72-1029

TRANSNUCLEAR WEST

August 31, 2001
DCS-TNW0108-05

Mr. Timothy Kobetz
Project Manager, Spent Fuel Project Office
U.S. Nuclear Regulatory Commission
11555 Rockville Pike
Rockville, MD 20852

Subject: Response to Request for Additional Information (RAI) No. 2 and Submittal of Revision 5 of the Advanced NUHOMS® Storage System Application (TAC No. L23203)

Reference: Request for Additional Information (No. 2) Regarding Approval of Advanced NUHOMS® Storage System (TAC No. L23203), August 8, 2001

Dear Mr. Kobetz:

Transnuclear West Inc. herewith submits a comprehensive response to the Reference RAI. In addition, the affected pages of the proprietary and non-proprietary versions of the Advanced NUHOMS® SAR have been updated and are included in this submittal. This submittal does not contain any proprietary information.

Please contact me at 510-744-6020 if you require any additional information in support of this submittal.

Sincerely,

U B Chopra

U. B. Chopra
Licensing Manager

Docket 72-1029

Transnuclear West Inc.
39300 Civic Center Drive, Suite 280, Fremont, CA 94538
Phone: 510-795-9800 • Fax: 510-744-6002

NMSS01 Public

Attachments:

1. Response to the RAI (non-proprietary, 14 copies)
2. Revision 5 replacement pages for the proprietary version of the Advanced NUHOMS® Storage System Application (10 copies).
3. Revision 5 replacement pages for the non-proprietary version of the Advanced NUHOMS® Storage System Application (4 copies).

cc: File: SCE-01-0007.01
Jorge Morales, SCE
Kristi DeBoi, SCE
David Pilmer, SCE

Attachment 1

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION
TRANSNUCLEAR WEST INC., TAC NO. L23203

Chapter 4 Thermal

Question 4-1

Provide a radial temperature profile through the container for the normal storage condition case at 14 kW or a higher heat load that bounds 14 kW.

Include all temperatures of all components along the radial line, including inner and outer DSC shell, guidesleeve, boral plate, and oversleeve, as well as temperatures in the spacer disc and multiple fuel cladding temperatures across each fuel assembly traversed by the radial line. The fuel cladding temperatures in the plot should include the peak cladding temperature in each fuel assembly in the plot. The staff requires this information to assess compliance with 10 CFR 72.122(h)(1).

Response Question 4-1

Requested Data:

The maximum heat load for a single fuel assembly, including control components, is 0.583 kW for SC fuel assemblies and 0.294 kW for MOX fuel assemblies. The maximum heat load per 24PT1-DSC, including any integral Control Components does not exceed 14 kW when loaded with all SC fuel assemblies and 13.706 kW when loaded with MOX fuel assemblies. SAR Section 12.2.1.c has been revised to reflect the maximum MOX fuel assembly heat load limit.

The MOX fuel configuration is addressed in this response due to the lower fuel clad temperature limit for the MOX fuel, 618°F versus 690°F for the SC fuel. Figure 1 of this RAI response provides a radial temperature profile through a 24PT1-DSC with a 13.706 kW heat load. This heat load represents the maximum heat load for a 24PT1-DSC containing one Mixed Oxide (MOX) fuel assembly and twenty three Stainless Steel Clad (SC) fuel assemblies. For a 14 kW DSC with all SC fuel assemblies, the maximum fuel clad temperature would be approximately 15°F higher than the results reported in Figure 1 for the MOX fuel configuration.

The temperature profile at any location across the 24PT1-DSC may be obtained by locating the y axis location of the component or position, as shown in Figures 4.4-6 and 4.4-7 of the SAR, and locating the corresponding temperature in Figure 1 of this RAI response. The peak fuel temperature for each fuel assembly region is located at the point closest to the center of the 24PT1-DSC within the fuel assembly region.

A discussion of the MOX fuel maximum decay heat load per 24PT1-DSC has been incorporated in SAR Section 4.0. Additionally, the thermal analysis results presented in SAR Table 4.1-3 for a 16 kW 24PT1-DSC heat load have been clarified. SAR Chapters 2 and 12 have also been revised to specify the maximum MOX fuel assembly heat load of 0.294 kW per fuel assembly with a maximum 24PT1-DSC heat load of 13.706 kW per 24PT1-DSC, including control components.

Discussion of TNW analysis versus NRC staff analysis:

The temperatures presented in SAR Chapter 4 are based on the results of analyses using the HEATING computer code approved for use by the NRC in NUREG 1536. The methodology used by TNW to model the internal components of the 24PT1-DSC is the same methodology used in several previously approved 10 CFR 71 and 10 CFR 72 licenses. Differences between TNW analysis temperatures and the temperatures shown in RAI Figure 1 appear to be due to several differences in inputs and modeling. For example, the RAI Figure 1 data appears to be based on a uniform 24PT1-DSC shell temperature along the circumference at the maximum 24PT1-DSC shell temperature. For a horizontal system like the Advanced NUHOMS® System, there is a significant temperature gradient from the top to the bottom of the shell with a minimum value at the bottom, a gradual increase around the circumference and a maximum value at the top of the shell. In addition, the methodology and material properties used to model the fuel assembly region appear to differ significantly.

The 24PT1-DSC peak cladding temperature given in the Request for Additional Information, Table 1, for a uniform shell temperature of 332°F, is 673 °F. Per SAR Table 4.4-4, the 24PT1-DSC peak shell temperature of 332°F is the result of the 117°F ambient off-normal case. As discussed above, the actual shell temperature is not uniform. For the 16 kW case, the 24PT1-DSC shell temperatures for the 117°F case are 332°F at the top, 315°F at the side and 287°F at the bottom when the 24PT1-DSC is in the AHSM in the horizontal storage configuration. The MOX fuel clad temperature limit is 1058°F for this case. A comparison of the RAI results to this limit provides a margin of 385°F.

