Enclosure 1

HI-2125263R0-NP

Dynamic Analysis of a Freestanding Cask Stack Subject to a Postulated Earthquake

Topical Report
On
Dynamic Analysis of a Freestanding Cask Stack Subject to a Postulated Earthquake

By

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GLOSSARY OF TERMS

APR means Average Predicted Response and is equal to the mean of the set of values for a particular measure (for example mean of support foundation reaction force from 15 time-history simulations).

BWR means Boiling Water Reactor

Commercial Spent Fuel or CSF refers to nuclear fuel used to produce energy in a commercial nuclear power plant.

CG means Center of Gravity.

COF means Coefficient of Friction.

CPR means Conservatively Predicted Response and is equal to the mean plus one standard deviation of the set of values for a particular measure from different simulations (i.e. displacement response from 15 time-history simulations, bolt force from 15 time-history simulations etc.).

DBE means Design Basis Earthquake.

Egress Bay is an alternate term for Truck Bay (see the definition of Truck Bay).

Enclosure Vessel is the confinement boundary of the MPC consisting of a thick baseplate at the bottom, a thin walled cylindrical shell in the middle and a thick circular top plate, all joined by ASME code welds to create a hermetically sealed enclosure.

FE means Finite Element based method which involves spatial discretization of the continuum.

FSAR is an acronym for Final Safety Analysis Report (10CFR72).

HERMIT is an acronym for **H**oltec **E**arthquake **R**esponse **Mi**tigator. This device consists of a low friction material interposed between the slab and the HI-STORM overpack and its support surface to attenuate the rocking motion of the Stack or cask during an earthquake.

HI-DAMP means a commercially available pliant visco-elastic material that may be interposed between mating surfaces to enhance dampening effects during an earthquake.

HI-TRAC is a generic term for the transfer cask used to house the MPC during MPC fuel loading, unloading, drying, sealing, and on-site transfer operations to a HI-STORM storage module or HI-STAR storage/transportation overpack. The HI-TRAC shields and protects the loaded MPC during short-term operations.

HI-STORM Vertical Ventilated Storage (VVS) System indicates all HI-STORM systems certified by the USNRC including the HI-STORM 100 (Docket # 72-1014) and the HI-STORM FW system (Docket # 72-1032)

HI-STORM 100 System consists of any loaded MPC model placed within any design variant of the HI-STORM overpack in Docket number 72-1014.

Important-to-Safety (ITS) means a function or condition required to store spent nuclear fuel safely; to prevent damage to spent nuclear fuel during handling and storage, and to provide reasonable assurance that spent nuclear fuel can be received, handled, packaged, stored, and retrieved without undue risk to the health and safety of the public.

Low Profile Transporter (LPT) is the generic name of the ancillary used to move a loaded or empty cask in a plant's "truck bay" and/or the haul path with the cask directly situated on a low lying platform founded on a structurally robust frame such that an uncontrolled lowering (free fall) of the cask is not credible.

MD means Mating Device, which is used for transferring loaded MPC from transfer cask (HI-TRAC) to the storage cask (HI-STORM) in Stack configuration.

Multi-Purpose Canister or MPC means the sealed canister consisting of a fuel basket for spent nuclear fuel storage, contained in a cylindrical canister shell (the MPC Enclosure Vessel). The MPC is the confinement boundary for storage conditions.

MPC Transfer means transfer of the MPC between the transfer cask and the storage module which begins when the MPC is lifted off the HI-TRAC bottom lid and ends when the MPC is supported from beneath by the storage module (or the reverse).

OBE means Operating Basis Earthquake. An OBE is an earthquake that could be expected to affect the site of a nuclear reactor, but for which the plant's power production equipment is designed to remain functional without undue risk to public health and safety.

Plant or **Station** means a Nuclear power plant.

PWR is an acronym for pressurized water reactor.

Safety Significant is a generic term to indicate Safety Related (Part 50) or Important to Safety (parts 71 and 72).

SNF is an acronym for spent nuclear fuel.

SSE means Safe Shutdown Earthquake. It is the maximum earthquake potential for which certain structures, systems, and components, important to safety, are designed to sustain and remain functional.

Stack means the assemblage of the HI-STORM, Mating Device, and the HI-TRAC in a vertical configuration during MPC Transfer.

Truck Bay means the reinforced concrete surface on which the MPC transfer would occur.

ZPA means Zero Period Acceleration.

TABLE OF CONTENTS

ABSTRACT

This document seeks NRC approval of a calculational framework and the establishment of associated acceptance criteria for analyzing the seismic response of the freestanding HI-STORM/HI-TRAC stack-up configuration inside a Part 50 facility. The alternative to using a freestanding stack configuration is to restrain the stack by fastening it to the Truck Bay structure. Unfortunately, industry experience shows that the restraint structures are bulky and difficult to install and dismantle, entail risk to the installation crew, restrict the flow of equipment and machinery into and out of the plant, and increase occupational dose during the MPC handling operations.

A major consideration in establishing the technical feasibility of a freestanding configuration is kinematic stability and physical integrity of the Stack under the postulated earthquakes for the Plant. To carry out the MPC transfer operation, the HI-TRAC transfer cask is mounted atop the recipient HI-STORM overpack with the Mating Device interposed between them. This three-body configuration is referred to as the *Stack* in this document. The seismic analysis of the stack consists of the following sequential steps:

1. Develop at least five sets of statistically independent acceleration time-histories derived from natural recorded earthquakes.

2. Prepare a dynamic model of the stack with a detailed articulation of the structural properties of its constituent components for implementation in LS-DYNA.

3. Run time-history analyses for each time-history set and obtain the stack's response as a function of time. Also run the time-history cases for representative values of COF at the Stack/Support interface.

4. Process the output data to obtain mean plus one standard deviation results for the stack's displacement, rotation and internal forces/moments. Compare the results with the acceptance criteria set down in this report to determine the relevant margins in the response parameters to quantify safety.

5. Compute the average of the maximum foundation reaction loads as articulated in this report to accord with the provision specified in ASCE 43-05 and determine the margin of safety in the Truck Bay slab's support structure.

Traditionally, the FSARs of nuclear plants ascribe two earthquakes of different probability and ground motion levels to the plant, which we refer to herein as the SSE and OBE. In most cases, it is necessary to analyze the Stack under both the SSE and the OBE events because the dynamic load associated with the OBE has a different (more severe) amplifier in the ACI Code used to qualify the Truck Bay slab. The analysis methodology described in this report will apply equally well to any earthquake.

