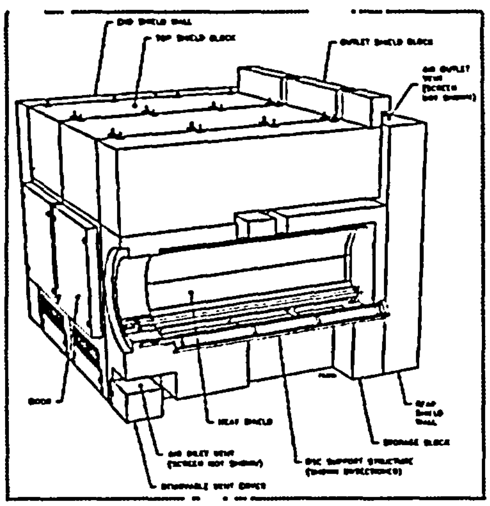
TRANSNUCLEAR

FINAL SAFETY ANALYSIS REPORT



72-1029

STANDARDIZED ADVANCED NUHOMS® HORIZONTAL MODULAR STORAGE SYSTEM FOR IRRADIATED NUCLEAR FUEL

NON-PROPRIETARY

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FOR THE

STANDARDIZED ADVANCED NUHOMS®

HORIZONTAL MODULAR STORAGE SYSTEM

FOR IRRADIATED NUCLEAR FUEL

NON-PROPRIETARY REPORT

By

Transnuclear, Inc.

Fremont, CA

February 2003

Executive Summary

This *Final* Safety Analysis Report *(FSAR)* provides the generic safety analysis for the standardized Advanced NUHOMS®[1] System for dry storage of light water reactor spent nuclear fuel assemblies. This system provides for the safe dry storage of spent fuel in a passive Independent Spent Fuel Storage Installation (ISFSI) which fully complies with the requirements of 10CFR72 and ANSI 57.9.

The FSAR describes the design and forms the basis for generic NRC certification of the standardized Advanced NUHOMS® System and will be used by 10CFR50/10CFR72 general license holders in accordance with 10CFR72 Subparts K and L. It is also suitable for reference in 10CFR72 site specific license applications.

The principal features of the standardized Advanced NUHOMS® System which differ from the previously approved NUHOMS® Systems are:

1. Modification to the C of C No. 1004 HSM (development of Advanced HSM, AHSM) to support qualification for sites with high seismic spectra and/or requirements for a significant reduction in ISFSI dose (e.g., due to congested reactor sites).

2. The AHSM configuration requires a minimum of three AHSMs tied together to limit sliding and uplift during a seismic event.

3. The Dry Shielded Canister used in this application, the 24PT1-DSC, is a modification to the FO-DSC (associated with C of C No. 9255 *and* Rancho Seco Materials License SNM-2510, Docket No. 72-11) with additional provisions allowing storage of intact and damaged fuel assemblies, along with control components in a single DSC.

The NUHOMS® System provides long-term interim storage for spent fuel assemblies which have been out of the reactor for a sufficient period of time and which comply with the criteria set forth in this Safety Analysis Report. The fuel assemblies are confined in a helium atmosphere by a dry shielded canister. The canister is protected and shielded by a massive reinforced concrete module. Decay heat is removed from the canister and the concrete module by a passive natural draft convection ventilation system.

The canisterized spent fuel assemblies are transferred from the plant's spent fuel pool to the concrete storage modules located at the ISFSI in a transfer cask. The cask is aligned with the storage module and the canister is inserted into the module by means of a hydraulic ram. The NUHOMS® System is a totally passive installation that is designed to provide shielding and safe confinement of spent fuel for a range of postulated accident conditions and natural phenomena.

The NUHOMS® System OS197 Cask (C of C No. 1004) is used for transfer operations for the Advanced NUHOMS® System. Evaluations of this cask in this application is limited to those areas where existing analysis (in the aforementioned C of C) is not bounding.

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[1] NUHOMS® is a registered trademark of Transnuclear, Inc.

LIST OF ACRONYMS

24PT1-DSC	PWR, 24 Fuel Assembly, Transportable Dry Shielded Canister
ACI	American Concrete Institute
AHSM	Advanced Horizontal Storage Module
AISC	American Institute of Steel Construction
ALARA	As Low as Reasonably Achievable
ANS	American Nuclear Society
ANSI	American National Standards Institute
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
AWS	American Welding Society
CFR	Code of Federal Regulations
CG	Center of Gravity
C of C	Certificate of Compliance
DBT	Design Basis Tornado
DE	Design Earthquake
DOE	Department of Energy
DSC	Dry Shielded Canister
EPRI	Electric Power Research Institute
FO-DSC	Fuel Only, Dry Shielded Canister, 10CFR 71 C of C 71-9255, Rancho Seco Docket 72-11
FSAR	Final Safety Analysis Report
GTCC	Greater Than Class C
HAC	Hypothetical Accident Conditions
HSM	Horizontal Storage Module
ID	Inside Diameter
IFBA	Integral Fuel and Burnable Absorber
ISFSI	Independent Spent Fuel Storage Installation
ISG	Interim Staff Guidance

LIST OF ACRONYMS

ITS	Important-to-Safety
LCO	Limiting Condition for Operation
LWR	Light Water Reactor
MOX	Mixed Oxide
MP187	MP187 Multi-Purpose Cask, 10CFR 71 C of C 71-9255
MRS	Monitored Retrieval Storage
MTU	Metric Tonne Uranium
MWD	Megawatt Days
NDE	Non Destructive Examination
NFAH	Non Fuel Assembly Hardware
NITS	Not-Important-To-Safety
NOC	Normal Operating Conditions
NRC	Nuclear Regulatory Commission
NS3	Trade name for Proprietary Solid Neutron Shielding Material
NSA	Neutron Source Assembly
OD	Outside Diameter
OS197	On-Site Transfer Cask, 10CFR 72 C of C #72-1004
PWR	Pressurized Water Reactor
QA	Quality Assurance
RCCA	Rod Cluster Control Assembly
RG	Regulatory Guide (published by USNRC)
SAR	Safety Analysis Report
SC	Stainless Steel Clad
SFA	Spent Fuel Assembly
SMUD	Sacramento Municipal Utilities District
SR	Surveillance Requirement
SSE	Safe Shutdown Earthquake

LIST OF ACRONYMS

TC	Transfer Cask
TP	Thimble Plug
TS	Technical Specification
USL	Upper Sub-Critical Limit
VDS	Vacuum Drying System
WE	Westinghouse
ZPA	Zero Period Acceleration

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1. GENERAL INFORMATION

This Safety Analysis Report (SAR) describes the design and forms the licensing basis for 10CFR 72, Subpart L certification of the Advanced NUHOMS® System dry spent fuel storage system. The Advanced NUHOMS® System provides for the horizontal storage of spent Pressurized Water Reactor (PWR) fuel assemblies in a dry shielded canister (24PT1-DSC) that is placed in an Advanced Horizontal Storage Module (AHSM). The Advanced NUHOMS® System is designed to be installed in an Independent Spent Fuel Storage Installation (ISFSI) at power reactor sites under the provision of a general license in accordance with 10CFR 72, Subpart K. This system has been specifically optimized for those sites with high seismic levels, limited space, and needs for superior radiation shielding performance.

The QA program applicable to this design satisfies the requirements of 10CFR 72, Subpart G and is described in Chapter 13. The format of this SAR follows the guidance of NRC Regulatory Guide 3.61 [1.2]. To facilitate NRC review of this application, this SAR has been prepared in compliance with the information and methods defined in NUREG-1536 [1.3], "Standard Review Plan for Dry Cask Storage Systems".

The Advanced NUHOMS® System is based on, and improves upon, the Standardized NUHOMS® System described in Certificate of Compliance (C of C) 72-1004 [1.9]. The 24PT1-DSC included in this application is nearly identical to that previously licensed for transportation in the NUHOMS® MP187 package (C of C 71-9255 [1.5]) and the Sacramento Municipal Utility District (SMUD) Rancho Seco Plant site specific license for on-site storage of spent fuel under 10CFR 72 (SNM-2510; Docket No. 72-11 [1.7]). The analysis methodology and criteria presented in this SAR are the same as those used in the above C of Cs.

The 24PT1-DSC has been modified from the FO-DSC [1.5] configuration to improve its resistance to corrosion in marine environments and to permit storage of control components integral with the fuel and/or damaged spent fuel assemblies. Protection afforded the public has been increased relative to the earlier design by increasing the strength of the concrete AHSM to support higher seismic loads and by substantially reducing radiation dose rates. Details of the system design, analyses, operation, and margins are provided in the remainder of this SAR.

Definitions of key terms used in this SAR are provided in Section 12.1.1.

1.1 Introduction

The type of fuel to be stored in the Advanced NUHOMS® System is Light Water Reactor (LWR) fuel of the PWR type. The Advanced NUHOMS® System accommodates up to 24 PWR fuel assemblies with stainless steel or zircaloy cladding, uranium dioxide (UO_2) or U-Pu mixed-oxide (MOX) fuel pellets, Integral Fuel Burnable Absorber (IFBA) assemblies, and Non-Fuel Assembly Hardware (NFAH). Provisions have been made, as discussed in Chapter 2, for storage of up to four stainless steel clad damaged fuel assemblies in lieu of an equal number of undamaged fuel assemblies or one failed MOX assembly with no other failed assemblies in the 24PT1-DSC. The physical and radiological characteristics of these payloads are provided in Chapter 2.

The Advanced NUHOMS® System consists of the following components (shown in Figure 1.1-1 and Figure 1.1-2):

- An Advanced Horizontal Storage Module (AHSM) that provides spent fuel decay heat removal, physical protection and radiological protection for the 24PT1-DSC. The AHSM consists primarily of thick concrete walls, a steel support structure for the 24PT1-DSC, and a thick concrete door. Each AHSM includes thermal monitoring instrumentation.

- A Dry Shielded Canister (24PT1-DSC) that provides confinement, an inert environment, structural support, and criticality control for 24 PWR fuel assemblies. The 24PT1-DSC shell is a welded stainless steel pressure vessel that includes thick shield plugs at either end to maintain occupational exposures ALARA. The 24PT1-DSC basket consists of spacer discs and support rods for structural support, geometry control, and heat transfer; and poisoned guidesleeves to aid in the insertion of fuel assemblies and to maintain subcriticality.

- AHSMs are arranged in arrays to minimize space and maximize self-shielding. Adjacent AHSMs are keyed and tied to provide maximum resistance to extreme environmental conditions including high seismic loads. The 24PT1-DSC is longitudinally restrained to prevent movement during seismic events. Arrays are fully expandable to permit modular expansion in support of operating power plants.

- The AHSM provides the bulk of the radiation shielding for the 24PT1-DSC. Thick concrete supplemental shield walls are used at either end of an AHSM array and along the back wall of single-row arrays to minimize radiation dose rates both onsite and offsite.

Approval of the Advanced NUHOMS® System components described above is sought under the provisions of 10CFR 72, Subpart L for use under the general license provisions of 10CFR 72, Subpart K. The components are intended for storage on a reinforced concrete pad at a nuclear power plant. In addition to these components, the system requires use of an onsite transfer cask, transfer trailer, and other auxiliary equipment that is described in this SAR. This equipment was previously certified under C of C 72-1004 and is not considered part of the Advanced NUHOMS® System subject to approval. Sufficient information for the transfer system and auxiliary equipment is included in this SAR to demonstrate that means for safe operation of the system are provided.

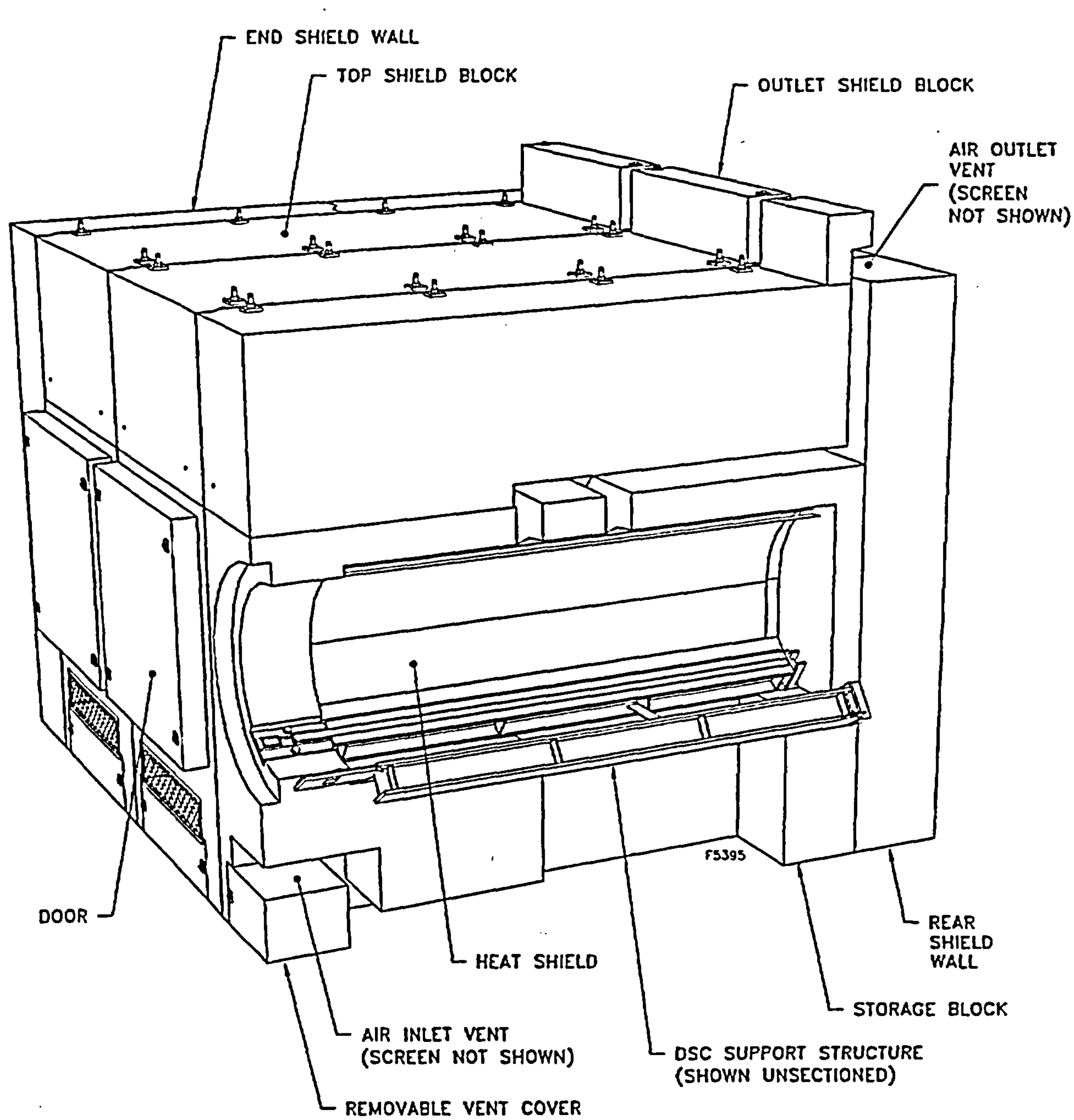
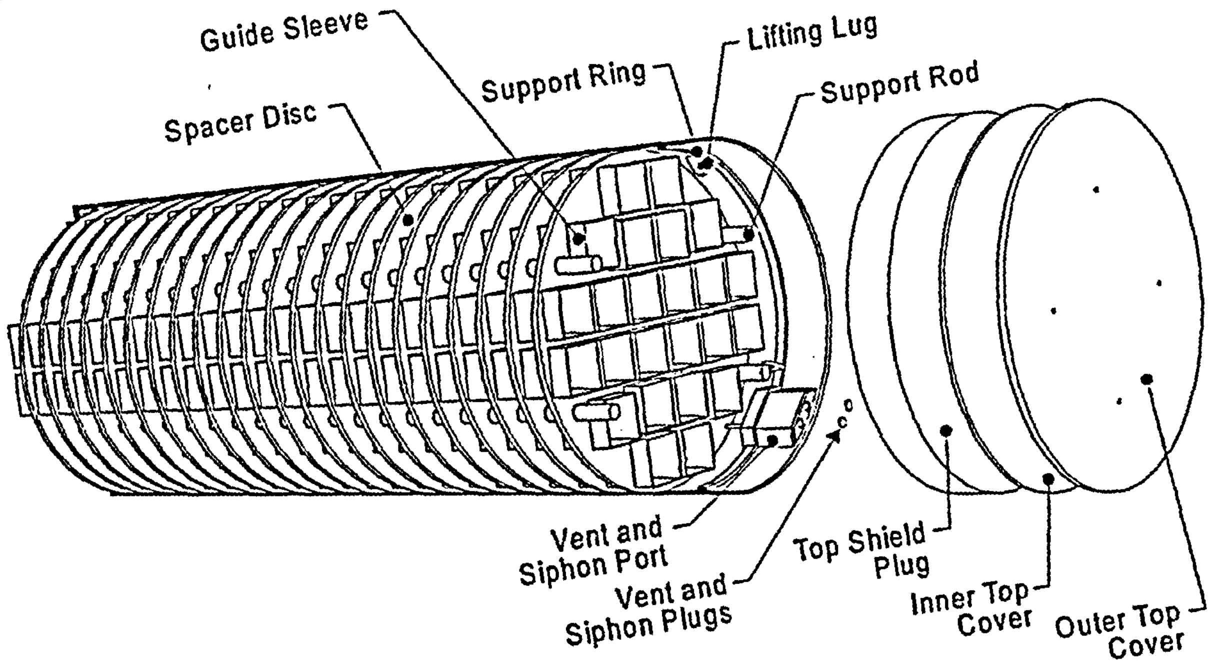


Figure 1.1-1
Advanced NUHOMS® System Horizontal Storage Module



Note: Bottom end of 24PT1-DSC not shown.

Figure 1.1-2
Advanced NUHOMS® System 24PT1-DSC

1.2 General Description of the Advanced NUHOMS® System

The Advanced NUHOMS® System provides for the horizontal, dry storage of canisterized Spent Fuel Assemblies (SFAs) in a concrete AHSM. The storage system components consist of a reinforced concrete AHSM and a stainless steel 24PT1-DSC confinement vessel which holds the SFAs. The general arrangement of the Advanced NUHOMS® System components is shown in Figure 1.2-1 and Figure 1.2-2. The defined ASME Code Boundaries for the 24PT1-DSC are shown in Figure 1.2-3.

In addition to these storage system components, the Advanced NUHOMS® System also utilizes transfer equipment to move the 24PT1-DSCs from the plant's fuel/reactor building, where they are loaded with SFAs and readied for storage, to the AHSMs where they are stored. This transfer system consists of a transfer cask, a lifting yoke, a hydraulic ram system, a prime mover for towing, a transfer trailer, a cask support skid, and a skid positioning system. This transfer system interfaces with the existing plant fuel pool, the cask handling crane, the site infrastructure (i.e. roadways and topography) and other site specific conditions and procedural requirements. Auxiliary equipment such as a cask/canister annulus seal, a vacuum drying system and an automated welding system are also used to facilitate canister loading, draining, drying, inerting, and sealing operations. This SAR addresses the design and analysis of the storage system components, including the 24PT1-DSC and the AHSM, which are important to safety in accordance with 10CFR 72. The transfer system and auxiliary equipment for the Advanced NUHOMS® System has been previously licensed under C of C 72-1004 [1.6].

During dry storage of the spent fuel, no active systems are required for the removal and dissipation of the decay heat from the fuel. The Advanced NUHOMS® System is designed to transfer the decay heat from the fuel to the canister, and from the canister to the surrounding air by conduction, radiation and natural convection.

Each canister is identified by a Model Number, 24PT1-XXX-VYYY, where XXX identifies the site for which the 24PT1-DSC was fabricated, V designates the 24PT1-DSC fabricator, and YYY is a sequential number corresponding to a specific canister.

The Advanced NUHOMS® System components do not include receptacles, valves, sampling ports, impact limiters, protrusions, or pressure relief systems.

1.2.1 Advanced NUHOMS® System Characteristics

1.2.1.1 Dry Shielded Canister (24PT1-DSC)

The key design parameters of the 24PT1-DSC are listed in Table 1.2-1. The cylindrical shell and the top and bottom cover plate assemblies form the pressure retaining confinement boundary for the spent fuel. The 24PT1-DSC is equipped with two shield plugs so that occupational doses at the ends are minimized for drying, sealing, handling, and transfer operations.

The 24PT1-DSC has redundant welds which join the shell and the top cover plate assemblies to form the confinement boundary. The cylindrical shell and inner bottom cover plate confinement boundary welds are fully compliant to Subsection NB of the ASME Code and are made during fabrication. The top closure confinement welds are made after fuel loading. Both top plug penetrations (siphon and vent ports) are welded after drying operations are complete. There are no credible accidents which could breach the confinement boundary of the 24PT1-DSC as documented in Chapter 11.

The 24PT1-DSC is designed for a maximum heat load of 14 kW. The internal basket assembly contains a storage position for each fuel assembly. The criticality analysis credits the fixed borated neutron absorbing material Boral™, placed between the fuel assemblies. The analysis does not take credit for soluble boron during loading operations. Subcriticality during wet loading, drying, sealing, transfer, and storage operations is maintained through the geometric separation of the fuel assemblies by the basket assembly and the neutron absorbing capability of the 24PT1-DSC materials.

Structural support for the PWR fuel and basket guidesleeves is provided by circular spacer disc plates. Axial support for the basket assembly is provided by four support rods. The support rods extend over the full length of the cavity with allowance provided for thermal growth of the support rods in the axial direction.

Stainless steel fuel spacers are used to center the short 14x14 Westinghouse fuel in the 24PT1-DSC. Stainless steel screened confinement cans (failed fuel cans), placed inside the 24PT1-DSC guidesleeves, are provided for storage of damaged fuel assemblies.

Dimensions of the 24PT1-DSC components described in the text and provided in figures and tables of this SAR are nominal dimensions for general system description purposes. Actual design dimensions are contained in the drawings in Section 1.5.2 of this SAR. For a discussion of the contents authorized to be stored in this DSC, see Section 2.1.1 of this SAR.

1.2.1.2 Advanced Horizontal Storage Module (AHSM)

Each AHSM provides a self-contained modular structure for storage of spent fuel canisterized in a 24PT1-DSC. The AHSM is constructed from reinforced concrete and structural steel. The thick concrete roof and walls provide substantial neutron and gamma shielding. Contact doses for the AHSM are designed to be ALARA. The key design parameters of the AHSM are listed in Table 1.2-1.

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

The AHSMs provide an independent, passive system with substantial structural capacity to ensure the safe dry storage of SFAs. To this end, the AHSMs are designed to ensure that normal transfer operations and postulated accidents or natural phenomena do not impair the 24PT1-DSC or pose a hazard to the public or plant personnel.

The AHSM provides a means of removing spent fuel decay heat by a combination of radiation, conduction and convection. Ambient air enters the AHSM through a ventilation inlet opening located in the lower front wall of the AHSM and circulates around the 24PT1-DSC and the heat shield. Air exits through an air outlet opening located in the top of the AHSM. Thermal monitoring is used to provide indication of AHSM performance or a blocked vent.

The AHSM is designed to remove up to 24 kW of decay heat from the 24PT1-DSC. Decay heat is rejected from the 24PT1-DSC to the AHSM air space by convection and then removed from the AHSM by natural circulation air flow (as discussed above, the 24PT1-DSC is currently limited to a total heat load of 14 kW). Heat is also radiated from the 24PT1-DSC surface to the heat shield and AHSM walls where the natural convection air flow and conduction through the walls aids in the removal of the decay heat. The passive cooling system for the AHSM is designed to assure that SFA peak cladding temperatures during long term storage remain below acceptable limits to ensure fuel cladding integrity.

The AHSMs are installed on a load bearing foundation which consists of a reinforced concrete basemat on a subgrade suitable to support the loads. The AHSMs are "tied" to adjacent AHSMs but are not tied to the basemat.

Dimensions of the AHSM components described in the text and provided in figures and tables of this SAR are nominal dimensions for general system description purposes. Actual design dimensions are contained in the drawings in Section 1.5.2 of this SAR.

1.2.1.3 Transfer Systems

1.2.1.3.1 On-Site Transfer Cask

The transfer cask used in the Advanced NUHOMS® System provides shielding and protection from potential hazards during 24PT1-DSC loading and closure operations and transfer to the AHSM. The transfer cask included in this SAR is the NUHOMS® OS-197 cask (C of C 72-1004) which is limited to on-site use under 10CFR 72. All information relating to design parameters for the transfer cask is located in the NUHOMS® FSAR [1.6].

1.2.1.3.2 Transfer Equipment

Transfer Trailer: The typical transfer trailer for the Advanced NUHOMS® System consists of a heavy industrial trailer used to transfer the empty cask, support skid and the loaded transfer cask between the plant's fuel/reactor building and the ISFSI. The trailer is designed to ride as low to the ground as possible to minimize the overall AHSM height and the transfer cask height during 24PT1-DSC transfer operations. The trailer is equipped with four hydraulic leveling jacks to provide vertical alignment of the cask with the AHSM. The trailer is towed by a conventional heavy haul truck tractor or other suitable prime mover.

Cask Support Skid: The cask support skid for the Advanced NUHOMS® System is the same as described in the FSAR [1.6] for the standard NUHOMS® System. Key design features include:

The skid is mounted on a surface with sliding support bearings and hydraulic positioners to provide alignment of the cask with the AHSM. Brackets with locking bolts are provided to prevent movement during trailer towing.

The hydraulic ram may be mounted on the skid or, as an option, the ram can be set-up using a frame structure bolted to the cask bottom and a rear support tripod.

The cask support skid is mounted on a low profile heavy haul industrial trailer.

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

Hydraulic Ram: The hydraulic ram system consists of a hydraulic cylinder with a capacity and a reach sufficient for 24PT1-DSC insertion into and retrieval from the AHSM. The design of the ram support system provides a direct load path for the hydraulic ram reaction forces during 24PT1-DSC insertion and retrieval. The system uses a rear ram support for alignment of the ram to the 24PT1-DSC, and trunnions as the front support. The design provides positive alignment of the major components during 24PT1-DSC insertion and retrieval.

1.2.2 Operational Features

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

1.2.2.1 Dry Run Operations

A dry run utilizing a 24PT1-DSC loaded with mock-up fuel assemblies will be performed prior to loading the first canister by each licensee to demonstrate the adequacy of training, familiarity of system components and operational procedures. Mock-up fuel assemblies shall provide a representation of the maximum fuel assembly cross sectional envelope and provide a reasonable approximation of fuel assembly length and weight. The licensee shall determine the quantity of mock-up fuel assemblies required for the dry run to demonstrate that the loading and unloading processes are sound and the operations personnel are adequately trained.

The loading and unloading operations which have an impact on safety will be verified and recorded according to the requirements detailed in Chapter 8. The operations include loading and identifying fuel assemblies, ensuring the fuel assemblies meet the fuel acceptance criteria, drying, backfilling and pressurizing the canister, gas sampling and transferring the loaded canister to the AHSM. Additionally, the ability to weld the top cover plates and open a sealed canister shall be demonstrated.

1.2.2.2 SFA Loading Operations

The primary operations (in sequence of occurrence) for the Advanced NUHOMS® System are:

1. Transfer Cask Preparation
2. 24PT1-DSC Preparation
3. Place 24PT1-DSC in Transfer Cask
4. Fill Transfer Cask/24PT1-DSC Annulus with Water and Seal
5. Fill 24PT1-DSC Cavity with Water
6. Lift Transfer Cask and Place in Fuel Pool
7. Spent Fuel Loading
8. Top Shield Plug Placement
9. Lifting Transfer Cask from Pool
10. Inner Top Cover Plate Sealing
11. Vacuum Drying and Backfilling
12. Outer Top Cover Plate Sealing
13. Transfer Cask/24PT1-DSC Annulus Draining and Transfer Cask Top Cover Plate Placement
14. Place Loaded Transfer Cask on Transfer Skid/Trailer
15. Move Loaded Transfer Cask to AHSM
16. Transfer Cask/AHSM Preparation and Alignment
17. Insertion of 24PT1-DSC into AHSM
18. AHSM 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.

<u>24PT1-DSC Preparation</u>: The internals and externals of the 24PT1-DSC are inspected and cleaned if necessary. This ensures that the 24PT1-DSC will meet plant cleanliness requirements for placement in the spent fuel pool.

<u>Place 24PT1-DSC in Transfer Cask</u>: The empty 24PT1-DSC is inserted into the transfer cask.

<u>Fill Transfer Cask/24PT1-DSC Annulus with Water and Seal</u>: The transfer cask/24PT1-DSC annulus is filled with uncontaminated water and is then sealed prior to placement in the pool. This prevents contamination of the 24PT1-DSC outer surface and the transfer cask inner surface by the pool water.

<u>Fill 24PT1-DSC Cavity with Water</u>: The 24PT1-DSC cavity is filled with pool or demineralized water to prevent an in-rush of water as the transfer cask is lowered into the pool.

<u>Lift Transfer Cask and Place in Fuel Pool</u>: The transfer cask, with the water-filled 24PT1-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.

<u>Spent Fuel Loading</u>: Spent fuel assemblies are placed into the 24PT1-DSC. This operation is identical to that presently used at plants for shipping cask loading.

<u>Top Shield Plug Placement</u>: This operation consists of placing the top shield plug into the 24PT1-DSC using the plant's crane or other suitable lifting device.

<u>Lifting Transfer Cask from Pool</u>: 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. The transfer cask liquid neutron shield, if left unfilled for weight reduction, shall be filled.

<u>Inner Top Cover Plate Sealing</u>: Using a pump, the water contained in the space above the top shield plug is drained. The inner top cover plate is placed onto the top shield plug and is welded to the shell. This weld provides the inner seal for the 24PT1-DSC.

<u>Vacuum Drying and Backfilling</u>: The initial blowdown of the 24PT1-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 24PT1-DSC is then evacuated to remove the residual liquid water and water vapor in the cavity. When the system pressure has stabilized, the 24PT1-DSC is backfilled with helium and re-evacuated. After the second evacuation, the 24PT1-DSC is again backfilled with helium and slightly pressurized. A helium sniff test of the inner seal weld is then performed. The helium pressure is then reduced, the helium lines removed, and the drain and fill port penetrations are welded closed.

Outer Top Cover Plate Sealing: After helium backfilling, the 24PT1-DSC outer top cover plate/vent and siphon cover plates are installed by using a partial penetration weld between the outer top cover plate and the shell. Following completion of the root pass a vacuum is drawn on the cavity formed between the inner and outer cover plates and a helium leak detector is used to verify that the primary confinement welds are leaktight per ANSI N14.5. The outer cover plate or shell weld and inner cover plate welds provide redundant seals at the upper end of the 24PT1-DSC.

Transfer Cask/24PT1-DSC Annulus Draining and Transfer Cask Top Cover Plate Placement: The transfer cask/24PT1-DSC annulus is drained. A swipe is then taken over the 24PT1-DSC exterior at the top cover plate and the upper portion of the shell. Demineralized water is flushed through the transfer cask/24PT1-DSC annulus, as required, to remove any contamination left on the 24PT1-DSC exterior. The transfer cask top cover plate is installed, using the plant's crane or other suitable lifting device, and bolted closed.

Place Loaded Transfer Cask on Transfer Skid/Trailer: The 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 AHSM: 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 AHSM into which the 24PT1-DSC is to be transferred.

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

Insertion of 24PT1-DSC into AHSM: After final alignment of the transfer cask, AHSM, and hydraulic ram, the 24PT1-DSC is pushed into the AHSM by the hydraulic ram.

AHSM Closure: Install 24PT1-DSC seismic restraint and install AHSM door. Seismic restraint readjustment will be performed after the 24PT1-DSC and AHSM rails have reached thermal equilibrium (approximately one week).

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, Boral™, in the 24PT1-DSC basket. 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 Advanced NUHOMS® System. The coating materials used in the design of the 24PT1-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 Advanced NUHOMS® System is a totally passive system so that consideration of operation shutdown modes is unnecessary.

1.2.2.3.4 Instrumentation

The Advanced NUHOMS® 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 24PT1-DSC for pressure or temperature during normal operations. The 24PT1-DSC is conservatively designed to perform its confinement function during all worst case normal, off-normal, and accident conditions. AHSM thermal monitoring is provided to meet the requirements of Chapter 12.

1.2.2.3.5 Maintenance and Surveillance

All maintenance and surveillance tasks are described in Chapter 9.

1.2.3 24PT1-DSC Contents

The 24PT1-DSC is designed to store up to 24 intact PWR Westinghouse 14x14 (WE 14x14) fuel assemblies with or without Rod Cluster Control Assemblies (RCCAs), Neutron Source Assemblies (NSAs), or Thimble Plug Assemblies (TPAs). The 24PT1-DSC is also designed for storage of up to 20 intact fuel assemblies plus four damaged fuel assemblies in specially designed failed fuel cans. A description of the fuel assemblies including the damaged fuel assemblies is provided in Chapter 2. The maximum allowable initial enrichment of the fuel to be stored is 4.05 weight % U-235 and the maximum burnup is 45,000 MWd/MTU. The fuel must be cooled at least 10 years prior to storage. The 24PT1-DSC design limits WE 14x14 fuel assemblies to a maximum heat load of 0.583 kW per assembly for a total of 14 kW per 24PT1-DSC. This limitation is required to ensure that the heat load per foot of 24PT1-DSC length does not exceed that analyzed in this SAR for the short length fuel.

The criticality control features of the Advanced NUHOMS® 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 Advanced NUHOMS® 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 24PT1-DSC cavity is addressed in Chapter 4.

Table 1.2-1
Key Design Parameters of the Advanced NUHOMS® System Components

Dry Shielded Canister (24PT1-DSC)	
Overall Length (in)	186.5 (max)
Outside Diameter (in)	67.2
Cavity Length (in)	167.0
Shell Thickness (in)	5/8
Design Weight of Loaded 24PT1-DSC (lbs.)	82,000
Materials of Construction	Stainless Steel Shell Assembly and Internals, Carbon Steel Shield Plugs (Top Plug Coated), Coated Carbon Steel Spacer Discs
Neutron Absorbing Material	Boral™
Internal Atmosphere	Helium

Advanced Horizontal Storage Module (AHSM):	
Overall length (without shield walls)	19'-7"
Overall width (without shield walls)	8'-5"
Overall height	20'7"
Total Weight not including 24PT1-DSC (lbs.)	320,000
Materials of Construction	Reinforced Concrete and Structural Steel
Heat Removal	Conduction, Convection, and Radiation

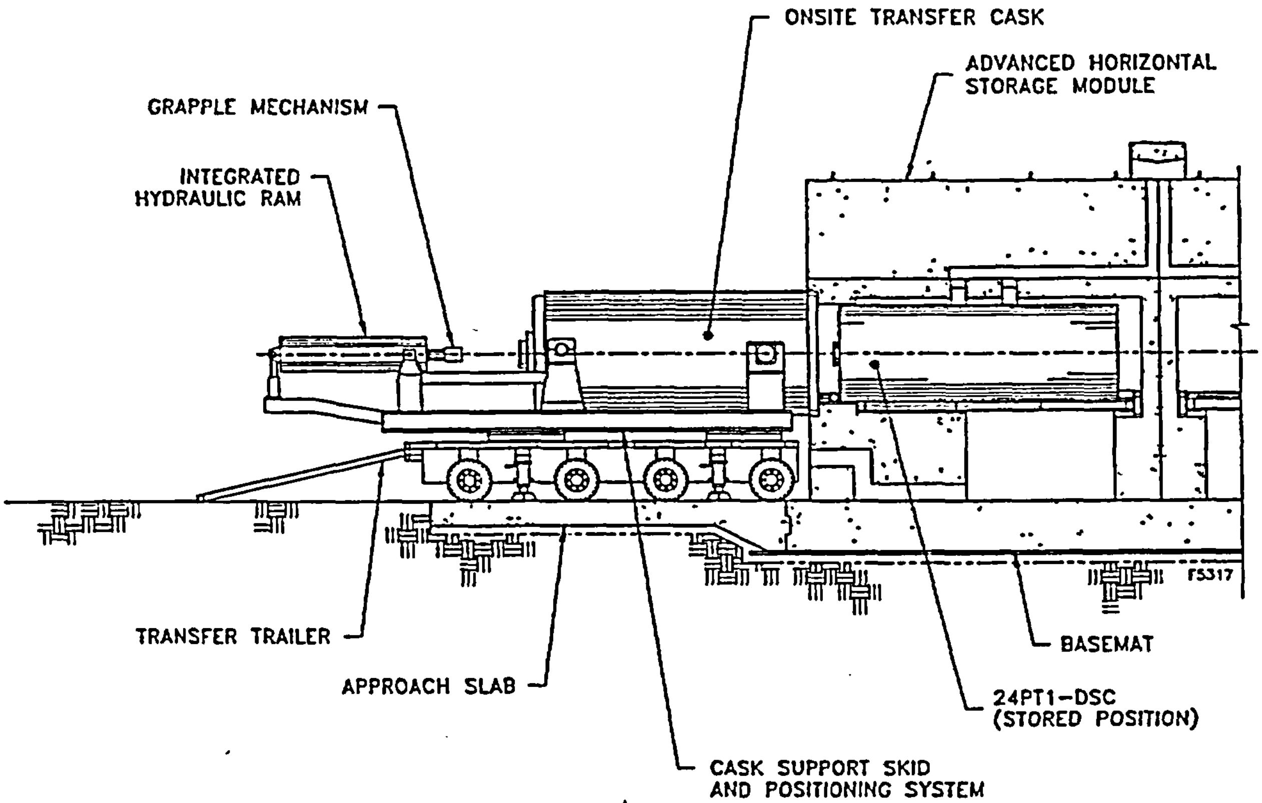


Figure 1.2-1
Advanced NUHOMS® System Components, Structures, and Transfer Equipment – Elevation View (Typical)

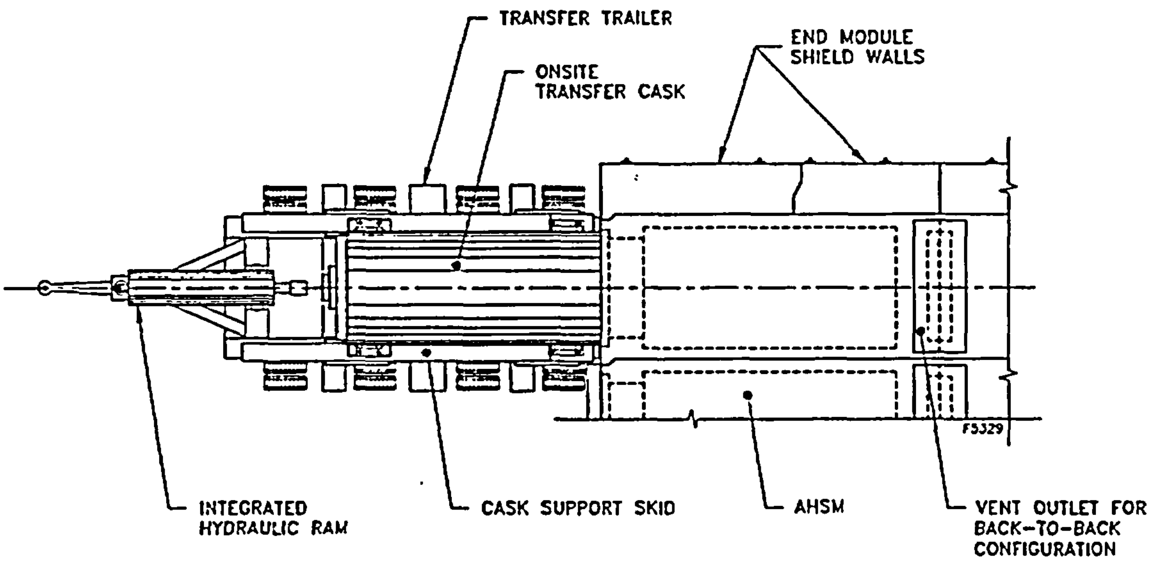


Figure 1.2-2
Advanced NUHOMS® System Components, Structures, and Transfer Equipment – Plan View (Typical)

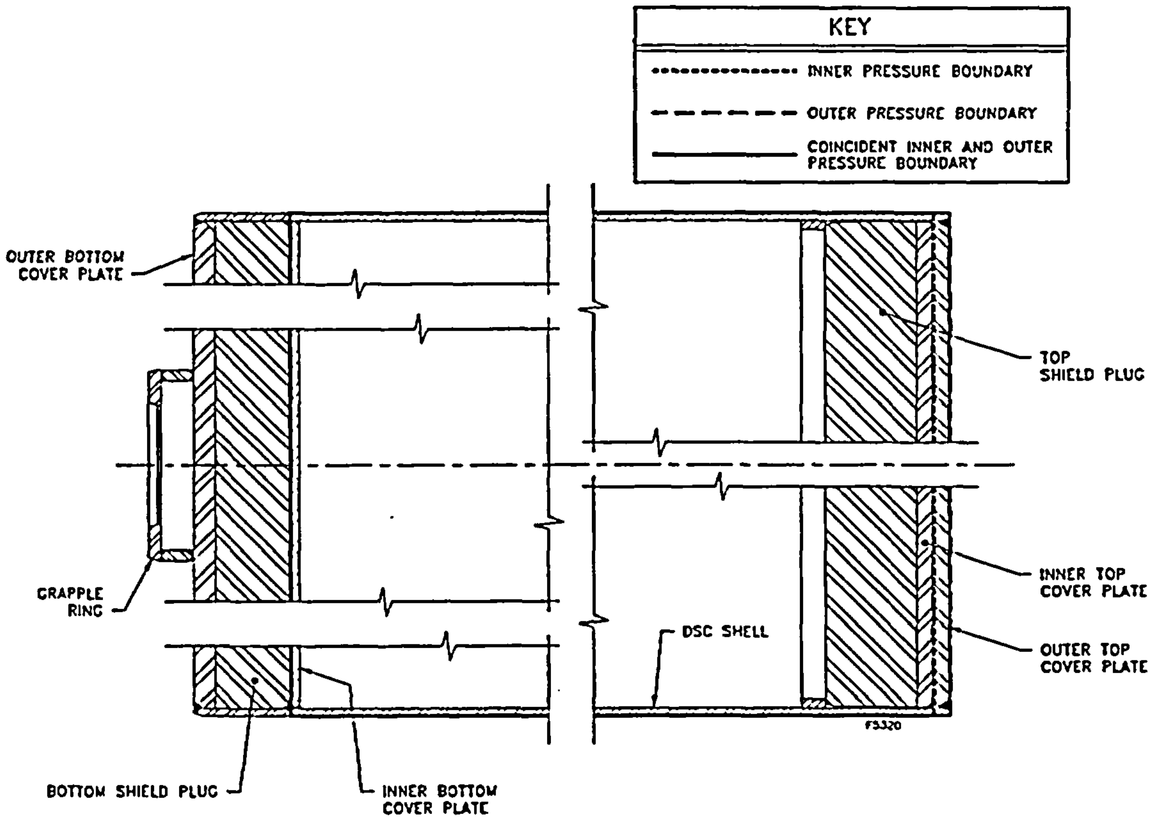


Figure 1.2-3
24PT1-DSC ASME Code Boundaries

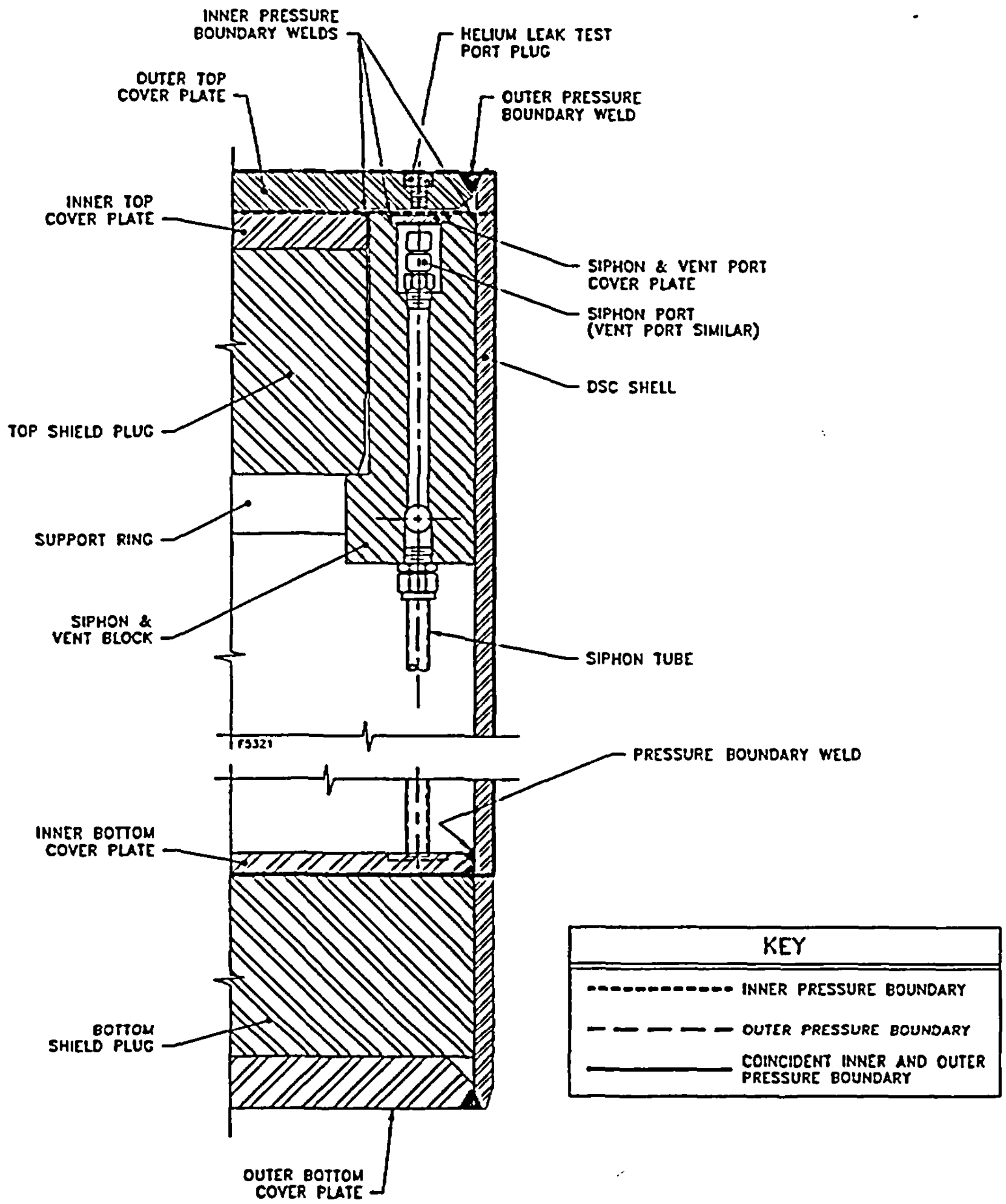


Figure 1.2-3
24PT1-DSC ASME Code Boundaries

(Concluded)

1.3 Identification of Agents and Contractors

The prime contractor for design and procurement of the Advanced NUHOMS® System components is Transnuclear, Inc. (TN) of Fremont, California. *TN* will subcontract the fabrication, testing, on-site construction, and QA services as necessary to qualified firms on a project specific basis in accordance with *TN* QA program requirements.

