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12.3-1 NUHOMS-32P DSC KENO V.a CRITICALITY MODEL

LIST OF ACRONYMS

ACI	American Concrete Institute
AISC	American Institute of Steel Construction
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
B&PV	Boiler and Pressure Vessel
CCNPP	Calvert Cliffs Nuclear Power Plant
CE	Combustion Engineering, Inc.
CFR	Code of Federal Regulations
CSAS25	Criticality Safety Analysis Sequence No. 25
DSC	Dry Shielded Canister
HSM	Horizontal Storage Module
HSM-HB	High Burnup Horizontal Storage Module
ISFSI	Independent Spent Fuel Storage Installation
NUHOMS	Nutech Horizontal Modular Storage®
TR	Topical Report
USAR	Updated Safety Analysis Report
USL	Upper Subcriticality Limit
VAP	Value Added Pellet

12.0 NUHOMS-32P DRY SHIELDED CANISTER

An evaluation of the Nutech Horizontal Modular Storage (NUHOMS)-32P Dry Shielded Canister (DSC) used in the NUHOMS dry storage system is presented in this Chapter. Chapter 1 is revised to include information for both the NUHOMS-24P and NUHOMS-32P DSCs. Chapters 2 through 11 primarily apply to the NUHOMS-24P DSC, whereas Sections 12.2 through 12.11 provide the same information as it applies to the NUHOMS-32P DSC.

General references are identified throughout the body of this chapter, and are listed in Section 12.12. General references are intended to provide background information or additional detail that the reader may refer to in order to learn more about a particular topic presented in this document, but are not considered part of the Updated Safety Analysis Report (USAR). A referenced document shall be considered to be a part of the USAR only if it is clearly annotated as being "incorporated by reference" in Chapter 12 of this report. Documents that are incorporated by reference are subject to the same administrative controls and regulatory requirements as the USAR.

12.1 INTRODUCTION AND GENERAL DESCRIPTION OF INSTALLATION

The introduction and general description of the NUHOMS-32P is integrated into Chapter 1.

12.2 SITE CHARACTERISTICS

The Calvert Cliffs Independent Spent Fuel Storage Installation (ISFSI) site characteristics are discussed in Chapter 2. The evaluation presented in Chapter 2 is not affected by the addition of the NUHOMS-32P DSC as part of the NUHOMS System.

12.3 PRINCIPAL DESIGN CRITERIA

12.3.1 PURPOSE OF THE CALVERT CLIFFS INDEPENDENT SPENT FUEL STORAGE INSTALLATION

Information contained in Section 3.1 is applicable to the NUHOMS-32P DSC design as well.

12.3.2 STRUCTURAL AND MECHANICAL SAFETY CRITERIA

Compared to the existing NUHOMS-24P DSC, the main difference in the principal design parameters for the NUHOMS-32P DSC consists of an increase in canister weight, radiological source, and decay heat due to the addition of eight more fuel assemblies plus modifications to the DSC basket assembly. The NUHOMS-32P DSC is handled and stored in the HSM in the same manner as the NUHOMS-24P DSC. The NUHOMS-32P DSC is handled and stored in the HSM-HB in a similar manner to the HSM with slight differences during HSM-HB loading due to design differences. The environmental conditions and natural phenomena for a NUHOMS-32P DSC are the same as those described in Section 3.2 except as discussed below.

12.3.2.1 Tornado Wind and Tornado-Generated Missile Loadings

For the HSM, the principal tornado wind and tornado-generated missile loading criteria are not dependent on the type of DSC employed and, therefore, are the same for the NUHOMS-32P and NUHOMS-24P DSCs. The tornado wind and tornado-generated missile loading criteria are described in Section 3.2.1 for the HSM. They are based on Reference 3.1, which applies to the NUHOMS-24P DSC, but are applicable to the NUHOMS-32P DSC as well.

For the HSM-HB, the principal tornado wind is the same as the HSM. The tornado generated missiles are those corresponding to the HSM-H design (Reference 12.77) and are either more conservative or the same as the HSM. The HSM-HB tornado missile criteria are derived using the same basis as the HSM (Reference 3.8). The tornado wind and tornado-generated missile loading criteria are described in Section 3.2.1.

Evaluation of the NUHOMS-32P DSC for tornado wind and tornado generated missiles is presented in Section 12.8.2.2.

12.3.2.2 Water Level (Flood) Design

As stated in Section 3.2.2, the Calvert Cliffs ISFSI is not subject to flooding. Therefore, the type of DSC and horizontal storage module HSM/HSM-HB used is independent of the flood water level.

12.3.2.3 Seismic Design

For the HSM, the principal seismic loading criteria are not dependent on the type of DSC employed and, therefore, are the same for the NUHOMS-32P and NUHOMS-24P DSCs. The seismic loading criteria are described in Section 3.2.3.

For the HSM-HB, the principal seismic loading criteria are those corresponding to the HSM-H design (Reference 12.77) and are more

conservative than those described in Section 3.2.3 for the HSM. The HSM-HB seismic criteria derived using the same basis as the HSM (NRC RG 1.60 and 1.61). The seismic loading criteria are described in Section 3.2.3.

Evaluation for the use of the NUHOMS-32P DSCs for seismic loading is presented in Section 12.8.2.3.

12.3.2.4 Snow and Ice Loadings

The snow and ice loads are the same for the NUHOMS-32P and NUHOMS-24P DSCs and are described in Section 3.2.4.

12.3.2.5 Combined Load Criteria

12.3.2.5.1 HSM and HSM-HB

The Calvert Cliffs site-specific load combinations matrix and design criteria for the HSM storing the NUHOMS-32P and NUHOMS-24P DSCs are the same and are presented in Section 3.2.5.1 and Table 3.2-2. These load combinations have also been evaluated for storage of a NUHOMS-32P DSC in the high burnup horizontal storage module (HSM-HB).

Structural evaluation of the HSM for the NUHOMS-32P DSC is presented in Section 12.8.

12.3.2.5.2 NUHOMS-32P DSC

The Calvert Cliffs site-specific load combinations for the NUHOMS-32P DSC are presented in Table 12.3-6.

Structural evaluation of the NUHOMS-32P DSC basket assembly is presented in Section 12.8.

12.3.2.5.3 NUHOMS Transfer Cask

The same transfer cask is used for the NUHOMS-32P and NUHOMS-24P DSCs. The Calvert Cliffs site-specific load combinations and allowable stress criteria for the transfer cask are the same as those presented in Section 3.2.5.3.

Structural evaluation of the transfer cask for the NUHOMS-32P DSC is presented in Section 12.8.

12.3.2.5.4 NUHOMS System Transfer Equipment

The load combinations and acceptance criteria for the transfer equipment are not affected by the use of the NUHOMS-32P DSC and are the same as those in Section 3.2.5.4.

12.3.2.6 Weld Requirements

The NUHOMS-32P DSC shell assembly welded joint details are the same as for the NUHOMS-24P DSC shell assembly (References 12.35 through 12.46).

The NUHOMS-32P DSC basket structure welded joint details are shown in References 12.35 through 12.46. Full penetration welds in the DSC basket assembly are examined by progressive penetrant test examination in accordance with the requirements of paragraph NG-5231 of the American Society of Mechanical Engineers (ASME) Code Section III, Subsection NG (References 12.26 and 12.41).

Weld analysis results for the NUHOMS-32P DSC and the transfer cask are presented below.

DSC Shell and Basket Assembly Welds (Reference 12.22)

- Shell Welds

The DSC Shell can be manufactured from pieces of cylindrical plates. These shell pieces are welded together by full penetration welds, both longitudinally and circumferentially. The weld is also 100% radiographed.

- Support Ring Welds

The Support Ring consists of a 1.75" high tapered ring and a 0.25" high plate that are welded to the DSC shell. When the Support Ring is loaded, the 1/4" fillet weld between the ring and plate is in compression, and the upper ring will bear against the lower plate. The welds that require analysis are the two 1/4" groove welds at the top and bottom of the Support Ring weldment. The Support Ring supports the weight of the top lead shield plug assembly, conservatively assumed to weigh 8,000 lbs. The Support Ring self-weight is an additional 300 lbs. The critical loading condition occurs during the 75g bottom end vertical drop. The Service Level D allowable weld stress at the DSC design temperature of 380°F is 22.55 ksi. The calculated weld shear and tensile stress is within allowable limits.

- Lead Shield Plug Assembly Welds

Each of the four top shield plug assembly round bars are welded to the inner cover plate by a 5/16" fillet weld. The 1.5" diameter bars are loaded only during preliminary handling of the top shield plug assembly. In all other cases, the weld is in compression. The weight of the top shield plug assembly is conservatively 8,000 lbs. The allowable stress at room temperature is 10.0 ksi. Conservatively assuming that two of the four plugs carry the load, the calculated stress on the weld is within the allowable limits.

- Top Shield Plug Pressure Boundary Weld

The inner cover plate on the top shield plug is welded to the DSC shell by a 3/16" groove weld. The highest load on the weld occurs during the 100 psig accident pressure load case. The pressure is applied to the top inner cover plate and loads the weld in pure shear. The Service Level D allowable weld stress at 380°F is 22.55 ksi. The calculated stress is within allowable limits.

- Top Cover Plate Weld

The top cover plate is welded to the DSC by a groove weld, which has a ½" minimum throat. The maximum load occurs during the bottom end drop, where the weld is loaded by the weight of the outer cover plate at 75g. The Service Level D allowable weld stress at 380°F is 22.55 ksi. The calculated shear stress on the weld is within allowable limits.

- Bottom Cover Plate Weld

The bottom end structural weld is a full penetration weld and is 100% radiographed.

- Bottom Lead Casing Plate Welds

The bottom lead casing plate is welded to the lead casing shell plate by a 1/4" groove weld. During a lifting of the DSC into the transfer cask, the shearing load on this weld is equal to the dead weight of the bottom shield plug and the bottom lead liner plate (conservatively 7,500 lbs). The allowable stress at room temperature is 10.0 ksi. The calculated weld shear stress is within allowable limits.

The lead casing shell is welded to the bottom cover plate by a 1/4" groove weld on the outside, and a 1/8" fillet weld on the inside. These welds carry the same loads as the 1/4" groove weld between the lead liner plate and the lead casing shell and are acceptable.

The 5/16" bottom weld applied to the plug post and bottom cover plate interface is a non-structural weld.

- Grapple Ring Assembly Welds

The grapple ring is welded to the grapple ring shell by a full penetration groove weld.

The grapple ring assembly plate is welded to the grapple ring shell on the inside by a 3/8" groove weld with a 1/8" fillet weld, and on the outside by a 1/4" fillet weld. These welds carry some of the lead shield during a vertical lift. The 1/4" groove weld is adequate under this loading condition.

The grapple ring shell is welded to the inner cover plate by a full penetration weld with a 1/8" fillet cover weld.

A 1/8" cover fillet weld over a 3/8" groove weld is applied to the outside of the grapple ring shell and the bottom cover plate interface. Conservatively ignoring the cover fillet weld, the 3/8" groove weld is loaded by a maximum of 95,000 lbs when the DSC is pushed by the ram assembly. The Service Level A allowable stress at 380°F is 9.48 ksi. The calculated total shear stress on the weld is within the allowable limit.

- Vent and Siphon Port Welds

The plates welded to the vent and siphon ports form part of the pressure boundary. The plates are 3.40" in diameter, and are welded to the drain

and fill ports by 3/16" groove welds. Under worst case conditions, the plates carry a pressure of 100 psig. The Service Level D allowable weld stress at 350°F is 22.55 ksi. The calculated weld stress is within the minimum allowable stress.

- Guide Sleeve Fusion Weld

The weld strength of each fusion weld nugget connecting the fuel compartment guide sleeves of the DSC basket structure is required to be determined by shear tests using test specimens made from production material and shall have a minimum capacity of 16.0 kips at 70°F (Reference 12.41). The allowable design strength of the fusion weld is established by applying a safety factor of 2 and correction for the 600°F design temperature (Reference 12.28).

Correcting for reduction in the weld allowable stress from 75 ksi at room temperature to 63.4 ksi at 600°F, the minimum provided weld capacity at 600°F is 15.5 kips. The calculated load in the fusion weld connection of the fuel compartment guide sleeves is within the minimum allowable stress.

Transfer Cask Welds (Reference 12.25)

- Weld At Inner Bottom Cover Plate/Ram Access Penetration Ring

This weld is analyzed for the critical lift handling condition and the vertical bottom drop accident condition.

- Critical Lift Handling Condition

  The inner bottom cover plate supports the weight of the DSC, conservatively taken to be 95 kips (Reference 12.34), during the critical lift condition. The load is increased by 15% to account for motion loads. The fuel and DSC are considered to load the cask base plate as a uniform pressure load. The remaining weight of the DSC, which includes the basket, shell, and top plate are conservatively represented as a pressure load that decreases toward the center of the plate. The calculated fillet weld size required is 0.35" (Reference 12.25). The existing 3/8" minimum weld size is adequate.

- Vertical Drop Condition (Level D)

  The weld stress for this condition is based on the results of the calculation for the NUHOMS-24P DSC (Reference 12.50) for the transfer cask vertical bottom drop accident and scaling up the stress by a factor of 1.1 to reflect the weight increase of the NUHOMS-32P DSC. The weld stress (using stainless steel allowables) is within the minimum allowable stress of 22.4 ksi.

- Weld at Cask Inner Shell Plate/ Top Flange Ring

The weld stress is based on the results of calculation for the NUHOMS-24P DSC (Reference 12.50) for transfer cask vertical bottom drop accident and scaling up by a factor of 1.1 the stress to reflect the weight increase of the

NUHOMS-32P DSC. The calculated weld stress is less than the allowable stress of 22.4 ksi.

The analyses described above demonstrate that the important-to-safety components of the Calvert Cliffs ISFSI with NUHOMS-32P DSC are adequate to withstand all postulated loads and loading combinations.

12.3.3 SAFETY PROTECTION SYSTEMS

12.3.3.1 General

Section 3.3 discusses the Calvert Cliffs ISFSI design for the safe and secure long-term containment and storage of spent fuel. The NUHOMS-32P DSC is designed for storage of spent nuclear fuel as described in Section 3.3.1 and in the following subsections.

12.3.3.2 Protection by Multiple Confinement Barriers and Systems

The NUHOMS-32P DSC provides confinement of the spent fuel similar to the NUHOMS-24P DSC. Sealing of the NUHOMS-32P DSC is leak tested in accordance with American National Standards Institute (ANSI) N14.5 after loading and sealing the canister, as described in Section 3.3.2.

Containment of radioactive material associated with spent fuel assemblies is provided by fuel cladding, the DSC stainless steel shell and double seal welded primary and secondary closures. As described in Section 3.3.2, there are no credible events that will breach a DSC to provide a possible leakage path to the environment.

12.3.3.3 Protection by Equipment and Instrumentation Selection

The protection by equipment and instrumentation is not impacted by the use of the NUHOMS-32P DSC, and remains the same as presented in Section 3.3.3.

12.3.3.4 Nuclear Criticality Safety

The NUHOMS-32P DSC internals are designed to provide nuclear criticality safety during all phases of NUHOMS system operations and storage, including wet loading operations and postulated accident conditions. The Calvert Cliffs site-specific NUHOMS-32P DSC design satisfies the requirements of 10 Code of Federal Regulations (CFR) 72.124 for normal, off-normal, and accident conditions.

12.3.3.4.1 Control Methods for Prevention of Criticality

Criticality control is provided during the transfer cask fuel loading, DSC drying and sealing (wet conditions), and the transfer and storage phases (dry conditions). Control methods for the prevention of criticality under wet conditions consist of the physical properties of the fuel, fixed neutron absorbers in the NUHOMS-32P basket, 2,450 ppm soluble boron in the spent fuel pool water, and Calvert Cliffs' administrative controls for fuel identification, verification, and handling.

Rigorous measures are taken to exclude the possibility of introducing moderator into the DSC cavity during the dry operations of transfer and storage. Prior to these operations, the DSC is vacuum dried, backfilled with helium, double seal welded, and helium leak tested to assure weld integrity. Therefore, under normal operating conditions there is no possibility of a criticality incident. Since the transfer cask and HSM are designed to provide adequate drop and/or missile protection for the DSC, there is no credible accident scenario which would result in the possibility of the entrance of a moderator into the DSC; nor is there a credible accident scenario which would prohibit the canister from being opened and re-flooded.

12.3.3.4.2 Design Parameters for Criticality Model

The design basis criticality analysis uses design parameters for Combusting Engineering, Inc. (CE) design 14x14 standard and Value Added Pellet (VAP) fuel assemblies containing UO_2 enriched up to 4.5 wt% U^{235} with geometry and fuel characteristics as shown in Table 3.3-3. Only VAP Batches 1NT, 1T, 2S, 1V, 1W, and 2T (excluding 2TF and 2TW lead fuel assemblies) are analyzed for loading in the NUHOMS-32P DSC. The nominal dimensions of the NUHOMS-32P DSC are provided in Table 12.3-1. The geometry is illustrated in Figure 12.3-1. A summary of the design parameters for the criticality analysis is presented in Table 12.3-2.