Holtec concludes that the proposed calculational framework and acceptance criteria provide a reasonable assurance of adequate protection.

1.0 Introduction

The seismic analysis of the stack consisting of a HI-TRAC transfer cask mounted atop a HI-STORM storage overpack with an intervening Mating Device fastened to both casks (the "Stack") is the subject of this topical report. This topical report is intended to provide a standard analysis procedure for analyzing the Stack. The calculational framework presented in this report has evolved from the string of analyses performed by Holtec International for various nuclear plants since the earliest deployments of HI-STORM systems. It is, however, not intended to be designated as the only acceptable method to be used in future Stack analyses or to invalidate prior analyses. Rather, its sole objective is to offer to HI-STORM users an NRC-approved methodology for evaluating the seismic stability of an unrestrained Stack such that the need for seismic restraints would be obviated if their analysis met the acceptance criteria contained herein.

The Stack, as shown in Figure 1.1, is an assemblage of three interconnected structures consisting of a freestanding upright thick walled storage overpack, a thick walled Mating Device, and a thick walled transfer cask. In addition, there is a freestanding MPC inside the transfer cask that is free to rattle inside the transfer cask during an earthquake. This is the most limiting stack condition since the CG of the stack is at its maximum height when the MPC is inside the transfer cask. When the MPC is lowered into the HI-STORM, the aspect ratio of the stack (CG height divided by HI-STORM base diameter) decreases, which enhances stability. During MPC downloading the MPC is connected to the overhead crane, and therefore the MPC and its contents are protected from a tip over of the stack.

The seismic response analysis is guided by NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants" (SRP) 3.7.1 [1.1]. In addition, American Society of Civil Engineers (ASCE) publications [1.2, 1.3] have been consulted for additional guidance as necessary. Finally, the 2010 issue of the American Society of Mechanical Engineers (ASME) code [1.4] has been used to set the allowable stress limits in the bolts and fasteners that connect the Stack components.

The objective of this report is to provide HI-STORM 100 users with an approved calculational framework to quantify the margins of safety for a freestanding Stack at a specific plant under its prescribed SSE and OBE. An implicit objective is to give the plant owner the option to avoid the installation of seismic restraints in plants (see photo of a restraint system at a typical plant in Figure 1.2) that meet the acceptance criteria for freestanding deployment. Industry experience shows that the restraint structures are bulky, difficult to install and dismantle, entail risk to the installation crew, restrict the flow of equipment and machinery into and out of the plant, and are a source of increased occupational dose during the MPC handling operations.

The considerations above provided the motivation to develop a suitable analysis framework that may be used to evaluate the need for a Stack restraint with a reasonable margin of safety. For a detailed discussion of the system components that comprise the Stack, the reader is referred to the HI-STORM FSAR [1.5, 1.6]

Finally, the analysis procedure presented in this report can be used to analyze any Stack made up of a HI-STORM overpack, a Mating Device, and a HI-TRAC transfer cask containing an MPC. All component models certified or used in Holtec's Part 72 dockets can be analyzed using the methodology described in this report.

1.1 Scope and Purpose

This report provides a methodology for determining the dynamic response of a Stack under an earthquake. The analysis procedure presented in this report can be used to analyze any Stack made up of a HI-STORM overpack, a Mating Device, and a HI-TRAC transfer cask containing an MPC. All component models certified or used in Holtec's Part 72 dockets can be analyzed using the methodology described in this report. However, it is recognized that the support conditions may vary from plant to plant. For example, the HI-STORM Bottom Plate may be supported on an LPT (see Glossary) or directly on the Truck Bay slab. In some cases, the LPT may be fastened to the Stack to further enhance the Stack's resistance to tip over. The Truck Bay slab itself may be founded on grade or may be an elevated reinforced concrete structure. The interface condition may be further affected by the use of a controlled friction interface device (HERMIT) and/or an energy dampener (HI-DAMP) to improve the stack's response. Likewise, the extent of fixity at the Mating Device to cask junctions may vary due to number and size of fasteners employed and their level of pre-stress. The HI-TRAC transfer cask may or may not have a top lid installed. The potential variations in the end conditions and structural configuration of the Stack make it impractical to develop an all-encompassing single analysis model and seek NRC's approval of it. Therefore, this topical report seeks to obtain regulatory approval of a *calculational framework* which may be applied to model specific cases. In particular, the regulatory endorsement of the analysis model is sought in the following areas:

a. Generation of multiple statistically independent acceleration time histories corresponding to the plant's response spectra.

b. Modeling of the HI-STORM/Mating Device/HI-TRAC/MPC assemblage in LS-DYNA including the fasteners used to connect interfacing parts.

c. Treatment of the energy dissipation effects in LS-DYNA due to impact, material hysteresis, etc.

d. The criteria used to insure convergence of the LS-DYNA solution.

The expectation is that the stability analysis of the stack for a particular plant will be carried out using an LS-DYNA model that properly reflects the geometric attributes of physical problem and is in full conformance with the calculational framework approved by the NRC via this topical report.

1.2 Applicability

This report seeks to establish a standardized method to model the essential features of a Stack to analyze it under a postulated earthquake. In the past, a number of dynamic analysis models have been used by different analysts in the industry and incorporated in plants' safety evaluation through the 50.59 process. It is not the objective of the topical report to require such plants to reanalyze their Stack because the available data indicates that the analysis method set down in this report does not indicate a safety deficiency in the prior qualification methods. This topical report therefore will be mainly used by new sites or those that wish to reconsider their use of restraints.

Holtec expects that most Plants will be able to adopt the framework presented in this report by using the 10 CFR 50.59 process. The calculation framework in this topical report may differ from that described in a Plant's FSAR, but since it will be approved for the intended purpose as described in 10 CFR 50.59 (a)(2)(ii), it is not expected that it will be considered a change in the method of evaluation.

An NRC SER on this topical report will enable the HI-STORM user sites to conduct their 50.59 evaluations by reference to this report obviating the potential need for an operating license amendment request, therefore NRC's review and approval of this report will save both industry and NRC resources.

Although this report is focused on the classical Stack, it is evident that the calculational framework provided herein can be used to analyze less complex sub-structures such as a free standing HI-STORM or HI-TRAC arrayed individually.

