S

MAY 15 2000

STA 4 (5)

ENGINEERING DATA TRANSMITTAL

Page 1 of

1. EDT 629126

2. To: (Receiving Organization) Technical Operations				3. From: (Originating Organization) CSB Project				4. Related EDT No.: N/A			
5. Proj./Prog./Dept./Div.: SNF Project				6. Design Authority/Design Agent/Cog. Engr.: C. E. Swenson				7. Purchase Order No.: N/A			
8. Originator Remarks: For release								9. Equip./Component No.: MHM			
								10. System/Bldg./Facility: CSB			
								12. Major Assm. Dwg. No.: N/A			
11. Receiver Remarks: 11A. Design Baseline Document? ☐ Yes ☒ No USQ LIKE # CSB-00-025								13. Permit/Permit Application No.: N/A			
								14. Required Response Date: N/A			
15. DATA TRANSMITTED								(F)	(G)	(H)	(I)
(A) Item No.	(B) Document/Drawing No.	(C) Sheet No.	(D) Rev. No.	(E) Title or Description of Data Transmitted				Approval Designator	Reason for Transmittal	Originator Disposition	Receiver Disposition
1	SNF-6248	all	0	Evaluation of				S ^N	1	1	1
				Multi-Canister Overpack							
				Handling Machine Uplift							
				Restraint for a Seismic							
				Event During Repositioning							
				Operations							
16. KEY											
Approval Designator (F)			Reason for Transmittal (G)					Disposition (H) & (I)			
E, S, Q, D OR N/A (See WHC-CM-3-5, Sec. 12.7)			1. Approval 2. Release 3. Information 4. Review 5. Post-Review 6. Dist. (Receipt Acknow. Required)					1. Approved 2. Approved w/comment 3. Disapproved w/comment 4. Reviewed no/comment 5. Reviewed w/comment 6. Receipt acknowledged			
17. SIGNATURE/DISTRIBUTION (See Approval Designator for required signatures)											
(G) Reason	(H) Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN	(G) Reason	(H) Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN
1	I	Design Authority CE Swenson	<i>C. E. Swenson</i>	4/27/00	S8-07	1	I	GD Bazinet	<i>GD Bazinet</i>	5/3/00	S8-06
		Design Agent				6		B. J. Craig			R3-26
		Cog. Eng.				6		SNF Project Files			R3-11
1	I	Cog. Mgr. AS Daughtfidge	<i>AS Daughtfidge</i>	5/11/00	R3-86			CSB " "			S8-06
1	I	QA SS Moss	<i>Stephen Scott Moss</i>	5/11/00	R3-11						
1	I	Safety RL Garrett	<i>RL Garrett</i>		R3-26						
		Env.									
18. <i>WW Waddel</i> WW Waddel Signature of EDT Originator			19. <i>C. E. Swenson</i> C. E. Swenson Authorized Representative for Receiving Organization			20. <i>AS Daughtfidge</i> AS Daughtfidge Design Authority/ Cognizant Manager			21. DOE APPROVAL (if required) Ctrl No. _____ ☐ Approved ☐ Approved w/comments ☐ Disapproved w/comments		

Evaluation of Multi-Canister Overpack Handling Machine Uplift Restraint for a Seismic Event During Repositioning Operations

C. E. Swenson
Fluor Hanford

M. D. Northey
B. V. Winkel
M&D Professional Services

Date Published
April 2000

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Project Hanford Management Contractor for the
U.S. Department of Energy under Contract DE-AC06-96RL13200

Fluor Hanford
P.O. Box 1000
Richland, Washington

Release Approval

5/11/00
Date

Release Stamp

TRADEMARK DISCLAIMER

Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors.

This report has been reproduced from the best available copy.