Additional analyses are performed for fuel misloads and accidents. The design parameters for misloads and accidents are also presented in Table 12.3-2.

12.3.3.4.3 Criticality Analysis Methods

Effective neutron multiplication factors, k_{eff}, are calculated using the Criticality Safety Analysis Sequence No. 25 (CSAS25), of the SCALE-4.4 package of codes, and the 44 Group ENDF-V cross-section library. The CSAS25 control module allows simplified data input to the functional modules BONAMI-S, NITAWL-S, and KENO V.a. These modules process the required cross-sections and calculate the k_{eff} of the system. BONAMI-S performs resonance self-shielding calculations for nuclides that have Bondarenko data associated with their cross sections. NITAWL-S applies a Nordheim resonance self-shielding correction to nuclides having resonance parameters. Finally, KENO V.a calculates the k_{eff} of a three-dimensional system. A sufficiently large number of neutron histories are run so that the standard deviation is below 0.0010 for all calculations.

The final k_{eff} that is calculated represents the maximum value of the effective multiplication factor with a 95% probability at a 95% confidence level (95/95). The "worst case" k_{eff} values from the CSAS25 output are adjusted for uncertainty, such that:

$$k_{eff} = k_{keno} + 2\sigma_{keno}$$

A series of 121 benchmark criticality calculations are documented in Reference 12.6. These calculations assume unirradiated fuel in the criticality analysis and use the SCALE-4.4 computer code package. The upper subcriticality limit (USL), as described in Section 4 of NUREG/CR-6361 (Reference 12.5), is determined using the results of these 121 benchmark calculations. The benchmark problems used to perform this verification are representative of benchmark arrays of commercial light water reactor fuels with the following characteristics:

- water moderation
- boron neutron absorbers
- unirradiated light water reactor type fuel (no fission products or "burnup credit")
- near room temperature (vs. reactor operating temperature)
- close reflection
- uranium oxide fuel

The 121 uranium oxide experiments are chosen to model a wide range of uranium enrichments, fuel pin pitches, assembly separation, water/fuel ratio, concentration of soluble boron and control elements in order to test the codes ability to accurately calculate k_{eff}. The minimum value of the USL from Reference 12.6 over the parameter range (in this case, the assembly separation distance) is 0.9422. This USL value (0.9422) is based on a methodology bias and an administrative 5% margin on criticality. That is, $k_{eff} < USL$, ensures that k_{eff} is less than 0.95 (with 95% probability and 95% confidence) when bias and uncertainty are taken into account.

For the criticality analyses, the criticality limits are shown in the following equation:

$$k_{eff} = (k_{keno} + 2\sigma_{keno}) \leq 0.9422$$

12.3.3.4.4 Normal Conditions (References 12.7 and 12.71)

The calculated normal condition, "worst-case," reactivity (maximum k_{eff}) of a fully loaded Calvert Cliffs NUHOMS-32P DSC is 0.9412. This is below the USL (0.9422), thus confirming that the "worst case" k_{eff} is $\leq$ 0.95. It conservatively includes allowances for uncertainties due to fuel positioning, basket rail modeling, compartment tube

dimensions, poison plate thickness, and optimum moderator density. The "worst case" configuration includes the following:

- no credit for burnable absorbers in the fuel rods (e.g., erbia, etc.),
- fuel is unirradiated,
- the maximum uniform enrichment, 4.5 wt% U^{235}, for all 32 assemblies,
- an "inward" loading of all the 32 CE 14x14 standard or VAP fuel assemblies (i.e., all fuel assemblies are shifted toward the center of the DSC),
- credit for 90% of the absorber material (B^{10}) in the fixed neutron absorbers in the NUHOMS-32P basket assembly,
- a minimum compartment tube dimension of 8.47",
- an internal moderator (soluble boron at 2,450 ppm) density of 70%,
- an external (to the DSC and internal to the transfer cask) moderator (pure water) density of 10%,
- AREVA fuel was not analyzed.

To evaluate assemblies containing vacancies and inert stainless steel rods, Reference 12.58 utilizes the same methodology as Reference 12.7 to analyze criticality under normal conditions. No changes were made to the computer code software and version or to the characteristics of the KENO V.a models other than the changing of the fuel array input to include vacancies and inert stainless steel pins. The material specification used for the stainless steel rods is consistent with the methodology in Reference 12.7. The calculated 95/95 (95% probability and 95% confidence) k_{eff} for all cases analyzed are below the USL of 0.9422.

12.3.3.4.5 Off-Normal Conditions (References 12.8 and 12.71)

Four postulated off-normal conditions are analyzed:

- The misloading of AREVA or VAP fuel assemblies into the DSC with an initial enrichment of 5.0 wt% U^{235},
- Cask Drop Accidents,
- B^{10} Absorber Plates at Minimum Thickness, and
- Optimum Moderator Density.

These analyses confirm that the off-normal conditions will not result in a DSC storage array with a reactivity higher than the USL of 0.9422.

Misloading of AREVA or VAP Assemblies (5 wt% U^{235})

AREVA or VAP fuel assemblies with enrichments exceeding 4.5 wt% U^{235} are not currently licensed for storage in

NUHOMS-32P canisters. However because it resides in the spent fuel pool, a misload of higher enriched AREVA or VAP fuel into a canister was analyzed. The criticality analysis for the fuel misloads demonstrates that a maximum of one AREVA or VAP fuel assembly at an enrichment of 5.0 wt% U^{235} can be misloaded and transferred under optimum moderator density conditions. The k_{eff} for this case is 0.9418.

Reference 12.58 shows a clear and expected trend of lower k_{eff} with increasing number of fuel rods removed. This trend applies to the case of accidental misloading of VAP or AREVA assemblies as well. Therefore, there is no impact on the misload criticality analysis results as presented above.

Cask Drop Accidents

The criticality analysis for the cask drop accidents demonstrates that the most reactive configuration is the triple contingency accident involving fuel damage, optimum pitch (due to grid deformation), and optimum moderator density. For the helium-moderated system, the k_{eff} is 0.5737 which is below the USL (0.9422). For the borated water moderated system, the maximum k_{eff} is 0.9413, which is also below the USL (0.9422).

Reference 12.59 determines the structural adequacy of a standard fuel assembly with burnup $< 47{,}000$ MWD/MTU containing vacancies following a cask drop event. The results show that the bending stresses are acceptable provided that no more than two vacancies are in any one column or row of the fuel assembly. It is not required that the vacancies be adjacent. Vacancies are restricted for fuel with burnup between 47,000 MWD/MTU and 52,000 MWD/MTU pending further structural analysis. The criticality analysis of Reference 12.58 has postulated that an assembly containing numerous vacancies can be postulated to be rearranged into a 13x13 array if grid spacer integrity is compromised. Reference 12.58 has analyzed a 13x13 array with maximum pitch separation and has determined that the k_{eff} of such a scenario is 0.9012. The most reactive case, with vacancies, was found to be when one vacancy was present in each of the four center assemblies. The assemblies were modeled in the standard 14x14 array and at optimum fuel rod pitch; the resulting k_{eff} is 0.9390. Both of these scenarios results in a k_{eff} less than the bounding analysis which finds the k_{eff} to be 0.9413. All of these values are less than the USL of 0.9422.

B10 Poison Plate Thickness Variation

The criticality analysis for sensitivity to B^{10} absorber plate thickness demonstrates that there is enough conservatism in the plate loading of 10.0 mg B^{10}/cm^2 to offset changes in reactivity due to a reduction in thickness. Credit is taken for

90% of the B^{10} loading in the analysis. For the normal case, with an absorber plate thickness of 0.04", the maximum k_{eff} is calculated to be 0.9412 (Reference 12.7). For the "worst case," with a B^{10} loading of 8.964 mg/cm^2, a thickness of 0.035", and optimum moderator density, the k_{eff}, is calculated to be 0.9357 (Reference 12.8).

Section 12.3.3.4.7 has a detailed discussion on poison plate acceptance testing.

Optimum Moderation

Since all reported reactivities include an allowance for optimum moderator density, and all reported reactivities are less than the USL, a criticality event due to moderator density alone is not credible. For a misload of a 5% enriched VAP or AREVA assembly, optimum moderator density will not result in criticality, provided that at least 2,450 ppm of boron is present in the water inside the DSC. Therefore subcriticality is assured, even in the event that a flooded DSC remains out of the pool long enough for boiling to occur.

12.3.3.4.6 Criticality Analysis Method Verification

The analysis method which ensures a subcriticality margin of greater then 5% under all normal conditions uses the CSAS25, of the SCALE-4.4 package of codes, and the 44 Group ENDF-V cross-section library.

A series of 121 benchmark criticality calculations are documented in Reference 12.6. These calculations assume unirradiated fuel in the criticality analysis and use the SCALE-4.4 computer code package to demonstrate its applicability and to establish methods bias and variability.

12.3.3.4.7 B^{10} Poison Plate Testing

Description

The poison plates consist of wrought aluminum containing boron, which is isotopically enriched to approximately 95 wt% B^{10}. Because of the negligibly low solubility of boron in solid aluminum, the boron appears entirely as discrete second phase particles of AlB_2 in the aluminum matrix. The effect on the properties of the matrix aluminum alloy are those typically associated with a uniform fine (1-10 micron) dispersion of an inert equiaxed second phase.

The nominal plate thickness is 0.04".

The nominal boron concentration is 3.9 wt%. The design minimum B^{10} areal density is 0.0100g B^{10}/cm^2.

Functional Requirements of Poison Plates

The poison plates serve as a neutron absorber for criticality control and as a heat conduction path. The NUHOMS-32P DSC safety analysis does not rely upon their mechanical strength. The radiation and temperature environment in the cask is not severe enough to damage the aluminum matrix that retains the boron-containing particles. To assure performance of the plates' important-to-safety functions, the critical variables that need to be verified are thermal conductivity and B^{10} areal density.

Borated Aluminum Test Coupon and Lot Definitions

Test coupons will be taken so that there is at least one coupon contiguous with each plate. These coupons will be used for neutron transmission and thermal conductivity testing.

A lot is defined as all the plates produced from a single cast ingot, or all the plates produced from a single heat.

Thermal Conductivity Testing of Poison Plates

The poison plate material is qualification-tested to verify that the thermal conductivity equals or exceeds the design requirements.

Testing may be by American Society for Testing and Materials (ASTM) E1225 (Reference 12.51), ASTM E1461 (Reference 12.52), or equivalent method.

B10 Areal Density Testing of Poison Plates

The testing program for the NUHOMS-32P DSC poison plates meet the requirements of NUREG/CR-5661 (Reference 12.53).

The effective B^{10} content is verified by neutron transmission testing of the coupons. The transmission through the coupons is compared with transmission through calibrated standards. The neutron transmission testing measurements are taken using a collimated neutron beam. The neutron transmission test procedure includes provisions to vary the selected measurement location along the coupon length.

The acceptance criterion for neutron transmission testing is that the B^{10} areal density, minus 3σ based on the number of neutrons counted for that measurement, must be greater than or equal to the minimum value 0.0100g B^{10}/cm^2.

Macroscopic uniformity of B^{10} distribution is verified by neutron radioscopy/radiography of the coupons. The acceptance criterion is that there is uniform luminance across

the coupon. This inspection shall cover the entire coupon. If a coupon fails this test, the associated plate is rejected.

In addition, a statistical analysis of the neutron transmission results for all plates in a lot is performed. This analysis shall demonstrate, using a one-sided tolerance limit factor for a normal distribution with at least 95% probability, the areal density is greater than or equal to the specified minimum value of 0.0100g B^{10}/cm^2 with 95% confidence level.

12.3.3.5 Radiological Protection

The discussion presented in Section 3.3.5 is not affected by the addition of the NUHOMS-32P DSC to the NUHOMS System. See Section 12.7 for additional discussion on radiation protection design considerations for the NUHOMS-32P DSC.

12.3.3.6 Fire and Explosions Protection

The discussion presented in Section 3.3.6 is applicable to NUHOMS-32P DSC. The effects of a forest fire around the facility are discussed in Section 12.8.2.10.

12.3.3.7 Materials Handling and Storage

The evaluation presented in Section 3.3.7 is not affected by the addition of the NUHOMS-32P DSC to the NUHOMS system, with the exception of peak cladding temperatures which are higher than those of the NUHOMS-24P DSC. For long-term storage, HSM passive ventilation maintains the maximum normal operating fuel clad temperature at 620°F or less (assuming 103°F ambient temperature) as documented in Reference 12.1. During short-term conditions, such as DSC draining and drying, transfer of the DSC to/from the HSM and off-normal and accident temperature excursions (References 12.1, 12.2, 12.3, and 12.4), the fuel cladding temperature maximum value is 838°F (Reference 12.9), which is significantly less than the maximum allowable value of 1,058°F.

12.3.3.8 Industrial and Chemical Safety

The discussion presented in Section 3.3.8 is not affected by the addition of the NUHOMS-32P DSC to the NUHOMS System.

12.3.4 CLASSIFICATION OF STRUCTURES, COMPONENTS, AND SYSTEMS

The discussion presented in Section 3.4 is not affected by the addition of the NUHOMS-32P DSC to the NUHOMS System.

12.3.5 DECOMMISSIONING CONSIDERATIONS

The discussion presented in Section 3.5 is not affected by the addition of the NUHOMS-32P DSC to the NUHOMS System.

12.3.6 SUMMARY OF DESIGN CRITERIA

Tables 12.3-3 to 12.3-5 provided a summary of the design criteria information for the normal, off-normal, and accident conditions for the NUHOMS-32P DSCs, respectively.

TABLE 12.3-1
NUHOMS-32P DRY SHIELDED CANISTER DIMENSIONS

GEOMETRY DESCRIPTION	NOMINAL DIMENSIONS (inches)
Guide Sleeve Inside Diameter	8.50
Guide Sleeve Thickness	0.1874
Center to Center Spacing	9.125
Stainless Steel Strip Thickness	0.25
Aluminum + Poison Plate Thickness	0.25
Basket Assembly Length	158.0 max.
DSC Shell Outside Diameter	67.25
DSC Shell Inside Diameter	66.0
DSC Shell Length (with grapple ring)	176.5
DSC Shell Thickness	0.625
Top Shield Plug Thickness	6.25 [(a)]
Top Cover Plate Thickness	1.25
DSC Lead Shielding Thickness	
• Top Shield Plug	4.0 min.
• Bottom Shield Plug	4.25 min.
Vent / Siphon Port Tube Inside Diameter	1.05

(a) The top casing plate which is part of the top shielding plug has been determined, using ultrasonic testing inspections, to have a reduced plate thickness. All of the 32Ps top casing plates have a reduced plate thickness from 0.75” to a new potential minimum thickness to as low as 0.27”. Reference 12.66 and 12.67 qualified a new top casing plate thickness of 0.25” for all of the 32P DSCs. The nominal thickness of 6.25” for the top shielding plug remains unchanged. The details of the 32Ps casing plate thicknesses have been evaluated in ECP-11-000793.

TABLE 12.3-2
DESIGN PARAMETERS FOR CRITICALITY ANALYSIS OF THE NUHOMS-32P DSC

PARAMETERS	DESIGN VALUE
FUEL ASSEMBLIES	
Number/Type	32/CE design 14x14
Rod Array	14x14[(d)]
Number of Fuel Rods	176[(c)]
Number of Control Rod Guide Tubes	5
Number of Instrument Tubes	1 (1 of the 5 guide tubes)
Rod Pitch (inches)	0.580
Burnup Credit	Not Applicable for NUHOMS-32P DSC
FISSILE CONTENT	
wt% U^{235}	4.5 max.
wt% U^{235} (misload)	5.0 max.
FUEL PELLETS	
Density (standard)	96.0% Theoretical
Density (VAP)	95.0% Theoretical (max Batches 1NT, 1T, 2S, 1V, 1W & 2T)
Density (AREVA or VAP misload)	96.66% Theoretical
Diameter (inches) (standard)	0.3765[(a)]
Diameter (inches) (AREVA or VAP)	0.3810
FUEL ROD CLADDING Material	Zircaloy-4 or Zirlo (VAP only), M5 (AREVA misload)
Thickness (inches) (standard)	0.028[(a)]
Thickness (inches) (VAP or AREVA)	0.026
Outside Diameter (inches)	0.440
CONTROL ROD GUIDE TUBES	
Material	Zircaloy-4
Thickness (inches)	0.040
Outside Diameter (inches)	1.115
INSTRUMENT TUBE	
Material	Zircaloy-4
Thickness (inches)	0.040
Outside Diameter (inches)	1.115
DSC COMPARTMENTS	
Material	Stainless Steel
Thickness (inches)	0.1874
Inside Diameter (inches)	8.5
DSC POISON PLATES	
Number	150
Material	Borated Aluminum Alloy or Boron Aluminum Metal Matrix Composite
Density (g/cm^3)	2.693
Thickness (inches)	0.04
B^{10} Areal density (mg/cm^2)	10
Location	See Figure 12.3-1

TABLE 12.3-2
DESIGN PARAMETERS FOR CRITICALITY ANALYSIS OF THE NUHOMS-32P DSC

PARAMETERS		DESIGN VALUE
DSC FILL MATERIAL		
Material	(wet)	Borated Water (2,450 ppm min)
Moderator Density	(wet)	0.01% to 100%
Material	(dry)	helium
Moderator Density	(dry)	1.785E-04 g/cm^3 /atm
DSC SHELL		
Material		Stainless Steel
Thickness (inches)		0.625
Outside Diameter (inches)		67.25
CASK		
Material		Stainless Steel/Lead
Thickness (inches)		6.25[(b)]
Outside Diameter (inches)		80.5[(b)]

(a) The fuel pellet outside diameter and clad thickness varied slightly for Fuel Batches A, B, and C in Units 1 and 2. These variances do not affect the results of the design basis analysis.