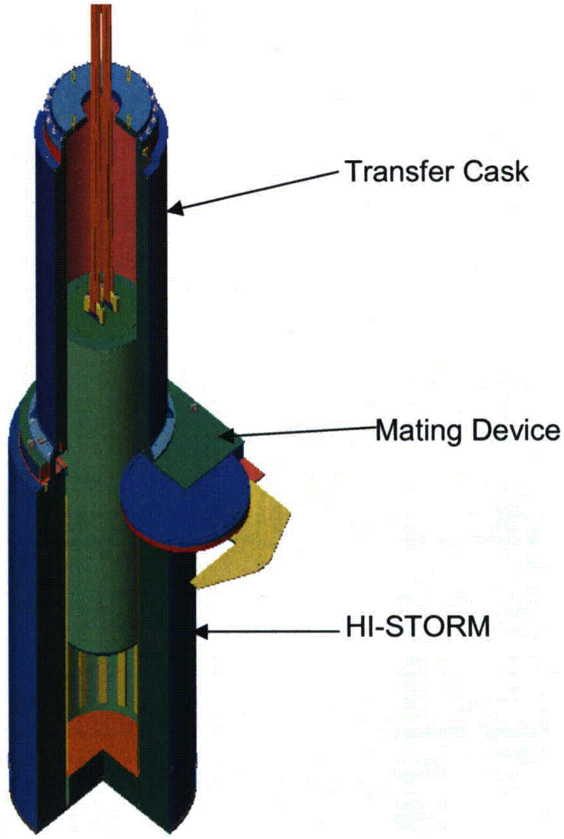

Figure 1.1 Pictorial View of the "Stack"

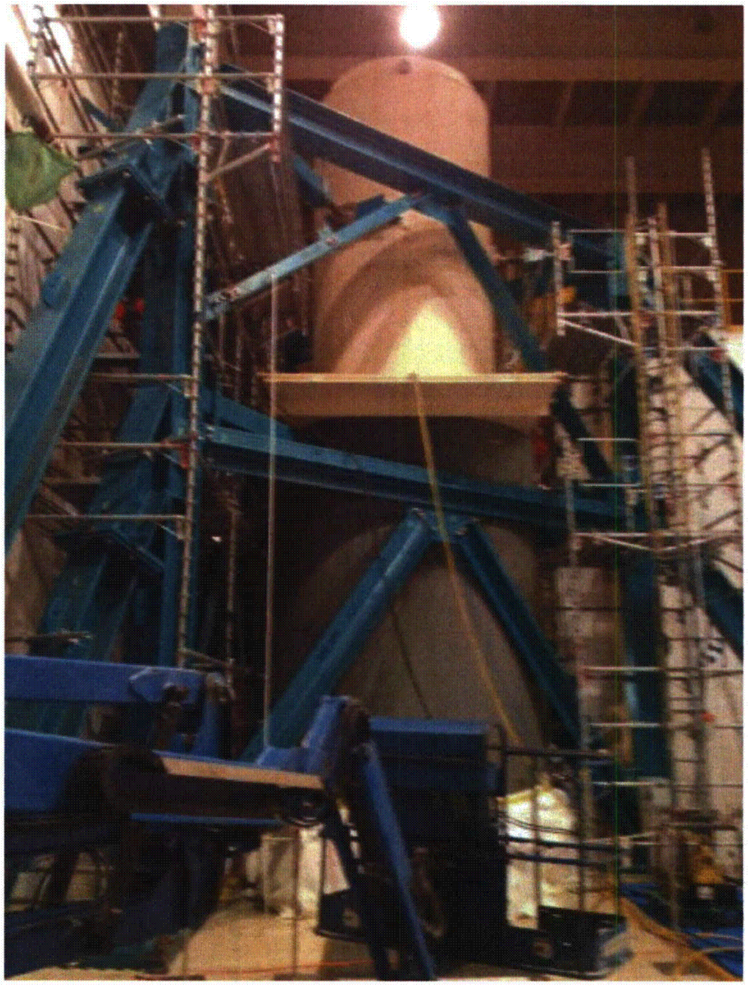

Figure 1.2 A Typical Restraint System Installed Around a "Stack"

2.0 Computer Code, Document Classification and QA Protocol and Computer Files

2.1 Computer Code

Computer code LS-DYNA [2.1], endorsed by the USNRC in Holtec Dockets 72-1014 and 72-1032, is used as the principal vehicle for the dynamic analysis in this report.

LS-DYNA is a general purpose finite element code for analyzing the large deformation static and dynamic response of structures including structures coupled to fluids. The main solution methodology is based on explicit time integration and is therefore well suited for the examination of the response to shock loadings and earthquakes. A contact-impact algorithm allows difficult contact problems to be easily treated. Spatial discretization is achieved by the use of four node tetrahedron and eight node solid elements, two node beam elements, three and four node shell elements, eight node solid shell elements, truss elements, membrane elements, discrete elements, and rigid bodies. A variety of element formulations are available for each element type. Adaptive re-meshing is available for shell elements which enable regional refinement of shell element mesh in the solution stage. LS-DYNA currently contains approximately one hundred constitutive models and ten equations-of-state to cover a wide range of material behavior.

LS-DYNA is maintained in a QA-validated status in Holtec's Configuration Control system. As is true of all widely used codes, LS-DYNA will inevitably undergo future updates. A future update however can be used in the Stack simulation analysis model only if the code has been requalified using the example problem in this report *in addition to* the standard re-benchmarking requirements mandated by the Holtec's QA program for all code updates.

2.2 Document Classification and QA Protocol

This document is classified as "Safety Significant" under Holtec International's quality assurance system. In order to gain acceptance as a *safety significant* document in the Company's quality assurance system, this document is required to undergo a rigorous review and concurrence process. This report is prepared pursuant to the latest revisions of Holtec Quality Procedures HQP 3.2 and 3.3, which require that all analyses utilized in support of the design of a safety-related or important-to-safety structure, component, or system be fully documented such that the analyses can be reproduced at *any time in the future* by a specialist trained in the discipline(s) involved.

This report will be saved as a Permanent Record under the Company's QA System.

