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TOPICAL REPORT ON FREESTANDING STACK-UP ANALYSIS METHODOLOGY DURING A SEISMIC EVENT

Pre-submittal Meeting

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A Presentation to NRC

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Presentation Overview

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- Purpose and Scope of the Topical Report
- Holtec's Perspective on Topical Report
- Technical Approach
  - Benchmarking of ANSYS Non-Linear Model
  - Input Time Histories
  - Coefficient of Restitution/Damping Considerations
  - Modeling of Mating Device
- Schedule
- Open Discussion

Purpose and Scope of the Topical Report

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- ✓ Report addresses a 10CFR50 controlled evolution at an operating nuclear power plant
- ✓ Report is expected to be referenced by multiple licensees in a number of license amendment requests or 50.59 evaluations
- ✓ Report contains complete and detailed information on the specific subject presented
- ✓ NRC approval of the report will increase the efficiency of the review process for applications that reference the report
- ✓ Report will enable Holtec to serve its dry storage clients with clarity in the matter of stack-up seismic analysis and facilitate smooth NRC inspection of dry storage implementations.

Holtec's Perspective on Topical Report

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- Topical Report will help the Company's clients across the country formulate their safety evaluation of stack-ups with full knowledge of NRC's position.
- Topical Report will present one acceptable methodology
  - Approval of Topical Report would not invalidate existing stack-up analyses at plants that have established dry storage programs
  - Approval of Topical Report would not *a priori* exclude the use of other methods for performing freestanding stack-up analysis
- Topical Report and SER would be applicable to all USNRC Part 50 facilities and Holtec's Part 72 dockets and could be referenced by licensees and Holtec in future 50.59 and 72.48 evaluations
- Topical Report will increase the efficiency of inspections

Technical Approach – Computer Code Validation

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- Seismic response of freestanding stack-up will be analyzed using time history analysis method and ANSYS finite element code
- ANSYS model will be validated by simulating the free rocking motion of a rigid block and comparing the numerical results with the experimental test results obtained by ElGawady et. al. [1] or a similar reference
  - Validation model will use “rough contact” option in ANSYS in order to mimic the physical tests and prevent sliding of the rigid block
- Stack-up model will use the same non-linear contact elements and 3-D solid elements as the validation model
  - Upper and lower bound coefficient of friction (COF) values will be assigned to the contact elements to capture sliding motion of the stack-up

[1] ElGawady M, Ma Q, Butterworth J, Ingham J, “Effects of interface material on the performance of free rocking blocks”, Earthquake Engineering and Structural Dynamics, 2011,40:375-392.

Technical Approach – Input Time Histories

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- Input time histories will be developed based on Reg. Guide 1.60 spectra scaled to a Peak Ground Acceleration (PGA) of 0.3 g
- Input time histories will meet all requirements of SRP 3.7.1 Rev. 3 for non-linear analysis
  - Based on real recorded ground motions
  - Phasing of Fourier components must be maintained
  - Use more than 4 sets of input time histories
  - Computed 5% damped response spectra (based on average of time histories) must envelope target response spectra
  - Each set of 3 components must be statistically independent (i.e., correlation coefficient < 0.16)
- Real recorded ground motions will be selected from PEER database based on spectral shape, total time duration, strong motion duration, and time step size

Technical Approach – Input Time Histories (cont.)

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- Time history scaling will be performed using Matlab based on the methodology described in [2]
  - Holtec is not aware of any commercially available computer codes that can perform spectral matching of real recorded ground motions in accordance with SRP 3.7.1 Rev. 3 (i.e., phasing of Fourier components must be maintained)
- Input motion will be applied to the ANSYS stack-up model in the form of acceleration time histories
  - Acceleration time histories will be baseline corrected such that final velocity is zero (i.e., first-order baseline correction)
  - Acceleration time histories will be applied to the stack-up foundation simultaneously in three orthogonal directions

[2] Fahjan Y, Ozdemir Z, Keypour H, "Procedures for Real Earthquake Time Histories Scaling and Application to Fit Iranian Design Spectra", SEE 5, Tehran, Iran, May 2007.

Technical Approach – Coefficient of Restitution/Damping Considerations

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- Coefficient of restitution, r, for the stack-up can be obtained using one of the following two methods:
  - Calculate "r " using formula developed by Housner [3] for the free rocking response of rigid block
    - > Since the bodies are assumed rigid, no change in displacement occurs during impact and no body-forces do work during instantaneous impact
    - > Also assumes no bouncing of rigid block
  - Calculate "r" based on detailed finite element analysis of free rocking response of stack-up using LS-DYNA
    - > Avoids assumptions associated with Housner model
    - > Frictional energy losses must be accounted for when calculating "r"
  - Determine "r" based on physical testing of interface materials
    - > Vendor test data indicates polymeric material used in LPT (i.e., Fabreeka pad) has a logarithmic decrement of 0.69 and an equivalent damping percentage of 14.3%

[3] Housner G, "The behaviour of inverted pendulum structures during earthquakes", Bulletin of Seismology Society of America, 1963, 53(2):403-417

Technical Approach – Coefficient of Restitution/Damping Considerations (cont.)