The design activities for the Advanced NUHOMS® Safety Analysis Report were performed by *TN* and subcontractors in accordance with *TN* QA program requirements. *TN* is responsible for the design and analysis of the 24PT1-DSC, the AHSM, the on-site transfer cask, and the associated transfer equipment.

Closure activities associated with welding the top cover plates on the 24PT1-DSC following fuel loading are typically performed by the licensee under the licensee's NRC approved QA program.

1.4 Generic Cask Arrays

The 24PT1-DSC containing the SFAs is transferred to, and stored in, an AHSM in the horizontal position. Multiple AHSMs are grouped together to form arrays whose size is determined to meet plant-specific needs. Arrays of AHSMs are arranged within the ISFSI site on a concrete basemat(s) with the entire area enclosed by a security fence. Individual AHSMs are arranged adjacent to each other. The decay heat for each AHSM is primarily removed by internal natural circulation flow and conduction through the AHSM walls. Figures 1.4-1, 1.4-2, and 1.4-3 show typical layouts for Advanced NUHOMS® ISFSIs which are capable of modular expansion to any capacity. These are typical layouts only and do not represent limitations in number of modules, number of rows, and orientation of modules in rows. An empty module is required at the end of an array to allow for future expansion. Back to back module configurations require expansion in pairs. Expansion can be accomplished as necessary by the licensee provided the criteria of 10CFR 72.104, 10CFR 72.106 and Chapter 12 are met. The parameters of interest in planning the installation layout are the configuration of the AHSM array and an area in front of each AHSM to provide adequate space for backing and aligning the transfer trailer. The minimum required array size to meet the high seismic design criteria is three AHSMs in a single row array (no maximum array size is specified, however, licensee evaluation of site requirements may impose a maximum array size). The licensee will install the basemat for the AHSMs. The basemat will provide sufficient space to allow for AHSM sliding during a seismic event.

Figure removed under 10 CFR 2.390

Figure 1.4-1
Typical Double Module Row Advanced NUHOMS® System ISFSI Layout

Figure removed under 10 CFR 2.390

Figure 1.4-2
Typical Single Module Row Advanced NUHOMS® System ISFSI Layout

Figure removed under 10 CFR 2.390

Figure 1.4-3
Typical Combined Single and Double Module Row Advanced NUHOMS® System ISFSI Layout

1.5 Supplemental Data

1.5.1 References

[1.1] 10CFR 72, Rules and Regulations, Title 10, Code of Federal Regulations - Energy, U.S. Nuclear Regulatory Commission, Washington, D.C., "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste."

[1.2] U.S. Nuclear Regulatory Commission, Regulatory Guide 3.61, Standard Format and Content for a Topical Safety Analysis Report for a Spent Fuel Dry Storage Cask, February 1989.

[1.3] U.S. Nuclear Regulatory Commission, "Standard Review Plan for Dry Cask Storage Systems," NUREG 1536, U.S. NRC (January 1997).

[1.4] Nuclear Regulatory Commission, Safety Evaluation Report of Safety Analysis Report for the Standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel, December 1994, USNRC Docket No. 72-1004, File NUH003.0103.02.

[1.5] *TN*, Safety Analysis Report for the NUHOMS® MP187 Multi-Purpose Cask, NUH-005, Revision *16, July 2002*, USNRC Docket No. 71-9255.

[1.6] TN West, Final Safety Analysis Report for the Standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel, Revision *6, November 2001*, File NUH003.0103, *USNRC Docket No. 72-1004.*

[1.7] Rancho Seco Independent Spent Fuel Storage Installation, *Final* Safety Analysis Report, Revision *0, November 2000, USNRC Docket No. 72-11.*

[1.8] 10CFR 71, Rules and Regulations, Title 10, Code of Federal Regulations - Energy, U.S. Nuclear Regulatory Commission, Washington, D.C., "Packaging and Transportation of Radioactive Material."

[1.9] NRC Certificate of Compliance 72-1004, NUHOMS® General License Spent Fuel Storage System, Amendment No. *4, February 2002.*

1.5.2 Drawings

- 24PT1-DSC: NUH-05-4010*NP*, Rev. *2*
- AHSM: NUH-03-4011*NP*, Rev. *1*

Figure removed under 10 CFR 2.390

ITEM NO	QTY REQ'D	PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION	MATERIAL SPECIFICATION

PARTS LIST

ALL DIMENSIONS ARE APPLICABLE AT 70°F AND ALL TOLERANCING APPLIES AFTER WELDING AND FINAL ASSEMBLY UNLESS NOTED OTHERWISE.

DIMENSIONS ARE IN INCHES AND DEGREES UNLESS NOTED OTHERWISE. DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH ASME Y14.5M-1994

BREAK AND DEBURR ALL SHARP EDGES

3rd ANGLE PROJECTION

DO NOT SCALE DRAWING

TRANSNUCLEAR

SAFETY ANALYSIS REPORT
GENERAL LICENSE
NUHOMS®24PT1-DSC
MAIN ASSEMBLY

FILE NO.	DWG NO.	SCALE	SHEET	REV NO.
NUH005 4010	NUH-05-4010NP	NONE	1 OF 3	3

Figure removed under 10 CFR 2.390

ALL DIMENSIONS ARE APPLICABLE AT 70°F AND ALL TOLERANCING APPLIES AFTER WELDING AND FINAL ASSEMBLY UNLESS NOTED OTHERWISE	TRANSNUCLEAR
DIMENSIONS ARE IN INCHES AND DEGREES UNLESS NOTED OTHERWISE. DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH ASME Y14.5M-1994	
BREAK AND DEBURR ALL SHARP EDGES	TITLE: SAFETY ANALYSIS REPORT GENERAL LICENSE NUHOMS® 24PT1-DSC MAIN ASSEMBLY
3rd ANGLE PROJECTION	
DO NOT SCALE DRAWING	FILE NO: NUH005 4010 · DWG NO: NUH-05-4010NP · SCALE: NONE · SHEET: 2 OF 3 · REV NO: 3

Figure removed under 10 CFR 2.390

ALL DIMENSIONS ARE APPLICABLE AT 70°F AND ALL TOLERANCING APPLIES AFTER WELDING AND FINAL ASSEMBLY UNLESS NOTED OTHERWISE.	TRANSNUCLEAR
DIMENSIONS ARE IN INCHES AND DEGREES UNLESS NOTED OTHERWISE DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH ASME Y14.5M-1994	
BREAK AND DEBURR ALL SHARP EDGES	SAFETY ANALYSIS REPORT GENERAL LICENSE NUHOMS®24PT1-DSC MAIN ASSEMBLY
3rd ANGLE PROJECTION	
DO NOT SCALE DRAWING	NUH005.4010 | NUH-05-4010NP | NONE | 3 OF 3 | 3

Figure removed under 10 CFR 2.390

ALL DIMENSIONS ARE APPLICABLE AT 70°F AND ALL TOLERANCING APPLIES AFTER WELDING AND FINAL MACHINING UNLESS NOTED OTHERWISE.	TRANSNUCLEAR				
DIMENSIONS ARE IN INCHES AND DEGREES UNLESS NOTED OTHERWISE DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH ASME Y14.5M-1994					
BREAK AND DEBURR ALL SHARP EDGES	TITLE: SAFETY ANALYSIS REPORT GENERAL LICENSE NUHOMS® ADVANCED HORIZONTAL STORAGE MODULE MAIN ASSEMBLY				
3rd ANGLE PROJECTION					
DO NOT SCALE DRAWING	FILE NO. NUH003 4011	DWG. NO. NUH-03-4011NP	SCALE NONE	SHEET 1 OF 5	REV. NO. 2

Figure removed under 10 CFR 2.390

ALL DIMENSIONS ARE APPLICABLE AT 70°F AND ALL TOLERANCING APPLIES AFTER WELDING AND FINAL MACHINING UNLESS NOTED OTHERWISE	TRANSNUCLEAR
DIMENSIONS ARE IN INCHES AND DEGREES UNLESS NOTED OTHERWISE DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH ASME Y14.5M-1994	
BREAK AND DEBURR ALL SHARP EDGES	SAFETY ANALYSIS REPORT GENERAL LICENSE NUHOMS© ADVANCED HORIZONTAL STORAGE MODULE MAIN ASSEMBLY
3rd ANGLE PROJECTION	
DO NOT SCALE DRAWING	NUH003 4011 | NUH-03-4011NP | NONE | 2 OF 3 | 2

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ALL DIMENSIONS ARE APPLICABLE AT 70°F AND ALL TOLERANCING APPLIES AFTER WELDING AND FINAL MACHINING UNLESS NOTED OTHERWISE.	TRANSNUCLEAR
DIMENSIONS ARE IN INCHES AND DEGREES UNLESS NOTED OTHERWISE DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH ASME Y14.5M-1994	
BREAK AND DEBURR ALL SHARP EDGES	SAFETY ANALYSIS REPORT GENERAL LICENSE NUHOMS® ADVANCED HORIZONTAL STORAGE MODULE MAIN ASSEMBLY
3rd ANGLE PROJECTION	
DO NOT SCALE DRAWING	NUH003.4011 / NUH-03-4011NP / NONE / 3 OF 3 / 2

Figure removed under 10 CFR 2.390

ALL DIMENSIONS ARE APPLICABLE AT 70°F AND ALL TOLERANCING APPLIES AFTER WELDING AND FINAL MACHINING UNLESS NOTED OTHERWISE.	TRANSNUCLEAR
DIMENSIONS ARE IN INCHES AND DEGREES UNLESS NOTED OTHERWISE DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH ASME Y14.5M-1994	
BREAK AND DEBURR ALL SHARP EDGES	TITLE: SAFETY ANALYSIS REPORT GENERAL LICENSE NUHOMS® ADVANCED HORIZONTAL STORAGE MODULE MAIN ASSEMBLY
3rd ANGLE PROJECTION	
DO NOT SCALE DRAWING	FILE NO. NUH003 4011 / DWG NO. NUH-03-4011NP / SCALE NONE / SHEET 4 OF 5 / REV NO. 2

Figure removed under 10 CFR 2.390

ALL DIMENSIONS ARE APPLICABLE AT 70°F AND ALL TOLERANCING APPLIES AFTER WELDING AND FINAL MACHINING UNLESS NOTED OTHERWISE.	TRANSNUCLEAR
DIMENSIONS ARE IN INCHES AND DEGREES UNLESS NOTED OTHERWISE. DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH ASME Y14.5M-1994	
BREAK AND DEBURR ALL SHARP EDGES	SAFETY ANALYSIS REPORT GENERAL LICENSE NUHOMS® ADVANCED HORIZONTAL STORAGE MODULE MAIN ASSEMBLY
3rd ANGLE PROJECTION	
DO NOT SCALE DRAWING	NUH003 4011 | NUH-03-4011NP | NONE | 5 OF 5 | 2

Accession Number	Title/Description Includes Est. Page Count	Document Date	Document Type	Author Affiliation(s)	Addressee Affiliation(s)	Docket Number
ML040560200	02/06/04-Revision 1 to 21T-04-0049, "Integrated Safety Analysis Summary, Blended Low-Enriched Uranium Preparation Facility.". 451 Page(s)	2/6/2004	Report, Technical	Nuclear Fuel Services, Inc	NRC/Document Control Desk, NRC/NMSS	07000143
ML050120051	21T-04-0049, "Integrated Safety Analysis Summary, Blended Low-Enriched Uranium Preparation Facility," Revision 1.. 451 Page(s)	2/6/2004	Report, Technical	Nuclear Fuel Services, Inc	NRC/NMSS	07000143
	. Page(s)					

2. PRINCIPAL DESIGN CRITERIA

2.1 Spent Fuel to be Stored

The Advanced NUHOMS® System components have currently been designed for the storage of 24 Westinghouse 14x14 (WE 14x14) PWR fuel assemblies. Authorization for storage of this payload only is requested. Additional payloads may be defined in future amendments to this application.

This payload consists of intact and/or damaged WE 14x14 assemblies including stainless steel or zircaloy cladding, UO_2 or mixed-oxide (MOX) fuel pellets, with or without integral control components, and/or damaged fuel.

The thermal and radiological characteristics for the PWR spent fuel were generated using the SCALE computer code package. Spent fuel with various combinations of burnup, decay heat, enrichment, and cooling time can be stored in the 24PT1-DSC as long as the values for decay heat, gamma and neutron sources, including spectra, remain within the design limits specified in Table 2.1-2. Free volume in the 24PT1-DSC cavity and fuel rod fill gas pressures are 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 PWR fuel which falls within the geometric, thermal, and nuclear limits established for the design basis fuel can be stored in the 24PT1-DSC.

2.1.1 Detailed Payload Description

This payload consists of 24 PWR WE 14x14 fuel assemblies, either UO_2 (stainless steel clad) or mixed-oxide (zircaloy clad). Also included in the payload are fuel assemblies utilizing boron coated fuel pellets, Integral Fuel Burnable Absorber (IFBA) assemblies. Each 24PT1-DSC can accommodate a maximum of four damaged WE 14x14 stainless steel clad (SC) fuel assemblies, with the remaining assemblies intact WE 14x14 SC assemblies. One damaged MOX assembly may also be accommodated, with the remaining assemblies (up to 23) intact WE 14x14 SC fuel assemblies. Additionally, each 24PT1-DSC accommodates the storage of integral control components in the WE 14x14 assemblies as described below. The physical characteristics for the PWR fuel assembly types are shown in Table 2.1-1. The fuel to be stored in the 24PT1-DSC is limited to fuel with a maximum initial enrichment of 4.05 weight % U-235. The maximum allowable burnup is given as a function of initial fuel enrichment but does not exceed 45,000 MWd/MTU. The minimum cooling time is ten years for SC fuel assemblies and 20 years for MOX fuel assemblies.

Table 2.1-3 presents the thermal and radiological source terms for the Non-Fuel Assembly Hardware (NFAH) which includes Rod Cluster Control Assemblies (RCCAs), Neutron Source Assemblies (NSAs) or Thimble Plug Assemblies (TPAs). These values are consistent with the cumulative exposures and cooling times of the fuel assemblies. The gamma spectra for the RCCAs, NSAs and TPAs are presented in Chapter 5.

The stainless steel clad fuel assembly without RCCAs, NSAs or TPAs is 'used for stability calculations (wind, tornado, missiles, flood and seismic) due to the lighter weight of the contents and the slightly higher center of gravity.

The 24PT1-DSC may also include two empty fuel slots and/or multiple dummy fuel assemblies. Dummy assemblies have approximately the same weight and center of gravity as a SC fuel assembly. The empty slots must be located at symmetrical locations about the 0-180° and 90-270° axes. The 24PT1-DSC center of gravity, under all loading conditions (including two empty slots and/or dummy fuel assemblies) must be maintained within 0.1" of its design basis (symmetrical loading) radial position to ensure that deviations in the center of gravity are minimal in order to maintain the validity of the structural analyses.

The reduction in weight due to two empty slots will tend to slightly reduce stresses for the 24PT1-DSC, transfer cask and AHSM for the various load conditions. Empty slots and/or multiple dummy fuel assemblies will not have any other impact on the structural analysis based on the controls imposed on the dummy assembly size and cg, and the cg location for a 24PT1-DSC with empty slots.

The effect of two empty slots and/or multiple dummy fuel assemblies on the thermal analysis is bounded by the 24 fuel assembly analyses since these configurations result in heat loads less than the design basis, thus reducing the 24PT1-DSC, cask and AHSM temperatures. The effect of these configurations on the 24PT1-DSC thermal stresses may result in a slight increase in spacer disc thermal stresses if the empty slots and/or dummy assemblies are located on the outer perimeter of the 24PT1-DSC. However, this effect is localized and will not impact the controlling 24PT1-DSC structural analysis load combinations (these load conditions exclude thermal stresses).

The effect of two empty slots and/or multiple dummy fuel assemblies on the shielding analysis is bounded by the 24 fuel assembly analyses since the neutron and gamma source terms are reduced.

The effect of two empty slots and/or multiple dummy fuel assemblies on the criticality analysis is bounded by the analyses for 24 fuel assemblies since the reduction in the source of neutrons has a greater effect than the increased moderation for the undermoderated fuel assemblies. The volume in which the dummy assembly or empty slot is located sees the same number of neutrons entering the region from adjacent assemblies but does not generate additional neutrons since no fuel is present in the volume. The effect of an increase in moderator volume is mitigated by the fact that the moderated neutrons must pass through poison plates before they can interact with fuel in adjacent guidesleeves. This effect can be seen in the results provided in SAR Table 6.4-1 for the Normal Operating Condition, Assembly Position Case. A comparison of the case in which the fuel assemblies are positioned inward towards the centerline versus the case in which the fuel assemblies are positioned radially outward from the center, indicates that the case with fuel outward, which increases moderator between the assemblies, results in a reduction in $k_{eff}+2\sigma$ from 0.8659 to 0.8404. This increase in moderation and reduction in k_{eff} is smaller than that which would result from an empty slot or dummy fuel assembly and therefore bounds the empty slot and dummy assembly configuration described above

Damaged fuel may include assemblies with known or suspected cladding defects greater than hairline cracks or pinhole leaks, up to and including broken rods, portions of broken rods and rods with missing sections. Damaged fuel assemblies shall be encapsulated in individual failed fuel cans that confine any loose material and gross fuel particles to a known, subcritical volume during normal, off-normal and accident conditions and to facilitate handling and retrievability. The criticality analysis provided in Chapter 6 requires that no more than 14 fuel pins (rods) in each assembly exhibit damage. A visual inspection of assemblies will be performed prior to placement of the fuel in the 24PT1-DSC, which may then be placed in storage or transported anytime thereafter without further fuel inspection.

Table 2.1-1
Spent Fuel Assembly Physical Characteristics

Parameter	WE 14x14 SC[1]	WE 14x14 MOX[1]
Number of Rods	180	180
Cross Section (in)	7.763	7.763
Unirradiated Length (in)	138.5	138.5
Fuel Rod Pitch (in)	0.556	0.556
Fuel Rod O.D. (in)	0.422	0.422
Clad Material	Type 304 SS	Zircaloy-4
Clad Thickness (in)	0.0165	0.0243
Pellet O.D. (in)	0.3835	0.3659
Max. initial ^{235}U Enrichment (%wt)	4.05	Note 2
Theoretical Density (%)	93-95	91
Active Fuel Length (in)	120	119.4
Max. U Content (kg)	375	Note 3
Ave. U Content (kg)	366.3	Note 3
Assembly Weight (lbs)	1210	1150
Max. Assembly Weight incl NFAH[4] (lbs)	1320	1320

(1) Nominal values shown unless stated otherwise
(2) Mixed-Oxide assemblies with 0.71 weight % U-235 and fissile Pu weight of 2.84 weight % (64 rods), 3.10 weight % (92 rods), and 3.31 weight % (24 rods)
(3) Total weight of Pu is 11.24 kg and the total weight of U is 311.225 kg
(4) Weights of TPAs and NSAs are enveloped by RCCAs

Table 2.1-2
Spent Fuel Assembly Thermal and Radiological Characteristics

Parameter	WE 14x14 SC	WE 14x14 MOX
Initial ^{235}U Enrichment (%wt) [2]	3.12-4.05	Note 1
Burnup (MWd/MTU)	45,000	25,000
Minimum Cooling Time (years)	10	20
Decay Heat (kW/assy)	0.581[4] or less	0.292[4] or less
Gamma Source (γ/sec/assy)[3]	3.43E+15	9.57E+14
Neutron Source (n/sec/assy)[3]	2.84E+08	4.90E+07

(1) Mixed-Oxide assemblies with 0.71 weight % U-235 and maximum fissile Pu weight percent of 2.84 (64 rods), 3.10 (92 rods), and 3.31 (24 rods)
(2) Burnups for minimum initial enrichments are utilized in the shielding analysis
(3) Gamma/neutron source spectrum by energy group is presented in Chapter 5
(4) Decay heat for fuel assembly excluding control components. Decay heat for control components (0 002 kW per assembly maximum) is specified in Table 2 1-3

Table 2.1-3
Non-Fuel Assembly Hardware Thermal and Radiological Characteristics

Parameter	RCCAs	TPAs	NSAs
Gamma Source[1] (γ/sec/assy)	7.60E+12	5.04E+12	1.20E+13
Decay heat (Watts)	1.90	1.2	1.66

(1) Gamma source by energy group is presented in Chapter 5.

2.2 Design Criteria for Environmental Conditions and Natural Phenomena

The 24PT1-DSC and AHSM 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 24PT1-DSC and AHSM ensures that their exposure to credible site hazards does not impair their safety functions.

The design criteria satisfy the requirements of 10CFR Part 72 [2.1]. 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 24PT1-DSC. The loading conditions are evaluated to determine the type and magnitude of loads induced on the 24PT1-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 [2.7]. 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 24PT1-DSC Shell Assembly important to safety components. Subsections NG and NF of the Code apply to the 24PT1-DSC Basket Assembly. The AHSM loads and load combinations are developed in accordance with the requirements of ANSI 57.9 [2.10] and ASCE 7-95 [2.8]. The AHSM component stresses are evaluated based on the applicable ACI and AISC standards specified.

2.2.1 Tornado and Wind Loadings

The Advanced NUHOMS® System is designed to resist the most severe tornado and wind loads specified by NRC Regulatory Guide 1.76 [2.2] and NUREG-0800 [2.3], Section 3.5.1.4. The AHSM 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 AHSM.

There are no credible wind loads applied to the 24PT1-DSC as the AHSM and transfer cask provide the required environmental protection. The case of the canister inside the AHSM is evaluated in Chapter 3 for the associated pressure drop condition.

Since the Advanced NUHOMS® System on-site transfer cask (TC) is used infrequently and for short durations, the possibility of a tornado funnel cloud enveloping the TC/24PT1-DSC during transit to the AHSM 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 (evaluated in References [2.14] and [2.15]).

2.2.1.1 Applicable Design Parameters

The design basis tornado (DBT) intensities used for the AHSM are obtained from NRC Regulatory Guide 1.76. 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.

2.2.1.2 Determination of Forces on Structures

The effects of a DBT are evaluated for the AHSM. Tornado loads are generated for three separate loading phenomena:

1. Pressure or suction forces created by drag as air impinges and flows past the AHSM with a maximum tornado wind speed of 360 mph,

2. Suction forces due to a tornado generated pressure drop or differential pressure load of 3 psi, and

3. Impact forces created by tornado-generated missiles impinging on the AHSM.

The determination of the DBT velocity pressure is in accordance with the requirements of ASCE 7 [2.8]. The resistance to overturning and sliding of the AHSM under these design pressures is determined in Chapters 3 and 11.

2.2.1.3 Tornado Missiles

The determination of impact forces created by DBT generated missiles for the AHSM is based on the criteria provided by NUREG-0800 [2.3], Section 3.5.1.4, III.4. Accordingly, four types of missiles are postulated:

- Utility wooden pole, 13.5" diameter, 35' long, 1,500 lbs, traveling 294 fps

- Armor piercing artillery shell, 8" diameter, 276 lbs, traveling 185 fps

- Steel pipe, 12" diameter, schedule 40, 30 ft long, 1,500 lbs, traveling 205 fps

- Deformable massive missile simulated by a 4,000 lbs automobile traveling through the air not more than 25 ft above ground with a contact area of 20 ft^2, impacting at normal incidence with a horizontal velocity of 195 fps

In determining the overall effects of a DBT missile impact, overturning, and sliding of the AHSM, the force due to the deformable massive missile impact is applied to the structure at the most adverse location. Conservation of momentum is used to demonstrate that sliding and/or tipping of a single module will not result in an unacceptable condition for the module. The coefficient of restitution is conservatively assumed to be zero so that 100% of the missile energy is transferred to the module. The missile energy is assumed to be dissipated as sliding friction, or an increase in potential energy due to raising the center of gravity with the force evenly distributed over the impact area. These overall effects are evaluated in Chapters 3 and 11.

For the local damage analysis of the AHSM for DBT missiles, the postulated missiles shall be used for the evaluation of concrete penetration, scabbing and perforation thickness. The modified NDRC empirical formula shall be used for this evaluation as recommended in NUREG-0800 [2.3], Section 3.5.3.

Evaluation for the effects of small diameter solid spherical missiles on the 24PT1-DSC is not required, as there are no openings in the AHSM which lead directly to the canister. Blocked vents which could result from tornado/wind debris are addressed in Chapters 3 and 11.

2.2.2 Water Level (Flood) Design

The 24PT1-DSC and AHSM are designed for an enveloping design basis flood, postulated to result from natural phenomena such as tsunami, and seiches, as specified by 10CFR 72.122(b). For the purpose of this generic evaluation, a flood height of 50 feet with a water velocity of 15 fps is used. The 24PT1-DSC is subjected to an external hydrostatic pressure equivalent to the 50 feet head of water or 21.7 psi. The AHSM is evaluated for the effects of a water current of 15 fps impinging on the sides of a submerged AHSM. For the flood case that submerges the AHSM, the inside of the AHSM will be rapidly filled with water through the AHSM vents. Therefore, the AHSM components are not evaluated for the resulting static head of water. The effects of flooding and submergence on the canister are addressed in Chapters 3, 4 and 11.

2.2.2.1 Flood Elevations

It is anticipated that the 24PT1-DSC and AHSM will be located on flood-dry sites. However, as stated above, the AHSM and 24PT1-DSC are designed for a flood elevation 50 ft. above the base of the AHSM.

2.2.2.2 Phenomena Considered in Design Load Calculations

The AHSM is designed to withstand loads from forces developed by the probable maximum flood including dynamic phenomena such as momentum and drag. The 24PT1-DSC is designed for the hydrostatic head equal to 50 ft. water submergence.

2.2.2.3 Flood Force Application

All flood loadings and effects from floods on the Advanced NUHOMS® System are discussed in Chapters 3 and 11.

2.2.2.4 Flood Protection

Flood protection measures for the Advanced NUHOMS® System are discussed in Chapters 3 and 11.

2.2.3 Seismic Design

Seismic design criteria are dependent on the specific site location. These criteria are established based on the general requirements as stated in 10CFR Part 72.102. The design earthquake (DE) for use in the design of the casks must be equivalent to the safe shutdown earthquake (SSE) for a co-located nuclear power plant, the site of which has been evaluated under the criteria of 10CFR 100, Appendix A.

2.2.3.1 Input Criteria

The design basis response spectra of the Advanced NUHOMS® System design is based on the standard spectrum shape in NRC Regulatory Guide 1.60 [2.4], anchored at 1.5g ZPA for the horizontal direction. The vertical design spectrum is set at two-thirds of the horizontal direction over the entire frequency range. The horizontal and vertical spectra are specified at the top of the basemat.

The horizontal and vertical components of the design response spectra are shown in Figure 2.2-1 and Figure 2.2-2.

2.2.3.2 Seismic-System Analyses

1. Seismic Analysis Methods. Both linear and non-linear analysis methods are used to determine the maximum seismic response of the Advanced NUHOMS® System. These analytical methods are discussed in Chapters 3 and 11.

2. Methods to Determine Overturning Moments. Non-linear analysis methods are used to determine overturning moments of the AHSM. These analysis methods are discussed in Chapters 3 and 11.

2.2.4 Snow and Ice Loadings

Snow and ice loads for the AHSM are derived from ASCE 7 [2.8]. The maximum 100 year roof snow load, specified for most areas of the continental United States for an unheated structure, of 110 psf is assumed. There are no credible snow and ice loads applied to the 24PT1-DSC as the AHSM and TC provide the environmental protection. Snow and ice loads for the TC with a loaded 24PT1-DSC are negligible due to the smooth curved surface of the cask, the heat rejection of the SFAs, and the infrequent short term use of the cask.

2.2.5 Tsunami

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

2.2.6 Lightning

A lightning strike will not cause a significant thermal effect on the AHSM or stored 24PT1-DSC. The effects on the AHSM resulting from a lightning strike are discussed in Chapter 11.

2.2.7 Combined Load Criteria

2.2.7.1 Advanced Horizontal Storage Module

The reinforced concrete AHSM is designed to meet the requirements of ACI 349-97 [2.6]. The alternate temperature criteria of NUREG-1536 will be utilized as discussed in Chapters 3 and 11. The ultimate strength method of analysis is utilized with the appropriate strength reduction factors as described in Chapter 3. The load combinations specified in Section 6.17.3.1 of ANSI 57.9-1984 [2.10] are used for combining normal operating, off-normal, and accident loads for the AHSM. All seven load combinations specified are considered and the governing combinations and the appropriate load factors are presented in Chapter 3. The resulting AHSM load combinations and load factors are presented in Chapter 3. The effects of duty cycle on the AHSM are considered and found to have negligible effect on the design. The corresponding structural design evaluation for the 24PT1-DSC support structure is presented in Chapter 3.

2.2.7.2 24PT1-DSC

The 24PT1-DSC is designed by analysis to meet the stress intensity allowables of the ASME Boiler and Pressure Vessel Code (1992 Edition with 1994 Addenda) Section III, Division I, Subsection NB as modified by Code Case N-595-1, NG and NF for Class 1 components and supports [2.7]. The 24PT1-DSC is conservatively designed by utilizing linear elastic or non-linear elastic-plastic analysis methods. The load combinations considered for the 24PT1-DSC normal, off-normal and postulated accident loadings are described in Chapter 3. ASME Code Service Level A and B allowables are used for normal and off-normal operating conditions. Service Level C and D allowables are used for accident conditions such as a postulated cask drop accident. Using these acceptance criteria ensures that in the event of a design basis drop accident, the 24PT1-DSC confinement boundary is not breached. The maximum shear stress theory is used to calculate principal stresses. Normal operational stresses are combined with the appropriate off-normal and accident stresses. It is assumed that only one postulated accident condition occurs at any one time. The accident analyses are documented in Chapter 11. The structural evaluation for the 24PT1-DSC is documented in Chapter 3.

2.2.8 Burial Under Debris

Debris resulting from natural phenomena or accidents that may affect system performance are to be determined by the licensee. Such debris can result from floods, wind storms, or land slides. The principal effect is typically on thermal performance. See Chapter 11 for a generic evaluation of AHSM burial.

2.2.9 Thermal Conditions

The Advanced NUHOMS® System component temperatures and thermal gradients are affected by the following thermal conditions:

- Fuel Loading
- Decay Heat

- Beginning of Storage Unloading
- Ambient Variations
- Lightning
- Fire

The thermal conditions which are of concern structurally are the temperature distributions in the system and the differential thermal expansion of interfacing components. See detailed analyses in Chapters 3, 4 and 11.

2.2.9.1 Fuel Loading

The 24PT1-DSC/transfer cask is loaded in a spent fuel pool under water. The 24PT1-DSC inner surfaces are cooled by pool water and the 24PT1-DSC outer surface is cooled by water contained in the 24PT1-DSC/transfer cask annulus; therefore, the thermal gradients established during fuel loading will be negligible.

2.2.9.2 Decay Heat

After the 24PT1-DSC/transfer cask is loaded and removed from the pool, the temperatures will gradually reach steady state conditions. The temperature gradients in the 24PT1-DSC/TC have an insignificant effect on structural integrity.

Thermal analysis calculations were performed for different ambient and decay heat load conditions. The methods used to obtain these results are discussed in Chapter 4. The effect on structural integrity are addressed in Chapters 3 and 11.

2.2.9.3 Beginning of Storage Unloading

Beginning of storage unloading would occur if it were necessary to place the 24PT1-DSC back into the pool at the beginning of storage after it had been loaded and reached thermal equilibrium. Prior to unloading fuel, the 24PT1-DSC and fuel would be cooled by circulating water through the 24PT1-DSC. Therefore, cool water would contact the hotter 24PT1-DSC inner surfaces. The thermal gradients in the 24PT1-DSC body due to this condition are small and would have an insignificant effect on the cask body. The fuel cladding stresses during beginning of storage unloading is evaluated in Chapter 3.

2.2.9.4 Ambient Variations

Because the combined AHSM and 24PT1-DSC thermal inertia is large, the 24PT1-DSC temperature response to changes in atmospheric conditions will be relatively slow. Ambient temperature variations due to changes in atmospheric conditions i.e., sun, ice, snow, rain and wind will not affect the performance of the 24PT1-DSC. The cyclical variation of insolation during a day will also create insignificant thermal gradients.

The thermal effects due to ambient variations and conditions are discussed in further detail in Chapter 4.

2.2.9.5 Lightning

Thermal effects due to lightning are discussed in Chapter 11.

2.2.9.6 Fire

It is demonstrated in Chapter 11 that the 24PT1-DSC/transfer cask will maintain confinement integrity during and after the postulated fire accident.

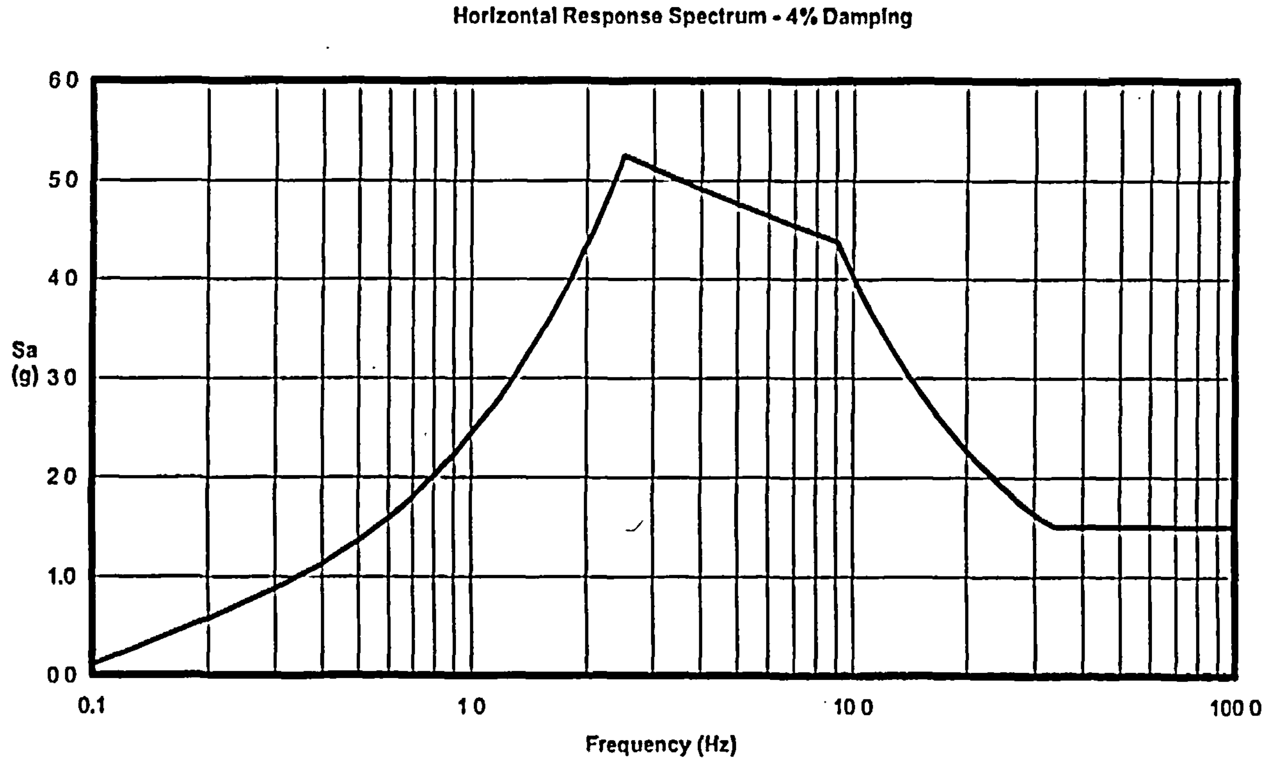

Figure 2.2-1
AHSM Base Input Horizontal Response Spectra for 1.5g ZPA

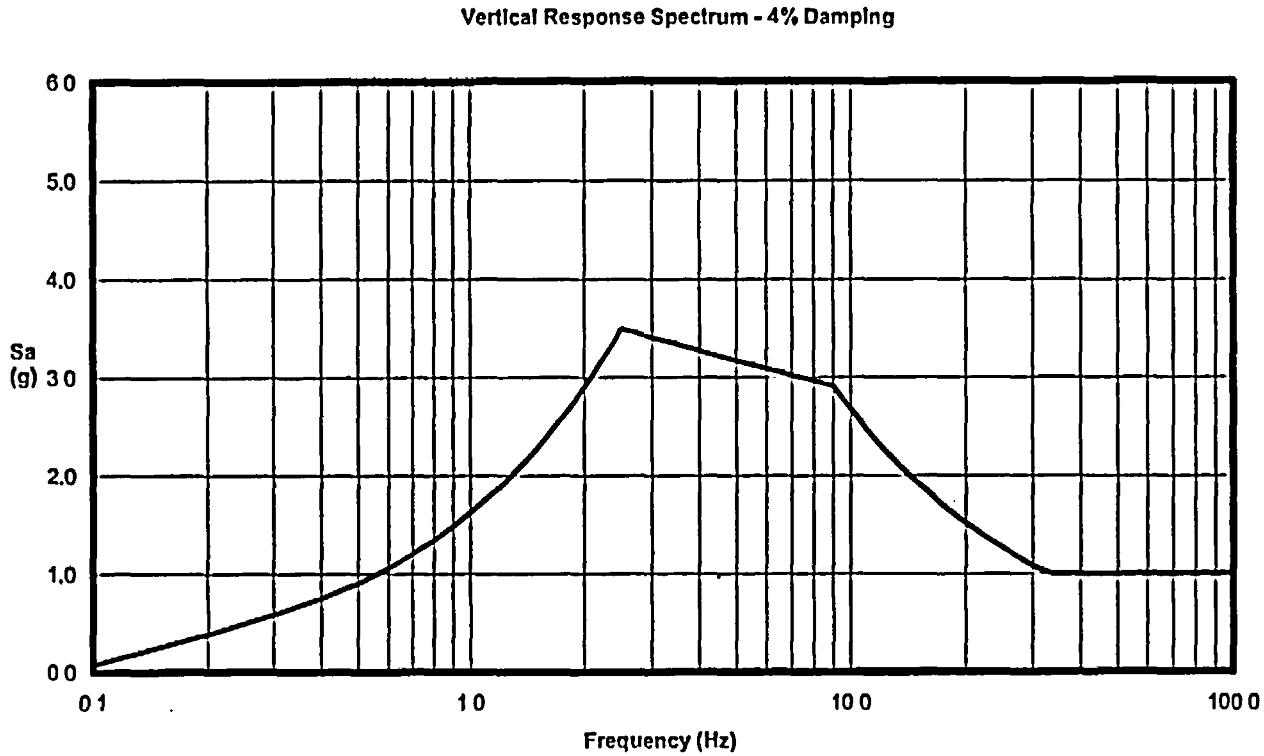

Figure 2.2-2
AHSM Base Input Vertical Response Spectra for 1.0g ZPA

2.3 Safety Protection Systems

2.3.1 General

The Advanced NUHOMS® System is designed to provide long term storage of spent fuel. The canister materials are selected such that degradation is not expected during the storage period. The 24PT1-DSC cylindrical shell, and the top and bottom cover plate assemblies form the pressure retaining confinement boundary for the spent fuel. The 24PT1-DSC is equipped with two shield plugs to minimize occupational doses at the ends during drying, sealing, and handling operations. The 24PT1-DSC top closure has redundant welds which join the shell and the top cover plate assemblies to form the confinement boundary as defined by ASME Code Case N-595-1 [2.7]. The 24PT1-DSC shell and bottom end assembly confinement boundary weld is made during fabrication of the 24PT1-DSC. The top closure confinement welds are made after fuel loading. Both top plug penetrations (siphon and vent ports) are redundantly welded after drying operations are complete.

The Advanced NUHOMS® System is designed for safe and secure, long-term confinement and dry storage of SFAs. The key elements of the Advanced NUHOMS® System and their operation which require special design consideration are:

A. Minimizing the contamination of the 24PT1-DSC exterior by fuel pool water.

B. The 24PT1-DSC top end, double closure welds form dual pressure retaining confinement boundaries and maintain a helium atmosphere.

C. Minimizing personnel radiation exposure during 24PT1-DSC loading, closure, and transfer operations.

D. The coating materials used in the design of the 24PT1-DSC are chosen to minimize hydrogen generation.

E. Design of the AHSM and 24PT1-DSC for postulated accidents.

F. Design of the AHSM passive ventilation system for effective decay heat removal to ensure the integrity of the fuel cladding. The AHSM is designed with no active safety systems.

G. Design of the 24PT1-DSC to ensure subcriticality.

2.3.2 Protection by Multiple Confinement Barriers and Systems

2.3.2.1 Confinement Barriers and Systems

The radioactive material which the Advanced NUHOMS® System ISFSI confines is the spent fuel assemblies and the associated contaminated or activated materials.

During fuel loading operations, the radioactive material in the plant's fuel pool is prevented from contacting the 24PT1-DSC exterior by filling the cask/24PT1-DSC annulus with uncontaminated, demineralized water prior to placing the cask and 24PT1-DSC in the fuel pool. In addition, the cask/24PT1-DSC annulus opening at the top of the cask is sealed using an inflatable seal to prevent pool water from entering the annulus. This procedure minimizes the likelihood of contaminating the 24PT1-DSC exterior surface. The combination of the above operations assures that the 24PT1-DSC surface loose contamination levels are within those required for shipping cask externals. Compliance with these contamination limits is assured by taking surface swipes of the upper end of the 24PT1-DSC before transferring the cask from the fuel building.

Once inside the 24PT1-DSC, the SFAs are confined by the 24PT1-DSC shell and the top and bottom cover plates. The fuel cladding integrity is ensured by maintaining the storage cladding temperatures below levels which are known to cause degradation of the cladding. In addition, the SFAs are stored in an inert atmosphere to prevent degradation of the cladding, specifically cladding rupture due to oxidation and its resulting volumetric expansion of the fuel. Thus, a helium atmosphere for the 24PT1-DSC is incorporated in the design to protect the fuel cladding integrity by inhibiting the ingress of oxygen into the cavity.

Helium is known to leak through valves, mechanical seals, and escape through very small passages because it has a small atomic diameter, is an inert element, and exists in a monatomic species. Helium will not, to any practical extent, diffuse through stainless steel. For this reason the 24PT1-DSC has been designed as a welded confinement pressure vessel with no mechanical or electrical penetrations and is tested to demonstrate that it is leaktight in accordance with ANSI N14.5 requirements [2.16]. See Chapter 7 for a detailed discussion of the confinement boundary design.

The 24PT1-DSC itself has a series of barriers to ensure the confinement of radioactive materials. The cylindrical shell is fabricated from rolled ASME stainless steel plate which is joined with full penetration welds that are 100% inspected by non-destructive examination. All top and bottom end closure welds are multiple-layer welds. This effectively eliminates any pinhole leaks which might occur in a single pass weld, since the chance of pinholes being in alignment on successive weld passes is not credible. Furthermore, the cover plates are sealed by separate, redundant closure welds. Pressure boundary welds and welders are qualified in accordance with Section IX of the ASME B&PV Code and inspected according to the appropriate articles of Section III, Division 1, Subsection NB. These criteria insure that the as-deposited weld filler metal is as sound as the parent metal of the pressure vessel.

Pressure monitoring instrumentation is not used since penetration of the pressure boundary would be required. The penetration itself would then become a potential leakage path and by its presence compromise the integrity of the 24PT1-DSC design. The shell and welded cover plates provide total confinement of radioactive materials. Once the 24PT1-DSC is sealed, there are no credible events, as discussed in Chapter 11, which could fail the cylindrical shell or the closure plates which form the confinement boundary.

2.3.2.2 24PT1-DSC Cooling

The AHSM 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 effect (ΔP_s) provided by the height difference between the bottom of the 24PT1-DSC and the AHSM top air outlet. This pressure difference is larger than the flow pressure drop (ΔP_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 24PT1-DSC. Therefore, an off-gas monitoring system is not required for the AHSM. The only time an off-gas system is required is during 24PT1-DSC drying operations. During this operation, the spent fuel pool or plant's radwaste system is used to process the air and helium evacuated from the 24PT1-DSC.

2.3.3 Protection by Equipment and Instrumentation Selection

2.3.3.1 Equipment

The AHSM, 24PT1-DSC, and transfer cask encompass equipment which is important to safety. Other equipment important to safety associated with the Advanced NUHOMS® 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 operating license.