2.3 Computer Files

All computer files related to this analysis report are saved on the Holtec Network in the following directory:

G:\Generic\generic Reports\HI-2125263 Dynamic Analysis Free Standing Cask\Rev 0

3.0 Problem Description

The Stack consists of four inter-connected components, namely:

i. The HI-STORM overpack (made of a double wall steel shell structure filled with shielding concrete) arrayed on the Truck Bay slab without its top lid.

ii. The Mating Device made of a steel weldment filled with shielding grout.

iii. The HI-TRAC transfer cask made of interconnected concentric steel cylinders with lead as the gamma shielding material.

iv. The MPC consists of a thick baseplate at the bottom, a thin walled cylindrical shell and a thick circular top plate. MPC stores the spent fuel and forms the primary containment boundary.

The following essential features of the stack are relevant to its structural analysis:

a. The Mating Device, mounted atop the HI-STORM overpack, is equipped with a centering piece that protrudes inside the HI-STORM cavity. However, the centering piece is not credited in the analysis as a lateral restraint device. The interface friction in combination with the Mating Device bolts restrains the Mating Device against lateral sliding.

b. The Truck Bay support foundation typically consists of a thick reinforced concrete slab supported on grade, on concrete caissons, or on columns. Intuitively, such a foundation is quite stiff. The HI-STORM overpack is staged on the Truck Bay slab with shims, as necessary, such that the entire circumference of its baseplate is supported by the foundation slab. In the dynamic model constructed in this report, it is assumed that a HI-DAMP pad has been interposed between the baseplate of the HI-STORM and the Truck Bay slab. HI-DAMP is a commercially available synthetic material that is widely used in the industry to filter out vibration and noise [3.1]. In the case of earthquakes, HI-DAMP has the additional merit of introducing a relatively flexible vertical spring and an impact damper that helps sequester the dynamic response of the Stack from the stiffness characteristics of the slab. If the Stack is erected on a Low Profile Transporter (LPT) with outboard shims, which are supported by the Truck Bay slab from below, then the analytical model must account for the geometry and stiffness of the LPT and shims.

c. In addition to HI-DAMP, this analysis assumes the use of HERMIT, [3.2], which narrows the range of uncertainty in the interface friction coefficient underneath HI-STORM. HERMIT has been employed to reduce the rocking action of the Stack under the postulated earthquake event at a number of nuclear plants. HERMIT and HI-DAMP are classified as important-to-safety and are subject to independent testing of their critical characteristics under Holtec's quality procedures. The acceptable service life of HERMIT and HI-DAMP are specified in their Purchasing Specifications. HI-DAMP and HERMIT are effective means to mitigate the effect of earthquakes on the Stack. They are assumed to be present in the example problem in this report. However, it is possible to obtain an acceptable result without them depending on the strengths of the SSE and OBE and the capacity of the Truck Bay slab. If HI-DAMP and/or HERMIT are not used, then the interface properties (stiffness, damping, and/or coefficient of friction) at the base of the HI-STORM must be adjusted accordingly.

d. The bolts joining the Mating Device to the casks below and above are installed without any pre-stress or significant torque. This is ALARA and structurally advantageous because a small amount of rotation of the HI-TRAC with respect to the HI-STORM/Mating Device assemblage that may occur due to stretching of the bolts during a seismic event is known to help ameliorate the Stack's dynamic response.

e. Both the contact interfaces within the Stack, namely the Mating Device/HI-STORM and HI-TRAC/Mating Device interfaces, are mono-metallic (steel on steel), and they can experience lift-off, causing increased loads on the Mating Device bolts, if the seismic forces and moments so dictate.

The mathematical model of this structure, described in a later section herein, is intended to be in full accord with its physical embodiment summarized above.

4.0 Analysis Objectives

The objectives of the dynamic analysis are:

1. Determine if the Stack configuration is kinematically stable as a freestanding structure under the postulated seismic event.

2. Determine the floor loads on the Truck Bay slab exerted by the Stack during the postulated seismic events to enable structural integrity evaluations of the slab.

3. Determine the loads on the HI-STORM/Mating Device and HI-TRAC/Mating Device bolts and contact interfaces during the postulated seismic event to enable structural integrity evaluations of the bolts and other Stack components (i.e., HI-TRAC, Mating Device, and HI-STORM).

4.1 LS-DYNA Finite Element Model

[PROPRIETARY INFORMATION REMOVED]

4.2 Modeling Assumptions

[PROPRIETARY INFORMATION REMOVED]

5.0 Acceptance Criteria

5.1 Seismic Response of the Stack

[PROPRIETARY INFORMATION REMOVED]

5.2 Foundation Slab Structure

Pursuant to ASCE 43-05 [Section 3.2.2 of 1.3], the APR (see Glossary) of maximum impact force on the slab must not exceed its load bearing capacity.

However, the scope of this topical report is limited to the quantification of the support foundation reaction load and is not intended for the comprehensive structural evaluation of the floor slab.

6.0 Acceleration Time Histories

6.1 Applicable Requirements

The multiple sets of real acceleration time histories can be generated in accordance with Section II.1.B, Option 2 of [1.1]. Specifically, the following criteria must be met when using multiple real time-histories for a non-linear analysis:

1. The minimum number of time-histories must be at least five.

2. Multiple sets of real ground motion time-histories shall be used to represent the design basis spectra. Each set of time-histories shall be selected from real recorded ground motions appropriate for the characteristic low and high frequency events. The amplitude of these ground motions may be scaled and the drift in the phase separation of the Fourier harmonics shall be preserved to accord with the corresponding seed time history to the extent reasonably practicable.

3. The strong motion duration (defined as the time required for the Arias Intensity to rise from 5% to 75%) for each time-history must be at least 6.0 seconds.

4. The multiple time-histories are acceptable if the average calculated response spectra generated from these time-histories envelope the target response spectra (i.e., design basis spectra for the plant).

5. An acceptable method to demonstrate the adequacy of a set of multiple time-histories, in terms of enveloping requirements and having sufficient power over the frequency range of interest, is to follow the procedures described below (restated from Option 1, Approach 2 of [1.1]):

   (a) The time-history shall have a sufficiently small time increment and sufficiently long duration. Records shall have a Nyquist frequency of at least 50 Hz (i.e., a time increment of at most 0.01 seconds) and a total duration of at least 20 seconds.

   (b) Spectral acceleration shall be computed at a minimum of 100 points per frequency decade, uniformly spaced over the log frequency scale from 0.1 Hz to 50 Hz or the Nyquist frequency. The comparison of the response spectrum obtained from the artificial ground motion time-history with the target response spectrum shall be made at each frequency computed in the frequency range of interest.

