The ASME Code service limits are used in the structural analyses for definition of allowable stresses and allowable stress intensities, as applicable. Allowable stresses and stress intensities for structural analyses are tabulated in Chapter 3. These service limits are matched with normal, off-normal, and accident condition loads combinations in the following subsections.

The MPC confinement boundary is required to meet Section III, Class 1, Subsection NB stress intensity limits. Table 2.2.10 lists the stress intensity limits for Design and Service Levels A, B, and D for Class 1 structures extracted from the ASME Code. Table 2.2.12 lists allowable stress limits for the steel structure of the HI-STORM FW overpack and HI-TRAC VW transfer cask which are analyzed to meet the stress limits of Subsection NF, Class 3 for loadings defined as service levels A, B, and D are applicable.

2.2.6 Loads

Subsections 2.2.1, 2.2.2, and 2.2.3 describe the design criteria for normal, off-normal, and accident conditions, respectively. The loads are listed in Tables 2.2.7 and 2.2.13, along with the applicable acceptance criteria.

2.2.7 Design Basis Loads

Where appropriate, for each loading type, a bounding value is selected in this FSAR to impute an additional margin for the associated loading events. Such bounding loads are referred to as Design Basis Loads (DBL) in this FSAR. For example, the Design Basis External Pressure on the MPC, set down in Table 2.2.1, is a DBL, as it grossly exceeds any credible external pressure that may be postulated for an ISFSI site.

2.2.8 Allowable Limits

The stress intensity limits for the MPC confinement boundary for the design condition and the service conditions are provided in Table 2.2.10. The MPC confinement boundary stress intensity limits are obtained from ASME Code, Section III, Subsection NB. The displacement limit for the MPC fuel basket is expressed as a dimensionless parameter θ defined as [2.2.11]

$$\theta = \frac{\delta}{w}$$

where δ is defined as the maximum permanent deformation~~total deflection~~ sustained by the basket panels under the loading event and *w* is the nominal inside (width) dimension of the storage cell. The limiting value of θ is provided in Table 2.2.11. Finally, the steel structure of the overpack and the HI-TRAC VW must meet the stress limits of Subsection NF of ASME Code, Section III for the applicable service conditions.

The following definitions of terms apply to the tables on stress intensity limits; these definitions are the same as those used throughout the ASME Code:

Table 2.2.11

STRUCTURAL DESIGN CRITERIA FOR THE FUEL BASKET

PARAMETER	VALUE
Minimum service temperature	-40ºF
Maximum permanent~~total~~ (lateral) deformation~~deflection~~ in the active fuel region - dimensionless	0.005

which can be integrated over the limits $\theta_1 = 0$ to $\theta_1 = \theta_{2f}$ (Figure 3.4.8). The final angular velocity θ_1 at the time instant just prior to contact with the ISFSI pad is given by the expression

$$\dot{\theta}_1 (t_B) = \sqrt{\frac{2\,Mgr}{I_A}(1 - \cos\theta_{2f})}$$

where, from Figure 3.4.8,

$$\theta_{2f} = \cos^{-1}\left(\frac{d}{2r}\right)$$

This equation establishes the initial conditions for the final phase of the tip-over analysis; namely, the portion of the motion when the cask is decelerated by the resistive force at the ISFSI pad interface. Using the data germane to HI-STORM FW (Table 3.4.11) and the above equations, the angular velocity of impact is calculated as

$$\dot{\theta}_1 (t_B) = 1.45 \text{ rad/sec}$$

The LS-DYNA analysis to characterize the response of the HI-STORM FW system under the non-mechanistic tipover event is focused on two principal demonstrations, namely:

(i) The permanent lateral deformation of the basket panels in the active fuel region is less than the limiting value in Table 2.2.11.

(ii) The impact between the MPC guide tubes and the MPC does not cause a thru-wall penetration of the MPC shell.

Three~~Four~~ LS-DYNA finite element models are developed to simulate the postulated tipover event of HI-STORM FW storage cask with loaded MPC-37~~, MPC-44,~~ MPC-89 and MPC-32ML with standard fuel baskets~~, respectively~~. The ~~three~~ LS-DYNA models are constructed according to the dimensions specified in the licensing drawings included in Section 1.5; the tallest configuration for each MPC enclosure type is considered to ensure a bounding tipover analysis. Because of geometric and loading symmetries, a half model of the loaded cask and impact target (i.e., the ISFSI pad) is considered in the analysis. The LS-DYNA models of the HI-STORM FW overpack and the MPC are described in Subsections 3.1.3.1 and 3.1.3.2, respectively. ~~The tipover analysis for MPC-44 is postulated only in the HI-STORM FW Version E overpack.~~

The ISFSI pad LS-DYNA model, which consists of a 320”×100”×36” concrete pad and the underlying subgrade (800”×275”×470” in size) with non-reflective lateral and bottom surface boundaries, is identical to that used in the HI-STORM 100 tipover analysis documented in the HI-STORM 100 FSAR [3.1.4]. All structural members of the loaded cask are explicitly modeled so that any violation of the acceptance criteria can be found by examining the LS-DYNA simulation results (note: the fuel assembly, which is not expected to fail in a tipover event, is modeled as an elastic rectangular body). This is an improvement compared with the approach taken in the HI-STORM

100 tipover analysis, where the loaded MPC was modeled as a cylinder and therefore the structural integrity of the MPC and fuel basket had to be analyzed separately based on the rigid body deceleration result of the cask. Except for the fuel basket, which is divided into four parts based on the temperature distribution of the basket, each structural member of the cask is modeled as an independent part in the LS-DYNA model. Note that the critical weld connection between the MPC shell and the MPC lid is treated as a separate part and modeled with solid elements. Each of the two LS-DYNA models consists of forty-two parts, which are discretized with sufficiently high mesh density; very fine grids are used in modeling the MPC enclosure vessel, especially in the areas where high stress gradients are expected (e.g., initial impact location with the overpack). To ensure numerical accuracy, full integration thin shell and thick shell elements with 10 though-thickness integration points or multi-layer solid elements are used. The LS-DYNA tipover model consists of over 470,000 nodes and 255,000 elements for HI-STORM FW with loaded MPC-37, and the model for the cask with loaded MPC-89 consists of over 689,000 nodes and 350,000 elements. The tipover model with loaded MPC-32ML consists of 451,310 nodes and 278,646 elements [3.4.28].

