WCS-CISF-16-002

Enclosure 13

Public Version of Changed WCS CISF Application and SAR Pages, Interim Revision 1

Non-Proprietary

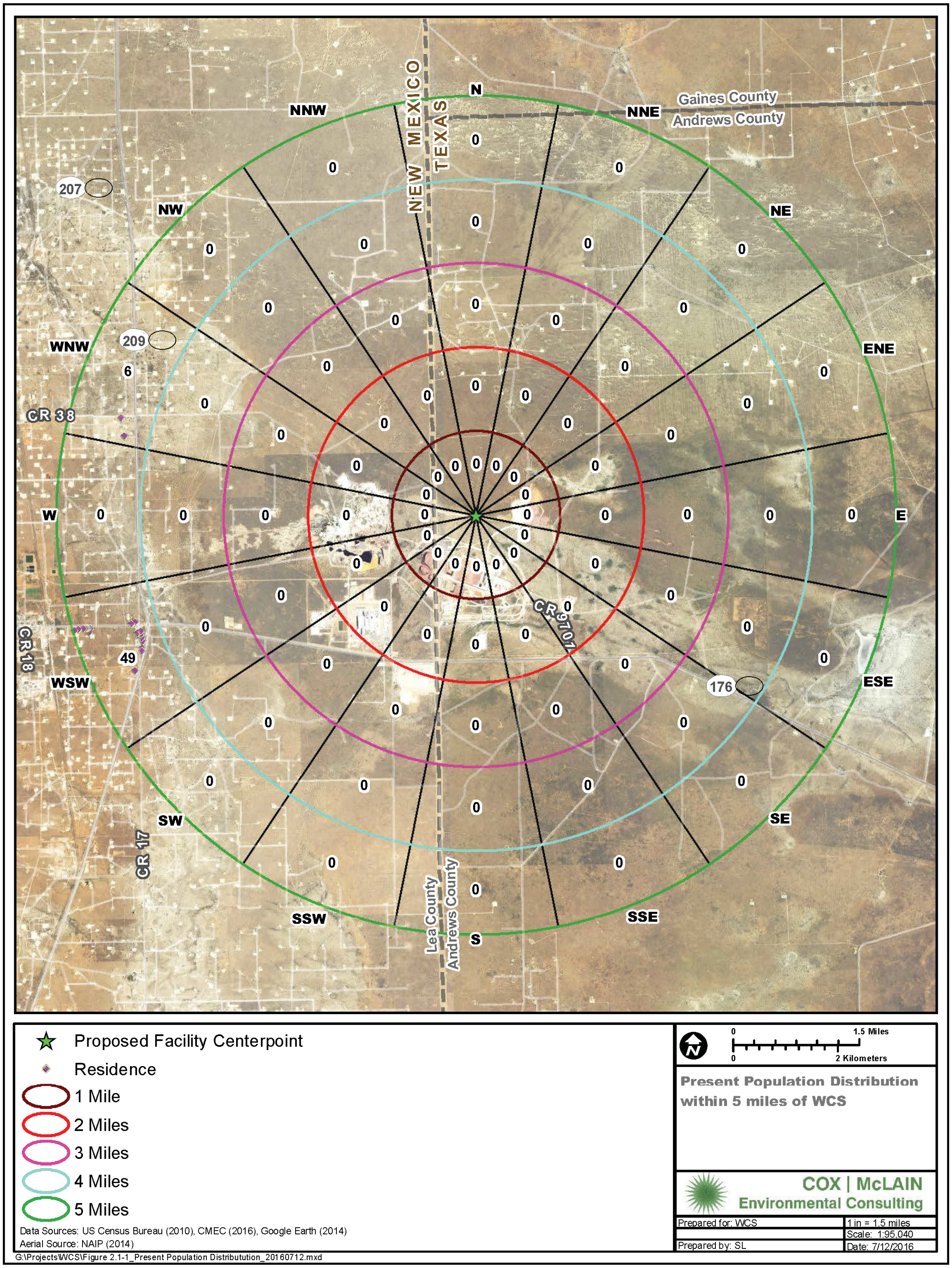

Figure 2-19
Present Population Distribution within 5 Miles of WCS

All Indicated Changes are in response to RSI NP-2.1

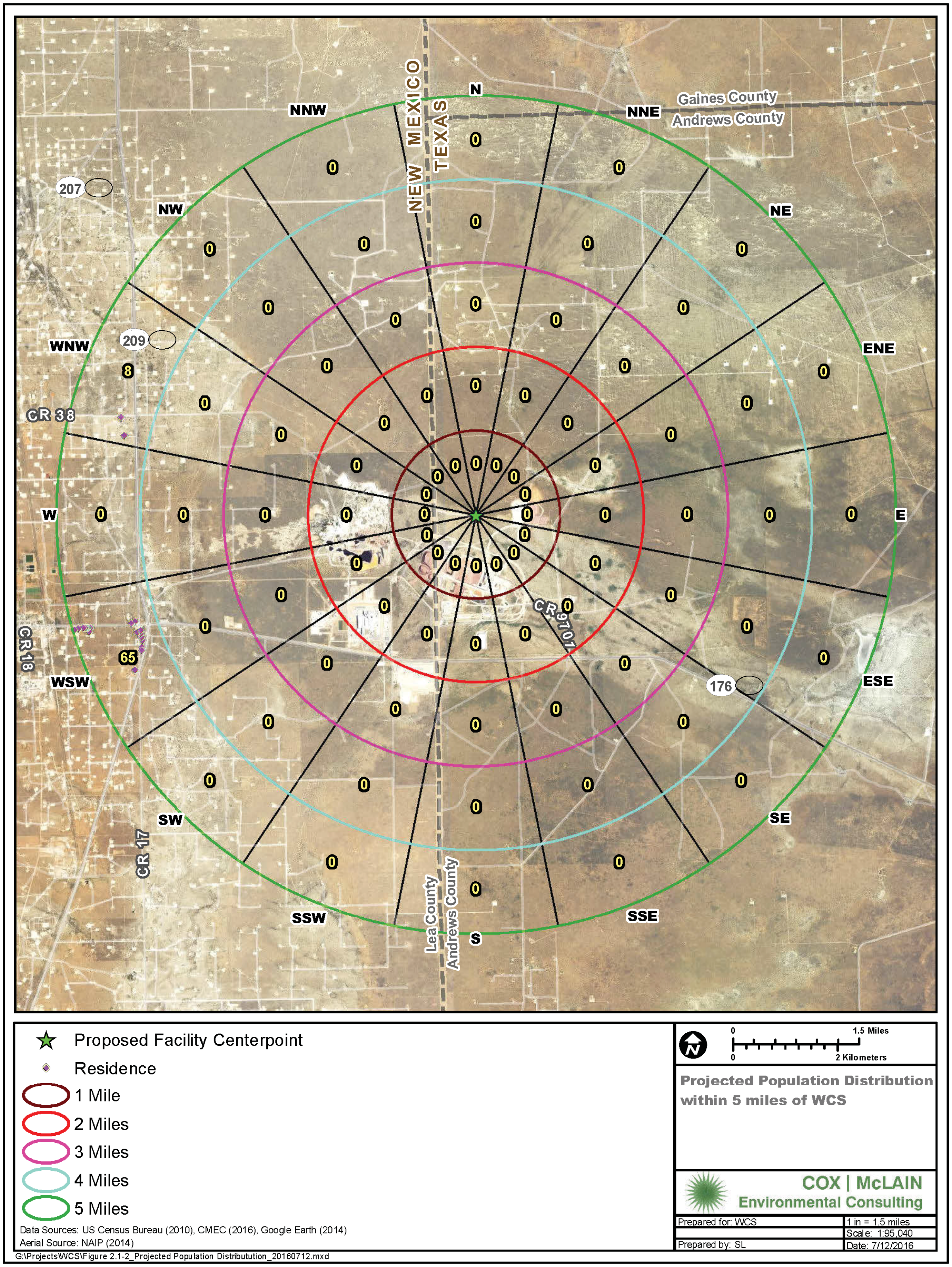

Figure 2-20
Projected Population Distribution within 5 Miles of WCS

All Indicated Changes are in response to RSI NP-2.1

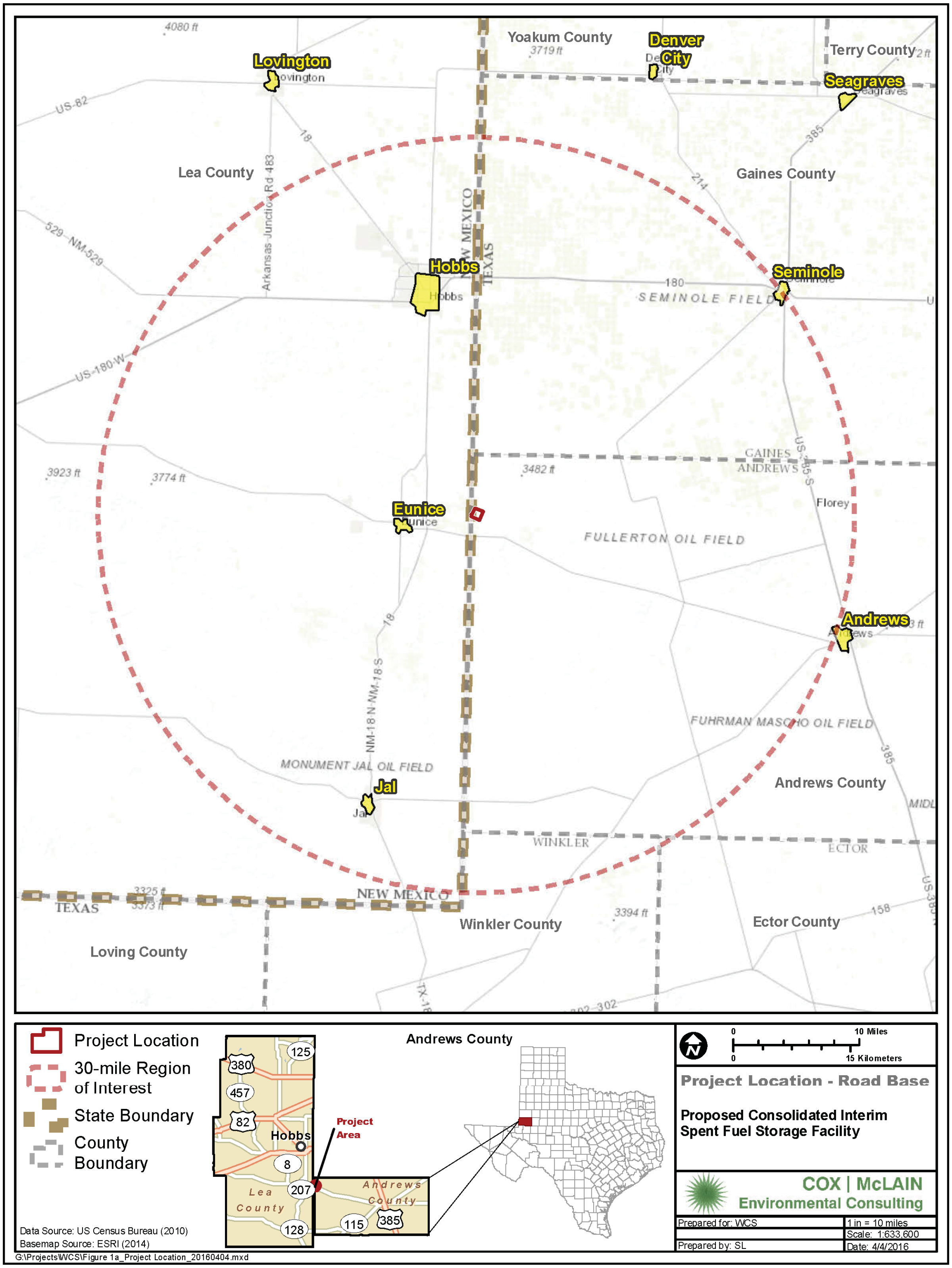

Figure 2-25
Project Location-Road Base

All Indicated Changes are in response to RSI NP-2.1

7.6 Other Structures, Systems, and Components Subject to NRC Approval

This section describes the structural design, design criteria and design analysis for the storage pads for the NUHOMS® and NAC Systems.

7.6.1 Storage Pads *for VCCs*

The WCS CISF storage pads are conventional cast-in-place reinforced concrete mat foundation structures. They provide a level and stable surface for placement and storage of VCCs. The pads are designed for normal operating loads, severe environmental loads and extreme environmental loads as referenced by NUREG-1567 [7-28]. The storage pads for the NAC VCCs are designed as ITS structures as described below.

The purpose of this evaluation is to structurally qualify the WCS CISF Storage Pad designs for the vertical systems. The licensing-basis WCS CISF VCC configuration is a 3x8 array of MAGNASTOR casks, which envelopes the other NAC International casks to be stored at the WCS CISF. The qualification is conducted in accordance with the NUREG-0800 [7-43], NUREG-1536 [7-42] and NUREG-1567 [7-28]. A geotechnical liquefaction and elastic settlement analysis is performed as part of Calculation NAC004-CALC-02 [7-48].

7.6.1.1 Design Inputs

All Indicated Changes are in response to RSI NP-5.4

7.6.1.10 Results and Conclusions

Based on the evaluations performed, it is concluded that the licensing design of the NAC storage pad for Andrews, TX meets all of the applicable structural requirements of NUREG-1567 [7-28] with reference to NUREG-1536 [7-42] and NUREG-0800 [7-43]. Therefore, the NAC storage pad for Andrews, TX is qualified and acceptable. The WCS CISF licensing design includes consideration of four cask configurations on the pad based on systematically loading the pad with casks from one short side moving across to the other. Seismic, operational wind, and tornado wind were all considered to act on the casks. In the case of an SSE event, the VCCs do not overturn; however, the casks could slide up to *1.32* in (considering a safety factor of two). Furthermore, the concrete pad could slide up to *1.06* in (considering a safety factor of two).

Impact from cask drop or tornado-generated missiles was not considered with respect to the storage pad. The casks are already qualified for impact conditions and impact to the storage pad is an accident condition where damage is acceptable as long as there is no loss of function. The VCT was considered at several locations while fully supporting a cask. Operational wind load was applied to the VCT; however, seismic and tornado wind were not considered given that cask movements are infrequent evolutions.

7.6.2 Soil Liquefaction *and VCC Storage Pad Settlement*

The purpose of this evaluation is to determine the liquefaction potential and elastic settlement of the *VCC* storage pad located at the WCS CISF in Andrews, Texas.

The scope of work included:

- Review of Drawing NAC004-C-001, Rev. 0 showing the dimensions and general arrangement of the storage pad [7-30], and review of Drawing NAC004-C-002, Rev. 0 showing the structural concrete plan, sections, and details [7-37].
- Review of "Report of Geotechnical Exploration" performed by GEOServices, LLC [7-32].
- Liquefaction potential evaluation using the data from reference [7-32].
- Elastic settlement evaluation under static loading conditions using the data from reference [7-32].

7.6.2.1 Design Basis

[ ]

All Indicated Changes are in response to RSI NP-5.4

[ ]

7.6.2.6 Results and Conclusions

Based on the evaluation presented, it is concluded that overall the soils below the storage pad are not susceptible to liquefaction.

Based on analysis, the estimated settlement at the center of the storage pad (assuming the pad to be flexible for settlement purposes) for a uniform bearing pressure of 3,000 psf is on the order of 0.15 to 0.3 inch, with a differential settlement (between the corner and center of the concrete pad) on the order of ¼ inch or less.

7.6.3 Soil Structure Interaction *of the VCC Storage Pad*

This section documents the Soil Structure Interaction (SSI) analysis to support a concrete pad design for the *VCC* storage pads located at the WCS CISF in Andrews Country, Texas. The analysis is conducted in accordance with NUREG-0800 [7-43].

The SSI analysis considers the concrete pad design with the MAGNASTOR VCC, which envelopes the NAC-UMS and NAC-MPC VCCs to be stored at the WCS CISF, for 4 cask load configurations, 3 soil cases, and 3 time histories, totaling 36 analysis cases to obtain enveloping maximum accelerations at the VCC center of gravities, the concrete pad center of gravity, and an evaluation for sliding and overturning of the VCCs. The SSI analysis supports structural design of the *VCC* storage pad system.

7.6.3.1 Design Basis

[ ]

All Indicated Changes are in response to RSI NP-5.4

Proprietary Information on This Page
Withheld Pursuant to 10 CFR 2.390

7.6.3.4 Results and Conclusions

Following SSI analysis of 36 analysis cases it was found that the enveloping maximum accelerations at the MAGNASTOR Cask center of gravity are as follows:

- 0.45g in the X/E-W Direction for Case *30*, Coyote Lake earthquake on *UB* soil at cask CG B1 for cask configuration 4
- 0. *42g* in the Y/N-S Direction for Case 30, Coyote Lake earthquake on UB at cask CG A2 for cask configuration 4
- 0.28g in the Z/Vertical Direction for Case 22, Norcia earthquake on LB soil at cask CG B3 for cask configuration 3

The MAGNASTOR cask envelopes all other vertical VCC types to be stored at the WCS CISF. Through examining the instantaneous coefficient of friction demand, it is deemed that cask sliding is likely to occur for at least 1 cask due to a maximum coefficient of friction demand of 0.46, which is greater than the coefficient of friction of 0.35 for cask steel-to-concrete contact for a light broom finish on the concrete pad.

Through examining the instantaneous factor of safety against overturning following evaluation of the cask CG accelerations obtained from deterministic SSI analysis, it is deemed that overturning *will* not occur for any casks with a minimum observed overturning factor of safety of *1.22*, which is greater than the required factor of safety against overturning of 1.1.

7.6.4 *Soil Structure Interaction of the NUHOMS® NITS Storage Pad*

This section documents the soil-structure interaction (SSI) analysis performed for the NUHOMS® HSM storage pad located at the WCS CISF in Andrews County, Texas. The SSI analysis is conducted in accordance with the guidance in NUREG-0800 [7-43].

The SSI analysis considers the concrete pad loaded with all AHSMs. The AHSM bounds the weight and center of gravity (CG) height of the other NUHOMS® HSM types planned to be stored at the WCS CISF and, thus, represents a bounding HSM for purposes of the SSI analysis.

As shown in Table 7-29, the SSI analysis is performed using three HSM loading configurations, three sets of strain-compatible soil properties, and three sets of spectrally matched time histories. Thus, a total of 27 SSI analyses were performed, which addresses variations in the sequence of loading the storage pad, and uncertainties in the ground motions and soil parameters. The SSI results consist of enveloping accelerations at the center of gravity of the HSMs and acceleration response spectra at the base and center of gravity of the HSMs.

All Indicated Changes are in response to RSI NP-5.4

The maximum response accelerations at the center of gravity of the HSMs are used in the structural evaluation of the concrete pad, as documented in Section 7.6.5. *The acceleration response spectra and the maximum accelerations at the center of gravity of the HSM are also used in the seismic evaluation of the HSMs for the SSI loading. Maximum HSM sliding and rocking uplift are also evaluated.*

7.6.4.1 Strain-Compatible Soil Properties

All Indicated Changes are in response to RSI NP-5.4

7.6.4.2 Spectrally Matched Earthquake Time Histories

The input time histories for SSI analysis are provided in the Seismic Hazard Evaluation and Development of Seismic Design Ground Motions Report [7-33]. Three sets of input time history were developed in [7-33], in accordance with the Standard Review Plan [7-43], Section 3.7.1. The three sets of earthquake time histories are named after their respective seeds, namely the 1979 Coyote Lake, the 1979 Norcia (Italy) and the 1986 North Palm Springs earthquakes, each consisting of three orthogonal components (two horizontal and one vertical). The three time history sets are used for the SSI analyses and the results are enveloped to conservatively account for variability in the ground motions. The response spectra for the spectrally matched time histories, along with their respective acceleration, velocity, displacement, and normalized Arias intensity plots for each of the three components of the three sets of earthquakes used in the SSI analyses are shown in Figure 50 through Figure 67 of Reference [7-33].

7.6.4.3 SSI Analysis Model Description

The SSI analyses are performed using the SASSI computer code [7-63]. Analyses are performed separately for each earthquake component and for each directional component. The acceleration time histories used to generate response spectra are obtained by the arithmetic summation of the collinear contributions from each input direction. The maximum accelerations are obtained by combining the collinear responses by the SRSS combination rule.

To account for variability in sequence of loading the storage pad, three HSM loading sequence configurations are considered: two partial loading configurations consisting of arrays of 22 HSMs and 42 HSMs placed back-to-back, and the fully loaded configuration consisting of an array of 92 HSMs placed back-to-back. These loading configurations are shown schematically in Figure 7-31*, as "Initial Loading", "Second Loading," and "Full," respectively.*

The SASSI SSI finite element model representing the concrete pad is generated with plate elements with the properties listed below.

- *Pad Dimensions: Length = 478.82 ft; Width = 49.20 ft*
- *Thickness: 3.0 ft*
- *f'_c (28-day concrete strength) = 4,000 psi*
- *Unit weight = 0.15 kcf*
- *Poisson's ratio = 0.17*
- *Young's modulus $E = 57{,}000x(4{,}000)^{1/2} = 3.605x10^6$ psi = 519,120 ksf*
- *Damping: $\xi = 4\%$*

All Indicated Changes are in response to RSI NP-5.4

Each HSM is modeled using a vertical beam from its base to the center of gravity of the loaded HSM. The weight and weight moments of inertia of each module are lumped at the center of gravity of the HSM. The material and geometric properties of the beam representing the module are adjusted to match the lowest frequencies of the AHSM in each direction.

The properties of the AHSM are given below:

- *Dimensions: Width = 101 in.; Depth = 235 in.; Height w/o vent covers = 222 in.*
- *Center of gravity (loaded) with respect to a front corner:*

  X = 50.50 in. (horizontal transverse direction)

  Y = 111.34 in. (horizontal longitudinal direction)

  Z = 121.34 in. (vertical direction)
- *Weights and rotational inertia used in analyses*

  Weight AHSM empty = 334.4 kips

  Weight of loaded DSC = 100 kips

  Loaded AHSM: Wxx (CG) = 24,204 k-ft^2 (Mxx = 9.02x10^6 lb-in-sec^2)

  Loaded AHSM: Wyy (CG) = 13,712 k-ft^2 (Myy = 5.11x10^6 lb-in- sec^2)

  Loaded AHSM: Wzz (CG) = 16,556 k-ft^2 (Mzz = 6.17x10^6 lb-in-sec^2)

  Weight of end shield wall = 197.4 kips

  Shield wall thickness = 3 ft

  End shield wall Wxx = 11,949 k-ft^2

  End shield wall Wyy = 5,778 k-ft^2

  End shield wall Wzz = 6,467 k-ft^2
- *Lowest frequencies of the loaded module*

  $f_{longitudinal}$ *= 32.35 hz*

  $f_{transverse}$ *= 37.69 hz*

  $f_{vertical}$ *= 48.47 hz*
- *HSM damping*

  ξ *= 7%*

The bases of the modules are modeled with horizontal rigid beams located at an elevation consistent with the surface of the pad (Z = 1.5 ft).

Each module is connected to the pad by three-dimensional rigid springs at six points. The configuration of the springs does not prevent the pad from bending and are configured to minimize any stiffening effects on the concrete pad. The vertical springs force the six points of vertical connection to remain on a plane; however, the pad inside the area defined by those six vertical connection points is able to experience bending deformations.

The HSMs located at the ends of each loading campaign have an end shield wall attached to them. These end shield walls are added to the respective HSM model as a lump weight and weight moment of inertia connected to the center of gravity of the HSM by a rigid beam.

The SASSI [7-63] SSI models of the storage pad for each loading configuration are shown in Figure 7-33, Figure 7-34, and Figure 7-35 for the 22, 42 and 92 loading configurations, respectively.

The concrete pad is analyzed as surface founded at the bottom of the excavation depth using corresponding surface input motions compatible with the strain compatible soil profiles. The SASSI [7-63] computer program is used for SSI analyses.

7.6.4.4 SSI Results

As shown in Table 7-29, are the 27 SSI analyses performed for three different configurations of storage units on the pads, for three input earthquakes, and for three sets of soil properties.

7.6.4.4.1 Maximum Accelerations and Envelope Response Spectra

The maximum calculated acceleration at the center of gravity of the casks for each of the 27 cases evaluated are presented in Table 7-34.

As shown in these tables, the maximum accelerations at the CG of the modules are:

[ ]

The envelopes of the acceleration response spectra at the base and CG of the HSMs are shown in Figure 7-36 through Figure 7-38, and Figure 7-39 through Figure 7-41, respectively. These spectra are the envelope of the spectra for all modules, all loading cases, all soil properties, and all input earthquakes.

All Indicated Changes are in response to RSI NP-5.4

7.6.4.4.2 *Sliding and Rocking Stability Evaluations*

The potential for sliding of the HSMs is evaluated in this section. For each SSI response time history earthquake, each soil case, each loading configuration, and at each time step the following expression is calculated:

$$\mu_e(t) = [(a_x(t)^2 + a_y(t)^2)^{1/2}]/(1-a_z(t))$$

Where:

$\mu_e(t)$ *is the coefficient of friction needed to prevent sliding at each time step*

$a_x(t)$ *is the acceleration at the CG of the module in the X direction at time t*

$a_y(t)$ *is the acceleration at the CG of the module in the Y direction at time t*

$a_z(t)$ *is the acceleration at the CG of the module in the Z direction at time t*

The coefficient of friction μ *between the bottom of the module and the concrete pad is 0.6 [7-29]. Thus, if the maximum value of* $\mu_e(t)$ *is lower than 0.6, then no sliding occurs.*

Figure 7-42, Figure 7-43, and Figure 7-44 show the controlling results for the 22, 42 and 92 loading configurations, respectively. These plots represent the maximum value for all the time steps of the time history. These results show that the end module has the potential for sliding for the UB soil case for the Coyote Lake and Norcia earthquakes. The higher friction demand is for the Norcia earthquake for the first loading (22 modules on the pad). The sliding distance for this case is calculated using the conservative approach given in [7-44].

Effective coefficient of friction μ_e

$$\mu_e = \mu\ [1-0.4A_z/g]$$

Where μ *is the coefficient of friction = 0.6, and*

A_z *is the vertical peak input acceleration:* $A_z/g = 0.35$ *(the CG value was conservatively used).*

$$\mu_e = 0.6\ [1-0.4 \times 0.35] = 0.516$$

Sliding coefficient c_s:

$$c_s = 2\mu_e g = 2 \times 0.516 \times 386.4 = 398.77$$

$$c_s/g = 1.032$$

Best estimate sliding distance δ_s

All Indicated Changes are in response to RSI NP-5.4

$\delta_s = c_s/(2\pi f_{es})^{1/2}$

f_{es} is the lowest frequency at which the horizontal 10% damped spectral acceleration SA_{vh} equals c_s, where

$SA_{vh} = [SA_{h1}^2 + 0.16SA_{h2}^2]^{1/2}$

in which SA_{h1} and SA_{h2} are the 10% damped spectral accelerations for each of the two orthogonal horizontal components, where SA_{h1} is the larger of the two spectral accelerations.

Conservatively, the 7% damped horizontal spectra for the critical module (UB soil, Norcia earthquake, 22-loading configuration, end module) are used. Two calculations were made: one with the spectra at the base of the module, and the other with the spectra at the CG of the module.

For the case of using the spectra at the base,

[ ]

7.6.4.4.3 <u>*Rocking Evaluation*</u>

The potential of each module to rock and uplift during an earthquake is evaluated in this section. For each earthquake, soil case, loading and at each time step the rocking potential around the YY axis is evaluated.

For the case of modules without a shield wall, the following expression is calculated at each time step:

Overturning moment $M_o(t) = a_x(t) \times H_{cg\text{-}HSM}$

Restoring moment $M_r(t) = (1 - a_z(t)) \times R$

Overturning potential $O_p(t) = M_r(t) / M_o(t)$

$a_x(t)$ *is the horizontal acceleration in the X direction at time t*

$a_z(t)$ *is the vertical acceleration at time t*

$H_{cg\text{-}HSM}$ *is the HSM CG height = 10.11 ft*

R is half of the width of the module = 4.21 ft

For the case of modules with a shield wall, the following expressions are calculated at each time step:

When the acceleration $a_x(t)$ *is in the direction toward the module side without the shield wall:*

Overturning moment $M_o(t) = a_x(t) \times (H_{cg\text{-}HSM} \times W_{HSM} + H_{cg\text{-}wall} \times W_{wall})$

Restoring moment $M_r(t) = (1\text{-}a_z(t)) \times (W_{HSM} \times R + W_{wall} \times (2R + 1.5))$

When the acceleration $a_x(t)$ *is in the direction toward the module side with the shield wall (assuming that the shield wall is rigidly connected to the module):*

Overturning moment $M_o(t) = a_x(t) \times (H_{cg\text{-}HSM} \times W_{HSM} + H_{cg\text{-}wall} \times W_{wall})$

Restoring moment $M_r(t) = (1\text{-}a_z(t)) \times (W_{HSM} \times (R + 3) + W_{wall} \times 1.5)$

Overturning potential $O_p(t) = M_r(t) / M_o(t)$

$H_{cg\text{-}wall}$ *is the wall CG height = 9.25 ft*

W_{HSM} *is the HSM weight = 434.3 kips*

W_{wall} *is the wall weight = 197.4 kips*

Thus, if the maximum $O_p(t)$ *is lower than 1 then no uplift will occur.*

Figure 7-45, Figure 7-46, and Figure 7-47 show plots of enveloping maximum rocking overturning potential of each HSM, for the 22, 42 and 92 loading configurations, respectively, for all soil cases and for all three earthquakes. It is seen that the Coyote Lake earthquake controls for the three loading configurations. The maximum $O_p(t)$ *value for all time steps is plotted in these figures.*

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These results show that the highest potential for rocking occurs for the UB soil case, 22 HSMs loading configuration, and for the Coyote Lake. Therefore, the rocking angle and the uplift height are calculated for the controlling HSM using the conservative approach given in [7-44].

Horizontal spectral acceleration capacity SAH_{CAP}*:*

$SAH_{CAP} = 2g(f_1(\theta) - 1)/(F_H\, F_V\, \theta)$

$f_1(\theta) = \cos\theta + a \times \sin\theta$

$a = R / H_{cg\text{-}HSM} = 4.21/10.11 = 0.4164$

The static instability angle α *is defined in [7-44] as:*

$\alpha = \tan^{-1}(a) = 22.6$ *degrees*

$F_H = 1$ *(since the lateral mass is equal to the vertical mass)*

$F_V = [1 + ((a/F_H)*(SAV/SAH))^2]^{1/2}$

θ *is the rotation angle.*

SAV/SAH is the ratio of vertical to horizontal spectral accelerations determined at the effective rocking frequency f_e *and effective damping* β_e*.*

$f_e = (1/2\pi) \times [(2\,(f_1(\theta)\,-1)\,g\,/\,(C_I\,\theta^2\,H_{cg\text{-}HSM})]^2$

$\beta_e = \gamma / [4\pi^2 + \gamma^2]^{1/2}$

$C_I = I_B / M\,H^2_{cg\text{-}HSM}$

$\gamma = -2\,LN(C_R)$

$C_R = [1 - (2\,a^2 / C_I)]$

I_B *is the mass moment of inertia of the module about the rotation edge.*

$I_B = I_{CG} + M\,H^2_{cg\text{-}HSM} = 5{,}109{,}998.76 + 1{,}123.96 \times 121.32^2 = 21{,}653{,}122.4$ *lb-in-sec*^{2}

M is the module mass = 1,123.96 lb-sec^2*/in*

This is an iterative process until the horizontal spectral demand SAH_{DEM} *equals the* SAH_{CAP} *for a rotation angle (*θ*), an effective rocking frequency (*f_e*), and an effective damping(* β_e*).*

The maximum uplift height is:

$$H_U = 2\,R\,\sin\theta$$

Table 7-35 lists the values of the parameters for the calculation of the rotational angle and the uplift height. From Table 7-35, the maximum rotation angle is calculated as: $\theta = 0.0008$ radians = 0.046 degrees. This is much smaller than the instability angle: $\alpha = 22.6$ degrees required to overturn the HSM. The maximum uplift is calculated as: $H_U = 0.0808$ inches.

Thus, it is concluded that the rocking angle and uplift are very small.

7.6.4.4.4 Results and Conclusions

The AHSM was selected for the SSI analyses of the NUHOMS® storage pad. The AHSM envelopes all other HSMs because it bounds the weight and CG height of all the other HSM types planned to be loaded at the WCS CISF.

From the SSI evaluation of 27 analysis cases it was determined that the enveloping maximum accelerations at the HSMs center of gravity are as follows:

[ ]

Based on a coefficient of friction, μ, of 0.6 between the bottom of the HSM and the concrete pad documented in Section 8.2.2.2 (A)(ii) of [7-29], the calculated maximum sliding that may occur is 0.188 in. The maximum HSM tipping rotation is calculated to be 0.046 degrees, which corresponds to 0.08 in. of HSM uplift. Both the calculated sliding distance and rotation angle are considered negligible.

7.6.5 NUHOMS® NITS Storage Pad Design

The WCS CISF storage pad for the NUHOMS® HSMs is a commercial grade reinforced concrete surface structure that is classified as not important to safety (NITS). The storage pad consists of a cast-in-place, 36 in. thick reinforced concrete basemat structure.