(b) Exclusive of the cask neutron shield.

(c) Fuel Rods/Assembly (32P)

Standard fuel assemblies with burnup < 47,000 MWD/MTU to be stored in 32P DSCs may contain up to two vacancies in any column or row; the vacancies do not need to be adjacent. Vacancies that violate this configuration are to be filled with stainless steel replacement rods.

Fuel assemblies to be stored in the 32P DSC may also contain a varying number of irradiated stainless steel replacement rods depending on the rods' exposure and time of cooling as shown in Table 9.4-3. An unlimited number of unirradiated stainless steel rods is permissible.

(d) Accident analyses for fuel assemblies containing vacancies considers multiple array configurations. See Reference 12.58 for details.

TABLE 12.3-3
NUHOMS-32P SUMMARY OF DESIGN CRITERIA FOR NORMAL OPERATING CONDITIONS

COMPONENT	DESIGN LOAD TYPE	REFERENCE	DESIGN PARAMETERS	APPLICABLE CODE
HSM/HSM-HB	Dead Load	TR 8.1.1.5	Dead weight including loaded DSC*	ANSI 57.9-1984 ACI 349-85 and ACI 349R-85
	Load Combination	USAR Table 3.2-2	Load combination methodology	ANSI 57.9-1984 Sec 6.17.1.1
	Design Basis Operating Temperature		DSC with spent fuel rejecting 21.12 kW decay heat. Ambient air temperature range -3°F to 103°F	ANSI 57.9-1984
	Normal Handling Loads	TR 8.1.1.4	Hydraulic ram load: 20,000 lb*	ANSI 57.9-1984
	Snow and Ice Loads	USAR 3.2.4	Design load: 200 psf (included in live load)	ANSI 57.9-1984
	Live Loads	TR 8.1.1.5	Design load: 200 psf	ANSI 57.9-1984
	Shielding	USAR 4.2.3.1	Contact dose rate on HSM exterior surface ≤ 20 mrem/hr. HSM door ≤ 100 mrem/hr.	ANSI 57.9-1984
DSC	Dead Loads		Weight of loaded DSC: 91,000 lb nominal, 95,000 lb enveloping	ANSI 57.9-1984
	Design Basis Internal Pressure Load		DSC internal pressure 10.1 psig	ANSI 57.9-1984
	Structural Design	TR Table 3.2-6	Service Level A and B	ASME B&PV Code Sec III, Div 1, NB, Class 1
	Design Basis Operating Temperature Loads		DSC decay heat 21.12 kW. Ambient air temperature -3°F to 103°F	ANSI 57.9-1984
	Operational Handling	USAR Table 3.2-1	Hydraulic ram load: 20,000 lb	ANSI 57.9-1984
	Criticality	USAR 12.3.3.4	K_{eff} less than 0.95	ANSI 57.9-1984

TABLE 12.3-3
NUHOMS-32P SUMMARY OF DESIGN CRITERIA FOR NORMAL OPERATING CONDITIONS

COMPONENT	DESIGN LOAD TYPE	REFERENCE	DESIGN PARAMETERS	APPLICABLE CODE
DSC Support Assembly	Operational Handling	USAR 12.8.1.1.4	DSC reaction load with hydraulic ram load: 20,000 lb	ANSI 57.9-1984
Transfer Cask	Normal Operating Condition	TR Table 3.2-8	Service Level A and B	ASME B&PV Code Sec III, Div 1, Class 2, NC-3200
Structure:				
Shell, Rings, etc.	Dead Loads	USAR 12.8.1.1.9	a) Vertical orientation, self weight + loaded DSC + water in cavity: 220,000 lb enveloping	ANSI 57.9-1984
			b) Horizontal orientation, self weight + loaded DSC on transfer skid: 220,000 lb enveloping	ANSI 57.9-1984
	Snow and Ice Loads	USAR 3.2.4	External surface temperature of cask will preclude buildup of snow and ice loads when in use: 0 psf	10 CFR 72.122
	Design Basis Operating Temperature Loads		Loaded DSC rejecting 21.12 kW decay heat. Ambient air temperature range -3°F to 103°F	ANSI 57.9-1984
	Shielding	USAR 12.7.1.2	Contact dose rate ≤ 200 mrem/hr.	ANSI 57.9-1984
Transfer Cask Upper Trunnions	Operational Handling	USAR 12.8.1.1.9	a) Upper lifting trunnions while in Auxiliary Building: i) Stress must be less than yield stress for 6 times critical load of 126,500 lb/trunnion nominal	ANSI N14.6-1978
		USAR 12.8.1.1.9	ii) Stress must be less than ultimate stress for 10 times critical load	

TABLE 12.3-3
NUHOMS-32P SUMMARY OF DESIGN CRITERIA FOR NORMAL OPERATING CONDITIONS

COMPONENT	DESIGN LOAD TYPE	REFERENCE	DESIGN PARAMETERS	APPLICABLE CODE
		USAR Table 3.2-1	b) Upper lifting trunnions for on-site transfer: i) Dead Load +/- 1g vertically ii) Dead Load +/- 1g axially iii) Dead Load +/- 1g laterally iv) Dead Load (+/- 1/2g vertically +/- 1/2g axially + 1/2g laterally)	ASME B&PV Code Sec III, Div 1, Class 2, NC-3200
Lower Trunnions	Operational Handling	USAR 12.8.1.1.9	Lower support trunnions weight of loaded cask during downloading and transit to HSM	ASME B&PV Code Sec III, Div 1, Class 2, NC-3200
Shell	Operational Handling	USAR 12.8.1.1.9	Hydraulic ram load due to friction of extracting loaded DSC: 20,000 lb	ANSI 57.9-1984
Bolts	Normal Operation	TR Table 3.2-9	Service levels A, B, and C Avg stress less than 2 S_m Max stress less than 3 S_m	ASME B&PV Code Section III, Div 1, Class 2, NC-3200

(ASME B&PV Code-1983, with Addenda up to 1985 for HSM and Transfer Cask)
(ASME B&PV Code-1998, with Addenda up to 1999 for DSC)

* Value shown for HSM. HSM-HB design parameters envelope the HSM.

TABLE 12.3-4
NUHOMS-32P SUMMARY OF DESIGN PARAMETERS FOR OFF-NORMAL OPERATING CONDITIONS

COMPONENT	DESIGN LOAD TYPE	REFERENCE	DESIGN PARAMETERS	APPLICABLE CODE
HSM/HSM-HB	Off-Normal Temperature		-3°F and 103°F ambient temperature*	ANSI 57.9-1984
	Jammed Condition Handling	USAR 12.8.1.2.1	Hydraulic ram load equal to 80,000 lb	ANSI 57.9-1984
	Load Combination	USAR Table 3.2-2	Load combination methodology	ANSI 57.9-1984 Sec 6.17.1.1
DSC	Off-normal Temperature		-3°F and 103°F ambient temperature	ANSI 57.9-1984
	Off-normal Pressure		DSC internal pressure 10.8 psig	ANSI 57.9-1984
	Blowdown Pressure		DSC internal pressure: 40.0 psig	10 CFR 72.122(b)
	Jammed Condition Handling	USAR 12.8.1.2.1	Hydraulic ram load equal to 80,000 lb	ANSI 57.9-1984
	Structural Design Off-Normal Conditions	TR Table 3.2-6	Service Level C	ASME B&PV Code Sec III, Div 1, NB, Class 1
DSC Support	Jammed Handling Condition	USAR 12.8.1.2.1	Hydraulic ram load: 80,000 lb	ANSI 57.9-1984
	Load Combination	TR Table 8.2-11	Load combination methodology	ANSI 57.9-1984
Transfer Cask	Off-normal Temperature		-3°F and 103°F ambient temperature	ANSI 57.9-1984
	Jammed Condition Handling	USAR 12.8.1.2.1	Hydraulic ram load: 80,000 lb	ANSI 57.9-1984
	Structural Design Off-Normal Conditions	TR Table 3.2-8	Service Level C	ASME B&PV Code Sec III, Div 1, Class 2, NC-3200
	Bolts, Off-Normal Conditions	TR Table 3.2-9	Service Level C Avg stress less than 2 S_m Max stress less than 3 S_m	ASME B&PV Code Sec III, Div 1 Class 2, NC-3200

* HSM-HB design parameters envelope the HSM.

TABLE 12.3-5
NUHOMS-32P SUMMARY OF DESIGN CRITERIA FOR ACCIDENT CONDITIONS

COMPONENT	DESIGN LOAD TYPE	REFERENCE	DESIGN PARAMETERS	APPLICABLE CODE
HSM	Design Basis Tornado	USAR 3.2.1	Max velocity 360 mph Max wind pressure 304 psf	RG 1.76 ANSI 58.1 1982
	Load Combination	USAR Table 3.2-2	Load Combination Methodology	ANSI 57.9-1984 Sec 6.17.1.1
	Design Basis Tornado Missiles	TR 3.2.1.2	Max velocity 126 mph Types: Automobile, 3,967 lb 8" diam shell, 276 lb 1" solid sphere	NUREG-0800 Sec 3.5.1.4
	Flood	USAR 2.4.2	Dry Site	
	Seismic	USAR 12.3.2.3	Horizontal ground acceleration 0.15g (both directions) Vertical ground acceleration 0.10g 7% critical damping	NRC RGs 1.60 and 1.61
	Accident Condition Temperature	USAR 12.8.2.7	HSM vents (inlet/outlet) blocked for 36 hrs or less. HSM inside surface temp: 387°F	ANSI 57.9-1984
	Fire	USAR 12.8.2.10	1 hour forest fire 65' from HSM	
	Explosions	USAR 8.2.11	Probability of liquefied natural gas spill affecting HSM $< 10^{-7}$	NUREG-0800 Section 2.2.3
HSM-HB	Design Basis Tornado	USAR 3.2.1	Max velocity 360 mph Max wind pressure 344 psf	RG 1.76 ASCE 7-95
	Load Combination	USAR Table 3.2-2	Load Combination Methodology	ANSI 57.9-1984
	Design Basis Tornado Missiles	USAR 12.3.2.1	Automobile, 4,000 lb, 195 fps 8" diam shell, 276 lb, 185 fps 12" steel pipe, 1500 lb, 205 fps 6” steel pipe, 285 lbs, 230 fps Wood plank, 200 lbs, 440 fps (300mph) 3” steel pipe, 115 lbs, 268 fps 1” steel rod, 8 lbs, 317 fps	NUREG-0800 Sec 3.5.1.4

TABLE 12.3-5
NUHOMS-32P SUMMARY OF DESIGN CRITERIA FOR ACCIDENT CONDITIONS

COMPONENT	DESIGN LOAD TYPE	REFERENCE	DESIGN PARAMETERS	APPLICABLE CODE
	Flood	USAR 12.3.2.2	Dry Site	
	Seismic	USAR 12.3.2.3	Horizontal ground acceleration 0.3g (both directions) Vertical ground acceleration 0.2g 7% critical damping	NRC RGs 1.60 and 1.61
	Accident Condition Temperature		HSM-HB vents (inlet/outlet) blocked for 36 hours or less. HSM-HB inside surface temp: 333°F	ANSI 57.9-1984
	Fire	USAR 12.8.2.10	1 hour forest fire 65' from HSM-HB	
	Explosions	USAR 8.2.11	Probability of liquefied natural gas spill affecting HSM-HB $< 10^{-7}$	NUREG-0800 Section 2.2.3
DSC	Accident Drop	USAR 12.8.2.5	Equivalent static deceleration: 75g vertical end drop 75g horizontal side drop 25g corner drop with slap down (corresponds to an 80" drop height) Structural damping during drop: 10%	RG 1.61
	Flood	TR 3.2.2	Maximum water height: 50'	10 CFR 72.122(b)
	Seismic	USAR 12.8.2.3.2	Horizontal acceleration: 1.5g Vertical acceleration: 1.0g 3% critical damping	NRC RGs 1.60 and 1.61
	Accident Internal Pressure (HSM/HSM-HB vents blocked)	USAR 12.8.2.7	DSC internal pressure: 100 psig based on 100% fuel clad rupture and fill gas release, and ambient air temp. = 103°F. DSC shell temperature: 571°F (HSM) 473°F(HSM-HB) Blocked vent time = 36 hrs	10 CFR 72.122(b)

TABLE 12.3-5
NUHOMS-32P SUMMARY OF DESIGN CRITERIA FOR ACCIDENT CONDITIONS

COMPONENT	DESIGN LOAD TYPE	REFERENCE	DESIGN PARAMETERS	APPLICABLE CODE
	Accident Conditions	TR Table 3.2-6	Service Level D	ASME B&PV Code Sec III, Div 1, NB, Class 1
	Reflood Pressure	USAR 12.8.2	DSC internal pressure: 40.0 psig	10 CFR 72.122(i)
DSC Support Assembly	Seismic	USAR 12.8.2.3.2	DSC reaction loads: Horizontal acceleration: 0.61g Vertical acceleration: 0.39g 7% critical damping	NRC RGs 1.60 and 1.61
	Load Combination	USAR Table 12.8-4	Load combination methodology	ANSI 57.9-1984 Sec 6.17.3.2.1
Transfer Cask	Design Basis Tornado	TR 3.2.1	Max wind velocity: 360 mph Max wind pressure: 397 psf	NRC RG 1.76, ANSI 58.1-1982
	Design Basis Tornado Missiles	TR 3.2.1	Automobile, 3967 lb 8" diameter shell, 276 lb	NUREG-0800 Sec 3.5.1.4
	Flood	TR 3.2.2	Cask use to be restricted by administrative controls	10 CFR 72.122
	Seismic	USAR 3.2.3	Horizontal ground acceleration: 0.25g (both directions) Vertical acceleration: 0.17g 3% critical damping	NRC RGs 1.60 and 1.61

TABLE 12.3-5
NUHOMS-32P SUMMARY OF DESIGN CRITERIA FOR ACCIDENT CONDITIONS

COMPONENT	DESIGN LOAD TYPE	REFERENCE	DESIGN PARAMETERS	APPLICABLE CODE
	Accident Drop	USAR 12.8.2.5	Equivalent static deceleration: 75g vertical end drop 75g horizontal side drop 25g corner drop with slapdown (corresponds to an 80" drop height)	10 CFR 72.122(b)
			Structural damping during drop 10%	RG 1.61
	Bolts, Accident Drop	TR Table 3.2-9	Service Level D	ASME B&PV Code Sec III, Div 1, Class 2, NC-3200
	Structural Design, Accident	TR Table 3.2-8	Service Level D	ASME B&PV Code Sec III, Div 1, Class 2, NC-3200
	Internal Pressure	--	Not applicable because DSC provides pressure boundary	10 CFR 72.122(b)

For more information see Reference 3.14.

TABLE 12.3-6
NUHOMS-32P DSC DESIGN LOAD COMBINATIONS

Load Case[1]			Normal Operating Conditions				Off-Normal Conditions				Emergency and Accident Conditions[2]										
Type		I.D.	1	2	3	4	1	2	3	4	1	2	3	4	5	6	1	2	3	4	5
Dead Weight	Empty DSC	DW_1	X																		
	DSC w/water	DW_2		X																	
	DSC w/fuel	DW_3			X	X	X	X	X	X	X	X	X		X	X	X		X	X	X
Thermal	Inside HSM: normal	T_{nh}				X					X	X			X						
	Inside Cask: normal	T_{nc}		X	X		X									X				X	
	Inside HSM: off-normal	T_{ho}							X				X								
	Inside Cask: off-normal	T_{co}						X		X											
	Inside HSM: Accident	T_{ha}																			X
	Inside Cask: Accident	T_{ca}															X		X		
Internal Pressure	Normal Operating	P_n			X		X				X	X	X		X	X					
	Hydrostatic	P_h		X																	
	Off-normal (blowdown)	P_b				X		X	X	X											
	Accident (inner boundary)	P_{a1}																	X	X	X
	Accident (outer boundary)	P_{a2}															X				
Handling Loads	Normal DSC Transfer	L_n			X	X						X									
	Off-normal (jammed DSC)	L_o					X	X	X						X	X					
Accident Loads	Cask Drop	DL																		X	
	Seismic	E									X										
ASME B&PV Code Service Level			A	A	A	A	B	B	B	B	C	C	C	C	C	C	D	D	D	D	D
Load Combination No.			A_1	A_2	A_3	A_4	B_1	B_2	B_3	B_4	C_1	C_2	C_3	C_4	C_5	C_6	D_1	D_2	D_3	D_4	D_5

(1) The Table has been modified to include hydrostatic and blowdown pressure and to delete the flooding accident load for which no analysis is required.