The same ISFSI concrete pad material model used for the HI-STORM 100 tipover analysis reported in [3.1.4] is repeated for the HI-STORM FW tipover analysis. Specifically, the concrete pad behavior is characterized using the same LS-DYNA material model (i.e., MAT_PSEUDO_TENSOR or MAT_016) as for the end drop and tipover analyses of the HI-STORM 100 storage cask (the only difference between the HI-STORM FW reference ISFSI concrete pad model and the model of the HI-STORM 100 Set B ISFSI concrete pad is thickness). Moreover, the subgrade is also conservatively modeled as an elastic material as before. Note that this ISFSI pad material modeling approach was originally taken in the USNRC approved storage cask tipover and end drop LS-DYNA analyses [3.4.5] where a good correlation was obtained between the analysis results and the test results.

To assess the potential damage of the cask caused by the tipover accident, an LS-DYNA nonlinear material model with strain rate effect is used to model the responses of all HI-STORM FW cask structural members based on the true stress-strain curves of the corresponding materials. Note that the strain rate effect for the fuel basket material, i.e., Metamic HT, is not considered for conservatism.

Figures 3.4.9A through 3.4.9C depict the three finite-element tipover analysis models developed for the bounding HI-STORM FW cask configurations with loaded MPC-37, MPC-89 and MPC-32ML, respectively.

As shown in Figure 3.4.15~~ and [3.4.31]~~, the fuel basket does not experience significant plastic deformation in the active fuel region to exceed the acceptable limits; plastic deformation is essentially limited locally in cells near the top of the basket beyond the active fuel region for the MPC-37~~, MPC-44,~~ MPC-89 and MPC-32ML standard baskets. The fuel basket is considered to be structurally safe since it can continue maintaining appropriate spacing between fuel assemblies after the tipover event. The MPC enclosure vessel experiences minor plastic deformation at the impact locations with the overpack guide tubes; the maximum local plastic strain (10.9%, see Figure 3.4.16) is well below the failure strain of the material and smaller than the plastic strain limit (i.e., at least 0.2 for stainless steel) recommended by [3.4.6] for ASME NB components. Similarly, local plastic which is considered to be acceptable from the perspectives of shielding and criticality. Note that the basket corner welds are not considered in the tip-over analysis for conservatism. The fuel baskets in both Case 1 and Case 2 corner configuration are considered to be structurally safe as they can continue to maintain appropriate spacing between fuel assemblies after the tipover event. The MPC enclosure vessel experiences minor plastic deformation at the impact locations with the overpack guide tubes; the maximum local plastic strain (9.0%, see Figures 3.4.16D & 3.4.16E) is well below the failure strain of the material and smaller than the plastic strain limit (i.e., at least 0.2 for stainless steel) recommended by [3.4.6] for ASME NB components. Similarly, local plastic deformation occurs in the overpack shear ring near the cask-to-pad impact location as shown in Figure 3.4.17D and 3.4.17E. However, the shielding capacity of overpack will not be compromised by the tipover accident and there is no gross plastic deformation in the overpack inner shell to affect the retrievability of the MPC. In addition, the cask closure lid bolts are demonstrated to be structurally safe after the tipover event, only a small plastic strain is observed in the bolt near the impact location (see Figures 3.4.18D & 3.4.18E). Therefore, the cask lid will not dislodge after the tipover event. Finally, the peak rigid body decelerations, measured for the HI-STORM FW lid concrete, are shown to be 60.91 g's for Case 1 and 62.82 g's for Case 2 in the vertical direction (see Figures 3.4.19D & 3.4.19E) and 17.80 g's for Case 1 and 17.75 g's for Case 2 in the horizontal direction (see Figures 3.4.20D & 3.4.20E). Note that the deceleration time histories are filtered using the LS-DYNA built-in Butterworth filter with a cut-off frequency of 350 Hz; the same filter was used for the HI-STORM 100 non-mechanistic tipover analysis.

The non-mechanistic tipover analysis for HI-STORM FW Version E cask is performed in [3.4.30] using the same method used for HI-STORM FW cask in [3.4.11] and it is demonstrated in [3.4.30] that all of the acceptance criteria, discussed above, are satisfied.

The structural analyses of the HI-STORM FW lids [3.4.13] are performed using bounding peak rigid body deceleration forces; therefore, the results are applicable to the non-mechanistic tipover event with target foundation concrete strength specified in Table 2.2.9. It is concluded that the lids will not suffer any gross loss of shielding and will remain attached to the cask bodies.

3.4.4.1.4b Load Case 4: Non-Mechanistic Tipover of MPC-89 CBS Basket Design

[

PROPRIETARY INFORMATION WITHHELD PER 10CFR2.390

]

For the ISFSI pad, t~~T~~he bounding target foundation properties per Table 2.2.9 are utilized.