The storage pad is designed for normal operating loads, natural phenomena loads, and severe environmental loads. The storage pad is constructed using 4,000 psi 28 day compressive strength concrete. Reinforcing consists of #11 ASTM A 706 or ASTM A 615, Grade 60 steel rebar of 60,000 psi yield strength meeting the caveats in ACI 349, Section 21.2.5, spaced at 10 inches each way each face.

The NUHOMS® storage pad design is shown in Figure 7-53.

All Indicated Changes are in response to RSI NP-5.4

7.6.5.1 Design Inputs

Material Properties

[ ]

Soil Properties

[ ]

Design Loads

Dead Load *- The design dead load consists of the weight of the reinforced concrete pad.*

Live Load *- Live loads include the weight of loaded HSMs, and operational loads (handling equipment and occupancy load).*

- *Weight of bounding AHSM loaded with heaviest DSC, increased by 5%,* $W_{AHSM+DSC}$ *= 449.8 kip* *(Ref. [7-29], Table R.3-1)*
- *Weight of End Shield Wall, increased by 5% = 197.4 kips*
- *Height of* HSM_{AHSM} *= 222 in* *(Ref. [7-29], Section R.1.5)*
- *Height of CG of HSM, including DSC,* CG_{AHSM} *= 121.3 in* *(Ref. [7-29], Section R.1.5)*
- *Footprint dimensions of* HSM_{AHSM} *= 101 in x 235 in* *(Ref. [7-29], Section R.1.5)*
- *300 Ton installation capacity crane: total loaded weight = 1010 kips*

All Indicated Changes are in response to RSI NP-5.4

Snow Load *- The ground snow load of 10 psf, per Figure 7-1, ASCE 7- 05 [7-34], at the WCS CISF is enveloped by the live load.*

Thermal Load *- The maximum thermal load corresponds to the short term blocked vent condition. Thus, the thermal load is inconsequential insofar as the pad's structural integrity is concerned; the development of significant thermal stresses in the pad for a short term event are inhibited due to the low thermal conductivity of the concrete and the large thermal mass of the pad. Therefore, thermal loads are considered negligible.*

Flood Load *- Flood load is not part of the analysis because the Storage Pad is located above the flood elevation. A flood plain study was performed for the site in Reference [7-50] which shows that the Storage Pad is above the 100-year, 500-year, and probable maximum precipitation (PMP) flood levels.*

Rain Load *- The rain load due to ponding is negligible for the Storage Pad as the approach slabs are sloped to carry all rain water away from the HSMs.*

Wind Load *- Design basis wind pressure (W) and design basis tornado wind pressure (W_t) are governed by the seismic loads. By inspection the tornado wind load governs the regular wind load.*

*Per Reference [7-35], the postulated maximum tornado wind speed is 230 mph for Region I, which is conservative because Andrews, Texas is in Region II. The corresponding wind pressure is calculated using the methods of ASCE 7-10, [7-64]. The equivalent velocity pressure is $0.00256*230^2=135.4$ psf. This wind load is applied to the front face of the HSM array since a side load will be resisted by all of the HSMs in a given row. This equates to a force: 135.4 psf * 8'-5" (width) * 20'-7" (height) * 1.3 = 30,494 lbs, where 1.3 is a shape factor per ASCE 7-10.*

*The maximum seismic acceleration in the front-to-back (i.e., longitudinal) direction of the HSM resulting from the SSI analyses documented in Section 7.6.4 is 0.416g. Considering the weight of the HSM of 449.8 kips (see Live Load section above), the calculated longitudinal seismic load is: 0.416 * 449,800 lbs = 187,117 lbs. This is significantly higher than the maximum tornado wind loading of 30,494 lbs. Therefore, seismic governs.*

All Indicated Changes are in response to RSI NP-5.4

Seismic Inertia Load *- The 10,000-year return period earthquake response spectra were developed as part of the site-specific seismic hazard evaluation in Reference [7-33]. These are SSE equivalent ground motions. The strain-compatible soil properties and ground motion time histories documented in [7-33] were used as input to the SSI analyses.*

As discussed in Section 7.6.4*, a total of 27 SSI analyses are performed accounting for variations in input ground motions (3 sets of time histories), soil properties (3 sets of soil properties), and storage pad loading sequence configurations (two partial loadings and a fully loaded pad). The results of all 27 SSI analyses are enveloped to provide the enveloping maximum accelerations at the HSMs center of gravity (CG) used for pad design. The enveloping maximum bounding acceleration values at the CG of the loaded HSMs used for the design of the storage pad are:*

[ ]

Tornado-Missile Impact Load *- The NUHOMS® HSMs are evaluated for tornado missile impact as documented in the applicable UFSAR (e.g., Reference [7-29] for the HSM Models 80 and 102). Tornado-missile impact directly to the storage pad is not considered here because such an extreme condition would result in localized damage to the storage pad, but not result in a loss of stability of the storage pad. In the case of such an accident, the storage pad would need to be evaluated and repaired as needed. This is consistent with Table 3-3, NUREG-1536 [7-42], which states for the tornado load case that*

> *"[t]he load combination (capacity/demand >1.00 for all sections) shall be satisfied without missile loadings. Missile loadings are additive (concurrent) to the loads caused by wind pressure and other loads; however, local damage may be permitted at the point of impact if there is no loss of intended function of any structure important to safety."*

7.6.5.2 *<u>Design Basis</u>*

The design of the WCS CISF NITS storage pad is in accordance with the provisions of ACI 349-06 [7-31] and NUREG-1536 [7-42].

All Indicated Changes are in response to RSI NP-5.4

7.6.5.3 Load Combinations

In accordance with Section 5.4.3.4, NUREG-1567 [7-28], load combinations for reinforced concrete structures including Independent Spent Fuel Storage Installations (ISFSIs) shall meet the requirements of Table 3-3, NUREG-1536 [7-42], and ACI 349 [7-31]. Load combinations from these two sources are presented only for the applicable loads described in Section 7.6.5.1. Non applicable loads (e.g., piping, pipe break, soil, etc.) or loads not considered per the above discussion (thermal, snow, rain, wind and flooding) are not included. Only the seismic load is considered. The ACI 318-08 [7-39] load combinations are enveloped by ACI 349-06 [7-31] load combinations.

ACI 349-06 Load Combinations

$U = 1.4D$ *(Ref. [7-31], Eq. 9-1)*

$U = 1.2D + 1.6L$ *(Ref. [7-31], Eq. 9-2)*

$U = 1.2D + 0.8L$ *(Ref. [7-31], Eq. 9-3)*

$U = D + 0.8L + E_{SS}$ *(Ref. [7-31], Eq. 9-6)*

$U = D + 0.8L$ *(Ref. [7-31], Eq. 9-8)*

**Note: All dead loads are considered at 0.9 where the dead load reduces the effects of other loads. Similarly, live loads are taken as zero where the live load reduces the effects of other loads.*

NUREG-1536 Load Combinations

$U = 1.4D + 1.7L$ *(Ref. [7-42], Table 3-3)*

$U = 1.05D + 1.275L$ *(Ref. [7-42], Table 3-3)*

$U = D + L + E_{SS}$ *(Ref. [7-42], Table 3-3)*

**Note: All dead loads are reduced by 5% where dead load reduces the effect of other loads.*

Governing Load Combinations

Governing load combinations are compiled based on the code required load combinations, considerations for reduced dead and live load effects, and directions of seismic excitation. The governing load combinations evaluated in the design of the storage pad are:

$U \geq 1.4D + 1.7L$

$U \geq D + L \pm E_{SS}$

All Indicated Changes are in response to RSI NP-5.4

7.6.5.4 *Analysis Methodology*

Equivalent static analyses of the storage pad are performed using finite element models developed using the ANSYS program [7-65]. The analysis methodology is based on elastic small displacement theory except for the presence of contact elements between the bottom of the pad and the top of its supporting soil. This feature allows the pad to lift off the soil should the physics of the problem require that to occur.

The analyses consider the sequence of HSM installation on the storage pad. Thus, five separate finite element models are developed, which consider four partially loaded configurations and a fully load pad configuration. The five analysis models are listed in Table 7-36*.*

The five models consist of four partially loaded storage pad models with two, four, eleven, and twenty one rows of back-to-back HSMs, and a model of the fully loaded storage pad. The model configurations were selected to provide bounding internal forces and moments resulting from the applicable loads presented in Section 7.6.5.3*. Table* 7-36 *summarizes the five finite element models. Figure* 7-48 *shows the finite element model for the fully loaded pad configuration consisting of a 2 x 46 array of AHSMs. The model includes the soil supporting the storage pad (elements in red), the storage pad (elements in light blue), and the HSMs (elements in dark blue). All the models are similar except for the number of HSMs modeled on the storage pad.*

The SSI analysis discussed in Section 7.6.4 *determined the bounding maximum accelerations at the CG of the HSMs. The bounding accelerations correspond to the Upper Bound soil property case, 2x11 HSM array loading configuration, and the Coyote Lake and Norcia earthquake seismic inputs. These controlling maximum accelerations and enveloping values used in the structural evaluation of the storage pad are shown in Table* 7-37*.*

The peak accelerations in the two horizontal directions and the vertical direction applied at the CG of each HSM are used as the seismic accelerations to compute the internal stresses due to seismic loads. These internal stresses are then integrated to determine the internal forces and moments in the storage pad. These forces and moments are used to size the reinforcement and evaluate concrete stresses in accordance with ACI 349-06.

Concrete Pad Modeling

The pad is modeled using ANSYS SOLID45 8-node brick elements. No special features of the element are invoked. Thus the element uses its full integration scheme. In order to develop accurate internal forces and moments, four elements are used through the thickness of the pad. The mesh of the pad around the HSM is designed to accommodate the configuration of the HSMs. The concrete is designated Material Type 1 and is assumed to be homogenous with Young's modulus equal to 57,000 $\sqrt{f'c}$ *psi.*

All Indicated Changes are in response to RSI NP-5.4

The dimensions of the NUHOMS® storage pad model are: 480'-0" long x 50'-0" wide x 3'-0" thick. The loaded footprint is 465'-2" (length) and 39"-2" (width). Thus the ISFSI pad length includes an extra 7 feet on either end along the length of the pad and 5 feet on either side of the pad in the transverse direction, as described in the SSI analysis in Section 7.6.4. *The pad dimensions are rounded up to 480 feet x 50 feet for analysis purposes.*

The pad is to be constructed with 4,000 psi compressive strength concrete, elastic Young's modulus, E = 57,000 $\sqrt{4000}$ *=3,605 ksi, and a Poisson's ratio of 0.17. These concrete properties are consistent with the SSI analysis. The concrete unit weight is taken at 135 pcf. This value was chosen to satisfy the ACI 349-06 requirement that stipulates the use of 90% of the dead weight if it assists in the load combination (Section 9.2.3 of [*7-31*]). The lighter dead weight of the concrete requires the pad to flex more than it otherwise would in order to resist the effect of overturning by the application of the horizontal seismic load at the CG of the HSMs. The concrete pad elements are the only part of the model with a weight density.*

A gap of 0.2 ft is modeled between the concrete storage pad and the adjacent soil along the perimeter. This gap ensures that the soil does not artificially constrain bending of the concrete pad.

Soil Modeling

*The soil is modeled using nine material properties divided into nine layers of elements, which are modeled using the ANSYS SOLID45 8-node brick elements. As with the use of this element for the pad, no special features of this element were invoked. The thickness, depth and material properties of each soil layer in the ANSYS model are consistent with the values provided in [*7-32*]. Figure* 7-49 *shows the soil layers and the material properties of each layer used in the ANSYS model.*

In conjunction with depth, the soil model is also required to extend beyond the edges of the concrete pad footprint a distance that will mitigate any boundary condition effects that could affect the pad results. Therefore, the soil extends 1.5 times the soil depth or (100 1.5=) 150 ft beyond the edge of the pad in all horizontal directions. This meets the requirement of St. Venant's Principle, which requires an extension of at least 1.0 times the soil depth. Figure* 7-50 *shows the soil model with the concrete pad elements removed. Figure* 7-50 *show the various soil materials using different colors for the elements in each layer corresponding to those shown in Figure* 7-49.

The soil material properties used are the static properties, equal to or lower than the dynamic soil properties and, therefore, conservative for use in an equivalent static analysis.

*The soil properties used in the equivalent static analysis are given in Appendix C of [*7-32*] and are listed in Table* 7-38.

All Indicated Changes are in response to RSI NP-5.4

Contact Elements

The pad rests on the soil through the use of target/contact elements placed at the interface between the pad and the soil elements.

The contact elements are generated using the ANSYS "Contact Wizard" that uses surface to surface contact elements. The ANSYS software requires that the contact elements be specified between two surfaces, a "target" surface and a "contact" surface, which are defined as two different element types. The bottom surface of the pad is designated the "target" surface, Element Type #6, TARGE170, and the top surface of the soil is designated the "contact" surface, Element Type #7, CONTA173. These elements transmit compression and shear loads from one surface to the other. No tensile forces are transmitted through this interface. These elements are, therefore, non-linear elements.

These elements are actually surfaces that overlay the structural elements and they can be thought of as permitting the interfacing characteristics desired, i.e., permitting compressive and shear forces between the surfaces when penetration is attempted, and permitting separation between the surfaces with no forces present when gaps are present. An alignment of the meshes of the two surfaces such that the nodes are coincident is not necessary. ANSYS handles all the necessary geometric details to create the compression and shear only elements. The element stiffness and convergence parameters are computed from the geometry and material properties of the underlying elements.

The CONTA173 elements utilize KEYOPT (12) = 1 which translates into a "rough" contact surface between the bottom of the pad and the soil. This is considered conservative because by fixing the pad the internal forces in the pad can be maximized.

AHSM

*The ANSYS models used for the structural analysis consider that the storage pad is loaded with AHSMs. The AHSM bounds the weight and CG of the other HSM types planned to be used at the WCS CISF. The AHSM is also the HSM with the smallest footprint. Thus, use of the AHSM provides for a bounding storage pad design. The weights used in the ANSYS models are increased by 5% to 449.8 kips (334.3 kips (HSM) + 110 * 1.05 kips (DSC)) for the loaded AHSM and 197.4 kips for the end shield wall.*

All Indicated Changes are in response to RSI NP-5.4

For purposes of the analysis the AHSMs are modeled as block assemblies using SOLID45 elements that are attached directly to the surface of the concrete pad. The top elevation of the block assembly representing the HSM corresponds to the CGs of the AHSM. The HSMs are modeled to the height of the CG above the pad surface, which is 121.3 in. In this modeling approach the function of the block assemblies representing the HSMs is to transmit the seismic inertial loads and HSM weight to the pad. The loads applied to the pseudo HSM CG are transferred to the base through another contact element application with a "pilot node" option. The node representing the HSM CG is paired with the rest of the nodes at the same elevation of the HSM. The node at the CG is set as the pilot node. The weight and the seismic loads are applied at this pilot node at each pseudo HSM block assembly. Thus, the pilot node becomes the master node and the rest of the paired nodes become slaves. The applied forces are distributed to the slave nodes following a rigid-body principle. The HSM distributes the force onto the pad by the theory of elasticity. The definition and application of the loads are described below. The modeling approach described above maximizes the moments delivered to the storage pad due to the horizontal seismic load. Figure 7-51 *shows the pseudo HSM block assemblies.*

The HSMs are modeled with Element Type #2. Element Type #2 is the ANSYS SOLID45 8-node brick element. No special features of this element are invoked. Thus, the element uses its full integration scheme, and its extra displacement shapes are included. Since each HSM a separate unit, a 2-in. gap is modeled between the side walls and rear walls of the HSM block assemblies. This is shown in Figure 7-52.

*Consistent with Table 8.1-3, [*7-29*], the Young's Modulus for the pseudo HSM material is based on a 28-day concrete compressive strength of 5,000 psi, which correlates to a modulus of elasticity of 4,000 ksi. Additionally, the Poisson's ratio is set to 0.2 for the HSM material.*

Boundary Conditions

*The only boundary conditions in the models are on the soil mass. The nodes of the soil elements are constrained normal to the bottom and normal to the sides on all sides of the soil. The sides of the soil mass are far enough away (1.5 * soil depth) from the pad that boundary conditions do not significantly affect the response of the pad.*

7.6.5.5 *Analysis Results*

The five ANSYS analysis models discussed in Section 7.6.5.4 *are analyzed for the load combinations discussed in Section* 7.6.5.3*. Since these are static analyses the seismic load combination includes additional cases to consider sign reversal of the applied maximum seismic accelerations resulting from the SSI analysis described in Section* 7.6.4*, and shown in Table* 7-37.

All Indicated Changes are in response to RSI NP-5.4

The stresses output by the SOLID45 elements are post-processed to calculate the maximum internal moments and shear forces. Table 7-39 summarizes the results for each of the five loading configuration analysis models. The enveloped max/min values of the moments and shear forces obtained from all five models used for the design of the pad are summarized in Table 7-40.

Acceptance Criteria

Shear:

$\phi V_n \geq V_u$, *Section 11.1.1 of ACI 349 [7-31]*

$\phi = 0.75$ *for Shear, Section 9.3.2.3 of ACI 349 [7-31]*

Bending:

$\phi M_n \geq M_u$

$\phi = 0.9$ *for Bending, Section 9.3.2.1 of ACI 349 [7-31]*

Reinforcement:

Minimum Reinforcement = $A_{s,min} = \frac{3\sqrt{f'c}}{fy} b_w * d$, *Eq. 10-3 ACI 349 [7-31]*

But Not Less than, $\frac{200 * b_w * d}{f_y}$, *Section 10.5.1 of ACI 349 [7-31]*

Sizing of Reinforcement/ ACI Code Requirements

The reinforcement is evaluated for the ACI 349-06 Code requirements and consists of #11 bars at 10 inches on center top and bottom, each way, with mechanical splices specified as 11L Bar Locks. As an alternative, lap splices may be used in lieu of mechanical splices. The mechanical coupler is the more critical case because it reduces the effective depth of the section.

The main reinforcement in X direction is calculated as:

$d_{slab1} = 36"\text{-}3" - 3.1" \div 2 = 31.45"$	*Effective depth*
$M_u = 234{,}235 lbf - in$	*Design moment from Table 7-40*
$A_{11} = 1.56 in^2$	*Cross section of #11*
$f_c' = 4000 psi$	*Compressive strength of concrete*
$F_y = 60 ksi$	*Tensile strength of rebar*

All Indicated Changes are in response to RSI NP-5.4

$R_t = \frac{M_u}{0.9 \times 1in \times d_{slab1}^2} = 263psi$ *Flexural resistance factor*

$\rho = 0.0045 + \frac{263-259}{287-259} \times 0.0005 = 0.0046$ *Reinforcement ratio*

$A_s = \rho \times 10in \times d_{slab1} = 1.45in^2$ *Steel required per 10" wide.*

Therefore, provide # 11 rebar @ 10" o.c. = 1.56 in². OK

The main reinforcement in Y direction is calculated as:

$d_{slab2} = 36\text{-}3''3.1 - 1.41 \div 2 = 29.2"$ *Effective depth*

$M_u = 186{,}555lbf - in$ *Design moment from Table 7-40*

$R_t = \frac{M_u}{0.9 \times 1in \times d_{slab2}^2} = 243psi$ *Flexural resistance factor*

$\rho = 0.004 + \frac{259-243}{259-232} \times 0.0005 = 0.0043$ *Reinforcement ratio*

$A_s = \rho \times 10in \times d_{slab2} = 1.26in^2$ *Steel required per 10" wide.*

Therefore, provide # 11 rebar @ 10" o.c. = 1.56 in². OK

The shear capacity of the pad per ACI 349 is:

$0.75 \times 2 \times \sqrt{4000}psi \times d_{slab1} = 2984lbf/in$
Shear capacity of 1" wide pad in X direction

$0.75 \times 2 \times \sqrt{4000}psi \times d_{slab2} = 2770lbf/in$
Shear capacity of 1" wide pad in Y direction

The maximum enveloping shear demand force at a distance "d" away from the edge of the HSM array is 2769.8 lbf/in and 2760.9 lbf/in the X and Y directions, respectively. Therefore, the maximum interaction ratio for shear is as follows:

In X direction: 2769.8/2984=92.8%

In Y direction: 2760.9/2770=99.7%

Thus, no shear reinforcement is required.

All Indicated Changes are in response to RSI NP-5.4

Construction Joint Assessment

The pad will be constructed in multiple sections which will require construction joints. The reinforcement sized for the internal forces and moments will continuously run through the construction joints into the following section of concrete. This reinforcement is evaluated to determine if additional shear reinforcement is required at each construction joint.

Take the maximum shear load to equal the shear capacity of concrete pad, 2770 lbf/in,

F_z *= 2,770 lb/in.*

Over 10 inches F_z *= 2,770 lb/in * 10 in = 27,700 lb per 10 inches*

Using the methodology shown in Section 11.7 of ACI 349-06, the required shear transfer reinforcement area, A_{vf}*, is defined by:*

$$A_{vf} = \frac{V_n}{\phi f_y * \mu}$$

Where:

V_n *= 27,700 lb per 10 inches*

Φ *=0.75 for shear*

f_y *= 60,000 psi*

μ *=1.0 (ACI 349-06, Section 11.7.4.3, concrete placed against hardened concrete with surface intentionally roughened as specified in ACI 349-06, Section 11.7.9)*

$$A_{vf} = \frac{27{,}700 lb}{0.75 * 60{,}000 psi * 1.0} = 0.62\ in^2$$

Area of Steel provided = 2 # 11@10" o.c.= 2x1.41 in^2 *= 2.82* in^2 *> 0.62* in^2*, OK*

No additional shear reinforcement is necessary across the construction joints.

Skin Reinforcement Assessment

*In order to better control cracking of the concrete at the perimeter edges, additional reinforcement, known as "skin reinforcement" is computed in accordance with Section 10.6.4 of [*7-31*].*

The spacing of reinforcement closest to the tension face shall not exceed the following equation:

$$s = 15 * \left(\frac{40000}{f_s}\right) - 2.5 * c_c < 12 * \frac{40000}{f_s} \qquad \textit{Eq. 10-4 [7-31]}$$

Where:

s = vertical spacing of skin reinforcement

$f_s = 0.4*f_y = 0.4 * 60,000$ psi = 24,000 psi

c_c = 2" = least distance from surface of reinforcement to the tension face

$$s = 15 * \left(\frac{40000}{24000}\right) - 2.5 * 2" = 20"$$

$$12 * \left(\frac{40000}{24000}\right) = 20"$$

20" = 20" OK

Since the slab is 36 in. thick, more than one row of skin reinforcement will be necessary to maintain a spacing of 20 in. Use two layers of skin reinforcement spaced at 10 in.

Punching Shear Evaluation

The controlling load case for punching shear occurs during HSM installation with the loaded crane located on the pad. For purposes of this evaluation, a 300 ton crane capacity is assumed and a conservative total weight of 1010 kips is used with a square outrigger pad of 24in. x 24 in.

The punching shear capacity of the pad is checked under the scenario that the crane is on the verge of tipping over. The entire weight of the machine, counter weight and its maximum payload are supported by one outrigger leg. This is an extreme loading case for evaluation of the pad.

The effective depth of the pad is 36"-3"-3.1"/2=31.45", in which 3 in. is the concrete cover and 3.1 in. is the diameter of the coupler. The perimeter of the punching shear area is 4 x (31.45"+ 24") = 221.8". The punching shear area is 221.8" x 31.45" = 6975.68 in^2.

The factored punching shear capacity per ACI 349-06 is 0.75 x 4x (4000psi)$^{1/2}$ x 6975.68 in^2= 1,323,542 lbf or 1324 kips. The factor of safety is 1324/1010 = 1.31. Therefore, the pad is adequate for punching shear.

Bearing Pressure

The bearing stress demand is calculated for the following load combinations:

All Indicated Changes are in response to RSI NP-5.4

Case 1: DL+LL

Case 2: DL+LL+ Seismic

The entire weight of the pad installed with 92 fully loaded HSMs is considered in the evaluations. The maximum seismic accelerations of 0.548g lateral and 0.433g vertical is used for the seismic load combination. The resulting bearing stress demand is 2.273 ksf and 4.238 ksf for load combinations Case 1 and Case 2, respectively.

The ultimate bearing capacity is calculated using the Meyerhof's equations for vertical loading and inclined loading in Table 4-1 and Table 4-3 of [7-54] in consideration of Case 1 and Case 2 load combinations, respectively. The ultimate capacity for vertical loading is calculated as 64.45 ksf. The ultimate capacity for seismic loading is 12.105 ksf. Therefore, the factors of safety are 28.3 and 2.8 for Case 1 and Case 2, respectively.

<u>Elastic Settlement</u>

[ ]

All Indicated Changes are in response to RSI NP-5.4

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Table 7-29
Analyzed Cases

Case	Earthquake	Number of Modules on the Pad	Soil Properties
1	Coyote Lake	22	Best Estimate
2			Lower Bound
3			Upper Bound
4		42	Best Estimate
5			Lower Bound
6			Upper Bound
7		92	Best Estimate
8			Lower Bound
9			Upper Bound
10	Norcia	22	Best Estimate
11			Lower Bound
12			Upper Bound
13		42	Best Estimate
14			Lower Bound
15			Upper Bound
16		92	Best Estimate
17			Lower Bound
18			Upper Bound
19	Palm Springs	22	Best Estimate
20			Lower Bound
21			Upper Bound
22		42	Best Estimate
23			Lower Bound
24			Upper Bound
25		92	Best Estimate
26			Lower Bound
27			Upper Bound

All Indicated Changes are in response to RSI NP-5.4

Proprietary Information on Page 7-136 through 7-141
Withheld Pursuant to 10 CFR 2.390

All Indicated Changes are in response to RSI NP-5.4

Table 7-33
"Maximum" Passing Frequencies due to Soil and Pad Modeling

Soil Case	$f = Vs/(5xh_{soil})$ [hz]	$f = Vs/(5xh_{pad})$ [hz]
BE	*32.81*	*34.48*
LB	*25.10*	*25.82*
UB	*42.77*	*46.04*

All Indicated Changes are in response to RSI NP-5.4

Proprietary Information on Page 7-143 through 7-144
Withheld Pursuant to 10 CFR 2.390

All Indicated Changes are in response to RSI NP-5.4

Table 7-36
ANSYS Finite Element Models for Storage Pad Structural Evaluation

Model Identification	***Model Description***
HSMFUL	*Fully Loaded Pad (2x46=92 AHSM)*
HSM2CSK	*Two Rows Back-to-Back HSMs (2x2=4 AHSM)*
HSM4CSK	*Four Rows Back-to-Back HSMs (2x4=8 AHSM)*
HSMQUA	*Eleven Rows Back-to-Back HSMs (2x11=22 AHSM)*
HSMHAL	*Twenty One Rows Back-to-Back HSMs (2x21=42 AHSM)*

All Indicated Changes are in response to RSI NP-5.4

Proprietary Information on Page 7-146 through 7-147
Withheld Pursuant to 10 CFR 2.390

All Indicated Changes are in response to RSI NP-5.4

Table 7-39
Design Force/Moment Values for Evaluation
Maxima and Minima (lbf and in-lbf) Per Inch Width
(2 Sheets)

		HSMFUL	HSM2CSK	HSM4CSK	HSMQUA	HSMHAL
Case 2	Max. M_y	234,235	161,267	187,440	215,014	219,311
	Min. M_y	-21,732	-38,812	-45,974	-54,473	-56,694
	Max. F_{xz}	6,570	5,847	6,593	7,975	8,240
	Min. F_{xz}	-6,739	-4,681	-5,572	-6,502	-6,724
	Max. M_x	15,906	4,907	8,698	14,456	15,413
	Min. M_x	-186,555	-129,217	-154,110	-179,726	-186,018
	Max. F_{yz}	3,971	2,895	3,490	4,113	4,262
	Min. F_{yz}	-3,971	-2,895	-3,490	-4,113	-4,262
	Design(*) F_{xz}	2632.8	2693.1	2764.2	2674.1	2766.8
	Design(*) F_{yz}	2653.4	2711.3	2531.9	2705.1	2626.5
Case 3	Max. M_y	198,194	156,482	175,601	197,601	203,317
	Min. M_y	-16,444	-33,554	-38,897	-45,133	-47,847
	Max. F_{xz}	4,878	4,980	5,483	6,476	6,776
	Min. F_{xz}	-6,440	-4,091	-4,907	-5,796	-6,100
	Max. M_x	31,939	29,944	38,148	48,429	54,682
	Min. M_x	-158,963	-113,135	-133,856	-153,307	-162,745
	Max. F_{yz}	3,370	2,255	2,743	3,223	3,383
	Min. F_{yz}	-3,543	-2,446	-2,961	-3,450	-3,667
	Design(*) F_{xz}	2655.0	2732.0	2741.8	2758.4	2667.4
	Design(*) F_{yz}	1929.3	2088.9	2742.8	2124.6	2702.1
Case 4	Max. M_y	111,550	159,455	182,299	215,455	231,521
	Min. M_y	-26,583	-33,538	-39,997	-48,287	-52,183
	Max. F_{xz}	5,132	5,221	5,886	7,213	7,717
	Min. F_{xz}	-2,026	-3,821	-4,514	-5,154	-5,312
	Max. M_x	48,169	22,033	31,418	43,624	51,765
	Min. M_x	-70,744	-114,418	-137,809	-160,922	-171,569
	Max. F_{yz}	2,088	2,274	2,714	3,205	3,394
	Min. F_{yz}	-1,437	-2,632	-3,193	-3,761	-4,005

All Indicated Changes are in response to RSI NP-5.4

Table 7-39
Design Force/Moment Values for Evaluation
Maxima and Minima (lbf and in-lbf) Per Inch Width
(2 Sheets)

		HSMFUL	HSM2CSK	HSM4CSK	HSMQUA	HSMHAL
	Design(*) F_{xz}	2769.8	2755.1	2764.3	2764.8	2763.7
	Design(*) F_{yz}	2088.3	2274.2	2714.2	2363.5	2715.8
Case 5	Max. M_y	175,331	82,868	94,618	114,252	124,927
	Min. M_y	-86,111	-36,105	-40,937	-37,709	-44,050
	Max. F_{xz}	6,563	3,707	3,604	4,765	5,291
	Min. F_{xz}	-4,732	-1,696	-1,966	-2,161	-2,147
	Max. M_x	25,949	38,929	40,148	48,063	55,045
	Min. M_x	-145,478	-52,751	-60,789	-66,352	-65,557
	Max. F_{yz}	2,756	2,287	2,565	3,022	3,349
	Min. F_{yz}	-2,943	-1,370	-1,778	-2,452	-2,932
	Design(*) F_{xz}	2767.4	2768.6	2731.8	2750.0	2763.8
	Design(*) F_{yz}	2756.0	2286.8	2564.6	2760.9	2609.1
Case 6	Max. M_y		156,481	175,600	197,601	203,318
	Min. M_y		-33,554	-38,897	-45,133	-47,847
	Max. F_{xz}		4,980	5,483	6,476	6,776
	Min. F_{xz}		-4,091	-4,907	-5,796	-6,100
	Max. M_x		38,661	42,708	54,310	63,487
	Min. M_x		-113,684	-136,935	-160,351	-166,453
	Max. F_{yz}		2,446	2,961	3,450	3,667
	Min. F_{yz}		-2,255	-2,743	-3,223	-3,383
	Design(*) F_{xz}		2732.0	2741.8	2758.3	2667.5
	Design(*) F_{yz}		2446.1	2491.8	2705.2	2650.0

(*): According to ACI 349, the design shear force is to be taken at 'd' away from the edge of the HSM module, where 'd" is the effective depth of the concrete pad.

All Indicated Changes are in response to RSI NP-5.4

Table 7-40
Enveloping Design Forces and Moments (lbf and in-lbf) Per Inch Width

Component	*Design Values*
M_y	*234,235*
M_x	*-186,555*
$F_{yz}^{(*)}$	*2,760.9*
$F_{xz}^{(*)}$	*2,769.8*

According to ACI 349, the design shear force is to be taken at 'd' away from the edge of the HSM module, where 'd" is the effective depth of the concrete pad.

