HOLTEC INTERNATIONAL

Holtec Center, 555 Lincoln Drive West, Marlton, NJ 08053
Telephone (856) 797-0900
Fax (856) 797-0909

Mr. John Goshen
c/o Document Control Desk
U. S. Nuclear Regulatory Commission
Washington, DC 20555-0001

November 22, 2011

Subject: Technical Information Exchange Meeting on the stability analysis of freestanding stack-up configurations – re-transmittal of Technical Memo.

References:
[1] USNRC Docket No. 72-1014, TAC No. L24476
[2] Holtec Letter 5014730, dated November 14, 2011

Dear Mr. Goshen:

On November 1, 2011, NRC hosted a technical information exchange on stability analysis of freestanding stack-up configurations between industry representatives and members of its Staff. On November 14, 2011 [2] Holtec transmitted to the NRC Technical Memo TM-SF-117 to summarize key observations from the meeting. Regretfully, we have found a typographical error in the original technical memo. This letter transmits Revision 1 of the technical memo and should be considered a complete replacement for Holtec letter 5014730 [2]. Holtec requests letter 5014730 and its attachments be removed from the NRC Agencywide Documents Access Management System (ADAMS).

Attachment #	Content	Proprietary Status	Number of Pages
1	Holtec Memo TM-SF-117R1	Proprietary	7
2	Holtec Memo TM-SF-117R1-NP	Non-Proprietary	7

Attachment 3 is an affidavit requesting the information in Attachment 1 be withheld from the public in accordance with 10 CFR 2.390 due to its proprietary nature.

If you have any questions regarding this transmittal, please do not hesitate to contact me at 856-797-0900 x3687.

Sincerely,

Tammy S. Morin
Licensing Manager
Holtec Technical Services, Holtec International

cc: Mr. Douglas Weaver, USNRC
Holtec Group 1 (w/o attachments)

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Document ID: 5014731

AFFIDAVIT PURSUANT TO 10 CFR 2.390

I, Tammy S. Morin, 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 Attachment 1 to Holtec letter 5014731, which 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).

(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 and 4.b 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 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.

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(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)

Ms. Tammy S. Morin, being duly sworn, deposes and says:

That she 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 22nd day of November, 2011.

Tammy S. Morin
Holtec International

Subscribed and sworn before me this 22nd day of November, 2011.

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

Technical Memo TM-SF-117-NP*

[Holtec Proprietary Text Removed]

Date: November 22, 2011 (Rev. 1)

Subject: Stability Analysis of Freestanding Stack-up

Keywords: Stack-up; Damping; SRP 3.7.1

On November 1, 2011, the NRC hosted a technical information exchange on stability analysis of freestanding stack-up configurations between industry representatives and members of its staff. The purpose of the meeting was to discuss methodologies for conducting analysis of the freestanding stack-up configuration during vertical dry cask spent fuel loading operations. During the meeting, presentations were given by the NRC (Dr. Gordon Bjorkman), NAC International (Mike Yaksh), Comanche Peak (Bruce Henley), and Holtec (Chuck Bullard).

The meeting was very valuable insomuch as it provided important insight into the NRC's concerns and expectations relative to freestanding stack-up analysis, and it provided a venue for plant personnel and cask vendors to share their experiences and recommendations with the NRC staff. The NRC is working towards the development of a guidance document on performing stability analysis of freestanding stack-up configurations.

Below I have summarized my key observations from the meeting [Holtec Proprietary Text Removed].

*[Holtec Proprietary Text Removed]

A. Minimum Safety Factor Against Overturning

The NRC in its presentation quantified what they consider to be an acceptable margin of safety against overturning. Specifically, Dr. Bjorkman indicated that a stack-up configuration would be considered stable if the 84^{th} percentile non-exceedance (mean plus one standard deviation) displacement of the stack-up (based on a minimum of five non-linear time history simulations) is less than the critical angle by a factor of 2 or greater. This is a positive development from Holtec's point of view because:

i) it gives clarity to NRC's previous mandate to "preclude overturning of the freestanding stack-up configuration with an extremely high level of certainty" [1], and;

[Holtec Proprietary Text Removed]

B. Synthetic vs. Real Recorded Time Histories

Dr. Bjorkman emphasized in his presentation the difficulties associated with simulating the response of rigid structures to ground motion, which is highly sensitive to initial conditions and the "details" of the ground motion. Because of these factors, the NRC expects real recorded ground motions to be used when performing non-linear time history analysis of stack-up configurations (which is also consistent with the guidance from NUREG-0800, Section 3.7.1 [2]).