[

PROPRIETARY INFORMATION WITHHELD PER 10CFR2.390

]

The complete details of the finite element model, input data and results are archived in the calculation package [3.4.11]. In summary, the results of the tipover analysis ~~The following conclusions~~ demonstrate that all safety criteria are satisfied for the cask system with MPC-89 CBS basket design, which means:~~.~~

i. The permanent lateral deflection of the most heavily loaded basket panel in the active fuel region complies with the deflection criterion in Table 2.2.11.
ii. [PROPRIETARY INFORMATION WITHHELD PER 10CFR2.390]
iii. The plastic strains in the MPC enclosure vessel remain below the allowable material plastic strain limit.
iv. The cask closure lid does not dislodge after the tipover event, i.e., the closure lid bolts remain in-tact.
v. The structural analyses of cask closure lids are performed in [3.4.13] using bounding peak deceleration values; therefore, the lids do not suffer any gross loss of shielding.

3.4.4.1.4c Load Case 4: Non-Mechanistic Tipover of MPC-44 Basket Design

The tipover analysis for MPC-44 is postulated only in the HI-STORM FW Version E overpack. The same modelling approach described in subparagraph 3.4.4.1.4a is used to construct the tipover model in LS-DYNA, except that the standard HI-STORM FW overpack is replaced by the Version E overpack, and the MPC-44 replaces the MPC-37. The fully assembled tipover model for the MPC-44 inside the HI-STORM FW Version E overpack is shown in Figure 3.4.9D. The finite element model of the MPC-44 CBS basket is shown in Figure 3.4.12E. The continuous basket shims are modelled using the same approach employed for the MPC-89 CBS, which is described in subparagraph 3.4.4.1.4b. Lastly, the finite element model of the ISFSI is the same as described above in subparagraph 3.4.4.1.4a. For the ISFSI pad, the bounding target foundation properties per Table 2.2.9 are utilized.

Like other basket designs, the response of the MPC-44 CBS basket during the tipover event is predominantly elastic with very localized areas of plasticity, as shown in Figure 3.4.15E. Nonetheless, to insure compliance with the allowable limit in Subsection 2.2.8, the maximum lateral deformation of the most heavily loaded CBS basket panel, at any elevation within the active fuel region, is obtained from the LS-DYNA solution and reported in Table 3.4.19.

The complete details of the finite element model, input data and results are archived in the calculation package [3.4.30]. In summary, the results of the tipover analysis demonstrate that all safety criteria are satisfied for the cask system with MPC-44 basket design, which means:

i. The lateral deflection of the most heavily loaded basket panel in the active fuel region complies with the deflection criterion in Table 2.2.11.
ii. The CBS remain attached to the basket maintaining their physical integrity.
iii. The plastic strains in the MPC enclosure vessel remain below the allowable material plastic strain limit.
iv. The cask closure lid does not dislodge after the tipover event, i.e., the closure lid bolts remain in-tact.
v. The structural analyses of cask closure lids are performed in [3.4.13] using bounding peak deceleration values; therefore, the lids do not suffer any gross loss of shielding.

~~The tipover analysis is performed for the MPC-44 basket design using the existing design basis tipover model in LS-DYNA where the MPC-37 standard basket and aluminum shims are replaced with a fully articulated MPC-44 basket. The bounding target foundation properties per Table 2.2.9 are utilized.~~

~~The details of the finite element model, input data and results are archived in the calculation package [3.4.30]. The following conclusions demonstrate that all safety criteria are satisfied for the cask system with MPC-44 basket design.~~
~~The lateral deflection of the most heavily loaded basket panel in the active fuel region complies with the deflection criterion in Table 2.2.11.~~
~~The shims remain attached to the basket maintaining its physical integrity.~~
~~The plastic strains in the MPC enclosure vessel remain below the allowable material plastic strain limit.~~
~~The cask closure lid does not dislodge after the tipover event, i.e., the closure lid bolts remain in-tact.~~
~~The structural analyses of cask closure lids are performed in [3.4.13] using bounding peak deceleration values; therefore, the lids do not suffer any gross loss of shielding.~~

3.4.4.1.4d Load Case 4: Non-Mechanistic Tipover of MPC-37P Basket Design

The tipover analysis of HI-STORM FW Version E cask with MPC-37P basket is not explicitly performed because of the following reasons:

a. -MPC-37P basket panels are thicker than that of MPC-37 basket per licensing

Table 3.4.19

PERMANENT LATERAL DEFLECTION OF FUEL BASKET PANELS DUE TO NON-MECHANISTIC TIPOVER

Fuel Basket Type	Max. Calculated Deflection (in)	Allowable Limit[†] (in)	Safety Factor
MPC-89 CBS	0.021	0.030	1.43
MPC-44 CBS	0.011	0.0405	3.68

[†] Equal to 0.005 times the cell inner dimension per Subsection 2.2.8 and Table 2.2.11. Cell inner dimension obtained from drawing package in Section 1.5.