2.3.3.2 Instrumentation

The Advanced NUHOMS® System is a totally passive system. No safety-related instrumentation is necessary for monitoring the 24PT1-DSC. The maximum temperatures and pressures are conservatively bounded by analyses. Therefore, there is no need for monitoring the internal cavity of the 24PT1-DSC for pressure or temperature during normal operations. The 24PT1-DSC is conservatively designed to perform its confinement function during all worst case normal, off-normal, and postulated accident conditions. AHSM thermal monitoring is provided to meet the requirements of Chapter 12.

2.3.4 Nuclear Criticality Safety

2.3.4.1 Control Methods for Prevention of Criticality

The design criteria for criticality is that the effective neutron multiplication factor, k_{eff}, including statistical uncertainties and bias, shall be less than 0.95 for all postulated arrangements of fuel within the canister. The 24PT1-DSC incorporates Boral™ sheets as fixed neutron absorbing materials to provide criticality control. The efficacy of Boral™ is discussed in Chapter 6.

The 24PT1-DSC has been 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 water. The methods of criticality control are in accordance with the requirements of 10CFR 72.124.

Criticality analysis is performed using the SCALE computer code package 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 Advanced NUHOMS® 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 WE 14x14 SC fuel assemblies and MOX zircaloy clad fuel assemblies. These analyses do not credit the neutron absorption capability of the TPAs, RCCAs, or IFBAs.

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 Section 6.5.

2.3.5 Radiological Protection

The Advanced NUHOMS® 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 Advanced NUHOMS® System ISFSI operations and the ISFSI ALARA evaluation are provided in Chapter 10.

2.3.5.1 Access Control

The Advanced NUHOMS® 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.

In addition to the controlled access, a method of providing a security tamper seal on the AHSM door may be included after insertion of a loaded 24PT1-DSC. This may be, but is not limited to, one of the following:

Tack welding the AHSM access door

Tack welding 2 or more closure bolts on the AHSM access door

Tamper seals

2.3.5.2 Shielding

Shielding has the objective of assuring that radiation dose rates at key locations are at acceptable levels for those locations. Three locations are of particular interest:

(1) Immediate Vicinity of the AHSM

(2) Restricted Area Boundary

(3) Controlled Area Boundary

Dose rates in the immediate vicinity of the AHSM are important for consideration of occupational exposure. Because of the passive nature of storage with this system, occupational tasks related to the system are infrequent and short in duration. Expected personnel exposures due to operational and maintenance activities are discussed in Section 10.3. The estimated occupational doses for personnel comply with applicable requirements (occupational dose limits).

Dose rates at the restricted area boundary are selected so that monitoring of radiation exposure to people outside the restricted area is not required. Dose rates at the controlled area boundary are in accordance with applicable regulatory guides.

2.3.5.3 Radiological Alarm System

There are no radiological alarms required for the Advanced NUHOMS® System. There are no credible events which result in releases of radioactive products or unacceptable increases in direct radiation.

2.3.6 Fire and Explosion Protection

The Advanced NUHOMS® System AHSM and 24PT1-DSC do not contain flammable materials. The concrete and steel used for their fabrication can withstand any credible fire hazard. There is no fixed fire suppression system within the boundaries of the ISFSI. An evaluation of the system engulfed in a minor fuel fire is provided in Chapter 11. Due to the large thermal mass of the AHSM, any minor fires in the vicinity of the ISFSI would raise the AHSM temperature by only a few degrees and will not affect the confinement capability of the 24PT1-DSC.

ISFSI initiated explosions are not considered credible since explosive materials are not present in the fission product or cover gases within the 24PT1-DSC cavity. Externally initiated explosions are considered to be bounded by the design basis tornado generated missile load analysis. As indicated in Chapter 11, overpressures of a few psi can be conservatively postulated to occur at the ISFSI as a result of accidents involving explosive materials which are stored or transported near the site. This impact is significantly less than that postulated to result from the tornado wind loading and missile impact analysis, as described in Section 2.2.1, and is well within the design basis of the AHSM. The licensee will evaluate the site specific external hazards to demonstrate these are bounded by the tornado effects.

2.3.7 Acceptance Tests and Maintenance

2.3.7.1 Acceptance Test

The acceptance tests and criteria for visual inspections, leak testing of components, valves, gaskets, shielding integrity, thermal acceptance and neutron absorbers are discussed in Chapter 9.

2.3.7.2 Maintenance Program

Because of their passive nature, the storage modules will require little, if any, maintenance over the lifetime of the ISFSI. The maintenance program is discussed in Chapter 9.

2.4 Decommissioning Considerations

The 24PT1-DSC is designed to interface with a 10CFR 71 transportation system for the eventual off-site transport of canisters by the DOE to either a monitored retrievable storage facility (MRS) or a permanent geologic repository, as discussed in Chapter 14. Decommissioning of the Advanced NUHOMS® System ISFSI will be performed in a manner consistent with the decommissioning of the plant itself since all Advanced NUHOMS® System components are constructed of materials similar to those found in existing plants. The 24PT1-DSC is compatible with wet or dry unloading facilities.

If the fuel is removed from the 24PT1-DSC at the plant prior to shipment, the 24PT1-DSC will likely be internally contaminated by crud from the spent fuel and may be slightly activated by spontaneous neutron emissions from the spent fuel. The 24PT1-DSC internals may be cleaned to remove surface contamination and disposed of as low-level waste. Alternatively, if the contamination and activation levels are small enough (to be determined on a case-by-case basis), it may be possible to decontaminate the 24PT1-DSC and dispose of it as commercial scrap.

While the intent for the Advanced NUHOMS® System includes the eventual disposal of each 24PT1-DSC should fuel removal be required, current closure weld designs do not preclude future development of a non-destructive closure removal technique that allows for reuse of the 24PT1-DSC shell/basket assembly. Economic and technical conditions existing at the time of fuel removal would be assessed prior to making a decision to reuse the 24PT1-DSC.

The exact decommissioning plan for the ISFSI will be dependent on the DOE's fuel transportation system capability and requirements for a specific plant. Because of the minimal contamination of the outer surface of the 24PT1-DSC, no contamination is expected on the internal surfaces of an AHSM. It is anticipated that the prefabricated AHSMs can be dismantled and disposed of using commercial demolition and disposal techniques. Alternatively, the AHSMs may be refurbished and reused at another site or at the MRS for storage of intact 24PT1-DSCs transported from the plant.

2.5 Structures, Systems and Components Important to Safety

Table 2.5-1 provides a list of major Advanced NUHOMS® System ISFSI components and their classification. Table 2.5-1 identifies all structures, systems and components that are "Important To Safety" (ITS). Components are classified in accordance with the criteria of 10CFR 72. Structures, systems, and components classified as ITS are defined in 10CFR 72.3 as those features of the ISFSI whose function is:

A. To maintain the conditions required to store spent fuel safely.

B. To prevent damage to the spent fuel container during handling and storage.

C. To provide reasonable assurance that spent fuel can be received, handled, packaged, stored, and retrieved without undue risk to the health and safety of the public.

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

2.5.1 Dry Shielded Canister

The 24PT1-DSC provides fuel assembly support required to maintain the fuel geometry for criticality control. Accidental criticality inside a 24PT1-DSC could lead to off-site doses comparable with the limits in 10CFR 100 which must be prevented. The 24PT1-DSC also provides the confinement boundary for radioactive materials. Therefore, the 24PT1-DSC is designed to remain intact under all accident conditions identified in Chapter 11 without losing its function to provide confinement of the spent fuel assemblies. The 24PT1-DSC is designed, constructed, and tested in accordance with a QA program incorporating a graded quality approach for ITS requirements as defined by 10CFR 72, Subpart G, paragraph 72.140(b) and described in Chapter 13.

The welding materials required to make the closure welds on the 24PT1-DSC inner and outer top cover plates shall be fabricated to the same ASME Code criteria as the 24PT1-DSC shell (Subsection NB, Class 1).

2.5.2 Advanced Horizontal Storage Module

The AHSM is considered ITS since it provides physical protection and shielding for the spent fuel container (24PT1-DSC) during storage. The reinforced concrete AHSM is designed in accordance with ACI 349-97 [2.6] and built to ACI-318 [2.13]. The level of testing, inspection, and documentation provided during construction and maintenance is in accordance with the quality assurance requirements as defined in 10CFR 72, Subpart G and as described in Chapter 13. Thermal instrumentation for monitoring AHSM concrete temperatures is considered "Not Important To Safety" (NITS).

2.5.3 ISFSI Basemat and Approach Slabs

The ISFSI basemat and approach slabs are considered NITS and are designed, constructed, maintained, and tested as commercial grade items.

Licensees are required to perform an assessment to confirm that the license seismic criteria described in Section 2.2.3 are met.

2.5.4 Transfer Equipment

2.5.4.1 Transfer Cask and Yoke

The on-site transfer cask is ITS since it protects the spent fuel canister (24PT1-DSC) during handling and is part of the primary load path used while handling the 24PT1-DSC in the fuel/reactor building. An accidental drop of a loaded transfer cask (weighing approximately 100 tons) has the potential for creating conditions in the plant which must be evaluated. These possible drop conditions are evaluated with respect to the impact on the 24PT1-DSC in Chapters 3 and 11. Therefore, the transfer cask is designed, constructed, and tested in accordance with a QA program incorporating a graded quality approach for ITS requirements as defined by 10CFR 72, Subpart G, paragraph 72.140(b) and described in Chapter 13.

The lifting yoke used for handling the transfer cask within the fuel/reactor building is designed and procured as a "safety related" component as it is used by the licensee (utility) under their 10CFR 50 program. The lifting yoke is designed in accordance with the requirements of NUREG-0612 [2.11] and ANSI N14.6-96 [2.12] for non-redundant yokes.

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

2.5.4.2 Other Transfer Equipment

The Advanced NUHOMS® System transfer equipment (i.e., ram, skid, transfer trailer) are necessary for the successful loading of the 24PT1-DSC into the AHSM. However, the analyses described in Chapter 11 demonstrate that the performance of these items are not required to provide reasonable assurance that spent fuel can be received, handled, packaged, stored, and retrieved without undue risk to the health and safety of the public. Therefore, these components are considered NITS and need not comply with the requirements of 10CFR 72. These components are designed, constructed, and tested in accordance with good industry practices.

2.5.5 Auxiliary Equipment

The vacuum drying system and the automated welding system are NITS. Performance of these items is not required to provide reasonable assurance that spent fuel can be received, handled, packaged, stored, and retrieved without undue risk to the health and safety of the public. Failure of any part of these systems may result in a delay of operations, but will not result in a hazard to the public or operating personnel. Therefore, these components need not comply with the requirements of 10CFR 72. These components are designed, constructed, and tested in accordance with good industry practices.

Table 2.5-1
Advanced NUHOMS® System Major Components and Safety Classification

Component	10CFR 72 Classification[1]
Dry Storage Canister (24PT1-DSC)	
Guidesleeves	Important to Safety
Spacer Discs	Important to Safety
Support Rods	Important to Safety
Shield Plugs (Top and Bottom)	Important to Safety
Shell	Important to Safety
Cover Plates (Top and Bottom)	Important to Safety
DSC Support Ring	*Important to Safety*
Siphon and Vent Block	*Important to Safety*
Siphon and Vent Port Cover Plates	*Important to Safety*
Grapple Ring and Grapple Support	*Important to Safety*
Weld Filler Metal	Important to Safety
Failed Fuel Can	*Important to Safety*
Horizontal Storage Module (AHSM)	
Reinforced Concrete	Important to Safety
24PT1-DSC Support Structure	Important to Safety
Thermal Instrumentation	Not Important to Safety
AHSM/Cask Restraint	*Important to Safety*
ISFSI Basemat and Approach Slabs	Not Important to Safety
Transfer Equipment	
On-site Transfer Cask	Important to Safety
Cask Lifting Yoke	Safety Related[2]
Transfer Trailer/Skid	Not Important to Safety
Ram Assembly	Not Important to Safety
Dry Film Lubricant	*Not Important to Safety*
Auxiliary Equipment	
Vacuum Drying System	Not Important to Safety
Automatic Welding System	Not Important to Safety
Transfer Cask/DSC Annulus Seal	Not Important to Safety

(1) Structures, systems and components "important to safety" are defined in 10CFR 72 3 as those features of the ISFSI whose function is (1) to maintain the conditions required to store spent fuel safely, (2) to prevent damage to the spent fuel container during handling and storage, or (3) to provide reasonable assurance that spent fuel can be received, handled, packaged, stored, and retrieved without undue risk to the health and safety of the public

(2) Yoke and rigid or sling lifting members are classified as "Safety Related" in accordance with 10CFR 50.

2.6 Supplemental Information

2.6.1 References

[2.1] U.S. Government, "Licensing Requirements for the Storage of Spent Fuel in an Independent Spent Fuel Storage Installation (ISFSI)," Title 10 Code of Federal Regulations, Part 72, Office of the Federal Register, Washington, D.C.

[2.2] U.S. Atomic Energy Commission, "Design Basis Tornado for Nuclear Power Plants," Regulatory Guide 1.76 (1974).

[2.3] U.S. Nuclear Regulatory Commission, Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants, Revision 2, (1981).

[2.4] U.S. Atomic Energy Commission, "Design Response Spectra for Seismic Design of Nuclear Power Plants," Regulatory Guide 1.60, Revision 1 (1973).

[2.5] U.S. Atomic Energy Commission, "Damping Values for Seismic Design of Nuclear Power Plants," Regulatory Guide 1.61 (1973).

[2.6] American Concrete Institute, Code Requirements for Nuclear Safety Related Concrete Structures, ACI 349-97.

[2.7] American Society of Mechanical Engineers, ASME Boiler and Pressure Vessel Code, Section III, Division 1, 1992 Edition with 1994 Addenda, including exceptions allowed by Code Case N-595-1.

[2.8] American Society of Civil Engineers, ASCE 7-95, Minimum Design Loads for Buildings and Other Structures, (formerly ANSI A58.1).

[2.9] Not Used.

[2.10] American National Standards Institute, American Nuclear Society, ANSI/ANS 57.9-1984, Design Criteria for an Independent Spent Fuel Storage Installation (Dry Storage Type).

[2.11] NRC NUREG-0612, Control of Heavy Loads at Nuclear Power Plants, July 1980.

[2.12] American National Standards Institute, ANSI N14.6-1996, American National Standard for Special Lifting Device for Shipping Containers Weighing 10,000 lbs. or More for Nuclear Materials.

[2.13] American Concrete Institute, "Building Code Requirements for Reinforced Concrete," ACI-318, 1*989 (92)*.

[2.14] TN West, Final Safety Analysis Report for the Standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel, Revision *6, November 2001*, File NUH003.0103.

[2.15] Rancho Seco Independent Spent Fuel Storage Installation, *Final* Safety Analysis Report, Revision *0, November 2000, USNRC Docket Number 72-11.*

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3. STRUCTURAL EVALUATION

3.1 Structural Design

This chapter describes the design and analyses related to the structural performance of the Important-to-Safety components are defined in Section 2.5.

Specifically, this chapter addresses the structural evaluation of the Advanced NUHOMS® System 24PT1-DSC and AHSM. On-site transfer of a loaded 24PT1-DSC will be performed utilizing the NRC approved NUHOMS® OS197 transfer cask and, therefore, the transfer system is not part of this application. The OS197 safety analyses are contained in the NUHOMS® FSAR [3.15] These analyses envelope the 24PT1-DSC configuration.

The overall design bases for the Advanced NUHOMS® System are described in Chapter 2. This Chapter discusses the structural design criteria and associated design bases applicable to the 24PT1-DSC and AHSM. This Chapter also describes the ability of these components to perform their design function during normal and off-normal operating conditions, as well as under postulated accident conditions and extreme natural phenomena events.

3.1.1 Discussion

The Advanced NUHOMS® System consists of the 24PT1-DSC, a high-integrity stainless steel dry shielded canister that provides for the dry storage of spent fuel assemblies (SFAs) in an inert atmosphere, and the AHSM, a massive reinforced concrete storage module that houses and provides environmental protection and shielding to the 24PT1-DSC. The 24PT1-DSC is placed inside the AHSM, via a transfer cask.

Multiple AHSMs are grouped together to form arrays in single or double rows to provide storage capacity consistent with available site space and reactor SFA discharge rates. The AHSMs are placed next to and in contact with each other and tied together to form a continuous array. An array must have a minimum of three AHSMs in order to meet stability requirements under the postulated design earthquake.

For purposes of the structural analyses and agreement with the criteria set forth in Regulatory Guide 3.61 [3.5] and NUREG 1536 [3.7], a single Advanced NUHOMS® System 24PT1-DSC plus an AHSM form the "cask" cited in [3.5] and [3.7].

Fabrication and construction specifications are utilized in accordance with 10CFR 72 [3.1]. The codes and standards used for the design, fabrication, and construction of the Advanced NUHOMS® System components, equipment, and structures are summarized in Table 3.1-1 and are identified throughout the SAR. Exceptions to the ASME Code [3.11] are provided in Table 3.1-14 and Table 3.6-15.

3.1.1.1 General Description of the 24PT1-DSC

The principal characteristics of the 24PT1-DSC are described in Section 1.2.1 and shown in Figure 1.1-2. The drawings in Section 1.5.2 provide the principal dimensions and design parameters of the 24PT1-DSC.

For purposes of the structural analysis, the 24PT1-DSC is divided into the 24PT1-DSC shell assembly and the internal basket assembly. The 24PT1-DSC shell assembly, shown in Figure 3.1-1, includes the pressure retaining confinement boundary for the spent fuel, and consists primarily of a cylindrical shell, and the top and bottom cover plate assemblies. The 24PT1-DSC pressure boundary (shown in Figure 3.1-1) consists of the cylindrical shell, the inner bottom cover plate, the inner and outer top cover plates, and the associated welds. The outer top cover plate provides a redundant pressure-retaining boundary in accordance with the requirements of ASME Section III Code Case N-595-1 [3.11].

The remaining 24PT1-DSC shell assembly components include the outer bottom cover plate, the solid shield plugs (one at each end of the 24PT1-DSC assembly), the grapple ring assembly, support ring, and the lifting lugs. The shield plugs provide biological shielding during fuel loading operations and storage of a loaded 24PT1-DSC. The grapple ring assembly is welded to the outer bottom cover plate for the purpose of inserting/extracting the 24PT1-DSC from the Advanced Horizontal Storage Module (AHSM). The support ring, welded to the cylindrical shell, supports the top shield plug. Four lifting lugs are welded to the inside of the cylindrical shell and the support ring and are used to lift the unloaded 24PT1-DSC into the transfer cask prior to fuel loading operations.

All pressure boundary components are constructed of Type 316 stainless steel. Non-pressure boundary components welded to the pressure boundary components are also constructed of Type 316 stainless steel. The shield plugs are constructed of A36 carbon steel. The shield plugs are constrained by, but not mechanically fastened to, the stainless steel 24PT1-DSC shell assembly components, allowing free thermal expansion of the dissimilar materials.

The 24PT1-DSC cylindrical shell and bottom end assembly (which includes the inner and outer bottom cover plates, the bottom shield plug and the grapple ring assembly), and the internal basket assembly, are shop-fabricated (and assembled) components. The top shield plug and inner and outer top cover plates are installed at the plant after the spent fuel assemblies have been loaded into the 24PT1-DSC internal basket.

The 24PT1-DSC shell assembly is designed, fabricated, examined and tested in accordance with the requirements of Subsection NB of the ASME Code including Code Case N-595-1 [3.11]. The circumferential and longitudinal shell plate weld seams are multi-layer full penetration butt welds. The butt weld joints are fully radiographed and inspected according to the requirements of NB-5000 of the ASME Boiler and Pressure Vessel Code. The full penetration inner bottom cover plate to shell weld is inspected to the same Code standards, using either radiographic or ultrasonic inspection methods.

The 24PT1-DSC top closure is compliant with Code Case N-595-1 and NRC's ISG-4 [3.8]. The top cover plates are sealed by separate, redundant closure welds. The inner top cover plate is welded to the 24PT1-DSC shell to form the inner pressure boundary at the top end of the 24PT1-DSC, as shown in Figure 3.1-2. The secondary, outer, pressure boundary is provided by the outer top cover plate. All closure welds are multiple-layer welds. This effectively eliminates any pinhole leaks which may occur in a single-pass weld, since the chance of pinholes being in alignment on successive weld passes is negligibly small. Also, both welds are examined by multi-level liquid penetrant to effectively eliminate through wall leaks.

The top end assembly of the 24PT1-DSC design incorporates a vent siphon block, with two small-diameter tubing penetrations into the 24PT1-DSC cavity for draining and filling operations. One penetration, the vent port, is terminated at the bottom of the shield plug assembly. The other port is attached to a siphon tube, which continues to the bottom of the 24PT1-DSC cavity. Both ports include dog-leg type, offsets to prevent radiation streaming. The vent and siphon ports terminate in normally closed quick-connect fittings. Both ports are used to remove water from the 24PT1-DSC during the drying and sealing operations.

During fabrication, leak tests of the 24PT1-DSC shell assembly are performed in accordance with ANSI N14.5-1997, [3.10] to demonstrate that the shell is leaktight ($1x10^{-7}$ std. cm^3/sec).

The DSC inner top cover closure weld, including the vent and siphon block subassembly welds, are also leak tested after fuel loading to demonstrate that ANSI N14.5 leaktight criteria is met following installation of the outer cover plate root pass weld.

The stringent design and fabrication requirements described above ensure that the pressure retaining confinement function is maintained for the design life of the 24PT1-DSC. Pressure monitoring instrumentation is not used since penetration of the pressure boundary would be required. The penetration itself would then become a potential leakage path and, by its presence, compromise the leaktightness of the 24PT1-DSC design.

During draining, backfilling, and leak testing, a "Strongback Device" may be installed to minimize deformation of the inner top cover plate during blowdown. The strongback is bolted to the top flange of the transfer cask and provides support to the inner cover plate during those operations that may involve significant pressurization of the 24PT1-DSC cavity.

Transfer of the 24PT1-DSC from the transfer cask into the AHSM is performed using a hydraulic ram that applies a load to the outer bottom cover plate, at the center of the DSC. During insertion of the 24PT1-DSC into the AHSM, the load is shared by the outer bottom cover plate, the bottom shield plug, and the inner bottom cover plate.

Frictional loads during 24PT1-DSC transfer are reduced by application of a dry film lubricant to the hardened nitronic surface on the support rails of the AHSM and the transfer cask. The lubricant chosen for this application is a tightly adhering inorganic lubricant with an inorganic binder. The dry film lubricant provides a thin, clean, dry, layer of lubricating solids that is intended to reduce wear, and prevent galling in metals. It is applied as a thin sprayed coating, similar to paint, using a carefully controlled process. The lubricant is not affected by water and is designed to be highly resistant to aggressive chemicals. This product is designed for radiation service and has a low coefficient of sliding friction for stainless steel.

The internal basket assembly, shown in Figure 3.1-3, provides structural support for, and geometric separation of, the SFAs. The basket assembly consists of 24 stainless steel guidesleeve assemblies, 26 carbon steel spacer discs, and four-support rod/spacer sleeve assemblies. The support rods and spacer sleeves are fabricated of martensitic stainless steel that is precipitation hardened to obtain the desired mechanical properties. Stainless steel fuel spacers are used to center the short 14x14 Westinghouse fuel in the 24PT1-DSC.

The spacer disc details, shown in Figure 3.1-4, identify the twenty-four cutouts for the SFAs and the holes for the four support rods. The spacer discs maintain cross-sectional spacing and provide support for the fuel assemblies and the guidesleeves when the 24PT1-DSC is in the horizontal position. When the 24PT1-DSC is in the vertical position, the spacer discs are held in place by the support rods and spacer sleeves; the rod assemblies maintain longitudinal separation between discs during all normal operating and postulated accident conditions.

The 24PT1-DSC allows storage of damaged fuel assemblies in a stainless steel failed fuel can. The failed fuel can construction is similar to that of the guidesleeve with a smaller width to allow storage within a guidesleeve. The failed fuel can includes a welded bottom closure and a removable top closure. The top closure allows lifting of the failed fuel can with the enclosed fuel assembly. The failed fuel can design incorporates screens at the top and bottom to contain fuel debris and allow water fill/drainage.

3.1.1.2 General Description of the AHSM

The AHSM is a free standing reinforced concrete structure designed to provide environmental protection and radiological shielding for the 24PT1-DSC. Each AHSM provides a self contained modular structure for the storage of a 24PT1-DSC containing up to 24 PWR SFAs. The AHSM provides heat rejection from the spent fuel decay heat by a combination of radiation, conduction and convection. Schematic sketches of the AHSM showing the different components and overall dimensions are provided in Figure 3.1-5 through Figure 3.1-7. The drawings in Section 1.5.2 provide the principal dimensions and design parameters of the AHSM.

The AHSM is a reinforced concrete structure consisting of two separate units: a base storage unit, where the 24PT1-DSC is stored, and a top shield block that serves to provide environmental protection and radiation shielding. The top shield block is attached to the base unit by vertical ties. Three-foot thick shield walls are installed behind each AHSM (single row array only) and at the ends of each row to provide additional shielding.

The AHSM modules may be prefabricated offsite, then transported to the ISFSI site and installed on a 3-foot thick (minimum) reinforced concrete basemat. The AHSMs are tied together and placed next to, and in contact with, adjacent module(s) to form continuous single or double row arrays. If subjected to a design basis earthquake, the AHSMs are free to slide on the reinforced concrete basemat. An array must have a minimum of three AHSMs in a row in order to meet stability requirements under the postulated design earthquake.

The top shield block is tied to the base storage unit by eight steel rods in the vertical direction and by interlocking concrete keys in the horizontal directions. Similarly, adjacent AHSMs are connected to each other with module-to-module ties located at the top and bottom of the AHSMs. The top ties are integrated into the roof unit and consist of reinforced concrete tie "beams", with the rebar between adjacent modules mechanically connected. The bottom ties consist of steel rods connecting adjacent base storage units. The top and bottom ties are designed to carry tensile loads to prevent module-to-module separation. A system of horizontal and vertical keys, located between adjacent modules, restrain relative horizontal (front-to-back) and vertical (rocking) movement between AHSMs.

The 24PT1-DSC is supported inside the base storage unit on two stainless steel rails. The rail assembly spans between the front block and the rear wall of the base storage unit and acts as a sliding surface during 24PT1-DSC insertion and retrieval.

The air inlet vent extends through the front block of the base unit. The base unit also provides the air inlet shielding. The air outlet vent is formed in the top shield block.

A removable block is provided below the air inlet to provide a means for cleanout of the inlet in case of accidental blockage.

For thermal protection of the AHSM concrete, a thin stainless steel heat shield is installed on the inside of the base storage unit. The heat shield guides cooling air flow through the AHSM.

The AHSM shield door is a combination rectangular/circular concrete block located in the front face circular opening of the base unit. The steel-backed concrete door provides missile protection and shielding for the 24PT1-DSC.

Shield walls are provided at each end of a module array to provide the required missile and shielding protection. Similarly, a shield wall is used at the rear of each module for the single row module arrays.

During 24PT1-DSC insertion/retrieval operations, the transfer cask is docked with the AHSM and mechanically secured to *the AHSM cask restraint* embedments provided in the front of the AHSM base unit. These embedments are equally spaced on either side of the AHSM access opening and serve a dual function: to support the door and to restrain the transfer cask during insertion/retrieval of the 24PT1-DSC.

3.1.2 24PT1-DSC and AHSM Design Criteria

This section addresses component specific design criteria, loads, and load combinations for the structural analyses of the 24PT1-DSC and the AHSM.

The reinforced concrete AHSM, including the 24PT1-DSC support structure, and the 24PT1-DSC are important to safety NUHOMS® 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 [3.1] and ANSI 57.9 [3.9]. These include tornado and wind, seismic, and flood design criteria.

3.1.2.1 24PT1-DSC Design Criteria

3.1.2.1.1 Stress Criteria

The 24PT1-DSC is designed utilizing linear elastic and non-linear elastic-plastic analytical methods. ASME Code Service Level A and B allowables are used for normal and off-normal operating conditions, respectively. Service Level C and D allowables are used for accident conditions.

The 24PT1-DSC shell is designed by analysis to meet the criteria of the ASME Boiler and Pressure Vessel Code Section III, Division 1, Subsection NB, 1992 Edition through 1994 Addenda, supplemented by Code Case N-595-1 [3.11] and ISG-4 [3.8]. Stress criteria for pressure boundary components are summarized in Table 3.1-2 of this section. Stress criteria for (partial penetration) pressure boundary top closure welds are summarized in Table 3.1-3.

The major internal basket components, spacer discs and guidesleeve assemblies, are designed to the criteria of ASME B&PV Code, Subsection NG as summarized in Table 3.1-4. The support rods and spacer sleeves are designed to the criteria of ASME B&PV Code, Subsection NF. The Boral™ neutron absorbing material is non-Code and is not considered a load-carrying component.

3.1.2.1.2 Stability Criteria

Stability of the 24PT1-DSC shell assembly is addressed for those load conditions in which the 24PT1-DSC is under external hydrostatic pressure (e.g., vacuum drying and external flood load cases) and/or axial compression, (e.g., loading the shell due to the shield plug's deadweight). Stability criteria are from ASME Section III, NB-3133.3 and NB-3133.6.

For the basket assembly, global stability is provided by the 24PT1-DSC shell, which provides continuous lateral support at each spacer disc. Local stability of individual basket components (spacer discs, support rod/spacer sleeve assemblies, guidesleeves assemblies) is addressed as described below.

Stability of the spacer discs is demonstrated using an eigenvalue buckling analysis and the criteria of ASME Section III, Appendix F. With the spacer disc loaded by the 75g-side drop, the eigenvalue analysis determines the margin to buckling (i.e., the multiple of the 75g load that would result in stability failure). In accordance with Appendix F, where the allowable load is 2/3 of the calculated stability load, an eigenvalue of greater than 1.5 demonstrates acceptable qualification of the discs.

Stability of the guidesleeves is assessed by evaluation of both overall guidesleeve stability and single panel stability. Overall stability is evaluated by considering the guidesleeve as a column under axial loads, laterally supported at the spacer discs, and applying the column stability criteria of NF-3322.1 and NF-1334.3. Panel stability is evaluated using equations from Roark [3.19] for plates under in-plane loading.

Compressive loads in the support rod assembly are carried by the spacer sleeves. Stability of the spacer sleeves is addressed using the criteria for combined axial compression and bending loads from Subsection NF and Appendix F for linear supports.

3.1.2.1.3 Loads and Load Combinations

The loads and load combinations considered for the 24PT1-DSC consist of the normal, off-normal, and postulated accident conditions listed in Table 3.1-5. The table also includes the applicable ASME Service Level for each combination.

Normal operating design conditions consist of events that occur regularly, or in the course of normal operation of the NUHOMS® System. Off-normal operating design conditions are events that occur with moderate frequency or as specified by NUREG 1536 [3.7]. Analyses also are provided for a range of hypothetical accidents in accordance with 10CFR 72 [3.1]. Further discussion of accident conditions is provided in Chapter 11.

The resulting stresses in the 24PT1-DSC components are evaluated and combined in accordance with the load combinations in Table 3.1-5, and compared with the designated Code limits.

3.1.2.1.3.1 Deadweight

Deadweight for the 24PT1-DSC includes the self-weight of the loaded 24PT1-DSC, including basket assembly components, cover plates, control components and stored fuel. In the vertical orientation, the basket assembly components do not carry the fuel weight, as the fuel weight is transferred to the inner bottom cover plate. In the horizontal orientation, the guidesleeves provide full support for the fuel and transfer the load to the spacer discs, which distribute the fuel weight to the 24PT1-DSC shell.

3.1.2.1.3.2 Internal and External Pressure

Internal pressure loads for the 24PT1-DSC are developed as described in Chapter 4. The bounding normal, off-normal, and accident pressures used for the structural analyses of the 24PT1-DSC are given in Table 3.1-6.

Load cases which include external pressures are given in Table 3.1-7.

The internal basket components, such as the support rod assemblies, spacer discs, *fuel spacers,* and guidesleeves, are not affected by pressure loads.

3.1.2.1.3.3 Thermal Loads

The 24PT1-DSC is analyzed for the thermal conditions summarized in Table 3.1-8. The thermal analyses of the 24PT1-DSC are presented in Chapter 4 and provide maximum and minimum 24PT1-DSC component temperatures, as well as 3-D temperature distributions.

The basket assembly components are evaluated for the thermal conditions shown in Table 3.1-8. Thermal stresses due to gradients in the plane of the spacer disc are evaluated. The support rod assemblies are evaluated for the thermal stresses due to clamping the dissimilar spacer sleeves and spacer discs together. Each basket assembly component is checked to ensure adequate gaps exist between the basket assembly components and the shell assembly to prevent or limit restrained differential thermal expansion.

3.1.2.1.3.4 DSC Transfer/Handling Loads

There are two categories of transfer and handling loads: (1) inertial loads associated with moving the 24PT1-DSC (transfer handling) and (2) loads associated with inserting the 24PT1-DSC into and retrieving the 24PT1-DSC from the AHSM (AHSM loading/unloading).

Transfer handling loads are inertial loads exerted on the loaded 24PT1-DSC that result from on-site handling and transfer between the fuel handling/loading area and the ISFSI. The 24PT1-DSC is evaluated for the following four independent load cases:

±1.0g Axial + Gravity

±1.0g Transverse + Gravity

±1.0g Vertical + Gravity

(±½ g Axial ± ½ g Transverse ± ½ g Vertical) + Gravity

24PT1-DSC transfer/handling loads and inertial loads are applied to the 24PT1-DSC shell and internal basket components.

AHSM loading/unloading loads are applied to the 24PT1-DSC as it is pushed out of, or pulled into, the transfer cask. To load the AHSM, a hydraulic ram applies a load to the center of the 24PT1-DSC outer bottom cover plate at the center of the grapple ring assembly. To unload the AHSM, the 24PT1-DSC is extracted using grapples that fit into the grapple ring. The loads applied by the hydraulic ram are balanced by friction between the 24PT1-DSC shell and the cask and/or AHSM rails. The assumption for loading and unloading operations, based on experience with loading NUHOMS® canisters, are shown below:

Operating Condition	Loading (kips)	Unloading (kips)
Normal	60	60
Off-Normal	80	60
Accident	NA	80

Loads associated with loading/unloading the AHSM do not affect the basket components. Thus, only the shell assembly is evaluated for the AHSM loading/unloading loads.

3.1.2.1.3.5 Cask Drop

The 24PT1-DSC is analyzed for a 75g-side drop and a 25g-corner drop at 30° from the horizontal. Further discussion of the design basis for the postulated cask drops is provided in Chapter 11.

The 24PT1-DSC is not handled in the vertical orientation once loaded on the transfer trailer; thus end drops of the cask are not credible events for operations performed under 10CFR 72. However, for purposes of bounding the 25g-corner drop, and as part of 10CFR 71 and 10CFR 50 evaluations, the 24PT1-DSC is also analyzed for a 60g bottom end drop.

Drop loads are applied as equivalent static loads. Drops are only postulated for the 24PT1-DSC when positioned inside the transfer cask and cannot occur once the 24PT1-DSC is transferred into the AHSM.

3.1.2.1.3.6 Seismic Loads

As described in Section 11.2.1.2.4, the seismic analyses of the 24PT1-DSC inside the AHSM show that the maximum inertial accelerations of the 24PT1-DSC are limited to 1.4g in the horizontal directions. The horizontal acceleration specified applies to a system that is free to slide with a friction coefficient equal to or less than 0.7. However, the 24PT1-DSC is conservatively evaluated for the following equivalent static seismic accelerations:

±6.0g Vertical

±6.0g Transverse

±6.0g Longitudinal

3.1.2.1.3.7 Flood Loads

The flood condition is defined as a 50-foot static head of water. This equates to an external pressure on the 24PT1-DSC of 22 psi, which is applied uniformly.

3.1.2.2 AHSM Design Criteria

The AHSM concrete and steel components are designed to the requirements of ACI 349 [3.12] and the AISC Manual of Steel Construction [3.13], respectively, using the load combinations prescribed by ANSI 57.9 [3.9]. The following loads due to environmental and operational conditions are considered.

3.1.2.2.1 Environmental Conditions

This section provides the generic environmental conditions used in generating the design basis loads for the NUHOMS® AHSM. The load definitions provide enveloping loads for the contiguous United States. The extreme environmental and natural phenomena design criteria discussed below comply with the requirements of 10CFR 72.122 [3.1] and ANSI 57.9 [3.9].

AHSMs designed for areas susceptible to freeze/thaw conditions require air entrainment controls in the concrete design mix in accordance with ACI 318 [3.20] *requirements. AHSMs in non-freeze/thaw environment do not require controls on the air entrainment in the concrete mix.*

3.1.2.2.1.1 Dead Load

Dead load is the weight of the structure and attachments including permanently installed equipment.

3.1.2.2.1.2 Wind and Tornado

The AHSM is designed for the most severe tornado and wind loads specified by NRC Regulatory Guide 1.76 and NUREG-0800 [3.6]. The AHSM is designed to withstand tornado missiles specified for Region I in Section 3.5.1.4 of NUREG-0800 [3.6]. 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 AHSM.

3.1.2.2.1.3 Snow and Ice

Snow and ice loads for the AHSM are derived from ASCE 7 [3.14]. The maximum 100 year roof snow load, specified for most areas of the continental United States for an unheated structure, of 110 psf is used as the design basis snow load.

3.1.2.2.1.4 Seismic

The design basis response spectrum of NRC Regulatory Guide 1.60 [3.2], is selected for the AHSM design earthquake defined in 10CFR 72.102(a)(2) [3.1]. The Regulatory Guide 1.60 spectrum is anchored at 1.5g ZPA for the horizontal direction. The response spectrum for the vertical direction is 2/3 of the horizontal across the entire frequency range. A damping value of four percent of critical damping [3.3] is used for the AHSM.

3.1.2.2.1.5 Flood

The AHSM is designed for an enveloping design basis flood, as specified by 10CFR 72.122(b) [3.1]. For the purpose of this evaluation, a flood height of 50 feet with a water velocity of 15 fps is used. For the flood case that submerges the AHSM, the inside of the AHSM will be rapidly filled with water through the AHSM vent. Therefore, the AHSM components are not evaluated for static pressure due to the head of water. Velocity pressure (drag) on the AHSM as a rigid body is used for AHSM stability check.

3.1.2.2.1.6 Thermal Loading

The AHSM is analyzed for the full range of plausible natural weather temperatures and fluctuations with the maximum heat dissipation from the stored canisters. The following conditions are used in the thermal analysis:

- Off-normal ambient temperature range of –40°F (without insolation) to 117°F with full insolation.
- Normal ambient temperature range of 0°F (without insolation) to 104°F (with insolation), with 70°F (with insolation) as the design lifetime average ambient temperature.
- Relative humidity of 100%.
- Complete blockage of all inlet and outlet cooling vents at the maximum off-normal temperature of 117°F and maximum insolation. The maximum time of the blocked vent transient is 40 hours as discussed in Chapter 4.

3.1.2.2.2 Normal Operating Conditions

3.1.2.2.2.1 Live Loads

In accordance with the requirements of [3.7], the canister is treated as a live load when stored in the AHSM. The live load is varied between 0% and 100% to simulate the most adverse conditions for the AHSM.

The design basis live load includes a load of 200 psf applied to the full area of the AHSM top shield block. This load includes the effects of snow and ice loads plus miscellaneous conduits, ladders, and lights, etc. that may be added to the roof. The weight of the canister is applied to the 24PT1-DSC support structure as a live load.

3.1.2.2.2.2 Normal Operational Handling Loads

Normal operational handling loads on the AHSM are the result of canister transfer operations. Normal operation assumes the canister is sliding over the support structure due to a hydraulic ram force of up to 60,000 lbs. applied at the grapple ring and resisted by an axial load in each support rail. The weight of the canister is applied to the support structure as a distributed load for this case.

3.1.2.2.2.3 Normal Thermal Loads

Normal thermal loads on the AHSM include the effects of the design basis internal heat load generated by the canister and the effects of normal ambient conditions.

3.1.2.2.3 Off-Normal Operational Loads

3.1.2.2.3.1 Off-Normal Operational Handling Loads

Off-normal operational handling loads are the result of a canister getting stuck or jammed during transfer into or out of the AHSM. The design basis off-normal operating load is due to a hydraulic ram force of 80,000 lbs. during 24PT1-DSC insertion and 60,000 lbs. during 24PT1-DSC retrieval, applied at the grapple ring. The axial load is transferred to the AHSM at the binding point between the canister and support structure. In addition, half the loaded weight of the canister is applied as a concentrated load at midspan of the AHSM support structure.

3.1.2.2.3.2 Off-Normal Thermal Loads

The off-normal thermal loads include the maximum canister internal heat load, plus the effects of off-normal ambient conditions.

3.1.2.2.4 Accident Operational Loads

3.1.2.2.4.1 Accident Thermal Loads

The postulated accident thermal event occurs due to blockage of the air inlet and outlet vents under off-normal ambient temperatures.

3.1.2.2.4.2 Fire and Explosion Overpressure

Overpressure due to externally initiated fires and explosions are assumed to be bounded by the design basis tornado wind pressure. 10CFR 72, Subpart K requires licensees to confirm that no conditions exist near the ISFSI that would result in pressure loads due to off-site explosions, which would exceed the loads postulated for tornado suction, missile or wind effects.

3.1.2.2.5 Design Load Combinations

In accordance with ANSI 57.9, [3.9] the design basis concrete loads are multiplied by load factors and combined in load combinations to simulate the most adverse load conditions considering credible variations in magnitude and direction. The nominal ultimate concrete strength is reduced by the strength reduction factors provided in Table 3.1-9 to obtain the design strength of concrete.

The load combinations specified in [3.9] are used for combining normal operating, off-normal and accident loads for the AHSM. All seven-load combinations specified are considered and governing combinations are selected for detailed design and analysis. The resulting AHSM load combinations and the appropriate load factors are presented in Table 3.1-10. The corresponding structural design criteria for the 24PT1-DSC support structure are summarized in Table 3.1-11 and Table 3.1-12.

The overturning and sliding load combinations and factors of safety for the tornado and flood loading cases are provided in Table 3.1-13. For the Design Earthquake, the analysis presented in Chapter 11 shows that an AHSM array may slide up to a maximum of 44 inches without any significant tipping. This guarantees the safe retrieval of all stored 24PT1-DSCs.

3.1.2.3 Exceptions to the ASME Code for the 24PT1-DSC

This section documents and justifies deviations from the ASME Code Section III, Division 1 requirements. The 24PT1-DSC is a not a Code-stamped vessel and, as such, the services of an Authorized Nuclear Inspector (ANI) are not required. The design of the 24PT1-DSC and internal basket components is specified to meet the technical provisions of the ASME B&PV Code.

The following sections of the ASME Code apply to the technical requirements for the design, fabrication, testing, and inspection of the 24PT1-DSC's:

- Section II for materials.
- Section III for materials, design, fabrication, testing, inspection, and over pressure protection.
- Section V for non-destructive examination.
- Section IX for welder and welding procedure qualifications.

3.1.2.3.1 Code Exceptions

Areas of exceptions to the ASME Code can be broken down into three basic areas. These are:

- Code General Requirements
- Technical design
- Component fabrication, inspection, and examination

Although each of these areas are interrelated, the exceptions come under different authorities.

3.1.2.3.2 <u>Code General Requirements</u>

The 24PT1-DSCs will typically be procured under the technical requirements of the Code without requiring the use of an Authorized Inspector or the application of an N-stamp. Hence, many of the administrative items that would allow the 24PT1-DSC to be stamped are not typically in place. This includes such things as a Design Specification certified by a professional engineer, a formal overpressure protection report; and requiring design and fabrication work to be done by firm(s) holding an N-stamp. These items have no affect on the functionality of the component, it does affect its ability to comply with the requirements of the ASME Code. The qualifications of the firms and personnel, procedures used to develop the design reports and fabrication specifications, and the lack of an N-stamp vendor are all exceptions to the requirements of Subsection NCA. Hence, the 24PT1-DSC is not compliant with Subsection NCA.

3.1.2.3.3 <u>Technical Compliance</u>

Technical compliance is compliance with Code design rules and materials specification, processes, joint configurations, etc. The evaluation and design performed for the 24PT1-DSC components are based on compliance with Section III of the ASME Code as modified by Code Case N-595-1, NRC Regulatory Guides and NUREG. Table 3.1-14 provides a discussion of technical exceptions to the Code provisions for materials, fabrication, examination, and testing. The exceptions to the design portions of the Code are typically the result of not meeting Subsection NCA of the Code. The top closure weld details and lack of pressure testing for the completed pressure boundary are in compliance with Code Case N-595-1. Similarly, the internal basket is designed to the rules of Subsection NF and/or NG with the exceptions listed in Table 3.1-15.

3.1.2.3.4 <u>Fabrication, Inspection, and Examination of Components</u>

There are no specific exceptions taken to the Code inspection requirements, except a non-ASME Code certified fabricator is permitted to build the 24PT1-DSCs. Neither an Authorized Nuclear Inspector (ANI) nor Code certified shop is required by the procurement documents to fabricate or inspect the 24PT1-DSC. Therefore, the role of the Certificate Holder is not required to be met for the fabrication and inspection process. Fabrication exceptions are provided in Table 3.1-14 and Table 3.1-15.

