchmark problems are run to verify the codes, methodology and cross section library and to determine calculational bias and uncertainties. Chapter 6 of the SAR presents the NUHOMS® HD System criticality analyses.

In the criticality calculation, the fuel assemblies and canister geometries are explicitly modeled. Each fuel pin and each guide tube is represented within each assembly.

Reactivity analyses were performed for CE 14x14, WE 15x15 and WE 17x17 classes of fuel assemblies. These analyses do not credit the neutron absorption capability of the NFAH where applicable (only to WE 15x15 and WE 17x17 class of fuel assemblies).

#### 2.3.4.2 Error Contingency Criteria

Provision for error contingency is built into the criterion used in Section 2.3.4.1. The criterion is common practice for licensing submittals. Because conservative assumptions are made in modeling, it is not necessary to introduce additional contingency for error.

#### 2.3.4.3 Verification Analysis-Benchmarking

Evaluation and verification against critical benchmarking experiments are described in Chapter 6, Section 6.5.

### 2.3.5 Radiological Protection

The NUHOMS® HD System ISFSI is designed to maintain on-site and off-site doses as low as reasonably achievable (ALARA) during transfer operations and long-term storage conditions. ISFSI operating procedures, shielding design, and access controls provide the necessary radiological protection to assure radiological exposures to station personnel and the public are ALARA. Further details concerning on-site and off-site dose rates resulting from NUHOMS® 32PTH HD System, ISFSI operations and the ISFSI ALARA evaluation are provided in Chapter 10.

#### 2.3.5.1 Access Control

The NUHOMS® HD System ISFSI will typically be located within the owner controlled area of an operating plant. A separate protected area consisting of a double fenced, double gated, lighted area may be installed around the ISFSI. Access is then controlled by locked gates, and guards are stationed when the gates are open. The licensee's Security Plan must describe the devices employed to detect unauthorized access to the facility. The specific procedures for controlling access to the ISFSI site and the restricted area within the site per 10CFR 72, Subpart H shall be addressed by the licensee's physical security and safeguards contingency plans. The system will not require the continuous presence of operators or maintenance personnel.

**Table 2-1**
**Spent Fuel Assembly Physical Characteristics**

| Parameter | 15x15 WE &WES | 17 x 17 WE | 17x17 MK BW | 17x17 WEV | 17x17 WEOFA | 14x14 CE |
|---|---|---|---|---|---|---|
| Maximum Assembly Average Initial Enrichment, wt % U235 (max) | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 |
| Clad Material | Zr-4/Zirlo | Zr-4/Zirlo | M5 | Zr-4/Zirlo | Zr-4/Zirlo | Zr-4/Zirlo |
| No of fuel rods | 204 | 264 | 264 | 264 | 264 | 176 |
| No of guide/instrument tubes | 21 | 25 | 25 | 25 | 25 | 5 |
| Assembly Length(3) | 162.2 | 162.4 | 162.4 | 162.4 | 162.4 | 159.5 |
| Max Uranium Loading (MTU) | 467 | 467 | 476 | 467 | 467 | 385 |
| Assembly Cross Section | 8.424 x 8.424 | 8.426 x 8.426 | 8.425 x 8.425 | 8.426 x 8.426 | 8.426 x 8.426 | 8.25 x 8.25 |
| Max Assembly Weight with Insert components(4) | 1528 | 157533 | 1554 | 1533 | 1533 | 1450(5) |

(1) Nominal values shown unless stated otherwise
(2) All dimensions are inches
(3) Includes allowance for irradiation growth
(4) Weights of TPAs and VSIs are enveloped by BPRAs
(5) Without NFAHs

# Table 2-2

## Fuel Qualification Table(s)

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

$$F1 = A + B*X1 + C*X2 + D*X1^2 + E*X1*X2 + F*X2^2$$
$$DH = F1*Exp(\{[1-(5/X3)]*G\}*[(X3/X1)^H]*[(X2/X1)^I])$$

where,

- F1 Intermediate Function, basically the Thermal source at 5 year cooling
- X1 Assembly Burnup in GWD/MTU
- X2 Maximum Assembly Average Initial Enrichment in wt % U-235 (max 5%, min: Zone 1- 1.5%, Zone 2 -1 6% Zone 3- 2 5%)
- X3 Cooling Time in Years (min 5 yrs)

A=13 69479 B= 25 79539 C= -3 547739 D= 0 307917 E= -3.809025
F= 14.00256 G= -0.831522 H= 0.078607 I= -0.095900

**Examples for Zone 1a -1050 watts (Burnup GWD/MTU)**

| Maximum Assembly Average Initial Enrichment (wt. % U-235) | 5 Years | 6 Years | 7 Years | 8 Years | 10 Years | 15 Years |
|---|---|---|---|---|---|---|
| 1.50 | 32.8 | 37.2 | 40.7 | 43.7 | 48.1 | 55.2 |
| 2.50 | 34.7 | 39.2 | 42.7 | 45.6 | 50.0 | 57.0 |
| 3.00 | 35.5 | 40.1 | 43.6 | 46.5 | 51.0 | 57.9 |
| 3.50 | 36.2 | 40.9 | 44.5 | 47.4 | 52.0 | 58.9 |
| 4.00 | 36.8 | 41.5 | 45.3 | 48.3 | 52.8 | 59.9 |
| 4.50 | 37.2 | 42.1 | 45.9 | 49.0 | 53 7 | 60.0 |

**Examples for Zone 1b -800 watts (Burnup GWD/MTU)**

| Maximum Assembly Average Initial Enrichment (wt. % U-235) | 5 Years | 6 Years | 7 Years | 8 Years | 10 Years | 15 Years |
|---|---|---|---|---|---|---|
| 1.50 | 26.3 | 30.0 | 32.9 | 35.4 | 39.2 | 45.2 |
| 2.00 | 27.1 | 30.8 | 33.8 | 36.2 | 40.0 | 46.0 |
| 2.50 | 27.7 | 31.5 | 34.5 | 37.0 | 40.8 | 46.7 |
| 3.00 | 28.2 | 32.1 | 35.2 | 37.7 | 41.5 | 47.5 |
| 3.50 | 28.5 | 32.5 | 35.7 | 38.3 | 42.2 | 48.3 |
| 4.00 | 28.5 | 32.9 | 36.2 | 38.8 | 42.8 | 49.0 |
| 4.50 | 28.5 | 33.0 | 36.4 | 39.2 | 43.3 | 49.7 |

# Table 2-2

## Fuel Qualification Table(s) (concluded)

### Examples for Zone 2 -1100 watts (Burnup GWD/MTU)

| Maximum Assembly Average Initial Enrichment (wt. % U-235) | 5 Years | 6 Years | 7 Years | 8 Years | 10 Years | 15 Years |
|---|---|---|---|---|---|---|
| 1.60 | 34.2 | 39.8 | 42.4 | 45.4 | 50.0 | 57.3 |
| 2.50 | 36.0 | 40.6 | 44.2 | 47.2 | 51.7 | 58.9 |
| 3.00 | 36.9 | 41.5 | 45.2 | 48.2 | 52.8 | 59.9 |
| 3.50 | 37.6 | 42.4 | 46.1 | 49.1 | 53.7 | 60.0 |
| 4.00 | 38.3 | 43.1 | 46.9 | 50.0 | 54.7 | 60.0 |
| 4.50 | 38.7 | 43.8 | 47.7 | 50.8 | 55.6 | 60.0 |

### Examples for Zone 3 -1500 watts (Burnup GWD/MTU)

| Maximum Assembly Average Initial Enrichment (wt. % U-235) | 5 Years | 6 Years | 7 Years | 8 Years |
|---|---|---|---|---|
| 3.50 | 47.9 | 53.5 | 57.8 | 60.0 |
| 4.00 | 48.9 | 54.6 | 59.0 | 60.0 |
| 4.25 | 49.4 | 55.1 | 59.5 | 60.0 |
| 4.50 | 49.9 | 55.6 | 60.0 | 60.0 |

**Table 2-3**
**Bounding Spent Fuel Assembly Thermal and Radiological Characteristics**

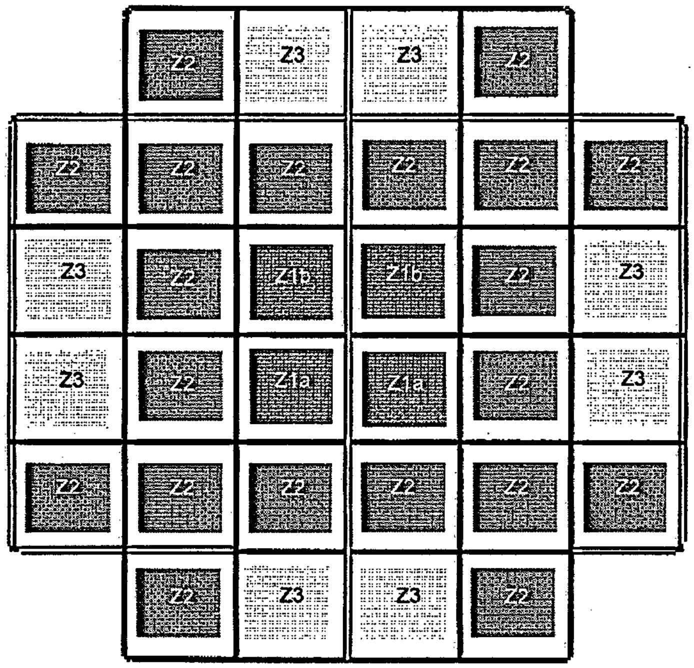
| Parameter | 17x17 MkBW |
|---|---|
| Enrichment (%wt U-235) | 4.0[3] |
| Burnup (MWd/MTU) | 60,000 |
| Minimum Cooling Time (years) | 7 |
| Decay Heat (kW/assy) | 1.5[1] or less |
| Gamma Source (γ/sec/DSC)[2] | 2.22E+17 |
| Neutron Source (n/sec/DSC)[2] | 3.52E+10 |

(1) Decay heat for fuel assembly excluding control components Decay heat for control components (0 009 kW per assembly maximum) is specified in Table 2-4
(2) Gamma/neutron source spectrum by energy group per fuel assembly is presented in Chapter 5
(3) For criticality max enrichment is 5 0%wt

**Table 2-4**
**Non-Fuel Assembly Hardware Thermal and Radiological Characteristics**

| Parameter | BPRA (Bounding) |
|---|---|
| Gamma Source[1] (γ/sec/assy) | 2.30E+14 |
| Decay heat (Watts/assy)[2] | 9 |

(1) Four days cooled, 30 GWD/MTU source
(2) Five years cooled, 30 GWD/MTU source
(3) Gamma source by energy group is presented in Chapter 5




For 15x15 and 17x17 Assemblies

- $Q_{zi}$ is the max decay heat per assembly in zone i
- Total Decay Heat ≤ 34.8 kW
- 4 fuel assemblies in zone 1 with
  - total decay heat ≤ 3.2 kW
  - $Q_{z1a} \leq 1.05$ kW in the lower compartments
  - $Q_{z1b} \leq 0.8$ kW in the upper compartments
- 20 fuel assemblies in zone 2 with $Q_{z2} \leq 1.1$ kW
- 8 fuel assemblies in zone 3 with $Q_{z3} \leq 1.5$ kW

For CE 14x14 Assemblies

$Q_{zi}$ is the max decay heat per assembly in zone i
Total Decay Heat ≤ 33.8 kW
4 fuel assemblies in zone 1 with $Q_{z1} \leq 0.775$ kW
20 assemblies in zone 2 with $Q_{z2} \leq 1.068$ kW
8 fuel assemblies in zone 3 with $Q_{z3} \leq 1.5$ kW

**Figure 2-1**
**Heat Load Zones**

CHAPTER 3
STRUCTURAL EVALUATION

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is provided to seal the bottom hydraulic ram access penetration of the cask (by 12-1/2 in high strength bolts with O-ring) during fuel loading and transferring the canister to the ISFSI. Drawing 10494-72-15 provides the part list for the NUHOMS®-OS187H transfer cask. Drawing 10494-72-16 shows the overall configuration of the NUHOMS®-OS187H transfer cask. Drawing 10494-72-17 shows the details of the transfer cask top cover The remaining drawings (10494-72-18 through 10494-72-21) show the details of the remaining individual components that make up the transfer cask.

The following sections provide physical and functional descriptions of each major component of the transfer cask. Detail drawings showing dimensions of significance to the safety analyses, welding and NDE information, as well as a complete materials list are provided in Chapter 1, Section 1.5. Reference to these drawings is made in the following physical description sections, and in general, throughout this SAR.

A. Transfer Cask Body and Structural Components

The shell or cask body cylinder assembly is an open ended (at the top) cylindrical unit with an integral closed bottom end. This assembly consists of concentric inner shell and outer shell (both SA-240 Type 304), welded to massive closure flanges (SA-240 Gr. Type 304) at the top and bottom ends. The inner shell is 0.50 inches thick and has a 70.50 inch inside diameter. The outer shell is the primary structural shell and is 1.5 inches to 2.0 inches thick, and has an 82.70 inch outside diameter. The annulus between the shells is filled with lead shielding. The lead gamma shield is 3.60 inch thick and is poured into the annulus in a molten state using a carefully controlled procedure.

The transfer cask bottom end assembly consists of a 2.00 inch bottom end plate and a 0.75 inch bottom neutron shield plate, that sandwich a 2.25 inch think resin neutron shield. The RAM access penetration at the center of the bottom end assembly is used during insertion/removal operations to and from the HSM-H The RAM access penetration is four inches thick in the radial direction and 4.25 inches thick in the axial direction. A cover plate is provided to seal the bottom hydraulic ram access penetration of the cask (by 12-1/2 in. high strength bolts with O-ring) during fuel loading and transferring the canister to the ISFSI

The transfer cask top cover consists of a 3 inch thick structural plate constructed from SA-240, Type XM-19, and a top radial neutron shield constructed from resin encased in a 0.25 inch thick SA-240 Type 304 stainless steel shell. The top cover is fastened to the top flange of the transfer cask body with 24-1.5 inch diameter SA-540 Grade B24 Class 1 high strength steel bolts. The top closure is designed to maintain confinement of the 32PTH DSC inside the transfer cask during all normal, off normal and hypothetical accident conditions.

The transfer cask body provides additional radiation shielding and structural support for the 32PTH DSC. It also maintains an inert atmosphere (helium) in the cask cavity. Helium assists in heat removal during transfer operations and provides a non-reactive environment. To preclude air in-leakage, the cask cavity is pressurized with helium to above atmospheric pressure.

The NUHOMS®-OS187H transfer cask is designed, fabricated, examined and tested in accordance with the requirements of Subsection NC [7] of the ASME Code to the maximum practical extent. Alternatives to the ASME Code are discussed in Section 3.10.

B. Gamma and Radial Neutron Shielding

The lead and steel shells of the transfer cask provide shielding between the DSC and the exterior surface of the package for the attenuation of gamma radiation.

Axial neutron shielding is primarily provided by a borated polyester resin compound. The resin compound is cast into stainless steel cavities on the outside surface of the top closure and bottom assembly.

The resin material is an unsaturated polyester cross-linked with styrene, with about 50% weight mineral and fiberglass reinforcement. The components are polyester resin, styrene monomer, alpha methyl styrene, aluminum oxide, zinc borate, and chopped fiberglass which produce the elemental resin composition is shown in Chapter 5, Table 5-17.

Radial neutron shielding is primarily provided by liquid water enclosed in a radial outer stainless steel shield shell. The shield shell around the neutron shield consists of a cylindrical shell section, with closure plates at each end. The closure plates are welded to the outer surface of the structural shell of the cask body. The outer shield shell has no structural function other than to provide an enclosure for the neutron shield water. The shell is made of SA-240 Type 304 stainless steel.

C. Tiedown and Lifting Devices

There are four trunnions welded to the exterior of the structural shell of the transfer cask. There are two front trunnions located on opposite sides of the cask near the top closure, and two rear trunnions located similarly, near the bottom of the cask. The two top trunnions are used to first lift the cask, containing a canister and an empty basket, into a fuel pool for loading of the spent fuel. After the spent fuel has been loaded into the basket, the cask is lifted to a decontamination area. After draining and drying of the pool water, welding of the canister cover, and bolting of the cask cover, the cask is placed in a trailer for transfer to ISFSI. The cask is vertically lifted onto the trailer and is initially supported by the bottom trunnions which are mated to transfer trailer. Then the cask is allowed to pivot about the bottom trunnions, into a horizontal position until the top trunnions rest on their supports in the trailer. The trunnions are secured to the skid's trunnion tower.

Appendix 3.9.2

This appendix describes the detail analysis of the TC for all the loading conditions. For the drop loads, the TC is analyzed for the 75g side and end drops. The results for the TC corner drop using LS-DYNA is reported in Appendix 3.9.10 (page 3.9.10-14).

Appendix 3.9.3

This appendix describes the detail analysis of the TC top cover bolt and ram cover bolt due to the 22g corner drop. The stress analysis is performed in accordance with NUREG/CR-6007.

Appendix 3.9.4

This appendix describes the detailed analysis of the TC lead slump and inner shell buckling analysis. A 75g end drop load is used for these analyses.

Appendix 3.9.8

This appendix describes the detailed structural analysis of the fuel cladding due to the following loads.

| | |
|---|---|
| 10CFR72 (Normal & Off-Normal loads): | |
| | 1g down (dead weight), transfer loads (1g longitudinal, 1g transverse, and 1g vertical). |
| 10CFR71 (Normal loads): | 30g (1 foot side drop)<br>1 foot end drop will be addressed in the 10CFR71 application. |

### 3.1.2 Design Criteria

This section specifies the design requirements of the NUHOMS® HD system. The system consists of the Transportable Dry Shielded Canister (DSC), the Horizontal Storage Module, HSM-H and the OS-187H onsite transfer cask. The system is designed for high burnup fuel, up to 60 GWD/MTU, with a maximum assembly average initial enrichment of 5 wt. % U-235. The design will be based on the NUHOMS® design concept of horizontal storage, and is intended for use with a compatible transport cask.

General design requirements include structural, thermal, nuclear criticality safety, confinement/containment, and radiological protection criteria.

The overall storage system consists of three major components:

- 32PTH Dry Storage Container
- 32PTH Horizontal Storage Module
- OS187H Transfer Cask

The reinforced concrete 32PTH HSM-H, including the 32PTH-DSC support structure, the 32PTH-DSC, and the structural components of the OS187H transfer cask are important to safety of NUHOMS® HD System components. Consequently, they are designed and analyzed to perform their intended functions under the extreme environmental and natural phenomena specified in 10CFR 72.122 [3] and ANSI 57.9 [9]. These include tornado and wind, seismic, and flood design criteria.

This section addresses component specific design criteria, loads, and load combinations for the structural analyses of the 32PTH DSC, 32PTH HSM-H and the OS187H Transfer Cask.

## 3.2 Weights

The nominal DSC, HSM-H and OS187H Transfer Cask geometry is used to compute the weights of the NUHOMS® HD system components.

The following densities are used to compute the component weights.

NUHOMS® HD Component Material Densities

| Material | Density (lb./in$^3$.) | Reference |
|---|---|---|
| Stainless Steel | 0.29 | 10 |
| Aluminum | 0.098 | 10 |
| Water | 0.0361 | 10 |
| Lead | 0.41 | 10 |
| Resin (neutron shield) | 0.057 | Table 5-17, Chapter 5 |

### 3.2.1 32PTH DSC Weight

The total weight of the loaded 32PTH DSC is 108.76 kips (54.38 tons). The weights of the major individual subassemblies are listed in following table.

32PTH DSC Summary of Nominal Component Weights

| Component | Nominal Weight (lbs. x 1000) |
|---|---|
| Canister Shell | 5.86 |
| Outer Top Cover Plate | 2.14 |
| Top Shield Plug and Support Ring | 10.71 |
| Bottom Shield Plug | 9.42 |
| Grapple Ring | 0.06 |
| **Total Canister Assembly** | **28.19** |
| Fuel Compartments (32) | 10.02 |
| Aluminum Plates | 3.73 |
| Poison Plates | 0.55 |
| Stainless Steel Plates | 1.94 |
| Small Support Rails (4) | 3.24 |
| ½ Large Support Rails (8) | 10.38 |
| **Total Fuel Basket** | **29.85** |
| **Total Empty DSC (Basket & Canister)** | **58.04** |
| Fuel Assembly Weight (32) @ 1585 lbs/assembly | 50.72 |
| **Total Loaded DSC Weight** | **108.76** |

## 3.5 Fuel Rods General Standards for 32PTH DSC

This section provides the temperature criteria used in the 32PTH DSC thermal evaluation for the safe storage and handling of SFA's in accordance with the requirements of 10CFR 72. This section also contains the analysis of the thermal and irradiation growth of the fuel assemblies to ensure adequate space exists within the 32PTH DSC cavity for the fuel assemblies to grow thermally under all conditions.

In addition, this section provides an evaluation of the fuel rod stresses and critical buckling loads 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 ISG11, revision 3. 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 fuel assemblies were calculated to ensure there is adequate space for the fuel assemblies to grow within the 32PTH DSC canister cavity. Detail thermal expansion evaluations of canister cavity versus lengths of basket and fuel assembly, canister ID vs. basket OD, canister OD vs. transfer cask ID, and overall length of canister vs. transfer cask cavity length are included in Appendix 3.9.1, Section 3.9.1.4.

The extreme metal temperatures for the fuel cladding and canister under different cases are obtained from Chapter 4 for computation of the differential length growth. These temperatures are conservatively rounded and used in this calculation as listed in the following table.

**Thermal Expansion Evaluation Cases**

| Cases \ Component Temperature | Length Growth Between Fuel Cladding and Canister | |
|---|---|---|
| | **Fuel Cladding Temp. (°F)** | **Canister (DSC Shell) Temp. (°F)** |
| Vacuum Drying | 750 | 210 |
| Transfer | 730 | 390 |
| Storage – Off Normal | 700 | 310 |
| Storage – Blocked Vent | 810 | 500 |

The following table summaries the minimum gap between the canister cavity and the fuel assembly in the above thermal cases.

| | Thermal Load Cases | | | |
|---|---|---|---|---|
| | Vacuum Drying | Transfer | Storage – Off Normal | Storage – Blocked Vent |
| Fuel assembly length | 162.4 in. | 162.4 in. | 162.4 in. | 162.4 in. |
| Total thermal growth | 0.4 in. | 0.38 in. | 0.36 in. | 0.43 in. |
| Irradiation growth | 1.25 in. | 1.25 in. | 1.25 in. | 1.25 in. |
| **Total fuel assembly length after thermal growth** | **164.05 in.** | **164.03 in.** | **164.01 in.** | **164.08 in.** |
| Min. canister cavity length | 164.5 in. | 164.5 in. | 164.5 in. | 164.5 in. |
| Canister thermal growth | 0.2 in. | 0.5 in. | 0.3 in. | 0.69 in. |
| **Canister cavity length after thermal growth** | **164.7 in.** | **165.0 in.** | **164.8 in.** | **165.19 in.** |
| **Min. calculated gap** | **0.65 in.** | **0.97 in.** | **0.79 in.** | **1.11 in.** |

Based on the evaluations, there is adequate space within the 32PTH DSC cavity for thermal and irradiation growth of the fuel assemblies and spacers.

### 3.5.3 Fuel Rod Integrity During Drop Scenario

The purpose of this section is to calculate zircaloy clad fuel cladding stresses due to a transfer cask side drop.

#### 3.5.3.1 Side Drop

The fuel rod side impact stresses are computed by treating the fuel rod as a continuous beam supported at locations of spacer grids. Continuous beam theory is used to determine the maximum bending moment in the entire beam. An ANSYS [33] finite element model of the fuel rod is created for each fuel type, using PIPE16 elements. The details of the finite element model geometry and equivalent densities are given computed in Table 3-12. The dimensions (lengths) of the fuel cladding for each fuel type are taken from reference [11]. The weight of fuel pellets is incorporated in the cladding model by using equivalent densities. The weights of the top and bottom end fittings are distributed to the top and bottom spans of the fuel rod cladding models (Span $L_T$ and Span $L_B$ in Table 3-12). The typical details of finite element model and boundary conditions of fuel type WE15x15 are shown on Figure 3-2.

The maximum bending stress corresponding to the maximum bending moment in the cladding tubes is calculated. The fuel gas internal pressure is also considered in the calculation. The cladding axial tensile stress due to the gas pressure is added to the bending stress due to the 75g drop load. In this elastic analysis, the 75g side drop load is applied as an acceleration. The maximum bending stresses for the fuel cladding from the ANSYS analyses are shown on Figures 3-3 to 3-7 and also summarized in Table 3-13.

#### 3.5.3.2 End Drop

The structural integrity of the fuel cladding due to the end drop loading condition will be evaluated by the user under the 10CFR50 site license.

#### 3.5.3.3 Results

Side Drop

Table 3-13 summarizes the maximum bending stresses in various specified fuel cladding during the 75g side drop of their transfer cask. All of the combined stresses are less than the yield strength of the irradiated cladding material (93,950 psi) with ample margin of safety. The maximum combined stress was calculated to be 76,931 psi in the cladding of the WE 15-15 fuel. It is less than the cladding yield strength of 93,950 psi at 725 °F.

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canister is presented in Appendix 3.9.1, Section 3.9.1.3.2 (page 3.9.1-36). The DSC canister shell buckling evaluation is presented in Appendix 3.9.1, Section 3.9.1.3.3 (page 3.9.1-61).

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. 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.

The ANSYS calculated stresses are the total stresses of the combined membrane, bending, and peak stresses. These total stresses are conservatively taken to be membrane stresses ($P_m$) as well as membrane plus bending stresses ($P_L + P_b$) and are evaluated against their corresponding ASME code stress limits. In the case where the total stresses, evaluated in this manner, exceed the ASME allowable stresses, a detailed stress linearization is performed to separate the membrane, bending, and peak stresses. The linearized stresses are then compared to their proper Code allowable stresses. ASME B&PV Code Subsection NB [12] is used for evaluation of loads under normal conditions. The thermal stress intensities are classified as secondary stress intensities, $Q$, for code evaluations.

Material properties obtained from Reference 10 for the 32PTH DSC canister materials, taken at the highest metal temperature of 500° F (from thermal evaluation presented in Chapter 4). The ANSYS Multilinear Kinematic Harding material option of inelastic analysis is employed in the analyses of all canister accident side drops. A multi-linear stress-strain curve for type 304 stainless steel at 500° F is constructed using the yield and tensile stress values taken from Reference 10.

Elastic and elastic-plastic analyses are performed to calculate the stresses in the 32PTH DSC canister under the transfer and storage loads. These detail load cases are summarized in Appendix 3.9.1, Tables 3.9.1-9, 3.9.1-10 and 3.9.1-19.

The calculated stresses in the canister shell due to normal transfer loading conditions are summarized in Appendix 3.9.1, Tables 3.9.1-11, 12, 15, and 16. The stresses due to normal storage loading conditions are summarized in Appendix 3.9.1, Tables 3.9.1-20, and 21.

An alternate 32PTH DSC canister design with a composite top and/or bottom is also evaluated for their structural adequacy.

Details of the structural evaluation of the alternate canister composite bottom design under loads of normal conditions are provided in Appendix 3.9.1, Section 3.9.1.3.4 (page 3.9.1-64). For the alternate canister composite bottom design, the stresses in the canister under the normal transfer loading conditions are summarized in Appendix 3.9.1, Tables 3.9.1-24, 25, 26, and 27. The loads under the normal storage conditions are bounded by the loads under the normal transfer conditions.

Under the loads of both the normal transfer and storage conditions, the stresses generated in the canister will not be significantly different between the canister designs with an one-piece top and with a composite top. SAR Drawing 10494–72–4, Rev. 0 shows the alternate composite top.

As described in Chapter 8, Section 8.1.1.3, operation steps 7 and 13, a maximum of 60 psig air pressure may be applied at the canister vent port to assist draining of the water. The canister is structurally evaluated for this 60 psi internal pressure using the 2-D ANSYS finite element model described in Appendix 3.9.1, Section 3.9.1.3.2. The outer cover plate of the canister is removed from the 2-D model, since it is not yet installed during the application of this 60 psig nitrogen or helium pressure. The maximum primary stress intensity and the maximum primary plus secondary stress intensity in the canister during the application of 60 psig pressure are calculated to be 8,247 psi and 26,070 psi, respectively. Their corresponding stress limits as per ASME B&PV Code Subsection NB [12] are 16,400 psig and 49,200 psi, respectively. The application of 60 psig pressure to the canister is therefore acceptable.

Based on the results of these analyses, the design of the 32PTH DSC canister is structurally adequate with respect to both transfer and storage loads under the normal conditions.