   (c) The average of the computed response spectra of the modified real recorded time-histories shall not fall more than 10% below the target response spectrum at any one frequency. To prevent response spectra in large frequency windows from falling below the target response spectrum, the response spectra within a frequency window of no larger than ±10% centered on the frequency shall be allowed to fall below the target response spectrum. This corresponds to response spectra at no more than 9 adjacent frequency points defined in (b) above from falling below the target response spectrum.

(d) The average of the computed response spectra of the accelerograms (i.e., modified real recorded time-histories) shall not exceed the target response spectrum at any frequency by more than 30% (a factor of 1.3) in the frequency range of interest. If the average response spectrum for the accelerograms exceeds the target response spectrum by more than 30% at any frequency range, the average power spectral density of the accelerograms need to be computed and shown to not have significant gaps in energy at any frequency over this frequency range. The power spectral density function represents the energy distribution at the frequencies of interest.

6. Additionally, the time-history set (2 horizontal and 1 vertical) must be statistically independent. This is demonstrated by calculating the cross correlation coefficient for each time-history with each of the other two components. The absolute value of each of the three correlation coefficients must be less than 0.16.

6.2 Methodology

[PROPRIETARY INFORMATION REMOVED]

7.0 Example Problem

[PROPRIETARY INFORMATION REMOVED]

8.0 Conclusion

The seismic analysis results in the preceding section indicate that the Stack meets all kinematic criteria under a postulated seismic event. Specifically,

a. The HI-STORM/HI-TRAC Stack has large safety margins against over-turning and sliding.

b. The HI-STORM-to-MD and HI-TRAC-to-MD bolted connections are in compliance with the ASME, Section III, Subsection NF stress limits and show large safety factors.

The large safety margins conclude that a lateral restraint system is unnecessary for this example problem.

[PROPRIETARY INFORMATION REMOVED]

In the preceding example problem the 3D acceleration time-histories were generated from a plant specific response spectra whose ZPA levels in the two horizontal directions is 0.26 g each and the vertical seismic ZPA is 0.31 g. Using the ZPA as a measure of an earthquake's strength, it follows that the HI-STORM Stack is indeed quite stable as a freestanding structure. The ZPA is, however, a crude measure of stability under a low frequency input such as an earthquake. Analyses show that the rocking and precessional behavior of the Stack is much more heavily influenced by the strength of the low frequency harmonics in the earthquake. Therefore, the seismic stability analysis of each stack, therefore, is a plant-specific effort.

9.0 References

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[1.2] ASCE 4-98, "Seismic Analysis of Safety-Related Nuclear Structures and Commentary", 2000.

[1.3] ASCE 43-05, "Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities", 2005.

[1.4] ASME Boiler and Pressure Vessel Code, Section III, Subsection NF and ASME Section III, Appendices, 2010.

[1.5] Holtec International , Safety Analysis Report for the HI-STORM 100 System, Holtec Report HI-2002444, Revision 10, USNRC Docket # 72-1014.

[1.6] Holtec International, Safety Analysis Report for the HI-STORM FW MPC Storage System, Holtec Report HI-2114830, Revision 0, USNRC Docket # 72-1032.

[1.7] Holtec Report HI-2125170, Rev 1, "Material Testing Report for Nylatron Calibrated Low Friction Material".

[1.8] NUREG/CR-6865, "Parametric Evaluation of Seismic Behavior of Freestanding Spent Fuel Dry Cask Storage Systems".

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[3.1] "Reducing Structure-Borne Noise & Impact Shock and Vibration", Fabreeka pads, FAB 1000-201 03/11, Fabreeka International, Inc., 2011.

[3.2] USPTO Patent Number 6,848,223B2,"Seismic Cask Stabilization Device", by K.P. Singh & A.I. Soler, assigned to Holtec International (Feb. 2005).

[4.1] Witte, M., et al., "Evaluation of Low-Velocity Impacts Tests of Solid Steel Billet onto Concrete Pads, and Application to Generic ISFSI Storage Cask for Tipover and Side Drop", Lawrence Livermore National Laboratory, UCRL-ID-126295, Livermore, California, March 1997.

[4.2] Machinery's Handbook, 27th Edition, 2004, Industrial Press, Inc.

[4.3] "Damping Values for Seismic Design of Nuclear Power Plants", U.S. Nuclear Regulatory Commission Regulatory Guide 1.61, Revision 1, March 2007.

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[4.6] Holtec Report HI-2115003, "Effective Damping Associated with Rotational impact of the HI-STORM/HI-TRAC Stack on a Stiff Reinforced Concrete Slab", Revision 2.

[4.7] Mark's Standard Handbook for Mechanical Engineers, 10th Edition.

[5.1] NUREG-0800, Standard Review Plan 3.8.4, "Other Seismic Category I Structures", Revision 3, 2007.

[5.2] NUREG-0800, Standard Review Plan 3.8.5, "Foundations", Revision 3, 2010.

[5.3] Bjorkman, G.S., "Methodologies Acceptable to the Staff for Performing Seismic Stability Analysis of a Stack-up Configuration within a 10 CFR Part 50 Facility", SFST Technical Exchange on Stack-up Analysis, November 1, 2011.

[5.4] Holtec International, Safety Analysis Report on the HI-STAR 100 Cask System, Holtec Report HI-951251, Revision 15, USNRC Docket # 71-9261.

[6.1] EZ-FRISK™ 7.62 Build 001, Software for Earthquake Ground Motion Estimation, 1999-2011, Risk Engineering, Inc.

[6.2] Fahjan, Y. M., Ozdemir, Z., and Keypour, H., "Procedures For Real Earthquake Time-histories Scaling and Application to Fit Iranian Design Spectra", International Institute of Earthquake Engineering and Seismology (IIEES), SEE 5, 2007.

[6.3] http://peer.berkeley.edu/peer_ground_motion_database, The Pacific Earthquake Engineering Research Center (PEER) ground motion database.

[6.4] Not Used.

[6.5] Holtec Report HI-2125276, Revision 0, "Dynamic Analysis of Freestanding Stack-up at Byron/Braidwood".

[7.1] Drawings of Stack Components: HI-STORM Dwg. - 3996 Rev. 39, Mating Device Dwg. - 4150 Rev. 14, HI-TRAC Dwg. - 6115 Rev. 13 and MPC Dwg. - 3753 Rev. 32.