Table 3.1-1
Codes and Standards for the Fabrication and Construction of Principal Components

Component, Equipment, Structure	Code of Construction
24PT1-DSC	ASME Code, Section III, 1992 Edition through 1994 Addenda, supplemented by Code Case N-595-1 and ISG 4, Rev. 2.
AHSM	- ACI 318-*89 (92)* - AWS D1.1-98 - AWS D1.6-99 - ACI 349-97 - AISC Ninth Edition - Load Combinations from ANSI 57.9-1984

Table 3.1-2
Summary of Stress Criteria for Components Evaluated Using Subsection NB

Service Level	Stress Category
Level A[1][2]	$P_m \le 1.0S_m$ $P_L \le 1.5S_m$ $P_m\ (or\ P_L) + P_b \le 1.5S_m$ $P_m\ (or\ P_L) + P_b + Q \le 3.0S_m$
Level B[1][3]	$P_m \le 1.0S_m$ $P_L \le 1.5S_m$ $P_m\ (or\ P_L) + P_b \le 1.5S_m$ $P_m\ (or\ P_L) + P_b + Q \le 3.0S_m$
Level C[4]	$P_m \le \max(1.2S_m, 1.0S_y)$ $P_L \le \max(1.8S_m, 1.5S_y)$ $P_m\ (or\ P_L) + P_b \le \max(1.8S_m, 1.5S_y)$
Carbon Steel Components (e.g., Shield Plugs)	
Level D Elastic Analysis[4]	$P_m \le 0.7S_u$ $P_m\ (or\ P_L) + P_b \le 1.0S_u$
Level D Plastic Analysis[4]	$P_m \le 0.7S_u$ $P_m\ (or\ P_L) + P_b \le 0.9S_u$
Austenitic Steel Components (e.g., Shell)	
Level D Elastic Analysis[4]	$P_m \le \min(2.4S_m, 0.7S_u)$ $P_m\ (or\ P_L) + P_b \le \min(3.6S_m, 1.0S_u)$
Level D Plastic Analysis[4]	$P_m \le \max(0.7S_u, S_y + (S_u - S_y)/3)$ $P_m\ (or\ P_L) + P_b \le 0.9S_u$

(1) The secondary stress limit may be exceeded provided the criteria of NB-3228 5 are satisfied.

(2) There are no specific limits on primary stresses for Level A events However, the stresses due to primary loads during normal service must be computed and combined with the effects of other loadings in satisfying other limits. See NB-3222.1.

(3) The 10% increase in allowables from NB-3223 (a) may be applicable for load combinations for which the pressure exceeds the design pressure

(4) Evaluation of secondary stresses not required for Level C and D events

Table 3.1-3
Stress Criteria for Partial Penetration Pressure Boundary Welds

Service Level	Allowable Primary Stress	Primary and Secondary	Notes
Level A	0.8 S_m	0.8 (3.0 S_m)	Note 1
Level B	0.8 S_m	0.8 (3.0 S_m)	Note 1
Level C	greater of 0.8 (1.2 S_m) or 0.8 S_y	N/A	Note 1
Level D Elastic	lesser of 0.8 (2.4 S_m) or 0.8 (0.7 S_u)	N/A	Note 1
Level D Plastic	greater of 0.8 (0.7 S_u) or 0.8 (S_y + 1/3 (S_u-S_y))	N/A	Note 1

Note:

1. These limits are based on Code Case N-595-1 and ISG-4

Table 3.1-4
Summary of Stress Criteria for Components Evaluated Using Subsection NG

Service Level	Stress Category
Level A/B[1]	$P_m \le 1.0S_m$ $P_m + P_b \le 1.5S_m$ $P_m + P_b + Q \le 3.0S_m$ (*note* 3)
Level C[2] Elastic Analysis	$P_m \le 1.5S_m$ $P_m + P_b \le 2.25S_m$
Ferritic Steel Components	
Level D[2][4] Elastic Analysis	$P_m \le 0.7S_u$ $P_m + P_b \le 1.0S_u$
Level D[2][4] Plastic Analysis	$P_m \le 0.7S_u$ $P_m + P_b \le 0.9S_u$
Austenitic Steel Components (e.g., Guidesleeves)	
Level D[2][4] Elastic Analysis	$P_m \le \min(2.4S_m, 0.7S_u)$ $P_m + P_b \le \min(3.6S_m, 1.0S_u)$
Level D[2][4] Plastic Analysis	$P_m \le \max(0.7S_u, S_y + 1/3(S_u - S_y))$ $P_m + P_b \le 0.9S_u$

Notes:

1. There are no pressure loads on spacer discs, therefore the 10% increase permitted by NG-3223 (a) for pressures exceeding the design pressure does not apply.
2. Evaluation of secondary stresses not required for Level C and D events
3. This limit may be exceeded provided the requirements of NG-3228.3 are satisfied, see NG-3222.2 and NG-3228.3
4. Level D criteria are taken from Appendix F of the ASME Code

Table 3.1-5
24PT1-DSC Load Combinations and Service Levels

Load Case		Normal Operating Conditions							Off-Normal Conditions				Accident Conditions					
		1	2	3	4	5	6	7	1	2	3	4	1	2	3	4	5	6
Dead Weight Load	Vertical/Horizontal DSC, Empty	X	X(10)															
	Vertical, DSC w/Fuel + Water			X(10)														
	Vertical, DSC w/Fuel				X(5)				X				X	X				
	Horizontal, DSC w/Fuel					X	X	X		X	X	X		X	X	X	X	X
Thermal Load	Inside HSM, 0° to 104°F						X	X										X
	Inside Cask: 0° to 120°F		X	X	X	X			X				X	X				
	Inside HSM, -40° to 117°F										X	X				X	X	
	Inside Cask 0° to 117°F (1)									X								
	Inside HSM Blocked Vents; 117°F														X			
External Pressure			X	X					X				X				X	
Internal Pressure Load	Hydrostatic Pressure		X	X														
	Normal Pressure (4)				X	X	X	X										
	Off-Normal Pressure (4)									X	X	X	X(7)	X		X		X
	Accident Pressure (3)														X			
DSC Loading Operation Pressure (11)									X									
Handling/ Transfer Loads	Handling Loads	X				X(8)												
	Normal DSC Transfer					X(8)		X										
	Off-Normal DSC Transfer									X		X						
	Accident DSC Transfer																	X
Cask Drop Load (side and corner drop)(9)														X				
Seismic Load																X		
Flooding Load																	X	
ASME Code Service Level		A	A	A	A	A	A	A	B	B	B	B	D	D	D	D	C	C
Analysis Load Cases in Section 3.6, Table 3 6-1		NO-3 NO-4	FL-1 FL-2 FL-3	FL-4 FL-5 FL-6	TL-1 TL-2 TL-3 TL-4	TR-1 to TR-8 LD-1 LD-2	HSM-1 HSM-2	UL-1 UL-2	DD-1 DD-2 DD-3 DD-4 DD-5	LD-3 LD-4	HSM-3 HSM-4 HSM-5 HSM-6	UL-3 UL-4	RF-1	TR-10 TR-11	HSM-11	HSM-9 HSM-10	HSM-12 HSM-13	UL-5

NOTES:

1. Outside fuel building, at temperatures over 100°F, a sunshade is required over the Transfer Cask. Temperatures for the 117°F with shade are enveloped by the 100°F without sunshade case.
2. **NOT USED.**
3. Accident pressure for Service Level C condition is applied to inner top and bottom cover plates Accident pressures on the inner and outer top and bottom cover plates are evaluated for Service Level D allowables
4. 10 psig is used for normal pressure. 20 psig is used for and off-normal pressure
5. 24PT1-DSC inside cask is horizontal for load cases TL-3, TL-4
6. **NOT USED.**
7. Reflood pressure is 20 psig
8. Handling loads apply to inertial TR-1 to TR-8. Transfer loads apply to LD-1 and LD-2.
9. Both horizontal and corner drop cases are considered.
10. Cask in vertical orientation only for those load cases
11. Pressure varies from 0° psia (vacuum drying), to Hydrostatic + 20 psi (blowdown).

Table 3.1-6
24PT1-DSC Internal Pressure Loads

Operating Condition	Internal Pressure	ASME Service Level
Normal Pressure	10 psig	A
Off-Normal Pressure	20 psig	B
Accident Pressure	60 psig	D
Design	10 psig	Design

Table 3.1-7
24PT1-DSC External Pressure Loads

Operating Condition	External Pressure	ASME Service Level
Fuel Loading and Draining & Drying Cases	Hydrostatic(1)	B
Vacuum Drying	14.7 psig + Hydrostatic(1)	B
Accident Flood	22 psig(2)	C

Notes:

1 Hydrostatic pressure is the maximum static head of water in the transfer cask annulus of 7.1 psig

2 External pressure of 22 psig is due to 50-foot static head of water.

Table 3.1-8
24PT1-DSC Thermal Conditions

Operating Conditions	24PT1-DSC Location	Minimum Ambient Temperature	Maximum Ambient Temperature
Normal	Transfer Cask (Inside Fuel Building)	0°F	120°F
	Transfer Cask[(1)]	0°F	104°F
	AHSM	0°F	104°F
Off-Normal	Transfer Cask[(1)]	0°F[(4)]	117°F[(2)]
	AHSM	-40°F	117°F
Accident	AHSM (blocked vents) [(3)]	-40°F	117°F

Notes:

1. Analyses of the OS197 transfer cask have been presented to the NRC in Docket 72-1004
2. A sunshade is required for the transfer cask to transport the DSC at ambient temperatures greater than 100°F (per C of C 72-1004).
3. 24PT1-DSC thermal stress for the blocked vent case are not evaluated because secondary stresses are not required to be evaluated for Level D events
4. Operation of the OS197 transfer cask is limited to ambient temperatures above 0°F. However, the DSC inside the transfer cask is analyzed at -40°F

Table 3.1-9
AHSM Ultimate Strength Reduction Factors

Type of Stress	Reduction Factor
Flexure	0.9
Axial Tension	0.9
Axial Compression	0.7
Shear	0.85
Torsion	0.85
Bearing	0.7

Table 3.1-10
Concrete Structure – Load Combinations

Number	Load Combination	Event
1	U > 1.4 DW + 1.7 (LL + RO)	Normal
2	U > 1.05 DW + 1.275 (LL + TN + WW)	Off-Normal – Wind
3	U > 1.05 DW + 1.275 (LL + TN + RA)	Off-Normal – Handling
4	U > DW + LL + TN + EQ	Accident – Earthquake
5	U > DW + LL + TN + WT	Accident – Tornado
6	U > DW + LL + TN + FL	Accident – Flood
7	U > DW + LL + TA	Accident – Thermal

The load combinations presented in Table 3 1-10, Table 3.1-11 and Table 3 1-13 use the following notation

S	Required steel strength
S_v	Required steel shear strength
U	Required concrete strength
O/S	Overturning and Sliding Resistance
DW	Dead Load
LL	Live Load
RO	Normal Handling Load
TN	Normal Thermal Load
WW	Wind Load. The tornado wind load is conservatively used for normal and off-normal events.
WT	Tornado Wind Load including tornado generated missile loads.
RA	Off-Normal Handling Load
EQ	Earthquake Load
TA	Envelope of Off-Normal and Accident Thermal Loads
FL	Flood Load

The AHSM is an above ground structure that is founded on a separate basemat, and as such the AHSM is not subjected to lateral soil pressures (HH) or soil reaction loads (GG).

Table 3.1-11
Steel Structures Allowable Stress Design – Load Combinations

Number	Load Combination	Event
1	S > DW + LL + RO	Normal
2	1.3 S > DW + LL + WW	Off-Normal – Wind
3	1.3 S > DW + LL + TN + RA	Off-Normal – Handling
4	(1.5 S or 1.4 S_v) > DW + LL + TN + WW	Off-Normal – Wind with Thermal
5	(1.6 S or 1.4 S_v) > DW + LL + TN + EQ	Accident – Earthquake
6	(1.6 S or 1.4 S_v) > DW + LL + TN + WT	Accident – Tornado
7	(1.6 S or 1.4 S_v) > DW + LL + TN + FL	Accident – Flood
8	(1.7 S or 1 4 S_v) > DW + LL + TA	Accident – Thermal

Notation used in the above combinations is defined in Table 3 1-10.

The AHSM is an above ground structure that is founded on a separate basemat, and as such the AHSM is not subjected to lateral soil pressures (HH) or soil reaction loads (GG)

Table 3.1-12
Structural Design Criteria for DSC Support Structure

Allowable Stress (S)	
Stress Type	**Stress Value(1)**
Tensile	0.60 S_y
Compressive	(See Note 2)
Bending	0.66S_y or 0.75S_y (3)
Shear	0.40 S_y (4)
Interaction	(See Note 5)

Notes:

(1) Values of S_y versus temperature for stainless steel are given in Table 3 3-3.
(2) Equations H1-1, H1-2 and H1-3 of AISC Manual [3.13] are used as appropriate.
(3) 0 66S_y for major axis bending and 0 75S_y for minor axis bending
(4) Maximum allowable shear stress is limited to 1.4S (0.56 S_y)
(5) Interaction equations per the AISC specification are used as appropriate

Table 3.1-13
Overturning and Sliding – Load Combinations

Number	Load Combination	Event
1	O/S ≥ 1.5 DW	Normal and Off-Normal
2	O/S ≥ 1.1 (DW + WT)	Accident – Tornado
3	O/S ≥ 1.1 (DW + FL)	Accident – Flood

Notation used in the above combinations is defined in Table 3 1-10.

Table 3.1-14
ASME Code Exceptions for the 24PT1-DSC (NB)

Reference ASME Code Section/Article	Code Requirement	Exception, Justification & Compensatory Measures
NCA	All	Not compliant with NCA
NB-1100	Requirements for Code Stamping of Components	The 24PT1-DSC shell is designed & fabricated in accordance with the ASME Code, Section III, Subsection NB to the maximum extent practical. However, Code Stamping is not required. As Code Stamping is not required, the fabricator is not required to hold an ASME "N" or "NPT" stamp, or to be ASME Certified.
NB-2130 NB-4121	Material must be supplied by ASME approved material suppliers Material Certification by Certificate Holder	All materials designated as ASME on the SAR drawings are obtained from ASME approved MM or MS supplier(s) with ASME CMTR's. Material is certified to meet all ASME Code criteria but is not eligible for certification or Code Stamping if a non-ASME fabricator is used. As the fabricator is not required to be ASME certified, material certification to NB-2130 is not possible. Material traceability & certification are maintained in accordance with TNW's NRC approved QA program
NB-6111	All completed pressure retaining systems shall be pressure tested	The shield plug support ring and vent and siphon block are not pressure tested due to the manufacturing sequence. The support ring is not a pressure-retaining item and the siphon block weld is helium leak tested after fuel is loaded and the inner top closure plate installed.
NB-7000	Overpressure Protection	No overpressure protection is provided for the 24PT1-DSC. The function of the 24PT1-DSC is to contain radioactive materials under normal, off-normal and hypothetical accident conditions postulated to occur during transportation and storage. The 24PT1-DSC is designed to withstand the maximum internal pressure considering 100% fuel rod failure at maximum accident temperature. The 24PT1-DSC is pressure tested to 120% of normal operating design pressure. An overpressure protection report is not prepared for the DSC.
NB-8000	Requirements for nameplates, stamping & reports per NCA-8000	The 24PT1-DSC nameplate provides the information required by 10CFR 71, 49CFR173 and 10CFR 72 as appropriate. Code stamping is not required for the 24PT1-DSC. QA Data packages are prepared in accordance with the requirements of 10CFR 71, 10CFR 72 and TNW's approved QA program.

Table 3.1-15
ASME Code Exceptions for the 24PT1-DSC (NG/NF)
(24PT1-DSC Basket Code Exceptions)

Reference ASME Code Section/Article	Code Requirement	Exception, Justification & Compensatory Measures
NCA	All	Not compliant with NCA
NG/NF-1100	Requirements for Code Stamping of Components	The 24PT1-DSC baskets are designed & fabricated in accordance with the ASME Code, Section III, Subsection NG/NF to the maximum extent practical as described in the 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 NG/NF-4121	Material must be supplied by ASME approved material suppliers Material Certification by Certificate Holder	All materials designated as ASME on the SAR drawings are obtained from ASME approved MM or MS supplier with ASME CMTR's. Material is certified to meet all ASME Code criteria but is not eligible for certification or Code Stamping if a non-ASME fabricator is used. As the fabricator is not required to be ASME certified, material certification to NG/NF-2130 is not possible. Material traceability & certification are maintained in accordance with TNW's NRC approved QA program.
Table NG-3352-1	Permissible Joint Efficiency Factors	Joint efficiency (quality) factor of 1 is assumed for the guidesleeve longitudinal weld. Table NG-3352-1 permits a quality factor of 0.5 for full penetration weld with visual inspection. Inspection of both faces provides n= (2*0.5)=1. This is justified by this gauge of material (0.12 inch) with visual examination of both surfaces which ensures that any significant deficiencies would be observed and corrected

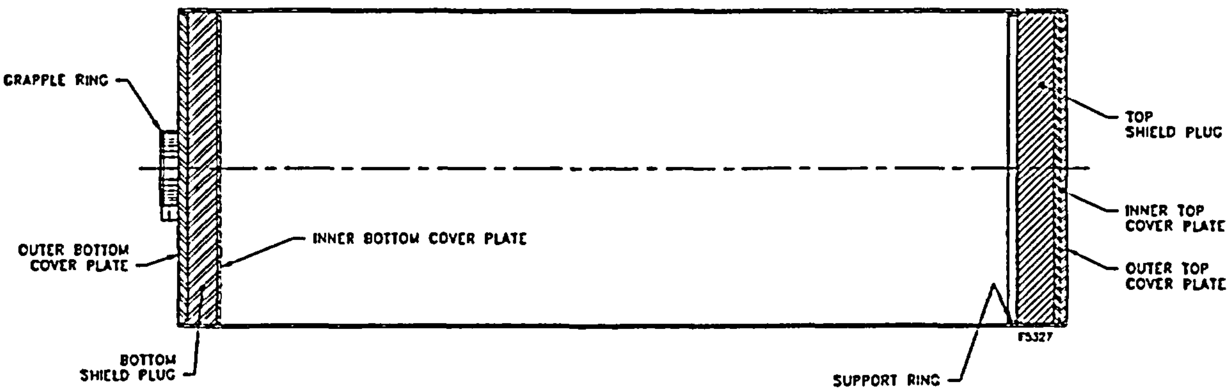


Figure 3.1-1
<u>Advanced NUHOMS® System 24PT1-DSC Canister Shell Assembly</u>

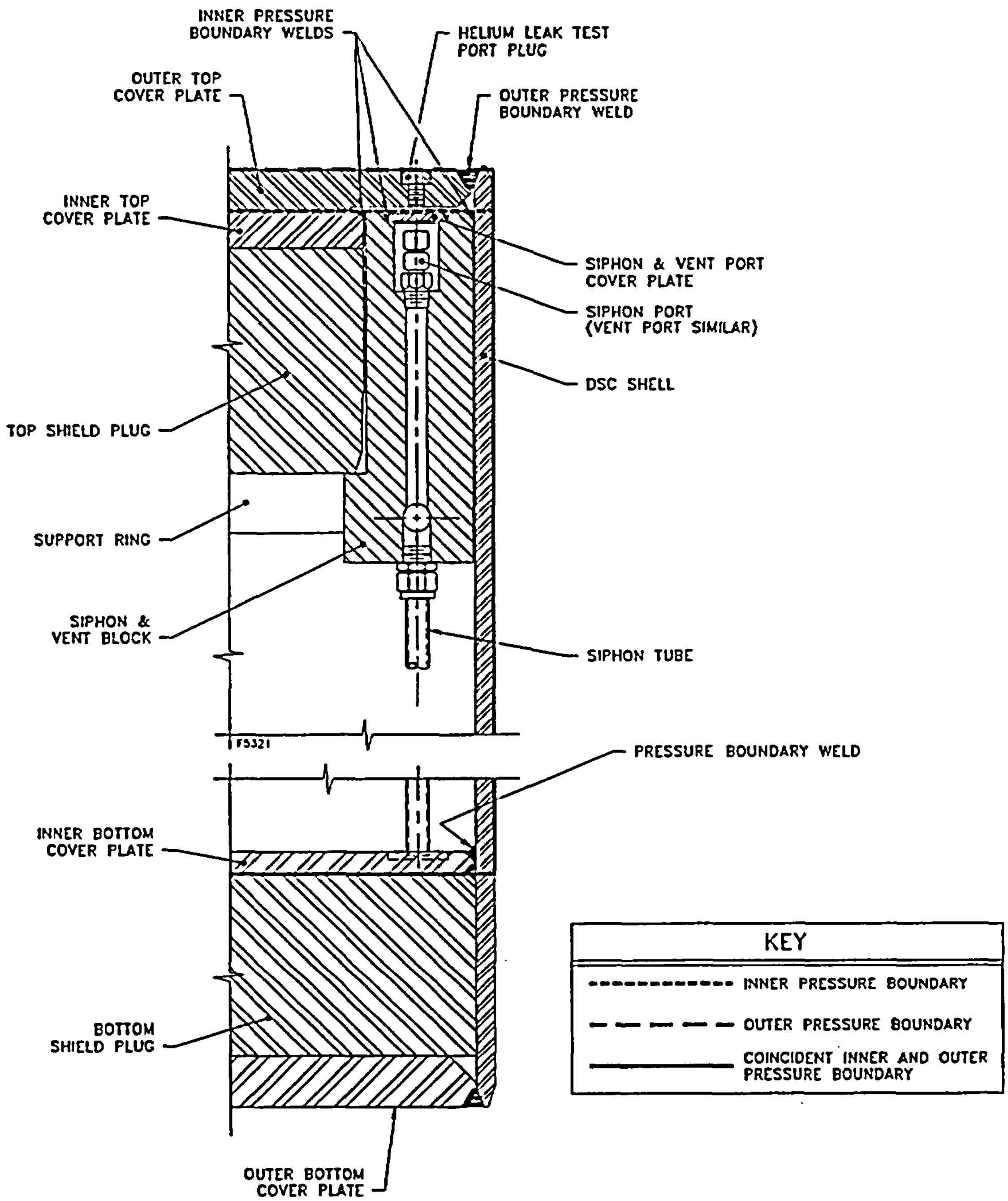


Figure 3.1-2
24PT1-DSC Pressure Boundary Location

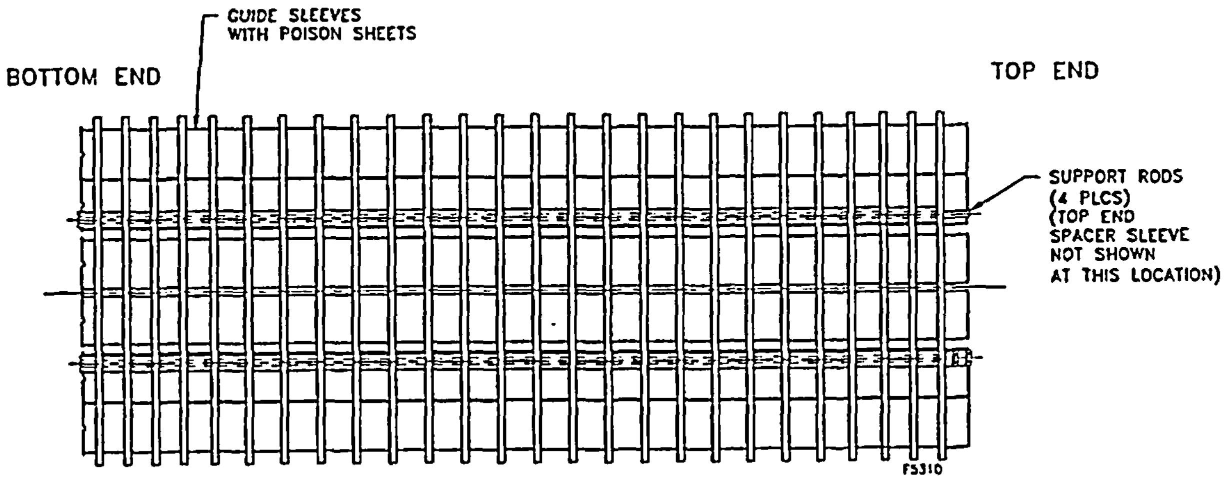


Figure 3.1-3
Advanced NUHOMS® System 24PT1-DSC Canister Basket (Side View)

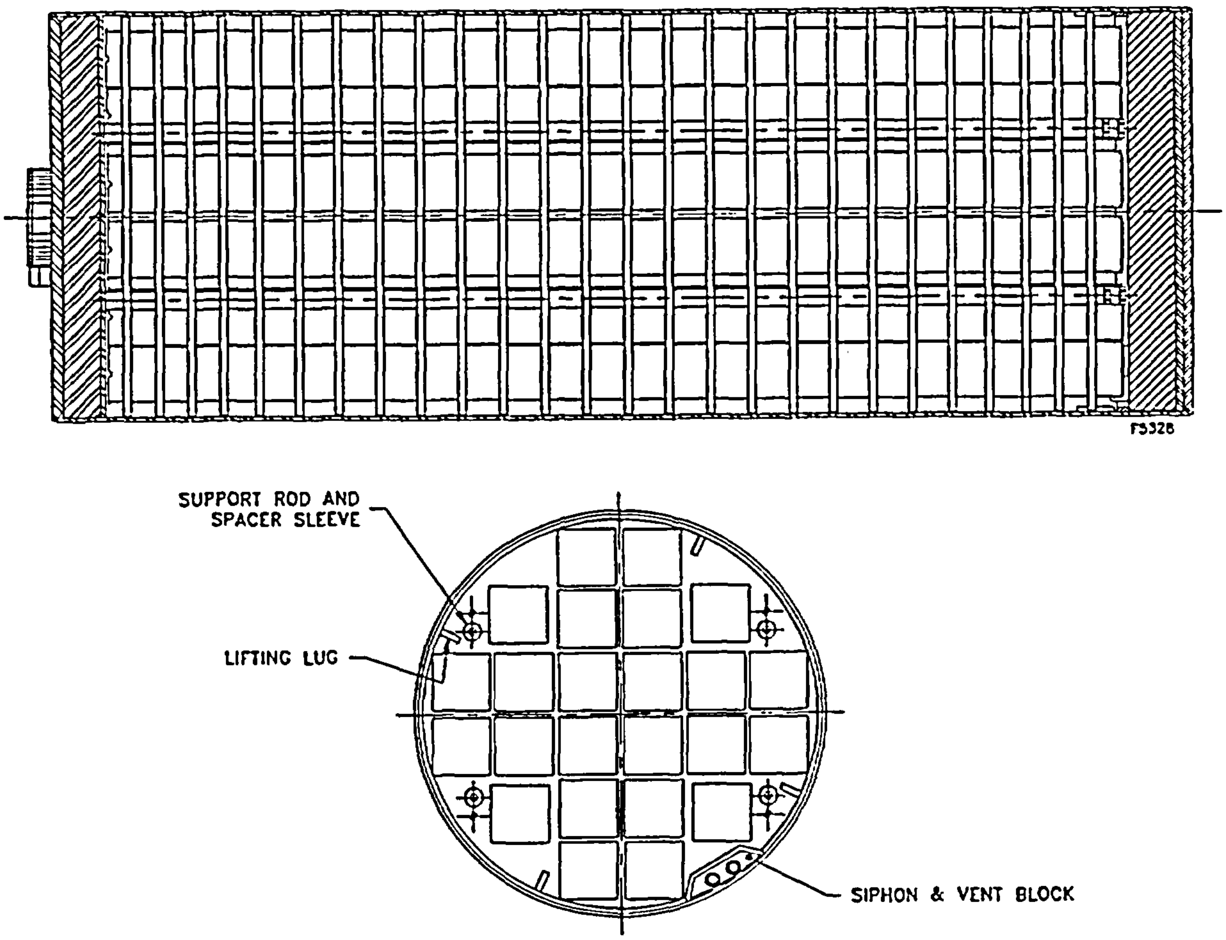


Figure 3.1-4
Advanced NUHOMS® System 24PT1-DSC Canister Basket & Shell (Side and End View)

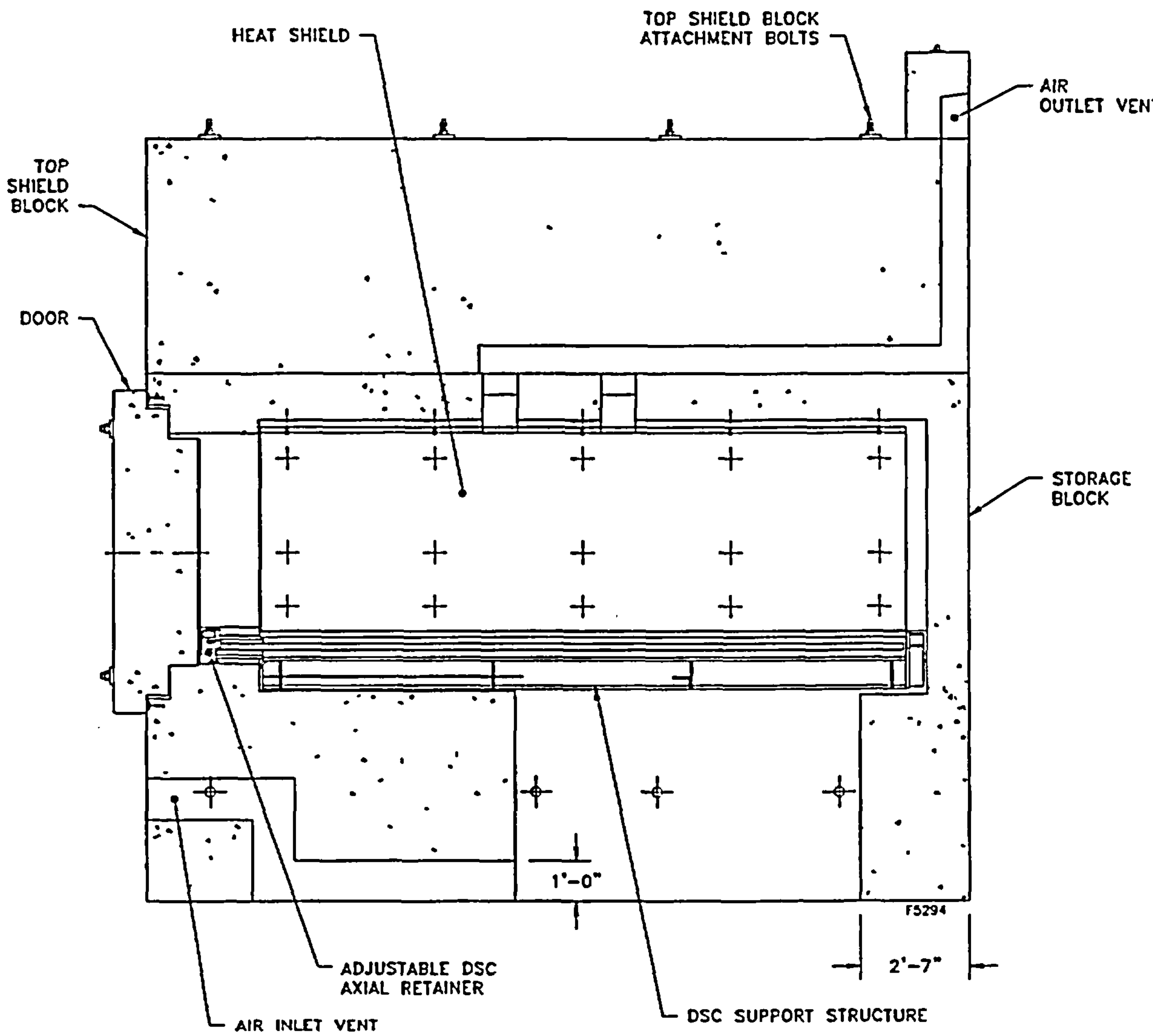


Figure 3.1-5
Prefabricated AHSM – Longitudinal Section

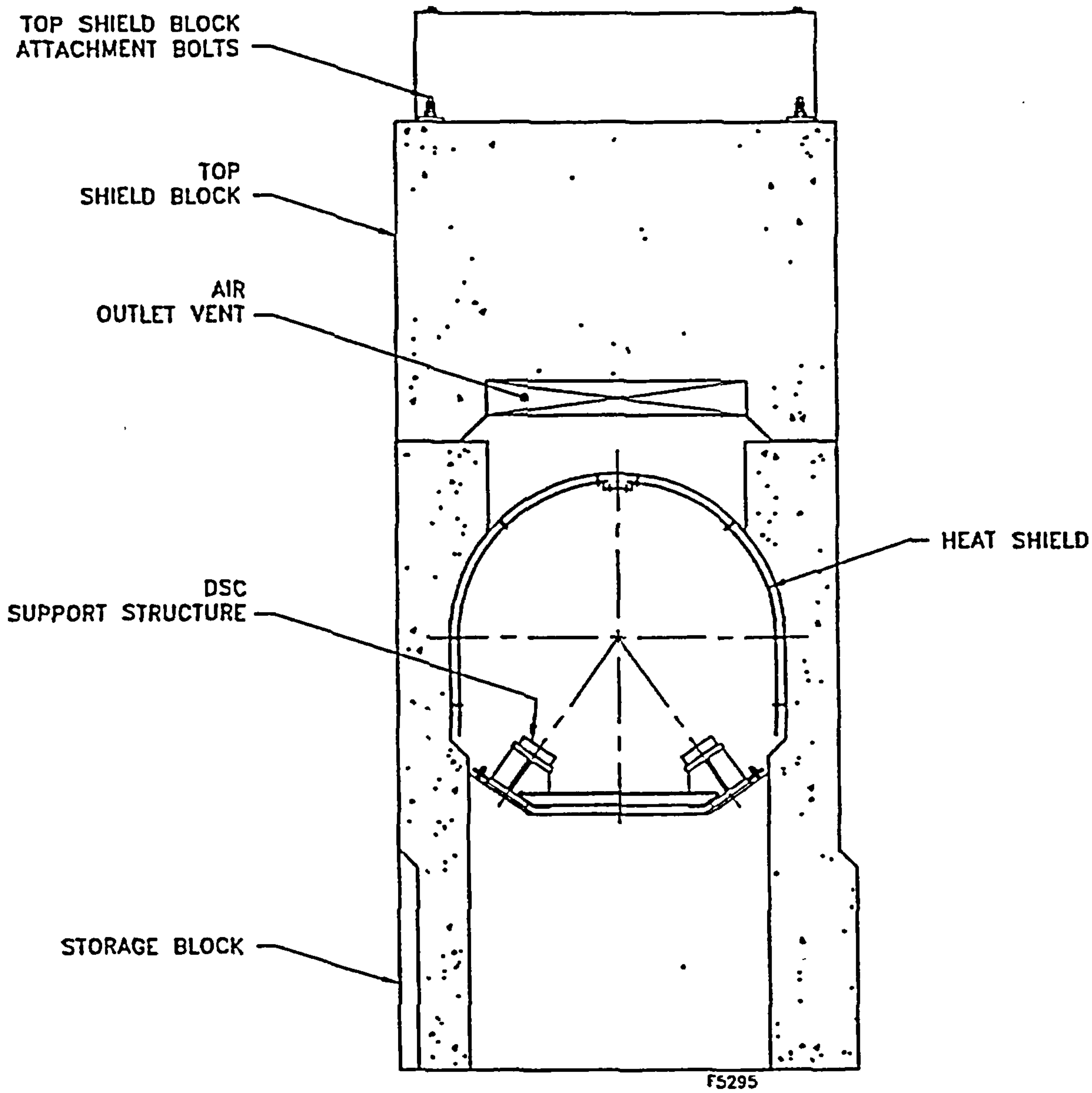


Figure 3.1-6
Prefabricated AHSM – Cross Section

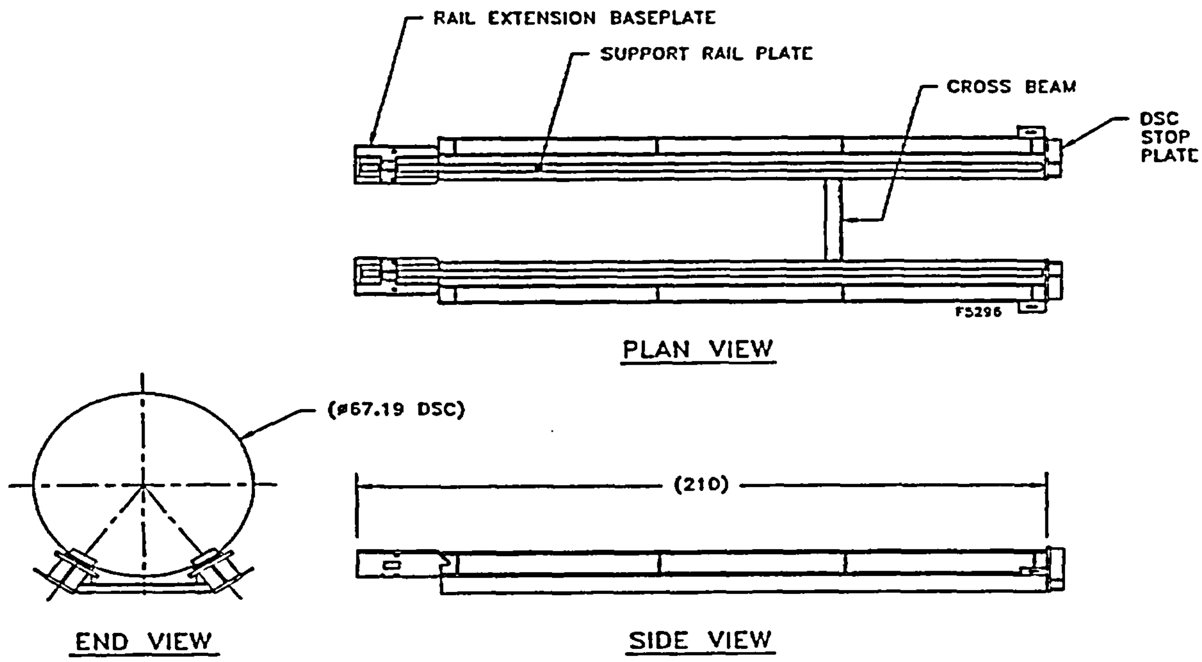


Figure 3.1-7
Shop Fabricated 24PT1-DSC Support Structure

3.2 Weights and Centers of Gravity

The weight and center of gravity of a 24PT1-DSC loaded with Westinghouse 14x14 fuel is listed in Table 3.2-1. The radial center of gravity is on the axis of the 24PT1-DSC.

The total weight of the 24PT1-DSC includes the shell assembly, the internal basket assembly, and the fuel. Fuel spacers are used with the Westinghouse 14x14 fuel to center the fuel within the 24PT1-DSC cavity.

Table 3.2-1 also gives an upper and lower bound weight and center of gravity of the AHSM. For an upper bound weight, the AHSM is assumed to be loaded with a 24PT1-DSC that conservatively weighs 82,000 lbs., and for the lower bound weight the AHSM is assumed to be unloaded.

A variation in the weight distribution is allowed provided the radial center of gravity does not deviate from the 24PT1-DSC centerline by more than 0.1".

Table 3.2-1
Weights and Centers of Gravity of the 24PT1-DSC

	Component	Weight(5) (lbs)
24PT1-DSC Canister(3)	Shell Assembly	15,600
	Basket Assembly	18,700
	Top Shield Plug	7,400
	Inner Top Cover Plate	1,200
	Outer Top Cover Plate	1,400
	Fuel Spacers	2,700
	Westinghouse 14x14 Fuel including NFAH	31,700
	TOTAL	78,400(6)
	Center of Gravity	91.5 inches(1)
Loaded AHSM(4)	Weight	400,300
	Center of Gravity	121.1 inches(2)
Unloaded AHSM	Weight	318,300
	Center of Gravity	126.1 inches(2)

Notes:

(1) See Figure 3.2-1 for the location of the center of gravity relative to the outside edge of the outer bottom cover plate of the 24PT1-DSC.

(2) See Figure 3.2-2 for the location of the center of gravity relative to the bottom of the AHSM

(3) The total 24PT1-DSC weight includes Westinghouse 14x14 Fuel and non fuel assembly hardware (NFAH)

(4) The total loaded weight of a loaded AHSM includes a loaded 24PT1-DSC that conservatively weighs 82,000 lbs.

(5) The weight values are rounded to the nearest 100 lbs.

(6) Four failed fuel cans would weigh an additional 1,000 lbs., (approx)

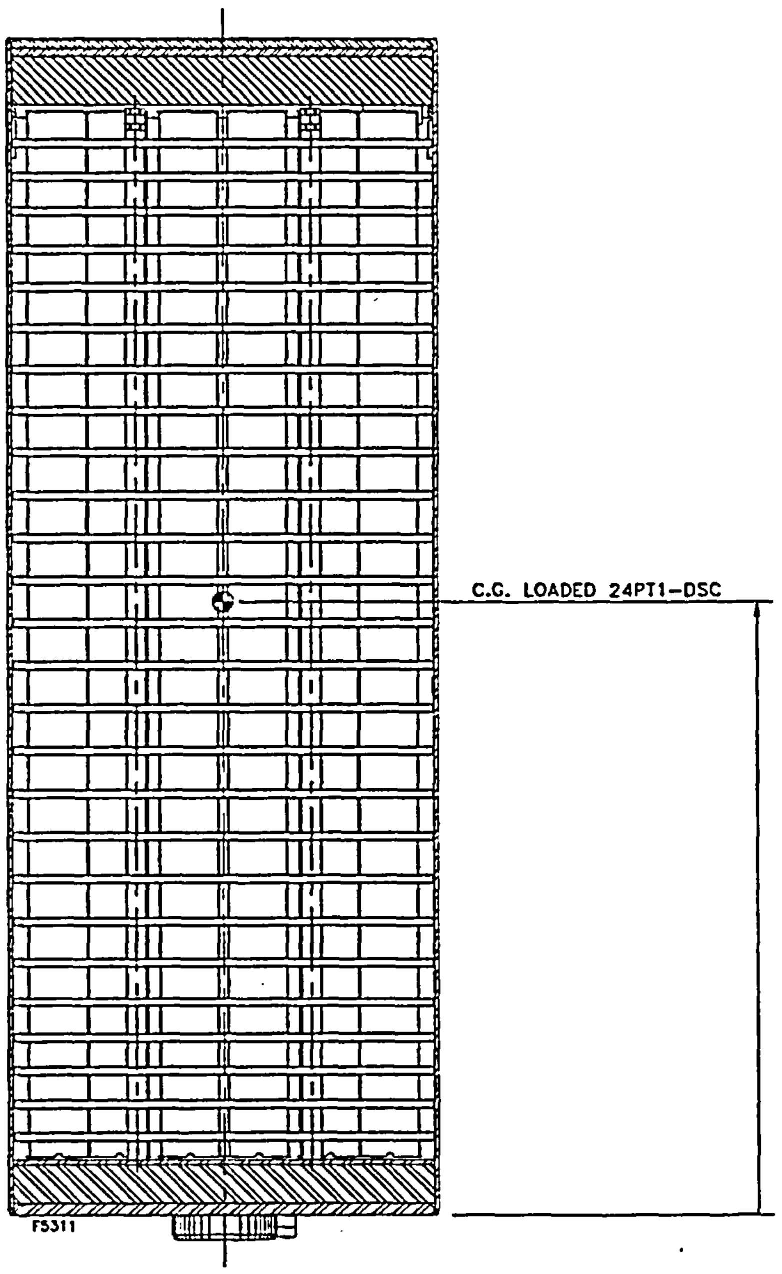


Figure 3.2-1
Schematic Location of Center of Gravity of the 24PT1-DSC

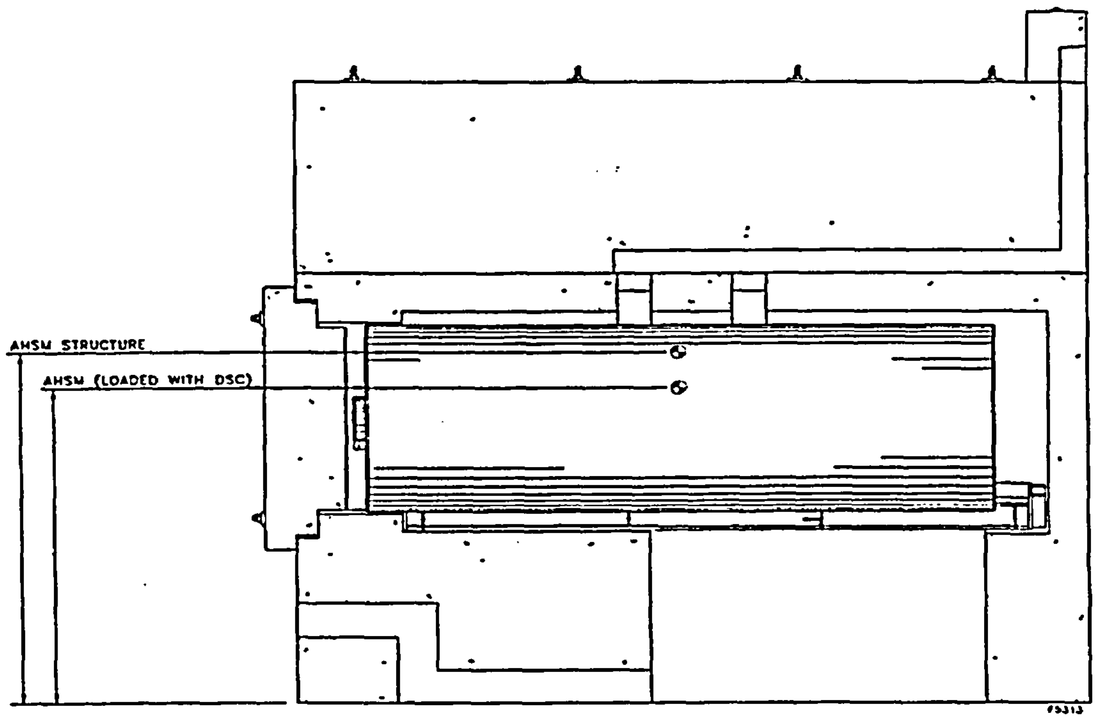


Figure 3.2-2
Schematic Location of Center of Gravity of the 24PT1-DSC in the AHSM

3.3 Mechanical Properties of Materials

3.3.1 24PT1-DSC Material Properties

The principal materials of construction for the Advanced NUHOMS® 24PT1-DSC are stainless and carbon steel. The 24PT1-DSC cylindrical shell and cover plates are constructed from SA-240 Type 316 stainless steel. The shield plugs are constructed from ASTM A36 carbon steel. The 24PT1-DSC basket assembly guidesleeve and oversleeve assemblies are constructed from SA-240 Type 304 stainless steel. The support rods and spacer sleeves are fabricated from SA-564 Type 630 precipitation hardened martensitic stainless steel. The spacer discs are fabricated from SA-537 Class 2 carbon steel. The neutron absorber plates are constructed from boron carbide/aluminum metal matrix composite material. The carbon steel top shield plug and the spacer discs are coated with electroless nickel.

