TRANSNUCLEAR
AN AREVA COMPANY

E-22577
August 16, 2005

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

Subject: NUHOMS® HD Storage System Docket No. 72-01030.
(TAC No. L23738)

Dear Mr. Sebrosky:

Transnuclear, Inc. formally requests the removal of the fuel cladding 75g end drop analysis presented in Chapter 3, Section 3.5.3.2 and cladding one-foot end drop analysis described in Appendix 3.9.8, Section 3.9.8.10 of the NUHOMS® HD System Safety Analysis Report. The SAR did not demonstrate the structural integrity of the fuel cladding during these events. However, as stated in Section 3.1.1.4 of SAR (new section added with this submittal), the end drop evaluation is not considered a credible event during 10CFR72 transfer operations. All lifts of the DSC in the transfer cask prior to transfer are governed under the nuclear plant's 10 CFR 50 Heavy Lifts Program.

As a result of the changes requested above, enclosed are 7 copies of revised SAR pages on a replacement basis. Changes have been incorporated into Chapters 4, 8, and 12 which address draining and vacuum drying operations. Also the source term table in Chapter 12 has been modified to show the total DSC source instead of the assembly source. This assures the thermal and shielding evaluations are consistent with the fuel qualification procedure. Additional revised SAR pages from our response to RAI2 (E-22383) will be incorporated into the FSAR.

Evaluations of the end drop on the DSC, basket and transfer cask are adequately addressed in the current Safety Analysis Report and no revisions are necessary.

Transportability in accordance with 72.236(m), is addressed below.

Although it has not been demonstrated that the fuel cladding will remain intact during an end drop, the DSC canister and internals have been evaluated for an end drop load of 75 g's. This value is equal or higher transportation systems using impact limiters.

7135 Minstrel Way, Suite 300, Columbia, MD 21045
Phone: 410-910-6900 • Fax: 410-910-6902

It is the intent to license the 32PTH canister for transport inside a transport cask with impact limiters similar to the MP-197. This cask was drop tested on the end. Measured acceleration values were between 62 and 70 g's.

Therefore it is reasonable to expect that a transport cask with impact limiters can be designed to limit the g-loads for the end drop to less than 75 g's Fuel cladding evaluations for this type of load have been successfully performed in other applications, and will be evaluated in the transport application.

If you have any questions regarding this submittal, please contact Mike Mason at 914-347-2345 or Tara Neider at 410-910-6860.

Sincerely,

Tara Neider
Senior Vice President Engineering

Revised SAR Pages:

- 2-3
- 3-iii, 3-9, 3-9a, 3-19, 3-29 thru 3-33, 3-41, Table 3-13
- 3.9.1-56a
- 3.9.7-1
- 3.9.8-i, 3.9.8-iii, 3.9.8-3/4, 3.9.8-15, 3.9.8-20, 3.9.8-24 through 3.9.8-28
- 3.9.10-1
- 4-29/30, 4-33/34
- 7-4
- 8-1, 8-4 through 8-6
- 11-8, 11-9
- 12-17, 12-20, 12-31, Table 12-3

Note Figures 3.9.8-6 thru 3.9.8-14 are deleted

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

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

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

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

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

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

The structural integrity of the fuel cladding due to the side drop is analyzed in Section 3.5.3. The end and corner drops are not considered credible during storage and transfer. The structural integrity of the fuel cladding due to these loads will be addressed by the users under their site license (10CR50).

2.2 Design Criteria for Environmental Conditions and Natural Phenomena

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

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

2.2.1 Tornado and Wind Loadings

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

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

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

2.2.1.1 Applicable Design Parameters

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

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The top trunnions are constructed from SA-182 Type FXM-19 and the bottom trunnions are constructed from SA-182 Type 304. Both materials are stainless steel forgings. The top trunnions are designed fabricated and tested in accordance with ANSI N14.6 [8] as single failure proof lifting devices. Consequently they are designed with a factor of safety of six against the material yield strength and a factor of ten against the material ultimate strength.

D. Operational Features

The NUHOMS®-OS187H transfer cask is not considered to be operationally complex and is designed to be compatible with spent fuel pool loading/unloading methods. All operational features are readily apparent from inspection of the General Arrangement Drawings provided in Chapter 1, Section 1.5. The sequential steps to be followed for cask loading, testing, and unloading operations are provided in Chapter 8.

3.1.1.4 Discussion of NUHOMS® HD System Drop Analysis

All lifting of the TC loaded with the DSC must be made within the existing heavy loads requirements and procedures of the licensed nuclear power plant. The TC design has been reviewed under 10 CFR Part 72 and found to meet NUREG-0612 and ANSI N14.6.

The transfer cask is transported to the ISFSI in a horizontal configuration. Therefore the only credible drop accident during storage or transfer operations is a side drop. The transfer cask, canister and fuel cladding are analyzed for these credible accidents in the appendices listed below.

In addition, a vertical or corner drop accident may be credible under 10CFR50 during loading onto the trailer or during transport operations governed under 10CFR71. The transfer cask and canister have been evaluated for these postulated accidents. However, the fuel cladding integrity has not been demonstrated for these accident scenarios. An additional safety review by the user is required to demonstrate fuel cladding integrity under 10CFR50 or to demonstrate that the drop accidents are not credible.

The drop analyses of the NUHOMS® HD components are performed in the following Appendices.

Appendix 3.9.1

This appendix describes the detail analysis of the canister and basket for all the loading conditions. For the drop loads, the canister is analyzed for the 75g side and end drops. The canister end closure welds are analyzed for the 22g corner drop.

The basket is analyzed for 75g the side and end drops. The basket is not analyzed for the 22g corner drop since the 75g end drop analysis bounds the 22g corner drop.

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Appendix 3.9.2

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

Appendix 3.9.3

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

Appendix 3.9.4

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

Appendix 3.9.8

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

10CFR72 (Normal & Off-Normal loads):

1g down (dead weight), transfer loads (1g longitudinal, 1g transverse, and 1g vertical).

