A PRE-SUBMITTAL BRIEFING
to
SFST (USNRC)
on
THE HI-STORM FW UNDERGROUND VERTICAL VENTILATED MODULE

by

Ms. Tammy Morin, Mr. Chuck Bullard and Dr. John Zhai
Holtec International
March 24, 2011

MEETING OBJECTIVES AND AGENDA

1. Provide an overview of the design features of the HI-STORM FWU Vertical Ventilated Module (VVM).
2. FWU Structural/SSI Presentation
3. FWU Thermal Presentation
4. Discussion on Schedule and FSAR Format

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HI-STORM FWU COMPONENTS

- Vertical Ventilated Module containing an MPC.
- Similar to HI-STORM 100U (DOCKET NO. 72-1014).
- Components
  - HI-STORM FWU VVM
  - MPC-37 OR MPC-89
  - HI-TRAC VW

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HI-STORM FWU VVM

1. The VVM is made from two concentric shells of steel joined by radial connectors.
   1. Cavity Enclosure Container
   2. Divider Shell
2. A thick baseplate joins both shells at the bottom.
3. The inlet ducts are located radially around the VVM lid. The outlet duct is in center of the VVM lid, with air exiting at the top of the lid.

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HI-STORM FWU VVM

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MPC FUEL BASKETS

- Two fuel basket designs in a common diameter MPC enclosure vessel.
  - MPC-37 holds 37 PWR assemblies
  - MPC-89 holds 89 BWR assemblies
- Basket made of structurally qualified Metamic-HT instead of stainless steel

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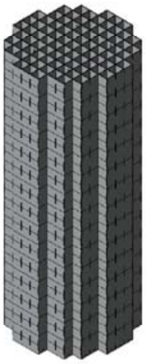

MPC-89 BWR FUEL BASKET

(89 STORAGE CELLS)

IN PERSPECTIVE VIEW

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HI-TRAC VW TRANSFER CASK

1. Variable height and variable weight implemented in the design
2. Steel-lead-steel construction with water jacket serving to provide (as-needed) neutron attenuation.
3. Evolved from HI-TRAC 125D with the following improvements:
   - Trunnions (locations of radiation streaming) eliminated from the design
   - Bottom flange region redesigned to maximize gamma shielding
4. Water jacket configured to promote internal circulation to maximize heat dissipation.

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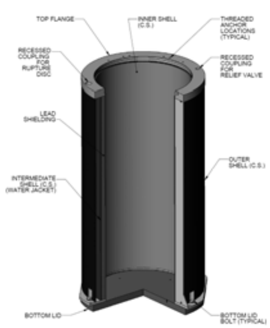

CUT-AWAY VIEW OF HI-TRAC VW

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HEAVY LOAD HANDLING

- Loaded HI-TRAC shall always be carried in the vertical orientation (no horizontal handling).
- All heavy load handling outside the Part 50 structure (i.e., within Part 72 scope) shall be by single-failure-proof cask transporter.
- All lifting devices shall meet the applicable sections of NUREG-0612 AND ANSI N14.6 stress limits.
- A drop accident within the Part 72 scope of operations is *not* credible.
- MPC transfer from HI-TRAC directly into VVM at ISFSI.

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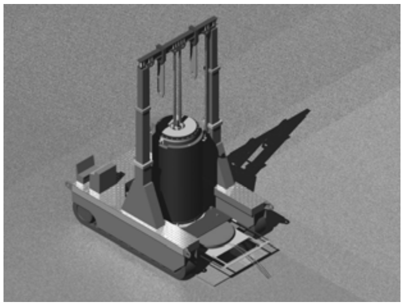

MPC TRANSFER INTO A VVM AT THE ISFSI

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HI-STORM FWU
Soil Structure Interaction Analysis

Presentation to NRC
March 24, 2011
by
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Introduction

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- HI-STORM FWU is the underground version of the HI-STORM FW spent fuel storage system, which is currently in final rule making and scheduled to be approved in April 2011.
- NRC is reviewing a smaller underground storage system HI-STORM 100U (LAR 1014-9), whose structural evaluation for the seismic loading condition was re-performed to eliminate the limitations in the current FSAR.
- The HI-STORM FWU soil structure interaction analysis under seismic condition is essentially the same as the methodology developed for the HI-STORM 100U system.