Table 3.3-1 contains the ASME Code material properties for SA-240 Type 316 stainless steel material. Material properties for the A36 carbon steel shield plugs are contained in Table 3.3-2.

ASME Code material properties for the SA-240 Type 304 stainless steel guidesleeves and oversleeves are contained in Table 3.3-3. ASME Code material properties for the SA-537 Class 2 carbon steel spacer discs are contained in Table 3.3-4. ASME Code material properties for the SA-564 Type 630 support rods and spacer sleeves are contained in Table 3.3-5.

3.3.1.1 Radiation Effects on 24PT1-DSC Materials

Gamma radiation has no significant effect on metals. The effect of fast neutron irradiation of metals is a function of the integrated fast neutron fluence, which is on the order of 1×10^{15} neutrons/cm^2 inside the 24PT1-DSC after 50 years. Studies on fast neutron damage in stainless steel, and low alloy steels rarely evaluate damage below 10^{17} n/cm^2 because it is not significant [3.40]. Extrapolation of the data available down to the 10^{15} range confirms that there will be no measurable neutron damage to any of the 24PT1-DSC metallic components.

3.3.1.2 Weld Material

Welding processes, welders and welding materials used for the welding of the 24PT1-DSC meet the requirements of the appropriate ASME Section III subsections and Section IX. Non-Code welds meet the provisions of Section IX of the ASME Code or AWS D1.1 [3.38] or D1.6 [3.39]. Weld metal material properties meet the requirements of Section II of the ASME Code or associated AWS requirements.

3.3.1.3 Brittle Fracture

Brittle fracture is not a concern for the stainless steel components. For the SA-537 Class 2 carbon steel spacer discs, a T_{NDT} of less than or equal to –80°F is specified in accordance with the requirements of NUREG/CR-1815 for 10CFR 71 transportation [3.37].

3.3.2 AHSM Material Properties

The temperature dependent material properties for concrete and reinforcing steel are provided in Table 3.3-6 and Table 3.3-7. The material properties of the Type 304 Stainless Steel rails are identical to the ASME Code properties listed in Table 3.3-3.

3.3.2.1 Radiation Effects on AHSM Concrete

The accumulated neutron flux over a 40 year service life of the AHSM is estimated to be 1.5E14 neutrons/cm^2. From the study by Hilsdorf, Kropp, and Koch [3.23], the compressive strength and modulus of elasticity of concrete is not affected by a neutron flux of this magnitude.

The gamma energy flux deposited in the AHSM concrete is 1.7E9 MeV/cm^2-sec. or 3.0E-4 watt/cm^2. According to ANSI/ANS-6.4-1977 [3.24], the temperature rise in concrete due to this level of radiation is negligible. Thus, radiation effects on concrete strength are not evaluated further for the AHSM design.

3.3.3 Materials Durability

As shown in Table 3.3-1 through Table 3.3-7, all materials meet the appropriate requirements of the ASME Code, ACI Code, and ASTM Standards. The durability of the steel components is well beyond the design life of the applicable components. The specifications controlling the mix of concrete, specified minimum concrete strength requirements, and fabrication control ensure durability of the materials for this application.

Table 3.3-1
ASME Code Material Properties for SA-240 Type 316 Stainless Steel

SA-240 Type 316 Stainless Steel Plate (16Cr-12Ni-2Mo)

Temp. °F	ASME Code Material Properties						
	S_m (ksi)	S_y (ksi)	S_u (ksi)	E ($x10^6$ psi)	α_{inst} ($10^{-6}\,°F^{-1}$)	α_{avg} ($10^{-6}\,°F^{-1}$)	k BTU/hr-ft-°F
-100	--	--	--	29.1	--	--	--
-20	20.0	30.0	75.0	--	--	--	--
70	--	--	--	28.3	8.42	--	7.7
100	20.0	30.0	75.0	--	8.59	8.54	7.9
150	--	--	--	--	8.84	8.64	8.2
200	20.0	25.8	75.0	27.6	9.09	8.76	8.4
250	--	--	--	--	9.33	8.88	8.7
300	20.0	23.3	73.4	27.0	9.56	8.97	9.0
350	--	--	--	--	9.76	9.11	9.2
400	19.3	21.4	71.8	26.5	9.95	9.21	9.5
450	--	--	--	--	10.10	9.32	9.8
500	18.0	19.9	71.8	25.8	10.25	9.42	10.0
550	--	--	--	--	10.38	9.50	10.3
600	17.0	18.8	71.8	25.3	10.51	9.60	10.5
650	16.7	18.5	71.8	--	10.64	9.69	10.7
700	16.3	18.1	71.8	24.8	10.76	9.76	11.0
750	16.1	17.8	71.4	--	10.87	9.81	11.2
800	15.9	17.6	70.9	24.1	10.98	9.90	11.5
Reference (ASME II)	Table 2A	Table Y-1	Table U	Table TM-1 Group G	Table TE-1 (18Cr-13Ni -3Mo & 16Cr-12Ni-2Mo)		Table TCD 16Cr-12Ni-2Mo

Table 3.3-2
Material Properties for ASTM A36 Carbon Steel

(Properties are taken from ASME Code Section II for SA-36 Steel.
The ASME material specification is identical to the ASTM A36 steel specification)

A-36 Carbon Steel (C-Mn-Si) Plate

Temp. °F	ASME Code Material Properties						
	S_m (ksi)	S_y (ksi)	$S_u^{(1)}$ (ksi)	E ($x10^6$ psi)	α_{inst} (10^{-6} °F^{-1})	α_{avg} (10^{-6} °F^{-1})	k BTU/hr-ft-°F
-100	--	--	--	30.2	--	--	--
-20	19.3	36.0	58.0	--	--	--	--
70	--	--	--	29.5	5.42	--	23.6
100	19.3	36.0	58.0	--	5.65	5.53	23.9
150	--	--	--	--	6.03	5.71	24.2
200	19.3	32.8	58.0	28.8	6.39	5.89	24.4
250	--	--	--	--	6.73	6.09	24.4
300	19.3	31.9	58.0	28.3	7.04	6.26	24.4
350	--	--	--	--	7.33	6.43	24.3
400	19.3	30.8	58.0	27.7	7.60	6.61	24.2
450	--	--	--	--	7.85	6.77	23.9
500	19.3	29.1	58.0	27.3	8.07	6.91	23.7
550	--	--	--	--	8.28	7.06	23.4
600	17.7	26.6	58.0	26.7	8.46	7.17	23.1
650	17.4	26.1	58.0	--	8.62	7.30	22.7
700	17.3	25.9	58.0	25.5	8.75	7.41	22.4
750	not permitted at temperatures above 700°F				8.87	7.50	22.0
800	--	--	--	--	8.96	7.59	21.7
Reference (ASME II)	Table 2A	Table Y-1	Table U	Table TM-1 C ≤ 0.30%	Table TE-1 (Group C)		Table TCD (C-Mn-Si)

Notes: 1. S_u from Table Y-1, temperature dependence based on similar carbon steels.

Table 3.3-3
ASME Code Material Properties for SA-240 Type 304 Stainless Steel

SA-240 Type 304 Stainless Steel Plate (18Cr-8Ni)

Temp. °F	ASME Code Material Properties						
	S_m (ksi)	S_y (ksi)	S_u (ksi)	E ($x10^6$ psi)	α_{inst} (10^{-6} °F^{-1})	α_{avg} (10^{-6} °F^{-1})	k BTU/hr-ft-°F
-100	--	--	--	29.1	--	--	--
-20	20.0	30.0	75.0	--	--	--	--
70	--	--	--	28.3	8.46	--	8.6
100	20.0	30.0	75.0	--	8.63	8.55	8.7
150	--	--	--	--	8.87	8 67	9.0
200	20.0	25.0	71.0	27.6	9.08	8.79	9.3
250	--	--	--	--	9.27	8.90	9.6
300	20.0	22.5	66.0	27.0	9.46	9.00	9.8
350	--	--	--	--	9.64	9.10	10.1
400	18.7	20.7	64.4	26 5	9.80	9.19	10.4
450	--	--	--	--	9.95	9.28	10.6
500	17.5	19.4	63.5	25.8	10.10	9.37	10.9
550	--	--	--	--	10.25	9.45	11.1
600	16.4	18.2	63.5	25.3	10.38	9.53	11.3
650	16.2	17.9	63.5	--	10.50	9.61	11.6
700	16.0	17.7	63.5	24.8	10.60	9.69	11.8
750	15.6	17.3	63.1	--	10.70	9.76	12.0
800	15.2	16.8	62.7	24.1	10.79	9.82	12.2
Reference (ASME II)	Table 2A	Table Y-1	Table U	Table TM-1 Group G	Table TE-1 18Cr-8Ni & 18Cr-11Ni		Table TCD

Table 3.3-4
ASME Code Material Properties for SA-537 Class 2 Carbon Steel

SA-537 Class 2 Carbon Steel (C-Mn-Si) Plate

Temp. °F	ASME Code Material Properties						
	S_m (1) (ksi)	S_y (1) (ksi)	S_u (1) (ksi)	E ($\times 10^6$ psi)	α_{inst} (10^{-6} °F^{-1})	α_{avg} (10^{-6} °F^{-1})	k BTU/hr-ft-°F
-100	--	--	--	30.2	--	--	--
-20	26.7	60 0	80.0	--	--	--	--
70	--	--	--	29.5	5.42	--	23.6
100	26.7	60.0	80 0	--	5.65	5.53	23.9
150	--	--	--	--	6.03	5.71	24.2
200	26.7	55.0	80.0	28.8	6.39	5.89	24.4
250	--	--	--	--	6.73	6.09	24.4
300	26.7	52.2	80.0	28.3	7.04	6.26	24 4
350	--	--	--	--	7.33	6.43	24.3
400	26 4	50.0	79.3	27.7	7.60	6.61	24.2
450	--	--	--	--	7.85	6.77	23.9
500	26.4	47.6	79.3	27.3	8.07	6.91	23.7
550	--	--	--	--	8 28	7.06	23.4
600	26.4	46.0	79.3	26.7	8.46	7.17	23.1
650	26.2	45.2	78.8	--	8.62	7.30	22.7
700	25.9	44.5	77.8	25.5	8.75	7.41	22 4
750	not permitted at temperatures above 700°F						
800	--	--	--	--	--	--	
Reference (ASME II)	Table 2A t ≤ 2½"	Table Y-1 t ≤ 2½"	Table U t ≤ 2½"	Table TM-1 C ≤ 0 30%	Table TE-1 (Group C)		Table TCD (C-Mn-Si)

Notes: 1. These properties only apply to material 2½ inches thick or less.

Table 3.3-5
ASME Code Material Properties for SA-564 Type 630 Steel

SA-564 Type 630 Precipitation Hardened Martensitic Stainless Steel (17Cr-4Ni-4Cu)

Temp. °F	ASME Code Material Properties[1,2]						
	S_m (ksi)	S_y (ksi)	S_u (ksi)	E ($x10^6$ psi)	α_{inst} (10^{-6} °F^{-1})	α_{avg} (10^{-6} °F^{-1})	k BTU/hr-ft-°F
-100	--	--	--		--	--	--
-20	46.7	115.0	140.0	--	--	--	--
70	--	--	--		5.89	--	9.9
100	46.7	115.0	140.0	--	5.89	5.89	10.1
150	--	--	--	--	5.89	5.89	10.4
200	46.7	106.3	140.0		5.90	5.90	10.6
250	--	--	--	--	5.90	5.90	10.9
300	46.7	101.9	140.0		5.90	5.90	11.2
350	--	--	--	--	5.91	5.91	11.4
400	45 5	98.3	136 3		5.91	5.91	11.7
450	--	--	--	--	5.91	5.91	12.0
500	44.4	95.2	133 2		5.91	5.91	12.2
550	--	--	--	--	5.93	5.93	12.5
600	43 8	92.8	131.4		5.96	5.93	12.7
650	43.5	91.5	--	--	5.99	5.93	13.0
700	not permitted at temperatures above 650°F						
750							
800	--	--	--	--	--	--	
Reference (ASME II)	Table 2A	Table Y-1	Table U	Table TM-1	Table TE-1 (17Cr-4Ni-4Cu)		Table TCD (17Cr-4Ni-4Cu)

Notes: 1. This material has reduced toughness at room temperature after exposure for about 5000 hr at 600°F and after shorter exposure above 650°F. (See Note B1(3) of Table Y-1, Note B1(2) of Table U, and Note B1(12) of Table 2A).

2. These values apply to material in the H1100 condition. See Note B1(6) of Table 2A , Note B1(5) of Table Y-1, and Note B1(5) of Table U

Table 3.3-6
Concrete Material Properties at Temperature

Material	Temperature (°F)	28 Day Compressive Strength, f_c' (ksi)	Modulus of Elasticity, E (1.0E3 ksi)
Concrete Normal Weight[(1)] 5000 psi Strength	100	5.0	4.0
	200	5.0	3.6
	300	4.8	3.3
	400	4.5	3.0
	500	4.5	2.9

Note:

(1) Concrete data obtained from Handbook of Concrete Engineering [3.25]

Table 3.3-7
Reinforcing Steel Material Properties at Temperature

Material	Temperature (°F)	Yield Strength (ksi)	Modulus of Elasticity, E (1.0E3 ksi)
Reinforcing Steel ASTM A615 Grade 60(1)	100	60.0	29.0
	200	57.0	28.4
	300	54.0	27.8
	400	51.0	27.3
	500	51.0	27.0

Note:
(1) Reinforcing Steel data obtained from Handbook of Concrete Engineering [3.25]

3.4 General Standards for 24PT1-DSC and AHSM

3.4.1 Chemical and Galvanic Reactions

The materials of the 24PT1-DSC shell and basket assemblies and AHSM components have been reviewed to determine whether chemical, galvanic or other reactions among the materials, contents and environment might occur during any phase of loading, unloading, handling or storage. This review is summarized below:

The 24PT1-DSC AHSM are exposed to the following environments:

- During loading and unloading, the canister is inside of the transfer cask. Thus, the exterior of the canister will not be exposed to pool water. The annulus between the transfer cask and canister is filled with demineralized water and is covered with an inflatable seal.
- The interior surfaces of the canister, top shield plug, and the basket will be exposed to (borated) pool water. The transfer cask and canister are kept in the spent fuel pool for only a short period of time, typically about 6 hours to load or unload fuel, and 2 hours to lift the loaded transfer cask/canister out of the spent fuel pool. An additional 12 to 24 hours is typically needed to decontaminate the cask and remove the water for vacuum drying of the SFA's
- The canister is thoroughly dried by a vacuum drying process before storage. It is then backfilled with helium, thus providing a non-corrosive environment. During storage, the interior of the canister is exposed only to the helium environment. The helium environment does not support chemical or galvanic reactions because both moisture and oxygen must be present for a reaction to occur.
- During storage, the exterior of the canister is protected by the concrete AHSM. The AHSM is vented, so the exterior of the canister is exposed to the atmosphere. The canister is fabricated from austenitic stainless steel which is generally resistant to corrosion.
- The support steel in the AHSM that is in contact with the 24PT1-DSC is also stainless steel.
- AHSM carbon steel embeds are coated to protect them from corrosion or may utilize equivalent strength stainless steel components as necessary when used in harsh environments.

Materials used for the Advanced NUHOMS® 24PT1-DSC are shown in the Parts List of Drawing NUH-05-4010, provided in Section 1.5.2. The canister shell material is SA-240 Type 316 Stainless Steel. The top shield plug material is A36 carbon steel plated with an electroless nickel coating. The bottom shield plug is sealed within the shell and inner and outer bottom cover plates and thus it does not come in contact with the external environment.

The basket assembly consists of SA-537 Class 2 carbon steel spacer discs which are blasted clean and coated with electroless nickel. The guidesleeve assemblies, which consist of guidesleeves, oversleeves, and connecting shim plates are Type 304 stainless steel. Neutron absorber plates are constructed from boron carbide/aluminum metal matrix composite (neutron poison) plates and are sandwiched between the guidesleeves and oversleeves. Each guidesleeve assembly contains either two or four neutron absorber plates depending upon its location within the basket assembly. The oversleeves are welded to the guidesleeves. The neutron poison is not welded or bolted to the guidesleeve, but is held in place by the oversleeves and the shim plates. The support rod assemblies consist of SA-564 Type 630 martensitic stainless steel rod and spacer sleeves located in between the spacer discs. The basket assembly is held in position by the nominal pretension force of 40 kips applied to each support rod during assembly.

Potential sources of chemical or galvanic reactions are the interaction between the carbon steel based spacer discs, the aluminum-based neutron poison and stainless steel within the basket and the pool water, and the interaction of the stainless steel top cover plates with the top carbon steel shield plugs.

Typical water chemistry in a PWR Spent Fuel pool is as follows:

pH (77°F)	4.5-9.0
Chloride, max	0.15 ppm
Fluoride, max	0.1 ppm
Dissolved Air, max	Saturated
Lithium, max	2.5 ppm
Boric Acid	2100-2600 ppm
Pool Temperature Range	40 - 140°F

3.4.1.1 Behavior of Austenitic Stainless Steel in Borated Water

With the exception of the shield plugs, spacer discs, and neutron poison plates (carbon steel, carbon steel, and Boral™ respectively), all parts of the 24PT1-DSC are made from stainless steel. Stainless steel does not exhibit general corrosion when immersed in borated water.

Stress corrosion cracking in the stainless steel welds is also not expected to occur, since these welds are not highly stressed during normal operations. There may be some residual fabrication stresses as a result of welding of the stainless steel guidesleeves and fusion welds between the stainless steel plates of the guidesleeves and oversleeves. Of the corrosive agents that could initiate stress corrosion cracking in the stainless steel welds, only the combination of chloride ions with dissolved oxygen occurs in spent fuel pool water. Although stress corrosion cracking can take place at very low chloride concentrations and temperatures such as those in spent fuel pools (less than 10 ppb and 160°F, respectively), the effect of low chloride concentration and low temperature is to greatly increase the initiation time, that is, the period during which the corrodent is breaking down the passive oxide film on the stainless steel surface. Below 60°C (140°F), stress corrosion cracking of austenitic stainless steel does not occur at all. At 100°C (212°F), chloride concentration on the order of 15% is required to initiate stress corrosion cracking [3.26]. At 288°C (550°F), with tensile stress at 100% of yield in PWR water containing 100 ppm O_2, time to crack is about 40 days in sensitized 304 stainless steel [3.26]. Thus, the combination of low chlorides, low temperature and short time of exposure to the corrosive environment eliminates the possibility of stress corrosion cracking in the guidesleeve welds. The predicted maximum guidesleeves temperature in the pool is 150°F.

3.4.1.2 Behavior of Boral™ in Borated Water

Boral™ is a proven neutron poison used extensively in spent fuel storage racks. The short term exposure of the material to borated water in the spent fuel storage canisters will have significantly less effect on the Boral™ than that experienced in spent fuel pools.

3.4.1.3 Electroless Nickel Plated Carbon Steel

The carbon steel top shield plug and the spacer discs are plated with electroless nickel. This coating is similar to the coating used on the Standard NUHOMS® 52B canister (C of C 72-1004) [3.15]. This coating has been evaluated for potential galvanic reactions in Transnuclear West's response to NRC Bulletin 96-04 [3.28]. The reported corrosion rates are insignificant in PWR pools, and will result in a negligible rate of reaction for the 24PT1-DSC systems.

3.4.1.4 Hydrogen Generation

During the initial passivation state, small amounts of hydrogen gas may be generated in the 24PT1-DSC. The passivation stage may occur prior to submersion into the spent fuel pool. Any amounts of hydrogen generated in the canister will be insignificant and will not result in a flammable gas mixture within the canister [3.28].

3.4.1.5 Effect of Galvanic Reactions on the Performance of the System

There are no significant galvanic reactions that could reduce the overall integrity of the canister, or its contents, during storage.

There are no reactions that would cause binding of the mechanical surfaces or the fuel to guidesleeves due to galvanic or chemical reactions.

There is no significant degradation of any safety component caused directly by the effects of the reactions, or by the effects of the reactions combined with the effects of long-term exposure of the materials to neutron or gamma radiation, high temperatures, or other possible conditions.

The canister and fuel cladding thermal properties are provided in Chapter 4. The emissivity of the basket components ranges from 0.10 for Boral™ sheets to 0.4 for stainless steel. If the stainless steel is oxidized, this value would increase, improving heat transfer. Therefore, the passivation reactions would improve the thermal properties of the 24PT1-DSC materials.

3.4.2 Positive Closure

Positive closure is provided by the redundant closure welds for the inner and outer top cover plates and the leak-tight (tested per ANSI N14.5 [3.10]) 24PT1-DSC shell assembly.

3.4.3 Lifting Devices

There are no permanent lifting devices used for lifting a loaded 24PT1-DSC (the loaded 24PT1-DSC is always inside a transfer/transportation cask during handling).

The evaluation of lifting devices is performed in the transfer system (see References [3.15], [3.16], and [3.31]).

3.4.4 Heat

3.4.4.1 Summary of Pressures and Temperatures

Temperatures and pressures for the 24PT1-DSC and AHSM are described in Chapter 4. Section 4.4, Section 4.5, and Section 4.6 describe the thermal evaluations performed for normal, off-normal, and accident conditions, respectively. Section 4.7 describes the thermal evaluations during fuel loading/unloading operations. Maximum and minimum temperatures for the various components of the Advanced NUHOMS® System for normal, off-normal, and accident conditions are summarized in Table 4.1-3, Table 4.1-4, and Table 4.1-5, respectively. These temperatures are used for the structural evaluations documented in Section 3.6. Stress allowables for the cask components are a function of component temperature. The temperatures used to perform the structural analysis are based on actual calculated temperatures or conservatively selected higher temperatures.

Table 4.4-11 provides a summary of the maximum 24PT1-DSC pressures for normal, off-normal and accident conditions. The pressures used in the 24PT1-DSC stress analyses, as summarized in Table 3.1-6, bound those summarized in *Table 4.4-11*.

3.4.4.2 Differential Thermal Expansion

Potential interference due to differential thermal expansion between the 24PT1-DSC shell assembly and the basket assembly components is evaluated in the longitudinal and radial directions of the 24PT1-DSC.

- In the radial direction, the gaps between the spacer discs and the inside of the 24PT1-DSC shell are evaluated for possible interference due to differential thermal expansion of the materials because of the differences in their coefficients of thermal expansion. The analyses show that for the worst case statistical stack up of tolerances, the radial gap between the spacer disc and the inside of the shell will close, but will not impose significant stresses in the 24PT1-DSC shell or the spacer disc.
- For the following interfaces, design clearances are established to ensure that there are no thermal interferences.
    - Guidesleeve to 24PT1-DSC Cavity (Length)
    - Guidesleeve to Spacer Disc Fuel Cutout
    - Neutron Absorber (Boral™) to Oversleeve
    - Support Rod Assembly to 24PT1-DSC Cavity (Length)

- SFA's and Fuel Spacer to 24PT1-DSC Cavity (Length)
- AHSM rail to 24PT1-DSC

- The coefficient of thermal expansion of the spacer disc material is slightly greater than the coefficient of thermal expansion of the support rod/spacer sleeve material. Thus, as the basket temperature increases, the spacer disc(s) will tend to expand faster than the rod assembly. This will increase tension in the support rod and increase compression in the spacer sleeves (similar to increasing the initial preload in the rod assembly). For a temperature rise from 70°F to 600°F, the load increase is less than 3.5 kips. Stresses from this load are included in the analysis of the rod assembly.
- Differential expansion between the (carbon steel) shield plug(s) and the (Type 316) shell is addressed in the thermal stress analyses (ANSYS) of the shell. Since the coefficient of expansion of the shell is significantly higher than the coefficient of expansion for the enclosed plug(s), thermal interferences are minimized.

3.4.4.3 Stress Calculations

The stress analyses have been performed using the acceptance criteria and load combinations presented in Section 3.1.2. The structural analyses for the 24PT1-DSC and the AHSM are summarized in Sections 3.6.1 and 3.6.2, respectively.

The stress analyses for the 24PT1-DSC are summarized in Section 3.6.1.1 for the shell assembly and Section 3.6.1.2 for the basket assembly components. Table 3.6-1 lists the detailed load combinations for the 24PT1-DSC. Finite element models of the shell assembly and the spacer discs have been developed, and detailed computer analyses have been performed using the ANSYS [3.22] computer program. The guidesleeves, support rods, damaged fuel canisters, and fuel spacers have been analyzed using a combination of ANSYS finite element models and hand calculations.

The structural analyses of the AHSM are summarized in Section 3.6.2. Table 3.6-10 is a summary of the AHSM design loading criteria. Table 3.6-12 and Table 3.6-13 summarize the load combinations for the AHSM and AHSM support steel structure, respectively.

3.4.4.3.1 24PT1-DSC Shell Assembly

Table 3.6-4 summarizes the maximum stress intensities in the 24PT1-DSC shell assembly components for the controlling load combinations for normal and off-normal operating conditions (ASME Service Levels A and B). Similarly, Table 3.6-5 and Table 3.6-6 summarize the maximum stress intensities in the 24PT1-DSC shell assembly components for the controlling accident conditions load combinations. All the stresses in the 24PT1-DSC confinement boundary assembly are acceptable.

3.4.4.3.2 Basket Assembly

The stress analyses results for the basket assembly are summarized in Table 3.6-7, Table 3.6-8 and Table 3.6-9. Table 3.6-7 presents a summary of the maximum stress intensities obtained for the spacer discs for the controlling load combinations.

Table 3.6-8 presents a summary of the maximum stress intensities for the guidesleeves. The highest stress ratio is 0.54 and corresponds to the side drop accident case. Table 3.6-9 presents a summary of the highest interaction ratios for the support rod assemblies. The highest interaction ratio is 0.58 and corresponds to the side drop accident case. Both the guidesleeves and support rod assemblies are shown to have sufficient margin to ensure that these components perform their intended design function.

The analyses presented in Section 3.6 demonstrate that even in the extreme unlikely hypothetical accident scenarios, there is sufficient margin to ensure that the basket components perform their intended function.

3.4.4.3.3 AHSM

The stresses for the AHSM components are compared to their allowables in Table 3.6-15 through Table 3.6-21.

3.4.4.4 Comparison with Allowable Stresses

The stresses for each of the major components of the 24PT1-DSC are compared to their allowables in Table 3.6-2 through Table 3.6-9. The stresses for the AHSM components are compared to their allowables in Table 3.6-15 and Table 3.6-19 through Table 3.6-21.

3.4.5 Cold

The AHSM and 24PT1-DSC have been designed for operation at a daily average ambient temperatures as low as –40°F. The shielding materials are all solids, so there is no concern over freezing.

The SA 240 Type 316 stainless steel along with the E316 weld metal are not subject to brittle fracture for the range of operating temperatures of the 24PT1-DSC. Carbon steel spacer disc materials are procured with a $T_{NDT} \leq$-80°F to meet the requirements of NUREG/CR 1815 for brittle fracture.

3.5 Fuel Rods General Standards for 24PT1-DSC

This section provides the temperature criteria used in the 24PT1-DSC thermal evaluation for the safe storage and handling of SFA's in accordance with the requirements of 10CFR 72 in order to ensure a very low probability of rod failure during long term storage and to protect against gross failures during short term events. Short term events include transfer operations, off-normal conditions, accident conditions, and other short term operational events. These acceptance criteria apply for the following fuel types: Westinghouse 14x14 stainless steel clad and Westinghouse 14x14 MOX Zircalloy clad fuel assemblies.

This section also contains the analysis of the thermal and irradiation growth of the fuel assemblies to ensure adequate space exists within the 24PT1-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

3.5.1.1 Westinghouse 14x14 MOX Zircalloy Clad Fuel

3.5.1.1.1 Temperature Limit for Long Term Storage

The peak cladding temperature limit at the beginning of long term storage is determined according to PNL-6189 [3.29] for Zircalloy clad fuel. The peak clad temperature limit at the beginning of storage shall apply to the long term 70°F ambient case for 24PT1-DSC storage in the AHSM. This is the maximum lifetime average ambient temperature of the ISFSI site. The curves of cladding stress limit vs. dry storage cladding temperature limits for Zircalloy clad fuel were obtained using the methodology given in PNL-6189 [3.29].

The Zircalloy clad MOX fuel has the parameters given in Table 3.5-1.

The temperature limit for the Zircalloy clad fuel was determined graphically by plotting the midwall hoop-stress equation given in PNL-6189 [3.29] on the Commercial Spent Fuel Management Program (CSFM) generic limit curves. The acceptable long term average temperature limit is given in Table 3.5-2. This limit is derived based on a 50 year design life in accordance with the PNL-6189 methodology and is applicable only to the long term average temperature condition (70°F ambient temperature).

3.5.1.1.2 Temperature Limit for Short Term Events

Since the maximum burnup of the MOX fuel rods is below that of the rods which were tested to 1058°F in PNL-4835 [3.32] the results of PNL-4835 can be applied to the MOX assemblies for short term events. Fuel cladding temperatures are therefore maintained below 1,058°F for the short term events defined in Section 3.1.

3.5.1.2 Westinghouse 14x14 Stainless Steel Clad Fuel

3.5.1.2.1 Temperature Limit for Long Term Storage

The peak cladding temperature limit at the beginning of long term storage for WE 14x14 stainless steel clad fuel is determined according to EPRI TR-106440 [3.30]. The failure mechanisms detailed in Reference [3.29] were evaluated to determine the bounding failure mechanism. The bounding failure mechanism which gave the lowest temperature limit was determined to be creep failure. The temperature limit to prevent creep failure over the design life was determined by using a steady state shear strain rate for irradiated fuel rods from curves for shear stress vs temperature for a 50 year time to failure from Reference [3.30].

The temperature limit for the stainless steel clad fuel was derived using the conservative parameters given in Table 3.5-1. The resulting long term average temperature limit is given in Table 3.5-2.

3.5.1.2.2 Temperature Limit for Short Term Events

The stainless steel cladding temperature limit for short term events is conservatively assumed to be 806°F. This is based on data given Reference [3.30] for the sensitization of stainless steel at elevated temperatures in a non-inert environment. The 24PT1-DSC is inerted with helium for storage and transfer, so the use of a non-inert temperature limit is conservative.

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 24PT1-DSC cavity. The reference temperature for material properties is assumed to be 70°F.

The thermal growth is calculated based on the fuel assembly parameters given in Table 3.5-3. The length of the 24PT1-DSC cavity requires that stainless steel spacers be placed above and below each fuel assembly, with a total length as shown in Table 3.5-3. The 24PT1-DSC minimum cavity length assumed for the calculation is given in Table 3.5-3. Thermal expansion coefficients for the materials considered are given in Chapter 4.

Based on the results shown in Chapter 4, the vacuum drying case produces the highest fuel cladding temperatures coupled with relatively low 24PT1-DSC shell temperatures due to the water-filled cask annulus. Therefore, this case results in the bounding thermal growth for all operating conditions. Component temperatures calculated using steady state results from Chapter 4 for 16 kW heat are conservatively used.

There is adequate space within the 24PT1-DSC cavity for thermal and irradiation growth of the fuel assemblies and spacers. The minimum gaps calculated are given in Table 3.5-3.

3.5.3 Fuel Rod Integrity During Drop Scenario

The purpose of this section is to calculate WE 14x14 stainless steel clad (SC) and WE 14x14 Zircaloy clad Mixed Oxide (MOX) fuel rod stresses and critical buckling loads due to cask side and end drop incidents. Fuel assembly properties for this evaluation are provided in Table 3.5-4. Material properties used are provided in Table 3.5-5 fuel assembly loads are identified in Table 3.5-6.

3.5.3.1 Methodology

3.5.3.1.1 Side Drop

The side drop analysis methodology is the same for both types of fuel assemblies. The critical g-load for a side drop is determined by calculating the bending stresses in the fuel rod due to the weight of the cladding and fuel and combining the results with the axial stress due to the internal pressure.

The maximum bending moment for a beam with fixed supports is:

$$M = \frac{w_o L^2}{12}$$

where w_o is the weight per unit length of the fuel rod and L is the length of one span of a fuel rod (the distance between grid straps). The weight of the fuel rod is equal to the total weight of the fuel assembly (without thimble plugs and control components) divided by the number of fuel rods in the assembly. Thus, the calculated moment is conservative by including the weight of end fittings in the fuel rod weight.

The maximum bending stress due to a 1g load is:

$$\sigma_b = \frac{Mc}{I_{clad}}$$

where c is the distance from the centerline to the outermost fiber of the cladding, and I_{clad} is the moment of inertia of the cladding. The contribution of the fused fuel pellets to the bending stiffness of the fuel rod is conservatively ignored for the side drop case.

The axial stress due to pressure is equal to:

$$\sigma_{axial} = \frac{pr_o}{2t}$$

where p is the internal pressure, r_o is the mean radius of the cladding, and t is the cladding thickness.

The critical g-load for the fuel rod stresses to reach ultimate strength is determined by:

$$g_{cr} = \frac{\sigma_{ult} - \sigma_{axial}}{\sigma_b}$$

where σ_{ult} is the ultimate strength of the cladding material.

This critical g-load is compared to the 75g load requirements for a side drop.

3.5.3.1.2 Corner Drop

For the corner drop, the inertial forces of the fuel and cladding load the fuel rod in bending (side drop) and as a column having intermediate supports at each grid support. Loading in excess of the critical load causes the fuel rod segments to become unstable. The worst case is for the bottom segment which supports the entire fuel rod weight.

Conservatively, assuming that each fuel rod is pinned at the mid-plane of each grid support, the critical Euler buckling g-load is determined by:

$$g_{cr} = \frac{\pi^2 E_{equiv} I_{total}}{W_r L^2}$$

where E_{equiv} is the equivalent modulus of elasticity for the cladding and fuel, I_{total} is the moment of inertia for the cladding and the fuel, W_r is the weight of a fuel rod, and L is the length of one span of a fuel rod (the distance between grid straps). The weight of the fuel rod is conservatively calculated as the total dead weight of the fuel assembly (without thimble plugs and control components) divided by the number of fuel rods in the assembly.

The 25g corner drop is resolved into an axial (end) component of 13g and a side loading of 22g for the postulated 30° impact angle. Therefore, if the relationship,

$$\frac{13}{g_{cr\,axial}} + \frac{22}{g_{cr\,side}} \le 1.00$$

is met then the rod will not fail under the corner drop accelerations.

3.5.3.2 WE 14X14 (SC) Fuel

Using the geometric and material properties in Table 3.5-4 through Table 3.5-6 and the methodology in Section 3.5.3.1, the analysis of the WE 14x14 stainless steel clad fuel assemblies for 75g side and 25g corner drops and the methodology described above gives the following results.

The side drop allowable g-load is calculated to be 85.2g which exceeds the postulated 75g side load. For the corner drop, the critical buckling load is calculated to be 83.4g which, when combined with the side drop component, results in a ratio of 0.41. This provides a factor of safety of greater than 2 against fuel rod failure in a corner drop.

3.5.3.3 WE 14X14 (MOX) Fuel

Using the geometric and material properties in Table 3.5-4 through Table 3.5-6 and the methodology in Section 3.5.3.1, analysis of the MOX fuel Zircaloy-4 clad fuel assemblies for 75g side and 25g corner drops gives the following results. The side drop allowable g-loading is calculated to be 165g which exceeds the postulated 75g load. For the corner drop, the critical buckling load is calculated to be 71.5g which, when combined with the side drop component, results in a ratio of 0.32. This provides a factor of safety of greater than 3 against fuel rod failure in a corner drop.

3.5.3.4 Results

The fuel cladding for both the WE 14x14 stainless steel clad and Zircaloy-4 clad MOX assemblies will maintain structural integrity for both side and corner drop events.

3.5.4 Fuel Unloading

For unloading operations, the 24PT1-DSC will be filled with spent fuel pool water through the siphon port. During this filling operation, the 24PT1-DSC vent port is maintained open with effluents routed to the plant's off-gas monitoring system. The NUHOMS® operating procedures recommend that the 24PT1-DSC cavity atmosphere be sampled first before introducing any reflood water in the 24PT1-DSC cavity.

When the pool water is added to a 24PT1-DSC cavity containing hot fuel and basket components, some of the water will flash to steam causing internal cavity pressure to rise. This steam pressure is released through the vent port. The procedures also specify that the flow rate and temperatures of the reflood water be controlled to ensure that the internal pressure in the 24PT1-DSC cavity is maintained at less than or equal to 20 psig. The reflood for the 24PT1-DSC is considered as a Service Level D event. The 24PT1-DSC is also evaluated for a Service Level D pressure of 60 psig. Therefore, there is sufficient margin in the 24PT1-DSC internal pressure during the reflooding event to assure that the 24PT1-DSC will not be over pressurized.

The maximum fuel cladding temperature during the reflooding will be significantly less than the vacuum drying condition due to the presence of water/steam in the 24PT1-DSC cavity. The analysis presented in Chapter 4 shows that the maximum cladding temperature during steady state vacuum drying operation is 751°F. Therefore, the maximum cladding temperature during the reflooding operation will be less than 751°F. This is still considerably below the short term cladding temperature limit of 806°F. Therefore, no cladding damage is expected due to the reflood event. This is also substantiated by the operating experience gained with the loading and unloading of transportation packages like the IF-300 [3.35] which show that fuel cladding integrity is maintained during these operations and fuel handling and retrieval is not impacted.

Table 3.5-1
Fuel Rod Parameters Used to Determine Fuel Cladding Short and Long Term Temperature Limits

Parameter	WE 14x14 SS304 Bounding Values	WE 14x14 MOX Zirc Bounding Values
Rod Outer Diameter (in)	0.422	0.422
Rod thickness (in)	0.0165	0.0243
[redacted]		
Cooling Time (years)	n/a	30

Table 3.5-2
Fuel Cladding Temperature Limits

	WE 14x14 SS304 Limit	WE 14x14 MOX Zirc Limit
Long Term (°F)	690	618
Short Term (°F)	806	1058

Table 3.5-3
Summary of Fuel Assembly Thermal and Irradiation Growth Calculations

	WE 14x14 SS304	WE 14x14 MOX Zirc
[redacted]		
Fuel Rod Material	SS304	Zircalloy
Nozzle Material	SS304	SS304
[redacted]		
Minimum Cavity Length (in)	166.5	166.5
Fuel Assembly Temperature (°F)	848	848
Minimum Calculated Gap (in)	1.18	0.450

Table 3.5-4
Fuel Assembly Properties

Parameter	14 X 14 SC	14 X 14 MOX
[redacted]		
Clad Outside Diameter	0.422 inches	[redacted]
Clad Thickness	0.0165 inches	
Fuel Rod Length	126.68 inches	
Pellet Diameter	0.3835 inches	
Pin Pitch	0.556 inches	
Average Span Length Between Grid Straps [3.39]	21.11 inches	
Weight of Rod/Unit Length	0.052 lb/in	

Table 3.5-5
Fuel Cladding Material Properties

Stainless Steel Clad Parameter	Modulus of Elasticity	Yield Stress	Ultimate Strength
	(x10^6 psi)	(psi)	(psi)
Room Temperature (70°F)	28 3(1)	35,750 [3.37]	87,900 [3.37]
At 700°F	24.8(1)	21,093 [3.37]	74,422 [3 37]
Strain Rate Correction	N/A	25,000	24,000
Net Value	24.8	46,093	98,422
MOX Clad Parameter			
750°F	10.4 [3.34]	80,500 [3.34]	99,000 [3.35]

(1) Properties are given in Table 3.3-3.

Table 3.5-6
Fuel Assembly Loads

Fuel Assembly	Impact Load (g)		Internal Pressure (psi) [3.34]	
	Side	Corner	600°F	700°F
WE 14x14 (304 clad)	75	25(1)	2,727	2,984
MOX Fuel (Z-4 clad)	75	25(1)	1,464	1,602

(1) The postulated 25g corner drop angle is 30° The axial component is 12 5g and side loading component is 22g

Table 3.5-6
Fuel Assembly Loads

Fuel Assembly	Impact Load (g)		[redacted]
	Side	Corner	
WE 14x14 (304 clad)	75	25(1)	
MOX Fuel (Z-4 clad)	75	25(1)	

(1) The postulated 25g corner drop angle is 30° The axial component is 12 5g and side loading component is 22g

3.6 Supplemental Data

This section presents the structural analyses of the 24PT1-DSC and the AHSM. The analyses performed evaluates these two major Advanced NUHOMS® System components for the design criteria and loads described in Section 3.1.2. The structural analyses of the DSC are summarized in Section 3.6.1. The structural analyses of the AHSM are summarized in Section 3.6.2.

3.6.1 24PT1-DSC Structural Analysis

For the purposes of the structural analyses reported in this SAR, the 24PT1-DSC is divided in two primary components, the 24PT1-DSC shell assembly and the basket assembly. Section 3.6.1.1 presents the structural analyses of the 24PT1-DSC shell assembly and Section 3.6.1.2 presents the structural analyses of the 24PT1-DSC basket assembly.

The 24PT1-DSC shell assembly, shown in Figure 3.1-1 and Figure 3.1-2, forms the pressure retaining confinement boundary and consists primarily of a cylindrical shell, and the top and bottom cover plate assemblies. Non-pressure boundary components include the outer bottom cover plate, the top and bottom shield plugs, a grapple ring assembly, support ring, and four lifting lugs.

The nominal plate thickness for the cylindrical shell is 0.625 inches. The stress analyses conservatively assume a minimum plate thickness of 0.53 inches.

The basket assembly components include the spacer discs, the guidesleeve and neutron absorber plate assemblies, and the support rod assemblies.

3.6.1.1 24PT1-DSC Shell Assembly Structural Analysis

The 24PT1-DSC shell assembly is analyzed for the normal, off-normal and postulated accident load conditions specified in Section 3.1.2.1, utilizing finite element models and/or hand calculations and closed-form classical engineering solutions. The finite element models are developed using the ANSYS [3.22] computer program.

3.6.1.1.1 Applicable Loads and Load Combinations

The 24PT1-DSC loads and load combinations are discussed in Section 3.1.2.1.3. The 24PT1-DSC load combinations are detailed in Table 3.6-1.

3.6.1.1.2 ANSYS Models for Stress Analysis of the 24PT1-DSC

The 24PT1-DSC shell assembly is analyzed using ANSYS finite element models. The models are three-dimensional and include the cylindrical shell, the top and bottom outer and inner cover plates, the top and bottom shield plugs, the grapple ring and grapple ring support, and the support ring.

Four basic ANSYS finite element models are developed: two top-end half-length models and two bottom-end half-length models. These models are either quarter symmetry (90°) or half symmetry (180°) segments of the 24PT1-DSC shell assembly. A 90° (one-quarter) cross sectional segment is used for the analysis of load cases in which the loading is axisymmetric (e.g., vertical dead weight). A 180° (one-half) cross sectional segment is used for the analysis of load cases in which the loading is non-axisymmetric (e.g., horizontal dead weight and side drop, thermal stress analysis during storage conditions). Typical ANSYS models of the 24PT1-DSC shell assembly are shown in Figure 3.6-1 and Figure 3.6-2, for the top and bottom halves of the 24PT1-DSC shell assembly, respectively.

The shell assembly components (e. g., the cylindrical shell, cover plates, shield plugs, grapple ring assembly, support ring) are modeled using eight-node 3-D solid elements (ANSYS SOLID45). Each node has three translational degrees of freedom. The interface between the cover plates and the shield plugs and between the support ring and the top shield plug are modeled using non-linear contact elements (ANSYS CONTACT49). The contact elements allow the transfer of compressive loads only, allowing the interacting surfaces to slide freely with respect to one another.

3.6.1.1.3 24PT1-DSC Dead Load Analysis

Dead load analyses of the 24PT1-DSC are performed for both vertical and horizontal orientations of the 24PT1-DSC. In the vertical orientation, the 24PT1-DSC shell supports its own weight and the weight of the top end components. The weight of the fuel is uniformly distributed over the area of the inner bottom cover plate. When in the horizontal position, the 24PT1-DSC is either in the transfer cask or in the AHSM. In the horizontal orientation, the 24PT1-DSC shell assembly end components and the internal basket assembly bear against the 24PT1-DSC shell. The 24PT1-DSC shell assembly is supported by two 3" wide rails located at ± 18.5° (in the OS197 transfer cask) and ± 35° (in the AHSM) from the bottom centerline of the 24PT1-DSC, see Figure 3.6-3.

Dead load stresses are obtained from static analyses performed using the ANSYS finite element models described in Section 3.6.1.1.2. Both, the top-end half and bottom-end half models are analyzed for 1g loads, using the appropriate ANSYS finite element model and boundary conditions, (i.e., the 90° model is used for vertical dead weight analysis and the 180° model is used for the horizontal dead weight analysis).