10.0 Attachments

Appendix A: Inputs used in the FE Model (6 Pages) (Holtec Proprietary Information)

Appendix B: HI-STORM/HI-TRAC Stack Bolting Evaluation (6 Pages) (Holtec Proprietary Information)

Appendix C: Approved Computer Program List (9 Pages)

APPENDIX A: Inputs used in the FE Model

[THIS APPENDIX IS PROPRIETARY IN ITS ENTIRETY]

APPENDIX B: HI-STORM/HI-TRAC Stack Bolting Evaluation

[THIS APPENDIX IS PROPRIETARY IN ITS ENTIRETY]

HOLTEC APPROVED COMPUTER PROGRAM LIST [1]							REV. 239 January 18, 2013	
PROGRAM (Category)	**APPROVED IN USNRC PART 50 & 71/72 SER: (Docket #) [2]**	**VERSION (Executable)**	**CERTIFIED USERS FOR "A" CODES**	**CODE EXPERT**	**REMARKS: See report indicated for special limitations**	**OPERATING SYSTEM & VERSION (Service pack[4])**	**APPROVED COMPUTERS: Listed by ID**	**Indicate Computer ID(s) used**
ANSYS (A)	DOC 50-298 DOC 72-1014	11.0	MA, SPA, AB, CWB, RJ, PK, AL, HP, VRP, ER, IR, AIS, ZY, JZ, YC, VM, VS, NKS	CWB	HI-2012627	Windows XP (2)	1017, 1018, 1019, 1039, 1060	
		12.0	MA, SPA, AB, CWB, RJ, PK, AL, HP, VRP, ER, IR, AIS, ZY, JZ, YC, VM, VS, NKS	CWB	HI-2012627	Windows XP (2)	1016, 1017	
		12.1	MA, SPA, AB, CWB, RJ, PK, AL, HP, VRP, ER, IR, AIS, ZY, JZ, YC, VM, VS, NKS	CWB	HI-2012627	Windows XP (2)	1019, 1060	
						Windows 7 (0,1)	1021, 1023, 1025, 1031, 1032, 1044, 1093	
		13.0	MA, SPA, AB, CWB, RJ, PK, AL, HP, VRP, ER, IR, AIS, ZY, JZ, YC, VM, VS, NKS	CWB	HI-2012627	Windows XP (2)	1017, 1018, 1019	
						Windows 7 (0,1)	1023, 1025, 1031, 1038, 1044, 1127, 1139, 1187, 1888, 1189, 1190, 1179	
		14.0	MA, SPA, AB, CWB, RJ, PK, AL, HP, VRP, ER, IR, AIS, ZY, JZ, YC, VM, VS, NKS	CWB	HI-2012627	Windows 7 (0,1)	1162, 1044, 1187	

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HOLTEC APPROVED COMPUTER PROGRAM LIST [1]							REV. 239 January 18, 2013	
PROGRAM (Category)	**APPROVED IN USNRC PART 50 & 71/72 SER: (Docket #) [2]**	**VERSION (Executable)**	**CERTIFIED USERS FOR "A" CODES**	**CODE EXPERT**	**REMARKS: See report indicated for special limitations**	**OPERATING SYSTEM & VERSION (Service pack[4])**	**APPROVED COMPUTERS: Listed by ID**	**Indicate Computer ID(s) used**
AutoCad 2011 [5]		3.0	N/A	JAG	HI-2125187	Windows 7 (1)	1158, 1159	N/A
COMPRESS		Build 7140	N/A	VM	HI-2125173	Windows XP (2)	1058	
CASMO (A)	DOC 50-271 DOC 71-9336	4 – 2.05.14	SPA, BDB, KB, HF, SVF, TH, BK, DMM, VIM, ES, PS	SPA	HI-2104750	Windows XP (3)	1006	
		5M - 1.06.00	SPA, BDB, KB, HF, SVF, TH, BK, DMM, VIM, ES, PS	SPA	HI-2104750	Windows XP (2)	1008, 1013	
		5 – 2.00.00	SPA, BDB, KB, HF, SVF, TH, BK, DMM, VIM, ES, PS	SPA	HI-2104750	Windows 7 (0,1)	1051	
		5 – 2.02.00	SPA, BDB, KB, HF, SVF, TH, BK, DMM, VIM, ES, PS	SPA	HI-2104750	Windows 7 (0,1)	1051	
						Windows XP (2)	1008	
CORRE		1.3	N/A	CWB	N/A	Windows XP (3)	1020	
						Windows 7 (0,1)	1049	
DECAY		1.6	N/A	ER	N/A	Windows XP (2)	1016	
						Windows XP (3)	1016	
DECOR	DOC 50-423	1.3	N/A	ER	N/A	Windows XP (2)	1016	
						Windows XP (3)	1016	
						Windows 7 (0,1)	1027, 1193	
Dr. Beam Pro		1.0.5	N/A	CWB	N/A	Windows 7 (0,1)	1031, 1044, 1162	

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DYNAMO Suite (A)		1.0	AIS, CWB, VRP, HP, KKG	CWB	HI-2114848	Windows 7 (0,1)	1044, 1021	
Fluent (A)	DOC 50-368 DOC 72-1014	4.56	ER, IR, DMM, AHM, YL, INP, MH, JGR	ER	HI-981921	Windows XP (2)	1016	
						Windows XP (3)	1022	
						Windows 7 (0,1)	1027	
		6.3.26	ER, IR, DMM, AHM, YL, INP, MH, JGR	DMM	HI-2084036	Windows XP (2)	1002, 1003, 1016, 2003	
						Windows XP (3)	1001	
						Windows 7 (0,1)	1026, 1193, 1027, 1135	
						Red Hat Ent. (3.4.3-9.EL4) Linux (2.6.9-5)	1004	
						Red Hat Ent. (4.4.2-48) Linux (2.6.18-194.el5) Server Release 5.5	1070, 1071, 1072	
GENEQ		1.3	N/A	AIS, CWB	N/A	Windows XP (3)	1028	

