TRANSNUCLEAR

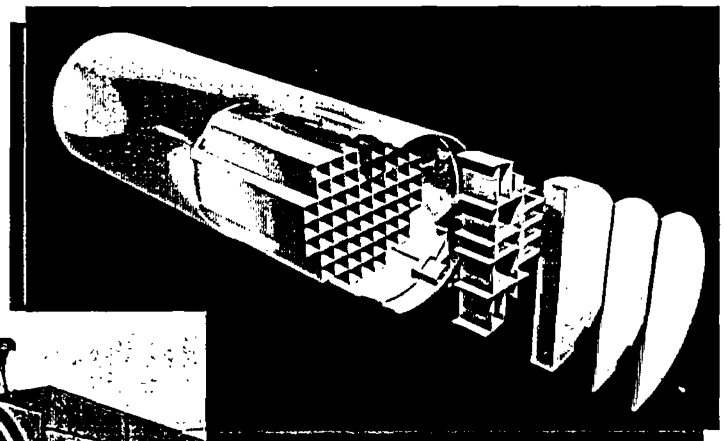
# FINAL SAFETY ANALYSIS REPORT

# STANDARDIZED NUHOMS MODULAR STORAGE SYSTEM FOR IRRADIATED NUCLEAR FUEL

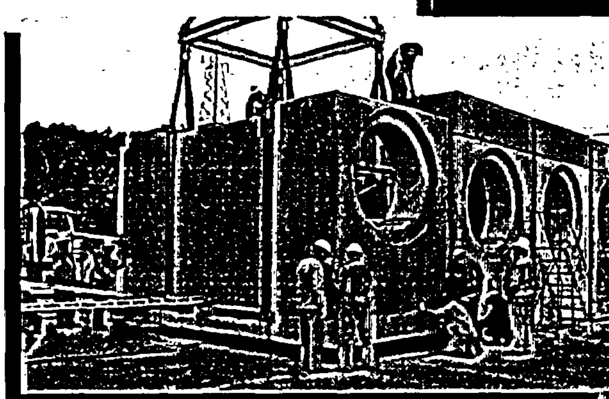
NON-PROPRIETARY

Vol. 1 of 4

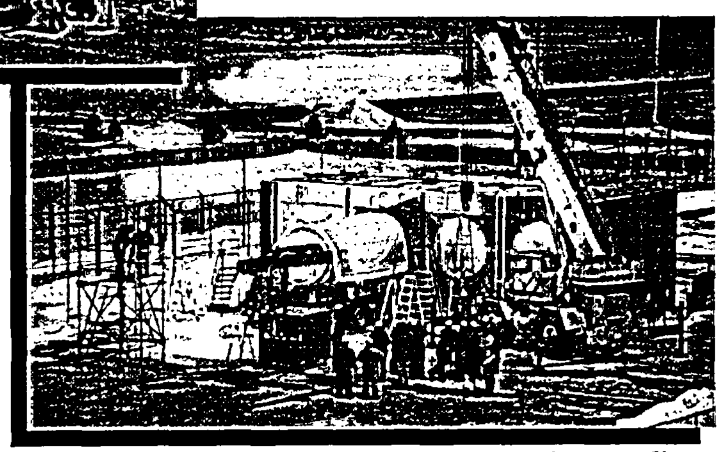
# Standardized NUHOMS®
# Horizontal Modular Storage System
# for Irradiated Nuclear Fuel



*61BT Dry Shielded Canister*



*HSM Placement*



*HSM Loading*



# FINAL SAFETY ANALYSIS REPORT
## Volume 1 of 4

TRANSNUCLEAR

# FINAL SAFETY ANALYSIS REPORT
# FOR THE
# STANDARDIZED NUHOMS®
# HORIZONTAL MODULAR STORAGE SYSTEM
# FOR IRRADIATED NUCLEAR FUEL

NON- PROPRIETARY

By
Transnuclear, Inc.
Hawthorne, NY

June 2004

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## EXECUTIVE SUMMARY

This Final Safety Analysis Report (No. NUH-003, Revision 8, NRC Docket No. 72-1004) provides the generic safety analysis for the standardized NUHOMS®[1] system for 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 related NUHOMS®-24P Topical Report (No. NUH-002, Revision 1A, NRC Project No. M-49) was approved by the U.S. Nuclear Regulatory Commission on April 21, 1989. The original NUHOMS®-07P Topical Report (No. NUH-001, Revision 1A, NRC Project No. M-39) was approved by the U.S. Nuclear Regulatory Commission on March 28, 1986.

This Final Safety Analysis Report (FSAR) formed the basis for generic NRC certification of the standardized 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. In January 1995, the USNRC issued a generic Certificate of Compliance to VECTRA for the standardized NUHOMS® canister/module horizontal cask storage system. The Nuclear Regulatory Commission staff does not intend to repeat the review in order to authorize the use of a standardized NUHOMS® ISFSI by a general license holder.

The principal features of the standardized NUHOMS® system which differ from the previously approved NUHOMS®-24P system are:

1. A free-standing prefabricated horizontal storage module founded on an ISFSI basemat which is not important to safety.

2. A standardized dry shielded canister for on-site dry storage and eventual off-site shipment of spent PWR or BWR fuel assemblies.

3. Removal of site specific dependencies to allow direct implementation by 10CFR72 general license holders.

4. Design qualification for five-year cooled PWR and BWR spent fuel.

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

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 FSAR. The fuel assemblies are confined in a helium atmosphere by a canister containment pressure vessel. 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. As a condition of the USNRC Certificate of Compliance, temperature monitoring of the concrete module is required.

Revision 4A of this FSAR consists of a revision to the previously submitted report and incorporates the conditions of use specified by the Certificate and US NRC's Safety Evaluation Report that were not included in earlier revisions, along with revisions to reflect design modifications and utility comments.

Revision 5 of this FSAR incorporates all design modifications and supporting analysis implemented per Condition 9 of USNRC Certificate of Compliance (CoC) since issuance of Revision 4A. It also incorporates changes due to approval of Amendments 1 and 2 to the CoC.

Revision 6 of this FSAR incorporates all design modifications implemented per Condition 9 of CoC 1004 since issuance of FSAR Revision 5. It also incorporates changes implemented under CoC Amendment No. 3.

Revision 7 of this FSAR incorporates all design modifications implemented per 72.48 since the issuance of FSAR Revision 6. It also incorporates changes implemented due to approval of Amendment No. 4 to CoC 1004.

Revision 8 of this FSAR incorporates design modifications implemented per 72.48 since the issuance of FSAR Revision 7. It also incorporates changes implemented due to approval of Amendments 5, 6 and 7 to CoC 1004.

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## LIST OF ABBREVIATIONS

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| | |
|---|---|
| ACI | American Concrete Institute |
| AISC | American Institute of Steel Construction |
| ALARA | As Low as is Reasonably Achievable |
| ANF | Advanced Nuclear Fuels |
| ANS | American Nuclear Society |
| ANSI | American National Standards Institute |
| ASME | American Society of Mechanical Engineers |
| ASTM | American Society for Testing and Materials |
| B&W | Babcock & Wilcox |
| BWR | Boiling Water Reactor |
| 10CFR | Code of Federal Regulations, Title 10 |
| CE | Combustion Engineering |
| DBT | Design Basis Tornado |
| DSC | Dry Shielded Canister |
| GE | General Electric |
| HSM | Horizontal Storage Module |
| ISFSI | Independent Spent Fuel Storage Installation |
| NDE | Non-Destructive Examination |
| NDRC | National Defense Research Committee |
| NFPA | National Fire Protection Association |
| NRC | Nuclear Regulatory Commission |
| NUHOMS | Nuclear Horizontal Modular Storage |
| NUREG | Nuclear Regulatory Guide |
| OBE | Operating Basis Earthquake |
| OSHA | Occupational Health and Safety Administration |
| PI | Project Instruction |
| PWR | Pressurized Water Reactor |
| QP | Quality Procedure |
| R.G. | NRC Regulatory Guide |
| FSAR | Final Safety Analysis Report |
| SFA | Spent Fuel Assembly |
| SSE | Safe Shutdown Earthquake |
| TC | Transfer Cask |
| TR | Topical Report |
| U.S. | United States |
| W | Westinghouse |
| atm | Atmosphere |
| bar | Bar |
| cm | centimeter |
| °C | degrees Centigrade |

## LIST OF ABBREVIATIONS

(Continued)

| | |
|---|---|
| °F | degrees Fahrenheit |
| fps | feet per second |
| ft/s | feet per second |
| ft | foot |
| ft-lb | foot pounds |
| He | helium |
| in | inch |
| kg | kilogram |
| kW | kilowatt |
| k-in | kip inch |
| ksi | kips per square inch |
| MWD/MTU | megawatt days per metric ton uranium |
| MWe | megawatts electric |
| MWt | megawatts thermal |
| Hg | Mercury |
| m | meter |
| $Ci/cm^2$ | Curies per square centimeter |
| MeV | Megaelectron volt |
| mph | miles per hour |
| mm | millimeter |
| mrem/hr | millirem per hour |
| mR/hr | milliroentgen per hour |
| n | neutron |
| $k_{eff}$ | neutron multiplication factor, effective |
| kN | kilonewton |
| N | Newton |
| lb | pound |
| lbf | pounds-force |
| psf | pounds per square foot |
| psi | pounds per square inch |
| psia | pounds per square inch, absolute |
| psig | pounds per square inch, gauge |
| sec | second |
| sq. mi. | square mile |
| kips | thousand pounds |
| ton | ton |
| w/o | without |
| wt. % | weight % |

# 1. INTRODUCTION AND GENERAL DESCRIPTION OF INSTALLATION

This Final Safety Analysis Report (the terms, FSAR or SAR, are used interchangeably in this document) describes the design and forms the generic licensing basis for 10CFR72 Subpart L (1.1) certification of the standardized NUHOMS® horizontal cask system for dry storage of PWR or BWR spent nuclear fuel assemblies. The NUHOMS® system provides for the horizontal storage of spent fuel in a dry shielded canister (DSC) which is placed in a concrete horizontal storage module (HSM). The NUHOMS® system is designed to be installed at any reactor site or any new site where an independent spent fuel storage installation (ISFSI) is required.

The original NUHOMS® Topical Report (NUH-001, Revision 1A, NRC Project No. M-39) was approved by the United States Nuclear Regulatory Commission (NRC) on March 28, 1986 for storage of seven spent PWR fuel assemblies per DSC and HSM (NUHOMS®-07P) (1.12, 1.13). The NUHOMS®-07P system is designed to be compatible with the IF-300 shipping cask. The DSC internal basket incorporates borated guide sleeves to ensure criticality safety during wet loading operations without credit for burnup or soluble boron.

The NUHOMS® Topical Report was revised (NUH-002, Revision 0, NRC Docket No. M-49) to provide the generic design criteria and safety analysis for the larger 24 spent PWR fuel assembly design (NUHOMS®-24P) and its associated on-site transfer cask. NRC approval of the NUHOMS®-24P Topical Report was granted on April 26 1989 (1.10, 1.11). Unlike the NUHOMS®-07P design, no borated neutron absorbing material is used in the internal basket design of the NUHOMS®-24P DSC for criticality safety. Credit for soluble boron is used as the approval basis. Credit for burnup is also evaluated as an alternative design acceptance basis for the NUHOMS®-24P DSC design pending future generic acceptance by the NRC. The approved NUHOMS®-24P Topical Report forms the principal basis for the standardized NUHOMS® system presented in this FSAR. The NRC has issued Certificate of Compliance (CoC) 1004, dated January 23, 1995, for the standardized NUHOMS® system.

This FSAR also includes the NUHOMS®-52B DSC, which is designed to store 52 BWR fuel assemblies with the fuel assembly flow channels intact. The NUHOMS®-52B utilizes the same HSM as does the standardized NUHOMS®-24P DSC. New criticality, thermal and structural analyses for the 52B basket are included as are the specifications of spent fuel assemblies to be stored. The 52B basket includes fixed neutron absorbing plates for criticality safety, similar to that of the NUHOMS®-07P DSC. Unborated plates may be used pending a burnup credit analysis to be submitted when burnup credit is generically accepted by the NRC.

The NRC approved Amendment No. 1 to CoC 1004 on April 2000. This amendment reflects the transfer of the CoC from VECTRA Technologies, Inc. to Transnuclear West Inc.

Amendment No. 2 to CoC 1004, approved on September 5, 2000, adds fuel qualification tables and updates Fuel Specification 1.2.1 to reflect additional fuel parameters for both the PWR and BWR fuels. The fuel qualification tables provide a simplified approach for users of the

NUHOMS® storage system in selection of acceptable assemblies during loading. In addition, Amendment No. 2 authorizes the storage of Burnable Poison Rod Assemblies (BPRAs) in the NUHOMS®-24P long cavity DSC. A detailed description of the authorized contents and supporting analyses for the storage of PWR fuel with BPRAs is provided in Appendix J.

Amendment No. 3 to CoC 1004, approved on September 12, 2001, authorizes the addition of the NUHOMS®-61BT DSC to the standardized NUHOMS® system. The NUHOMS®-61BT DSC is designed to store 61 intact BWR fuel assemblies and meets the storage and transportation requirements of 10CFR72 and 10CFR71, respectively. A detailed description of the authorized contents and supporting safety analyses for this system are provided in Appendix K.

TN has added NUHOMS®-24PT2 DSC to the standardized NUHOMS® system. The NUHOMS®-24PT2 DSC is a modified version of the NUHOMS®-24P DSC, designed to store 24 intact PWR fuel assemblies with or without BPRAs. This DSC meets the storage and transportation requirements of 10CFR72 (CoC 1004) and 10CFR71 (CoC 9255), respectively. A detailed description of the authorized contents and supporting safety analyses for this system are provided in Appendix L.

Amendment No. 4 to CoC 1004, approved on February 12, 2002, authorizes the addition of low burn-up spent fuel in the NUHOMS®-24P DSC.

Amendment No. 5 to CoC 1004, approved on January 7, 2004, authorizes the addition of the NUHOMS®-32PT DSC to the standardized NUHOMS® system. The NUHOMS®-32PT DSC is designed to store 32 intact PWR fuel assemblies and meets the storage and transportation requirements of 10CFR72 and 10CFR71, respectively. A detailed description of the authorized contents and supporting safety analyses for this system are provided in Appendix M.

Amendment No. 6 to CoC 1004, approved on December 22, 2003, adds NUHOMS®-24PHB DSC to the standardized NUHOMS® system. The NUHOMS®-24PHB DSC is designed to store a total of 24 intact B&W 15x15 fuel assemblies with an assembly average burnup of up to 55,000 MWd/MTU and an initial enrichment of up to 4.5 weight % U-235. The 24PHB DSC is designed for storage in the existing Model 102 NUHOMS® HSM and for transfer in the existing standard, or OS197 or OS197H transfer cask. A detailed description of the authorized contents and supporting safety analyses for the 24PHB DSC are provided in Appendix N.

Amendment No. 7 to CoC 1004, approved on March 3, 2004, authorizes the addition of new fuel types and damaged fuel to the list of authorized contents for the Standardized NUHOMS®-61BT system (Appendix K).

Chapters 1 though 8 and Appendices A through H of this FSAR provide the supporting licensing basis for the Standardized NUHOMS®-24P and -52B systems only.

A complete description of the new systems addressed by the above listed amendments, including supporting safety analysis, is located within self-contained Appendices to this FSAR as summarized in the following table:

| **Amendment No.** | **Description** | **Location of Supporting Licensing Basis** |
|---|---|---|
| 3 | Addition of the NUHOMS®-61BT DSC to the contents of the Standardized NUHOMS® system | Appendix K |
| N/A | Addition of the NUHOMS®-24PT2 DSC to the contents of the Standardized NUHOMS® system | Appendix L |
| 4 | Addition of low burnup fuel to the contents of the NUHOMS®-24P DSC | Chapter 3 |
| 5 | Addition of the NUHOMS®-32PT DSC to the Standardized NUHOMS® system | Appendix M |
| 6 | Addition of the NUHOMS®-24PHB DSC to the Standardized NUHOMS® system | Appendix N |
| 7 | Addition of damaged fuel to the contents of the NUHOMS®-61BT DSC | Appendix K |

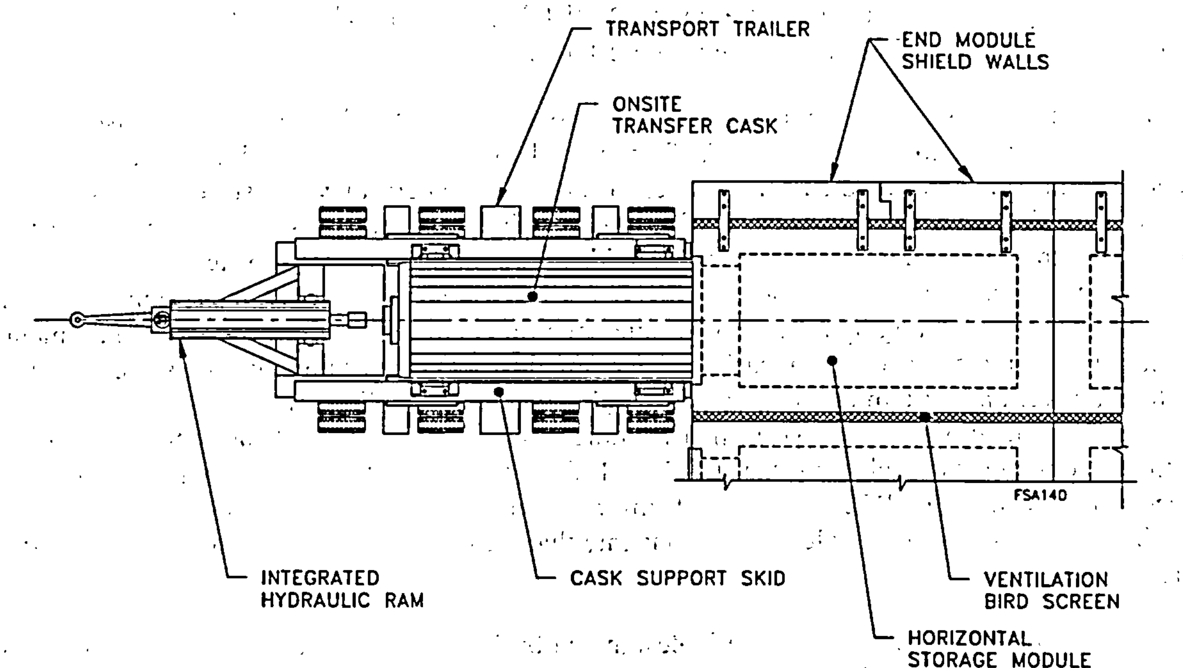



**Figure 1.1-3**
**NUHOMS® System Components, Structures, and Transfer Equipment**
**Plan View**

## 1.2 General Description of Installation

### 1.2.1 Arrangement of Major Structures and Equipment

The NUHOMS® system provides for the horizontal, dry storage of canisterized SFAs in a concrete HSM. The cask storage system components for NUHOMS® consist of a reinforced concrete HSM and a DSC containment vessel with an internal basket assembly which holds the SFAs. The general arrangement of a typical NUHOMS® ISFSI and the system components are shown in Figure 1.1-1, Figure 1.1-2 and Figure 1.1-3.

In addition to these cask storage system components, the NUHOMS® system also utilizes transfer equipment to move the DSCs from the plant's fuel/reactor building, where they are loaded with SFAs and readied for storage, to the HSMs 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 transport 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 automatic welding system are also used to facilitate canister loading, draining, drying, inerting, and sealing operations. This SAR primarily addresses the design and analysis of the cask storage system components, including the DSC and the HSM, which are important to safety in accordance with 10CFR72. Sufficient information for the transfer system and auxiliary equipment is also included solely to demonstrate that means for safe operation of the system are provided.

Each NUHOMS® system model type is designated by NUHOMS®-XXY. The two digits (XX) refer to the number of fuel assemblies stored in the DSC, and the character (Y) is a P for PWR, or B for BWR, to designate the type of fuel stored. A fourth character (T) is added, if applicable, to designate that the DSC is intended for transportation in a 10CFR71 approved package. The number of HSMs to be erected at any one time depends on individual plant discharge rates and storage capacity needs, and will be addressed by the licensee. Examples of typical ISFSI initial capacity and future expansion provisions for PWR and BWR plants are shown in Table 1.2-1. Dimensions of the NUHOMS® system components as described in the text, figures and tables of this SAR are nominal dimensions and for general system description purposes. Actual design dimensions of the NUHOMS® system components are contained in Appendix E drawings of this SAR.

This SAR describes only the standardized NUHOMS® system, including the design of the DSC and the HSM, which can be utilized to accommodate internal baskets which hold 24 or 32 PWR or 52 channeled BWR or 61 channeled or unchanneled BWR fuel assemblies. The system can accommodate a wide range of plant specific conditions and spent fuel characteristics. Future baskets may be designed to hold a greater number of fuel assemblies in a canister shell assembly with the same envelope dimensions. Figure 1.2-1 shows the internal basket arrangements for various DSCs.

The outside diameter for all NUHOMS® canisters excluding the NUHOMS®-07P canisters is standardized to facilitate compatibility. This permits the design of the module and transfer system to be standardized and simplifies the interfaces for eventual off-site shipment of intact canisters by the DOE. The overall length of the canisters may be increased or reduced to accommodate specific fuel assembly types or individual utility needs. "Standard" length PWR and BWR canisters are discussed in detail in the body of this SAR. The long-cavity PWR canister is evaluated in Appendices H and J of this SAR. Other cavity lengths may be included at a later time. NUHOMS®-61BT and -24PT2 systems are evaluated in Appendices K and L, respectively.

This SAR deals specifically with the NUHOMS® DSC and HSM which have been standardized for all plants. ISFSI capacities will vary; however, it is unlikely that a licensee would store less than the number of fuel assemblies corresponding to one year's reactor core discharge. This SAR addresses both a single HSM and HSMs which are grouped together to form arrays of any size. The standardized prefabricated HSM used to form HSM arrays is shown in Figure 1.2-2 (Model 102) and Figure 1.2-2a (Model 80). The specific size of each HSM array will vary depending on the licensee's fuel storage requirements. This SAR provides the design description and analyses for HSM arrays ranging in size from a single standalone HSM up to a 2x10 array of 20 back-to-back side-by-side HSMs. HSM arrays larger than 2x10 are also acceptable since each module is a free-standing unit which is uncoupled structurally and thermally from the adjacent modules and the ISFSI basemat.

### 1.2.2 Principal Design Criteria

The principal design criteria and parameters upon which this SAR is based are summarized in Table 1.2-2.

Structural Features: The HSM is a low profile, reinforced concrete structure designed to withstand all normal condition loads as well as the abnormal condition loads created by earthquakes, tornadoes, flooding, and other natural phenomena. The HSM is also designed to withstand abnormal condition loadings postulated to occur during design basis accident conditions such as a complete loss of ventilation.

The structural features of the DSC design depend, to a large extent, on the postulated design basis transfer cask drop accident (described in Section 8.2.5). The DSC shell, the redundant closures on each end, and the DSC internals are designed to ensure that the intended safety functions of the system are not impaired following a postulated transfer cask drop accident. The limits established for equivalent decelerations due to a postulated drop accident are intended to be bounding. They envelop a range of conditions such as the transfer cask handling operations, the type of handling equipment used, the transfer cask on-site transport route, the maximum feasible drop height and orientation, and the conditions of the impacted surface. The structural safety features of the NUHOMS® system are described in Chapters 4 and 8.

Decay Heat Removal: The decay heat of the SFAs during storage in the HSM is removed from the DSC by natural circulation convection and by conduction through the HSM walls and roof. Air enters near the bottom of the HSM, circulates and rises around the DSC and exits through shielded openings near the top of the HSM. The cross-sectional areas of the air inlet and outlet openings, and the interior flow paths are designed to optimize ventilation air flow in the HSM for decay heat removal including worst case extreme summer ambient conditions. The thermal performance features of the NUHOMS® system are described in Chapters 4 and 8.

