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Subject: USNRC Docket No. 72-1014; TAC No. L22221
HI-STORM 100 Storage Application
HI-STORM TSAR, Revision 10

References: 1. Holtec Project 5014
2. Holtec Letter, B. Gutherman to NRC, dated February 1, 2000

Dear Sir:

In accordance with our recent verbal commitments and the Reference 2 letter, Holtec International is pleased to forward replacement pages comprising Revision 10 of the HI-STORM 100 System Topical Safety Analysis Report (TSAR). This revision includes changes to reflect the resolution of comments received by the NRC during the rulemaking process. In addition, several editorial corrections have been made. Changes in the affected chapters are described in the enclosed document entitled "Summary of Changes in Revision 10."

Thank you for your continued support in the HI-STORM 100 review process. We look forward to receiving the final Certificate of Compliance and Safety Evaluation Report by July 31, 2000.

If you have any questions or require additional information, please contact us.

Sincerely,

Brian Gutherman, P.E.
Licensing Manager

Approval:

K.P. Singh, Ph.D, P.E.
President and CEO

cc: Ms. Marissa Bailey, USNRC (w/14 copies of TSAR Rev. 10, including instructions)
Mr. E. William Brach, USNRC (w/o encl.)

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Exhibit 139
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HOLTEC INTERNATIONAL

REPORT NO. HI-951312

TOPICAL SAFETY ANALYSIS REPORT FOR

THE HI-STORM 100 CASK SYSTEM

VOLUME I OF II

Table 1.D.1: Requirements on Plain Concrete

ITEM	APPLICABLE LIMIT OR REFERENCE
Density (Minimum)	146 (lb/cubic feet)
Specified Compressive Strength	4,000 psi (min.)
Compressive and Bearing Stress Limit	Per ACI 318-95
Cement Type and Mill Test Report	Type II; Section 3.2 (ASTM C 150 or ASTM C595)
Aggregate Type	Section 3.3 (including ASTM C33(Note 2))
Nominal Maximum Aggregate Size	3/4 (inch)
Water Quality	Per Section 3.4
Material Testing	Per Section 3.1
Admixtures	Per Section 3.6
Air Content	6%[1] (Table 4.5.1)
Maximum Water to Cement Ratio	0.5 (Table 4.5.2)
Maximum Water Soluble Chloride Ion Cl in Concrete	1.00 percent by weight of cement (Table 4.5.4)
Concrete Quality	Per Chapter 4 of ACI 349
Mixing and Placing	Per Chapter 5 of ACI 349
Consolidation	Per ACI 309-87
Quality Assurance	Per Holtec Quality Assurance Manual, 10 CFR Part 72, Appendix G commitments
Maximum Local Temperature Limit Under Normal and Off-normal Conditions	200°F (See Note 3)
Maximum Local Temperature Limit Under Accident Conditions	350°F (Appendix A, Subsection A.4.2)
Aggregate Maximum Value[2] of Coefficient of Thermal Expansion (tangent in the range of 70°F to 100°F)	6E-06 inch/inch/°F (NUREG-1536, 3.V.2.b.i.(2)(c)2.b)

Notes:

1. All section and table references are to ACI 349 (85).
2. The coarse aggregate shall meet the requirements of ASTM C33 for class designation 1S from Table 3. However, if the requirements of ASTM C33 cannot be met, concrete that has been shown by special tests or actual service to produce concrete of adequate strength and durability meeting the requirements of Tables 1.D.1 and 1.D.2 is acceptable in accordance with ACI 349 Section 3.3.2.
3. The 200 °F long term temperature limit is specified in accordance with Paragraph A.4.3 of ACI 349 for normal conditions. The 200 °F long term temperature limit is based on (1) the use of Type II cement, specified aggregate criteria, and the specified compressive stress in Table 1.D.1, (2) the relatively small increase in long term temperature limit over the 150°F specified in Paragraph A.4.1, and (3) the very low maximum stresses calculated for normal and off-normal conditions in Section 3.4 of this TSAR.

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1 This limit is specified to accommodate severe exposure to freezing and thawing (Table 4.5.1).

2 The following aggregate types are a priori acceptable: limestone, dolomite, marble, basalt, granite, gabbro, or rhyolite. The thermal expansion coefficient limit does not apply when these aggregates are used. Careful consideration shall be given to the potential of long-term degradation of concrete due to chemical reactions between the aggregate and cement selected for HI-STORM 100 overpack concrete.

The total weight used in the analysis is approximately 2,000 lb. lighter than the HI-STORM 100 containing the lightest weight MPC.