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Introduction

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Introduction

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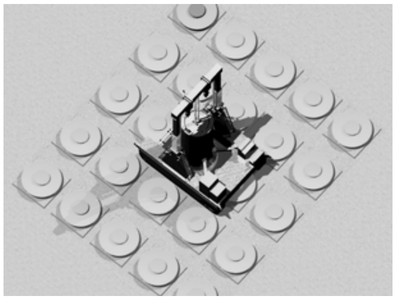

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Design Parameter Comparison of HI-STORM FWU and HI-STORM 100U

Design Parameters	HI-STORM FWU	HI-STORM 100U
Maximum MPC Weight	116,400 lbs	90,000 lbs
Maximum VVM Height	246 inches	223.06 inches
VVM Diameter	97 inches	86 inches
ISFSI Pitch	15.5 feet	14 feet
Loaded Transporter Weight	450,000 lbs	400,000 lbs

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Design Differences Between HI-STORM FWU and HI-STORM 100U

- Vertical Interface Pad (VIP) and Top Surface Pad (TSP) are cast together as one monolithic structure for HI-STORM FWU
- For HI-STORM FWU, the TSP thickness is increased to 30” minimum (versus 24” for HI-STORM 100U)
- HI-STORM FWU lid is reconfigured to improve shielding and thermal performance

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Objectives of HI-STORM FWU SSI Analyses

- To establish the minimum soil property requirements for the HI-STORM FWU ISFSI site and the Design Basis Earthquake Response Spectra to allow the deployment of the underground spent fuel storage system at most US nuclear power plant sites.

- Obtain the bounding loads experienced by the cask structural members, the stored fuel and the ISFSI concrete members under the design basis seismic loading condition for subsequent structural integrity analyses.

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Outline of the SSI Analysis Methodology

1. Perform a two-step SHAKE/LS-DYNA soil seismic response analysis to establish the lower bound ISFSI site soil properties and to establish the Design Basis Earthquake.

2. Perform seismic time history simulations using the LS-DYNA HI-STORM FWU ISFSI model to obtain the bounding responses of both the cask and the ISFSI structure members.

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SHAKE Soil Seismic Response Analysis

- Use the lower shear wave velocity profile of US nuclear power plants (taken from NUREG/CR-6865) to perform SHAKE analyses for soil layers with a minimum total thickness of 100 feet.

- Synthetic time histories developed from Regulatory Guide 1.60 response spectrum are designated as the rock outcrop motion and scaled (to 0.583 g's for the horizontal direction and to 0.483 g's for the vertical direction) to yield the target ground surface ZPAs (i.e., 1.0 g's in the horizontal direction and 0.75 g's in the vertical direction).

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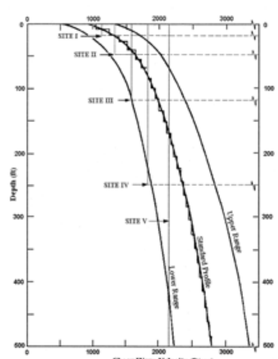

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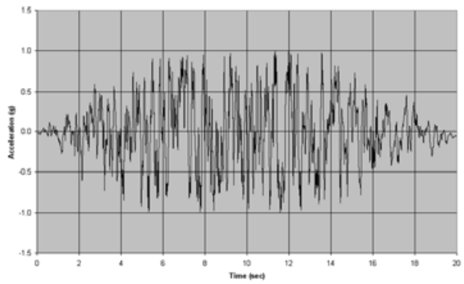
SHAKE Soil Seismic Response Analysis



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Results of SHAKE Analysis (Horizontal Direction)