External Atmosphere Criteria: Given the corrosion resistant properties of materials and the coatings used for construction of the NUHOMS® system components, and the warm, dry environment which exists within the HSM, no limits on the range of acceptable external atmospheric conditions are required. All components are either stainless steel, are coated with inorganic coatings, or are galvanized. Hence, all metallic materials are protected against corrosion. The interior of the HSM is a concrete surface and is void of any substance which would be conducive to the growth of any organic or vegetative matter. The design of the HSM also provides for drainage of ambient moisture which further eliminates any need for external atmospheric limitation.

The ambient temperatures selected for the design of the NUHOMS® system range from -40°F to 125°F, with a lifetime average ambient temperature of 70°F. The extreme ambient temperatures of -40°F and 125°F are expected to last for a short period of time, i.e., on the order of hours. The minimum and maximum average ambient temperatures of 0°F and 100°F are expected to last for longer periods of time, i.e., on the order of days.

### 1.2.3 Operating and Fuel Handling Systems

Some handling equipment and support systems within the plant needed to implement the NUHOMS® system are covered by the licensee's 10CFR50 operating license. The on-site transfer cask is designed to satisfy a range of plant specific conditions and requirements. The general operations for a typical NUHOMS® system installation are summarized in Table 1.2-3. A more detailed procedure for this sequence of operations is provided in Section 5.1, Appendices K, L, M, and N. The majority of the fuel handling operations involving the DSC and transfer cask (i.e. fuel loading, draining and drying, transport trailer loading etc.) utilize procedures similar to those already in place at reactor sites for SFA shipment. The remaining operations (canister sealing, cask-HSM alignment and DSC transfer) are unique to the NUHOMS® system.

### 1.2.4 Safety Features

The principal safety features of a NUHOMS® ISFSI include the high integrity containment for the confinement of spent fuel materials, the axial shielding provided by the DSC, and the extensive biological shielding and protection against extreme natural phenomena provided by the massive reinforced concrete HSM. The shielding materials incorporated into the DSC and HSM designs reduce the gamma and neutron flux emanating from the SFAs so that the dose rate at the ISFSI fence is within 10CFR72 limits and is ALARA. The radiological safety features of the NUHOMS® system are described in Chapters 3 and 7.

The DSC and HSM are designed and constructed in accordance with industry accepted codes and practices for important to safety systems under an approved Quality Assurance program as

## 1.3 General Systems Description

The components, structures and equipment which make up the NUHOMS® system are listed in Table 1.3-1. The following subsections briefly describe the design features and operation of these NUHOMS® system elements.

### 1.3.1 Storage Systems Descriptions

#### 1.3.1.1 Dry Shielded Canister

The principal design features of the NUHOMS® DSC are listed in Table 1.3-1 and shown in Figure 1.3-1, Figure 1.3-1a, Figure 1.3-1b, Figure 1.3-1c, Figure 1.3-2 and Figure 1.3-3. Table 1.2-2 lists the capacity, dimensions and design parameters for the NUHOMS® DSC. The cylindrical shell, and the top and bottom cover plate assemblies form the pressure retaining containment boundary for the spent fuel. The DSC is equipped with two shield plugs so that occupational doses at the ends are minimized for drying, sealing, and handling operations.

The DSC has double, redundant seal welds which join the shell and the top and bottom cover plate assemblies to form the containment boundary. The bottom end assembly containment boundary welds are made during fabrication of the DSC. The top end assembly containment boundary welds are made after fuel loading. Both top plug penetrations (siphon and vent ports) are redundantly sealed after DSC drying operations are complete. This assures that no single failure of the DSC top or bottom end assemblies will breach the DSC containment boundary. Furthermore, there are no credible accidents which could breach the containment boundary of the DSC as documented by this SAR.

The internal basket assembly contains a storage position for each fuel assembly. The criticality analysis performed for the NUHOMS®-24P, 24PT2, and 24PHB DSC for PWR fuel accounts for fuel burnup or takes credit for soluble boron and demonstrates that fixed borated neutron absorbing material is not required in the basket assembly for criticality control. The Boral® of the 24PT2 DSC is modeled only as unborated aluminum. Fixed neutron absorbing material is used for the NUHOMS® 61BT DSC for channeled and unchanneled BWR fuel and the NUHOMS®-52B DSC for channeled BWR fuel. Subcriticality during wet loading, drying, sealing, transfer, and storage operations is maintained through the geometric separation of the fuel assemblies by the DSC basket assembly and the neutron absorbing capability of the DSC materials of construction.

Structural support for the PWR fuel and basket guide sleeves or BWR fuel and channels in the lateral direction is provided by circular spacer disk plates in the 24P, 24PT2, 24PHB or 52B DSCs. Axial support for the NUHOMS®-24P DSC basket assembly is provided by four support rods which are welded to the spacer discs. Axial support for the NUHOMS®-24PT2 DSC basket assembly is provided by four preloaded support rods and spacer sleeves. Axial support for the NUHOMS®-52B DSC basket assembly is provided by six preloaded support rods and spacer sleeves. For the 24P, 24PT2, 24PHB, and 52B DSCs, the support rods extend over the full length of the DSC cavity and bear on the canister top and bottom end assemblies.

The 61BT DSC basket structure consists of assemblies of stainless steel fuel compartments held in place by basket rails and holddown ring. The four and nine compartment assemblies are held together by welded stainless steel boxes wrapped around the fuel compartments, which also retain the neutron absorber plates between the compartments in the assemblies. The borated aluminum or boron carbide/aluminum metal matrix composite plates (neutron absorber plates) provide the necessary criticality control and provide the heat conduction paths from the fuel assemblies to the cask cavity wall.

The 32PT DSC basket structure is a box type assembly of high strength XM-19 stainless steel surrounded by transition rails. Inside the compartments, around the fuel assemblies, the borated aluminum or Boralyn® plates (neutron poison plates) provide the necessary criticality control and provide the heat conduction paths from the fuel assemblies to the cask cavity wall. This method of construction forms a very strong structure of compartment assemblies which provide for storage of 32 fuel assemblies. Appendix M provides the details of the 32PT DSC.

1.3.1.2 Horizontal Storage Module

An isometric view of the two alternate designs of a prefabricated HSM utilized to form an array of HSMs is shown in Figure 1.2-2 and 1.2-2a. Each HSM provides a self-contained modular structure for storage of spent fuel canisterized in a DSC as illustrated in Figure 1.3-4. The HSM is constructed from reinforced concrete and structural steel. The thick concrete roof and walls of the HSM provide substantial neutron and gamma shielding. Contact doses for the HSM are designed to be ALARA.

The nominal thickness of the HSM roof and exterior walls of an HSM array for biological shielding is about three feet. Separate shielding walls are utilized at the end of a module row to provide the required thickness. Similarly, an additional shield wall is used at the rear of the module if the ISFSI is configured as single module rows. Sufficient shielding between HSMs in an HSM array to prevent scatter in adjacent HSMs during loading and retrieval operations is provided by thick concrete side walls. The inlet and outlet vents are designed to take advantage of the self-shielding of adjacent HSMs.

The HSM provides a means of removing spent fuel decay heat by a combination of radiation, conduction and convection. Ambient air enters the HSM through ventilation inlet openings in the lower side walls of the HSM and circulates around the DSC and the heat shield. Air exits the HSM through outlet openings in the upper side walls of the HSM. Adjacent modules are spaced to provide a ventilation flow path between modules.

Decay heat is rejected from the DSC to the HSM air space by convection and then is removed from the HSM by a natural circulation air flow. Heat is also radiated from the DSC surface to the heat shield and HSM walls where again the natural convection air flow and conduction through the walls removes the heat. Figure 1.3-5 shows the ventilation flow paths for the DSC and the HSM. The passive cooling system for the HSM is designed to assure that peak cladding temperatures during long term storage remain below acceptable limits to ensure fuel cladding integrity.

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

The HSMs are constructed on a load bearing foundation which consists of a reinforced concrete basemat on compacted engineered fill. The HSMs are located in a fenced, secured location with between the edge of the cover plate and the DSC shell. This weld provides the inner seal for the DSC.

<u>DSC Drying and Backfilling:</u> The initial blow-down of the DSC is accomplished by pressurizing the vent port with nitrogen, helium or shop air. The remaining liquid water in the DSC cavity is forced out the siphon tube and routed back to the fuel pool or to the plant's liquid radwaste processing system, as appropriate. The DSC is then evacuated to remove the residual liquid water and water vapor in the DSC cavity. When the system pressure has stabilized, the DSC is backfilled with helium and re-evacuated. The second backfill and evacuation ensures that the reactive gases remaining are less than 0.25% by volume. After the second evacuation, the DSC is again backfilled with helium and slightly pressurized. A helium leak test of the inner seal weld is then performed. The helium pressure is then reduced, the helium lines removed, and the siphon and vent port penetrations seal welded closed.

<u>Outer DSC Sealing:</u> After helium backfilling, the DSC outer top cover plate is installed by placing a second seal weld between the cover plate and the DSC shell. Together with the inner seal weld, this weld provides a redundant seal at the upper end of the DSC. The lower end has redundant seal welds which are installed and tested during fabrication. The NUHOMS®-61BT, 32PT and 24PHB DSCs are designed and tested to be leak tight per ANSI N14.5-1997 as described in Appendices K, M, and N, respectively.

<u>Cask/DSC Annulus Draining and Top Cover Plate Placement:</u> The transfer cask is drained, removing the demineralized water from the cask/DSC annulus. A swipe is then taken over the DSC exterior at the DSC top cover plate and the upper portion of the DSC shell. Clean demineralized water is flushed through the cask/DSC annulus to remove any contamination left on the DSC exterior as required. The transfer cask top cover plate is then put in place using the plant's crane. The cask lid is bolted closed for subsequent handling operations.

<u>Placement of Cask on Transport Trailer Skid:</u> The transfer cask is then lifted onto the cask support skid. The plant's crane is used to downend the cask from a vertical to a horizontal position. The cask is then secured to the skid and readied for the subsequent transport operations.

<u>Transport of Loaded Cask to HSM:</u> Once loaded and secured, the transport trailer is towed to the ISFSI along a predetermined route on a prepared road surface. Upon entering the ISFSI secured area, the transfer cask is generally positioned and aligned with the particular HSM in which a DSC is to be transferred.

<u>Cask/HSM Preparation:</u> At the ISFSI with the transfer cask generally positioned in front of the HSM, the cask top cover plate is removed. The transfer trailer is then backed into close proximity with the HSM and the HSM door is removed. The skid positioning system is used for the final alignment and docking of the cask with the HSM.

<u>Loading DSC into HSM:</u> After final alignment of the transfer cask, HSM, and hydraulic ram; the DSC is pushed into the HSM by the hydraulic ram (located at the rear of the cask).

Storage: After the DSC is inside the HSM, the hydraulic ram is disengaged from the DSC and withdrawn through the cask. The transfer trailer is pulled away, the DSC axial retainer is inserted and the HSM access door installed. The DSC is now in safe storage within the HSM.

Retrieval: For retrieval, the transfer cask is positioned and the DSC is transferred from the HSM to the cask. The hydraulic ram is used to pull the DSC into the cask. All transfer operations are performed in the same manner as previously described. Once back in the cask, the DSC with its SFAs is ready for return to the plant fuel pool or for direct off-site shipment to a repository or another storage location.

### 1.3.4 Arrangement of Storage Structures

The DSC, containing the SFAs, is transferred to, and stored in, the HSM in the horizontal position. Multiple HSMs are grouped together to form arrays whose size is determined to meet plant-specific needs. Arrays of HSMs are arranged within the ISFSI site on a concrete pad(s) with the entire area enclosed by a security fence. Individual HSMs are arranged adjacent to each other, spaced a small distance apart for ventilation. The decay heat for each HSM is primarily removed by internal natural circulation flow and not by conduction through the HSM walls. Figure 1.3-11, Figure 1.3-12 and Figure 1.3-13 show typical layouts for NUHOMS® ISFSIs which are capable of modular expansion to any capacity. The parameters of interest in planning the installation layout are the configuration of the HSM array and an area in front of each HSM to provide adequate space for backing and aligning the transport trailer.

There is no explicit requirement regarding the sequence of HSM loading. It is expected that all loading sequences will leave one or more HSMs vacant for a period of time prior to loading.

Table 1.3-1

Components, Structures and Equipment for the Standardized NUHOMS® System

**Dry Shielded Canister**[(1) (2)]

Internal Basket Assembly:

| | |
|---|---|
| Guide Sleeves | (24 for 24P, 24PHB & 24PT2) |
| Oversleeves | (24P, 24PHB & 24PT2) |
| Fixed Neutron Absorbers | (88 for 52B; 72 for 24PT2) |
| Spacer Disks | (8 for 24P & 24PHB; 9 for 52B; 26 for 24PT2) |
| Support Rods | (4 for 24P & 24PHB; 6 for 52B; 4 for 24PT2) |
| Spacer Sleeves | (52B & 24PT2) |

Cylindrical Shell

Shield Plugs (top and bottom)

Inner and Outer Cover Plates (top and bottom)

Siphon and Vent Port

Grapple Ring

**Horizontal Storage Module**

Reinforced Concrete Walls, Roof, and Floor

DSC Support Structure

DSC Axial Retainer

Cask Docking Flange and Cask Restraint Eyes

Heat Shield

Shielded Access Door

Ventilation Air Openings (four inlets, four outlets)

(1) For the NUHOMS®-61BT DSC, see Appendix K.
(2) For the NUHOMS®-32PT DSC, see Appendix M.

**Table 1.3-1**
**Components, Structures and Equipment for the Standardized NUHOMS® System**
**(concluded)**

**On-Site TC**

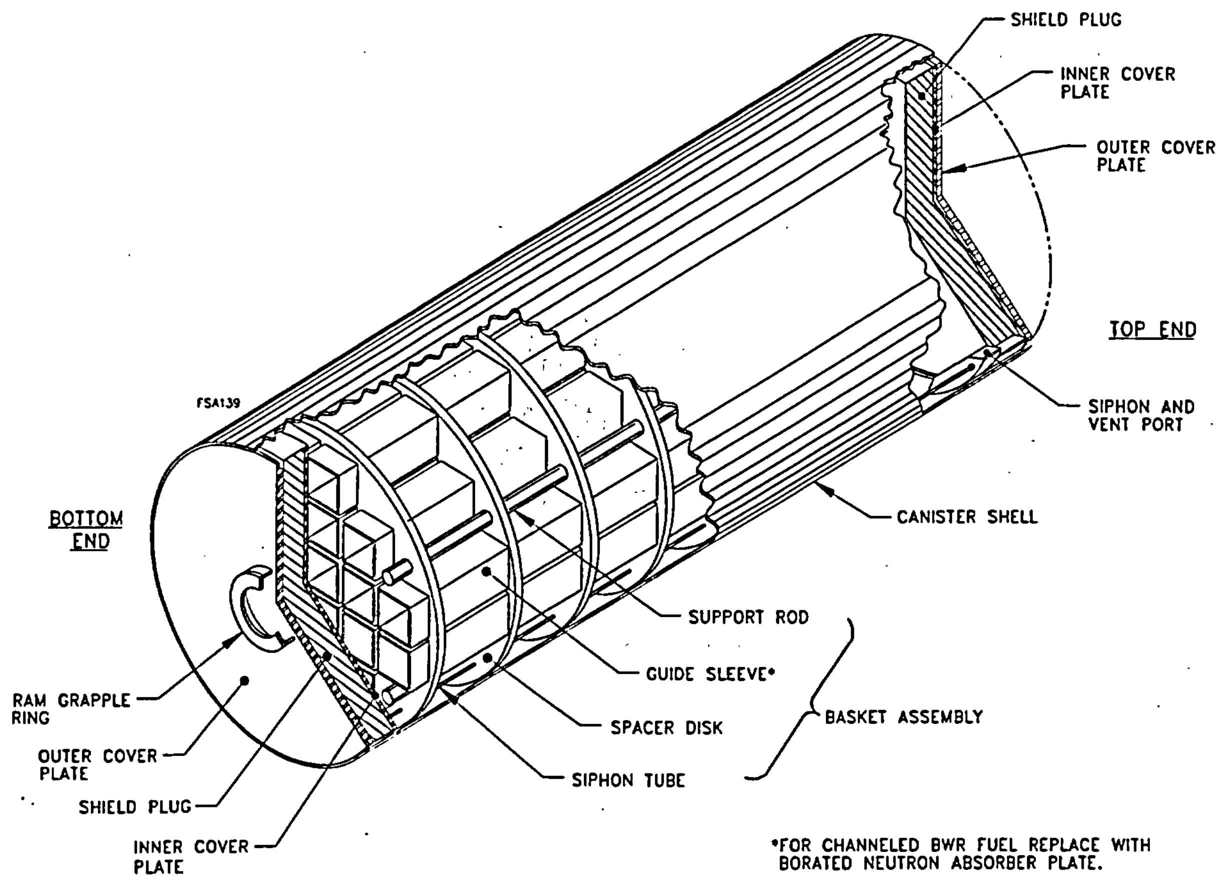
- Cask Structural Shell Assembly
- Bolted Top Cover Plate
- Upper Lifting Trunnions
- Lower Support Trunnions
- Lead Gamma Shielding
- Inner Liner
- Outer Jacket
- Neutron Shielding
- Ram Access Penetration Cover Plate

**Transport Trailer**

- Heavy-Haul Industrial Trailer
- Cask Support Skid
- Skid Positioning System

**Hydraulic Ram System**

- Hydraulic Cylinder and Supports
- Hydraulic Power Supply
- Grapple Assembly




Note: Appendix N.1.5 shows the outer top cover plate and the test port plug details for the 24PHB DSC.