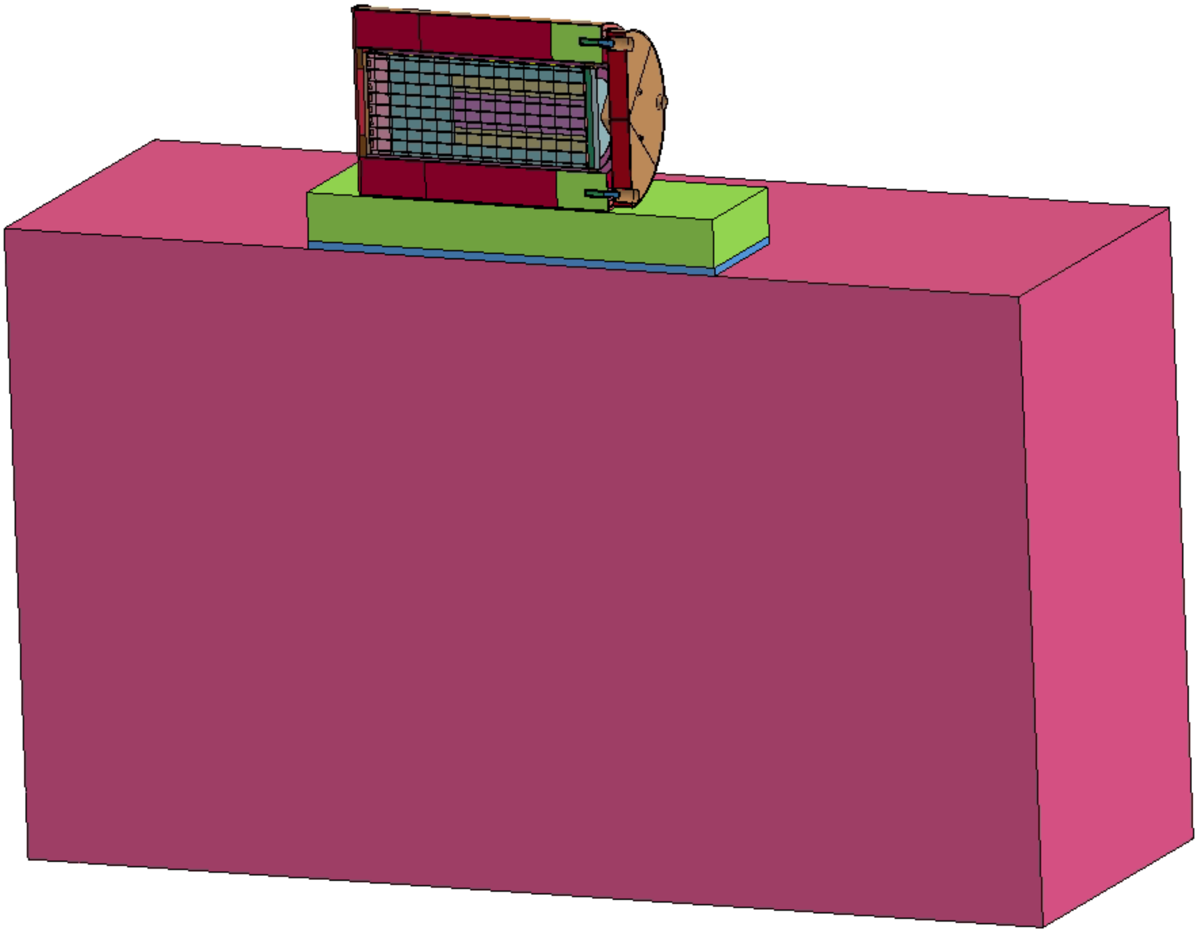

Figure 3.4.9D: LS-DYNA Tipover Model – HI STORM FW Version E Loaded with MPC-44

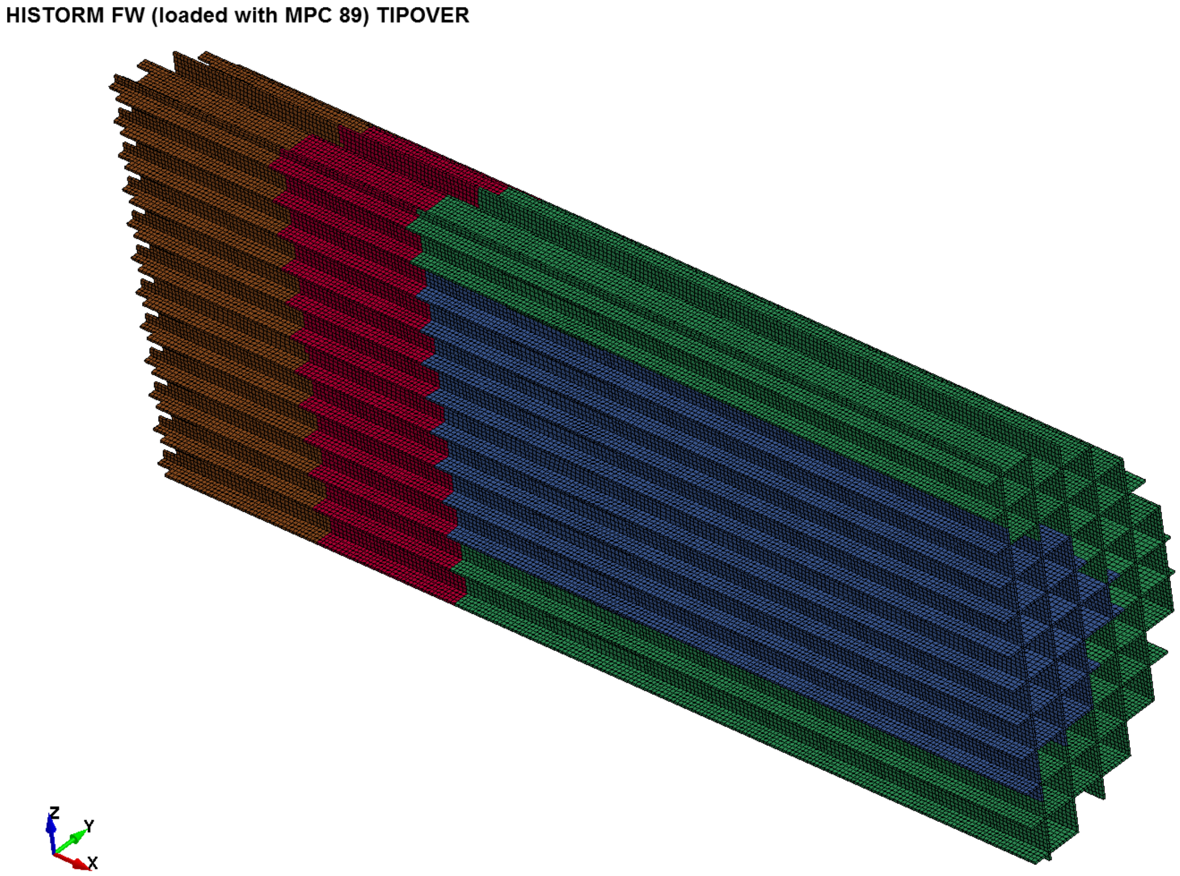

Figure 3.4.12D: LS-DYNA Model – MPC-89 CBS Fuel Basket
(note: the different colors represent regions with bounding