The appropriate case for the evaluation of long term storage fuel cladding temperatures is the 70°F long term average ambient temperature condition. The 24PT1-DSC shell temperatures for this case are 297°F at the top, 281°F at the side and 254°F at the bottom. The MOX fuel clad temperature limit is 618°F for this case.

The maximum fuel clad temperature calculated in the SAR for the 70°F long term average ambient temperatures with a 16 kW canister heat load is 604°F. The cladding temperature limit for MOX and SC fuel are 618°F and 690°F, respectively. Based on the results presented in SAR Table 4.1-3, the margin to these limits in the SAR analysis is 14°F and 86°F for MOX and SC fuel assemblies, respectively. The analysis for 16 kW per 24PT1-DSC (0.667 kW per fuel assembly) provides additional conservatism since the Technical Specification heat load limit for the UO_2 stainless steel clad (SC) fuel is 14 kW per 24PT1-DSC and 0.583 kW per fuel assembly, including control components. A technical specification limit for the MOX fuel of 0.294 kW per fuel assembly, including control components, and 13.706 kW per 24PT1-DSC when loaded with MOX fuel assemblies, has been added to SAR Chapter 12.

An additional HEATING run which is representative of the 24PT1-DSC Technical Specification heat load (13.706 kW representing the maximum heat load for a 24PT1-DSC with MOX fuel) has been performed using a 70°F ambient temperature. The Technical Specification heat load limit analysis results in a maximum MOX fuel cladding temperature of 558°F. A margin of 60°F is demonstrated when compared to the 618°F fuel clad temperature limit.

Figure 1 of this RAI response provides the temperature profile through the highest temperature locations in the 13.706 kW 24PT1-DSC analysis with the 70 °F ambient long term storage case. Two plots are provided to represent the fuel assembly temperature at the hottest cross section through a spacer disc and at the hottest location between spacer discs (Z = 0.625" and Z = 3.375" as shown in SAR Figure 4.4-8).

TNW believes that a detailed comparison of the model used to generate the data in RAI Figure 1 with the TNW analysis will result in the identification of conservatisms in the RAI Figure 1 model and analytical approach which, when eliminated, would result in good agreement between the two models.

TNW requests a copy of the analysis supporting the temperature profile provided in RAI Figure 1, including appropriate references for material properties and configurations used which differ from the TNW analysis. This information is requested in order for TNW to understand the model used by the staff.

Question 4-2

Provide the values specified for the width of the gap between the spacer disc and the DSC shell, and all other gaps in the HEATING7 model used to determine the DSC radial temperature profile requested in Question 4-1 above.

This should include a justification of the gaps used in the HEATING7 thermal model based on using the most conservative design basis tolerances. The staff requires this information to assess compliance with 10 CFR 72.122(h)(1).

Response Question 4-2

Table 1 of this RAI response provides a summary of the gaps included in the thermal analysis model. Also included is the equivalent maximum SAR gap. The gaps shown on the SAR drawing are smaller than the gaps modeled in the thermal analysis thereby ensuring a conservative temperature profile.

Question 4-3

Provide an explanation of how thermal expansion of the materials were taken into account and how the gaps in the model were determined.

The explanation should include: 1) whether the gaps differ from the values reported on the drawings included in the SAR; and 2) a justification of the thermal expansion values for each of the materials involved in the analysis. The staff requires this information to assess compliance with 10 CFR 72.122(h)(1).

Response to Question 4-3

Thermal expansion of material was conservatively not considered in the gaps used in the TNW thermal model. See the response to RAI Question 4-2 above for a list of gaps and a comparison to the gaps based on the SAR drawing. The gaps described are ambient temperature gaps and do not credit a decrease in any gap size due to differential thermal growth of the components.

Figure 1 24PT1-DSC Temperature profile

Legend:

Orientation of axes is consistent with SAR Figures 4.4-6, 4.4-7 and 4.4-8

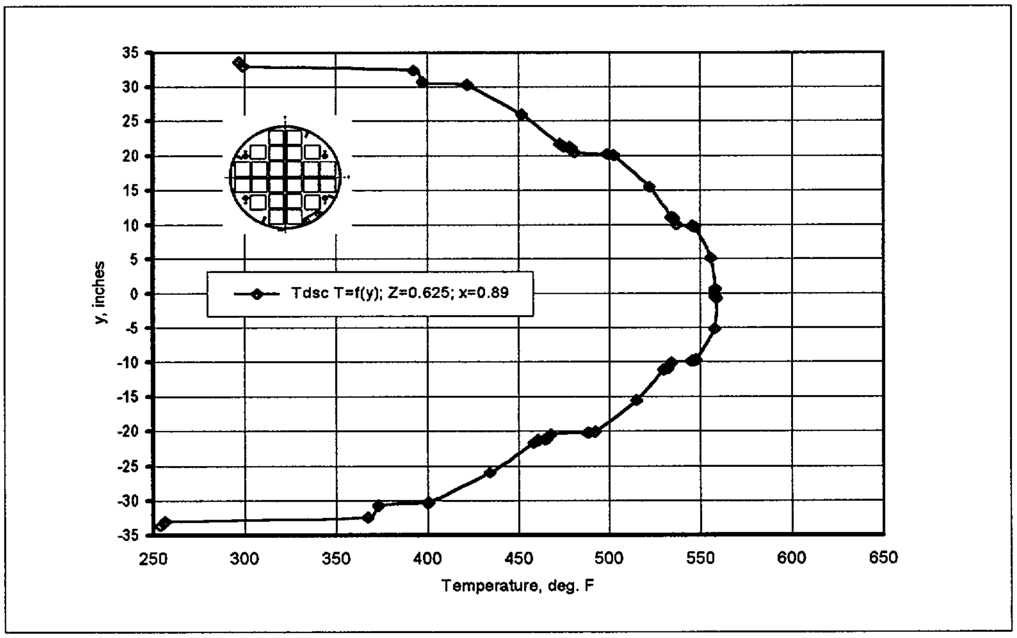
X axis – along horizontal axis of the 24PT1-DSC during storage, in the plane of the spacer disc, all data at x = 0.89", 0.89" from center of spacer disc containing the highest 24PT1-DSC temperature