**Figure 1.3-1**
**NUHOMS® Dry Shielded Canister Assembly Components**

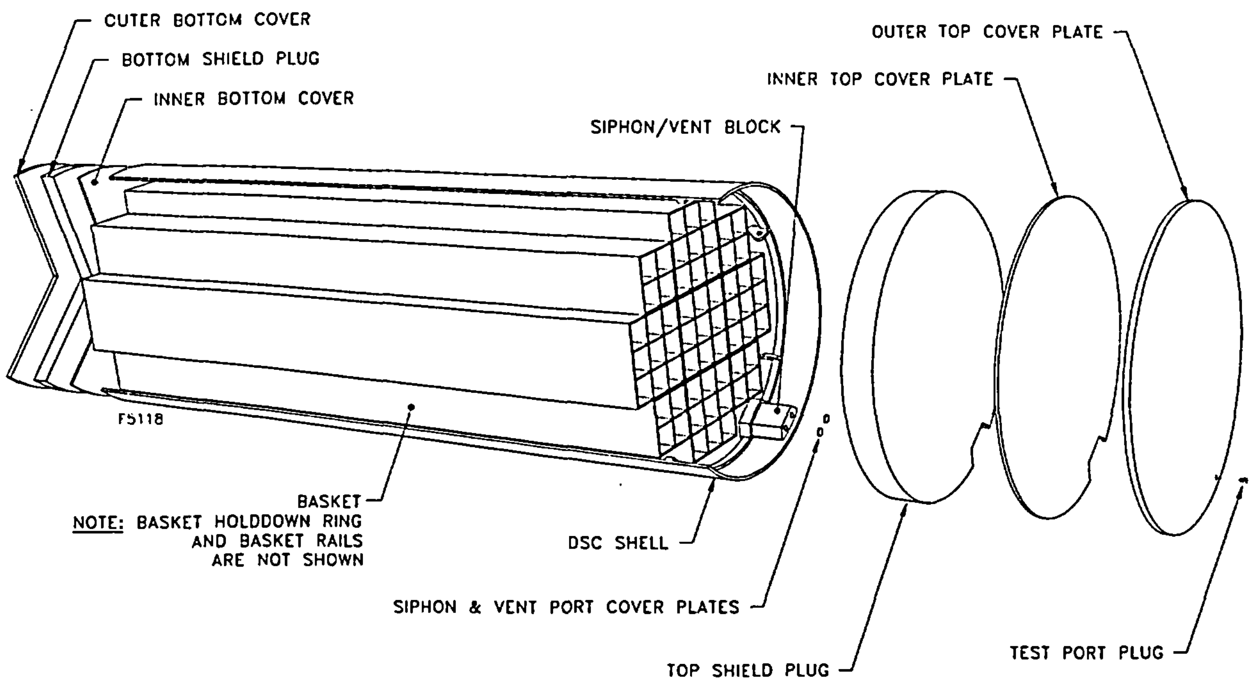



**Figure 1.3-1a**
**NUHOMS®-61BT DSC Components**

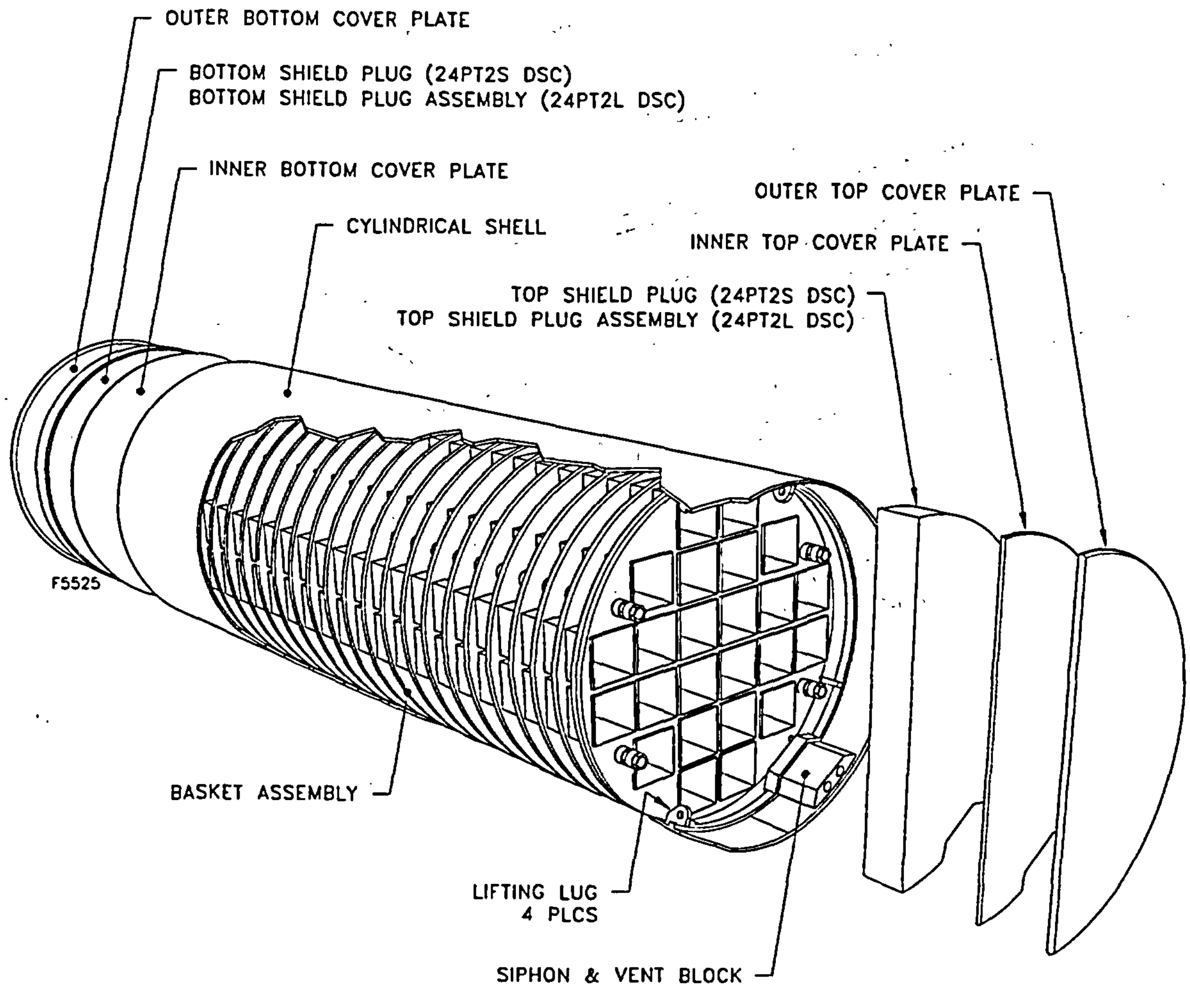



**Figure 1.3-1b**
**NUHOMS®-24PT2 DSC Components**

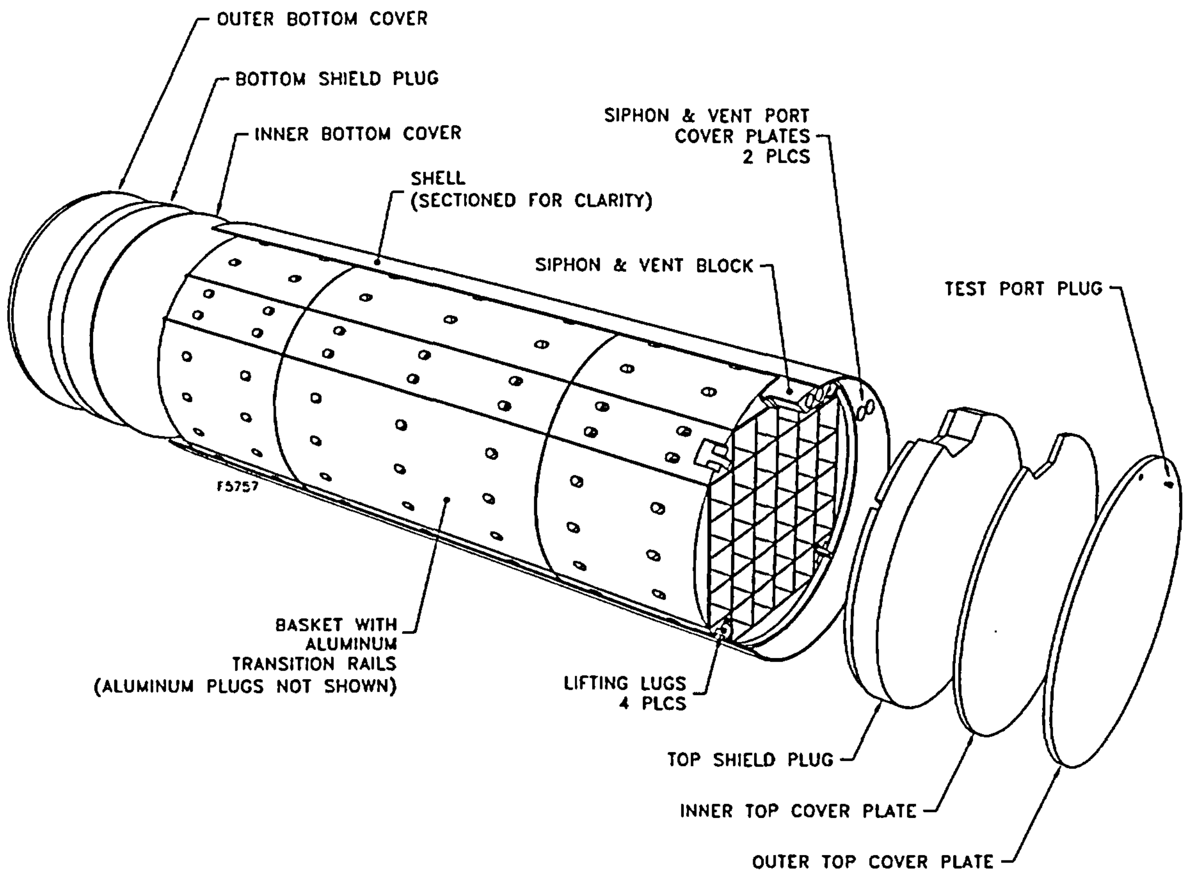



**Figure 1.3-1c**
**NUHOMS®-32PT DSC Components**

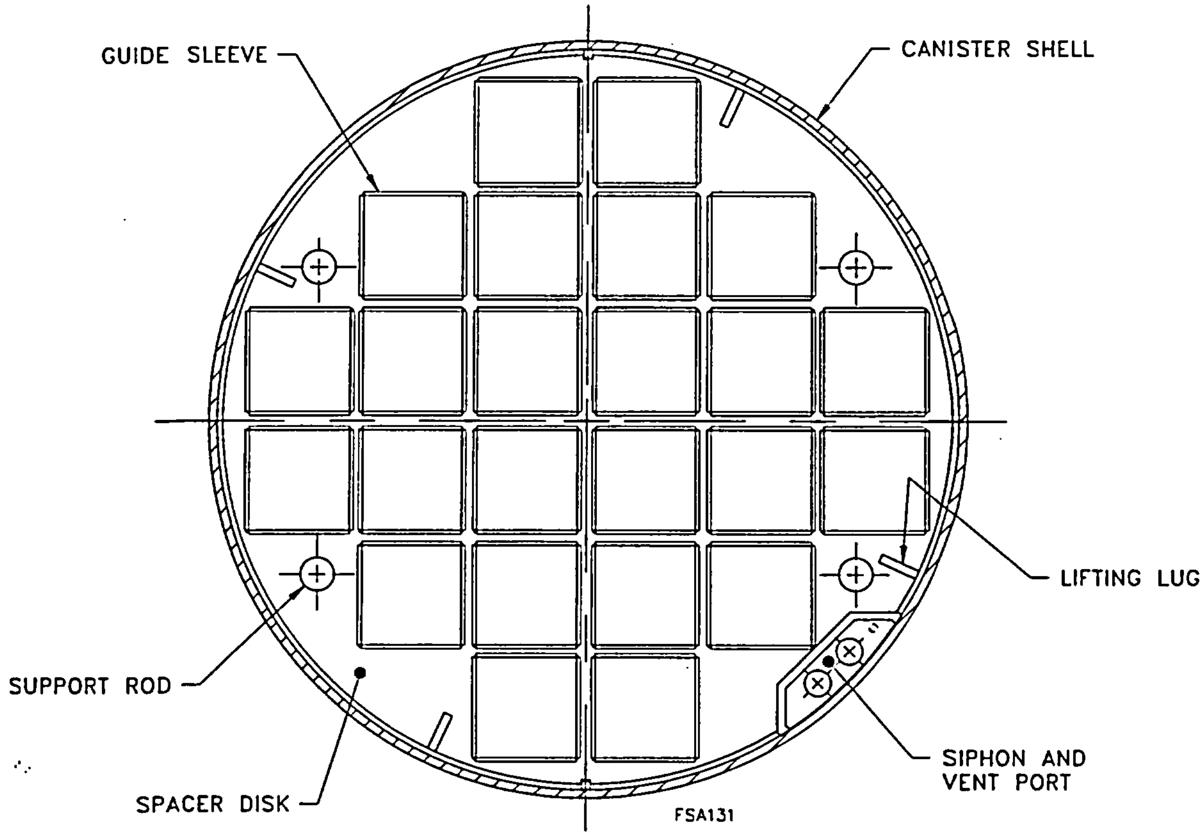



**Figure 1.3-2**
**NUHOMS®-24P Drv Shielded Canister Cross-Section**

# 3. PRINCIPAL DESIGN CRITERIA

## 3.1 Purpose of Installation

The NUHOMS® system provides an ISFSI for horizontal, dry storage (in a helium atmosphere) of SFAs in a high integrity stainless steel DSC which is placed inside a massive reinforced concrete HSM. The function of the DSCs and HSMs is to provide for the safe, controlled, long-term storage of SFAs.

The standardized NUHOMS® system can be utilized to store a wide range of the various light water reactor fuel assembly types which presently reside in spent fuel pools. This SAR addresses the most common types of both PWR and BWR spent fuel. The following subsection provides a description of the spent fuel assemblies which are acceptable for storage using the standardized NUHOMS® system.

The storage capacity of a single standardized NUHOMS® DSC and HSM is 24 PWR fuel assemblies or 52 or 61 BWR fuel assemblies. Multiple HSMs can be grouped together to form arrays which provide the needed storage capacity consistent with available site space and reactor fuel discharge rates.

### 3.1.1 Material to be Stored

The inventory of PWR fuel types which currently resides in spent fuel pools in the U.S. is shown in Figure 3.1-1. B&W 15x15 fuel is selected as the enveloping fuel design for a wide range of PWR fuel types as it is the most reactive and has the most limiting physical characteristics. Table 3.1-1 lists the principal design parameters for the B&W 15x15 fuel selected as the design basis for the standardized NUHOMS®-24P and -24PT2 systems documented in this SAR. Table 3.1-1a lists the PWR fuel assembly designs (with or without BPRAs) that have currently been demonstrated to be suitable for storage in the standardized NUHOMS®-24P and -24PT2 systems provided they meet the requirements of the Technical Specifications of CoC 1004. Similarly, the inventory of BWR fuel types residing in spent fuel pools in the U.S. is shown in Figure 3.1-2. GE 7x7 fuel is selected as the enveloping fuel design for a wide range of BWR fuel types. Table 3.1-2 lists the principal design parameters for the GE 7x7 fuel selected as the design basis for the standardized NUHOMS®-52B system documented in this SAR. Table 3.1-2a lists the BWR fuel designs which have currently been demonstrated to be suitable for storage in the standardized NUHOMS®-52B system provided they meet the requirements of the Technical Specifications of CoC No. 1004. system. Appendices K, M and N list the principal design parameters for the NUHOMS®-61BT, 32PT, and 24PHB system, respectively.

The following acceptance criteria is established for BWR and PWR fuels other than the SAR design basis fuels.

A. For shielding, the gamma and neutron source strengths (from fuel and BPRAs, if applicable) and resulting HSM contact roof doses must be less than or equal to the limits set forth by this SAR.

B. For thermal, if applicable, the total DSC decay heat , including the decay heat from BPRAs and the resulting temperatures must be less than or equal to the limits set forth by this SAR.

C. For criticality, the initial enrichment and resulting reactivity must be less than or equal to the limits set forth by this SAR.

D. For structural, the fuel weight (including the BPRA weight, if applicable) and the total weight of the DSC and transfer cask must be less than or equal to the limits set forth by this SAR.

The operating controls and limits for PWR and BWR fuel qualified for dry storage in the standardized NUHOMS® system are specified in Technical Specifications 1.2 of CoC 1004. The parameters for acceptable candidate fuel assemblies for dry storage are described further in the subsections which follow.

#### 3.1.1.1 Physical Characteristics

The standardized NUHOMS® system can be utilized to store the PWR and BWR fuel assemblies shown in Figure 3.1-1 and Figure 3.1-2 and in Fuel Specification 1.2.1 of CoC 1004. The PWR fuel types which exist are more varied as indicated by Table 3.1-3. PWR assemblies with installed Burnable Poison Rod Assemblies (BPRAs) may be stored provided the total physical, radiological, and thermal parameters are bounded by Table 3.1-1 and in Fuel Specification 1.2.1 of CoC 1004. Refer to Appendix J of this SAR for a detailed discussion of BPRAs authorized for storage. The key physical parameters of interest are the weight, length, and cross-sectional dimensions. The values of these parameters form the basis for the mechanical and structural design of the DSC and its internals. The DSC and transfer cask designs for the NUHOMS® system presented in this SAR are based on the B&W 15x15 fuel assembly parameters listed in Table 3.1-1 and the GE 7x7 fuel assembly parameters listed in Table 3.1-2.

#### 3.1.1.2 Thermal Characteristics

The key parameters utilized to determine the heat removal requirements for the NUHOMS® system design is the SFA decay heat power. The total decay heat power per spent fuel assembly is dependent on the average burnup per assembly and the cooling time. To a lesser extent, total decay heat power is dependent on the initial enrichment, specific power (MW/MTU) and neutron flux energy spectrum. The total heat rejected to the DSC and HSM for PWR fuel is conservatively taken to be less than or equal to 1.00 kilowatt per fuel assembly (24.0 kW/DSC) for fuel which is cooled 5 years or more. Similarly, the heat rejected from BWR fuel is conservatively taken to be less than or equal to be 0.37 kilowatt per fuel assembly (19.2 kW/DSC for the 52B DSC) for fuel which is cooled 5 years or more. Other cooling times are acceptable provided the total batch average decay heat per canister are not exceeded.

For thermal characteristics, fuel assembly burnup and cooling time can be used to determine the acceptability of a candidate SFA for dry storage using the NUHOMS® system. As such, if the burnup and cooling time for an assembly are known, the Fuel Specification 1.2.1 of CoC 1004 and/or fuel specific calculations can be used to determine its acceptability for dry storage using the NUHOMS® system. Established methods, such as specific ORIGEN calculations for a candidate fuel assembly to determine calorimetry or burnup test measurements, are acceptable for determining the acceptability of the candidate SFA. A simplified approach for users of the NUHOMS® storage system in selection of acceptable fuel assemblies during loading is provided in Tables 3.1-8a, 3.1-8b and 3.1-8c.

#### 3.1.1.3 Radiological Characteristics

The limits for three fuel management parameters including initial enrichment, burnup, and cooling time as specified in Fuel Specification 1.2.1 of CoC 1004 must be met. Using these parameters as acceptance criteria, existing records and plant procedures form the basis for controlling the selection and placement of candidate fuel assemblies.

### 3.1.2 General Operating Functions

Functional Overview of the Installation (for information only)

A NUHOMS® ISFSI is designed to maximize the use of existing plant features and equipment, and to minimize the need to add or modify equipment. The ISFSI may be located away from the existing plant security boundary such that a separate protected area is created. The only services required from the plant during the ongoing passive storage mode is through security surveillance equipment located in the plant Central Alarm Station (CAS) and Secondary Alarm Station (SAS). The ISFSI should be included in routine daily security patrols for the plant site conducted by the licensee. The power provided for the ISFSI security system and lighting is obtained from a retail source. Other support services from the plant are necessary only during DSC transfer and retrieval operations.

For the NUHOMS® system, SFAs are loaded into the DSC as discussed in Section 1.3. During loading, the DSC is resting in the cavity of the transfer cask, in the fuel pool cask laydown area. After removal from the pool, the DSC is dried and backfilled with helium. After drying, the DSC (still inside the transfer cask) is moved to the cask skid/trailer and transported to the ISFSI. The DSC is pushed from the transfer cask into the HSM by a hydraulic ram.

Once inside the HSM, the DSC and its payload of SFAs is in passive dry storage. Safe storage in the HSM is assured by a natural convection heat removal system, and massive concrete walls and slabs which act as biological radiation shields. The storage operation of the HSMs and DSCs is totally passive. No active systems are required.

3.1.2.1 Handling and Transfer Equipment

The handling and transfer equipment required to implement the NUHOMS® system includes a cask handling crane at the reactor fuel pool, a cask lifting yoke, a transfer cask, a cask support skid and positioning system, a low profile heavy haul transport trailer and a hydraulic ram system. This equipment is designed and tested to applicable governmental and industrial standards and is maintained and operated according to the manufacturer's specifications. Performance criteria for this equipment, excluding the fuel/reactor building cask handling crane, is given in the following sections. The criteria are summarized in Table 3.1-7.

On-Site Transfer Cask: The on-site transfer cask used for the NUHOMS® system has certain basic features. The DSC is transferred from the plant's fuel pool to the HSM inside the transfer cask. The cask provides neutron and gamma shielding adequate for biological protection at the outer surface of the cask. The cask is capable of rotation, from the vertical to the horizontal position on the support skid. The cask has a top cover plate which is fitted with a lifting eye allowing removal when the cask is oriented horizontally. The cask is capable of rejecting the design basis decay heat load to the atmosphere assuming the most severe ambient conditions postulated to occur during normal, off-normal and accident conditions. For the NUHOMS®-24P, 24PHB DSC or the NUHOMS®-24PT2 DSC, the standardized transfer cask has a cylindrical cavity of 1.73m (68 inches) diameter and 4.75m (186.75 inches) in length and a maximum dry payload capacity of 36,000 Kg (80,000 pounds). For the NUHOMS®-52B or NUHOMS®-61BT, the standardized transfer cask is fitted with an extension collar to accommodate the longer BWR DSC and fuel. Alternatively, the OS197 and OS197H transfer casks with a full length cavity of 5.0m (196.75 inches) may be used for the NUHOMS®-24P, 24PHB (with cask spacer), NUHOMS®-52B, NUHOMS®-61BT DSCs, NUHOMS®-24PT2 DSC (with cask spacer) or NUHOMS®-32PT DSC (with cask spacer). The OS197 and OS197H casks can carry a maximum dry payload of 44,100 kg (97,250 lb) and 52,600 kg (116,000 lb), respectively. The cask and the associated lifting yoke are designed and operated such that the consequences of a postulated drop satisfy the current 10CFR50 licensing bases for the vast majority of plants.

The NUHOMS® transfer cask is designed to meet the requirements of 10CFR72 (3.6) for normal, off-normal and accident conditions. The NUHOMS® transfer cask is designed for the following conditions:

| | | |
|---|---|---|
| A. | Seismic | Reg. Guide 1.60 (3.11) and 1.61 (3.12) |

Table 3.1-1
Principal Acceptance Parameters for PWR Fuel to be Stored in the Standardized NUHOMS®-24P DSC

| Title or Parameter | Specifications |
|---|---|
| Fuel | Only intact, unconsolidated PWR fuel assemblies (with or without BPRAs) with the following requirements. |
| Physical Parameters (without BPRAs) | |
| Maximum Assembly Length (unirradiated)<br>• With Burnup ≤ 45,000 MWd/MTU | 165.75 in (standard cavity)<br>171.71 in (long cavity) |
| Nominal Cross Sectional Envelope | 8.536 in |
| Maximum Assembly Weight | 1682 lbs |
| No. of Assemblies per DSC | ≤ 24 intact assemblies |
| Fuel Cladding | Zircalloy-clad fuel with no known or suspected gross cladding breaches |
| Physical Parameters (with BPRAs) | |
| Maximum Assembly + BPRA Length (unirradiated)<br>• With Burnup >32,000 and ≤ 45,000 MWd/MTU<br>• With Burnup ≤ 32,000 MWd/MTU | 171.71 in (long cavity)<br>171.96 in (long cavity) |
| Nominal Cross Sectional Envelope | 8.536 in |
| Maximum Assembly + BPRA Weight | 1682 lbs |
| No. of Assemblies per DSC | ≤ 24 intact assemblies |
| No. of BPRAs per DSC | ≤ 24 BPRAs |
| Fuel Cladding | Zircalloy-clad fuel with no known or suspected gross cladding breaches |
| Nuclear Parameters | |
| Fuel Initial Enrichment | ≤ 4.0 wt. % U-235 |
| Fuel Burnup and Cooling Time | Per Table 3.1-8a (without BPRAs)<br>or<br>Per Table 3.1-8c (with BPRAs) |
| BPRA Cooling Time (Minimum) | 5 years for B&W Designs<br>10 years for Westinghouse Designs |
| Alternate Nuclear Parameters | |
| Initial Enrichment | ≤ 4.0 wt. % U-235 |
| Burnup | ≤ 40,000 MWd/MTU and per Figure 3.3-3 |
| Decay Heat (Fuel + BPRA) | ≤ 1.0 kW per assembly |
| Neutron Fuel Source | ≤ $2.23 \times 10^{8}$ n/sec per assy with spectrum bounded by that in Chapter 7 of FSAR |
| Gamma (Fuel + BPRA) Source | ≤ $7.45 \times 10^{15}$ g/sec per assy with spectrum bounded by that in Chapter 7 of FSAR |

Table 3.1-1a

PWR Fuel Assembly Designs Suitable for Storage in the Standardized NUHOMS®-24P DSC

| Type[1] | Nominal Cross Sectional Envelope (in) | Maximum Assembly Unirradiated Length *(Standard Cavity) (w/o* BPRAs) (in)* | Maximum Assembly Unirradiated Length *(with BPRAs) (Long Cavity)* (in) | Maximum Assembly Weight *(w/o* BPRAs)* (lbs) | Maximum Assembly Weight *(with BPRAs)* (lbs) | Heavy Metal Weight (kg-U) | Cladding Material |
|---|---|---|---|---|---|---|---|
| B&W 15x15[8] | 8.536 | 165.75 | 171.71/ 171.96[9] | 1682.0 | 1682.0 | 475.0 | Zircaloy |
| CE 14x14 Fort Calhoun[2] | 8.100 | 147.00 | *n/a* | 1220.0 | *n/a* | 365.6 | Zircaloy |
| CE 15x15 Palisades[3] | 8.250 | 149.00 | *n/a* | 1360.0 | *n/a* | 412.4 | Zircaloy |
| CE 14x14 Standard/Generic | 8.100 | 157.00 | *n/a* | 1270.0 | *n/a* | 382.2 | Zircaloy |
| Westinghouse 14x14[5] | 7.763 | 160.13 | *n/a* | 1302.0 | *n/a* | 405.0 | Zircaloy |
| Westinghouse 15x15[6] | 8.434 | 160.10 | *n/a* | 1472.0 | *n/a* | 460.0 | Zircaloy |
| Westinghouse 17x17[7] | 8.434 | 160.10 | 167.220 | 1482.0 | 1663.2 | 461.0 | Zircaloy |
| Enveloping Value | 8.536 | 165.75 | 171.710/ 171.96[9] | 1682.0 | 1682.0 | 475.0 | |

(1) Each fuel assembly must be qualified for storage per 72-1004 CoC Technical Specifications.
(2) Includes Exxon/ANF FT. CALHOUN 14 X 14 ANF
(3) Includes Exxon/ANF 15x15 CE
(4) Not used
(5) Includes Exxon/ANF 14x14 Westinghouse
(6) Includes Exxon/ANF 15x15 Westinghouse
(7) Includes Babcock and Wilcox WE 17 X 17 B&W Mark BW
(8) Excludes Westinghouse 15x15 reload fuel for B&W 15x15 reactors
(9) Maximum allowed burnup is 32,000 MWd/MTU for the 171.96 long assemblies (with BPRAs)

* w/o means without

Table 3.1-2

Principal Acceptance Parameters for BWR Fuel to be Stored in NUHOMS® -52B DSC

| Title or Parameter | Specifications |
|---|---|
| Fuel | Only intact, unconsolidated BWR fuel assemblies with the following requirements |
| Physical Parameters | |
| Maximum Assembly Length (unirradiated) | 176.16 in |
| Nominal Cross-Sectional Envelope* | 5.454 in |
| Maximum Assembly Weight | 725 lbs |
| No. of Assemblies per DSC | ≤ 52 intact channeled assemblies |
| Fuel Cladding | Zircaloy-clad fuel with no known or suspected gross cladding breaches |
| Nuclear Parameters | |
| Fuel Initial Lattice Enrichment | ≤ 4.0 wt. % U-235 |
| Fuel Burnup and Cooling Time | Per Table 3.1-8b |
| Alternate Nuclear Parameters | |
| Initial Enrichment | ≤ 4.0 wt. % U-235 |
| Burnup | ≤ 35,000 MWd/MTU and per Figure 3.3-3 |
| Decay Heat | ≤ 0.37 kW per assembly |
| Neutron Source | ≤ 1.01 x $10^8$ n/sec per assy with spectrum bounded by that in Chapter 7 of FSAR |
| Gamma Source | ≤ 2.63 x $10^{15}$ g/sec per assy with spectrum bounded by that in Chapter 7 of FSAR |

* Cross-Sectional Envelope is the outside dimension of the fuel channel.

Table 3.1-2a

BWR Fuel Assembly Designs Suitable for Storage in NUHOMS®-52B DSC

| Type[(1)] | Channeled Width (in) | Unirradiated Length (in) | Assembly Weight (lbs) | Heavy Metal Weight (kg-U) | Cladding Material |
|---|---|---|---|---|---|
| GE 6x6 Dresden-1[(2)] | 4.850 | 136.00 | 400 | 111.4 | Zircaloy-2 |
| GE 7x7[(3)] | 5.438 | 175.87 | 690 | 194.9 | Zircaloy-2 |
| GE 8x8[(4)] | 5.440 | 176.05 | 690 | 186.7 | Zircaloy-2 |
| Limit: | 5.454 | 176.16 | 725 | 198.0 | |

(1) Each fuel assembly must be qualified for storage per Technical Specifications of CoC 1004.

(2) Includes Exxon/ANF DRESDEN-1 6x6 ANF.