temperatures of 365˚C, 300˚C, 300˚C and 200˚C, respectively)

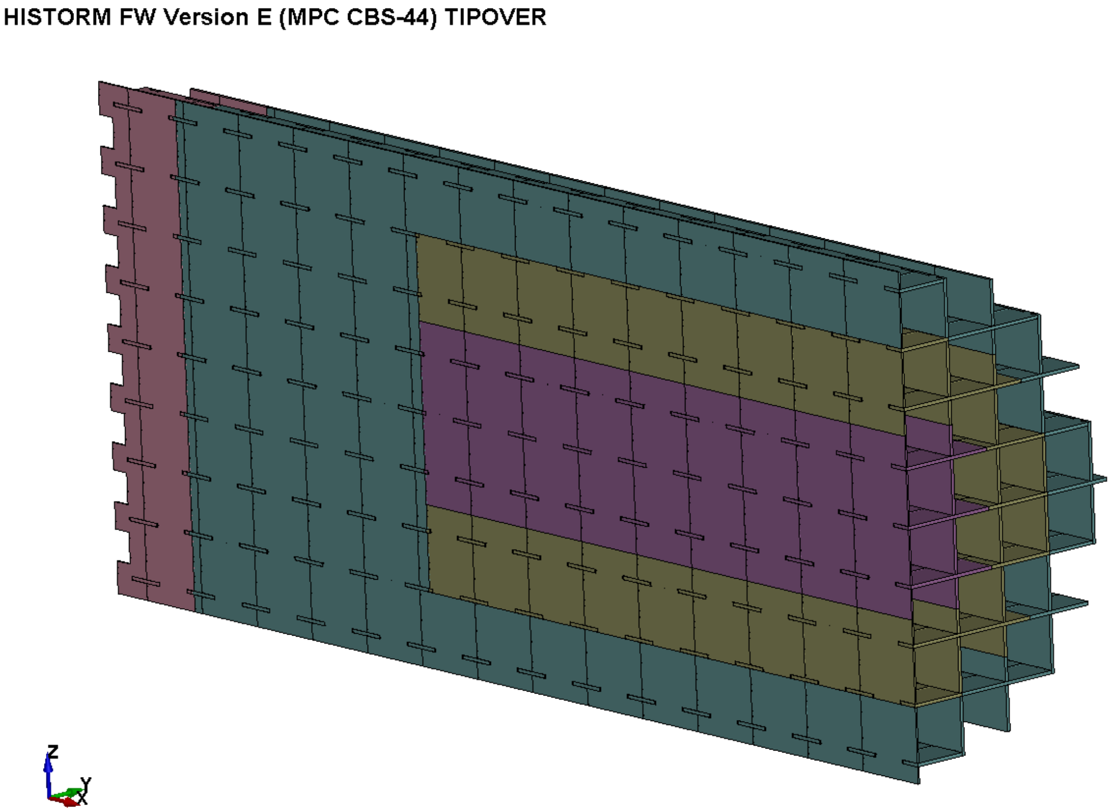

Figure 3.4.12E: LS-DYNA Model – MPC-44 CBS Fuel Basket
(note: the different colors represent regions with bounding temperatures of 380˚C, 365˚C, 325˚C and 250˚C, respectively)