Layer	Depth to Middle of Layer (ft)	Total Unit Weight (kcf)	Damping Used (%)	Shear Modulus (ksf)	Maximum Shear Strain (%)	Maximum Shear Stress (psf)	Shear Wave Velocity (fps)	Depth to Top of Layer (ft)	Peak Acceleration (g)	G/Gmax Curve	Damping Curve
1	2.25	.11	7.8	826	.02985	246.57	491.7242	0	1.008	No. 1 G/	No.1 da
2	6.75	.11	12.8	757.2	.09606	727.33	470.8005	4.5	1.00316	No. 1 G/	No.1 da
3	11.25	.11	15	617.5	.197	1216.52	425.1577	9	.98918	No. 1 G/	No.1 da
4	15.75	.11	15	608.2	.27947	1699.77	421.944	13.5	.96499	No. 1 G/	No.1 da
5	19.5	.11	15	700.9	.30003	2102.86	452.9598	18	.95226	No. 1 G/	No.1 da
6	23.5	.12	15	816.9	.31248	2552.8	468.1896	21	.9454	No. 1 G/	No.1 da
7	28.5	.12	15	736.3	.42287	3113.72	444.4928			No. 1 G/	No.1 da
8	33.5	.12	15	736.8	.49538	3649.8	444.6437	31	.91211	No. 1 G/	No.1 da
9	38.5	.12	15	749.5	.55333	4147.23	448.4594			No. 1 G/	No.1 da
10	43.5	.12	15	742.9	.62089	4612.68	446.4805	41	.86841	No. 1 G/	No.1 da
11	48.5	.12	15	843.2	.59805	5042.76	475.6666			No. 1 G/	No.1 da
12	53.5	.12	15	794	.68484	5437.46	461.5806	51	.77995	No. 1 G/	No.1 da
13	58.5	.12	15	803.5	.72133	5795.7	464.3338			No. 1 G/	No.1 da
14	63.5	.12	15	844.4	.72395	6113.34	476.0049			No. 1 G/	No.1 da
15	68.5	.12	15	863.8	.73895	6383.12	481.4419	66	.57964	No. 1 G/	No.1 da
16	73.5	.12	15	899.6	.73368	6600.2	491.3173			No. 1 G/	No.1 da
17	78.5	.12	15	968.9	.69891	6771.77	509.8904			No. 1 G/	No.1 da
18	83.5	.12	15	1021.5	.67191	6863.86	523.548	81	.54874	No. 1 G/	No.1 da
19	88.5	.12	15	1085.2	.63703	6913.23	539.6252			No. 1 G/	No.1 da
20	93.5	.12	15	1186.1	.58055	6886.17	564.1544			No. 1 G/	No.1 da
21	98.5	.12	15	1237.4	.55825	6907.95	576.2254			No. 1 G/	No.1 da
22	Base							101	.53654		

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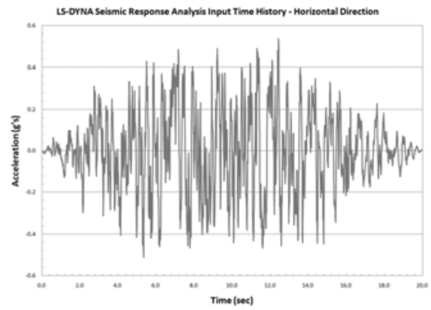
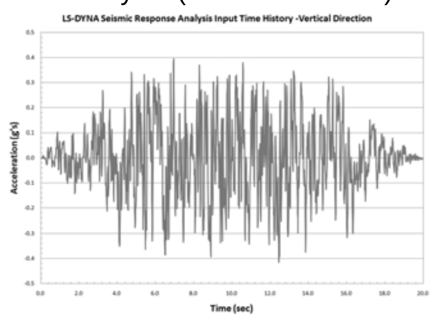
Results of SHAKE Analysis (Vertical Direction)