Analysis of a single mass impacting a spring with a given initial velocity shows that both the maximum deceleration "a_M" of the mass and the time duration of contact with the spring "t_c" are related to the dropped weight "w" and drop height "h" as follows:

$$a_M \sim \frac{\sqrt{h}}{\sqrt{w}}; t_c \sim \sqrt{w}$$

Therefore, the most conservatism is introduced into the results by using the minimum weight. It is emphasized that the finite element model described in the foregoing is identical in its approach to the "Holtec model" described in the benchmark report [3.A.4]. Gaps between the MPC and the overpack are included in the model.

3.A.6 Impact Velocity

a. Linear Velocity: Vertical Drops

For the vertical drop event, the impact velocity, v, is readily calculated from the Newtonian formula:

$$v = \sqrt{(2gh)}$$

where

g = acceleration due to gravity
h = free-fall height

b. Angular Velocity: Tip-Over

The tipover event is an artificial construct wherein the HI-STORM 100 overpack is assumed to be perched on its edge with its C.G. directly over the pivot point A (Figure 3.A.16). In this orientation, the overpack begins its downward rotation with zero initial velocity. Towards the end of the tip-over, the overpack is horizontal with its downward velocity ranging from zero at the pivot point (point A) to a maximum at the farthest point of impact (point E in Figure 3.A.17). The angular velocity at the instant of impact defines the downward velocity distribution along the contact line.

In the following, an explicit expression for calculating the angular velocity of the cask at the instant when it impacts on the ISFSI pad is derived. Referring to Figure 3.A.16, let r be the length AC where C is the cask centroid. Therefore,

$$r = \left(\frac{d^2}{4} + h^2 \right)^{1/2}$$

The mass moment of inertia of the HI-STORM 100 System, considered as a rigid body, can be written about an axis through point A, as

$$I_A = I_c + \frac{W}{g} r^2$$

where I_c is the mass moment of inertia about a parallel axis through the cask centroid C and W is the weight of the cask (W = Mg).

Let $\theta_1(t)$ be the rotation angle between a vertical line and the line AC. The equation of motion for rotation of the cask around point A, during the time interval prior to contact with the ISFSI pad, is

$$I_A \frac{d^2\theta_1}{dt^2} = Mgr \sin\theta_1$$

This equation can be rewritten in the form

$$\frac{I_A}{2} \frac{d(\dot{\theta}_1)^2}{d\theta_1} = Mgr \sin\theta_1$$

which can be integrated over the limits $\theta_1 = 0$ to $\theta_1 = \theta_{2f}$ (See Figure 3.A.17).

The final angular velocity θ_1 at the time instant just prior to contact with the ISFSI pad is given by the expression

$$\dot{\theta}_1(t_B)=\sqrt{\frac{2\,Mgr}{I_A}(1-\cos\theta_{2f})}$$

where, from Figure 3.A.17

$$\theta_{2f}=\cos^{-1}\left(\frac{d}{2r_1}\right)$$

This equation establishes the initial conditions for the final phase of the tip-over analysis; namely, the portion of the motion when the cask is decelerated by the resistive force at the ISFSI pad interface.

Using the data germane to HI-STORM 100 (Table 3.A.3), and the above equations, the angular velocity of impact is calculated as 1.49 rad/sec.

3.A.7 Results

It has been previously demonstrated in the benchmark report[3.A.4] that bounding rigid body decelerations are achieved if the cask is assumed to be rigid with only the target (ISFSI pad) considered as an energy absorbing media. Therefore, for the determination of the bounding decelerations reported in this appendix, the HI-STORM storage overpack was conservatively made rigid except for the radial channels that position the MPC inside of the overpack. The MPC material behavior was characterized in the identical manner used in the Livermore Laboratory analysis as was the target ISFSI pad and underlying soil. The LS-DYNA3D time-history results are processed using the Butterworth filter (in conformance with the LLNL methodology) to establish the rigid body motion time-history of the cask. The material points on the cask where the acceleration displacement and velocity are computed for each of the drop scenarios are shown in Figure 3.A.18.

Node 82533 (Channel A1), which is located at the center of the outer surface of the baseplate, serves as the reference point for end-drop scenarios.

Node 84392 (Channel A2), which is located at the center of the cask top lid outer surface, serves as the reference point for the tipover scenario with the pivot point indicated as Point 0 in Figure 3.A.18.

The final results are shown in Table 3.A.4.

