STONE & WEBSTER ENGINEERING CORPORATION

CLIENT & PROJECT	PAGE 1 OF 9 PLUS 1 PG OF ATTACHMENTS
Private Fuel Storage Facility - Private Fuel, LLC	
CALCULATION TITLE **Evaluation of Concrete Storage Pad Target Hardness**	QA CATEGORY (X) X I - NUCLEAR SAFETY RELATED __ II __ III __ OTHER

CALCULATION IDENTIFICATION NUMBER

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APPROVALS - SIGNATURE & DATE

PREPARER(S)/DATE(S)	REVIEWER(S)/DATE(S)	INDEPENDENT * REVIEWER(S)/DATE(S)	REV. NO. OR NEW CALC. NO	SUPERSEDES CALC. NO. OR REV. NO.	CONFIRMATION REQUIRED (X) YES	NO
S.C. SMITH 5/28/97 Stan Smith	S.P. JACOB 6/9/97 Steve P. Jacob	SP JACOB 6/9/97 Steve P. Jacob	0	NA		X

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S.C. Smith 5/15/97	S.P. JACOB 6-9-97	S.P. JACOB 6-9-97

SUBJECT/TITLE	QA CATEGORY/CODE CLASS
PFSF Pad Stiffness Evaluation	I

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(Revisions, Additions, Deletions, Etc.)

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OBJECTIVE:

The purpose of this calculation is to evaluate the stiffness or target hardness of the spent fuel storage pads to ensure that these values are within the design limits specified in the Holtec HI-Storm Storage Cask SAR and the Sierra Nuclear Corporation (SNC) TranStor Storage Cask SAR. A pad stiffness or target hardness value below the specified value is required to ensure that the maximum deceleration experienced by the cask and the fuel canister due to a horizontal cask drop or tip over accident is below the specified design basis values.

References:

1. Topical Safety Analysis Report for the HIGH-STORM 100 Cask System, Holtec Report HI-951312, Rev 1, HOLTEC International.

2. EPRI Report: Structural Design of Concrete Storage Pads For Spent Fuel Casks, EPRI NP-7551, Final Report August 1991.

3. Storage Facility Design Criteria - Private Fuel Storage Facility, J.O. No. 05996.01, Revision 1, December 31, 1997.

4. SWEC Interoffice Memorandum: Geotech Design Criteria - Pads, From: NT Georges To: SM Macie, March 28, 1997.

5. Safety Analysis Report for the TranStor Storage Cask System, SNC-96-72SAR, Revision B, Sierra Nuclear Corporation, March 1997.

6. TranStor Concrete Cask Hypothetical Tipover Analyses, SNC No. TSL01-10.06.70, Sierra Nuclear Corporation, 3/6/97.

7. Notes On ACI 318-95, Portland Cement Association, 1996.

8. Code Requirements for Nuclear Safety Related Concrete Structures (ACI 349-90), ANSI/ACI 349-90, American Concrete Institute, 1990.

CALCULATION METHOD & ASSUMPTIONS:

Pad stiffness/target hardness values for the pads will be calculated using the methods used in the respective cask SAR'S.

HOLTEC specifies an upper bound pad stiffness value of 30.65 x 10^6 k/in which shall not be exceeded in order to keep canister/cask forces below the cask design basis limit of 45g [Ref. 1, pg. 3.A-14]. The stiffness of the site-specific pad/soil combination will be calculated and compared to the specified upper bound value.

SNC assumes specific pad/soil parameters and develops a Target hardness number in accordance with EPRI NP-7551 [Refs. 2 & 6] to develop the forces on the cask and canister. The target hardness value for the site-specific pad/soil combination will be calculated and new design accelerations calculated. These new design accelerations will then be compared to the design basis accelerations for the canister and cask. The design basis acceleration for the canister is 44 g [Ref. 6, pg. 7].