The following table summarizes the results of the analysis described in detail in Appendix 3.9.7.

| Drop Orientation | Peak Deceleration (gs) | Target Penetration Depth (in.) |
|---|---|---|
| End Drop | 49 | 3.10 |
| Side Drop | 44 | 2.5 |
| Corner Drop | 16 | 6.5 |

The ranges of drop scenarios conservatively selected for design are:

1. A horizontal side drop from a height of 80 inches (75g horizontal drop).

2. Vertical end drops for the NUHOMS® HD system are non-mechanistic and thus, no end drops are postulated for the 32PTH DSC. However, 75g vertical end drop analyses are performed as a means of enveloping the 16g corner drop (in conjunction with the 75g horizontal side drop).

3. An oblique corner drop from a height of 80 inches at an angle of 30° to the horizontal, onto the top or bottom corner of the Transfer Cask. This case is not specifically evaluated. The side drop and end drop cases envelop the corner drop.

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32. Harper, Charles A., ed., "Handbook of Plastics and Elastomers," McGraw-Hill, 1975

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35. Rashid, Nickel and James, "Structural Design of Concrete Storage Pads for Spent Fuel Casks", EPRI NP-7551, August 1991.

36. "Handbook of Concrete Engineering," Mark Fintel, September 1974

37. UCID – 21246, "Dynamic Impact Effects on Spent Fuel Assemblies," Lawrence Livermore National Laboratory, October 20, 1987.

38. K. J. Geelhood and C. E. Beyer, " PNNL Stress/Strain Correlation for Zircaloy", March 2005.

## 3.9 Appendices

The detailed structural analyses of the NUHOMS® HD system are included in the following appendices:

| | |
|---|---|
| Appendix 3.9.1 | 32PTH DSC (Canister and Basket) Structural Analysis |
| Appendix 3.9.2 | OS187H Transfer Cask Body Structural Analysis |
| Appendix 3.9.3 | OS187H Transfer Cask Top Cover and RAM Access Cover Bolt Analyses |
| Appendix 3.9.4 | OS187H Transfer Cask Lead Slump and Inner Shell Buckling Analysis |
| Appendix 3.9.5 | OS187H Transfer Cask Trunnion Analysis |
| Appendix 3.9.6 | OS187H Transfer Cask Shield Panel Structural Analysis |
| Appendix 3.9.7 | OS187H Transfer Cask Impact Analysis |
| Appendix 3.9.8 | Damaged Fuel Cladding Structural Evaluation |
| Appendix 3.9.9 | HSM-H Structural Analysis |
| Appendix 3.9.10 | OS187H Transfer Cask Dynamic Impact Analysis |
| Appendix 3.9.11 | 32PTH DSC Dynamic Impact Analysis |

## 3.10 ASME Code Alternatives

The confinement boundary of the 32PTH DSC canister shell, the inner top cover/shield plug, the inner bottom cover, the siphon vent block, and the siphon/vent port cover plate are designed, fabricated and inspected in accordance with the ASME Code Subsections NB to the maximum practical extent. The basket is designed, fabricated and inspected in accordance with ASME Code Subsection NG to the maximum practical extent. Other canister components (such as outer bottom cover and shield plugs) are not governed by the ASME Code.

**ASME Code Alternatives for the 32PTH DSC**

| Reference ASME Code Section/Article | Code Requirement | Alternatives, Justification & Compensatory Measures |
|---|---|---|
| NCA | All | Not compliant with NCA |
| NB-1100 | Requirements for Code Stamping of Components | The canister shell, the inner top cover/shield plug, The shell bottom, the inner bottom cover (alternate bottom design), and the siphon/vent port cover are designed & fabricated in accordance with the ASME Code, Section III, Subsection NB to the maximum extent practical. However, Code Stamping is not required. As Code Stamping is not required, the fabricator is not required to hold an ASME "N" or "NPT" stamp, or to be ASME Certified. |
| NB-2130<br><br>NB-4121 | Material must be supplied by ASME approved material suppliers<br><br>Material Certification by Certificate Holder | Material is certified to meet all ASME Code criteria but is not eligible for certification or Code Stamping if a non-ASME fabricator is used. As the fabricator is not required to be ASME certified, material certification to NB-2130 is not possible. Material traceability & certification are maintained in accordance with TN's NRC approved QA program. |
| NB-4243 and NB-5230 | Category C weld joints in vessels and similar weld joints in other components shall be full penetration joints. This welds shall be examined by UT or RT and either PT or MT | The joint between the outer top cover and inner top cover/shield plug and shell are design and fabricated per ASME Code Case N-595-3. The welds are partial penetration welds and the root and final layer are PT examined. |
| NB-2531 | Vent & siphon Port Cover; straight beam UT per SA-578 for all plates for vessel | SA-578 applies to 3/8" and thicker plate only; allow alternate UT techniques to achieve meaningful UT results. |
| NB-6100 and 6200 | All completed pressure retaining systems shall be pressure tested | The inner top cover/shield plug assembly is not pressure tested due to the manufacturing sequence. The inner top cover/shield plug assembly weld is helium leak tested when fuel is loaded and then covered with the outer top closure plate. |

| Reference ASME Code Section/Article | Code Requirement | Alternatives, Justification & Compensatory Measures |
|---|---|---|
| NB-7000 | Overpressure Protection | No overpressure protection is provided for the 32PTH DSC. The function of the 32PTH DSC is to contain radioactive materials under normal, off-normal, and hypothetical accident conditions postulated to occur during transportation. The 32PTH DSC is designed to withstand the maximum internal pressure considering 100% fuel rod failure at maximum accident temperature. The 32PTH DSC is pressure tested in accordance with the requirements of 10CFR71 and TN's approved QA program. |
| NB-8000 | Requirements for nameplates, stamping & reports per NCA-8000 | The 32PTH DSC nameplates provide the information required by 10CFR71, 49CFR173, and 10CFR72 as appropriate. Code stamping is not required for the 32PTH DSC. QA Data packages are prepared in accordance with the requirements of 10CFR71, 10CFR72, and TN's approved QA program. |
| NB-1132 | Attachments with a pressure retaining function, including stiffeners, shall be considered part of the component. | Outer bottom cover (item 52), bottom plate (item 55), bottom casing plate (item 61), side casing plate (item 62), top shield plug shield plate (item 69), grapple ring and grapple ring support are outside code jurisdiction; these components together are much larger than required to provide stiffening for the confinement boundary cover. These component welds are subject to root and final PT examinations. |

## ASME Code Alternatives for the 32PTH DSC Fuel Basket

| Reference ASME Code Section/Article | Code Requirement | Alternatives, Justification & Compensatory Measures |
|---|---|---|
| NG-1100 | Requirement for Code Stamping of Components | The 32PTH DSC baskets are designed & fabricated in accordance with the ASME Code, Section III, Subsection NG to the maximum extent practical as described in the SAR, but Code Stamping is not required. As Code Stamping is not required, the fabricator is not required to hold an ASME N or NPT stamp or be ASME Certified. |
| NG-2000 | Use of ASME Material | Material is certified to meet all ASME Code criteria but is not eligible for certification or Code Stamping if a non-ASME fabricator is used. As the fabricator is not required to be ASME certified, material certification to NG-2130 is not possible. Material traceability & certification are maintained in accordance with TN's NRC approved QA program. The poison material and aluminum plates are not used for structural analysis, but to provide criticality control and heat transfer. They are not ASME Code Class I materials. See note 1. |
| NCA | All | Not compliant with NCA as no code stamp is used. |

Note:

1. Because Subsection NCA does not apply, the NCA-3820 requirements for accreditation or qualification of material organizations do not apply. CMTR's shall be provided using NCA-3862 for guidance.

**Table 3-12**
**Input Data for Fuel Rod Cladding Side Drop ANSYS Runs**

| Item | WE 15x15 | WE 17x17Std | 17x17 MkBW | WE 17x17V5H | WE 17x17 OFA | CE 14x14 Std |
|---|---|---|---|---|---|---|
| Number of Supports(1) | 7 | 8 | 8 | 8 | 8 | 8 |
| Number Of Spans(1) | 6 | 7 | 7 | 7 | 7 | 7 |
| Total Length, L (in) (1) | 152.152 | 151.635 | 151.635 | 151.635 | 151.635 | 147.174 |
| Span $L_1$ (in) (1) | 22.657 | 22.93 | 22.93 | 22.93 | 22.93 | 17.36 |
| Span $L_2$ (in) (1) | 24.69 | 19.05 | 19.05 | 19.05 | 19.05 | 17.36 |
| Span $L_3$ (in) (1) | 24.69 | 19.05 | 19.05 | 19.05 | 19.05 | 17.36 |
| Span $L_4$ (in) (1) | 24.69 | 19.05 | 19.05 | 19.05 | 19.05 | 17.36 |
| Span $L_5$ (in) (1) | 24.69 | 19.05 | 19.05 | 19.05 | 19.05 | 17.36 |
| Span $L_6$ (in) (1) | 17.46 | 18.95 | 18.95 | 18.95 | 18.95 | 17.36 |
| Span $L_7$ (in) (1) | - | 19.19 | 19.19 | 19.19 | 19.19 | 17.36 |
| Span $L_B$ (in) (1) | 1.775 | 1.204 | 1.204 | 1.204 | 1.204 | 8.495 |
| Span $L_T$ (in) (1) | 1.00 | 1.161 | 1.161 | 1.161 | 1.161 | 5.159 |
| Cladding Tube, $D_O$ (in) | 0.4193 | 0.3713 | 0.3713 | 0.3713 | 0.3573 | 0.4373 |
| Cladding Tube, $t_{(Corroded)}$ (in)(8) | 0.0216 | 0.0198 | 0.0213 | 0.0198 | 0.0198 | 0.0253 |
| Cladding Tube, $D_I$ (in) | 0.3761 | 0.3317 | 0.3287 | 0.3317 | 0.3177 | 0.3867 |
| Cladding Tube Volume, $V_t$ ($in^3/in$)(2) | 0.026987 | 0.02186 | 0.02342 | 0.02186 | 0.020994 | 0.032747 |
| Tube Weight, $w_1$ (lb/in)(3) | 0.006315 | 0.005116 | 0.00548 | 0.005116 | 0.004913 | 0.007663 |
| Fuel Pellet, D (in) | 0.3659 | 0.3225 | 0.3195 | 0.3225 | 0.3088 | 0.3765 |
| Pellet Weight, $w_2$ (lb/in)(4) | 0.040378 | 0.031368 | 0.030787 | 0.031368 | 0.028759 | 0.042751 |
| (Tube+Pellet) $w_s$ (lb/in) | 0.046693 | 0.036484 | 0.036267 | 0.036484 | 0.033672 | 0.050414 |
| Tube Eqv. Density, $\rho_e$ ($lb/in^3$)(5) | 1.730 | 1.669 | 1.549 | 1.669 | 1.604 | 1.540 |
| Weight Bottom Fitting, $W_B$ (lb) | 12.566 | 12.566 | 12.566 | 12.566 | 12.566 | 12.566 |
| Weight Top Fitting, $W_T$ (lb) | 17.416 | 18.012 | 18.012 | 18.012 | 18.012 | 18.012 |
| $Tube_{Bot}$ Eqv. Density, $\rho_B$ ($lb/in^3$)(6) | 3.02 | 3.48 | 3.24 | 3.48 | 3.49 | 1.80 |
| $Tube_{Top}$ Eqv. Density, $\rho_T$ ($lb/in^3$)(7) | 4.89 | 4.36 | 4.06 | 4.36 | 4.41 | 2.13 |

Notes:

(1) Number of supports and span lengths are taken from [11]. Support grids are 1.5 in. wide.

(2) $V_t = \pi/4[D_o^2 - D_i^2] \times 1.0$

(3) $W_1 w_1 = V_t \times \rho_{tube} = V_t \times 0.234$ lb/in

(4) $W_2 w_2 = \pi/4[D^2] \times 1.0 \times \rho_{Pellet} = \pi/4[D^2] \times 0.384$ lb/in

(5) $\rho_e = w_s / V_t$

(6) $\rho_B = [w_s + W_B/(\text{No. of tubes} \times L_B)] / V_t$

(7) $\rho_T = [w_s + W_T/(\text{No. of tubes} \times L_T)] / V_t$

(8) Clad thickness reduced by 0.0027 in to account for an assumed oxide layer of 120 microns

## Table 3-13
## Maximum Fuel Rod Cladding Axial Stresses During 75g Side Drop

| Fuel Assembly Type | WE15x15 | WE 17x17std | 17x17 MkBW | WE 17x17 Vantage5H | WE 17x17 OFA | CE 14× 14 Std |
|---|---|---|---|---|---|---|
| Fuel Cladding OD, D (in) | 0.4193 | 0.3713 | 0.3713 | 0.3713 | 0.3573 | 0.4373 |
| Clad Thick. (Corr.), t (in) (1) | 0.0216 | 0.0198 | 0.0213 | 0.0198 | 0.0198 | 0.0253 |
| Average Radius, R (in) (2) | 0.1989 | 0.1758 | 0.1725 | 0.1758 | 0.1688 | 0.2060 |
| Fuel Pallet OD, $D_P$ (in) (1) | 0.3659 | 0.3225 | 0.3195 | 0.3225 | 0.3088 | 0.3765 |
| Number of Spans, N(8) | 6 | 7 | 7 | 7 | 7 | 7 |
| Max. Span Length (in)(8) | 24.69 | 22.93 | 22.93 | 22.93 | 22.93 | 17.36 |
| No. of Rods, N (1) | 204 | 264 | 264 | 264 | 264 | 176 |
| Cladding Tube Weight (lb/in)(3) | 0.006315 | 0.005116 | 0.00548 | 0.005116 | 0.004913 | 0.007663 |
| Fuel Pellet Weight (lb/in)(4) | 0.040378 | 0.031368 | 0.030787 | 0.031368 | 0.028759 | 0.042751 |
| $W_S$, [Tube + Pellet] (lb/in) | 0.046693 | 0.036484 | 0.036267 | 0.036484 | 0.033672 | 0.050414 |
| 30 Foot Side Drop - Equivalent g load | 75 | 75 | 75 | 75 | 75 | 75 |
| Max. Bending Stress, $S_b$ (psi) (5) | 66,642 | 63,230 | 59,160 | 63,230 | 63,442 | 47,725 |
| Internal Pressure, P (psi) | 2,235 | 2,235 | 2,235 | 2,235 | 2,235 | 2,235 |
| Pressure Axial Stress, $S_{press}$ (psi) (6) | 10,289 | 9,921 | 9,183 | 9,921 | 9,525 | 9,100 |
| $S_{Max} = S_b + S_{press}$ (psi) | 76,931 | 73,151 | 68,343 | 73,151 | 72,967 | 56,825 |
| Allowable Stress, $S_{all} = S_y$ (psi)(7) | 93,950 | 93,950 | 93,950 | 93,950 | 93,950 | 93,950 |
| Factor of Safety, ($S_y/S_{Max}$) | 1.22 | 1.28 | 1.37 | 1.28 | 1.29 | 1.65 |

Notes:
(1) Reduction of wall thickness by 0.0027 inch
(2) R = (D-t)/2
(3) Cladding Tube Weight = $[\pi / 4 \times (D^2 - (D - 2t)^2)] \times \rho_t = [\pi / 4 \times (D^2 - (D - 2t)^2)] \times 0.234$ lb/in.
(4) Fuel Pellet Weight = $[(\pi / 4) \times D_p^2] \times \rho_p = [(\pi / 4) \times D_p^2] \times 0.384$ lb/in.
(5) See Figures 3-3 to 3-7.
(6) $S_{pressure} = (P \times R) / (2 \times t)$
(7) Yield strength of high burn up Zircaloy cladding tube at 725 °F based on the reference paper by K. J. Geelhood and C. E. Beyer, " PNNL Stress/Strain Correlation for Zircaloy", March 2005 with strain rate at 0.5 $s^{-1}$.
(8) From Table 3-12

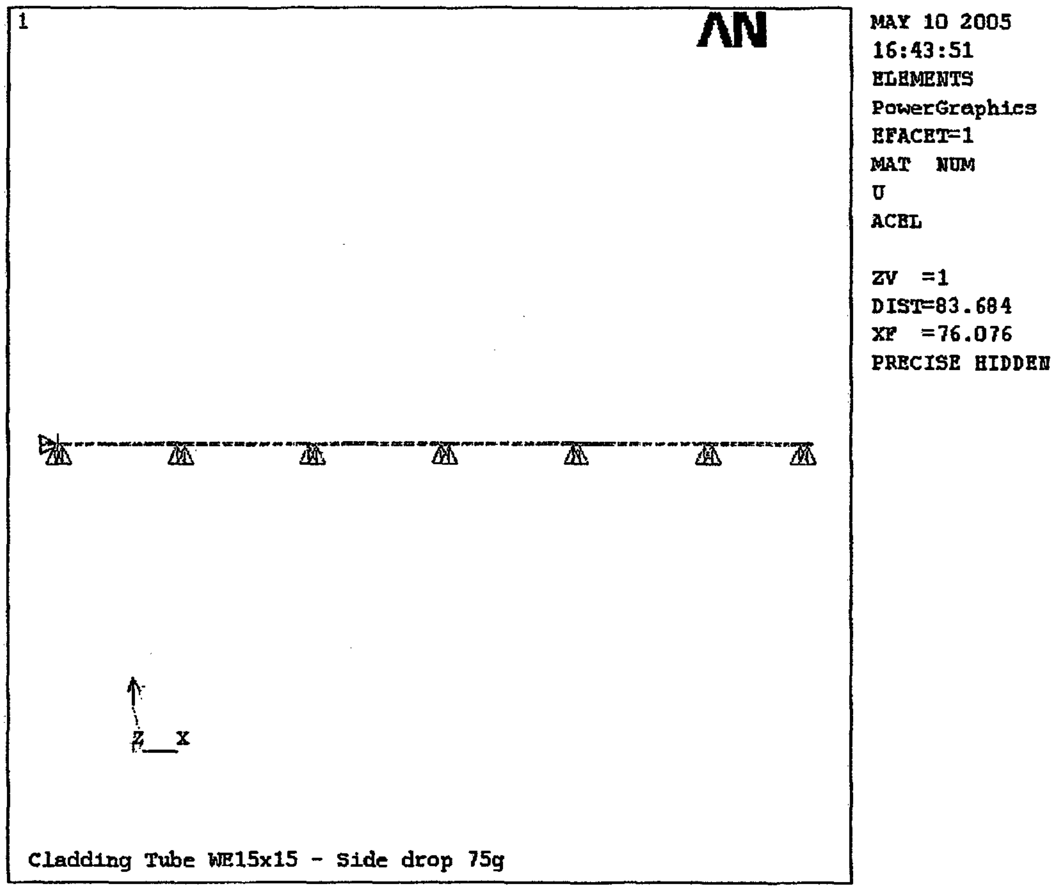


**Figure 3-2**
**Finite Element Model and Boundary Conditions WE 15x15**

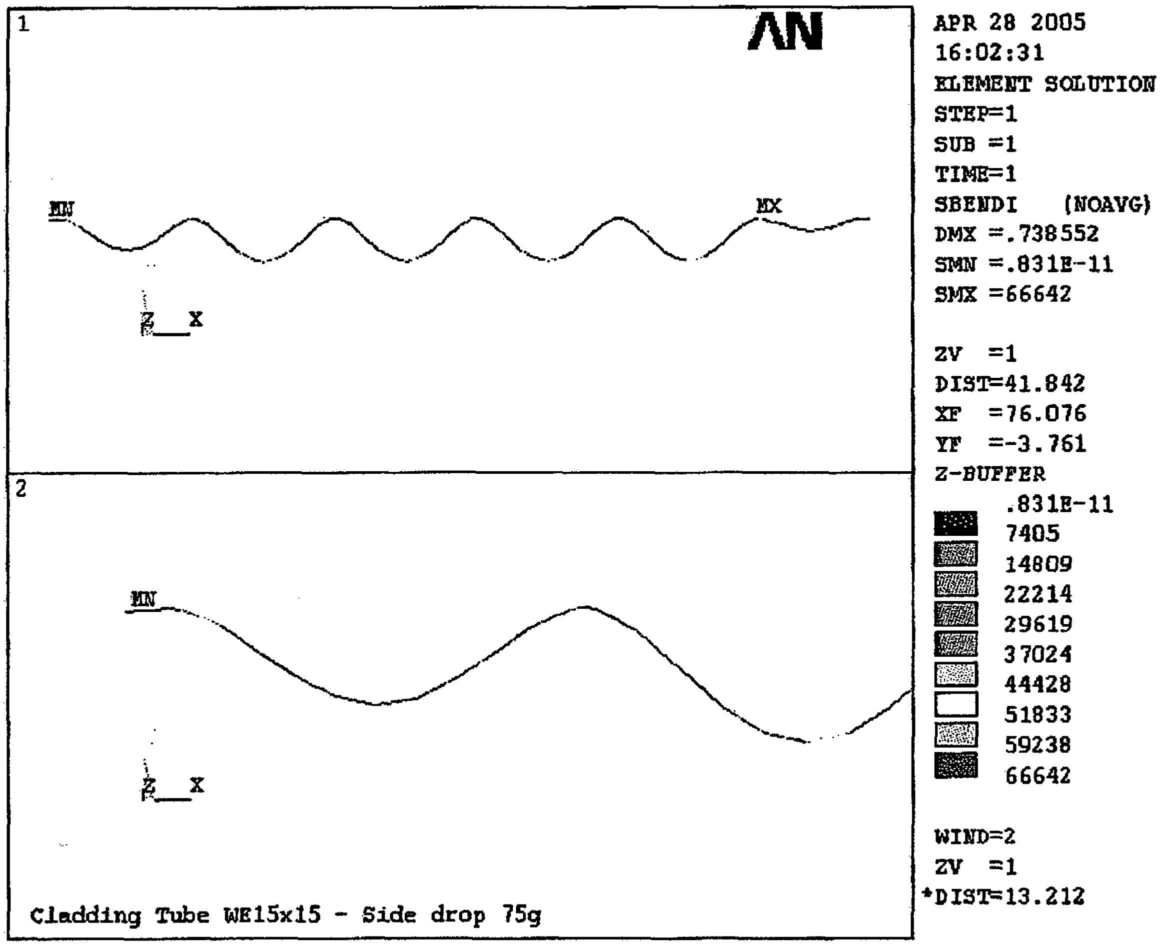


**Figure 3-3**
**Bending stress – WE 15x15**
(The bottom figure is enlarged view of span)

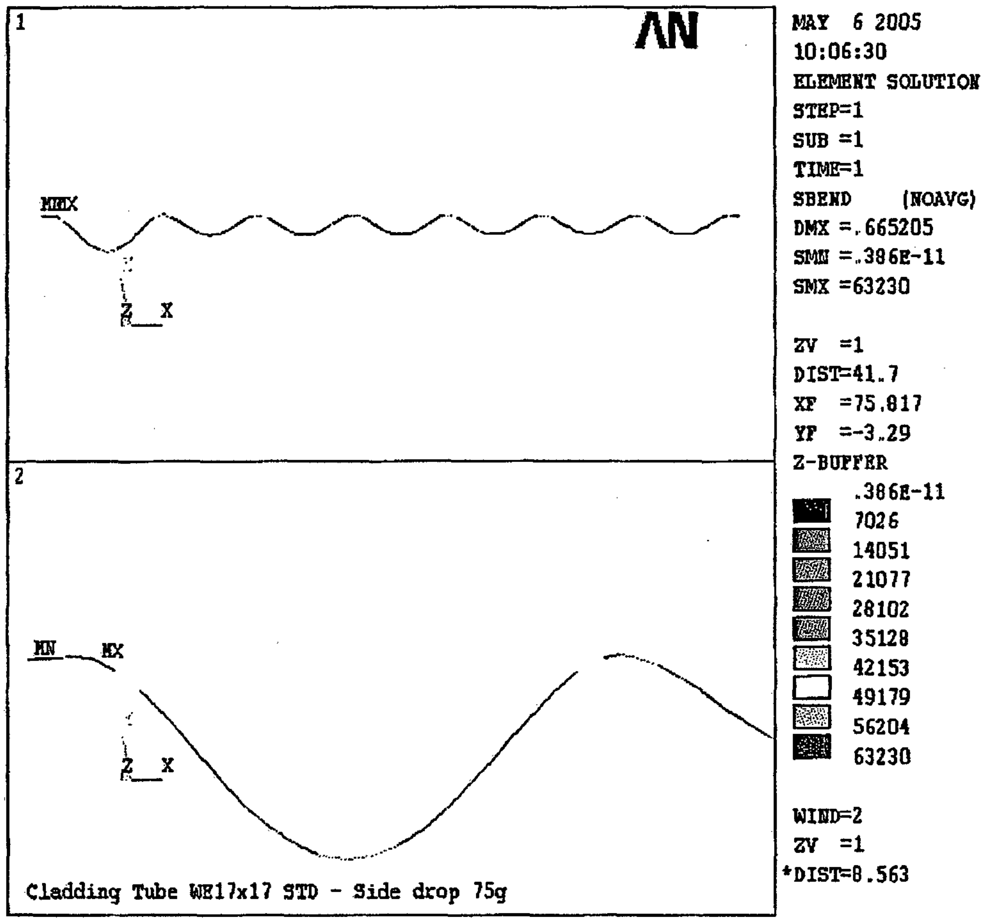


Figure 3-4
**Bending stress – WE 17x17 Std and WE 17x17 Vantage 5H**
(The bottom figure is an enlarged view of the span)