10CFR71 (Normal loads): 30g (1 foot side drop)
1 foot end drop will be addressed in the 10CFR71 application.

3.1.2 Design Criteria

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

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

The overall storage system consists of three major components:

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

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

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

3.3.3 OS187H Transfer Cask Material Properties

The principal material of construction for the OS187H transfer cask is Type 304 stainless steel. The transfer cask structural, inner and outer neutron shield shells and the bottom closure assembly are constructed from SA-240 Type 304 stainless steel. The primary structural member of the top cover plate is constructed from SA-240 Type XM-19 stainless steel. Table 3-5 contains the ASME Code material properties for SA-240 Type 304 stainless steel material. ASME Code material properties for the top cover material (SA-240 Type XM-19) are given in Table 3-8.

The transfer cask top cover and ram access cover bolts are constructed from SA-540 Grade B24 Cass 1. ASME Code material properties for SA-540 Grade B24 Class 1 are given in Table 3-9.

Material properties for ASTM B-29 (Chemical Lead), which is used for the transfer cask radial gamma shield, are given in Table 3-10.

The outer radial neutron shield consists of a SA-240 Type 304 stainless steel shell that contains the neutron absorbing material (water). The top and bottom axial neutron absorber resin material is, described in Section 3.1.1.3 B. No structural credit is taken for the neutron absorber material, except for through the thickness load transmission. Material Properties for the resin are given in Table 3-11.

3.3.3.1 Radiation Effects on the Transfer Cask Materials

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

3.3.3.2 Transfer Cask Weld Material

Welding processes, welders and welding materials used for the welding of the 32PTH DSC meet the requirements of the appropriate ASME Section III subsections and Section IX. Non-Code welds meet the provisions of Section IX of the ASME Code or AWS D1.1 [18] or D1.6 [19]. Weld metal material properties meet the requirements of Section II of the ASME Code or associated AWS requirements.

3.3.3.3 Transfer Cask Brittle Fracture

Brittle fracture is not a concern for the stainless steel components, which comprises all structural components of the cask.

3.4 General Standards for 32PTH DSC, HSM-H, and OS187H TC

3.4.1 Chemical and Galvanic Reactions

The materials of the DSC shell and basket assemblies, the HSM-H, and the transfer cask components have been reviewed to determine whether chemical, galvanic or other reactions among the materials, contents and environment might occur during any phase of loading, unloading, handling or storage.

The canister, transfer cask, and HSM-H are exposed to the following environments:

- During loading and unloading, the canister is inside of the transfer cask. Thus, the exterior of the canister will not be exposed to pool water. The annulus between the transfer cask and canister is filled with clean water and sealed.
- The interior surfaces of the canister, top shield plug, and the basket will be exposed to (borated) pool water. The transfer cask and canister are kept in the spent fuel pool for only about 6 hours to load or unload fuel, and 2 hours to lift the loaded transfer cask/canister out of the spent fuel pool. An additional 12 to 24 hours is typically needed to decontaminate the cask, weld the DSC cover, and drain the water.
- The canister is vacuum dried before storage. It is then backfilled with helium, thus providing a non-corrosive environment. During storage, the interior of the canister is exposed only to the helium environment. The dry helium environment does not support chemical or galvanic reactions.
- During storage, the exterior of the canister is protected by the concrete HSM-H. The HSM-H is vented, so the exterior of the canister is exposed to the atmosphere. The exterior is exposed to the weather.

Materials used for the DSC, transfer cask, and HSM-H are shown in the parts lists of the drawings provided in Chapter 1, Section 1.5.

Within the canister, there is a basket with support rails made from SA-240 Type 304 stainless steel with aluminum inserts. The basket structure consists of an assembly of stainless steel tubes (fuel compartments) separated by aluminum and neutron absorber plates. The basket fuel compartments are constructed from Type 304 stainless steel. The neutron absorber is borated aluminum alloy or composite sandwiched. The neutron poison plates are not welded or bolted to the fuel compartments, but are held in place by the fuel compartments and the stainless steel structural plates. The aluminum thermal conduction plates are constructed from Type 1100 aluminum.

The only potential galvanic couples are the low alloy steel transfer cask bolts and hoist rings with stainless steel, and stainless steel with aluminum in the DSC. The lid, test, drain cover, and ram cover bolts will be exposed to the weather or pool water for only a short period during DSC transfer. Galvanic corrosion during transfer will be negligible and will have no adverse affect on

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

3.5.3 Fuel Rod Integrity During Drop Scenario

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

3.5.3.1 Side Drop

The fuel rod side impact stresses are computed by treating the fuel rod as a continuous beam supported at locations of spacer grids. Continuous beam theory is used to determine the maximum bending moment in the entire beam. The maximum bending stress corresponding to the maximum bending moment in the cladding tubes is then calculated. The fuel gas internal pressure is also considered in the calculation. The cladding axial tensile stress due to the gas pressure is added to the bending stress due to the 75g drop load. The combined stresses in each cladding for different fuel assemblies are computed and tabulated in Table 3-12. It shows that among all fuel assemblies the highest axial stress is calculated to be 58,710 psi in the cladding of WE17×17OFA fuel assembly. This highest stress is lower than the yield strength of zircaloy (69,500 psi at 725 °F).

3.5.3.2 End Drop

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

3.5.3.3 Results

Side Drop

Table 3-12 summarizes the maximum bending stresses in various specified fuel cladding during the 75g side drop of their transfer cask. The maximum bending stress was calculated to be 58,710 psi in the cladding of fuel WE17x17OFA. It is less than the cladding yield strength of 69,500 psi at 725 °F. It is, therefore, concluded that the fuel cladding will not fail under the 75g side drop load.

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3.5.4 Fuel Unloading

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

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

The maximum fuel cladding temperature during reflooding process is significantly less than the vacuum drying condition owing to the presence of water/steam in the DSC cavity. Hence, the peak cladding temperature during the reflooding operation will be less than 734°F calculated for vacuum drying procedure A in Chapter 4, Section 4.5.1 when water circulates in the annulus between the DSC and transfer cask.

