Enclosure 3 to E-51276

Replacement Pages for ANUH-01.0150, Standardized Advanced NUHOMS® UFSAR, Revision 8

(Public Version)

ANUH-01.0150
Revision 8

NON-PROPRIETARY

UPDATED FINAL SAFETY ANALYSIS REPORT

FOR THE

STANDARDIZED ADVANCED NUHOMS®

HORIZONTAL MODULAR STORAGE SYSTEM

FOR IRRADIATED NUCLEAR FUEL

By

TN Americas LLC[1]
Columbia, MD

August 2018

[1] *TN Americas LLC, formerly AREVA TN, and Transnuclear, Inc. (herein referred to as TN Americas LLC, AREVA TN, Transnuclear, Inc., Transnuclear, or TN)*

The proprietary notice is withheld from this public SAR version.

REVISION LOG SHEET

UFSAR Revision	Date	Record of Changes/FCNs	Changed Pages
0	3/19/03	None	All
1	3/21/05	FCNs 721029-39, 40, 62, 65, 81, 89, 92, 124, 126, 165, 169 & 175	See List of Effective Pages
2	8/17/06	FCNs 721029-182, 185, 103 R-1, 162 R-1, 166, 173 R-1, 176 R-1,177 and 204	See List of Effective Pages
3	8/15/08	FCNs 721029-202, 205, 206, 208, 215, 220, 222 R1, 232, 239, 246, 257, 272	See List of Effective Pages
4	8/12/10	FCNs 721029-275, 280 R-1, 285, 294, 303, 311, 312 R-1, 316	See List of Effective Pages
5	8/13/12	FCNs 721029-339, 348 R-1, 351 R-1, 352, 353, 354, 356, 364	See List of Effective Pages
6	8/13/14	FCN 721029-385	See List of Effective Pages
7	8/11/16	FCN 721029-374 R-1, 378 R-1, 386 R-1, 394, 407 R-1, 414, 415, 416 R-1, 417	See List of Effective Pages
8	*8/13/18*	*FCN 721029-418, 419 R-1, 420 R-1, 421, 422*	*See List of Effective Pages*

Executive Summary

This Updated Final Safety Analysis Report (UFSAR) provides the generic safety analysis for the standardized Advanced NUHOMS®[1] System for dry storage of light water reactor spent nuclear fuel assemblies. This system provides for the safe dry storage of spent fuel in a passive Independent Spent Fuel Storage Installation (ISFSI) which fully complies with the requirements of 10 CFR Part 72 and ANSI 57.9.

The UFSAR describes the design and forms the basis for generic NRC certification of the standardized Advanced NUHOMS® System and will be used by 10 CFR Part 50/10 CFR Part 72 general license holders in accordance with 10 CFR 72 Subparts K and L. It is also suitable for reference in 10 CFR Part 72 site specific license applications.

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

1. Modification to the C of C No. 1004 HSM (development of Advanced HSM, AHSM) to support qualification for sites with high seismic spectra and/or requirements for a significant reduction in ISFSI dose (e.g., due to congested reactor sites).
2. The AHSM configuration requires a minimum of three AHSMs tied together to limit sliding and uplift during a seismic event.
3. The Dry Shielded Canister used in this application, the 24PT1-DSC, is a modification to the FO-DSC (associated with C of C No. 9255 and Rancho Seco Materials License SNM-2510, Docket No. 72-11) with additional provisions allowing storage of intact and damaged fuel assemblies, along with control components in a single DSC.

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

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

Auxiliary equipment and the transfer system, including the transfer casks, were previously certified under C of C 1004 and are not considered part of the standardized Advanced NUHOMS® System subject to approval under C of C 1029. Sufficient information for the transfer system and auxiliary equipment is included in this UFSAR to demonstrate that means for safe operation of the system are provided.

Revision 1 of this UFSAR incorporates modifications implemented under the provisions of 10 CFR 72.48 from March 20, 2003 through March 20, 2005.

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

Revision 2 of this UFSAR incorporates changes implemented due to the approval of CoC 1029 Amendment 1, effective May 16, 2005. It also incorporates modifications implemented per 10 CFR 72.48 from March 21, 2005 through August 15, 2006.

Revision 3 of this UFSAR incorporates modifications implemented per 10 CFR 72.48 from August 16, 2006 through August 15, 2008. This revision also includes a full list of effective pages.

Revision 4 of this UFSAR incorporates modifications implemented per 10 CFR 72.48 from August 16, 2008 through August 12, 2010.

Revision 5 of this UFSAR incorporates modifications implemented per 10 CFR 72.48 from August 13, 2010 through August 13, 2012.

Revision 6 of this UFSAR incorporates modifications implemented per 10 CFR 72.48 from August 14, 2012 through August 13, 2014.

Revision 7 of this UFSAR incorporates changes implemented due to the approval of CoC 1029 Amendment 3, effective February 23, 2015. It also incorporates modifications implemented per 10 CFR 72.48 from August 14, 2014 through August 11, 2016.

Revision 8 of this UFSAR incorporates modifications implemented per 10 CFR 72.48 from August 12, 2016 through August 13, 2018.

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[1] Because SAR drawings were revised throughout the licensing period, their revision level may be higher than the overall UFSAR revision level.

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[1] Because SAR drawings were revised throughout the licensing period, their revision level may be higher than the overall UFSAR revision level.