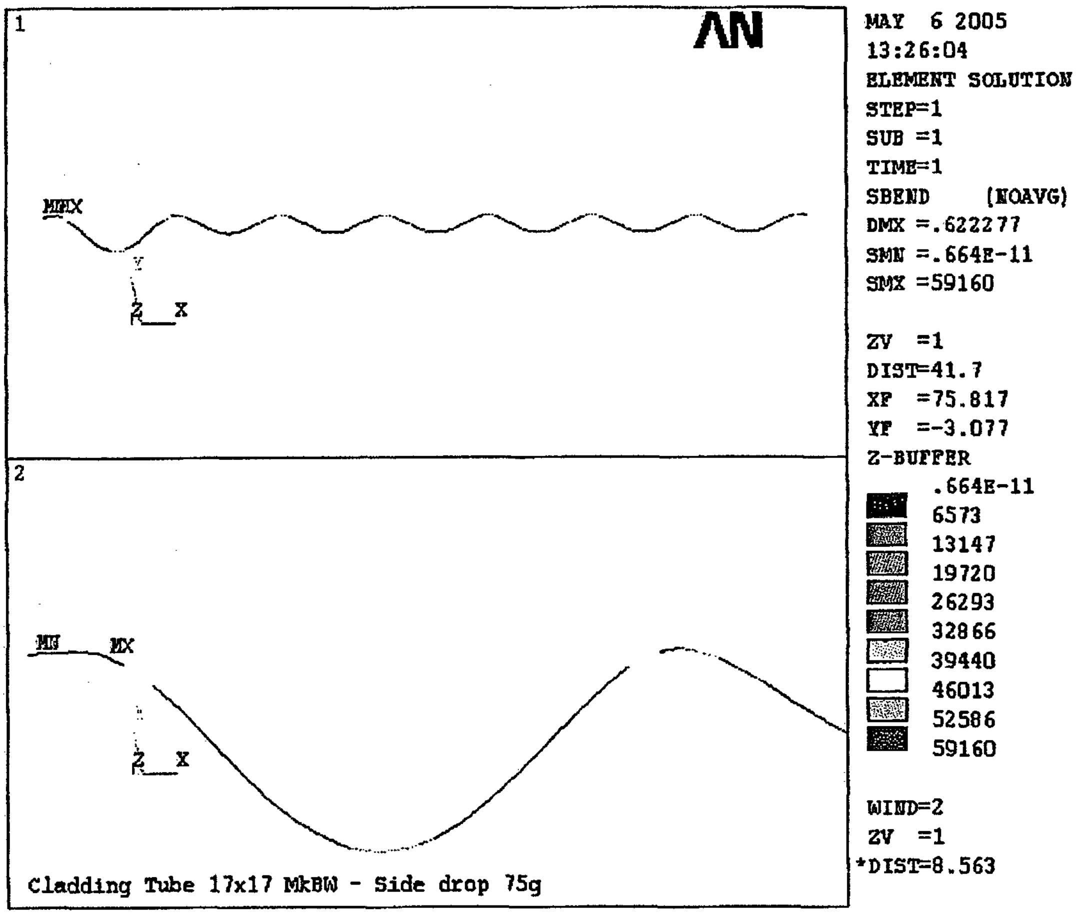


**Figure 3-5**
**Bending stress – 17x17 MkBW**
(The bottom figure is an enlarged view of the span)

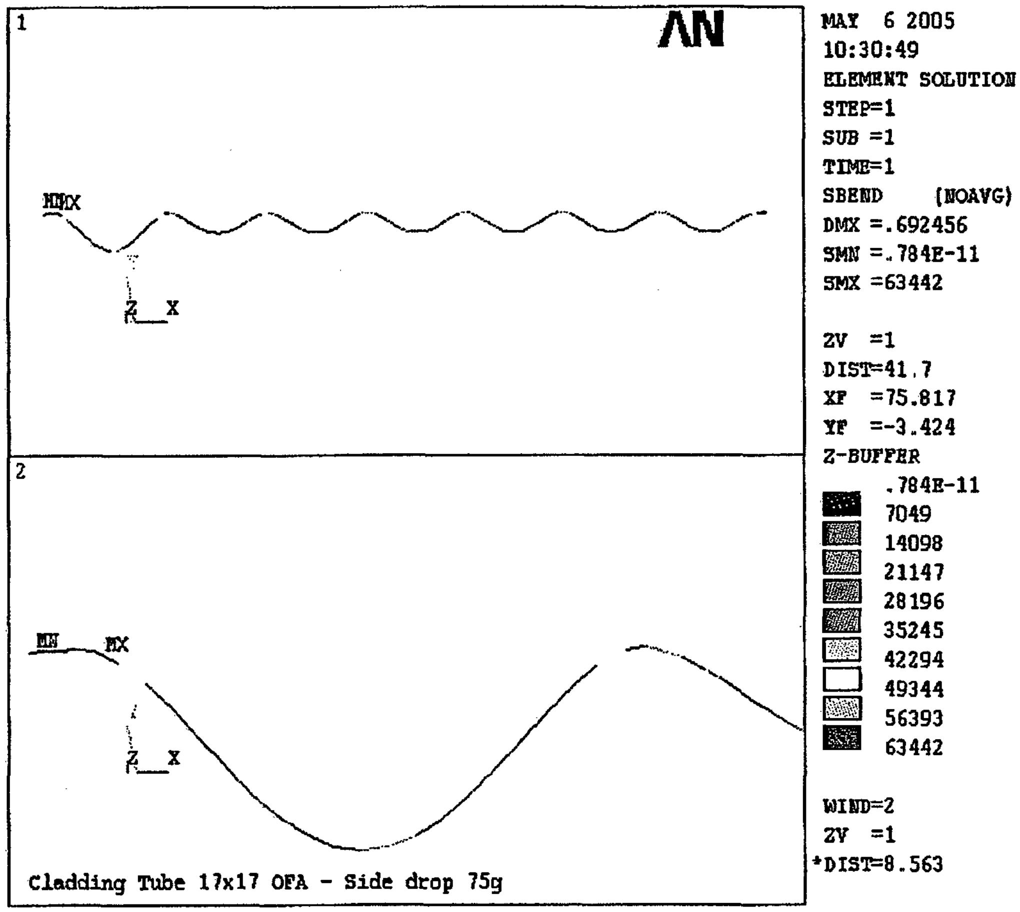


**Figure 3-6**
**Bending stress – WE 17x17 OFA**
(The bottom figure is an enlarged view of the span)

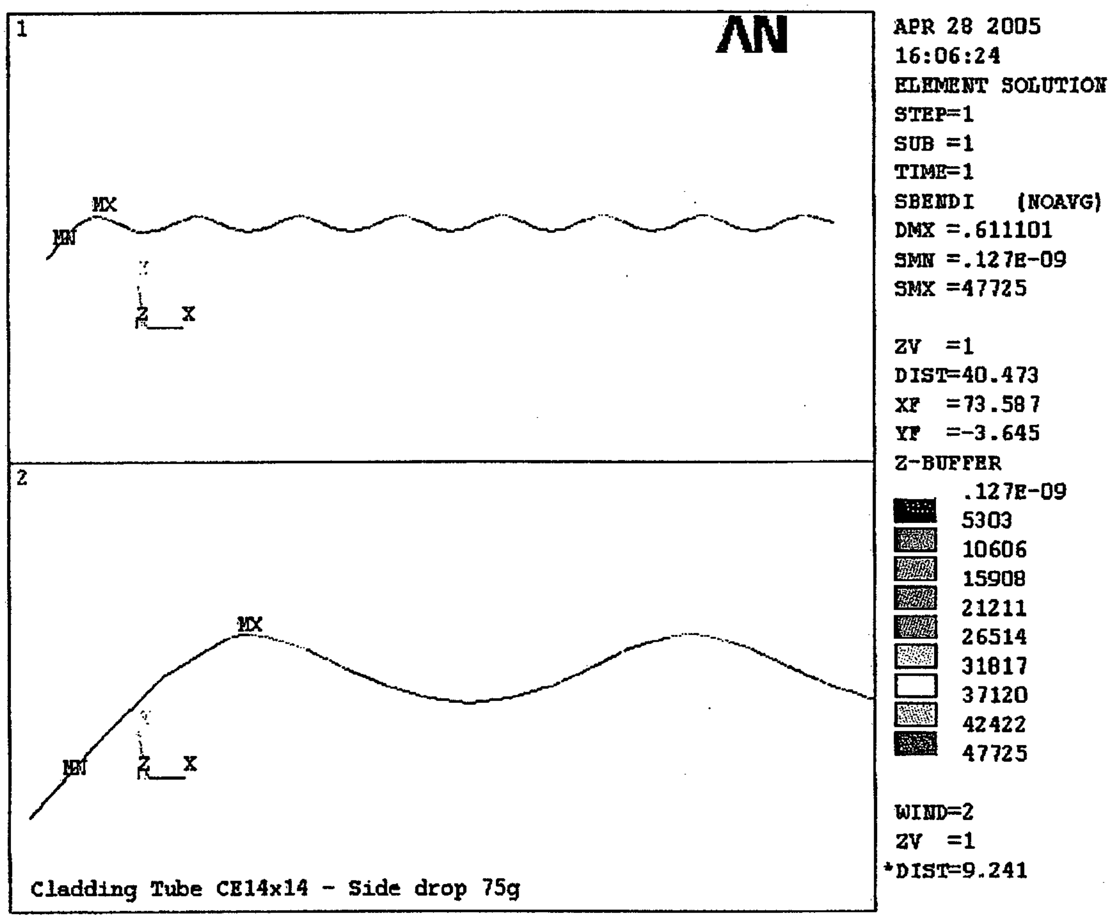


**Figure 3-7**
**Bending stress – CE 17x17 Std**
(The bottom figure is an enlarged view of the span)

APPENDIX 3.9.6
OS187H TRANSFER CASK SHIELD PANEL STURCTURAL ANALYSIS

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APPENDIX 3.9.7
OS187H TRANSFER CASK IMPACT ANALYSIS

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## 3.9.8 DAMAGED FUEL CLADDING STRUCTURAL EVALUATION

### 3.9.8.1 Introduction

The purpose of this appendix is to demonstrate structural integrity of the damaged fuel cladding in the NUHOMS® 32PTH DSC following normal and off-normal loading conditions of storage and onsite transfer (required for Part 72 License) and normal condition of offsite transport (required for Part 71 License).

In this appendix, the damaged fuel is defined as: "damaged PWR fuel assemblies are fuel assemblies containing missing or partial fuel rods or fuel rods with known or suspected cladding defects greater than hairline cracks or pinhole leaks. The extent of cladding damage in the fuel rods is to be limited such that a fuel pellet is not able to pass through the damaged cladding during handling and retrievability is assured following Normal/Off-Normal conditions".

This appendix evaluates stresses in the fuel cladding associated with normal and off-normal conditions of on-site transfer/storage and off-site transport. It also presents a fracture mechanics assessment of the cladding using conservative assumptions regarding defect size geometry and amount of oxidation in the cladding material. These evaluations demonstrate the structural integrity of the damaged fuel cladding under normal and off-normal conditions.

The NUHOMS® 32PTH DSC is designed to store 32 intact fuel assemblies, or no more than 16 damaged and the remainder intact, for a total of 32 standard PWR fuel assemblies per canister. All the fuel assemblies, intact or damaged, consist of PWR fuel assemblies with Zircaloy cladding. Damaged fuel assemblies may only be stored in the center compartments of the NUHOMS® 32PTH DSC, as shown in Chapter 2, Figure 2-2.

### 3 9 8.2 Design Input / Data

The design inputs, taken from References [2] and [12], are modified to include the reduction in cladding thickness due to oxidation. They are documented in the following table.

| Fuel Assembly Type | WE15x15 | WE 17x17std | 17x17 MkBW | WE 17x17 Vantage5H | WE 17x17 OFA | CE 14x14 Std | Notes |
|---|---|---|---|---|---|---|---|
| Fuel Assembly Weight (lb) | 1,555 | 1,575 | 1,575 | 1,575 | 1,575 | 1,450 | (1,2) |
| No. of Rods | 204 | 264 | 264 | 264 | 264 | 176 | (1) |
| Active Fuel Length (in) | 144.0 | 144 0 | 144 0 | 144.0 | 144 0 | 137.0 | (1) |
| No. of Internal Spacers | 6 | 6 | 6 | 6 | 6 | 7 | (3) |
| Max. Fuel Rod Span (in) | 27 0 | 25 0 | 25.0 | 25.0 | 25.0 | 17.0 | (5) |
| Fuel Rod OD (in) | 0.4193 | 0.3713 | 0.3713 | 0.3713 | 0.3573 | 0.4373 | (1,4) |
| Clad Thickness (in) | 0.0216 | 0 0198 | 0.0213 | 0 0198 | 0.0198 | 0 0253 | (1,4) |
| Fuel Pellet OD (in) | 0 3659 | 0.3225 | 0.3195 | 0.3225 | 0 3088 | 0.3765 | (1) |
| Fuel Tube Area ($in^2$) | 0.0270 | 0 0219 | 0 0234 | 0.0219 | 0.0210 | 0 0327 | |
| Fuel Tube M.I. ($in^4$) | 5.35E-04 | 3 39E-04 | 3 60E-04 | 3.39E-04 | 3.00E-04 | 6.97E-04 | |
| | | | | | | | |
| | | | | | | | |
| Fuel Rod Weight (lb) | 7.62 | 5.97 | 5.97 | 5 97 | 5.97 | 8 24 | (6) |
| Irradiated Yield Stress (psi) | 69,500 | 69,500 | 69,500 | 69,500 | 69,500 | 69,500 | (7) |
| Young's Modulus (psi) | 10.6E6 | 10.6E6 | 10 6E6 | 10.6E6 | 10.6E6 | 10.6E6 | (8) |

Notes:

1. Data are obtained from Chapter 2, Table 2-1
2. The fuel assembly weight includes BPRA weight.
3. The number of internal spacers is obtained from (Ref 12)
4. Include 0.00270 in thickness reduction to account for maximum oxide thickness.
5. Maximum fuel rod span is obtained from (Ref 12) and have been rounded up to whole number
6. Fuel rod weight = Fuel Assembly Weight / No. of Rods.
7. Data are obtained from Figure 3.9 8-5 at 725 °F temperature
8. Data is obtained from (Ref 3)

3.9.8.10 One Foot End Drop Damaged Fuel Evaluation

The structural integrity of the fuel cladding due to the one-foot end drop loading condition will be analyzed in the 10CFR71 application.

### 3.9.8.11 One Foot Side Drop Damaged Fuel Evaluation

During off site transport (Part 71) the damaged fuel assemblies need to be evaluated for 1 foot side drop. The transport operation is carried out using the MP 187H Cask, with the DSC and the impact limiters in the horizontal position.

The maximum g load acting on the damaged fuel rods under 1 foot side drop load = 30g. The damaged fuel rod structural integrity under 1 foot side drop load is assessed by computing the bending stress in the rod and comparing it with the yield stress of the cladding material. The fracture assessment of the damaged fuel rod structural integrity is made by using two fracture geometries (ruptured sections) as described below

It is assumed that the damaged fuel tube is burst at the spacers (supports) location, which is the location of maximum bending moment. The loading assumed is on the opposite side of the rod at the burst location. The following two geometries, used for the fracture evaluation of the damaged fuel rods, are based on these assumptions.

Fracture Geometry #1: The first geometry is shown in Figure 3.9.8-1. In this damage mode the fuel tube is assumed to bulge from diameter D to diameter W ($W \geq D$) and rupture to a hole of diameter (2a) at the bulge location. It is assumed that $(2a/w) = 0.5$ for this geometry.

Fracture Geometry #2: The second geometry is shown in Figure 3.9.8-2. The stress intensities factors for this geometry are determined using the solution for a tube with a crack subjected to pure bending moment given in Reference 13. This evaluation is based on a crack length to diameter ratio of 0.47 (or $2a/D_m=0.47$).

The basis for the 0.5 (ruptured hole to tude diameter ratio) for fracture geometry #1 and 0.47 (crack length to tube diameter ratio) for fracture geometry #2 are the experimental tests on "as received" Zircalloy fuel tubes with measured burst temperatures of up to 909°C, which showed flaw opening to diameter ratios of 0.4 to 0.5 [16].

#### 3.9.8.11.1 Structural Integrity Evaluation with Fracture Geometry #1

The fracture geometry #1 (Ruptured Section) is shown in Figure 3.9.8-1. With reference to Figure 3.9.8-1, the methodology for computing the stress intensity factor $K_I$ is as follows:

Fuel Rod OD = D

Oxidized Clad Thickness = t

Average radius, R = (D-t)/2

I = net tube MI.

Span Length = S

Assume (2a/W) = 0.5, where 2a = ruptured hole diameter,

W = bulged fuel tube diameter ≥ D.

Stress Intensity Factor, $K_I = (Y)(P*a^{1/2})/(t*W)$, [Reference 14, Fig. 8.7(c)]

Where:

Y = 2.11 {established using (2a/W) = 0.5 (for Forman et al. case) in Figure 3.9.8-3 }

P = average tensile force at the crack which is expressed as a function of moment on the cross section as:

$= (2MR^2t)/I$ (See Table 3.9.8-8)

$W = \pi R$

$M = 0.1058(W_s*S^2)$ (See Appendix 2 of Reference 3)

$W_s$ = 30g Fuel Rod Weight / Length

Bending Stress = MD / 2I

Using the methodology described above, the stress intensity factors, $K_I$ for the prescribed condition are computed and presented in the following table.

| Fuel Assembly Type | WE15x15 | WE 17x17Std | 17x17 MkBW | WE 17x17 Vantage 5H | WE17x17 OFA | CE 14x14 Std |
|---|---|---|---|---|---|---|
| Fuel Rod OD, D (in) | 0.4193 | 0.3713 | 0.3713 | 0.3713 | 0.3573 | 0.4373 |
| Clad Thickness, t (in) | 0.0216 | 0.0198 | 0.0213 | 0.0198 | 0.0198 | 0.0253 |
| Average Radius, R (in) | 0.1989 | 0.1758 | 0.1750 | 0.1758 | 0.1688 | 0.2060 |
| Fuel Tube M.I (in$^4$) | 5.35E-04 | 3.39E-04 | 3.60E-04 | 3.39E-04 | 3.00E-04 | 6.97E-04 |
| | | | | | | |
| | | | | | | |
| Span Length, S (in) | 27.0 | 25.0 | 25.0 | 25.0 | 25.0 | 17.0 |
| (2a/W) | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Y | 2.11 | 2.11 | 2.11 | 2.11 | 2.11 | 2.11 |
| W (in) | 0.62 | 0.55 | 0.55 | 0.55 | 0.53 | 0.65 |
| Fuel Assembly Weight (lb) | 1,555 | 1,575 | 1,575 | 1,575 | 1,575 | 1,450 |
| No of Rods | 204 | 264 | 264 | 264 | 264 | 176 |
| Active Fuel Length (in) | 144.0 | 144.0 | 144.0 | 144.0 | 144.0 | 137.0 |
| 1-Foot Side Drop Equivalent g load | 30 | 30 | 30 | 30 | 30 | 30 |
| $W_s$ (lb/in) | 1.59 | 1.24 | 1.24 | 1.24 | 1.24 | 1.80 |
| Moment, M (kip. in) | 0.12 | 0.08 | 0.08 | 0.08 | 0.08 | 0.06 |
| Bending Stress (psi) | 47,990 | 45,040 | 42,390 | 45,040 | 48,950 | 17,300 |
| P (kip) | 0.391 | 0.297 | 0.298 | 0.297 | 0.309 | 0.170 |
| $K_I$ (ksi in$^{1/2}$) | 24.2 | 21.3 | 19.9 | 21.3 | 22.6 | 8.8 |

The computed stress intensity factor is compared with experimentally obtained plane strain fracture toughness, $K_{IC}$ of irradiated Zircaloy cladding material as reported in [15].

Reference15 reports a $K_{IC}$ = 35 ksi $in^{1/2}$ at approximately 300°F which is greater than highest computed stress intensity factor, $K_I$ of 18.3 ksi $in^{1/2}$ presented in the above table.

Therefore, the structural integrity of the damaged fuel rods, which are conservatively assumed to rupture as shown in Figure 3.9.8-1, will be maintained.

3.9.8.11.2 Structural Integrity Evaluation with Fracture Geometry #2

This geometry is shown in Figure 3.9.8-2. Stress intensity factors are computed for a crack in a fuel tube subjected to a uniform bending moment (M) using formulae given in Reference 13. As per Reference 13, page 472:

$$K_I = \sigma (\pi * R_m * \theta)^{1/2} F(\theta)$$

where,

$$F(\theta) = 1 + 6.8*(\theta/\pi)^{3/2} - 13.6*(\theta/\pi)^{5/2} + 20.0*(\theta/\pi)^{7/2}$$

$\sigma$ = Bending Stress due to Uniform Moment 'M'

$R_m$ = Average radius of the fuel tube

2 $\theta$ = Angle which the crack makes at the center of the tube

$K_I$ = Stress Intensity Factor at the crack

The $K_I$ is computed for all the different fuel assemblies, and the results for all the fuel assemblies are presented in Table 3.9.8-1, 3.9.8-2, 3.9.8-3, 3.9.8-4 and 3.9.8-5.

Based on the computed $K_I$ using Fracture Geometries #1 & #2, a summary of the comparisons is presented as follows:

| | **Fracture Geometry #1 $K_I$** | **Fracture Geometry #2 $K_I$** |
|---|---|---|
| **WE 15x15** | 24.2 | 33.8 |
| **WE 17x17 Std.** | 21.3 | 29.9 |
| **17x17 MKBW** | 19.9 | 28.0 |
| **WE 17x17 Vantage 5H** | 21.3 | 29.9 |
| **WE 17x17 OFA** | 22.6 | 31.8 |
| **CE 14x14 Std** | 8.8 | 12.4 |

3.9.8.12 Conclusions

The maximum computed stresses in the fuel rods and their ratios to the irradiated yield stress of the cladding material are summarized in Table 3.9.8-6. From Table 3.9.8-6, it can be concluded that stresses for all load cases considered are significantly less than the yield stress of the Zircaloy cladding material (computed stresses are 4% to 49% of the yield stress).

It is important to note that, the stresses in the fuel rods for all analyzed normal and off normal load cases are compressive stresses (less than the critical buckling stress), except for the 1-foot transport condition side drop load.

For the 1-foot side drop it is demonstrated by using fracture mechanics procedures (by comparing computed stress intensity factors to critical crack initiation fracture toughness in Table 3.9.8-7), that the damaged fuel rods will maintain their structural integrity.

This calculation demonstrates that the fuel cladding in the NUHOMS® 32PTH DSC will retain its structural integrity when subjected to normal condition of storage and on site transfer loads. The fuel cladding will also maintain its integrity when subjected to a one-foot side drop during offsite transport. The fuel cladding integrity during the one-foot end drop and transport vibratory loads will be demonstrated in the 10CFR71 application. Therefore, the retrievability of the fuel assembly is assured when subjected to storage and transfer normal and off normal loads

## Table 3.9.8-1

## Westinghouse 15x15 - $K_I$ Calculation using Fracture Geometry #2

| | |
|---|---|
| OD (in) = | 0.4193 |
| t (in) = | 0.0216 |
| R / t = | 9.71 |
| Rm (in) = | 0.1989 |
| M (kip-in) = | 0.12 |
| | |
| Theta (radian) = | 0.47 |
| I ($in^4$) = | 5.34E-04 |
| Bending Stress (ksi) = | 47.99 |
| E (ksi) = | 10,600 |

| Theta (rad) | Theta/pi | Half Length (in) | F(Theta) | $K_I$ (ksi $in^{1/2}$) |
|---|---|---|---|---|
| 0.05 | 0.0159 | 0.0099 | 1.0132 | 8.6 |
| 0.10 | 0.0318 | 0.0199 | 1.0363 | 12.4 |
| 0.15 | 0.0477 | 0.0298 | 1.0646 | 15.6 |
| 0.20 | 0.0637 | 0.0398 | 1.0966 | 18.6 |
| 0.25 | 0.0796 | 0.0497 | 1.1312 | 21.5 |
| 0.30 | 0.0955 | 0.0597 | 1.1677 | 24.3 |
| 0.35 | 0.1114 | 0.0696 | 1.2058 | 27.1 |
| 0.40 | 0.1273 | 0.0795 | 1.2450 | 29.9 |
| 0.45 | 0.1432 | 0.0895 | 1.2853 | 32.7 |
| 0.47 | 0.1496 | 0.0935 | 1.3017 | 33.8 |
| 0.51 | 0.1623 | 0.1014 | 1.3348 | 36.2 |
| 0.52 | 0.1655 | 0.1034 | 1.3432 | 36.7 |
| 0.55 | 0.1751 | 0.1094 | 1.3686 | 38.5 |
| 0.60 | 0.1910 | 0.1193 | 1.4117 | 41.5 |
| 0.65 | 0.2069 | 0.1293 | 1.4557 | 44.5 |
| 0.70 | 0.2228 | 0.1392 | 1.5009 | 47.6 |

## Table 3.9.8-2

**Westinghouse 17x17 Std - $K_I$ Calculation using Fracture Geometry #2**

| | |
|---|---|
| OD (in) = | 0.3713 |
| t (in) = | 0.0198 |
| R / t = | 9.38 |
| Rm (in) = | 0.1758 |
| M (kip-in) = | 0.08 |
| | |
| Theta (radian) = | 0.47 |
| I ($in^4$) = | 3.39E-04 |
| Bending Stress (ksi) = | 45.04 |
| E (ksi) = | 10,600 |

| Theta (rad) | Theta/pi | Half Length (in) | F(Theta) | $K_I$ (ksi $in^{1/2}$) |
|---|---|---|---|---|
| 0.05 | 0.0159 | 0.0088 | 1.0132 | 7.6 |
| 0.10 | 0.0318 | 0.0176 | 1.0363 | 11.0 |
| 0.15 | 0.0477 | 0.0264 | 1.0646 | 13.8 |
| 0.20 | 0.0637 | 0.0352 | 1.0966 | 16.4 |
| 0.25 | 0.0796 | 0.0439 | 1.1312 | 18.9 |
| 0.30 | 0.0955 | 0.0527 | 1.1677 | 21.4 |
| 0.35 | 0.1114 | 0.0615 | 1.2058 | 23.9 |
| 0.40 | 0.1273 | 0.0703 | 1.2450 | 26.4 |
| 0.45 | 0.1432 | 0.0791 | 1.2853 | 28.9 |
| 0.47 | 0.1496 | 0.0826 | 1.3017 | 29.9 |
| 0.51 | 0.1623 | 0.0896 | 1.3348 | 31.9 |
| 0.52 | 0.1655 | 0.0914 | 1.3432 | 32.4 |
| 0.55 | 0.1751 | 0.0967 | 1.3686 | 34.0 |
| 0.60 | 0.1910 | 0.1055 | 1.4117 | 36.6 |
| 0.65 | 0.2069 | 0.1142 | 1.4557 | 39.3 |
| 0.70 | 0.2228 | 0.1230 | 1.5009 | 42.0 |

## Table 3.9.8-3

## Framatome 17x17 MKBW - $K_I$ Calculation using Fracture Geometry #2

| | |
|---|---|
| OD (in) = | 0.3713 |
| t (in) = | 0.0213 |
| R / t = | 8.72 |
| Rm (in) = | 0.1750 |
| M (kip-in) = | 0.08 |
| | |
| Theta (radian) = | 0.47 |
| I (in$^4$) = | 3.60E-04 |
| Bending Stress (ksi) = | 42.39 |
| E (ksi) = | 10,600 |

| Theta (rad) | Theta/pi | Half Length (in) | F(Theta) | $K_I$ (ksi in$^{1/2}$) |
|---|---|---|---|---|
| 0.05 | 0.0159 | 0.0088 | 1.0132 | 7.1 |
| 0.10 | 0.0318 | 0.0175 | 1.0363 | 10.3 |
| 0.15 | 0.0477 | 0.0263 | 1.0646 | 13.0 |
| 0.20 | 0.0637 | 0.0350 | 1.0966 | 15.4 |
| 0.25 | 0.0796 | 0.0438 | 1.1312 | 17.8 |
| 0.30 | 0.0955 | 0.0525 | 1.1677 | 20.1 |
| 0.35 | 0.1114 | 0.0613 | 1.2058 | 22.4 |
| 0.40 | 0.1273 | 0.0700 | 1.2450 | 24.7 |
| 0.45 | 0.1432 | 0.0788 | 1.2853 | 27.1 |
| 0.47 | 0.1496 | 0.0823 | 1.3017 | 28.0 |
| 0.51 | 0.1623 | 0.0893 | 1.3348 | 30.0 |
| 0.52 | 0.1655 | 0.0910 | 1.3432 | 30.4 |
| 0.55 | 0.1751 | 0.0963 | 1.3686 | 31.9 |
| 0.60 | 0.1910 | 0.1050 | 1.4117 | 34.4 |
| 0.65 | 0.2069 | 0.1138 | 1.4557 | 36.9 |
| 0.70 | 0.2228 | 0.1225 | 1.5009 | 39.5 |

## Table 3.9.8-4

## Westinghouse 17x17 Vantage 5H - $K_I$ Calculation using Fracture Geometry #2

| | |
|---|---|
| OD (in) = | 0.3713 |
| t (in) = | 0.0198 |
| R / t = | 9.38 |
| Rm (in) = | 0.1758 |
| M (kip-in) = | 0.08 |
| | |
| Theta (radian) = | 0.47 |
| I ($in^4$) = | 3.39E-04 |
| Bending Stress (ksi) = | 45.04 |
| E (ksi) = | 10,600 |

| Theta (rad) | Theta/pi | Half Length (in) | F(Theta) | $K_I$ (ksi $in^{1/2}$) |
|---|---|---|---|---|
| 0.05 | 0.0159 | 0.0088 | 1.0132 | 7.6 |
| 0.10 | 0.0318 | 0.0176 | 1.0363 | 11.0 |
| 0.15 | 0.0477 | 0.0264 | 1.0646 | 13.8 |
| 0.20 | 0.0637 | 0.0352 | 1.0966 | 16.4 |
| 0.25 | 0.0796 | 0.0439 | 1.1312 | 18.9 |
| 0.30 | 0.0955 | 0.0527 | 1.1677 | 21.4 |
| 0.35 | 0.1114 | 0.0615 | 1.2058 | 23.9 |
| 0.40 | 0.1273 | 0.0703 | 1.2450 | 26.4 |
| 0.45 | 0.1432 | 0.0791 | 1.2853 | 28.9 |
| 0.47 | 0.1496 | 0.0826 | 1.3017 | 29.9 |
| 0.51 | 0.1623 | 0.0896 | 1.3348 | 31.9 |
| 0.52 | 0.1655 | 0.0914 | 1.3432 | 32.4 |
| 0.55 | 0.1751 | 0.0967 | 1.3686 | 34.0 |
| 0.60 | 0.1910 | 0.1055 | 1.4117 | 36.6 |
| 0.65 | 0.2069 | 0.1142 | 1.4557 | 39.3 |
| 0.70 | 0.2228 | 0.1230 | 1.5009 | 42.0 |

## Table 3.9.8-5

## Westinghouse 17x17 OFA - $K_I$ Calculation using Fracture Geometry #2

| | |
|---|---|
| OD (in) = | 0.3573 |
| t (in) = | 0.0198 |
| R / t = | 9.02 |
| Rm (in) = | 0.1688 |
| M (kip-in) = | 0.08 |
| | |
| Theta (radian) = | 0.47 |
| I (in$^4$) = | 3.00E-04 |
| Bending Stress (ksi) = | 48.95 |
| E (ksi) = | 10,600 |

| Theta (rad) | Theta/pi | Half Length (in) | F(Theta) | $K_I$ (ksi in$^{1/2}$) |
|---|---|---|---|---|
| 0.05 | 0.0159 | 0.0084 | 1.0132 | 8.1 |
| 0.10 | 0.0318 | 0.0169 | 1.0363 | 11.7 |
| 0.15 | 0.0477 | 0.0253 | 1.0646 | 14.7 |
| 0.20 | 0.0637 | 0.0338 | 1.0966 | 17.5 |
| 0.25 | 0.0796 | 0.0422 | 1.1312 | 20.2 |
| 0.30 | 0.0955 | 0.0506 | 1.1677 | 22.8 |
| 0.35 | 0.1114 | 0.0591 | 1.2058 | 25.4 |
| 0.40 | 0.1273 | 0.0675 | 1.2450 | 28.1 |
| 0.45 | 0.1432 | 0.0759 | 1.2853 | 30.7 |
| 0.47 | 0.1496 | 0.0793 | 1.3017 | 31.8 |
| 0.51 | 0.1623 | 0.0861 | 1.3348 | 34.0 |
| 0.52 | 0.1655 | 0.0878 | 1.3432 | 34.5 |
| 0.55 | 0.1751 | 0.0928 | 1.3686 | 36.2 |
| 0.60 | 0.1910 | 0.1013 | 1.4117 | 39.0 |
| 0.65 | 0.2069 | 0.1097 | 1.4557 | 41.8 |
| 0.70 | 0.2228 | 0.1181 | 1.5009 | 44.8 |

## Table 3.9.8-6

## Combustion Engineering 14x14 - $K_I$ Calculation using Fracture Geometry #2

| | |
|---|---|
| OD (in) = | 0.4373 |
| t (in) = | 0.0253 |
| R / t = | 8.64 |
| Rm (in) = | 0.2060 |
| M (kip-in) = | 0.06 |
| | |
| Theta (radian) = | 0.47 |
| I ($in^4$) = | 6.97E-04 |
| Bending Stress (ksi) = | 17.30 |
| E (ksi) = | 10,600 |

| Theta (rad) | Theta/pi | Half Length (in) | F(Theta) | $K_I$ (ksi $in^{1/2}$) |
|---|---|---|---|---|
| 0.05 | 0.0159 | 0.0103 | 1.0132 | 3.2 |
| 0.10 | 0.0318 | 0.0206 | 1.0363 | 4.6 |
| 0.15 | 0.0477 | 0.0309 | 1.0646 | 5.7 |
| 0.20 | 0.0637 | 0.0412 | 1.0966 | 6.8 |
| 0.25 | 0.0796 | 0.0515 | 1.1312 | 7.9 |
| 0.30 | 0.0955 | 0.0618 | 1.1677 | 8.9 |
| 0.35 | 0.1114 | 0.0721 | 1.2058 | 9.9 |
| 0.40 | 0.1273 | 0.0824 | 1.2450 | 11.0 |
| 0.45 | 0.1432 | 0.0927 | 1.2853 | 12.0 |
| 0.47 | 0.1496 | 0.0968 | 1.3017 | 12.4 |
| 0.51 | 0.1623 | 0.1051 | 1.3348 | 13.3 |
| 0.52 | 0.1655 | 0.1071 | 1.3432 | 13.5 |
| 0.55 | 0.1751 | 0.1133 | 1.3686 | 14.1 |
| 0.60 | 0.1910 | 0.1236 | 1.4117 | 15.2 |
| 0.65 | 0.2069 | 0.1339 | 1.4557 | 16.3 |
| 0.70 | 0.2228 | 0.1442 | 1.5009 | 17.5 |

**Table 3.9.8-7**

**Summary - Maximum Fuel Rod Stresses and Stress Ratios**

| Normal and Off Normal Load Case | Maximum (1) Stress (psi) | Stress (2) Ratio |
|---|---|---|
| On site Transport and Transfer Operations | 2,865 | 0.04 |
| | | |
| One-foot Side Drop (Part 71) | 48,950 | 0.70 |

Notes:
(1) Maximum stress for all fuel assemblies.
(2) Stress ratio = maximum stress / 69,500 (yield stress for Zircaloy cladding).