To evaluate the effects of the thermal loads on the fuel cladding during reflooding operations, a conservative high fuel rod temperature of 750°F and a conservative low quench water temperature of 50°F are used. These evaluations are performed in Chapter 4, Section 4.5.2. The calculated maximum fuel cladding stress is 25,910 psi. This calculated maximum stress is much less than the claddings yield stress of 69,500 psi. Therefore, cladding integrity is maintained during reflooding operation.

3.6 Normal Conditions of Storage and Transfer

This section presents the structural analyses of the 32PTH DSC, the HSM-H and the OS187H Transfer Cask subjected to normal conditions of storage and transfer. The analyses performed evaluate these three major NUHOMS® HD System components for the design criteria described in Section 3.1.2 of this chapter.

The 32PTH DSC is subjected to both storage and transfer loading conditions, while the HSM-H is only subjected to storage loading conditions and the OS187H Transfer Cask is only subjected to transfer loading conditions.

Numerical analyses have been performed for the normal and accident conditions, as well as for the lifting loads. In general, numerical analyses have been performed for the regulatory events. These analyses are summarized in the main body of this section, and described in detail in Appendices 3.9.1 through 3.9.9.

The detailed structural analysis of the NUHOMS® HD System is included in the following appendices:

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

The structural integrity of the fuel cladding due to the end and corner drops has not been demonstrated and should be addressed by the users under their 10CFR50 programs.

3.6.1 32PTH DSC Normal Conditions Structural Analysis

Details of the structural analysis of the 32PTH DSC are provided on Appendix 3.9.1. The Fuel Basket and Canister are analyzed independently. The Fuel Basket is analyzed in Appendix 3.9.1, Section 3.9.1.2, while the Canister is analyzed in Appendix 3.9.1, Section 3.9.1.3. Three separate finite element models are constructed for the structural evaluation of the fuel basket while four finite element models are used for the structural evaluation of the canister shell.

3.6.1.1 32PTH DSC Fuel Basket Normal Condition Structural Evaluation

The fuel basket stress analysis is performed for normal condition loads during fuel transfer and storage. The detailed stress analysis is presented in Appendix 3.9.1, Section 3.9.1.2.3. A summary of the fuel basket load cases is provided in Appendix 3.9.1, Section 3.9.1.2.2.

The basket stress analysis is performed using a finite element method for the transfer handling, storage dead weight, and both transfer and storage thermal load cases. A 3-dimensional cross-section finite element model is utilized to evaluate the effect of transverse inertial loads on the fuel basket. The finite element model is described in detail in Appendix 3.9.1, Section 3.9.1.2.3.A (page 3.9.1-7). Analytical calculations are used for the vertical dead weight load case.

The mechanical properties of structural materials used in the basket, rail and canister are shown in the Appendix 3.9.1, Tables 3.9.1-1 and 3.9.1-2 as a function of temperature. All structural components of the fuel basket and support rails are constructed from SA-240, Type 304 stainless steel, with properties taken from AMSE B&PV Code [10].

ANSYS nonlinear elastic stress analyses are conducted for computing the elastic stresses in the fuel basket model. The nonlinearity of analysis results from the gaps in the model. In general, for each load case, the maximum total load is applied in small steps. The automatic time stepping program option "Autots" is activated. This option lets the program decide the actual size of the load-substep for a converged solution. Where shell elements are used, the shell middle surface nodal stress intensity is the membrane stress intensity and top or bottom surface stress intensity is the membrane plus bending stress intensity.

The calculated stresses in the 32PTH DSC fuel basket under normal conditions are summarized and compared with the corresponding ASME code allowable stresses for transfer load cases in Appendix 3.9.1, Table 3.9.1-3 and storage load cases in Appendix 3.9.1, Table 3.9.1-5.

The fusion weld is qualified by a pull test (shear). The required minimum test load is 16.5 kips. This load corresponds to the maximum fusion weld loads generated during a 75*g* hypothetical accident impact with a safety factor of 2 and a correction for material strength for room temperature testing. The maximum force generated in the fusion welds due to transfer load is 246 lb (Appendix 3.9.1, page 3.9.1-11) and thermal load in fusion weld during transfer is 1,253lb (Appendix 3.9.1, page 3.9.1-14). The combined load is 1,499 lb (1.5kip). This combined load is much smaller than the required test load of 16.5 kips.

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

3.6.1.2 32PTH DSC Canister Shell Normal Condition Structural Evaluation

This section summarizes the evaluation of the structural adequacy of the 32PTH DSC canister under all applied normal condition loads. Detail evaluation of the stresses generated in the

3.7 Off Normal and Hypothetical Accident Conditions

This section presents the structural analyses of the 32PTH DSC, the HSM-H and the OS187H Transfer Cask subjected to off normal and hypothetical accident conditions of storage and transfer. The analyses are summarized in Sections 3.7.1, 3.7.2 and 3.7.3 of this chapter and are evaluated against the design criteria described in Section 3.1.2 of this chapter.

The 32PTH DSC is subjected to both storage and transfer loading conditions, while the HSM-H is only subjected to storage loading conditions and the OS187H Transfer Cask is only subjected to transfer loading conditions.

The structural integrity of the fuel cladding due to end and corner drops has not been demonstrated and should be addressed by the users under their 10CFR50 programs.

3.7.1 32PTH DSC Off Normal and Accident Conditions Structural Analysis

Details of the structural analysis of the 32PTH DSC are provided in Appendix 3.9.1. The Fuel Basket and Canister are analyzed independently. The Fuel Basket is analyzed in Appendix 3.9.1, Section 3.9.1.2, while the Canister is analyzed in Section 3.9.1.3. Three separate finite element models are constructed for the structural evaluation of the fuel basket, while four finite element models are used for the structural evaluation of the canister shell.