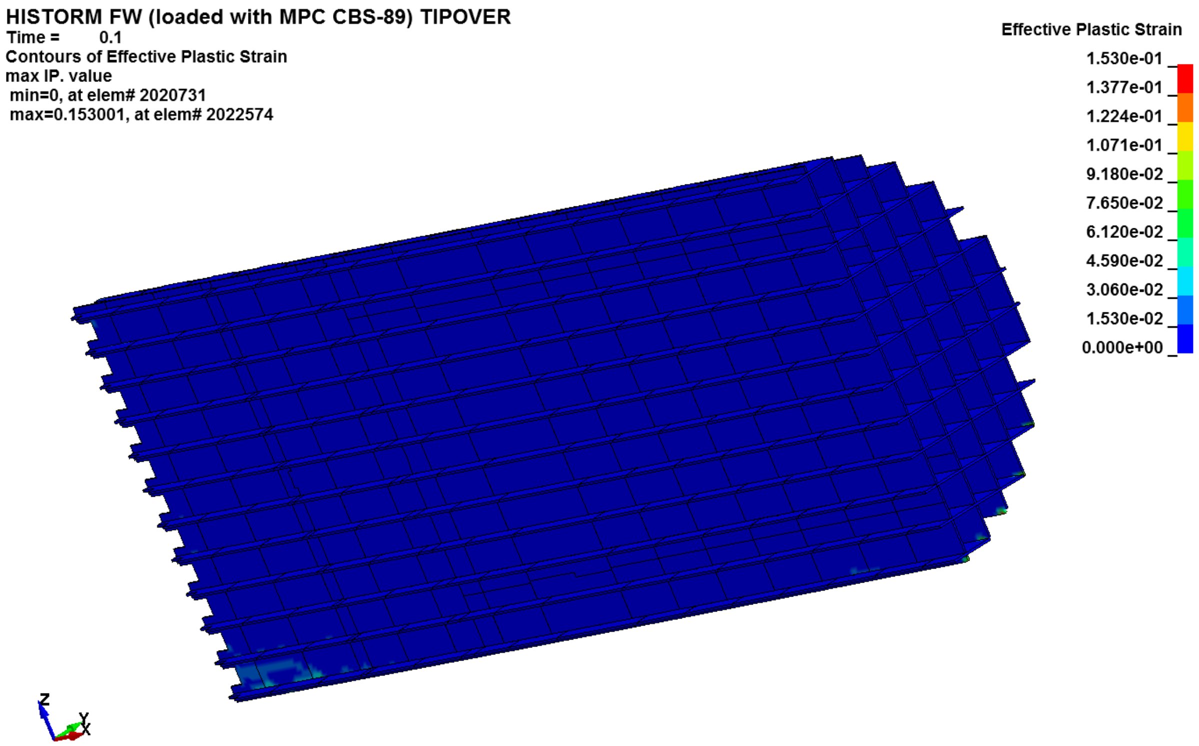

Figure 3.4.15D: Maximum Plastic Strain – MPC-89 CBS Fuel Basket

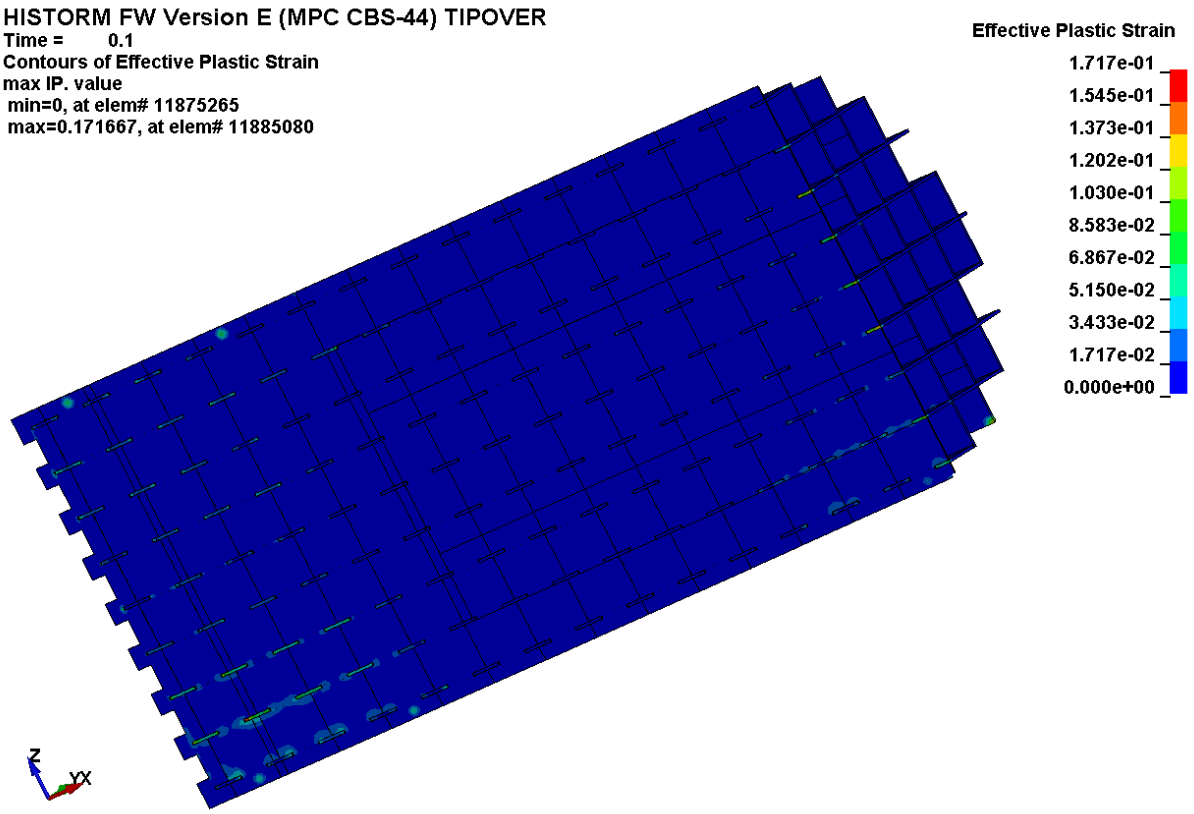

Figure 3.4.15E: Maximum Plastic Strain – MPC-44 CBS Fuel Basket

Table 1.I.1.1: Principle System Components QA Designation	
Principle System Components	**QA Designation**
HI-STORM FW UVH Overpack	ITS
HI-TRAC VW Transfer Casks (Table 1.I.1.2)	ITS
MPCs (Table 1.I.1.2)	ITS

Table 1.I.1.2 Principal Components Subject to Certification Associated with the Version UVH in the HI-STORM FW System

Component I.D.	Characteristic	Function	Comment
MPC-37 Standard (Certified in Rev 0 of the CoC)	Storage for 37 PWR fuel assemblies	Provide confinement to its contents under normal, off-normal and accident conditions and during Part 72 Short Term operations	All MPC Fuel Baskets are made of Metamic-HT. ~~Versions of these MPCs are listed in Table 1.0.1.~~
MPC-89 Standard (certified in Rev 0 of the CoC)	Storage for 89 BWR fuel assemblies		
MPC-44CBS (Certification sought in Rev 7 of the CoC)	Storage for 44 PWR fuel assemblies		
HI-TRAC VW (certified in Rev 0 of the CoC), HI-TRAC VW Version V (certified in Rev 5 of the CoC), HI-TRAC VW Version V2 (certified in Rev 5 of the CoC)	Variable weight transfer cask available in unventilated and ventilated versions	The transfer cask is indispensable to execute Short Term operations.	Version UVH is configured to utilize the same HI-TRAC models as other “FW” overpack models.