(3) Includes Exxon/ANF GE BWR 7x7 ANF.

(4) Includes Exxon/ANF GE BWR 8x8 ANF.

in Section 6.17.3.1 of ANSI 57.9-1984 are used for combining normal operating, off-normal, and accident loads for the HSM. All seven load combinations specified are considered and the governing combinations are selected for detailed design and analysis. The resulting HSM load combinations and the appropriate load factors are presented in Table 3.2-5. The effects of duty cycle on the HSM are considered and found to have negligible effect on the design. The corresponding structural design criteria for the DSC support structure are summarized in Table 3.2-8 and Table 3.2-10. The HSM load combination results with 24P and 52B DSCs are presented in Section 8.2.10. Appendices K, L, M and N provide the HSM load combination results for the NUHOMS®-61BT, 24PT2, 32PT and 24PHB DSCs, respectively.

3.2.5.2 Dry Shielded Canister

With the exceptions noted in Table 4.8-1 and Table 4.8-2, the DSC is designed by analysis to meet the stress intensity allowables of the ASME Boiler and Pressure Vessel Code (1983 Edition with Winter 1985 Addenda) (3.14) Section III, Division 1, Subsection NB for Class 1 components (for the DSC pressure boundary components), and Subsection NF for Class 1 plate and shell supports (for the internal basket assembly components). The DSC is conservatively designed by utilizing linear elastic or non-linear elastic-plastic analysis methods.

The load combinations considered for the DSC normal, off-normal and postulated accident loadings are shown in Table 3.2-6 for the 24P, 24PT2 and 52B DSCs and in Appendices K, M, and N for 61BT, 32PT, and 24PHB DSCs, respectively. ASME Code Service Levels A and B allowables are conservatively used for normal and off-normal operating conditions. Service Levels C and D allowables are used for accident conditions such as a postulated cask drop accident. 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 effects of fatigue on the DSC due to thermal and pressure cycling are addressed in Section 8.2-10.

The DSC pressure boundary components which include the DSC shell and cover plates are designed using the stress criteria of the ASME B&PV Code Subsection NB. The shell longitudinal and circumferential welds are full penetration welds fabricated and inspected in accordance with Subsection NB. The cover plates to shell welds are partial penetration welds, designed using a "joint efficiency" factor of 0.6 on the ASME Code Subsection NB criteria. Table 3.2-9a summarizes the stress design criteria for the pressure boundary components of the DSC. In addition to stress criteria, buckling of the DSC shell is evaluated using the ASME Code Subsection NB (for Service Levels A,B, C) and ASME Code Appendix F (for Service Level D) stability criteria.

The 24P DSC basket components include the spacer discs, support rods, guide sleeves oversleeves, and their associated welds. The 24PT2 and 52B DSC basket components include the spacer discs, support rod and spacer sleeve assemblies, neutron absorber plates (poison plates), poison plate support bars and connecting hardware. Table 3.2-9b summarizes the stress criteria for DSC non-pressure boundary components (except for support rods). The spacer discs are designed using the component stress criteria from ASME Code Subsection NB (for Service Levels A, B, C) and ASME Code Appendix F (Service Level D, Elastic and Elastic/Plastic analysis). The support rods are designed using the criteria of ASME Code Subsection NF for linear type component supports (for Service levels A, B, C) and ASME Code Appendix F (for Service Level D stress or stability criteria). For Service Level A the limits of NF-3322 are used. For Service Levels B and C the factors of Table NF-3523(b)-1 are used. For Service Level D, the criteria from Appendix F is used. The 24P guide sleeves and oversleeves are designed using the stress criteria of ASME Code Subsection NB and ASME Code Appendix F, and the stability criteria of Subsection NF and Appendix F, as applicable. All non-pressure boundary partial penetration and fillet welds are designed using the stress criteria of ASME Code Subsection NF and ASME Code Appendix F.

Other components of the DSC include the support ring, the lifting lugs, the shield plugs, the grapple ring and grapple ring support plate, and all welds associated with these components. The support ring is designed using the ASME Code Subsection NB criteria. The associated weld to the DSC shell is a partial penetration weld evaluated to the ASME Code Subsection NF and Appendix F requirements, as applicable. The lifting lugs and associated welds are designed using Subsection NF allowables. The grapple ring, grapple ring support plates and associated welds are designed using the ASME Code Subsection NB design criteria. The shield plugs are non-pressure boundary components and need only to maintain their structural integrity. The shield plugs are evaluated using Subsection NB primary stress limits. The shield plugs stiffener welds in the long cavity basket are full penetration welds designed to Subsection NF.

### 3.2.5.3 On-site Transfer Cask

The on-site transfer cask is a non-pressure retaining component which conservatively is designed by analysis to meet the stress allowables of the ASME Code (3.14) Subsection NC for Class 2 components. The cask is conservatively designed by utilizing linear elastic analysis methods. The load combinations considered for the transfer cask normal, off-normal, and postulated accident loadings are shown in Table 3.2-7. Service Levels A and B allowables are used for all normal operating and off-normal loadings. Service Levels C and D allowables are used for load combinations which include postulated accident loadings. Allowable stress limits for the upper lifting trunnions and upper trunnion sleeves are conservatively developed to meet the requirements of ANSI N14.6-1993 (3.37) for a non-redundant lifting device for all cask movements within the fuel/reactor building. The maximum shear stress theory is used to calculate principal stresses in the cask structural shell. The appropriate dead load and thermal stresses are combined with the calculated drop accident scenario stresses to determine the worst case design stresses. The transfer cask structural design criteria are summarized in Table 3.2-11 and Table 3.2-12. The transfer cask accident analyses are presented in Section 8.2. The effects of fatigue on the transfer cask due to thermal cycling are addressed in Section 8.2.10. Appendices K, L, and N address the effects of handling the NUHOMS®-61BT, -24PT2, and 24PHB DSC in the transfer cask, respectively. The effects of handling the NUHOMS®-32PT DSC in the OS197 or OS197H transfer cask are addressed in Appendix M.

Table 3.2-1
Summary of NUHOMS® Component Design Loadings

| Component | Design Load Type | SAR Section Reference | Design Parameters | Applicable Codes |
|---|---|---|---|---|
| Horizontal Storage Module(1): | — | — | — | ACI 349-85, ACI 349R-85 (design); ACI 318-83 (construction only) |
| | Design Basis Wind Load | 3.2.1 | Max. wind pressure : 397 psf<br>Max. speed: 360 mph | NRC Reg. Guide 1.76 and ANSI A58.1 1982 |
| | Design basis tornado wind load + Missile load | 3.2.1 | Maximum wind speed of 360 mph, and a pressure drop of 3 psi + Missile types: Automobile, 4000 lbs, 195 fps; 8" diameter shell, 276 lbs, 185fps; 1 in. diameter, solid steel sphere; wood plank, 4 in x 12 in x 12 ft, 200 lbs, 440 fps. | NRC Reg. Guide 1.76 and ANSI A58.1, 1982. NUREG-0800, Section 3.5.1.4 |
| | Flood | 3.2.2 | Maximum water height: 50 feet<br>Maximum velocity: 15 ft./sec. | 10CFR72.122(b) |
| | Seismic | 3.2.3 | Hor. ground acceleration: 0.25g (both directions) Vert. ground acceleration: 0.17g with Reg. Guide 1.60 spectra at 7% damping. | NRC Reg. Guides 1.60 & 1.61 |
| | Snow and Ice | 3.2.4 | Maximum load: 110 psf (included in live load) | ANSI A58.1-1982 |
| | Dead Load | 8.1.1.5 | Dead weight including loaded DSC (concrete density of 150 pcf) | ANSI 57.9-1984 |
| | Normal and Off-Normal Operating Temperatures | 8.1.1.5 | DSC with spent fuel rejecting 24.0 kW of decay heat for 5 yr. cooling time. Ambient air temperature range of -40°F to 125°F for off-normal case | ANSI 57.9-1984 |

(1) See Appendix K for information associated with the NUHOMS®-61BT DSC.

Table 3.2-1
Summary of NUHOMS® Component Design Loadings
(continued)

| Component | Design Load Type | SAR Section Reference | Design Parameters | Applicable Codes |
|---|---|---|---|---|
| | Accident Condition Temperatures | 8.2.7.2 | Same as off-normal conditions with HSM vents blocked for 40 hours | ANSI 57.9-1984 |
| | Normal Handling Loads | 8.1.1.1 | For concrete component evaluation<br>80,000 lb.(DSC HSM insertion)<br>60,000 lb (DSC HSM extraction) | ANSI 57.9-1984 |
| | Off-normal Handling Loads | 8.1.1.4 | For concrete component evaluation<br>80,000 lb (DSC HSM insertion)<br>80,000 lb (DSC HSM extraction) | ANSI 57.9-1984 |
| | Live Load | 8.1.1.5 | Design load: 200 psf (includes snow and ice loads) | ANSI 57.9-1984 |
| | Fire and Explosions | 3.3.6 | Enveloped by other design basis events | 10CFR72.122(c) |
| **Dry Shielded Canister[(1)]:** | --- | --- | --- | ASME Code, Section III, Subsection NB, Class 1 Component |
| | Flood | 3.2.2 | Maximum water height: 50 ft. | 10CFR72.122(b) |
| | Seismic | 3.2.2 | Horizontal ground acc.: 0.25g<br>Vertical ground acc.: 0.17g | NRC Reg. Guides 1.60 & 1.61 |
| | Dead Load | 8.1.1.2 | Weight of loaded 24P & 52B DSC: 80,000 lb. enveloping.<br>Weight of loaded 24PT2 DSC: 85,000 lb. enveloping. | ANSI 57.9-1984 |
| | Normal and Off-Normal Pressure | 8.1.1.2 | Enveloping internal pressure of ≤10.0 psig | 10CFR72.122(h) |
| | Test Pressure | 8.1.1.2 | Enveloping internal pressure of 12 psig applied w/o DSC outer top cover plate | 10CFR72.122(h) |

(1) See Appendices K, M and N for information associated with the NUHOMS®-61BT, 32PT and 24PHB DSCs, respectively.

Table 3.2-1
Summary of NUHOMS® Component Design Loadings
(continued)

| Component | Design Load Type | SAR Section Reference | Design Parameters | Applicable Codes |
|---|---|---|---|---|
| | Normal and Off-Normal Operating Temperature | 8.1.1.2, 8.1.2.2 | DSC with spent fuel rejecting 24.0 kW (PWR) or 19.2 kW (BWR) decay heat for 5 year cooling time. Ambient air temperature -40°F to 125°F | ANSI 57.9-1984 |
| | Normal Handling Loads | 8.1.1.2 | 1. Hydraulic ram load of 80,000 lb.(DSC HSM insertion) 60,000 lb (DSC HSM extraction)<br>2. Transfer (to/from ISFSI) Loads of:<br>2a. +/-1.0g axial<br>2b. +/-1.0g transverse<br>2c. +/-1.0g vertical<br>2d. +/-0.5g axial +/-0.5g transverse +/-0.5g vertical | ANSI 57.9-1984 |
| | Off-Normal Handling Loads | 8.1.2.1 | Hydraulic ram load of: 80,000 lb. (DSC HSM insertion) 80,000 lb (DSC HSM extraction) | ANSI-57.9-1984 |
| | Accidental Cask Drop Loads | 8.2.5 | Equivalent static deceleration of 75g for vertical end drop and horizontal side drops, and 25g oblique corner drop | 10CFR72.122(b) |
| | Accident Internal Pressure | 8.2.7<br>8.2.9 | Enveloping internal pressure of ≤60 psig based on 100% fuel cladding rupture and fill gas release, 30% fission gas release, and ambient air temperature of 125°F | 10CFR72.122(h) |
| **Dry Shielded Canister Steel Support Structure(1):** | --- | --- | --- | AISC Specification for Structural Steel Buildings |
| | Dead Weight | 8.1.1.4 | Loaded DSC plus self weight | ANSI-57.9-1984 |
| | Seismic | 3.2.3 | DSC reaction loads with horizontal ground acc. of 0.25g and vertical ground acc. of 0.17g | NRC Reg. Guides 1.60 & 1.61 |

(1) See Appendices K, M and N for information associated with the NUHOMS®-61BT, 32PT and 24PHB DSCs, respectively.

Table 3.2-1
Summary of NUHOMS® Component Design Loadings
(continued)

| Component | Design Load Type | SAR Section Reference | Design Parameters | Applicable Codes |
|---|---|---|---|---|
| | Normal Handling Loads | 8.1.1.4 | Friction load of 29,580 lbs applied to both rails for support structure evaluation. This load is applied as a live load. | ANSI-57.9-1984 |
| | Off-normal Handling Loads | 8.1.2.1 | For steel support structure evaluation, this load is 80,000 lbs plus a vertical load of 25,500 lbs applied to each rail, one rail at a time. | ANSI-57.9-1984 |
| **On-site[1] Transfer Cask:** | --- | --- | --- | ASME Code Section III, Subsection NC, Class 2 Component[2] |
| | Design Basis Tornado Wind | 3.2.1 | Max. wind pressure: 397 psf<br>Max. wind speed: 360 mph | NRC Reg. Guide 1.76 and ANSI A58.1-1982 |
| | Flood | 3.2.2 | Not included in design basis due to infrequent short duration use of cask | 10CFR72.122(b) |
| | Seismic | 3.2.3 | Horizontal ground acc.: 0.25g<br>Vertical ground acc.: 0.17g | NRC Reg. Guides 1.60 & 1.61 |
| | Snow and Ice | 3.2.4 | External surface temp. and smooth circular section will preclude build-up of snow and ice loads when cask is in use | 10CFR72.122(b) |

(1) The transfer cask is not part of the cask storage system which for NUHOMS® consists of the canister and module.

(2) ASME Subsection NCA does not apply.

**Table 3.2-1**
**Summary of NUHOMS® Component Design Loadings**
(continued)

| Component | Design Load Type | SAR Section Reference | Design Parameters | Applicable Codes |
|---|---|---|---|---|
| | Dead Weight | 8.1.1.9 | a. Vertical orientation, self weight with loaded DSC and water in cavity(2) | ANSI 57.9-1984 |
| | | | b. Horizontal orientation self weight with loaded DSC on transfer skid(3) | ANSI 57.9-1984 |
| | Normal and Off-normal Operating Temperatures | 8.1.1.9, 8.1.2.2 | Loaded DSC rejecting 24.0 kw decay heat with 5 yr. cooling time. Ambient air temperature range: -40°F to 125°F w/solar shield, -40°F to 100°F w/o solar shield. | ANSI 57.9-1984 |
| | Normal Handling Loads | 8.1.1.9 | a. Upper lifting trunnions - in fuel/reactor building: Stresses ≤ yield with 6 x load and ≤ ultimate with 10 x load | ANSI N14.6-1993(1) |
| | | | b. Upper lifting trunnions - on-site transfer | ASME Section III |
| | | | c. Lower support trunnions: proportional weight of loaded cask during downending and transit to HSM | ASME Section III |
| | | | d. Hydraulic ram load of 80,000 lb. (DSC HSM insertion) and 60,000 lb (DSC HSM extraction) | ANSI 57.9-1984 |

(1) The trunnion design stress allowables are consistent with that of lifting devices governed by ANSI N14.6.

(2) The total analyzed dead weight loads for the standardized, OS197, and OS197H transfer casks are 200,000 lbs, 208,500 lbs and 250,000 lbs, respectively.

(3) The total analyzed cask payloads loads for the standardized, OS197, and OS197H casks are 80,000 lbs, 97,250 lbs, and 116,000 lbs, respectively.

Table 3.2-1
Summary of NUHOMS® Component Design Loadings
(continued)

| Component | Design Load Type | SAR Section Reference | Design Parameters | Applicable Codes |
|---|---|---|---|---|
| | Off-normal Handling Loads | 8.1.2.1 | Hydraulic ram load of 80,000 lb.(DSC HSM insertion) 80,000 lb (DSC HSM extraction) | ANSI 57.9-1984 |
| | Accidental Cask Drop Loads | 8.2.5 | Equivalent static deceleration of 75g for vertical end drops and horizontal side drops, and 25g for oblique corner drop | 10CFR72.122(b) |
| | Fire and Explosions | 3.3.6 | Enveloped by other design basis events | 10CFR72.122(c) |
| | Internal Pressure | --- | N/A - DSC provides pressure boundary | 10CFR72.122(h) |

## Table 3.2-6
## DSC Load Combinations and Service Levels[10]

| Load Case | | Normal Operating Conditions | | | | | | | | Off-Normal Conditions | | | | Accident Conditions | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Dead Weight Load | Vertical/Horizontal DSC, Empty | X | X | | | | | | | | | | | | | | | | | | | |
| | Vertical, DSC w/Fuel + Water | | | X | | | | | | | | | | X | | | | | | | | |
| | Vertical, DSC w/Fuel | | | | X | X(5) | | | | | | | X | | X(9) | | | | | | | |
| | Horizontal, DSC w/Fuel | | X | | | | X | X | X | X | X | X | | | X(9) | X | X | X | X | X | X | X |
| Thermal Load | Inside HSM: 0° to 100°F | | | | | | | X | X | | | | | | | | | X | X | X | X | X |
| | Inside Cask: 0° to 100°F (1) | | X | X | X | X | X | | | | | | X | X | X | | | | | | | |
| | Inside HSM: -40° to 125°F | | | | | | | | | | X | X | | | | X | | | | | | |
| | Inside Cask -40° to 125°F | | | | | | | | X | | | | | | | | | | | | | |
| | Inside HSM: Blocked Vents; 125°F | | | | | | | | | | | | | | | | X | | | | | |
| External Pressure | | | X | X | X | | | | | | | | X | X | | | | | | X | | |
| Internal Pressure Load | Hydrostatic Pressure | | X(6) | X | | | | | | | | | | X | | | | | | | | |
| | Normal Pressure (4) | | | | | X | X | X | X | | | | | | | | | X | | | | |
| | Off-Normal Pressure (4) | | | | | | | | | X | X | X | X(7) | | | | | | | | | |
| | Accident Pressure (3) | | | | | | | | | | | | | | X | X | X | | X | | X | X |
| Test Pressure | | | | | X | | | | | | | | | | | | | | | | | |
| Lifting/ Handling Loads | Lifting Loads | X | | | | | | | | | | | | | | | | | | | | |
| | Normal DSC Transfer | | | | | | X | | X | | | | | | | | | | | | | |
| | Off-Normal DSC Transfer | | | | | | | | | X | | X | | | | | | | | | | |
| | Accident DSC Transfer | | | | | | | | | | | | | | | | | | | | X | X |
| Cask Drop Load (end, side, or corner drop) | | | | | | | | | | | | | | | X | | | | | | | |
| Seismic Load | | | | | | | | | | | | | | X(8) | | | | X | X | | | |
| Flooding Load | | | | | | | | | | | | | | | | | | | | X | | |
| ASME Code Service Level | | A | A | A | A | A | A | A | A | B | B | B | B | C | D | C | D | C | C | C | C | D |
| Analysis Load Cases in Chapter 8, Table 8.2-24 | | NO-3 NO-4 | FL-1 FL-2 FL-3 | FL-4 FL-5 FL-6 | DD-1 DD-2 DD-3 DD-4 DD-5 | TL-1 TL-2 TL-3 TL-4 | TR-1 to TR-8 LD-1 LD-2 LD-3 | HSM-2 | UL-1 UL-2 UL-3 | LD-4 LD-5 LD-6 LD-7 | HSM-1 HSM-3 | UL-4 UL-5 UL-6 | RF-1 | FL-7 | TR-9 TR-10 TR-11 | HSM-4 | HSM-5 HSM-6 | HSM-7 HSM-8 | HSM-8a | HSM-9 HSM-10 | UL-7 | UL-8 |

NOTES:

1. At temperatures over 100°F, a sunshade is required over the Transfer Cask. Temperatures for the 125°F with shade are enveloped by the 100°F without sun shade case.

2. The stress limits of ASME Code NB-3226 apply.

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 conservatively used for Normal and Off-normal pressure.

5. DSC inside cask is laydown to horizontal for load cases TL-3, TL-4.

6. Internal hydrostatic pressure. Applies to FL-3, FL-4.

7. Reflood pressure is 20 psig.

8. Fuel deck seismic loads are assumed enveloped by handling loads.

9. Both horizontal and vertical drop cases are considered.

10. See Appendices K, M, and N for information associated with the NUHOMS®-61BT, 32PT, and 24PHB DSCs, respectively.

Table 3.2-9a

Stress Design Criteria for DSC Pressure Boundary Components[3], [4]

| Item | Stress Type | Stress Values[1] | | | |
|---|---|---|---|---|---|
| | | Service Levels A & B | Service Level C | Service Level D (Austenitic Components) | |
| | | | | Elastic | Elastic/Plastic |
| DSC[2] | Primary Membrane | $S_m$ | Greater of 1.2 $S_m$ or $S_y$ | Smaller of 2.4 $S_m$ or 0.7 $S_u$ | Greater of 0.7$S_u$ or $S_y$+1/3($S_u$-$S_y$) |
| | Primary Membrane + Bending | 1.5 $S_m$ | Greater of 1.8 $S_m$ or 1.5 $S_y$ | Smaller of 3.6 $S_m$ or $S_u$ | 0.9 $S_u$ |
| | Primary + Secondary | 3.0 $S_m$ | N/A | N/A | N/A |
| DSC Partial Penetration Welds | Primary | 0.6 $S_m$ | Greater of 0.72$S_m$ or 0.6 $S_y$ | Smaller of 1.44$S_m$ or 0.42 $S_u$ | Greater of 0.42$S_u$ or 0.6($S_y$+1/3($S_u$-$S_y$)) |
| | Primary + Secondary | 0.6(3.0 $S_m$) | N/A | N/A | N/A |

(1) Values of $S_y$, $S_m$, and $S_u$ versus temperature are given in Table 8.1-3.

(2) Includes full penetration volumetrically inspected welds

(3) Pressure boundary components are DSC shell, inner and outer (top and bottom) cover plates and associated welds.

(4) See Appendices K and M for the NUHOMS®-61BT and 32PT DSCs, respectively.

Table 3.2-9b

Stress Design Criteria for DSC Non-Pressure Boundary Components [1],[5]

| Item | Stress Type | Stress Values[2] | | | | | |
|---|---|---|---|---|---|---|---|
| | | Service Levels A & B | Service Level C | Service Level D | | | |
| | | | | (Ferritic Components) | | (Austenitic Components) | |
| | | | | Elastic | Elastic/ Plastic | Elastic | Elastic/ Plastic |
| DSC Non-pressure boundary components [3] | Primary Membrane | $S_m$ | Greater of 1.2 $S_m$ or $S_y$ | 0.7 $S_u$ | 0.7$S_u$ | Smaller of 2.4 $S_m$ or 0.7 $S_u$ | Greater of 0.7$S_u$ or $S_y$+1/3($S_u$-$S_y$) |
| | Primary Membrane + Bending | 1.5 $S_m$ | Greater of 1.8 $S_m$ or 1.5 $S_y$ | 1.0 $S_u$ | 0.9 $S_u$ | Smaller of 3.6 $S_m$ or $S_u$ | Smaller than 0.9 $S_u$ |
| | Primary + Secondary | 3.0 $S_m$ | N/A | N/A | N/A | N/A | N/A |
| DSC Non-Pressure Boundary Partial Penetration and Fillet Welds[4] | Weld Metal | Level A: 0.3 $S_u$ Level B: 0.4 $S_u$ | 0.45$S_u$ | 0.60$S_u$ | 0.60$S_u$ | 0.6$S_u$ | 0.60$S_u$ |
| | Base metal | Level A: 0.40 $S_y$ Level B: 0.53 $S_y$ | 0.60$S_y$ | 0.80$S_y$ | 0.80$S_y$ | 0.8$S_y$ | 0.80$S_y$ |

(1) Applies to DSC Spacer Discs, Guide sleeves (24P), Oversleeves (24P), Shield Plugs, Support Ring, Poison Plates and Grapple Ring. Criteria do not apply to Support Rods and Lifting Lugs.

(2) Values of $S_y$, $S_m$, and $S_u$ versus temperature are given in Table 8.1-3.