Site Specific values for calculating the pad/soil stiffness or target hardness values are:

PFSF Concrete Pad Design Values [Ref. 3]:
f'c = 4,000 psi
Poisson's Ratio = .15 (assumed)
Pad thickness = 3 ft

PFSF Soil Design Values (in-situ) [Ref. 4, pg. 4-9]:
Poissons Ratio = 0.433
Shear Modulus = 688 ksf = 4,778 psi
Elastic Modulus = 1,915 ksf = 13,299 psi

Cask Data:

	HI-STORM [Ref. 1, Sect 1.5 & Table 3.2.1]	TranStor [Ref. 5, Tables 1.2-4 & 3.2-1]
Cask Diameter (in)	132.5	136
Height of Cask (in)	231.25	220
Weight of Cask (Max) (lbs)	353,796	309,130
Weight of Cask (Min) (lbs)*	302,761	290,000 [Ref. 6]

*Minimum cask weight will give higher target hardness values and therefore higher deceleration values.

CONCLUSIONS:

HOLTEC Cask:

The calculation herein shows that the stiffness of the PFSF pad is bounded by the HOLTEC pad stiffness criteria. Therefore a tip over or drop accident at the site will not exceed the design basis values of the HOLTEC cask and internals.

TranStor Cask:

The calculation herein shows that the site specific PFSF pad target hardness value is bounded by the TranStor target hardness analysis. Therefore a tip over accident at the site will not exceed the design basis values of the TranStor cask and internals.

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SUBJECT/TITLE: PAD STIFFNESS EVALUATION

QA CATEGORY/CODE CLASS: I

HI-STORM STORAGE CASK (HOLTEC)

THE HOLTEC STORAGE CASK TIPOVER ANALYSIS IS BASED ON THE FOLLOWING CASK PARAMETERS [REF 1 p 3.4-12]

CASK DIA (d) = 132.5"

HEIGHT OF CASK (ℓ) = 236.25 IN

WEIGHT OF CASK (MAXIMUM) = 353,796# (USE 354,000#)

FROM REF 2 p 2-4

$$\delta_e = \frac{W}{2rk}\left(1 - e^{-\beta r}\cos\beta r\right)$$

δ_e = DISPLACEMENT DUE TO THE CASK STATIC WEIGHT ON THE TARGET FOR COMBINED PAD SUBSOIL SYSTEM. (END DROP WILL CONTROL)

Where: $\beta = \left(\frac{E_s}{4D_c}\right)^{1/4}$

$$D_c = \frac{E_c h^3}{12(1-\nu_c^2)} \quad \text{(CONC SLAB RIGIDITY)}$$

$$K = \frac{\pi E_s}{(1-\nu_s^2)} \quad \text{(FOUNDATION MODULUS)}$$

$$E_c = 57{,}000\,(f_c')^{1/2} = 57{,}000\,(4000)^{1/2} = 3{,}604{,}000 \text{ psi} \quad [\text{REF 8 } \S\ 8.5]$$

$$D_c = \frac{3{,}604{,}000\,(36\text{ IN})^3}{12(1-.15^2)} = 1.43\times10^{10}\ \#/\text{IN}^2$$

$$K = \frac{\pi\ 1.33\times10^4 \text{ psi}}{(1-.433^2)} = 51{,}425\ \#/\text{IN}^2$$

$$\beta = \left[\frac{1.33\times10^4 \text{ psi}}{4(1.43\times10^{10}\ \text{IN}^\#)}\right]^{1/4} = .022$$

$$\beta r = .022\left(\frac{132.5''}{2}\right) = 1.45 \text{ RADIANS} = 83.4^\circ$$

$$\delta_e = \frac{3.54\times10^5\ \#}{2(66.25'')\,5.14\times10^4\ \#/\text{IN}^2}\left(1 - e^{-1.45}\cos 83.4\right)$$

$$\delta_e = .0520\left[1 - .235(.115)\right] = .0506 \text{ IN}$$

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QA CATEGORY/CODE CLASS: I

$$K_F = \frac{P}{\delta_e} = \frac{3.54 \times 10^5 \#}{.051 \text{ in}} = 6.9 \times 10^6 \#/\text{in}$$

INCREASE THE TARGET STIFFNESS BY THE MAXIMUM DYNAMIC LOAD AMPLIFICATION FACTOR (DLA)

$DLA_{max} = 1.56$ [REF 1, p 3.X-10 FOR LID TOP PL]

$K = 1.56(6.9 \times 10^6 \#/\text{in}) = 10.8 \times 10^6 \#/\text{in}$

$10.8 \times 10^6 \#/\text{in} < 30.65 \times 10^6 \#/\text{in}$ O.K.
[REF 1, p 3.A-14

∴ THE SITE SPECIFIC TARGET STIFFNESS IS BOUNDED BY THE HOLTEC DESIGN BASIS STIFFNESS VALUE & THE CASK TIPOVER ACCELERATION VALUES WILL BE SMALLER THAN THE CASK/CANISTER DESIGN BASIS ACCELERATIONS.