Layer	Depth to Middle of Layer (ft)	Total Unit Weight (kcf)	Damping Used (%)	Shear Modulus (ksf)	Maximum Shear Strain (%)	Maximum Shear Stress (psf)	Shear Wave Velocity (fps)	Depth to Top of Layer (ft)	Peak Acceleration (g)	G/Gmax Curve	Damping Curve
1	2.25	.11	7.8	9086.4	.00206	187.11	1630.901	0	.75045	No. 1 G/	No.1 da
2	6.75	.11	12.8	8329.5	.00687	572.04	1561.497	4.5	.74923	No. 1 G/	No.1 da
3	11.25	.11	15	6792.6	.01407	955.44	1410.099	9	.74509	No. 1 G/	No.1 da
4	15.75	.11	15	6689.9	.01987	1329.34	1399.399	13.5	.7399	No. 1 G/	No.1 da
5	19.5	.11	15	7709.9	.0212	1634.6	1502.298	18	.73131	No. 1 G/	No.1 da
6	23.5	.12	15	8985.8	.02194	1971.56	1552.801	21	.72355	No. 1 G/	No.1 da
7	28.5	.12	15	8099.1	.02958	2395.83	1474.198			No. 1 G/	No.1 da
8	33.5	.12	15	8104.6	.03463	2806.54	1474.698	31	.68028	No. 1 G/	No.1 da
9	38.5	.12	15	8244.8	.03885	3203.3	1487.399			No. 1 G/	No.1 da
10	43.5	.12	15	8171.8	.04388	3585.99	1480.799	41	.63559	No. 1 G/	No.1 da
11	48.5	.12	15	9275.1	.04262	3953.38	1577.599			No. 1 G/	No.1 da
12	53.5	.12	15	8734.1	.04927	4303.39	1530.898	51	.59813	No. 1 G/	No.1 da
13	58.5	.12	15	8838.3	.05238	4629.63	1540.003			No. 1 G/	No.1 da
14	63.5	.12	15	9288	.05302	4924.48	1578.696			No. 1 G/	No.1 da
15	68.5	.12	15	9502.2	.05452	5180.9	1596.796	66	.53021	No. 1 G/	No.1 da
16	73.5	.12	15	9895.4	.0545	5392.78	1629.499			No. 1 G/	No.1 da
17	78.5	.12	15	10657.7	.05301	5649.16	1691.099			No. 1 G/	No.1 da
18	83.5	.12	15	11236.3	.05242	5889.96	1736.397	81	.48973	No. 1 G/	No.1 da
19	88.5	.12	15	11936.7	.05105	6093.98	1789.697			No. 1 G/	No.1 da
20	93.5	.12	15	13047.3	.04796	6257.48	1871.103			No. 1 G/	No.1 da
21	98.5	.12	15	13611.1	.0473	6437.97	1911.102			No. 1 G/	No.1 da
22	Base							101	.41649		

Acceleration Time History at the Base of Soil Layers (Horizontal Direction)



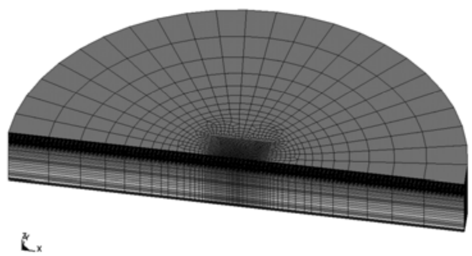
Acceleration Time History at the Base of Soil Layers (Vertical Direction)



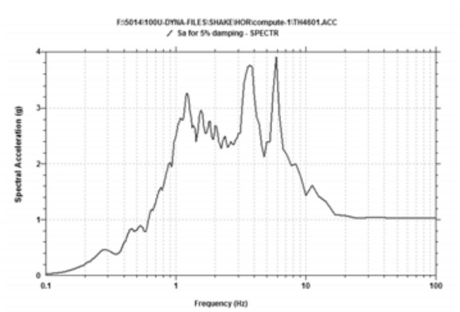
LS-DYNA Soil Seismic Response Analysis

- The LS-DYNA soil model consists of two soil layers with properties determined based on the averaged strain compatible soil properties obtained from the SHAKE analysis for soil layers above and below the ISFSI Support Foundation Pad (SFP) elevation.
- The input acceleration time history at the base of the soil layers is taken from SHAKE analysis result. The "slave boundary condition" is used per NUREG/CR-6865.
- Seismic response spectra generated from the LS-DYNA acceleration time history results at both the ground surface elevation and the SFP elevation define the Design Basis Earthquake.