Printed in the United States of America

Total Pages: 86

Evaluation of Multi- Canister Overpack Handling Machine Uplift Restraint for a Seismic Event During Repositioning Operations

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Project Hanford Management Contractor for the
U.S. Department of Energy under Contract DE-AC06-96RL13200

Fluor Hanford

P.O. Box 1000

Richland, Washington

M&D Professional Services, Inc.		CALCULATION COVER SHEET		Page 1	
				Calculation No. 00-0002-E	
				Revision No. 0	
PROJECT NAME: SNF			CLIENT: Fluor Daniel Hanford		
TITLE: EVALUATION OF MHM UPLIFT RESTRAINT HARDWARE FOR A SEISMIC EVENT OCCURRING DURING MHM REPOSITIONING OPERATIONS					
PROBLEM STATEMENT: This calculation addresses the structural adequacy of the MCO Handling Machine (MHM) seismic uplift restraints for a design basis earthquake event when the active seismic restraints are not engaged.					
REVISION	AFFECTED PAGES	REVISION DESCRIPTION	NAME, INITIALS & DATE OF PREPARER(S)	NAME, INITIALS & DATE OF CHECKER(S)	
0	1-26 A1-A6 B1-B9 C1-C10 D1-D18 E1-E7 F1-F7	Initial issue	Bob Winkel <i>B. Winkel</i> 4-18-00 Mike Northey <i>Mike Northey</i> 4/18/00 Bob Winkel <i>B. Winkel</i> 4-18-00 Bob Winkel <i>B. Winkel</i> 4-18-00 Bob Winkel <i>B. Winkel</i> 4-18-00 Mike Northey <i>Mike Northey</i> 4/18/00 Mike Northey <i>Mike Northey</i> 4/18/00 Milon Meyer <i>M. Meyer</i> 4/18/00	Mike Northey <i>Mike Northey</i> 4/18/00 Bob Winkel <i>B. Winkel</i> 4-18-00 Mike Northey <i>Mike Northey</i> 4/18/00 Mike Northey <i>Mike Northey</i> 4/18/00 Milon Meyer <i>M. Meyer</i> 4/18/00 Bob Winkel <i>B. Winkel</i> 4-18-00 Bob Winkel <i>B. Winkel</i> 4-18-00	

M&D Professional Services	CALCULATION SHEET		Page No. 2 of 26
Client / Location Fluor Daniel Hanford	Prepared By / Date <i>B.W.</i> 4-18-00	Calculation No. 00-0002-E	
Subject MHM Trolley Uplift Constraint Loading	Checked By / Date <i>MON</i> 4/18/00	Revision No. 0	
Ref. Drawing(s) EDERER Drawing No. C-3466	Revised By / Date	Supporting Document No.	

TABLE OF CONTENTS

Section	Page
CALCULATION COVER SHEET	1
TABLE OF CONTENTS	2
LIST OF FIGURES	3
LIST OF TABLES	4
EVALUATION OF MHM UPLIFT RESTRAINT HARDWARE FOR A SEISMIC EVENT OCCURRING DURING MHM REPOSITIONING OPERATIONS	5
1.0 INTRODUCTION	5
2.0 SUMMARY AND CONCLUSIONS	6
2.1 BRIDGE UPLIFT RESTRAINTS	6
2.2 TROLLEY UPLIFT RESTRAINTS	6
2.3 CONCLUSION	7
3.0 MHM/MCO HARDWARE DISCUSSION	7
4.0 DESIGN INPUT AND ASSUMPTIONS	9
5.0 EVALUATION APPROACH	10
6.0 SIMPLIFIED FINITE ELEMENT MODEL DEVELOPMENT	11
6.1 MODEL DESCRIPTION	11
6.2 SIMPLIFIED MODEL ADEQUACY EVALUATION	15
7.0 NONLINEAR TIME HISTORY ANALYSIS	18
7.1 TIME HISTORY INPUT	18
7.2 NONLINEAR TIME HISTORY ANALYSIS DETAILS	18
7.3 BRIDGE UPLIFT RESTRAINT STRUCTURAL EVALUATION	24
8.0 REFERENCES	25
APPENDIX A CENTER OF GRAVITY CALCULATION	A1
APPENDIX B ANSYS TM INPUT LISTINGS	B1
APPENDIX C ALSTHOM EMAIL CORRESPONDENCE	C1
APPENDIX D TIME HISTORY ANALYSIS INPUT	D1
APPENDIX E BRIDGE UPLIFT RESTRAINT CALCULATIONS	E1
APPENDIX F FRICTION COEFFICIENT DATA	F1

M&D Professional Services	CALCULATION SHEET		Page No. 3 of 26
Client / Location Fluor Daniel Hanford	Prepared By / Date <i>BW</i> 4-18-00	Calculation No. 00-0002-E	
Subject MHM Trolley Uplift Constraint Loading	Checked By / Date <i>MOR</i> 4/18/00	Revision No. 0	
Ref. Drawing(s) EDERER Drawing No. C-3466	Revised By / Date	Supporting Document No.	