Z axis – along longitudinal axis of the 24PT1-DSC

Y axis – along vertical axis of DSC during storage mode

Temperature profile at the hottest cross-section of spacer discs, Z = 0.625"

13.706 kW, T_{amb} = 70°F, $T_{shell\ top}$ = 297°F, $T_{shell\ side}$ = 281°F, $T_{shell\ bottom}$ = 254°F



Temperature profile at the hottest cross-section between spacer discs, Z= 3.375"

13.706 kW, T_{amb} = 70°F, $T_{shell\ top}$ = 297°F, $T_{shell\ side}$ = 281°F, $T_{shell\ bottom}$ = 254°F

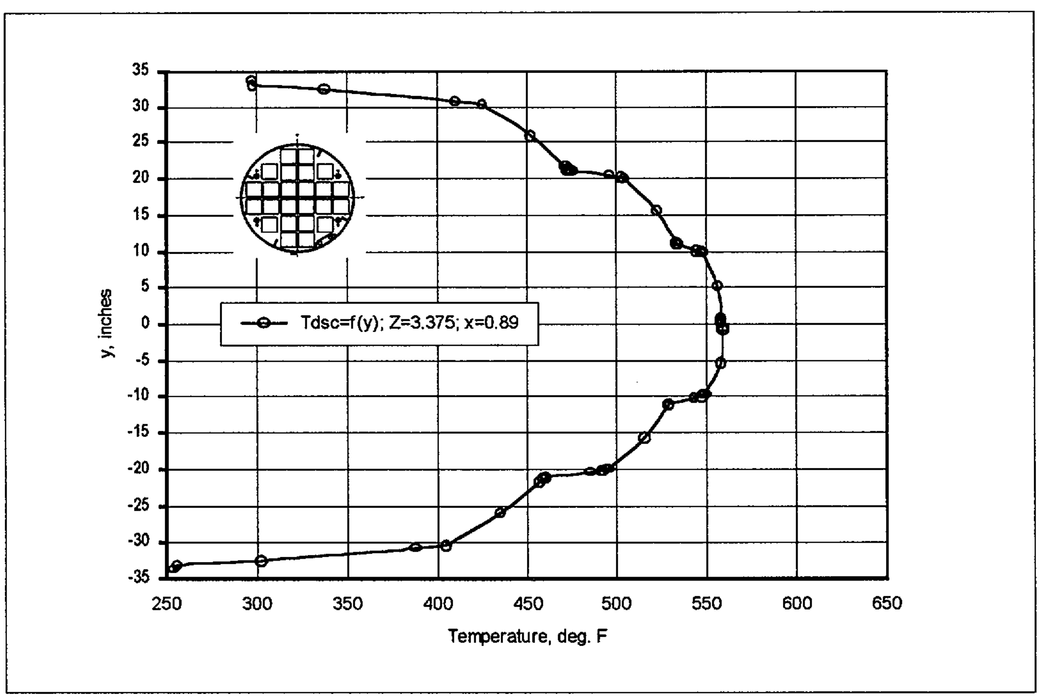


Table 1 Gaps between components at the spacer disc plane[1]

Top Half of Spacer Disc

Component of the model (from the top to the bottom of 24PT1-DSC)	**HEATING Model Region Number of Gap (SAR Figures 4.4-6 and 4.4-7)**	**Gap width Δy (along 24PT1-DSC, storage configuration, vertical axis), per HEATING Model** (in)	**Maximum Gap width from SAR Drawings** (in)
Shell			
Gap	100	0.625	0.435
Spacer disc			
Gap	657	0.3125	0.1165
Guide sleeve			
Fuel region 1			
Guide sleeve			
Gap	413	0.025	0
Poison plate			
Gap	501	0.0055	0
Over-sleeve			
Spacer disc			
Gap	625	0.185	0.1211
Over-sleeve			
Gap	502	0.0055	0
Poison plate			
Gap	415	0.025	0
Guide sleeve			
Fuel region 2			
Guide sleeve			
Gap	420	0.025	0
Poison plate			
Gap	504	0.0055	0
Over-sleeve			
Spacer disc			
Gap	Equiv. To 625, Fuel Region 2	0.185	0.1197
Over-sleeve			
Gap	Equiv. To 502, Fuel Region 2	0.0055	0
Poison plate			
Gap	Equiv. To 415, Fuel Region 2	0.025	0
Guide sleeve			
Fuel region 4			
Guide sleeve			
Gap	Equiv. To 420, Fuel Region 2	0.025	0
Poison plate			
Gap	Equiv. To 504, Fuel Region 2	0.0055	0
Over-sleeve			
Spacer disc			

[1] Gap dimensions specified are at x = .89” and z = .625”.

Table 1 Gaps between components at the spacer disc plane (continued)[1]

Bottom Half of Spacer Disc

Component of the model (from the top to the bottom of 24PT1-DSC)	**HEATING Model Region Number of Gap (SAR Figures 4.4-6 and 4.4-7)**[2]	**Gap width Δy (along 24PT1-DSC, storage configuration, vertical axis), per HEATING Model** (in)	**Maximum Gap width from SAR Drawings** (in)
Spacer disc			
Over-sleeve			
Gap		0.0055	0
Poison plate			
Gap		0.025	0
Guide sleeve			
Fuel reg. 1004			
Guide sleeve			
Gap		0.025	0
Poison plate			
Gap		0.0055	0
Over-sleeve			
Gap		0.185	0.1197
Spacer disc			
Over-sleeve			
Gap		0.0055	0
Poison plate			
Gap		0.025	0
Guide sleeve			
Fuel reg. 1002			
Guide sleeve			
Gap		0.025	0
Poison plate			
Gap		0.0055	0
Over-sleeve			
Gap		0.185	0.1211
Spacer disc			
Over-sleeve			
Gap		0.0055	0
Poison plate			
Gap		0.025	0
Guide sleeve			
Fuel reg. 1001			
Guide sleeve			
Gap		0.3125	0.1165
Spacer disc			
Gap		0.625	0.435
Shell			

[1] Gap dimensions specified are at x = .89" and z = .625".