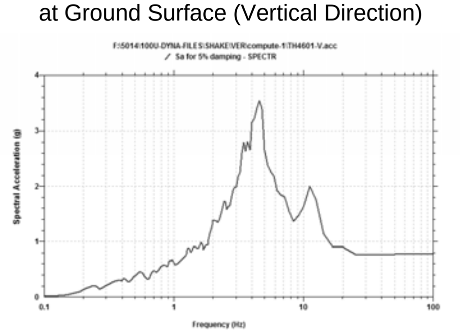
LS-DYNA Seismic Response Analysis Model



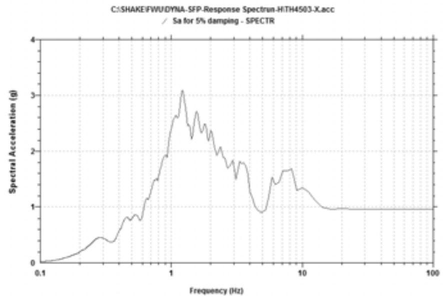
Design Basis Earthquake Response Spectrum at Ground Surface (Horizontal Direction)



Design Basis Earthquake Response Spectrum at Ground Surface (Vertical Direction)



Design Basis Earthquake Response Spectrum at the SFP Elevation (Horizontal Direction)



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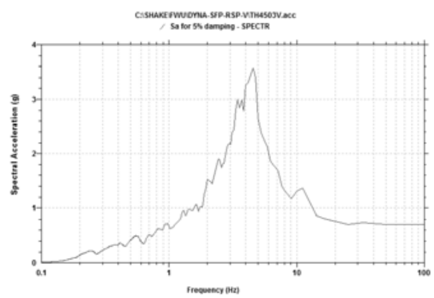
Design Basis Earthquake Response Spectrum at the SFP Elevation (Vertical Direction)



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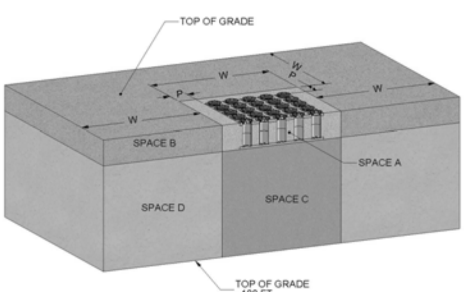
HI-STORM FWU Subgrade and Undergrade Space Nomenclature



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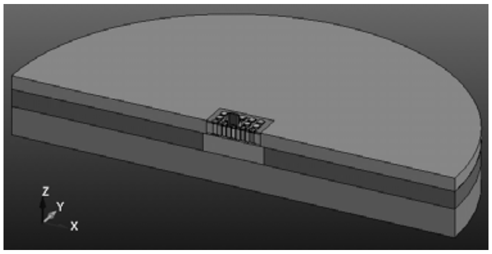
HI-STORM FWU ISFSI Site Minimum Soil Property Requirement

Space	Density (lbf/ft^3)	Strain Compatible Shear Wave Velocity (ft/sec)	Note
A	120	500	This space typically contains engineered fill
B	110	450	This space typically contains native soil
C	120	485	This space may be remediated with vertical reinforcement such as pilings to limit settlement
D	120	485	This space typically contains native soil

LS-DYNA Soil-Structure Model of the HI-STORM FWU ISFSI

- The LS-DYNA soil-structure model is developed based on the 5x5 ISFSI configuration and consists of loaded HI-STORM FWU VVMs, concrete pads and 4 soil regions of the same total thickness as in the soil seismic response analysis. The configuration with retaining walls during the ISFSI expansion is also considered.
- The input acceleration time history at the base of the soil layers is identical to that used in the soil seismic response analysis. The "slave boundary condition" is also used.