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SUBJECT/TITLE: PAD STIFFNESS EVALUATION

QA CATEGORY/CODE CLASS: I

TRANSTOR STORAGE CASK (SNC)

THE TRANSTOR STORAGE CASK TIP-OVER ANALYSIS IS BASED ON A PAD WITH THE FOLLOWING PARAMETERS

PAD THICKNESS = 36" = 36" FOR PFSF
f'_c OF CONCRETE = 3000 < 4,000 psi FOR PFSF
E_c OF CONCRETE = 3.1×10^6 psi < 3.604×10^6 psi FOR PFSF
POISSONS RATIO (ν_s) = 0.45 > .433 FOR PFSF
E_s (SOIL) = 6.0×10^4 psi > 1.33×10^4 FOR PFSF
[REF 6, p 2]

THE TRANSTOR ANALYSIS CALCULATED A TARGET HARDNESS VALUE OF 9.113×10^3 FOR THE PAD [REF 6, p 7]

SINCE THE PROPOSED PFSF PAD IS SIZED DIFFERENTLY FROM THE TRANSTOR PAD, CALCULATE THE REVISED TARGET HARDNESS VALUE.

HORIZONTAL TIP OVER

$$D_c = \frac{E_c h^3}{12(1-\nu_c^2)} = \frac{3{,}604{,}000\,psi\,(36\,in)^3}{12(1-.15^2)} = 1.43 \times 10^{10}\ \#/in^2$$

$$I_c = \frac{1}{12} L h^3 = 1/12\,(220)(36\,in)^3 = 8.55 \times 10^5\ in^4$$

$$\beta = \left(\frac{E_s}{4 E_c I_c}\right)^{1/4} = \left[\frac{1.33 \times 10^4}{4(3.6 \times 10^6)(8.63 \times 10^5)}\right]^{1/4} = .0057$$

$$A = DL = 10\,in\,(220\,in) = 2.20 \times 10^3\ in^2$$

FIND M_u FOR PAD (1" WIDE STRIP) (10" @ 12 EW T&B) [REF 7 P10-4]

$$\rho = \frac{A_s}{bd} = \frac{1.27\,in^2}{12"(36" - 3" - 1")} = .0033$$

$$\omega = \rho \frac{f_y}{f'_c} = .0033\left(\frac{60\,ksi}{4\,ksi}\right) = .0495$$

$$\frac{M_N}{f'_c b d^2} = .0485 \qquad M_N = .0485 f'_c b d^2$$

$$M_N = .0485(4000\,psi)\,12"(32")^2$$

$$M_N = 2{,}383{,}872\ in\#$$

$$M_u = \phi M_N = .90(2{,}383{,}872\,in\#) = 2{,}145{,}485\,in\# = 179\ k\text{-}ft$$

$$= 2.15 \times 10^6\ in\#$$

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PAD STIFFNESS EVALUATION	I

$$S_{\text{TARGET HARDNESS}} = \frac{2 A E_s N_u f'_c}{(h_{CASK})^3 B} = \frac{2(2.20\times10^3)(1.33\times10^4)\,2.15\times10^6(4\times10^3)}{(2.90\times10^5)^3\,.0057}$$

$S = 3.62\times10^3 < 9.113\times10^3$ FOR TRANSTOR PAD

FROM FIG. 27 [REF 2] MAXIMUM FORCE = 11.0g FOR 70" DROP

8g < 17g [REF 6 p 7 of 11]

MAXIMUM DECELERATION FOR DROP FROM ANY HEIGHT [REF 2, p 2-46]

$G = -15.35 + 3.85 \ln S = -15.35 + 3.85 \ln(3.62\times10^3) = 16.8g$

16.2g < 19.8g [REF 6, p 6 of 11]

REF 6 CHECKED STRUCTURAL CAPACITY OF CASK & INTERNALS BASED ON 19.8g WHICH YIELDED A MINIMUM FACTOR OF SAFETY OF 1.04. SINCE SITE SPECIFIC MAXIMUM DECELERATION IS 16.2g, TRANSTOR CASK ANALYSIS BOUNDS THE SITE SPECIFIC VALUES GENERATED HEREIN.