In addition, when the 24PT1-DSC is in the horizontal position, the fuel-loaded spacer discs of the basket assembly bear on the inner surface of the 24PT1-DSC shell. Shell stresses in the region of the spacer discs, resulting from the spacer disc loads, are evaluated using an ANSYS finite element model that includes the spacer disc and a portion of the shell and interfacing transfer cask. This model is described in Section 3.6.1.2.3.

The 24PT1-DSC shell assembly components are evaluated for primary membrane stress, membrane plus bending stress, and for primary plus secondary stress intensities. Enveloping 24PT1-DSC maximum stress intensities for the dead load condition are summarized in Table 3.6-2.

3.6.1.1.4 24PT1-DSC Pressure Analysis

The 24PT1-DSC shell assembly is analyzed for the normal, off-normal and accident condition pressures listed in Table 3.1-6.

Two load distributions are considered: One with the inner top and bottom cover plates pressurized and one with the outer top cover plate pressurized.

- The inner pressure boundary, defined by the cylindrical shell, inner bottom cover plate, inner top cover plate, and the associated welds, is evaluated for normal, off-normal and accident internal pressures of 10 psig, 20 psig, and 60 psig, respectively.
- The outer pressure boundary, defined by the cylindrical shell, inner bottom cover plate, outer top cover plate, and the associated welds is evaluated for an off-normal pressure of 20 psig and an accident pressure of 60 psig.

The 24PT1-DSC is also evaluated for internal and external hydrostatic pressures which may occur during fuel loading operations. Operations which may subject the 24PT1-DSC shell to "external" pressure include the vacuum drying load cases. External pressure evaluations are performed using hand calculations and conservatively assuming the maximum hydrostatic pressure is applied to the entire shell.

Stability of the 24PT1-DSC shell under combined axial load and external pressure is evaluated using the following interaction equation, where the allowables are developed using NB-3133.

$$\frac{\text{applied axial stress}}{\text{allowable axial stress}} + \frac{\text{applied external pressure}}{\text{allowable external pressure}} \leq 1.0$$

Enveloping 24PT1-DSC maximum stress intensities for the normal and off-normal pressure load conditions are summarized in Table 3.6-2. Maximum stress intensities for the accident pressure of 60 psig are reported in Table 3.6-3.

3.6.1.1.5 24PT1-DSC Thermal Stress Analysis

Chapter 4 presents the results of the thermal analyses of the 24PT1-DSC for the ambient temperature conditions summarized in Table 3.1-8.

The Chapter 4 temperature distributions are imposed onto the ANSYS models described in Section 3.6.1.1.2 to evaluate thermal stresses. As stated previously, the 24PT1-DSC shell assembly materials are SA 240 Type 316 stainless steel with the exception of the shield plugs which are A36 carbon steel. The A36 carbon steel has a lower coefficient of thermal expansion than the 316 stainless steel. Because these dissimilar materials are not mechanically fastened, there are no thermal stresses due to restrained boundary conditions and, thus, the thermal stresses in the 24PT1-DSC shell assembly components are due primarily to thermal gradients.

The Chapter 4 results show that the thermal gradients are primarily along the axial and tangential directions of the 24PT1-DSC. No significant thermal gradients exist through the wall of the 24PT1-DSC. Stresses resulting from thermal gradients are classified as secondary stresses and are evaluated for Service Level A and B conditions. Maximum stress intensities resulting from the thermal stress analyses are summarized in Table 3.6-2.

The evaluation for potential interferences due to differential thermal expansion between the 24PT1-DSC shell assembly and the basket assembly components is presented in Section 3.4.4.2.

3.6.1.1.6 <u>24PT1-DSC Operational and Transfer Handling Load Analysis</u>

Stress analyses are performed for two categories of transfer and handling loads: (1) inertial loads associated with moving the 24PT1-DSC (on-site transfer handling loads) and (2) loads associated with loading the 24PT1-DSC into and unloading the 24PT1-DSC from the AHSM.

3.6.1.1.6.1 <u>24PT1-DSC Onsite Transfer Handling Loads</u>

Transfer handling loads are inertial loads on the loaded 24PT1-DSC resulting from on-site handling and transfer between the fuel handling/loading area and the ISFSI. The inertial conditions during transfer are discussed in Section 3.1.2.1.3.4. The fuel and guidesleeve assemblies are assumed to bear against the inner bottom cover plate or the top shield plug during axial handling loads. This results in a pressure on the top or bottom inner cover plate of 16 psi.

The controlling stresses from these analyses are tabulated in Table 3.6-2.

3.6.1.1.6.2 <u>24PT1-DSC Loading/Unloading into AHSM</u>

To load the 24PT1-DSC into the AHSM, the 24PT1-DSC is pushed out of the transfer cask using a hydraulic ram. The applied force from the hydraulic ram, specified in Section 3.1.2.1.3.4, is applied to the center of the 24PT1-DSC outer bottom cover plate. The ANSYS finite element model shown in Figure 3.6-2 is used to calculate the stresses in the DSC shell assembly. The ram load is applied to the cover plate in the form of two arcs, assuming that the load is concentrated at the barrel diameter, excluding the cutouts for extension of the grapple arms.

To unload the AHSM, the 24PT1-DSC is pulled using grapples that fit into the grapple ring. For analysis of grapple pull loading, the 180° ANSYS finite element model of the bottom half 24PT1-DSC assembly is further refined in the area of the grapple assembly and outer cover plate. The load is applied to the grapple ring plate nodes corresponding to the contact area between the ram grapple arms and the grapple ring plate. The stresses in the 24PT1-DSC outer bottom cover plate and grapple ring resulting from the 24PT1-DSC retrieval load are evaluated.

The controlling stress intensities from these analyses are tabulated in Table 3.6-2.

3.6.1.1.7 <u>Cask Drop</u>

Drop loads are applied as static loads corresponding to the postulated drop accelerations. Drops are postulated for the 24PT1-DSC when positioned inside the transfer cask. A 75g side drop and a 25g corner drop (at 30° from horizontal) are postulated for the 24PT1-DSC. The load path for the postulated side drop is identical to that described in Section 3.6.1.1.3 for dead weight in a horizontal position.

The controlling stress intensities for the 75g side drop are tabulated in Table 3.6-3. The 25g corner drop is considered to be bounded by the 75g horizontal drop and the 60g 10CFR 50 and 10CFR 71 end drop.

3.6.1.1.8 Seismic Analysis

The seismic analysis of the 24PT1-DSC shell is performed using closed-form calculations. A frequency analysis was performed to determine first mode frequencies of the 24PT1-DSC in the axial and transverse directions.

3.6.1.1.8.1 24PT1-DSC Shell Frequency Evaluation

Lower bound estimates of the fundamental frequencies of the 24PT1-DSC are calculated for both transverse and axial directions of the 24PT1-DSC shell. A lower bound first bending mode frequency is calculated based on the assumption that the 24PT1-DSC shell is a simply supported beam under a uniform load equal to the gross weight of the loaded package. Using equations from Roark [3.19] for a simple supported beam, a first mode transverse frequency of 53.4 Hz. is calculated Similarly, a lower bound axial frequency of 42.8 Hz. is calculated by assuming the axial stiffness of the 24PT1-DSC and the weight of the loaded 24PT1-DSC.

3.6.1.1.8.2 24PT1-DSC Shell Assembly Seismic Stress Analyses

The seismic loading consists of 6g acceleration applied simultaneously as an equivalent static load in each orthogonal direction. The results for each direction are combined by SRSS.

The 24PT1-DSC, inside the AHSM, is analyzed for lateral seismic loads as a simple supported beam. The maximum bending stresses in the DSC shell, induced by 6g accelerations in each horizontal transverse direction are combined with the axial stress due to axial seismic forces to calculate the maximum stress intensities.

In the 24PT1-DSC shell axial direction, the critical structural component is the 3/16-inch inner top cover plate weld to the 24PT1-DSC shell. This weld is loaded directly in shear because of the high bending stiffness of the top shield plug. The inertia load applied to the weld consists of the weight of the fuel, the entire basket assembly, and the top shield plug.

The seismic stresses of basket assembly components of the 24PT1-DSC (e.g., spacer discs, support rods, guidesleeves) for the design basis 6g seismic loads are not explicitly evaluated as they are clearly bounded by the 75g side drop and 60g end drop stresses.

The controlling stress intensities for the seismic loads are tabulated in Table 3.6-3.

3.6.1.1.9 Summary Discussion of the 24PT1-DSC Stress Analyses Results

The calculated stresses for each load case are combined in accordance with the load combinations presented in Table 3.1-5. The maximum calculated 24PT1-DSC shell assembly stress intensities for normal, off-normal, and accident load combinations are shown in Table 3.6-4 through Table 3.6-6.

3.6.1.2 24PT1-DSC Basket Assembly Structural Analysis

3.6.1.2.1 Loads and Load Combinations for the Basket Assembly

The basket assembly is analyzed for normal/off-normal and postulated accident conditions as discussed in Section 3.1.2.1.3. The basket assembly loads and load combinations are based on those summarized in Table 3.1-5 for the 24PT1-DSC. However, they are simplified because the basket assembly is not a pressure boundary and, thus, is not affected by pressure loads.

3.6.1.2.2 Stress Analysis of the Guidesleeve Assemblies

The guidesleeve assemblies consist of guidesleeve tubes, oversleeves, and shim plates, fabricated from SA-240, Type 304 stainless steel. In addition, neutron absorber plates are sandwiched between the guidesleeves and oversleeves. Depending on its location in the basket, each guidesleeve assembly contains two or four neutron absorber plates such that there are two absorber plates between any two adjacent SFAs. The neutron absorber plates are not welded or bolted to the stainless steel guidesleeve, but are held in place by the geometry of the oversleeves and the shim plates. The oversleeves and shim plates are welded to the guidesleeves.

The structural component of the guidesleeve assembly is the guidesleeve tube. The neutron absorber plates provide criticality control only and are not used for structural support. No credit is taken for the structural capacity of the neutron absorber plates.

Stress analyses of the guidesleeve assemblies are performed using a combination of closed-form calculations and finite element analyses using an ANSYS model of the guidesleeve. Elastic analyses are used for normal conditions, whereas elastic-plastic analyses are used for the postulated side drop accident load case.

An enveloping temperature of 700°F is used for the analyses of the guidesleeve assemblies for all load cases, except: (1) vacuum drying, and (2) AHSM storage with blocked vents, for which an enveloping temperature of 800°F is used (per Tables 4.1-3 through 4.1-5).

Loads applicable to the guidesleeve analyses include loads due to deadweight, onsite handling, 75g side drop and 25g corner drop accidents, and the inertial loads due to a postulated seismic event. As described in Section 3.4.4.2, fabrication clearances are provided to allow unrestrained expansion of the guidesleeves in the axial and radial directions. Thus, there are no stresses resulting from thermal loads.

Also, the guidesleeve assemblies are not affected by pressure loads or loads associated with loading and unloading the AHSM.

Lateral loads on the guidesleeve assemblies are evaluated using an ANSYS [3.22] model of the guidesleeve. Loads considered include horizontal dead weight, on-site handling, seismic, and the 75g side drop accident, as defined in Section 3.1.2.1.3. In the ANSYS analyses, the load from the fuel is applied as a uniform pressure on the guidesleeve panels, without taking credit for the structural capacity of the fuel assemblies, the oversleeves, or the neutron absorber panels.

As described in Section 3.1.2.1.2, for axial loading, stability criteria are applied in addition to the stress criteria of Table 3.1-4.

Table 3.6-8 shows a summary of the maximum stresses in the guidesleeves for the load cases analyzed. The stresses in the oversleeve and the shim plates are small compared to the stresses in the guidesleeve tubes; therefore, only the stresses for the guidesleeves are summarized. The results show that the guidesleeve assembly stresses meet the stress criteria from Subsection NG.

3.6.1.2.3 Stress Analysis of the Spacer Discs

The stress analysis of the spacer disc is performed using 3-D finite element models developed using the ANSYS 5.3 program [3.22]. Three basic model types are developed: (1) a half-symmetry (180°) model and a full symmetry (360°) model used for analyzing in-plane loads, (2) a quarter-symmetry (90°) model for analyzing out-of-plane loads, and, (3) a model for analyzing thermal loads.

The in-plane models are shown in Figure 3.6-4 and Figure 3.6-5. The in-plane models are used for the horizontal dead weight and horizontal side drop analyses. Included in the model are the spacer disc, DSC shell, transfer cask rails, and inner liner of the transfer cask. The interfaces between these components are modeled using contact elements, with the inner liner of the transfer cask being the outer boundary for the system. The spacer disc, shell, and cask rails are modeled using 3D solid elements (Solid45). The half symmetry (180°) model, as shown in Figure 3.6-4, is used for analyzing symmetric loads, such as horizontal dead weight and the side drop case. The full symmetry (360°) model, as shown in Figure 3.6-5, is used for the 18.5° and 45° side drop cases. The fuel and guidesleeve loads are applied to the spacer disc ligaments as pressure loads.

The out-of-plane model is a 90° (quarter-symmetry) model developed, using ANSYS Shell43 elements and is shown in Figure 3.6-6. The out-of-plane model is used for the vertical dead weight and end drop analyses. The fuel does not load the spacer discs out of plane; therefore, no fuel loads are applied to the spacer disc. Analyses were performed modeling the connection between the spacer disc and the support rod as both pinned and fixed to determine "worst case" stresses.

The 24PT1-DSC spacer discs are evaluated using the criteria from Subsection NG. The normal and off-normal conditions include vertical and horizontal dead weight, transfer handling, and thermal loads during transport and storage. Accident loads include the 75g accelerations due to the accidental horizontal drop of the cask and seismic loads due to the design basis earthquake. The thermal load conditions such as those experienced during on-site transfer, storage, and draining and drying have been discussed in Section 3.1.2.1.3. The spacer discs are not affected by pressure loads.

Thermal stresses are analyzed using a 180° half symmetry model, which is based on the in-plane (Solid45) model shown in Figure 3.6-4. The thermal model includes the spacer disc only. Temperature distributions from the Chapter 4 thermal analyses are imposed onto the spacer disc. The stress analysis includes the thermal gradients in the plane of the spacer disc, with no gradient through the thickness of the discs.

With the exception of thermal loads, all loads on the spacer discs (e.g., inertial loads, fuel loads) are evaluated and combined within the ANSYS analyses. As required for normal and off-normal conditions, thermal and "non-thermal" loads are combined as follows.

1. For out-of-plane loads, evaluated with the Shell43 models described above, stress intensities at the mid-thickness of the element are classified as general membrane stress, P_m. Stress intensities at the element surfaces (top and bottom) are classified as primary membrane plus bending, $P_m + P_b$. These values are used directly in the compliance evaluations of primary stress.

2. For in-plane loads, evaluated with the Solid45 models described above, stresses are linearized (using ANSYS) across the ligaments at the edges of the fuel cutouts and at critical locations between the fuel cutouts and the outside edge of the spacer disc. The results are classified as P_m and $P_m + P_b$ and are used in the Code compliance evaluations of primary stress.

3. Results from the thermal stress analyses are also linearized across the ligaments at the edges of the fuel cutouts and at critical locations between the fuel cutouts and the outside edge of the spacer disc. The results are classified as secondary membrane and secondary membrane plus bending stress intensities. These stress intensities are classified as secondary (Q).

4. To determine the primary plus secondary stress, the maximum non-thermal membrane plus bending stress intensities ($P_m + P_b$) are combined absolutely with the maximum thermal stress intensities. Since the primary stress intensities ($P_m + P_b$) for the normal loads combinations are typically small, the maximum primary stresses are typically combined with the maximum secondary stresses even though the maximums may occur at different locations in the spacer disc.

The horizontal and vertical deadweight stress intensities are computed using the in-plane and out-of-plane models, respectively. Stress intensities for the transfer handling cases are computed by scaling stress intensities from the deadweight analyses. The stress checks for handling loads are used to envelop the horizontal deadweight stresses.

For the vacuum drying, horizontal deadweight, and handling analyses, the primary plus secondary stress intensity exceeds $3S_m$ in localized section(s) of the spacer disc. For these locations, qualification is demonstrated using the simplified elastic-plastic analysis methodology of NG-3228.3. NG-3228.3 allows the $3S_m$ limit on primary plus secondary stress to be exceeded provided limits on thermal membrane stress and alternating stresses are satisfied. Additional justification for the acceptability of these stresses is obtained by reviewing a breakdown of the stress. Stresses from thermal gradients across the spacer disc are the most significant part of the primary plus secondary stress in the spacer discs (compare ($P_m + P_b$) to ($P_m + P_b + Q$) in Table 3.6-7). During the transfer and AHSM storage operations, the maximum difference in primary plus secondary stress intensity, for any location on the disc, is less than 6.0 ksi from the extreme cold case (-40°F) to the extreme hot case (117°F). Thus the most significant part of the combined ($P_m + P_b + Q$) stress is a 'one time' initial heatup, followed by cool down over the life of the DSC.

The alternating portion of the stress is small, much less than $2S_y$ or $3S_m$, and stresses will "shake down" to elastic action. Thus the secondary stresses in the spacer discs are acceptable.

For the accident side drop analyses, elastic-plastic stress analyses are performed using the in-plane model with a plastic modulus equal to 5% of the elastic modulus. Three drop orientations are considered: 0°, 18.5° (directly on the cask rail), and 45°. Material properties at 700° F are used. Results for the drop analyses are described below and are summarized in Table 3.6-7.

- 0° Drop - Table 3.6-7 includes two sets of results for the 0° drop, corresponding to the two most highly stressed sections of the spacer disc. The material temperature at the maximum stresses location is less than 500°F , thus the maximums stresses are compared to the allowables at 500°F. An enveloping temperature of 700°F is used to determine allowables for all other points on the disc. 700°F envelops the maximum temperature calculated for the spacer discs during on-site transfer (117°F ambient while in the transfer cask).
- 18.5° and 45° Drop - Stresses for the 18.5° and 45° drop cases are within allowables at the enveloping disc temperature of 700°F.
- 60g 10CFR 71 End Drop - Stresses for the 60g 10CFR 71 end drop are taken from the out-of-plane model. As shown by the results listed in Table 3.6-7, all stresses are below the allowable values.

The stress intensities due to seismic loading are enveloped by the 75g side drops and 60g end drops.

In addition to the stress analyses, an analysis is performed to demonstrate the stability of the spacer discs under in-plane loading. This analysis uses the in-plane model shown in Figure 3.6-5. With the spacer disc loaded by the 75g side drop loads and the thermal loads producing the highest compressive stresses (-40°F in the OS197 transfer cask) an eigenvalue buckling analysis is performed to determine the margin to buckling. The margin (factor of safety) against elastic instability is calculated as 1.91, which meets the stability criteria specified in Section 3.1.2.1.2.

As shown in Table 3.6-7, the spacer disc stresses are acceptable for all normal, off-normal and postulated accident conditions.

3.6.1.2.4 Stress Analysis of the Support Rod/Spacer Sleeve Assemblies

The 24PT1-DSC support rod assemblies, including the support rods, spacer sleeves and support rod to spacer sleeve mechanical connections, are analyzed using the criteria of Subsection NF and Appendix F for linear component supports. The criteria of NF-3322.1(e)(i) and F-1334.5 for combined axial compression and bending are applied to the spacer sleeves. The (tension only) rods are evaluated using the criteria of NF-3322.1(a) and NF-1334.1.

The support rod assemblies are designed to meet the allowables for all applicable load combinations for preloads varying from 0 to 65 kips. Support rod temperatures are less than 600°F for all conditions except the (accident) blocked vent storage. For blocked vent storage, temperatures are below 650°F.

For the support rod assembly, the load combinations listed in Table 3.6-1 are simplified by the following:

(a) the support rod assemblies are unaffected by pressure loads,

(b) the support rods are unaffected by loading/unloading the 24PT1-DSC, and

(c) thermal expansion of the support rod assemblies is not constrained by the 24PT1-DSC cavity.

Accident conditions that affect the support rods are the postulated 75g horizontal drop and 25g corner drop, and the postulated seismic events. The basket assembly components have also been evaluated for the effects of the 10CFR 71 60g end drops. The 25g corner drop is considered to be bounded by the 75g horizontal drop and the 60g 10CFR 71 end drop. As noted in Section 11, the 60g end drop is not a credible event for on-site (i.e., 10CFR 72) operation of the Advanced NUHOMS® System.

The spacer sleeves are loaded in compression by the support rod preload and in compression and bending by the spacer discs.

The analyses of the spacer sleeves are performed using a combination of closed-form calculations and ANSYS [3.22] finite element analyses.

For loads along the axis of the 24PT1-DSC (e.g., vertical deadweight), the load distributions in the support rod assemblies are evaluated using a simple ANSYS beam model. The model includes the support rods and spacer sleeves with the moment and axial force from each spacer disc applied to the assembly. The stress checks for the spacer sleeves are performed using the interaction equations of NF-3322.1(c)(1).

Table 3.6-9 summarizes the results for the critical load combinations.

The threaded spacer sleeve mechanical connections are designed to maintain the geometry of the support rod assemblies. A mechanical pin at the bottom spacer sleeve may be used to prevent the bottom spacer sleeve from loosening. To prevent the top spacer sleeve from rotating, a double nut design is used. The outer nut at the top end of the support rod assembly is installed as a "Jam" nut.

As shown in Table 3.6-9, the support rod assembly stresses meet ASME Code allowables.

3.6.1.2.5 <u>Stress Analysis of the Failed Fuel Cans and Fuel Spacers</u>

Failed fuel cans are used to provide confinement for "damaged" fuel assemblies. Since the wall thickness of the failed fuel cans is slightly greater than the thickness of the guidesleeve tubes (and the two assemblies act in parallel to carry fuel loads), the failed fuel can stresses are enveloped by the guidesleeve stresses. Thus, no specific analysis is presented for the failed fuel cans.

Fuel spacers are used to locate Westinghouse 14x14 fuel assemblies in the center of the 24PT1-DSC cavity.

The fuel spacers are evaluated for normal and off-normal load combinations using the criteria of Subsection NG. Loads considered include fuel weight and handling loads.

There is no constrained thermal expansion in the fuel spacers and they are not affected by insertion/retrieval loads.

The fuel spacers are evaluated for a conservative 120g equivalent side drop (horizontal) acceleration. The maximum fuel spacer stresses due to lateral loads are due to the self weight of the material and result in a maximum axial stress of 0.4 ksi and a panel bending stress of 6.0 ksi.

The critical design basis axial load applied to the fuel spacer is the weight of the fuel assembly plus the opposite fuel spacer times the maximum postulated axial acceleration of 60g. This results in an applied axial load of 84 kips. Analyzing the fuel spacer as a pinned-pinned column in accordance with Paragraph F-1334.3(b)(1) of Appendix F to Section III, Division I of [3.11] *results in an axial stress of 8.0 ksi. The Service Level D allowable stress at a very conservative 700°F temperature is 15.7 ksi which results in a stress ratio of 0.51. This results in a large margin of safety against initial buckling of the fuel spacer and ensures the fuel locations assumed in the criticality analysis are maintained.*

3.6.1.3 Fatigue Evaluation

The 24PT1-DSC shell has been evaluated for fatigue in accordance with the rules of NB-3222.4 to show that a detailed fatigue evaluation is not required.

3.6.2 Structural Analysis of the AHSM

3.6.2.1 Introduction to AHSM

The reinforced concrete, 24PT1-DSC support steel, structural welds, miscellaneous components and embedments of the AHSM are important to safety. Consequently, they are designed and analyzed to perform their intended functions under the extreme environmental and natural phenomena specified in 10CFR 72.122 [3.1] and ANSI-57.9 [3.9].

Table 3.6-10 summarizes the design loads for the AHSM system components. The table also presents the applicable codes and standards for development of these loads. The extreme environmental and natural phenomena design criteria discussed below comply with the requirements of 10CFR 72.122 and ANSI 57.9.

3.6.2.2 Loads and Load Combinations

3.6.2.2.1 Dead Loads (DW)

Dead load includes the weight of the AHSM concrete structure, and the steel structure (the 24PT1-DSC weight is considered as a live load rather than a dead load). Creep and shrinkage reduce the thermal stresses. Therefore, for the evaluation of the concrete structure, creep and shrinkage forces are conservatively neglected.

The dead load is varied by +5% from the estimated value to simulate the most adverse loading condition in accordance with ANSI-57.9 [3.9].

3.6.2.2.2 Live Loads (LL)

Live loads include a roof design basis snow and ice load of 110 psf conservatively derived from ASCE 7-95 [3.14]. For the purpose of this analysis, a total live load of 200 psf (which includes snow and ice load) is used to envelope all postulated live loading, including such items as ladders, handrails, conduits, etc. added for personnel protection. In addition, the normal handling loads (RO), and off-normal handling loads (RA), and the 24PT1-DSC weight are treated as live loads for the concrete component evaluation.

In accordance with ANSI-57.9 [3.9], the live load is varied between 0% and 100% of the estimated load to simulate the most adverse conditions for the structure.

3.6.2.2.3 Normal Operating Thermal Loads (TN)

Normal thermal loads are the thermally induced stresses for the temperature gradients resulting from the 24PT1-DSC heat load and insolation on the AHSM. To evaluate the effects of thermal loads on the AHSM, heat transfer analyses for a range of normal ambient temperatures (0°F, 70°F and 104°F) are performed with a 24PT1-DSC heat load of 24 kW. The temperature distribution for all three cases are used in the analysis for concrete component evaluation.

3.6.2.2.4 Tornado Generated Loads (WT)

The most severe tornado generated wind and missile loads specified by NRC Regulatory Guide 1.76 [3.4] and NUREG-0800 [3.6] are selected as the design basis. The extreme design basis wind loads are less severe than tornado generated wind loads and therefore do not need to be addressed.

The design basis tornado (DBT) wind intensities used for the AHSM design are obtained from NRC Regulatory Guide 1.76 [3.4]. Region I intensities are utilized since they result in the most severe loading parameters. For this region, the maximum wind speed is 360 mph, the rotational speed is 290 mph and the maximum translational speed is 70 mph. The radius of the maximum rotational speed is 150 ft, the pressure drop across the tornado is 3 psi and the rate of pressure drop is 2 psi per second [3.4].

Tornado loads are generated for three separate loading phenomena:

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

The DBT velocity pressure is computed based on the following equation specified in ASCE 7-95 [3.14].

$$q_v = 0.00256\ K_z * K_{zt} * I * V^2 \text{ lb/sq ft}$$

Where:

K_z = velocity pressure exposure coefficient equal to 0.9 applied to the full AHSM height of 18.5 ft for level C exposure (Table 6-3 of [3.14])

K_{zt} = 1.0 for level C exposure and structures with height less than 30 ft. (Section 6.5.5 of [3.14]).

I = Importance Factor equal to 1.15 (Table 6-2 of [3.14])

Since the generic design basis AHSM dimensions are relatively small compared to 150 ft rotational radius of the DBT, the velocity value of combined rotational and translational wind velocity of 360 mph is conservatively used in the above equation to compute the DBT velocity pressure of 344 psf.

The calculated DBT velocity pressure is converted to a design wind pressure by multiplying this value by the appropriate pressure coefficient (C_p) and gust effect factor (G) specified in Figure 6-3 and Section 6.6.1 of ASCE 7-95 [3.14]. A gust effect factor of 0.85 for exposure level C from Section 6.6.1 of [3.14] is used to compute the wind pressure. The magnitude and direction of the design pressures for various AHSM surfaces and the corresponding pressure coefficients times gust factor (GC_p) are tabulated in Table 3.6-11.

The determination of impact forces created by DBT generated missiles for the AHSM is based on the criteria provided by NUREG-0800, Section 3.5.1.4, III.4 [3.6]. Accordingly, four types of missiles are postulated :

1. Utility wooden pole, 13.5" diameter, 35' long, Weight = 1500 lbs, Impact velocity = 294 fps.
2. Armor piercing artillery shell 8" diameter, Weight = 276 lbs, Impact velocity = 185 fps.
3. Steel pipe, 12" diameter, Schedule 40, 30 ft long, Weight = 1500 lbs, Impact velocity = 205 fps.
4. Automobile traveling through the air not more than 25 ft above the ground and having contact area of 20 sq. ft, Weight = 4000 lbs, Impact Horizontal Velocity = 195 fps.

3.6.2.2.5 Normal Handling Loads (RO)

The most significant normal operational loading condition for the AHSM components is the sliding of the 24PT1-DSC from the transfer cask into the AHSM. Friction forces are developed between the sliding surfaces of the 24PT1-DSC, the transfer cask and the AHSM support rails.

Normal operation assumes the canister is sliding over the support structure due to a hydraulic ram force of up to 60,000 lbs applied to the 24PT1-DSC base. It is assumed that the 60 kips is resisted by an axial load (30 kips) in each support rail and front embedments. In addition the 24PT1-DSC weight is applied as a distributed load on both the rails.

The concrete module is evaluated for 60 kip 24PT1-DSC insertion and retrieval load applied as a live load.

3.6.2.2.6 Off-Normal Operating Thermal Loads (TO)

This load case is the same as the normal thermal load but with an ambient temperature range from -40°F to 117°F. The temperature distribution for the extreme ambient conditions are used in the analysis for the concrete component evaluation.

3.6.2.2.7 Off-Normal Handling Loads (RA)

This load case assumes that the transfer cask is not accurately aligned with respect to the AHSM resulting in binding of the 24PT1-DSC during a transfer operation causing the hydraulic pressure in the ram to increase. The ram force is limited to a maximum load of 80 kips during insertion and 60 kips during retrieval. Therefore, for the steel support structure, the off-normal jammed canister load (RA) is defined as an axial load on one rail of 80 kips during insertion and 60 kips during retrieval, plus a vertical load of one half the 24PT1-DSC weight (on both rails) at the most critical location. The off-normal operating handling loads are considered as live loads for the design of the concrete components.

3.6.2.2.8 Earthquake Loads (EQ)

As described in Chapter 11, Section 11.2.1, the design basis accelerations for the AHSM are 1.5g in two horizontal directions and 1.0g vertical. In addition, the top shield block response is conservatively amplified to 2.25g (horizontal) to allow for the effect of ungrouted shear keys.

3.6.2.2.9 Flood Loads (FL)

As described in Section 3.1.2.2, the AHSM is designed for a flood height of 50 feet and water velocity of 15 fps. The AHSM is evaluated for the effects of a water current of 15 fps impinging on the side of a submerged AHSM. Under 50 feet of water, the inside of the AHSM is rapidly filled with water. Therefore, the AHSM components are not evaluated for the 50 feet static head of water.

3.6.2.2.10 Accident Condition Thermal Loads (TA)

For the accident thermal event, the inlet and outlet vents are postulated to be blocked for 40 hours with the extreme ambient temperatures of -40°F and 117°F. This condition is identified as the 40 hour blocked vent condition. The temperature distribution for each case is used in the analysis to qualify concrete components.

3.6.2.2.11 Load Combinations for Concrete Component Evaluation

The required strength, U, for critical sections of concrete is calculated in accordance with the requirements of ANSI 57.9 [3.9] and Chapter 9 of ACI 349 [3.12], including the strength reduction factors defined in ACI 349, Section 9.3.

The concrete design loads are multiplied by load factors and combined to simulate the most adverse load conditions. The load combinations described in Table 3.6-12 are used to evaluate the concrete components.

3.6.2.2.12 Load Combinations for Support Structure Evaluation

The required steel strength, S, and required shear strength, S_v for critical sections of steel structure are calculated in accordance with the requirements of AISC Allowable Stress Design (ASD) method [3.13]. For the steel structure components the normal (TN), off-normal (TO) and accident (TA) thermal cases cause additional stresses. However, the steel support structure is protected from design wind load (WW), Tornado wind and missile impact loads (WT) and Flood loads (FL) by the concrete components of the AHSM. Therefore, these loads do not cause stresses in the steel support structure. Accordingly, the load combinations shown in Table 3.6-13 are used for qualification of the steel components.

3.6.2.3 Stress Analysis

3.6.2.3.1 Finite Element Model of the AHSM Concrete and Steel Structure for Mechanical Load Analysis

The structural analysis of an individual module provides a conservative estimate of the response of the AHSM structural elements under the postulated static and dynamic loads for any AHSM array configuration. The frame and shear wall action of the AHSM concrete components are considered the primary structural system resisting the loads. The analytical model is evaluated for normal operating, off-normal, and postulated accident loads acting on the AHSM.

A three-dimensional ANSYS finite element model of the AHSM, including all the concrete components, was developed. The eight-node brick element (ANSYS element type SOLID45) was used to model the concrete structure. At least four layers of brick elements were used to model each concrete component thickness. Each node of the eight-node brick element has three translational degrees of freedom. The 24PT1-DSC was modeled using the beam elements (ANSYS element type BEAM4). The rails and the cross members were also modeled using the beam elements with appropriate stiffness. The mass of the 24PT1-DSC was lumped at the nodes representing the 24PT1-DSC using lumped mass elements (ANSYS element type MASS21). A plot of the ANSYS model is shown in Figure 3.6-7. A plot of the support structure model (which includes the 24PT1-DSC, rails and the cross members) is shown in Figure 3.6-8 and is included in the ANSYS concrete structure model.

The 24PT1-DSC support structure analytical model was incorporated into the AHSM analytical model. The various normal, off-normal and accident loads were applied to the analytical model and internal forces and moments were computed by performing a linear elastic finite element analysis.

The node coupling option of ANSYS was used to represent the appropriate connection between the different concrete components of the AHSM model. The connections of the support structure to the concrete structure were modeled also using the node coupling option. Conservatively, fixed base analyses were performed, thus maximizing the AHSM design forces and moments.

3.6.2.3.2 Finite Element Model of the AHSM Concrete Structure for Thermal Stress Analysis

Thermal stress analyses of the AHSM were performed using a three-dimensional finite element model, which includes only the concrete components. The connections of the door and the support structure rails to the AHSM concrete structure are designed such that free thermal growth is permitted in these members when the AHSM is subjected to thermal loads. Because of the free thermal growth, the door and the support structure do not induce thermal stresses in the concrete components of the AHSM. Therefore, the analytical model of the AHSM for thermal stress analysis of the concrete components does not include the 24PT1-DSC support structure or the AHSM door. The top shield block unit and the base unit are uncoupled. The ANSYS models used to perform thermal stress analysis of the concrete components are shown in Figure 3.6-9 and Figure 3.6-10.

For the thermal load analysis, the model base is restrained at one set of end nodes (in axial and lateral directions) and friction forces are applied at the base, in the axial and lateral directions at the opposite set of end nodes to represent sliding due to thermal expansion/contraction. Also, for this analysis, all the nodes at the base are restrained in the vertical direction.

3.6.2.4 AHSM Analysis Results

The Advanced NUHOMS® modular storage system has the flexibility of arranging modules in arrays of single or double module rows. The exact number of AHSMs in an array is dependent on plant specific needs. In order to qualify the design for a range of Advanced NUHOMS® System ISFSI applications, a single free standing AHSM is evaluated. The AHSM structural analysis includes an evaluation of normal operating, off-normal and postulated accident loads for the AHSM. The structural analysis of an individual module provides a conservative methodology for evaluating the response of the AHSM structural elements under various static and dynamic loads for any form of AHSM array.

3.6.2.4.1 Evaluation of Concrete Structure

The ultimate strength method is used to evaluate forces for the design of the AHSM reinforced concrete structure. For purposes of concrete design evaluation the AHSM is broken down into a number of components, as shown on Figure 3.6-11, Figure 3.6-12, and Figure 3.6-13. Internal forces and moments in each of these components are calculated and reinforcement is provided to meet the minimum flexural and shear reinforcement requirements of ACI 349 [3.12]. The available design strength exceeds that required for the factored design loads specified in Section 3.6.2.2. AHSM construction details such as construction joints and reinforcement bar splices will be detailed on the construction drawings.

The normal operating, off-normal and accident loads are applied to the analytical models described in the Section 3.6.2.3 and the AHSM internal axial and shear forces and moments calculated by performing a linear elastic finite element analysis. A single free-standing AHSM provides the governing case for load combinations that include extreme environmental and natural phenomenon events such as tornado wind loads, and flooding conditions. The postulated response investigated for each of these cases includes the potential for sliding or overturning of the single free-standing AHSM which envelopes that of an AHSM array. The analysis also shows that thermal loads control the reinforcement requirements for the AHSM concrete components.

For the dead weight analysis, the weight of the AHSM plus the 24PT1-DSC support structure weights are applied to the analytical model shown in Figure 3.6-7 and Figure 3.6-8 which represents a single free standing AHSM. A uniform load of 200 psf and 24PT1-DSC weight is applied to the analytical model as a live load.

The following relationships from the ACI code are used to compute capacities of the concrete components:

ϕ = Strength reduction factor

A_s = Area of reinforcing steel in tension

A_{st} = Total area of the reinforcing steel

A_g = Gross area of concrete section

fy = Yield strength of reinforcing steel

f_c' = Compressive strength of concrete

d = Distance of the top fiber of concrete from the center of the rebar

b = Width of the section = 12"

T = Depth of the section

Ultimate Moment Capacity (M_u)

$M_u = \phi M_n = \phi A_s f_y (d-a/2)$

where $a = (A_s f_y)/(0.85 f_c' b)$

Ultimate Tension Capacity (P_{tu})

$P_{tu} = \phi A_{st} f_y$

$\phi = 0.9$

$A_{st} = 2A_s$ (The reinforcement in two opposite faces are assumed to be same)

Ultimate Compression Capacity (P_{cu})

$P_{cu} = \phi P_n = 0.8\phi[0.85 f_c' (A_g - A_{st}) + f_y A_{st}]$

$A_{st} = 2A_s$, $\phi = 0.7$

Ultimate In-Plane Shear Capacity (V_{ui})

$V_{ui} = \phi A_g (2\sqrt{f_c'} + \rho_n f_y)$

$\phi = 0.85$, $\rho_n = (2A_s/bT)$

Ultimate Out-Plane Shear Capacity (V_{uo})

$V_{uo} = \phi 2 \sqrt{f_c'} (bd)$

$\phi = 0.85$

The computed shear and moment capacities for all the concrete components of the AHSM, based on the preceding equations from ACI 349 [3.12], are provided in Table 3.6-14. The capacities calculated in Table 3.6-14 for the accident condition consider a 10% reduction in compressive strength of the concrete and yield strength of the reinforcing rebar materials due to concrete temperatures exceeding 300°F.

The load combination results for each component are presented in Table 3.6-15. The notations for components of forces and moments and the concrete component planes in which capacities are computed are shown in Figure 3.6-14.

For all thermal conditions, the results of load combinations (factored to include the ACI Code load factors) are compared with the flexure and shear strength capacities for the various AHSM concrete sections (calculated using the ultimate strength method of the ACI code). The results of the analyses and comparison with the AHSM bending and shear capacities are shown in Table 3.6-15. All load combination results are below the computed section capacities.

3.6.2.4.2 Evaluation of Support Steel

The support rails, rail stiffener plates, extension plates and cross members (Figure 3.6-15) of the 24PT1-DSC support structure are evaluated using the allowable stress design method of the AISC Manual of Steel Construction [3.13]. The load combination results for each of these components are provided in Table 3.6-16 through Table 3.6-18.

The support rail stress comparison results are presented in Table 3.6-19. The extension plate and cross member stress comparison results are presented in Table 3.6-20.

3.6.2.4.3 Evaluation of Shield Door

The shield door is free to grow in the radial direction when subjected to thermal loads; therefore, there will be no stresses in the door due to thermal growth. The dead weight, tornado wind, differential pressure and flood loads cause insignificant stresses in the door compared to stresses due to missile impact load. Therefore, the door is evaluated only for the missile impact load. The computed maximum ductility ratio for the door is less than 5 (compared to the allowable ductility of 10) obtained for the 12 inch diameter Sch. 40 steel pipe missile.

3.6.2.4.4 Evaluation of the Top Heat Shield

The top heat shield consists of U.S. standard 12 gage uncoated hot or cold rolled sheets of stainless steel material. The heat shield is attached to the concrete by steel studs. The natural frequency of a typical stud is conservatively estimated to be *39.2* Hz. The maximum interaction ratio for the stud is computed to be *0.95*. The natural frequency of the stainless steel heat shield is estimated to be *15.9* Hz. The maximum stress in the top heat shield is computed to be 11.5 ksi, which is less than the allowable stress of *17.1* ksi.

3.6.2.4.5 Evaluation of the Seismic Retainers

Each of the two front seismic retainers consist of a capped tube steel embedment located within each rail extension baseplate embedment and a tube steel retainer assembly that drops into the embedment cavity after 24PT1-DSC transfer is complete. The retainer is adjusted by a set screw to minimize the gap between the retainer and the 24PT1-DSC. The drop-in retainer extends approximately 5" above the rail to provide axial restraint of the 24PT1-DSC. The maximum seismically induced load in the retainer is 63.8 kips. The maximum shear stress in the retainer is 17.8 ksi and the allowable shear stress is 22.7 ksi. The maximum bending stress is 29.0 ksi and allowable bending stress is 42.9 ksi.

3.6.2.4.6 Evaluation of AHSM Keys and the Ties

To provide stability for an ISFSI array during a design basis seismic event, the AHSMs are tied together in a minimum array size of three AHSMs plus shield walls. The AHSMs are tied together using tie beams at the top shield block and tie rods at the bottom of the base unit. The top tie beams resist module separation due to out of phase tipping and relative sliding between the modules in the transverse direction. The bottom ties resist the relative sliding between modules. The top tie beams and the bottom ties are also designed to accommodate a 5% accidental torsional load due to seismic excitation.

The top shield block attachment to the base unit includes two shear keys. In addition to resisting seismic shear, these keys are designed to handle the shear due to missile impact on the front face of the roof. The top shield block is attached to the base unit in the vertical direction by eight threaded rods.

The module to module connection consists of shear keys in the bottom portion of the base unit. The in-phase tipping between the modules is resisted by the vertical shear key and the relative sliding between the modules in the longitudinal direction will be resisted by the horizontal shear key. All shear keys are designed using the shear-friction criteria of Reference [3.12]. Table 3.6-21 provides a comparison of forces resisted by the keys and the ties and their capacities. The resisting force for all keys and ties is always less than the capacity.

Table 3.6-1
24PT1-DSC On-Site Load Combinations

Summary of On-Site DSC Load Cases (Part 1)

	Horizontal DW		Vertical DW		Internal	External	Ambient Thermal Condition and	Lifting	Other	Service
	DSC	Fuel	DSC	Fuel	Pressure(6)	Pressure	DSC Location	Loads	Loads	Level
NON-OPERATIONAL LOAD CASES										
NO-1 Fab Leak Testing	–	–	–	–	–	14.7 psia	70°F	–	155 kip axial	Test
NO-2 Fab Leak Testing	–	–	–	–	12 psig	–	70°F	–	155 kip axial	Test
NO-3 DSC Uprighting	X	–	–	–	–	–	70°F	X	–	A
NO-4 DSC Vertical Lift	–	–	X	–	–	–	70°F	X	–	A
FUEL LOADING LOAD CASES										
FL-1 DSC/Cask Filling	–	–	Cask	–	–	Hydrostatic	120°F Cask	–	–	A
FL-2 DSC/Cask Filling	–	–	Cask	–	Hydrostatic	Hydrostatic	120°F Cask	–	–	A
FL-3 DSC/Cask Xfer	–	–	Cask	–	Hydrostatic	Hydrostatic	120°F Cask	–	–	A
FL-4 Fuel Loading	–	–	Cask	X	Hydrostatic	Hydrostatic	120°F Cask	–	–	A
FL-5 Xfer to Decon	–	–	Cask	X	Hydrostatic	Hydrostatic	120°F Cask	–	–	A
FL-6 Inner Cover Plate Welding	–	–	Cask	X	Hydrostatic	Hydrostatic	120°F Cask	–	–	A
FL-7 Fuel Deck Seismic Loading	–	–	Cask	X	Hydrostatic	Hydrostatic	120°F Cask	–	Note 9	C
DRAINING AND DRYING LOAD CASES										
DD-1 DSC Blowdown	–	–	Cask	X	Hydrostatic + 20 psig	Hydrostatic	120°F Cask	–	–	B
DD-2 Vacuum Drying	–	–	Cask	X	0 psig	Hydrostatic + 14.7 psig	120°F Cask	–	–	B
DD-3 Helium Backfill	–	–	Cask	X	12 psig	Hydrostatic	120°F Cask	–	–	B
DD-4 Final Helium Backfill	–	–	Cask	X	3.0 psig	Hydrostatic	120°F Cask	–	–	B
DD-5 Outer Cover Plate Welding	–	–	Cask	X	3.0 psig	Hydrostatic	120°F Cask	–	–	B
TRANSFER TRAILER LOADING										
TL-1 Vertical Xfer to Trailer			Cask	X	≤ 10.0 psig	–	0°F Cask	–	–	A
TL-2 "			Cask	X	≤ 10.0 psig	–	120°F Cask	–	–	A
TL-3 Laydown	Cask	X			≤ 10.0 psig	–	0°F Cask	–	–	A
TL-4 "	Cask	X			≤ 10.0 psig	–	120°F Cask	–	–	A

	Horizontal DW		Vertical DW		Internal	External	Ambient Thermal Condition and	Handling	Other	Service
	DSC	Fuel	DSC	Fuel	Pressure(6)	Pressure	DSC Location	Loads	Loads	Level
TRANSFER TO / FROM ISFSI										
TR-1 Axial Load - Cold	Cask	X	–	–	≤ 10.0 psig	–	0°F Cask	1g Axial	–	A
TR-2 Transverse Load - Cold	Cask	X	–	–	≤ 10.0 psig	–	0°F Cask	1g Transverse	–	A
TR-3 Vertical Load - Cold	Cask	X	–	–	≤ 10.0 psig	–	0°F Cask	1g Vertical	–	A
TR-4 Oblique Load - Cold	Cask	X	–	–	≤ 10.0 psig	–	0°F Cask	½g Axial + ½g Trans + ½g Vert	–	A
TR-5 Axial Load - Hot	Cask	X	–	–	≤ 10.0 psig	–	104°F Cask	1g Axial	–	A
TR-6 Transverse Load - Hot	Cask	X	–	–	≤ 10.0 psig	–	104°F Cask	1g Transverse	–	A
TR-7 Vertical Load - Hot	Cask	X	–	–	≤ 10.0 psig	–	104°F Cask	1g Vertical	–	A
TR-8 Oblique Load - Hot	Cask	X	–	–	≤ 10.0 psig	–	104°F Cask	½g Axial + ½g Trans + ½g Vert	–	A
n/a Top End Drop	This drop is not credible for the horizontal NUHOMS system									
TR-9 Bottom End Drop	This drop is not credible for the horizontal NUHOMS system									
TR-10 Side Drop	Note 1		–	–	≤ 20.0 psig	–	104°F Cask(2)		75g Drop(1)	D
TR-11 Corner Drop	Note 1		–	–	≤ 20.0 psig	–	104°F Cask(2)		25g Drop(1)(5)	D

Notes

1. Drop accelerations include gravity effects. Therefore, it is not necesary to add an additional 1.0g (gravity) load.
2. For level D events, only the maximum temperature case is considered. (Thermal stresses are not limited for Level D events and maximum temperatures result in minimum allowables.)
3. Flood load is an external pressure equivalent to 50 ft. of water.
4. BV = AHSM Vents are blocked.
5. Corner drop is at 30 degrees from horizontal.