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HTRI XIST		6.00	N/A	KK	N/A	Windows 7	1101, 1121	
LONGOR	DOC 50-305	1.1	N/A	ER	N/A	Windows XP (2)	1016	
						Windows XP (3)	1016	
LS-DYNA (A)	DOC 50-298 DOC 72-1014	971 (ls971sR4.2)	AB, SPA, RJ, AL, HP, VRP, KPS, AIS, JZ, ZY	JZ	N/A	Windows XP (2)	1018	
		971 (ls971sR5.0)	AB, SPA, RJ, AL, HP, VRP, KPS, AIS, JZ, ZY	JZ	N/A	Windows 7 (0,1)	1031, 1032, 1188, 1189, 1190	
		971 (ls971dR5.0)	AB, SPA, RJ, AL, HP, VRP, KPS, AIS, JZ, ZY	JZ	N/A	Windows 7 (0,1)	1025, 1093, 1188, 1189, 1190	
		971 (mpp971dR5.0)	AB, SPA, RJ, AL, HP, VRP, KPS, AIS, JZ, ZY	JZ	N/A	Windows Server HPC 2008	1033, 1034, 1035, 1036, 1037	
		971 (mpp971sR5.0)	AB, SPA, RJ, AL, HP, VRP, KPS, AIS, JZ, ZY	JZ	N/A	Windows Server HPC 2008	1033, 1034, 1035, 1036, 1037	
		971 (ls971sR6.0.0)	AB, SPA, RJ, AL, HP, VRP, KPS, AIS, JZ, ZY	JZ	N/A	Windows 7 (0,1)	1025, 1187, 1188, 1189, 1190	1188, 1189, 1190
		971 (ls971dR6.0.0)	AB, SPA, RJ, AL, HP, VRP, KPS, AIS, JZ, ZY	JZ	N/A	Windows 7 (0,1)	1025, 1187, 1188, 1189, 1190	

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		971 (mpp971dR6.0.0)	AB, SPA, RJ, AL, HP, VRP, KPS, AIS, JZ, ZY	JZ	N/A	Windows Server HPC 2008	1033, 1034, 1035, 1036, 1037	1033, 1034, 1035, 1036, 1037
		971 (mpp971sR6.0.0)	AB, SPA, RJ, AL, HP, VRP, KPS, AIS, JZ, ZY	JZ	N/A	Windows Server HPC 2008	1033, 1034, 1035, 1036, 1037	1033, 1034, 1035, 1036, 1037
MACCS2		1.13.1	N/A	SPA	HI-2104750	Windows XP (3)	1041	
MCNP (A)	DOC 50-368 DOC 71-9336	4A	SPA, BDB, KB, HF, SVF, TH, BK, DMM, VIM, ES, PS, KKN	KB	HI-2104750	Windows XP (2)	1008, 1002	
						Windows XP (3)	1006, 1009, 1010, 2001, 2002	
						Windows 7 (0,1)	1011, 1013, 1014, 1015, 1030, 1051, 1113, 1114, 1115, 1232, 1233, 1234, 1235	
		4B	SPA, BDB, KB, HF, SVF, TH, BK, DMM, VIM, ES, PS, KKN	KB	HI-2104750	Windows XP (3)	2001, 2002	
						Windows 7 (0,1)	1051, 1233	

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		5.1.40	SPA, BDB, KB, HF, SVF, TH, BK, DMM, VIM, ES, PS, KKN	KB	HI-2104750	Windows XP (2)	1002, 1003, 1008	
						Windows XP (3)	1006, 1009, 1010, 1012, 2001, 2002	
						Windows 7 (0,1)	1011, 1014, 1015, 1051, 1113, 1114, 1115, 1232, 1233, 1234, 1235	
MCNP (A)	DOC 50-368 DOC 71-9336	5.1.51	SPA, BDB, KB, HF, SVF, TH, BK, DMM, VIM, ES, PS, KKN	KB	HI-2104750	Windows XP (2)	1002, 1003, 1008, 2003	
						Windows XP (3)	1006, 1009, 1010, 2001, 2002,	
						Windows 7 (0,1)	1011, 1013, 1014, 1015, 1051, 1076, 1113, 1114, 1115, 1232, 1233, 1234, 1235	
						Windows Server 2008 rev. 2 (1)	1243	
MR216 (A)		2.40	AIS, CWB, VRP, HP, KKG	CWB	HI-2125267	Windows 7 (0,1)	1049	
MULPOOLD		2.3	N/A	ER	N/A	Windows XP (2)	1016	
						Windows XP (3)	1016	

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						Windows 7 (0,1)	1026, 1193	
Nanotec Wet Chemistry		1.0	N/A	Pravin Kumar	N/A	Windows Server 2003 revision 2	1146	
ONEPOOL		1.7	N/A	ER	N/A	Windows XP (2)	1016	
						Windows XP (3)	1016	
ORIGEN2		486	N/A	ER	HI-92784	Windows XP (2)	1016	
						Windows XP (3)	1016	
ORIGEN-S, SAS2H, KENO-Va, NITAWL & BONAMI (Modules of SCALE 4.3)	DOC 50-346 DOC 71-9336	4.3	KB, SPA, BK	KB, SPA	N/A	Windows 2000 (2)	1050	
ORIGEN-S & SAS2H (Modules of SCALE 4.4)	DOC 50-346 DOC 71-9336	4.4	N/A	KB, SPA	N/A	Windows XP (3)	1006, 1009, 1010,	
						Windows 7 (0,1)	1232, 1233, 1234, 1235	
ORIGEN-S, SAS2H & KENO-VI (Modules of SCALE 5.1)[7]		5.1	KB, SPA, BK	KB, SPA	N/A	Windows 7 (0,1)	1011, 1013, 1113, 1015, 1076, 1088, 1232, 1233, 1235	
						Windows XP (3)	2002, 2004, 2005, 2007	

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SHAKE 2000		7.6.0	N/A	AIS	N/A	Windows 7 (0,1)	1044, 1093, 1025	
		7.7.0	N/A	AIS	N/A	Windows 7 (0,1)	1021	
ShapeBuilder		4.0	N/A	VRP	HI-2053361	Windows XP (3)	1020	
						Windows 7 (0,1)	1038, 1049	
		6.0	N/A	VRP	HI-2053361	Windows 7 (0,1)	1044	
SolidWorks 2010 [3]		4.0	N/A	LDV	HI-2012761	Windows XP (2)	1077, 1081, 1082, 1083, 1085, 1086	N/A
						Windows 7 (0,1)	1078, 1079, 1080, 1084	N/A
STER		5.04	N/A	ER	N/A	Windows XP (3)	1016	
SX		1.0	N/A	KB	N/A	Windows 7 (0, 1)	1011, 1013, 1015, 1051, 1076, 1088, 1093, 1108, 1113, 1114, 1115. 1232, 1233, 1234, 1235	
						Windows XP (2)	1008	
						Windows XP (3)	1006, 1009, 1010	
TBOIL		1.11	N/A	ER	N/A	Windows XP (2)	1016	

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						Windows XP (3)	1016	
VERSUP		1.0	N/A	AIS	N/A	Windows XP (2)	1016	
Visual Nastran	DOC 50-133 DOC 72-27	2004	N/A	AIS, CWB	N/A	Windows XP (2)	1017, 1018	
						Windows XP (3)	1020, 1028	
						Windows 7 (0,1)	1044, 1045	

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AFFIDAVIT PURSUANT TO 10 CFR 2.390

I, P. Stefan Anton, being duly sworn, depose and state as follows:

(1) I have reviewed the information described in paragraph (2) which is sought to be withheld, and am authorized to apply for its withholding.