**Table 3.9.8-8**

**Summary - Computed Fuel Tube Stress Intensity Factors and Ratios**

| Fracture Geometry | Max $K_I$ [(1)] (ksi $in^{1/2}$) | $K_{IC}$ [(2)] (ksi $in^{1/2}$) | Ratio Max $K_I$ / $K_{IC}$ |
|---|---|---|---|
| Geometry #1 | 24 2 | 35 0 | 0 69 |
| Geometry #2 | 33 8 | 35.0 | 0.97 |

Notes:

1. Maximum $K_I$ for all fuel assemblies.
2. $K_{IC}$ = Crack initiation fracture toughness (plane strain fracture toughness).

Comparably, the maximum effective stress (Von Mises stress) in the cask structure shell is calculated to be 29.12 ksi (see Figure 3.9.10-21 of this Appendix) from the LS-DYNA dynamic analysis. This indicates that the static stress analysis using drop load of 75g is a very conservative approach, which produces about twice stress value of that produced by the dynamic LS-DYNA analysis.

5. Figure 3.9.10-23 shows the maximum effective stress (Von Mises stress) in transfer cask due to CG over corner drop from LS-DYNA analysis. The maximum effective stress at cask top cover plate is about 34.49 ksi, which is less than its allowable stress of 94.2 ksi (SA-240, Type XM 19 at 300°F). The maximum effective stress in the structural shell is about 24.0 ksi, which is less than its allowable stress of 66.2 ksi (SA-240, Type 304 at 300°F).

For g loads (including dynamic load factor) to be used for canister and basket structural analyses are described in Appendix 3.9.11.

3.9.10.6 References

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# THERMAL EVALUATION

## 4.1 Discussion

The NUHOMS®-32PTH DSC is designed to passively reject decay heat during storage and transfer for normal, off-normal, and accident conditions while maintaining temperatures and pressures within specified limits. Objectives of the thermal analyses performed for this evaluation include:

- Determination of maximum and minimum temperatures with respect to material limits to ensure components perform their intended safety functions,
- Determination of temperature distributions to support the calculation of thermal stresses,
- Determination of maximum DSC internal pressures for normal, off-normal, and accident conditions, and
- Determination of the maximum fuel cladding temperature, and to confirm that this temperature will remain sufficiently low to prevent unacceptable degradation of the fuel during storage.

To establish the heat removal capability, several thermal design criteria are established for the System. These are:

- Maximum temperatures of the containment structural components must not adversely affect the containment function.
- To maintain the stability of the neutron shield resin in the transfer cask (TC) during normal transfer conditions, a maximum allowable temperature of 300°F is set for the neutron shield material [1].
- A maximum fuel cladding temperature limit of 400°C (752°F) has been established for normal conditions of storage and for short-term storage operations such as transfer and vacuum drying [2]. During off-normal storage and accident conditions, the fuel cladding temperature limit is 570°C (1058°F) [2].
- A maximum temperature limit of 327°C (620°F) is considered for the lead in the transfer cask, corresponding to the melting point [3].

- The ambient temperature range for normal operation is 0 to 100°F (-18 to 38°C). The minimum and maximum off-normal ambient temperatures are -20°F (-29 °C) and 115°F (46°C) respectively. In general, all the thermal criteria are associated with maximum temperature limits and not minimum temperatures. All materials can be subjected to a minimum environment temperature of -20°F (-29 °C) without adverse effects.

- The maximum DSC internal pressure during normal and off-normal conditions must be below the design pressures of 15 psig and 20 psig respectively. For accident cases, the maximum DSC internal pressure must be lower than 70 psig during storage and lower than 120 psig during transfer operation.

The NUHOMS®-32PTH DSC is analyzed based on a maximum heat load of 34.8 kW from 32 fuel assemblies with a maximum heat load of 1.5 kW per assembly. For CE 14x14 fuel assembly the maximum total heat load is limited to 33.8 kW The loading requirements described in Section 4.3.1.3 are used to develop the bounding load configurations.

A description of the detailed analyses performed for normal/off-normal conditions is provided in Section 4.3, and accident conditions in Section 4.4. The thermal analyses performed for the loading and unloading conditions are described in Section 4.5. DSC internal pressures are discussed in Section 4.6.

The analyses consider the effect of the decay heat flux varying axially along a fuel assembly. The axial decay heat profile for a PWR fuel assembly is based on [4]. Section 4.7 describes the calculated peaking factors and the methodology to apply the axial heat profile in the model.

Fuel assemblies are considered as homogenized materials in the fuel compartments. The effective thermal conductivity of the fuel assemblies used in the thermal analysis is based on the conservative assumption that heat transfer within the fuel region occurs only by conduction and radiation where any convection heat transfer is neglected. The lowest effective properties among the applicable fuel assemblies are selected to perform the thermal analysis. Section 4.8 presents the calculation that determines the bounding effective thermal properties of the applicable fuel assemblies.

The thermal evaluation concludes that with a design basis heat load of 34.8 kW and the loading requirements described in Section 4.3.1.3, all design criteria are satisfied.

The following conservative assumptions are considered in developing the finite element model to maximize the fuel cladding temperature:

- No convection occurs within the DSC cavity,
- The basket containing the fuel assemblies is centered axially in the DSC cavity,
- Heat transfer across the contact gaps within the basket occurs only by gasous conduction.

The following gaps are considered between components in the model at thermal equilibrium:

- 0.010” gap between each two adjacent basket plates except for the following cases:
  - between the aluminum inserts and the stainless steel rails – this gap is considered to be at least 0.020”
  - between the aluminum and the poison plates, when applicable. The aluminum plate and the poison plate are sandwiched between fuel compartments. For ease of modeling the 0.010” gaps are placed on both sides of the paired plates. These gaps account for the total contact resistance between the four plates shown in Figure 4-13, Detail B.
- 0.010” gap between the basket plates and aluminum rails
- 0.100” radial gap between rails and inner shell (see Section 4.11 for justification)

The axial cold gap of 0.07” between the stainless steel support plates and the aluminum plates is divided into a 0.01” axial gap at the bottom and a 0.060” axial gap at the top of the stainless steel plate. All dimensions of the canister are at nominal values. Details of the finite element model are shown in Figures 4-12 to 4-14.

Five basket types in two categories are designed for NUHOMS-32PTH DSC. Relevant characteristics of these basket types are listed below.

| Basket type | I | II |
|---|---|---|
| A | Boron Aluminum, or Metal | Boral® |
| B | Matrix Composites (MMC) | Maximum thickness 0.075” |
| C | Maximum thickness 0.187” | |
| D | | Not applicable |
| E | | Not applicable |

Aluminum plates are to be paired with the poison plates to make a nominal thickness of 0.5”. The conductivity of the borated aluminum/MMC plate depends on the boron content and the fabrication procedure. To bound the maximum component temperature, the maximum thickness of the boron containing plate (0.1875”) is considered in the model for basket type I.

Paired Boral®/ aluminum plates are used in basket type II. An effective conductivity is calculated for the paired Boral® / aluminum plates, as discussed in Section 4.2. Other combination of aluminum and poison plates that satisfies the conductivity requirements in Chapter 9 can be used in the basket.

Heat transfer from the fuel regions occurs only by conduction through the basket plates and the rails. Conduction and radiation heat transfer are considered between the rails and the DSC shell. Conduction through components is modeled using SOLID70 elements.

Radiation between the rails and the DSC shell is modeled using radiation LINK31 elements using the same methodology as described in Section 4.3.1.1. Axial radiation is also considered between the top and bottom surfaces of the fuel assemblies to the shield plugs. The emissivity of the heavily oxidized top and bottom surfaces of the fuel assemblies are considered to be 0.9.

Steady State Boundary conditions for the DSC Model

The nodal temperatures of the DSC shell are retrieved from the transfer cask or HSM-H models described in Sections 4.3.1.1 and 4.3.1.2, and applied to the corresponding nodes in the DSC model via a macro described in Appendix 4.16.1.

The SOLID70 elements representing the homogenized fuel are given heat generating boundary conditions in the region of the active fuel length. Active fuel length is considered to be 144" [20] beginning at approximately 4.0" above the bottom of the fuel assembly [20]. Fuel assembly has a total length of 162" in the model. Peaking factors to apply the axial decay heat profile for the homogenized fuel region are calculated in Section 4.7.

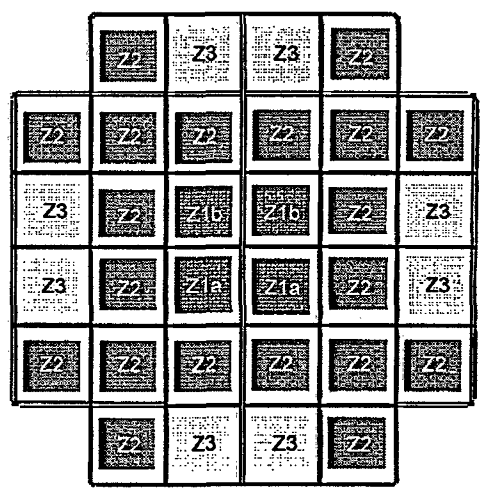
The maximum heat load per canister is 33.8 kW for CE14x14 fuel assemblies and 34.8 kW for other fuel assemblies. Since CE14x14 fuel assembly has a shorter active fuel length than the other assemblies, a lower total heat load is considered for CE14x14 assembly to avoid a high heat generating rate. The maximum decay heat per assembly is 1.5 kW. Heat load zoning, as illustrated below, is used to maximize the number of higher heat load assemblies per DSC. The loading requirements are as follows.

For CE14x14 Assemblies

- $Q_{zi}$ is the maximum decay heat per assembly in zone i
- Total Decay Heat $\leq$ 33.8 kW
- 4 fuel assemblies in zone 1 with $Q_{z1} \leq 0.775$ kW
- 20 fuel assemblies in zone 2 with $Q_{z2} \leq 1.068$ kW
- 8 fuel assemblies in zone 3 with $Q_{z3} \leq 1.5$ kW

For other fuel Assemblies

- $Q_{zi}$ is the maximum decay heat per assembly in zone i
- Total Decay Heat $\leq$ 34.8 kW
- 4 fuel assemblies in zone 1 with
  - total decay heat $\leq$ 3.2 kW
  - $Q_{z1a} \leq 1.05$ kW in the lower compartments
  - $Q_{z1b} \leq 0.8$ kW in the upper compartments
- 20 fuel assemblies in zone 2 with $Q_{z2} \leq 1.1$ kW
- 8 fuel assemblies in zone 3 with $Q_{z3} \leq 1.5$ kW




Heat generation rates as a function of spent fuel parameters are calculated in Appendix 4.16.2. Five extreme loading configurations are considered to bound the maximum component temperatures. The loading configurations are shown in Figure 4-15. In the first configuration, the heat load in the core compartments is maximized, so that zone 1 has a uniform heat load of 0.8

## 4.5 Thermal Evaluation for Loading and Unloading Conditions

Fuel loading and unloading operations occur in the fuel handling building. During loading operation fuel assemblies are submerged in pool water permitting heat dissipation. After fuel loading is complete, the TC and 32PTH DSC are removed from the pool and the DSC is drained (nitrogen or helium is used to assist removal of water), backfilled with nitrogen or helium, dried, backfilled with helium and sealed. The TC will be sealed and backfilled with helium after sealing the DSC.

### 4.5.1 Vacuum Drying

The loading condition evaluated is the heatup of the DSC before transfer to the storage site. The 32PTH DSC heatup occurs during draining, vacuum drying, backfilling, and sealing of the DSC, when the DSC is contained in the TC in the vertical position inside the fuel handling building. At the design basis heat load, the water in the annulus between the DSC and the transfer cask could boil between the time the canister is drained, and the time it is backfilled with helium. There are two methods that may be utilized to prevent this; one is to monitor the temperature of the annulus water and if required, circulate or introduce fresh water to maintain the temperature below 180°F, the other is to simply drain the annulus water when it exceeds this temperature limit. In any of these methods, the DSC may be backfilled with helium after complete drainage of the water.

It is assumed in this evaluation that the complete drainage of water from the 32PTH DSC cavity may occur either before or after welding the DSC top shield plug. Partial drainage of water from the DSC cavity and from the annulus between the DSC and the TC is required to perform the welding. After drainage of cavity water (nitrogen or helium is used to assist removal of water), backfilling with nitrogen or helium is required.

Fuel cladding temperature must be maintained below 752°F as required in [2]. The following procedures are considered for limitation of fuel temperature between the time of complete drain and helium backfill of the 32PTH DSC

A. Annulus water temperature remains below 180°F by water flow or circulation in the annulus between the DSC and the TC, as required, for the entire vacuum drying process. A time limit is calculated for this procedure which includes all the activities after complete DSC drainage until DSC backfilling starts.

B. Water neither flows nor circulates in the annulus between the DSC and the TC. The water in the annulus will be drained as soon as its temperature exceeds 180°F. Two time limits are calculated for this procedure. Similar to procedure A, the first time limit starts after complete DSC drainage. The second time limit includes the activities after drainage of the annulus water to the point that DSC backfilling starts

C. This procedure is the same as procedure B except that the DSC will be backfilled with helium after drainage of the DSC water. To consider the worst case, it is assumed that backfilling of the DSC starts not immediately after drainage of the DSC water, but occurs after drainage of the annulus water. The two time limits described above for procedure B are also calculated for procedure C.

If one chooses to follow procedure C and backfill the DSC with helium after drainage of water, there is no time limit for completion of the vacuum drying process. The reason is the DSC shell temperature is maintained at temperatures lower than the values calculated for the storage conditions. With helium in the DSC cavity, the fuel cladding temperature is well below the values calculated for the off-normal storage conditions in Section 4.3.6, and would never approach the allowable limit of 752°F.

After completion of the vacuum drying, the DSC must be sealed, the annulus between the DSC and the transfer cask must be drained (if not already drained), the cask must be sealed and backfilled with helium. To ensure the integrity of the fuel cladding, a time limit is considered for performing the activities after vacuum drying until backfilling of the transfer cask starts. This time limit is calculated for procedure B, which has the shortest time limits of all three procedures. For the other procedures, specifically procedure A, the time limit to seal and backfill the transfer cask is significantly longer

Parts of the above procedures might be combined together to build a new procedure The time limit for the new procedure can be calculated from appropriate combination of the resultant transient curves discussed in Section 4.5.1.4.

Transient thermal analyses are performed to determine the component temperatures at the end of each procedure separately. A bounding initial average temperature is considered to start the transient analysis.

The three-dimensional model of the 32PTH DSC within the TC described in Section 4.4.1.1 is slightly modified to analyze the vacuum drying procedures. The model contains a half slice of the 32PTH DSC within the TC. The modifications are:

- The DSC is centered in the transfer cask cavity
- The effective conductivity of fuel assemblies are changed to the values reported for vacuum conditions in Section 4.2
- Air conductivity is given to the elements representing the gas and gaps within the basket
- It is considered that the annulus between the DSC and the TC is initially filled with water
- Radiation is not considered between the basket rails and the DSC shell

All the other material properties remain unchanged.

Free convection and radiation are combined together to calculate the total heat transfer coefficient from the TC outer surface to the ambient. Due to the large outer diameter of the TC, the free convection coefficient approaches that for a vertical flat plate. The correlations to calculate the free convection coefficient on vertical plates are discussed in Section 4.11. Following inputs are considered to calculate the total heat transfer coefficient on the outer surface of the transfer cask in this evaluation.

- Ambient temperature in the fuel handling building is 100°F.
- Height of the cylinder is 173", which is approximately the length of the neutron shield panel.
- Surface emissivity of the transfer cask is 0.9 (see Section 4.2 for painted surfaces)

A decay heat load of 34.8 kW is considered for all the transient runs. The decay heat is applied as heat generating boundary conditions on the elements representing the homogenized fuel assemblies with a peaking factor of 1.1. Loading configuration 1 is considered for this purpose. Adiabatic boundary conditions are applied on the top and bottom faces of the slice model for conservatism. The other boundary conditions are discussed separately for each procedure in Sections 4.5.1.1 to 4.5.1.3.

An average, initial temperature at the beginning of the transient runs is calculated for the 32PTH DSC and transfer cask as follows.

Initial Temperature 1 = initial pool temperature +
average heat up rate with water in DSC × duration of lifting +
average heat up rate without water in DSC × duration of drainage
when water from the DSC cavity is drained completely before the welding process

and

Initial Temperature 2 = initial pool temperature +
average heat up rate with water in DSC × duration of lifting +
average heat up rate with water in DSC × duration of welding
when water from the DSC cavity is drained completely after the welding process

Following assumptions are considered to calculate the initial temperature:

- Initial pool temperature is 115°F
- No heat dissipation occurs from the transfer cask outer surface
- All the decay heat is used to heat up the transfer cask and its content
- Lifting the transfer cask from the pool to the fuel handling building and performing the required inspections take 2 hours
- Drainage (pumping) of water from the DSC takes 4 hours

The average heat up rate is defined as:

$$heat\ up\ rate = \frac{Q}{M\,\overline{C}_p}$$

Q = total decay heat load = 34.8 kW (118748 Btu/hr)
M = total weight (lbm)
$\overline{C}_p$ = average specific heat (Btu/lbm-°F)

The average specific heat is the mass average specific heat of all of the components.

$$\overline{C}_p = \frac{\sum m_i\,C_{p,i}}{M}$$

The components volumes and weights are taken from Chapter 3. Specific heat values increase generally at higher temperatures. Specific heats of the components are taken at about 100°F, which results in higher initial temperature and increases the conservatism in the model. A summary of the heat up rate calculation is shown in Table 4-7. The initial average temperature of the transfer cask and its content is then:

Initial average temp 1 = 115 + 3.2 × 2 + 4.5 × 4 = 139.4°F
with initial pool temperature =115°F
average heat up rate during lifting = 3.2°F /hr (see Table 1)
duration of lifting = 2 hrs
average heat up rate after drainage of DSC = 4.5 °F /hr (see Table 1)
duration of draining water from DSC = 4 hrs

Initial average temp 2 = 115 + 3.2 × 2 + 3.2 × 10 = 153.4°F
with initial pool temperature =115°F
average heat up rate during lifting = 3.2°F /hr (see Table 1)
duration of lifting = 2 hrs
average heat up rate before drainage of DSC = 3.2°F /hr (see Table 1)
duration of welding the DSC shield plug = 10 hrs

For conservatism, an initial temperature of 160°F is considered for the TC and its content at the start of the transient runs.

#### 4.5.1.1 Boundary Conditions for Procedure A

Adequate water should flow or circulated in the 32PTH DSC/TC annulus to prevent water from boiling. In this case the maximum surface temperature of the DSC shell does not exceed the boiling point of water. To simulate procedure A, it is assumed conservatively that the DSC shell temperature remains at 215°F during the entire vacuum drying process. The start time of simulation is after complete drainage of the DSC water.

Temperature gradient through the TC is determined by applying constant temperature of 215°F at the inner shell of the TC. Free convection and radiation boundary conditions are applied on the outer surface of the TC using the total heat transfer coefficient described in Section 4.11.

#### 4.5.1.2 Boundary Conditions for Procedure B

Conduction and free convection heat transfer are combined together to calculate an effective conductivity for the water in the annulus. The calculation of the effective conductivity for the water in the annulus is discussed in detail in Section 4.9.

After draining the water from the annulus, thermal properties of air (conduction only) are considered for the elements in the annulus between the 32PTH DSC and the TC. Free convection and radiation boundary conditions are applied on the outer surface of the TC using the total heat transfer coefficient described in Section 4.11.

Procedure B is also considered to calculate the time limit to backfill the transfer cask with helium after completion of the vacuum drying. For this purpose, the properties of the DSC backfill gas is changed to that of helium, and the fuel effective conductivities are changed to those calculated for helium atmosphere. Time of this change is 28 hours after complete drainage of DSC water or 14 hours after drainage of the annulus water. Other boundary conditions remain unchanged.

4.5.1.3 Boundary Conditions for Procedure C

The same boundary conditions as those described for procedure B are considered for Procedure C except that the 32PTH DSC is backfilled with helium after drainage of the annulus water. It is considered that it takes three hours until the helium replaces the nitrogen and water vapor within the DSC cavity completely. Before helium backfill, the model considers air conductivity for the DSC back fill gas. After the three hour period, the conductivity of back fill gas is changed to that of helium, and the fuel effective conductivities are changed to those calculated for helium atmosphere.

4.5.1.4 Evaluation of Vacuum Drying Procedure

Transient simulation of vacuum drying procedures gives the time-temperature history of the fuel assemblies with the maximum decay heat load of 34.8 kW. Duration of the vacuum process is limited to the time at which the maximum temperature of the fuel assemblies is close to the allowable limit of 752°F (400°C) [2]. A margin of about 20°F is considered for conservatism in determining the time limit for procedure A. The maximum fuel cladding temperatures are summarized in Table 4-8. Typical temperature distributions at the end of vacuum drying process are shown in Figure 4-34. Histories of the maximum component temperatures are shown in Figures 4-35 to 4-37.

As Table 4-8 shows, the vacuum drying can proceed up to 36 hours, if procedure A is followed For procedure B, the time limit to complete the vacuum drying is 14 hours after drainage of the annulus water or 28 hours after complete drainage of DSC water, whichever is the limiting time. For these evaluations it is assumed that nitrogen is used to assist removal of water and the DSC cavity is backfilled with nitrogen after draining of the bulk water in the cavity.

Backfilling the transfer cask must start within12 hours after completion of the vacuum drying, if one chooses to follow procedure B. The time limit to start backfilling the transfer cask with helium is significantly longer, if procedure A is followed. For procedure C, backfilling of the transfer cask with helium must start within 42 hours after complete DSC drainage or 28 hours after drainage of the annulus water based on the time-temperature history curve shown in Figure 4-37.

Should the decay heat load be lower than 34.8 kW, the time frame will increase for completion of the vacuum drying process. At some decay heat load, the maximum fuel cladding temperature remains always below the allowable limit regardless of the vacuum drying duration To determine the decay heat load at which the time limitation is not required, models of procedure A to C are investigated separately assuming steady state conditions. Uniform heat generating boundary conditions are applied on the fuel assemblies in the steady state analysis. The results summarized in Table 4-9 show that the fuel cladding temperature remains always below the allowable limit for 23.2 kW decay heat load using procedure A. Similarly, there is no time limit for vacuum drying with 16.0 kW and 22.4 kW using procedures B and C respectively.

Vacuum drying procedures A to C preclude any thermal cycling of fuel cladding. Backfilling the DSC with helium gas causes a one time temperature drop, which is not considered as a repeated thermal cycling. Re-evacuation of the DSC under helium atmosphere does not reduce the pressure sufficiently to decrease the thermal conductivity of helium. Therefore, evacuation and re-pressurizing the DSC under helium atmosphere proceed on a descending curve to the minimum steady state temperatures, and does not include any thermal cycling. It concludes that the limit of 65°C (118°F) considered for thermal cycling is not applicable for NUHOMS®-32PTH system.

### 4.5.2 Reflooding

For unloading operations, the DSC will be filled with the spend fuel pool water through the siphon port. During this filling, the DSC vent port is maintained open with effluents routed to the plant's off-gas monitoring system.

When the pool water is added to a DSC cavity containing hot fuel and basket components, some of the water will flash to steam causing internal cavity pressure to rise. The steam pressure is released through the vent port. The initial flow rate of the reflood water must be controlled such that the internal pressure in the DSC cavity does not exceed 20 psig. This is assured by monitoring the maximum internal pressure in the DSC cavity during reflood event. The reflood of the DSC is considered as a "Service Level D" event and the design pressure of the DSC is 120 psig. Therefore, there is sufficient margin in the DSC internal pressure during the reflooding event to ensure that the DSC will not be over pressurized.

The maximum fuel cladding temperature during reflooding process is significantly less than the vacuum drying condition owing to the presence of water/steam in the DSC cavity. Hence, the peak cladding temperature during the reflooding operation will be less than 734°F calculated for procedure A in Section 4.5.1 when water circulates in the annulus between the DSC and transfer cask.

To evaluate the effects of the thermal loads on the fuel cladding during reflooding operations, a conservative high fuel rod temperature of 750°F and a conservative low quench water temperature of 50°F are used.

The following material properties, corresponding to 750°F, are used in the evaluation.

| | | |
|---|---|---|
| Modulus of elasticity, $E = 10.4 \times 10^6$ psi $= 7.17 \times 10^{10}$ | (Pa) | [26] |
| Modulus of rigidity, $G = 2.47 \times 10^{10}$ | (PaPa) | [31] |
| Thermal expansion coefficient, $\alpha = 6.72 \times 10^{-6}$ | (1/K) | [31] |
| Yield stress, $Sy = 80{,}500$ psi $= 5.55 \times 10^8$ | (Pa) | [26] |
| Poisson's ratio, $\upsilon = \dfrac{E}{2G} - 1$ | | [27] |

The fuel cladding stress is evaluated as a hollow cylinder with an outer surface temperature of T (50°F), and the inner surface temperature of T+ΔT (750°F) using the following equations from [27].

## 5.2 Source Specification

Source terms are calculated with the SAS2H (ORIGEN-S) module of SCALE 4.4 [1]. The following sub-sections provide a discussion of the fuel assembly and Non-Fuel Assembly Hardware (NFAH) material weights and composition, gamma and neutron source terms and energy spectrum. The SAS2H results are used to develop source terms suitable for use in the shielding calculations.

There are five principal sources of radiation associated with the NUHOMS® 32PTH System that are of concern for radiation protection. These are:

1. Primary gamma radiation from the spent fuel
2. Primary gamma radiation from activation products in the structural materials found in the spent fuel assembly and the NFAH
3. Primary neutron radiation from the spent fuel
4. Neutrons produced from sub-critical multiplication in the fuel
5. Capture gammas from (n,γ) reactions in the NUHOMS® 32PTH System materials

The first three sources of radiation are evaluated using SAS2H. The capture gamma radiation and sub-critical multiplication are handled as part of the shielding analysis which is performed with MCNP.