[2] Because SAR drawings were revised throughout the licensing period, their revision level may be higher than the overall UFSAR revision level.

[3] Because SAR drawings were revised throughout the licensing period, their revision level may be higher than the overall UFSAR revision level.

[4] Because SAR drawings were revised throughout the licensing period, their revision level may be higher than the overall UFSAR revision level.

[5] Because SAR drawings were revised throughout the licensing period, their revision level may be higher than the overall UFSAR revision level.

[6] Because SAR drawings were revised throughout the licensing period, their revision level may be higher than the overall UFSAR revision level.

[7] Because SAR drawings were revised throughout the licensing period, their revision level may be higher than the overall UFSAR revision level.

[8] Because SAR drawings were revised throughout the licensing period, their revision level may be higher than the overall UFSAR revision level.

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

[1.5] TN, Safety Analysis Report for the NUHOMS® MP187 Multi-Purpose Cask, NUH-005, Revision 17, July 2003, USNRC Docket No. 71-9255.

[1.6] TN, Updated Final Safety Analysis Report for the Standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel, Revision 9, February 2006, File NUH003.0103, USNRC Docket No. 72-1004.

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

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

[1.9] NRC Certificate of Compliance 72-1004, NUHOMS® General License Spent Fuel Storage System, Amendment No. 8, December 2005.

1.5.2 Drawings

- 24PT1-DSC: NUH-05-4010, Rev. *6* (PROPRIETARY)

- AHSM: NUH-03-4011, Rev. *8* (PROPRIETARY)

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Proprietary and Security Related Information for Drawing NUH-05-4010-SAR, Rev. 6 Withheld Pursuant to 10 CFR 2.390

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Proprietary and Security Related Information for Drawing NUH-03-4011-SAR, Rev. 8 Withheld Pursuant to 10 CFR 2.390

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

Component[3]	10 CFR Part 72 Classification[1]
Dry Storage Canister (24PT1-DSC)	
Guidesleeves	Important to Safety
Spacer Discs	Important to Safety
Support Rods	Important to Safety
Shield Plugs (Top and Bottom)	Important to Safety
Shell	Important to Safety
Cover Plates (Top and Bottom)	Important to Safety
DSC Support Ring	Important to Safety
Siphon and Vent Block	Important to Safety
Siphon and Vent Port Cover Plates	Important to Safety
Grapple Ring and Grapple Support	Important to Safety
Weld Filler Metal	Important to Safety
Failed Fuel Can	Important to Safety
Electroless nickel coating	*Not Important to Safety*
Horizontal Storage Module (AHSM)	
Reinforced Concrete	Important to Safety
24PT1-DSC Support Structure	Important to Safety
Thermal Instrumentation	Not Important to Safety
AHSM/Cask Restraint	Important to Safety
Galvanized and zinc rich coatings	*Not Important to Safety*
ISFSI Basemat and Approach Slabs	Not Important to Safety
Transfer Equipment	
On-site Transfer Cask	Important to Safety
Cask Lifting Yoke	Safety Related[2]
Transfer Trailer/Skid	Not Important to Safety
Ram Assembly	Not Important to Safety
Dry Film Lubricant	Not Important to Safety
Auxiliary Equipment	
Vacuum Drying System	Not Important to Safety
Automatic Welding System	Not Important to Safety
Transfer Cask/DSC Annulus Seal	Not Important to Safety

(1) Structures, systems and components "important to safety" are defined in 10 CFR 72.3 as those features of the ISFSI whose function is (1) to maintain the conditions required to store spent fuel safely, (2) to prevent damage to the spent fuel container during handling and storage, or (3) to provide reasonable assurance that spent fuel can be received, handled, packaged, stored, and retrieved without undue risk to the health and safety of the public.

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

(3) For safety classification of individual parts, see the drawings in Section 1.5.2.

4.4 Thermal Evaluation for Normal Conditions of Storage and Transfer

4.4.1 Overview of Thermal Analysis for Normal Conditions of Storage and Transfer

This section of the UFSAR describes the thermal analysis of the AHSM and 24PT1-DSC. The analytical models of the AHSM, the 24PT1-DSC, and the transfer cask are described and the calculation results are summarized below. The thermophysical properties of the Advanced NUHOMS® System components used in the thermal analysis are listed in Section 4.2. The following evaluations are performed for the Advanced NUHOMS® System:

1. Thermal Analysis of the 24PT1-DSC in the AHSM (Section 4.4.2),
2. Thermal Analysis of the 24PT1-DSC in the Transfer Cask (Section 4.4.3),
3. Thermal Analysis of the 24PT1-DSC basket (Section 4.4.4).

4.4.2 Thermal Model of the 24PT1-DSC Inside the AHSM

For normal condition of storage, the Advanced NUHOMS® System components are evaluated for a range of design basis ambient temperatures. The system components are evaluated for the average ambient temperatures given in Table 4.1-1. Ambient temperatures within this range are assumed to occur for a sufficient duration to cause a steady-state temperature distribution in the Advanced NUHOMS® System components. The lifetime average ambient temperature for the 40 year service life is taken as 70 °F. The "stress-free" temperature for material properties is also 70 °F.