LIST OF FIGURES

Figure 3-1 - Trolley, Bridge, and Turret Illustration	8
Figure 3-2 - MHM Trolley Seismic Constraints	8
Figure 3-3 - MHM Trolley Seismic Uplift Constraint Geometry and Potential Loading	9
Figure 6-1 - Beam Centerline Plot of MHM Simplified Model	13
Figure 6-2 - Model Plot Showing Beam Element Cross-Sectional Dimensions	14
Figure 6-3 - Simplified Model Fundamental Mode Shape	15
Figure 6-4 - Comparison of ALSTHOM and Simplified Model Seismic Trolley/Bridge Interface Force Predictions	16
Figure 6-5 - Comparison of ALSTHOM and the Simplified Model Bridge Wheel Reaction Loads	17
Figure 7-1 - Damping Versus Frequency, Alpha-Beta Damping	19
Figure 7-2 - Trolley/Bridge Interface Elements for Nonlinear Time History Analysis	21
Figure 7-3 - Trolley Wheel Interface Force Predictions, 2 nd Time History	21
Figure 7-4 - Wheel Interface Gap Predictions, 1 st Time History	22
Figure 7-5 - Trolley East-West Movement Predictions, 2 nd Time History	23

M&D Professional Services	CALCULATION SHEET		Page No. 4 of 26
Client / Location Fluor Daniel Hanford	Prepared By / Date <i>B. White</i> 4-18-00	Calculation No. 00-0002-E	
Subject MHM Trolley Uplift Constraint Loading	Checked By / Date <i>MDA</i> 4/18/00	Revision No. 0	
Ref. Drawing(s) EDERER Drawing No. C-3466	Revised By / Date	Supporting Document No.	

LIST OF TABLES

Table 4-1 – Analysis Input Parameters.....	9
--	---

M&D Professional Services	CALCULATION SHEET		Page No. 5 of 26
Client / Location Fluor Daniel Hanford	Prepared By / Date <i>BW</i> 4-18-00	Calculation No. 00-0002-E	
Subject MHM Trolley Uplift Constraint Loading	Checked By / Date <i>MON</i> 4/18/00	Revision No. 0	
Ref. Drawing(s) EDERER Drawing No. C-3466	Revised By / Date	Supporting Document No.	

EVALUATION OF MHM UPLIFT RESTRAINT HARDWARE FOR A SEISMIC EVENT OCCURRING DURING MHM REPOSITIONING OPERATIONS

1.0 INTRODUCTION

Insertion of the Multi-Canister Overpack (MCO) assemblies into the Canister Storage Building (CSB) storage tubes involves the use of the MCO Handling Machine (MHM). During MCO storage tube insertion operations, inadvertent movement of the MHM is prevented by engaging seismic restraints ("active restraints") located adjacent to both the bridge and trolley wheels. During MHM repositioning operations, the active restraints are not engaged. When the active seismic restraints are not engaged, the only functioning seismic restraints are non-engageable ("passive") wheel uplift restraints which function only if the wheel uplift is sufficient to close the nominal 0.5-inch gap at the uplift restraint interface.

The MHM was designed and analyzed in accordance with ASME NOG-1-1995 (Reference 1). The ALSTHOM seismic analysis (Reference 3) reported seismic loads on the MHM uplift restraints and EDERER performed corresponding structural calculations (Reference 11) to demonstrate structural adequacy of the seismic uplift restraint hardware. The ALSTHOM and EDERER calculations were performed for a parked MHM with the active seismic restraints engaged, resulting in uplift restraint loading only in the vertical direction. In support of development of the CSB Safety Analysis Report (SAR), an evaluation of the MHM seismic response was requested for the case where the active seismic restraints are not engaged.