HI-STORM FWU Soil-Structure Model 1



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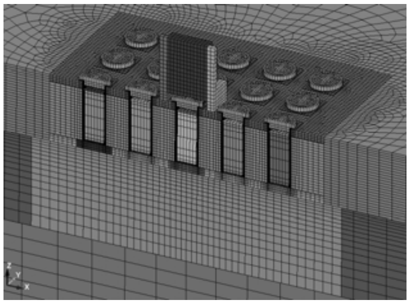
HI-STORM FWU Soil-Structure Model 1



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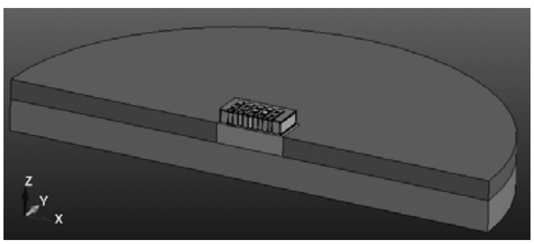
HI-STORM FWU Soil-Structure Model 2



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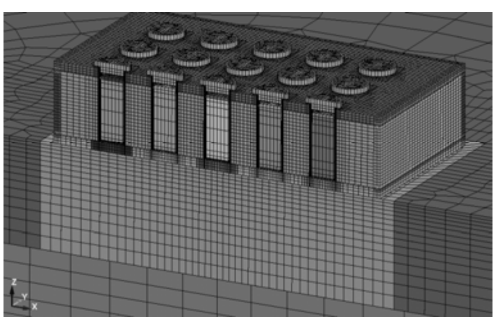
HI-STORM FWU Soil-Structure Model 2



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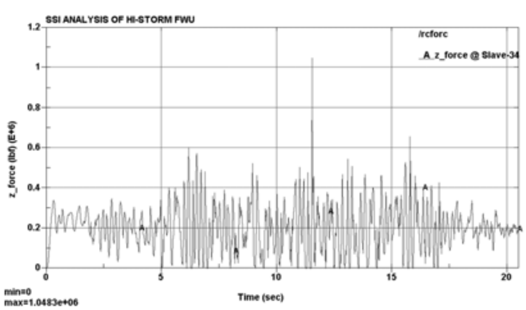
Essential Attributes of the Soil-Structure LS-DYNA Models

- The SFP is fully loaded with 5x5 VVMs
- MPC is modeled as a rigid cylinder
- The divider shell and the Cavity Enclosure Container (CEC) are modeled using elastic thick shell elements
- Elastic material model is used for all concrete parts except for the Top Surface Pad (TSP), which is characterized by an inelastic concrete material model (MAT_016)
- A loaded Vertical Cask Transporter (VCT) is assumed to be at the center of the ISFSI except for the configuration with retaining walls.

LS-DYNA SSI Runs

Run No.	Model Description
1	Soil-Structure Model 1 with 100% concrete modulus for the SFP
2	Soil-Structure Model 1 with 50% concrete modulus for the SFP
3	Soil-Structure Model 2 with 100% concrete modulus for the SFP
4	Soil-Structure Model 2 with 50% concrete modulus for the SFP

SSI Analysis Results – Peak Load on SFP



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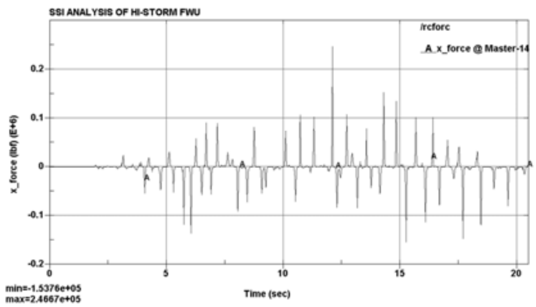
SSI Analysis Results – Peak Load on MPC Guides



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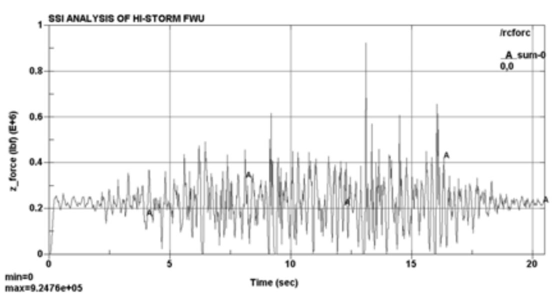
SSI Analysis Results – Peak VCT Load on TSP



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Criteria for Qualifying a Candidate ISFSI Based Under Generic Part 72 License

1. The site's response spectra at both ground surface and SFP elevations are enveloped by the Design Basis Response Spectra.
2. The soil properties of the candidate site are greater than the minimum required values.