3.7.1.1 32PTH DSC Fuel Basket Off Normal and Accident Condition Structural Analysis

3.7.1.1.1 32PTH Fuel Basket Off Normal and Accident Condition Stress Analysis

The fuel basket stress analyses are performed for off normal and accident condition loads during fuel transfer and storage. The detailed stress analysis is presented in Appendix 3.9.1, Section 3.9.1.2.3 (page 3.9.1-7). A summary of the fuel basket load cases is provided in Section 3.9.1.2.2 (page 3.9.1-5).

The basket stress analyses are performed using a finite element method for the transfer side drop impact loads, as well as, storage seismic loads, and both transfer and storage thermal load cases. A 3-dimensional cross-section finite element model is utilized to evaluate the effect of transverse inertial loads on the fuel basket. The finite element model is described in detail in Appendix 3.9.1, Section 3.9.1.2.3.A (page 3.9.1-7). Analytical calculations are used for the axisymmetric transfer end drop load case.

The mechanical properties of structural materials used in the basket, rail and canister are shown in the Appendix 3.9.1, Tables 3.9.1-1 and 3.9.1-2 as a function of temperature. All structural components of the fuel basket and support rails are constructed from SA-240, Type 304 stainless steel, with properties taken from AMSE B&PV Code [10].

Nonlinear elastic stress analyses are conducted for computing the elastic stresses in the fuel basket model. The nonlinearity of analysis results from the gaps in the model. In general, for each load case, the maximum total load is applied in small steps. The ANSYS automatic time stepping program option "Autots" is activated. This option lets the program decide the actual size of the load-substep for a converged solution. Where shell elements are used, the shell middle surface nodal stress intensity is the membrane stress intensity and the top or bottom surface stress intensity is the membrane plus bending stress intensity.

The calculated stresses in the 32PTH DSC fuel basket is summarized and compared with their corresponding ASME code allowable stresses. Tables 3.9.1-4a and 3.9.1-4b of Appendix 3.9.1 show these summaries for the transfer accident loads and Table 3.9.1-5 for the storage accident loads.

The maximum shear load in the fusion welds during the accident loading condition is calculated in Appendix 3.9.1 (page 3.9.1-16). The calculated maximum shear force during side drop is 6,897 lb.

The fusion weld is qualified by a pull test (shear). The minimum test load is 16.5 kips. This test load includes a safety factor of 2 and a correction for material strength for room temperature testing.

Based on the results of these analyses, the design of the 32PTH DSC basket is structurally adequate with respect to off-normal and accident conditions of transfer and storage loads.

Table 3-13

Table Deleted

The weld stresses at outer top cover and inner top cover plates are summarized and compared with code allowables in the following table.

Summary of Weld Shear Stresses and Allowables

Weld	Load	Stress Type	Maximum Stress (ksi)	Allowable (ksi)	Factor of Safety
Between Outer Top Cover and Shell	75g Side Drop + 30 psig Internal Pressure	Shear	13.78	18.64	1.35
	75g Side Drop +15 psig External Pressure	Shear	13.68	18.64	1.36
Between Inner Top Cover and Shell	75g Side Drop + 30 psig Internal	Shear	13.30	17.4	1.31
	75g Side Drop +15 psig External Pressure	Shear	13.38	17.4	1.30

The canister corner drop load case is analyzed as follows.

- Finite Element Model

The 3D canister finite element model as described in Appendix 3.9.1, Section 3.9.1.3.2, page 3.9.1-40) is used for calculating the canister corner drop. The finite element model is shown on Figure 3.9.1-27.

- Loading and Boundary Conditions

The transfer cask cavity length is 186.6" and the canister length is 185.75". The gap between the inside surface of the transfer cask lid and outer surface of the canister outer top cover is 0.85". For storage the end drop is not a creditable event. The transfer cask is transferred in a horizontal position held by the transfer trailer. During the rotation of the transfer cask from vertical to horizontal, the cask could slide into the ground and incur a corner drop if a non-single failure proof crane is used. The only possible corner drop is impact to the bottom end of the transfer cask. However, for weld shear stress calculation it is conservatively assumed that the internal weight (basket + fuel assemblies) will impact the inner surface of the canister inner top cover without any support from transfer cask lid.

The maximum axial G load calculated from LS-DYNA as described in Appendix 3.9.11 is 21g (Appendix 3.9.11, Section 3.9.11.6). For conservatism an axial g load of 22g is used for the analysis.

This inertial load is uniformly distributed over the inner surface of the canister inner top cover with a radius of 34.375 in. This equivalent uniform pressure, P_{in}, exerted on the canister inner top cover by the weight of the internals under a 22*g* load is calculated as follows.

$$P = [(81,500 \times 22) / (\pi \times 34.375^2)] = 483 \text{ psi.}$$

The canister internal pressure of 30 psi is also added to the above calculated inertial pressure, therefore the total pressure used for the analysis is 513 psi.

The loading and boundary condition plots are shown on Figures 3.9.1-28 and 3.9.1-29, repetitively. This boundary condition shows that all the internal loads impact to the inner surface of the canister inner top cover without any support from the transfer cask lid.

- Analysis Results

The results of the analyses are summarized in the following table.

Summary of Weld Shear Stresses and Allowables

Load Case	Weld	Stress Type	Maximum Stress (ksi)	Allowable (ksi)	Factor of Safety
Canister Corner Drop + 30 psi Internal Pressure	Between Outer Top Cover and Shell	Shear	9.60	18.64	1.94
	Between Inner Top Cover and Shell	Shear	9.66	17.4	1.80

Summary of DSC Component Maximum Stress Intensities and Allowables

Load Case	Component	Stress Type	Calculated Max. Stress Intensity (Ksi)	Allowable Membrance Stress Intensity (Ksi)[1]	Factor of Safety
Canister Corner Drop + 30 psi	Canister Shell	$P_L + P_b$	20.46	44.38	2.17
	Canister Outer Top Cover	$P_L + P_b$	16.39	44.38	2.71
	Canister Inner Top Cover	$P_L + P_b$	15.83	41.44	2.62

Note:

1. Allowable stresses are taken from Appendix 3.9.1, Table 3.9.1-7. Since the calculated maximum membrane plus bending stress intensity ($P_L + P_b$) is less than the allowable membrane stress intensity (P_m), therefore only maximum membrane plus bending stress intensity ($P_L + P_b$) is reported.