(3) Only primary stress limits apply to the Shield Plugs.

(4) Grapple ring welds are full penetration Subsection NB welds.

(5) See Appendices K and M for the NUHOMS®-61BT and 32PT DSCs, respectively.

## 3.3 Safety Protection System

### 3.3.1 General

The NUHOMS® system is designed for safe and secure, long-term containment and dry storage of SFAs. The components, structures, and equipment which are designed to assure that this safety objective is met are shown in Table 3.3-1. The key elements of the NUHOMS® system and its operation which require special design consideration are:

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

B. The double closure seal welds on the DSC shell to form a pressure retaining containment boundary and to maintain a helium atmosphere.

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

D. Design of the transfer cask and DSC for postulated accidents.

E. Design of the HSM passive ventilation system for effective decay heat removal to ensure the integrity of the fuel cladding.

F. Design of the DSC basket assembly to ensure subcriticality.

These items are addressed in the following subsections.

### 3.3.2 Protection by Multiple Confinement Barriers and Systems

#### 3.3.2.1 Confinement Barriers and Systems

The radioactive material which the NUHOMS® ISFSI confines is the spent fuel assemblies and the associated contaminated materials. These radioactive materials are confined by the multiple barriers listed in Table 3.3-2.

During fuel loading operations, the radioactive material in the plant's fuel pool is prevented from contacting the DSC exterior by filling the cask/DSC annulus and DSC with uncontaminated, demineralized water prior to placing the cask and DSC in the fuel pool. This places uncontaminated water in the annulus between the DSC and cask interior. In addition, the cask/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 DSC exterior surface. The combination of the above operations assures that the DSC surface loose contamination levels are within those required for shipping cask externals (see Section 3.3.7.1). Compliance with these contamination limits is assured by taking surface swipes of the upper end of the DSC while resting in the cask in the decon area.

Once inside the DSC, the SFAs are confined by the DSC shell and by multiple barriers at each end of the DSC. As listed in Table 3.3-2, the fuel cladding is the first barrier for confinement of radioactive materials. The fuel cladding is protected by maintaining the cladding temperatures during storage below those levels which may cause degradation of the cladding. In addition, the SFAs are stored in an inert atmosphere to prevent degradation of the fuel, specifically cladding rupture due to oxidation and its resulting volumetric expansion of the fuel. Thus, a helium atmosphere for the DSC is incorporated in the design to protect the fuel cladding integrity by inhibiting the ingress of oxygen into the DSC cavity.

Helium is known to leak through valves, mechanical seals, and escape through very small passages because of its small atomic diameter and because it is an inert element and exists in a monatomic species. Negligible leakage rates can be achieved with careful design of vessel closures. Helium will not, to any practical extent, diffuse through stainless steel (3.33). For this reason the DSC has been designed as a redundant weld-sealed containment pressure vessel with no mechanical or electrical penetrations. The NUHOMS®-32PT and 24PHB DSC are designed to meet the leak tight criteria discussed in Appendices M and N, respectively.

The DSC itself has a series of barriers to ensure the confinement of radioactive materials. The DSC cylindrical shell is fabricated from rolled ASME stainless steel plate which is joined with full penetration 100% radiographed welds. All top and bottom end closure welds are multiple-layer welds. This effectively eliminates a pinhole leak which might occur in a single layer weld, since the chance of pinholes being in alignment on successive weld layers is not credible. Furthermore, the DSC cover plates are sealed by separate, redundant closure welds. All the DSC pressure boundary welds are inspected according to the appropriate articles of the ASME Boiler and Pressure Vessel Code, Section III, Division 1, Subsection NB except as noted in the Table 4.8-1. This criteria insures that the weld filler metal is as sound as the parent metal of the pressure vessel. The NUHOMS®-61BT DSC is designed and tested to meet the leak tight criteria discussed in Appendix K.

Pressure monitoring instrumentation is not used since penetration of the pressure boundary would be required. The penetration itself would then become a potential leakage path and by its presence compromise the integrity of the DSC design. The DSC shell and welded cover plates provide total confinement of radioactive materials. Once the DSC is sealed, there are no credible events which could fail the DSC cylindrical shell or the double closure plates which form the DSC containment pressure boundary. This is discussed further in Chapter 8.

$U_{MECH}$ = mechanical uncertainty ($2\sigma$)

All the mechanical uncertainties are considered independent, hence they are calculated by adding in quadrature. The previous sections and Table 3.3-24 provide detailed discussion of each of the terms in $U_{MECH}$.

3.3.4.3.2 Off-Normal Conditions (NUHOMS®-52B)

A. Misloading of One or More Unirradiated Fuel Assemblies into the DSC

The NUHOMS®-52B criticality analysis does not include credit for burnup. All fuel is assumed to be unirradiated, therefore there is no impact on $k_{eff}$ if such fuel is inadvertently loaded.

B. Optimum Moderation

The moderator density study reveals that intermediate moderator densities (as in boiling or reflood splashing) have a negative effect on reactivity. It is determined, however, that very cold water (with a slightly higher density than 20°C water) would result in a slightly higher $k_{eff}$. This effect is included in the baseline $k_{eff}$ as part of the mechanical uncertainty.

C. Loss of an Absorber Panel

Loss of one or more absorber sheets is not proposed as a credible accident. It is included only to demonstrate the inherent criticality safety of the NUHOMS®-52B design. The analysis is performed by analyzing the system with first one, then four of the central neutron absorbing sheets absent from the model.

The results are summarized in Table 3.3-23. This design is capable of suffering the loss of an entire central absorber sheet (presumably the most important sheet) with a positive reactivity change of only 0.010 $\Delta k$. Table 3.3-23

Clearly, manufacturing defects in the specified width, thickness, or straightness of a single sheet would have negligible impact on the overall system reactivity. Removal of the innermost four absorber sheets, however, would result in an increase in $k_{eff}$ of 0.050 $\Delta k$.

D. Flooded ISFSI Site

The flooded site case is modeled using KENO and is found to have a reactivity of approximately 0.34; thus it is not a limiting scenario.

3.3.4.3.3 Safety Criteria Compliance (NUHOMS®-52B)

The calculated worst-case $k_{eff}$ value for a fully loaded NUHOMS®-52B DSC flooded with pure unborated water is 0.919. This calculated maximum $k_{eff}$ includes consideration of all calculational, geometrical, and material uncertainties and biases at a 95/95 tolerance level as required by ANSI/ANS 57.2-1983 to demonstrate criticality safety.

Additionally, there are no credible off-normal conditions which could increase reactivity beyond the normal conditions considered above.

The analyses presented in this SAR section demonstrate that the ANSI/ANS 57.2-1983 criteria limiting $k_{eff}$ to 0.95 is satisfied under all postulated conditions for the NUHOMS®-52B.

3.3.4.4 NUHOMS®-61BT DSC Criticality Safety

The NUHOMS®-61BT DSC criticality analyses are described in Appendix K.

3.3.4.5 NUHOMS®-24PT2 DSC Criticality Safety

The NUHOMS®-24PT2 DSC criticality analyses are described in Appendix L.

3.3.4.6 NUHOMS®-32PT DSC Criticality Safety

The NUHOMS®-32PT DSC criticality analyses are described in Appendix M.

3.3.4.7 NUHOMS®-24PHB DSC Criticality Safety

The NUHOMS®-24PHB DSC criticality analyses are described in Appendix N.

3.3.5 Radiological Protection

The NUHOMS® ISFSI is designed to maintain on-site and off-site doses 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 on on-site and off-site doses resulting from NUHOMS® ISFSI operations and the ISFSI ALARA evaluation are provided in Chapter 7. Appendices K, L, M and N provide the on-site and off-site doses resulting from the use of NUHOMS®-61BT, 24PT2, 32PT and 24PHB systems, respectively, at an ISFSI.

3.3.5.1 Access Control

The NUHOMS® ISFSI is located within the owner controlled area of the plant. A separate protected area consisting of a double fenced, double gated, lighted area is generally installed around the ISFSI. Access is controlled by locked gates, and guards are stationed when the gates are open. The licensee's Security Plan should describe the remote sensing devices which are employed to detect unauthorized access to the facility.

In addition to the controlled access, a method of providing a security tamper seal may be implemented after insertion of a loaded DSC. The form to use could be, but is not limited to, one of the following:

Tack welding an HSM access door

Fully welding an HSM access door

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

Tamper seals

Existing HSM closure bolt torquing

The HSM access door weighs approximately three tons and requires heavy equipment for removal. This ensures that there is ample time to respond to an unauthorized entry into the ISFSI before access can be gained to any radiological material.

3.3.5.2 Shielding

For the NUHOMS® system, shielding is provided by the HSM, transfer cask, and shield plugs of the DSC. The NUHOMS® standardized HSM is designed to minimize the surface dose to limit occupational exposure and the dose at the ISFSI fence. Experience has confirmed that the dose rates for the HSM are extremely low. A shield wall may be removed for a period of time as part of facility installation or expansion. However, if applicable, compensatory measures shall be taken for radiation shielding. The NUHOMS® transfer cask and the DSC top shield plug are designed to limit the surface dose rates (gamma and neutron) ALARA. Temporary neutron shielding may be placed on the DSC shield plug and top cover plate during closure operations. Similarly, additional temporary shielding may be used to further reduce surface doses. Radiation zone maps of the HSM, cask, DSC surfaces and the area around these components are provided in Chapter 7 for the NUHOMS®-24P and NUHOMS®-52B systems. Appendices K, L, M, and N provide the results with the NUHOMS®-61BT, 24PT2, 32PT, and 24PHB DSCs, respectively.

3.3.5.3 Radiological Alarm Systems

There are no radiological alarms required for the NUHOMS® ISFSI.

### 3.3.6 Fire and Explosion Protection

The NUHOMS® HSM and DSC contain no flammable material and 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. The facility should be located such that the plant fire brigade can respond to any fire emergency using portable fire suppression equipment.

ISFSI initiated explosions are not considered credible since no explosive materials are present in the fission product or cover gases. Externally initiated explosions are considered to be bounded by the design basis tornado generated missile load analysis presented in Section 8.2.2. Licensees are required by 10CFR72 Subpart K to confirm that no conditions exist near the ISFSI that would result in pressures due to off-site explosions which would exceed those postulated herein for tornado missile or wind effects. An HSM shield wall(s), which protects against missiles, may be removed for a period of time. However, compensatory measures shall be considered to protect against missiles, if necessary.

Although not explicitly required by the current 10CFR72 (no specific load case), the NUHOMS® design has been reviewed with regard to its susceptibility to sabotage. The issue of sabotage was addressed during public hearings on the TN West Standardized NUHOMS® system (3.67). The specific issues related to sabotage discussed during this hearing were attacks by a truck bomb, a hand held bomb, and a shaped charge placed by saboteurs approaching on foot.

A summary of the conclusions of this review reflecting the expert opinion [3.67] from the public hearing testimony are presented below:

Due to the rugged construction of the HSM, it would take large amounts of explosive (more than 50,000 lbs. of explosive) at very close distances in order to inflict any severe damage to the NUHOMS® facility. It was determined that, due to plant security and vehicle barriers, the scenario of truck bombs is not a feasible scenario. In addition, an explosion resulting from a shaped charge or hand held bomb was not deemed to be severe enough to penetrate a 24" thick concrete shield wall, a 6" air gap, another 18" thick interior concrete wall, and then through the 5/8" thick stainless steel shell of the DSC to cause a leak of radioactive material.

Considering the scenario of someone placing a shape charge inside the HSM through the bottom air vent at a distance below dry shielded canisters sufficient to cause leakage of radioactive material, experiments show [3.67] that the amount of leakage (escape) is much less than 1% of the inventory. The majority of the leakage would remain within the HSM shielded by the concrete walls, rather than escaping through the vents. Consequently, any potential release of radioactive material would be minor.

It should also be noted that a recent regulatory mandate [3.68 and 3.69] has required all U.S. utilities owning and operating nuclear plants to evaluate and protect their facility against the threat of sabotage by car or truck bomb. This evaluation has resulted in increased protection of the plant's vital areas through adoption of explosion-proof barriers and gates. Site specific ISFSI locations within the plant's protected area would be subject to the requirements of this mandate, thus requiring the applicants to ensure the same level of barrier protection for ISFSIs to safeguard against possible sabotage.

Licensees are required to verify that loadings resulting from potential fires and explosions are acceptable in accordance with 10CFR72.212(b)(2).

### 3.3.7 Materials Handling and Storage

#### 3.3.7.1 Spent Fuel Handling and Storage

All spent fuel handling outside the plant's fuel pool is performed with the fuel assemblies contained in the DSC. Subcriticality during all phases of handling and storage is discussed in Section 3.3.4. The criterion for a safe configuration is an effective mean plus two-sigma neutron multiplication factor ($k_{eff}$) of 0.95. Section 3.3 calculations show that the expected $k_{eff}$ value is below this limit.

Lift height restrictions are imposed on the TC and DSC with regard to their location and load temperatures. These restrictions are provided in Technical Specifications 1.2.10 and 1.2.13.

##### 3.3.7.1.1 Cladding Temperature Limits

Maximum allowable cladding temperature limits are determined for both BWR and PWR design basis fuel according to the methodology presented in Reference 3.21. The maximum allowable average cladding temperature for long term storage is based on the end of life hoop stress in the cladding and the cladding temperature at the beginning of dry storage. The method is estimated to calculate a storage temperature limit that will result in a probability of cladding breach of less than 0.5% in the peak rod during storage. Using this methodology produces cladding temperature limit of 381°C for design basis PWR fuel and 394°C for the design basis BWR fuel cooled for five years or more. Appendix K addresses the cladding temperature limits for the BWR fuel in the NUHOMS®-61BT DSC and Appendix L addresses the cladding temperature limits for the PWR fuel in the NUHOMS®-24PT2 DSC. Since the damage mechanism in this methodology is thermal creep, the temperature limits are based on an average long term ambient temperature during storage of 70°F.

381°C (718°F) and 394°C (741°F) are the cladding temperature limits calculated for design basis 5-year cooled PWR and BWR fuel, respectively. Three steps were taken to extend the same methodology to the range of cooling times in the Fuel Qualification Table shown in 72-1004 CoC technical specifications. First, the same thermal computer models used to perform the design basis cladding temperature calculation were run parametrically to determine cladding temperature vs. heat input for the PWR and BWR baskets. Second, the methodology of Reference 3.21 was used to develop a relationship between the maximum cladding temperature limit vs. cooling times beyond 5 years. This relationship is shown as a function of fuel burnup in Figure 3.3-17 for PWR fuel and in Figure 3.3-18 for BWR fuel. Third, these two functions were combined to obtain maximum heat input vs. cooling time. In this way, each cell of the Fuel Qualification Table has its own unique cladding temperature limit based on the same methodology as was used for the design basis fuel assemblies.

Higher cladding temperatures may be sustained for brief periods without affecting cladding integrity, however. During short term conditions such as DSC drying, transfer of the DSC to and from the HSM, and off-normal and accident temperature excursions, the maximum fuel cladding temperature is limited to 570°C (1,058°F) or less. This value is based on the results of experiments which have shown that Zircaloy clad rods subjected to short term temperature excursions below 570°C did not show indications of failure (3.20).

Appendices M and N address the cladding temperature limits and the associated bases for the fuel stored in the NUHOMS®-32PT and 24PHB DSCs, respectively.

3.3.7.1.2 <u>Fuel Rod Horizontal Storage Effects</u>

There is considerable industry experience in the shipment of fuel assemblies in the horizontal position without any indication of fuel rod creep or sag. During overseas shipments, spent fuel assemblies remain horizontal for up to two to three months with estimated cladding temperatures up to 385°C. It should also be noted that the environment for shipping fuel assemblies, given the handling and transportation shock loadings and vibrations is much harsher than that of passive environment of dry storage.

Analytical studies of fuel rod creep behavior have also been conducted in conjunction with the NRC approval of the NUHOMS®-24P TR as documented in Reference 3.51. The studies utilized the creep equation of M. Peehs, et. al. to determine whether creep of fuel were found to be less than 1% for the total storage period. The deflection of the fuel rods between spacer grids was calculated directly since creep effects were found to be negligible. Using standard beam theory for a uniformly loaded tubular beam, conservatively neglecting the bending stiffness of the fuel itself, the maximum deflection over the storage period was found to be 0.015 inches. Deflections of such magnitude do not impede retrieval of the fuel assemblies from the DSC, therefore these effects are not evaluated further.

3.3.7.1.3 <u>Surface Contamination Limits</u>

DSC exterior contamination is minimized by preventing spent fuel pool water from contacting the DSC exterior. DSC loading procedures require that the annulus between the transfer cask and DSC be filled with demineralized water and sealed prior to immersion in the spent fuel pool. Annulus sealing is accomplished by an inflatable seal between the transfer cask and DSC. The combination of the above operations provides assurance that the DSC exterior surface has less residual contamination than required for

### 3.4.5 Auxiliary Equipment

The vacuum drying system and the automatic welding system are not "important to safety". 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 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 10CFR72. These components are designed, constructed, and tested in accordance with good industry practices.

Table 3.4-1
NUHOMS® Major Components and Safety Classification

| Component | 10CFR72 Classification |
|---|---|
| Dry Storage Canister (DSC) [4] | Important to Safety [1] |
| Guide Sleeves (24P and 24PHB) | |
| Oversleeves (24P and 24PHB)) | |
| Oversleeves (24PT2) | |
| Spacer Disks | |
| Support Rods | |
| Spacer Sleeves (52B only) | |
| Support Bars (52B only) | |
| Neutron Absorbing Plates (52B only) | |
| Shield Plugs [3] | |
| DSC Shell | |
| Cover Plates | |
| Grapple Ring and Grapple Support | |
| Siphon and Vent Block | |
| Siphon and Vent Port Cover Plates | |
| DSC Support Ring | |
| Weld Filler Metal | |
| Horizontal Storage Module (HSM) | Important to Safety [1] |
| Reinforced Concrete | |
| DSC Support Structure | |
| ISFSI Basemat and Approach Slabs | Not Important to Safety |
| Transfer Equipment | |
| On-site Transfer Cask | Important to Safety [1] |
| Cask Lifting Yoke | Safety Related [2] |
| Transport Trailer/Skid | Not Important to Safety |
| Ram Assembly | Not Important to Safety |
| Dry Film Lubricant | Not Important to Safety |
| | Not Important to Safety |
| Auxiliary Equipment | |
| Vacuum Drying System | |
| Automatic Welding System | |

(1) Structures, systems and components "important to safety" are defined in 10CFR72.3 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 10CFR50.

(3) For 24P Long Cavity, 24PT2L, and 24PHB DSCs.

(4) See Appendices K and M for the NUHOMS®-61BT and 32PT DSC components and safety classification.

## 4.2 Storage Structures

### 4.2.1 Structural Specifications

The design bases for the NUHOMS® ISFSI are described in Chapter 3. Fabrication and construction specifications will be utilized in accordance with 10CFR72 (4.1) and industry codes and standards. The codes and standards used for fabrication and construction the NUHOMS® components, equipment, and structures are identified throughout the SAR. They are summarized as follows:

| Component, Equipment, Structure | Code of Construction |
|---|---|
| DSC | ASME Code, Section III, Division 1, 1983 Edition with Winter 1985 Addenda (4.5) Subsection NB, Subsection NF, and Appendix F with exceptions as noted in Section 4.8 of this SAR. |
| Transfer Cask | ASME Code, Section III, Division 1, 1983 Edition with Winter 1985 Addenda (4.5) Subsection NC as applicable for non-pressure retaining vessels, with exceptions as noted in Section 4.9 of this SAR. |
| HSM | ACI-318-83 Code (4.10) |
| DSC Supports | AISC Specification, 1990, Ninth Edition (4.11) |
| Transfer Equipment | AISC, ANSI, AWS and/or other applicable Standards |

The ASME Code boundaries for the 24P and 52B DSCs and the transfer cask are identified on the corresponding Appendix E drawings. The code boundary for the NUHOMS®-61BT, 24PT2, 32PT, and 24PHB DSCs are provided in Appendices K, L, M, and N, respectively.

4.2.2 Installation Layout

The specific layout of the ISFSI will be developed by the licensee in accordance with the requirements of 10CFR72. Layouts for typical NUHOMS® ISFSIs are shown in Figures 1.3-11 through 1.3-13. The functional features of the NUHOMS® storage structures are shown on the Appendix E drawings. Radioactive particulate matter and gaseous fission products are confined within the DSC as discussed in Sections 1.2 and 1.3.

4.2.3 Individual Unit Description

4.2.3.1 Dry Shielded Canister

The following description is applicable to the 24P, 24PHB, and 52B DSC designs. Any differences in the 24PHB configuration relative to the 24P DSC are described in Appendix N. The design description for the 61BT, 24PT2 and 32PT DSCs is included in Appendices K, L and M, respectively. The DSC is a high integrity stainless steel welded pressure vessel that provides confinement of radioactive materials, encapsulates the fuel in a helium atmosphere, and, when placed in the transfer cask, provides biological shielding during DSC closure and transfer operations. With the exceptions noted in Section 4.8, the DSC shell assembly and associated subcomponents conform to the requirements of the ASME B&PV Code Section III, Division 1, Subsection NB while the DSC basket assembly conforms to Subsection NF. The NUHOMS® DSC design is illustrated in Figures 1.3-1 through 1.3-3. Drawings for the standardized, 24PT2, 32PT and 24PHB DSC are contained in Appendices E, L, M and N, respectively.

The DSC cylindrical shell is fabricated from rolled and butt-welded stainless steel plate material as shown in Figure 4.2-1. Stainless steel cover plates and thick carbon steel or lead encased in steel shielding material form the DSC top and bottom end assemblies. The cover plates are double seal welded to the DSC shell to form the containment pressure boundary.

The DSC shell, and top and bottom end assemblies enclose a non-pressure retaining basket assembly which serves as the structural support for the SFAs as shown in Figure 4.2-2 and Figure 4.2-3. The primary components of the basket assembly are the spacer discs, which maintain cross sectional spacing of (and provide lateral support to) the fuel assemblies within the DSC, and the support rods, which hold the spacer discs in place and maintain longitudinal separation of the spacer discs during a postulated cask drop accident.

The PWR NUHOMS-24P fuel basket assembly consists of 24 stainless steel guide sleeves, eight carbon steel spacer discs and four Type XM-19 stainless steel support rods. The inner guidesleeves in the assembly are equipped with stainless steel oversleeves placed at both ends of the basket assembly between the two top and bottom spacer discs. No connection exists between the spacer discs and the guidesleeves. Guidesleeve stops fabricated from stainless steel plate strips and plug welded to the sides of the guidesleeves prevent removal of the guidesleeves from the basket if a fuel assembly becomes stuck during insertion or removal. Criticality control is achieved by use of water with dissolved boron in the DSC cavity as described in Section 3.3.