[Holtec Proprietary Text Removed]...we plan to perform a sensitivity analysis using modified real recorded time histories to measure the difference in results between Holtec generated synthetic time histories and modified real recorded time histories. Our aim is to show that the peak displacement obtained using 5 sets of synthetic time histories is equal to or greater than the 84^{th} percentile displacement using 5 sets of real recorded time histories. If this cannot be demonstrated, then the results from the sensitivity analysis will be used to establish/recommend an increased factor of safety (greater than 2) against overturning for stability analyses performed using synthetic time histories. [Holtec Proprietary Text Removed].

C. Rigid Body Impact Damping

In his presentation, Dr. Bjorkman noted that two types of damping exist in the rocking of a solid (non-rigid) body: material damping and "rigid body impact damping". He described rigid body impact damping as resulting "solely from considering the conservation of momentum of a rocking rigid body". More importantly he posited that "only material damping shall be used in the time history rocking analysis, since impact damping is already accounted for in the rocking of a rigid body". This assertion seems to be based in part on the paper authored by Yim et. al. [3], which derives the following equation for the kinetic energy ratio, r, for the rocking response of a rigid block:

$$r = \left[1 - \frac{W}{g}\frac{R^2}{I_o}\left(1 - \cos 2\theta_c\right)\right]^2$$

Note that the above equation depends only on the size and mass of the block, not its material. This implies that if a rigid body (with zero material damping) is tipped upwards and then allowed to rock back and forth due to gravity that it will eventually come to rest. This in turn would lead to the following conclusion. If a non-linear time history analysis is performed to predict the rocking response of a rigid block, wherein the rigid block is explicitly modeled as a freestanding body having the proper size and mass, then the analyst should not specify any additional damping (i.e., rigid body impact damping is already accounted for in the solution based on the physics of the problem).

After careful consideration of Dr. Bjorkman's remarks and a closer review of [3], we believe that an important assumption in [3] may have been overlooked, which would affect the conclusion with regards to damping. Specifically, in order to derive the above equation for 'r', the authors of [3] assumed that the impact between the rigid block and the rigid base is "such that there is no bouncing of the block." In other words, the local impacts at the centers of rotation (points O and O' in Figure 1 of [3]) are assumed to be inelastic. It is noted that the same equation is also derived in [5], in which the author writes:

> "If the impact is assumed to be inelastic (no bouncing), the rotation continues smoothly about the point O' and the moment of momentum about point O' is conserved."

Without this assumption, the above equation cannot be derived (see Appendix 1 for derivation). This simplifying assumption is what causes energy to be dissipated from the rocking rigid body, leading to a coefficient of restitution less than one.

Of course, in a non-linear time history analysis, no assumptions are made regarding the bouncing behavior of the rigid body (i.e., stack-up). The only mechanisms to remove energy from the system are through material damping and friction. To illustrate this point, we simulated in LS-DYNA an essentially rigid cylinder rocking on a rigid foundation under gravity, with zero material damping and a coefficient of friction of 1.0 at the foundation interface. While the cylinder does eventually come to rest, it is solely because of the frictional energy losses. This is evident from the time history plots of the system potential energy versus the frictional energy losses. The rigid cylinder comes to rest at the exact time instant when the accumulated frictional energy losses equal the initial potential energy of the cylinder at time zero. There are no energy losses due to "rigid body impact damping". Incidentally, it should be noted that the COR equation derived in [3] (and also in Appendix 1 to this memo) does not include energy losses due to friction at the contact interface.