(2) For emergency and accident load combinations, the DSC shall not be allowed to deform to an extent that would prevent retrieval of spent fuel. For Service Level D, the DSC internal components need only comply with deformation limits that will allow the retrieval of spent fuel. In addition, both end plug assemblies shall maintain their ability to provide shielding for personnel during DSC handling operations.

12.4 INSTALLATION DESIGN

The discussion presented in Chapter 4 is not affected by the addition of the NUHOMS-32P DSC to the NUHOMS System. Chapter 4 describes the installation design associated with the Calvert Cliffs ISFSI and related systems. The narrative describes the installation design unique to the NUHOMS systems, such as the storage structures, auxiliary systems, decontamination systems, transfer cask repair and maintenance, and the fuel handling operation systems. The Calvert Cliffs ISFSI is a self-contained, passive storage facility, which requires no auxiliary systems.

12.5 OPERATION SYSTEMS

The discussion presented in Chapter 5 is not affected by the addition of the NUHOMS-32P DSC to the NUHOMS System. Chapter 5 describes the operation of the Calvert Cliffs ISFSI. The narrative describes operations unique to the NUHOMS systems, such as draining, drying, and closure of the DSC. Although some operational details are provided, the description is not intended to limit or restrict operation of the facility. Operational procedures may be revised according to the requirements of the plant, provided that the limiting conditions of operation are not exceeded.

12.6 SITE GENERATED WASTE CONFINEMENT AND MANAGEMENT

The discussion presented in Chapter 6 is not affected by the addition of the NUHOMS-32P DSC to the NUHOMS System. Chapter 6 describes the on-site waste sources, off-gas treatment and ventilation, liquid waste treatment and retention, solid wastes and radiological impact of normal operations of the Calvert Cliffs ISFSI.

12.7 RADIATION PROTECTION

The NUHOMS-32P DSC provides enhanced shielding which helps to compensate for the additional spent fuel elements. Dose rates for the NUHOMS-32P DSC are presented in Table 12.7-1. The Calvert Cliffs site-specific NUHOMS-32P DSC design meets the requirements of 10 CFR 72.104 and 10 CFR 72.106 for normal, off-normal, and accident conditions.

The principal design features of the NUHOMS-32P DSC are listed in Table 1.3-1 and shown in Figure 12.3-1. Tables 1.2-1 and 12.3-1 lists the capacity, dimensions, and design parameters for the NUHOMS-32P DSC.

The differences between the NUHOMS-32P DSC and NUHOMS-24P DSC that affect shielding and radiation protection are:

- an increase from 24 to 32 spent fuel assemblies,
- an addition of full-length aluminum plates (borated and non-borated) between the guide sleeves,
- an addition of full-length stainless steel rails and aluminum rail inserts between the DSC stainless steel cylindrical shell and the outside guide sleeves,
- a redesign of the top shield plug (including vent and siphon ports), and
- increasing the assembly neutron source term from 2.23E+08 n/sec/assy to 4.175E+08 n/sec/assy (Reference 12.47).

The radiation protection and shielding aspects of the NUHOMS-32P DSC, and the effects of these differences, are addressed in detail below.

12.7.1 ENSURING THAT THE OCCUPATIONAL RADIATION EXPOSURES ARE AS LOW AS REASONABLY ACHIEVABLE

12.7.1.1 Policy Considerations

The discussion in Section 7.1.1 is unchanged and equally applicable to the NUHOMS-32P DSC.

12.7.1.2 Design Considerations – NUHOMS-32P DSC

NUHOMS-32P DSCs can store 32 spent fuel assemblies as opposed to NUHOMS-24P DSCs that store 24. Thus the radiation source is significantly increased in the NUHOMS-32P DSC. The design considerations which ensure that occupational exposures for the NUHOMS ISFSI are as low as reasonably achievable, are discussed in Section 7.1.2. The following paragraphs, which are numbered to correspond with Section 7.1.2, discuss differences in the NUHOMS-24P and NUHOMS-32P designs which affect the shielding design considerations.

1-7. Same as Section 7.1.2.

8. Section 7.1.2 states that the cavity of the NUHOMS-24P DSC will be submerged in the spent fuel pool for about 12 hours and, on removal from the pool, will contain borated water from the spent fuel pool for less than 50 hours. Because of the larger number of fuel assemblies (32 opposed to 24) to be stored in the NUHOMS-32P DSC, it is expected that the DSC will be submerged in the pool for a longer

period of time than the NUHOMS-24P DSC. This additional submersion time does not affect the performance of the austenitic stainless steel as discussed in Section 7.1.2. The NUHOMS-32P DSC also contains aluminum plates (borated and un-borated). There is a substantial body of industry experience with exposure of aluminum to borated and unborated water and its performance is not affected by the pool conditions.

9-15. Same as Section 7.1.2.

12.7.1.3 Operational Considerations

The discussion in Section 7.1.3 is unchanged and equally applicable to the NUHOMS-32P DSC.

12.7.2 RADIATION SOURCES – NUHOMS-32P

12.7.2.1 Characterization of Sources

The neutron and gamma source-terms used to analyze the NUHOMS-32P DSC are based on the following spent fuel assembly:

1. The bounding neutron source was based on the spent fuel assembly with an initial enrichment of 3.4% U^{235}, a 52,000 MWD/MTU discharge burnup, and a cooling time of 16 years;

2. The bounding gamma source was based on the spent fuel assembly with an enrichment of 4.3% U^{235}, a burnup of 40,000 MWD/MTU, and a cooling time of 7 years.

The design basis neutron source per fuel assembly that is used to calculate dose rates from the NUHOMS-32P DSC is increased from 2.23E+08 n/sec/assy to 4.175E+08 n/sec/assy. This increase accounts for the fact that some Calvert Cliffs spent fuel assemblies with a thermal output $\leq$ 660 watts have a neutron source $\geq$ 2.23E+08 n/sec/assy. This NUHOMS-32P DSC design basis source, 4.175E+08 n/sec/assy, bounds all assemblies that have an initial U^{235} enrichment $\leq$ 4.5%, burnup $\leq$ 52,000 MWD/MTU, and a thermal output $\leq$ 660 W. The neutron source-term is further increased by a factor 1.107 to account for axial peaking.

The design basis gamma source per fuel assembly for the NUHOMS-32P DSC is 1.61E+15 Mev/sec/assembly that is slightly higher than the source used for the NUHOMS-24P DSC that is 1.53E+15 Mev/sec/assembly.

The neutron and gamma source spectra calculated using the SAS2H sequence of the SCALE 4.4 computer code (Reference 12.63) are provided in Table 3.1.4. SAS2H is a control module that implements an analytic sequence of which the functional modules are BONAMI-S, NITAWL-II, XSDRNPM-S, COUPLE, and ORIGEN-S. ORIGEN-S, which is essentially an updated version of ORIGEN2.1, performs point depletion calculations to provide updated isotopic concentrations. Following the SAS2H depletion, a decay-only ORIGEN-S run is utilized to obtain the thermal and radiological assembly source terms and spectra in the desired

energy group structure at 60 different times following shutdown. The SAS2H/ORIGEN-S code system was verified, validated and used in accordance with the CCNPP software qualification program.

The addition of stainless steel rods to the fuel assembly increases Co-60 activity due to impurities resulting in a harder spectrum and the need for extended cooling times. Details of the changed gamma source are presented in Reference 12.58. The additional loading criteria for assemblies with irradiated stainless steel replacement rods are presented in Table 9.4-3.

The ORIGEN-ARP sequence of the SCALE 6.0 code system (Reference 12.76) may also be used in place of the SAS2H sequence of SCALE 4.4 for NUHOMS-32P DSC fuel characterization. ORIGEN-ARP (Automatic Rapid Processing) uses an algorithm that allows the generation of cross-section libraries for the ORIGEN-S code by interpolation over cross-section libraries pre-generated by the SAS2H or TRITON sequences of SCALE. To ensure that the level of conservatism is essentially the same or greater than that of the SAS2H sequence of SCALE 4.4, the calculated minimum cooling times to reach the NUHOMS-32P design basis neutron, gamma, and thermal source terms must be biased upwards by 3.1% when using SCALE 6 ORIGEN-ARP with the included CE 14x14 cross-section libraries (Reference 12.75).

12.7.2.2 Airborne Radioactive Material Sources

The discussion in Section 7.2.2 is unchanged and equally applicable to the NUHOMS-24P DSC and NUHOMS-32P DSC.

12.7.3 RADIATION PROTECTION DESIGN FEATURES – NUHOMS-32P

12.7.3.1 Installation Design Features

The discussion in Section 7.3.1 is applicable to the NUHOMS-32P DSC.

12.7.3.2 Shielding

The shielding analyses that support the NUHOMS-32P DSC are identical in form and methodology to the design basis analyses that support the NUHOMS-24P DSC. The methodology and model are described in detail in References 12.29 through 12.33. A comparison to actual NUHOMS-24P DSC data demonstrates that the methodology and model are conservative (Reference 12.33).

The results of the shielding analyses are presented in Table 12.7-1. In most cases, the calculated dose rates outside the NUHOMS-32P DSC are higher than the NUHOMS-24P DSC due to eight additional spent fuel assemblies and increased neutron source-term. The shielding provided by the NUHOMS-32P basket assembly helps to compensate for the increased radiation from the additional fuel assemblies.

12.7.3.3 Ventilation

The discussion in Section 7.3.3 is applicable to the NUHOMS-32P DSC.

12.7.3.4 Area Radiation and Airborne Radioactivity Monitoring Instrumentation

The discussion in Section 7.3.4 is applicable to the NUHOMS-32P DSC.

12.7.4 ESTIMATED ON-SITE COLLECTIVE DOSE ASSESSMENT

12.7.4.1 Operational Exposure

The discussion of Section 7.4.1 is applicable to NUHOMS-32P DSC.

12.7.4.2 Storage Term Exposure

The discussion of Section 7.4.2 is applicable to NUHOMS-32P DSC.

12.7.5 HEALTH PHYSICS PROGRAM

The discussion in Section 7.5 is unchanged and equally applicable to the NUHOMS-24P DSC and NUHOMS-32P DSC.

12.7.6 ESTIMATED OFF-SITE COLLECTIVE DOSE ASSESSMENT

12.7.6.1 Effluent and Environmental Monitoring Program

The discussion in Section 7.6.1 is applicable to the NUHOMS-32P DSC.

12.7.6.2 Analysis of Multiple Contribution

The discussion in Section 7.6.2 is applicable to the NUHOMS-32P DSC.

12.7.6.3 Estimated Dose Equivalents

The discussion in Section 7.6.3 is applicable to the NUHOMS-32P DSC.

12.7.6.4 Liquid Release

The discussion in Section 7.6.4 is applicable to the NUHOMS-32P DSC.

TABLE 12.7-1
NUHOMS-32P SHIELDING ANALYSIS RESULTS - NOMINAL DOSE RATES (mrem/hr)

LOCATION	NEUTRON[c]	GAMMA[c] (PRI + SEC)	TOTAL[c]
NUHOMS-32P DSC in HSM			
1. HSM Wall or Roof	0.5	13	13.5
2. HSM Air Outlet	1.3	74.1	75.4
3. Center of Door	5.9	8	13.9
4. Doorway (Maximum, 1 ft. into opening)	1247	3412	4659
5. Air Inlet Vent	1	60	61
6. 1m from HSM Door	3	5.9	8.9
NUHOMS-32P DSC in HSM-HB			
1. HSM Wall or Roof	0.7	4.7	5.4
2. HSM Air Outlet	6.2	41.9	48.1
3. Center of Door	0.2	0.4	0.6
4. Doorway (Maximum, 1 ft. into opening)	668	3206	3874
5. Air Inlet Vent	3.7	85.2	88.9
6. 1m from HSM Door	0.2	0.5	0.7
NUHOMS-32P DSC in Cask			
1. Centerline DSC Shield Plug (Flooded DSC) [a]	1.4	178.2	180
2. DSC Cover Plate (Dry DSC)			
2.1 Center	58	148	206
2.2A Edge[b] (Wet Gap)	112	114	226
2.2B Edge[b] (Dry Gap)	158	192	350
3. Transfer Cask			
3.1 Side	90	74	164
3.2 Top	8	4.8	12.8
3.3 Bottom	110	105	215

[a] The DSC/cask annular gap is filled with water. All but the top 6" of the DSC inner cavity is filled with water.

[b] Nominal at edge of cover plate. The total dose rate is approximately a factor of 3 lower at the top edge of the transfer cask, and several times higher inside the dry annulus.

[c] From References 12.29, 12.30, and 12.31.

12.8 ACCIDENT ANALYSIS – NUHOMS-32P

Analyses of all design events for the NUHOMS-24P DSC have been reanalyzed for the NUHOMS-32P DSC. The results are reported in this section in the same format as in Chapter 8. The analytical assumptions, methodology, and computer codes used to generate the results in this section are identical to those used in Chapter 8 unless otherwise noted in the text.

12.8.1 NORMAL AND OFF-NORMAL OPERATIONS

This section follows the format of Section 8.1 and includes the evaluation of the normal and off-normal events for the NUHOMS-32P DSC.

12.8.1.1 Normal Operation Structural Analysis

The normal operating loads for the NUHOMS-32P important to safety components are shown in Table 8.1-1 of Reference 12.21. A comprehensive structural analysis of the NUHOMS-32P DSC was performed and documented in Reference 12.22.

12.8.1.1.1 Normal Operation Structural Analysis

The loads applicable to the normal operation structural analysis such as the dead weight load, internal pressure load, thermal load, handling loads, and live loads are calculated on the same bases as described in detail in Section 8.1.1.1.

12.8.1.1.2 DSC Analysis

Stresses were evaluated in the DSC due to:

A. Dead Weight Loads
B. Design Basis Normal Operating Internal Pressure Loads
C. Normal Operating Thermal Loads
D. Normal Operation Handling Loads

The NUHOMS-32P DSC is analyzed using analytical methods comparable to those described for the NUHOMS-24P DSC in Section 8.1.1.2. The ANSYS analytical model used for the analysis of dead weight, pressure, thermal, and handling loads is similar to that used in the evaluation of the NUHOMS-24P DSC, modified as necessary to reflect the NUHOMS-32P shell assembly. The ANSYS analysis model is described in Reference 12.22. Stresses due to normal operating pressures are based on a bounding internal pressure of 30 psig, applied as a uniform load to the inner boundary of the analytical model. Also considered was the external hydrostatic pressure loading on the DSC shell, when the 3/8" annulus between the DSC shell and the transfer cask is filled with water. Circumferential shell temperature variations are analyzed using the ANSYS three-dimensional solid shell model. The NUHOMS-32P DSC stresses remain within ASME code allowable stresses (Reference 12.24).

12.8.1.1.3 DSC Internal Basket Analysis

The DSC basket analysis was performed for:

A. Dead Weight Loads
B. Thermal Loads

The fuel assembly weight of 1,450 lbs (Reference 12.34) and 158" length (Reference 12.28) are used in the analysis. The basket temperature is taken as 650°F uniform. The peripheral rail temperature is taken as 500°F uniform.

The three-dimensional finite element analysis ANSYS model used in the evaluation is described in Reference 12.28. The analysis model consists of a 10.28" slice of the NUHOMS-32P DSC basket, rails, and canister using SHELL 43 elements, with appropriate boundary conditions applied at the cut faces of the model. The fuel assembly and aluminum plates are not included in the analysis model. The fuel assembly weight is applied as pressure on the basket plates. The weight of the aluminum plates is accounted for by increasing the density of stainless steel tubes. The aluminum plate stiffness is conservatively neglected in the analysis. The fusion welds connecting the fuels compartment guide sleeves and the bolts connecting the rails are modeled by three-dimensional PIPE20 elements. Gap elements (CONTACT 52) are used to simulate the interface between the basket rails and inner side of canister as well as between outer side of canister and inside of transfer cask.

The results of the analysis show that the stresses in the DSC are within the allowable stress limits (Reference 12.27).

12.8.1.1.4 DSC Support Assembly Analysis

The Calvert Cliffs HSM DSC support assembly components are the same as described in Section 8.1.1.4.