3.9.7 OS187H TRANSFER CASK IMPACT ANALYSIS

3.9.7.1 Introduction

The purpose of this appendix is to present the evaluation of the peak decelerations of NUHOMS® OS187H Transfer Cask during impact, subsequent to the hypothetical accident drop onto the concrete pad/soil system during transfer operations. The hypothetical accident condition drop consists of 80 inch end drop, side drop and center of gravity (C.G.) over corner drop. The 80 inch end drop and CG over corner drop are not credible events under 10CFR72 storage and transfer operations. However, this analysis is included to support credible accidents under 10CFR50. The fuel cladding integrity has not been demonstrated for these accident scenarios. An additional safety review by the user is required to demonstrate fuel cladding integrity under 10CFR50.

For the impact analysis, the transfer cask is assumed rigid as compared to the flexibility of the concrete slab/soil system. The methodology described in Reference 1 is used in this evaluation.

The cask is approximated by a cylinder 197.07 inches long and 81.7 inches in diameter. The effect of the outer shield shell, which is very thin relative to the main structural body of the transfer cask, is neglected. Also, small variations around top cover and cylinder are neglected. The stiffness variation due to the neglected items of the transfer cask is negligible.

The OS187H Transfer Cask is assumed to impact a 36 inch thick concrete pad, with #11 rebar on 12" spacing, at top and bottom of the pad, and 2" coverage.

3.9.7.2 Material Properties

The following material properties, taken from Reference 1, are assumed to model the design basis concrete pad and soil foundation.

E_c = Concrete elastic modulus = 3.6×10^6 psi.
σ_u = Ultimate concrete strength = 4,000 psi.
E_s = Sub-soil modulus = 60,000 psi. (higher value gives higher g load)
S_y = Rebar yield strength = 60,000 psi.
ν_c = Poisson's ratio of concrete = 0.17
ν_s = Poisson's ratio of soil = 0.49

3.9.7.3 Component Weights

The 32PTH DSC and OS187H Transfer Cask component weights are tabulated in Section 3.2. The following component weights relevant to this analysis are summarized below.

Empty Canister Weight = 28.19 kips
Fuel Basket Weight = 29.85 kips
Fuel Assembly Weight (32) = 50.72 kips
Transfer Cask Weight = 119.95 kips

Total Weight, W = 228.71 kips.

For conservative estimating the g load, a lower weight, 226.9 kips, is used for the impact analysis (lower weight gives higher g load).

3.9.7.4 Geometry and Nomenclature

The technical data used for transfer cask and concrete slab/soil system are:

W = Weight of cask = 226,900 lbs
R = Cask outer radius = 81.7/2 = 40.85 in
A = cask foot print area = $\pi\ (40.85)^2$ = 5,242.4 in^2
L = cask length = 197.07 in.
E_c = Concrete elastic modulus = 3.6×10^6 psi
σ_u = Ultimate concrete strength = 4,000 psi
υ_c = Poisson's ratio of concrete = 0.17
h_c = Concrete pad thickness = 36 inches
S_y = Rebar yield strength = 60,000 psi
E_s = Sub-soil modulus = 60,000 psi (high value of E_s gives higher g load)
υ_s = Poisson's ratio of soil = 0.49
A_s = Rebar (#11) area = $\pi/4\ (1.41)^2$ = 1.56 in^2

APPENDIX 3.9.8
DAMAGED FUEL CLADDING STRUCTURAL EVALUATION

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3.9.8.3 Loads

3.9.8.3.1 Part 72 Normal and Off-normal Condition Loads

The damaged fuel inside the DSC is subjected to following normal and off normal condition Part 72 loads:

- Dead Weight
- Internal Pressure
- Thermal
- Transfer Load (Inertia Loads associated with moving the DSC from the fuel loading area to the ISFSI site), which consists of 1g in the longitudinal, 1g in the transverse and 1g in the vertical direction.
- HSM Loading/Unloading (Normal loads associated with inserting the DSC into and retrieving the DSC from the HSM)
- Jammed Canister Load (Off normal loads associated with jamming the DSC during DSC insertion into the HSM)

The stresses due to the dead weight are insignificant. No internal pressure is assumed for the damaged fuel. The cladding is assumed to be able to expand due to thermal loads and thus no thermal-induced stresses are considered. However, the temperature of the cladding is considered for selection of allowable stresses at temperature. Therefore, the structural integrity of the damaged fuel is evaluated in this appendix only for the Transfer/Handling loads (DSC Loading/transfer to ISFSI, HSM Loading/Unloading, and Jammed Canister Load conditions).

3.9.8.3.2 Part 71 Normal Condition Loads

The structural integrity of the fuel cladding for the normal condition Part 71 load is evaluated only for the one-foot side drop condition in this application. The one-foot end drop and vibratory loads will be addressed in the 10CFR71 application.

Note that for the normal and accident off-site transport drops, the impact limiters are attached at both ends of the horizontal loaded cask.

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3.9.8.10 One Foot End Drop Damaged Fuel Evaluation

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

3.9.8.11 One Foot Side Drop Damaged Fuel Evaluation

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

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

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

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

Fracture Geometry #2: The second geometry is shown in Figure 3.9.8-2. The stress intensities factors for this geometry are determined using the solution for a tube with a crack subjected to pure bending moment given in Reference 13. This evaluation is based on a crack length to diameter ratio of 0.5 (or $2a/D_m=0.5$).