All Indicated Changes are in response to RSI NP-5.4

Initial Loading			Second Loading			Full		
1	2	end walls	1	2	end walls	1	2	end walls
3	4		3	4		3	4	
5	6		5	6		5	6	
7	8		7	8		7	8	
9	10		9	10		9	10	
11	12	1st Loading	11	12	1st Loading	11	12	1st Loading
13	14		13	14		13	14	
15	16		15	16		15	16	
17	18		17	18		17	18	
19	20		19	20		19	20	
21	22	end walls	21	22	end walls	21	22	end walls
			23	24	end walls	23	24	end walls
			25	26		25	26	
			27	28		27	28	
			29	30		29	30	
			31	32	2nd Loading	31	32	2nd Loading
			33	34		33	34	
			35	36		35	36	
			37	38		37	38	
			39	40		39	40	
			41	42	end walls	41	42	end walls
						43	44	end walls
						45	46	
						47	48	
						49	50	
						51	52	
						53	54	
						55	56	
						57	58	3rd Loading
						59	60	
						61	62	
						63	64	
						65	66	
						67	68	
						69	70	
						71	72	
						73	74	
						75	76	
						77	78	
						79	80	
						81	82	
						83	84	
						85	86	
						87	88	
						89	90	
						91	92	end walls

Figure 7-31

WCS CISF Storage Pad Analyzed Loading Configurations

All Indicated Changes are in response to RSI NP-5.4

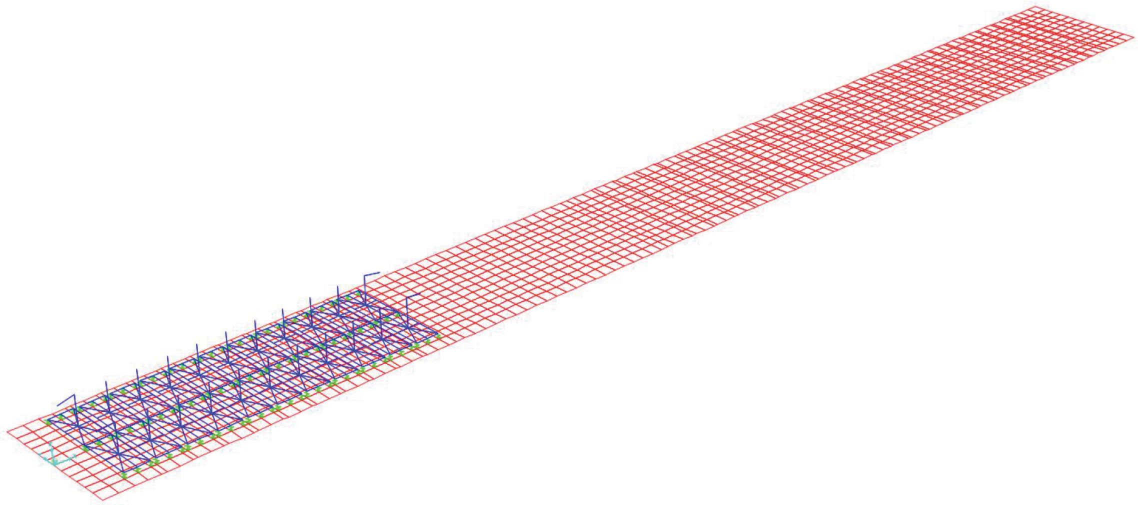

Figure 7-33
SASSI Model of Storage Pad with 22 HSMs Loaded

All Indicated Changes are in response to RSI NP-5.4

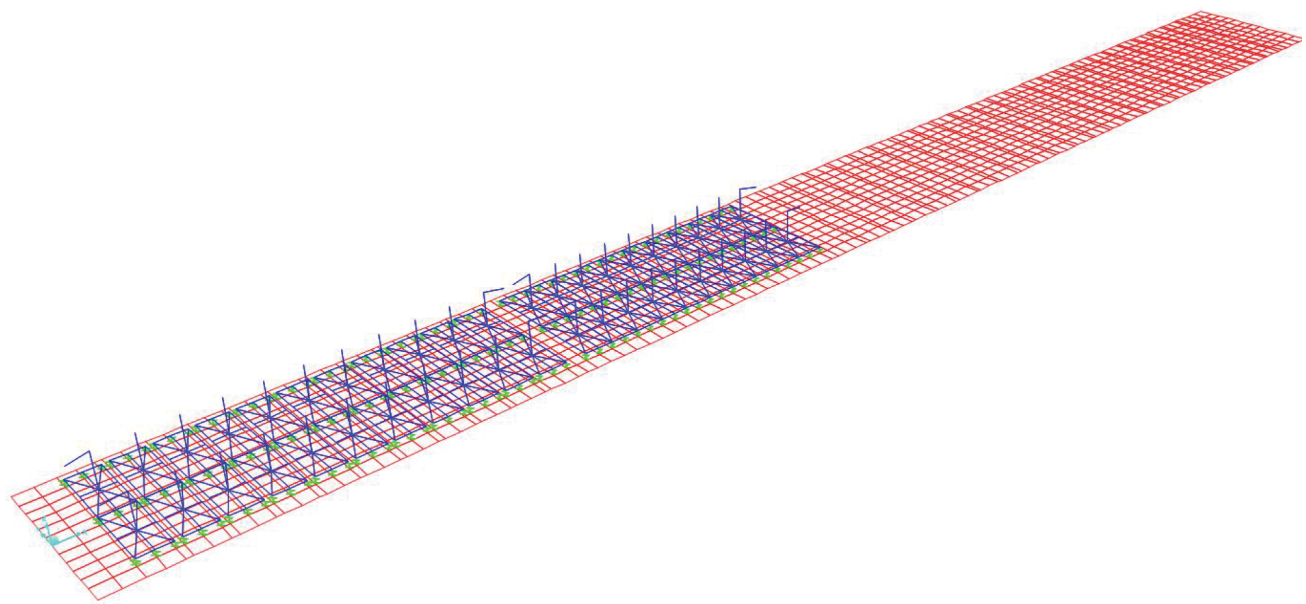

Figure 7-34
SASSI Model of Storage Pad with 42 HSMs Loaded

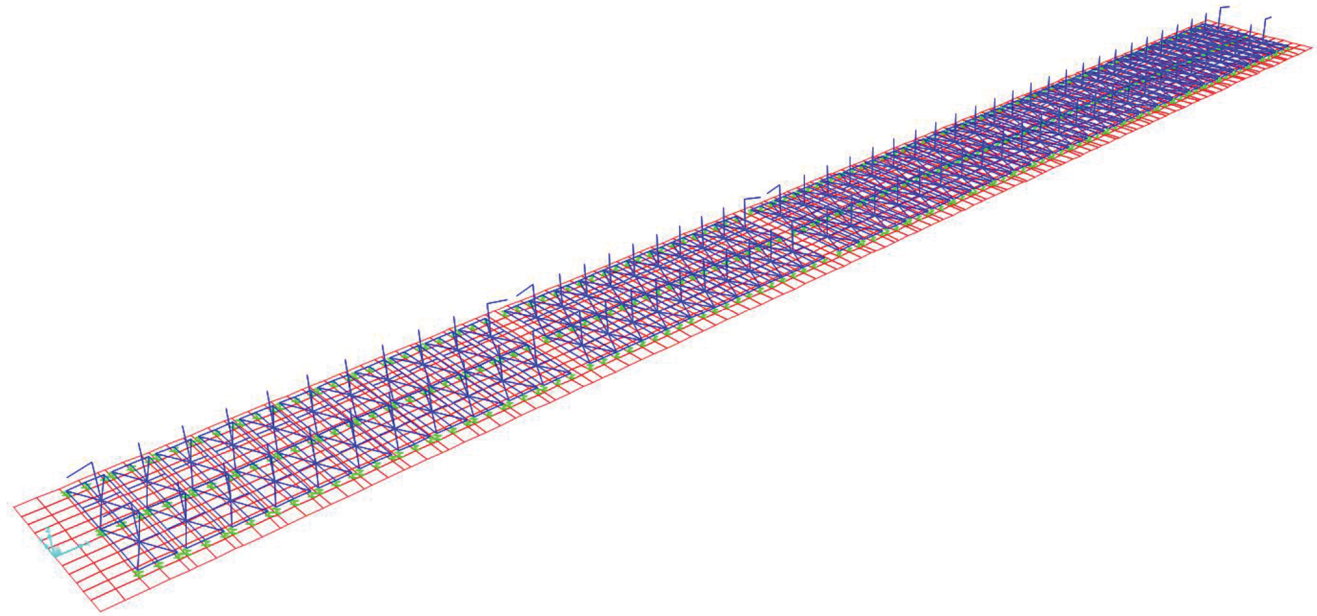

Figure 7-35
SASSI Model of Storage Pad with 92 HSMs Loaded

All Indicated Changes are in response to RSI NP-5.4

Proprietary Information on Pages 7-186 through 7-191
Withheld Pursuant to 10 CFR 2.390

All Indicated Changes are in response to RSI NP-5.4

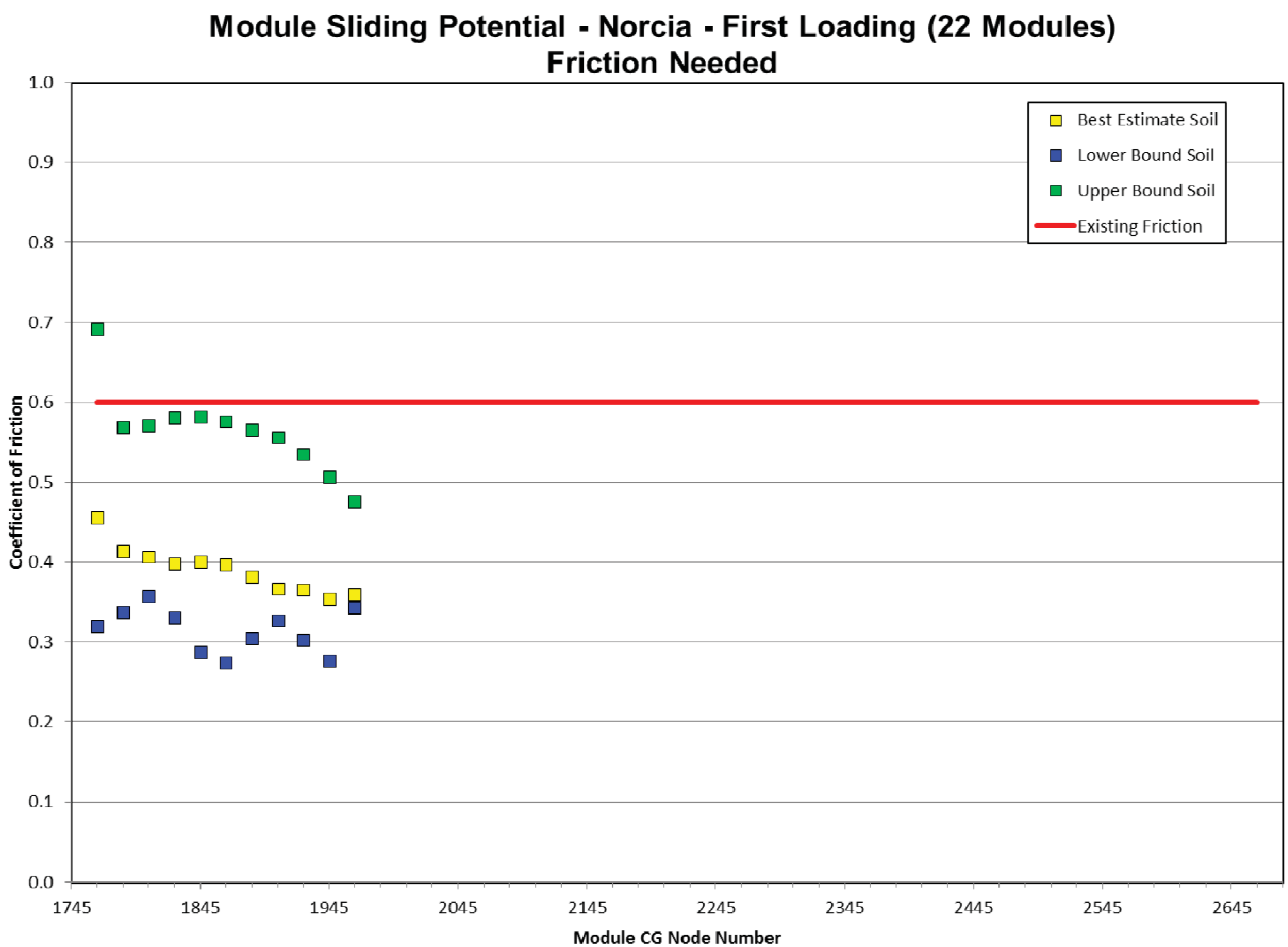

Figure 7-42
Sliding Potential – Norcia Earthquake Loading Configuration: 22 HSMs on the Pad

All Indicated Changes are in response to RSI NP-5.4

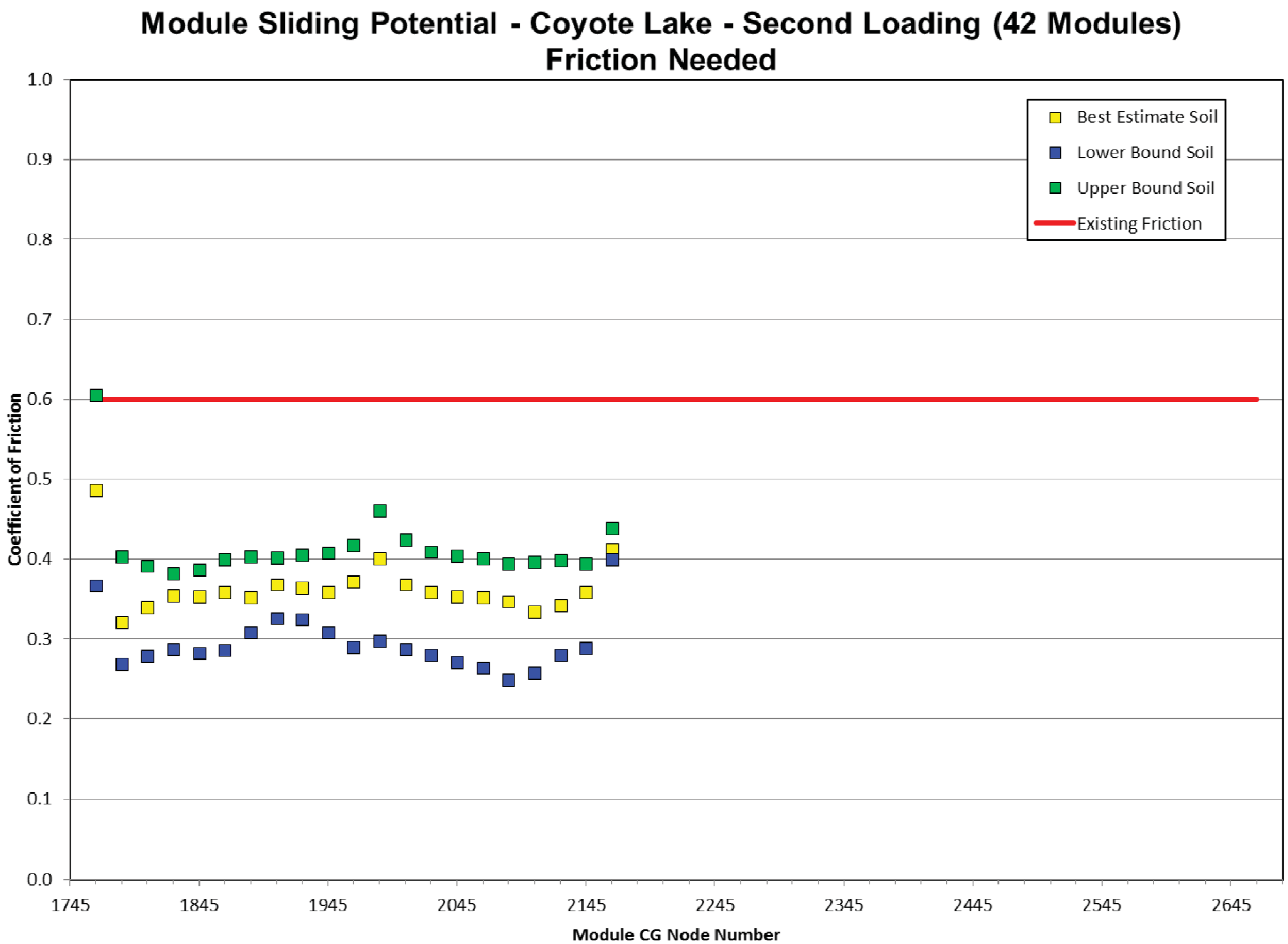

Figure 7-43
Sliding Potential – Coyote Lake Earthquake Loading Configuration: 42 HSMs on the Pad

All Indicated Changes are in response to RSI NP-5.4

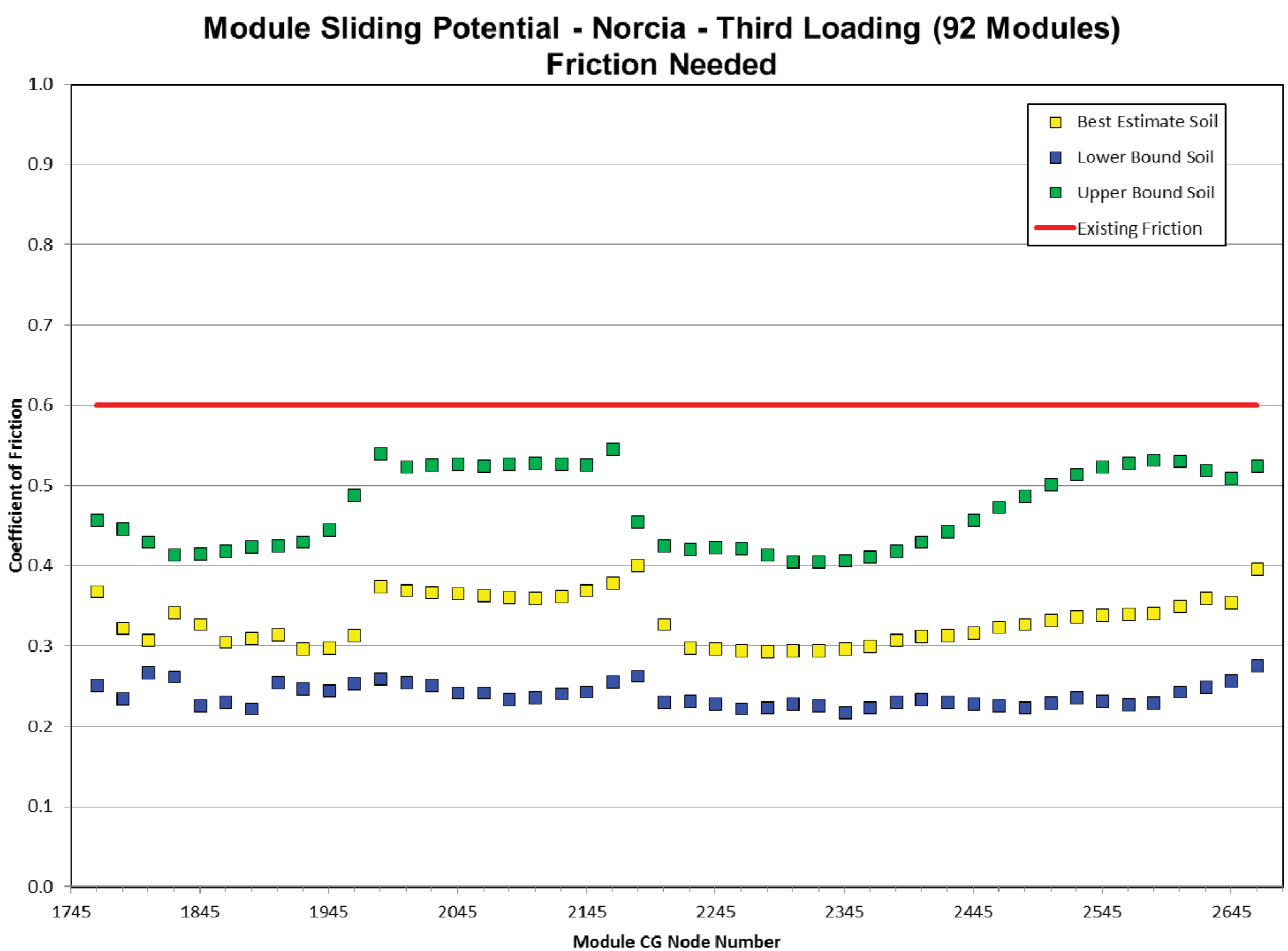

Figure 7-44
Sliding Potential – Norcia Earthquake Loading Configuration: 92 HSMs on the Pad

All Indicated Changes are in response to RSI NP-5.4

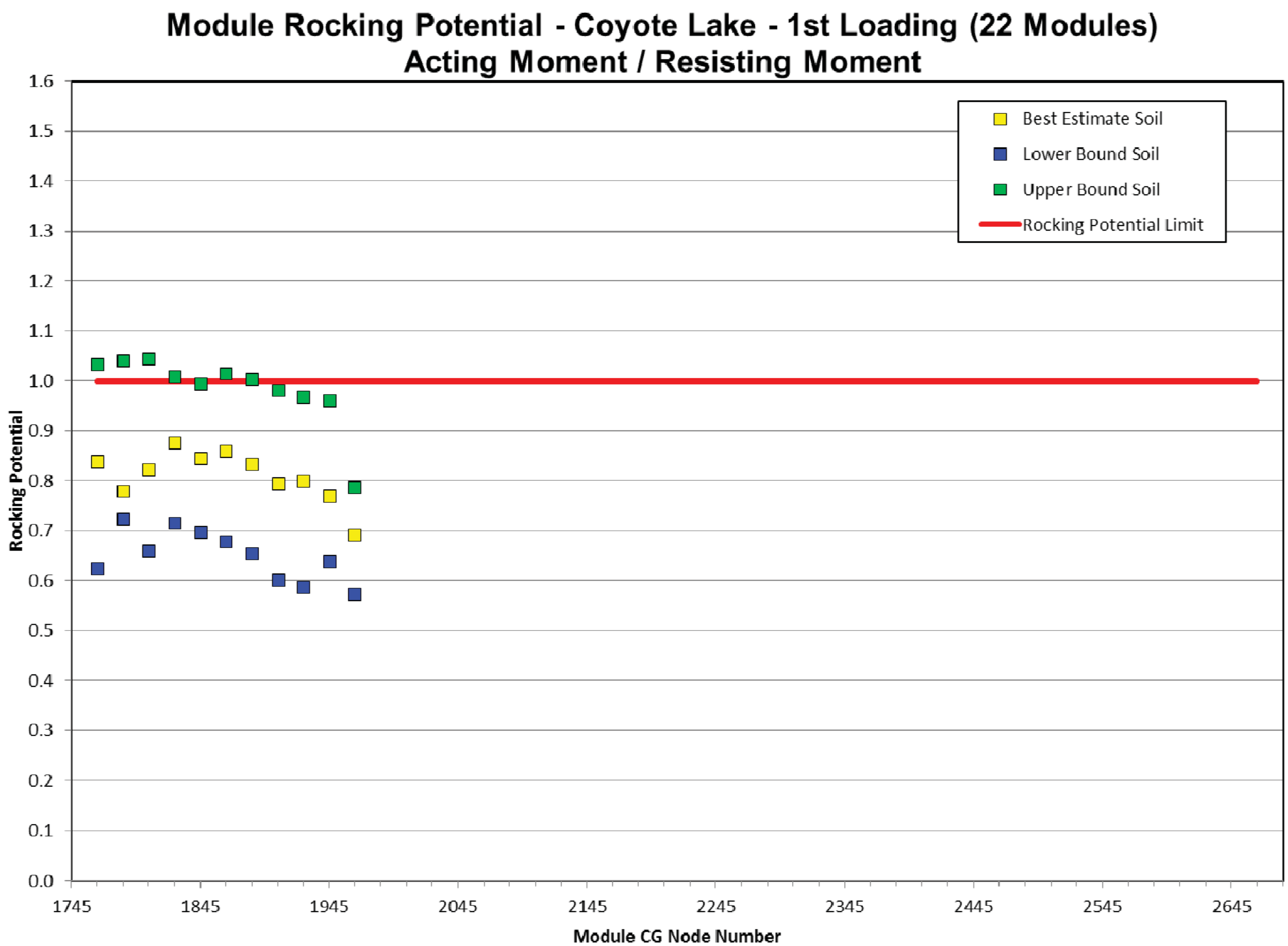

Figure 7-45
Rocking Potential – Coyote Lake Earthquake Loading Configuration: 22 HSMs on the Pad

All Indicated Changes are in response to RSI NP-5.4

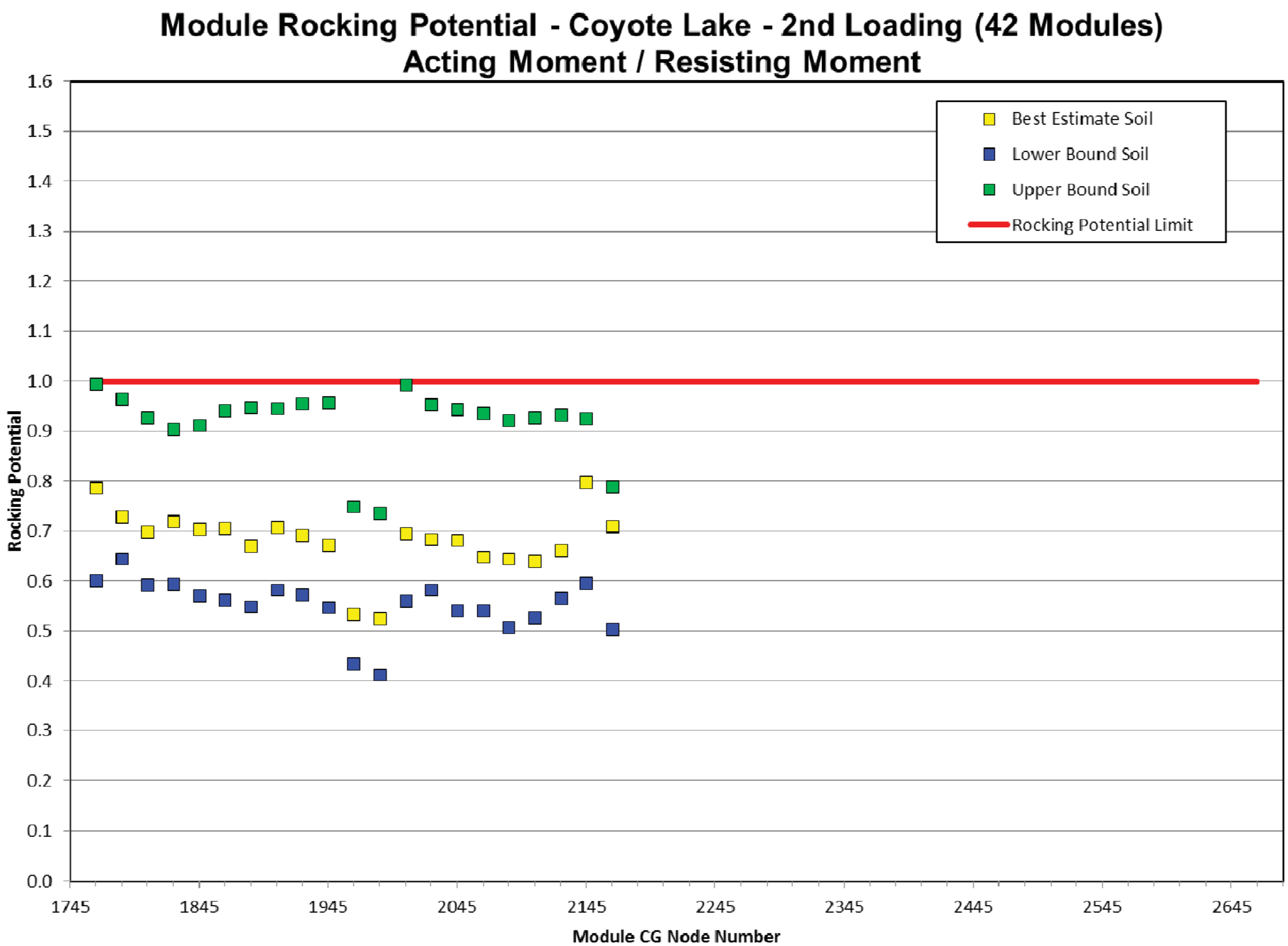

Figure 7-46
Rocking Potential – Coyote Lake Earthquake Loading Configuration: 42 HSMs on the Pad

All Indicated Changes are in response to RSI NP-5.4

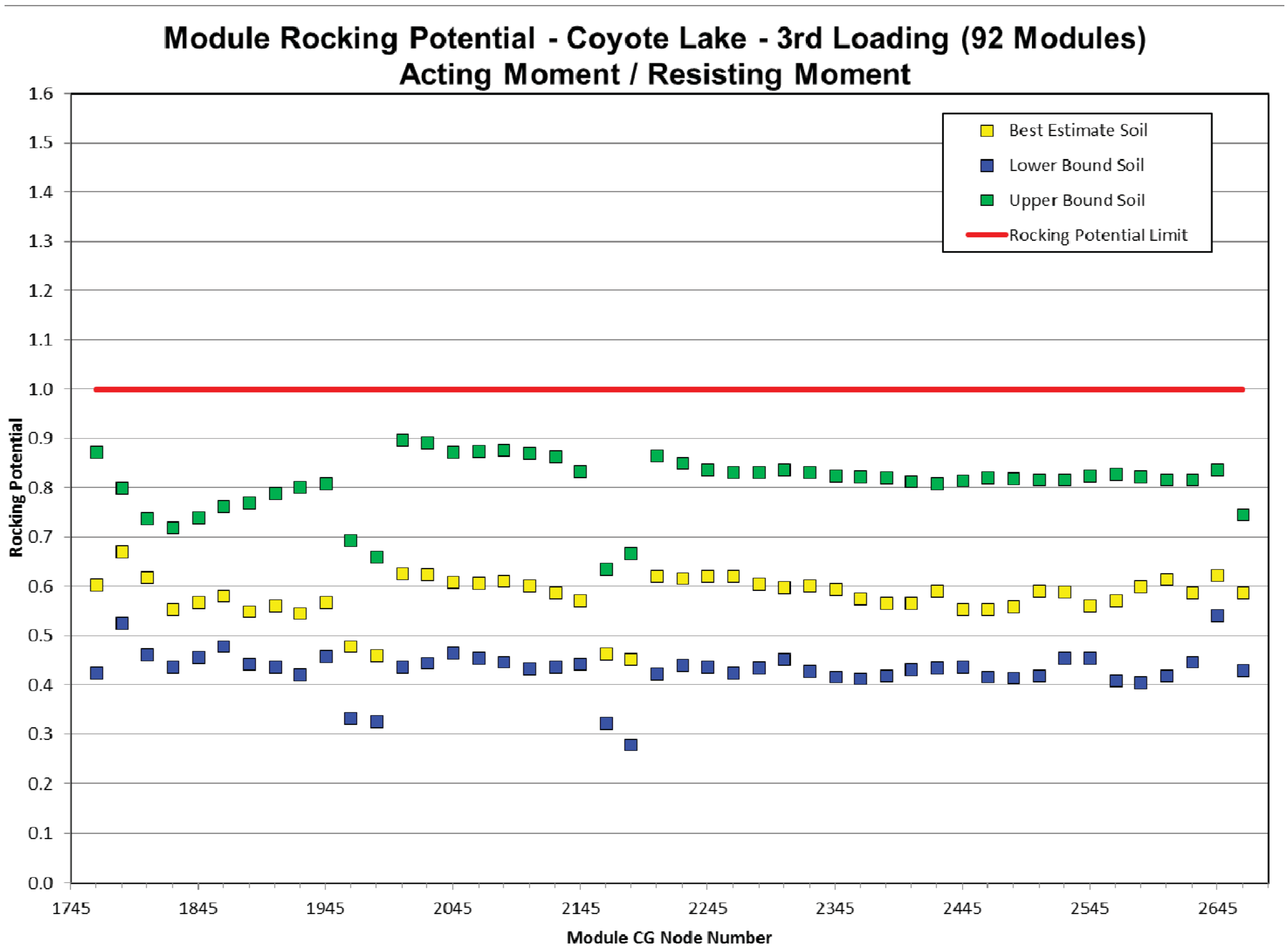

Figure 7-47
Rocking Potential – Coyote Lake Earthquake Loading Configuration: 92 HSMs on the Pad

All Indicated Changes are in response to RSI NP-5.4

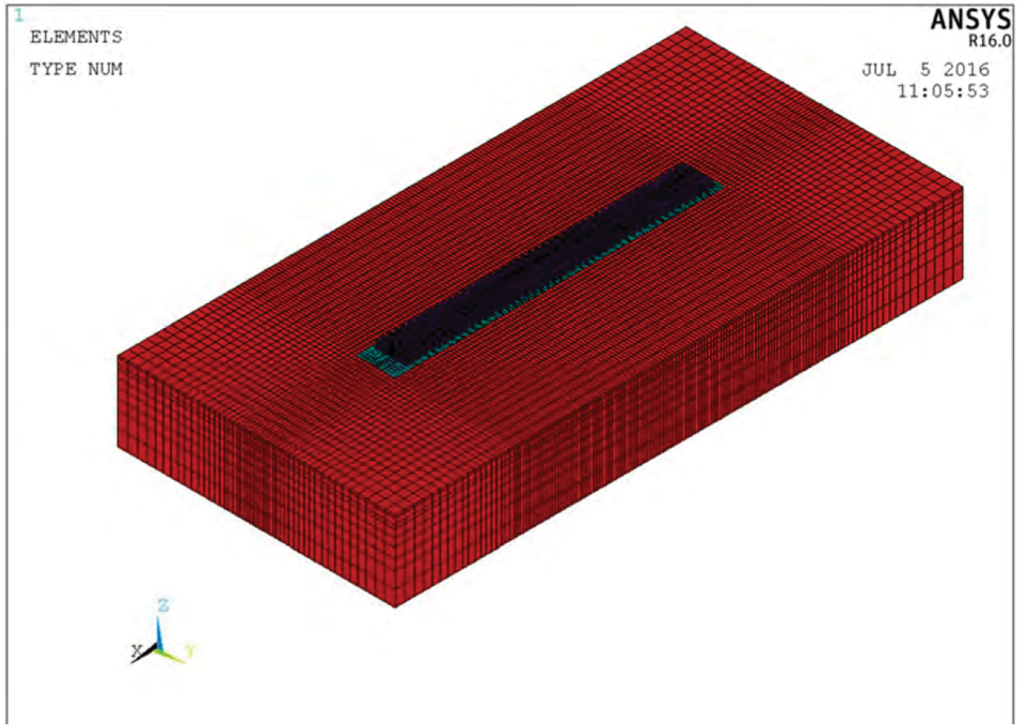

Figure 7-48
HSMFUL – ANSYS Model: Fully Loaded Pad Configuration– 2 x 46 AHSM Array