The neutron flux during reactor operation is peaked in the active fuel (in-core) region of the fuel assembly and drops off rapidly outside the in-core region. Much of the fuel assembly hardware is outside of the in-core region of the fuel assembly. To account for this reduction in neutron flux, each fuel assembly type is divided into four exposure zones. A neutron flux (fluence) correction is applied to each region to account for this reduction in neutron flux outside the in-core region. The correction factors are given in Table 5-6. The four exposure zones, or regions are [4]:

Bottom—location of fuel assembly bottom nozzle and fuel rod end plugs
In-core—location of active fuel
Plenum—location of fuel rod plenum spring and top plug
Top—location of top nozzle

The Framatome MK BW 17x17 assembly is the bounding fuel assembly design for shielding purposes because it has the highest initial heavy metal loading as compared to the 14x14, 15x15, and other 17x17 fuel assemblies which are also authorized contents of the NUHOMS®-32PTH DSC and described in Chapter 2. The SAS2H/ORIGEN-S modules of the SCALE code with the 44 group ENDF/B-V library are used to generate the gamma and neutron source terms. For the bounding MK BW 17x17 fuel assembly, an initial enrichment of 4.0 wt% U-235 is assumed. The fuel assembly is irradiated with a constant specific power of 25 MW/assy to a total burnup of 60 GWD/MTU. A conservative three-cycle operating history is utilized with a 20 day down time between each cycle. The fuel assembly masses for each irradiation region are listed in Table 5-7.

Data for the W17x17 assembly is from Reference [7]. Some values for the 15x15 were assumed to be the same as the W17x17. The design-basis heavy metal weight is 0.476 MTU. These masses are irradiated in the appropriate fuel assembly region in the SAS2H/ORIGEN-S models. The mass of hardware for the MK BW assembly is the greatest; however, the source term from the irradiated hardware for the W 17x17 is bounding.

If reconstituted fuel assemblies (considered as intact fuel in the criticality analyses) with stainless steel rods undergo further irradiation, their gamma source term shall be bounded by the total design basis gamma source terms (on a per DSC basis) shown (on an assembly basis) in Table 5-10 for the design basis fuel assembly.

IPA

The IPA materials and masses for each irradiation zone are listed in Table 5-8. These materials are irradiated in the appropriate zone for fourteen cycles of operation. The TPA is irradiated to an equivalent assembly life burnup of 210 GWd/MTU over 14 cycles. The model assumes that the TPA is irradiated in an assembly each with an initial enrichment of 3.50 weight % U-235. The fuel assembly, containing the TPA, is burned for three cycles with a burnup of 15 GWd/MTU per cycle. This is equivalent to an assembly life burnup of 45 GWd/MTU over the three cycles. The results for a cooling time of 20 years are increased by the ratio of 14/3 to achieve the equivalent 210 GWD/MTU source.

BPRA

The BPRA materials and masses for each irradiation zone are also listed in Table 5-8. These materials are irradiated in the appropriate zone for three cycles of operation. The model assumes that the BPRA is irradiated in an assembly each with an initial enrichment of 3.50 weight % U-235. The fuel assembly containing the BPRA is burned for three cycles with a burnup of 10 GWd/MTU per cycle. This is equivalent to an assembly life burnup of 30 GWd/MTU over the three cycles. The source term for the BPRA is taken at 4 days cooling time

VSI

VSIs are very similar in design to burnable poison rod assemblies: the stainless steel baseplate and hold-down spring assembly designs are identical to those used on older Westinghouse BPRAs. Each VSI contains 24 solid Zircalloy-4 damper rods that are attached to the hold-down assembly using a crimp nut top connector. The damper rods are the same diameter and length as BPRA rodlets. The VSIs are assumed to be equivalent in source strength to BPRAs.

Elemental Compositions of Structural Materials

To account for the source terms due to the elemental composition of the fuel assembly and NFAH structural materials the following methodology is used:

1) The material composition for each irradiation region is determined for the assembly and NFAH type.

2) The elemental compositions for each of the structural materials present in each region is determined by multiplying the total weight of each material in a specific irradiation zone (Table 5-7) by the elemental compositions. The fuel assembly and NFAH elemental composition, including impurities, for each material are taken from Reference [7].

3) The results of each material are summed to determine the total elemental composition for each irradiation zone.

4) The elemental composition is multiplied by the appropriate flux factor given in Table 5-6.

5) Finally, the elemental composition is entered in the light element card of the SAS2H input. The elemental composition for the fuel assembly is shown in Table 5-9.

The SAS2H calculation applies the total flux to the light elements; therefore, the total composition must be adjusted by the appropriate flux factor in the input. A SAS2H input is created for each irradiation zone of each fuel assembly and NFAH type. An example input file for the active fuel zone is shown in Section 5.5.2.

5.1.1 Gamma Sources

Source terms for the fuel bounding Framatome Mk BW 17x17 fuel assembly and associated burnup/initial enrichment/cooling times and NFAH components are calculated with SAS2H module and the 44 group ENDF/B-V library. The SAS2H calculated contributions from actinides, fission products, and activation products, as applicable, are included for each irradiation region. The 7-year post irradiation cooling time results for the Mk BW 17x17 fuel with 60 GWD/MTU burnup, and 4.0 wt % U-235 initial enrichment are shown in Table 5-10 The post irradiation cooling time results for the TPA, and BPRA are shown in Table 5-11, and Table 5-12, respectively.

Based on the results presented in Table 5-11 and Table 5-12 (maximum gamma source term) the design basis NFAH is the BPRA. The spectrum is dominated by Co-60 for all NFAH. These design basis fuel assembly sources with the BPRA source are used in the MCNP calculations to determine the bounding dose rates on and around the NUHOMS® 32PTH System, including the Transfer Cask.

5.1.2 Neutron Source

The total neutron source for the NUHOMS® 32PTH System is also calculated with SAS2H. The total neutron sources for the Mk BW 17x17 assembly is summarized in Table 5-13. Again, the design basis source term is for 60 GWd/MTU burnup, 4.00 weight % U-235 initial enrichment and 7-year cooling time. The neutron source term consists primarily of spontaneous fission neutrons (largely from Cm-244) with ($\alpha$,O-18) sources of lesser importance, both causing secondary fission neutrons. The overall spectrum is well represented by the Cm-244 fission spectrum.

## 5.3 Model Specification

The neutron and gamma dose rates on the surface of the HSM-H, and on the surface, and at 1.5 and 3 feet from the surface of the OS187H Transfer Cask are evaluated with the Monte Carlo transport code MCNP [2, 6]. The flux-to-dose conversion factors specified by the ANSI/ANS 6.1.1-1977 5, are used and provided in Table 5-14.

### 5.3.1 Description of the Radial and Axial Shielding Configurations

Figure 5-1 is a sketch of an HSM-H cut away at the mid-vertical plane. Figure 5-3 is also a cut through the vertical mid-plane, the 32PTH-DSC is shown in phantom lines, and the front door is at the left hand side. The rear wall of the HSM-H module has a minimum thickness of 1 foot. A 3-foot shield wall is placed along the rear and sides of the HSM-H, as shown in Figure 5-1.

The MCNP computer models are built to evaluate the dose rate along the front wall surface, the rear shield wall surface, the vent openings, the roof surface, and on the side shield walls.

Figure 5-4 shows the shielding configuration of the OS187H transfer cask.

#### 5.3.1.1 Storage Configuration

A three-dimensional MCNP model was developed for the HSM-H Model The HSM length was designated as the x axis (North-South direction), the width as the y axis (East-West direction), and the HSM height as the z axis. The HSM door is designated as the S side and the –x direction, with the E wall as the –y direction. The roof is the +z direction. The E wall is designated as a reflective boundary and an end shield wall (3 ft thick) is attached to the W wall. The geometry of nearly all components of the HSM is Cartesian, except for the 32PTH-DSC, which is cylindrical. The MCNP model is a full 3-D representation of a single DSC inside the HSM-H with the reflective boundary, end and side shield walls. A three foot thick concrete shield wall is placed at the rear of the HSM. A NUHOMS®-32PTH-DSC MCNP model was developed for the transfer cask analysis, discussed below. This model was revised slightly and located within the HSM model. The DSC support rails are not included in the model. The heat shields are modeled as flat plates without fins or louvers and horizontal vent "liner" plates (2cm thk) are modeled in the top side vents.

Two liners are used for gamma dose attenuation at the bottom vents. The "top" liner is a 1-inch steel plate, positioned at the roof of the bottom vent The "front" liner is a 1-inch steel plate, at the side of the inlet vent (near the HSM front). Due to modeling constraints the "front" liner is modeled as part of the vent. This simplification does not impact the overall gamma dose rates.

#### 5.3.1.2 Loading/Unloading Configurations

The dose rates on the surface, and at 1.5 and 3 feet from the surface of the 32PTH-DSC/ Transfer Cask are evaluated with MCNP. Three different key configurations in the loading/unloading of the spent fuel are analyzed. The three different stages modeled are, (1) Decontamination, (2) Dry Welding and (3) Transfer. Calculations are performed assuming no temporary shielding is utilized for in the configurations, which is normally done at the sites.

**Table 6-1**
**Maximum Assembly Average Initial Enrichment for Each Fuel Design for both Intact and Damaged Fuel Assemblies**

| Assembly Class and Type | Maximum Assembly Average Initial enrichment of U-235 as a Function of Soluble Boron Concentration and Fixed Poison Loading (Basket Type) | | | | |
|---|---|---|---|---|---|
| | Basket Type(1) | Minimum Soluble Boron Concentration | | | |
| | | 2000 ppm | 2300 ppm | 2400 ppm | 2500 ppm |
| CE 14x14 Fuel Assembly (Intact Fuel Loading without BPRA) | A | 4.05 | 4.40 | 4.45 | 4.55 |
| | B | 4.55 | 4.90 | 5.00 | - |
| | C | 4.70 | 5.00 | - | - |
| | D | 5.00 | - | - | - |
| | E | - | - | - | - |
| WE 15x15 Fuel Assembly (with and without BPRAs) | A | 3.50 | 3.70 | 3.80 | 3.90 |
| | B | 3.80 | 4.10 | 4.20 | 4.30 |
| | C | 3.95 | 4.25 | 4.35 | 4.45 |
| | D | 4.20 | 4.50 | 4.70 | 4.80 |
| | E | 4.50 | 4.80 | 4.90 | 5.00 |
| WE 17x17 Fuel Assembly (with and without BPRAs) | A | 3.50 | 3.70 | 3.80 | 3.90 |
| | B | 3.80 | 4.10 | 4.20 | 4.30 |
| | C | 3.95 | 4.25 | 4.35 | 4.45 |
| | D | 4.20 | 4.50 | 4.60 | 4.70 |
| | E | 4.45 | 4.70 | 4.90 | 5.00 |
| CE 14x14 Fuel Assembly (Damaged Fuel Loading without BPRAs) | A | 3.90 | 4.20 | 4.25 | 4.35 |
| | B | 4.35 | 4.70 | 4.80 | 4.90 |
| | C | 4.50 | 4.85 | 4.95 | 5.00 |
| | D | 4.85 | 5.00 | - | - |
| | E | 5.00 | - | - | - |
| WE 15x15 Fuel Assembly (with and without BPRAs – with BPRAs bounds all Damaged Fuel Loading) | A | 3.40 | 3.60 | 3.70 | 3.80 |
| | B | 3.75 | 4.00 | 4.10 | 4.20 |
| | C | 3.85 | 4.15 | 4.25 | 4.35 |
| | D | 4.10 | 4.40 | 4.50 | 4.60 |
| | E | 4.35 | 4.70 | 4.80 | 4.90 |
| WE 17x17 Fuel Assembly (with and without BPRAs – with BPRAs bounds all Damaged Fuel Loading) | A | 3.40 | 3.60 | 3.70 | 3.80 |
| | B | 3.75 | 4.00 | 4.10 | 4.20 |
| | C | 3.85 | 4.15 | 4.25 | 4.35 |
| | D | 4.10 | 4.40 | 4.50 | 4.60 |
| | E | 4.30 | 4.65 | 4.80 | 4.90 |

(1) Basket Types are classified according to the fixed poison loading

## Table 6-3
## Authorized Contents for NUHOMS®-32PTH DSC

| Assembly Type(1) | Array |
|---|---|
| Westinghouse 17x17 Standard (WE 17x17)<br>Westinghouse 17x17 Vantage 5H (WEV 17x17) | 17x17 |
| Westinghouse 17x17 OFA (WEO 17x17) | 17x17 |
| Framatome ANP Advanced MK BW 17x17 (FR 17x17) | 17x17 |
| Westinghouse 15x15 Standard (WE 15x15)<br>Westinghouse 15x15 Surry Improved (WES15x15) | 15x15 |
| CE 14x14 Standard (CE 14x14 Std) | 14x14 |

(1) Equivalent reload fuel assemblies that are enveloped by the fuel assembly design characteristics listed above are also acceptable.

## Table 6-4
## Fuel Assembly Design Parameters(2) for Criticality Analysis

| Manufacturer(1) | Array | Version | Active Fuel Length (inches) | # Fuel Rods per Assembly | Pitch (inches) | Fuel Pellet OD (inches) |
|---|---|---|---|---|---|---|
| Westinghouse | 17x17 | Standard<br>Vantage | 144 | 264 | 0 4960 | 0.3225 |
| Westinghouse | 17x17 | OFA | 144 | 264 | 0.4960 | 0.3088 |
| Framatome | 17x17 | MK BW | 144 | 264 | 0.4960 | 0.3195 |
| Westinghouse | 15x15 | Std / Surry | 144 | 204 | 0.5630 | 0.3669 |
| CE | 14x14 | Std | 137 | 176 | 0.5800 | 0.3765 |
| CE | 14x14 | Ft. Calhoun | 128 | 176 | 0.5800 | 0.3815 |
| | | | | | | |
| **Manufacturer(1)** | **Array** | **Version** | **Clad Thickness (inches)** | **Clad OD (inches)** | **Guide Tube OD Inst. Tube OD (inches)** | **Guide Tube ID Inst. Tube ID (inches)** |
| Westinghouse | 17x17 | Standard<br>Vantage | 0.0225 | 0.374 | 24 @ 0.4820<br>1 @ 0.4740 | 24 @ 0.4500<br>1 @ 0.4440 |
| Westinghouse | 17x17 | OFA | 0 0225 | 0 360 | 24 @ 0 4820<br>1 @ 0.4740 | 24 @ 0 4500<br>1 @ 0.4440 |
| Framatome | 17x17 | MK BW | 0.0225 | 0 374 | 24 @ 0.4820<br>1 @ 0.4820 | 24 @ 0 4500<br>1 @ 0.4500 |
| Westinghouse | 15x15 | Std / Surry | 0.0243 | 0.422 | 20 @ 0.5450<br>1 @ 0.5450 | 20 @ 0.5100<br>1 @ 0.5100 |
| CE | 14x14 | Std | 0.0280 | 0.440 | 5 @ 1.115 | 5 @ 1.035 |
| CE | 14x14 | Ft. Calhoun | 0.0280 | 0.440 | 5 @ 1.115 | 5 @ 1.035 |
| | | | | | | |

(1) Equivalent reload fuel assemblies that are enveloped by the fuel assembly design characteristics listed above are also acceptable

(2) All Dimensions shown are nominal

**Table 6-7**
**NUHOMS®-32PTH - Fixed Poison Loading Requirements**

| Basket Type | Borated Aluminum Loading | Boral® Loading |
|---|---|---|
| A | 7.0 mg B-10/cm$^2$<br>Thickness = 0.050" | 9.0 mg B-10/cm$^2$<br>Thickness = 0.075" |
| B | 15 0 mg B-10/cm$^2$<br>Thickness = 0.075" | 19.0 mg B-10/cm$^2$<br>Thickness = 0.075" |
| C | 20.0 mg B-10/cm$^2$<br>Thickness = 0.075" | 25.0 mg B-10/cm$^2$<br>Thickness = 0.075" |
| D | 32.0 mg B-10/cm$^2$<br>Thickness = 0.125" | Not Applicable |
| E | 50.0 mg B-10/cm$^2$<br>Thickness = 0.187" | Not Applicable |

Note: New neutron absorbers or changes to existing absorbers will be qualified as per information provided in Chapter 9.

# 8 OPERATING PROCEDURES

This chapter outlines a sequence of operations to be incorporated into procedures for preparation of the NUHOMS® HD System DSC, loading of fuel, closure of the DSC, transport to the ISFSI, transfer into the HSM-H-H, monitoring operations, and retrieval and unloading. Operations are presented in their anticipated approximate performance sequence. Alternate sequencing that achieves the same purpose is acceptable. Temporary shielding may be used throughout as appropriate to maintain doses as low as reasonable achievable (ALARA). Use nitrogen or helium to assist in removal of water. After water is drained from the DSC, (sections 8.1.1.2 & 8.1.1.3), the DSC shall be backfilled with nitrogen or helium.

## 8.1 Procedures for Loading the DSC and Transfer to the HSM-H

### 8.1.1 Narrative Description

The following steps describe the recommended generic operating procedures for the NUHOMS® System. A list of major equipment used during loading and unloading operations is provided in Table 8-1. A pictorial representation of key phases of this process is provided in Figure 8-1.

#### 8.1.1.1 Transfer Cask and DSC Preparation

1. Verify by plant records or other means that candidate fuel assemblies meet the physical, thermal and radiological criteria specified in the Technical Specifications.
2. Clean or decontaminate the transfer cask as necessary to meet licensee pool and ALARA requirements, and to minimize transfer of contamination from the cask cavity to the DSC exterior.
3. Examine the transfer cask cavity for any physical damage
4. Verify specified lubrication of the transfer cask rails.
5. Examine the DSC for any physical damage and for cleanliness. Verify that bottom fuel spacers or damaged fuel bottom end caps, if required, are present in all fuel compartments. Remove damaged fuel top end caps if they are in place. Record the DSC serial number which is located on the grappling ring. Verify the basket type by identifying the last character in the serial number.
6. Install lifting rods and eyes into the four threaded sockets in the bottom of the DSC cavity. Verify specified thread engagement.
7. Lift the DSC into the cask cavity and rotate the DSC to match the transfer cask alignment marks.
8. Remove the lifting rods and eyes.
9. Fill the transfer cask/DSC annulus with clean water.
10. Seal the top of the annulus, using for example an inflatable seal.
11. A tank filled with clean water, and kept above the pool surface may be connected to the top vent port of the transfer cask via a hose to provide a

positive pressure in the annulus. This is an optional arrangement, which provides additional assurance that contaminated water from the fuel pool will not enter the annulus. Do not pressurize this tank, nor raise it sufficiently high to float the DSC. For the 32PTH DSC with a 69.75 inch OD, and an empty weight of 49,000 lb, a differential pressure of 12.8 psi, equivalent to 29.6 ft of pure water, would be sufficient to lift the DSC.

12. If the DSC top covers were trial fitted, they must be removed prior to filling the DSC with water. The vent port quick connect fitting in the inner top cover may be removed to facilitate hydrogen monitoring later. The drain port fitting may be either left in place or removed – water may be pumped from the DSC either with or without the fitting.

13. Fill the DSC with water from the fuel pool or an equivalent source. Optionally, this may be done at the time of immersing the cask in the pool. If the pool water is allowed flow over the transfer cask lip and into the DSC, provision must be made to protect the annulus seal from being dislodged by the water running over it.

14. Optionally, secure a sheet of suitable material to the bottom of the cask to minimize the potential for ground-in contamination. This step may be done at any convenient time prior to immersion.

15. Prior to the cask being lifted into the fuel pool, the water level in the pool should be adjusted as necessary to accommodate the transfer cask and DSC volume. If the water placed in the DSC cavity was obtained from the fuel pool, a level adjustment may not be necessary.

8.1.1.2 DSC Fuel Loading

1. Verify proper engagement of the lifting yoke with the transfer cask lifting trunnions.

2. Lift the transfer cask / DSC and position them over the cask loading area of the spent fuel pool

3. Lower the cask into the fuel pool until the bottom of the cask is at the height of the fuel pool surface. As the cask is lowered into the pool, spray the exterior surface of the cask with clean water to minimize surface adhesion of contamination.

4. Place the cask in the location of the fuel pool designated as the cask loading area.

5. Disengage the lifting yoke from the transfer cask lifting trunnions and move the yoke clear of the cask. Spray the lifting yoke with clean water if it is raised out of the fuel pool.

6. Load pre-selected spent fuel assemblies into the DSC basket compartments. The licensee shall develop procedures to verify that the boron content of the water conforms to the Technical Specifications, and that fuel identifications are verified and documented. Damaged fuel must be loaded only in designated compartments fitted with a damaged fuel bottom end cap.

7. After all the fuel assemblies have been placed into the DSC and their identities verified, install damaged fuel top end caps into designated compartments containing damaged fuel.

8. Lower the top shield plug in the DSC, aligning it with the guide on the DSC wall, and engaging the drain tube, until it seats on its support ring

9. Visually verify that the inner top cover is properly seated in the DSC. Reseat if necessary.

10. Position the lifting yoke and verify that it is properly engaged with the transfer cask trunnions.

11. Lift the transfer cask to the pool surface and spray the exposed portion of the cask with clean water.

12. Drain any water from above the inner top cover plate back to the spent fuel pool. Up to about 1300 gallons of water may be removed from the DSC prior to lifting the transfer cask clear of the pool surface. Nitrogen or helium will be used to assist the removal of water. The DSC shall be backfilled with nitrogen or helium after drainage of bulk water.

13. Lift the cask from the fuel pool, continuing to spray the cask with clean water.

14. Move the cask with loaded DSC to the area designated for DSC draining and closure operations. The set-down area should be level or slightly sloped toward the DSC drain tube.

#### 8.1.1.3 DSC Closing, Drying, and Backfilling

1. Fill the transfer cask liquid neutron shield if it was drained for weight reduction during preceding operations.

2. Decontaminate the transfer cask exterior.

3. Disengage the rigging from the inner top cover, and remove the eyebolts. Disengage the lifting yoke from the trunnions.

4. Disconnect the annulus overpressure tank if one was used, decontaminate the exposed surfaces of the DSC shell perimeter, remove any remaining water from the top of the annulus seal, and remove the seal.

5. Open the cask cavity drain port and allow water from the annulus to drain out until the water level is approximately twelve inches below the top of the DSC shell. Take swipes around the outer surface of the DSC shell to verify conformance with Technical Specification limits

6. Cover the transfer cask / DSC annulus to prevent debris and weld splatter from entering the annulus.

7. If water was not drained from the DSC earlier, connect a pump to the DSC drain port and remove 100 to 1300 gallons of water. Use nitrogen or helium to assist the removal of water. This lowers the water sufficiently to allow welding of the inner top cover, while keeping about half of the water in the DSC to cool the spent fuel (N.B. step 14 below). Up to 60 psig of nitrogen, or helium gas may be applied at the vent port to assist the water pump.

8 Install the automated welding machine onto the inner top cover.

9. Continuous hydrogen monitoring during the welding of the inner top cover is required [1]. Insert a hydrogen monitor intake line through the vent port such that it terminates just below the inner top cover. Temperature monitoring of the TC cavity/annulus water is also requires, see step 14.

10. Verify that the hydrogen concentration does not exceed 2.4% [1]. If this limit is exceeded, stop all welding operations and purge the DSC cavity with helium (or other inert gas) via the vent port to reduce hydrogen concentration safely below the 2.4% limit.

11 Complete the top shield plug welding and specified non-destructive examinations. The weld must be made in at least two layers.

12. Remove the automated welding machine.

13. Pump remaining water from the DSC. Remove as much free standing water as possible to shorten vacuum drying time. Up to 60 psig of nitrogen, or helium gas may be applied at the vent port to assist the water pump.

14 There are three methods described in Chapter 4 to assure that the fuel temperature limit is not exceeded during vacuum drying. Each method is associated with a time limit for vacuum drying, starting from the time that pumping of liquid water from the DSC is complete. As required by the technique chosen, either

   a) install annulus water circulation equipment, or

   b) drain annulus water if temperature exceeds 180°F

   c) for either a or b, the DSC may be evacuated to 100 mbar or lower, and backfill with helium to atmospheric pressure prior to start of vacuum drying.

All helium used in backfilling operations shall be at least 99.99% pure (this may be done as part of step 15).

15. Connect a vacuum pump / helium backfill manifold to the vent port or to both the vent and drain ports. The quick connect fittings may be removed and replaced with stainless steel pipe nipple / vacuum hose adapters to improve vacuum conductance. Make provision to prevent icing, for example by avoiding traps (low sections) in the vacuum line. Provide appropriate measures as required to control any airborne radionuclides in the vacuum pump exhaust. Purge air from the helium backfill manifold.

    Optionally, leak test the manifold and the connections to the DSC. The DSC may be pressurized to no more than 15 psig for leak testing

16. Evacuate the DSC to the pressure required by the Technical Specification for vacuum drying, and isolate the vacuum pump. The isolation valve should be as near to the DSC as possible, with a pressure gauge on the DSC side of the valve.

17. Maintain the water condition in the transfer cask / DSC annulus as required by the technique chosen (step 14).

18. If the Technical Specification is satisfied, i.e., if the pressure remains below the specified limit for the required duration with the pump isolated, continue to the next step. If not, repeat steps 16 and 17.

19. Purge air from the backfill manifold, open the isolation valve, and backfill the DSC cavity with helium to atmospheric pressure, or slightly over.

20. If the quick connect fittings were removed for vacuum drying, remove the vacuum line adapters from the ports, and re-install the quick connect fittings using suitable pipe thread sealant.

21. Evacuate the DSC through the vent port quick connect fitting to a pressure of 100 mbar or less.

22. Backfill the DSC with helium to the pressure specified in the Technical Specifications, and disconnect the vacuum / backfill manifold from the DSC.

23. Repeat steps 21 and 22 if the DSC interior is exposed to nitrogen during any succeeding operations.

24. Weld the covers over the vent and drain ports, performing non-destructive examination as required by the Technical Specifications. The welds shall have at least two layers.

25. Install the automated welding machine onto the outer top cover plate and place the outer top cover plate with the welding system onto the DSC. Verify correct rotational alignment of the cover and the DSC shell.

26. Complete the outer top cover welding and specified non-destructive examinations. The weld must be made in at least two layers

27. Remove everything except the DSC from the transfer cask cavity: welding machine, protective covering from the transfer cask / DSC annulus, annulus temperature monitoring or water circulation equipment, temporary shielding, etc.

28. Install the transfer cask lid and bolt it.

29. Evacuate the transfer cask cavity to below 100 mbar, and backfill with helium to the Technical Specification pressure.

8.1.1.4 Transfer Cask Downending and Transport to ISFSI

1. Drain or fill the transfer cask liquid neutron shield, as required by licensee ALARA requirements and crane weight limits.

2. The transfer trailer should be positioned so that the cask support skid is accessible to the crane with the trailer supported on its vertical jacks. If required due to space limitations, the

3. Engage the lifting yoke and lift the transfer cask over the cask support skid onto the transfer trailer.

4. Position the cask lower trunnions onto the transfer trailer support skid pillow blocks.

5. Move the crane while simultaneously lowering the cask until the cask upper trunnions are just above the support skid upper trunnion pillow blocks.

6 Verify that the cask and trunnion pillow blocks are properly aligned.

7 Lower the cask onto the skid until the weight of the cask is distributed to the trunnion pillow blocks.

8. Verify that the trunnions are properly seated onto the skid and install the trunnion tower closure plates.

8.1.1.5 DSC Transfer to the HSM-H-H

1. The maximum lifting height and ambient temperature requirements of the Technical Specifications must be met during transfer from the fuel building to the HSM-H.

(b) Boron carbide-aluminum metal matrix composite

(c) Boral®

The 32PTH DSC safety analyses do not rely upon the tensile strength of these materials. The radiation and temperature environment in the cask is not sufficiently severe to damage these metallic/ceramic materials. To assure performance of the neutron absorber's design function only the presence of B10 and the uniformity of its distribution need to be verified, with testing requirements specific to each material. The boron content of these materials is given in Table 9-1.

9.1.7.1 Boron Aluminum Alloy (Borated Aluminum)

The material is an ingot metallurgy product with boron precipitating as a uniform fine dispersion of discrete $AlB_2$ or $TiB_2$ particles in the matrix of 1000 or 6000 series aluminum.

Boron is added to the aluminum in the quantity necessary to provide the specified minimum B10 areal density in the final product, with sufficient margin to minimize rejection, typically 10 % excess. The amount will depend on whether boron with the natural isotopic distribution of the isotopes B10 and B11, or boron enriched in B10 is used. Practical manufacturing considerations limit the boron content in aluminum to 5% by weight.