3.I.3.8 Non-Mechanistic Tip-over

Non-mechanistic tip-over of the freestanding HI-STORM FW system consisting of the Version UVH overpack and three variants of MPC (~~MPC-37,~~ MPC-44 CBS and standard versions of MPC-37 and MPC-89) is considered herein. The solution uses the same methodology that was employed in the system's original certification documented in Subparagraph 3.4.4.1.4. The physical problem subject to the present analysis is different from the original problem in two respects; they are:

(a) As ascertained in Chapter 4.I, there is smaller clearance between the MPC and the overpack under the design basis heat load and as a result, there are no MPC guide tubes that participate in the cask's dynamics during its impact with pad.

(b) The top lid-to-cask body connectivity has been improved such that the lid strikes the ISFSI pad without applying any shear load on the anchor bolts. Thus, the impact of the lid is decoupled from that of the cask body which materially reduces the angular momentum of the cask as it collides with the pad during tip-over. The anchor bolts still serve the safety function of keeping the MPC confined within the cask's radiation shield against the centrifugal force generated by the tip-over event.

The LS-DYNA model of the system, therefore, considers the cask body and its MPC with a small annular clearance between them striking the pad as an assemblage with limited lateral kinematic freedom. The ability of the closure lid to constrain the MPC within the confines of the overpack is also evaluated. The target foundation properties per Tables 2.2.9 and 2.I.0.1 are utilized. In case the target properties are not bounded by those in Table 2.2.9 and 2.I.0.1, a site-specific analysis using the model described in [3.4.31] will be required to demonstrate satisfaction of acceptance criteria in Paragraph 2.2.3(b).

~~The details of the finite element model, input data and results are archived in the calculation package [3.4.31].~~ The ISFSI pad LS-DYNA model, which consists of a 320”×100”×36” concrete pad plus 4” thick mudmat and the underlying subgrade (800”×250”×470” in size) with non-reflective lateral and bottom surface boundaries, is identical to that used for standard FW cask in Subparagraph 3.4.4.1.4. All structural members of the loaded cask are explicitly modeled so that any violation of the acceptance criteria can be found by examining the LS-DYNA simulation results (note: the fuel assembly, which is not expected to fail in a tipover event, is modeled as an elastic rectangular body).

Except for the fuel basket, which is divided into four parts based on the temperature distribution of the basket, each structural member of the cask is modeled as an independent part in the LS-DYNA model. Note that the critical weld connection between the MPC shell and the MPC lid is treated as a separate part and modeled with solid elements. Each of the three LS-DYNA models, for different basket types, are discretized with sufficiently high mesh density; very fine grids are used in modeling the MPC enclosure vessel, especially in the areas where high stress gradients are expected (e.g., initial impact location with the overpack). To ensure numerical accuracy, thick shell elements with 10 though-thickness integration points or multi-layer solid elements are used. In all three LS-DYNA models, the HI-STORM FW Version UVH cask is rotated by 1 degree (in the counter clockwise direction) leading to a vertical gap of approximately 4.34 inches between the ISFSI pad and top impact location of the storage cask. This is done to ensure that all loads are applied prior to cask's impact with the ground.

The same ISFSI concrete pad material model used for the standard HI-STORM FW tipover analysis in Subparagraph 3.4.4.1.4 is adopted for the HI-STORM FW Version UVH tipover analysis. Specifically, the concrete pad behavior is characterized using the same LS-DYNA material model (i.e., MAT_PSEUDO_TENSOR or MAT_016) as for the tipover analysis of the standard HI-STORM FW cask in Subparagraph 3.4.4.1.4. Similarly, the subgrade is also conservatively modeled as an elastic material. Note that this ISFSI pad material modeling approach was originally taken in the USNRC approved storage cask tipover and end drop LS-DYNA analyses [3.4.5] where a good correlation was obtained between the analysis results and the test results.

To assess the potential damage of the cask caused by the tipover accident, an LS-DYNA nonlinear material model with strain rate effect is used to model the responses of all HI-STORM FW Version UVH cask structural members based on the true stress-strain curves of corresponding materials. Note that the strain rate effect for the fuel basket material, i.e., Metamic-HT, is not considered for conservatism.

Figure 3.I.3.3 depicts the finite element tipover analysis model developed for the HI-STORM FW Version UVH cask configurations with loaded MPC-37. Identical models are prepared for the HI-STORM FW Version UVH cask loaded with MPC-89 and MPC-44. Table 3.I.3.9 summarizes the maximum plastic strain results for each MPC fuel basket, along with the corresponding material failure strains. The plastic strain contours are plotted in Figures 3.I.3.4 through 3.I.3.6 for all three fuel baskets. It is observed from these three figures that the strains within the active fuel region are mainly elastic, and the peak strains are below the material failure strain limit. Plastic deformation occurs only in localized areas of the peripheral cells of all three baskets (MPC-37, MPC-89 and MPC-44) near the top of the basket or in the bottom mouse hole region beyond the active fuel region. The MPC-44 is the limiting basket design from a tipover perspective based on the strain contours plotted in Figures 3.I.3.4 through 3.I.3.6. This is because the visible plastic strain regions are more widespread, and the strain values are also higher for the MPC-44. Therefore, the MPC-44 is further evaluated to determine the maximum permanent deformation of the heaviest loaded basket panel for direct comparison with the allowable limit in Table 2.2.11. The deflection results are summarized in Table 3.I.3.12.