The AHSM is cooled by a natural draft of air entering through the air inlet opening located in the lower front wall of the AHSM, and exiting through the air outlet opening located in the top of the AHSM. Cooler air at the prevailing ambient conditions is drawn into the AHSM. The cooler air flows from the bottom of the AHSM along the outer 24PT1-DSC surface where it is warmed by the decay heat of the spent fuel inside the 24PT1-DSC. The warmed air flows along the ceiling of the AHSM and exits through the air outlet opening. The AHSM vent geometries and flow paths for ventilation air are illustrated in Figure 4.4-1.

The AHSM roof and front wall are the primary concrete surfaces conducting heat to the outside environment. For the analytical purpose of calculating maximum temperatures, an AHSM centered in a group of AHSMs, each loaded with a 24PT1-DSC, is assumed. Rows of modules are assumed to exist back to back for this model. For the analytical purpose of calculating maximum concrete temperature gradients, an AHSM alone, with no adjacent modules or rear shield wall, is assumed.

A metal heat shield is placed around the upper half of the 24PT1-DSC to shield the AHSM concrete surfaces above and to the side of the 24PT1-DSC from thermal radiation effects. The location and geometry of the heat shield is shown in Figure 4.4-6 and on the AHSM drawings contained in Chapter 1. The heat shield protects the AHSM surfaces above and to the side of the 24PT1-DSC from direct thermal radiation emanating from the 24PT1-DSC surface and significantly increases the combined surface area for convection cooling inside the AHSM. The

temperature calculated in two consecutive iterations indicating that stable convergence is achieved. The remaining thermal-hydraulic parameters used in the AHSM heat transfer calculations are given in Section 4.4.*3*.

The results of the HEATING7 analysis for the AHSM are in the form of temperature distribution profiles. The resulting temperature profiles show the steady state temperature distribution of the 24PT1-DSC shell assembly at various locations throughout the AHSM.

The calculated AHSM concrete temperatures are used in the structural analysis for long term thermal loads which occur during normal operating conditions. The AHSM thermal analysis results are also used to obtain steady state temperature distributions for the outer surface of the 24PT1-DSC for the range of design basis ambient conditions. These steady state surface temperatures are used as a temperature boundary condition for the 24PT1-DSC model, described in Section 4.4.4.

4.4.2.3 Description of Cases Evaluated for the AHSM

The AHSM thermal analyses are performed for the design basis normal ambient air temperatures defined in Section 4.1. These include a total of three cases with ambient air entering and/or surrounding the AHSM at the temperatures listed in Table 4.4-1, noting that a daily average of the maximum summer ambient condition was used in accordance with Section 4.1.

Temperature distributions of the concrete are used to determine thermal stresses in the structure for all three normal cases.

The AHSM thermal model also includes the 24PT1-DSC shell, top and bottom plates and shield plugs, as shown in Figure 4.4-2 and Figure 4.4-5. The temperature profiles generated for the top and bottom cover plates and shield plugs, as well as the cylindrical shell are used to determine thermal stresses within these components. The normal cases which are considered are listed in Table 4.4-8.

4.4.2.4 AHSM Thermal Model Results

The results of the AHSM thermal analysis are shown in Table 4.4-3 for the heat shield, support steel and concrete for a heat load of 24 kW. The maximum temperatures are compared to their material limits in Table 4.1-3 for normal operation. The 24PT1-DSC shell results for lower decay heats of 16 and 14 kW, which are used to generate the 24PT1-DSC basket temperature profiles, are given in Table 4.4-4.

The maximum temperature results for the 24PT1-DSC shell assembly are given in Table 4.4-5 for a heat load of 24 kW. Maximum temperatures of the 24PT1-DSC shell assembly are verified to be within their material limits, as defined in the ASME B&PV Code [4.7] in Table 4.1-3 (data provided in this table are the enveloping temperatures for the storage and transfer cases).

4.4.3 Thermal Model of 24PT1-DSC in the Transfer Cask

4.4.3.1 Model Description

The transfer cask analysis for the OS197 transfer cask has already been performed for 24 kW [4.17]. For the current fuel types and heat loads considered, the same model is utilized with the ambient conditions consistent with Table 4.1-1. This model is an axisymmetric two dimensional model which includes the cask and the 24PT1-DSC shell assembly. The 24PT1-DSC cavity is modeled as a homogenous region. The 24PT1-DSC shell assembly dimensions are nearly identical to those used in the previous analysis. The cover plates and shell assembly in the old model are stainless steel, type 304, as opposed to stainless steel, type 316 for the 24PT1-DSC design. But based on Section *4.4.3*, the difference in thermal conductivity of these two materials is very small and would have a negligible impact on the results.

4.4.3.2 Description of Cases Evaluated for the 24PT1-DSC Inside OS197 Transfer Cask

The transfer cask normal thermal analyses are performed for the range of design basis ambient air temperatures defined in Section 4.1 for normal conditions. The transfer cask thermal analysis is not performed for the design life average temperature since this case is needed only for the storage in the AHSM to ensure the integrity of the fuel cladding and is enveloped by the other normal cases. In accordance with NUREG-1536 [4.5], the short term fuel cladding temperature limit applies to all transfer cask operations.

The thermal stress analysis of the 24PT1-DSC shell assembly is based on the temperature results from the previous analysis of the OS197 cask and shell assembly with 24 kW heat load [4.17]. Three dimensional temperature profiles of the 24PT1-DSC shell and top and bottom cover plates and shield plugs are used from the prior results of the OS197 transfer cask analysis with 24 kW heat load for use in thermal stress calculations. The cases which are used to determine thermal stresses for normal conditions are listed in Table 4.4-8.