Notes continued on following page...

Table 3.6-1
On-Site Load Combinations
(Concluded)

Summary of On-Site DSC Load Cases (Part 2)

AHSM LOADING	Horizontal DW DSC	Horizontal DW Fuel	Vertical DW DSC	Vertical DW Fuel	Internal Pressure[8]	External Pressure	Ambient Thermal Condition and DSC Location	Handling Loads	Other Loads	Service Level
LD-1 Normal Loading - Cold	Cask	X	–	–	≤ 10.0 psig	–	0°F Cask	+60 Kip[9]	–	A
LD-2 Normal Loading - Hot	Cask	X	–	–	≤ 10.0 psig	–	104°F Cask	+60 Kip[9]	–	A
LD-3 Off-Normal Loading - Cold	Cask	X	–	–	≤ 20.0 psig	–	0°F Cask	+80 Kip[9]	10% Failed Fuel	B
LD-4 Off-Normal Loading - Hot	Cask	X	–	–	≤ 20.0 psig	–	117°F Cask	+80 Kip[9]	10% Failed Fuel	B
AHSM STORAGE										
HSM-1 Normal Storage - Cold	HSM	X	–	–	≤ 10.0 psig	–	0°F HSM	–	–	A
HSM-2 Normal Storage - Hot	HSM	X	–	–	≤ 10.0 psig	–	104°F HSM	–	–	A
HSM-3 Off-Normal Storage - Cold	HSM	X	–	–	≤ 20.0 psig	–	-40°F HSM	–	10% Failed Fuel	B
HSM-4 Off-Normal Storage - Hot	HSM	X	–	–	≤ 20.0 psig	–	117°F HSM	–	10% Failed Fuel	B
HSM-5 Off-Normal Storage / Outer - Cold	HSM	X	–	–	≤ 20.0 psig[6]	–	-40°F HSM	–	10% Failed Fuel	B
HSM-6 Off-Normal Storage / Outer - Hot	HSM	X	–	–	≤ 20.0 psig[6]	–	117°F HSM	–	10% Failed Fuel	B
HSM-7 Not Used	–	–	–	–	–	–	–	–	–	–
HSM-8 Not Used	–	–	–	–	–	–	–	–	–	
HSM-9 EQ - Cold	HSM	X	–	–	≤ 20.0 psig	–	-40°F HSM	–	EQ + 10% FF	D
HSM-10 EQ - Hot	HSM	X	–	–	≤ 20.0 psig	–	117°F HSM	–	EQ + 10% FF	D
HSM-11 Blocked Vent Storage	HSM	X	–	–	≤ 60.0 psig[7]	–	117°F HSM/BV[4]	–	100% Failed Fuel	D
HSM-12 Flood Load (50' H_2O) - Cold	HSM	X	–	–	0 psig	22 psig[3]	0°F HSM	–	Flood[3]	C
HSM-13 Flood Load (50' H_2O) - Hot	HSM	X	–	–	0 psig	22 psig[3]	117°F HSM	–	Flood[3]	C

AHSM UNLOADING	Horizontal DW DSC	Horizontal DW Fuel	Vertical DW DSC	Vertical DW Fuel	Internal Pressure[8]	External Pressure	Thermal Condition	Handling Loads	Other Loads	Service Level
UL-1 Normal Unloading - Cold	HSM	X	–	–	≤ 10.0 psig	–	0°F HSM	-60 Kip	–	A
UL-2 Normal Unloading - Hot	HSM	X	–	–	≤ 10.0 psig	–	104°F HSM	-60 Kip	–	A
UL-3 Off-Normal Unloading - Cold	HSM	X	–	–	≤ 20.0 psig	–	0°F HSM	-60 Kip	–	B
UL-4 Off-Normal Unloading - Hot	HSM	X	–	–	≤ 20.0 psig	–	117°F HSM	-60 Kip	–	B
UL-5 Accident Unloading - FF/Hot	HSM	X	–	–	≤ 20.0 psig	–	104°F HSM	-80 kip	10% Failed Fuel	C

DSC Unloading/Reflood	Horizontal DW DSC	Horizontal DW Fuel	Vertical DW DSC	Vertical DW Fuel	Internal Pressure	External Pressure	Thermal Condition	Handling Loads	Other Loads	Service Level
RF-1 DSC Reflood	–	–	Cask	X	20.0 psig (max)	Hydrostatic	120°F Cask[2]	–	–	D

Notes (continued)

6. This pressure is applied to the outer pressure boundary
7. This pressure should be considered on both the inner and outer pressure boundaries (i.e., inner and outer top cover plates)
8. Unless noted otherwise, pressure is applied to the inner pressure boundary
9. AHSM insertion loads and internal pressure loads are in opposition

Table 3.6-2
24PT1-DSC Shell Assembly Normal and Off-Normal Operating Condition Maximum Stress Intensities

Component	Stress Type	Stress Intensity (ksi)						
		Dead Weight		Normal Internal Pressure	Off-Normal Internal Pressure	Thermal	Normal Handling	Off-Normal Handling
		Vertical	Horiz.					
Shell	Primary Membrane	0.9	2.6	1.7	3.4	N/A	17.0	22.6
	Membrane + Bending	2.9	3.1	4.4	8.8	N/A	23.0	30.6
	Primary + Secondary	2.9	3.1	8.2	16.4	22.2	25.1	23.8
Outer Top Cover Plate	Primary Membrane	0.2	1.1	1.3	2.6	N/A	0.0[1]	0.0[1]
	Membrane + Bending	0.4	1.7	4.0	8.0	N/A	0.0[1]	0.0[1]
	Primary + Secondary	0.4	1.7	4.5	9.0	13.2	0.0[1]	0.0[1]
Inner Top Cover Plate	Primary Membrane	1.7	0.6	0.4	0.8	N/A	0.0[1]	0.0[1]
	Membrane + Bending	1.9	1.7	3.9	7.8	N/A	0.0[1]	0.0[1]
	Primary + Secondary	1.9	1.7	3.9	7.8	11.2	0.0[1]	0.0[1]
Outer Bottom Cover Plate	Primary Membrane	1.3	0.7	0.6	1.2	N/A	15.1	20.1
	Membrane + Bending	2.2	1.2	1.1	2.2	N/A	23.9	31.9
	Primary + Secondary	2.2	1.2	1.1	2.2	19.6	23.9	31.9
Inner Bottom Cover Plate	Primary Membrane	0.2	0.7	0.3	0.6	N/A	9.9	13.2
	Membrane + Bending	0.8	0.8	0.7	1.4	N/A	12.5	16.7
	Primary + Secondary	0.8	0.8	0.7	1.4	17.3	17.8	17.9
Support Ring	Primary Membrane	0.3	0.2	0.5	1.0	N/A	N/A	N/A
	Membrane + Bending	0.3	0.2	0.6	1.2	N/A	N/A	N/A
	Primary + Secondary	0.3	0.2	0.6	1.2	4.2	N/A	N/A

Notes:
(1) The top cover plates are not loaded by AHSM insertion/extraction

Table 3.6-3
24PT1-DSC Shell Assembly Accident Condition Maximum Stress Intensities

Component	Stress Type	Stress Intensity (ksi)			
		Flood	Seismic	Drop Accident[1]	Accident Pressure
Shell	Primary Membrane	1.6	10.2	29.8	10.2
	Membrane + Bending	2.9	17.4	34 2	26.4
Outer Top Cover Plate	Primary Membrane	0.2	1.2	36.9	7.8
	Membrane + Bending	0.5	2.4	52 5	24.0
Inner Top Cover Plate	Primary Membrane	0.2	10 2	25 3	2 4
	Membrane + Bending	0.5	11.4	38.4	23.4
Outer Bottom Cover Plate	Primary Membrane	0.3	7.8	23 3	3.6
	Membrane + Bending	0.5	13.2	34 1	6.6
Inner Bottom Cover Plate	Primary Membrane	0 8	1.2	39.1	1.8
	Membrane + Bending	1.6	4.8	40.1	4 2
Support Ring	Primary Membrane	1.4	1.8	14 2	3.0
	Membrane + Bending	1.9	1.8	24.9	3 6

Notes:
(1) Envelope of 75g side drop and 25g corner drop

Table 3.6-4
24PT1-DSC Shell Assembly Results for Normal and Off-Normal Load Combinations

Component	Stress Type	Controlling Load Combination	Stress Intensity (ksi)		Stress Ratio
			Calculated	Allowable	
Shell	Primary Membrane	UL-4	17.1	18 6	0.92
	Membrane + Bending	UL-4	24.3	27.9	0.87
	Primary + Secondary	UL-4	30.5	55.9	0.55
Outer Top Cover Plate	Primary Membrane	HSM-3 / HSM-4	4.5	16 7	0.27
	Membrane + Bending	HSM-3 / HSM-4	15.7	25.0	0.63
	Primary + Secondary	HSM-3 / HSM-4	15 7	50.1	0 31
Inner Top Cover Plate	Primary Membrane	TR-1 / TR-5	2.7	16 7	0.16
	Membrane + Bending	DD-1	19.1	27.0	0.71
	Primary + Secondary	DD-1	42.9	54.0	0.79
Outer Bottom Cover Plate	Primary Membrane	UL-4	17.0	18.6	0.91
	Membrane + Bending	UL-4	27.2	27.9	0 97
	Primary + Secondary	UL-4	27.2	55 9	0 49
Inner Bottom Cover Plate	Primary Membrane	UL-3 / UL-4	11.1	16 7	0.67
	Membrane + Bending	UL-3 / UL-4	14.8	25 0	0 59
	Primary + Secondary	LD-3	20.1	50 1	0.40
Support Ring	Primary Membrane	HSM-3 / HSM-4	1.2	16 7	0.07
	Membrane + Bending	HSM-3 / HSM-4	1.4	25 0	0.05
	Primary + Secondary	TR-1	4.8	50 1	0.10
Inner Top Cover Plate to Shell Weld	Primary	TR-3 / TR-7	7.5	10 0	0 75
	Primary + Secondary	TR-7	12.8	30 1	0 42
Outer Top Cover Plate to Shell Weld	Primary	TR-3 / TR-7	2.8	10 0	0.28
	Primary + Secondary	TR-3	16 9	30.1	0 56
Outer Bottom Cover Plate to Shell Weld	Primary	UL-3 / UL-4	8 6	10 0	0 86
	Primary + Secondary	LD-3	24 2	30 1	0.80

Note:
1. The shell seam welds and the inner bottom cover plate to shell weld are full penetration welds in compliance with Subsection NB. Qualification of the welds is demonstrated by qualification of the shell and cover plate

Table 3.6-5
24PT1-DSC Shell Assembly Results for Accident Level C Load Combinations

Component	Stress Type	Controlling Load Combination	Stress Intensity (ksi)		Stress Ratio
			Calculated	Allowable	
Shell	Primary Membrane	UL-5	22.5	23.2	0.97
	Membrane + Bending	UL-5	31.8	34.7	0.92
	Primary + Secondary	N/A	N/A	N/A	N/A
Outer Top Cover Plate	Primary Membrane	HSM-13	1.3	20.0	0.07
	Membrane + Bending	HSM-13	2.2	30.0	0.07
	Primary + Secondary	N/A	N/A	N/A	N/A
Inner Top Cover Plate	Primary Membrane	HSM-13	0.2	20.0	0.01
	Membrane + Bending	HSM-13	0.5	30.0	0.02
	Primary + Secondary	N/A	N/A	N/A	N/A
Outer Bottom Cover Plate	Primary Membrane	UL-5	21.6	23.2	0.93
	Membrane + Bending	UL-5	32.8	34.7	0.95
	Primary + Secondary	N/A	N/A	N/A	N/A
Inner Bottom Cover Plate	Primary Membrane	UL-5	14.4	20.0	0.72
	Membrane + Bending	UL-5	19.0	30.0	0.63
	Primary + Secondary	N/A	N/A	N/A	N/A
Support Ring	Primary Membrane	HSM-13	1.6	20.0	0.08
	Membrane + Bending	HSM-13	2.2	30.0	0.07
	Primary + Secondary	N/A	N/A	N/A	N/A
Inner Top Cover Plate to Shell Weld	Primary	HSM-13	3.1	12.0	0.26
Outer Top Cover Plate to Shell Weld	Primary	HSM-4	2.4	10.0	0.24
Outer Bottom Cover Plate to Shell Weld	Primary	UL-5	10.9	12.0	0.90

Note:

1. The shell seam welds and the inner bottom cover plate to shell weld are full penetration welds in compliance with Subsection NB Qualification of the welds is demonstrated by qualification of the shell and cover plate

Table 3.6-6
24PT1-DSC Shell Assembly Results for Accident Level D Load Combinations

Component	Stress Type	Controlling Load Combination	Stress Intensity (ksi)		Stress Ratio
			Calculated	Allowable	
Shell	Primary Membrane	TR-10	29.8	50.2	0.59
	Membrane + Bending	TR-10	38 2	64.6	0 59
Outer Top Cover Plate	Primary Membrane	TR-10	35 4	50 2	0.71
	Membrane + Bending	TR-10	52 1	64.6	0 81
Inner Top Cover Plate	Primary Membrane	TR-10	25 3	50 2	0.50
	Membrane + Bending	TR-10	41.8	64 6	0 65
Outer Bottom Cover Plate	Primary Membrane	TR-10	23 2	50 2	0.46
	Membrane + Bending	TR-10	34.1	64.6	0 53
Inner Bottom Cover Plate	Primary Membrane	TR-10	39 1	50.2	0 78
	Membrane + Bending	TR-10	40 1	64 6	0.62
Support Ring	Primary Membrane	TR-9	6 12	40.0	0.15
	Membrane + Bending	TR-9	10.60	60.1	0.18
Inner Top Cover Plate to Shell Weld	Primary	TR-10	24.0	30.2	0 80
Outer Top Cover Plate to Shell Weld	Primary	TR-10	12.3	30.2	0.41
Outer Bottom Cover Plate to Shell Weld	Primary	TR-10	6.7	30.2	0.22

Note:

1 The shell seam welds and the inner bottom cover plate to shell weld are full penetration welds in compliance with Subsection NB Qualification of the welds is demonstrated by qualification of the shell and cover plate.

Table 3.6-7
Summary of Spacer Disc Maximum Stress Ratios

Loading	Service Level	Stress Classification	Stress Intensity (ksi)	Allowable Stress[2] (ksi)	Maximum Stress Ratio
Vertical Dead Weight	A	P_m	0.35	25 9	0.01
	A	P_m+P_b	1.41	38.9	0.04
Vacuum Drying (DD-2) at perimeter	A	P_m+P_b+Q	95.5	Note 1	Note 1
Vacuum Drying (DD-2) at ligament	A	P_m+P_b+Q	30 3	77.7	0.39
Horizontal Dead Weight	A/B	P_m	Enveloped by Handling		
& AHSM Storage	A/B	P_m+P_b			
(HSM-1 through HSM-4)	A/B	P_m+P_b+Q			
Handling	A	P_m	4.9	25.9	0.19
(TR-1 through TR-8)	A	P_m+P_b	17.4	38.9	0.45
At perimeter	A	P_m+P_b+Q	88 5	Note 1	Note 1
At ligaments	A	P_m+P_b+Q	33 7	77.7	0 43
End Drop[5]	D	P_m	15 7	54.5	0.29
(TR-9)	D	P_m+P_b	52.9	70.0	0.76
0° Side Drop[2][3]	D	P_m	54.7	55 5	0.99
at cask rail location	D	P_m+P_b	57.0	71 4	0.80
0° Side Drop[3]	D	P_m	51.8	54 5	0.95
all other locations	D	P_m+P_b	67.9	70 0	0 97
18.5° Side Drop[3]	D	P_m	54.2	54.5	0.99
	D	P_m+P_b	69.7	70.0	1.00
45° Side Drop[3]	D	P_m	49 3	54.5	0.90
	D	P_m+P_b	69.7	70.0	1.00
Seismic	D	P_m	Enveloped by Drops[4]		
(HSM-9 and HSM-10)	D	P_m+P_b			

Notes:

(1) Qualification is based on the simplified elastic-plastic analysis methodology of NG-3228 3.

(2) Stress allowables are based on the maximum temperature of 700°F allowed by the ASME Code for SA-537 Class 2 steel, with the exception of the cask rail location for the 0° side drop case, where the maximum temperature is less than 500° F.

(3) All ligaments in the drop analyses were modeled using minimum thicknesses

(4) The SRSS resultant of 6g's in each orthogonal direction is 10.4g. Therefore, the level D earthquake is bounded by the 75g side drop and the enveloping 60g end drop

(5) The 60g end drop is not a credible event for the 10CFR72 license However, it is included as a bounding result for other load conditions such as the 25g corner drop and the Level D seismic load.

Table 3.6-8
Summary of Guidesleeve Assembly Maximum Stress Ratios

Loading	Service Level	Stress Classification	Stress Intensity (ksi)	Allowable Stress Intensity (ksi)	Maximum Stress Ratio
Vertical Dead Weight	A	f_a	0.10	5.92 [1]	0.02
Horizontal Dead Weight	A	P_m	0.080	16.0	0.01
	A	P_m+P_b	0.885	24.0	0.04
	A	P_m+P_b+Q	0.89[2]	48.0	0.02
Handling	A	P_m	0.20	16.0	0.01
	A	P_m+P_b	2.21	24.0	0.09
	A	P_m+P_b+Q	2.21	48.0	0.05
	A	f_a	0.24	6.24	0.04
End Drop	D	f_a	5.70	10.6	0.54
Side Drop	D	P_m	10.1	44.5	0.23
	D	P_m+P_b	26.8	57.2	0.47
Seismic	A	P_m	0.48	38.4	0.01
	A	P_m+P_b	5.31	57.6	0.09
	A	f_a	0.57	10.6	0.05

Notes:

(1) Allowables for vertical dead weight are conservatively taken at 800°F, which is an enveloping temperature for the draining and drying operation

Table 3.6-9
Summary of Results for Support Rod Assemblies

A. Summary of Interaction Ratios in the Spacer Sleeves			
Loading	Service Level	Maximum Interaction (2)	Allowable
Vertical Dead Weight	A	0.21	1.0
Horizontal Dead Weight	A	0.21	1.0
Handling (Axial)	A	0.33	1.0
Handling (Lateral)	A	0.21	1.0
60g End Drop(4)	D	0.58	1.0
75g Side Drop	D	0.22	1.0
Seismic	D	Enveloped by Drops	

B. Summary of Support Rod Stresses[1]					
Load Combination	Axial Load (Kips)	F_t (ksi)	$F_t^{(3)}$(ksi)	Ratio	*Ratio(5)*
65K Preload (70°F)	65.0K	53.0K	69.0	*0.97*	*0.93*
65K Preload + 600°F	61.5K	50.1K	55.7	0.90	*0 94*
65K Preload + 600°F + 1g	61.2K	49.9K	55.7	0.90	*0.94*
65K Preload + 600°F + 60g	47.7K	38.9K	92.0	0.42	*0.52*

Notes:
1. All stresses are calculated using a maximum assembled preload of 65 Kips. Preloads less than 65K are acceptable and will reduce stresses in the support rod assembly Preload is not required for qualification of the rod assembly.
2. The reported interaction ratios are the maximum values from Equations 20 through 22 of NF 3322.1(e)(1)
3. Allowable stresses for rod tension taken at 70°F or 600°F as appropriate
4. End drops are not postulated for on-site operation of the horizontal NUHOMS® system. These results are provided to ensure the qualification for postulated 25g 30° corner drop
5. *Ratios are for support rods with optional thread reliefs*

Table 3.6-10
Summary of AHSM Design Loading

Design Load Type	Load Notation	Design Parameters	Applicable Codes
Dead load	DW	Includes 150 pcf concrete structure, steel support structure	ANSI/ANS 57.9-1984 [3.9]
Live loads	LL	Design load of 200 psf, which includes snow and ice load (110 psf) This load case also includes normal and off-normal handling loads on the concrete module 24PT1-DSC weight is treated as a live load.	ANSI/ANS 57.9-1984 [3.9] ASCE 7-95 [3.14]
Normal operating temperatures	TN	24PT1-DSC with spent fuel rejecting 24.0 kW of decay heat Ambient air temperatures 0°F, 70°F and 104°F Reference temperature = 70°F	ANSI/ANS 57.9-1984 [3 9]
Off-normal operating temperatures	TO	24PT1-DSC with spent fuel rejecting 24.0 kW of decay heat Ambient air temperatures -40°F and 117°F Reference temperature = 70°F	ANSI/ANS 57.9-1984 [3 9]
Design basis wind load	WW	Enveloped by tornado generated wind load (WT)	ASCE 7-95 [3 14]
Normal handling load (along DSC axis)	RO	For the concrete module this load is applied as a live load. For the steel support structure the magnitude of this load is the maximum ram load of ±60000 lbs. applied to both rails. The concrete module is evaluated for 60 kip 24PT1-DSC insertion load and 60 kip 24PT1-DSC retrieval load applied as a live load The 24PT1-DSC weight is applied as a distributed load	ASCE 7-95 [3 14]
Off-normal handling load (along DSC axis)	RA	For the concrete module this load is applied as a live load. For the steel support structure the magnitude of this load is 80000 lbs (24PT1-DSC insertion) and 60000 lbs (24PT1-DSC retrieval) applied to one rail plus a vertical load of half the 24PT1-DSC weight applied to each rail as a point load at the most critical location.	ANSI/ANS 57.9-1984 [3.9]
Seismic load	EQ	Horizontal ground acceleration of 1.5g with Reg Guide 1.60 spectra at 4% damping and vertical ground acceleration of 1.0g (2/3 of horizontal). The horizontal ground acceleration is amplified to 2.25g for the top shield block assembly.	NRC Regulatory Guide 1.60 and 1.61. [3.2, 3.3]
Flood load	FL	Maximum water height of 50' and maximum velocity of water 15'/sec	10CFR 72.122b [3.1]
Accident condition temperature (40 hr.)	TA	Same as off-normal condition with ambient temp -40° F, 117° F and AHSM vents blocked for 40 hrs. Reference temperature = 70°F	ANSI 57.9-1984 [3.9]
Design basis tornado wind load	WT	Maximum wind speed of 360 mph, and a pressure drop of 3 psi	ASCE 7-95 [3 14] NRC Reg. Guide 1.76 [3 4]
Design basis tornado missile load	WM	(a) Utility pole,Wt=1500 lbs., V = 294fps (b) Steel Rod,Wt=276 lbs., V=185fps (c) Steel Pipe,Wt=1500 lbs , V=205fps (d) Automobile,Wt=4000 lbs , V=195 fps	NUREG-0800, Section 3 5.1.4 [3.6]

Table 3.6-11
Design Pressures for Tornado Wind Loading

Wall Orientation[1]	Velocity Pressure (psf)	Pressure Coefficient[2]	Max/Min Design Pressure (psf)[3]	Max/Min Design Pressure (psf)[4]
Front	344	+0 68	234	+397
Left	344	-0.60	-207	-357
Rear	344	-0.43	-148	-196
Right	344	-0.60	-207	-357
Top	344	-0 60	-207	-357

Notes:

(1) Wind direction assumed to be from front Wind loads from other directions may be found by rotating Table values to desired wind direction

(2) Pressure coff = Gust factor(0.85)* Max/Min pressure coff from Fig. 6-3 of [3.14]

(3) These values are actual computed values based on coefficients from Fig. 6-3 of [3 14]

(4) Conservatively, these values are used

Table 3.6-12
AHSM Concrete Load Combinations

No.	Combination Identifier	Load Combination
C1C	COMB1C	U > 1.4*DW+1.7*(LL+RO)
C2C	COMB2C	U > 1.05*DW+1.275*(LL+TN+WW)
C3C	COMB3C	U > 1.05*DW + 1.275*(LL+TN+RA)
C4C	COMB4C	U > DW+LL+TN+EQ
C5C	COMB5C	U > DW+LL+TN+WT
C6C	COMB6C	U > DW+LL+TN+FL
C7C	COMB7C	U > DW+LL+MAX(TO and TA)

Table 3.6-13
AHSM Support Steel Structure Load Combinations

No.	Identifier	Load Combination
C1S	COMB1S	S > DW+LL+TN[(1), (2)]
C2S	COMB2S	S > DW+RO[(3), (4)]
C3S	COMB3S	1.3S > DW+TN+RA[(3), (4)]
C4S	COMB4S	(1.6S or 1.4S_v) > DW+LL+TN+EQ[(2)]
C5S	COMB5S	(1.7S or 1.4S_v) > DW+LL+MAX (TO and TA)[(2)]

Notes:

(1) This normal operating load combination applies to 24PT1-DSC storage condition

(2) 24PT1-DSC weight is included as live load (LL) for this condition; the 24PT1-DSC spans between end supports

(3) These load combinations represent normal and off-normal handling conditions

(4) 24PT1-DSC weight is included as a direct load on the rail during handling

Table 3.6-14
Ultimate Capacities of Concrete Components

Component [4]	Thermal Condition	V_{ul}[1] Kips/ft	V_{uo1}[1] Kips/ft	V_{uo2}[1] kips/ft	M_{u1}[1] Kip-in/ft	M_{u2}[1] kip-in/ft
B1	Normal	196.9	40.4	40.4	2185.6	2185.6
(T=31.0", #8@6")	Accident	178.6	38.3	38.3	1955.9	1955.9
B2/B3	Normal	108.7	19.3	19.3	583.9	583.9
(T=16.0", #6@6")	Accident	98.5	18.3	18.3	522.5	522.5
B4[2]	Normal	-	-	-	-	-
	Accident	-	-	-	-	-
B5[3]	Normal	197.6	41.1	41.1	2225.8	2225.8
(T=31.5 ", #8@6")	Accident	179.3	39.0	39.0	1991.9	1991.9
B5	Normal	223.6	66.7	66.7	3656.2	3656.2
(T=49.5", #8@6")	Accident	203.9	63.3	63.3	3271.7	3271.7
S1	Normal	102.9	13.5	13.5	402.6	402.6
(T=12.0", #6@6")	Accident	93.0	12.8	12.8	360.3	360.3
S2/S3	Normal	102.9	13.5	13 5	402.6	402.6
(T=12.0", #6@6")	Accident	93.0	12.8	12.8	360.3	360.3
S4	Normal	105.1	15.7	15 7	470.6	470.6
(T=13.5", #6@6")	Accident	95.1	14.9	14.9	421.1	421.1
T1/T2	Normal	238.8	82.2	82.2	4522.4	4522.4
(T=60.0", #8@6")	Accident	218.3	78.0	78.0	4046.8	4046.8

Notes:

1. V_{ul} = Minimum of ultimate in plane shear capacities in planes 1 and 2 (Figure 3.6-14)
   V_{uo1} = Ultimate out of plane shear capacity in plane 1
   V_{uo2} = Ultimate out of plane shear capacity in plane 2
   M_{u1} = Ultimate moment capacity in plane 1
   M_{u2} = Ultimate moment capacity in plane 2
2. B4 *is not a load bearing concrete component Therefore, results are not reported for this component*
3. Thickness of this component includes 24.5" (of component B5) + 6" (of component S5)
4. For purposes of design evaluation, the AHSM is broken down into components. Location of each component is shown in Figure 3 6-11 through Figure 3.6-13. Alternate rebar size and placement may be used which provides equivalent concrete section properties

Table 3.6-15
Comparison of Highest Combined Shear Forces/Moments with the Capacities

Component [3]	Load Comb. [1]	Quantity	V_l Kips/ft	V_{o1} kips/ft	V_{o2} kips/ft	M_1 kip-in/ft	M_2 kip-in/ft
B1 (T=31.0") #8@6" Rear Wall (Base Section)	Comb 1c thru 6c	Computed	41.37	17.43	20 4	649 46	931.24
		Capacity	196 9	40 4	40 4	2185 6	2185.6
		Ratio	0.21	0.43	0.51	0.30	0.43
	Comb7c	Computed	9 68	21.30	27.92	676.6	596.89
		Capacity	178 6	38 3	38 3	1955 9	1955.9
		Ratio	0.06	0.56	0.73	0.35	0.31
B2/B3 (T=16.0") #6@6" Side Walls (Base Section)	Comb 1c thru 6c	Computed	27.28	14.31	14.91	129.79	86.08
		Capacity	108.7	19.3	19.3	583.9	583.9
		Ratio	0.25	0.74	0.78	0.23	0.15
	Comb7c	Computed	26 53	13.55	14.10	122 21	163.55
		Capacity	98.5	18.3	18 3	522.5	522 5
		Ratio	0.27	0.74	0.77	0.24	0.32
B4[2] Front Beam (Base Section)	-	-	-	-	-	-	-
B5/S5 (T=31.5") #8@6" Front Slab (Base Section)	Comb 1c thru 6c	Computed	52 08	39.8	39 98	644 82	1824 48
		Capacity	197.6	41.1	41.1	2225 8	2225.8
		Ratio	0.27	0.97	0.78	0.29	0.82
	Comb7c	Computed	77.77	35.8	36 12	1079 77	1164.74
		Capacity	179 3	39.0	39.0	1991.90	1991.9
		Ratio	0.44	0.92	0.81	0.55	0.59
B5 (T=49.5") #8@6") Middle Slab (Base Section)	Comb1c thru 6C	Computed	52.88	47.17	23 91	1356.12	2364.04
		Capacity	223 6	66 70	66.70	3556.2	3556.2
		Ratio	0.24	0.72	0.36	0.39	0.67
	Comb7c	Computed	90.28	31.45	36 79	1732.51	3094.88
		Capacity	203 9	63.30	63.30	3271.70	3271.70
		Ratio	0.45	0.50	0.59	0.53	0.95

Notes:

1. Comb 1c thru 6c include normal thermal, Comb 7c include accident thermal
2. B4 *is not a load bearing concrete component Therefore, results are not reported for this component.*
3. For purposes of design evaluation, the AHSM is broken down into components Location of each component is shown in Figure 3 6-11 through Figure 3 6-13

Table 3.6-15
Comparison of Highest Combined Shear Forces/Moments with the Capacities (concluded)

Component [3]	Load Comb.[1]	Quantity	V_l kips/ft	V_{o1} kips/ft	V_{o2} kips/ft	M_1 kip-in/ft	M_2 kip-in/ft
S1 (T=12.0") #6@6" Rear Wall (Storage Section)	Comb 1c Thru 6c	Computed	15 43	6 11	6.29	54 51	67.41
		Capacity	102.90	13 50	13.50	402.60	402.60
		Ratio	0.15	0.46	0.47	0.14	0.17
	Comb7c	Computed	7.34	8 25	9.11	57.49	103.30
		Capacity	93.00	12 80	12.80	360 30	360 30
		Ratio	0.08	0.65	0.72	0.16	0.29
S2/S3 (T=12") #6@6" Side Walls (Storage Section)	Comb 1c Thru 6c	Computed	41.86	10.36	9 37	323 25	145 41
		Capacity	102 9	13 5	13 5	402.6	402.6
		Ratio	0.41	0.77	0.70	0.81	0.37
	Comb7c	Computed	50 93	12.24	8 39	228 45	258.49
		Capacity	93 0	12.8	12.8	360 3	360 3
		Ratio	0.55	0.96	0.66	0.64	0.72
S4 (T=13 5") #6@6" Slab (Storage Section)	Comb 1c thru 6c	Computed	14 19	13.56	9.27	217.36	118.00
		Capacity	105 1	15 7	15 7	470.6	470 6
		Ratio	0.14	0.87	0.59	0.46	0.25
	Comb7c	Computed	9.72	10.13	7.81	279 55	160.52
		Capacity	95.1	14 9	14.9	421.1	421.1
		Ratio	0.11	0.68	0.53	0.67	0.38
T1/T2 (T=60 0") #8@6" Roof	Comb 1c thru 6c	Computed	12.51	24.23	20.94	610 25	563.09
		Capacity	238 8	82.2	82 2	4522 4	4522.4
		Ratio	0.05	0.30	0.30	0.14	0.13
	Comb7c	Computed	5.43	3 14	4 33	1228 98	1247.94
		Capacity	218.3	78.0	78.0	4046.8	4046.8
		Ratio	0.03	0.04	0.06	0.31	0.31

Notes:

1. Comb 1c thru 6c include normal thermal, Comb 7c include accident thermal
2. B4 behaves as a horizontal beam
3. For purposes of design evaluation, the AHSM is broken down into components. Location of each component is shown IFigure 3 6-11 through Figure 3 6-13

Table 3.6-16
Maximum/Minimum Forces/Moments in the Rail Components in the Local System

Load Combination		F_x Kips	F_y Kips	F_z Kips	M_x kip-in	M_y kip-in	M_z Kip-in
C1S	MAX	0.0	2.0	4.1	65.5	122.8	0.1
	MIN	0.0	-3.0	-3.2	-65.5	-129.2	-202.5
C2S	MAX	30.0	2.0	15.5	10.1	341.4	62.5
	MIN	-30.0	-2.0	-11.9	-10.2	-280.3	-62.6
C3S	MAX	80.0	4.9	20.5	65.2	413.2	23.6
	MIN	-60.0	-11.73	-15.9	-74.4	-892.5	-265.4
C4S	MAX	2.7(1)	2.8	4.9	75.9	134.8	0.3
	MIN	-2.7(1)	-3.5	-3.5	-75.8	-141.1	-213.0
C5S	MAX	0.0	3.5	7.4	134.5	259.9	0.1
	MIN	0.0	-5.1	-6.3	-134.5	-265.3	-372.4

Note:

(1) The seismic effect of 24PT1-DSC axial load on the rails (due to 24PT1-DSC impacting the canister stop plate) is included by adding axial load of 63 75 kips (1.5*85 kips/2rails = 63 75kips per rail) to 2.7 kips Therefore the total axial load = 66 5 kips is used to qualify the rails for this load combination.

Table 3.6-17
Maximum/Minimum Forces/Moments in the Rail Extension Plates in the Local System

Load Combination		F_x Kips	F_y Kips	F_z Kips	M_x kip-in	M_y kip-in	M_z Kip-in
C1S	MAX	0.0	1.98	2.93	0.	36.1	0.0
	MIN	0.0	-2.98	-2.86	0.	-37.08	-37.66
C2S	MAX	30.0	0.4	0.1	0.	0.54	4.7
	MIN	-30.0	-0.4	0.1	0.	-0.73	-4.6
C3S	MAX	80.0	1.87	3 23	0	40.6	23.6
	MIN	-60.0	-11.73	-3.2	0	-40.9	-148.8
C4S	MAX	2.71(1)	-1.82	2.95	0	36.24	0.0
	MIN	-2.71(1)	-3.14	-2.87	0	-37.21	-39.67
C5S	MAX	0.	-2.02	5.23	0	65.81	0.0
	MIN	0.	-5.10	-5.20	0	-66.48	-64.58

Note:

(1) The seismic effect of 24PT1-DSC axial load on the rails (due to 24PT1-DSC impacting the canister stop plate) is included by adding axial load of 63.75 kips (1.5*85 kips/2 rails = 63.75 kips per rail) to 2.7 kips Therefore, the total axial load of 66.5 kips is used to qualify the rails for this load combination

Table 3.6-18
Maximum/Minimum Axial Forces in the Cross Member Components

Load Combination		Fx Kips
C1S	MAX	22.3
	MIN	-31.5
C2S	MAX	3.2
	MIN	-2 1
C3S	MAX	22.0
	MIN	-33.6
C4S	MAX	22.4
	MIN	-31.8
C5S	MAX	45.2
	MIN	-60.5

Table 3.6-19
Rail Component, Results of Evaluation

Load Comb.	Interaction Ratio	Shear Stress Ratio	Stiffener Plate Stress Ratio
C1S	0.37	0.74	*0.57*
C2S	0.38	0.33	0.10
C3S	0.89	0.82	*0.56*
C4S	0.36	0.61	*0.47*
C5S	0.49	0.98	*0.97*

Table 3.6-20
Extension Plates and Cross Members, Results of Evaluation

Load Comb.	Extension Plates Interaction Ratio	Cross Members	
		Tensile Stress Ratio	Compression Stress Ratio
C1S	0.62	0.49	0.79
C2S	0.62	0.10	0.10
C3S	0.99	0.37	0.65
C4S	0.62	0.31	0.50
C5S	0.97	0.69	0.99

Table 3.6-21
Computed Forces and Capacities of Ties and Keys

#	Tie/Key	Force (kips)	Capacity (kips)	Ratio
1	Tie Beam at Top (3 Beams)	779	1017	0.77
2	Bottom Tie Rod (4 Rods)	210	*303.6*	*0.70*
3	Key between Top Shield Block and Base Unit (Transverse)	424	*1134*	*0.38*
4	Key between Top Shield Block and Base Unit (Longitudinal)	*354*	*2268*	*0.16*
5	Vertical Tie Rods between Top Shield Block and Base Unit (8 Rods)	382.4	*471.0*	*0.81*
6	Vertical Shear Key between Modules	1182	1605	0.74
7	Horizontal Shear Key between Modules	420	504	0.84

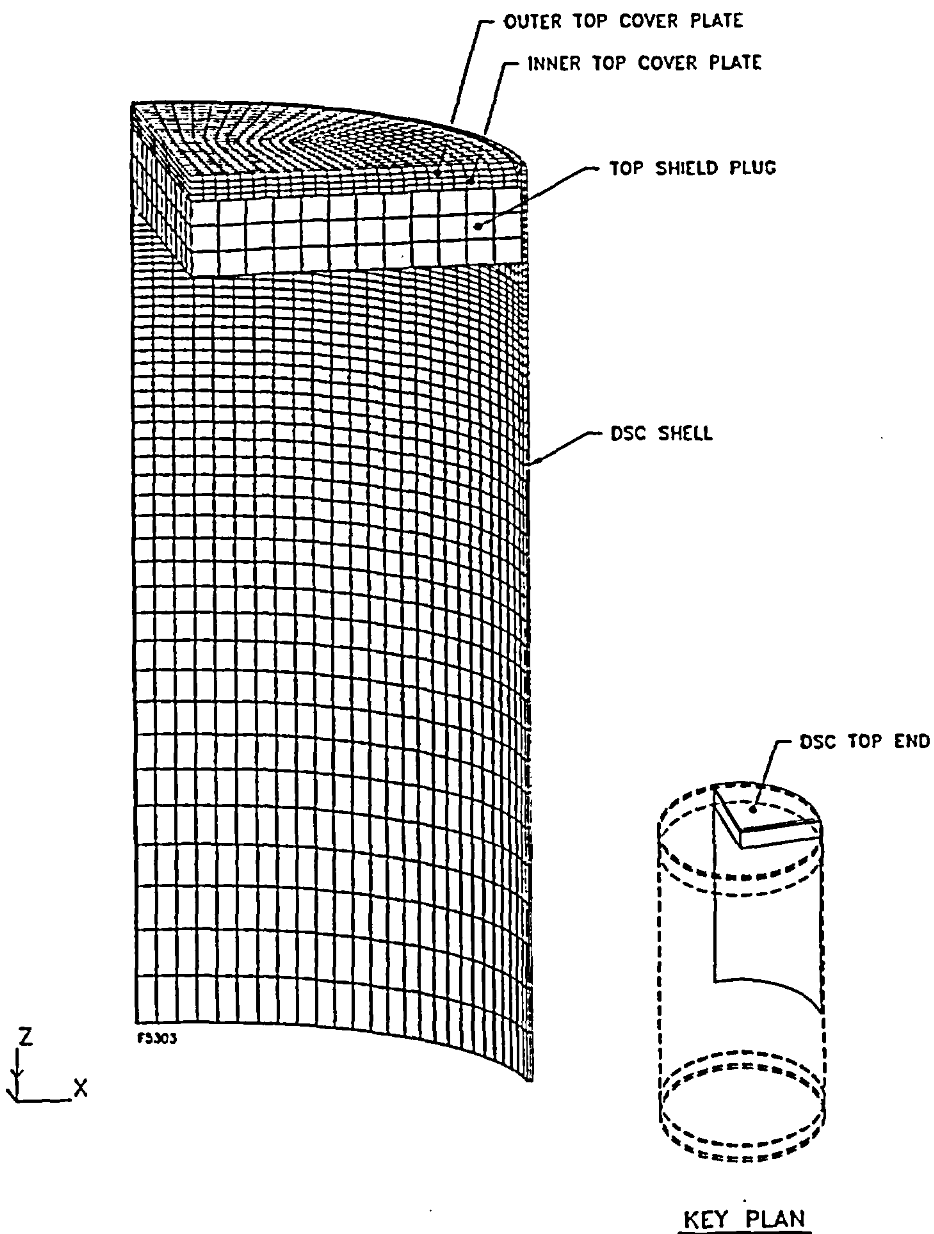


Figure 3.6-1
24PT1-DSC Shell Assembly Top End 90° ANSYS Model

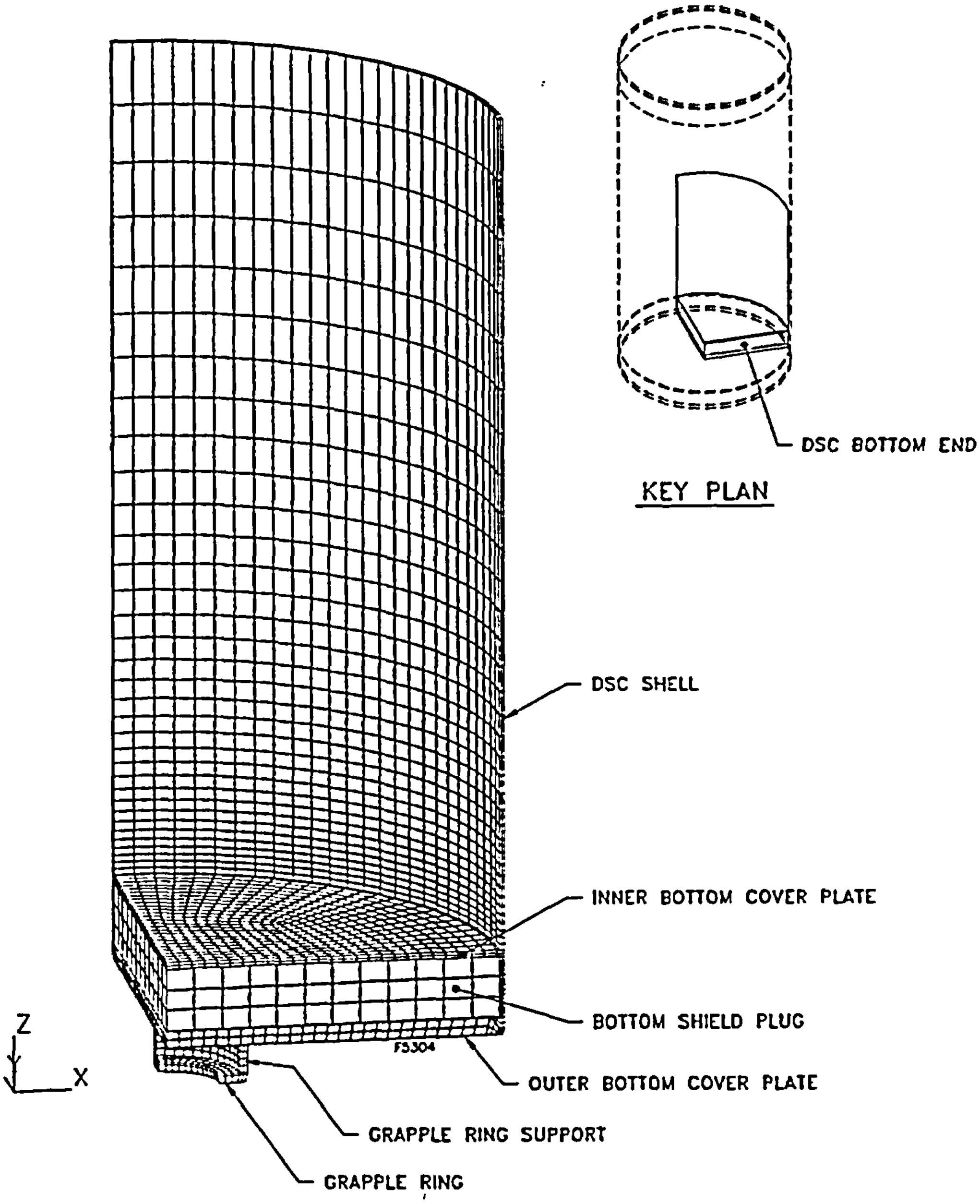
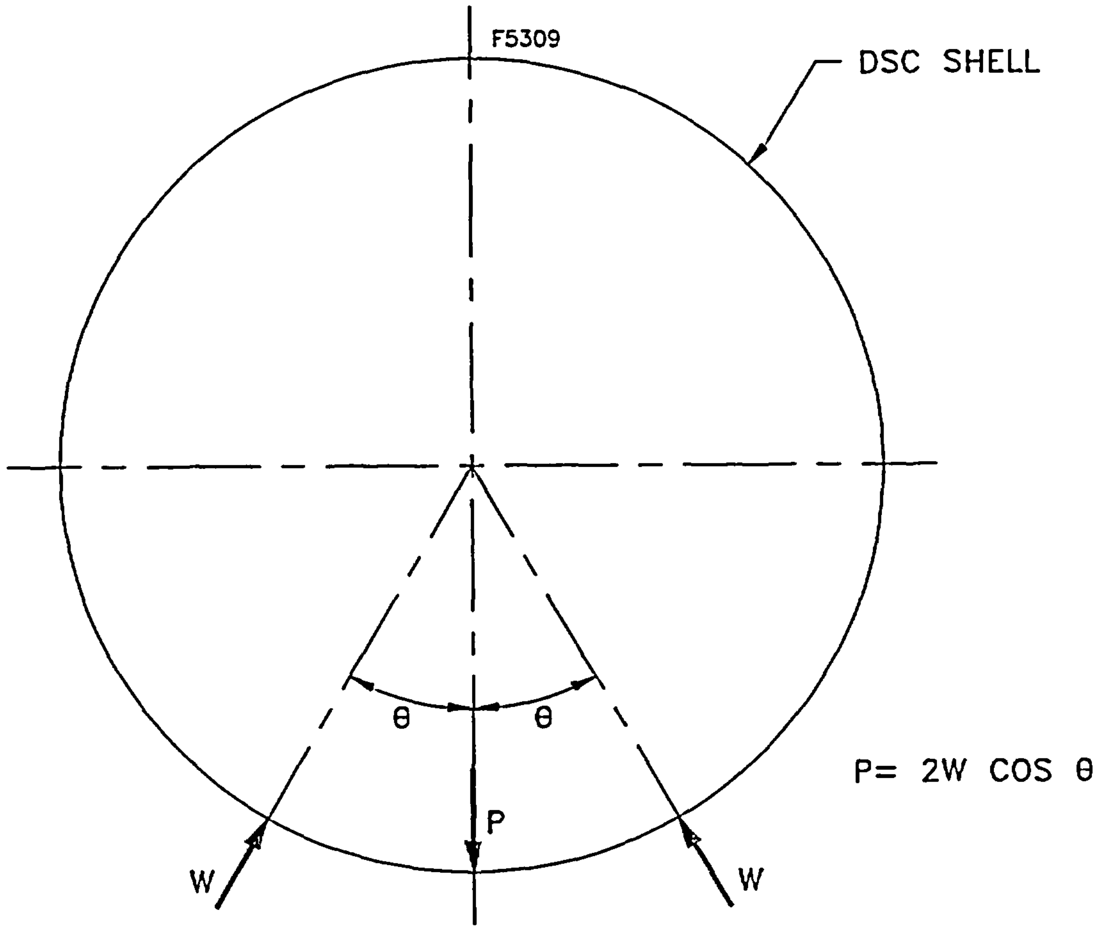


Figure 3.6-2
24PT1-DSC Shell Assembly Bottom End 90° ANSYS Model



KEY:
P= DEAD WEIGHT OF LOADED DSC.
W= DSC SUPPORT RAIL REACTION.