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- *Material damping* for the stack-up components will be in accordance with Reg. Guide 1.61 recommended values (i.e., 4% for welded/bolted steel with friction connections for SSE)

Technical Approach – Modeling of Mating Device

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- Mating Device interfaces will be explicitly modeled (i.e., behavior of bolted joints will not be assumed *a priori*)
- Mating Device bolts will be modeled using tension-only spar elements (LINK180)
  - Location and number of bolts in ANSYS model will be consistent with actual hardware
    - 10 bolts connecting HI-TRAC to Mating Device
    - 2 bolts connecting HI-STORM to Mating Device
  - Tensile prestress will be applied to the bolts prior to time history simulation
- Compression contact between HI-TRAC, HI-STORM, and Mating Device will be simulated using point-to-point contact elements (CONTA178)

Technical Approach – Modeling of Mating Device (cont.)

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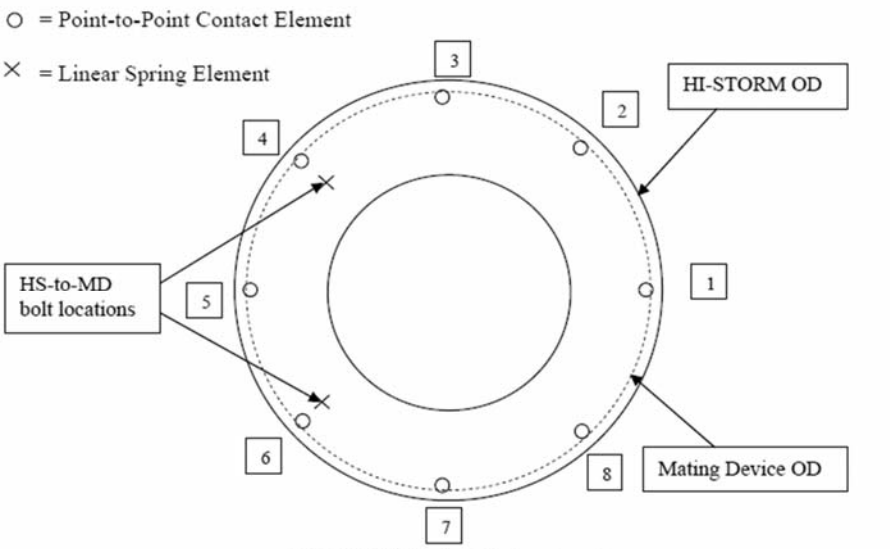

HI-STORM/Mating Device Interface

Technical Approach – Modeling of Mating Device (cont.)

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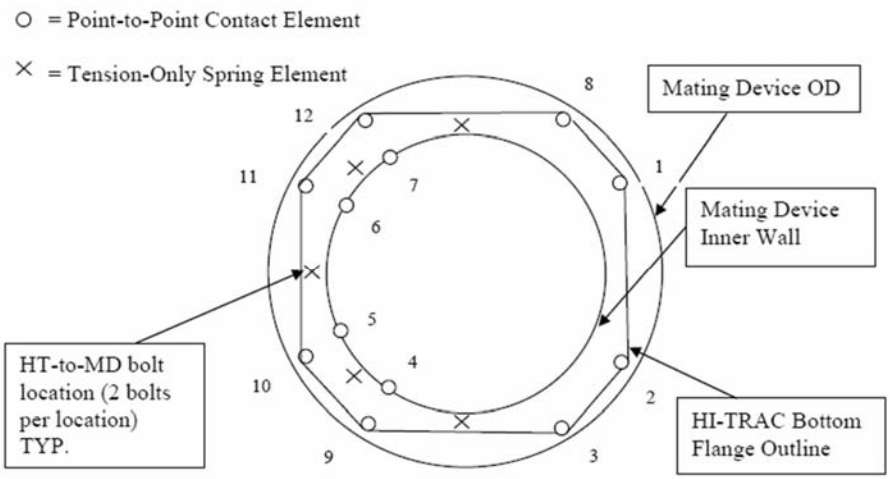

HI-TRAC/Mating Device Interface

Schedule

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- Topical Report to be submitted for review in August 2012

Open Discussion

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