The basis for the 0.5 crack length to equivalent plate width/diameter ratio for fracture geometries #1 and #2 is the experimental tests on "as received" Zircalloy fuel tubes with measured burst temperatures of up to 909°C, which showed flaw opening to diameter ratios of 0.4 to 0.5 [16]. The (2a/W) or ($2a/D_m$) ratios used in this appendix are 0.5.

3.9.8.11.1 Structural Integrity Evaluation with Fracture Geometry #1

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

Fuel Rod OD = D

Oxidized Clad Thickness = t

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

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

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

3.9.8.11.2 Structural Integrity Evaluation with Fracture Geometry #2

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

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

where,

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

σ = Bending Stress due to Uniform Moment 'M'

R_m = Average radius of the fuel tube

2 θ = Angle which the crack makes at the center of the tube

K_I = Stress Intensity Factor at the crack

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

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

	Fracture Geometry #1 K_I	Fracture Geometry #2 K_I
WE 15x15	18.3	27.8
WE 17x17 Std.	16.6	25.3
17x17 MKBW	16.4	25.1
WE 17x17 Vantage 5H	16.6	25.3
WE 17x17 OFA	18.2	27.8
CE 14x14 Std	7.3	11.2

3.9.8.12 Conclusions

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

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

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

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

(77°F) and 350°C (662°F) are used to develop the strength vs. temperature curves. In the laboratory strength test, the test results will be affected by a lot of factors, such as size of test specimen, specimen selection, instrument calibration, etc.. Therefore it is reasonable to utilize average test strength because it is a representative on the data. These two curves are depicted in Figure 3.9.8-5. The values at higher temperatures are obtained by extending the curves.

S_y = 69,500 psi (725°F)
S_y = 67,500 psi (750°F)

S_u = 81,000 psi (725°F)
S_u = 79,000 psi (750°F)

The maximum fuel cladding temperature is calculated to be 723°F during the cask transfer operation (Chapter 4, Table 4-1). Therefore, the cladding material strength properties at temperature of 725°F will be used for structural integrity evaluations.

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APPENDIX 3.9.10

OS187H TRANSFER CASK DYNAMIC IMPACT ANALYSIS

3.9.10.1 Introduction

The purpose of this calculation is to determine the rigid body accelerations for the NUHOMS®-OS187H Transfer Cask during the hypothetical accident condition 80 inch free drop during fuel transfer. The drop orientations analyzed in this appendix are 80 inch side drop (10CFR72) and 80 inch corner drop (10CFR50).

The rigid body transfer cask accelerations are predicted numerically by the LS-DYNA 3D explicit nonlinear dynamic analysis finite element solver, Version 970 [1]. The methodology used in performing this analysis is based on work conducted at the Lawrence Livermore National Laboratory, where an analysis methodology is developed and validated through comparisons with test data [2][3]. Validation of the dynamic impact analyses presented herein is achieved through comparison of a previous TN-32 Dry Storage Cask Tipover Analysis with a similar analysis performed by Lawrence Livermore National Labs (LLNL). The results of these analyses are used as input to the detailed static analyses for the cask body presented in Appendix 3.9.2.

The results of these analyses are also used as input to the static analyses of the cask internal basket and canister structures (presented in Appendix 3.9.1) by including dynamic application factors (See Appendix 3.9.11).

3.9.10.2 Analysis Software

The LS-DYNA [1] finite element program was used for the analyses presented in this Appendix. Model generation was performed using the ANSYS [4] finite element program. Data filtering was performed using the LS-PREPOST software supplied with LS-DYNA.

LS-DYNA is a general purpose, explicit finite element program used to model the nonlinear dynamic response of three-dimensional models. Applications of LS-DYNA include crash worthiness, sheet metal forming, high velocity impact, explosive phenomena, drop tests, etc.

ANSYS is a general purpose program capable of solving structural, mechanical, electrical, electromagnetic, electronic, thermal, fluid, and biomedical problems. It has extensive preprocessing (model generation), solution, postprocessing, and graphics capabilities.

3.9.10.3 Validation of the LS-DYNA Impact Analysis

In order to validate the accuracy of the HUNOMS®-OS187H Transfer Cask impact analysis, a tipover analysis of the TN-32 cask is performed and compared with the LLNL [2] results based on the TN-32 cask geometry.

The following table lists key dimensions and weights of the LLNL and Transnuclear TN-32 Model3.

	LLNL Model	TN-32 Model
Cask ID	68.75"	68.75"
Cask OD	87.75"	87.75"
Cask Cavity Length	163.25"	163.25"
Cask Overall Length	184"	184"
Weight Including Internals	232,000 lb	232,000 lb
Cask Material	Carbon Steel	Carbon Steel

These two models have the same geometry and weight, therefore it is a reasonable approach to use the TN-32 model to validate the accuracy of the LS-DYNA impact analysis.

LLNL Model

The finite element model of the LLNL model is described in the LLNL report [2]. A plot of the finite element model is shown in Figure 3.9.10-1 of this Appendix for reference.

TN-32 Model

The finite element model of the TN-32 is developed in a similar manner to those models represented in LLNL report. The cask and basket meshes are simplified and totally independent of each other with surface-to-surface contact elements transferring load between the two components. Contact surfaces are also used between the cask and concrete pad and between the concrete pad and the soil.

The TN-32 finite element model is made up of four components: cask body, cask internals, concrete and soil. Each of these components is modeled using 3-D 8-node brick elements. The finite element models were developed in ANSYS and transferred to LS-DYNA through the ANSYS-LS-DYNA interface. Modifications were made to the LS-DYNA input to add the material definition and state variables since they are not available through the ANSYS translator. The geometries of the cask and basket have been simplified since the purpose of the analysis is to predict the rigid body response of the cask. Features on the cask such as the trunnions, neutron shield and weather cover are neglected in terms of stiffness but their weight is lumped into the density of the cask. Figures 3.9.10-2 and 3.9.10-3 illustrate the finite element model of the cask, basket, concrete, and soil. Mesh sizes in this analysis are in reasonable agreement with those represented in LLNL report [2]. The concrete material is modeled with all elements having a constant length of 10 inches since the concrete material law can be dependent on mesh size.