The criticality calculations in Chapter 6 take credit for 90% of the minimum specified B10 areal density of borated aluminum. The basis for this credit is the B10 areal density acceptance testing, which will be as specified in Section 9.5.2. The specified acceptance testing assures that at any location in the material, the minimum specified areal density of B10 will be found with 95% probability and 95% confidence.

Visual inspections shall follow the recommendations in Aluminum Standards and Data, Chapter 4 "Quality Control, Visual Inspection of Aluminum Mill Products and Castings"[5]. In particular, blisters and widespread rough surface conditions such as die chatter or porosity will not be acceptable, while local or cosmetic conditions such as scratches, nicks, die lines, inclusions, abrasion, isolated pores, or discoloration are acceptable.

9.1.7.2 Boron Carbide / Aluminum Metal Matrix Composites (MMC)

The material is a composite of fine boron carbide particles in an aluminum 1000 or 6000 series matrix. The material may be produced by, either direct chill casting, powder metallurgy, or thermal spray techniques. In either case it is a low-porosity product, with a metallurgically bonded matrix. Practical manufacturing considerations limit the boron carbide content to 35% by volume.

Prior to use in the 32PTH DSC, MMC's shall pass the qualification testing specified in Section 9.5.3, and shall subsequently be subject to the process controls specified in Section 9.5.4.

The criticality calculations in Chapter 6 take credit for 90% of the minimum specified B10 areal density of MMC's. The basis for this credit is the B10 areal density acceptance testing, which is specified in Section 9.5.2. The specified acceptance testing assures that at any location in the material, the minimum specified areal density of B10 will be found with 95% probability and 95% confidence.

Visual inspections shall follow the recommendations in Aluminum Standards and Data, Chapter 4 "Quality Control, Visual Inspection of Aluminum Mill Products and Castings" [5]. In particular, blisters and widespread rough surface conditions such as die chatter or porosity will not be acceptable, while local or cosmetic conditions such as scratches, nicks, die lines, inclusions, abrasion, isolated pores, or discoloration are acceptable. References to metal matrix composites throughout this chapter are not intended to refer to Boral®, which is described in the following section.

9.1.7.3 Boral®

This material consists of a core of aluminum and boron carbide powders between two outer layers of aluminum, mechanically bonded by hot-rolling an "ingot" consisting of an aluminum box filled with blended boron carbide and aluminum powders. The core is slightly porous. The manufacturer reports that the size of the boron carbide particles in the finished product is about 50 microns average.

The criticality calculations take credit for 75% of the minimum specified B10 areal density of Boral®, based on acceptance testing. In the 32PTH basket design, the neutron absorber is captured between and supported by the stainless steel basket tubes and the bars to which the tubes are welded, assuring that the material will remain in place to perform its neutron absorbing function under all operating conditions for the lifetime of the DSC.

B10 areal density will be verified by chemical analysis and by certification of the B10 isotopic fraction for the boron carbide powder, or by neutron transmission testing. A coupon is taken from the corners of the sheet produced from each ingot. Areal density testing is performed on an approximately 1 $cm^2$ area of the thinnest coupon. If the measured areal density is below that specified, the all material produced from that ingot will be either rejected, or accepted only on the basis of alternate verification of B10 areal density for each of the final pieces produced from that ingot.

A Boral® lot is defined as a group of consecutively rolled ingots, with a single final thickness and boron carbide loading, using the same lot of boron carbide powder. The sampling rate for areal density testing will be at least 20% and will be sufficient that the lower tolerance limit for the lot will exceed the specified minimum areal density. The lower tolerance limit is defined as the mean value of areal density for the sample, less K times the standard deviation, where K is the one-sided tolerance limit factor for the sample size, a normal distribution, and 95% probability and 95% confidence. The statistical verification is not required if the lot is subjected to 100% inspection.

Visual inspections shall verify that the Boral® core is not exposed through the face of the sheet at any location.

# 10. RADIATION PROTECTION

## 10.1 Ensuring That Occupational Radiation Exposures Are As Low As Reasonably Achievable (ALARA)

### 10.1.1 Policy Considerations

The licensee's radiation safety and ALARA policies should be applied to the ISFSI. The ALARA program should follow the general guidelines of Regulatory Guides 1.8 4, 8.8 1, 8.10 3 and 10 CFR 20 6. ISFSI personnel should be trained in the proper operation, inspection, repair and maintenance of the NUHOMS® HD System and updated on ALARA practices and dose reduction techniques. Implementation of ISFSI procedures should be reviewed by the licensee to ensure ALARA exposure.

### 10.1.2 Design Considerations

The thick inner cover of the DSC is designed to minimize exposure during draining, drying, and closure operations. The vent and drain ports are designed for maximum water flow rate and vacuum conductance to minimize the time (and thereby the exposure) associated with draining and vacuum drying. The design of the cover welds minimizes exposure during closure operations. The welds are designed to be easily performed by remote welding equipment. Because the cover welds are not used to lift the canister, they are relatively small, reducing the time needed to complete them. Because they are austenitic welds, no pre-heating is required. In accordance with NRC Interim Staff Guidance 18 [10], leak testing is not required, and the exposure associated with leak testing is eliminated.

Lead, steel, water, and borated plastic in the transfer cask provide required gamma and neutron shielding during transfer activities. The exterior of the transfer cask is decontaminated prior to transfer to the ISFSI, thereby minimizing exposure of personnel to surface contamination.

The NUHOMS® HSM-H storage modules include no active components which require periodic maintenance thereby minimizing potential personnel dose due to maintenance activities

The shielding design features of the storage modules storage minimize occupational exposure for any activities on or near the ISFSI. These features are:

- The DSCs are loaded and sealed prior to transfer to the ISFSI. Seals are austenitic stainless welds with at least two layers.
- The fuel will not be unloaded nor will the DSCs be opened at the ISFSI unless the ISFSI is specifically licensed for these purposes.
- The fuel is stored in a dry inert environment inside the DSCs so that no radioactive liquid is available for leakage.

- The DSCs are sealed with a helium atmosphere to prevent oxidation of the fuel. The leaktight design features are described in Chapter 7.
- The DSCs are heavily shielded on both ends to reduce external dose rates. The shielding design features are discussed in Chapter 5.
- No radioactive material will be discharged during storage since the DSC is designed and fabricated to be leaktight.
- The DSC outside surface is contamination free due to the use of clean water sealed in the annulus between the cask and DSC during loading operations.
- HSM's provide thick concrete shielding, while placement of modules immediately adjacent to one another enhances the effectiveness of this shielding.

Regulatory Position 2 of Regulatory Guide 8.8 1, is incorporated into the design considerations, as described below:

- Regulatory Position 2a on access control is met by use of a fence with a locked gate that surrounds the ISFSI and prevents unauthorized access.
- Regulatory Position 2b on radiation shielding is met by the heavy shielding of the NUHOMS® System which minimizes personnel exposures.
- Regulatory Position 2c on process instrumentation and controls is met by designing the instrumentation for a long service life and locating readouts in a low dose rate location. The use of thermocouples for temperature measurements located in embedded thermowells provides reliable, easily maintainable instrumentation for this monitoring function
- Regulatory Position 2d on control of airborne contaminants may be applicable for vacuum drying operations of DSCs containing damaged fuel. Diversion of the vacuum pump exhaust to an appropriate filtration system is recommended in the Chapter 8 operations. The regulatory position does not apply during transfer or storage because neither gaseous releases nor significant surface contamination are expected.
- Regulatory Position 2e on crud control is not applicable to the ISFSI because there are no systems at the ISFSI that could transport crud. The leaktight DSC design ensures that spent fuel crud will not be released or transferred from the DSC. Draining back to the spent fuel pool provides control over any crud that could be entrained in the outflow from the DSC draining operations.
- Regulatory Position 2f on decontamination is met because the transfer cask is decontaminated prior to transfer to the ISFSI. The transfer cask accessible surfaces are designed to facilitate decontamination.
- Regulatory Position 2g on radiation monitoring does not apply. There is no need for airborne radioactivity monitoring because the DSCs are sealed by leaktight welds. Airborne radioactivity due to damaged fuel is discussed under Regulatory Position 2d

## 10.3 Estimated Onsite Collective Dose Assessment

This section provides estimates of occupational for typical ISFSI operations. Offsite dose rates for normal and anticipated conditions controlled by 10 CFR 72.104 are addressed in Section 10.2. Dose rates from accident conditions controlled by 10 CFR 72.106 are addressed in Chapters 5 and 11.

Assumed annual occupancy times, including the anticipated maximum total hours per year for any individual and total person-hours per year for all personnel for each radiation area during normal operation and anticipated operational occurrences will be evaluated by the licensee in a 10 CFR 72.212 evaluation to address the site specific ISFSI layout, inspection, and maintenance requirements. In addition, the estimated annual collective doses associated with loading operations will be addressed by the licensee in a 10 CFR 72.212 evaluation.

### 10.3.1 DSC Loading, Transfer and Storage Operations

The estimated occupational exposures to ISFSI personnel during loading, transfer, and storage of the DSC (time and manpower may vary depending on individual ISFSI practices) is shown in Table 10-1. The task times, number of personnel required and total doses are listed in this table. The total dose is estimated to be 2.2 rem per loaded canister. This is a bounding estimate; measured doses from Standardized NUHOMS® System loading campaigns have been 600 mrem or lower per canister for normal operations.

The average distance for a given operation takes into account that the operator may be in contact with the transfer cask, but this duration will be limited. For draining activities and vacuum drying the attachment of fittings will take place closer to the cask than the operation of the pumps. For decontamination activities, although operators could be near the cask for some activities, other parts of the operation could be performed from farther away. For this reason, 1 foot or 3 feet is an appropriate average distance for these operations.

The operator's hands may be in a high dose rate location momentarily, for example when connecting fittings at the ports. This does not translate into a whole-body dose, and therefore, these localized streaming effects are not considered here.

For operations near the top end of the 32PTH DSC, most of the work will take place around the perimeter and a smaller portion will take place directly over the shielded inner top cover.

Regulatory Guide 8.34 [7] is to be employed in defining the on-site occupational dose and monitoring requirements.

### 10.3.2 DSC Retrieval Operations

Occupational exposures to ISFSI personnel during 32PTH DSC retrieval are similar to those exposures calculated for 32PTH DSC insertion. Dose rates for retrieval operations will be lower than those for insertion operations due to radioactive decay of the spent fuel inside the HSM. Therefore, the dose rates for 32PTH DSC retrieval are bounded by the dose rates calculated for insertion.

10.3.3 Fuel Unloading Operations

The process of unloading the 32PTH DSC is similar to that used for loading the 32PTH DSC. The identical ALARA procedures utilized for loading should also be applied to unloading.

Occupational exposures to plant personnel are bounded by those exposures calculated for 32PTH DSC loading.

10.3.4 Maintenance Operations

The dose rate for surveillance activities is obtained from Table 10-5, Table 10-6, and Table 10-7 for doses rates 6.1 meters from the front of an HSM-H. The 6.1 meter dose rate is a conservative estimate for surveillance activities. The HSM-H surface dose rate provided in Chapter 5 is a conservative estimate for thermocouple maintenance activities including calibration and repair. The surface dose rate calculated in Chapter 5 also provides a conservative estimate of a dose rate at 3 feet from the HSM-H which may be encountered during operations associated with removal of debris from HSM-H vents.

The ISFSI license applicant will evaluate the additional dose to station personnel from ISFSI operations, based on the particular storage configuration and site personnel requirements.

10.3.5 Doses During ISFSI Array Expansion

ISFSI expansion should be planned to eliminate the need for entry into a module adjacent to a loaded module. Similarly, during array expansion, when the shield wall is removed, personnel access to the area should be controlled. For a module separated from a loaded HSM-H by an empty module, with temporary shielding at the vent ports of the empty module, the resulting dose will be less than that calculated in Chapter 5 for the side dose rate of an array with an installed shield wall.

| Components | SAR Sections |
|---|---|
| Basket | Appendix 3.9.1, Section 3.9.1.2.3 (pages 3.9.1-15 to 19) |
| Canister | Appendix 3.9.1, Load Cases 6 through 17, (pages 3.9.1-46 to 50 ) |
| Transfer Cask | Appendix 3.9.2, Load Cases 7 through 9 (pages 3.9.2-24 to 25) |
| Fuel Cladding | Section 3.5.3, Appendix 3.9.8 |

Accident Dose Calculation

Based on analysis results presented in Appendix 3.9.1 and Appendix 3.9.2, the accidental transfer cask drop scenarios do not breach the transfer cask/32PTH DSC confinement boundaries. The function of transfer cask lead shielding is not compromised by these drops. The transfer cask neutron shield, however, may be damaged in an accidental drop.

The transfer cask surface dose rate, with the neutron shield intact for the 32PTH DSC in the transfer cask is calculated in Chapter 5 of this SAR as 384 mrem/hr gamma and 125 mrem/hr neutron.

The dose rate at the transfer cask surface due to the loss of the neutron shield is also calculated; at 1 meter from the cask, the peak dose is 186 mrem/hr gamma and 2200 mrem/hr neutron. The dose at the site boundary would be significantly below 2.4 rem/hr and thus meet the acceptance criteria of 5 rem.

Corrective Actions

The DSC will be inspected for damage, and the DSC opened and the fuel removed for inspection, as necessary. Removal of the transfer cask top cover plate may require cutting of the bolts in the event of a corner drop onto the top end. These operations will take place in the plant fuel building decontamination area and spent fuel pool after recovery of the transfer cask. Following recovery of the transfer cask and unloading of the DSC, the transfer cask will be inspected, repaired and tested as appropriate prior to reuse.

For recovery of the cask and contents, it may be necessary to develop a special sling/lifting apparatus to move the transfer cask from the drop site to the fuel pool. This may require several weeks of planning to ensure all steps are correctly organized. During this time, lead blankets may be added to the transfer cask to minimize on-site exposure to site operations personnel The transfer cask would be roped off to ensure the safety of the site personnel.

### 11.3.2 Earthquake

Cause of Accident

The seismic design criteria for the NUHOMS® HD System is consistent with the criteria set forth in Chapter 2, Section 2.2.3, with the exception that the NRC Regulatory Guide 1.60 (R.G. 1.60) [3] response spectra is anchored to a maximum ground acceleration of 0.30g (instead of 0.25g) for the horizontal components and 0.20g (instead of 0.17g) for the vertical component. The results of the frequency analysis of the HSM-H structure (which includes a simplified model of the DSC) yield a lowest frequency of 23.2 Hz in the transverse direction and 28.4 Hz in the longitudinal direction. The lowest vertical frequency exceeds 33 Hz. Thus, based on the R.G. 1.60 response spectra amplifications, the corresponding seismic accelerations used for the design of the HSM-H are 0.37g and 0.33g in the transverse and longitudinal directions respectively and 0.20g in the vertical direction. The corresponding accelerations applicable to the DSC are 0.41g and 0.36g in the transverse and longitudinal directions, respectively, and 0.20g in the vertical direction.

Accident Analysis

The seismic analyses of the components which are important to safety are analyzed as follows:

| Components | SAR Sections |
|---|---|
| Basket | Appendix 3.9.1, Section 3.9.1.2.3 (page 3.9.1-21) |
| Canister | Appendix 3.9.1, Section 3.9.1.3.2 (page 3.9.1-58) |
| Transfer Cask | Appendix 3.9.2, Load Case 6 (page 3.9.2-22) |
| HSM-H | Appendix 3.9.9, Section 3.9.9.2 (page 3.9.9-23) |

The results of these analyses show that seismic stresses are well below ASME code allowables.

Accident Dose Calculations

All the components which are important to safety are designed and analyzed to withstand the design basis earthquake accident. Hence, no radiation is released and there is no associated dose increase due to this event.

Corrective Actions

After a seismic event, all components would be inspected for damage. Any debris would be removed. An evaluation would be performed to determine if the system components were still within the licensed design basis.

## 11.3.5 Flood

Cause of Accident

Flooding conditions simulating a range of flood types, such as tsunami and seiches as specified in 10CFR72.122 (b) are considered. In addition, floods resulting from other sources, such as high water from a river or a broken dam, are postulated as the cause of the accident

Accident Analysis

The HSM-H is evaluated for flooding in Appendix 3.9.9, Section 3.9.9.10.3. Based on the evaluation presented in that section, the HSM-H will withstand the design basis flood.

Accident Dose Calculation

The radiation dose due to flooding of the HSM-H is negligible. Flooding does not breach the confinement boundary. Therefore radioactive material inside the DSC will remain sealed in the DSC and, therefore, will not contaminate the encroaching flood water.

Corrective Actions

Because of the location and geometry of the HSM-H vents, it is unlikely that any significant amount of silt would enter an HSM-H should flooding occur. Any silt deposits would be removed using a pump suction hose or fire hose inserted through the inlet vent to suck the silt out, or produce a high velocity water flow to flush the silt through the HSM-H inlet vents.

## 11.3.6 Blockage of HSM-H Air Inlet and Outlet Openings

This accident conservatively postulates the complete blockage of the ventilation air inlet and outlet openings of the HSM-H.

Cause of Accident

Since the NUHOMS® HSM-Hs are located outdoors; there is a remote probability that the ventilation air inlet and outlet openings could become blocked by debris from such unlikely events as floods and tornados. The NUHOMS® design features such as the perimeter security fence and the redundant protected location of the air inlet and outlet openings reduce the probability of occurrence of such an accident. Nevertheless, for this conservative generic analysis, such an accident is postulated to occur and is analyzed.

Accident Analysis

The thermal evaluation of this event is presented in Chapter 4, Section 4 for 32PTH DSC (34.8 kw) and Amendment #8, Section P.4 for 24PTH DSC (40.8 kw). The analysis performed for HSM-H with 24PTH DSC bounding the values for HSM-H with 32PTH DSC. Therefore, the temperatures determined in Amendment #8, Section P.4 are used in the HSM-H structural evaluation of this event, which is presented in Appendix 3.9.9, Section 3.9.9.10.4. The structural evaluation of the 32PTH DSC based on the thermal evaluation presented in Chapter 4 of this SAR is presented in Appendix 3.9.1, storage load case 6 (page 3.9.1-59).

Accident Dose Calculation

There are no off-site dose consequences as a result of this accident. The only significant dose increase is that related to the recovery operation where it is conservatively estimated that the on-site workers will receive an additional dose of no more than one man-rem during the eight hour period it is estimated may be required for removal of debris from the air inlet and outlet openings in the HSM-H.

Corrective Actions

Debris removal is all that is required to recover from a postulated blockage of the HSM ventilation air inlets and outlets. Cooling will begin immediately following removal of the debris from the inlets and outlets. The amount and nature of debris can vary, but even in the most extreme case, manual means or readily available equipment can be used to remove debris.

The debris is conservatively assumed to remain in place for 34 hours. The last seven hours of this period are assumed to be the time required to completely remove all the debris before the natural circulation air flow can be restored.

### 11.3.7 Lightning

Cause of Accident

The likelihood of lightning striking the HSM-H and causing an off-normal condition is not considered to be a credible event. Lightning protection system requirements are site specific and depend upon the frequency of occurrences of lightning storms in the proposed ISFSI location and the degree of protection offered by other grounded structures in the proximity of the HSM-Hs. The addition of simple lightning protection equipment, required by plant criteria, to HSM-H structures (i.e., grounded handrails, ladders, etc.) is considered a miscellaneous attachment.

Accident Analysis

Should lightning strike in the vicinity of the HSM-H the normal storage operations of the HSM-H will not be affected. The current discharged by the lightning will follow the low impedance path offered by the surrounding structures. Therefore, the HSM-H will not be damaged by the heat or mechanical forces generated by current passing through the higher impedance concrete. Since the HSM-H requires no equipment for its continued operation, the resulting current surge from the lightning will not affect the normal operation of the HSM-H.

CHAPTER 12
TECHNICAL SPECIFICATIONS FOR THE NUHOMS® HD SYSTEM

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# 12 OPERATING CONTROLS AND LIMITS

## 12.1 Use and Application

### 12.1.1 Definitions

NOTE

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

| Term | Definition |
|---|---|
| ACTIONS | ACTIONS shall be that part of a Specification that prescribes Required Actions to be taken under designated Conditions within specified Completion Times. |
| HORIZONTAL STORAGE MODULE (HSM-H) | The HSM-H is a reinforced concrete structure for storage of a loaded 32PTH DSC at a spent fuel storage installation. |
| DAMAGED FUEL ASSEMBLY | A DAMAGED FUEL ASSEMBLY is a fuel assembly with known or suspected cladding defects greater than pinhole leaks or hairline cracks and which can be handled by normal means. |
| DRY SHIELDED CANISTER (32PTH DSC) | A 32PTH DSC is a welded pressure vessel that provides confinement of INTACT or DAMAGED FUEL ASSEMBLIES in an inert atmosphere. |
| INDEPENDENT SPENT FUEL STORAGE INSTALLATION (ISFSI) | The facility within a perimeter fence licensed for storage of spent fuel within HSM-Hs. |
| INTACT FUEL ASSEMBLY | Spent Nuclear Fuel Assemblies without known or suspected cladding defects greater than pinhole leaks or hairline cracks and which can be handled by normal means. |
| LOADING OPERATIONS | LOADING OPERATIONS include all licensed activities on a 32PTH DSC while it is being loaded with INTACT or DAMAGED FUEL ASSEMBLIES, and in a TRANSFER CASK while it is being loaded with a 32PTH DSC containing INTACT or DAMAGED FUEL ASSEMBLIES. LOADING OPERATIONS begin when the first INTACT or DAMAGED FUEL ASSEMBLY is placed in the 32PTH DSC and end when the TRANSFER CASK is ready for TRANSFER OPERATIONS. |
| STORAGE OPERATIONS | STORAGE OPERATIONS include all licensed activities that are performed at the ISFSI while a 32PTH DSC containing INTACT or DAMAGED FUEL ASSEMBLIES is located in an HSM-H on the storage pad within the ISFSI perimeter. |

12.1.1 Definitions (continued)

| | |
|---|---|
| TRANSFER CASK (TC) | The TRANSFER CASK consists of a licensed NUHOMS® OS187H onsite transfer cask. The TRANSFER CASK will be placed on a transfer trailer for movement of a 32PTH DSC to the HSM-H. |
| TRANSFER OPERATIONS | TRANSFER OPERATIONS include all licensed activities involving the movement of a TRANSFER CASK loaded with a 32PTH DSC containing INTACT or DAMAGED FUEL ASSEMBLIES. TRANSFER OPERATIONS begin when the TRANSFER CASK is placed on the transfer trailer following LOADING OPERATIONS and end when the 32PTH DSC is located in an HSM-H on the storage pad within the ISFSI perimeter. |
| UNLOADING OPERATIONS | UNLOADING OPERATIONS include all licensed activities on a 32PTH DSC to unload INTACT or DAMAGED FUEL ASSEMBLIES. UNLOADING OPERATIONS begin when the 32PTH DSC is removed from the HSM-H and end when the last INTACT or DAMAGED FUEL ASSEMBLY has been removed from the 32PTH DSC. |

## 12.1.2 Logical Connectors

PURPOSE

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

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

BACKGROUND

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

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

EXAMPLES

The following examples illustrate the use of logical connectors:

EXAMPLE 12.1.2-1

ACTIONS

| CONDITION | REQUIRED ACTION | COMPLETION TIME |
|---|---|---|
| A. LCO (Limiting Condition for Operation) not met. | A.1 Verify...<br><br>AND<br><br>A.2 Restore... | |

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

(continued)

12.1.2 Logical Connectors (continued)

EXAMPLES (continued)

EXAMPLE 12.1.2-2

ACTIONS

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

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

## 12.1.3 Completion Times

| | |
|---|---|
| PURPOSE | The purpose of this section is to establish the Completion Time convention and to provide guidance for its use. |
| BACKGROUND | Limiting Conditions for Operation (LCOs) specify the lowest functional capability or performance levels of equipment required for safe operation of the facility. The ACTIONS associated with an LCO state Conditions that typically describe the ways in which the requirements of the LCO are not met. Specified with each stated Condition are Required Action(s) and Completion Times(s). |
| DESCRIPTION | The Completion Time is the amount of time allowed for completing a Required Action. It is referenced to the time of discovery of a situation (e.g., equipment or variable not within limits) that requires entering an ACTIONS Condition unless otherwise specified, providing the facility is in a specified condition stated in the Applicability of the LCO. Required Actions must be completed prior to the expiration of the specified Completion Time. An ACTIONS Condition remains in effect and the Required Actions apply until the Condition no longer exists or the facility is not within the LCO Applicability.<br><br>Once a Condition has been entered, subsequent subsystems, components, or variables expressed in the Condition, discovered to be not within limits, will not result in separate entry into the Condition unless specifically stated. The Required Actions of the Condition continue to apply to each additional failure, with Completion Times based on initial entry into the Condition. |

(continued)

12.1.3 Completion Times (continued)

EXAMPLES

EXAMPLE 12.1.3-1

ACTIONS

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

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

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

EXAMPLES

EXAMPLE 12.1.3-2

ACTIONS

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

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

(continued)

12.1.3 Completion Times (continued)

EXAMPLES (continued)

EXAMPLE 12.1.3-3

ACTIONS

------------------------------------------ NOTE ------------------------------------------

*Separate Condition entry is allowed for each component.*

------------------------------------------------------------------------------------------

| CONDITION | REQUIRED ACTION | COMPLETION TIME |
|---|---|---|
| A. LCO not met. | A.1 Restore compliance with LCO. | 4 hours |
| B. Required Action and associated Completion Time not met. | B.1 Perform Action B.1.<br><br>AND<br><br>B.2 Perform Action B.2. | 12 hours<br><br><br><br>36 hours |

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

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

IMMEDIATE COMPLETION TIME

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

12.1.4 Frequency

| | |
|---|---|
| PURPOSE | The purpose of this section is to define the proper use and application of Frequency requirements |
| DESCRIPTION | Each Surveillance Requirement (SR) has a specified Frequency in which the Surveillance must be met in order to meet the associated Limiting Condition for Operation (LCO). An understanding of the correct application of the specified Frequency is necessary for compliance with the SR.<br><br>The "Specified Frequency" is referred to throughout this section and each of the Specifications of Section 12.3, Surveillance Requirement (SR) Applicability. The "Specified Frequency" consists of the requirements of the Frequency column of each SR, as well as certain Notes in the Surveillance column that modify performance requirements.<br><br>Situations where a Surveillance could be required (i.e., its Frequency could expire), but where it is not possible or not desired that it be performed until sometime after the associated LCO is within its Applicability, represent potential SR 12.3.0.4 conflicts. To avoid these conflicts, the SR (i.e., the Surveillance or the Frequency) is stated such that it is only "required" when it can be and should be performed. With a SR satisfied, SR 12.3.0.4 imposes no restriction.<br><br>(continued) |

12.1.4 Frequency (continued)

EXAMPLES (continued)

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

EXAMPLE 12.1.4-1

SURVEILLANCE REQUIREMENTS

| SURVEILLANCE | FREQUENCY |
|---|---|
| Verify pressure within limit. | 12 hours |

Example 12.1.4-1 contains the type of SR most often encountered in the Technical Specifications (TS). The Frequency specifies an interval (12 hours) during which the associated Surveillance must be performed at least one time. Performance of the Surveillance initiates the subsequent interval. Although the Frequency is stated as 12 hours, an extension of the time interval to 1.25 times the stated Frequency is allowed by SR 12.3.0.2 for operational flexibility. The measurement of this interval continues at all times, even when the SR is not required to be met per SR 12.3.0.1 (such as when the equipment is determined to not meet the LCO, a variable is outside specified limits, or the unit is outside the Applicability of the LCO). If the interval specified by SR 12.3.0.2 is exceeded while the facility is in a condition specified in the Applicability of the LCO, the LCO is not met in accordance with SR 12.3.0.1.

If the interval as specified by SR 12.3.0.2 is exceeded while the facility is not in a condition specified in the Applicability of the LCO for which performance of the SR is required, the Surveillance must be performed within the Frequency requirements of SR 12.3.0.2 prior to entry into the specified condition. Failure to do so would result in a violation of SR 12.3.0.4.

(continued)

12.1.4 Frequency (continued)

EXAMPLES (continued)

EXAMPLE 12.1.4-2

SURVEILLANCE REQUIREMENTS

| SURVEILLANCE | FREQUENCY |
|---|---|
| Verify flow is within limits. | Once within 12 hours prior to starting activity<br><br>AND<br><br>24 hours thereafter |

Example 12.1.4-2 has two Frequencies. The first is a one-time performance Frequency, and the second is of the type shown in Example 12.1.4-1. The logical connector "AND" indicates that both Frequency requirements must be met. Each time the example activity is to be performed, the Surveillance must be performed prior to starting the activity.

The use of "once" indicates a single performance will satisfy the specified Frequency (assuming no other Frequencies are connected by "AND"). This type of Frequency does not qualify for the 25% extension allowed by SR 12.3.0.2.