The HSM DSC support assembly was reevaluated for the following loads by scaling the results of the NUHOMS-24P DSC evaluation to reflect the weight increase of the NUHOMS-32P DSC. The allowable stresses are taken at a bounding temperature of 600°F for all conditions, including normal operation (Reference 12.23).

A. Dead Weight Loads
B. Normal Operational Handling Loads
C. Thermal Loads

The calculated stresses were small, and the vertical deflections under the transfer cask loading were less than 0.1".

The HSM-HB support structure consists of two rail assemblies, each at 30 degrees from the vertical center line of the DSC. Two cross members connect the two rail assemblies by two gusset plates welded to the rail web and the flanges. The steel support structure supports the DSC stored inside the module. Each rail assembly of the DSC support structure consists of the following components:

1. A 12x96 Rail Section 187" long made up of ASTM A992 material.
2. A 1" thick slotted plate made up of A572 Grade 50 material.
3. A 3/16" thick support plate made up of nitronic 60 (RC 29-35) material which provides a smooth support for the DSC to slide.
4. A rail extension flange which consists of 1" thick flange plate (A572, Grade 50 material), and 3/16" thick rail support extension plate (nitronic 60 material).

The rail extension flange is attached to a 1" thick embedded base plate (A36 material) by two 1-1/2" bolts. For all normal operating conditions the DSC support steel temperature is assumed to be 300°F (556°F for accident blocked vent condition).

The HSM-HB DSC support was evaluated for the same types of loads as listed for the HSM above. The calculated stresses were small and meet all code allowables. (Reference 12.72)

12.8.1.1.5 HSM/HSM-HB Analysis

The same HSM array size (2x6) used in Section 8.1.1.5 was used for the NUHOMS-32P DSC. The HSM-HB arrangement used is that of two 1x12 back-to-back arrays. A DSC mass enveloping that of the NUHOMS-32P DSC is used for HSM-HB. The following loads are considered in the structural analysis for normal operation loads.

A. HSM/HSM-HB Dead and Live Loads

The dead and live loads were evaluated using the ANSYS methodology as discussed in Reference 12.23 (HSM) and Reference 12.72 (HSM-HB) for the NUHOMS-32P DSC.

B. Concrete Creep and Shrinkage Loads

Loads due to creep and shrinkage of the concrete are determined by the same methodology described in Section 8.1.1.5.B.

C. HSM Thermal Loads

The thermal loads, temperature-dependent material properties, analysis approach, and analysis results are documented in Reference 12.23 (HSM) and Reference 12.73 (HSM-HB).

Conservatively, an enveloping design temperature of 400°F is used for all conditions for HSM, including normal operation (Reference 12.23).

D. Radiation Effect on HSM Concrete

The effects of radiation on the HSM concrete were determined to be negligible for the NUHOMS-24P DSC in Section 8.1.1.5.D. The effect of radiation on the HSM/HSM-HB concrete remains negligible for the NUHOMS-32P DSC. The neutron fluence from the NUHOMS-32P DSC remains below the threshold for neutron induced degradation of concrete and the gamma flux is less than the NUHOMS-24P DSC value.

E. HSM/HSM-HB Design Analysis

Structural re-evaluation of the concrete structure, DSC support structure, and miscellaneous components for the effects of the increased weight and thermal load of the NUHOMS-32P DSC are documented in Reference 12.23 (HSM) and Reference 12.72 (HSM-HB).

For the HSM the effects of the weight increase are addressed either by scaling the existing stress results of the NUHOMS-24P DSC analyses or by reanalysis of the affected components.

The thermal load evaluation of the HSM concrete structure is performed with the ANSYS computer program using a representative 2-D analytical model of the HSM.

The thermal load evaluation of the HSM-HB concrete structure is performed with the ANSYS computer program using a half-symmetric 3-D finite element model of the HSM-HB containing the NUHOMS-32P DSC.

The results of the evaluation confirm that the normal operation moment and shear in the HSM concrete structure are less than the ultimate moment and shear capacity shown in Table 8.1-8 of Chapter 8.

12.8.1.1.6 HSM Door Analysis

The discussion in Section 8.1.1.6 is applicable to the NUHOMS-32P DSC.

The HSM-HB front shield door is a composite door, which consists of a rectangular steel face plate at the front attached to a circular reinforced concrete block at the rear. The circular concrete block is inset into the HSM-HB doorway and the rectangular steel face plate of the door is attached to the front wall concrete using four bolts anchored through four embedments.

The shield door is free to grow in the radial direction when subjected to thermal loads. Therefore, there will be no stresses in the door due to thermal growth. The dead weight, tornado wind, differential pressure, and flood loads cause insignificant stresses in the door compared to stresses due to missile impact load. Therefore, the door is evaluated only for the missile impact load. The computed maximum ductility ratio for the door is less than 1 (compared to the allowable ductility of 20) (Reference 12.72, Section 10.2.5 Part A).

For the door anchorage, the controlling load is tornado generated differential pressure drop load. The maximum tensile force per bolt (there are four bolts that attach the door assembly to the front concrete wall of the HSM-HB) is 4.5 kips. This is less than the allowable load per bolt of 44.3 kips (Reference 12.72, Section C6.2). The concrete pull-out strength is conservatively estimated as 24 kips which is greater than the ultimate capacity of the four bolts, thus satisfying the ductility requirements of the ACI Code.

12.8.1.1.7 Heat Shield Analysis

The discussion in Section 8.1.1.7 is applicable to the NUHOMS-32P DSC in the HSM. Similar to the HSM, the HSM-HB provides flat stain less steel heat shields on the side walls of the base unit and under the roof.

The HSM-HB top heat shield consists of two heat shield panels. Each panel has a 12 gauge 304 stainless steel sheet which is 0.1054" thick. Both the panels of the roof heat shield are suspended from the roof by fifteen rods of ½" diameter ASTM A193, Grade B7 in three rows, bolted to the sheets. The combined axial and bending stress in the rods is 59.5 ksi. The allowable stress is 70.2 ksi (Reference 12.72, B5.1). The HSM-HB side heat shield consists of four 12 gauge 304 stainless steel supported off the base unit side wall by thirty four rod stand-offs threaded into concrete embedments. The maximum axial and bending stress in the rods is about 1.4 ksi and 79.3 ksi, respectively. The axial and bending stress allowable for the rods is 67.9 ksi and 112.3 ksi, respectively

(Reference 12.72, B5.2). The maximum temperature used in the stress analysis of the heat shields is 270°F (Reference 12.72, B3.1), which bounds the temperatures determined for storage of the NUHOMS-32P DSC for normal and off-normal conditions (Reference 12.73).

12.8.1.1.8 HSM/HSM-HB Seismic Restraint for DSC

The HSM seismic restraint is described in Section 8.1.1.8. The HSM-HB seismic restraint consists of a tube steel embedment located within the bottom center of the round access opening of the HSM-HB, and a tube steel retainer assembly that drops into the embedment cavity after the NUHOMS-32P DSC transfer is complete. The drop-in retainer extends approximately 4 inches above the rail to provide axial restraint of the NUHOMS-32P DSC. Details of the analysis of the Calvert Cliffs DSC seismic restraint is provided in Reference 12.23 (HSM) and Reference 12.72 (HSM-HB).

12.8.1.1.9 Transfer Cask Analysis

The same transfer cask is used to transport the NUHOMS-24P and NUHOMS-32P DSCs and was re-evaluated for the same normal operation loads identified in Section 8.1.1.9, but considering the increased weight of the NUHOMS-32P DSC payload. A bounding design temperature of 400°F is used for both normal and off-normal operating conditions.

Re-evaluation of the transfer cask for the increased weight of the NUHOMS-32P DSC payload, based on the stress results of the ANSYS analyses of the transfer cask, is presented in Reference 12.25.

The resulting maximum dead weight, thermal, and handling stresses in the transfer cask and its components are within the allowable stress limits.

12.8.1.2 Off-Normal Load Structural Analysis

The off-normal loads for the NUHOMS-32P DSC are the same as those identified in Section 8.1.2.

12.8.1.2.1 Jammed DSC During Transfer

This off-normal condition results from the DSC becoming jammed in the transfer cask or the HSM/HSM-HB during the transfer operation.

A. Postulated Cause of Jammed DSC

The discussion in Section 8.1.2.1.A is applicable to the NUHOMS-32P DSC.

B. Detection of Jammed NUHOMS-32P DSC

The discussion in Section 8.1.2.1.B is applicable to the NUHOMS-32P DSC.

C. Analysis of Effects and Consequences

The analyses of the NUHOMS-32P DSC under the assumed jamming and binding conditions are documented in Reference 12.22.

The stresses on the NUHOMS-32P DSC body have been analyzed for a maximum ram force of 95,000 lbf. The calculated stresses were much less than the ASME code allowable stress criteria. Therefore, plastic deformation of the NUHOMS-32P DSC body will not occur and there is no potential for rupture.

D. Corrective Actions

The courses of action open to the system operators to correct a jammed NUHOMS-32P DSC are described in Section 8.1.2.1.D.

12.8.1.2.2 Off-Normal Thermal Loads Analysis

Structural analyses of the ISFSI components for off-normal thermal loads are discussed below using the same temperature extremes of -3°F and 103°F as the NUHOMS-24P design.

A. HSM/HSM-HB Off-Normal Thermal Analysis

The methodology used for the off-normal thermal loads structural analysis of the HSM/HSM-HB concrete structure storing the loaded NUHOMS-32P DSC is the same as for the normal thermal loads structural analysis of the structure described in Section 12.8.1.1.5.C. The DSC support assembly is designed with slotted holes as described in Section 8.1.2.2.A and, therefore, the increase in temperature has no effect on the DSC support structure.

B. DSC Off-Normal Thermal Analysis

Off-normal thermal loads structural analysis of the NUHOMS-32P DSC shell assembly and the DSC fuel basket assembly for the DSC inside the HSM/ HSM-HB are performed using the same methodology as for the normal thermal loads structural analyses of these components.

As discussed in Section 12.8.1.1.9, the off-normal thermal loads for the transfer cask are identical to the normal thermal loads. Therefore, the off-normal thermal loads for the DSC inside the transfer cask are identical to the normal thermal loads for the DSC inside the transfer cask, and are not considered further.

C. Transfer Cask Off-Normal Thermal Analysis

As previously stated, the off-normal thermal loads for the transfer cask are identical to the normal thermal loads. Therefore, the off-normal thermal loads for the transfer cask are not considered further.

12.8.1.3 Thermal Hydraulic Analyses

The following evaluations have been performed for the Calvert Cliffs ISFSI:

A. Thermal Analysis of the HSM
B. Thermal Analysis of the DSC in the HSM
C. Thermal Analysis of the DSC in the Transfer Cask

The analytical models of the HSM, the NUHOMS-32P DSC, and the transfer cask are described in References 12.11 (HSM), Reference 12.12 (DSC in the HSM), and 12.10 (DSC in the transfer cask). The analytical models of the NUHOMS-32P DSC in the HSM-HB are described in References 12.73 and 12.74.

The method described in References 12.13 and 12.18 is used for calculating the effective thermal conductivity of the spent fuel assemblies.

The primary portion of the thermal evaluation of the NUHOMS-32P design uses a methodology that differs from the thermal analysis methodology utilized for the NUHOMS-24P. The NUHOMS-32P thermal methodology has three major new features:

- Solution Method – ANSYS finite element
- Model Geometry – 3D
- Treatment of Effective Transverse Thermal Conductivity of Fuel – A detailed finite element model of the spent fuel according to method of the TRW Spent Nuclear Fuel Effective Conductivity Report (Reference 12.14)

The new methodology for the NUHOMS-32P DSC in the HSM and transfer cask has been compared in detail with the methodology used for the thermal analysis of the Transnuclear NUHOMS-32PT design (Reference 12.54). The use of the NUHOMS-32PT methodology is appropriate for the Calvert Cliffs ISFSI with the NUHOMS-32P DSC per Reference 12.55.

The radial effective thermal conductivity for helium backfill conditions is determined by creating a two-dimensional finite element ANSYS model of the fuel assembly centered within a basket compartment. The outer surfaces, representing the fuel compartment walls, are held at a constant

temperature, and decay heat is applied to the fuel pellets within the model. A maximum fuel assembly temperature is then determined. From the heat load, maximum fuel temperature, and outer surface temperature, the effective fuel conductivity can be determined via an equation given in Reference 12.14.

The axial effective conductivity (K_{axl}) is determined directly from the geometry and conductivities of the fuel components.

Mass-weighted averages are used in the determination of the effective density (ρ_{eff}) and specific heat values ($C_{p,eff}$).

The effective properties of the fuel are shown in Reference 12.13.

The HSM-HB with NUHOMS-32P DSC thermal analyses are performed using methods, assumptions, and conservatism identical to those for the NUHOMS-24PTH DSC design in the HSM-H (Reference 12.77). The use of the NUHOMS-24PTH/HSM-H methodology is appropriate for the Calvert Cliffs ISFSI with the NUHOMS-32P/HSM-HB per Reference 12.78.

The thermal analyses are performed with the following ambient air temperatures:

A. Normal Conditions

The discussion in Section 8.1.3.A is applicable to the NUHOMS-32P DSC.

B. Off-Normal Condition

The discussion in Section 8.1.3.B is applicable to the NUHOMS-32P DSC.

C. Accident Condition

An extreme summer condition with an ambient temperature of 103°F was considered in Reference 12.2. In addition, the HSM vents are assumed to be completely blocked for a period of 36 hours or less. A solar heat flux of 127 Btu/hr-ft^2 is conservatively included to maximize the HSM concrete temperatures.

No thermal accident conditions are considered for the transfer cask.

12.8.1.3.1 Thermal Analysis of the HSM

The HSM/HSM-HB thermal analyses are performed for the ambient air temperatures defined in Section 12.8.1.3.

The decay heat load is transferred from the DSC to the HSM/HSM-HB air space by convection and then is removed from the HSM/HSM-HB by natural convection air flow. Heat is also radiated from the DSC surface to the heat shield and HSM/HSM-HB walls where the natural convection air flow and conduction through the walls removes the heat. The solar

heat flux is applied only to the HSM/HSM-HB roof. Heat transfer from the outer surface of the HSM/HSM-HB roof is by natural convection and radiation to the ambient air. Heat transfer from the HSM/HSM-HB floor slab is by conduction to the soil below.

Maximum temperatures on the DSC outer surfaces and the concrete inner and outer surfaces are calculated for the normal, off-normal winter, and off-normal summer ambient conditions, and the postulated accident conditions with blocked HSM/HSM-HB vents.

12.8.1.3.2 Thermal Analysis of the DSC in the HSM

The DSC and fuel assembly heat transfer analysis with the DSC inside the HSM/HSM-HB was performed for the ambient air temperatures defined in Section 12.8.1.3. The analytical model is described in Reference 12.12 for HSM and Reference 12.73 for HSM-HB. The cases of interest are those that maximize fuel cladding temperature (summer ambient conditions) as described in References 12.1 and 12.2. Reference 12.9 evaluates the impact of aluminum/poison material plates in the DSC basket assembly on the maximum component temperatures. In the analysis, an effective conductivity is determined for the aluminum/poison plates and is substituted for that of the all aluminum interior basket plates in the model from Reference 12.12. The modified model is run for normal, off-normal, and blocked vent conditions. The analysis shows that the modified plates have a negligible impact on maximum component temperatures. The temperatures from these cases are used to derive the DSC internal pressures in Reference 12.17.

Reference 12.79 demonstrates that the effective thermal conductivity of a metal matrix composite poison plate paired with an aluminum plate also meets or exceeds the effective thermal conductivity of the basket in the design basis model.

The maximum allowable cladding temperature for long-term storage is 335°C as discussed in Section 8.1.3.2.

The acceptable peak clad temperature limit for accident conditions for ISFSI storage is the same as the generic NUHOMS-24P DSC design (Reference 8.26). This limit is based on the empirical work presented in Reference 8.27. The peak fuel clad temperature limit (short-term) of 570°C (1,058°F) is specified in the off-normal DSC thermal calculation (Reference 12.1 for HSM and Reference 12.73 for HSM-HB).

12.8.1.3.3 Thermal Analysis of the DSC in the Transfer Cask

The thermal analyses for the cases with the DSC inside the transfer cask are performed for the ambient air temperatures defined in Section 12.8.1.3. The analyses are conducted using the model described in Reference 12.12.

Maximum fuel cladding and DSC shell temperatures are calculated for the normal ambient temperature of 70°F, abnormal summer ambient temperature of 103°F and the postulated accident conditions with blocked HSM vents.

In the models presented in Reference 12.10, the gap size between the inner shell of the transfer cask and the outer shell of the DSC is assumed uniform in all directions. Reference 12.19 performs a sensitivity analysis of gap symmetry between the DSC and transfer cask. In addition, Reference 12.20 investigates the sensitivity of maximum temperatures to axial gap size. For the asymmetries and gap sizes investigated, there is little impact on the maximum component temperatures.