All Indicated Changes are in response to RSI NP-5.4

Young's Modulus E (psi)	Poisson's Ratio v			Material Name Used in ANSYS
9796	0.35	LAYER 1	3 ft	Material 4
9796	0.35	LAYER 2	7 ft	Material 5
28289	0.35	LAYER 3	5 ft	Material 6
32667	0.35	LAYER 4	10 ft	Material 7
32667	0.35	LAYER 5	10 ft	Material 8
95255	0.35	LAYER 6	12.5 ft	Material 9
95255	0.35	LAYER 7	12.5 ft	Material 10
72263	0.35	LAYER 8	20 ft	Material 11
72263	0.35	LAYER 9	20 ft	Material 12

Figure 7-49
Soil Properties

All Indicated Changes are in response to RSI NP-5.4

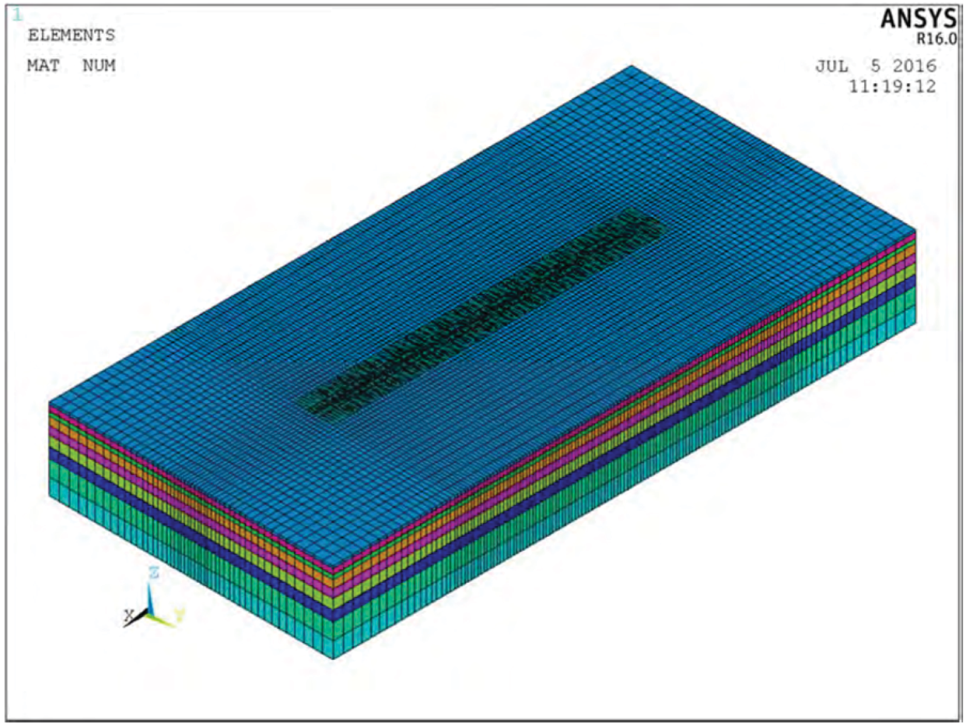

Figure 7-50
Overview of the Soil Layers in ANSYS Model

All Indicated Changes are in response to RSI NP-5.4

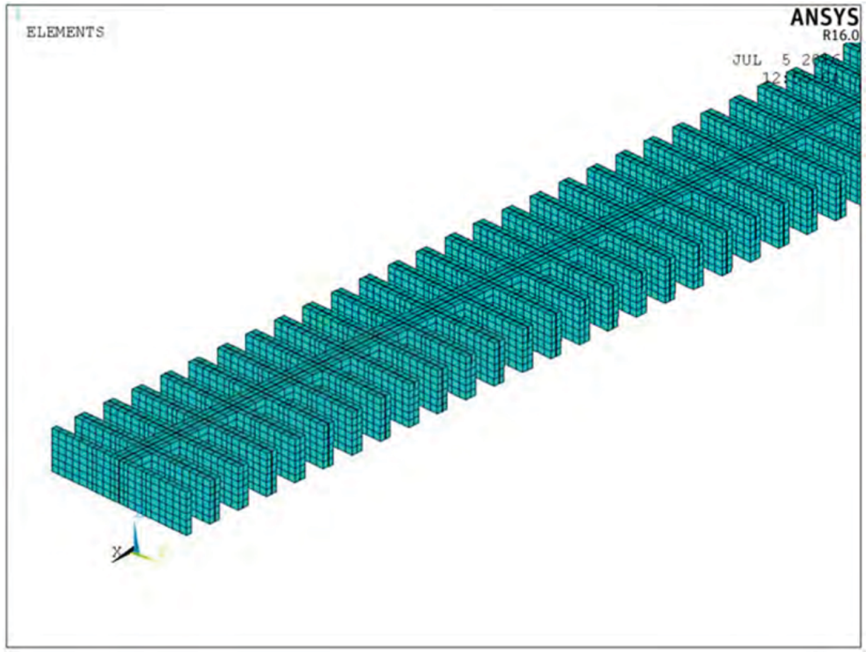

Figure 7-51
Overview of HSM Modeling

All Indicated Changes are in response to RSI NP-5.4

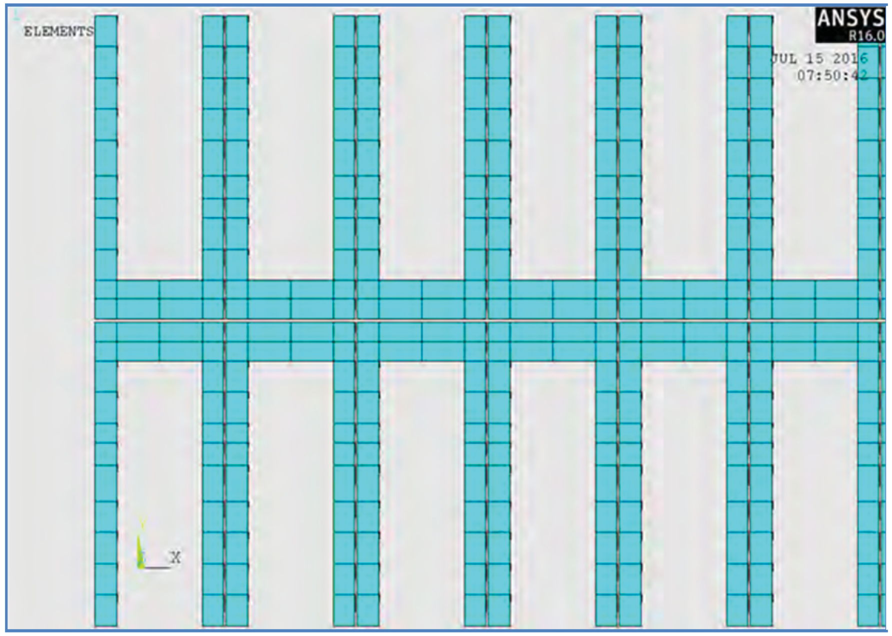

Figure 7-52
2-inch Gap between Modeled HSMs

All Indicated Changes are in response to RSI NP-5.4

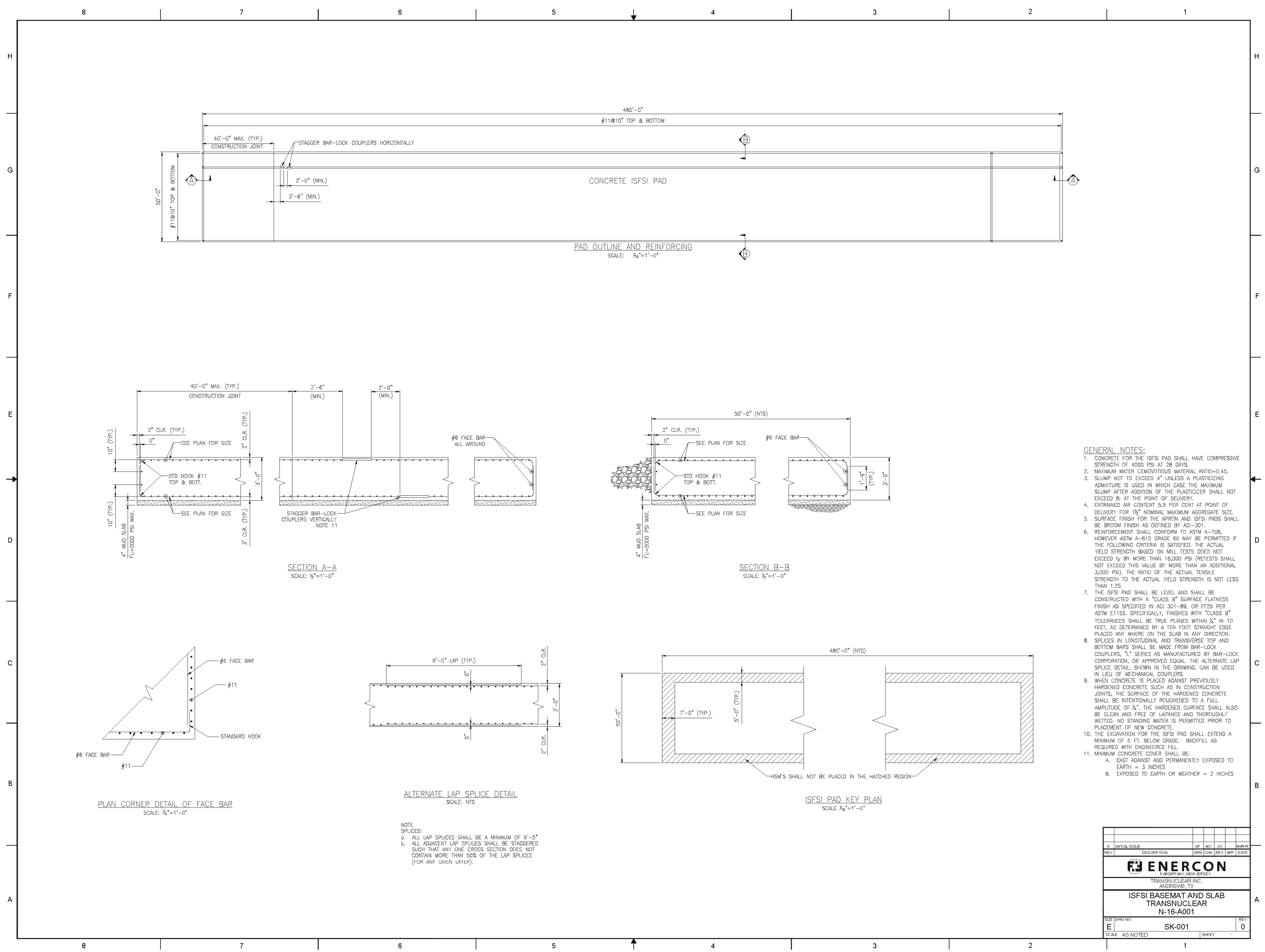

Figure 7-53
NUHOMS® NITS Pad Design

All Indicated Changes are in response to RSI NP-5.4

9.4 Estimated On-Site Collective Dose Assessment

On-site dose rates are computed for the proposed storage configuration using the MCNP5 v1.40 and MCNP6 version 1.0 computer programs. The dose to workers due to a loading operation is also estimated based upon dose rate information in existing storage FSARs and transportation SARs. The dose to workers due to loading is provided in the Appendices for each system as listed in Table 9-4.

9.4.1 Radiation Dose Rate Within the Controlled Area

Figure 9-1 provides an overview of the WCS CISF Facility and the surrounding area. Detector locations D1 through D16 are placed in the vicinity of the CISF, as indicated in Figure 9-1 to provide an idea of the general dose rates.

A close-up view of the storage area is provided in Figure 9-2 with detector locations for DSB-01 through DSB-10 located within the protected area.

Alarming Radiation Monitoring (ARM) and dosimeter locations in the Cask Handling Building are shown in Figure 1-7.

NUHOMS® Systems

The HSMs are loaded back-to-back in a single row. Sacramento Municipal Utility District (SMUD) fuel is modeled in a 2x11 array of HSM Model 80s at the eastern end of the WCS CISF. San Onofre Nuclear Generating Station (SONGS) fuel is modeled in a 2x10 array of AHSMs, and Millstone fuel is modeled in two arrays (2x25 and 2x28) of HSM Model 102s.

On-site dose rate contributions from the NUHOMS® Storage Overpacks are computed for the proposed storage configuration using MCNP5. Average calculated neutron and gamma dose rates on the surfaces of the various HSM modules are obtained from the respective FSARs [9-3, 9-4, 9-5] and are summarized in Table 9-1. Note that the HSM surface dose rates for the HSM Model 102 are conservatively increased from the reference FSAR values.

The arrays of HSMs are modeled as solid concrete boxes resting on a concrete pad 1.5 feet thick, and a surface source is modeled on each of the HSM array surfaces to reproduce the applicable HSM surface dose rates indicated in Table 9-1. Source particles are started using an outward cosine distribution and spectra applicable to each HSM system.

The outer boundary of the MCNP5 models is a sphere with a radius of approximately 7.6 km. Gamma and neutron radiation may scatter from atmospheric air down to the detector dose points (i.e., skyshine). Ground is modeled as soil 3 feet thick to capture ground scatter. Therefore, skyshine radiation is explicitly included in the dose rate results, as well as direct radiation and ground scatter.

All Indicated Changes are in response to RSI NP-7.1

No credit is taken for the presence of any landscape features or site buildings, which would provide additional shielding. In addition to the HSMs, a number of vertical casks are adjacent to the HSM, as indicated in *Figure 9-2*. No credit is taken for any blocking provided by the vertical casks.

NAC Systems

The WCS CISF is modeled explicitly. Shielding by NAC systems and AREVA TN HSMs is included in the model. Dose rates are calculated using point detectors and superimposed mesh tallies. For the location specific dose rates, point detectors were used. Neutron, gamma, and neutron-induced gammas (N-Gamma) are accounted for in the shielding evaluation. Neutron induced gammas generated within the cask shielding are included in the imported gamma surface currents. N-Gamma cases and results for the VCCs only include gammas induced from neutron interactions in air surrounding the cask systems.

9.4.1.1 Dose Rate Results

Dose rates are computed at various locations around the WCS CISF using point detectors, as indicated on Figure 9-1 *and Figure 9-2*. Dose rates are computed for gamma radiation, neutron radiation and secondary gamma radiation created when neutrons are absorbed in air, soil or concrete. Fluxes are converted to dose rates using ANSI/ANS-6.1.1-1977 flux to dose rate conversion factors.

The total dose rate is computed as the sum of the gamma, neutron, and secondary gamma components. The gamma and neutron dose rate is approximately 90% and 10% of the total dose rate, respectively. The 1-sigma MCNP statistical uncertainty is also provided for the total dose rate. All reported dose rate results are well-converged. Coordinates of the detectors are given in the State Plane Coordinate System (SPCS).

Dose rate results for the *general area around the WCS CISF* are summarized in Table 9-5. Dose rate results for the locations around the *facility and protected area of* the WCS CISF are summarized in Table 9-6. Coordinates of the detectors are given in the State Plane Coordinate System (SPCS).

9.4.1.2 Direct Dose Rate

The point detector output provides both the total and uncollided dose rate. The uncollided dose rate is representative of the “direct” component of the dose rate. The direct dose rate is provided in Table 9-5 and Table 9-6 in the “Direct” column.

9.4.1.3 Air Scattered Dose Rate

The air scattered or skyshine dose rate is provided in Table 9-5 and Table 9-6 in the “Skyshine” column and is estimated by subtracting the direct dose rate from the total dose rate. It may be observed that the direct dose rate is dominant close to the storage overpacks (< 20 m) but skyshine becomes dominant farther from the storage overpacks (> 20 m).

All Indicated Changes are in response to RSI NP-7.1

9.4.2 Doses to Workers

Section 2.1 of the Technical Specifications [9-13] lists the NRC approved canisters authorized for storage at the WCS CISF. Table 9-4 provides the cross reference to the applicable appendix and section for each canister/storage overpack where the Occupational Exposure for each system is discussed. The NUHOMS® systems do not require workers to approach the modules to perform surveillance of maintenance activities, therefore the only occupational exposure associated with the NUHOMS® systems is placing the canisters into storage and retrieving them again for off-site shipment. For the vertical systems the applicable appendices listed in Table 9-4 provide occupational exposures due to surveillance activities required for the VCCs.

In order to maintain radiation doses within ALARA constraints, unrestricted access to the CISF radiologically controlled area(s) (RCAs) within the Protected Area Boundary (PA, see Figure 1-2) will only be allowed for Radiation Workers. Non-Radiation Workers (including WCS employees who are not Radiation Workers) will only have limited access within an RCA and be escorted by a Radiation Worker (using a 1-to-5 Radiation Worker to Non-Radiation Worker ratio).

Construction workers will be considered Non-Radiation Workers and the radiation dose limits in 10 CFR 20 Subpart D will apply to them. Should all of Phase 1 construction not be completed upon the receipt of the first canister for storage, then construction areas will be established outside RCAs to maintain dose rates to construction workers below 2 mrem/hr. Laydown and material and equipment storage areas will be located in consideration of area dose rates to maintain worker doses ALARA.

RCAs located within the WCS CISF will be established around ongoing cask handling in the CHB and transfer operations along the transport haul route, and for loaded storage overpacks in the storage area.

All Indicated Changes are in response to RSI NP-12.4

Table 9-5
Dose Rates around the WCS CISF

	Coordinates (ft)		Dose Rate (mrem/hr)						
Detector	Easting	Northing	Gamma	Neutron	(n,γ)	Total	σ	Direct	Skyshine
General Area									
D1	562321.81	6878484.76	4.64E-01	3.98E-02	1.85E-03	5.06E-01	1%	1.38E-01	3.68E-01
D2	562485.67	6878849.66	1.61E-01	1.36E-02	7.76E-04	1.76E-01	2%	3.76E-02	1.38E-01
D3	562649.54	6879214.55	5.17E-02	3.59E-03	2.67E-04	5.56E-02	4%	9.20E-03	4.64E-02
D4	562813.40	6879579.45	1.46E-02	1.09E-03	1.21E-04	1.58E-02	2%	2.61E-03	1.32E-02
D5	562989.56	6879971.71	4.65E-03	3.04E-04	4.64E-05	5.00E-03	5%	7.48E-04	4.25E-03
D6	563655.49	6879672.66	6.12E-03	4.44E-04	6.79E-05	6.63E-03	3%	9.24E-04	5.70E-03
D7	564066.00	6879488.31	5.42E-03	3.51E-04	5.31E-05	5.83E-03	2%	9.19E-04	4.91E-03
D8	564476.50	6879303.96	3.96E-03	2.10E-04	4.12E-05	4.21E-03	3%	6.97E-04	3.51E-03
D9	565142.44	6879004.91	1.22E-03	6.08E-05	1.82E-05	1.30E-03	2%	2.17E-04	1.08E-03
D10	564966.28	6878612.65	2.95E-03	2.02E-04	3.14E-05	3.19E-03	5%	4.76E-04	2.71E-03
D11	564802.42	6878247.75	6.14E-03	3.66E-04	4.77E-05	6.55E-03	4%	9.52E-04	5.60E-03
D12	564638.55	6877882.85	9.26E-03	6.49E-04	8.67E-05	1.00E-02	2%	1.45E-03	8.54E-03
D13	564474.69	6877517.96	1.07E-02	9.00E-04	9.19E-05	1.17E-02	2%	1.12E-03	1.06E-02
D14	563481.03	6877087.22	8.38E-02	6.73E-03	4.29E-04	9.09E-02	2%	7.90E-03	8.30E-02
D15	563070.52	6877271.57	2.49E-01	2.28E-02	1.34E-03	2.73E-01	1%	1.17E-02	2.62E-01
D16	562660.01	6877455.92	4.23E-01	4.00E-02	2.26E-03	4.65E-01	1%	2.67E-02	4.38E-01

1. Detector locations shown on Figure 9-1.
2. Total = Direct + Skyshine.

All Indicated Changes are in response to RSI NP-7.1

Table 9-6
Dose Rates around *the* Facility *and the Protected Area*

	Coordinates (ft)		Dose Rate (mrem/hr)						
Detector	**Easting**	**Northing**	**Gamma**	**Neutron**	**(n,γ)**	**Total**	**σ**	**Direct**	**Skyshine**
Locations around Facility									
P-001	560770.85	6878102.44	2.85E-03	2.05E-04	3.94E-05	3.09E-03	3%	4.49E-04	2.65E-03
P-002	561762.03	6877972.59	8.79E-02	6.32E-03	4.97E-04	9.48E-02	3%	1.66E-02	7.82E-02
P-003	562193.28	6878120.44	6.29E-01	4.87E-02	2.32E-03	6.80E-01	1%	1.98E-01	4.82E-01
P-004	562816.16	6877498.49	6.43E-01	5.70E-02	3.28E-03	7.03E-01	1%	4.92E-02	6.54E-01
P-005	563088.75	6877495.24	7.12E-01	6.62E-02	3.36E-03	7.82E-01	1%	6.28E-02	7.19E-01
P-006	563039.04	6877384.55	4.17E-01	4.05E-02	2.05E-03	4.60E-01	1%	2.58E-02	4.34E-01
P-007	562618.87	6876671.78	2.27E-02	2.00E-03	1.85E-04	2.48E-02	2%	9.45E-04	2.39E-02
P-008	562452.84	6877970.98	2.66E+00	2.04E-01	1.15E-02	2.88E+00	1%	1.03E+00	1.85E+00
Locations around the Protected Area									
DSB-01	562386.26	6878066.83	2.68E+00	1.59E-01	7.27E-03	2.85E+00	2%	1.24E+00	1.60E+00
DSB-02	562580.56	6877804.00	1.64E+00	1.71E-01	9.80E-03	1.83E+00	1%	2.82E-01	1.54E+00
DSB-03	562465.86	6877548.58	3.82E-01	4.27E-02	2.08E-03	4.27E-01	2%	2.51E-02	4.02E-01
DSB-04	562805.88	6878305.73	4.54E+00	2.82E-01	1.05E-02	4.84E+00	1%	2.25E+00	2.59E+00
DSB-05	562740.16	6877732.33	1.77E+00	1.70E-01	1.06E-02	1.95E+00	1%	3.22E-01	1.63E+00
DSB-06	562625.45	6877476.91	4.46E-01	4.22E-02	2.34E-03	4.91E-01	3%	2.71E-02	4.64E-01
DSB-07	562965.47	6878234.06	5.06E+00	2.82E-01	1.19E-02	5.35E+00	1%	2.45E+00	2.90E+00
DSB-08	563083.74	6877578.04	1.13E+00	1.11E-01	5.56E-03	1.25E+00	2%	1.60E-01	1.09E+00
DSB-09	562969.03	6877322.61	3.14E-01	2.85E-02	1.57E-03	3.44E-01	2%	1.71E-02	3.27E-01
DSB-10	563309.05	6878079.77	2.95E+00	1.77E-01	7.12E-03	3.14E+00	1%	1.27E+00	1.87E+00

1. Detector locations shown on Figure 9-2.
2. Total = Direct + Skyshine.

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Figure 9-3
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All Indicated Changes are in response to RSI NP-7.1

A.3.3 Design Criteria for Environmental Conditions and Natural Phenomena

A.3.3.1 Tornado Wind and Tornado Missiles

The design basis tornado wind and tornado missiles for the NUHOMS®-MP187 Cask System are provided in Section 3.2.1 of Volume 1 of reference [A.3-1]. The NUHOMS®-MP187 Cask System components are designed and conservatively evaluated for the most severe tornado and missiles anywhere within the United States (Region I as defined in NRC Regulatory Guide 1.76 [A.3-8]) while the WCS CISF is in Region II, a less severe location with respect to tornado and tornado missiles.

The HSM protects the DSC from adverse environmental effects and is the principal structure exposed to tornado wind and missile loads. Furthermore, all components of the HSM (regardless of their safety classification) are designed to withstand tornadoes and tornado-based missiles. The MP187 cask protects the DSC during transit to the Storage Pad from adverse environmental effects such as tornado winds and missiles.

A.3.3.2 Water Level (Flood) Design

Although the Rancho Seco site is a dry site not subject to flooding, the DSCs and HSM are designed for an enveloping design basis flood, postulated to result from natural phenomena as specified by 10 CFR 72.122(b). The system is evaluated for a postulated flood height of 50 feet with a water velocity of 15 fps.

The DSCs are evaluated for an external hydrostatic pressure equivalent to the 50 feet head of water. The HSM is evaluated for the effects of a water current of 15 fps impinging on the sides of a submerged HSM. For the flood case that submerges the HSM, the inside of the HSM will rapidly fill with water through the HSM vents.

The flood used in the evaluation of the NUHOMS®-MP187 Cask System components envelopes the WCS CISF maximum postulated flood height of 1.1 inches with a speed of 1.7 fps.

A.3.3.3 Seismic Design

The seismic criteria for the NUHOMS®-MP187 Cask System are provided *by the enveloping acceleration response spectra at the WCS concrete pad base and HSM center of gravity obtained by the WCS CISF soil-structure interaction (SSI) analysis. The SSI analysis is based on the WCS CISF site-specific ground motion in the form of the 10,000-year return period uniform hazard spectra as described in Section 7.6.4*.

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Table A.3-1
Summary of WCS CISF Principal Design Criteria
(4 pages)

Design Parameter	WCS CISF Design Criteria	Condition	NUHOMS®-MP187 Design Criteria
Floods	Flood height 1.1 inches Water velocity 1.7 ft/s	Accident (Bounded)	*Rancho Seco SAR Table 3-1 of Volume 2* Flood height 50 ft Water velocity 15 ft/s
Seismic (Ground Motion)	Site-specific ground-surface uniform hazard response spectra (UHRS) with 1E-4 annual frequency of exceedance (AFE) having peak ground acceleration (PGA) of 0.250 g horizontal and 0.175 g vertical. (Table 1-5 and Figure 1-5)	Accident (*Evaluated*)	*See Evaluations in Sections 7.6.4, 7.6.5 and A.7.5*
Vent Blockage	For NUHOMS® Systems: Inlet and outlet vents blocked 40 hrs	Accident (Same)	*Rancho Seco SAR Section 8.3.5 of Volume 2* Inlet and outlet vents blocked 40 hrs
Fire/Explosion	For NUHOMS® Systems: Equivalent fire 300 gallons of diesel fuel	Accident (Same)	*Rancho Seco SAR Section 8.2.1 of Volume 1 and Appendix B* Equivalent fire 300 gallons of diesel fuel
Cask Drop	For NUHOMS® Systems: Transfer Cask Horizontal side drop or slap down 80 inches(3)	Accident (Same)	*Rancho Seco SAR Section 8.2.1 of Volume 1 and Appendix B* Transfer Cask Horizontal side drop or slap down 80 inches(3)
Transfer Load	For NUHOMS® Systems only: Normal insertion load 60 kips Normal extraction load 60 kips	Normal (Same)	*Rancho Seco SAR Appendix B page 8.1-26* Normal insertion load 60 kips Normal extraction load 60 kips
Transfer Load	For NUHOMS® Systems only: Maximum insertion load 80 kips Maximum extraction load 80 kips	Off-Normal/ Accident (Same)	*Rancho Seco SAR Appendix B page 8.1-29* Maximum insertion load 80 kips Maximum extraction load 80 kips
Ambient Temperatures	Normal temperature 44.1 – 81.5°F	Normal (Bounded)	*Rancho Seco SAR Section 8.1.1.3 of Volume 1* Normal temperature 0 - *101*°F(1)

All Indicated Changes are in response to RSI NP-5.4

A.7.1 Discussion

As discussed in Chapter 1.0, the canisters from the Rancho Seco ISFSI will be transported to the WCS CISF in the NUHOMS®-MP187 Multi-Purpose Cask, licensed under NRC Certificate of Compliance 9255 [A.7-2]. At the WCS CISF, the canisters are to be stored inside the Standardized NUHOMS® HSM Model 80. The canisters, licensed for storage at the Rancho Seco ISFSI under NRC SNM-2510 [A.7-1], are described in Section 4.2.5.2 of Volume I of [A.7-4]. The HSM Model 80, licensed under NRC Certificate of Compliance 1004 [A.7-6], is described in Section 4.2.3.2 of [A.7-3]. The MP187 cask is to be used for on-site transfer and handling operations at the WCS CISF. The MP187 cask, licensed for on-site transfer at the Rancho Seco ISFSI under NRC SNM-2510 [A.7-1], is described in Section 4.2.5.3 of Volume I of [A.7-4].

As stated in Section 1.2 of Volume I of [A.7-4], the canisters are stored within the HSMs installed at the Rancho Seco ISFSI. The HSM design for the Rancho Seco ISFSI is based on the HSM design as described in the Standardized NUHOMS® UFSAR, Revision 4A. *Appendix B of [A.7-4] contains the applicable page from the Standardized NUHOMS® UFSAR Revision 4A, as listed on the Appendix B list of pages. Appendix B of [A.7-4] is henceforth cited as [A.7-5].* A subsequent revision of the Standardized NUHOMS® UFSAR implemented certain design modifications to the HSM; and the revised HSM configuration was eventually designated as the HSM Model 80. See Section 1.3.1.2 of [A.7-3]. The main design modifications implemented in included:

1) the steel cask docking ring flange is eliminated so that the cask docking flange is formed in concrete during casting of the base unit,
2) the support rail extension plate anchorage is modified to eliminate field welding, and,
3) a drop-in tube steel is used as the axial retainer, so that the door is no longer in the load path for axial restraint of the canister.

These modifications were shown not to have an adverse effect on the intended safety functions of the HSM. Therefore, the Rancho Seco ISFSI HSMs and the HSM Model 80 are equivalent and can be substituted at the WCS CISF without affecting the licensing basis of the canisters as contained in [A.7-4].

The MP187 cask is a multi-purpose cask designed and evaluated as a transfer cask for use in loading HSMs under 10 CFR Part 72 [A.7-1] [A.7-4] and as a transportation cask for off-site shipments under the provisions of 10 CFR Part 71 [A.7-2] [A.7-7]. The evaluation of the MP187 cask as a transfer cask is based on Revision 13 of drawing NUH-05-4001 (Cask Main Assembly) and Revision 8 of NUH-05-4003 (Cask On-Site Transfer Arrangement), as shown in Volume IV of [A.7-4]. The current revision of NUH-05-4001 is Revision 15 as shown in Section 1.3.2 of [A.7-7]. There are no significant design differences in the cask main assembly configuration between these two revisions.

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A.7.2 Summary of Mechanical Properties of Materials

As described in Sections 1.2.1 and 1.2.2 of Volume I of [A.7-4], the Rancho Seco canisters and HSM designs are based on the Standardized NUHOMS® design for the 24P DSC*, which is discussed in Appendix B of the Rancho Seco FSAR* [A.7-5], with modifications made to the basket design to qualify the Rancho Seco canisters for off-site transport. Per Section 8.1.1.3 of Volume I of [A.7-4], the mechanical properties of materials of construction for the canisters and the HSMs at the Rancho Seco ISFSI are the same as those presented in Table 8.1-3 of *Appendix B of the Rancho Seco FSAR* [A.7-5]. Mechanical properties for the MP187 cask are provided in Section 2.3 of [A.7-7].

The material specifications for the canisters and the MP187 cask are provided in the drawings contained in Volume IV of [A.7-4]. Material properties of the Standardized NUHOMS® HSM Model 80 are presented in Table 8.1-3 of [A.7-3]. Material specifications for the HSM Model 80 are provided in the HSM drawings contained in Appendix E.2 of [A.7-3].

All Indicated Changes are in response to RSI MD NP-1.1

A.7.4 Structural Analysis of HSM Model 80 with a Canister (Storage Configuration)

As described in Section 3.2 of Volume I of [A.7-4], the canisters are designed by analysis to meet the stress intensity allowables of the ASME Boiler and Pressure Vessel Code (1992 Code, 1993 Addendum) Section III, Division I, Subsection NB, NF, and NG for Class I components and supports.

The canisters' design approach, design criteria and load combinations for storage in the HSM are discussed in Section 3.2.5.2 of Volume II of [A.7-4]. Table 3-5 of [A.7-4] summarizes the storage load combinations and ASME Code Service Levels for the canisters.

As stated in Volume II of [A.7-4], the Rancho Seco HSM design is similar to the Standardized NUHOMS® HSM design. As discussed in Section A.7.1 the Standardized NUHOMS® HSM design that formed the basis for the licensing of the Rancho Seco HSM*, which is discussed in Appendix B of the Rancho Seco FSAR* [A.7-5] was subsequently designated as the HSM Model 80 in [A.7-3]. The loads for the HSM concrete and DSC steel support structure shown in Table 3.2-1 of [A.7-3] are the same or bound the loads in Table 3-1 and Table 3-2 of Volume II of [A.7-4]. The HSM Model 80 is evaluated in [A.7-3] for canister weights that bound the bounding weight of 81.2 kips for the canisters. (e.g. the evaluation of the HSM Model 80 loaded with a 61BT DSC (weight of 88.39 kips, per Table K.3.2-1 of [A.7-3]) is presented in Sections K.3.7.3.4 and K.3.7.3.5 of [A.7-3]).

