Deflection Design Criteria in Previous FSAR

In Amendment No. 0 of the HI-STORM FW FSAR, Holtec referred to the deflection criterion in different, sometimes ambiguous, ways. But it is clear that the only technical basis for the deflection criterion was for a total deflection limit, and the FSAR concludes that this deflection criterion was met. However, Holtec did not provide any analysis results to support this conclusion. Similar statements made to support Amendment No. 7 were determined to be inaccurate when the staff requested analysis results to support a similar conclusion. The following presents sections of the FSARs, SERs, and analysis reports to illustrate the issue.

Revision 0 of the HI-STORM FW FSAR was submitted for HI-STORM FW Amendment No. 0. The design criteria for the storage system are described in chapter 2 of the FSAR Rev. 0 (ML112380795, ML112700702 for proprietary version). Figures 1 and 2 show that the design criteria for the basket is maximum total deflection. Figure 3 shows that FSAR reference 2.2.11 is the technical basis for the deflection limit. This reference is to Holtec's position paper DS-331, "Structural Acceptance Criteria for the Metamic-HT Fuel Basket," which describes maximum total deflection.

DS-331, which is incorporated into the FSAR by reference, is the only description of the technical basis for the deflection criterion. All other statements about the criterion in the FSAR are simply mentioning the criterion and do not attempt to provide a technical basis or definition of the criterion. A technical basis is needed to relate deflection values to material properties and structural performance.

Figure 4 shows that the Amendment No. 0 FSAR did refer to the deflection limit as "plastic deformation." FSAR statements mentioning the criterion refer to it as a variety of different terms. This led the staff to request Holtec clarify the deflection criterion, RAI 3-10. This statement, like most others mentioning the criterion, refers to the maximum total deflection criterion in FSAR Table 2.2.11.

Figure 5 describes the safety goal of the deflection design criteria. The structural evaluation must show that under the basket does not displace more than the amount assumed in the criticality analysis. This should be demonstrated by checking that the deflections in the finite element analysis results are less than the deflection limit in Table 2.2.11. This should be checked for every basket and is part of verifying that the criterion is met. The structural evaluation must also show that the basket can achieve this deflection without failure. This demonstration is presented in DS-331 to validate the criterion.

Figure 6 shows that the FSAR stated that the FEA results demonstrated that the appropriate spacing between fuel assemblies was maintained. This suggests that the deflection criterion was met. The reference to plastic deformation at the beginning of this passage is discussing plastic strain results, not deflections.

Figure 7 is from the SER approving HI-STORM FW FSAR Amendment No. 0. This is the staff's discussion of the design criterion. In it, the staff refers to the criterion as "permanent deformation," which is not a term used for the criterion in the FSAR but is used in the tipover analysis report. There is no more detailed discussion of the fuel basket criterion in the SER.

During the HI-STORM FW Amendment No. 7 review, the staff encountered a similar FSAR statement that the deflection criterion was met, see Figure 8. The staff discovered a statement in the tipover analysis report, HI-2200503 Revision 3, suggesting that there was no permanent deformation of the fuel baskets, see Figure 9.

The staff issued RAI 3-9 requesting Holtec provide analysis results supporting this conclusion. After clarification calls with Holtec, Holtec submitted Revision 5 of HI-2200503, which demonstrated that there were permanent deformations in the basket.

Prior to the Amendment No. 7 review, Holtec had not provided any deflection results for HI-STORM FW fuel baskets.

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 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.

Figure 1: FSAR Rev. 0 Section 2.2.8 describing the design criteria for the fuel baskets as maximum total deflection.

Table 2.2.11

STRUCTURAL DESIGN CRITERIA FOR THE FUEL BASKET

PARAMETER	VALUE
Minimum service temperature	-40°F
Maximum total (lateral) deflection in the active fuel region - dimensionless	0.005

Figure 2: FSAR Rev. 0 Table 2.2.11 listing the maximum total deflection limit.

The fuel basket, made of Metamic-HT, is subject to the requirements in Appendix 1.B and is designed to a specific (lateral) deformation limit of its walls under accident conditions of loading (credible and non-mechanistic) (see Table 2.2.11). The basis for the lateral deflection limit in the active fuel region, θ, is provided in [2.2.11].