4.5 Thermal Evaluation for Loading and Unloading Conditions

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

4.5.1 Vacuum Drying

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

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

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

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

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

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

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

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

Parts of the above procedures might be combined together to build a new procedure. The time limit for the new procedure can be calculated from appropriate combination of the resultant transient curves discussed in Section 0.

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

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

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

All the other material properties remain unchanged.

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

- Ambient temperature in the fuel handling building is 100°F.
- Height of the cylinder is 173", which is approximately the length of the neutron shield panel.

4.5.1.3 Boundary Conditions for Procedure C

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

4.5.1.4 Evaluation of Vacuum Drying Procedure

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

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

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

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

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

4.5.2 Reflooding

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

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

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

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

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

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

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

7.2 Requirements for Normal Conditions of Storage

The 32PTH DSC shell is designed to prevent the leakage of radioactive materials. No discernable undetected leakage is credible and the dose at the controlled area boundary from atmospheric release is negligible.

7.2.1 Release of Radioactive Material

Analyses for determining the annual dose equivalent to an individual located at the site boundary or outside the controlled area resulting from releases of radioactive material are not required in accordance with NRC Spent Fuel Project Office Interim Staff Guidance-5 (ISG-5) [3], since the 32PTH DSC is designed to have no credible leakage. Analyses required for determining the annual dose equivalent based on direct radiation for normal, off-normal, and accident conditions are discussed in Chapter 10.

7.2.2 Pressurization of Confinement Vessel

The design provides for drying and evacuation of the 32PTH DSC interior as part of the loading operations. The design is acceptable for the pressures that may be experienced during these operations as discussed in Chapter 4. On completion of fuel loading, the gas fill of the 32PTH DSC interior is at a pressure level that will maintain a non-reactive environment for at least the 40 year storage life of the 32PTH DSC interior under normal, off-normal, and accident conditions.

7.3 Confinement Requirements for Hypothetical Accident Conditions

7.3.1 Fission Gas Products

The 32PTH DSC confinement boundary is designed to prevent the leakage of radioactive materials. The analyses presented in Chapters 3 and 11 demonstrate that the confinement boundary is not compromised following hypothetical accident conditions. Therefore, estimating the maximum quantity of fission gas products is not necessary in accordance with ISG-5[3].

7.3.2 Release of Contents

The 32PTH DSC confinement boundary is designed to prevent the leakage of radioactive materials. The analyses presented in Chapters 3 and 11 demonstrate that the confinement boundary is not compromised following hypothetical accident conditions. End and corner drops are not considered credible events during storage and transfer. However, the DSC and transfer cask have been evaluated for these drops to support evaluations required for postulated events under 10CFR50 and 10CFR71. The cladding integrity must be demonstrated by the user for 10CFR50 postulated end drops and will be evaluated in the 10CFR71 transport safety analysis report for hypothetical accidents during transports. Therefore, confinement analyses for the release of radioactive materials are not necessary in accordance with ISG-5 [3].

8 OPERATING PROCEDURES

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

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

8.1.1 Narrative Description

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

8.1.1.1 Transfer Cask and DSC Preparation

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

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

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

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

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

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

8.1.1.2 DSC Fuel Loading

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

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

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

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

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

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

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

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

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

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

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

12. Drain any water from above the inner top cover plate back to the spent fuel pool. Up to about 1300 gallons of water may be removed from the DSC prior to lifting the transfer cask clear of the pool surface.

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

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

8.1.1.3 DSC Closing, Drying, and Backfilling

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

2. Decontaminate the transfer cask exterior.

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

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

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

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

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

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

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

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

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

12. Remove the automated welding machine.

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

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

    a) install annulus water circulation equipment, or

    b) drain annulus water if temperature exceeds 180°F

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

28. Install the transfer cask lid and bolt it.

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

8.1.1.4 Transfer Cask Downending and Transport to ISFSI

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

2. The transfer trailer should be positioned so that the cask support skid is accessible to the crane with the trailer supported on its vertical jacks. If required due to space limitations, the crane may remain in a stationary position while the cask support skid and trailer translate underneath the cask as it is downended, (the trailer cannot be supported on the vertical jacks.)

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

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

5. Move the crane while simultaneously lowering the cask until the cask upper trunnions are just above the support skid upper trunnion pillow blocks. Alternatively, if the crane is to remain stationary as identified above, slowly move the trailer and support skid as the cask is lowered until the upper trunnions are just above the support skid upper trunnion pillow blocks.

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

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

8. Verify the trunnions are properly seated onto the skid and install the trunnion tower closure plates. Refill the cask liquid neutron shield, if it was drained in step 1 above.

11.3 Postulated Accident

The design basis accident events specified by ANSI/ANS 57.9-1984 [2] and other postulated accidents that may affect the normal safe operation of the NUHOMS® HD System are addressed in this section.

The following sections provide descriptions of the analyses performed for each accident condition. The analyses demonstrate that the requirements of 10CFR 72.122 are met and that adequate safety margins exist for the NUHOMS® HD System design. The resulting accident condition stresses in the NUHOMS® HD System components are evaluated and compared with the applicable code limits set forth in Chapter 2.

Radiological calculations are performed to confirm that on-site and off-site dose rates are within acceptable limits.

The postulated accident conditions addressed in this section include:

- Cask Drop
- Earthquake
- Tornado Wind Pressure and Tornado Generated Missiles
- Flood
- Blockage of HSM-H Air Inlet and Outlet Openings
- Lightning
- Fire/Explosion

11.3.1 Cask Drop

Cause of Accident

As described in Chapter 8, handling operations involving hoisting and movement of the on-site transfer cask and 32PTH DSC are typically performed inside the plant's fuel handling building. These include utilizing the crane for placement of the empty 32PTH DSC into the transfer cask cavity, lifting the transfer cask/32PTH DSC into and out of the plant's spent fuel pool, and placement of the transfer cask/32PTH DSC onto the transport skid/trailer. An analysis of the plant's lifting devices used for these operations, including the crane and lifting yoke, is needed to address a postulated drop accident for the transfer cask and its contents. The postulated drop accident scenarios addressed in the plant's 10CFR 50 licensing basis are plant specific and should be addressed by the licensee.