[2] Fuel Regions 1001, 1002 and 1004 are a mirror image of fuel regions 1, 2 and 4.

ATTACHMENT 2
ANUH-01.0150, Revision 5
Changed Pages
(Only pages with changes are included, pages that have changed due to changes in page breaks need not be included in this attachment but will be included in the final revision upon ECN incorporation and issue of SAR revision. See list of effective pages attached for a complete list of pages associated with this revision.)

ANUH-01.0150
Revision 5

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

PROPRIETARY REPORT

By
Transnuclear West Inc., (TN West)
Fremont, CA

Revision 5
August 2001

Executive Summary

Revisions 1, 2, 3, *4* and *5* of this Safety Analysis Report incorporate changes based on the initial and supplemental responses to NRC Request for *Additional* Information.

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

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

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

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

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

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

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

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

NUHOMS® System is a totally passive installation that is designed to provide shielding and safe confinement of spent fuel for a range of postulated accident conditions and natural phenomena.

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

LIST OF EFFECTIVE PAGES

All pages Revision 1 with the following exceptions:

PAGE	REVISION
Cover Page	*5*
Executive Summary, page iii	*5*
Table of Contents, page viii	2
Table of Contents, page xi	3
List of Tables, page xix	3
List of Figures, page xxiii	4
List of Effective Pages, page xxiv	*5*
2.1-2	3
2.1-2a	3
2.1-4	*5*
4.1-1	*5*
4.1-6	*5*
4.1-7	3
4.1-8	3
4.4-1	3
4.4-4	3
4.4-4a	3
4.4-17	3
6.4-5	3
6.4-14	3
6.4-14a	3
6.4-15	3
8.1-1	3
8.1-3	3
12.2-1	*5*
12.2-2	2
12.2-3	4
12.3-6	3
12.4-1	4
12.4-1a	4
12.4-3	3
12.4-4	3

Table 2.1-1
Spent Fuel Assembly Physical Characteristics

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

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

Table 2.1-2
Spent Fuel Assembly Thermal and Radiological Characteristics

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

(1) Mixed-Oxide assemblies with 0.71 weight % U-235 and maximum fissile Pu weight percent of 2.84 (64 rods), 3.10 (92 rods), and 3.31 (24 rods)
(2) Burnups for minimum initial enrichments are utilized in the shielding analysis
(3) Gamma/neutron source spectrum by energy group is presented in Chapter 5.
(4) Decay heat for fuel assembly excluding control components. Decay heat for control components (0.002 kW per assembly maximum) is specified in Table 2.1-3.

4. THERMAL EVALUATION

The development of the thermal analysis of the Advanced NUHOMS® System involved consideration of several limiting decay heat loads for individual components as summarized below:

- A maximum decay heat load of 24 kW was used for the evaluation of AHSM (concrete and support steel) and 24PT1-DSC shell assembly.
- A maximum decay heat load of 14 kW and 16 kW was used for the evaluation of 24PT1-DSC basket assembly and fuel cladding.

The maximum design decay heat load for the 24PT1-DSC is 14 kW when loaded with all SC fuel assemblies and 13.706 kW when loaded with MOX fuel assemblies. The use of 24 kW and 16 kW for the scenarios discussed in this section adds margin to the 14 kW design basis thermal analyses.

4.1 Discussion

4.1.1 Overview and Purpose of Thermal Analysis

The Advanced NUHOMS® System is designed to passively reject decay heat under normal and off-normal conditions of storage, accident and loading/unloading conditions while maintaining canister temperatures and pressures within specified limits. The Advanced NUHOMS® System components considered in the thermal analysis are the concrete module (AHSM), canister (24PT1-DSC), and transfer cask.

The Advanced NUHOMS® System falls under the jurisdiction of 10CFR Part 72 when used as a component of an ISFSI. To establish the heat removal capability, several thermal design criteria are established for the Advanced NUHOMS® System. These are:

- Pressures within the 24PT1-DSC cavity are within design values considered for structural and confinement analyses.
- Maximum and minimum temperatures of the confinement structural components must not adversely affect the confinement function.
- Maintaining fuel cladding integrity during storage is a key design consideration. To minimize degradation that can occur over the storage duration, the maximum initial storage fuel cladding temperature is determined as a function of the initial fuel age using the guidelines provided by the Pacific Northwest Laboratory [4.1] for Zircalloy clad fuel and EPRI for stainless steel clad fuel [4.2]. These temperature limits are derived and reported in Section 3.5. For short term events and accident conditions, the fuel temperature limits are also derived and reported in Section 3.5.
- Thermal stresses for the AHSM, 24PT1-DSC, and transfer cask, when appropriately combined with other loads, will be maintained at acceptable levels to ensure the confinement integrity of the Advanced NUHOMS® System (see Chapters 3 and 11).

Chapter 2 presents the principal design bases for the Advanced NUHOMS® System.

The AHSMs are designed to passively cool the 24PT1-DSC primarily by buoyancy driven air flow through an opening in the base of the module, which allows ambient air to be drawn into the AHSM to cool the canister. The hot air exits through a vent in the top shield block, creating a stack effect. The AHSM is also cooled from the top and front surfaces by convection and radiation to the prevailing ambient environment.