Table 3.A.4: Results

Drop Event	Max. Displ (in)	Impact Velocity (in/sec)	Max. Acc. (g's)	Acc. Pulse Duration (msec.)
End-11"	0.696	92.20	44.13	2.96
Tipover Cask Top[1]	4.903	341.3	48.41	9.76
Tipover (Basket Top)	4.368	304.03	43.12	--
Tipover (with Increased Initial Clearance) Cask Top[1]	4.998	341.3	48.52	10.0
Tipover (with Increased Initial Clearance) (Basket Top)	4.452	304.03	43.22	--

1 The distance of the top of the fuel basket is 206" from the pivot point. The distance of the top of the cask is 231.25" from the pivot point. Therefore, all displacements, velocities, and accelerations at the top of the fuel basket are 89.08% of those at the cask top (206"/231.25").

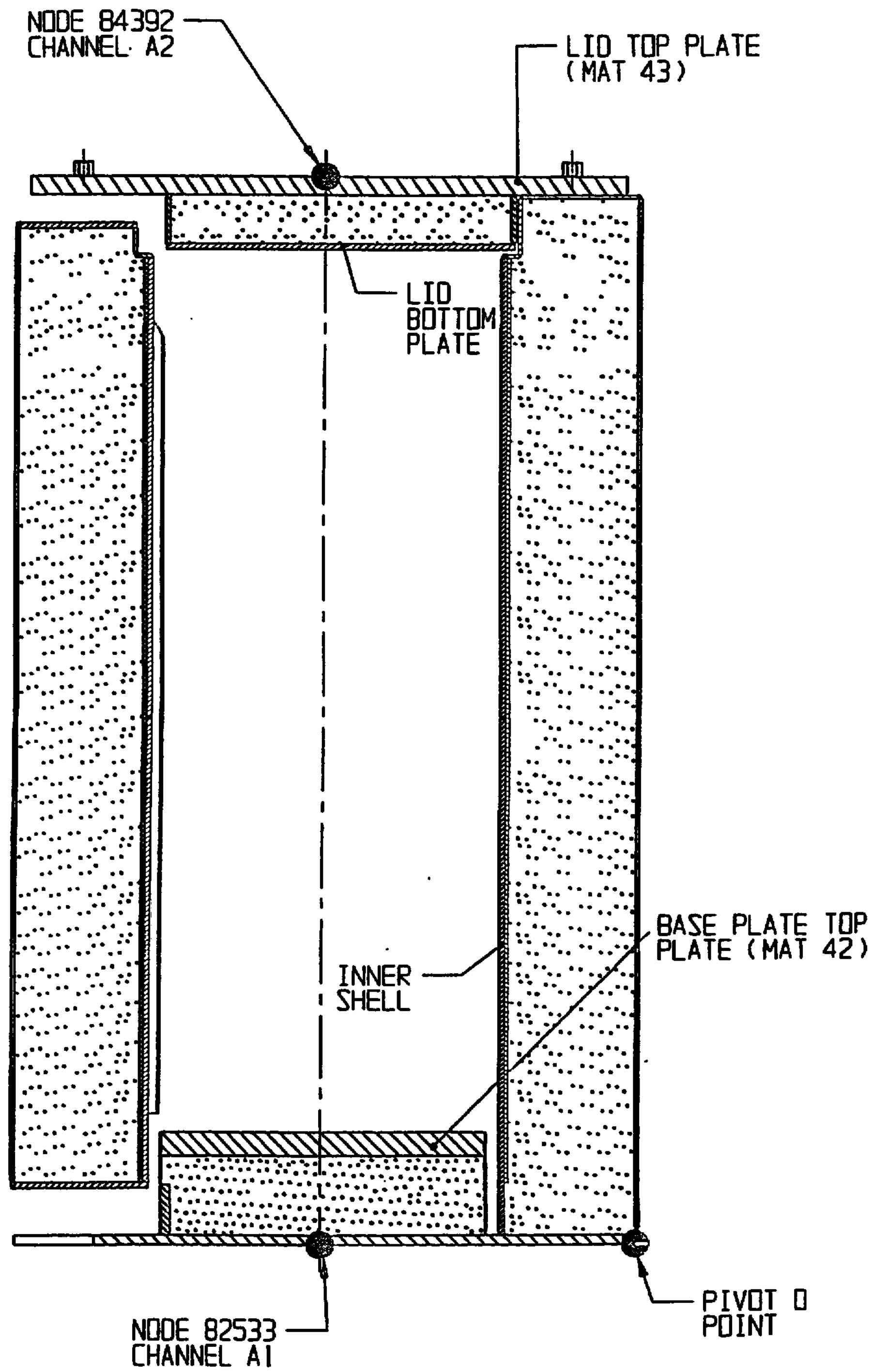

FIGURE 3.A.18; MEASUREMENT POINTS AND CORRESPONDING FINITE-ELEMENT MODEL NODES

The results from the case 1 analysis in the attachment are appropriate to examine the non-mechanistic tipover analysis. It is determined there that the diametrical change under the load is 0.11". This demonstrates that there is no restraint to remove the MPC after the tipover since a positive clearance is still maintained. (0.1875" is the radial gap prior to the accident).
The other cases considered in the attachment are for potential use elsewhere.