θ = 18.5° IN TRANSFER CASK
θ = 35° IN AHSM

Figure 3.6-3
24PT1-DSC Load Support for Shell and Spacer Disc Analyses

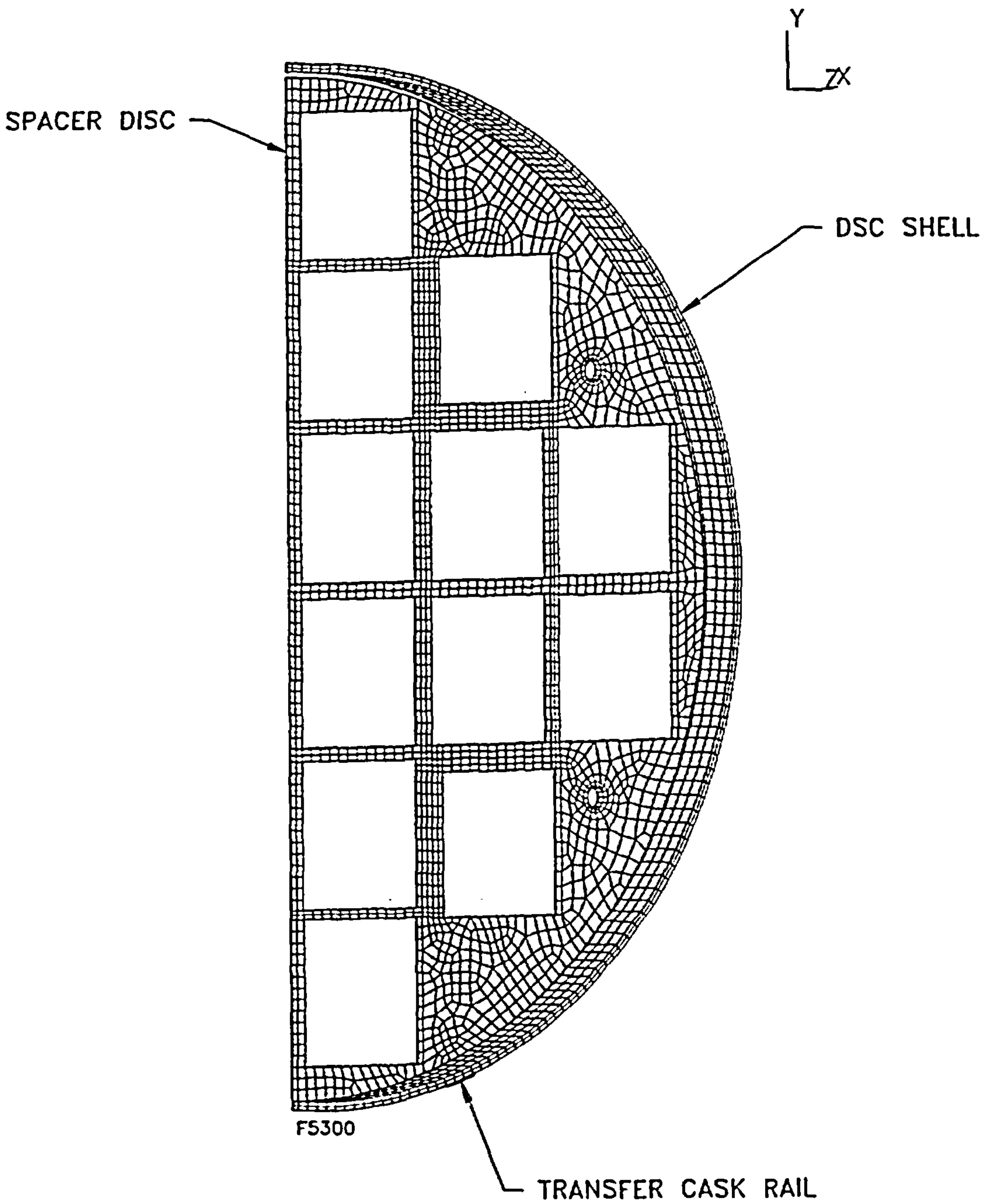


Figure 3.6-4
24PT1-DSC Spacer Disc Side Drop ANSYS Model (Half Symmetry)
(Cask Not Shown for Clarity)

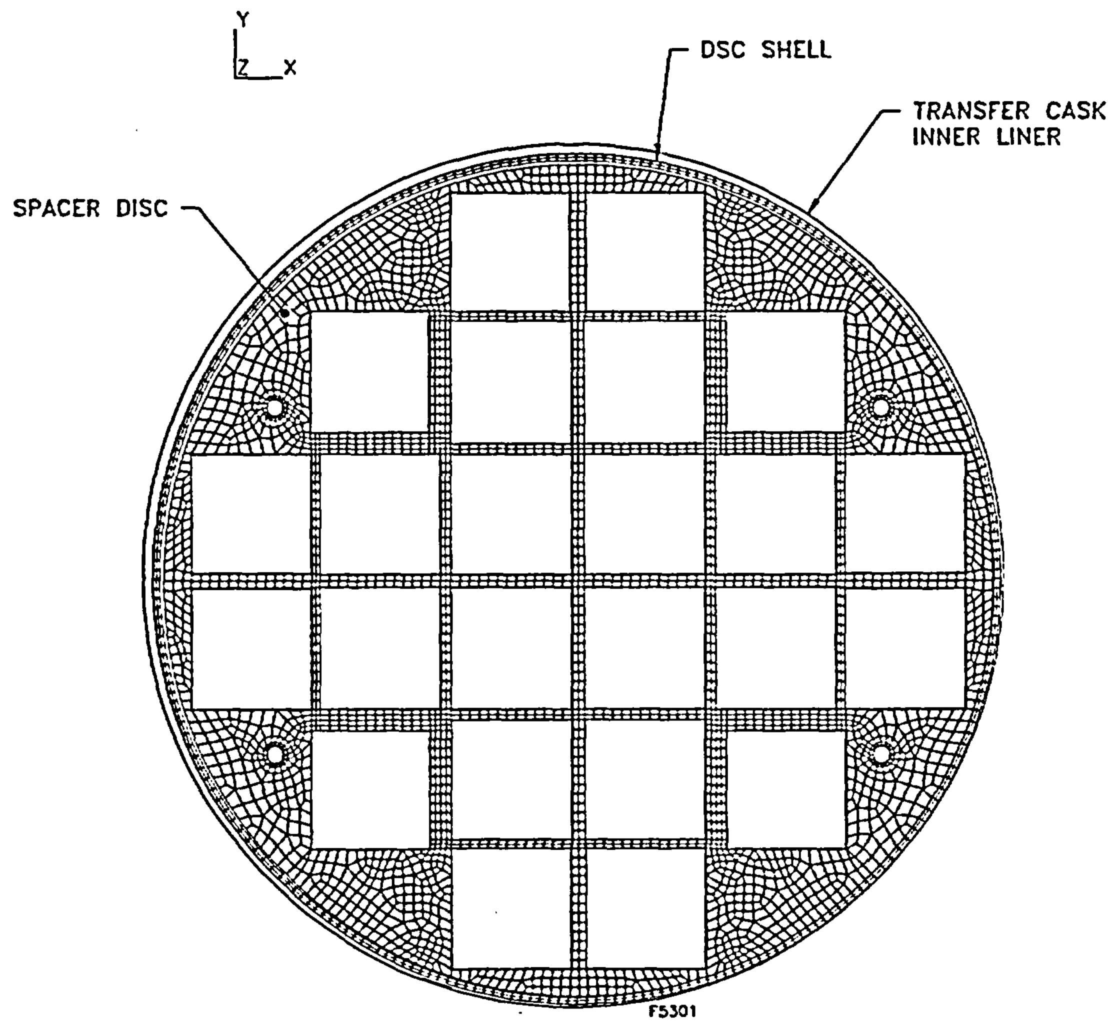


Figure 3.6-5
24PT1-DSC Spacer Disc Side Drop ANSYS Model (Full Symmetry)
(Model Shown is for 45° Drop Orientation)

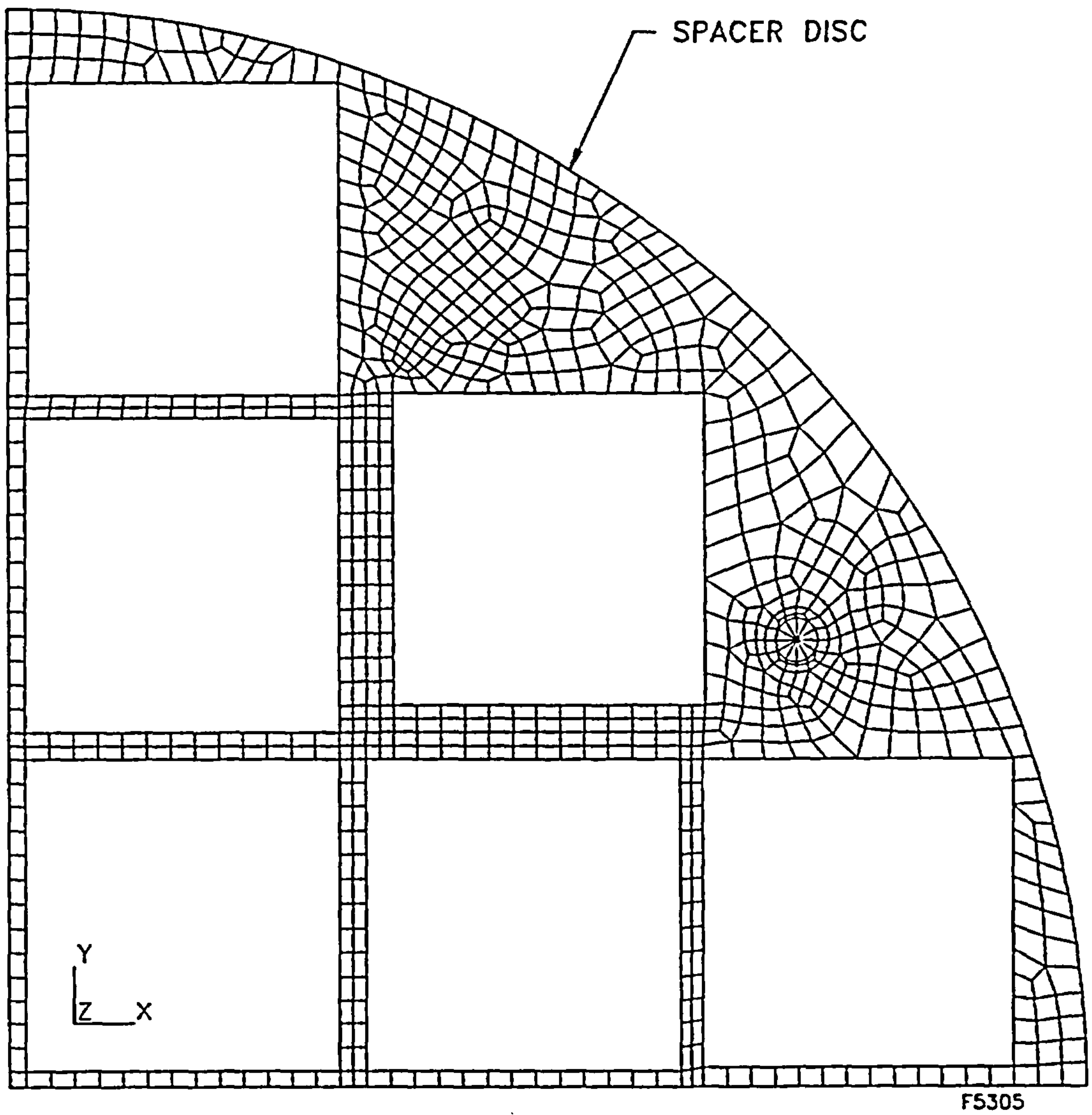


Figure 3.6-6
24PT1-DSC Spacer Disc ANSYS Model for Axial Loads (Quarter Symmetry)

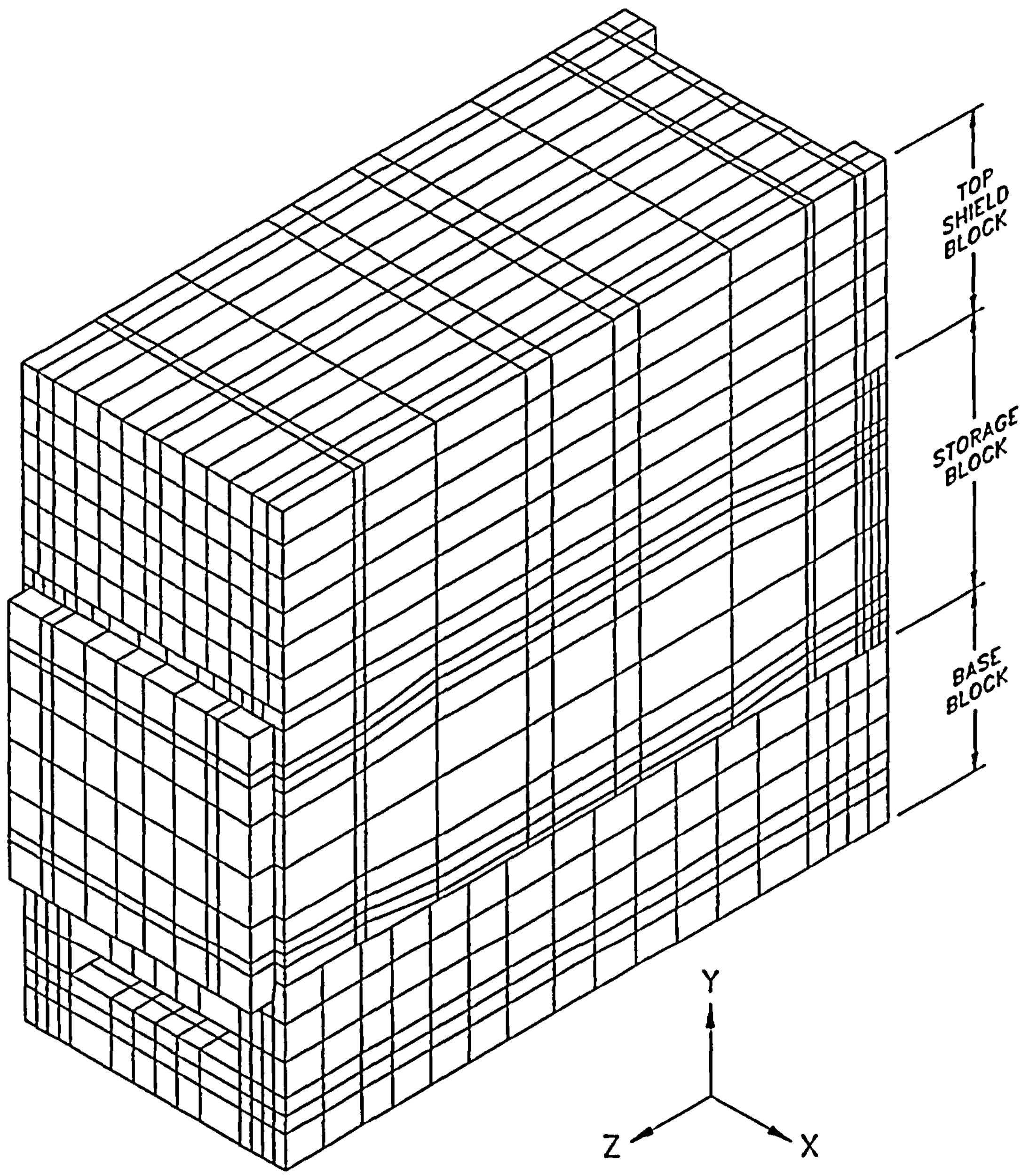


Figure 3.6-7
ANSYS Model of the AHSM

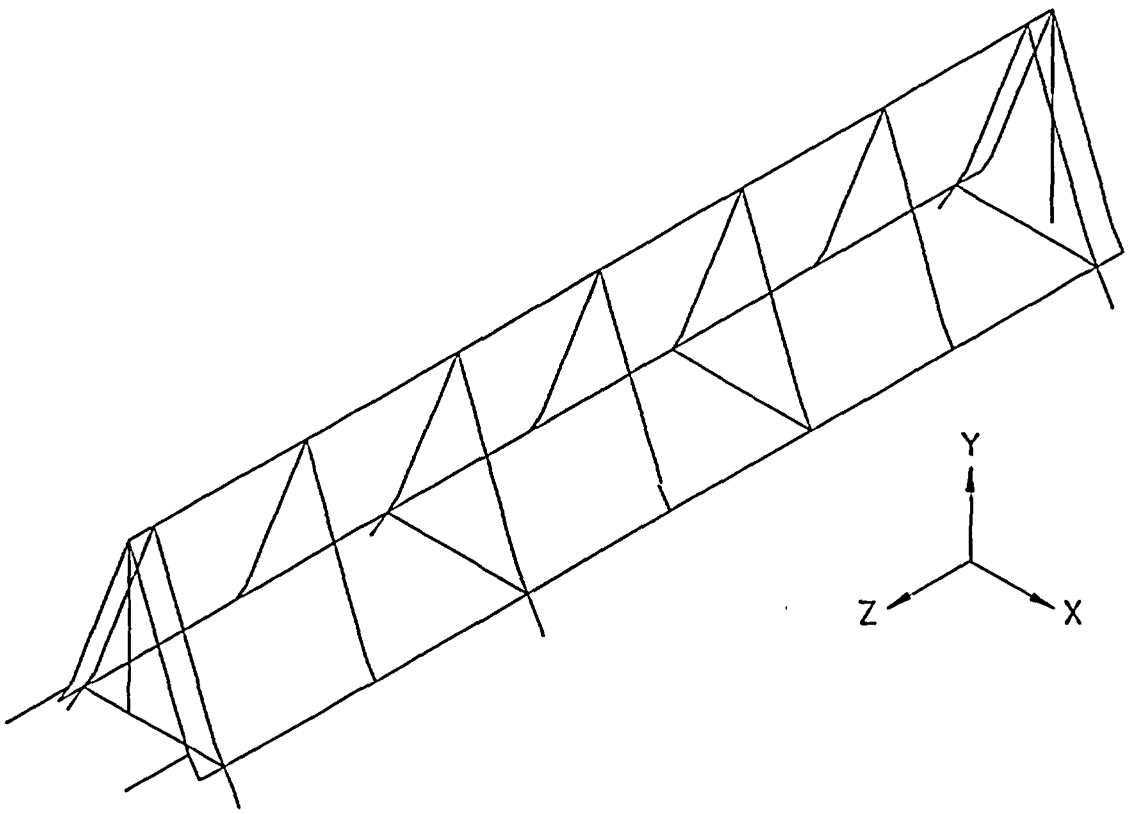


Figure 3.6-8
ANSYS Model of the DSC and the DSC Support Structure

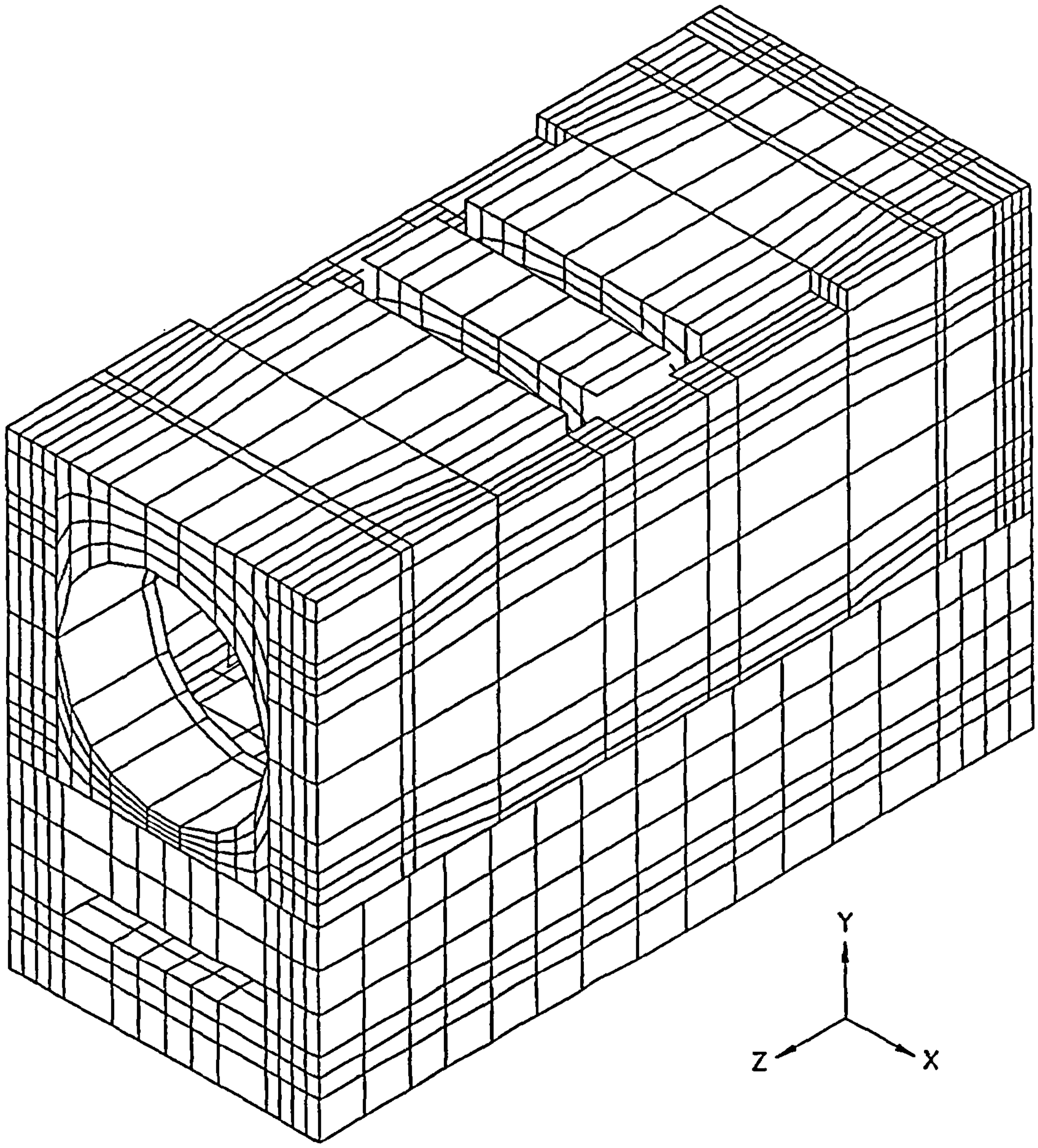


Figure 3.6-9
ANSYS Model of the AHSM Base Storage Block for Thermal Stress Analysis

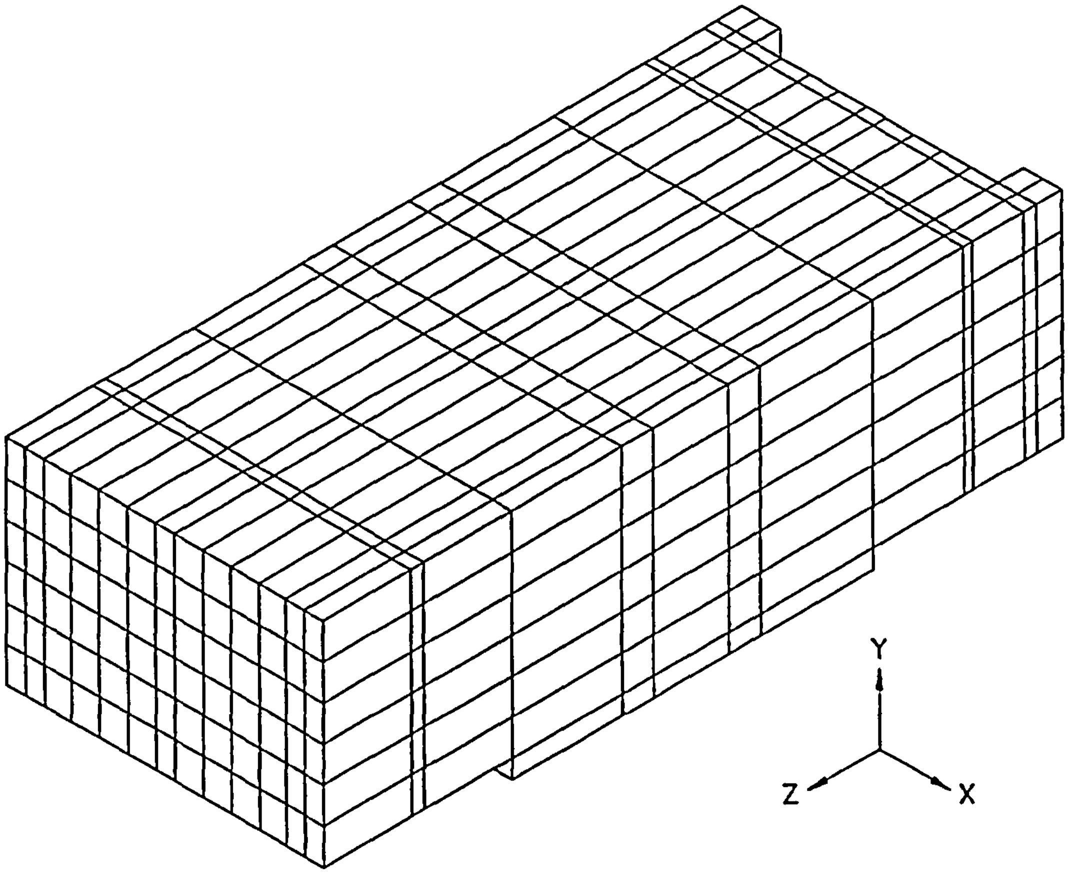


Figure 3.6-10
ANSYS Model of the AHSM Top Shield Block for Thermal Stress Analysis

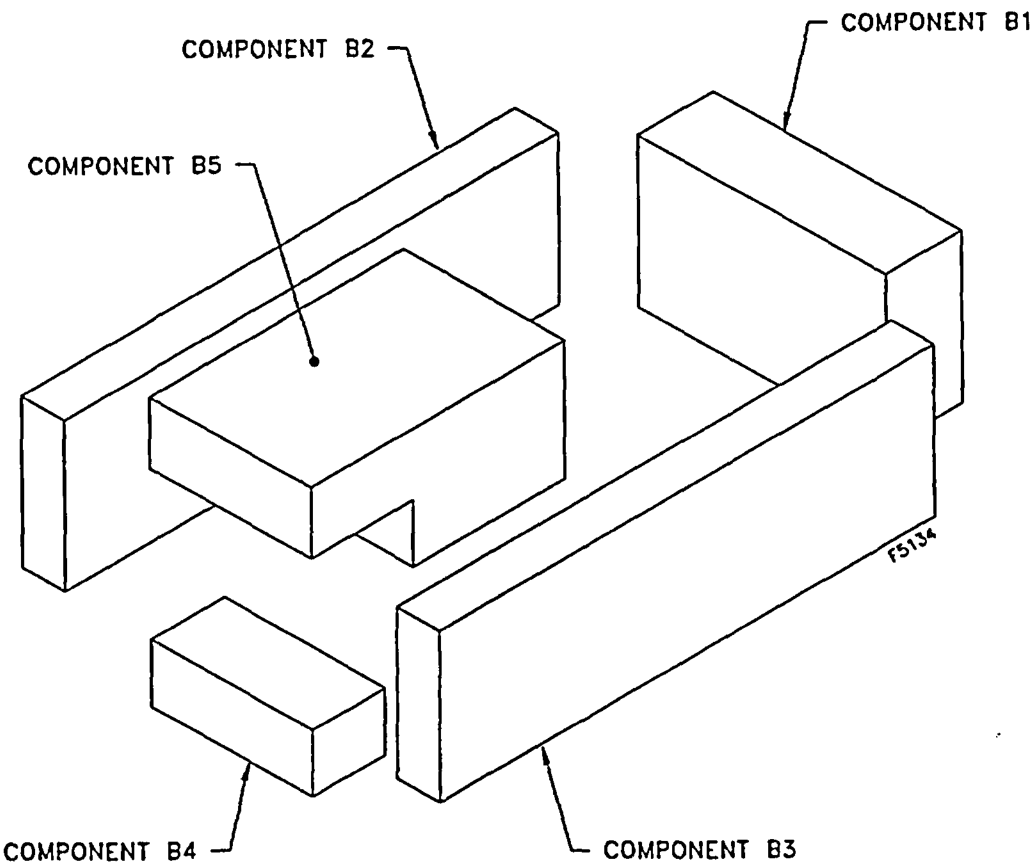


Figure 3.6-11
Concrete Components in the Lower Base Storage Block

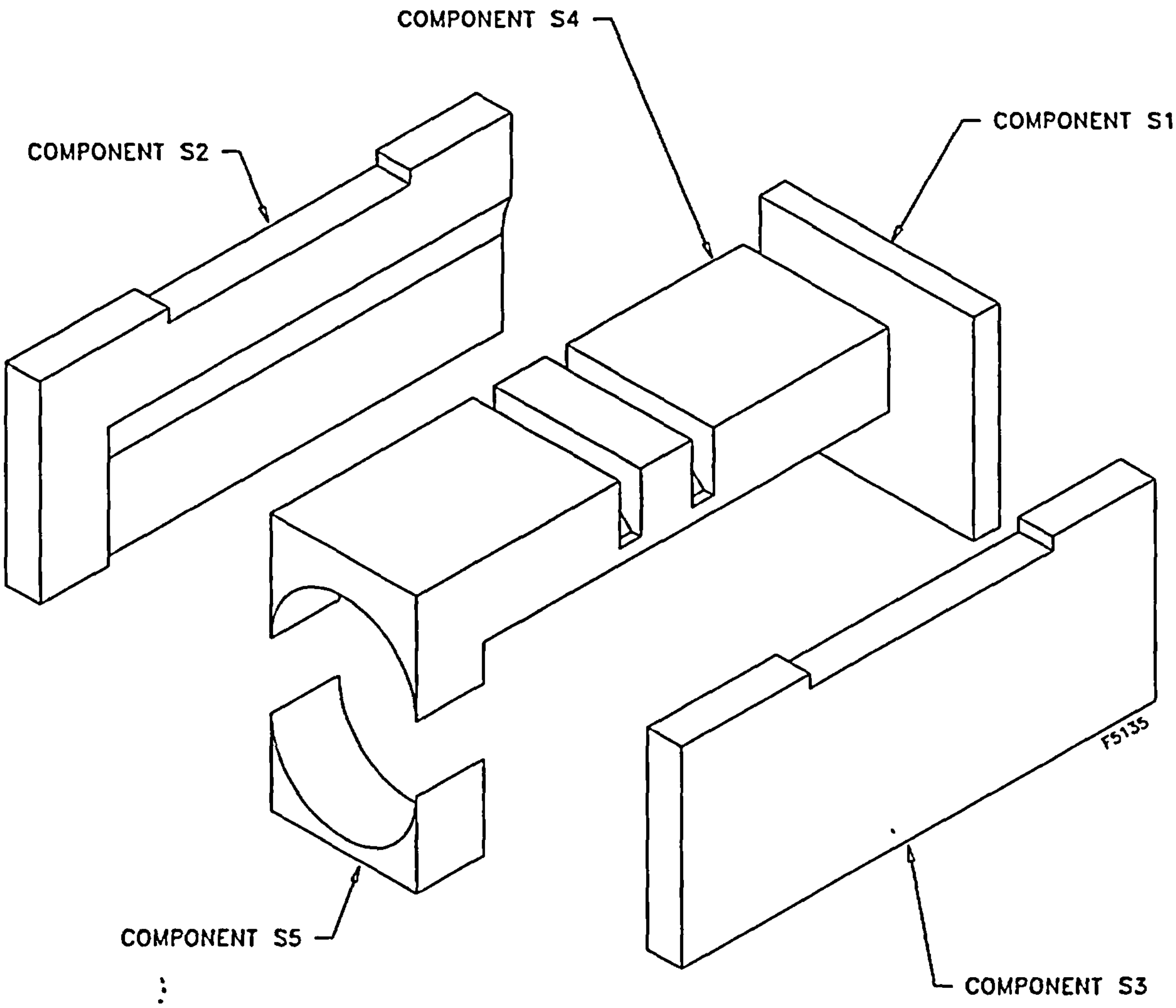


Figure 3.6-12
Concrete Components in the Upper Base Storage Block

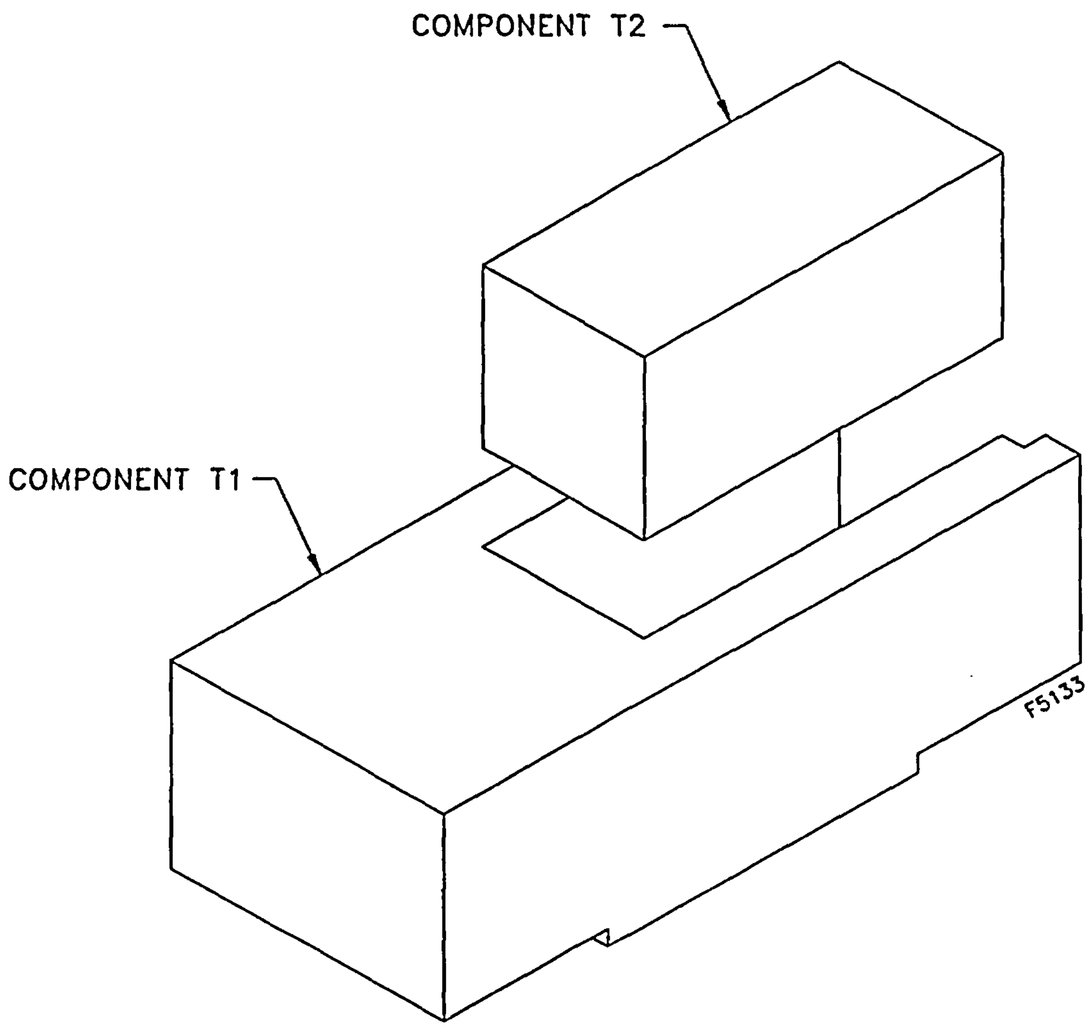


Figure 3.6-13
Concrete Components in the Top Shield Block

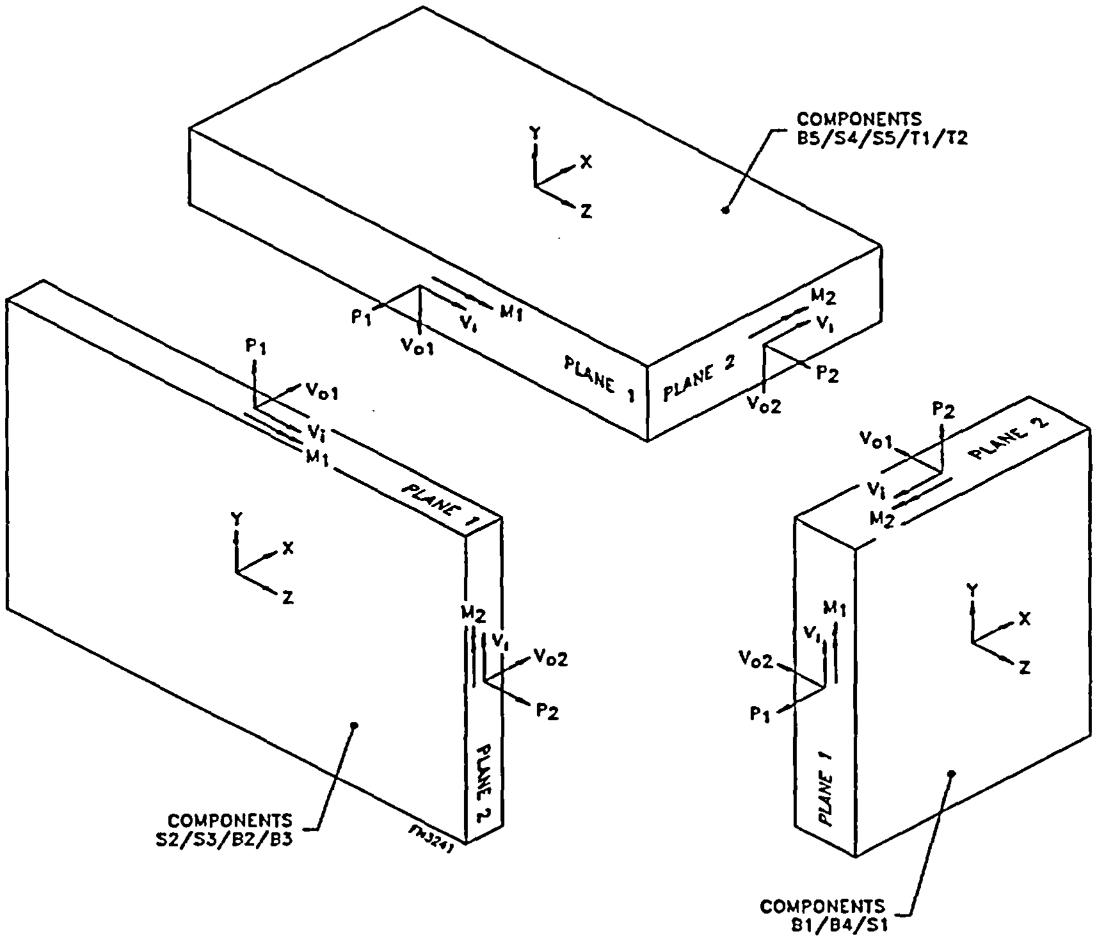


Figure 3.6-14
Symbolic Notations of Force and Moment Capacities
(Also for Computed Forces and Moments)

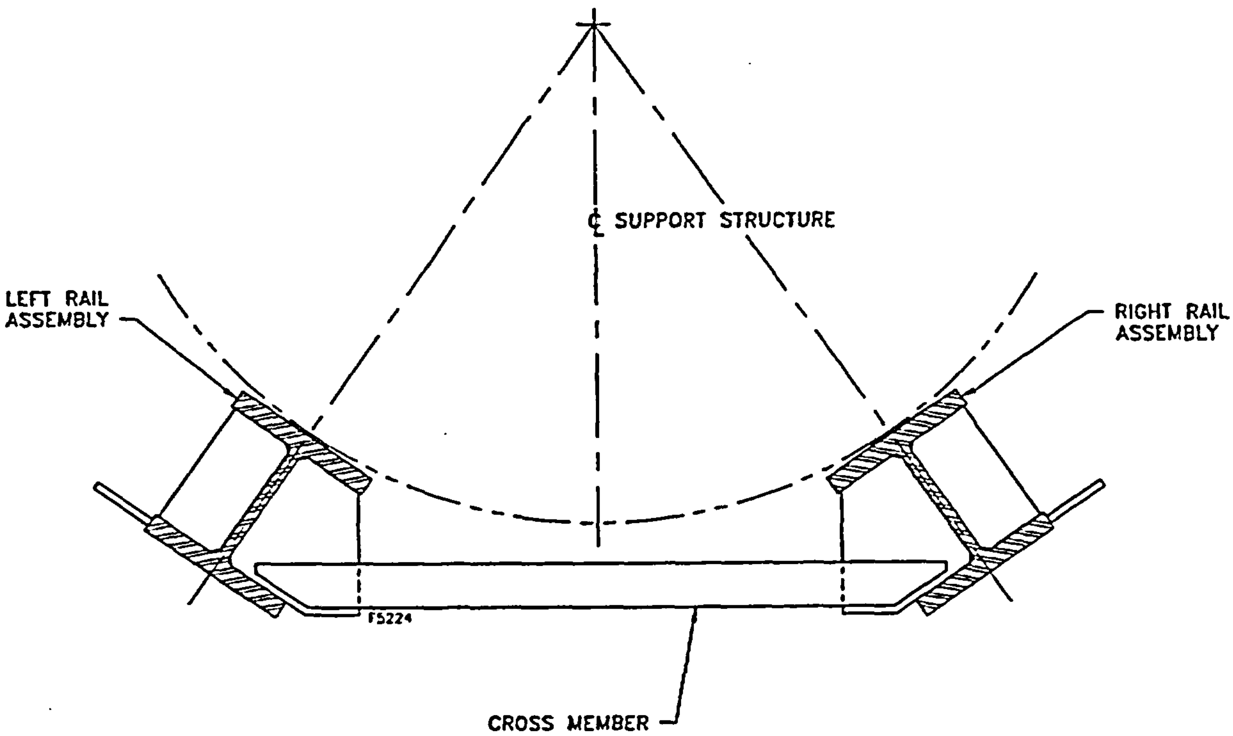


Figure 3.6-15
Components of AHSM Support Structure

3.6.3 References

[3.1] CFR Title 10, Part 72, Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste.

[3.2] NRC Regulatory Guide 1.60, Design Response Spectra for Seismic Design of Nuclear Power Plants, Revision 1, 1973.

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