The design approach, design criteria, and loading combinations for the reinforced concrete HSM Model 80 and its DSC steel support structure are discussed in Section 3.2.5 of [A.7-3]. Table 3.2-5 and Table 3.2-8 of [A.7-3] provide the loads and load combinations for the HSM concrete and DSC steel support structure, respectively. These are the same as those shown in Volume II of [A.7-4], Table 3-4 and Table 3-6 and discussed in Section 3.2.5.1. Both the Rancho Seco HSM and the HSM Model 80 are designed in accordance with the requirements of the ACI "Code Requirements for Nuclear Safety Related Concrete Structures" ACI 349-85 (concrete) and the AISC "Specification for Structural Steel Buildings", Ninth Edition, 1989 (DSC steel support structure). Table 3.2-10 of [A.7-3] summarizes the design criteria for the DSC steel support steel structure. This is the same as presented in Table 3-8 of Volume II of [A.7-4].

The discussion above establishes that the HSM as described in Volume II of [A.7-4] and the HSM Model 80 as described in [A.7-3] have the same geometry and are based on the same design criteria. Furthermore, as discussed in Chapter 3, (with the exception of seismic loading criteria), the loading and structural design criteria for the Rancho Seco ISFSI and the Standardized NUHOMS® components bound the WCS CISF design requirements. The seismic load is reconciled in Section A.7.5.2 and Section A.7.5.3 for the canisters and the HSM Model 80, respectively. Therefore, the HSM Model 80 as described in [A.7-3] is acceptable for storage of the canisters at the WCS CISF.

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Volume II, Section 8.3 of [A.7-4] states that the accident condition loadings for the canisters loaded in the Rancho Seco HSM are the same or bounded by the 24P DSC in the HSM, *as discussed in Appendix B of the Rancho Seco FSAR* [A.7-5].

The structural analyses of the HSM Model 80 for accident conditions are presented in Section 8.2 of [A.7-3]. Table 8.2-3 presents the structural analyses results for the HSM Model 80 for accident conditions.

The original HSM in *Appendix B of the Rancho Seco FSAR* [A.7-5] was subsequently designated as the HSM Model 80 in [A.7-3]. Thus, the results for the canisters in [A.7-4] and the HSM Model 80 in [A.7-3] are applicable, except for the seismic load evaluations. Seismic reconciliation evaluations as described in Section A.7.5 address the site-specific ground motion at WCS CISF.

A.7.4.3 Load Combinations

HSM Model 80 enveloping load combination results are summarized in Table 8.2-18, Table 8.2-19, and Table 8.2-20 of [A.7-3]. The stress results for the HSM Model 80 presented in Table 8.2-18, Table 8.2-19, and Table 8.2-20 are bounding when the HSM Model 80 is loaded with a canister.

The enveloping load combination results summarized in Table 8-15, Table 8-16, and Table 8-17 of Volume I of [A.7-4] bound the storage specific loads for the FO DSC and GTCC waste canister.

The enveloping load combination results summarized in Table 8-18, Table 8-19, and Table 8-20 of Volume I of [A.7-4] bound the storage specific loads for the FC DSC.

The enveloping load combination results summarized in Table 8-21, Table 8-22, and Table 8-23 of Volume I of [A.7-4] bound the storage specific loads for the FF DSC.

All Indicated Changes are in response to RSI MD NP-1.1

A.7.5 Seismic Reconciliation of the MP187 Cask, Canisters, and HSM Model 80

The site-specific seismic ground motion developed for the WCS CISF in the form of the 10,000-year return period uniform hazard response spectra for the horizontal and vertical directions are described in Chapter 2. A comparison of the site-specific response spectra for the WCS CISF ground motion and the Regulatory Guide 1.60 design-basis ground motions' response spectra are shown in Figure A.7-1 for 3%, 5%, and 7% damping values. This comparison indicates that for system frequencies above about 10 Hz (horizontal direction) and 9 Hz (vertical direction), the WCS CISF spectral accelerations are higher than the design basis spectral accelerations. The ZPA values of 0.25g (horizontal) and 0.175g (vertical) for the WCS CISF ground motion are essentially the same as those for the Rancho Seco IFSFI and the Standardized NUHOMS® System.

This section summarizes the stress reconciliation of the MP187 cask, the canisters, and the HSM Model 80 *using the enveloped acceleration spectra at the HSMs center of gravity (CG) and base derived from the WCS concrete pad soil-structure interaction (SSI) analysis.*

A.7.5.1 MP187 Cask

The MP187 cask is a multi-purpose cask, designed as a transfer cask for use in loading HSMs under the provisions of 10 CFR 72, and as a transportation cask for off-site shipment under the provisions of 10 CFR 71. Due to the cask's design to meet off-site shipping requirements, large factors of safety are afforded for on-site transfer operations.

As noted in Volume I, Section 1.2 and Volume III, Section 8 of [A.7-4], the MP187 cask was intended to be licensed under 10 CFR 72 for storage of a canister if required to recover from an off-normal event at the ISFSI. Although ultimately not licensed as a storage component, the fact that it was designed to meet the storage requirements under 10 CFR Part 72 provides the MP187 cask with additional uncredited safety margins.

As noted in Section 3.2.3 of Volume I of [A.7-4], based on the calculated cask structural frequencies of 17.9 (ovalling mode) and 83 Hz (beam mode), an amplification factor of 2.5 and a multimode factor of 1.5 are applied to the R.G. 1.60 ZPA acceleration of 0.25g (horizontal) and 0.17g (vertical). This resulted in equivalent static accelerations for the horizontal and vertical directions of 0.95g and 0.65g. The R.G. 1.60 response spectrum amplification for 2% damping at 17.9 Hz is 1.8 (a higher amplification factor of 2.5 was conservatively used in the design basis evaluation). Thus, the 0.95g used for the MP187 cask design basis seismic evaluation has margin to accommodate the increased spectral amplifications for the WCS CISF.

All Indicated Changes are in response to RSI NP-5.4

This factor is applied to the governing seismic stress in Table 8-8 of Volume I of [A.7-4]. As reported in Table 8-8 of Volume I of [A.7-4] the maximum seismic stress is 3.4 ksi. The load combination results are shown in Table 8-13 of Volume I. Per Note 2 of Table 8-13 the seismic load combinations C1 and C2 are enveloped into a bounding load combination C1/C2. The enveloping bounding load combination C1/C2 consists of deadweight stress (2.4 ksi from Table 8-3), normal handling (3.7 ksi from Table 8-3), accident pressure (0.5 ksi from Table 8-8), and seismic (3.4 ksi from Table 8-8). Table 8-13 shows that the controlling stress ratio is 0.42 and corresponds to the cask outer shell primary stress of 10 ksi. Using the above-calculated factor the seismic stress of 3.4 ksi is increased to *3.4x2.17 = 7.38 ksi.* Moreover, per Volume I, Section 8.2.3, accident pressure loads apply only for a hypothetical storage condition. When used as a transfer cask the MP187 cask is not required to hold pressure. Therefore, in this evaluation the 0.5 ksi accident pressure is removed from the load combination. The updated C1/C2 load combination now renders a total stress of *13.5* ksi, or a stress ratio of 0.*56*.

Furthermore, the maximum stress ratio in Table 8-13 is 0.81 and corresponds to a non-seismic load combination (C4). It is concluded that seismic load is not the controlling load at the WCS CISF and the bounding load stress margins for the MP187 cask, as documented in [A.7-4], remain unchanged.

A.7.5.2 Canisters

SSI analyses were performed for the pad with high level waste storage units at the Andrews, TX waste storage facility site. These analyses are presented in Section 7.6.4. One of the purposes of the analyses was to determine the envelope of the acceleration response spectra at the HSM center of gravity. The +/-15% peak-broadened HSM CG response spectra for damping values of 7%, 3%, and 2% are shown in Figures D.7-7 through D.7-9.

All Indicated Changes are in response to RSI NP-5.4

Based on NRC Reg. Guide 1.61 [A.7-8], a damping value of three percent is used for the DSC seismic analysis. The resulting stresses in the DSC shell due to the vertical and horizontal seismic loads are determined and reconciled with the original seismic analysis for the individual DSCs.

DSC Natural Frequency Calculation

ANSYS [A.7-9] finite element analyses are used to determine the natural frequencies of the DSCs. Since the FC and FF DSCs have ASTM B29 Lead in the shield plug assemblies a bounding model is developed to envelop the critical dimensions of the DSCs. Similarly FO, 61BT, and 61BTH Type 1 DSCs have steel shield plugs a bounding model is developed to envelop the critical dimensions of the DSCs. These critical dimensions and the dimensions used in the bounding model are summarized in Table A.7-1 and Table A.7-2.

Since a half symmetry model is used, symmetry boundary conditions were applied on the symmetry surface. Furthermore, the DSC was restrained radially along two lines of nodes at the outer diameter; at plane of symmetry and at 0.61 inch, which is less than the half-rail width. All nodes on the outer surface of outer top cover plate and DSC shell within the axial retainer area (3 inch x 2.44 inch) are also restrained in the axial direction. The boundary conditions are shown in Figure A.7-2.

Two different analyses are performed to encompass the directional loading of the basket and spent fuel assemblies. The first analysis is performed where the basket and spent fuel assemblies mass is lumped on the bottom of the top shield plug. This analysis simulates the axial direction seismic load. In the second analysis, the basket and spent fuel assemblies mass is lumped on the DSC shell inner surface. This analysis simulates the vertical and lateral direction seismic load.

The lowest mode for each model is shown in Figure A.7-3 and Figure A.7-4.

[ ]

As shown in the modal analyses, the differences between all of the DSCs are minimal from the stiffness perspective. The 61BT and 61BTH Type 1 DSCs were shown to be stable when loaded in the HSM-HS [A.7-3]. The stability was shown by performing non-linear time-history analysis [Section U.3.7.2.1 of A.7-3]. The angle of the rail is at 30 degrees for both HSM-HS and HSM-80/102. Due to the same rail angle and a bounding spectra analysis, it is concluded that the DSCs will remain stable on the HSM rails.

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Per Section 8.2.4.3 in Volume I and Section 8.3.2.2 in Volume II of [A.7-4] the canister shell components are evaluated for seismic loading of 3.0g and 1.0g for the horizontal and vertical directions, respectively. The basket components (spacer disc, support rods) are evaluated for 1.5g and 1.0g for the horizontal and vertical directions, respectively.

The seismic evaluation shows that the seismic accelerations used in the original seismic evaluations of the DSCs bound the seismic demand accelerations from the WCS CISF site-specific loading.

A.7.5.3 HSM Model 80

The seismic reconciliation of the HSM Model 80 is described in D.7.3.1.

All Indicated Changes are in response to RSI NP-5.4

A.7.8 References

A.7-1 U.S. Nuclear Regulatory Commission, “License for Independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste,” License Number SNM-2510, Docket Number 72-11.

A.7-2 U.S. Nuclear Regulatory Commission, “Certificate of Compliance No. 9255, Revision 12 for the Model No. NUHOMS®-MP187 Multi-Purpose Cask (Docket 71-9255).

A.7-3 AREVA TN Document NUH-003, Revision 14, “Updated Final Safety Analysis Report for the Standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel.” (Basis for NRC CoC 72-1004).

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A.7-4 “Rancho Seco Independent Spent Fuel Storage Installation Safety Analysis Report,” NRC Docket No. 72-11, Revision 4.

A.7-5 *Appendix B to “Rancho Seco Independent Spent Fuel Storage Installation Safety Analysis Report,” NRC Docket No. 72-11, Revision 4.*

A.7-6 U.S. Nuclear Regulatory Commission, “Certificate of Compliance for Spent Fuel Storage Casks,” Certificate No. 1004, Docket 72-1004, Amendment 13 for the Standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel.

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A.7-7 AREVA TN Document NUH-05-151 Rev. 17, “NUHOMS®-MP187 Multi-Purpose Transportation Package Safety Analysis Report.” (Basis for NRC CoC 71-9255).

A.7-8 *Regulatory Guide 1.61, “Damping Values for Seismic Design of Nuclear Power Plants,” U.S. Nuclear Regulatory Commission, Revision 1, March 2007.*

A.7-9 ANSYS Computer Code and User's Manual, Version 14.

RSI NP-5.4

Table A.7-1
Summary of FC and FF DSC Dimensions

	FC	***FF***	***ANSYS Model***
Outer Top Cover Plate (in)	*1.25*	*1.25*	*1.25*
Inner Top Cover Plate (in)	*0.75*	*0.75*	*0.75*
Top Shield Plug Assembly (in)	*5.13*	*5.00*	*5.00*
Inner Bottom Cover Plate (in)	*0.75*	*0.75*	*0.75*
Bottom Shield Plug Assembly (in)	*5.25*	*5.25*	*5.25*
DSC Shell Outer Diameter (in)	*67.19*	*67.19*	*67.19*
DSC Shell Thickness (in)	*0.63*	*0.63*	*0.63*
Total Length (except grapple ring) (in)	*186.2*	*186.5*	*186.2*
Basket + Spent fuel assemblies weight (kips)	*58.31*	*52.10*	*60.00*

Table A.7-2
Summary of FO, 61BT, and 61BTH Type 1 Dimensions

	FO	*61BT*	*61BTH Type 1*	*ANSYS Model*
Outer Top Cover Plate (in)	*1.25*	*1.25*	*1.25*	*1.25*
Inner Top Cover Plate (in)	*0.75*	*0.75*	*0.75*	*0.75*
Top Shield Plug (in)	*8.25*	*7.00*	*7.00*	*7.00*
Inner Bottom Cover Plate (in)	*0.75*	*0.75*	*1.69*	*0.75*
Outer Bottom Cover Plate (in)	*1.75*	*1.75*	*1.70*	*1.75*
Bottom Shield Plug (in)	*6.25*	*5.00*	*4.00*	*5.00*
DSC Shell Outer Diameter (in)	*67.19*	*67.25*	*67.25*	*67.25*
DSC Shell Thickness (in)	*0.63*	*0.5*	*0.5*	*0.5*
Total Length (except grapple ring) (in)	*186.2*	*196.04*	*196.04*	*196.04*
Basket + Spent fuel assemblies weight (kips)	*55.20*	*65.9*	*66.4*	*70.00*

All Indicated Changes are in response to RSI NP-5.4

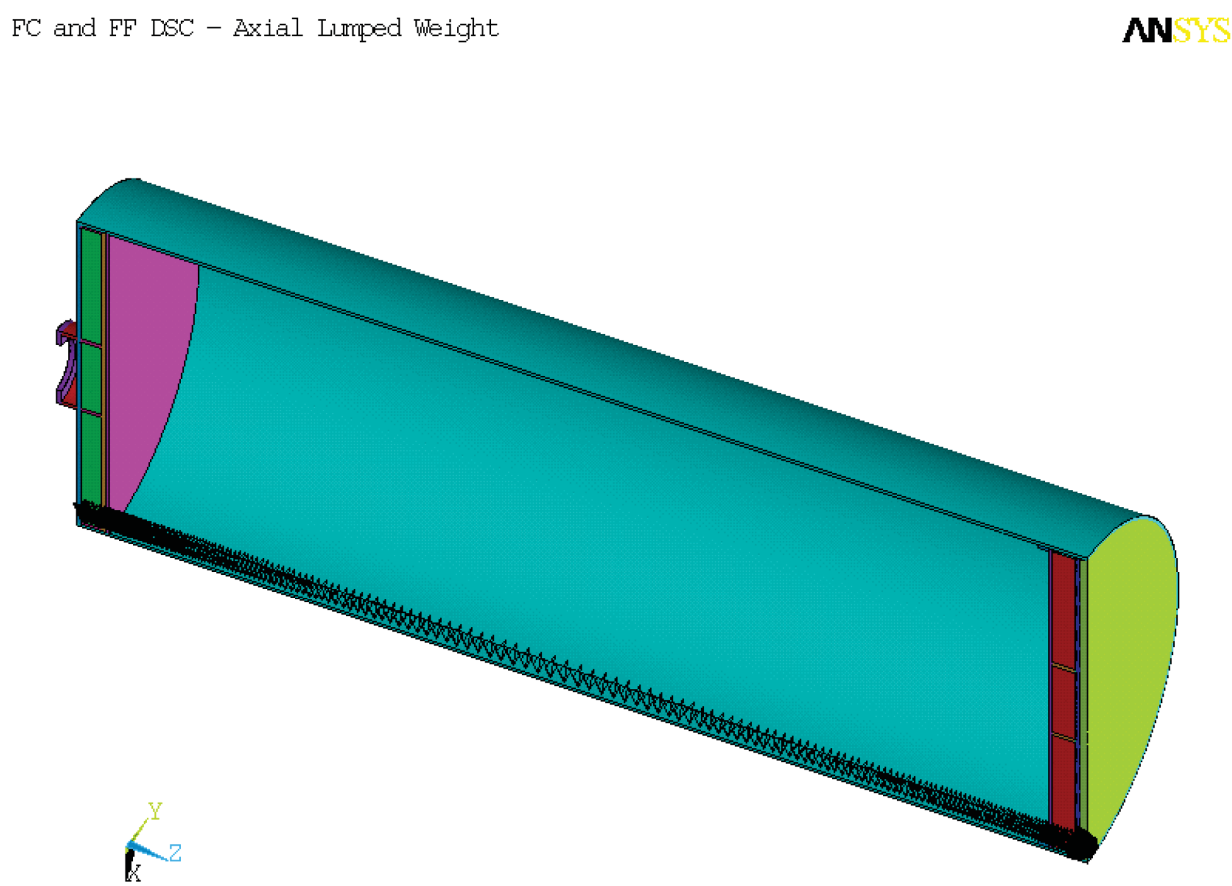

Figure A.7-2
DSC Models Boundary Conditions

All Indicated Changes are in response to RSI NP-5.4

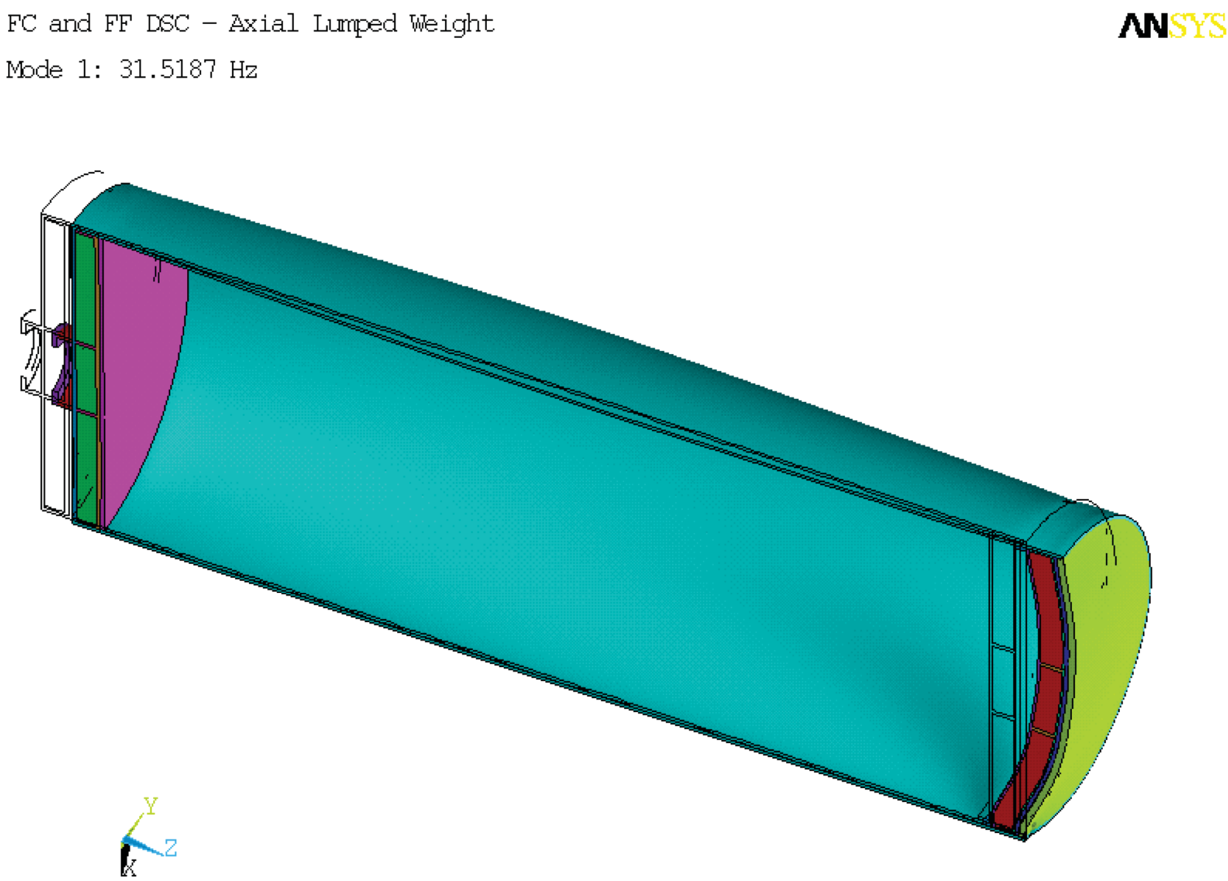

Figure A.7-3
FC and FF Axial Direction DSC Model – First Mode Shape

All Indicated Changes are in response to RSI NP-5.4

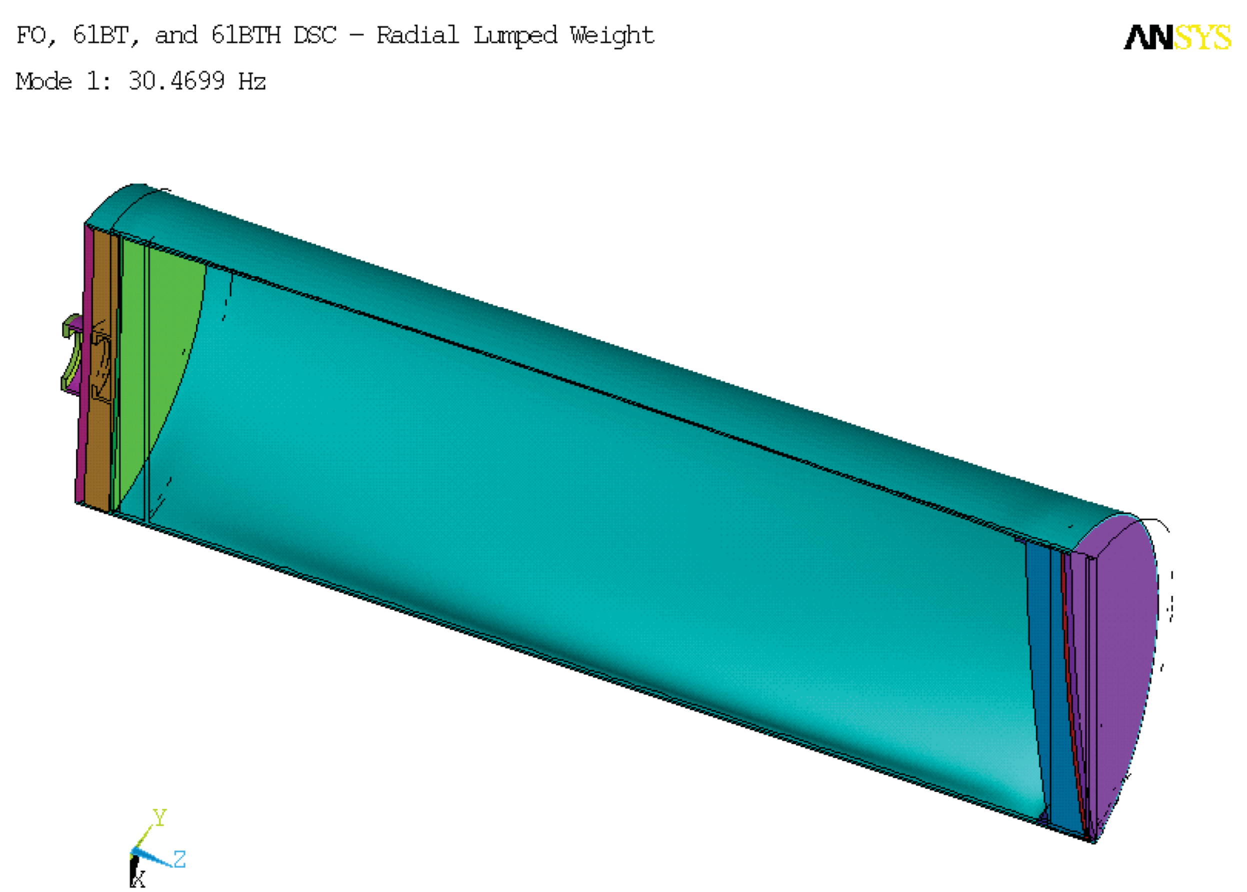

Figure A.7-4
FO, 61BT, and 61BTH Type 1 Radial Direction DSC Model – First Mode Shape

All Indicated Changes are in response to RSI NP-5.4

Proprietary Information on Page A.7-24 through A.7-25
Withheld Pursuant to 10 CFR 2.390

A.11.2 Potential Release Source Term

As noted in Section A.11.1 the FO-, FC-, FF- DSCs, a non-mechanistic leakage rate of 10^{-5} std cm^3/sec is postulated. The actinides and fission products for a B&W 15x15 fuel assembly are computed using SCALE6/ORIGEN-ARP. Two isotopic sets are considered, based on the design basis neutron and gamma sources. The design basis neutron source has a burnup of 38,268 MWd/MTU, enrichment of 3.18% U-235, and was discharged in 1983. The design basis gamma source has a burnup of 34,143 MWd/MTHM, enrichment of 3.21% U-235, and was discharged in 1989. The two source terms considered are decayed until June 2020, which corresponds to the placement of the first canisters at the Waste Control Specialists, LLC (WCS) Consolidated Interim Storage Facility (CISF). The reported source term in Table A.11-1 is the maximum value of the two isotopic sets considered. *The design basis radioactive inventory for the confinement evaluation included in reference [A.11-1] was determined using these same bounding fuel assemblies as documented in Section 7.2.1 of Volume I of [A.11-1] (See also calculation 2069-0507, Revision 0 included in Volume IV of [A.11-1]).*

The crud source is determined based on 140 μCi/cm^2 Co-60 on the surfaces of the SNF rods at the time of discharge [A.11-3]. The design basis gamma assembly was discharged in 1989, or 31 years decay until loading. Therefore, the crud source term in Table A.11-1 is decayed 31 years.

All Indicated Changes are in response to RSI NP-9.7

3. Calculate the isotope specific leak rates by multiplying the specific activities by the seal leak rate for each condition.

4. Determine the dose to the whole body, thyroid, lens of the eye, skin, and other critical organs from inhalation and immersion exposures at the controlled area boundary. Atmospheric dispersion factors are determined using Regulatory Guide 1.145 [A.11-8] and dose conversion factors are taken from EPA Guidance Reports No. 11 [A.11-9] and No. 12 [A.11-10].

A.11.3.2 Specific Activities for Release

Specific activities for release are computed for the canister based on SNF assembly activities in Table A.11-1 and normal, off-normal, and accident release fractions in Table A.11-4. The specific activities are based on 24 SNF *design basis* assemblies per canister and a cavity free volume of 5,592,315 cm^3. The specific activities for release are provided in Table A.11-5. *The maximum number of fuel assemblies in any canister is 24 SNF assemblies; therefore, this assumption bounds all of the loaded FO-, FC- and FF-DSCs.*

A.11.3.3 Leakage Rates

A leak rate in the units std·cm^3/sec corresponds to a leak of dry air at a temperature of 25°C from a pressure of 1 atm (absolute) to a pressure of 0.01 atm (absolute). Because the canister contains an atmosphere that is primarily helium at various temperatures and pressures, the specified standard leak rate must be adjusted for the change in gas, temperature, and pressure. The design basis conditions for the canisters are provided in Table 8-2a of [A.11-1]. Using the method from ANSI N14.5 [A.11-2] and a leakage hole length assumed to be the size of the weld length (3/16 inches), the hole diameter is computed to be 4.7611x10^{-4} cm for a leakage rate of 10^{-5} std·cm^3/sec.

Based on ANSI N14.5, the computed leakage rates for the three operating conditions are:

- Normal condition leakage rate = 4.4914x10^{-6} cm^3/sec
- Off-normal condition leakage rate = 7.5892x10^{-6} cm^3/sec
- Accident condition leakage rate = 2.5413x10^{-5} cm^3/sec

The isotope specific leak rates (Q_i - Ci/sec) used in the exposure calculations are equal to the number of canisters, multiplied by the specific activity, multiplied by the leakage rate, or:

$$Q_i = N \cdot S_i \cdot L$$

where: N is the number of canisters

S_i is the specific activity of nuclide i (Ci/cm^3)

All Indicated Changes are in response to RSI NP-9.7

A.12.2.3 Earthquakes

Cause of Accident

Site-specific ground-surface uniform hazard response spectra (UHRS) with 1E-4 annual frequency of exceedance (AFE) having peak ground acceleration (PGA) of 0.250 g horizontal and 0.175 g vertical are shown in Table 1-2, Table 1-5 and Figure 1-5. *The site-specific response spectra are used in the WCS CISF SSI analysis to obtain the enveloped acceleration spectra at the HSM CG and base.* Section A.7.5 demonstrates that the enveloping *WCS CISF site-specific* seismic forces remain below their applicable capacities for the NUHOMS® MP187 Cask System components.

Accident Analysis

The structural, thermal, and radiological consequences and the recovery measures required to mitigate an earthquake are addressed in Sections 8.3.2.2, 8.3.2.1 of Volume II and 8.3.2.1 of Volume III of [A.12-1]. In addition, Chapter A.8 demonstrates that the thermal analysis performed for the NUHOMS® MP187 Cask System in [A.12-1] is bounding for WCS CISF conditions.

A.12.2.4 Lightning

Cause of Accident

The likelihood of lightning striking the HSM Model 80 and causing an off-normal or accident condition is not considered a credible event. Simple lightning protection equipment for the HSM structures is considered a miscellaneous attachment acceptable per the HSM design.

Accident Analysis

Should lightning strike in the vicinity of the HSM the normal storage operations of the HSM will not be affected. The current discharged by the lightning will follow the low impedance path offered by the surrounding structures or the grounding system installed around each block of HSMs. The heat or mechanical forces generated by current passing through the higher impedance concrete will not damage the HSM. Since the HSM requires no equipment for its continued operation, the resulting current surge from the lightning will not affect the normal operation of the HSM.

Since no accident conditions will develop as the result of a lightning strike near the HSM, no corrective action would be necessary. In addition, there would be no radiological consequences

All Indicated Changes are in response to RSI NP-5.4

B.3.3 Design Criteria for Environmental Conditions and Natural Phenomena

B.3.3.1 Tornado Wind and Tornado Missiles

The design basis tornado wind and tornado missiles for the Standardized Advanced NUHOMS® Horizontal Modular Storage System AHSM are provided in Section 2.2.1 of reference [B.3-1] and for the NUHOMS®-MP187 cask in Section 3.2.1 of Volume 1 of reference [B.3-2]. The Standardized Advanced NUHOMS® Horizontal Modular Storage System components are designed and conservatively evaluated for the most severe tornado and missiles anywhere within the United States (Region I as defined in NRC Regulatory Guide 1.76 [B.3-9]) while the WCS CISF is in Region II, a less severe location with respect to tornado and tornado missiles.

The AHSM protects the DSC from adverse environmental effects and is the principal structure exposed to tornado wind and missile loads. Furthermore, all components of the AHSM (regardless of their safety classification) are designed to withstand tornadoes and tornado-based missiles. The MP187 cask protects the DSC during transit to the Storage Pad from adverse environmental effects such as tornado winds and missiles.

B.3.3.2 Water Level (Flood) Design

The 24PT1 DSCs and AHSMs are designed for an enveloping design basis flood, postulated to result from natural phenomena as specified by 10 CFR 72.122(b). The system is evaluated for a flood height of 50 feet with a water velocity of 15 fps.

The DSCs are subjected to an external hydrostatic pressure equivalent to the 50 feet head of water. The AHSM is evaluated for the effects of a water current of 15 fps impinging on the sides of a submerged AHSM. For the flood case that submerges the AHSM, the inside of the AHSM will rapidly fill with water through the AHSM vents.

The flood used in the evaluation of the Standardized Advanced NUHOMS® Horizontal Modular Storage System components envelopes the WCS CISF maximum flood height of 1.1 inches with a speed of 1.7 fps.

B.3.3.3 Seismic Design

The seismic criteria for the Standardized Advanced NUHOMS® Horizontal Modular Storage System AHSM are provided in Section 2.2.3 of reference [B.3-1]. This system was designed for very high seismic regions, such as the west coast, and as such the design basis earthquake shown in Figures 2.2-1 and 2.2-2 of reference [B.3-1] for the AHSM easily envelops *the enveloping acceleration response spectra at the WCS concrete pad base and HSM center of gravity obtained by the WCS CISF soil-structure interaction (SSI) analysis* at all frequencies as demonstrated in Sections B.7.5 and B.7.8. Due to the very low accelerations, the ties between the individual modules and the shear keys used to transfer vertical motions are not required at the WCS CISF.