New cases are performed only in order to provide 24PT1-DSC shell temperature boundary conditions for the 24PT1-DSC basket thermal model. A single temperature for the 24PT1-DSC shell is extracted from the results of the transfer cask thermal analysis for use in the 24PT1-DSC basket thermal analysis.

4.4.3.3 Transfer Cask Thermal Model Results

The maximum temperature results for the shell assembly during transfer operations are presented in Table 4.4-5. These results are for 24 kW heat load, and are from the previous thermal analysis of the OS197 transfer cask [4.17]. These results are used in the structural analysis described in Chapter 3. The maximum temperature of the 24PT1-DSC shell for 16 kW decay heat, which bounds the design basis decay heat of 14 kW, is given in Table 4.4-4. These temperatures are used as boundary conditions in the 24PT1-DSC basket thermal analysis presented in Section 4.4.5.

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Table 4.4-12
Technical Specifications *5.2.5.b* Temperature Monitoring Limits for the 24PT1-DSC

	Max Temp (°F)	Max Temp Rise (°F) (in 24 hours)
Single Thermocouple (y = 34.5", x = 0, z = 4.75")	225	80[1]
Dual Thermocouple (y = 60", x = +/-15", z = -11.25")	175	8[2]

1. Based on a 24 kW DSC heat load, as noted in Technical Specification Section 5.2.5.*b* at the analyzed location in the AHSM base.
2. Based on a 14 kW DSC heat load, at the dual "as-built" thermocouple locations provided in the AHSM roof. A limit of 3 °F applies if the surveillance period is 12 hours instead of 24 hours.

4.5 Thermal Evaluation for Off-Normal Conditions

4.5.1 Overview of Off-Normal Analysis

For off-normal conditions of storage, the Advanced NUHOMS® System components are evaluated for a range of extreme ambient temperatures listed in Table 4.1-1. Should these extreme conditions ever occur, they would be expected to last for a very short time. Nevertheless, these ambient temperatures are conservatively assumed to occur for a sufficient duration to cause a steady-state temperature distribution in the Advanced NUHOMS® System components. For off-normal and accident summer ambient conditions, 123 BTU/hr.-ft^2, is conservatively applied to the AHSM roof surface. The enveloping solar heat flux of 123 Btu/hr-ft^2 Reference [4.20] for the extreme off-normal case is based on a flat horizontal surface averaged over a 24 hour day [4.5]. Solar heat loads are conservatively neglected for the AHSM thermal analysis for off-normal winter ambient conditions. The solar heat loads are listed in Table 4.1-1.

The same models are used for the 24PT1-DSC inside the AHSM, the 24PT1-DSC inside the transfer cask, and the 24PT1-DSC basket as described in Sections 4.4.2, 4.4.*3* and 4.4.4, respectively. For the transfer cask, a sunshade is required to be placed over the cask for temperatures above 100°F. This requirement is listed in Reference [4.17].

4.5.2 Thermal Analysis Results

The maximum AHSM temperatures for this condition are listed Table 4.4-3. The maximum 24PT1-DSC shell assembly temperatures for off-normal conditions are given in Table 4.4-5 for 24 kW, and Table 4.4-4 for 16 and 14 kW. The maximum 24PT1-DSC basket assembly temperatures for the 14 and 16 kW cases are given in Table 4.4-6. The maximum fuel cladding temperature results for off-normal conditions is given in Table 4.4-7. The AHSM, 24PT1-DSC, and fuel cladding maximum temperatures are compared against their limits in Table 4.1-4 or off-normal conditions.

The cases providing data for thermal stress analyses are given in Table 4.4-8.

4.5.3 Maximum Pressure

The methodology for calculating the maximum pressure in the 24PT1-DSC cavity during off-normal conditions is described in Section 4.4.8. The criterion for the off-normal pressure is established by accounting for the possible presence of fission gases in the 24PT1-DSC cavity which will reduce the effective cover gas conductivity, and thus increase temperatures and pressures.

Based on the basket temperature results in Table 4.4-6 and the fuel cladding temperature results of Table 4.4-7, the maximum pressure in the 24PT1-DSC cavity for off-normal conditions will occur while it is in the transfer cask during the maximum normal summer ambient conditions. These temperatures bound the maximum off-normal ambient temperature case because of the required sunshade over the cask. The resulting maximum average helium temperature for the off-normal case is given in Table 4.4-11.

maximum 24PT1-DSC basket component and fuel cladding temperatures with a steady state evaluation of the 24PT1-DSC basket.

The initial conditions for the transient analysis correspond to the steady state temperatures calculated at the off-normal analysis extreme ambient temperatures. The heat source included in the analysis is 24 kW for the qualification of the concrete and 14 kW for the qualification of the 24PT1-DSC. The solution is carried out to 40 hours. At that time, corrective action is required to restore natural circulation air flow to the AHSM. The maximum concrete temperature during the 40 hour blocked vent condition is given in Table 4.4-3. The maximum 24PT1-DSC shell assembly and basket component temperatures for the blocked vent accident are given in Table 4.4-5 and Table 4.4-6, respectively. The maximum fuel cladding temperature for the 40 hour blocked vent accident are given in Table 4.4-7.