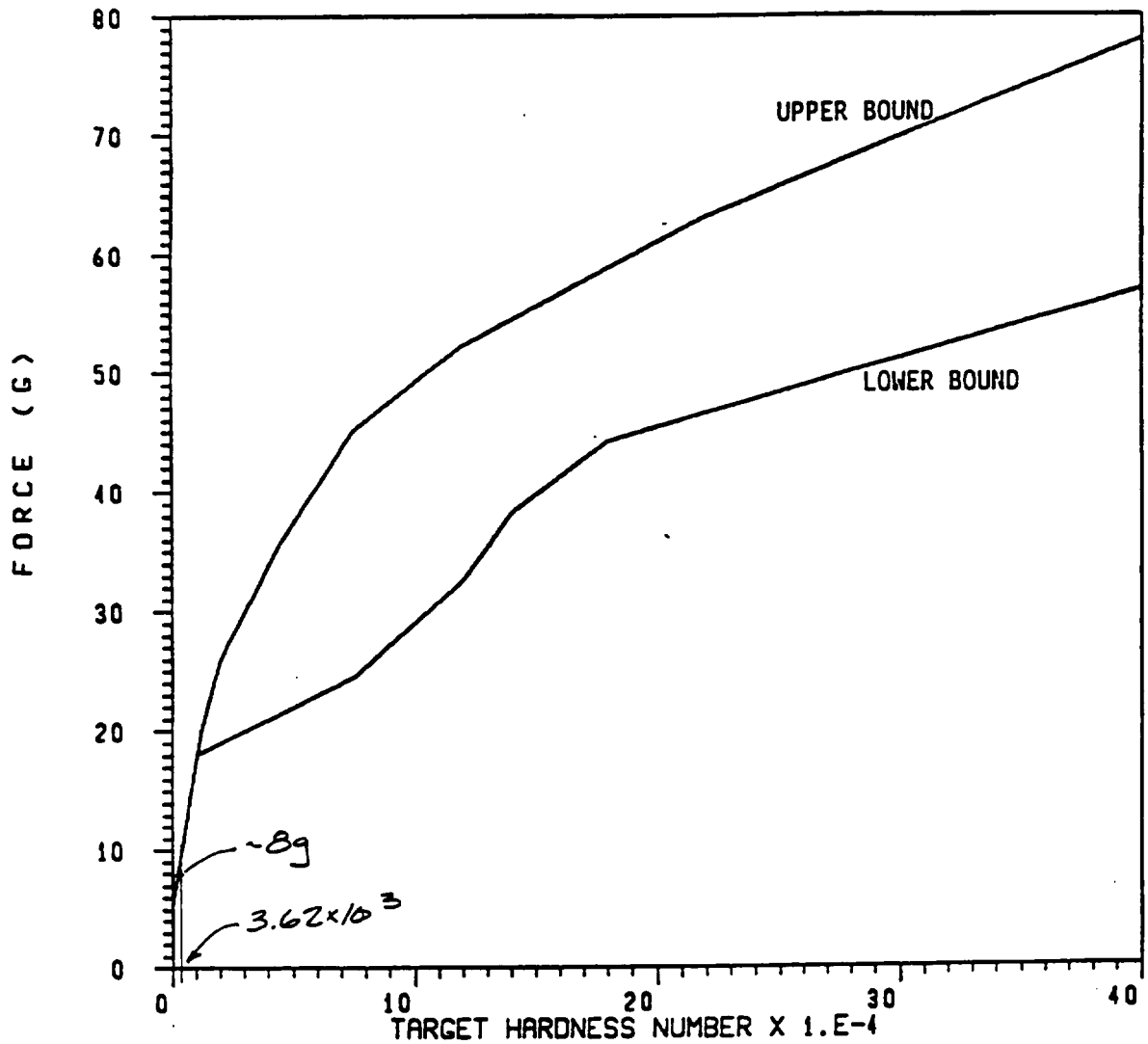

Figure 27. Force vs. Target Hardness Number for 70" Drop Height