All Indicated Changes are in response to RSI NP-5.4

B.7.5 Seismic Reconciliation of the Advanced NUHOMS® 24PT1 DSC and AHSM Storage Components and the MP187 Transfer Cask

The site-specific seismic ground motion developed for the WCS CISF in the form of the 10,000-year return period uniform hazard response spectra for the horizontal and vertical directions are described in Chapter 2.

As described in Section 2.2.3.1 of [B.7-1] the design basis seismic design criteria for the canister and AHSM components consists of the standard NRC Regulatory Guide 1.60 response spectrum shape anchored at a ZPA of 1.5g for the horizontal direction. The vertical spectrum is set at two-thirds of the horizontal direction over the entire frequency range. The horizontal and vertical spectra are specified at the top of the basemat. The horizontal and vertical components of the design response spectra, at 4% damping, are shown in Figure 2.2-1 and Figure 2.2-2 of [B.7-1].

A comparison of the seismic design basis for the Standardized Advanced NUHOMS® components and the *±15% peak broadened response spectra obtained at the center of gravity (CG) level from the soil structure interaction analysis of the WCS pad* are shown in Figure B.7-2 for the horizontal and vertical directions.

As shown in Figure B.7-2, the design basis seismic criteria for the canister and AHSM significantly exceed the seismic criteria for the *AHSMs and 24PT1s on the WCS pad*. Hence, the canister and the AHSM designs have significant margins and no reconciliation for seismic loads needs to be performed for these components.

As discussed in Appendix A.7, the design basis response spectra for the MP187 cask is the standard NRC Regulatory Guide 1.60 spectrum shape anchored at 0.25g for the horizontal direction and 0.17g for the vertical direction. These spectra are compared to the WCS CISF site-specific spectra in Figure A.7-1, for damping values of 3%, 5%, and 7%. *The WCS CISF site-specific spectra are compared to the ±15% peak broadened response spectra at the HSM base, which are obtained from the soil-structure interaction analysis of the WCS pad, in Figure A.7-5 and A.7-6 for a damping value of 3%.*

The discussion in Section B.7.3 demonstrates the similarity of the canister, described in [B.7-1], and the FO- DSC, described in [B.7-4]. Therefore, the seismic reconciliation of the MP187 cask loaded with a bounding FO-, FC- and FF- DSC presented in Section A.7.5.1 is applicable to the MP187 cask loaded with a 24PT1 DSC.

All Indicated Changes are in response to RSI NP-5.4

B.7.8.6 Tornado & *Missile Impact* Loads Analysis - Stability Evaluations

Cask Stability for Design Basis Tornado Wind Pressure Load

The restoring moment will be the smallest for the assembly with minimum weight. Conservatively, the total weight of the loaded cask and transfer trailer and skid, W_c, is taken as 270 kips (refer to Section B.7.8.1, Assumption 2). The restoring moment, M_{st} = (Total Weight) × (Half Width of the Trailer) = 270 × 5.25 = 1,417.50 kips-ft.

The maximum overturning moment (M_{ot}) for the cask-skid-trailer due to DBT wind pressure is calculated by taking both the windward force and the leeward force into account. Conservatively, it is assumed that the wind loads on the windward side and leeward side are the same and are equal to the design wind load, F = 16.14 kips (calculated in Section B.7.8.5.1)

Per Figure B.7-3, the height corresponding to the centerline of the MP187 Cask is taken as the point of load application: H=(42+15+83.5/2) = 98.75 inches = 8.23 ft.

Therefore, the overturning moment, M_{ot} = 2×F×H = 2× 16.14 x (8.23) = 265.66 kip-ft

Factor of safety against overturning $\dfrac{M_{st}}{M_{ot}} = \dfrac{1417.50}{265.66} = 5.34$

Cask Stability for Massive Missile Impact Load

A stability analysis is performed to analyze the most critical impact, when the missile hits the cask on the side. However, it is conservatively assumed that the missile hits the top most point of the cask as shown in Figure B.7-4.

The Case B missile from Table B.7-5, i.e. the massive high kinetic energy automobile missile, is used since it produces the maximum force and the highest overturning moment. Conservatively, the impact is assumed as perfectly inelastic

Using the geometrical relations of Figure B.7-4 and the missile characteristics from Table B.7-5, the evaluation is based on conservation of momentum at impact and the conservation of energy to estimate the angle of rotation, θ, due to the impact (cask stops rotating when the angular velocity after impact becomes zero).

The resultant formula for the angle of rotation due to impact, θ, for the analyzed geometry has the following form:

$$\sin(\phi+\theta) = \frac{(R_1 V_i M_m)^2}{2W_c R_2[(I_c)_o + R_1^{\,2} M_m]} + \sin\phi$$

with:

All Indicated Changes are in response to RSI NP-5.4

$$t = \frac{\left(\frac{M_m V_m^2}{2}\right)^{2/3}}{672d} = 0.42 \text{ inch}$$

In the above relation:

t = the maximum thickness of plate material leading to onset of plate puncture (inch),

d = the diameter of the punch/missile (= 6.625 inch),

M_m = the mass of the striking missile, (=287/32.2 = 8.91 lbm),

V_m = the velocity of the striking missile normal to target surface (=134.81 fps).

Reference [B.7-11] recommends increasing the thickness, t, by 25 percent to prevent perforation. Therefore, the minimum thickness required to prevent perforation of the MP187 cask is 0.53 inch.

B.7.8.9 Summary of Results

The factor of safety on overturning from DBT tornado wind pressure load is 5.34.

The resultant stresses for the bounding individual DBT, missile impact and combined tornado load are summarized in Table B.7-8 and Table B.7-9, respectively. The primary membrane stress and combined membrane plus bending stresses due to DBT and missile impact are below the allowable stresses.

The minimum thickness of the steel components required to prevent perforation by tornado missiles is found to be 0.53 inch, which is less than the thickness of the MP187 cask Outer Shell, Top Cover Plate, and RAM Closure Plate of 2.49 inches, 6.50 inches, and 3.18 inches, respectively.

The maximum rotation angle of the MP187 cask transfer configuration due to combined tornado wind plus massive missile impact load is θ=3.0°, which is significantly below the permissible angle of rotation, 10.85°.

All Indicated Changes are in response to RSI NP-5.4

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Accident Analysis

The structural, thermal, and radiological consequences and the recovery measures required to mitigate the effects of a drop accident are addressed in Section 8.2.1.3 of Volume I of [B.12-5] for the MP187 cask in the transfer configuration. Section 3.6 of [B.12-1] demonstrates that the canister remains leak tight and the basket maintains its configuration following the drop event. In addition, Chapter B.8 demonstrates that the thermal analysis performed for the NUHOMS® MP187 Cask System in [B.12-1] is bounding for WCS CISF conditions.

Corrective Action

Consistent with Section 11.2.5.4 of [B.12-1], the canister will be inspected for damage, as necessary. Removal of the transfer cask top cover plate may require cutting of the bolts in the event of a corner drop onto the top end. These operations will take place in the Cask Handling Building.

Following recovery of the transfer cask and transfer of the canister in the AHSM, the transfer cask will be inspected, repaired and tested as appropriate prior to reuse.

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

B.12.2.3 Earthquakes

Cause of Accident

Site-specific ground-surface uniform hazard response spectra (UHRS) with 1E-4 annual frequency of exceedance (AFE) having peak ground acceleration (PGA) of 0.250 g horizontal and 0.175 g vertical are shown in Table 1-2, Table 1-5 and Figure 1-5. *The site-specific response spectra are used in the WCS CISF SSI analysis to obtain the enveloped acceleration spectra at the HSM CG and base.* Section B.7.5 demonstrates that the enveloping *WCS CISF site-specific* seismic forces remain below their applicable capacities for the MP187 cask and Standardized Advanced NUHOMS® System components.

Accident Analysis

The structural and thermal consequences of an earthquake are addressed in Section 11.2.1.2 of [B.12-1]. The MP187 cask, when mounted on the transfer vehicle during an earthquake is subjected to stresses which are bounded by the 80-inch cask drop analysis. In addition, Chapter B.8 demonstrates that the thermal analysis performed for the Standardized Advanced NUHOMS® System in [B.12-1] is bounding for WCS CISF conditions.

All Indicated Changes are in response to RSI NP-5.4

C.3.3 Design Criteria for Environmental Conditions and Natural Phenomena

C.3.3.1 Tornado Wind and Tornado Missiles

The design basis tornado wind and tornado missiles for the Standardized NUHOMS® Horizontal Modular Storage System HSM Model 102 are provided in Section K.2.2.1 and Section 3.2.1 of reference [C.3-1] and in Table C.3-1 for the NUHOMS®-MP197HB cask. The 61BT-DSC and HSM Model 102 components are designed and conservatively evaluated for the most severe tornado winds and missiles postulated to occur anywhere within the United States (Region I as defined in NRC Regulatory Guide 1.76 [C.3-8]) while the WCS CISF is in Region II, a less severe location with respect to tornado and tornado missiles. The MP197HB cask is evaluated against the Region II tornado and tornado missiles as described in Appendix C.7.

The HSM protects the DSC from adverse environmental effects and is the principal structure exposed to tornado wind and missile loads. Furthermore, all components of the HSM (regardless of their safety classification) are designed to withstand tornado winds and tornado-based missiles. The MP197HB cask protects the DSC during transit to the Storage Pad from adverse environmental effects such as tornado winds and missiles.

C.3.3.2 Water Level (Flood) Design

The DSCs and HSM are designed for an enveloping design basis flood, postulated to result from natural phenomena as specified by 10 CFR 72.122(b). The system is evaluated for a flood height of 50 feet with a water velocity of 15 fps.

The DSCs are subjected to an external hydrostatic pressure equivalent to the 50 feet head of water. The HSM is evaluated for the effects of a water current of 15 fps impinging on the sides of a submerged HSM. For the flood case that submerges the HSM, the inside of the HSM will rapidly fill with water through the HSM vents.

The flood used in the evaluation of the Standardized NUHOMS®-61BT System components envelopes the WCS CISF maximum flood height of 1.1 inches with a speed of 1.7 fps.

C.3.3.3 Seismic Design

The seismic criteria for the Standardized NUHOMS® System HSM Model 102 are provided in Section K.2.2.3 and Section 3.2.3 of reference [C.3-1]. *The site-specific seismic ground motion developed for the WCS CISF in the form of the 10,000-year return period uniform hazard response spectrum for the horizontal and vertical directions are described in Chapter 2. Those spectra are used to derive the enveloped acceleration spectra at the WCS concrete pad base and HSM center of gravity. These enveloped spectra are the design seismic basis for the NUHOMS®-61BT System components.*

All Indicated Changes are in response to RSI NP-5.4

Table C.3-1
Summary of WCS CISF Principal Design Criteria
(4 pages)

Design Parameter	WCS CISF Design Criteria	Condition	NUHOMS®-61BT Design Criteria
Tornado (HSM Missile)	Automobile 4000 lb, 112 ft/s Schedule 40 Pipe 287 lb, 112 ft/s Solid Steel Sphere 0.147 lb, 23 ft/s	Accident (Bounded)	*Standardized NUHOMS® SAR Section 3.2.1 and Section K.2.2.1* Automobile 4000 lb, 195 ft/s 8" diameter shell 276 lb, 185 ft/s Solid Steel Sphere 0.147 lb, 23 ft/s Wood plank missile 1500 lb, 440 ft/s
Tornado (MP197HB Missile)	Automobile 4000 lb, 112 ft/s Schedule 40 Pipe 287 lb, 112 ft/s Solid Steel Sphere 0.147 lb, 23 ft/s	Accident (Same)	*Section C.7.7.1 (New Evaluation)* Automobile 4000 lb, 112 ft/s Schedule 40 Pipe 287 lb, 112 ft/s Solid Steel Sphere 0.147 lb, 23 ft/s
Floods	Flood height 1.1 inches Water velocity 1.7 ft/s	Accident (Bounded)	*Standardized NUHOMS® SAR Sections 3.2.2 and Section K.2.2.2* Flood height 50 ft Water velocity 15 ft/s
Seismic (Ground Motion)	Site-specific ground-surface uniform hazard response spectra (UHRS) with 1E-4 annual frequency of exceedance (AFE) having peak ground acceleration (PGA) of 0.250 g horizontal and 0.175 g vertical. (Table 1-5 and Figure 1-5)	Accident (*Evaluated*)	*See Evaluations in Section 7.6.4, 7.6.5, C.7.3 and C.7.5.3.*
Vent Blockage	For NUHOMS® Systems: Inlet and outlet vents blocked 40 hrs	Accident (Same)	*Standardized NUHOMS® SAR Section K.4.6.1* Inlet and outlet vents blocked 40 hrs
Fire/Explosion	For NUHOMS® Systems: Equivalent fire 300 gallons of diesel fuel	Accident (Same)	*Section C.8.5 (New Evaluation) Standardized NUHOMS® SAR Section K.4.6.5* Equivalent fire 300 gallons of diesel fuel

All Indicated Changes are in response to RSI NP-5.4

C.7.3 Seismic Reconciliation of the 61BT DSC, HSM Model 102, and MP197HB Cask

The site-specific seismic ground motion developed for the WCS CISF in the form of the 10,000-year return period uniform hazard response spectrum for the horizontal and vertical directions are described in Chapter 2. A comparison of the site-specific response spectra for the WCS CISF ground motion and the Regulatory Guide 1.60 design-basis ground motions' response spectra are shown in Figure C.7-25 for 3%, 5%, and 7% damping values. This comparison indicates that for system frequencies above about 10 Hz (horizontal direction) and 9 Hz (vertical direction), the WCS CISF spectral accelerations are higher than the design basis spectral accelerations. The ZPA values of 0.25g (horizontal) and 0.17g (vertical) for the WCS CISF ground motion are the same as those for the Standardized NUHOMS® System.

This section describes the reconciliation evaluations of the 61BT DSC, HSM Model 102, and MP197HB cask *using the enveloping response spectra at the HSM CG and base, which are obtained from the soil-structure interaction (SSI) analysis of the WCS CISF. Comparisons of the 3%-damped WCS CISF 10,000-year return period uniform hazard response spectra and +/-15% peak-broadened HSM base response spectra from the WCS CISF SSI analysis in the HSM's transverse, longitudinal, and vertical directions are shown in Figure C.7-26 and Figure C.7-27. The +/-15% peak-broadened HSM Base response spectra for damping values of 7%, 3%, and 2% are shown in Figure C.7-28 through Figure C.7-30.*

C.7.3.1 HSM Model 102

The reconciliation of the seismic loading on the HSM Model 102 is contained in Section D.7.3.1. Section D.7.3.1 considers the WCS CISF site-specific seismic loading on the HSM Model 102 loaded with a 61BTH Type 1 DSC, the weight of which bounds the 61BT DSC.

C.7.3.2 MP197HB Transfer Cask

The MP197HB Cask is designed as a transportation cask for off-site shipment under the provisions of 10 CFR 71. Due to the cask's design to meet off-site shipping requirements, large factors of safety are afforded for on-site transfer operations.

The MP197HB cask consists of a 2.75″ thick steel outer shell, a 3.0″ thick layer of lead, and a 1.25″ thick steel inner shell. *Soil-structure interaction (SSI) analyses were performed for the pad with high level waste storage units at the Andrews, TX waste storage facility site. These analyses are presented in Section 7.6.4. One of the purposes of the analyses was to determine the envelope of the acceleration response spectra at the HSM base, at the pad level. The +/-15% broadened envelope of the acceleration response spectra at the base of the HSM modules are shown in Figure C.7-26 and Figure C.7-27, for the cask transverse, longitudinal and vertical directions.*

All Indicated Changes are in response to RSI NP-5.4

Therefore, it is concluded that the MP197HB cask is acceptable for the WCS CISF site-specific seismic loading.

C.7.3.3 61BT DSC

Per Section K.3.7.3 of Reference [C.7-13], the canister shell components are evaluated for seismic loading of 3.0g and 1.0g for the horizontal and vertical directions, respectively. The basket components are evaluated for a bounding acceleration of 2g in each of the axial, transverse, and vertical direction [Section K.3.6.1.3.4 of C.7-13].

All Indicated Changes are in response to RSI NP-5.4

C.7.5.2 Off-Normal Loads

The structural analyses for off-normal loads is contained in Section K.3.6.2 of [C.7-13]. Two limiting off-normal events are defined which envelope the range of expected off-normal structural loads:

- Jammed Canister During Transfer:
  The analysis of the jammed 61BT canister during transfer is identical to the analysis of the 52B canister contained in Section 8.1.2 of [C.7-13]. All stresses are within the ASME code limits. As discussed in Section C.7.5, the analysis of this condition for transfer in the OS197 transfer cask is equivalent and applicable for transfer in the MP197HB cask.

- Off-Normal Thermal Loads:
  Off-Normal ambient temperatures are defined as -40 °F and 125 °F for the 61BT DSC. The stress results presented in Table K.3.6-4 of [C.7-13] show that the canister stress limits are satisfied for the off-normal thermal loads. The thermal stress analyses in Section K.3.4.4.3 of [C.7-13] show that the stress limits for the basket are satisfied for the off-normal thermal loads. As discussed in Section C.7.4, the thermal stress analyses of the 61BT DSC for transfer in the OS197 transfer cask are applicable for transfer in the MP197HB cask.

C.7.5.3 Accident Loads

The structural analysis of the 61BT DSC for accident loads is presented in Section K.3.7 of [C.7-13]. The following accident conditions affect the canister and are evaluated:

<u>Earthquake</u>

The seismic load is reconciled in Section C.7.3. As concluded in Section C.7.3, the 61BT DSC is acceptable for storage at the WCS CISF.

<u>Flood</u>

Evaluation of the canister for flood loads is contained in Section K.3.7.4.2 of [C.7-13]. The ASME Code methodology in NB-3133.3 is used to show that there is a safety margin of at least 1.8 against buckling of the canister shell. The shell stresses are calculated using an ANSYS finite element model and are shown to be much less than the ASME Service Level C allowable values.

<u>Accidental Cask Drop</u>

The 61BT DSC evaluations for the accident drop cases are presented in Section K.3.7.5 of [C.7-13]. Equivalent static loading of 75g is used to evaluate the effects of the drops.

All Indicated Changes are in response to RSI NP-5.4

HSM Reinforced Concrete

- Tornado Winds and Tornado Generated Missiles
  Evaluation of the HSM for tornado wind and missile effects is presented in Section 8.2.2 of [C.7-13]. The safety margins against overturning and sliding of the HSM are determined using hand calculations. The resistance of the HSM concrete to tornado-generated missile perforation and scabbing is determined using the National Defense Research Committee formula with additional margin added based on the requirements of ACI 349-85. The HSM door is also shown to be adequate to protect against missile impact. Table 8.2-3 of [C.7-13] provides the results of the analyses for tornado wind and tornado missile loads.

  Additional evaluations are performed for the massive missile. The maximum sliding distance of the HSM due to massive missile impact is found to be 0.58" and the maximum tipping angle of rotation is found to be 1.12° which is much less than the critical angle leading to tip-over of the HSM. The global structural effects of the massive missile impact are also evaluated and found to be acceptable.

- Earthquake
  As described in Section 8.2.3.2 of [C.7-13], the HSM is evaluated for accident level seismic loads using the Reg. Guide 1.60 response spectra anchored at 0.25g and 0.17g in the horizontal and vertical directions, respectively. A damping value of 7% is used. The resulting forces and moments in the HSM components are shown in Table 8.2-3 of [C.7-13].

  A factor of safety of 1.17 against overturning and 1.24 against sliding due to seismic load is calculated.

  A seismic reconciliation for the WCS CISF site-specific *seismic loading* is performed in Section C.7.3.1.

- Flood
  Section 8.2.4 of [C.7-13] evaluates the HSM for the effects of flood loading. The safety factors against overturning and sliding are 1.55 and 1.13, respectively. Table 8.2-3 of [C.7-13] provides the results of the analyses for flood loading.

- Lightening
  As discussed in Section 8.2.6 of [C.7-13], lightening is found not to affect the normal operation of the HSM.

- Blocked Vent Thermal Loads
  As described in Section 8.2.7 of [C.7-13], the HSM is analyzed for thermal stresses due to the blocked vent condition. Table 8.2-3 of [C.7-13] provides the results of the analyses for the blocked vent thermal load case.

All Indicated Changes are in response to RSI NP-5.4

DSC Axial Retainer

Section 8.2.3.2(C)(iii) of [C.7-13] evaluates the DSC axial retainer for a seismic load of 0.40g using a canister weight of 102 kips and an impact factor of 1.5. The seismic reconciliation of the HSM Model 102 in Section D.7.3.1 *evaluates the axial retainer considering* the WCS CISF site-specific load.

C.7.6.4 Load Combinations

Section 8.2.10 of [C.7-13] describes the combination of the applicable normal, off-normal, and accident load cases.

- HSM Reinforced Concrete
  The governing calculated bending moments and shear forces for each applicable load combination are shown in Table 8.2-18 of [C.7-13]. The same table also lists the ultimate capacities of each section and shows that the design strength of the HSM is greater than the strength required for the most critical load combinations.

- DSC Steel Support Structure
  The applicable loads on the DSC steel support structure are combined into three governing load cases. The resulting maximum stresses are compared to the AISC code allowables in Table 8.2-19 of [C.7-13]. The same load combinations are used for the DSC steel support structure connecting elements. The maximum connection loads are shown in Table 8.2-20 of [C.7-13]. The structural steel design is based on the requirements of the AISC specification for structural steel buildings, 1989 version, and the embedments are designed in accordance with the requirements of ACI 349-85.

C.7.7 Structural Analysis of MP197HB Cask as On-Site Transfer Cask

C.7.7.1 General Information

This section presents the structural evaluations of the MP197HB cask for on-site transfer operations at the WCS CISF loaded with either the 61BT or 61BTH Type 1 DSC. The evaluations consist of *finite element* analyses and hand calculations to demonstrate that the MP197HB cask meets the requirements of 10 CFR Part 72.

Section C.7.7.2 discusses the evaluations and results for Normal and Off-Normal Conditions. Section C.7.7.3 discusses the analyses for Accident Conditions. The stability, stresses, and penetration resistance of the MP197HB cask due to design basis tornado, seismic loads, and missile impact are presented in Section C.7.7.4.

Key structural dimensions and weights of the MP197HB cask are summarized in Table C.7-9 and compared with the MP187 cask and the OS197 transfer cask licensed for on-site transfer operations in [C.7-12] and [C.7-13], respectively.

Figure C.7-1 identifies key components of the MP197HB cask body ANSYS finite element model. This model is the same as the model used in [C.7-1], which was reviewed and approved by the NRC for the MP197HB transportation license CoC 71-9302. Cask body stresses are examined for the following seven structural components: Outer Shell, Inner Shell, Top Cover Plate (Lid), Top Flange, Bottom Flange, Bottom Plate, and RAM (Access) Closure Plate. Individual design elements of the MP197HB cask, such as lid bolts and neutron shield shell, are structurally qualified by reference to analyses conducted for the cask for bounding loads documented in [C.7-1].

C.7.7.1.1 Finite Element Analysis Models

The ANSYS code Release 14.0, [C.7-14], is used for the evaluations of normal, off-Normal, and accident condition events. The FEA models employed in [C.7-1] and described in [C.7-1] Appendix A.2.13.1.2 (3D models) and [C.7-1] Appendix A.2.13.3.2 (axisymmetric model) are utilized to the maximum possible extent and adapted to fit the requirements of analyses for the WCS CISF. The original models were generated by means of the ANSYS code, Release 10.0. The ANSYS model features specific to Normal and Off-Normal Condition evaluations are delineated in Section C.7.7.2.2. Section C.7.7.3.2 presents model features specific to Accident Condition evaluations. Key common features for all employed models are outlined below.

All Indicated Changes are in response to RSI NP-5.4

W_m = weight of missile =4000 lb. (Table C.7-13)

Schedule 40 Pipe Missile (Table C.7-13 – Case A)

The impact force is calculated using the principle of conservation of momentum and the relation $F\Delta T = G_f - G_i$:

$$F = \frac{M_m(V_i - V_f)}{(T_f - T_i)} = \frac{M_m(V_i - V_f)}{(\Delta T)} = \frac{287 \times (134.81 - 0)}{32.2 \times 0.05 \times 1000} = 24.03\, kips$$

where:

ΔT = the time of contact
= 0.05 sec (conservatively shorter than impact time 0.075 sec from [C.7-7])

G_f $= M_m V_f = 0$ the linear momentum after impact at time $T = T_f$

G_i = $M_m V_i$ the linear momentum at time $T = T_i$

V_i = total striking velocity of the missile = $\sqrt{112^2 + (0.67 \times 112)^2} = 134.81$ fps (Table C.7-13)

M_m = the mass of the missile

C.7.7.4.6 Tornado & *Missile Impact* Loads Analysis - Stability Evaluations

C.7.7.4.6.1 Cask Stability for Design Basis Tornado Wind Pressure Load

The restoring moment will be the smallest for the assembly with minimum weight. Conservatively, the total weight of the loaded cask and transfer vehicle and skid - W_c is taken as 245 kips (refer Section C.7.7.4.1, Assumption 2). The restoring moment, M_{st} = (Total Weight) × (Half Width of the transfer vehicle) = 245 × 5.5 = 1,347.5 kips-ft.

The maximum overturning moment (M_{ot}) for the cask/skid/transfer vehicle due to DBT wind pressure is calculated by taking windward force and leeward force into account. Conservatively, it is assumed that the wind load in windward side and leeward side is same and is equal to the design wind load, F = 17.14 kips (calculated in Section C.7.7.4.5.1)

Per Figure C.7-22, the height corresponding to the centerline of the MP197HB cask is taken as the point of load application: H=43+17+84.5/2 = 102.25 inches = 8.52 ft.

Therefore, the overturning moment, M_{ot} = 2×F×H = 2× 17.14 x (8.52) = 292.1 kips-ft

All Indicated Changes are in response to RSI NP-5.4

Factor of safety against overturning

$$\frac{M_{st}}{M_{ot}} = \frac{1347.5}{292.1} = 4.61$$

C.7.7.4.6.2 Cask Stability for Massive Missile Impact Load

A stability analysis is performed to analyze the most critical impact, when the missile hits the cask on the side. However, it is conservatively assumed that the missile hits the top most point of the cask as shown in Figure C.7-23.

The Case B missile from Table C.7-13, i.e. the massive high kinetic energy automobile missile, is used since it produces the maximum force and the highest overturning moment. Conservatively, the impact is assumed as perfectly inelastic

Using the geometrical relations of Figure C.7-23 and the missile characteristics from Table C.7-13, the evaluation is based on conservation of momentum at impact and the conservation of energy to estimate the angle of rotation θ due to the impact (cask stops rotating when the angular velocity after impact becomes zero).

The resultant formula for angle of rotation due to impact θ for the analyzed geometry has the following form:

$$\sin(\phi + \theta) = \frac{(R_1 V_i M_m)^2}{2W_c R_2[(I_c)_o + R_1^2 M_m]} + \sin\phi$$

with:

$$\phi = \tan^{-1}(L_1/R) = \tan^{-1}\left(\frac{43+17+84.5/2}{5.5\times 12}\right) = 57.16°$$

(refer to Figure C.7-22 and Figure C.7-23),

$(H_i)_o$ = the angular momentum about point O before impact $= R_1 V_i M_m$ (Figure C.7-23),

$(H_a)_o$ = the angular momentum about point O after impact $= R_1^2 \omega_i M_m + (I_c)_o \omega_i$ (Figure C.7-23),

R_1 $= \sqrt{L^2 + R^2} = \sqrt{12.04^2 + 5.5^2} = 13.24\ ft$ is the distance from point O to the impact point (Figure C.7-23),

R_2 $= \sqrt{L_1^2 + R^2} = \sqrt{8.52^2 + 5.5^2} = 10.14\ ft$ is the distance from point O to the center of the cask. (Figure C.7-23),

All Indicated Changes are in response to RSI NP-5.4

d = the diameter of the punch/missile (6.625 inch, refer Table C.7-13),

E_F = the incipient puncture energy of the prismatic cask jacket (inch - lb).

The threshold thickness values causing perforation for the Outer Shell, Top Cover Plate and RAM Closure Plate according to Nelms' correlation are 0.43 inch, 0.43 inch, and 0.43 inch, respectively.

C.7.7.4.8.2 Ballistic Research Laboratory Formula Evaluation

In the Ballistic Research Laboratory report, the relation for the determination of the thickness is also directly proportional to mass and velocity and inversely proportional to diameter of the missile.

$$t = \frac{\left(\frac{M_m V_m^2}{2}\right)^{2/3}}{672d} = 0.42 \text{ inch}$$

In above relation:

t = the maximum thickness of plate material leading to an onset of plate puncture (inch),

d = the diameter of the punch/missile (= 6.625 inch),

M_m = the mass of the striking missile, (=287/32.2 = 8.91 lbm),

V_m = the velocity of the striking missile normal to target surface (=134.81 fps).

Reference [C.7-7] recommends increasing the thickness, t, by 25 percent to prevent perforation. Therefore, the minimum thickness required to prevent perforation of the MP197HB cask is 0.53 inch.

C.7.7.4.9 Summary of Results

Factor of safety on overturning from DBT tornado load is 4.61, which is greater than the required safety factor of 1.1.

The resultant stresses for the bounding individual DBT, missile impact and combined tornado load are summarized in Table C.7-16 and Table C.7-17, respectively. The primary membrane stress intensity and combined membrane plus bending stresses due to DBT and missile impact are below the allowable stresses.

The minimum thickness of the steel components required to prevent perforation by tornado missiles is found to be 0.53 inch, which is less than the thickness of the MP197HB cask outer shell, Top Cover Plate, and RAM Closure Plate of 2.75 inches, 4.5 inches, and 2.5 inches, respectively.

All Indicated Changes are in response to RSI NP-5.4

C.7-17 US NRC Document NUREG/CR-6007 "Stress Analysis of Closure Bolts for Shipping Casks."

C.7-18 ANSI N14.6-1993 American National Standard for Radioactive Materials – "Special Lifting Devices for Shipping Containers Weighing 10,000 Pounds (4500 kg) or More," 1993.

C.7-19 Blevins, Robert D. Formulas for Natural Frequency and Mode Shape. 2001.

C.7-20 Regulatory Guide 1.61, "Damping Values for Seismic Design of Nuclear Power Plants," U.S. Nuclear Regulatory Commission, Revision 1, March 2007.