3.B.7 Conclusion

Classical ring solutions have been presented for use in examination of the ovalization of the storage overpack. The solutions have been derived using the weight of the storage overpack without an MPC. The weight has been amplified by 45 to represent a bounding accident condition. It is shown by analysis that ready retrievability of the fuel is maintained after a tipover accident.

11.2.2.4 HI-STORM Overpack Handling Accident Corrective Action

Following a handling accident, the ISFSI operator shall first perform a radiological and visual inspection to determine the extent of the damage to the overpack. Special handling procedures, as required, will be developed and approved by the ISFSI operator.

If upon inspection of the MPC, structural damage of the MPC is observed, the MPC is to be returned to the facility for fuel unloading in accordance with Chapter 8. After unloading, the structural damage of the MPC shall be assessed and a determination shall be made if repairs will enable the MPC to return to service. Likewise, the HI-STORM overpack shall be thoroughly inspected and a determination shall be made if repairs will enable the HI-STORM overpack to return to service. Subsequent to the repairs, the equipment shall be inspected and appropriate tests shall be performed to certify the HI-STORM 100 System for service. If the equipment cannot be repaired and returned to service, the equipment shall be disposed of in accordance with the appropriate regulations.

11.2.3 Tip-Over

11.2.3.1 Cause of Tip-Over

The analysis of the HI-STORM 100 System has shown that the overpack does not tip over as a result of the accidents (i.e., tornado missiles, flood water velocity, and seismic activity) analyzed in this section. It is highly unlikely that the overpack will tip-over during on-site movement because of the low handling height limit. The tip-over accident is stipulated as a non-mechanistic accident.

11.2.3.2 Tip-Over Analysis

The tip-over accident analysis evaluates the effects of the loaded overpack tipping-over onto a reinforced concrete pad. The tip-over analysis is provided in Section 3.4. The structural analysis provided in Appendix 3.A demonstrates that the resultant deceleration loading on the MPC as a result of the tip-over accident is less than the design basis 45g's. The analysis shows that the HI-STORM 100 System meets all structural requirements and there is no adverse effect on the structural, confinement, thermal, or subcriticality performance of the MPC. However, the side impact will cause some localized damage to the concrete and outer shell of the overpack in the radial area of impact.

Structural

The structural evaluation of the MPC presented in Section 3.4 demonstrates that under a 45g loading the stresses are well within the allowable values. Analysis presented in Chapter 3 shows that the concrete shields attached to the underside and top of the overpack lid remains attached. As a result of the tip-over accident there will be localized crushing of the concrete in the area of impact.

Thermal

The thermal analysis of the overpack and MPC is based on vertical storage. The thermal consequences of this accident while the overpack is in the horizontal orientation are bounded by the burial under debris accident evaluated in Subsection 11.2.14. Damage to the overpack will be limited as discussed above. As the structural analysis demonstrates that there is no significant change in the MPC or overpack, once the overpack and MPC are returned to their vertical orientation there is no effect on the thermal performance of the system.

Shielding

The effect on the shielding performance of the system as a result of this event is limited to a localized decrease in the shielding thickness of the concrete.

Criticality

There is no effect on the criticality control features of the system as a result of this event.

Confinement

There is no effect on the confinement function of the MPC as a result of this event. As discussed in the structural evaluation above, all stresses remain within allowable values, assuring confinement boundary integrity.

Radiation Protection

Since there is a very localized reduction in shielding and no effect on the confinement capabilities as discussed above, there is no effect on occupational or public exposures as a result of this accident event.

Based on this evaluation, it is concluded that the accident pressure does not affect the safe operation of the HI-STORM 100 System.

11.2.3.3 Tip-Over Dose Calculations

The tip-over accident could cause localized damage to the radial concrete shield and outer steel shell where the overpack impacts the surface. The overpack surface dose rate in the affected area could increase due to the damage. However, there should be no noticeable increase in the ISFSI site or boundary dose rate, because the affected areas will be small and localized. The analysis of the tip-over accident has shown that the MPC confinement barrier will not be compromised and, therefore, there will be no release of radioactivity or increase in site-boundary dose rates.