"Thereafter" indicates future performances must be established per SR 12.3.0.2, but only after a specified condition is first met (i.e., the "once" performance in this example). If the specified activity is canceled or not performed, the measurement of both intervals stops. New intervals start upon preparing to restart the specified activity.

(continued)

12.1.4 Frequency (continued)

EXAMPLES (continued)

EXAMPLE 12.1.4-3

SURVEILLANCE REQUIREMENTS

| SURVEILLANCE | FREQUENCY |
|---|---|
| -------------------NOTE------------------- Not required to be met until 96 hours after verifying the helium leak rate is within limit. | Once after verifying the helium leak rate is within limit. |
| Verify 32PTH DSC vacuum drying pressure is within limit. | |

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

Once the helium leak rate has been verified to be acceptable, 96 hours, plus the extension allowed by SR 12.3.0.2, would be allowed for completing the Surveillance for the vacuum drying pressure. If the Surveillance was not performed within this 96 hour interval, there would then be a failure to perform the Surveillance within the specified Frequency, and the provisions of SR 12.3.0.3 would apply.

## 12.2 Functional and Operating Limits

### 12.2.1 Fuel to be Stored in the 32PTH DSC

The spent nuclear fuel to be stored in each 32PTH DSC/HSM-H at the ISFSI shall meet the following requirements:

a. Fuel shall be INTACT FUEL ASSEMBLIES or DAMAGED FUEL ASSEMBLIES. DAMAGED FUEL ASSEMBLIES shall be placed in basket fuel compartments which contain top and bottom end caps. Damaged fuel assemblies shall be stored in the 16 inner-most basket fuel compartments, as shown in Figure 12-1.

b. Fuel types shall be limited to the following:

Westinghouse 15 x 15 (WE 15 x 15) Standard Assemblies
Westinghouse Surry Improved 15 x 15 (WES 15 x 15) Assemblies
Westinghouse 17 x 17 (WE 17 x 17) Standard Assemblies
Westinghouse 17 x 17 Vantage 5H (WEV 17 x 17) Assemblies
Westinghouse 17x17 OFA Assemblies (WEO 17x17)
Framatome ANP Advanced MK BW 17 x 17 Assemblies
Combustion Engineering 14x14 (CE 14x14) Assemblies

The fuel assemblies are specified in Table 12-1. Equivalent reload fuel assemblies that are enveloped by the fuel assembly design characteristics listed in Table 12-2 for a given assembly class are also acceptable for storage.

Fuel burnup and cooling time is to be consistent with the limitations specified in Table 12-4.

NFAHs stored integral to the assemblies in a 32PTH DSC, shall be limited to Burnable Poison Rod Assemblies (BPRAs), Thimble Plug Assemblies (TPAs), and Vibration Suppressor Inserts (VSIs). The NFAHs stored shall have acceptable combinations of burnup and cooling time described in Table 12-5. CE 14x14 fuel assemblies are to be stored without NFAHs.

(continued)

12.2.1 Fuel to be Stored in the 32PTH DS (continued)

c. The maximum heat load for a single fuel assembly, including insert components, is 1.5 kW. The maximum heat load per 32PTH DSC, including any integral insert components, shall not exceed 34.8 kW for 15x15 or 17x17 assemblies and 33.8 kW for CE 14x14 assemblies. The total 32PTH DSC shielding source term is given in Table 12-3. Any fuel assembly that is thermally qualified from Table 12-4 is acceptable from a shielding perspective, since the maximum decay heat load is 1.5 kW and only 8 are allowed in the 32PTH DSC. The shielding analysis assumes 32, 1.5 kW assemblies are in the 32PTH DSC. Fuel assemblies may be qualified for four (4) heat load zones designated as Zones 1a, 1b, 2 and 3. Figure 12-2 shows the heat load zone locations. Table 12-4 identifies the acceptable combinations of enrichment, burnup and cooling times.

d. Fuel can be stored in the 32PTH DSC in any of the following configurations:

   1) A maximum of 32 INTACT fuel assemblies; or

   2) Up to 16 DAMAGED FUEL ASSEMBLIES, with the balance INTACT FUEL ASSEMBLIES.

e. Fuel dimensions and weights are provided in Table 12-2.

f. The maximum neutron and gamma source terms are provided in Table 12-3.

12.2.2 Functional and Operating Limits Violations

If any Functional and Operating Limit of 12.2.1 is violated, the following actions shall be completed:

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

12.2.2.2 Within 24 hours, notify the NRC Operations Center.

12.2.2.3 Within 30 days, submit a special report which describes the cause of the violation and the actions taken to restore compliance and prevent recurrence.

## 12.3 Limiting Condition for Operation (LCO) and Surveillance Requirement (SR) Applicability

| | |
|---|---|
| LCO 12.3.0.1 | LCOs shall be met during specified conditions in the Applicability, except as provided in LCO 12.3.0.2. |
| LCO 12.3.0.2 | Upon discovery of a failure to meet an LCO, the Required Actions of the associated Conditions shall be met, except as provided in LCO 12.3.0.5.<br><br>If the LCO is met or is no longer applicable prior to expiration of the specified Completion Time(s), completion of the Required Action(s) is not required, unless otherwise stated. |
| LCO 12.3.0.3 | Not applicable to a spent fuel storage cask. |
| LCO 12.3.0.4 | When an LCO is not met, entry into a specified condition in the Applicability shall not be made except when the associated ACTIONS to be entered permit continued operation in the specified condition in the Applicability for an unlimited period of time. This Specification shall not prevent changes in specified conditions in the Applicability that are required to comply with ACTIONS, or that are related to the unloading of a 32PTH DSC.<br><br>Exceptions to this Specification are stated in the individual Specifications. These exceptions allow entry into specified conditions in the Applicability when the associated ACTIONS to be entered allow operation in the specified condition in the Applicability only for a limited period of time. |
| LCO 12.3.0.5 | Equipment removed from service or not in service in compliance with ACTIONS may be returned to service under administrative control solely to perform testing required to demonstrate it meets the LCO or that other equipment meets the LCO. This is an exception to LCO 12.3.0.2 for the system returned to service under administrative control to perform the testing required to demonstrate that the LCO is met. |
| LCO 12.3.0.6 | Not applicable to a spent fuel storage cask. |
| LCO 12.3.0.7 | Not applicable to a spent fuel storage cask. |

(continued)

12.3 Limiting Condition for Operation (LCO) and Surveillance Requirement (SR) Applicability (continued)

| | |
|---|---|
| SR 12.3.0.1 | SRs shall be met during the specified conditions in the Applicability for individual LCOs, unless otherwise stated in the SR. Failure to meet a Surveillance, whether such failure is experienced during the performance of the Surveillance or between performances of the Surveillance, shall be failure to meet the LCO. Failure to perform a Surveillance within the specified Frequency shall be failure to meet the LCO except as provided in SR 12.3.0.3. Surveillances do not have to be performed on equipment or variables outside specified limits. |
| SR 12.3.0.2 | The specified Frequency for each SR is met if the Surveillance is performed within 1.25 times the interval specified in the Frequency, as measured from the previous performance or as measured from the time a specified condition of the Frequency is met.<br><br>For Frequencies specified as "once," the above interval extension does not apply. If a Completion Time requires periodic performance on a "once per . . ." basis, the above Frequency extension applies to each performance after the initial performance.<br><br>Exceptions to this Specification are stated in the individual Specifications. |
| SR 12.3.0.3 | If it is discovered that a Surveillance was not performed within its specified Frequency, then compliance with the requirement to declare the LCO not met may be delayed, from the time of discovery, up to 24 hours or up to the limit of the specified Frequency, whichever is less. This delay period is permitted to allow performance of the Surveillance.<br><br>If the Surveillance is not performed within the delay period, the LCO must immediately be declared not met, and the applicable Condition(s) must be entered.<br><br>When the Surveillance is performed within the delay period and the Surveillance is not met, the LCO must immediately be declared not met, and the applicable Condition(s) must be entered. |
| SR 12.3.0.4 | Entry into a specified condition in the Applicability of an LCO shall not be made unless the LCO's Surveillances have been met within their specified Frequency. This provision shall not prevent entry into specified conditions in the Applicability that are required to comply with ACTIONS or that are related to the unloading of a 32PTH DSC. |

12.3.1 32PTH DSC Fuel Integrity

12.3.1.1 32PTH DSC Vacuum Drying Time (Duration) and Pressure

LCO 12.3.1.1

Duration: Vacuum Drying of the 32PTH DSC shall be achieved within the following time durations after drainage of bulk water (blowdown):

Notes:
1. The DSC shall be backfilled with nitrogen or helium after drainage of bulk water.
2. Nitrogen or helium will be used to assist the removal of water prior to welding the inner top cover.

**Procedure A** – Water in the TC cavity/annulus remains below 180°F

| **Heat Load (kW)** | Time Limit |
|---|---|
| kW ≤ 23.2 | No limit |
| 23.2< kW ≤ 34.8 | 36 hours after DSC water drainage |
| 23.2< kW ≤ 34.8 | No limit if helium backfill after DSC water drainage |

**Procedure B** – Water in the TC cavity/annulus is drained when it exceeds 180°F

| **Heat Load (kW)** | Time Limit |
|---|---|
| kW ≤ 16.0 | No limit |
| 16.0< kW ≤ 34.8 | 28 hours after DSC water drainage or 14 hours after drainage of TC cavity/annulus water, which ever is limiting |

**Procedure C** – Water in the TC cavity/annulus is drained when it exceeds 180°F and after DSC water drainage the DSC is backfilled with helium.

| **Heat Load (kW)** | Time Limit |
|---|---|
| kW ≤ 22.4 | No limit |
| 22.4< kW ≤ 34.8 | 42 hours after DSC water drainage or 28 hours after drainage of TC cavity/annulus water, which ever is limiting |

Pressure: The 32PTH DSC vacuum drying pressure shall be sustained at or below 3 Torr (3 mm Hg) absolute for a period of at least 30 minutes following stepped evacuation.

APPLICABILITY: During LOADING OPERATIONS.

12.3.1 32PTH DSC Fuel Integrity (continued)

ACTIONS

--------------------------------NOTE--------------------------------------

*This specification is applicable to all 32PTH DSCs.*

---------------------------------------------------------------------------------

| CONDITION | REQUIRED ACTION | COMPLETION TIME |
|---|---|---|
| A. 32PTH DSC vacuum drying pressure limit not met:<br><br><u>Procedure A</u>, within 30 hours for a DSC with heat load greater than 23.2 kW.<br><br><u>Procedure B</u>, within either 22 hours after DSC water drainage or 8 hours after annulus water drainage for a DSC with heat load greater than 16.0 kW.<br><br><u>Procedure C</u>, within either 36 hours after DSC water drainage or 22 hours after annulus water drainage for a DSC with heat load greater than 22.4 kW. | A.1 Establish helium pressure of at least 0.5 atm and no greater than 20 psig in the 32PTH DSC.<br><br><u>OR</u><br><br>A.2 Flood the DSC with spent fuel pool water submerging all fuel assemblies. | 6 hours<br><br><br><br>6 hours |

SURVEILLANCE REQUIREMENTS

| SURVEILLANCE | | FREQUENCY |
|---|---|---|
| S.R.12.3.1.1 | Verify that the 32PTH DSC vacuum pressure is less than, or equal to, 3 Torr (3 mm Hg) absolute for at least 30 minutes, within the specified total time duration based on heat load. | Once per 32PTH DSC, after an acceptable NDE of the top shield plug weld. |

12.3.1.2 32PTH DSC Helium Backfill Pressure

LCO 12.3.1.2 32PTH DSC helium backfill pressure shall be 2.5 ± 1 psig (stable for 30 minutes after filling) after completion of vacuum drying.

APPLICABILITY: During LOADING OPERATIONS.

ACTIONS

---------- NOTE ----------

*This specification is applicable to all 32PTH DSCs.*

| CONDITION | REQUIRED ACTION | COMPLETION TIME |
|---|---|---|
| *Note: Not applicable until SR 12.3.1.2 is performed.* | | |
| A. The required backfill pressure cannot be obtained or stabilized. | A.1 Establish the 32PTH DSC helium backfill pressure to within the limit. | 24 hours |
| | OR | |
| | A.2 Flood the DSC with spent fuel pool water submerging all fuel assemblies. | 24 hours |

SURVEILLANCE REQUIREMENTS

| SURVEILLANCE | FREQUENCY |
|---|---|
| S.R.12.3.1.2 Verify that the 32PTH DSC helium backfill pressure is 2.5 ± 1 psig. | Once per 32PTH DSC, after the completion of TS 12.3.1.1 actions. |

12.3.1.3 Transfer Cask Cavity Helium Backfill Pressure

LCO 12.3.1.3 OS187H transfer cask cavity/annulus helium backfill shall be initiated within 9 hours after completion of 32PTH DSC helium backfill and the pressure shall be 2.0 ± 1 psig.

APPLICABILITY: During LOADING OPERATIONS.

ACTIONS

-------------------- NOTE --------------------
This specification is applicable to all 32PTH DSCs/OS187H TC.
----------------------------------------------

| CONDITION | REQUIRED ACTION | COMPLETION TIME |
|---|---|---|
| ----NOTE---- Note: Not applicable until SR 12.3.1.3 is performed. ------------ | | |
| A. The transfer cask annulus helium backfill can't be initiated within 8 hrs of 32PTH DSC helium backfill completion. | A.1 Flood the TC cavity/annulus with water | 1 hour |
| B. The required backfill pressure cannot be obtained or stabilized. | B.1 Establish the TC cavity/annulus helium backfill pressure to within the limit.<br><br><u>OR</u> | 18 hours |
| | B.2 Flood the TC cavity/annulus with water. | 18 hours |

SURVEILLANCE REQUIREMENTS

| SURVEILLANCE | | FREQUENCY |
|---|---|---|
| S.R.12.3.1.3 | Verify that the OS187H cavity/annulus helium backfill pressure is 2.0 ± 1 psig. | Once per 32PTH DSC, after the completion of TS 12.3.1.2 actions or after the installation of TC lid. |

12.3.2 Cask Criticality Control

LCO 12.3.2 The dissolved boron concentration of the spent fuel pool water and the water added to the cavity of a loaded DSC shall be at least the boron concentration shown in Table 12-7 for the basket type and fuel enrichment selected.

APPLICABILITY: During LOADING and UNLOADING OPERATIONS.

ACTIONS

---------- NOTE ----------
This specification is applicable to all 32PTH DSCs/OS187H TC.
--------------------------

| CONDITION | REQUIRED ACTION | COMPLETION TIME |
|---|---|---|
| A. Dissolved boron concentration limit not meet. | A.1 Suspend loading of fuel assemblies into DSC | Immediately |
| | AND | |
| | A.2 Remove all fuel assemblies from DSC | 24 hours |

SURVEILLANCE REQUIREMENTS

| SURVEILLANCE | | FREQUENCY |
|---|---|---|
| SR 12.3.2.1 | Verify dissolved boron concentration limit in spent fuel pool water and water to be added to the DSC cavity is met using two independent measurements. | Within 4 hours prior to commencing LOADING OPERATIONS<br><br>AND<br><br>48 hours thereafter while the DSC is in the spent fuel pool or while water is in the DSC. |
| SR 12.3.2.2 | Verify dissolved boron concentration limit in spent fuel pool water and water to be added to the DSC cavity is met using two independent measurements. | Once within 4 hours prior to flooding DSC during UNLOADING OPERATIONS<br><br>AND<br><br>48 hours thereafter while the DSC is in the spent fuel pool or while water is in the DSC. |

## 12.4 Design Features

The specifications in this section include the design characteristics of special importance to each of the physical barriers and to maintenance of safety margins in the NUHOMS® HD System design. The principal objective of this section is to describe the design envelope that may constrain any physical changes to essential equipment. Included in this section are the site environmental parameters that provide the bases for design, but are not inherently suited for description as LCOs.

### 12.4.1 Site

#### 12.4.1.1 Site Location

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

### 12.4.2 Storage System Features

#### 12.4.2.1 Storage Capacity

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

#### 12.4.2.2 Storage Pad

For sites for which soil-structure interaction is considered important, the licensee is to perform site-specific analysis considering the effects of soil-structure interaction. Amplified seismic spectra at the location of the HSM-H center of gravity (CG) is to be developed based on the SSI responses. HSM-H seismic analysis information is provided in SAR Appendix 3.9.9.10.2.

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

Additional requirements for the pad configuration are provided in Section 12.4.6.2.

(continued)

## 12.4 Design Features (continued)

### 12.4.3 Canister Criticality Control

The NUHOMS®-32PTH is designed for unirradiated fuel with an assembly average initial enrichment of less than or equal to 5.0 wt. % U-235 taking credit for soluble boron in the DSC cavity water during loading operations and the boron content in the poison plates of the DSC basket. The 32PTH DSC has multiple basket configurations, based on the material type and boron content in the poison plates, as listed in Table 12-6. Table 12-7 defines the requirements for boron concentration in the DSC cavity water as a function of the DSC basket type for the various intact and damaged fuel classes (most reactive) authorized for storage in the 32PTH DSC.

A Type I basket contains poison plates that are either, borated aluminum or MMC while a Type II basket contains Boral® poison plates. The basket types are further defined by the B-10 areal density in the plates, ranging from the lowest, Type A to the highest, Type E.

### 12.4.4 Codes and Standards

#### 12.4.4.1 Horizontal Storage Module (HSM-H)

The reinforced concrete HSM-H is designed to meet the requirements of ACI 349-97. Load combinations specified in ANSI 57.9-1984, Section 6.17.3.1 are used for combining normal operating, off-normal, and accident loads for the HSM-H.

#### 12.4.4.2 Dry Shielded Canister (32PTH DSC)

The 32PTH DSC is designed, fabricated and inspected to the maximum practical extent in accordance with ASME Boiler and Pressure Vessel Code Section III, Division 1, 1998 Edition with Addenda through 2000, including exceptions allowed by Code Case N-595-3, Subsections NB, NF, and NG for Class 1 components and supports. Code alternatives are discussed in 12.4.4.4.

#### 12.4.4.3 Transfer Cask (OS187H)

The OS187H Transfer Cask is designed, fabricated and inspected to the maximum practical extent in accordance with ASME Boiler and Pressure Vessel Code Section III, 1998 Edition with Addenda through 2000, Subsection NC for Class 2 vessels.

#### 12.4.4.4 Alternatives to Codes and Standards

ASME Code alternatives for the 32PTH DSC are listed below:

**DSC ASME Code Alternatives, Subsection NB**

| Reference ASME Code Section/Article | Code Requirement | Justification & Compensatory Measures |
|---|---|---|
| NCA | All | Not compliant with NCA |
| NB-1100 | Requirements for Code Stamping of Components | The canister shell, the inner top cover/shield plug, the inner bottom cover, and the siphon/vent port cover are designed & fabricated in accordance with the ASME Code, Section III, Subsection NB to the maximum extent practical. However, Code Stamping is not required. As Code Stamping is not required, the fabricator is not required to hold an ASME "N" or "NPT" stamp, or to be ASME Certified. |
| NB-2130<br><br>NB-4121 | Material must be supplied by ASME approved material suppliers<br><br>Material Certification by Certificate Holder | Material is certified to meet all ASME Code criteria but is not eligible for certification or Code Stamping if a non-ASME fabricator is used. As the fabricator is not required to be ASME certified, material certification to NB-2130 is not possible. Material traceability & certification are maintained in accordance with TN's NRC approved QA program. |
| NB-4243 and NB-5230 | Category C weld joints in vessels and similar weld joints in other components shall be full penetration joints. This welds shall be examined by UT or RT and either PT or MT | The joint between the outer top cover and inner top cover/shield plug and shell are design and fabricated per ASME Code Case N-595-3. The welds are partial penetration welds and the root and final layer are PT examined. |
| NB-2531 | Vent & siphon Port Cover; straight beam UT per SA-578 for all plates for vessel | SA-578 applies to 3/8" and thicker plate only; allow alternate UT techniques to achieve meaningful UT results. |
| NB-6100 and 6200 | All completed pressure retaining systems shall be pressure tested | The inner top cover/shield plug assembly is not pressure tested due to the manufacturing sequence. The inner top cover/shield plug assembly weld is helium leak tested when fuel is loaded and then covered with the outer top closure plate. |
| NB-7000 | Overpressure Protection | No overpressure protection is provided for the 32PTH DSC. The function of the 32PTH DSC is to contain radioactive materials under normal, off-normal, and hypothetical accident conditions postulated to occur during transportation. The 32PTH DSC is designed to withstand the maximum internal pressure considering 100% fuel rod failure at maximum accident temperature. The 32PTH DSC is pressure tested in accordance with the requirements of 10CFR71 and TN's approved QA program. |

**DSC ASME Code Alternatives, Subsection NB (concluded)**

| Reference ASME Code Section/Article | Code Requirement | Justification & Compensatory Measures |
|---|---|---|
| NB-8000 | Requirements for nameplates, stamping & reports per NCA-8000 | The 32PTH DSC nameplates provide the information required by 10CFR71, 49CFR173, and 10CFR72 as appropriate. Code stamping is not required for the 32PTH DSC. QA Data packages are prepared in accordance with the requirements of 10CFR71, 10CFR72, and TN's approved QA program. |
| NB-1132 | Attachments with a pressure retaining function, including stiffeners, shall be considered part of the component. | Outer bottom cover, bottom plate, bottom casing plate, side casing plate, top shield plug casing plate, lifting post, grapple ring and grapple ring support are outside code jurisdiction; these components together are much larger than required to provide stiffening for the confinement boundary cover. These component welds are subject to root and final PT examinations. |

**Basket ASME Code Alternatives, Subsection NG/NF**

| Reference ASME Code Section/Article | Code Requirement | Justification & Compensatory Measures |
|---|---|---|
| NCA | All | Not compliant with NCA |
| NG/NF-1100 | Requirements for Code Stamping of Components | The 32PTH DSC baskets are designed & fabricated in accordance with the ASME Code, Section III, Subsection NG to the maximum extent practical as described in the SAR, but Code Stamping is not required. As Code Stamping is not required, the fabricator is not required to hold an ASME N or NPT stamp or be ASME Certified. |
| NG/NF-2130<br><br>NG/NF-4121 | Material must be supplied by ASME approved material suppliers<br><br>Material Certification by Certificate Holder | Material is certified to meet all ASME Code criteria but is not eligible for certification or Code Stamping if a non-ASME fabricator is used. As the fabricator is not required to be ASME certified, material certification to NG/NF-2130 is not possible. Material traceability & certification are maintained in accordance with TN's NRC approved QA program. The poison material and aluminum plates are not used for structural analysis, but to provide criticality control and heat transfer. They are not ASME Code Class I materials. See note 1. |
| NG/NF-8000 | Requirements for nameplates, stamping & reports per NCA-8000 | The 32PTH DSC nameplates provide the information required by 10CFR71, 49CFR173, and 10CFR72 as appropriate. Code stamping is not required for the 32PTH DSC. QA Data packages are prepared in accordance with the requirements of 10CFR71, 10CFR72, and TN's approved QA program. |

Notes: 1. Because Subsection NCA does not apply, the NCA-3820 requirements for accreditation or qualification of material organizations do not apply. CMTR's shall be provided using NCA- 3862 for guidance.

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

1. The proposed alternatives would provide an acceptable level of quality and safety, or

2. Compliance with the specified requirements of ASME Code, Section III, 1998 Edition with Addenda through 2000 would result in hardship or unusual difficulty without a compensating increase in the level of quality and safety.

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

12.4 Design Features (continued)

12.4.5 HSM-H Side Heat Shields

The HSM-H utilizes side heat shields to protect the HSM-H concrete surfaces and provide for enhanced heat transfer within the HSM-H. Three side heat shield configurations have been evaluated in the SAR: finned side heat shields, flat anodized aluminum plates and flat galvanized steel plates. Limits on the heat load of the DSC's shall be established for the heat shield material types and configurations used through testing or analysis.

12.4.6 Storage Location Design Features

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

12.4.6.1 Storage Configuration

HSM-Hs are placed together in single rows or back to back arrays. An end shield wall is placed on the outside end of any loaded outside HSM-H. A rear shield wall is placed on the rear of any single row loaded HSM-H.

12.4.6.2 Concrete Storage Pad Properties to Limit 32PTH DSC Gravitational Loadings Due to Postulated Drops

The TC/32PTH DSC has been evaluated for drops of up to 80 inches onto a reinforced concrete storage pad. The evaluations are based on the concrete parameters specified in EPRI Report NP-7551, "Structural Design of Concrete Storage Pads for Spent Fuel Casks," August 1991.

(continued)

12.4 Design Features (continued)

12.4.6.3 Site Specific Parameters and Analyses

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

1. Tornado maximum wind speeds: 290 mph rotational
   70 mph translational

2. Flood levels up to 50 ft. and water velocity of 15 fps.

3. One-hundred year roof snow load of 110 psf.

4. Normal ambient temperatures of 0°F to 100°F.

5. Off-normal ambient temperature range of –20°F without solar insulation to 115°F with full solar insulation.

6. The potential for fires and explosions shall be addressed, based on site-specific considerations.

7. Supplemental Shielding: In cases where engineered features (i.e., berms, shield walls) are used to ensure that the requirements of 10CFR 72.104(a) are met, such features are to be considered important to safety and must be evaluated to determine the applicable Quality Assurance Category.

8. Seismic loads of up to 0.30g horizontal and up to 0.20 g vertical.

## 12.5 Administrative Controls

### 12.5.1 Procedures

Each user of the NUHOMS® HD System will prepare, review, and approve written procedures for all normal operations, maintenance, and testing at the ISFSI prior to its operation. Written procedures shall be established, implemented, and maintained covering the following activities that are important to safety:

- Organization and management
- Routine ISFSI operations
- Alarms and annunciators
- Emergency operations
- Design control and facility change/modification
- Control of surveillances and tests
- Control of special processes
- Maintenance
- Health physics, including ALARA practices
- Special nuclear material accountability
- Quality assurance, inspection, and audits
- Physical security and safeguards
- Records management
- Reporting
- All programs specified in Section 12.5.2

### 12.5.2 Programs

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

- Safety Review Program
- Training Program
- Radiological Environmental Monitoring Program
- Radiation Protection Program
- HSM-H Thermal Monitoring Program

#### 12.5.2.1 Safety Review Program

Users shall conduct safety reviews in accordance with 10CFR 72.48 to determine whether proposed changes, tests, and experiments require NRC approval before implementation. Changes to the Technical Specification Bases and other licensing basis documents will be conducted in accordance with approved administrative procedures.

Changes may be made to Technical Specification Bases and other licensing basis documents without prior NRC approval, provided the changes meet the criteria of 10CFR 72.48.

The safety review process will contain provisions to ensure that the Technical Specification Bases and other licensing basis documents are maintained consistent with the SAR.

Proposed changes that do not meet the criteria above will be reviewed and approved by the NRC before implementation. Changes to the Technical Specification Bases implemented without prior NRC approval will be provided to the NRC in accordance with 10CFR 72.48.

(continued)

12.5.2 Programs (continued)

12.5.2.2 Training Program

Training modules shall be developed as required by 10CFR 72. Training modules shall require a comprehensive program for the operation and maintenance of the NUHOMS® HD System and the independent spent fuel storage installation (ISFSI). The training modules shall include the following elements, at a minimum:

- NUHOMS® HD System design (overview)
- ISFSI Facility design (overview)
- Systems, Structures, and Components Important to Safety (overview)
- NUHOMS® HD System Safety Analysis Report (overview)
- NRC Safety Evaluation Report (overview)
- Certificate of Compliance conditions
- NUHOMS® HD System Technical Specifications
- Applicable Regulatory Requirements (e.g.,10CFR 72, Subpart K, 10CFR 20, 10 CFR Part 73)
- Required Instrumentation and Use
- Operating Experience Reviews
- NUHOMS® HD System and Maintenance procedures, including:
  - Fuel qualification and loading,
  - Rigging and handling,
  - Loading Operations as described in Chapter 8 of the SAR,
  - Unloading Operations including reflooding,
  - Auxiliary equipment operations and maintenance (i.e., welding operations, vacuum drying, helium backfilling and leak testing, reflooding),
  - Transfer operations including loading and unloading of the Transfer Vehicle,
  - ISFSI Surveillance operations,
  - Radiation Protection,
  - Maintenance, as described in Section 9.2 of the SAR,
  - Security, and
  - Off-normal and accident conditions, responses and corrective actions.

(continued)

12.5.2 Programs (continued)

12.5.2.3 Radiological Environmental Monitoring Program

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

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

12.5.2.4 Radiation Protection Program

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

a) As part of its evaluation pursuant to 10CFR 72.212, the licensee shall perform an analysis to confirm that the limits of 10CFR 20 and 10CFR 72.104 will be satisfied under the actual site conditions and configurations considering the planned number of 32PTH DSCs to be used and the planned fuel loading conditions.

b) A monitoring program to ensure the annual dose equivalent to any real individual located outside the ISFSI controlled area does not exceed regulatory limits is incorporated as part of the environmental monitoring program in the Radiological Environmental Monitoring Program of Section 12.5.2.3.

c) Following placement of each loaded Transfer Cask into the cask decontamination area and prior to transfer to the ISFSI, the 32PTH DSC smearable surface contamination levels on the outer top 1 foot surface of the 32PTH DSC shall be less than 2,200 dpm/100 $cm^2$ from beta and gamma emitting sources, and less than 220 dpm/100 $cm^2$ from alpha emitting sources.