In the recent stack-up analyses performed by Holtec [Holtec Proprietary Text Removed], we determined the coefficient of restitution of the stack-up by performing a series of LS-DYNA runs in which a deformable stack-up, with a specified initial angular velocity, impacts a concrete foundation [Holtec Proprietary Text Removed]. The minimum coefficient of restitution obtained from LS-DYNA was then converted into an equivalent damping percentage and assigned to the contact elements at the stack-up/ground interface in the ANSYS finite element model. [Holtec Proprietary Text Removed]

D. HI-TRAC/MPC Modeling

The NRC confirmed during the meeting that the canister (MPC) and the transfer cask (HI-TRAC) can be modeled as a single rigid body, for stability analysis purposes, when the nominal radial gap between them is small (< ½"). This accords with the stack-up analysis model implemented by Holtec, which combines the MPC and HI-TRAC into one solid cylinder. It is noted that the nominal radial gap between the MPC and the HI-TRAC is only 3/16".

References

[1] USNRC Letter from V. Ordaz to R. McCullum, June 30, 2011.

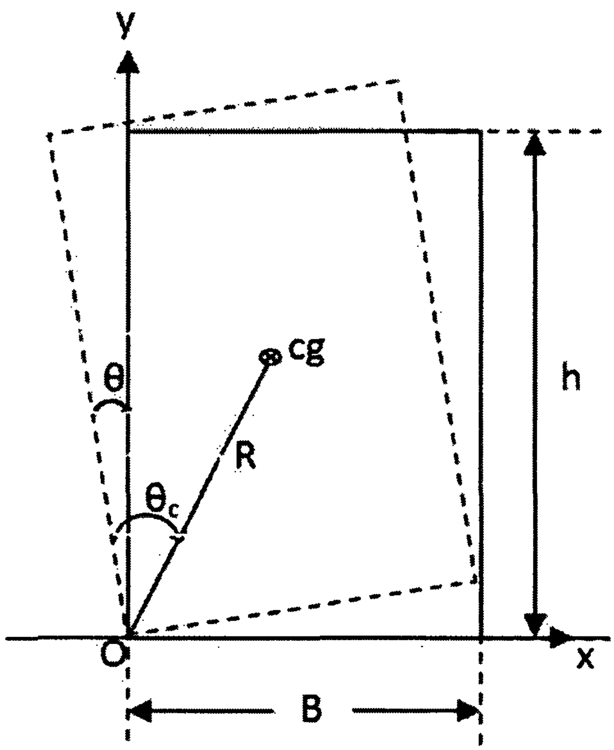
[2] NUREG-0800, Section 3.7.1, Revision 3.

[3] Yim, C., Chopra, A.K., and Penzien, J., "Rocking Response of Rigid Blocks to Earthquakes", Earthquake Engineering and Structural Dynamics, Vol. 8, 565-587 (1980).

[Holtec Proprietary Text Removed]

[5] Housner, G.W., "The Behavior of inverted Pendulum Structures During Earthquakes", Bulletin of the Seismological Society of America, Vol. 53, No. 2, pp. 403-417, February 1963.

Consider a rigid block of height h and width B (as shown in the figure below) which is initially displaced by an angle θ about point O and subsequently is allowed to rock.



The motion of the rocking block is governed by the Lagrangian Equation:

$$\frac{d}{dt}\left[\frac{\partial T}{\partial \dot{q}_i}\right] - \frac{\partial T}{\partial q_i} + \frac{\partial V}{\partial q_i} = \bar{Q}_i$$

Where: T = Kinetic Energy

V= Potential Energy

Q_i = Generalized Non-Conservative Force

Integrating Lagrangian Equation over the interval t ~ t+τ

$$\int_t^{t+\tau} \frac{d}{dt}\left[\frac{\partial T}{\partial \dot{q}_i}\right] dt - \int_t^{t+\tau} \frac{\partial T}{\partial q_i} dt + \int_t^{t+\tau} \frac{\partial V}{\partial q_i} dt = \int_t^{t+\tau} \bar{Q}_i dt$$