The MPC enclosure vessel also experiences minor plastic deformation at the impact location with overpack inner shell. The maximum local plastic strain is well below the failure strain of the material and also smaller than the conservatively established plastic strain design limit (i.e., at least 0.2 for stainless steel) recommended by [3.4.6] for ASME NB components. Local plastic deformation occurs in the overpack inner shell due to the interaction with the MPC closure lid. Similar local plastic deformation occurs in the top region of the overpack outer shell and in the overpack lid outer shell at the impact location with the ISFSI pad. The strains in the overpack (including the lid) remain below the material failure strain limit. Furthermore, the shielding capacity of overpack (including the lid) is not compromised by the tipover accident and there is no gross plastic deformation in the overpack inner shell to affect the retrievability of the MPC. In addition, the cask closure lid bolts are demonstrated to be structurally safe after the tipover event, only a negligibly small plastic strain is observed in the bolt.~~Figure 3.I.3.3 depicts the finite-element tipover analysis model developed for the HI-STORM FW Version UVH cask configurations with loaded MPC-37. Identical models are prepared for the HI-STORM FW Version UVH cask loaded with MPC-89 and MPC-44. Table 3.I.3.9 summarizes the maximum plastic strain results, along with the corresponding material failure strains.~~

~~From Figures 3.I.3.4 to 3.I.3.6 and Table 3.I.3.9, it is observed that the strains within the active fuel region are below the material failure strain limit. Local plastic deformation essentially develops only in a couple of peripheral cells of all three baskets (MPC-37, MPC-89 and MPC-44) near the top of the basket or in the bottom mouse hole region beyond the active fuel region. All three fuel baskets are structurally safe since they can continue maintaining appropriate spacing between fuel assemblies after the tipover event. The MPC enclosure vessel also experiences minor plastic deformation at the impact location with overpack inner shell; the maximum local plastic strain is well below the failure strain of the material and also smaller than the conservatively established plastic strain design limit (i.e., at least 0.2 for stainless steel) recommended by [3.4.6] for ASME NB components. Local plastic deformation occurs in the overpack inner shell due to the interaction with the MPC closure lid. Similar local plastic deformation occurs in the top region of the overpack outer shell and in the overpack lid outer shell at the impact location with the ISFSI pad. The strains in the overpack (including the lid) remain below the material failure strain limit. Furthermore, the shielding capacity of overpack (including the lid) is not compromised by the tipover accident and there is no gross plastic deformation in the overpack inner shell to affect the retrievability of the MPC. In addition, the cask closure lid bolts are demonstrated to be structurally safe after the tipover event, only a negligibly small plastic strain is observed in the bolt.~~

The complete details of the finite element model, input data and results are archived in the calculation package [3.4.31]. In summary, the results of the tipover analyses ~~The following conclusions~~ demonstrate that all safety criteria are satisfied for the Version UVH cask with MPC-37, MPC-44 and MPC-89 basket designs, which means:~~.~~

i. The lateral deflection of the most heavily loaded basket panel in the active fuel region complies with the deflection criterion in Table 2.2.11.
ii. The CBS~~shims in MPC-44 basket~~ remain attached to the MPC-44 fuel basket ~~it~~ maintaining their~~its~~ physical integrity.
iii. The plastic strains in the MPC enclosure vessel remain below the allowable material plastic strain limit.
iv. The cask closure lid does not dislodge after the tipover event, i.e., the closure lid bolts remain in-tact.
v. The lid or the cask body do not suffer any gross loss of shielding.

Table 3.I.3.10: STRESS RESULTS FOR HI-STORM FW VERSION UVH LID – NORMAL HANDLING

Item	**Calculated Value (ksi)**	**Allowable Limit (ksi)**	**Safety Factor**
Maximum Primary Membrane Stress	6.6 (conservative)	19.6	2.97
Maximum Primary Membrane Plus Bending Stress	6.6	29.4	4.45
Lift Lug-to-Base Plate Weld	0.474	7	14.76
Lift Lug – Tear Out	2.177	4.20	1.93

Table 3.I.3.11: GOVERNING STRESS RESULTS FOR HI-STORM FW VERSION UVH – NORMAL HANDLING AND PRESSURE LOADING

Item	**Calculated Value (ksi)***	**Allowable Limit (ksi)**	**Safety Factor**
Maximum Primary Membrane Stress (Overpack)	17.17	34.9	2.03
Maximum Primary Membrane Plus Bending Stress (Overpack)	30.89	52.4	1.70
Maximum Primary Membrane Stress (Lid)	9.56	34.9	3.65
Maximum Primary Membrane Plus Bending Stress (Lid)	17.16	52.4	3.05
*All the tabulated stresses correspond to the governing load case i.e., pressure case 5 in Subsection 3.I.3.2			

Table 3.I.3.12: PERMANENT LATERAL DEFLECTION OF FUEL BASKET PANELS DUE TO NON-MECHANISITC TIPOVER

Fuel Basket Type	Max. Calculated Deflection (in)	Allowable Limit[†] (in)	Safety Factor
MPC-44 CBS	0.0233	0.0405	1.74
[†] Equal to 0.005 times the cell inner dimension per Subsection 2.2.8 and Table 2.2.11. Cell inner dimension obtained from licensing drawing in Section 1.5.			