Reference 12.3 evaluates the impact of aluminum/poison material plates in the basket on the maximum component temperatures. In the analysis, an effective conductivity is determined for the aluminum/poison plates and is substituted for that of the all aluminum interior basket plates in the models from References 12.15 and 12.16. The analysis shows that the modified plates have a negligible impact on maximum component temperatures.

This also remains true for paired aluminum/metal matrix composite poison plates (Reference 12.79).

Use of NS-3 for the transfer cask neutron shield is discussed in Section 8.1.3.3.

12.8.2 ACCIDENTS

This section addresses design events of the third and fourth types as defined by ANSI/American Nuclear Society 57.9-1984 (Reference 8.2), and other credible accidents consistent with 10 CFR Part 72 which could impact the safe operation of the Calvert Cliffs ISFSI. The postulated events identified in Section 8.2 of Reference 8.1 and addressed therein for the Calvert Cliffs ISFSI are:

A. Loss of Air Outlet Shielding
B. Tornado Winds/Tornado Missile
C. Earthquake
D. Flood
E. Transfer Cask Drop
F. Lightning
G. Blockage of Air Inlets and Outlets

H. DSC Leakage
I. Accidental Pressurization of DSC

In addition, two additional Calvert Cliffs site-specific accidents have been identified and addressed. These are:

A. Forest Fire
B. Liquified Natural Gas Plant or Pipeline Spill or Explosion

The accidents considered, and the associated components affected by each accident, are summarized in Chapter 8, Table 8.2-1.

In the following sections, each accident condition is evaluated for applicability to the Calvert Cliffs ISFSI. For each applicable condition the accident cause, structural, thermal, radiological consequences, and recovery measures required to mitigate the accident are discussed. Where appropriate, resulting accident condition stresses were combined with those of normal operating loads in accordance with the load combination definitions of Section 12.3.2.5. Load combination results for the HSM/HSM-HB, NUHOMS-32P DSC, and transfer cask are discussed in Section 12.8.2.12.

Reflood pressure is included as an ASME Service Level D activity but is not identified as an accident.

12.8.2.1 Loss of Air Outlet Shielding

The discussion provided in Section 8.2.1 is applicable to NUHOMS-32P DSC in the HSM. As with the HSM, this accident is also not credible for the HSM-HB. The air outlet vent concrete covers of the HSM-HB are also designed to remain in place and withstand all design events including the effects of tornado missiles (Reference 12.72, Section 12.3).

12.8.2.2 Tornado Winds/Tornado Missile

The discussion provided in Section 8.2.2 is applicable to NUHOMS-32P DSC. Structural analysis of the HSM-HB concrete structure, DSC supports, and miscellaneous structural steel components of the HSM-HB also confirm integrity when subjected to tornado winds and missiles (Reference 12.72).

12.8.2.3 Earthquake

12.8.2.3.1 Cause of Accident

As specified in Section 3.2.3, a Design Basis Earthquake with peak ground acceleration values of 0.15g horizontal and 0.10g vertical is postulated to occur at the Calvert Cliffs ISFSI.

12.8.2.3.2 Accident Analysis

Earthquake loads for the evaluation of the HSM concrete structure, DSC support assembly in the HSM, and the transfer cask are determined by scaling the results of the NUHOMS-24P DSC seismic analysis reflecting the weight increase (References 12.23 and 12.25).

The methodology used for structural evaluation of the HSM-HB is identical to the methodology used for the evaluation of HSM-H for 24PTH DSC, 61BTH DSC, and 32PTH1 DSC in CoC 1004 and 32PTH DSC in CoC 1030 (References 12.77 and 12.80). A bounding calculation assuming a DSC weight of 110,000 lbs is used in this analysis. In addition, the analysis performed for the HSM-HB uses seismic accelerations of 0.3g horizontally and 0.2g vertically, with a 7% critical damping factor, which are twice the Calvert Cliffs ISFSI design basis seismic requirement. The use of this methodology is appropriate for the Calvert Cliffs ISFSI with the NUHOMS-32P DSC in the HSM-HB per Reference 12.78.

The NUHOMS-32P DSC and the DSC basket assembly earthquake loads were determined by a computer analysis (Reference 12.22).

A. DSC Seismic Analysis

1. DSC Seismic Analysis

Inside the HSM the combined earthquake load of 1.5g transverse, 1.5g axial, and 1.0g vertical is applied to the finite element model depicting the horizontal orientation of the DSC in storage. In addition to the seismic loads, 1.0g vertical acceleration is added to account for the self-weight effects.

A three-dimensional finite element model of the basket, rails, and the DSC canister was constructed by using the ANSYS computer program. Since the seismic loading is non-symmetric, a 360° model is used. Details of the analysis model and boundary conditions used are described in Reference 12.28. The finite element model used in the seismic analysis is shown in Reference 12.22.

A nonlinear stress analysis is conducted for computing the elastic stresses in basket and canister shell models using ANSYS computer program. The nonlinearity of analysis results from the gap elements used in the analysis model. Details of the analysis are documented in Reference 12.22 for the DSC canister and Reference 12.28 for the DSC basket assembly.

The resulting maximum stresses in the DSC canister and in the DSC basket assembly

remain within the specified ASME code allowable stress criteria.

2. DSC Seismic Stability Analysis

An evaluation for the potential of the NUHOMS-32P DSC to lift-off from the DSC support assembly rail during a seismic event is documented in Reference 12.22. The seismic loadings applied to the DSC that would cause instability are based on conservative rigid range seismic acceleration inputs to the HSM of 0.25g horizontal in both transverse and longitudinal directions, and 0.17g vertical. The stability analysis is based on showing that the overturning moment of the DSC on the HSM support structure is smaller than the restoring force moment due to gravity. The non-rigid body modes of the DSC do not contribute to overturning so that the use of the rigid body accelerations is appropriate.

The resultant horizontal acceleration used to calculate the overturning moment is based on the square root of sum of the square of 0.25g in both the transverse and longitudinal directions, equal to 0.35g. The vertical acceleration used to calculate the minimum restoring force is gravity less the vertical acceleration. The restoring moment is determined to be 1.37 times greater than the overturning moment (Reference 12.22). Therefore, the DSC canister is stable during a seismic accident.

Reference 12.72 (Section 5.9) demonstrates that the DSC also remains stable in the HSM-HB during a bounding seismic event. A margin of safety of 1.23 against DSC liftoff from the HSM-HB rails is determined.

B. HSM/HSM-HB Seismic Analysis

1. HSM/HSM-HB Seismic Stress Analysis

Seismic evaluation of the HSM concrete structure is performed using the same methodology as described in Section 8.2.3.2.B.1 for the NUHOMS-24P DSC, with scaled seismic forces applied to the STRUDL finite element analysis model to reflect the weight increase of the NUHOMS-32P DSC.

The resulting forces and moments in the HSM/ HSM-HB are found to be within the ultimate capacity (Reference 12.23 for HSM and Reference 12.72 for HSM-HB).

2. HSM/HSM-HB Seismic Stability Evaluation

There is no change in the dimensions of the HSM. As such, the seismic stability of the HSM is not affected by storing the NUHOMS-32P DSC.

Reference 12.72 demonstrates that overturning and sliding will not occur the HSM-HB during a bounding seismic event.

C. DSC Support Assembly Seismic Analysis

The NUHOMS-32P DSC support assembly geometry for the HSM and, therefore, the DSC support structure computer analysis model is the same as for the NUHOMS-24P DSC. The earthquake loads due to the effects of the weight increase of the NUHOMS-32P DSC are evaluated by scaling the NUHOMS-24P DSC seismic analysis results.

The stress evaluation of the HSM DSC support structure components is performed by hand calculations and the results are within acceptable limits (Reference 12.23).

Stress analyses for the HSM-HB support structure using a bounding DSC weight also demonstrates results within acceptable limits for a bounding seismic event (Reference 12.72, Section 9).

D. Transfer Cask Seismic Analysis

Seismic stresses for the transfer cask with a NUHOMS-32P DSC are determined by conservatively scaling the seismic analysis results of the transfer cask - NUHOMS-24P DSC assembly to account for the increased payload of the NUHOMS-32P (Reference 12.25). This conservative method assumes the weight of the entire transfer cask-DSC system increases by the DSC weight change of 36%, instead of the more accurate 10%. This is done because some components, such as the inner liner, are loaded primarily by the DSC and thus the stresses would be underestimated using the 10% assembly weight increase. The resulting stress intensities are significantly below the ASME Level C allowable stress

limits at the transfer cask design temperature of 400°F.

Seismic stability of the transfer cask is not a function of the DSC weight and, therefore, remains unaffected by the use of the NUHOMS-32P DSC.

12.8.2.3.3 Accident Dose Consequences

Major components of the Calvert Cliffs ISFSI have been designed and evaluated to withstand the forces generated by the Design Basis Earthquake. Hence, there are no dose consequences.

12.8.2.4 Flood

As discussed in Section 3.2.2, flood loads are not applicable to the Calvert Cliffs ISFSI.

12.8.2.5 Cask Drop

This section addresses the structural integrity of the transfer cask, the NUHOMS-32P DSC, and its internals under a postulated transfer cask accident condition.

12.8.2.5.1 Cause of Accident

As discussed in Section 8.2.5.1 of Reference 12.21, an actual drop event is not considered credible. However, consistent with the criteria of Reference 12.21, it is postulated that the transfer cask with the DSC inside will be subjected to an end, side, or oblique drop with a maximum height of 80" onto a thick concrete slab. A drop of greater than 80" is not considered because (a) transfer inside the Auxiliary Building will be performed using a single-failure-proof crane and (b) the transfer trailer and haul road are designed such that the transfer cask cannot be raised greater than 80" from the ground.

The transfer cask is transported along an asphalt or concrete paved road which is 16' wide and has 7 to 8’ shoulders. The road is approximately 3,300 linear feet with slopes which range from 0% to 3% except for an approximate 50’ length which carries a 5.7% slope. The roadbed is level except for a negligible 1% slope required to create a crown in the road for drainage and a transverse slope at any point along the transportation route of less than 10%. The shoulders are either level with the road or slope up from the road. In those locations where the paved road abuts up to existing blacktop, or concrete paving, the shoulder is discontinued. The shoulder may be paved, gravel, or soil and contain typical roadside fixtures, including curbs, fences, guard rails, and light poles which do not constitute potential puncture devices for the cask during a drop. The shoulders do not contain

items such as light pole pedestals which protrude above the shoulder surface and could represent a potential cask puncture device during a cask drop. For the entire route that the transfer cask is transported there will exist a minimum 8' wide zone that is at or above the roadbed elevation.

The transfer trailer braking system is not operable independent of the prime mover. However, failure of the prime mover will cause the trailer braking system to fail-safe, that is "lock tight."

12.8.2.5.2 Accident Analysis

The drop height (80"), drop orientations, the properties of the target concrete surface, and the methodology used for the evaluation of the transfer with the NUHOMS-32P DSC as payload are the same as described in Section 8.2.5.2.

The design basis cask drop decelerations are specified in Table 12.3-5.

NUHOMS-32P DSC

Four accidental drop orientations are postulated for analysis.

A. Top end vertical drop
B. Bottom end vertical drop
C. Horizontal side drop
D. Corner Drop

A. Top End Vertical Drop

A 360° three-dimensional finite element model of the basket, rails, and the NUHOMS-32P DSC was constructed with the ANSYS computer program. Gap elements are used to simulate the interface between the basket rails and inner side of the canister. Details of the analysis model and boundary conditions used are described in Reference 12.22.

Two loadings are applied to the top end drop case:

1. 75g drop load only.
2. 75g drop load with accident pressure (100 psig).

The weight of the basket and fuel assemblies is idealized as an equivalent pressure load against the inner cover plate of the top shield plug. The effect of the combined basket and fuel weight at a maximum 75g acceleration is simulated by equivalent pressure. The effect of the self-weight of the NUHOMS-32P DSC shell assembly at 75g is also applied to the analysis model.

The resulting maximum stress intensities for the "75g drop only" load case and for the "75g drop with accident pressure" show that the case without internal pressure is the bounding analysis.

The maximum stress intensity for the "75g drop only" load case is located in the bottom shield plug side casing. Since these maximum stress intensities are due to the moments at the junction of the respective plates and casings which resist the bending of the flat plates, these are classified as Q stresses in accordance with Note (2) of Table 3217-1 131 of the ASME Code (Reference 12.19) and are ignored for accident condition evaluation.

B. Bottom End Vertical Drop

The DSC shell assembly is analyzed for the bottom end vertical drop using the same three-dimensional ANSYS model described above and the same two loadings. The annular area on the bottom end of the model is fixed in the axial direction. This is the area on the bottom lead liner, which contacts the transfer cask.

As in the Top End Vertical Drop analysis, the case without internal pressure governs.

The maximum stress intensity for the "75g drop only" load case is located in the top shield plug side casing. Since this maximum stress intensity is due to the moments at the junction of the respective plates and casings which resist the bending of the top inner cover plate, it is classified as Q stress in accordance with Note (2) of Table 3217-1 131 of the ASME Code (Reference 12.19) and is ignored for accident condition evaluation.

C. Horizontal Side Drop

A NUHOMS-24P DSC shell assembly consisting of a spacer disk and guide sleeves has been analyzed in Reference 12.49. Because the spacer disks apply a series of concentrated loads, and the NUHOMS-32P basket design will apply a distributed load, the NUHOMS-24P DSC analysis results in Reference 12.49 are conservatively scaled by a factor of 1.37 to reflect the weight increase of the NUHOMS-32P DSC. In order to account for accident pressure, the side drop stress intensities are added directly to the accident pressure stress intensities. The net stress intensities are, therefore, very conservative.

D. Corner Drop

No evaluation is required for the comer drop since the stresses are bounded by the vertical drop stresses (Reference 12.49).

Summary of Results

The maximum membrane plus bending stress enveloping all the cask drop scenarios evaluated above are below the Level D allowable stresses for the NUHOMS-32P DSC during a cask drop accident (Reference 12.22).

The maximum shear load on the fusion weld connecting the guide sleeves is 6,378 lb (Reference 12.22). The required strength of the fusion weld by testing is 16 kips, (Reference 12.41) which allows a safety factor of 2.

NUHOMS-32P DSC Basket Assembly

A. Horizontal Side Drop

The basket and canister are analyzed for two modes of side drops. Firstly, the cask is assumed to drop away from the transfer support rails. Under this condition, 0°, 45°, and 60° orientation of side drops are evaluated to bound the possible maximum stress cases. Secondly, the side drop occurs on transfer cask support rails at 180° orientation. The load resulting from the fuel assembly weight, for 1g and 75g accelerations, is applied as equivalent pressure on the plates. At 0° and 180° orientations, the pressure acts only on the horizontal plates while at other orientations, it is divided in components to act on both horizontal and vertical plates of the basket.

A nonlinear static stress analysis of the DSC basket structural assembly is conducted for computing the stresses for the 0°, 45°, 60°, and 180° drop orientations. A three-dimensional ANSYS model was used for this evaluation. The maximum load of 75g was applied in each analysis. Details of the analysis are described in Reference 12.28.

Buckling is analyzed using a nonlinear finite element analysis of the basket by applying load at the 0°, 30°, and 45° orientations relative to the basket plates. A maximum load of 150g was applied in each analysis and automatic time stepping was initiated allowing the program to determine the actual size of the load sub-step for a converged solution. The last converged solution represents the buckling load. In all orientations analyzed, the buckling load exceeded the

USAR defined minimum applied load of 75g. Details of the analysis are described in Reference 12.65.

B. Vertical End Drop

During an end drop, the fuel assemblies and fuel compartments are forced against the bottom of the canister/cask. For any vertical or near vertical loading, the fuel assemblies react directly against the bottom or top end of the canister/cask and not through the basket structure as in lateral loading. It is only the dead weight of the basket that causes axial compressive stress during an end drop. Axial compressive stresses are conservatively computed by assuming that all load acts on the fuel compartment guide sleeves during an end drop.

Summary of Results

The enveloping maximum membrane plus bending stresses in the basket assembly structural components are below the ASME Code Level D allowable stresses for the NUHOMS-32P DSC basket assembly during a transfer cask drop accident.

Transfer Cask

The evaluation of the transfer cask drop accident with a NUHOMS-32P DSC is based on the results of the drop evaluation for NUHOMS-24P DSC using the ANSYS computer model. The maximum stress intensities for individual components of the transfer cask are obtained by scaling to reflect the increased weight of the loaded NUHOMS-32P DSC, and are compared to Level D elastic allowables.

No evaluation is required for the corner drop since the stresses are bounded by the vertical drop stresses (Reference 12.50).

A. Top and Bottom End Vertical Drops

In the end drops, nearly all of the DSC load is taken by the underlying end components of the transfer cask. Therefore, the stresses in these components are increased by a scaling factor of 1.51 to reflect the ratio of the weights of the NUHOMS-32P and NUHOMS-24P DSCs. The stresses in the remaining components of the transfer cask are the same with either DSC since the transfer cask weight remains unchanged.