If a seismic event occurs during MHM repositioning operations, a moving contact at a seismic uplift restraint would introduce a friction load on the restraint in the direction of the movement. These potential horizontal friction loads on the uplift restraints were not included in the existing restraint hardware design calculations. One of the purposes of the current evaluation is to address the structural adequacy of the MHM seismic uplift restraints with the addition of the horizontal friction associated with MHM repositioning movements.

During preliminary evaluations, questions were raised as to whether the EDERER calculations considered the latest ALSTHOM seismic analysis loads (See NCR No. 00-SNFP-0008, Reference 5). Further evaluation led to the conclusion that the EDERER calculations used appropriate vertical loading, but the uplift restraints would need to be re-analyzed and potentially modified to account for lateral (friction) loading. The disposition of NCR 00-SNFP-0008 will track the resolution of the uplift restraints seismic loading issues.

It is emphasized that the existence of a half-inch gap in the passive uplift restraint, introduced

M&D Professional Services	CALCULATION SHEET		Page No. 6 of 26
Client / Location Fluor Daniel Hanford	Prepared By / Date <i>BW</i> 4-18-00	Calculation No. 00-0002-E	
Subject MHM Trolley Uplift Constraint Loading	Checked By / Date <i>MDR</i> 4/18/00	Revision No. 0	
Ref. Drawing(s) EDERER Drawing No. C-3466	Revised By / Date	Supporting Document No.	

above, raises the possibility that the wheel uplifts may not be sufficient to load the uplift restraints during the CSB design basis earthquake (DBE) event. To accurately address this wheel uplift/gap closure issue requires a nonlinear seismic model. Since prior analyses were limited to linear seismic models, the issue of wheel uplift/gap closure was not addressed by the Reference 3 ALSTHOM seismic evaluation. In the current evaluation, a nonlinear seismic model is developed, which allows for a quantitative evaluation of the wheel uplift/gap closure issue.

2.0 SUMMARY AND CONCLUSIONS

There are two types of uplift restraints: 1) bridge uplift restraints, located at the CSB floor elevation near the bridge wheels, and 2) trolley uplift restraints located adjacent to the trolley wheels. The two uplift restraint designs are addressed separately below.

2.1 BRIDGE UPLIFT RESTRAINTS

Seismic uplift restraints located adjacent to the bridge wheels are relatively stout and have high capacity for frictional forces in the direction of bridge movement. Also, the bridge uplift restraint loads are relatively low. Using conservative frictional forces, the bridge uplift restraints are evaluated in Appendix E. The smallest safety margin for the bridge uplift restraints, with frictional forces included, is +2.30. It is emphasized that this safety margin is based upon conservative vertical uplift and horizontal friction loads. Based upon experience with the nonlinear analysis of the trolley uplift restraints, it is very likely that the bridge wheels will not experience lift off during a DBE, and the uplift restraints will not be loaded.

2.2 TROLLEY UPLIFT RESTRAINTS

Preliminary evaluations of the trolley seismic uplift restraints indicated that the uplift hardware has very little capacity for horizontal friction force loading. The preliminary loading on the trolley uplift hardware also was relatively high. These preliminary findings prompted the need for a relatively precise evaluation of the seismic response of the trolley/bridge interface loading. Simplified seismic models of the MHM geometry were developed which concentrated on the trolley/bridge interfaces (wheels and uplift restraints). The adequacy of the simple model was determined by making comparisons with the relatively complex ALSTHOM seismic model results. Results from a seismic analysis using a linear version of the simplified model were found to compare favorably with the ALSTHOM results. This conclusion provided confidence that a nonlinear time history analysis, using the simplified model, would provide a good estimate of the bridge/trolley interface seismic response.

Two nonlinear time history analyses were performed using two different statistically independent sets of seismic time histories as discussed in Section 7.1. A bounding trolley wheel uplift magnitude of 0.05 in. was predicted which is well below the nominal uplift gap of 0.5 in.

