<u>Supplemental Technical Summary to the Meeting Minutes on the Holtec/NRC public meeting dated Feb 27, 2013 on the methodology for ISFSI Pad Structural Analysis</u>

The following meeting summary supplements the minutes of the meeting on the ISFSI pad analysis held on Feb 27 at the NRC's headquarters [2]. It contains the substance of the detailed technical guidance provided by the Staff.

The cask support pad (CSP or Pad) for *freestanding* casks has been classified as a not-important-to-safety (NITS) structure in HI-STORM FSARs. Nevertheless, the HI-STORM FSAR requires the CSP to meet ACI-318 (2005) load combinations. This technical summary documents the methodology for CSP qualification that was finalized after NRC's input to Holtec's proposal [1] in the above mentioned public meeting. The February 27 meeting yielded the final closure to the dialog with the NRC that had begun with a public meeting on July 12, 2012. The guidance in this summary is being used in all CSP qualification work by Holtec International after the above mentioned meeting with the NRC to ensure uniformity of analysis approach and to provide a clear quantification of associated design margins. The guidance in this paper is not mandated for previously designed and built pads except for the LaSalle's pad whose regulatory review led to this standardization effort by Holtec with NRC's assistance.

Analysis Guidelines:

1. The candidate ISFSI pad design shall be subjected to the "non-mechanistic" tip over analysis on LS-DYNA as set forth in the FSAR and the acceptance criteria in the FSAR shall be shown to be met.

2. In the next step, the pad shall be analyzed for the governing load combinations set forth in the FSAR. The governing load combinations are (see Section 2.0.4.1 of the HI-STORM 100 FSAR for example):

    a. Load Combination # 1: $U_c > 1.4D + 1.7L$
    b. Load Combination # 2: $U_c > 1.05D + 1.275(L + F)$
    c. Load Combination # 3: $U_c > D + L + E$ (or W_t)

    where U_c = Ultimate strength, D = Dead load, L = Live load, F = Hydrological (Flood) load, E = Earthquake load, and W_t = Tornado load.

3. The above load combinations shall be used to evaluate the pad's compliance with ACI-318 provisions. In accordance with ACI-318, the effects of long term differential

settlement shall be included in Load Combination #1 only. As an additional measure of conservatism, the ISFSI pad owner may elect to invoke ACI 349 (which requires the effects of long term differential settlement to be considered in conjunction with seismic loading).

4. For sites with low design basis earthquake and minimal seismic amplification due to SSI effects, it is permissible to use SASSI to perform SSI analysis provided the assumption of linear response implicit to SASSI is borne out by the analysis results (i.e., no sliding or loss or full or partial contact between the cask and the pad). Otherwise, a non-linear SSI analysis on a recognized code such as LS-DYNA shall be implemented, as summarized below.

5. The SSI analysis, performed using the time history analysis method implemented in LS-DYNA shall utilize a minimum of five sets of time histories which are compliant with SRP 3.7.1.The time histories shall be real recorded or modified recorded, and the phasing of the Fourier components shall be preserved to the maximum extent practical (particularly in the low frequency range). Minor distortion of the phase angle spectrum due to baseline correction is permissible.

6. The strain compatible soil properties to be used as input to the SSI analysis model shall be determined using the computer code SHAKE2000. The strain compatible properties shall be computed for the Best Estimate, Lower Bound, and Upper Bound soil profiles.

7. The LS-DYNA coupled model shall include the soil foundation, the ISFSI pad, and a single freestanding cask. The size and depth of the soil foundation shall follow the guidance in ASCE 4-98 and NUREG/CR-6865. The ISFSI pad shall be modeled as a flexible plate (or shell) based upon the minimum design concrete compressive strength. The cask shall be positioned on the pad at a perimeter storage location. The coupled model shall permit uplift and sliding of the cask relative to the ISFSI pad.

8. The SSI analysis shall consider an upper bound coefficient of friction (COF) of 0.8 at the cask/pad interface to maximize rocking behavior. A COF value of 1.0 shall be specified at the pad/soil interface based on the guidance in NUREG/CR-6865.

9. To insure an adequate margin of safety against cask tip over, the input time history that yielded the maximum cask rocking angle (from among the 5 analyzed time history sets) shall be re-analyzed with a 10% amplification factor applied to the input motion.

10. A lower bound COF of 0.2 at the cask/pad interface shall also be analyzed to insure that there are no inter-cask impacts. In lieu of performing non-linear time history analyses

(using five sets of time histories), it is acceptable to compute the maximum sliding displacement of the cask based on a lower bound COF of 0.2 using the nomograms provided in NUREG/CR-6865 for a 95% confidence band.

11. The boundary conditions for the LS-DYNA model shall be the same as those employed in NUREG/CR-6865 (i.e., each ring of perimeter soil nodes shall be rigidly constrained to move together).

References:

[1] Holtec Letter No. 5014471 from Dr. Stefan Anton (Holtec) to Mr. Mark Lombard (USNRC) dated July 19, 2012 (ADAMS Accession ML12313A354).

[2] Summary of February 27, 2013 Meeting with Holtec International to Discuss Independent Spent Fuel Storage Installation Pad Design (TAC NO. L60452), March 19, 2013.