Within the canister, the internal basket assembly contains spacer discs, support rods, and guidesleeve assemblies. The guidesleeve assembly consists of a stainless steel guidesleeve and a Boral™ poison sheet(s) held in place by a thin oversleeve. Heat transfer through the basket structure in the radial direction is achieved by conduction and radiation through the guidesleeve assemblies, spacer disc plates, and the helium cover gas. Heat transfer in the axial direction is conservatively neglected in the analysis model.

4.1.2 Thermal Load Specification/Ambient Temperature

The ambient temperature ranges considered in the thermal analyses are given in Table 4.1-1. The canister and AHSM temperature response to changes in ambient conditions will be relatively slow because the AHSM thermal inertia is large. Therefore, daily average temperatures are derived to bound summer ambient conditions. For the summer ambient conditions, temperature averages are derived based on data from Reference [4.3] with the maximum temperatures from Table 4.1-1. Reference [4.3] provides factors for calculating the ambient temperature for each hour of the day based on the hottest temperature and the mean daily temperature range. The factors, together with the calculated temperatures, are given in Table 4.1-2. Conservative mean daily temperatures ranges from Reference [4.3], 20°F and 27°F temperature difference, are used for normal and off-normal conditions respectively.

For conservatism, maximum daily average ambient temperatures of 97°F and 107°F are used for thermal evaluations for normal and off-normal summer extreme ambient conditions respectively (these values bound the average temperatures calculated in Table 4.1-2). To be conservative, no averaging is done for winter extreme ambient conditions.

In general, all the thermal criteria are based on maximum temperature limits. The structural adequacy of pertinent materials at the minimum off-normal ambient temperature is addressed in Chapter 3.

The AHSM is analyzed based on a maximum heat load of 24 kW from 24 fuel assemblies with RCCAs, neutron sources, or TPAs. The 24PT1-DSC is analyzed based on a maximum heat load of 14 kW from 24 fuel assemblies with RCCAs, neutron sources, or TPAs. A peaking factor for a typical PWR fuel assembly of 1.08 based on Reference [4.4] is used in the analyses. The parameters of the fuel assembly types are given in Chapter 6. A description of the detailed analyses performed for normal conditions is provided in Section 4.4, off-normal conditions in Section 4.5, accident conditions in Section 4.6, and loading/unloading conditions in Section 4.7 A summary of the results from the analyses performed for normal, off-normal, and accident conditions, as well as maximum and minimum allowable temperatures, is provided in Table

Table 4.1-2
Temperature Variation for Extreme Summer Ambient Conditions

Time, Hour	% Daily Range[(1)]	Normal (°F)	Off-Normal (°F)
1	87	86.6	93.5
2	92	85.6	92.2
3	96	84.8	91.1
4	99	84.2	90.3
5	100	84.0	90.0
6	98	84.4	90.5
7	93	85.4	91.9
8	84	87.2	94.3
9	71	89.8	97.8
10	56	92.8	101.9
11	39	96.2	106.5
12	23	99.4	110.8
13	11	101.8	114.0
14	3	103.4	116.2
15	0	104.0	117.0
16	3	103.4	116.2
17	10	102.0	114.3
18	21	99.8	111.3
19	34	97.2	107.8
20	47	94.6	104.3
21	58	92.4	101.3
22	68	90.4	98.6
23	76	88.8	96.5
24	82	87.6	94.9
Averages		92.7	101.8

(1) Percentage of daily temperature range (see Section 4.1.2 for daily temperature range used for normal and off-normal conditions) below the maximum temperature at a given hour during the day, Reference [4.3], Chapter 26, Table 3.

Table 4.1-3
Component Minimum and Maximum Temperatures in the Advanced NUHOMS® System (Storage or Transfer Mode) for Normal Conditions

Component[3]		Maximum Storage Mode (F°)	Maximum[1] Transfer Mode (F°)	Minimum[2] (°F)	Allowable Range(°F) Ref
AHSM Concrete		219	N/A	0	0 to 300 [4.5]
AHSM Support Steel		351	N/A	0	0 to 2,600 [4.6]
AHSM Heat Shield		258	N/A	0	0 to 2,600 [4.6]
DSC Shell		399	439	0	0 to 800 [4.7]
DSC Top Outer Cover Plate		294	337	0	0 to 800 [4.7]
DSC Top Inner Cover Plate		296	337	0	0 to 800 [4.7]
DSC Top Shield Plug		316	345	0	0 to 700 [4.7]
DSC Bottom Inner Cover Plate		315	402	0	0 to 800 [4.7]
DSC Bottom Shield Plug		313	400	0	0 to 700 [4.7]
DSC Bottom Outer Cover Plate		299	393	0	0 to 800 [4.7]
DSC Spacer Disc		617	658	0	0 to 700 [4.7]
DSC Guidesleeve		618	658	0	0 to 800 [4.7]
DSC Oversleeve		618	658	0	0 to 800 [4.7]
DSC Support Rod/Spacer Sleeve		479	522	0	0 to 650 [4.7]
DSC Boral™ Sheet		618	658	0	0 to 850 [4.8]
WE 14x14 SS304 Fuel Cladding	*70°F long term average ambient*	*604*	*658*	0	0 to 806(4) Transfer Mode *0 to 690 Storage Mode*
	104°F short term maximum ambient	*618*	*658*	*0*	*0 to 806*[4]
WE 14x14 MOX Zirc Cladding	*70°F long term average ambient*	604	*658*	0	0 to 1058[4] Transfer Mode *0 to 618 Storage Mode*
	104°F short term maximum ambient	*618*	*658*	*0*	*0 to 1058*[4]

(1) Temperatures provided are conservatively based on a 14 kW DSC heat load in conjunction with a DSC shell temperature based on a 24 kW transfer cask analysis.