Since $\frac{\partial T}{\partial q_i}$ and $\frac{\partial V}{\partial q_i}$ remain finite during impact and τ could be arbitrarily small, the last two terms on the left hand side of the above equation can be ignored, i.e.,

$$\Delta\left[\frac{\partial T}{\partial \dot{q}_i}\right] = \left[\frac{\partial T}{\partial \dot{q}_i}\right]_{t+\tau} - \left[\frac{\partial T}{\partial \dot{q}_i}\right]_t = \int_t^{t+\tau} \bar{Q}_i dt$$

or

$$\Delta\left[\frac{\partial T}{\partial \dot{q}_i}\right] = P_i \text{ (Generalized Impulse)} \quad (1)$$

Apply Equation (1) to the problem for $\dot{x}, \dot{y}\ and \dot{\theta}$, for the kinetic energy of

$$T = \frac{1}{2}m\dot{x}^2 + \frac{1}{2}m\dot{y}^2 + \frac{1}{2}I_{cg}\dot{\theta}^2 \quad (2)$$

At the time of impact, $\theta = 0$ and subscripts 1 and 2 in the following equations represent the state just before and just after impact.

$$\Delta\left[\frac{\partial T}{\partial \dot{x}}\right] = m(\dot{x}_2 - \dot{x}_1) = P_x \quad (3)$$

$$\Delta\left[\frac{\partial T}{\partial \dot{y}}\right] = m(\dot{y}_2 - \dot{y}_1) = P_y \quad (4)$$

$$\Delta\left[\frac{\partial T}{\partial \dot{\theta}}\right] = I_{cg}(\dot{\theta}_2 - \dot{\theta}_1) = \frac{P_y B}{2} - P_x y_{cg} \quad (5)$$

Assume no bouncing of the block, i.e., rotation continues smoothly about the impact point O, the following relationship holds

$$\frac{B}{2}\dot{\theta}_2 + \dot{y}_2 = 0 \quad (6)$$

Substituting Equation (6) in Equation (4)

$$P_y = m\left(-\frac{B}{2}\dot{\theta}_2 - \frac{B}{2}\dot{\theta}_1\right) \quad (7)$$

Using the geometric relationship at pivot point O, Equation (3) can be rewritten as

$$P_x = m\left(y_{cg}\dot{\theta}_2 - y_{cg}\dot{\theta}_1\right) \quad (8)$$

Substituting Equations (7) and (8) in Equation (5)

$$I_{cg}(\dot{\theta}_2 - \dot{\theta}_1) = \frac{B}{2}m\left(-\frac{B}{2}\dot{\theta}_2 - \frac{B}{2}\dot{\theta}_1\right) - y_{cg}m(y_{cg}\dot{\theta}_2 - y_{cg}\dot{\theta}_1), \text{ or}$$

$$\left[I_{cg} + m\left(\frac{B}{2}\right)^2 + my_{cg}{}^2\right]\dot{\theta}_2 = \left[I_{cg} - m\left(\frac{B}{2}\right)^2 + my_{cg}{}^2\right]\dot{\theta}_1 \quad (10)$$

Note that

$$I_o = I_{cg} + m\left(\frac{B}{2}\right)^2 + my_{cg}{}^2$$

Therefore, Equation (10) can be rewritten as

$$I_o\dot{\theta}_2 = I_o\dot{\theta}_1 - 2m\left(\frac{B}{2}\right)^2\dot{\theta}_1 \quad (11)$$

Since $\frac{B}{2} = R\sin\theta_c$, Equation (11) can also be written as

$$I_o\dot{\theta}_1 - mRB\dot{\theta}_1\sin\theta_c = I_o\dot{\theta}_2 \quad (12)$$

Equation (12) is same as Equation (6) from [3]. The kinetic energy ratio, r, can be calculated per Equation (11) as

$$r = \left(\frac{\dot{\theta}_2}{\dot{\theta}_1}\right)^2 = \left[1 - \frac{B^2}{2}\frac{m}{I_o}\right]^2, \text{ or}$$

$$r = \left(\frac{\dot{\theta}_2}{\dot{\theta}_1}\right)^2 = \left[1 - \frac{mR^2}{I_o}(1 - cos2\theta_c)\right]^2 \quad (13)$$