The structural integrity of a VAP CE 14x14 fuel assembly with Zircaloy clad fuel rods loaded in a

NUHOMS-32P DSC when subjected to an 80-inch transfer cask end drop accident was evaluated using a two part method. VAP fuel dimensions are bounding for standard fuel in an end drop. First, the transfer cask is analyzed for the end drop with a drop height of 80 inches and a dynamic finite element analysis program (LS-DYNA) is used to determine the rigid body acceleration time history of the NUHOMS-32P cask during impact on a concrete pad with subgrade soil (Reference 12.64). The model consists of the cask, the simplified DSC structure, a concrete impact pad, and the subgrade soil. Only ½ of the cask, DSC structure, concrete, and soil are modeled as the entire arrangement is symmetric about the X-Y plane. The resulting rigid body acceleration time histories are computed by LS-DYNA for the bottom plates + resin and the circumferential shell. These time histories are then used as input to the second part of the analysis (Reference 12.60), which also used the LS-DYNA code, to determine the maximum principal strain in the fuel pin. To determine the strain ductility demand on the fuel cladding, the inelastic buckling capacity of the fuel rods needs to be taken into account. The approach is taken to analyze the fuel rod as an elastic-plastic beam-column with initial bowing under dynamic impact condition. The finite element model of a single fuel rod with lateral displacement constraints is used to study the structural adequacy of a fuel rod under an 80" end drop condition. An effective Zircaloy cladding thickness that is reduced by the maximum 125 micron oxide thickness recommended (Reference 12.70) for burnups between 50 and 60 GWd/MTU was used for this analysis. This oxide thickness is bounding for Zirlo clad fuel, which has a maximum oxide thickness that is less than 100 microns at a burnup of 52 GWd/MTU (Reference 12.68, Figure 4.5.2-1). In Reference 12.60, two different models are used to determine the maximum principal strain the fuel cladding, however, only the second model (i.e., "Model II"), where the unfiltered deceleration time history of the transfer cask end plate from Reference 12.64 is used, represents the approved design basis. The results show the maximum principal strain of the fuel assembly is 0.341% which is still far less than the yield strain of 0.926% at 750°F for the fuel assembly. This conclusion may also be applied to Zirlo clad fuel, which has strain capability and yield strength exceeding that of Zircaloy (Reference 12.68, Sections 5.3.5 and 5.3.7). Thus, cladding integrity is confirmed for transfer cask end drop accident conditions for the NUHOMS-32P.

B. Horizontal Side Drop

The effect of the added weight of the transfer cask with NUHOMS-32P DSC payload is accounted for by increasing the stresses in the transfer cask structural shell and the inner liner by a factor of 1.1. This increase factor reflects the increased combined weight of the transfer cask and the NUHOMS-32P DSC. This is conservative in that the NUHOMS-32P DSC basket assembly spreads the weight evenly along the length of the transfer cask, while the NUHOMS-24P DSC basket design uses spacer plates which apply concentrated pressure loads at the spacer plate locations. The stresses in the end components of the transfer cask are not changed since they do not see the effect of the increased payload.

The structural integrity of a CE 14x14 fuel assembly with Zircaloy clad fuel rods loaded in a NUHOMS-32P DSC when subjected to an 80-inch (75g) transfer cask side drop accident at 750°F is also evaluated (References 12.61 and 12.69). The cladding tube is analyzed by ANSYS 10.0 as a continuous beam by using the actual span lengths and spacer widths. The beam model is subjected to lateral loads due to cladding tube and fuel pellet mass inertia. An effective cladding thickness that is reduced by the maximum 125 micron oxide thickness recommended for burnups between 50 and 60 GWd/MTU was used for this analysis. Fuel rod stress with this level of oxidation was determined to be 38.5 ksi, for Standard CE 14x14 fuel and 45.4 ksi for VAP CE 14x14 fuel, which is well below the ASME code allowable cladding yield strength of 92 ksi for the cask side drop anaylysis. As discussed for end drop, this conclusion is also applicable to Zirlo clad CE 14x14 fuel, which has a lower oxidation rate and superior mechanical properties compared to Zircaloy (Reference 12.68). Thus, cladding integrity is confirmed for the transfer cask side drop accident condition for the NUHOMS-32P.

Summary of Results

The enveloping maximum membrane plus bending stresses are below allowable ASME Code Level D limits for the dropped transfer cask accident.

For the NUHOMS-32P, fuel rod cladding stress analyses were performed for the side and end drops using an effective cladding thickness that is reduced by the maximum 125 micron oxide thickness recommended for burnups between 50 and 60 GWd/MTU. The results indicate that drop

accident induced stresses in fuel rods with this level of oxidation will also remain below the fuel cladding yield strength. Thus, the structural integrity of the fuel cladding is confirmed for accident conditions (the cask drop event) for the extended burnup NUHOMS-32P.

12.8.2.5.3 Accident Dose Consequences

Dose calculations for the transfer cask drop accident with a NUHOMS-32P DSC use the same methodology and model as the calculations for the NUHOMS-24P DSC, and continue to assume that the neutron shielding is lost. The doses for the NUHOMS-32P DSC, with the increased neutron source term, are 1,251.2 mrem/hr on contact, and 145.5 mrem/hr at 15' (Reference 12.29). The contact dose rate, 1,251.2 mrem/hr, remains below the limit of 5 rem/hr for this accident (Section 4.7.3.3). The recovery dose to an on-site worker, at an average distance of 15', increases from 776 mrem to 1,164 mrem (145.5 mrem/hr x 8 hr = 1,164 mrem). The recovery dose remains below the limit of 5 rem at the site boundary since the total dose at 15' is much less than 5 rem.

12.8.2.6 Lightning

The lightning evaluation presented in Section 8.2.6 is not affected by the addition of the NUHOMS-32P DSC to the NUHOMS System.

12.8.2.7 Blockage of Air Inlets and Outlets

This accident is postulated to consist of the complete and total blockage of all HSM air inlets and outlets for a period of 36 hours.

12.8.2.7.1 Cause of Accident

See Section 8.2.7.1.

12.8.2.7.2 Accident Analysis

The stresses caused by the additional weight of debris blocking the air inlets and outlets are bounded by the structural consequences of other accidents described in this section (i.e., tornado and earthquake analyses). The thermal consequences of this accident result from heating of the DSC and HSM/HSM-HB due to the loss of natural convection cooling.

The thermal analyses to determine the temperature rise for the Calvert Cliffs HSM/HSM-HB and DSC components due to blocked vents are performed using the ANSYS finite element methodology (Reference 12.2 for HSM and Reference 12.74 for HSM-HB). The design basis pressure is considered in the DSC accident pressure evaluation presented in Section 12.8.2.9.

The thermally induced stresses for the HSM/HSM-HB for the blocked vent case are calculated using an ANSYS finite element model and the methodology discussed in Reference 12.23 for HSM and Reference 12.72 for HSM-HB. The thermally induced stresses for the DSC during accident conditions are addressed in Reference 12.22.

12.8.2.7.3 Accident Dose Consequences

The discussion in Section 8.2.7.3 is unchanged and is conservative for the NUHOMS-32P DSC in the HSM because the possible recovery dose is lower. The dose rate at the HSM air inlet vent for the NUHOMS-32P DSC is 61 mrem/hr (Reference 12.30), which is less than the 73 mrem/hr for the NUHOMS-24P DSC. The possible recovery dose incurred by an onsite worker for debris removal is 488 mrem (61 mrem/hr x 8 hr) for the NUHOMS-32P DSC, in the HSM which is less than the 584 mrem for the NUHOMS-24P DSC (Section 8.2.7.3).

The dose rate at the HSM-HB air inlet vent for the NUHOMS-32P DSC is 88.9 mrem/hr (Reference 12.30), not including credit for additional gamma shielding provided by the alternate bird screen design. This would increase the on-site worker 8-hour debris removal dose to 711 mrem for a NUHOMS-32P DSC in an HSM-HB.

12.8.2.8 Dry Shielded Canister Leakage

As described in Section 12.3.3.2, the DSC is designed to ensure no leakage and the analyses for normal and accident conditions have shown that there are no credible events which can breach the DSC pressure boundary or fail the double seal welds at each end of the DSC. However, a total and instantaneous leak of a single NUHOMS-32P DSC is postulated using the same methodology as in Section 8.2.8 except using a 24 month operating cycle (resulting in a release fraction of 9.13%).

The resulting calculated doses for the NUHOMS-32P DSC are:

Off-site total body dose:	0.71 mrem,
Off-site skin dose:	119.3 mrem.

These doses remain within the 10 CFR 72.106 limit of 5,000 mrem.

12.8.2.9 Accidental Pressurization of Dry Shielded Canister

This accident addresses the consequences of accidental pressurization of the NUHOMS-32P DSC.

12.8.2.9.1 Cause of Accident

See Section 8.2.9.1.

12.8.2.9.2 Accident Analysis

The maximum NUHOMS-32P DSC pressurization is calculated assuming that 100% of the fuel rods in a DSC rupture and release the fission and fuel rod fill gasses to the DSC cavity. The fuel rod fission gas release fraction is assumed to be 30% and the fuel rod fill gas release fraction is assumed to be 100%. The maximum fuel rod fill gas pressure is assumed to be 465 psia and is used to calculate the quantity of fill gas released from fuel rods to the DSC cavity during fuel rod rupture conditions. The internal DSC pressure is calculated at the maximum ambient temperature of 103°F and a solar heat flux of 127.0 Btu/hr-ft^2.

The limiting accident for DSC pressurization is the HSM blocked vent case as discussed in Section 12.8.2.7. Under these conditions, the gas temperatures in the DSC will rise to 735°F with a DSC internal pressure of 99.4 psig (Reference 12.17). This is based on a 48 hour vent blockage timeframe, which is conservative compared to the HSM blocked vent accident time of 36 hours in Section 12.8.2.7.

The maximum DSC pressure boundary stress intensities due to accident pressurization are calculated using 100 psig which bounds the 99.4 psig maximum DSC internal pressure. The calculated component stress intensities at 100 psig were determined to be below the allowable stress limits.

For NUHOMS-32P DSC, the maximum partial pressure of fill gas is 35% of the total gas pressure in the DSC, which is still not a major contributor to the accident DSC internal pressures.

The analysis of accidental pressurization of the DSC includes the effect of fuel burnup on internal fuel rod pressure by using the volume of fission gas generated in the fuel rod at the maximum burnup of 52,000 MWD/MTU. The results of the analysis show that the maximum DSC accident pressures are within the allowable design bases limits (Reference 12.62).

12.8.2.9.3 Accident Dose Calculations

Since the maximum NUHOMS-32P DSC accident pressure is within the design basis limits, there are no dose consequences.

12.8.2.10 Forest Fire

This postulated event involves a forest fire occurring in the woods adjacent to the Calvert Cliffs ISFSI.

12.8.2.10.1 Cause of Accident

See Section 8.2.10.1.

12.8.2.10.2 Accident Analysis

The initial parameters used in Section 8.2.10.2 for the forest fire evaluation remain unchanged for the NUHOMS-32P DSC with the exception of the initial HSM/HSM-HB concrete temperature. The NUHOMS-32P forest fire evaluation is based on an initial peak fuel region side wall concrete temperature of 183°F, which represents the average between the maximum inside and outside 3-foot concrete wall temperatures at 103°F ambient (Reference 12.56). This concrete temperature bounds that for storage of the NUHOMS-32P DSC in the HSM-HB (Reference 12.73, Figure 6-2). The damage to the wall, based on the HSM wall temperature gradient resulting from the fire, will be limited to a thickness of 6" into the wall (Reference 12.56). The remainder of the wall thickness will remain within American Concrete Institute 349 temperature limits. Fuel cladding temperature limits will be maintained within the fuel cladding short-term temperature limit. The effect of the surface cracking and spalling will be minimal with respect to the load capacity of the HSM/HSM-HB walls. The NUHOMS-32P DSC internal pressure limit (100 psig) will not be exceeded. The increase in HSM surface dose is from 13.5 mrem/hr to approximately 60.4 mrem/hr (Reference 12.30). This dose rate bounds storage of the NUHOMS-32P in the HSM-HB since the thickness of the roof and walls is 8 inches greater than the HSM. This increase is not considered a "significant increase in occupational exposure" for the necessary repair activities. Actions to mitigate the fire and repair the HSMs/HSM-HBs will ensure that offsite dose consequences will be limited and of short duration and will remain within the limits of 10 CFR 72.106.

12.8.2.10.3 Accident Dose Consequences

There are no accident dose consequences associated with the postulated forest fire accident.

12.8.2.11 Liquified Natural Gas Plant or Pipeline Spill or Explosion

Use of the NUHOMS-32P DSC design does not change the analysis described in Section 8.2.11.

12.8.2.12 Load Combinations

The load categories associated with normal, off-normal, and accident conditions have been described and analyzed in previous chapters. Evaluation of the load combination for the NUHOMS-32P important to safety components is addressed in this section.

The methodology used in combining normal, off-normal, and accident loads and their associated overload factors for various NUHOMS-32P components is presented in Reference 12.22. The load combination

analysis results showed that the calculated stresses are less than the code allowables for various load combinations shown in Tables 12.8-1, 12.8-2, 12.8-3, 12.8-4, 8.2-14, 8.2-15, and 8.2-16.

When compared to the NUHOMS-24P DSC, the confinement boundary stress allowables (Table 12.8-3) have been altered to an elastic/plastic analysis for all accident conditions except for the 100 psig applied to the inner pressure boundary combinations (D_3, D_4, & D_5)

Horizontal storage module enveloping load combination results were obtained based on a conservative interpretation of the Calvert Cliffs Nuclear Power Plant (CCNPP) calculation. The forces and moments, including thermal loads, are taken from the ANSYS output presented in Reference 12.23 for the poured in place HSM and Reference 12.72 for the HSM-HB.

The load combination analysis results show that the calculated stresses are less than the code allowable stresses for all the specified normal, off-normal, and accident condition load combinations.

12.8.2.13 Other Event Considerations

Use of the NUHOMS-32P DSC design does not change the analysis described in Section 8.2.13.

12.8.3 SITE CHARACTERISTICS AFFECTING SAFETY ANALYSIS

All site characteristics affecting safety analyses presented in this document are noted where they apply.

TABLE 12.8-1
NUHOMS-32P DRY SHIELDED CANISTER ENVELOPING LOAD COMBINATION RESULTS FOR NORMAL AND OFF-NORMAL LOADS

(ASME Service Levels A and B)

DSC COMPONENTS	STRESS TYPE	CONTROLLING[a] LOAD COMBINATION	ALLOWABLE[b][c] STRESS (ksi)
DSC Shell	Primary Membrane	B2	18.96
	Membrane + Bending	B2	28.44
	Primary + Secondary	B2	56.88
Bottom Cover Plate	Primary Membrane	A4	18.96
	Membrane + Bending	B2	28.44
	Primary + Secondary	B2	56.88
Top Pressure Plate	Primary Membrane	A3	18.96
	Membrane + Bending	A3	28.44
	Primary + Secondary	A3	56.88
Top Structural Plate	Primary Membrane	A4	18.96
	Membrane + Bending	A4	28.44
	Primary + Secondary	A4	56.88

(a) See Table 12.3-6 for load combination nomenclature.
(b) See Table 3-4 of Reference 12.22 for allowable stress criteria. Material properties were obtained from Table 3.5 of Reference 12.22 at a design temperature.
(c) Allowables are for stainless steel material at 380°F.

TABLE 12.8-2
NUHOMS-32P DRY SHIELDED CANISTER ENVELOPING LOAD COMBINATION RESULTS FOR ACCIDENT LOADS

(ASME Service Level C)

DSC COMPONENTS	STRESS TYPE	CONTROLLING[a] LOAD COMBINATION	ALLOWABLE[b][c] STRESS (ksi)
DSC Shell	Primary Membrane	C2	21.6
	Membrane + Bending	C1	32.4
Bottom Cover Plate	Primary Membrane	C2	21.6
	Membrane + Bending	C5	32.4
Top Pressure Plate	Primary Membrane	C2	21.6
	Membrane + Bending	C2	32.4
Top Structural Plate	Primary Membrane	C2	21.6
	Membrane + Bending	C1	32.4

(a) See Table 12.3-6 for load combination nomenclature.
(b) See Table 3-4 of Reference 12.22 for allowable stress criteria. Material properties were obtained from Table 3-5 of Reference 12.22 at a design temperature.
(c) Allowables are for stainless steel material at 460°F.