(2) The information sought to be withheld is information provided in Enclosure 2 to Holtec letter Document ID 2013001. This Enclosure contains Holtec Proprietary information.

(3) In making this application for withholding of proprietary information of which it is the owner, Holtec International relies upon the exemption from disclosure set forth in the Freedom of Information Act ("FOIA"), 5 USC Sec. 552(b)(4) and the Trade Secrets Act, 18 USC Sec. 1905, and NRC regulations 10CFR Part 9.17(a)(4), 2.390(a)(4), and 2.390(b)(1) for "trade secrets and commercial or financial information obtained from a person and privileged or confidential" (Exemption 4). The material for which exemption from disclosure is here sought is all "confidential commercial information", and some portions also qualify under the narrower definition of "trade secret", within the meanings assigned to those terms for purposes of FOIA Exemption 4 in, respectively, Critical Mass Energy Project v. Nuclear Regulatory Commission, 975F2d871 (DC Cir. 1992), and Public Citizen Health Research Group v. FDA, 704F2d1280 (DC Cir. 1983).

AFFIDAVIT PURSUANT TO 10 CFR 2.390

(4) Some examples of categories of information which fit into the definition of proprietary information are:

a. Information that discloses a process, method, or apparatus, including supporting data and analyses, where prevention of its use by Holtec's competitors without license from Holtec International constitutes a competitive economic advantage over other companies;

b. Information which, if used by a competitor, would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing of a similar product.

c. Information which reveals cost or price information, production, capacities, budget levels, or commercial strategies of Holtec International, its customers, or its suppliers;

d. Information which reveals aspects of past, present, or future Holtec International customer-funded development plans and programs of potential commercial value to Holtec International;

e. Information which discloses patentable subject matter for which it may be desirable to obtain patent protection.

The information sought to be withheld is considered to be proprietary for the reasons set forth in paragraphs 4.a, 4.b and 4.e, above.

(5) The information sought to be withheld is being submitted to the NRC in confidence. The information (including that compiled from many sources) is of a sort customarily held in confidence by Holtec International, and is in fact so held. The information sought to be withheld has, to the best of my knowledge and belief, consistently been held in confidence by Holtec International. No public disclosure has been made, and it is not available in public sources. All disclosures to third parties, including any required

AFFIDAVIT PURSUANT TO 10 CFR 2.390

transmittals to the NRC, have been made, or must be made, pursuant to regulatory provisions or proprietary agreements which provide for maintenance of the information in confidence. Its initial designation as proprietary information, and the subsequent steps taken to prevent its unauthorized disclosure, are as set forth in paragraphs (6) and (7) following.

(6) Initial approval of proprietary treatment of a document is made by the manager of the originating component, the person most likely to be acquainted with the value and sensitivity of the information in relation to industry knowledge. Access to such documents within Holtec International is limited on a "need to know" basis.

(7) The procedure for approval of external release of such a document typically requires review by the staff manager, project manager, principal scientist or other equivalent authority, by the manager of the cognizant marketing function (or his designee), and by the Legal Operation, for technical content, competitive effect, and determination of the accuracy of the proprietary designation. Disclosures outside Holtec International are limited to regulatory bodies, customers, and potential customers, and their agents, suppliers, and licensees, and others with a legitimate need for the information, and then only in accordance with appropriate regulatory provisions or proprietary agreements.

(8) The information classified as proprietary was developed and compiled by Holtec International at a significant cost to Holtec International. This information is classified as proprietary because it contains detailed descriptions of analytical approaches and methodologies not available elsewhere. This information would provide other parties, including competitors, with information from Holtec International's technical database and the results of evaluations performed by Holtec International. A substantial effort has been expended by Holtec International to develop this information. Release of this information would improve a competitor's position because it would enable Holtec's competitor to copy our technology and offer it for sale in competition with our company, causing us financial injury.

AFFIDAVIT PURSUANT TO 10 CFR 2.390

(9) Public disclosure of the information sought to be withheld is likely to cause substantial harm to Holtec International's competitive position and foreclose or reduce the availability of profit-making opportunities. The information is part of Holtec International's comprehensive spent fuel storage technology base, and its commercial value extends beyond the original development cost. The value of the technology base goes beyond the extensive physical database and analytical methodology, and includes development of the expertise to determine and apply the appropriate evaluation process.

The research, development, engineering, and analytical costs comprise a substantial investment of time and money by Holtec International.

The precise value of the expertise to devise an evaluation process and apply the correct analytical methodology is difficult to quantify, but it clearly is substantial.

Holtec International's competitive advantage will be lost if its competitors are able to use the results of the Holtec International experience to normalize or verify their own process or if they are able to claim an equivalent understanding by demonstrating that they can arrive at the same or similar conclusions.

The value of this information to Holtec International would be lost if the information were disclosed to the public. Making such information available to competitors without their having been required to undertake a similar expenditure of resources would unfairly provide competitors with a windfall, and deprive Holtec International of the opportunity to exercise its competitive advantage to seek an adequate return on its large investment in developing these very valuable analytical tools.

AFFIDAVIT PURSUANT TO 10 CFR 2.390

STATE OF NEW JERSEY)
) ss:
COUNTY OF BURLINGTON)

P. Stefan Anton, being duly sworn, deposes and says:

That he has read the foregoing affidavit and the matters stated therein are true and correct to the best of her knowledge, information, and belief.

Executed at Marlton, New Jersey, this 24th day of January, 2013.

Stefan Anton

P. Stefan Anton
Holtec International

Subscribed and sworn before me this 24th day of January, 2013.

Maria C Massi

MARIA C. MASSI
NOTARY PUBLIC OF NEW JERSEY
My Commission Expires April 25, 2015