These temperatures are below the associated safety limits for the AHSM or 24PT1-DSC. The short time exposure of the 24PT1-DSC and the spent fuel assemblies to the elevated temperatures will not cause any damage. The maximum 24PT1-DSC internal pressure during this event is calculated in Section 4.6.6.

In order to calculate the maximum thermal stresses in the concrete, additional runs were made with the side surfaces of the AHSM exposed to the prevailing ambient conditions to maximize gradients in the concrete, as discussed in Section 4.4.2.2. The thermal-induced stresses for the blocked vent case are presented for the AHSM in Chapter 3. Temperature profiles for both extreme ambient conditions were derived for the AHSM concrete for determining thermal stresses. These cases are listed in Table 4.4-8.

4.6.3 Transfer Cask Loss of Neutron Shield and Sunshade

The transfer cask and 24PT1-DSC are analyzed for a postulated accident in which the transfer cask loses the water annular neutron shielding and the required sunshade during transfer at the extreme off-normal summer ambient condition given in Table 4.1-1. Even though such a scenario would likely result in immediate corrective action, the duration of the accident is conservatively assumed to result in steady state temperature distributions in the transfer cask and 24PT1-DSC. This analysis was performed previously to support the addition of the OS197 transfer cask to the NUHOMS® design described in Reference [4.17]. Therefore, the cask has already been analyzed for such an event. As described in Section *4.4.3*, an identical model was used with a conservative heat load of 16 kW to determine the 24PT1-DSC shell temperatures so that an analysis of the 24PT1-DSC basket could be performed. The resulting maximum shell temperature is listed Table 4.4-4 for a conservative heat load of 16 kW. The 24PT1-DSC basket model used to determine the maximum fuel cladding and 24PT1-DSC basket component maximum temperatures is identical to that described in Section 4.4.4. This model is analyzed with 14 kW heat load for the shell temperature boundary condition derived for 16 kW heat load. The resulting maximum 24PT1-DSC basket component temperatures are listed in Table 4.4-6. The results in Table 4.4-6 show that this accident is bounded by the blocked vent analysis so that end point criteria for the 24PT1-DSC, such as cavity pressure, fuel cladding integrity, compliance of the 24PT1-DSC structural materials with ASME B&PV Code temperature limit criteria of the blocked vent scenario can be used.

4.6.4 Fire Accident Evaluation

The Advanced NUHOMS® System will be stored on a concrete basemat away from combustible material. Therefore, a credible fire would be very small and of short duration such as that due to a fire or explosion from a vehicle or portable crane. A hypothetical fire accident is evaluated for the Advanced NUHOMS® System based on a fuel fire, the source of fuel being a ruptured fuel tank of the canister transporter tow vehicle or any other source of combustible fuel. The bounding capacity of combustible fuel is assumed to be 300 gallons and the bounding hypothetical fire is an engulfing fire. In addition, the postulated fire can only occur during transfer operations when personnel will be present to rapidly effect extinguishment of the fire.

From IAEA requirements [4.23] for a transport (10 CFR Part 71) condition, the "pool" of fuel is assumed to extend 1 meter beyond the ends of the cask. For this analysis, a pool diameter of 201.5 inches, which is approximately 6 inches shorter than the nominal length of the cask is conservatively assumed to engulf the entire cask. The thickness of this fuel pool would be 2.17 inch. A fuel consumption rate of 0.15 in/min. was selected from a Sandia Report [4.24] concerning gasoline/tractor kerosene experimental burning rates. Therefore, the 300 gallons of fuel will sustain a fire for about 14 minutes and hence a 15 minute fire is conservatively evaluated. The fire parameters, other than time duration, from 10 CFR 71.73 [4.20] are used. The recommended fire temperature is 1475°F. Forced convection from the fire to the cask is described by using a constant heat transfer coefficient of 5.21E-4 Btu/min-in^2-°F, which is conservative based on measurements made at fire tests [4.24]. The recommendations of 10 CFR 71.73 are also used to determine the radiation heat transfer from the fire to the cask.

This conservative fire evaluation is only performed to demonstrate the confinement integrity and fuel retrievability of the Advanced NUHOMS® System.

The model of the 24PT1-DSC inside the OS197 transfer cask which is described in Section 4.4.*3* is used to determine the response of the DSC to the fire described above. The external boundary conditions of the OS197 transfer cask are set to the fire temperature and forced convection boundary conditions during the fire. Following the fire, the cask is subjected to the prevailing maximum off-normal ambient conditions. The initial temperature distribution is conservatively calculated at steady state conditions at the maximum off-normal ambient temperature with no sunshade. The transient analysis was performed in two steps; the fifteen-minute fire followed by a post fire heatup of the OS197 transfer cask and 24PT1-DSC. During the post fire heatup period, complete loss of the water in the annular neutron shield of the OS197 cask is assumed. Chapter 11 provides an evaluation of the *effect* on doses as a result of the potential loss of the neutron shield. The points monitored in the OS197 cask and 24PT1-DSC shell assembly are; (1) cask annular water neutron shield region, (2) cask structural steel, (3) the cask lead, (4) the 24PT1-DSC shell assembly, and (5) the cask lid.