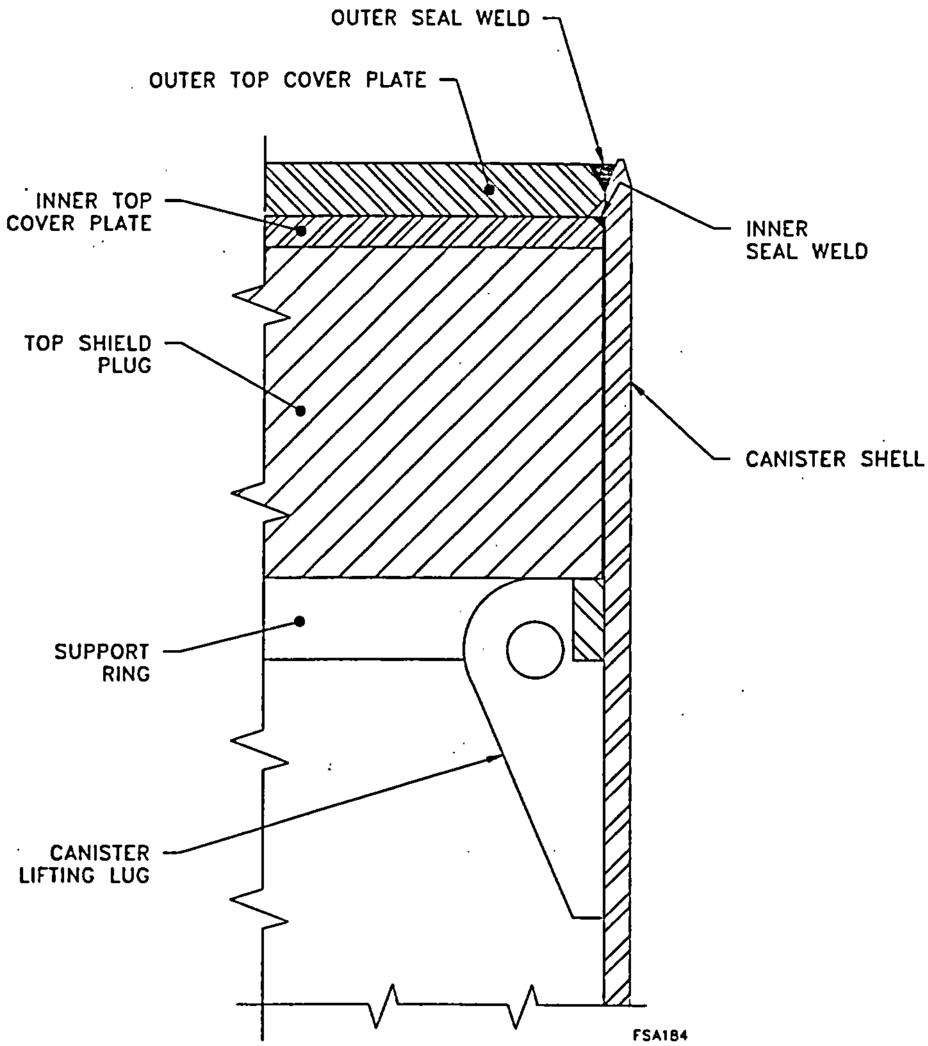
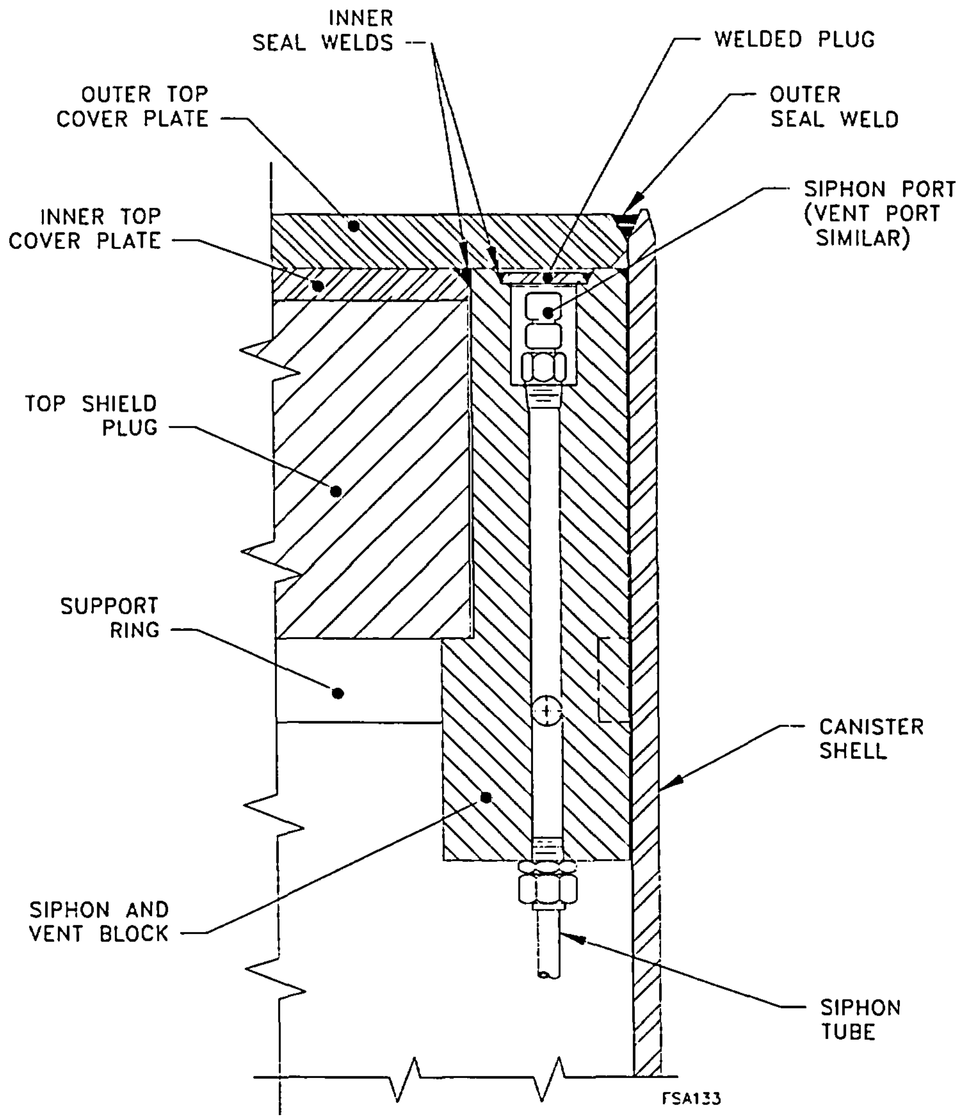



**Figure 4.2-4**
**DSC Top Shield Plug and Cover Plate Closure Welds**




Note: For 24PHB DSC outer top cover plate and test port plug weld closure details, see Appendix N.

**Figure 4.2-5**
**DSC Siphon and Vent Port Closure Welds**

# 5. OPERATION SYSTEMS

This Chapter presents the operating procedures for the standardized NUHOMS® system described in previous chapters and shown on the drawings in Appendix E for the 24P and 52B systems. The operating procedures for the 61BT, 24PT2, 32PT, and 24PHB systems are described in Appendices K. L, M, and N, respectively. The procedures include preparation of the DSC and fuel loading, closure of the DSC, transport to the ISFSI, DSC transfer into the HSM, monitoring operations, and DSC retrieval from the HSM. The standardized NUHOMS® transfer equipment, and the existing plant systems and equipment are used to accomplish these operations. Procedures are delineated here to describe how these operations are to be performed and are not intended to be limiting. Standard fuel and cask handling operations performed under the plant's 10CFR50 operating license are described in less detail. Existing operational procedures may be revised by the licensee and new ones may be developed according to the requirements of the plant, provided that the limiting conditions of operation specified in Technical Specifications, Functional and Operating Limits of the NUHOMS® CoC (5.6) are not exceeded.

## 5.1 Operation Description

The following sections outline the typical operating procedures for the standardized NUHOMS® system. These generic NUHOMS® procedures have been developed to minimize the amount of time required to complete the subject operations, to minimize personnel exposure, and to assure that all operations required for DSC loading, closure, transfer, and storage are performed safely. Plant specific ISFSI procedures are to be developed by each licensee in accordance with the requirements of 10CFR72.24 (h) and the guidance of Regulatory Guide 3.61 (5.7). The generic procedures presented here are provided as a guide for the preparation of plant specific procedures and serve to point out how the NUHOMS® system operations are to be accomplished. They are not intended to be limiting, in that the licensee may judge that alternate acceptable means are available to accomplish the same operational objective.

The generic operating procedures presented herein also do not address the use of auxiliary equipment which is optional or represents a level of detail which a licensee may choose to implement based on licensee preference. Examples of such auxiliary items are the Neutron Shield Overflow Tank (used with OS197 or OS197H Cask only), TC/DSC Annulus Pressurization Tank, and the Shield Plug Restraints.

### 5.1.1 Narrative Description

The following steps describe the recommended generic operating procedures for the standardized NUHOMS® system. Flowcharts of NUHOMS® system loading and retrieval operations are provided in Figure 5.1-1 and Figure 5.1-2, respectively.

#### 5.1.1.1 Preparation of the Transfer Cask and DSC

1. Prior to placement in dry storage, the candidate fuel assemblies are to be visually examined to insure that no known or suspected gross cladding breaches exist. Pinholes and hairline cracks are acceptable. Verification of fuel integrity may also be accomplished using suitable existing plant records. The assemblies shall be evaluated (by plant records or other means) to verify that they meet the physical, thermal and radiological criteria specified in Technical Specification 1.2.1.

2. Prior to being placed in service, the transfer cask is to be cleaned or decontaminated as necessary to insure a surface contamination level of less than those specified in Technical Specification 1.2.12.

3. Place the transfer cask in the vertical position in the cask decon area using the cask handling crane and the transfer cask lifting yoke.

4. Place scaffolding around the cask so that the top cover plate and surface of the cask are easily accessible to personnel.

5. Remove the transfer cask top cover plate and examine the cask cavity for any physical damage and ready the cask for service.

6. Examine the DSC for any physical damage which might have occurred since the receipt inspection was performed. The DSC is to be cleaned and any loose debris removed.

7. Using a crane, lower the DSC into the cask cavity by the internal lifting lugs and rotate the DSC to match the cask and DSC alignment marks.

8. Fill the cask-DSC annulus with clean, demineralized water. Place the inflatable seal into the upper cask liner recess and seal the cask-DSC annulus by pressurizing the seal with compressed air.

9. Fill the DSC cavity with water from the fuel pool or an equivalent source which meets the requirements of Technical Specification 1.2.15. For PWR fuel, the

## 7.2 Radiation Sources

### 7.2.1 Characterization of Sources

This section describes the design basis radiation source strengths and source geometries used for the standardized NUHOMS® 24P and 52B systems shielding design calculations. Appendices K, L, M, and N describe the same for the NUHOMS®-61BT, 24PT2, 32PT, and 24PHB systems, respectively.

The neutron and gamma radiation sources include the design basis PWR and BWR spent fuel, activated portions of the fuel assembly, and secondary gammas. All sources, except secondary gammas, are considered physically bound in the source region. Secondary gammas are produced by neutrons passing through shielding regions.

The design basis PWR spent fuel for the NUHOMS®-24P system has been subjected to an average fuel burnup of 40,000 MWD/MTU. The maximum initial enrichment is 4.0 weight percent U-235 and a post-irradiation cooling time equivalent to five years is assumed. Similarly, the design basis BWR spent fuel for the NUHOMS®-52B system has been subjected to an average fuel burnup of 35,000 MWD/MTU with a maximum initial enrichment of 4.0 weight percent U-235 and a cooling time of five years. Spent fuel assemblies which meet these criteria are bounded by the source strengths used in this analysis.

Neutron sources are based on spontaneous fission contributions from six nuclides (predominantly Cm-242, Cm-244, and Cm-246 isotopes), and $(\alpha,n)$ reactions due almost entirely to eight alpha emitters, (predominantly Pu-238, Cm-242, and Cm-244). The fission spectrum used in shielding calculations is a weighted combination of the principal contributors. The total neutron source strength for PWR fuel is 2.23E8 neutrons per second per assembly. Similarly, the total neutron source strength for BWR fuel is 1.01E8 neutrons per second per fuel assembly. The neutron energy spectrum and flux-to-dose conversion factors are presented in Table 7.2-1 and Table 7.2-2.

Gamma radiation sources include 70 principal fission product nuclides within the spent fuel, and several activation products and actinide elements present in the spent fuel and fuel assemblies. The gamma energy spectrum includes contributions from each source isotope as determined by ORIGEN calculations for the design basis spent fuel. The total gamma source strength for PWR fuel is 5.81E15 MeV/s/MTHM. Similarly the total gamma source strength for BWR fuel is 4.86E15 MeV/s/MTHM. The gamma energy spectrum and flux-to-dose conversion factors are presented in Table 7.2-3 and Table 7.2-4. The gamma source due to control components, which represents less than 10% of the fuel source, is addressed in Appendix H.

The source geometries for neutron shielding calculations are either cylindrical or slab, depending on whether neutron dose rates are required in the radial or axial direction around the DSC, respectively. Section 7.3.2 contains detailed descriptions of the neutron source model geometries.

The gamma shielding calculations are based on cylindrical source models. A source mesh is defined for each shielding model with increasingly finer mesh spacing near detectors. Symmetry is taken advantage of wherever possible to facilitate the use of more mesh points. Section 7.3.2 further describes the gamma source models.

### 7.2.2 Airborne Radioactive Material Sources

The release of airborne radioactive material is addressed for three phases of system operation: fuel handling in the spent fuel pool, drying and sealing of the DSC, and DSC transfer and storage. Potential airborne releases from irradiated fuel assemblies in the spent fuel pool are discussed in the plant's existing 10CFR50 license.

DSC drying and sealing operations are performed using procedures which prohibit airborne leakage. During these operations, all vent lines are routed to the plant's existing radwaste systems. Once the DSC is dried and sealed, there are no design basis accidents which could result in a breach of the DSC and the airborne release of radioactivity. Design provisions to preclude the release of gaseous fission products as a result of accident conditions are discussed in Section 8.2.8.

During transfer of the sealed DSC and subsequent storage in the HSM, the only postulated mechanism for the release of airborne radioactive material is the dispersion of non-fixed surface contamination on the DSC exterior. By filling the cask/DSC annulus with demineralized water, placing an inflatable seal over the annulus, and utilizing procedures which require examination of the annulus surfaces for smearable contamination, the contamination limits on the DSC can be kept below the permissible level for off-site shipments of fuel. Therefore, there is no possibility of significant radionuclide release from the DSC exterior surface during transfer or storage.

the axial direction to that of the DSC shield plugs. Figure 1.3-6 shows the physical arrangement of the transfer cask top and bottom end assembly.

Additional portable shielding during DSC handling, transport and transfer operations may be utilized by the licensee, if desired. Section 7.4 conservatively provides an assessment of design basis on-site doses without the use of portable shielding.

7.3.2.2 Shielding Analysis

This section describes the radiation shielding analytical methods and assumptions used in calculating NUHOMS® 24P and 52B systems dose rates during the handling and storage operations. Appendices K, L, M, and N describe the same for the NUHOMS®-61BT, 24PT2, 32PT, and 24PHB systems, respectively. The dose rates of interest are calculated at the locations listed in Table 7.3-2 for 5 year cooled design basis PWR fuel. Table 7.3-3 shows the dose rates for 10 year cooled PWR fuel which are included for information only. Figure 7.3-3 shows these locations on the HSM, DSC and transfer cask. The dose rates reported in Tables 7.3-2 and 7.3-3 for the DSC with the HSM are for HSM Model 80 which bounds the dose rates for HSM Model 102. The computer codes used for analysis are described below, each with a brief description of the input parameters generic to its use. Descriptions of the individual analytical models used in the analysis are also provided. Consistent with the relative design basis source strengths, the shielding analysis results for the NUHOMS®-24P envelop those of the NUHOMS®-52B systems, except on the bottom of the DSC. The bottom of the NUHOMS®-52B canister has 0.5" less steel shielding. The effect of this difference on the dose rates at the bottom surface of the transfer cask and the HSM with and without the door are provided in Tables 7.3-4 and 7.3-5 for 5 and 10 year cooled BWR fuel, respectively.

A. Computer Codes ANISN (7.1), a one-dimensional, discrete ordinates transport computer code, is used to obtain neutron and gamma dose rates at the outer HSM walls, and at the outside surface of the loaded transfer cask in the radial direction. ANISN is also used to obtain the axial neutron dose rates at the shield plugs of the DSC, the transfer cask, and outside the HSM access door. The CASK cross section library, which contains 22 neutron energy groups and 18 gamma energy groups, is applied in an $S_8P_3$ approximation for cylindrical or an $S_{16}P_3$ approximation for slab geometry, respectively (7.7). Calculated radiation fluxes are multiplied by flux-to-dose conversion factors (Table 7.2-1, Table 7.2-2, Table 7.2-3, and Table 7.2-4) to obtain final dose rates. The ANISN calculations use the coupled neutron and gamma libraries. Therefore, dose rates from both primary and secondary gammas are calculated in each run.

QAD-CGGP (7.2), a three-dimensional point-kernel code, is used for the axial gamma shielding analysis of the HSM access door, the DSC and cask end assemblies, the DSC-cask annular gap, and the HSM air vent penetrations. Mass attenuation and buildup factors are obtained from QAD-CGGP's internal library. The gamma energy spectrum is taken directly from ORIGEN.

Since QAD-CGGP calculates dose rates from primary gammas only, the primary gamma source strength in the active fuel region is increased for calculations in the axial direction of the DSC. This is done as a way to include the dose rate effect due to secondary gammas primarily generated in the shield plug material of the DSC and additional activation products located in the fuel assembly end fittings. Previous licensing calculations indicate that secondary gammas contribute only one percent of the total gamma radiation dose rate in the HSM concrete. Therefore, these effects are neglected for the QAD-CGGP analysis for the HSM concrete.

In order to substantiate increasing the primary gamma source strength when using QAD-CGGP for axial calculations, a set of benchmarking runs are performed. For this calibration analysis, QAD-CGGP is used to model an actual metal storage cask containing spent PWR fuel where the geometry of the cask and the contained fuel is similar to that of NUHOMS® and actual measured dose rates at the cask ends are available (7.10). As a result, it is concluded that increasing the primary gamma source strength in the active fuel region for the QAD-CGGP runs resulted in the maximum calculated dose rates at the cask ends meeting or slightly exceeding the maximum measured dose rates (average calculated dose rates exceeded average measured dose rates across the entire cask ends). Therefore, increasing the gamma source strength in the active fuel region when using QAD-CGGP for estimating gamma dose rates in the DSC axial direction results in conservative values.

Manual albedo calculations are used in conjunction with the fluxes calculated by QAD-CGGP and ANISN to provide upper bounds on the reflected dose rate at the HSM front wall and roof vent screens and the DSC/cask annular gap. The albedo method used is described in References 7.8 and 7.9.

B. HSM Surface Dose Rates The ANISN analytical model used to determine neutron and gamma dose rates outside the thick HSM walls (or roof) is presented in Appendix A. The DSC/HSM is represented by a cylindrical model which includes a homogenized, isotropic, self-shielding source region, the HSM heat shield, an air gap between the DSC and the thick concrete wall or roof. The effective radius of the source region is chosen to be the inside radius of the DSC. The mesh size in each material region is chosen to be on the order of one mean free path of neutrons through that material. A buckling factor correction for the infinite length model is made to estimate the dose rates at the active fuel region midplane.

C. Cask and HSM Axial Dose Rates An ANISN model of an infinite slab is also used to calculate the neutron dose rates in the axial direction (e.g., at the DSC top and bottom cover plate surfaces).

Appendix A illustrates the analytical QAD-CGGP models for the top and bottom axial dose rate calculations, respectively. A simple 3-D slab shield geometry and cylindrical source

Figure 7.3-4

Included in Appendix A

Figure 7.3-5

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Figure 7.3-6

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Figure 7.3-7

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Figure 7.3-8

Included in Appendix A

Figure 7.3-9

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Figure 7.3-10

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Figure 7.3-11

Included in Appendix A

## 7.4 Estimated On-Site Collective Dose Assessment

### 7.4.1 Operational Dose Assessment

This SAR section establishes the anticipated cumulative dose exposure to site personnel during the fuel handling and transfer activities associated with utilizing one NUHOMS® HSM for storage of one DSC. Chapter 5 describes in detail the NUHOMS® operational procedures, a number of which involve potential radiation exposure to personnel.

A summary of the operational procedures which result in radiation exposure to personnel is given in Table 7.4-1. The cumulative dose can be calculated by estimating the number of individuals performing each task and the amount of time associated with the operation. The resulting man-hour figures can then be multiplied by appropriate dose rates near the transfer cask surface, the exposed DSC top surface, or the HSM front wall. Dose rates can be obtained from the Section 7.3 results of dose rate versus distance from the cask side, DSC top end (with and without the top cover plate and cask lid in place) and HSM front wall for the 24P and 52B DSCs. Similar results with the NUHOMS®-61BT, 24PT2, 32PT, and 24PHB DSCs are provided in Appendices K, L, M, and N, respectively.

Every operational aspect of the NUHOMS® system, from canister loading through drying, sealing, transport, and transfer is designed to assure that exposure to occupational personnel is as low as reasonably achievable (ALARA). In addition, many engineered design features are incorporated into the NUHOMS® system which minimize occupational exposure to plant personnel during placement of fuel in dry storage as well as off-site dose to the nearest neighbor during long-term storage. The resulting dose at the ISFSI site boundary is to be within the limits specified by 10CFR72 and 40CFR190.

Based on the experience for an operating NUHOMS® system, the occupational dose for placing a canister of spent fuel into dry storage for the operational steps listed in Table 7.4-1 is less than 1.2[1] man-rem. With the use of effective procedures and experienced ISFSI personnel, the total accumulated dose can be reduced further below one man-rem per canister.

### 7.4.2 Site Dose Assessment

Dose rate maps are constructed from the shielding analysis described in the previous sections. Direct neutron and gamma flux, as well as the air-scattered radiation from the module surfaces are considered. Figure 7.4-2 and Figure 7.4-3 provide a dose rate map in the general vicinity of a 2x10 array and two 1x10 arrays containing ten year cooled fuel.

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[1] The expected small additional occupational dose when loading PWR fuel with BPRAs into a NUHOMS® Long Cavity DSC is presented in Appendix J of the SAR. Similar evaluation is presented in Appendices M and N for the NUHOMS®-32PT and 24PHB systems, respectively.

Ten year fuel is shown since it is a physical impossibility for a utility to have a facility full of five year fuel. In fact, given the average age of fuel in U.S. storage pools, and the most probable NUHOMS® loading schedules, filled NUHOMS® ISFSIs should have substantially older fuel than indicated in the Figures.

The surface radiation sources used for the direct and air scattered dose calculations are shown in Figure 7.4-5 and Figure 7.4-6. The energy distribution of the neutron and gamma fluxes is taken from the applicable calculation as described in the previous sections. Air-scattered dose rates are determined with the computer code Micro SKYSHINE (7.4); direct dose rates are calculated using the computer code MICROSHIELD (7.11). No credit is taken for shielding by nearby structures or terrain. Initial loading of all HSMs with the ten year cooled fuel is assumed. Dose rates for the PWR DSC are provided since these values bound the BWR DSC dose rates.

The ISFSI is generally surrounded by a large open area for operational and security purposes. Access to the storage modules is restricted such that during storage, no access is allowed except for security and surveillance inspection purposes. There are generally no work areas close to the ISFSI. Additional dose to plant workers due to exposure from the ISFSI is negligible. Inspection of the HSM air vents can be maintained ALARA by keeping inspection personnel back from the HSM front wall a distance which permits adequate inspection. Appendix N provides the evaluation for the NUHOMS®-24PHB system.

Since the site dose for an ISFSI is highly site specific, each licensee should perform a dose analysis in accordance with 10CFR72.212. The analysis should consider existing plant conditions, the site specific arrangement of the ISFSI, the characteristics of the spent fuel to be placed in dry storage, and relevant empirical data as appropriate. The on-site dose analysis should demonstrate compliance with the 10CFR 72.104(a) limits for normal conditions and 10CFR72.106 and 10CFR100 for accident conditions.