M&D Professional Services	CALCULATION SHEET		Page No. 7 of 26
Client / Location Fluor Daniel Hanford	Prepared By / Date <i>BW</i> 4-18-00	Calculation No. 00-0002-E	
Subject MHM Trolley Uplift Constraint Loading	Checked By / Date <i>MDN</i> 4/18/00	Revision No. 0	
Ref. Drawing(s) EDERER Drawing No. C-3466	Revised By / Date	Supporting Document No.	

Thus, a rigorous evaluation of the trolley/bridge interface DBE response, indicates that the trolley restraints will not be loaded during a CSB DBE event. A peak trolley wheel impact load of 277 kips was predicted, which is well below the ALSTHOM maximum value of 333 kips. Thus, the wheel impact seismic predictions do not indicate a need for a re-evaluation of the hardware associated with the wheel loading.

2.3 CONCLUSION

Based upon the analysis results discussed above, it is concluded that the existing MHM bridge and trolley uplift restraint hardware designs are adequate for a DBE event occurring during MHM repositioning operations. Therefore, no redesign of the uplift restraints is needed.

3.0 MHM/MCO HARDWARE DISCUSSION

The MHM assembly consists of a bridge, trolley, and turret, as shown in Figure 3-1. The 126-ft long bridge girders ride on north-south directed rails. The trolley rides on east-west rails which are positioned on top of the bridge girders. Adjacent to both the bridge and trolley wheels are seismic uplift restraints which are loaded if the sufficient wheel lift off occurs.

The turret reaches from the Canister Storage Building (CSB) floor to well above the trolley rails, and is supported by the trolley. This projection of the trolley/turret assembly well below the trolley frame results in an assembly center of gravity that is below the trolley wheels. This low center of gravity helps stabilize the trolley/turret assembly and reduces the possibility of tipping/falling of the trolley assembly during a seismic event.

M&D Professional Services	CALCULATION SHEET		Page No. 8 of 26
Client / Location Fluor Daniel Hanford	Prepared By / Date <i>BW</i> 4-18-00	Calculation No. 00-0002-E	
Subject MHM Trolley Uplift Constraint Loading	Checked By / Date <i>MDN</i> 4/19/00	Revision No. 0	
Ref. Drawing(s) EDERER Drawing No. C-3466	Revised By / Date	Supporting Document No.	

Figure 3-1 - Trolley, Bridge, and Turret Illustration

The MHM trolley seismic uplift restraints and wheels are illustrated in Figure 3-2. A nominal half-in. gap exists between the uplift restraint and the bridge flange interface. North-south trolley wheel movement is resisted by friction and flanges on the trolley wheels. When the MHM is positioned over a Multi-Canister Overpack (MCO) storage tube, east-west seismic restraints are activated to prevent trolley movement during MCO handling. The active seismic constraints consist of vertical plungers, which insert into slots positioned along the tracks as shown in Figure 3-2. An active/passive seismic restraint system is also used on the MHM bridge, with the active portion consisting of spring-loaded brakes. When the MHM is moving between storage tube positions, the active seismic restraints are not engaged. During MHM moving operations, a wheel uplift, induced by a seismic event, could result in lateral loads on the seismic uplift hardware, as illustrated in Figure 3-3.

Figure 3-2 - MHM Trolley Seismic Constraints

M&D Professional Services	CALCULATION SHEET	Page No. 9 of 26
Client / Location Fluor Daniel Hanford	Prepared By / Date <i>BW 4-18-00</i>	Calculation No. 00-0002-E
Subject MHM Trolley Uplift Constraint Loading	Checked By / Date <i>MON 4/18/00</i>	Revision No. 0
Ref. Drawing(s) EDERER Drawing No. C-3466	Revised By / Date	Supporting Document No.

Figure 3-3 - MHM Trolley Seismic Uplift Constraint Geometry and Potential Loading

4.0 DESIGN INPUT AND ASSUMPTIONS

The seismic analyses performed in the remainder of this report utilized the design/analysis input information summarized in Table 4-1.