The results of the analysis show that the cask neutron shields will be compromised as a result of the fire, but this will not impact the retrievability of the fuel, since the 24PT1-DSC shell assembly components are well within allowable temperatures. The maximum calculated DSC shell temperature for this conservative fire condition is 467 °F. Comparing this to the results for the 24PT1-DSC in Table 4.4-4 shows that this extremely conservative fire accident is bounded

4.7 Thermal Evaluation for Loading/Unloading Conditions

All fuel transfer operations occur when the 24PT1-DSC is in the spent fuel pool. The fuel is always submerged in free-flowing pool water permitting heat dissipation. After fuel loading is complete, the 24PT1-DSC is removed from the pool, drained, dried, and backfilled with helium.

The two loading conditions evaluated for the Advanced NUHOMS® System are the heatup of the 24PT1-DSC before its cavity can be backfilled with helium and the vacuum drying transient. Transient thermal analyses are performed to predict the heatup time history for the 24PT1-DSC components during these events.

The unloading operation considered is the reflood of the 24PT1-DSC with water.

4.7.1 Vacuum Drying Thermal Analysis

Analyses were performed for the vacuum drying condition in order to ensure that the fuel cladding and 24PT1-DSC structural component temperatures remain below the maximum allowable limits shown in Table 4.7-1. For every component except the spacer disc, steady state temperature distributions gave satisfactory results. To show compliance with the ASME B&PV Code [4.7] temperature limits for the spacer disc material, transient analyses were performed to determine the time to reach 700°F, the temperature limit for SA-537, Class 2 plate. These time limits for the vacuum drying case are shown in Table 4.7-2.

For the steady state analysis, the model is similar to the model described in Section *4.4.3* and shown in Figure 4.4-6, Figure 4.4-7, and Figure 4.4-8. The exception is that the helium regions are replaced with air. Assuming that the cavity is filled with air during the vacuum drying operation provides conservative results since during the majority of the vacuum drying operation, the 24PT1-DSC cavity void volume is filled with a mixture of air, water and water vapor, and no credit is taken for evaporation of water, which is a strong cooling mechanism that takes place during this operation. Air thermal conductivity does not change significantly at lower pressures, therefore, the use of a thermal conductivity for a pressure higher than 3 Torr is acceptable. In accordance with Chapter 8, water is required to be in the annulus between the 24PT1-DSC and the transfer cask during the vacuum drying process. Therefore, the 24PT1-DSC shell boundary is set to a temperature of 230°F as a conservative estimate of the shell wall temperature during this operation. A heat load of 14 kW is considered in computing the maximum fuel cladding temperature. The 14 kW heat load is also used to calculate the maximum 24PT1-DSC component temperatures. The resulting maximum temperatures are tabulated in Table 4.4-6 and Table 4.4-7 for the basket structural components and fuel cladding respectively.

For the transient analysis, the model from Section 4.4.4 is used with the constant temperature boundary condition described above and the change to the helium regions described above. The density and specific heat of the basket materials and fuel assembly from Section 4.2 are also used in the HEATING7 model. The time transient is measured from the beginning of the blowdown procedure to the beginning of the final helium backfill procedure. Therefore, the initial temperature of the basket is conservatively set to the saturation temperature of water as an initial condition. The transient vacuum drying case is performed for heat loads of 13 and 14 kW.

The Advanced NUHOMS® System finite difference model discussed in Section 4.4.*3* is modified for this transient analysis. The 24PT1-DSC inside the transfer cask model is modified to omit the top and bottom 24PT1-DSC cover plates and the top and bottom cask cover plates. Hence, the model conservatively does not credit any heat transfer in the axial direction. Homogenized effective thermal properties of the 24PT1-DSC cavity are calculated based on the weight, volume and material of the components. Radiation heat transfer within the 24PT1-DSC cavity is neglected. All temperatures in the 24PT1-DSC are initially assumed to be at the maximum spent fuel pool temperature. The exterior of the cask is assumed to radiate and convect heat to the prevailing ambient conditions of the fuel building. The analyses are performed for two separate maximum building and fuel pool conditions, which are given in Table 4.7-3. The results are tabulated in Table 4.7-3 and shown in Figure 4.7-2 for canister decay heat loads ranging from 10 to 14 kW for the 2 cases.

4.7.4 Pressure During Loading of Cask

The maximum pressure during cask blowdown is 20 psig (hydrostatic pressure of DSC water is balanced by hydrostatic pressure of DSC cask annulus). This is discussed in Chapter 3.

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A.1.5 Supplemental Data

A.1.5.1 References

[A1.1] U.S. Nuclear Regulatory Commission, Regulatory Guide 3.61, Standard Format and Content for a Topical Safety Analysis Report for a Spent Fuel Dry Storage Cask, February 1989.

[A1.2] 10 CFR Part 72, Rules and Regulations, Title 10, Code of Federal Regulations - Energy, U.S. Nuclear Regulatory Commission, Washington, D.C., "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste."

[A1.3] Deleted.

[A1.4] TN, Updated Final Safety Analysis Report for the Standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel, Revision 9, February 2006, US NRC Docket No. 72-1004.

[A1.5] NRC Certificate of Compliance 1004, NUHOMS® General License Spent Fuel Storage System, Amendment No. 8, December 2005, US NRC Docket No. 72-1004.