(2) For the minimum daily averaged temperature condition of 0°F ambient, the resulting component temperatures will approach 0°F if no credit is taken for the decay heat load.

(3) See Table 4.1-6 for the limiting heat loads for which each component was analyzed. Maximum 24PT1-DSC heat load for this application is 14 kW. Other heat loads used in the analyses provide conservatism and may be used in future amendments. The maximum AHSM heat load for this application is 24kW.

(4) These fuel cladding limits apply to the short term transients such as the transfer operations *and 104 °F temp. transient.*

12.2.0 Functional and Operating Limits

12.2.1 Fuel To Be Stored In The 24PT1-DSC

The spent nuclear fuel to be stored in each 24PT1-DSC/AHSM at the ISFSI shall meet the following requirements:

a. Fuel shall be INTACT FUEL ASSEMBLIES or DAMAGED FUEL ASSEMBLIES. DAMAGED FUEL ASSEMBLIES shall be placed in screened confinement cans (failed fuel cans) inside the 24PT1-DSC guidesleeves. Damaged fuel assemblies shall be stored in outermost guidesleeves located at the 45, 135, 225 and 315 degree azimuth locations.

b. Fuel types shall be limited to the following:

   UO_2 Westinghouse 14x14 (WE 14x14) Assemblies (with or without IFBA fuel rods), as specified in Table 12.2-1.

   WE 14x14 Mixed Oxide (MOX) Assemblies, as specified in Table 12.2-1

   Fuel burnup and cooling time is to be consistent with the limitations specified in Table 12.2-4 for UO2 fuel.

   Control Components stored integral to WE 14x14 Assemblies in a 24PT1-DSC, shall be limited to Rod Cluster Control Assemblies (RCCAs), Thimble Plug Assemblies (TPAs), and Neutron Source Assemblies (NSAs). Location of control components within a 24PT1-DSC shall be selected based on criteria which does not change the radial center of gravity by more than 0.1 inches.

c. The maximum heat load for a single fuel assembly, including control components, is 0.583 kW *for SC fuel assemblies and 0.294 kW for MOX fuel assemblies*. The maximum heat load per 24PT1-DSC, including any integral Control Components, shall not exceed 14 kW *when loaded with all SC fuel assemblies and 13.706 kW when loaded with MOX fuel assemblies.*

d. Fuel can be stored in the 24PT1-DSC in any of the following configurations:

   1) A maximum of 24 INTACT WE 14x14 MOX or SC fuel assemblies; or

   2) Up to four WE 14x14 SC DAMAGED FUEL ASSEMBLIES, with the balance INTACT WE 14x14 SC FUEL ASSEMBLIES; or

   3) One MOX DAMAGED FUEL ASSEMBLY with the balance INTACT WE 14x14 SC FUEL ASSEMBLIES.

   A 24PT1-DSC containing less than 24 fuel assemblies may contain dummy fuel assemblies in fuel assembly slots. The dummy fuel assemblies are unirradiated, stainless steel encased structures that approximate the weight and center of gravity of a fuel assembly. The effect of dummy assemblies or empty fuel *assembly slots on the radial center of gravity of the DSC must meet the requirements of Section 12.2.1.b.*

No more than two empty fuel assembly slots are allowed in each DSC. They must be located at symmetrical locations about the 0-180° and 90-270° axes.

No more than 14 fuel pins in each assembly may exhibit damage. A visual inspection of assemblies will be performed prior to placement of the fuel in the 24PT1-DSC, which may then be placed in storage or transported anytime thereafter without further fuel inspection.

e. Fuel dimensions and weights are provided in Table 12.2-2.

f. The maximum neutron and gamma source terms are provided in Table 12.2-3.

12.2.2 Functional and Operating Limits Violations

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

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

12.2.2.2 Within 24 hours, notify the NRC Operations Center.

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

ATTACHMENT 3

ADVANCED NUHOMS® SAR REVISED PAGES (REVISION 5)

NON-PROPRIETARY VERSION

SEE LIST OF EFFECTED PAGES FOR A COMPLETE LISTING OF PAGES TO BE REPLACED/ADDED

ANUH-01.0150
Revision 5

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

By

Transnuclear West Inc., (TN West)

Fremont, CA

Revision 5

August 2001

Executive Summary

Revisions 1, 2, 3, *4* and *5* of this Safety Analysis Report incorporate changes based on the initial and supplemental responses to NRC Request for *Additional* Information.

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

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

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

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

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

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

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

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

NUHOMS® System is a totally passive installation that is designed to provide shielding and safe confinement of spent fuel for a range of postulated accident conditions and natural phenomena.

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

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Table 2.1-1
Spent Fuel Assembly Physical Characteristics

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

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

Table 2.1-2
Spent Fuel Assembly Thermal and Radiological Characteristics

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

(1) Mixed-Oxide assemblies with 0.71 weight % U-235 and maximum fissile Pu weight percent of 2.84 (64 rods), 3.10 (92 rods), and 3.31 (24 rods)
(2) Burnups for minimum initial enrichments are utilized in the shielding analysis
(3) Gamma/neutron source spectrum by energy group is presented in Chapter 5.
(4) Decay heat for fuel assembly excluding control components. Decay heat for control components (0.002 kW per assembly maximum) is specified in Table 2.1-3.

4. THERMAL EVALUATION

The development of the thermal analysis of the Advanced NUHOMS® System involved consideration of several limiting decay heat loads for individual components as summarized below:

- A maximum decay heat load of 24 kW was used for the evaluation of AHSM (concrete and support steel) and 24PT1-DSC shell assembly.
- A maximum decay heat load of 14 kW and 16 kW was used for the evaluation of 24PT1-DSC basket assembly and fuel cladding.