Figure 3: FSAR Rev. 0 Section 2.2.4 stating that Reference 2.2.11 (DS-331) is the technical basis for the deflection limit.

The following requirements and acceptance criteria apply to the HI-STORM FW overpack under the tipover event:

i. In order to maximize the target stiffness (based on experience with ISFSI pad designs), the ISFSI pad and underlying soil are conservatively modeled using the data in Table 2.2.9.
ii. The tipover is simulated as a gravity-directed rotation of the cask from rest with its CG above its edge on the pad as the system's initial condition. The tipover begins when the cask is given an infinitesimal outward displacement in the radial plane of its tilted configuration.
iii. The MPC will remain in the HI-STORM FW overpack after the tipover event and the overpack will not suffer any ovalization which would preclude the removal of the MPC.
iv. The maximum plastic deformation sustained by the fuel basket panels is limited to the value given in Table 2.2.11.
v. The HI-STORM FW overpack will not suffer a significant loss of shielding.
vi. The confinement boundary will not be breached.

Figure 4: FSAR Rev. 0 Section 2.2.3 describing the maximum total deflection limit as plastic deformation.

The MPC fuel basket maintains the spent nuclear fuel in a subcritical arrangement. Its safe operation is assured by maintaining the physical configuration of the storage cell cavities intact in the aftermath of a non-mechanistic tipover event. This requirement is satisfied if the MPC fuel basket plates undergo a minimal deflection (see Table 2.2.11). The fuel basket strains are shown in Subsection 3.4.4.1.4 to remain essentially elastic, and, therefore, there is no impairment in the recoverability or retrievability of the fuel and the subcriticality of the stored fuel is unchallenged.

Figure 5: FSAR Rev. 0 Section 3.1.1 stating that demonstrating the deflection limit ensures safety.

As shown in Figure 3.4.15, the fuel basket does not experience any plastic deformation in the active fuel region; plastic deformation is limited locally in one periphery cell near the top of the basket beyond the active fuel region for both MPC-37 and MPC-89 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 (9.9%, 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

Figure 6: FSAR Rev. 0 Section 3.4.4.1.4 stating that the fuel basket is structurally safe during the tipover because it maintains spacing.

ISFSI pad design and bounding cask dimensions to maximize the potential damage. Results of the LS-DYNA analyses demonstrated that after the tipover event, the cask closure lid remained attached to the overpack body and the overpack did not suffer a significant loss of shielding; the MPC remained in the HI-STORM FW overpack and the latter did not suffer ovalization affecting the removal of the MPC; the MPC confinement boundary was not breached and the fuel basket panels in the active fuel region did not experience any permanent deformation to change the spacing between stored fuel assemblies.

Figure 7: SER Section 3.3.3.1 showing that the staff understood the fuel basket design criteria as permanent deformation.

The details of the finite element model, input data and results are archived in the calculation package [3.4.11]. The following conclusions demonstrate that all safety criteria are satisfied for the cask system with Version CBS basket designs.

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.

Figure 8: FSAR Rev. 9 stating the deflection limit was met for the CBS fuel basket designs.

LS-DYNA finite element analyses are performed for the postulated non-mechanistic tipover accident of HI-STORM FW Version E storage cask. Results of the LS-DYNA analyses

demonstrate that the fuel basket panels in the active fuel region do not experience any permanent deformation and hence do not affect the spacing between stored fuel assemblies.

Figure 9: HI-2200503 Rev. 3 Appendix C stating that the LS-DYNA results for the MPC-37 CBS demonstrate that the fuel basket panels do not experience any permanent deformation.

Table C.2: Maximum Permanent Deformation of MPC-37 CBS Basket

Panel Orientation	Max. Plastic Deflection (in)	Allowable Plastic Deflection Limit (in)*	Safety Factor
Horizontal	0.036	0.045	1.25

* Equal to 0.005 times the cell inner dimension. For MPC-37 CBS, the limit is 0.005 x 8.96" = 0.045

Figure 10: HI-2200503 Rev. 5 Table C.2 showing that the MPC-37 CBS basket does experience permanent deformation.