A.1.5.2 Drawings

- 24PT4-DSC: ANUH-01-4001, Rev. 7

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Proprietary and Security Related Information for Drawing ANUH-01-4001-SAR, Rev. 7 Withheld Pursuant to 10 CFR 2.390

8 7 6 5 4 3 2 1

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

COMPONENT(2)	10 CFR Part 72 (1) CLASSIFICATION
Dry Storage Canister (24PT4-DSC)	
Guidesleeves	Important to Safety
Spacer Discs	Important to Safety
Support Rods	Important to Safety
Shield Plugs (Top and Bottom)	Important to Safety
Shell	Important to Safety
Cover Plates (Top and Bottom)	Important to Safety
DSC Support Ring	Important to Safety
Siphon and Vent Block	Important to Safety
Siphon and Vent Port Cover Plates	Important to Safety
Grapple Ring and Grapple Support	Important to Safety
Weld Filler Metal	Important to Safety
Failed Fuel Can	Important to Safety
Electroless nickel coating	*Not Important to Safety*
Horizontal Storage Module (AHSM)	No change (See Table 2.5-1)
ISFSI Basemat and Approach Slabs	No change (See Table 2.5-1)
Transfer Equipment	No change (See Table 2.5-1)
Auxiliary Equipment	No change (See Table 2.5-1)

(1) Structures, systems and components "important to safety" are defined in 10 CFR 72.3 as those features of the ISFSI whose function is (1) to maintain the conditions required to store spent fuel safely, (2) to prevent damage to the spent fuel container during handling and storage, or (3) to provide reasonable assurance that spent fuel can be received, handled, packaged, stored, and retrieved without undue risk to the health and safety of the public.

(2) For safety classification of individual parts, see the drawings in Section A.1.5.2.

Table A.4.4-11
Technical Specifications *5.2.5.b* Temperature Monitoring Limits for the 24PT4 DSC

	Max Temp (°F)	**Max Temp Rise (°F) (in 12 hours)**
Single Thermocouple (y = 34.5", x = 0, z = 4.75")	225	30(1)
Dual Thermocouple (y = 60", x = +/-15", z = -11.25")	200	5(2)

1. Based on a 24 kW DSC heat load, as noted in Technical Specification Section 5.2.5.*b*. at the analyzed location in the AHSM base.
2. Based on a 24 kW DSC heat load, as noted in Technical Specification Section 5.2.5.*b*. at the "as-built" dual thermocouple locations provided in the AHSM roof.

Table B.2.5-1
NUHOMS® 32PTH2 System Major Components and Safety Classification

Component(1)	10 CFR Part 72 Classification
32PTH2 DSC Assembly	
DSC shell	Important to Safety
Inner and outer bottom cover plates	Important to Safety
Top and bottom shield plugs	Important to Safety
Inner and outer top cover plates	Important to Safety
Siphon/vent port cover plate	Important to Safety
Siphon and vent block	Important to Safety
DSC support ring	Important to Safety
Grapple ring and support	Important to Safety
Test port plug	Important to Safety
Weld filler metal	Important to Safety
Siphon tube	Not Important to Safety
Quick connect coupling	Not Important to Safety
Male connector	Not Important to Safety
Electroless nickel coating	Not Important to Safety
32PTH2 DSC Basket Assembly	
Fuel compartment	Important to Safety
Poison plate	Important to Safety
Basket plate	Important to Safety
Basket support plates (inserts)	Important to Safety
Basket rail	Important to Safety
Weld filler metal	Important to Safety
Top and bottom End Caps	Important to Safety
Alignment key	Not Important to Safety
AHSM-HS	
Reinforced Concrete	Important to Safety
32PTH2 DSC Support Rail	Important to Safety
Thermal Instrumentation	Not Important to Safety
AHSM-HS/OS200FC TC Restraint	Not Important to Safety
Galvanized and zinc rich coatings	*Not Important to Safety*
ISFSI Basemat and Approach Slabs	Not Important to Safety
Transfer Equipment	
OS200FC TC	Important to Safety
OS200FC TC Lifting Yoke	Safety Related
Transfer Trailer/Skid	Not Important to Safety
Ram Assembly	Not Important to Safety
Dry Film Lubricant	Not Important to Safety
Auxiliary Equipment	
Vacuum Drying System	Not Important to Safety
Automated Welding System	Not Important to Safety
OS200FC TC/32PTH2 DSC Annulus Seal	Not Important to Safety

(1) For safety classification of individual parts, see the drawings in Section B.1.5.2.

5. Connect the TC drain line to the TC, open the TC cavity drain port and allow water from the annulus to drain out until the water level is approximately twelve inches below the top edge of the 32PTH2 DSC shell. Take swipes around the outer surface of the 32PTH2 DSC shell and check for smearable contamination in accordance with the Technical Specification 5.2.4.d limits.

   CAUTION: Verify that no inadvertent draining of the TC neutron shield water has occurred.

   CAUTION: Radiation dose rates are expected to be high at the vent and siphon port locations. Use proper ALARA practices (e.g., use of temporary shielding, appropriate positioning of personnel, etc.) to minimize personnel exposure.

6. Drain approximately 60 gallons of water (as indicated on a flowmeter) from the 32PTH2 DSC back into the fuel pool or other suitable location. *Consistent with ISG-22 [B8.6] guidance and Technical Specification 3.1.1.c, helium at 1-3 psig is used to backfill the DSC with an inert gas as water is being removed from the DSC.* This will lower the water level in the DSC cavity approximately four inches below the bottom of the shield plug. As only the very top of the stainless steel end fittings of the fuel assembly are uncovered during this step, the DSC cavity does not require a helium backfill.