Table 7.4-1
NUHOMS® System Operations Enveloping Time
for Occupational Dose Calculations

(for information only)

| | Number of Workers | Completion Time[3] (hours) |
|---|---|---|
| **Location: Auxiliary Building and Fuel Pool** | | |
| Ready the DSC and Transfer Cask for Service | 2 | 4.0 |
| Place the DSC into the Transfer Cask | 3 | 1.0 |
| Fill the Cask/DSC Annulus with Clean Water and Install the Inflatable Seal | 2 | 2.0 |
| Fill the DSC Cavity with Water (borated for PWRs)[1] | 1 | 6.0 |
| Place the Cask Containing the DSC in the Fuel Pool | 5 | 1.0 |
| Verify and Load the Candidate Fuel Assemblies into the DSC | 3 | 8.0 |
| Place the Top Shield Plug on the DSC | 3 | 1.0 |
| Remove the Cask/DSC from the Fuel Pool and Place them in the Decon Area | 5 | 2.0 |
| **Location: Cask Decon Area** | | |
| Decontaminate the Outer Surface of the Cask[2] | 7 | 1.0 |
| Drain Water Above DSC Shield Plug | 3 | 1.0 |
| Decon the Top Region of the Cask and DSC | 2 | 1.0 |
| Remove a Small Volume of Water from the DSC Cavity[2] | 2 | 0.5 |
| Remove the Cask/DSC Annulus Seal and Set-up Welder | 2 | 1.5 |
| Weld the Inner Top Cover to the DSC Shell and Perform NDE (PT)[1] | 2 | 6.0 |
| Drain the Cask/DSC Annulus and the DSC Cavity[1] | 2 | 3.0 |
| Vacuum Dry and Backfill the DSC with Helium[1] | 2 | 16.0 |
| Helium Leak Test the Shield Plug Weld | 2 | 1.0 |
| Seal Weld the Prefabricated Plugs to the Vent and Siphon Port and Perform NDE (PT) | 2 | 1.5 |
| Fit-up the DSC Top Cover Plate | 2 | 1.0 |
| Weld the Outer Top Cover Plate to DSC Shell and Perform NDE (PT)[1] | 2 | 16.0 |
| Install the Cask Lid | 2 | 1.0 |

# 8. ANALYSIS OF DESIGN EVENTS

In previous chapters of this SAR, the features of the standardized NUHOMS® system which are important to safety have been identified and discussed. The purpose of this chapter is to present the engineering analyses for normal and off-normal operating conditions, and to establish and qualify the system for a range of credible and hypothetical accidents. As stated in Chapter 1, the analyses presented in this section are applicable to the standard length 24P and 52B canisters. An evaluation of the long cavity 24P canister, for the same design criteria, is provided in Appendix H and J. Appendices K, L, M, and N provide the evaluation for the NUHOMS®-61BT 24PT2, 32PT, and 24PHB DSC, respectively. Evaluations for other canisters and modules may be included as additional appendices at a later time.

In accordance with NRC Regulatory Guide 3.48 (8.1), the design events identified by ANSI/ANS 57.9-1984, (8.2) form the basis for the accident analyses performed for the standardized NUHOMS® system. Four categories of design events are defined. Design event Types I and II cover normal and off-normal events and are addressed in Section 8.1. Design event Types III and IV cover a range of postulated accident events and are addressed in Section 8.2. These events provide a means of establishing that the NUHOMS® system design satisfies the applicable operational and safety acceptance criteria as delineated herein.

It is important to note that, given the generic nature of this SAR, the majority of the analyses presented throughout this chapter are based on bounding conservative assumptions and methodologies, with the objective of establishing upper bound values for the responses of the primary components and structures of the standardized NUHOMS® system for the design basis events. Because of the conservative approach adopted herein, the reported temperatures and stresses in this chapter envelope the actual temperatures or states of stress for the various operating and postulated accident conditions. More rigorous and detailed analyses and/or more realistic assumptions and loading conditions would result in temperatures and states of stress which are significantly lower than the reported values.

## 8.1 Normal and Off-Normal Operations

Normal operating design conditions consist of a set of events that occur regularly, or frequently, in the course of normal operation of the NUHOMS® system. These normal operating conditions are addressed in Section 8.1.1. Off-normal operating design conditions are events that could occur with moderate frequency, possibly once during any calendar year of operation. These off-normal operating conditions are addressed in Section 8.1.2. The thermal-hydraulic, structural, and radiological analyses associated with these events are presented in the sections which follow.

### 8.1.1 Normal Operation Structural Analysis

Table 8.1-1 shows the normal operating loads for which the NUHOMS® safety-related components are designed. The table also lists the individual NUHOMS® components which are affected by each loading. The magnitude and characteristics of each load are described in Section 8.1.1.1.

The method of analysis and the analytical results for each load are described in Sections 8.1.1.2 through 8.1.1.9. The mechanical properties of materials employed in the structural analysis of the NUHOMS® system components are presented in Table 8.1-3.

#### 8.1.1.1 Normal Operating Loads

The normal operating loads for the NUHOMS® system components are:

1. Dead Weight Loads
2. Design Basis Internal and External Pressure Loads
3. Design Basis Thermal Loads
4. Operational Handling Loads
5. Design Basis Live Loads

These loads are described in detail in the following paragraphs.

A. Dead Weight Loads

Table 8.1-4 and Table 8.1-5 show the weights of various components of the NUHOMS® system. The dead weight of the component materials is determined based on nominal component dimensions.

A density value of 0.283 pound per cubic inch for carbon steel, 0.285 pound per cubic inch for stainless steel, 0.408 pound per cubic inch for lead shielding, and 0.064 pound per cubic inch for solid neutron shielding material are used in the dead weight calculations.

A nominal concrete density of 140 to 145 pounds per cubic foot is conservatively selected as a design basis for the shielding and thermal evaluations. A maximum nominal density of 150 pounds per cubic foot is conservatively assumed for the structural evaluation of the HSM.

transfer casks are discussed in this SAR. Table 8.1-20, Table 8.1-20a, and Table 8.1.20b summarize the calculated stresses for the normal operating loads for the standardized, OS197, and OS197H transfer casks, respectively. The methodology used to evaluate the transfer cask for the effects of normal operating loads is described in the following paragraphs. The analytical results and comparisons with the acceptance criteria defined in Section 3.2 are also presented in this section.

A. Transfer Cask Dead Weight Analysis

The effects of dead weight for a loaded transfer cask are evaluated for two cases. The first case evaluated is for the transfer cask hanging vertically by the two lifting trunnions, and loaded with its maximum payload. A maximum wet payload of 91,804 pounds is used in the analysis of the standardized cask, while a load of 102,410 pounds and 126,000 pounds is used for the OS197 and OS197H transfer casks, respectively.

The second dead weight load case evaluated for the transfer cask includes the loaded transfer cask resting in a horizontal position on the support skid transport trailer. In this orientation, the weight of the cask is shared between the lower support trunnions and the upper lifting trunnions resting in the pillow block supports of the support skid. The maximum dead load stresses are shown in Table 8.1-20, Table 8.1-20a, and Table 8.1-20b for the standardized, OS197, and OS197H transfer casks, respectively. The local stresses around the trunnions are included in the normal handling load case described in Paragraph B.

B. Transfer Cask Normal Handling Loads Analysis

The major components of the transfer cask affected by the normal handling loads are the structural shell including the top and bottom cover plates, the upper and lower trunnions, the upper trunnion assembly insert plates, and the structural shell local to the trunnions. As described for the dead weight analysis, there are two normal operating cask handling cases which form the design basis for the transfer cask. These cases are illustrated in Figure 8.1-30 and are summarized as follows:

(i) The transfer cask is oriented in the vertical position, loaded to its maximum estimated weight of 200,000 lbs, 208,500 lbs and 250,000 lbs for the standardized, OS197, and OS197H transfer casks, respectively, hanging by the upper lifting trunnions, and present in an area of the plant which requires conformance with the requirements of NUREG-0612. Accordingly, the allowable design stresses for the upper trunnions and their attachment welds are restricted to the smaller of one sixth of the material yield strength, or one tenth of the material ultimate strength for critical lifts. Allowable stresses for the remaining transfer cask components including the lower support trunnions are governed by the requirements of the ASME Code. The cask handling load is assumed to be shared equally between the two upper trunnions. An additional load factor of 15% is conservatively applied to account for the inertial effects of crane hoist motions in accordance with CMAA #70 recommendations. The transfer cask is designed so that the cask lifting yoke engages the outer most portion of the upper trunnion assembly. During the heaviest lift from the fuel pool, the cask/DSC contains water, the DSC top shield plug is in place, and the DSC and cask top cover plates are removed. For this condition the maximum ANSI N14.6 design load for the two upper trunnions of the standardized cask due to a vertical lift is conservatively assumed to be 100 kips per trunnion plus the 15% allowance, or 115 kips, acting vertically, with a moment arm measured from the center of the yoke lifting hook to the middle surface of the transfer cask structural shell. For the OS197 and OS197H transfer casks, the maximum load considered for the vertical lift per trunnion is 120 kips and 144 kips, respectively.

The maximum calculated upper trunnion stress for the standardized transfer cask under this load case is 5.5 ksi at the junction between the trunnion shoulder and the trunnion sleeve attached to the structural shell plate. This compares with the ANSI N14.6 allowable stress of 13.5 ksi for the trunnion material. The maximum weld stress is 6.7 ksi. The ANSI N14.6 allowable weld stress is 8.0 ksi. The maximum calculated stress intensity in the lower trunnion is 9.5 ksi, and the maximum weld stress is 12.6 ksi. These stresses compare with the ASME Code allowable value of 20 ksi.

For the critical lift of the OS197 transfer cask, the limiting stress occurs at the junction between the trunnion shoulder and the trunnion sleeve weld. The maximum weld stress ratio is 0.98 based on a stress of 5.08 ksi versus an allowable of 5.21 ksi.

The upper trunnion assembly of the OS197H cask is designed to accommodate a lifted load of 250,000 lbs. The limiting stress occurs in the upper trunnion sleeve. The maximum trunnion sleeve stress ratio is 0.87 based on a stress of 3.34 ksi versus an allowable of 3.82 ksi.

The maximum stress in the standardized transfer cask structural shell occurs in the thickened plate at the junction with the upper trunnion sleeves. Stresses in the structural shell are calculated using the WRC Bulletin No. 107 (8.54) method for the standardized transfer cask and an ANSYS finite element analysis for the OS197 and OS197H transfer casks. The maximum calculated stress intensity in the standardized transfer cask structural shell is 42.6 ksi compared with an ASME Code allowable stress intensity value of 67.5 ksi. For the OS197 the maximum calculated stress intensity in the cask structural shell for the critical lift combinations using finite element analysis is 19.6 ksi (23.5 ksi for the OS197H) versus an allowable of 60 ksi.

(ii) During transport of the DSC from the plant's fuel/reactor building to the ISFSI, the transfer cask is oriented in a horizontal position, and is firmly secured to the support skid/transport trailer. During this operation the cask/DSC is loaded with fuel with the DSC top shield plug and the DSC and cask top cover plates in place. The resulting trunnion loads are developed by taking the summation of moments about a horizontal axis to account for the fact that the upper trunnions are closer to the horizontal center of gravity of the cask and thus carry a greater part of the total cask weight compared with the lower support trunnions. The transfer cask is supported in pillow block supports at

Table 8.1-20
Maximum Standardized Transfer Cask Stresses for Normal Loads

| Transfer Cask Components | Stress Type | Load Type | | |
|---|---|---|---|---|
| | | Stress (ksi)[1] | | |
| | | Dead Weight | Thermal | Normal Handling |
| Transfer Cask Structural Shell | Primary Membrane | 0.7 | N/A | 0.5 |
| | Membrane + Bending | 0.9 | N/A | 4.1 |
| | Primary + Secondary | 0.9 | 18.4 | 42.6 |
| Top Cover Plate | Primary Membrane | 0.2 | N/A | N/A |
| | Membrane + Bending | 0.6 | N/A | 6.9 |
| | Primary + Secondary | 0.6 | 13.1 | 6.9 |
| Bottom End Assembly | Primary Membrane | 0.5 | N/A | N/A |
| | Membrane + Bending | 1.3 | N/A | 15.4 |
| | Primary + Secondary | 1.4 | 21.4 | 15.4 |
| Transfer Cask Collar for BWR DSC | Primary Membrane | 0.2 | N/A | 0.0 |
| | Membrane + Bending | 0.2 | N/A | 0.0 |
| | Primary + Secondary | 0.5 | 15.8 | 0.0 |

(1) Values shown are maximum irrespective of location.

Table 8.1-20a

Maximum OS197 Transfer Cask Stresses for Normal Loads

| Transfer Cask Components | Stress Type | Load Type<br>Stress (ksi)[1] | | |
|---|---|---|---|---|
| | | Dead Weight | Thermal | Normal Handling |
| Transfer Cask Structural Shell | Primary Membrane | 0.92 | N/A | 1.85 |
| | Membrane + Bending | 7.0 [2] | N/A | 14.0 [2] |
| | Primary + Secondary | 7.0 [2] | 9.9 | 14.0 [2] |
| Top Cover Plate | Primary Membrane | 0.0 | N/A | 0.61 |
| | Membrane + Bending | 0.23 | N/A | 4.5 |
| | Primary + Secondary | 0.23 | 3.0 | 4.5 |
| Bottom End Assembly | Primary Membrane | 0.45 | N/A | 0.56 |
| | Membrane + Bending | 6.3 | N/A | 7.2 |
| | Primary + Secondary | 6.3 | 6.0 | 7.2 |

(1) Values shown are maximum irrespective of location.
(2) Stresses in the transfer cask structural shell for these loads are governed by the local stresses at the trunnion interface. Stresses shown are for locations remote from the trunnions.

evaluate load sharing, and to ensure displacement compatibility between the transfer cask and DSC. The nodal degrees of freedom between the DSC shell and the inner surface of the transfer cask are decoupled in the tangential direction such that the DSC shell can move independently of the cask inner surface in this direction. However, they are coupled in the normal direction such that the DSC outer surface bears on the cask inner surface during a postulated drop accident.

A third model (Figure 8.2-10a) is used to evaluate the OS197 and OS197H transfer casks for DSC loading that is transferred through the cask rails. The cask inner liner and structural shell are modeled using 3-D quadrilateral shell elements. The lead gamma shield is modeled using 3-D brick elements.

The lead gamma shield is assumed to transfer only normal loads at the interface with the inner liner and structural shell. It is also assumed that there is no shear transfer between the lead gamma shield and the cask shells. The coincident nodes on the inner liner, gamma shield, and structural shell are coupled in the radial direction only to model the interface between the lead gamma shield and the cask shells.

(ii) Cask/DSC Loading Application

The loading due to the transfer cask horizontal drop is non-axisymmetric since it is reacted by a portion of the shell circumference. The loading is assumed to be uniform along the length of the cask. In order to apply this non-axisymmetric loading to the axisymmetric standardized cask models shown in Figure 8.2-9 and Figure 8.2-10, the loading is resolved into Fourier harmonics using the ANSYS PREP 6 routine. As shown in Appendix C.3, the first twelve Fourier harmonics are chosen to represent the impact force. These Fourier harmonics, expressed in terms of pressure loading, are applied to the exterior nodes of the impacted surface of the cask structural shell.

The DSC loading of the cask includes the DSC and its internals, factored by the equivalent static deceleration value of 75g. These loads are conservatively applied to the transfer cask inner liner at the spacer disk and end plug locations. As for the cask impact force, this loading acts over a portion of the DSC circumference, and is therefore non-axisymmetric. The loading is resolved into Fourier harmonics and the first eight harmonics are selected for application to the axisymmetric model. This loading assumed that the contact surface along DSC the circumference is similar to that obtained from the spacer disk horizontal drop analysis. This assumption does not have a significant impact on the outcome of the analysis since the stresses arise primarily from bearing.

The cask weight, factored by the deceleration values, is applied to the interior nodes of the cask analytical models with its appropriate harmonic components. The cask weight is assumed to have the same circumferential contact surface as the DSC. A detailed description of load development and application of the loads to the axisymmetric model is provided in Appendix C.3.

For the model of the OS197 and OS197H transfer casks, the load acting on the inner surface of the Cask inner liner due to the accelerated mass of the DSC, fuel, and the cask spacer is modeled as a uniform pressure acting over the inner liner elements in the region of the cask rails (centered at 18.5° on each side of the 180° azimuth). It is assumed the spacer assembly will have a minimal impact on the load distribution. The elements over which the pressure load is applied span an arc of 7.5°. In addition to the contents loading, a 75g side drop vertical acceleration load is also applied to the model.

(iii) Cask Stress Analysis

The enveloped results of the transfer cask analyses for a postulated horizontal drop accident show that the maximum primary membrane stress intensity for the standardized and OS197 transfer cask structural shells is 36.1 ksi (43.1 ksi for the OS197H). Similarly, the maximum primary membrane stress intensity in the standardized or OS197 transfer cask inner liner is 33.1 ksi (39.4 ksi for the OS197H). These stresses are combined with other load cases and compared with the ASME Code Service Level D allowable as described in Section 8.2.10. The calculated transfer cask stresses for the horizontal drop are tabulated in Table 8.2-9, Table 8.2-9a, and Table 8.29b for the standardized, OS197, and OS197H transfer casks, respectively.

(iv) Transfer Cask Collar Analysis

During the postulated horizontal cask drop, the shear forces from the cask lid/collar/DSC top cover are transferred to the cask body by the 3 inch thick shield ring of the cask collar. The maximum calculated shear stress in the shield ring is 0.5 ksi which is a small fraction of the ASME Code Service Level D allowables. The 1-3/4" cask collar to cask top flange bolts are not loaded during this postulated accident.

C. DSC Vertical Drop Analyses

For this drop accident case, the transfer cask is assumed to be oriented vertically and dropped onto a uniform unyielding surface. The vertical cask drop evaluation conservatively assumed that the transfer cask could be dropped onto either the top or bottom surfaces. No credit is taken for the energy absorbing capacity of the cask top or bottom cover plate assemblies during the drop. Therefore, the DSC is analyzed as though it is dropped on to an unyielding surface. The principal components of the DSC and internals affected by the vertical drop are the DSC shell, the inner and outer top cover plates, the shield plugs, the inner and outer bottom cover plates and the basket support rods.

The end drop with the bottom end of the DSC oriented downward is the more credible of the two possible vertical orientations. Nevertheless, an analysis for the DSC top end drop accident is also performed. For a postulated vertical drop, membrane stresses in the DSC shell and local stresses at the cover plate weld region discontinuities are evaluated.

(i) Transfer Cask Analysis Methodology

The ANSYS axisymmetric finite element models used to perform these analyses are described in Section 8.2.5.2. The loadings due to the postulated vertical drops are applied to the transfer cask analytical models in a symmetric manner. The individual models of the top and bottom cask regions shown in Figure 8.2-9 and Figure 8.2-10 are used for these analyses. The respective top or bottom impacted surface of the transfer cask is assumed to be uniformly supported vertically and the 75g equivalent static decelerations are applied to the models.

(ii) Transfer Cask Stress Analysis

The resulting primary membrane and membrane plus bending stresses due to the postulated end drop are tabulated in Table 8.2-9, Table 8.2-9a, and Table 8.2-9b for the standardized, OS197, and OS197H transfer casks, respectively. For the top end drop analysis, the stresses in the cover plates are relatively small since they arise primarily from bearing of the DSC and its contents on the cask top cover plate. The most critical vertical drop direction for the transfer cask top region is the bottom end drop, since this produced the maximum bending stress in the top cover plate. The maximum (enveloped between the standardized and OS197 casks) primary membrane plus bending stress in the cover plate is 38.3 ksi (36.8 ksi for the OS197H transfer cask). The maximum local membrane stresses in the cask structural shell and inner liner are 9.6 ksi and 12.9 ksi, respectively (the same for the OS197 and OS197H transfer cask). Similarly for the standardized transfer cask bottom region, the most critical drop direction is the top end drop producing a maximum primary membrane plus bending stress of 26.1 ksi in the cask bottom end plate (36.2 ksi and 34.8 ksi for the OS197 and OS197H transfer cask, respectively). These stresses are well below the appropriate ASME Code Service Level D allowables.

(iii) Transfer Cask Collar Analysis

During the postulated vertical end drop, the maximum compressive stress in the cask collar is 13 ksi and the maximum membrane stress intensity is 26.2 ksi. These stresses are well within the ASME Code Service Level D allowables.

E. On-site Transfer Cask/DSC Corner Drop Analyses

The possibility of a drop onto the top or bottom end corners of the transfer cask is extremely remote due to the limited cask handling operations of the NUHOMS® system, as discussed previously. Nevertheless, for this generic evaluation, a cask corner drop is conservatively postulated to occur onto a concrete surface with an equivalent static deceleration of 25g. The orientation of the drop is shown in Figure 8.2-3 as occurring at 30° to the horizontal. This is the largest drop orientation angle that can occur as the center of gravity of the cask passes beyond the back end of the transport trailer and pitches downward. The derivation of this load definition is contained in Appendix C.2.

It is probable that the cask support skid would remain firmly attached to the cask and would absorb considerable energy upon impact, thus reducing the transfer cask deceleration. In addition, this would further reduce the angle of the impact and the drop height. The combined support skid and transfer cask would act as a substantial energy absorbing mechanism thus significantly reducing the effects of impact loads on the DSC and the spent fuel assemblies. Also, for the postulated case of the cask sliding forward, the cask and skid may initially impact the tractor vehicle, prior to pitching onto the ground, with significant reductions in the resulting impact velocity and the energy imparted to the transfer cask and its contents.

(i) Cask/DSC Analysis Methodology

The combined transfer cask/DSC ANSYS linear elastic axisymmetric models used in the side drop and the end drop analyses as shown in Figure 8.2-9 and Figure 8.2-10, are used for the corner drop analyses. The postulated transfer cask corner drop accident results in a very complex loading function because it involves both symmetric and asymmetric load components in both the vertical and horizontal directions. The analysis involved the development of the impact force and the content loading and applying these loads to the axisymmetric model as Fourier harmonics. A complete description of the load development and application of the loads to the ANSYS models is provided in Appendix C.2.

(ii) Cask/DSC Stress Analysis

The resulting local primary membrane and primary bending stresses in the transfer cask due to both the postulated top and bottom corner drop analysis are tabulated in Table 8.2-9, Table 8.2-9a, and Table 8.2-9b for the standardized, OS197, and OS197H transfer casks, respectively. The resulting stresses in the DSC due to a cask corner drop are evaluated and found to be enveloped by those calculated for the 75g end and side drop analyses. As seen from the results, the DSC and transfer cask stress intensities are within the appropriate ASME Code Service Level D allowable limits.

(iii) Transfer Cask Collar Analysis

During the postulated oblique corner drop, the shear forces from the cask lid/DSC/collar are transferred to the cask body by the 3 inch thick shield ring of the cask collar. The tensile forces associated with the corner drop are transferred from the cask collar to the cask body by 16, 1-3/4-inch diameter bolts. The maximum calculated collar membrane stress intensity is 3.2 ksi and the maximum bolt stress is 74.3 ksi. These stresses are well within the ASME Code Service Level D allowables.

#### 8.2.5.3 Loss of Neutron Shield

This accident conservatively postulates loss of neutron shield on the OS197 transfer cask.

Table 8.2-9a

Maximum OS197 Transfer Cask Stresses for Drop Accident Loads

| Transfer Cask Components | Stress Type | Stress (ksi)[1] | | |
|---|---|---|---|---|
| | | Vertical | Horizontal | Corner[2] |
| Cylindrical Structural Shell | Primary Membrane | 9.6 | 36.1 | 6.8 |
| | Membrane + Bending | 9.6 | 43.2 | 20.6 |
| Top Cover Plate | Primary Membrane | 38.3 | 7.4 | 4.0 |
| | Membrane + Bending | 38.3 | 7.4 | 20.9 |
| Bottom End Plate | Primary Membrane | 36.2 | 7.4 | 0.0 |
| | Membrane + Bending | 36.2 | 7.4 | 49.0 |

(1) Values shown are maximums irrespective of location

(2) DSC was also included in corner drop analysis. DSC stresses for this case are enveloped by those for horizontal and vertical drop loads shown in Tables 8.2-7 and 8.2-8.

Table 8.2-9b

Maximum OS197H Transfer Cask Stresses for Drop Accident Loads

| Transfer Cask Components | Stress Type | Stress (ksi)[1] | | |
|---|---|---|---|---|
| | | Vertical | Horizontal | Corner[2] |
| Cylindrical Structural Shell | Primary Membrane | 9.6 | 43.1 | 8.1 |
| | Membrane + Bending | 9.6 | 51.5 | 24.7 |
| Top Cover Plate | Primary Membrane | 36.8 | 8.8 | 4.8 |
| | Membrane + Bending | 36.8 | 8.8 | 24.9 |
| Bottom End Plate | Primary Membrane | 34.8 | 8.8 | 0.0 |
| | Membrane + Bending | 34.8 | 8.8 | 58.6 |

(1) Values shown are maximums irrespective of location.