Table 4-1 – Analysis Input Parameters

Input Item	Value/Reference
MHM Drawings	Reference 14
MHM Assembly Weight	932,000 lbf
MHM Trolley/Turret Weight (Including MCO)	398,200 lbf Appendix B of Reference 7
ALSTHOM Seismic Analysis Results	Reference 3
ALSTHOM E Mail	Reference 4
MHM Assembly Base Response Spectra	Figures 16-18, Reference 3

The following assumptions have been utilized in the MHM trolley seismic uplift restraint loading evaluation and analysis:

- 1) The MHM bridge and trolley boundary conditions, specified in Table NOG-4154.3-1 (Reference 1), are assumed for the linear analyses. The NOG-1 boundary conditions result in trolley/bridge vertical coupling at all four corners of the trolley and east-west coupling of the two western trolley wheels. To allow vertical uplift and sliding of the trolley wheels, the

M&D Professional Services	CALCULATION SHEET		Page No. 10 of 26
Client / Location Fluor Daniel Hanford	Prepared By / Date <i>BW</i> 4-18-00	Calculation No. 00-0002-E	
Subject MHM Trolley Uplift Constraint Loading	Checked By / Date <i>MDR</i> 4/18/00	Revision No. 0	
Ref. Drawing(s) EDERER Drawing No. C-3466	Revised By / Date	Supporting Document No.	

nonlinear model introduces gap/friction elements at the wheels.

- 2) The ALSTHOM seismic model (Reference 3) was assumed to be an accurate representation of the MHM assembly geometry. The ALSTHOM seismic model was used to establish the trolley/turret center of gravity and validate the adequacy of the simplified model.
- 3) The bridge wheels were conservatively assumed to be coupled (infinite friction) to the bridge rails.
- 4) A conservative friction coefficient of 0.8 was assumed at the trolley west-wheel-to-rail interface for the nonlinear time history analysis.

5.0 EVALUATION APPROACH

As introduced in Section 1.0 the primary MHM structural issue associated with a seismic event occurring during MHM repositioning operations, is the potential for introducing lateral loads on the bridge and trolley seismic uplift restraints. Conservative preliminary calculations were performed using bounding lateral loads equal to the ALSTHOM predicted vertical loads times an appropriate friction coefficient. The results of the preliminary calculations indicated that the introduction of lateral loading is not a problem for the bridge uplift restraints, but indicated a structural inadequacy for the trolley uplift restraints. Final calculations for the bridge uplift restraints, including lateral friction loading, were generated and are provided in Appendix E.

Based upon the results of the preliminary structural evaluations, the current evaluation focused on the trolley uplift restraints. The evaluation was centered on the development of a simplified seismic model which concentrates on the trolley/bridge interfaces (trolley wheels and uplift restraints). A simplified model was generated for the purpose of performing nonlinear time history analyses. The following procedure summarizes the steps taken in the development and application of the simplified model:

1. The ALSTHOM seismic analysis was reviewed and evaluated relative to the trolley uplift restraint seismic loading. In the review process, a copy of the ALSTHOM model was obtained and several computer runs were made for the purpose of developing confidence in and familiarity with the model.
2. Using the ALSTHOM seismic computer model, trolley wheel reactions for 1 g loadings (north/south, east/west, and vertical) were used to determine the center of gravity of the trolley/turret hardware.
3. Using the bridge girder and trolley frame section properties from the ALSTHOM model plus the trolley/turret center of gravity location from Step 2, a relatively simple computer model of the MHM assembly was developed corresponding to ASME NOG-1 model illustrated in Figure NOG-4154.3-1 (Reference 1). Rigid links were used between the trolley frame and the trolley/turret center of gravity. The total mass of the trolley/turret assembly (398,200 lb) was concentrated at the center of gravity location. Gap elements were introduced at the trolley/bridge interfaces (compression only elements at the wheel/rail interfaces and tension

M&D Professional Services	CALCULATION SHEET		Page No. 11 of 26
Client / Location Fluor Daniel Hanford	Prepared By / Date <i>BW</i> 4-18-00	Calculation No. 00-0002-E	
Subject MHM Trolley Uplift Constraint Loading	Checked By / Date <i>MDR</i> 4/18/00	Revision No. 0	
Ref. Drawing(s) EDERER Drawing No. C-3466	Revised By / Date	Supporting Document No.	