The maximum design decay heat load for the 24PT1-DSC is 14 kW when loaded with all SC fuel assemblies and 13.706 kW when loaded with MOX fuel assemblies. The use of 24 kW and 16 kW for the scenarios discussed in this section adds margin to the 14 kW design basis thermal analyses.

4.1 Discussion

4.1.1 Overview and Purpose of Thermal Analysis

The Advanced NUHOMS® System is designed to passively reject decay heat under normal and off-normal conditions of storage, accident and loading/unloading conditions while maintaining canister temperatures and pressures within specified limits. The Advanced NUHOMS® System components considered in the thermal analysis are the concrete module (AHSM), canister (24PT1-DSC), and transfer cask.

The Advanced NUHOMS® System falls under the jurisdiction of 10CFR Part 72 when used as a component of an ISFSI. To establish the heat removal capability, several thermal design criteria are established for the Advanced NUHOMS® System. These are:

- Pressures within the 24PT1-DSC cavity are within design values considered for structural and confinement analyses.
- Maximum and minimum temperatures of the confinement structural components must not adversely affect the confinement function.
- Maintaining fuel cladding integrity during storage is a key design consideration. To minimize degradation that can occur over the storage duration, the maximum initial storage fuel cladding temperature is determined as a function of the initial fuel age using the guidelines provided by the Pacific Northwest Laboratory [4.1] for Zircalloy clad fuel and EPRI for stainless steel clad fuel [4.2]. These temperature limits are derived and reported in Section 3.5. For short term events and accident conditions, the fuel temperature limits are also derived and reported in Section 3.5.
- Thermal stresses for the AHSM, 24PT1-DSC, and transfer cask, when appropriately combined with other loads, will be maintained at acceptable levels to ensure the confinement integrity of the Advanced NUHOMS® System (see Chapters 3 and 11).

Chapter 2 presents the principal design bases for the Advanced NUHOMS® System.

The AHSMs are designed to passively cool the 24PT1-DSC primarily by buoyancy driven air flow through an opening in the base of the module, which allows ambient air to be drawn into the AHSM to cool the canister. The hot air exits through a vent in the top shield block, creating a stack effect. The AHSM is also cooled from the top and front surfaces by convection and radiation to the prevailing ambient environment.

Within the canister, the internal basket assembly contains spacer discs, support rods, and guidesleeve assemblies. The guidesleeve assembly consists of a stainless steel guidesleeve and a Boral™ poison sheet(s) held in place by a thin oversleeve. Heat transfer through the basket structure in the radial direction is achieved by conduction and radiation through the guidesleeve assemblies, spacer disc plates, and the helium cover gas. Heat transfer in the axial direction is conservatively neglected in the analysis model.

4.1.2 Thermal Load Specification/Ambient Temperature

The ambient temperature ranges considered in the thermal analyses are given in Table 4.1-1. The canister and AHSM temperature response to changes in ambient conditions will be relatively slow because the AHSM thermal inertia is large. Therefore, daily average temperatures are derived to bound summer ambient conditions. For the summer ambient conditions, temperature averages are derived based on data from Reference [4.3] with the maximum temperatures from Table 4.1-1. Reference [4.3] provides factors for calculating the ambient temperature for each hour of the day based on the hottest temperature and the mean daily temperature range. The factors, together with the calculated temperatures, are given in Table 4.1-2. Conservative mean daily temperatures ranges from Reference [4.3], 20°F and 27°F temperature difference, are used for normal and off-normal conditions respectively.

For conservatism, maximum daily average ambient temperatures of 97°F and 107°F are used for thermal evaluations for normal and off-normal summer extreme ambient conditions respectively (these values bound the average temperatures calculated in Table 4.1-2). To be conservative, no averaging is done for winter extreme ambient conditions.

In general, all the thermal criteria are based on maximum temperature limits. The structural adequacy of pertinent materials at the minimum off-normal ambient temperature is addressed in Chapter 3.

The AHSM is analyzed based on a maximum heat load of 24 kW from 24 fuel assemblies with RCCAs, neutron sources, or TPAs. The 24PT1-DSC is analyzed based on a maximum heat load of 14 kW from 24 fuel assemblies with RCCAs, neutron sources, or TPAs. A peaking factor for a typical PWR fuel assembly of 1.08 based on Reference [4.4] is used in the analyses. The parameters of the fuel assembly types are given in Chapter 6. A description of the detailed analyses performed for normal conditions is provided in Section 4.4, off-normal conditions in Section 4.5, accident conditions in Section 4.6, and loading/unloading conditions in Section 4.7 A summary of the results from the analyses performed for normal, off-normal, and accident conditions, as well as maximum and minimum allowable temperatures, is provided in Table

Table 4.1-2
Temperature Variation for Extreme Summer Ambient Conditions

Time, Hour	% Daily Range[(1)]	Normal (°F)	Off-Normal (°F)
1	87	86.6	93.5
2	92	85.6	92.2
3	96	84.8	91.1
4	99	84.2	90.3
5	100	84.0	90.0
6	98	84.4	90.5
7	93	85.4	91.9
8	84	87.2	94.3
9	71	89.8	97.8
10	56	92.8	101.9
11	39	96.2	106.5
12	23	99.4	110.8
13	11	101.8	114.0
14	3	103.4	116.2
15	0	104.0	117.0
16	3	103.4	116.2
17	10	102.0	114.3
18	21	99.8	111.3
19	34	97.2	107.8
20	47	94.6	104.3
21	58	92.4	101.3
22	68	90.4	98.6
23	76	88.8	96.5
24	82	87.6	94.9
Averages		92.7	101.8

(1) Percentage of daily temperature range (see Section 4.1.2 for daily temperature range used for normal and off-normal conditions) below the maximum temperature at a given hour during the day, Reference [4.3], Chapter 26, Table 3.