To demonstrate that the two criteria can be met, a SHAKE seismic response analysis needs to be performed for the candidate site.

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Scenarios for Site-Specific SSI Analysis Under 10CFR72.212

A. The site's response spectra are not completed enveloped by the Design Basis Response Spectra. However, the overall earthquake strength, represented by the resultant ZPA is bounded.

B. The strain compatible wave velocity in Space B and/or Space D, where the VVMs are not directly supported by the soil in these spaces, is less than the required minimum values.

THERMAL PRESENTATION ON THE HI-STORM FW UNDERGROUND VERTICAL VENTILATED MODULE

by

Holtec International
March 24, 2011

Design Features of HI-STORM FWU VVM

- **HI-STORM FWU VVM design is based on and improved from HI-STORM 100U:**
  - MPC sits on shims to create a plenum below MPC baseplate.
  - Large gap between the MPC lid and the VVM lid allows efficient heat dissipation from the MPC lid.
  - The inlet and outlet vents are 360º (axisymmetric) large area openings provided in the lid to allow for air in-flow and out-flow.
  - Insulation on the divider shell duct prevents heating of the incoming air during intake.
  - Openings in divider shell are taller than bottom plenum under the MPC; before a flood can block the vent, water would already be in contact with the MPC.
  - Wind Deflector Skirt surrounding the outlet vent minimizes the effect of the hot exhaust air from one VVM on the neighboring VVM inlet air.

Thermal Acceptance Criteria

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- **Fuel Cladding Integrity (ISG-11, Rev. 3)**
  - Transport Evaluation, Cladding Temperature Limit
    - 752°F (400°C) (normal)
    - 1058°F (570°C) (off-normal and accident)
  - Short Term Operations, Cladding Temperature Limit
    - 752°F (400°C) (high burnup fuel)
    - 1058°F (570°C) (moderate burnup fuel)
- **The internal pressure of the cask must remain within its design pressures for normal, off-normal, and accident conditions.**
- **The component materials must be maintained within their minimum and maximum temperature criteria under normal, off-normal, and accident conditions.**

Three-Dimensional Model of HI-STORM FWU

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- **Methodology same as the HI-STORM FW and HI-STORM 100U.**
  - The fuel basket, MPC shell, base, lid and VVM components are explicitly modeled.
  - The air flow passages, including inlet and outlet ducts, are explicitly modeled.
  - The fuel rod regions within the fuel basket are modeled as porous media with equivalent hydraulic resistance and thermal conductivities.
  - Flow of helium in the MPC is modeled as laminar flow.
  - Flow of cooling air outside of the MPC is treated as transitional flow using the standard k-ω model.
  - Insolation on the external surfaces of VVM and ground surface is based on the 12-hour levels prescribed in 10CFR71 averaged on a 24-hours basis

Three-Dimensional Model of HI-STORM FWU

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- **Same fuel storage heat load patterns will be evaluated as HI-STORM FW above ground system.**
- **All analyses performed for HI-STORM 100U will also be performed for HI-STORM FWU.**
- **The flood events will be evaluated explicitly.**
- **Wind effects will be included in the analyses. This will be carried out in two steps.**
  - An HI-STORM FWU array will be analyzed to determine the ambient air flow and temperature distribution surrounding each individual FWU VVM, for different wind speeds.
  - The bounding ambient conditions from the first step are applied on a single FWU VVM to determine component temperatures and MPC pressures.

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Schedule and FSAR Format

- Holtec plans to submit LAR in June 2011
- FWU VVM licensed under 72-1032 Docket as an alternative “overpack”.
- Safety analysis for FWU VVM will be presented as supplements to the main chapters of the HI-STORM FW System FSAR.
- Certificate of Compliance #1032 will contain the FWU VVM, however separate Technical Specifications will be developed to differentiate from the aboveground system.

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