(2) DSC was also included in corner drop analysis. DSC stresses for this case are enveloped by those for horizontal and vertical drop loads shown in Tables 8.2-7 and 8.2-8.

Table 8.2-21

**Standardized Transfer Cask Enveloping Load Combination Results for Normal and Off-Normal Loads (ASME Service Levels A and B)**

| Transfer Cask Component | Stress Type | Controlling Load Combination[1] | Stress (ksi) | |
|---|---|---|---|---|
| | | | Calculated | Allowable[2] |
| Structural Shell | Primary Membrane | A4 | 1.2 | 21.7 |
| | Membrane + Bending | A4 | 5.0 | 32.6 |
| | Primary + Secondary | A4 | 61.9 | 65.1 |
| Top Cover Plate | Primary Membrane | A1 | 0.2 | 21.7 |
| | Membrane + Bending | A4 | 7.1 | 32.6 |
| | Primary + Secondary | A4 | 20.2 | 65.1 |
| Bottom End Plate | Primary Membrane | A1 | 0.2 | 21.7 |
| | Membrane + Bending | A4 | 15.6 | 32.6 |
| | Primary + Secondary | A4 | 30.3 | 65.1 |

(1) See Table 3.2-7 for load combination nomenclature.

(2) See Table 3.2-11 for allowable stress criteria. Material properties were obtained from Table 8.1-3 at a design temperature of 400°F.

**Table 8.2-21a**
**OS197 Transfer Cask Enveloping Load Combination Results for Normal and Off-Normal Loads (ASME Service Levels A and B)**

| Transfer Cask Component | Stress Type | Stress (ksi)[1] | |
|---|---|---|---|
| | | Calculated[1] | Allowable[2] |
| Structural Shell | Primary Membrane | 1.8/7.9[4] | 20.0 |
| | Membrane + Bending | 14.0/19.5[4] | 30.0 |
| | Primary + Secondary | 25.4/41.4[4] | 60.0 |
| Top Cover Plate [3] | Primary Membrane | 0.61 | 18.7 |
| | Membrane + Bending | 4.5 | 28.1 |
| | Primary + Secondary | 10.8 | 56.1 |
| Bottom End Plate | Primary Membrane | 0.56 | 18.7 |
| | Membrane + Bending | 7.2 | 28.1 |
| | Primary + Secondary | 14.0 | 56.1 |

(1) The load combination for Levels A and B is dead weight plus thermal plus handling loads.

(2) See Table 3.2-11 for allowable stress criteria. Material properties for all components except the cask structural shell were obtained from Table 8.1-3 at a design temperature of 400°F. The cask structural shell allowables are based on a temperature of 250°F.

(3) Allowable stress values and calculated stress intensities are tabulated for the stainless steel cover plate.

(4) The leftmost stress value listed is for locations remote from the trunnions, while the rightmost stress value occurs in the region of the trunnions.

Table 8.2-22a
OS197 Transfer Cask Enveloping Load Combination Results
for Accident Loads (ASME Service Level C)

| Transfer Cask Component | Stress Type | Stress (ksi) | |
|---|---|---|---|
| | | Calculated[1] | Allowable[2] |
| Structural Shell | Primary Membrane | 3.4/8.1[4] | 24.0 |
| | Membrane + Bending | 27.6/19.5[4] | 36.0 |
| Top Cover Plate[3] | Primary Membrane | 0.61 | 22.4 |
| | Membrane + Bending | 4.8 | 33.7 |
| Bottom End Plate | Primary Membrane | 1.1 | 22.4 |
| | Membrane + Bending | 15.4 | 33.7 |

---

(1) The load combination for Level C include dead weight, thermal, handling and seismic loads

(2) See Table 3.2-11 for allowable stress criteria. Material properties for all components except the cask structural shell were obtained from Table 8.1-3 at a design temperature of 400°F. The cask structural shell allowables are based on a temperature of 250°F.

(3) Allowable stress values and calculated stress intensities are tabulated for the stainless steel cover plate.

(4) The lower stress value listed is for locations remote from the trunnions, while the higher stress value occurs in the region of the trunnions.

**Table 8.2-22b**
**OS197H Transfer Cask Enveloping Load Combination Results for Accident Loads (ASME Service Level C)**

| Transfer Cask Component | Stress Type | Stress (ksi) | |
|---|---|---|---|
| | | Calculated(1) | Allowable(2) |
| Structural Shell | Primary Membrane | 3.9/9.45(4) | 24.0 |
| | Membrane + Bending | 28.6/21.8(4) | 36.0 |
| Top Cover Plate(3) | Primary Membrane | 0.7 | 22.4 |
| | Membrane + Bending | 5.8 | 33.7 |
| Bottom End Plate | Primary Membrane | 2.9 | 22.4 |
| | Membrane + Bending | 22.3 | 33.7 |

(1) The load combination for Level C include dead weight, thermal, handling and seismic loads.

(2) See Table 3.2-11 for allowable stress criteria. Material properties for all components except the cask structural shell were obtained from Table 8.1-3 at a design temperature of 400°F. The cask structural shell allowables are based on a temperature of 250°F.

(3) Allowable stress values and calculated stress intensities are tabulated for the stainless steel cover plate.

(4) The leftmost stress value listed is for locations remote from the trunnions, while the rightmost stress value occurs in the region of the trunnions. The maximum stresses in the shell near the trunnions for Service Level C were evaluated against Service Level A/B allowables in Table 8.2-21a.

**Table 8.2-23**
**Standardized Transfer Cask Enveloping Load Combination Results for Accident Loads (ASME Service Level C)**

| Transfer Cask Component | Stress Type | Controlling Load Combination[1] | Stress (ksi) | |
|---|---|---|---|---|
| | | | Calculated | Allowable[2] |
| Structural Shell | Primary Membrane | C1 | 1.7 | 26.0 |
| | Membrane + Bending | C1 | 9.1 | 39.1 |
| Top Cover Plate | Primary Membrane | C1 | 0.2 | 26.0 |
| | Membrane + Bending | C1 | 14.0 | 39.1 |
| Bottom End Plate | Primary Membrane | C1 | 0.1 | 26.0 |
| | Membrane + Bending | C1 | 31.0 | 39.1 |

(1) See Table 3.2-7 for load combination nomenclature.

(2) See Table 3.2-11 for allowable stress criteria. Material properties were obtained from Table 8.1-3 at a design temperature of 400°F.

Table 8.2-23a

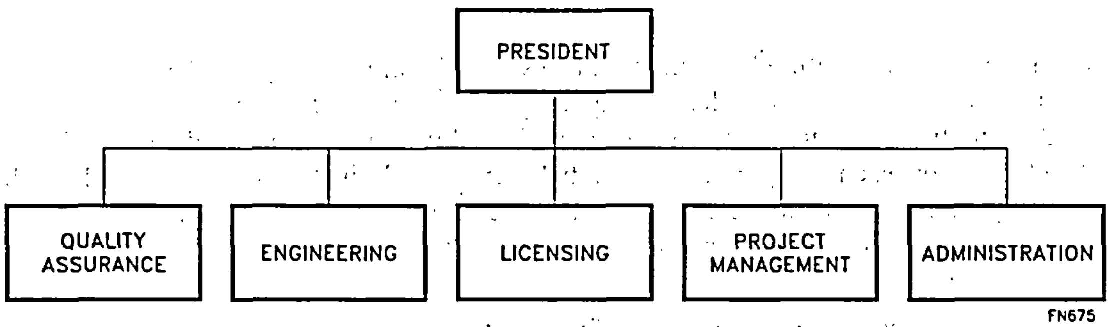
OS197 Transfer Cask Enveloping Load Combination Results for Accident Loads
(ASME Service Level D)

| Transfer Cask Component | Stress Type | Stress (ksi) | |
|---|---|---|---|
| | | Calculated[(1)] | Allowable[(2)] |
| Structural Shell | Primary Membrane | 36.1 | 48.0 |
| | Membrane + Bending | 43.2 | 68.5 |
| Top Cover Plate[(3)] | Primary Membrane | 38.3 | 44.9 |
| | Membrane + Bending | 38.3 | 64.4 |
| Bottom End Plate | Primary Membrane | 36.2 | 44.9 |
| | Membrane + Bending | 49.0 | 64.4 |

(1) The load combination for Level D include dead weight, thermal, handling and cask drop loads.

(2) See Table 3.2-11 for allowable stress criteria. Material properties for all components except the cask structural shell were obtained from Table 8.1-3 at a design temperature of 400°F. The cask structural shell allowables are based on a temperature of 250°F.

(3) Allowable stress values and calculated stress intensities are tabulated for the stainless steel cover plate.




Notes:

1. Licensing may report to Engineering.
2. Administrative activities may report to various other organizations.

**Figure 11.1-1**
**NUHOMS® Project Organization Chart**

## 11.2 "Important-to-Safety" and "Safety Related" NUHOMS® System Components

TN will apply the TN Quality Assurance Program to those NUHOMS® components for which TN has responsibility and which are "important to safety" and "safety related" as delineated in Section 3.4. These include the DSC with closure weld filler metal, the HSM, and the transfer cask. The lifting yoke is classified as "safety related".

Each item is first identified as "important to safety," "safety related" or "not important to safety." Items that are considered "important to safety" are further categorized using a graded quality approach. When the graded quality approach is used, a list shall be developed for each "important to safety" item which includes an assigned quality category consistent with the item's importance to safety. Quality categories shall be determined based on the guidance from Regulatory Guide 7.10:

Category A items are critical to safe operation. These items include structures, components, and systems whose failure or malfunction could result directly in a condition adversely affecting (1) safe spent fuel storage, (2) integrity of the spent fuel, or (3) public health and safety. This would include conditions as loss of primary containment with subsequent release of radioactive material, loss of shielding or an unsafe geometry compromising criticality control.

Category B items have a major impact on safety. These items include structures, components, and systems whose failure or malfunction could indirectly result in a condition adversely affecting (1) safe spent fuel storage, (2) integrity of the spent fuel, or (3) public health and safety. An unsafe operation could result only if a primary event occurs in conjunction with a secondary event or other failure or environmental occurrence.

Category C items have a minor impact on safety. These items include structures, components, and systems whose failure or malfunction would not significantly reduce the packaging effectiveness and would be unlikely to create a condition adversely affecting (1) safe spent fuel storage, (2) integrity of the spent fuel, or (3) public health and safety.

The Quality Assurance Program as described in paragraph 11.3 is applicable to each "important to safety" graded category and is limited as follows For "safety related" items the program is applied as described in Category A items. Appendix K provides clarification for the procurement of Category A items for the NUHOMS®-61BT DSC. Appendix L provides clarification for the procurement of Category A items for the NUHOMS®-24PT2 DSC. Appendix M provides clarification for the procurement of Category A items for the NUHOMS®-32PT DSC.

The first twelve Fourier harmonics used in the analysis are shown in Table C.3-2. A comparison between the input load and that calculated based on the first twelve Fourier coefficients is shown in Figure C.3-3.

## C.3.4 Content Loading

The cask contents loading (DSC plus internals) for the side drop consists of the lateral loading at the spacer disks and end plug locations. Loads are obtained by factoring the lateral loads (in terms of Fourier harmonics) for the corner drop analysis by 1/Sin 60° = 1.154.

The weight of the transfer is also applied in the same harmonic fashion as for the corner drop analysis except the loads are applied at the interior nodes of the 1-1/2" structural shell (Nodes 144, 241, 322, 363, 395, 427, 459, 499, 539, and 563). Also lateral loads (in terms of Fourier coefficients) are factored by 1/Sin 60° = 1.154.

## C.3.5 Boundary Conditions

For the side drop analysis, the cask top end model used in the corner drop analysis is used. The boundary conditions are the same as detailed for the corner drop analysis in Appendix C.2.

## C.3.6 Supplementary Analysis for the OS197 and OS197H Transfer Casks

A half-symmetry finite element model (see Figure 8.2-10a) is developed for the analysis of the OS197 and OS197H casks. The cask inner liner and structural shell are modeled using 3-D quadrilateral shell elements having three translational and three rotational degrees of freedom per node. The lead gamma shield is modeled using 3-D brick elements having three translational degrees of freedom per node.

The lead gamma shield is assumed to transfer only normal loads at the interface with the inner liner and structural shell. It is also assumed that there is no shear transfer between the lead gamma shield and the cask shells. The coincident nodes on the inner liner, gamma shield, and structural shell are coupled in the radial direction only to model the interface between the lead gamma shield and the cask shells.

The load acting on the inner surface of the cask inner liner due to the accelerated mass of the DSC, fuel, and spacer is modeled as a uniform pressure acting over the inner liner elements in the region of the cask rails (centered at 18.5° on each side of the 180° azimuth.) It is assumed the spacer assembly will have a minimal impact on the load distribution. The elements over which the pressure load is applied span an arc of 7.5°. Therefore, the magnitude of the uniform pressure load is:

| | | |
|---|---|---|
| P | = | 75W/20RL |
| where; | | |
| W | = | Weight of the dry loaded 24P DSC & Spacer |
| | = | 79,230 lbs. (use 80,000 pounds) |
| θ | = | 0.1309 radians (7.5°) |
| R | = | 34.25 inches, Mean radius of inner liner |
| L | = | 196.75 inches, Length of cask cavity |

Therefore,

| | | |
|---|---|---|
| P | = | (75)(80,000)/[2(0.1309)(34.25)(196.75)] |
| | = | 3,401 psi |

A uniform pressure of 3,250 psi was applied to the inner surface of those inner liner elements within the 7.5° half angle of contact. The computer model results were scaled up by 5.3% to obtain the stress results corresponding to the higher loading of 3,401 psi to accommodate a payload of 80,000 lbs.

In addition to the contents loading, a 75g side drop vertical acceleration load is also applied to the model.

Symmetry boundary conditions are applied to the nodes lying on the cask half symmetry plane and along the plane passing through the cask mid-length. The nodes at the end of the cask shells and gamma shielding (Z=0) are restrained from translating in the radial (UX) direction and from rotating about the radial (ROTX), circumferential (ROTY), and longitudinal (ROTZ) axes. The nodes at the end of the cask shells and gamma shielding are conservatively allowed to translate freely in the longitudinal direction, ignoring any coupling effect due to the cask end plates.

### C.3.7 Analysis Results

Stress intensities for the side drop analyses for various components of the Standardized, OS197, and OS197H transfer casks are reported in Section 8.2.

To qualify the OS197 and OS197H transfer casks for dry payloads of 97,250 lbs and 116,000 lbs, respectively, the maximum component stresses obtained from the vertical, horizontal, and corner drop analyses for a dry payload of 80,000 lbs were scaled to compute the maximum component stresses for the OS197 and OS197H transfer casks.

Because of fabrication concerns, the inner liner of the OS197 transfer cask is allowed to vary to a minimum of 0.38 inches. When considering a payload of 116,000 lbs for the OS197H transfer cask, the shell allowable minimum thickness is calculated to be 0.44 inches.

APPENDIX E

DRAWINGS FOR THE STANDARDIZED NUHOMS® SYSTEM

This appendix contains the following items:

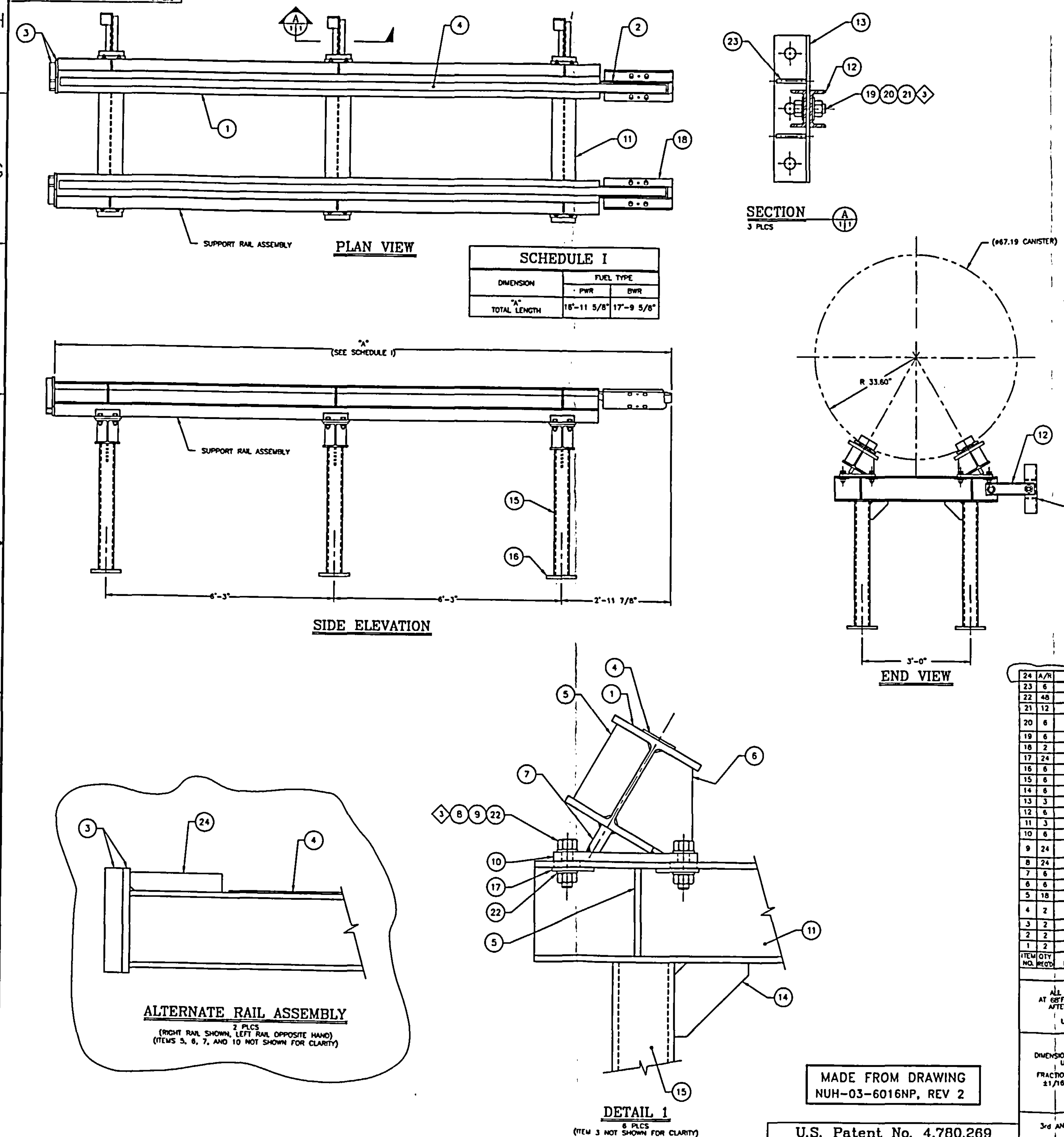
E.1 Drawings for NUHOMS® Dry Shielded Canisters

- E.1.1 Standardized NUHOMS®-24P DSC Drawings
- E.1.2 Standardized NUHOMS®-52B DSC Drawings
- E.1.3 Standardized NUHOMS®-24P Long Cavity DSC Drawings

E.2 Drawings for NUHOMS® Horizontal Storage Module

E.3 Drawings for NUHOMS® On-Site Transfer Cask

The drawings for the NUHOMS®-61BT, 24PT2 and 32PT DSCs are contained in Appendices K, L and M, respectively. The drawings for the NUHOMS®-24PHB DSCs are contained in Appendices E and N.




| SCHEDULE I | | |
|---|---|---|
| DIMENSION | FUEL TYPE | |
| | PWR | BWR |
| "A" TOTAL LENGTH | 18'-11 5/8" | 17'-9 5/8" |

## NOTES:

1. FABRICATE DSC SUPPORT STRUCTURE IN COMPLIANCE WITH TN SPECIFICATION NUH-03-115.
2. NOT USED.
3. FINAL ASSEMBLY OF DSC SUPPORT STRUCTURE RAILS AND FRAMES SHALL BE PERFORMED BY OTHERS IN ACCORDANCE WITH TN SPECIFICATION NUH-03-117.
4. NOT USED.
5. NOT USED.
6. NOT USED.
7. COAT ALL EXPOSED STEEL SURFACES IN ACCORDANCE WITH TN SPECIFICATION NUH-03-115.
8. NOT USED.
9. NOT USED.
10. REPLACEMENT MATERIAL MAY BE USED WITH TN APPROVAL.

| ITEM NO. | QTY REQ'D | PART OR IDENTIFYING NO. | NOMENCLATURE OR DESCRIPTION | MATERIAL SPECIFICATION | QUALITY CATEGORY |
|---|---|---|---|---|---|
| 24 | A/R | | DSC EXTENSION PLATE, 2" THK | ASTM A36 | B |
| 23 | 6 | | STIFFENER PLATE, 3/8" THK | ASTM A36 | B |
| 22 | 48 | | HARDENED WASHER, ø7/8" | ASTM F436 OR EQUIV | NITS |
| 21 | 12 | | HARDENED WASHER, ø1" | ASTM F436 OR EQUIV | NITS |
| 20 | 6 | | NUT, 1-8UNC-2B | ASTM A194 GR 2H OR A563 GR DH | B |
| 19 | 6 | | BOLT, 1-8UNC-2A X 2 1/2" LG | ASTM A325 | B |
| 18 | 2 | | RAIL BASEPLATE, 1" THK | ASTM A36 | B |
| 17 | 24 | | WASHER PLATE, 5/16" THK | ASTM A36 | NITS |
| 16 | 6 | | BASE PLATE, 1" THK | ASTM A36 | B |
| 15 | 6 | | LEG, TS 5 x 5 x 3/8" | ASTM A500 GR B | B |
| 14 | 6 | | GUSSET PLATE, 1/2" THK | ASTM A36 | B |
| 13 | 3 | | WALL ATTACHMENT ANGLE, L4 x 4 x 3/8" | ASTM A36 | B |
| 12 | 6 | | WALL ATTACHMENT CHANNEL, C4 x 7.25 | ASTM A36 | B |
| 11 | 3 | | CROSS BEAM, W8 x 40 | ASTM A36 | B |
| 10 | 6 | | MOUNTING PLATE, 3/4" THK | ASTM A36 | B |
| 9 | 24 | | NUT, 7/8-9UNC-2B | ASTM A194 GR 2H OR A563 GR DH | B |
| 8 | 24 | | BOLT, 7/8-9UNC-2A, 3" LG | ASTM A325 | B |
| 7 | 6 | | SUPPORT PLATE, 1" THK x 8" LG | ASTM A36 | B |
| 6 | 6 | | STIFFENER PLATE, 1/2" THK | ASTM A36 | B |
| 5 | 18 | | STIFFENER PLATE, 1/2" THK | ASTM A36 | B |
| 4 | 2 | | SUPPORT RAIL PLATE, 3/16" ±1/16" THK | NITRONIC® 60, RC 29-35 | NITS |
| 3 | 2 | | CANISTER STOP PLATE, 3/4" THK | ASTM A36 | B |
| 2 | 2 | | EXTENSION PLATE | ASTM A36 | B |
| 1 | 2 | | SUPPORT RAIL, W8 x 40 | ASTM A36 | B |

PARTS LIST

ALL DIMENSIONS ARE APPLICABLE AT 68°F AND ALL TOLERANCING APPLIES AFTER WELDING, FINAL MACHINING, AND CONCRETE CASTING UNLESS NOTED OTHERWISE

DIMENSIONS ARE IN INCHES AND DEGREES UNLESS NOTED OTHERWISE.
FRACTIONS ±1/16" DECIMALS .XX ± N/A .XXX ± N/A ANGLES ± 5°

3rd ANGLE PROJECTION

DO NOT SCALE DRAWING

TRANSNUCLEAR

STANDARDIZED NUHOMS® ISFSI HORIZONTAL STORAGE MODULE DSC SUPPORT STRUCTURE

DWG NO. NUH-03-6016NP-SAR | SCALE NONE | SHEET 1 OF 1 | REV NO 2

MADE FROM DRAWING NUH-03-6016NP, REV 2

U.S. Patent No. 4,780,269
Transnuclear, Inc.

E (34 X 44)

DWG NO. NUH-03-6016NP-SAR SHEET 1 OF 1