Table 4.1-3
Component Minimum and Maximum Temperatures in the Advanced NUHOMS® System (Storage or Transfer Mode) for Normal Conditions

Component(3)		Maximum Storage Mode (F°)	Maximum(1) Transfer Mode (F°)	Minimum(2) (°F)	Allowable Range(°F) Ref
AHSM Concrete		219	N/A	0	0 to 300 [4.5]
AHSM Support Steel		351	N/A	0	0 to 2,600 [4.6]
AHSM Heat Shield		258	N/A	0	0 to 2,600 [4.6]
DSC Shell		399	439	0	0 to 800 [4.7]
DSC Top Outer Cover Plate		294	337	0	0 to 800 [4.7]
DSC Top Inner Cover Plate		296	337	0	0 to 800 [4.7]
DSC Top Shield Plug		316	345	0	0 to 700 [4.7]
DSC Bottom Inner Cover Plate		315	402	0	0 to 800 [4.7]
DSC Bottom Shield Plug		313	400	0	0 to 700 [4.7]
DSC Bottom Outer Cover Plate		299	393	0	0 to 800 [4.7]
DSC Spacer Disc		617	658	0	0 to 700 [4.7]
DSC Guidesleeve		618	658	0	0 to 800 [4.7]
DSC Oversleeve		618	658	0	0 to 800 [4.7]
DSC Support Rod/Spacer Sleeve		479	522	0	0 to 650 [4.7]
DSC Boral™ Sheet		618	658	0	0 to 850 [4.8]
WE 14x14 SS304 Fuel Cladding	*70°F long term average ambient*	*604*	*658*	0	0 to 806(4) Transfer Mode *0 to 690 Storage Mode*
	104°F short term maximum ambient	*618*	*658*	*0*	*0 to 806(4)*
WE 14x14 MOX Zirc Cladding	*70°F long term average ambient*	604	*658*	0	0 to 1058(4) Transfer Mode *0 to 618 Storage Mode*
	104°F short term maximum ambient	*618*	*658*	*0*	*0 to 1058(4)*

(1) Temperatures provided are conservatively based on a 14 kW DSC heat load in conjunction with a DSC shell temperature based on a 24 kW transfer cask analysis.

(2) For the minimum daily averaged temperature condition of 0°F ambient, the resulting component temperatures will approach 0°F if no credit is taken for the decay heat load.

(3) See Table 4.1-6 for the limiting heat loads for which each component was analyzed. Maximum 24PT1-DSC heat load for this application is 14 kW. Other heat loads used in the analyses provide conservatism and may be used in future amendments. The maximum AHSM heat load for this application is 24kW.

(4) These fuel cladding limits apply to the short term transients such as the transfer operations *and 104 °F temp. transient.*

12.2.0 Functional and Operating Limits

12.2.1 Fuel To Be Stored In The 24PT1-DSC

The spent nuclear fuel to be stored in each 24PT1-DSC/AHSM at the ISFSI shall meet the following requirements:

a. Fuel shall be INTACT FUEL ASSEMBLIES or DAMAGED FUEL ASSEMBLIES. DAMAGED FUEL ASSEMBLIES shall be placed in screened confinement cans (failed fuel cans) inside the 24PT1-DSC guidesleeves. Damaged fuel assemblies shall be stored in outermost guidesleeves located at the 45, 135, 225 and 315 degree azimuth locations.

b. Fuel types shall be limited to the following:

UO_2 Westinghouse 14x14 (WE 14x14) Assemblies (with or without IFBA fuel rods), as specified in Table 12.2-1.

WE 14x14 Mixed Oxide (MOX) Assemblies, as specified in Table 12.2-1

Fuel burnup and cooling time is to be consistent with the limitations specified in Table 12.2-4 for UO2 fuel.

Control Components stored integral to WE 14x14 Assemblies in a 24PT1-DSC, shall be limited to Rod Cluster Control Assemblies (RCCAs), Thimble Plug Assemblies (TPAs), and Neutron Source Assemblies (NSAs). Location of control components within a 24PT1-DSC shall be selected based on criteria which does not change the radial center of gravity by more than 0.1 inches.

c. The maximum heat load for a single fuel assembly, including control components, is 0.583 kW *for SC fuel assemblies and 0.294 kW for MOX fuel assemblies*. The maximum heat load per 24PT1-DSC, including any integral Control Components, shall not exceed 14 kW *when loaded with all SC fuel assemblies and 13.706 kW when loaded with MOX fuel assemblies.*

d. Fuel can be stored in the 24PT1-DSC in any of the following configurations:

1) A maximum of 24 INTACT WE 14x14 MOX or SC fuel assemblies; or
2) Up to four WE 14x14 SC DAMAGED FUEL ASSEMBLIES, with the balance INTACT WE 14x14 SC FUEL ASSEMBLIES; or
3) One MOX DAMAGED FUEL ASSEMBLY with the balance INTACT WE 14x14 SC FUEL ASSEMBLIES.

A 24PT1-DSC containing less than 24 fuel assemblies may contain dummy fuel assemblies in fuel assembly slots. The dummy fuel assemblies are unirradiated, stainless steel encased structures that approximate the weight and center of gravity of a fuel assembly. The effect of dummy assemblies or empty fuel *assembly slots on the radial center of gravity of the DSC must meet the requirements of Section 12.2.1.b.*

No more than two empty fuel assembly slots are allowed in each DSC. They must be located at symmetrical locations about the 0-180° and 90-270° axes.

No more than 14 fuel pins in each assembly may exhibit damage. A visual inspection of assemblies will be performed prior to placement of the fuel in the 24PT1-DSC, which may then be placed in storage or transported anytime thereafter without further fuel inspection.

e. Fuel dimensions and weights are provided in Table 12.2-2.

f. The maximum neutron and gamma source terms are provided in Table 12.2-3.

12.2.2 Functional and Operating Limits Violations

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

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

12.2.2.2 Within 24 hours, notify the NRC Operations Center.

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