TABLE 12.8-3
NUHOMS-32P DRY SHIELDED CANISTER ENVELOPING LOAD COMBINATION RESULTS FOR ACCIDENT LOADS

(ASME Service Level D)[c]

DSC COMPONENTS	STRESS TYPE	CONTROLLING[a] LOAD COMBINATION	ELASTIC ALLOWABLE[b] STRESS (ksi)	ELASTIC-PLASTIC ALLOWABLE[d] STRESS (ksi)
DSC Shell	Primary Membrane	D2	43.2	44.6
	Membrane + Bending	D2	63.6	57.3
Bottom Cover Plate	Primary Membrane	D2	43.2	44.6
	Membrane + Bending	D2	63.6	57.3
Top Pressure Plate	Primary Membrane	D2	43.2	44.6
	Membrane + Bending	D2	63.6	57.3
Top Structural Plate	Primary Membrane	D2	43.2	44.6
	Membrane + Bending	D2	63.6	57.3
Basket Assembly	Primary Membrane	D2	44.4	
	Membrane + Bending	D2	57.0	
Top End Structural Weld	Primary	--	21.6	22.3
	Membrane + Bending		N/A	
Bottom End Structural Weld	Primary	--	45.1	45.1

For more information see Reference 12.22.

(a) See Table 12.3-6 for load combination nomenclature.
(b) See Table 3-4 of Reference 12.22 for allowable stress criteria. Material properties were obtained from Table 3-5 of Reference 12.22 at a design temperature.
(c) Allowables are for stainless steel material at 460°F.
(d) Used on 100 psi pressure applied at outer boundary case (D_5).

TABLE 12.8-4
NUHOMS-32P DRY SHIELDED CANISTER SUPPORT ASSEMBLY ENVELOPING LOAD COMBINATION RESULTS

		AISC Allowable Stress for HSM		
Component	**Load Combination**	**Axial (ksi)**	**Bending (ksi)**	**Shear (ksi)**
W8x48 Cross Beam	Normal Operation $DW_s + DW_c + HL_f$	15.5	17.6	10.6
	Off-Normal Operation $DW_s + HL_j$	26.3	29.9	18.0
	Accident $DW_s + DW_c + DBE$	24.8	28.1	16.7
W8x40 Support Rail	Normal Operation $DW_s + DW_c + HL_f$	14.6	17.6	10.6
	Off-Normal Operation $DW_s + HL_j$	24.8	29.9	18.0
	Accident $DW_s + DW_c + DBE$	23.4	28.1	16.7

KEY: DW_s = Dead Weight Support Assembly, HL_j = Off-normal Handling Loads-Jammed, DW_c = Dead Weight Canister, HL_f = Normal Loads Friction, DBE = Seismic Loads

NOTES:
Allowable stresses taken at 600°F to conservatively envelope all ambient temperature cases.
Allowables for $DW_s + DW_c + DBE$ increased by a factor of 1.6.

TABLE 12.8-4
NUHOMS-32P DRY SHIELDED CANISTER SUPPORT ASSEMBLY ENVELOPING LOAD COMBINATION RESULTS

AISC Allowable Stress Radios for HSM-HB

Rail Component Results

Load Comb.	Interaction Ratio	Shear Stress Ratio	Stiffener Plate Stress Ratio
C1S	0.35	0.67	0.19
C2S	0.58	0.84	0.00
C3S	0.58	0.93	0.22
C4S	0.51	0.96	0.18
C5S	0.40	0.63	0.55

Extension Plates and Cross Members Results

Load Comb.	Extension Plates Interaction Ratio	Cross Members Stress Ratio
C1S	0.77	0.25
C2S	0.77	0.32
C3S	0.71	0.21
C4S	0.60	0.25
C5S	0.71	0.33

12.9 CONDUCT OF OPERATIONS

The Calvert Cliffs ISFSI is operated under the same corporate management organization responsible for operation of the CCNPP. The conduct of operations for the Calvert Cliffs ISFSI are described in Chapter 9.0. The discussion presented in Chapter 9.0 is not affected by the addition of the NUHOMS-32P DSC to the NUHOMS System.

12.10 OPERATING CONTROLS AND LIMITS

The discussion presented in Chapter 10 is not affected by the addition of the NUHOMS-32P DSC to the CCNPP NUHOMS System.

12.11 QUALITY ASSURANCE

The quality assurance program for the Calvert Cliffs ISFSI covers the construction phase, the operational phase, and the decommissioning phase of structures, systems, and components of the Calvert Cliffs ISFSI important to safety. The Calvert Cliffs ISFSI quality assurance program is discussed in Chapter 11. The discussion presented in Chapter 11 is not affected by the addition of the NUHOMS-32P DSC to the CCNPP NUHOMS System.

12.12 REFERENCES

12.1 CCNPP Calculation No. CA06306, "DSC Thermal Analysis - Off Normal Conditions (Max. Summer Temperature)"

12.2 CCNPP Calculation No. CA06304, "HSM Thermal Analysis - Accident Conditions (Blocked Vents)"

12.3 CCNPP Calculation No. CA06313, "Thermal Analysis of Transfer Cask with Poison Material in Basket"

12.4 CCNPP Calculation No. CA06314, "Thermal Analysis of Vacuum Drying"

12.5 NUREG/6361, dated March 01, 1997, "Criticality Benchmark Guide for Light-Water-Reactor Fuel in Transportation and Storage Packages," March 01, 1997

12.6 CCNPP Calculation CA05895, "Criticality Benchmarks"

12.7 CCNPP Calculation CA06227, "Criticality Analysis of the NUHOMS-32P for Calvert Cliffs ISFSI"

12.8 CCNPP Calculation CA05896 "Criticality Analysis for Fuel Misloads and Accidents"

12.9 CCNPP Calculation CA06312, "Thermal Analysis of Storage Cases Poison Plates in Basket"

12.10 CCNPP Calculation No. CA06296, "Finite Element Models, Thermal Analysis"

12.11 CCNPP Calculation No. CA06301, "HSM Thermal Analysis - Normal Storage Conditions"

12.12 CCNPP Calculation No. CA06305, "DSC Thermal Analysis - Normal Storage Conditions"

12.13 CCNPP Calculation No. CA06295, "Effective Fuel Properties"

12.14 "Spent Nuclear Fuel Effective Conductivity Report," TRW Environmental Safety Systems, Inc., Document Identifier BBA000000-01717-5705-00010 Revision 00

12.15 CCNPP Calculation No. CA06297, "Transfer Thermal Analysis, 103°F"

12.16 CCNPP Calculation No. CA06298, "Transfer Thermal Analysis, -3°F Ambient"

12.17 CCNPP Calculation No. CA06300, "Maximum Operating Pressure, Storage and Transfer"

12.18 CCNPP Calculation No. CA06308, "Effective Fuel Properties for Vacuum Drying"

12.19 CCNPP Calculation No. CA06309, "Sensitivity of the Component Temperatures to the Position of the DSC in the Transfer Cask"

12.20 CCNPP Calculation No. CA06310, "Sensitivity of the Transfer Cask Thermal Analysis to the Axial Gaps Between DSC and Transfer Cask"

12.21 "The Topical Report for the NUTECH Horizontal Modular Storage System for Irradiated Nuclear Fuel NUHOMS-24P," Revision 1A

12.22 CCNPP Calculation No. CA06359, "NUHOMS 32P - DSC Structural Analysis"

12.23 CCNPP Calculation No. CA06364, "NUHOMS 32P - CCNP ISFS HSM Facility Evaluation"

12.24 ASME Boiler and Pressure Vessel Code, Section III, Division 1, Subsection NB and NC and Appendix F, 1998 Edition with 1999 Addenda

12.25 CCNPP Calculation No. CA06329, "NUHOMS-32P - Transfer Cask Structural Analysis"

12.26 ASME Boiler and Pressure Vessel Code, Section III, Division 1, Subsection NG and Appendix F, 1998 including 1999 Addenda

12.27 CCNPP Calculation No. CA06326, "NUHOMS 32P Basket Stress Analysis for Storage Loads (Normal and Accident)"

12.28 CCNPP Calculation No. CA06335, "Basket Stress Analysis Due to Accident Transfer Drop"

12.29 CCNPP Calculation No. CA06750, "Loading and Transfer Dose Rate for ISFSI 32P Burnup Extension"

12.30 CCNPP Calculation No. CA06751, " Horizontal Storage Module Dose Rates for ISFSI 32P Burnup Extension

12.31 CCNPP Calculation No. CA06327, "Shielding Evaluation with the New Top Shield Plug for NUHOMS-32P"

12.32 CCNPP Calculation No. CA05924, "Calvert Cliffs ISFSI/NUHOMS-24P Radiation Dose Rates for Cask Loading and Transfer"

12.33 CCNPP Calculation No. CA05925, "Calvert Cliffs ISFSI/NUHOMS-24P HSM Dose Rates"

12.34 CCNPP Calculation No. CA06319, "NUHOMS-32P – Weight Calculation of DSC/TC"

12.35 CCNPP Drawing 84218SH0001, "NUHOMS-32P DSC Shell & Bottom Plug Assembly" - DSCs CEG32P-L049 thru CEG32P-L072

CCNPP Drawing 84266SH0001, "NUHOMS-32P DSC Shell & Bottom Plug Assembly"- DSCs CEG32P-L073 thru CEG32P-L078

12.36 CCNPP Drawing 84219SH0001, "NUHOMS-32P DSC Shell & Siphon Pipe Assembly Details" - DSCs CEG32P-L049 thru CEG32P-L072

CCNPP Drawing 84266SH0002, "NUHOMS-32P DSC Shell & Siphon Pipe Assembly Details"- DSCs CEG32P-L073 thru CEG32P-L078

12.37 CCNPP Drawing 84220SH0001, "NUHOMS-32P DSC Siphon Pipe/Adapter & Lifting Block Details" - DSCs CEG32P-L049 thru CEG32P-L072

CCNPP Drawing 84266SH0003 "NUHOMS-32P DSC Siphon Pipe/Adapter & Lifting Block Details"- DSCs CEG32P-L073 thru CEG32P-L078

12.38 CCNPP Drawing 84221SH0001, "NUHOMS-32P DSC Top Shield Plug Details" - DSCs CEG32P-L049 thru CEG32P-L072

CCNPP Drawing 84266SH0004, "NUHOMS-32P DSC Top Shield Plug Details"- DSCs CEG32P-L073 thru CEG32P-L078

12.39 CCNPP Drawing 84222SH0001, "NUHOMS-32P Top Cover Plate & Siphon/Vent Port Covers" - DSCs CEG32P-L049 thru CEG32P-L072

CCNPP Drawing 84266SH0005, "NUHOMS-32P Top Cover Plate & Siphon/Vent Port Covers"- DSCs CEG32P-L073 thru CEG32P-L078

12.40 CCNPP Drawing 84223SH0001, "NUHOMS-32P DSC Basket Assembly" - DSCs CEG32P-L049 thru CEG32P-L072

CCNPP Drawing 84266SH0006, "NUHOMS-32P DSC Basket Assembly"- DSCs CEG32P-L073 thru CEG32P-L078

12.41 CCNPP Drawing 84224SH0001, "NUHOMS 32P DSC Basket Details" - DSCs CEG32P-L049 thru CEG32P-L072

CCNPP Drawing 84266SH0007, "NUHOMS 32P DSC Basket Details"- DSCs CEG32P-L073 thru CEG32P-L078

12.42 CCNPP Drawing 84225SH0001, "NUHOMS-32P DSC Basket Rails & Shims" - DSCs CEG32P-L049 thru CEG32P-L072

CCNPP Drawing 84266SH0008, "NUHOMS-32P DSC Basket Rails & Shims" DSCs-CEG32P-L073 thru CEG32P-L078

12.43 CCNPP Drawing 84226SH0001, "NUHOMS-32P DSC Basket Plate & Rail Inserts" - DSCs CEG32P-L049 thru CEG32P-L072

CCNPP Drawing 84266SH0009, "NUHOMS-32P DSC Basket Plate & Rail Inserts"-DSCs CEG32P-L073 thru CEG32P-L078

12.44 CCNPP Drawing 84227SH0001, "NUHOMS-32P DSC Parts List" - DSCs CEG32P-L049 thru CEG32P-L072

CCNPP Drawing 84266SH00010, "NUHOMS-32P DSC Parts List"- DSCs CEG32P-L073 thru CEG32P-L078

12.45 CCNPP Drawing 84234SH0001, "NUHOMS-32P DSC Final Assembly, Field Welding & Testing" - DSCs CEG32P-L049 thru CEG32P-L072

CCNPP Drawing 84266SH00011, "NUHOMS-32P DSC Final Assembly, Field Welding & Testing"- DSCs CEG32P-L073 thru CEG32P-L078

12.46 CCNPP Drawing 84235SH0001, "NUHOMS-32P DSC ASME Code Exceptions" - DSCs CEG32P-L049 thru CEG32P-L072

CCNPP Drawing 84266SH00012, "NUHOMS-32P DSC ASME Code Exceptions"-DSCs CEG32P-L073 thru CEG32P-L078

12.47 CCNPP Calculation No. CA06721, "Source Terms for ISFSI 32P Burnup Extension," Revision 0

12.48 CCNPP Calculation No. CA06637, "Sensitivity Analysis of Homogenized Fuel Region"

12.49 CCNPP Calculation No. CA04977, "NUTECH Horizontal Module System (NUHOMS) 24P ISFSI Shielded Canister Structural Analysis for Sixteen New Assemblies"

12.50 CCNPP Calculation No. CA04141, "ISFSI Transfer Cask Structural Analysis"

12.51 ASTM E1225, "Thermal Conductivity of Solids by Means of the Guarded-Comparative-Longitudinal Heat Flow Technique"

12.52 ASTM E1461, "Thermal Diffusivity of Solids by the Flash Method"

12.53 NUREG/CR-5661, "Recommendations for Preparing the Criticality Safety Evaluation of Transportation Packages," 1997

12.54 Nuclear Regulatory Commission Safety Evaluation Report, Docket No. 72-1004, Standardized NUHOMS Modular Storage System for Irradiated Nuclear Fuel, Certificate of Compliance No. 1004, Amendment 5 (NUHOMS-32PT System)

12.55 CCNPP 10 CFR 72.48 Safety Evaluation No. SE00163, Revision 1, "Use of NUHOMS-32P Dry Shielded Canister"

12.56 CCNPP Calculation No. CA06653, "Forest Fire Evaluation for the NUHOMS-32P for CCNPP"

12.57 CCNPP Calculation No. CA06629, "Forest Fire Radiological Evaluation for the NUHOMS-32P HSM for CCNPP"

12.58 CCNPP Calculation No. CA06367, "Comparison of the Radiological, Thermal, and Reactivity Characteristics of Assemblies with Missing or Inert Fuel Rods with the 32P ISFSI DSC Design Basis"

12.59 CCNPP Calculation No. CA06354, "Accidental Drop Loading Evaluation of 14x14 Fuel Assembly with Missing Fuel Rods"

12.60 CCNPP Calculation No. CA07295, Transnuclear Calculation No. NUH32P+.0204, "Fuel End Drop Analysis for NUH32P+ Using LS-DYNA," Revision 1, August 2010

12.61 CCNPP Calculation No. CA06822-0001, Transnuclear Calculation No. NUH32P+.0201, "NUHOMS 32P CE14x14 Fuel Cladding Strength Under Accident Side Drop Conditions," Revision 1, December 2008

12.62 CCNPP Calculation No. CA06771, Transnuclear Calculation No. NUH32P+.0402, "Effect of Updated Fuel Performance Data on NUHOMS 32P+ Internal Pressure," Revision 0, August 2007

12.63 SCALE 4.4, "A Modular Code System for Performing Standarized Computer Analysis for Licensing Evaluations," NUREG/CR-0200, Revision 6, September 1998

12.64 CCNPP Calculation No. CA07294, Transnuclear Calculation No. NUH32P+.0203, "32P+ Transfer Cask Impact onto the Concrete Pad LS-DYNA Analysis (80 inch End Drop)," Revision 0, March 2010

12.65 CCNPP Calculation No. CA07098, NUHOMS® 32P Basket Buckling Analysis Using Full ANSYS Model

12.66 CCNPP Calculation No. CA07660, NUHOMS 32P-DSC Side Drop Evaluation for Reduced Lead Plug Top Casing Plate Thickness

12.67 CCNPP Calculation No. CA07661, NUHOMS 32P-DSC Structural Analysis Due to Under Thickness of lead Plug Top Casing Plate

12.68 CENPD-404-P, “Implementation of Zirlo Cladding Material in CE Nuclear Power Fuel Assembly Designs”, Revision 0000

12.69 CCNPP Calculation CA07302, “PWR Fuel Rod Drop Accident Side Drop Loading Stress Analysis for NUHOMS 32PHB System”

12.70 CCNPP Calculation CA06758, “Fuel Performance Data for Calvert Cliffs Dry Storage (ISFSI) for Fuel Batches C1N through C1T and C2M through C2S”

12.71 CCNPP Calculation CA08032, “Criticality Analysis of the NUHOMS 32P Loaded with VAP Fuel for the Calvert Cliffs ISFSI”

12.72 CCNPP Calculation CA07307, “HSM-HB Structural Analysis for NUHOMS-32PHB System”

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