All Indicated Changes are in response to RSI NP-5.4

Table C.7-1
Load Combination and Service Levels for MP197HB Cask

Load Case [3]		**Normal Conditions**			**Off-Normal Conditions**		**Accident Conditions**					
Dead Load I Live Load			X			X	X					
Thermal w/canister	0° to 110 °F Ambient	X	X									
	-20° to 120 °F Ambient				X	X						
Cask Lift	2g Vertical + DW			X								
Transfer Handling Loads[1]	± 1g Vertical + DW	X			X							
	± 1g Axial + DW	X			X							
	± 1g Transverse + DW	X			X							
	± 1/2g Axial ±1/2g Transverse ±1/2g Vertical + DW	X			X							
HSM Loading/ Canister Transfer	Normal (110k) Insertion		X			X						
	Normal (80k) Retrieval		X			X						
	"Accident" (110k) Insertion						X					
	"Accident" (110k) Retrieval						X					
Seismic [2]	± *0.36g* Axial ± *0.53g* Transverse ± *0.44g* Vertical + DW							X				
Drop Loads	75g Vertical (End) Drop									X		
	25g (30°) Corner Drop										X	
	75g Side Drop											X
ASME Code Service Level		A	A	A	B	B	C	C	D	D	D	D

Notes:
1. Cases with transfer handling loads are subdivided into four (4) separate cases as follows:
   Subcase a: ± 1g Vertical + DW
   Subcase b: ± 1g Axial + DW
   Subcase c: ± 1g Transverse + DW
   Subcase d: ± 1/2g Axial ± 1/2g Transverse ± 1/2g Vertical + DW
2. Seismic Level C load is bounded by transfer load, Subcase d
3. Normal and Off-Normal Conditions evaluations account additionally for the Top Cover Plate bolt preload load

All Indicated Changes are in response to RSI NP-5.4

Proprietary Information on Page C.7-83 through C.7-87
Withheld Pursuant to 10 CFR 2.390

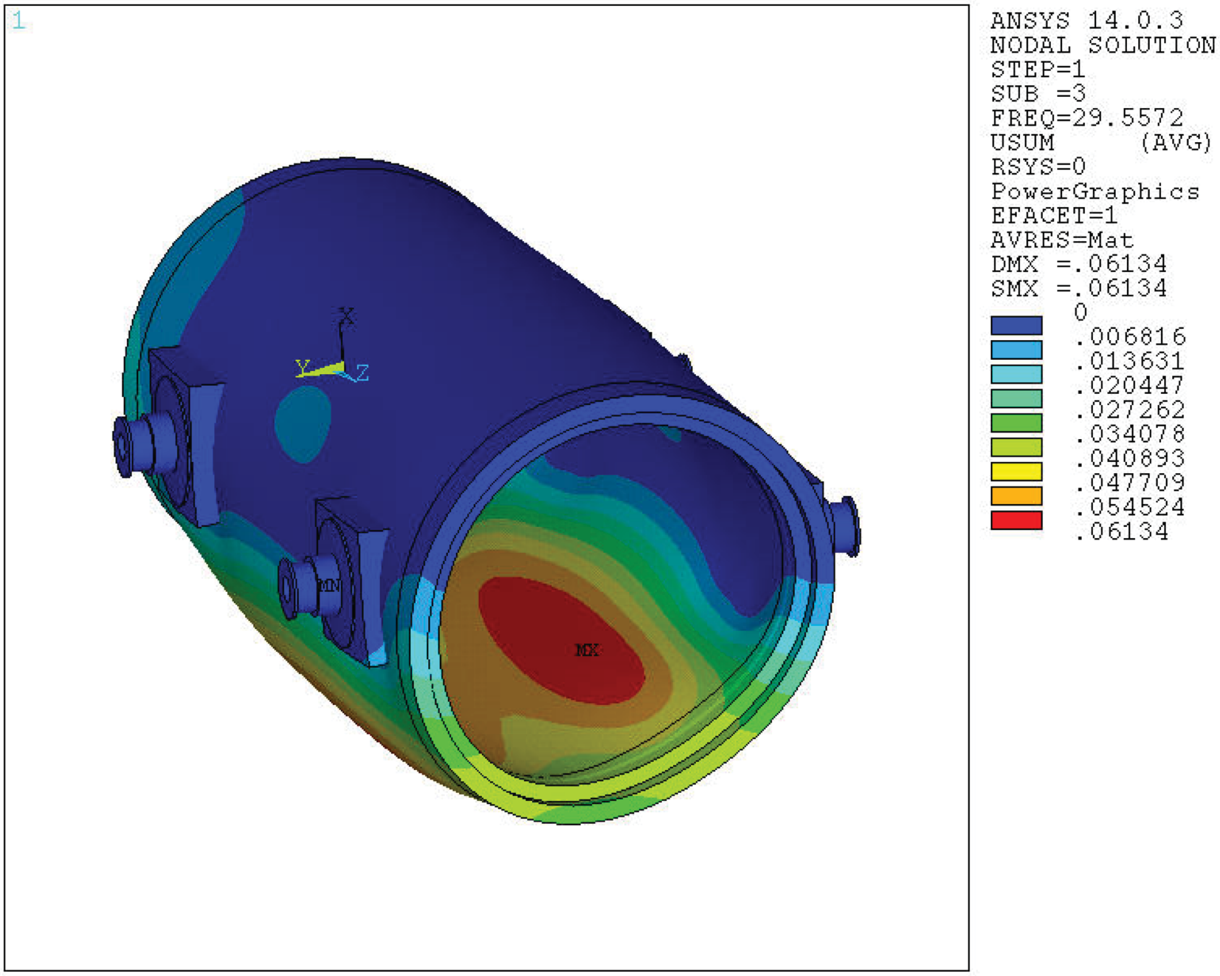

Figure C.7-31
Dominant frequency (29.6Hz) for transverse direction

All Indicated Changes are in response to RSI NP-5.4

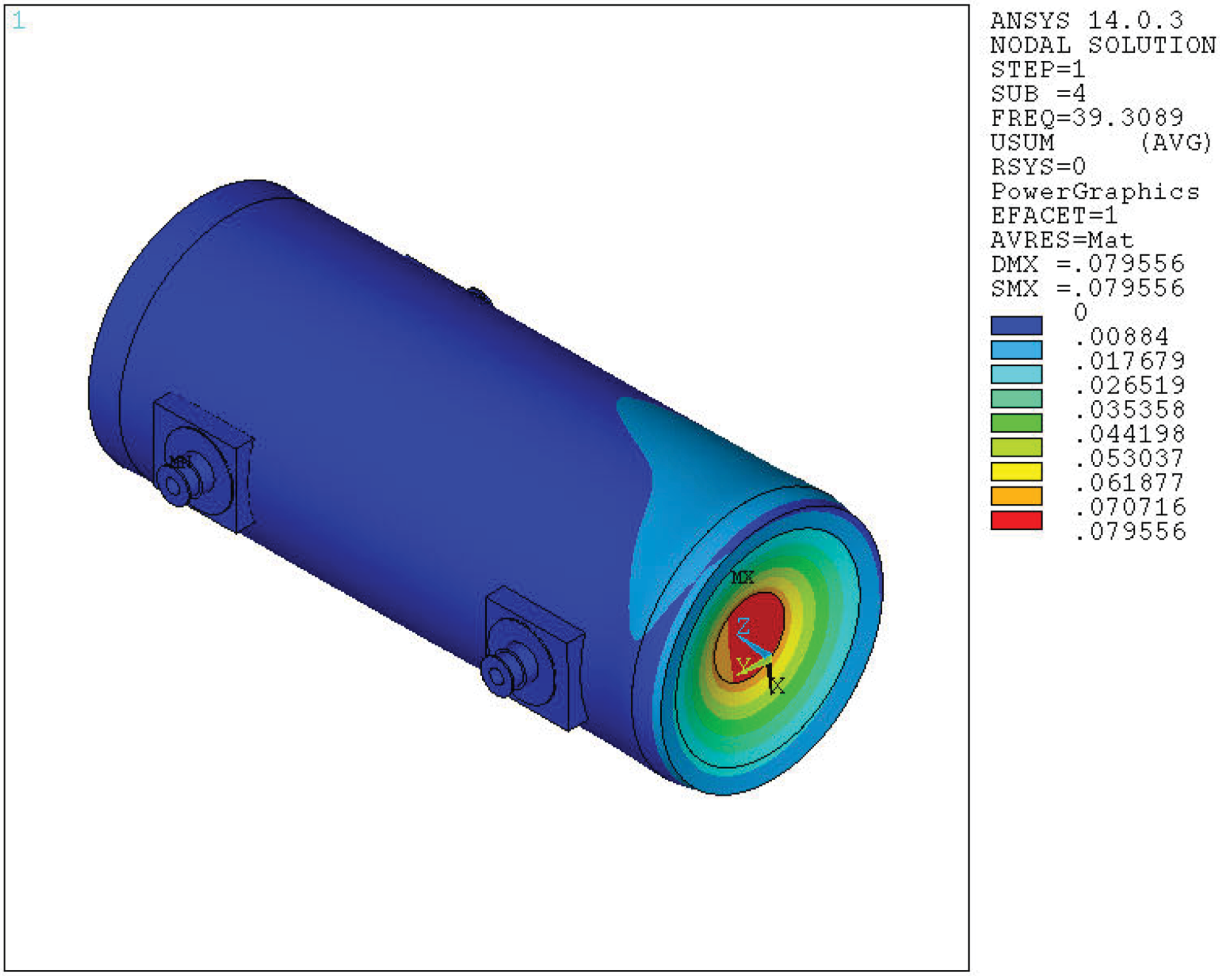

Figure C.7-32
Dominant frequency (39.3Hz) for longitudinal direction

All Indicated Changes are in response to RSI NP-5.4

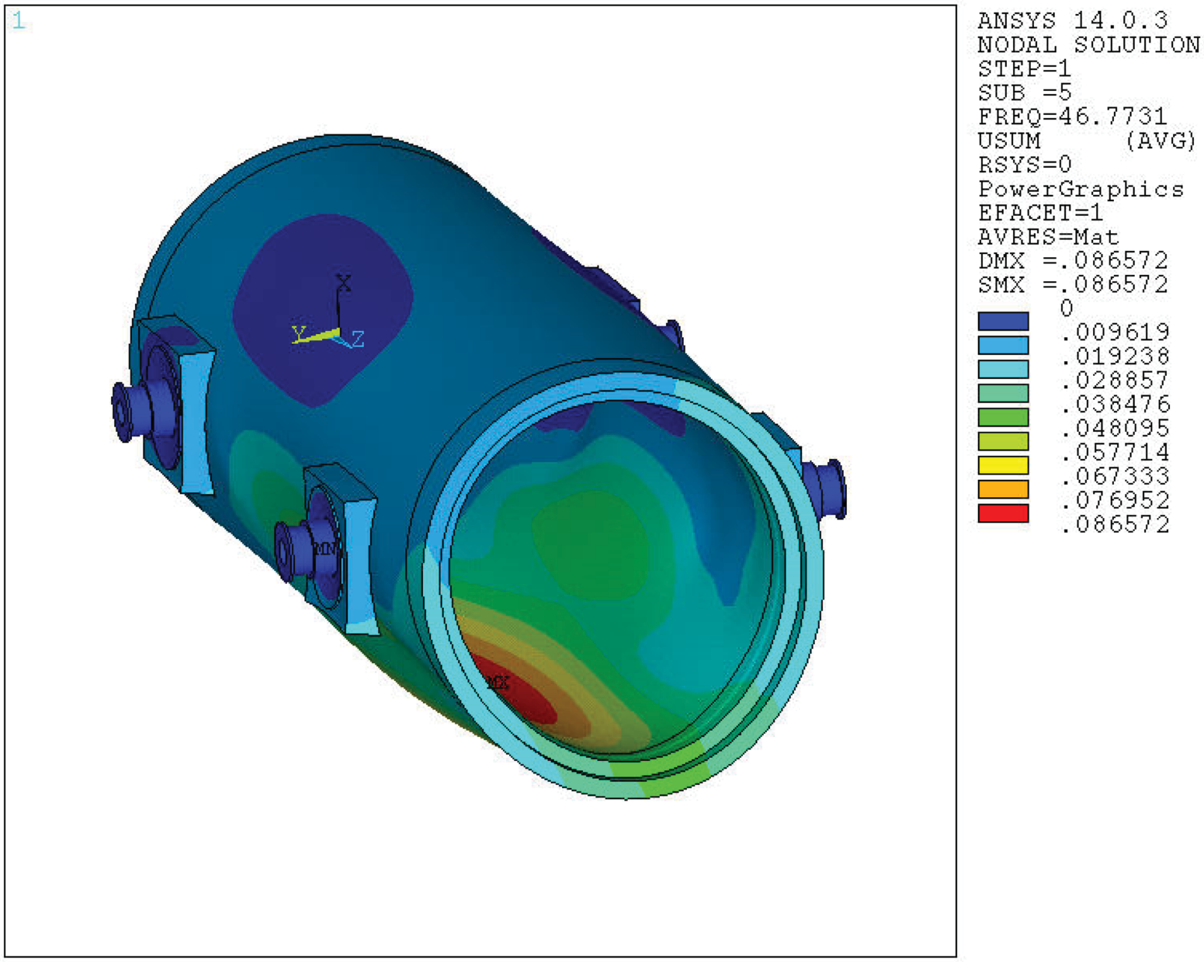

Figure C.7-33
Dominant frequency (46.8Hz) for vertical direction

All Indicated Changes are in response to RSI NP-5.4

C.12.2.3 Earthquakes

Cause of Accident

Site-specific ground-surface uniform hazard response spectra (UHRS) with 1E-4 annual frequency of exceedance (AFE) having peak ground acceleration (PGA) of 0.250 g horizontal and 0.175 g vertical are shown in Table 1-2, Table 1-5 and Figure 1-5. *The site-specific response spectra are used in the WCS CISF SSI analysis to obtain the enveloped acceleration spectra at the HSM CG and base. Section C.7.3 demonstrates that the MP197HB cask and Standardized NUHOMS® System components are structurally adequate for the WCS CISF site-specific seismic loading.*

Accident Analysis

The structural and thermal consequences of an earthquake are addressed in Sections K.11.2.2.2, 8.2.3.2 and K.3.7 of [C.12-1]. The MP197HB cask, when mounted on the transfer vehicle during an earthquake is evaluated in Appendix C.7. In addition, Chapter C.8 demonstrates that the thermal analysis performed for the Standardized NUHOMS® System in [C.12-1] is bounding for WCS CISF conditions.

Accident Dose Calculations

As documented in Section K.11.2.2.3 of [C.12-1], there are no radiological consequences as a result of a seismic event.

Corrective Actions

Consistent with Section K.11.2.2.4 of [C.12-1], inspection of HSM Model 102s subsequent to a significant earthquake is required to identify potential damage or change in HSM configuration. Repair of damage to HSM concrete components, including shield walls may be necessary. Movement of HSMs as a result of the seismic event will require evaluation and possible repositioning of HSMs and shielding to preseismic event configuration.

C.12.2.4 Lightning

Cause of Accident

As stated in Sections K.11.2.6.1 and 8.2.6 of [C.12-1], the likelihood of lightning striking the HSM and causing an off-normal or accident condition is not considered a credible event. Simple lightning protection equipment for the HSM structures is considered a miscellaneous attachment acceptable per the HSM design.

All Indicated Changes are in response to RSI NP-5.4

D.3.3 Design Criteria for Environmental Conditions and Natural Phenomena

D.3.3.1 Tornado Wind and Tornado Missiles

The design basis tornado wind and tornado missiles for the Standardized NUHOMS® Horizontal Modular Storage System HSM Model 102 are provided in Section T.2.2.1 and Section 3.2.5 of reference [D.3-1] and in Table D.3-1 for the NUHOMS®-MP197HB cask. The 61BTH-DSC and HSM Model 102 components are designed and conservatively evaluated for the most severe tornado and missiles anywhere within the United States (Region I as defined in NRC Regulatory Guide 1.76 [D.3-8]) while the WCS CISF is in Region II, a less severe location with respect to tornado and tornado missiles. The MP197HB cask is evaluated against the Region II tornado and tornado missiles as described in Appendix C.7.

The HSM protects the DSC from adverse environmental effects and is the principal structure exposed to tornado wind and missile loads. Furthermore, all components of the HSM (regardless of their safety classification) are designed to withstand tornadoes and tornado-based missiles. The MP197HB cask protects the DSC during transit to the Storage Pad from adverse environmental effects such as tornado winds and missiles.

D.3.3.2 Water Level (Flood) Design

The DSCs and HSM are designed for an enveloping design basis flood, postulated to result from natural phenomena as specified by 10 CFR 72.122(b). The system is evaluated for a flood height of 50 feet with a water velocity of 15 fps.

The DSCs are subjected to an external hydrostatic pressure equivalent to the 50 feet head of water. The HSM is evaluated for the effects of a water current of 15 fps impinging on the sides of a submerged HSM. For the flood case that submerges the HSM, the inside of the HSM will rapidly fill with water through the HSM vents.

The flood used in the evaluation of the Standardized NUHOMS®-61BTH Type 1 System components envelopes the WCS CISF maximum flood height of 1.1 inches with a speed of 1.7 fps.

D.3.3.3 Seismic Design

The seismic criteria for the Standardized NUHOMS® System HSM Model 102 are provided in Section T.2.2.3 and Section 8.2 of reference [D.3-1]. *The site-specific seismic ground motion developed for the WCS CISF in the form of the 10,000-year return period uniform hazard response spectrum for the horizontal and vertical directions are described in Chapter 2. Those spectra are used to derive the enveloped acceleration spectra at the WCS concrete pad base and HSM center of gravity. These enveloped spectra are the design seismic basis for the NUHOMS®-61BTH Type 1 System components.*

All Indicated Changes are in response to RSI NP-5.4

Table D.3-1
Summary of WCS CISF Principal Design Criteria
(5 pages)

Design Parameter	WCS CISF Design Criteria	Condition	NUHOMS®-61BTH Type 1 Design Criteria
Tornado (HSM Missile)	Automobile 4000 lb, 112 ft/s Schedule 40 Pipe 287 lb, 112 ft/s Solid Steel Sphere 0.147 lb, 23 ft/s	Accident (Bounded)	*Standardized NUHOMS® SAR Sections 3.2.1 and T.2.2.1* Automobile 4000 lb, 195 ft/s 8" diameter shell 276 lb, 185 ft/s Solid Steel Sphere 0.147 lb, 23 ft/s Wood plank missile 200 lb, 440 ft/s
Tornado (MP197HB Missile)	Automobile 4000 lb, 112 ft/s Schedule 40 Pipe 287 lb, 112 ft/s Solid Steel Sphere 0.147 lb, 23 ft/s	Accident (Same)	*Sections D.7.7 and C.7.7.1 (New Evaluation)* Automobile 4000 lb, 112 ft/s Schedule 40 Pipe 287 lb, 112 ft/s Solid Steel Sphere 0.147 lb, 23 ft/s
Floods	Flood height 1.1 inches Water velocity 1.7 ft/s	Accident (Bounded)	*Standardized NUHOMS® SAR Sections 3.2.2 and T.2.2.2* Flood height 50 ft Water velocity 15 ft/s
Seismic (Ground Motion)	Site-specific ground-surface uniform hazard response spectra (UHRS) with 1E-4 annual frequency of exceedance (AFE) having peak ground acceleration (PGA) of 0.250 g horizontal and 0.175 g vertical. (Table 1-5 and Figure 1-5)	Accident (*Evaluated*)	*See Evaluations in Sections 7.6.4, 7.6.5, D.7.5.3, and D.7.6*
Vent Blockage	For NUHOMS® Systems: Inlet and outlet vents blocked 40 hrs	Accident (Same)	*Standardized NUHOMS® SAR Section T.4.4.5* Inlet and outlet vents blocked 40 hrs
Fire/Explosion	For NUHOMS® Systems: Equivalent fire 300 gallons of diesel fuel	Accident (Same)	*Standardized NUHOMS® SAR Sections 3.3.6 and T.2.3.6* Equivalent fire 300 gallons of diesel fuel

All Indicated Changes are in response to RSI NP-5.4

D.7.3 Seismic Reconciliation of the Canister, HSM Model 102, and MP197HB Cask

The WCS CISF site-specific seismic ground motion developed for the WCS CISF in the form of the 10,000-year return period uniform hazard response spectra for the horizontal and vertical directions is described in Chapter 2. A comparison of the WCS CISF site-specific response spectra and the Regulatory Guide 1.60 response spectra is shown in Figure D.7-1 for 3%, 5%, and 7% damping values. This comparison indicates that for system frequencies above about 10 Hz (horizontal direction) and 9 Hz (vertical direction), the WCS CISF spectral accelerations are higher than the design basis spectral accelerations. The ZPA values of 0.25g (horizontal) and 0.175g (vertical) for the WCS CISF ground motion are essentially the same as those for the Standardized NUHOMS® System as documented in Section 3.2.3 of [D.7-2].

This section describes the reconciliation evaluations of the 61BTH Type 1 DSC and the HSM Model 102 *using the enveloping response spectra at the HSM CG and base, which are obtained from the soil-structure interaction (SSI) analysis of the WCS CISF. Comparisons of the 7%-damped WCS CISF 10,000-year return period uniform hazard response spectra and +/-15% peak-broadened HSM center of gravity (CG) response spectra from the WCS CISF SSI analysis in the HSM's transverse, longitudinal, and vertical directions are shown in Figure D.7-4, Figure D.7-5, and Figure D.7-6, respectively. The +/-15% peak-broadened HSM CG response spectra for damping values of 7%, 3%, and 2% are shown in Figure D.7-7 through Figure D.7-9.* Section C.7.3.2 presents the reconciliation evaluation of the MP197HB cask as a transfer cask.

D.7.3.1 HSM Model 80 and Model 102

The seismic analysis of the HSM (Model 80 and Model 102, *herein* referred *to* as "HSM") is described in Section 8.2.3 of [D.7-2]. This analysis is reconciled in consideration of the *enveloping response spectra at the HSM CG obtained from the WCS CISF SSI analysis, which are shown in Figure D.7-7 through Figure D.7-9.* The same analysis methodology as used for the seismic evaluation of the HSM in Section 8.2.3.2.B in [D.7-2] is used for this reconciliation evaluation.

A dynamic response spectrum analysis is performed using the HSM ANSYS model shown in Figure 8.1-22 of [D.7-2] and the *7% damped response spectra at the HSM CG obtained from the WCS CISF SSI analysis. The ANSYS code Release 10.0 [D.7-4] is used for the analysis. The model includes an 88.7 kips canister, which is the weight of the 61BTH Type 1 DSC and also the bounding weight of the canister types considered in this application.* The forces and moments in the various HSM concrete and steel components of the HSM are evaluated and compared to previous results as applicable.

All Indicated Changes are in response to RSI NP-5.4

D.7.3.1.1 HSM Modal Frequency Analysis

A modal frequency analysis is performed to extract the frequencies and associated mode shapes of the HSM model shown in Figure 8.1-22 of [D.7-2]. The modal analysis results indicate that the lowest frequency of *20.76* Hz corresponds to the DSC steel support structure in the transverse horizontal direction. The corresponding mode shapes are shown in Figure D.7-2 and Figure D.7-3. The *other* predominant frequencies corresponding to the HSM concrete/steel support structure are *28.90*Hz, *34.41* Hz, and *44.58* Hz in the axial, transverse, and vertical directions, respectively.

D.7.3.1.2 HSM Response Spectrum Analysis

The 7%-damped response spectra at the HSM CG obtained from the WCS CISF SSI analysis are applied to the ANSYS HSM model to perform a response spectrum analysis. Forces and moments resulting from the analysis are used in the seismic load combination (deadweight + live load + normal thermal + seismic loading).

The effect of the increase in canister weight on the non-seismic load combinations has been evaluated in [D.7-2] for a bounding canister weight of up to 102 kips for the 32PT DSC. Therefore, only the seismic load combination is addressed in this reconciliation evaluation.

The results of the seismic reconciliation analyses are discussed in the following sections.

D.7.3.1.3 Evaluation of the HSM Concrete Components

The forces and moments for each HSM subcomponent (roof slab, walls, floor slab) are determined for the WCS CISF spectra *obtained from the SSI analysis,* and then compared to their respective capacities, calculated as described in Section 8.1.1.5.E of [D.7-2]. The comparison is shown in Table D.7-1. As seen in this table, the demand-to-capacity ratios for all the HSM concrete subcomponents are less than 1.0. Therefore, the HSM concrete components are acceptable for the WCS CISF site-specific seismic loading.

D.7.3.1.4 Evaluation of the DSC Steel Support Structure

The forces and moments and resulting stresses for each DSC steel support structure component are determined for the WCS CISF spectra obtained from the SSI analysis, and then compared to AISC code allowables as described in Section 8.2.10.6 of [D.7-2]. As seen in the comparison shown in Table D.7-2, the maximum stresses or stress interaction ratios are less than the allowables. Therefore, the DSC steel support structure components are qualified and are acceptable for the WCS CISF site-specific seismic loading.

All Indicated Changes are in response to RSI NP-5.4

D.7.3.1.5 Evaluation of Miscellaneous Components

D.7.3.1.5.1 Evaluation of the DSC Axial Retainer

The evaluation of the DSC axial retainer is described in Section 8.2.3.2(C)(iii) of [D.7-2]. The seismic load on the retainer is calculated below for the WCS CISF site-specific seismic loading.

The maximum shear and bending stresses in the DSC axial retainer are 19.8 ksi and 25.8 ksi, respectively. The allowable shear and bending stresses are 23.5 ksi and 44.3 ksi, respectively. Therefore, the DSC axial retainer stresses are within allowable values.

D.7.3.1.5.2 Evaluation of the Heat Shields

The heat shield studs are evaluated for the axial, shear and bending forces due to the WCS CISF site-specific loading. The stiffness of the 3/8” diameter studs is calculated and used to determine the natural frequency of the heat shield panels in the in-plane directions. The corresponding seismic accelerations are combined with deadweight loading to determine the maximum loads on the studs. The maximum axial, bending, and shear stresses in the studs are found to be *1.59* ksi, *14.05* ksi, and *0.40* ksi, respectively. The maximum stress ratio is found to be *0.43* for combined axial plus bending stress.

Therefore, the heat shield plates and studs are acceptable for the WCS CISF seismic loading.

D.7.3.1.6 Evaluation of HSM Seismic Stability and Sliding

The HSM is evaluated for seismic *sliding and overturning stability* due to the WCS CISF site-specific loading. *The maximum sliding distance, rocking angle, and uplift height from the WCS CISF SSI analysis are 0.19", 0.05°, and 0.08", respectively.* Therefore, the sliding *and overturning stability* characteristics of the HSM are acceptable for the WCS CISF seismic loading.

All Indicated Changes are in response to RSI NP-5.4

D.7.3.2 MP197HB Cask as On-Site Transfer Cask

The seismic reconciliation is contained in Section C.7.3.2.

D.7.3.3 61BTH Type 1 DSC

Per Section T.3.7.2.1 of Reference [D.7-2], the canister shell components are evaluated for seismic loading of 3.0g and 1.0g for the horizontal and vertical directions, respectively. The basket components are evaluated for a bounding acceleration of 2g in each of the axial, transverse, and vertical direction [Section T.3.6.1.3.4 of D.7-2].

All Indicated Changes are in response to RSI NP-5.4

D.7.5.2 Off-Normal Loads

The structural analyses for off-normal loads is contained in Section T.3.6.2 of [D.7-2]. Two limiting off-normal events are defined which envelope the range of expected off-normal structural loads:

- Jammed Canister During Transfer

  Section T.3.6.2.1 of [D.7-2] presents a series of hand calculations to determine the stresses on the canister shell due to various postulated loading conditions (axial sticking of the canister, Binding of the canister). All stresses are within the ASME code limits.

- Off-Normal Thermal Loads

  Off-normal ambient temperatures are defined as -40 °F and 117 °F for the 61BTH Type 1 DSC in [D.7-2] Appendix T.3.6.2.2. The stress results presented in Table T.3.6-4 of [D.7-2] show that the canister stress limits are satisfied for the off-normal thermal loads. The thermal stress analyses in Section T.3.4.4.3 of [D.7-2] show that the stress limits for the basket are satisfied for the off-normal thermal loads. As discussed in Section D.7.4, the thermal stress analyses of the 61BTH Type 1 DSC for transfer in the OS197 transfer cask are applicable for transfer in the MP197HB cask.

D.7.5.3 Accident Loads

The structural analysis of the 61BTH Type 1 DSC for accident loads is presented in Section T.3.7 of [D.7-2]. The following accident conditions affect the canister and are evaluated:

- Earthquake

  The seismic load is reconciled in Section D.7.3.3. As concluded in Section C.7.3.3, the 61BTH Type 1 DSC is acceptable for storage at the WCS CISF.

- Flood

  Evaluation of the canister for flood loads is contained in Section T.3.7.3.2 of [D.7-2]. The ASME Code methodology in NB-3133.3 is used to show that there is a safety margin of at least 1.57 against buckling of the canister shell. The shell stresses are calculated using an ANSYS finite element model and are shown to be much less than the ASME Service Level C allowable values.

- Accidental Cask Drop

  The 61BTH Type 1 DSC evaluation of the accidental drop is documented in Section T.3.7.4 of [D.7-2]. Equivalent static loading of 75g is used to evaluate the effects of the drops.

All Indicated Changes are in response to RSI NP-5.4

D.7.6 Structural Analysis of HSM Model 102 with Canister (Storage Configuration)

The structural analysis of the HSM Model 102 reinforced concrete and DSC steel support structure for normal, off-normal, and accident conditions is presented in Sections 8.1.1, 8.1.2 and 8.2, respectively, of [D.7-2]. Loading types applicable to each affected component are summarized in Table 8.1-1, Table 8.1-2, and Table 8.2-1 for normal, off-normal, and accident conditions, respectively, of [D.7-2]. Results for normal and off-normal loads are summarized in Table 8.1-14 and Table 8.1-19 of [D.7-2]. Results for accident loads are presented in Table 8.2-3, Table 8.2-18, Table 8.2-19, and Table 8.2-20 of [D.7-2].

The analyses and results listed above were originally performed for a bounding canister weight of 80.0 kips. The maximum weight of the 61BTH Type 1 DSC is 88.7 kips [D.7-2 Table T.3.2-1]. As described in Paragraph T.3.6.1.4 of [D.7-2], the DSC steel support structure is evaluated in Appendix M of [D.7-2] for a bounding weight of 102 kips which bounds the maximum weight of the 61BTH Type 1 DSC.

As described in Paragraph T.3.6.1.5, the HSM is qualified in Appendix M of [D.7-2] for a bounding weight of 102 kips which bounds the maximum weight of the 61BTH Type 1 DSC.

The HSM door and heat shields are not affected by the weight of the canister, and therefore is qualified by the design basis calculations described in Section 8.1 and 8.2 of [D.7-2].

The reconciliation for the seismic loading on the HSM Model 102 is contained in Section D.7.3.1.

Summaries of the HSM Model 102 analyses for normal, off-normal, and accident conditions can be found in Sections C.7.6.1, C.7.6.2, and C.7.6.3, respectively. The load combinations and analysis results are summarized in Section C.7.6.4.

Based on these discussions, the stress ratios for the HSM Model 102 loaded with the 61BTH Type 1 canister at the WCS CISF are acceptable.

D.7.8 References

D.7-1 AREVA TN Document, NUH09.101 Rev. 17, "NUHOMS® -MP197 Transportation Package Safety Analysis Report." (Basis for NRC CoC 71-9302).

D.7-2 AREVA TN Document NUH-003, Revision 14, "Updated Final Safety Analysis Report for the Standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel." (Basis for NRC CoC 72-1004).

D.7-3 Blevins, Robert D. Formulas for Natural Frequency and Mode Shape. 2001.

D.7-4 ANSYS Computer Code and User's Manual, Version 10.0 A1.

All Indicated Changes are in response to RSI NP-5.4

Table D.7-1
Comparison of Seismic Load Combination Forces and Moments on HSM Concrete Components with Capacities (kip/ft, kip-in/ft)

Component	*Quantity*	*Shear, V_{o1} (Note 1)*	*Shear, V_{o2} (Note 1)*	*Moment, M_1 (Note 2)*	*Moment, M_2 (Note 2)*
Floor Slab	*Demand(3)*	*3.37*	*4.01*	*23.95*	*20.05*
	Capacity(4)	*13.50*	*14.60*	*206.00*	*223.00*
	Ratio	*0.25*	*0.27*	*0.12*	*0.09*
Roof Slab	*Demand(3)*	*4.78*	*5.79*	*112.67*	*113.71*
	Capacity(4)	*42.50*	*44.00*	*1753.00*	*1813.00*
	Ratio	*0.11*	*0.13*	*0.06*	*0.06*
Side Walls	*Demand(3)*	*14.02*	*5.59*	*116.52*	*133.90*
	Capacity(4)	*22.90*	*24.00*	*728.00*	*694.00*
	Ratio	*0.61*	*0.23*	*0.16*	*0.19*
Front Wall	*Demand(3)*	*22.84*	*36.74*	*260.26*	*242.27*
	Capacity(4)	*40.50*	*41.40*	*881.00*	*901.00*
	Ratio	*0.56*	*0.89*	*0.30*	*0.27*
Rear Wall	*Demand(3)*	*5.51*	*4.22*	*69.53*	*74.67*
	Capacity(4)	*14.30*	*15.30*	*305.00*	*457.00*
	Ratio	*0.39*	*0.28*	*0.23*	*0.16*

Notes:

1) V_{o1}, $V_{o2,}$ out of plane shear (beam shear)
2) M_1, M_2, out of plane moments (beam bending moments)
3) Maximum (absolute) values for Seismic Load combination for *spectra from WCS CISF SSI analysis.*
4) Concrete subcomponent capacities are calculated in accordance with ACI 349-85 and documented in Section 8.1.1.5.E of [D.7-2]

All Indicated Changes are in response to RSI NP-5.4

Table D.7-2

Comparison of Seismic Load Combination Stresses in DSC Support Structure Components with Capacities

Component	*Calculated Stress*						
	Axial (ksi)	***Strong Axis Bending (ksi)***	***Weak Axis Bending (ksi)***	***Shear (ksi)***	***Interaction Ratio (Demand /Capacity)***	***Allowable Tensile Stress (ksi)***	***Allowable Shear Stress (ksi)***
Rail	*1.96*	*3.03*	*12.49*	*4.97*	*0.48*	-	*18.1*
Cross Beam	*1.43*	*5.52*	*7.34*	*12.90*	*0.40*	-	*18.1*
Column	*6.84*	*4.41*	*4.44*	*0.25*	*0.56*	-	*18.1*
Wall Attachment Channel	*15.52*	-	-	-	-	*23.2*	-
Mounting Plate Bolt	*21.82*	-	-	-	-	*29.1*	-

Notes:
Allowable stresses taken at 270°F and increased by 60% in accordance with ANSI/ANS 57.9.