Once the transfer cask is loaded onto the transport skid/trailer and secured, it is pulled to the HSM-H site by a tractor vehicle. A predetermined route is chosen to minimize the potential hazards that could occur during transport. This movement is performed at very low speeds. System operating procedures and technical specification limits defining the safeguards to be provided ensure that the system design margins are not compromised. As a result, it is highly unlikely that any plausible incidents leading to a transfer cask drop accident could occur. Similarly, at the ISFSI site, the transport skid/trailer is backed-up to, and aligned with, the HSM-H using hydraulic positioning equipment. The transfer cask is then docked with, and secured to, the HSM-H access opening. The loaded 32PTH DSC is transferred to or from the HSM-H using a hydraulic ram system. The hold down mechanisms that secure the transfer cask to the transport skid/trailer remain in place at all times during the 32PTH DSC transport. As a result, there is no reasonable way during these operations for a cask drop accident to occur.

Lifts of the transfer cask loaded with the dry storage canister are made within the existing heavy loads requirements and procedures of the licensed nuclear power plant. The transfer cask design meets requirements of NUREG-0612 and ANSI N14.6.

The transfer cask is transported to the ISFSI in a horizontal configuration. Therefore the only credible drop accident during storage or transfer operation is a side drop.

The transfer cask and dry storage canister are evaluated for a postulated end and corner drop to demonstrate structural integrity during transport and plant handling. However the fuel cladding structural integrity has not been demonstrated for these scenarios. Therefore, the user is required to demonstrate fuel cladding structural integrity under 10CFR50 postulated drop accidents or demonstrate that the drop accidents are not credible.

Accident Analysis

The stress analyses are performed in Chapter 3, Appendix 3.9.1 for 32PTH DSC and Appendix 3.9.2 for the Transfer Cask.

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

Accident Dose Calculation

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

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

The dose rate at the transfer cask surface due to the loss of the neutron shield is also calculated; the peak dose is 400 mrem/hr gamma and 6049 mrem/hr neutron.

Corrective Actions

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

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

11.3.2 Earthquake

Cause of Accident

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

Accident Analysis

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

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

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

Accident Dose Calculations

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

Corrective Actions

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

12.3.1 32PTH DSC Fuel Integrity

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

LCO 12.3.1.1 Duration: Vacuum Drying of the 32PTH DSC shall be achieved within the following time durations after drainage of bulk water (blowdown):
Note: The DSC shall be backfilled with nitrogen or helium after drainage of bulk water.

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

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

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

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

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

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

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

APPLICABILITY: During LOADING OPERATIONS.

ACTIONS

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

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

SURVEILLANCE REQUIREMENTS

SURVEILLANCE	FREQUENCY
SR 12.3.1.1.1 Verify that the 32PTH DSC vacuum pressure is less than, or equal to, 3 Torr (3 mm Hg) absolute for at least 30 minutes, within the specified total time duration based on heat load.	Once per 32PTH DSC, after an acceptable NDE of the top shield plug weld.

12.3.1.2 32PTH DSC Helium Backfill Pressure

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

APPLICABILITY: During LOADING OPERATIONS.

ACTIONS

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

This specification is applicable to all 32PTH DSCs.

CONDITION	REQUIRED ACTION	COMPLETION TIME
Note: Not applicable until SR 12.3.1.2.1 is performed.		
A. The required backfill pressure cannot be obtained or stabilized.	A.1 Establish the 32PTH DSC helium backfill pressure to within the limit.	24 hours
	OR	
	A.2 Flood the DSC with water submerging all fuel assemblies.	24 hours

SURVEILLANCE REQUIREMENTS

SURVEILLANCE	FREQUENCY
SR 12.3.1.2.1 Verify that the 32PTH DSC helium backfill pressure is 2.5 ± 1 psig.	Once per 32PTH DSC, after the completion of TS 12.3.1.1 actions.

12.3.1.3 Transfer Cask Cavity Helium Backfill Pressure

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

APPLICABILITY: During LOADING OPERATIONS.

ACTIONS

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

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

CONDITION	REQUIRED ACTION	COMPLETION TIME
Note: Not applicable until SR 12.3.1.3.1 is performed.		
A. The transfer cask annulus helium backfill can't be initiated within 8 hrs of vacuum drying completion.	A.1 Flood the TC cavity/annulus with water	1 hour
B. The required backfill pressure cannot be obtained or stabilized.	B.1 Establish the TC cavity/annulus helium backfill pressure to within the limit.	18 hours
	OR	
	B.2 Flood the TC cavity/annulus with water.	18 hours

SURVEILLANCE REQUIREMENTS

SURVEILLANCE	FREQUENCY
SR 12.3.1.3.1 Verify that the OS187H cavity/annulus helium backfill pressure is 2.0 ± 1 psig.	Once per 32PTH DSC, after the completion of TS 12.3.1.2 actions or after the installation of TC lid

12.5.3 Lifting Controls

12.5.3.1 Transfer Cask Lifting Heights

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

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

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

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

12.5.3.2 Cask Drop

Inspection Requirement

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

Background

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

Safety Analysis

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

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

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

12.5.4 HSM Dose Rate Evaluation Program

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

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

2. On the basis of the analysis in TS 12.5.4.1, the licensee shall establish a set of HSM-H dose rate limits which are to be applied to 32PTH DSCs used at the site. Limits shall establish peak dose rates for:
   a. HSM-H front surface,
   b. HSM-H door centerline,
   c. End shield wall exterior

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

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

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

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

Table 12-3

Maximum Neutron and Gamma Source Terms

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

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

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