The contamination limits specified above are based on the allowed removable external radioactive contamination specified in 49 CFR 173.443 (as referenced in 10 CFR 71.87(i)) the system provides significant additional protection for the 32PTH DSC surface than the transportation configuration. The HSM-H will protect the 32PTH DSC from direct exposure to the elements and will therefore limit potential releases of removable contamination. The probability of any removable contamination being entrapped in the HSM-H air flow path released outside the HSM-H is considered extremely small.

(continued)

12.5.2 Programs (continued)

12.5.2.5 HSM-H Thermal Monitoring Program

This program provides guidance for temperature measurements that are used to monitor the thermal performance of each HSM-H. The intent of the program is to prevent conditions that could lead to exceeding the concrete and fuel clad temperature criteria.

a) HSM-H Air Temperature Difference

Following initial 32PTH DSC transfer to the HSM-H, the air temperature difference between ambient temperature and the roof vent temperature will be measured 24 hours after DSC insertion into the HSM and again 7 days after insertion into the HSM-H. If the air temperature differential is greater than 70°F, the air inlets and exits should be checked for blockage. If after removing any blockage found, the temperature difference is still ≥100°F, corrective actions and analysis of existing conditions will be performed in accordance with the site corrective action program to confirm that conditions adversely affecting the concrete or fuel cladding do not exist.

The specified air temperature rise ensures the fuel clad and concrete temperatures are maintained at or below acceptable long-term storage limits. If the temperature rise is ≤100°F, then the HSM-H and 32PTH DSC are performing as designed and no further temperature measurements are required.

b) HSM-H Inlets and Outlets (Front Wall and Roof Bird Screens)

Since the HSM-Hs are located outdoors, there is a possibility that the HSM-H air inlet and outlet openings could become blocked by debris. Although the ISFSI security fence and HSM-H bird screens reduce the probability of HSM-H air vent blockage, the ISFSI SAR postulates and analyzes the effects of air vent blockage.

The HSM-H design and accident analyses demonstrate the ability of the ISFSI to function safely if obstructions in the air inlets or outlets impair airflow through the HSM-H for extended periods. This specification ensures that blockage will not exist for periods longer than assumed in the analyses.

Site personnel will conduct a daily visual inspection of the air vents to ensure that HSM-H air vents are not blocked for more than 34 hours and that blockage will not exist for periods longer than assumed in the safety analysis.

(continued)

### 12.5.3 Lifting Controls

#### 12.5.3.1 Transfer Cask Lifting Heights

The lifting height of a loaded transfer cask/32PTH DSC, is limited as a function of location, as follows:

a) The maximum lift height and handling height for all TRANSFER OPERATIONS where the TC/32PTH is in the horizontal position on the trailer shall be 80 inches.

b) The maximum lift height of the transfer cask/32PTH DSC shall be restricted by site (10CFR50) limits for all handling operations except those listed in 12.5.3.1a above. An evaluation of the fuel cladding structural integrity shall be performed for all credible drops under the user's 10CFR50 heavy loads program.

These restrictions ensure that any 32PTH DSC drop as a function of location is within the bounds of the accident analysis.

#### 12.5.3.2 Cask Drop

Inspection Requirement

The 32PTH DSC will be inspected for damage after any transfer cask drop of fifteen inches or greater.

Background

TC/32PTH DSC handling and loading activities are controlled under the 10CFR 50 license until a loaded TC/32PTH DSC is placed on the transporter, at which time fuel handling activities are controlled under the 10CFR 72 license. Although the probability of dropping a loaded TC/32PTH DSC while en route from the Fuel Handling Building to the ISFSI is small, the potential exists to drop the cask 15 inches or more.

(continued)

12.5.3 Lifting Controls (continued)

12.5.3.2 Cask Drop (continued)

Safety Analysis

The analysis of bounding drop scenarios shows that the transfer cask will maintain the structural integrity of the 32PTH DSC confinement boundary from an analyzed side drop height of 80 inches. The 80-inch drop height envelopes the maximum height from the bottom of the transfer cask when secured to the transfer trailer while en route to the ISFSI.

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

1. The DSC will continue to provide confinement.

2. The transfer cask can continue to perform its design function regarding DSC transfer and shielding.

12.5.4 HSM Dose Rate Evaluation Program

This program provides a means to help ensure that the cask (DSC) is loaded properly and that the facility will meet the off-site dose requirements of 72.104(a).

1. As part of its evaluation pursuant to 10 CFR 72.212, the licensee shall perform an analysis to confirm that the limits of 10 CFR Part 20 and 10 CFR 72.104 will be satisfied under the actual site conditions and configurations considering the planned number of HSMs to be used and the planned fuel loading conditions.

2. On the basis of the analysis in TS 12.5.4.1, the licensee shall establish a set of HSM-H dose rate limits which are to be applied to 32PTH DSCs used at the site. Limits shall establish peak dose rates for:

   a. HSM-H front surface,
   b. HSM-H door centerline, and
   c. End shield wall exterior.

3. Notwithstanding the limits established in TS 12.5.4.2, the dose rate limits may not exceed the following values as calculated for a content of design basis fuel as follows:

   a. 800 mrem/hr at the front bird screen,
   b. 2 mrem/hr at the door centerline, and
   c. 2 mrem/hr at the end shield wall exterior.

4. If the measured dose rates do not meet the limits of TS 12.5.4.2 or TS 12.5.4.3, whichever are lower, the licensee shall take the following actions:

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

### 12.5.5 Concrete Testing

HSM-H concrete shall be tested for elevated temperatures to verify that there are no significant signs of spalling or cracking and that the concrete compressive strength is greater than that assumed in the structural analysis. Tests shall be performed at or above the calculated peak temperature and for a period no less than the 40 hour duration of HSM-H blocked vent transient for components exceeding 350 degrees F.

**Table 12-1**
**Fuel Specifications**

| Fuel Type | Maximum Assembly Average Initial Enrichment | Cladding Material | Minimum Cooling Time | Minimum Assembly Average Initial Enrichment | Maximum Burnup |
|---|---|---|---|---|---|
| WE 15x15<br>WES 15x15 | 5.0 weight %<br>U-235 | Zircalloy-4<br>Zirlo | 5 years | See Table 12-4 for Enrichment, Burnup, and Cooling Time Limits. | 60<br>GWD/MTU |
| WE 17x17<br>WEV 17x17<br>WE 17x17 OFA | 5.0 weight %<br>U-235 | Zircalloy-4<br>Zirlo | 5 years | See Table 12-4 for Enrichment, Burnup, and Cooling Time Limits | 60<br>GWd/MTU |
| Framatome MK<br>BW 17x17 | 5.0 weight %<br>U-235 | M5 | 5 years | See Table 12-4 for Enrichment, Burnup, and Cooling Time Limits | 60<br>GWd/MTU |
| CE 14x14 | 5.0 weight %<br>U-235 | Zircalloy-4<br>Zirlo | 5 years | See Table 12-4 for Enrichment, Burnup, and Cooling Time Limits | 60<br>GWd/MTU |
| NFAH | N/A | N/A | See Table 12-5 | | |

**Table 12-2**
**Fuel Dimension and Weights**

| Parameter | 15x15 WE &WES | 17 x 17 WE | 17x17 MK BW | 17x17 WEV | 17x17 WEOFA | 14x14 CE |
|---|---|---|---|---|---|---|
| Maximum Assembly Average Initial Enrichment, wt % U235 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 |
| Clad Material | Zr-4/Zirlo | Zr-4/Zirlo | M5 | Zr-4/Zirlo | Zr-4/Zirlo | Zr-4/Zirlo |
| No of fuel rods | 204 | 264 | 264 | 264 | 264 | 176 |
| No of guide/instrument tubes | 21 | 25 | 25 | 25 | 25 | 5 |
| Assembly Length(3) | 162.2 | 162.4 | 162.4 | 162.4 | 162.4 | 159.5 |
| Max Uranium Loading (MTU) | 467 | 467 | 476 | 467 | 467 | 385 |
| Assembly Cross Section | 8.424 x 8.424 | 8.426 x 8.426 | 8.425 x 8.425 | 8.426 x 8.426 | 8.426 x 8.426 | 8.25 x 8.25 |
| Max Assembly Weight with Insert components(4) | 1528 | 1575 | 1554 | 1533 | 1533 | 1450(5) |

(1) Nominal values shown unless stated otherwise
(2) All dimensions are inches
(3) Includes allowance for irradiation growth
(4) Weights of TPAs and VSIs are enveloped by BPRAs
(5) Without NFAHs

**Table 12-3**
**Maximum Neutron and Gamma Source Terms**

| Parameter | Framatome MK BW |
|---|---|
| Gamma Source (γ/sec/DSC) | 2.22E+17 |
| Neutron Source (n/sec/DSC) | 3.52E+10 |

| Parameter | BPRA |
|---|---|
| Gamma Source (γ/sec/assy)* | 2.30E+14 |
| Decay heat (Watts/assy)** | 9 |

* - 30GWD/MTU cooled 4 days
** - 30GWD/MTU cooled 5 years

**Table 12-4**
**Fuel Qualification Table(s)**

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

$$F1 = A + B*X1 + C*X2 + D*X1^2 + E*X1*X2 + F*X2^2$$
$$DH = F1*Exp(\{[1-(5/X3)]*G\}*[(X3/X1)^H]*[(X2/X1)^I])$$

where,

- F1 Intermediate Function, basically the Thermal source at 5 year cooling
- X1 Assembly Burnup in GWD/MTU
- X2 Maximum Assembly Average Initial Enrichment in wt. % U-235 (max 5%, min: Zone 1- 1.5%, Zone 2 -1.6% Zone 3- 2.5%)
- X3 Cooling Time in Years (min 5 yrs)

A = 13.69479 B=25.79539 C=-3.547739 D= 0.307917 E=-3.809025
F = 14.00256 G=-0.831522 H= 0.078607 I =-0.095900

**Examples for Zone 1a -1050 watts (Burnup GWD/MTU)**

| Maximum Assembly Average Initial Enrichment (wt. % U-235) | 5 Years | 6 Years | 7 Years | 8 Years | 10 Years | 15 Years |
|---|---|---|---|---|---|---|
| **1.50** | 32.8 | 37.2 | 40.7 | 43.7 | 48.1 | 55.2 |
| **2.50** | 34.7 | 39.2 | 42.7 | 45.6 | 50.0 | 57.0 |
| **3.00** | 35.5 | 40.1 | 43.6 | 46.5 | 51.0 | 57.9 |
| **3.50** | 36.2 | 40.9 | 44.5 | 47.4 | 52.0 | 58.9 |
| **4.00** | 36.8 | 41.5 | 45.3 | 48.3 | 52.8 | 59.9 |
| **4.50** | 37.2 | 42.1 | 45.9 | 49.0 | 53.7 | 60.0 |

**Examples for Zone 1b -800 watts (Burnup GWD/MTU)**

| Maximum Assembly Average Initial Enrichment (wt. % U-235) | 5 Years | 6 Years | 7 Years | 8 Years | 10 Years | 15 Years |
|---|---|---|---|---|---|---|
| **1.50** | 26.3 | 30.0 | 32.9 | 35.4 | 39.2 | 45.2 |
| **2.00** | 27.1 | 30.8 | 33.8 | 36.2 | 40.0 | 46.0 |
| **2.50** | 27.7 | 31.5 | 34.5 | 37.0 | 40.8 | 46.7 |
| **3.00** | 28.2 | 32.1 | 35.2 | 37.7 | 41.5 | 47.5 |
| **3.50** | 28.5 | 32.5 | 35.7 | 38.3 | 42.2 | 48.3 |
| **4.00** | 28.5 | 32.9 | 36.2 | 38.8 | 42.8 | 49.0 |
| **4.50** | 28.5 | 33.0 | 36.4 | 39.2 | 43.3 | 49.7 |

**Table 12-4**
**Fuel Qualification Table(s) (concluded)**
**Examples for Zone 2 -1100 watts (Burnup GWD/MTU)**

| Maximum Assembly Average Initial Enrichment (wt. % U-235) | 5 Years | 6 Years | 7 Years | 8 Years | 10 Years | 15 Years |
|---|---|---|---|---|---|---|
| **1.60** | 34.2 | 39.8 | 42.4 | 45.4 | 50.0 | 57.3 |
| **2.50** | 36.0 | 40.6 | 44.2 | 47.2 | 51.7 | 58.9 |
| **3.00** | 36.9 | 41.5 | 45.2 | 48.2 | 52.8 | 59.9 |
| **3.50** | 37.6 | 42.4 | 46.1 | 49.1 | 53.7 | 60.0 |
| **4.00** | 38.3 | 43.1 | 46.9 | 50.0 | 54.7 | 60.0 |
| **4.50** | 38.7 | 43.8 | 47.7 | 50.8 | 55.6 | 60.0 |

**Examples for Zone 3 -1500 watts (Burnup GWD/MTU)**

| Maximum Assembly Average Initial Enrichment (wt. % U-235) | 5 Years | 6 Years | 7 Years | 8 Years |
|---|---|---|---|---|
| **3.50** | 47.9 | 53.5 | 57.8 | 60.0 |
| **4.00** | 48.9 | 54.6 | 59.0 | 60.0 |
| **4.25** | 49.4 | 55.1 | 59.5 | 60.0 |
| **4.50** | 49.9 | 55.6 | 60.0 | 60.0 |

**Table 12-5**
**NFAH Thermal Qualification**

Minimum Cooling Time (years)

| NFAH | 30 GWD/MTU | 40 GWD/MTU | 50 GWD/MTU | 210 GWD/MTU |
|---|---|---|---|---|
| BPRA/VSI | 5 | 7 | 9 | - |
| TPA | | | | 2 |
| Criteria: Insert decay heat ≤ 9 watts | | | | |

**Table 12-6**
**B10 Specification for the NUHOMS®-32PTH Poison Plates**

| NUHOMS®-32PTH DSC Basket Type | Minimum B10 Areal Density, gm/cm$^2$ | |
|---|---|---|
| | Natural or Enriched Boron Aluminum Alloy / Metal Matrix Composite (MMC) (Type I) | Boral® (Type II) |
| A | 0.007 | 0.009 |
| B | 0.015 | 0.019 |
| C | 0.020 | 0.025 |
| D | 0.032 | N/A |
| E | 0.050 | N/A |

Note: The applicant will qualify new neutron absorbers or changes to existing absorbers per the information provided in Chapter 9 of the safety analysis report.

**Table 12-7**
**Maximum Initial Enrichment for Intact and Damaged Fuel Loading**

| Assembly Class and Type | Maximum Initial enrichment of U-235 as a Function of Soluble Boron Concentration and Fixed Poison Loading (Basket Type) | | | | |
|---|---|---|---|---|---|
| | Basket Type | Minimum Soluble Boron Concentration | | | |
| | | 2000 ppm | 2300 ppm | 2400 ppm | 2500 ppm |
| CE 14x14 Fuel Assembly (Intact Fuel Loading without BPRA) | A | 4.05 | 4.40 | 4.45 | 4.55 |
| | B | 4.55 | 4.90 | 5.00 | - |
| | C | 4.70 | 5.00 | - | - |
| | D | 5.00 | - | - | - |
| | E | - | - | - | - |
| WE 15x15 Fuel Assembly (with and without BPRAs) | A | 3.50 | 3.70 | 3.80 | 3.90 |
| | B | 3.80 | 4.10 | 4.20 | 4.30 |
| | C | 3.95 | 4.25 | 4.35 | 4.45 |
| | D | 4.20 | 4.50 | 4.70 | 4.80 |
| | E | 4.50 | 4.80 | 4.90 | 5.00 |
| WE 17x17 Fuel Assembly (with and without BPRAs) | A | 3.50 | 3.70 | 3.80 | 3.90 |
| | B | 3.80 | 4.10 | 4.20 | 4.30 |
| | C | 3.95 | 4.25 | 4.35 | 4.45 |
| | D | 4.20 | 4.50 | 4.60 | 4.70 |
| | E | 4.45 | 4.70 | 4.90 | 5.00 |
| CE 14x14 Fuel Assembly (Damaged Fuel Loading without BPRA) | A | 3.90 | 4.20 | 4.25 | 4.35 |
| | B | 4.35 | 4.70 | 4.80 | 4.90 |
| | C | 4.50 | 4.85 | 4.95 | 5.00 |
| | D | 4.85 | 5.00 | - | - |
| | E | 5.00 | - | - | - |
| WE 15x15 Fuel Assembly (with and without BPRAs – with BPRAs bounds all Damaged Fuel Loading) | A | 3.40 | 3.60 | 3.70 | 3.80 |
| | B | 3.75 | 4.00 | 4.10 | 4.20 |
| | C | 3.85 | 4.15 | 4.25 | 4.35 |
| | D | 4.10 | 4.40 | 4.50 | 4.60 |
| | E | 4.35 | 4.70 | 4.80 | 4.90 |
| WE 17x17 Fuel Assembly (with and without BPRAs – with BPRAs bounds all Damaged Fuel Loading) | A | 3.40 | 3.60 | 3.70 | 3.80 |
| | B | 3.75 | 4.00 | 4.10 | 4.20 |
| | C | 3.85 | 4.15 | 4.25 | 4.35 |
| | D | 4.10 | 4.40 | 4.50 | 4.60 |
| | E | 4.30 | 4.65 | 4.80 | 4.90 |

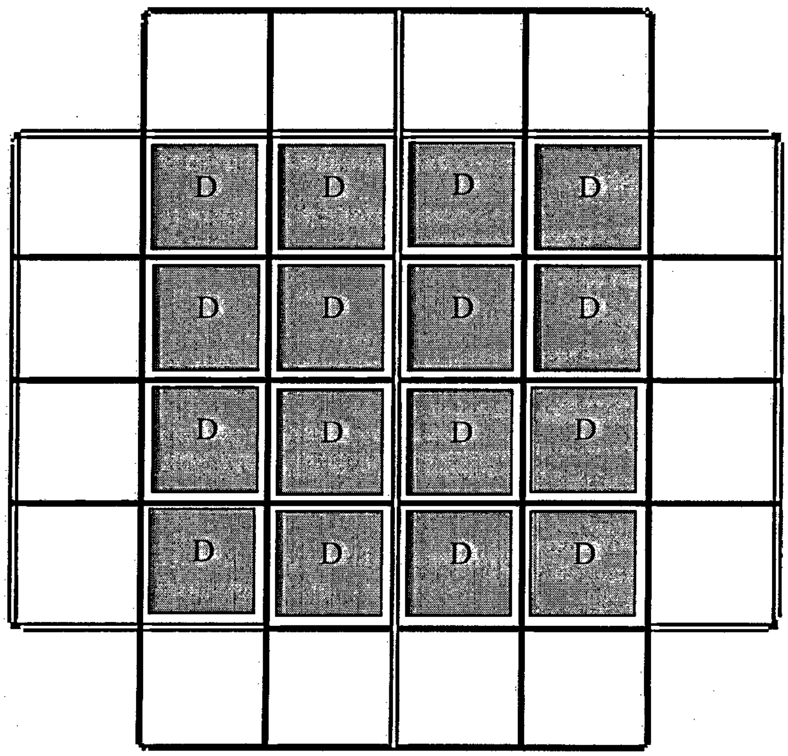
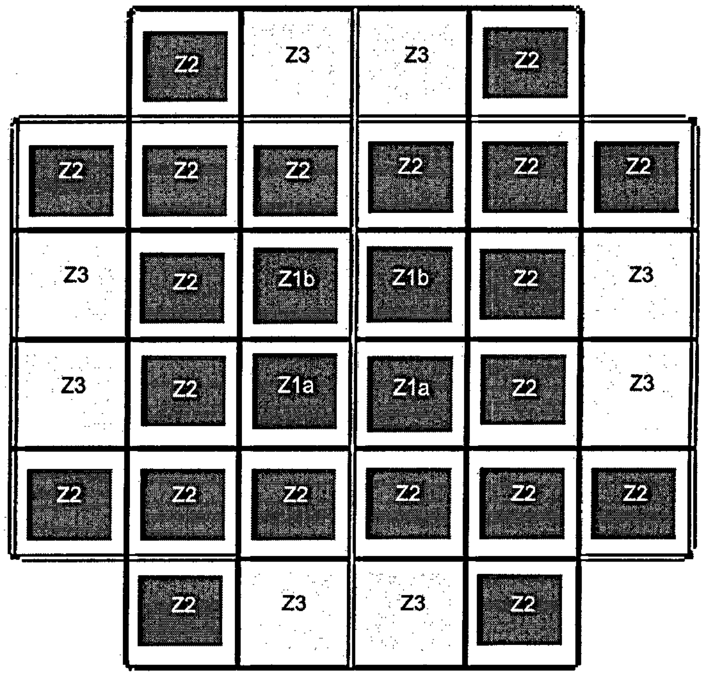



**Figure 12-1**
**Damaged Fuel Assembly Locations**




For CE 14x14 Assemblies

- $Q_{zi}$ is the maximum decay heat per assembly in zone i
- Total Decay Heat ≤ 33.8 kW
- 4 fuel assemblies in zone 1 with $Q_{z1}$ ≤0.775 kW
- 20 fuel assemblies in zone 2 with $Q_{z2}$ ≤ 1.068 kW
- 8 fuel assemblies in zone 3 with $Q_{z3}$ ≤ 1.5 kW

For other Assemblies

- $Q_{zi}$ is the maximum decay heat per assembly in zone i
- Total Decay Heat ≤ 34.8 kW
- 4 fuel assemblies in zone 1 with
  - total decay heat ≤ 3.2 kW
  - $Q_{z1a}$ ≤ 1.05 kW in the lower compartments
  - $Q_{z1b}$ ≤ 0.8 kW in the upper compartments
- 20 fuel assemblies in zone 2 with $Q_{z2}$ ≤ 1.1 kW
- 8 fuel assemblies in zone 3 with $Q_{z3}$ ≤ 1.5 kW

**Figure 12-2**
**Heat Load Zones**

The provisions of this Specification should not be interpreted as endorsing the failure to exercise the good practice of restoring systems or components to an appropriate status before entering an associated specified condition in the Applicability. However, in certain circumstances, failing to meet an SR will not result in SR 12.3.0.4 restricting a change in specified condition. When a system, subsystem, division, component, device, or variable is outside its specified limits, the associated SR(s) are not required to be performed, per SR 12.3.0.1, which states that Surveillances do not have to be performed on such equipment. When equipment does not meet the LCO, SR 12.3.0.4 does not apply to the associated SR(s) since the requirement for the SR(s) to be performed is removed. Therefore, failing to perform the Surveillance(s) within the specified Frequency does not result in an SR 12.3.0.4 restriction to changing specified conditions of the Applicability. However, since the LCO is not met in this instance, LCO 12.3.0.4 will govern any restrictions that may (or may not) apply to specified condition changes.

The provisions of SR 12.3.0.4 shall not prevent changes in specified conditions in the Applicability that are required to comply with ACTIONS. In addition, the provisions of SR 12.3.0.4 shall not prevent changes in specified conditions in the Applicability that are related to the unloading of a HSM-H or 32PTH DSC.

The precise requirements for performance of SRs are specified such that exceptions to SR 12.3.0.4 are not necessary. The specific time frames and conditions necessary for meeting the SRs are specified in the Frequency, in the Surveillance, or both. This allows performance of Surveillances when the prerequisite condition(s) specified in a Surveillance procedure require entry into the specified condition in the Applicability of the associated LCO prior to the performance or completion of a Surveillance. A Surveillance that could not be performed until after entering the LCO Applicability would have its Frequency specified such that it is not "due" until the specific conditions needed are met. Alternatively, the Surveillance may be stated in the form of a Note as not required (to be met or performed) until a particular event, condition, or time has been reached. Further discussion of the specific formats of SR annotation is found in Section 12.1.4, operation to proceed to a specified condition where other necessary post maintenance tests can be completed.

B 12.3.1 32PTH DSC FUEL INTEGRITY

B 12.3.1.1 32PTH DSC Vacuum Drying Time (Duration) and Pressure

BASES

BACKGROUND

A 32PTH DSC is placed in the spent fuel pool and loaded with fuel assemblies meeting the requirements of the Functional and Operating Limits. A shield plug is then placed on the 32PTH DSC. Subsequent operations involve moving the 32PTH DSC to the decontamination area and removing water from the 32PTH DSC. After the 32PTH DSC shield plug is secured, vacuum drying of the 32PTH DSC is performed, and the 32PTH DSC is backfilled with helium. During normal storage conditions, the fuel assemblies are stored in the 32PTH DSC with an inert helium atmosphere, which is a better conductor than nitrogen or vacuum, which results in lower fuel clad temperatures and provides an inert atmosphere during storage conditions.

32PTH DSC vacuum drying is utilized to remove residual moisture from the cavity after the 32PTH DSC has been drained of water. Any water which was not drained from the 32PTH DSC evaporates from fuel or basket surfaces due to the vacuum. This vacuum drying operation is aided by the temperature increase due to the heat generation of the fuel.

APPLICABLE SAFETY ANALYSIS

The confinement of radioactivity during the storage of spent fuel in a 32PTH DSC is ensured by the use of multiple confinement barriers and systems. The barriers relied upon are the fuel pellet matrix, the fuel cladding tubes in which the fuel pellets are contained, and the 32PTH DSC in which the fuel assemblies are stored. Long-term integrity of the fuel cladding depends on storage in an inert atmosphere. This protective environment is accomplished by removing water from the 32PTH DSC and backfilling the 32PTH DSC with an inert gas. The removal of water is necessary to prevent phase change–related pressure increase upon heatup. Time limits on vacuum drying >23.2 kW per Procedure A, >16 kW per Procedure B, and > 22.4 kW heat loads are required for keeping the fuel cladding under the maximum temperature limits. This SAR evaluates and documents that the 32PTH DSC confinement boundary is not compromised due to any normal, off-normal or accident condition postulated (SAR Chapter 3 and 11 structural analyses) and the fuel clad temperature remains below allowable values (SAR Chapter 4)

LCO

A stable vacuum pressure of < 3 torr further ensures that all liquid water has evaporated in the 32PTH DSC cavity, and that the resulting inventory of oxidizing gases in the 32PTH DSC is below 0.25 volume %.

APPLICABILITY

This is applicable to all 32PTH DSCs.

ACTIONS

The actions specified require establishment of a helium pressure of at least 0.5 atmosphere within the time limits specified in the LCO. The timeframe specified applies to the vacuum drying operations and the helium backfill operations. If the required vacuum can not be established within the timeframe specified in the Condition column of the Actions table, a helium atmosphere (with a pressure of at least 0.5 atmosphere) is to be established within 6 hours or perform an assessment and implementation of corrective actions to return the 32PTH DSC to an analyzed condition or reflood the DSC submerging all fuel assemblies. The 20 psig limit in the action section is conservatively below the maximum allowed blowdown pressure.

SURVEILLANCE REQUIREMENTS

Ensure a minimum oxidizing gas content.

REFERENCES

SAR Chapter 3 and 4

## B12.3.1 32PTH DSC FUEL INTEGRITY

### B 12.3.1.2 32PTH DSC Helium Backfill Pressure

BASES

BACKGROUND

A 32PTH DSC is placed in the spent fuel pool and loaded with fuel assemblies meeting the requirements of the Functional and Operating Limits. A shield plug is then placed on the 32PTH DSC. Subsequent operations involve moving the 32PTH DSC to the decontamination area and removing water from the 32PTH DSC. After the 32PTH DSC top shield plug is welded, vacuum drying of the 32PTH DSC is performed, and the 32PTH DSC is backfilled with helium. During normal storage conditions, the 32PTH DSC is backfilled with helium, which is a better conductor than nitrogen or vacuum, which results in lower fuel clad temperatures. The inert helium environment protects the fuel from potential oxidizing environments.

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APPLICABLE SAFETY ANALYSIS

Long-term integrity of the fuel cladding depends on storage in an inert atmosphere. SAR section 3.5 evaluates the effect of long term storage and short term temperature transients on fuel cladding integrity. Credit for the helium backfill pressure is taken to limit the potential for corrosion of the fuel cladding. SAR Chapter 4 evaluates the 32PTH DSC maximum pressure under normal, off-normal, and accident conditions.

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LCO

32PTH DSC backpressure is maintained within a range of pressure that will ensure maintenance of the helium backfill pressure over time and will not result in excessive 32PTH DSC pressure in normal, off-normal and accident conditions.

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APPLICABILITY

This specification is applicable to all 32PTH DSCs

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