All Indicated Changes are in response to RSI NP-5.4

Table D.7-3
Deleted

All Indicated Changes are in response to RSI NP-5.4

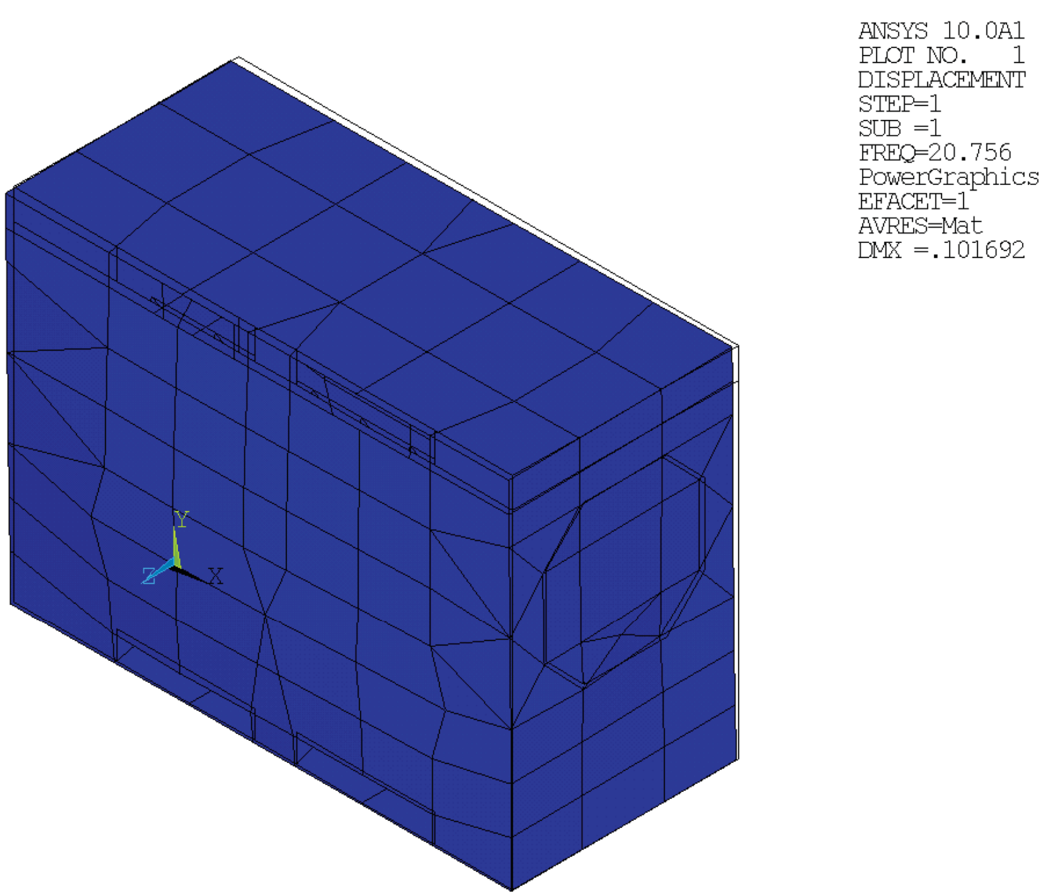

Figure D.7-2
HSM Mode Shape for Mode 1

All Indicated Changes are in response to RSI NP-5.4

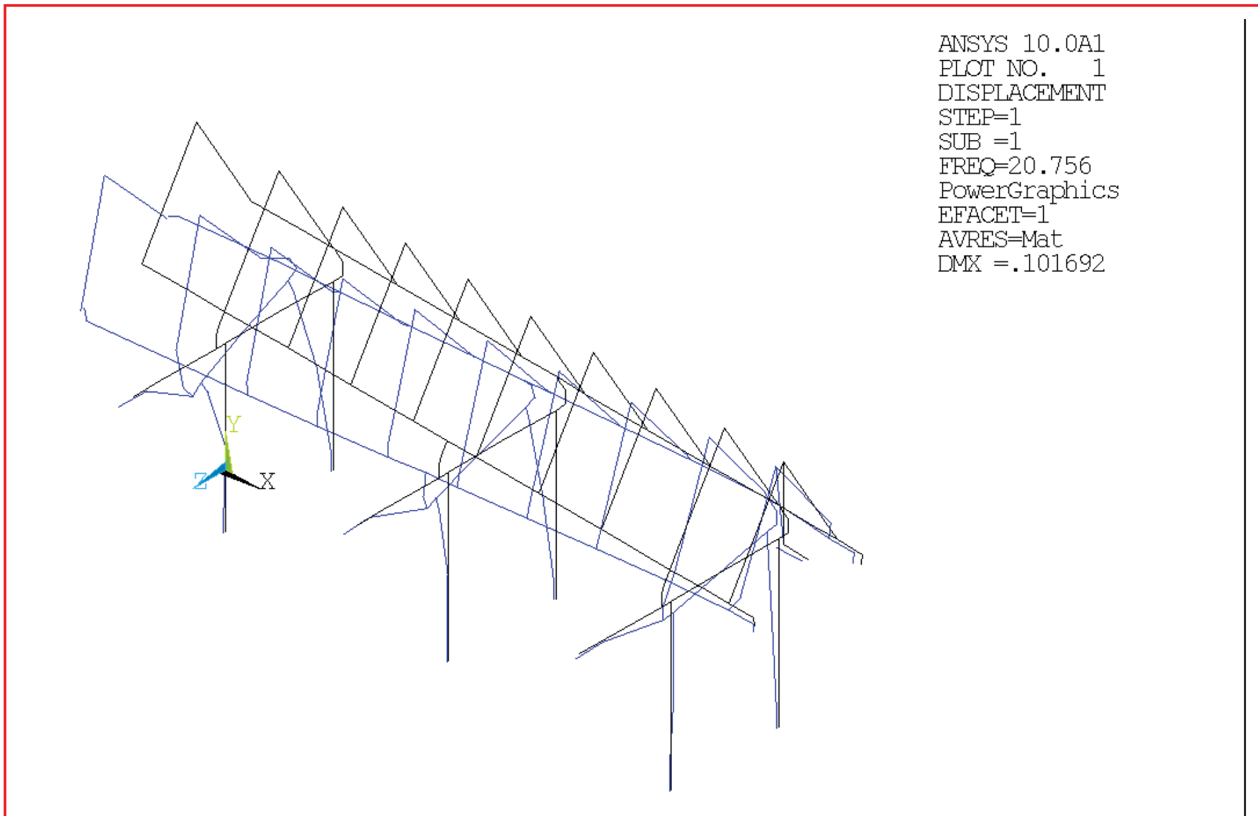

Figure D.7-3

Support Structure Mode Shape for Mode 1

All Indicated Changes are in response to RSI NP-5.4

Proprietary Information on Page D.7-23 through D.7-28
Withheld Pursuant to 10 CFR 2.390

D.12.2.3 Earthquakes

Cause of Accident

Site-specific ground-surface uniform hazard response spectra (UHRS) with 1E-4 annual frequency of exceedance (AFE) having peak ground acceleration (PGA) of 0.250 g horizontal and 0.175 g vertical are shown in Table 1-2, Table 1-5 and Figure 1-5. *The site-specific response spectra are used in the WCS CISF SSI analysis to obtain the enveloped acceleration spectra at the HSM CG and base. Section D.7.3 demonstrates that the MP197HB cask and Standardized NUHOMS® System components are structurally adequate for the WCS CISF site-specific seismic loading.*

Accident Analysis

The structural and thermal consequences of an earthquake are addressed in Sections T.11.2.2.2, 8.2.3.2 and T.3.7.2 of [D.12-1]. The MP197HB cask, when mounted on the transfer vehicle during an earthquake is evaluated in Appendix D.7. In addition, Chapter D.8 demonstrates that the thermal analysis performed for the Standardized NUHOMS® System in [D.12-1] is bounding for WCS CISF conditions.

Accident Dose Calculations

As documented in Section T.11.2.2.3 of [D.12-1], there are no radiological consequences as a result of a seismic event.

Corrective Actions

Consistent with Section T.11.2.2.4 of [D.12-1], inspection of HSM Model 102s subsequent to a significant earthquake is required to identify potential damage or change in HSM configuration. Repair of damage to HSM concrete components, including shield walls may be necessary. Movement of HSMs as a result of the seismic event will require evaluation and possible repositioning of HSMs and shielding to preseismic event configuration.

D.12.2.4 Lightning

Cause of Accident

As stated in Sections T.11.2.6.1 and 8.2.6 of [D.12-1], the likelihood of lightning striking the HSM and causing an off-normal or accident condition is not considered a credible event. Simple lightning protection equipment for the HSM structures is considered a miscellaneous attachment acceptable per the HSM design.

All Indicated Changes are in response to RSI NP-5.4

Table E.3-1
Summary of WCS CISF Principal Design Criteria
(5 pages)

Design Parameter	**WCS CISF Design Criteria**	**Condition**	**NAC-MPC Design Criteria**
Type of fuel	*Commercial, light water reactor spent fuel*	*Normal (Bounded)*	*NAC-MPC FSAR Section 2.1*
Storage Systems	*Transportable canisters and storage overpacks docketed by the NRC*	*Normal (Bounded)*	*72-1025* *71-9235*
Fuel Characteristics	*Criteria as specified in previously approved licenses for included systems*	*Normal (Bounded)*	*NAC-MPC FSAR Section 2.1*
Tornado (Wind Load)	*Max translational speed: 40 mph* *Max rotational speed: 160 mph* *Max tornado wind speed: 200 mph* *Radius of max rotational speed: 150 ft* *Tornado pressure drop: 0.9 psi* *Rate of pressure drop: 0.4 psi/sec*	*Accident (Bounded)*	***NAC-MPC FSAR Section 2.2.1.1*** *Max translational speed: 70 mph* *Max rotational speed: 290 mph* *Max tornado wind speed: 360 mph* *Radius of max rotational speed: 150 ft* *Tornado pressure drop: 3.0 psi* *Rate of pressure drop: 2.0 psi/sec*
Tornado (Missile)	*Automobile: 4000 lb, 112 ft/s (76.4 mph)* *Schedule 40 Pipe: 287 lb, 112 ft/s (76.4 mph)* *Solid Steel Sphere: 0.147 lb, 23 ft/s (15.7 mph)*	*Accident (Bounded)*	***NAC-MPC FSAR Section 2.2.1.3*** *Massive Missile: 3960 lb, 126 mph* *Rigid hardened steel: 275 lb, 126 mph* *Solid Steel Sphere: 0.15 lb, 126 mph*
Floods	*Flood height: 1.1 inches (0.0917 ft)* *Water velocity: 1.7 ft/s*	*Accident (Bounded)*	***NAC-MPC FSAR Section 2.2.2.1*** *Flood height: 50 ft* *Water velocity: 15 ft/s*

This table is associated with the response to RSI NP-5.2.
It was previously submitted in response to RSI NP-10.3 and is included with the changed SAR pages in this submittal as “information only.”

Table E.3-1
Summary of WCS CISF Principal Design Criteria
(5 pages)

Design Parameter	***WCS CISF Design Criteria***	***Condition***	***NAC-MPC Design Criteria***
Seismic (Ground Motion)	*Site-specific ground-surface uniform hazard response spectra (UHRS) with 1E-4 annual frequency of exceedance (AFE) having peak ground acceleration (PGA) of 0.250 g horizontal and 0.175 g vertical. (Table 1-5 and Figure 1-5)*	*Accident (Bounded)*	***NAC-MPC FSAR Section 2.2.3.1*** *Yankee-MPC and CY-MPC are designed to 0.25 g horizontal and 0.167 g vertical* ***NAC-MPC FSAR Section 2.A.2.1.1*** *MPC-LACBWR is designed to 0.45 g horizontal and 0.3 g vertical* ***NAC-MPC CoC, Technical Specification B 3.4, Section 3.c)*** *Alternatively, the design basis earthquake motion of the ISFSI pad maybe limited so that the acceleration g-load resulting from the collision of the two sliding casks remains bounded by the accident condition analyses presented in Chapter 11 of the NAC-MPC FSAR.*
Vent Blockage	*For MPC Systems:* *Inlet and outlet vents blocked 24 hrs*	*Accident (Same)*	***Yankee-MPC, NAC-MPC FSAR Section 11.2.8.4*** ***CY-MPC, NAC-MPC FSAR Section 11.2.8.4*** ***MPC-LACBWR, NAC-MPC FSAR Section 11.2.8.4*** *Inlet and outlet vents blocked: 24 hrs*
Fire/Explosion	*For MPC Systems:* *Equivalent fire 50 gallons of diesel fuel*	*Accident (Same)*	***NAC-MPC FSAR Section 11.2.5*** *Equivalent fire 50 gallons of diesel fuel*
Cask Drop	*For MPC Systems:* *Drop height 6 inches*	*Accident (Same)*	***NAC-MPC FSAR Section 11.2.11.2*** ***NAC-MPC FSAR Section 11.A.2.11.2*** *Drop height 6 inches*
Ambient Temperatures	*Normal temperature 44.1 – 81.5°F*	*Normal (Bounded)*	***NAC-MPC FSAR Section 2.2.6*** *Average Annual Ambient Temperature 75°F*
Off-Normal Temperature	*Minimum temperature 30.1°F* *Maximum temperature 94.6°F*	*Off-Normal (Bounded)*	***NAC-MPC FSAR Section 2.2.6*** *Minimum temperature -40°F* *Maximum temperature 100°F*

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Table E.3-1
Summary of WCS CISF Principal Design Criteria
(5 pages)

Design Parameter	***WCS CISF Design Criteria***	***Condition***	***NAC-MPC Design Criteria***
Extreme Temperature	*Maximum temperature 113°F*	*Accident (Bounded)*	***NAC-MPC FSAR Section 2.2.6*** *Maximum temperature 125°F*
Solar Load (Insolation)	*Horizontal flat surface insolation 2949.4 BTU/day-ft^2* *Curved surface solar insolation 1474.7 BTU/day-ft^2*	*Normal (Same)*	***Yankee-MPC, NAC-MPC FSAR Section 4.4.1.1.2*** ***CY-MPC, NAC-MPC FSAR Section 4.5.1.1*** ***MPC-LACBWR, NAC-MPC FSAR Section 4.A.3.1.1*** *Curved Surface: 1475 Btu/ft^2 for a 24-hour period.* *Flat Horizontal Surface: 2950 Btu/ft^2 for a 24-hour period.*
Snow and Ice	*Snow Load 10 psf*	*Normal (Bounded)*	***NAC-MPC FSAR Section 2.2.4*** *100 psf*
Dead Weight	*Per design basis for systems listed in Table 1-1*	*Normal (Same)*	*Yankee-MPC Canister – NAC-MPC FSAR Section 3.4.4.1.2* *Yankee-MPC Storage Cask – NAC-MPC FSAR Section 3.4.4.2.1* *CY-MPC Canister – NAC-MPC FSAR Section 3.4.4.3.2* *CY-MPC Storage Cask – NAC-MPC FSAR Section 3.4.4.4.1* *MPC-LACBWR Concrete Cask – NAC-MPC FSAR Section 3.A.4.4.3.1* *MPC-LACBWR Canister – NAC-MPC FSAR Section 3.A.4.4.1.2*
Internal and External Pressure Loads	*Per design basis for systems listed in Table 1-1*	*Normal (Same)*	*Yankee-MPC Canister – NAC-MPC FSAR Section 3.4.4.1.3* *CY-MPC Canister – NAC-MPC FSAR Section 3.4.4.3.2* *MPC-LACBWR Canister – NAC-MPC FSAR Section 3.A.4.4.1.3*
Design Basis Thermal Loads	*Per design basis for systems listed in Table 1-1*	*Normal (Same)*	*Yankee-MPC – NAC-MPC FSAR Section 4.4* *CY-MPC – NAC-MPC FSAR Section 4.5* *MPC-LACBWR – NAC-MPC FSAR Section 4.A*

This table is associated with the response to RSI NP-5.2.
It was previously submitted in response to RSI NP-10.3 and is included with the changed SAR pages in this submittal as “information only.”

Table E.3-1
Summary of WCS CISF Principal Design Criteria
(5 pages)

Design Parameter	***WCS CISF Design Criteria***	***Condition***	***NAC-MPC Design Criteria***
Operating Loads	*Per design basis for systems listed in Table 1-1*	*Normal (Same)*	*NAC-MPC – NAC-MPC FSAR Section 3.4.4 (Yankee-MPC and CY-MPC)* *MPC-LACBWR – NAC-MPC FSAR Section 3.A.4.4*
Live Loads	*Per design basis for systems listed in Table 1-1*	*Normal (Same)*	*Yankee-MPC Storage Cask – NAC-MPC FSAR Section 3.4.4.2.2* *CY-MPC Storage Cask – NAC-MPC FSAR Section 3.4.4.4.2* *MPC-LACBWR Concrete Cask – NAC-MPC FSAR Section 3.A.4.4.3.2*
Radiological Protection	*Public wholebody ≤ 5 Rem* *Public deep dose plus individual organ or tissue ≤ 50 Rem* *Public shallow dose to skin or extremities ≤ 50 mrem* *Public lens of eye ≤ 15 mrem*	*Accident (Same)*	***NAC-MPC FSAR Section 10.2.2*** *Public wholebody, organ or skin ≤ 5 Rem*
Radiological Protection	*Public wholebody ≤ 25 mrem/yr*[(1)] *Public thyroid ≤ 75 mrem/yr*[(1)] *Public critical organ ≤ 25 mrem/yr*[(1)]	*Normal (Same)*	***NAC-MPC FSAR Section 10.4*** *Exposure to the Public ≤ 25 mrem/yr*
Confinement	*Per design basis for systems listed in Table 1-1*	*N/A*	*NAC-MPC FSAR Chapter 7*
Nuclear Criticality	*Per design basis for systems listed in Table 1-1*	*N/A*	*NAC-MPC FSAR Chapter 6*
Decommissioning	*Minimize potential contamination*	*Normal (Same)*	***Yankee-MPC – NAC-MPC FSAR Section 2.4*** ***CY-MPC – NAC-MPC FSAR Section 2.4*** ***MPC-LACBWR – NAC-MPC FSAR Section 2.A.4*** *Minimize potential contamination*

This table is associated with the response to RSI NP-5.2.
It was previously submitted in response to RSI NP-10.3 and is included with the changed SAR pages in this submittal as “information only.”

Table E.3-1
Summary of WCS CISF Principal Design Criteria
(5 pages)

Design Parameter	***WCS CISF Design Criteria***	***Condition***	***NAC-MPC Design Criteria***
Materials Handling and Retrieval Capability	*Cask/canister handling system prevent breach of confinement boundary under all conditions* *Storage system allows ready retrieval of canister for shipment off-site*	*Normal (Same)*	*Cask/canister handling system prevent breach of confinement boundary under all conditions* *Storage system allows ready retrieval of canister for shipment off-site*

Note

1. *In accordance with 10 CFR 72.104(a)(3), limits include any other radiation from uranium fuel cycle operations within the region.*

This table is associated with the response to RSI NP-5.2.
It was previously submitted in response to RSI NP-10.3 and is included with the changed SAR pages in this submittal as “information only.”

Table F.3-1
Summary of WCS CISF Principal Design Criteria
(4 pages)

Design Parameter	***WCS CISF Design Criteria***	***Condition***	***NAC-UMS® Design Criteria***
Type of fuel	*Commercial, light water reactor spent fuel*	*Normal (Bounded)*	*WCS CISF SAR Appendix F, Section F.3.2*
Storage Systems	*Transportable canisters and storage overpacks docketed by the NRC*	*Normal (Bounded)*	*72-1015* *71-9270*
Fuel Characteristics	*Criteria as specified in previously approved licenses for included systems*	*Normal (Bounded)*	*WCS CISF SAR Appendix F, Section F.3.2*
Tornado (Wind Load)	*Max translational speed: 40 mph* *Max rotational speed: 160 mph* *Max tornado wind speed: 200 mph* *Radius of max rotational speed: 150 ft* *Tornado pressure drop: 0.9 psi* *Rate of pressure drop: 0.4 psi/sec*	*Accident (Bounded)*	***NAC-UMS FSAR Section 2.2.1.1*** *Max translational speed: 70 mph* *Max rotational speed: 290 mph* *Max tornado wind speed: 360 mph* *Radius of max rotational speed: 150 ft* *Tornado pressure drop: 3.0 psi* *Rate of pressure drop: 2.0 psi/sec*
Tornado (Missile)	*Automobile: 4000 lb, 112 ft/s (76.4 mph)* *Schedule 40 Pipe: 287 lb, 112 ft/s (76.4 mph)* *Solid Steel Sphere: 0.147 lb, 23 ft/s (15.7 mph)*	*Accident (Bounded)*	***NAC-UMS FSAR Section 2.2.1.3*** *Massive Missile: 4000 lb, 126 mph* *Rigid hardened steel: 280 lb, 126 mph* *Solid Steel Sphere: 0.15 lb, 126 mph*
Floods	*Flood height: 1.1 inches (0.0917 ft)* *Water velocity: 1.7 ft/s*	*Accident (Bounded)*	***NAC-UMS FSAR Section 11.2.9*** *Flood height: 50 ft* *Water velocity: 15 ft/s*

This table is associated with the response to RSI NP-5.2.
It was previously submitted in response to RSI NP-10.3 and is included with the changed SAR pages in this submittal as "information only."

Table F.3-1
Summary of WCS CISF Principal Design Criteria
(4 pages)

Design Parameter	***WCS CISF Design Criteria***	***Condition***	***NAC-UMS® Design Criteria***
Seismic (Ground Motion)	*Site-specific ground-surface uniform hazard response spectra (UHRS) with 1E-4 annual frequency of exceedance (AFE) having peak ground acceleration (PGA) of 0.250 g horizontal and 0.175 g vertical. (Table 1-5 and Figure 1-5)*	*Accident (Bounded)*	***NAC-UMS FSAR Section 11.2.8*** *The maximum allowable ground acceleration for the NAC-UMS system is 0.26g horizontal and 0.26g vertical.*
Vent Blockage	*For UMS Systems:* *Inlet and outlet vents blocked 24 hrs*	*Accident (Same)*	*Inlet and outlet vents blocked: 24 hrs*
Fire/Explosion	*For UMS Systems:* *Equivalent fire 50 gallons of diesel fuel*	*Accident (Same)*	***NAC-UMS FSAR Section 11.2.6.1*** *Equivalent fire 50 gallons of flammable fluid*
Cask Drop	*For UMS Systems:* *VCC's Drop height 24 inches*	*Accident (Same)*	***NAC-UMS FSAR Section 11.2.4*** *VCCs for UMS Systems:* *Drop height 24 inches*
Ambient Temperatures	*Normal temperature 44.1 – 81.5°F*	*Normal (Bounded)*	***NAC-UMS FSAR Section 2.2.6*** *Average Annual Ambient Temperature 76°F*
Off-Normal Temperature	*Minimum temperature 30.1°F* *Maximum temperature 94.6°F*	*Off-Normal (Bounded)*	***NAC-UMS FSAR Section 2.2.6*** *Minimum temperature -40°F* *Maximum temperature 106°F*
Extreme Temperature	*Maximum temperature 113°F*	*Accident (Bounded)*	***NAC-UMS FSAR Section 2.2.6*** *Maximum temperature 133°F*

This table is associated with the response to RSI NP-5.2.
It was previously submitted in response to RSI NP-10.3 and is included with the changed SAR pages in this submittal as “information only.”

Table F.3-1
Summary of WCS CISF Principal Design Criteria
(4 pages)

Design Parameter	***WCS CISF Design Criteria***	***Condition***	***NAC-UMS® Design Criteria***
Solar Load (Insolation)	*Horizontal flat surface insolation 2949.4 BTU/day-ft²* *Curved surface solar insolation 1474.7 BTU/day-ft²*	*Normal (Same)*	***NAC-UMS FSAR Section 4.4.1.1*** *Curved Surface: 1475 Btu/ft² for a 24-hour period.* *Flat Horizontal Surface: 2950 Btu/ft2 for a 24-hour period.*
Snow and Ice	*Snow Load 10 psf*	*Normal (Bounded)*	***NAC-UMS FSAR Section 3.4.4.2.2*** *101 psf*
Dead Weight	*Per design basis for systems listed in Table 1-1*	*Normal (Same)*	*Canister - NAC-UMS FSAR Section 3.4.4.1.2* *Cask - NAC-UMS FSAR Section 3.4.4.2.1*
Internal and External Pressure Loads	*Per design basis for systems listed in Table 1-1*	*Normal (Same)*	*Canister - NAC-UMS FSAR Section 3.4.4.1.3*
Design Basis Thermal Loads	*Per design basis for systems listed in Table 1-1*	*Normal (Same)*	*Canister - NAC-UMS FSAR Section 3.4.4.1.1* *Cask - NAC-UMS FSAR Section 3.4.4.2.3*
Operating Loads	*Per design basis for systems listed in Table 1-1*	*Normal (Same)*	*NAC-UMS FSAR Section 3.4.4*
Live Loads	*Per design basis for systems listed in Table 1-1*	*Normal (Same)*	*Cask - NAC-UMS FSAR Section 3.4.4.2.2*
Radiological Protection	*Public wholebody ≤ 5 Rem* *Public deep dose plus individual organ or tissue ≤ 50 Rem* *Public shallow dose to skin or extremities ≤ 50 mrem* *Public lens of eye ≤ 15 mrem*	*Accident (Same)*	***NAC-MPC FSAR 10.2.2*** *Public wholebody, organ or skin ≤ 5 Rem*

This table is associated with the response to RSI NP-5.2.
It was previously submitted in response to RSI NP-10.3 and is included with the changed SAR pages in this submittal as "information only."

Table F.3-1
Summary of WCS CISF Principal Design Criteria
(4 pages)

Design Parameter	***WCS CISF Design Criteria***	***Condition***	***NAC-UMS® Design Criteria***
Radiological Protection	*Public wholebody ≤ 25 mrem/yr*[(1)] *Public thyroid ≤ 75 mrem/yr*[(1)] *Public critical organ ≤ 25 mrem/yr*[(1)]	*Normal (Same)*	***NAC-MPC FSAR Section 10.4*** *Exposure to the Public ≤ 25 mrem/yr*
Confinement	*Per design basis for systems listed in Table 1-1*	*N/A*	*NAC-UMS FSAR Chapter 7*
Nuclear Criticality	*Per design basis for systems listed in Table 1-1*	*N/A*	*NAC-UMS FSAR Chapter 6*
Decommissioning	*Minimize potential contamination*	*Normal (Same)*	*Minimize potential contamination*
Materials Handling and Retrieval Capability	*Cask/canister handling system prevent breach of confinement boundary under all conditions* *Storage system allows ready retrieval of canister for shipment off-site*	*Normal (Same)*	*Cask/canister handling system prevent breach of confinement boundary under all conditions* *Storage system allows ready retrieval of canister for shipment off-site*

Note:

1. *In accordance with 10 CFR 72.104(a)(3) limits include any other radiation from uranium fuel cycle operations within the region.*

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Table G.3-1
Summary of WCS CISF Principal Design Criteria
(3 pages)

Design Parameter	***WCS CISF Design Criteria***	***Condition***	***MAGNASTOR® Design Criteria***
Type of fuel	*Commercial, light water reactor spent fuel*	*Normal (Bounded)*	*MAGNASTOR FSAR Section 2.2*
Storage Systems	*Transportable canisters and storage overpacks docketed by the NRC*	*Normal (Bounded)*	*72-1031* *71-9356 (Pending)*
Fuel Characteristics	*Criteria as specified in previously approved licenses for included systems*	*Normal (Bounded)*	*MAGNASTOR FSAR Section 2.2*
Tornado (Wind Load)	*Max translational speed: 40 mph* *Max rotational speed: 160 mph* *Max tornado wind speed: 200 mph* *Radius of max rotational speed: 150 ft* *Tornado pressure drop: 0.9 psi* *Rate of pressure drop: 0.4 psi/sec*	*Accident (Bounded)*	***MAGNASTOR FSAR Section 2.3.1.1*** *Max translational speed: 70 mph* *Max rotational speed: 290 mph* *Max tornado wind speed: 360 mph* *Radius of max rotational speed: 150 ft* *Tornado pressure drop: 3.0 psi* *Rate of pressure drop: 2.0 psi/sec*
Tornado (Missile)	*Automobile: 4000 lb, 112 ft/s (76.4 mph)* *Schedule 40 Pipe: 287 lb, 112 ft/s (76.4 mph)* *Solid Steel Sphere: 0.147 lb, 23 ft/s (15.7 mph)*	*Accident (Bounded)*	***MAGNASTOR FSAR Section 2.3.1.3*** *Massive Missile: 4000 lb, 126 mph* *Rigid hardened steel: 280 lb, 126 mph* *Solid Steel Sphere: 0.15 lb, 126 mph*
Floods	*Flood height: 1.1 inches (0.0917 ft)* *Water velocity: 1.7 ft/s*	*Accident (Bounded)*	***MAGNASTOR FSAR Section 2.3.2.1*** *Flood height: 50 ft* *Water velocity: 15 ft/s*
Seismic (Ground Motion)	*Site-specific ground-surface uniform hazard response spectra (UHRS) with 1E-4 annual frequency of exceedance (AFE) having peak ground acceleration (PGA) of 0.250 g horizontal and 0.175 g vertical. (Table 1-5 and Figure 1-5)*	*Accident (Bounded)*	***MAGNASTOR FSAR Section 2.3.3*** *The maximum allowable ground acceleration for the MAGNASTOR system is 0.37g horizontal and 0.25g vertical when the ISFSI pad does not incorporate the use of bollards*

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Table G.3-1
Summary of WCS CISF Principal Design Criteria
(3 pages)

Design Parameter	***WCS CISF Design Criteria***	***Condition***	***MAGNASTOR® Design Criteria***
Vent Blockage	*For MAGNASTOR® Systems: Inlet vents blocked 72 hrs*	*Accident (Same)*	***MAGNASTOR FSAR Section 4.6.3*** *Inlet vents blocked 72 hrs*
Fire/Explosion	*For MAGNASTOR® Systems: Equivalent fire 50 gallons of diesel fuel*	*Accident (Same)*	***MAGNASTOR FSAR Section 4.6.2*** *Equivalent fire 50 gallons of flammable liquid*
Cask Drop	*For MAGNASTOR® Systems: VCCs Drop height 24 inches*	*Accident (Same)*	***MAGNASTOR FSAR Section 12.2.4*** *VCCs for MAGNASTOR Systems: Drop height 24 inches*
Ambient Temperatures	*Normal temperature 44.1 – 81.5°F*	*Normal (Bounded)*	***MAGNASTOR FSAR Section 2.3.6*** *Normal operations temperature 76°F*
Off-Normal Temperature	*Minimum temperature 30.1°F Maximum temperature 94.6°F*	*Off-Normal (Bounded)*	***MAGNASTOR FSAR Section 2.3.6*** *Minimum temperature -40°F Maximum temperature 106°F*
Extreme Temperature	*Maximum temperature 113°F*	*Accident (Bounded)*	***MAGNASTOR FSAR Section 2.3.6*** *Maximum temperature 133°F*
Solar Load (Insolation)	*Horizontal flat surface insolation 2949.4 BTU/day-ft² Curved surface solar insolation 1474.7 BTU/day-ft²*	*Normal (Same)*	***MAGNASTOR FSAR Section 4.4.1.1*** *Curved Surface: 1475 Btu/ft² for a 24-hour period. Flat Horizontal Surface: 2950 Btu/ft² for a 24-hour period.*
Snow and Ice	*Snow Load 10 psf*	*Normal (Bounded)*	***MAGNASTOR FSAR Section 2.3.4*** *Snow Load: 100 psf*
Dead Weight	*Per design basis for systems listed in Table 1-1*	*Normal (Same)*	*TSC Dead Load – MAGNASTOR FSAR Section 3.5.1.2 Cask – MAGNASTOR FSAR Section 3.5.3.2*
Internal and External Pressure Loads	*Per design basis for systems listed in Table 1-1*	*Normal (Same)*	*TSC – MAGNASTOR FSAR Section 3.5.1*

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Table G.3-1
Summary of WCS CISF Principal Design Criteria
(3 pages)

Design Parameter	***WCS CISF Design Criteria***	***Condition***	***MAGNASTOR® Design Criteria***
Design Basis Thermal Loads	*Per design basis for systems listed in Table 1-1*	*Normal (Same)*	*TSC – MAGNASTOR FSAR Section 3.5.1*
Operating Loads	*Per design basis for systems listed in Table 1-1*	*Normal (Same)*	*Cask – MAGNASTOR FSAR Section 3.5.3*
Live Loads	*Per design basis for systems listed in Table 1-1*	*Normal (Same)*	*Cask – MAGNASTOR FSAR Section 3.5.3.2*
Radiological Protection	*Public wholebody ≤ 5 Rem* *Public deep dose plus individual organ or tissue ≤ 50 Rem* *Public shallow dose to skin or extremities ≤ 50 mrem* *Public lens of eye ≤ 15 mrem*	*Accident (Same)*	***MAGNASTOR FSAR Section 2.4.7.2*** *Public ≤ 5 Rem from any design base accident*
Radiological Protection	*Public wholebody ≤ 25 mrem/yr*[(1)] *Public thyroid ≤ 75 mrem/yr*[(1)] *Public critical organ ≤ 25 mrem/yr*[(1)]	*Normal (Same)*	***MAGNASTOR FSAR Section 2.4.7.2*** *Public wholebody ≤ 25 mrem/yr*
Confinement	*Per design basis for systems listed in Table 1-1*	*N/A*	*MAGNASTOR FSAR Chapter 7*
Nuclear Criticality	*Per design basis for systems listed in Table 1-1*	*N/A*	*MAGNASTOR FSAR Chapter 6*
Decommissioning	*Minimize potential contamination*	*Normal (Same)*	***MAGNASTOR FSAR Chapter 15*** *Minimize potential contamination*
Materials Handling and Retrieval Capability	*Cask/canister handling system prevent breach of confinement boundary under all conditions* *Storage system allows ready retrieval of canister for shipment off-site*	*Normal (Same)*	***MAGNASTOR FSAR Section 2.4.2*** *Cask/canister handling system prevent breach of confinement boundary under all conditions* *Storage system allows ready retrieval of canister for shipment off-site*

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Note

1. *In accordance with 10 CFR 72.104(a)(3) limits include any other radiation from uranium fuel cycle operations within the region.*

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