   CAUTION: Hydrogen concentration must be monitored as described in Step 10 below to ensure that the maximum allowable concentration of 2.4% is not exceeded.

7. Monitor TC/DSC annulus water level to be approximately twelve inches below the top of the DSC shell and replenish as necessary until drained.

   Possible approaches to monitoring/replenishing include, but are not limited to, monitoring the annulus water level using a sight glass (or tube) attached to the cask annulus drain port.

8. Install the automated welding machine onto the inner top cover plate and place the inner top cover plate with the automated welding machine onto the 32PTH2 DSC. Optionally, the inner top cover plate and the automated welding machine can be placed separately. Verify proper fit-up of the inner top cover plate with the 32PTH2 DSC shell.

9. Check radiation levels on the surface of the inner top cover plate. Temporary shielding may be installed as necessary to minimize personnel exposure.

10. Continuous hydrogen monitoring of the 32PTH2 DSC cavity during welding of the inner top cover plate is required [B8.2]. Connect a hydrogen monitor to the vent port using flexible tubing or a quick disconnect stem fitting to allow continuous monitoring of the atmosphere in the 32PTH2 DSC cavity during welding of the inner cover plate, in compliance with Technical Specification 5.2.6. Optionally, other methods may be used for continuous monitoring of the hydrogen concentration in the 32PTH2 DSC cavity during welding of the inner top cover plate, to comply with the Technical Specification.

11. Cover the TC/32PTH2 DSC annulus to prevent debris and weld splatter from entering the annulus.

12. Ready the automated welding machine and tack weld the inner top cover plate to the 32PTH2 DSC shell. Complete the inner top cover plate weldment (a minimum of two passes is required) and remove the automated welding machine.

CAUTION: Per Technical Specification 5.2.6, continuously monitor the hydrogen concentration in the 32PTH2 DSC cavity using the arrangement or other alternate methods described in Step 10 during the inner top cover plate welding operations. Verify that the measured hydrogen concentration does not exceed a safety limit of 2.4% [B8.2] and [B8.3]. If this limit is exceeded, stop all welding operations and purge the 32PTH2 DSC cavity to reduce the hydrogen concentration safely below the 2.4% limit.

13. Perform dye penetrant weld examination of the root and final layers of the inner top cover plate to shell weld in accordance with the Technical Specification 4.3.2 requirements.

14. Remove purge lines and connect the VDS to the 32PTH2 DSC siphon and vent ports.

15. Install temporary shielding to minimize personnel exposure throughout the subsequent welding operations as required.

16. a. If using the blowdown method to remove the cavity water, engage the helium supply (up to 20 psig) and open the valve on the vent port and allow helium to force the water from the 32PTH2 DSC cavity through the siphon port. *Use of helium is required per Technical Specification 3.1.1.c.*

    b. If using water pumps to remove water without blowdown, pump water from the 32PTH2 DSC while backfilling the cavity with helium.

CAUTION: Prior to removal of DSC cavity water, refill the DSC cavity with water to replace residual air with water. Do not over pressurize the cavity.

NOTE: Due to thermal expansion of DSC cavity water during welding operations, only approximately 30 gallons of water will be required to refill the DSC cavity.

17. Once the water stops flowing from the 32PTH2 DSC, close the siphon port and disengage the helium source and/or turn off the suction pump, as applicable.

18. Verify that the TC dose rates are compliant with the limits specified in Technical Specification 5.2.4.f.

19. Connect the hose from the vent port and the siphon port to the intake of the vacuum pump. Connect a hose from the discharge side of the VDS to the plant's radioactive waste system or spent fuel pool. Connect the VDS to a helium source.

CAUTION: Proceed cautiously when evacuating the 32PTH2 DSC to avoid freezing of the lines and fittings.

20. Open the valve on the suction side of the pump, start the VDS and draw a vacuum on the 32PTH2 DSC cavity. The cavity pressure should be reduced in steps to approximately 100 torr, 50 torr, 25 torr, 15 torr, 10 torr, 5 torr, and 3 torr. This staged drawdown will verify no ice blockage of the evacuation path. After pumping down to each level (these levels are optional), the pump is valved off and the cavity pressure monitored. The cavity pressure will rise as water and other volatiles in the cavity evaporate. When the cavity pressure stabilizes, the pump is valved in to complete the vacuum drying process. It may be necessary to repeat some steps, depending on the rate and extent of the pressure increase. Vacuum drying is complete when the pressure stabilizes for a minimum of 30 minutes at 3 torr or less as specified in Technical Specification 3.1.1.c.

[B8.4] SNT-TC-1A, “American Society for Nondestructive Testing, Personnel Qualification and Certification in Nondestructive Testing,” 1992.

[B8.5] U.S. Nuclear Regulatory Commission, NUREG-1536, "Standard Review Plan for Dry Cask Storage Systems - Final Report," U.S. Nuclear Regulatory Commission, Office of Nuclear Material Safety and Safeguards”, Revision 1, July 2010.

[B8.6] U.S. Nuclear Regulatory Commission, Interim Staff Guidance (ISG-22), “Potential Rod Splitting due to Exposures to an Oxidizing Atmosphere during Short-term Cask Loading Operations in LWR of Other Uranium Oxide Based Fuel.”