- only elements at the uplift restraint/bridge girder interfaces). For linear analysis purposes, the gap was locked and the interface element becomes a linear spring.
4. Using the model developed in Step 3, static acceleration loads were applied to determine the sensitivity of the interface forces to the interface stiffness (gap element spring constants). An estimate of the tension-only, gap-element spring constant was made by developing a finite element model of the trolley uplift restraint.
 5. Using the simplified model, equivalent static seismic analyses were performed using 1.5 times the peak spectral g values, as specified by the "Equivalent Static Load Method" discussed in Section II of Reference 8. Response spectrum seismic analyses were also performed with the simplified model. Comparisons were made with the ALSTHOM seismic analysis results as a check on the simplified model. Interface spring constant values were selected to give the best comparison to the ALSTHOM results. A modal analysis of the linear simplified model was performed to compare the dynamic properties of the simple model with the ALSTHOM model.
 6. Since the trolley/bridge interface load path is different for tension and compression loading (tension through the uplift restraints, compression through the wheels), ALSTHOM attempted to account for this nonlinearity with their linear model by running five different configurations (Cases A through E). Case C gave the highest uplift force. The Case C results were used to benchmark the linear simplified model results. Both wheel and uplift restraint loads were compared for the ALSTHOM and simplified model results.
 7. Response spectra and time history seismic analyses were performed using the linear version of the simplified model.
 8. A nonlinear time history analysis was performed for the purpose of predicting wheel liftoffs and uplift restraint gap closures.

The details of the simplified model development and applications follow below.

6.0 SIMPLIFIED FINITE ELEMENT MODEL DEVELOPMENT

6.1 MODEL DESCRIPTION

A simplified finite element model of the MHM assembly was developed using the ANSYSTM computer code. The first step in the simplified model development was to establish the center of gravity of the trolley/turret assembly (all hardware supported by the trolley wheels). The calculations establishing the trolley/turret assembly center of gravity are provided in Appendix A. As indicated, the calculated center of gravity is located about 10 in., horizontally from the center of the trolley and about 40 in. below the top of the trolley rail rails.

Plots of the simplified finite element model of the MHM accounting for the uplift/wheel offset and the half-inch gap are shown in Figure 6-1 and Figure 6-2. The model configuration and boundary

TM ANSYS is a registered trademark of ANSYS Analysis Inc.

M&D Professional Services	CALCULATION SHEET		Page No. 12 of 26
Client / Location Fluor Daniel Hanford	Prepared By / Date <i>BW</i> 4-18-00	Calculation No. 00-0002-E	
Subject MHM Trolley Uplift Constraint Loading	Checked By / Date <i>MDR</i> 4/18/00	Revision No. 0	
Ref. Drawing(s) EDERER Drawing No. C-3466	Revised By / Date	Supporting Document No.	

conditions correspond to Figure NOG-4154.3-1 of ASME NOG-1-1995. The model structural elements are limited to the primary structural elements of the bridge and trolley, i.e. the girders and connecting end beams for the bridge and the box beams of the trolley frame (including the diagonal corner braces). The quarter-point trolley location shown was selected to correspond to the highest seismic uplift force configuration reported in the ALSTHOM seismic analysis (Reference 3). The bounding nature of the quarter-point trolley location was confirmed by comparing results from a center-point trolley model (not shown). The boundary conditions at the bridge and trolley wheel locations correspond to the restraints specified by Table NOG-4154.3-1.

Gap elements were used at the bridge/trolley interface locations. The gap elements are located at the ends of the horizontal rigid links at the rail elevation. These links can be seen in Figure 3-1 as the small horizontal elements projecting inward from the corner of the trolley frame. The gap elements were used to properly account for the load path differences for the downward and upward bridge/trolley interface loading. That is, compression loads are carried through the wheel/track interface and tensile loads are carried at the seismic uplift constraint. The compressive and tensile interface locations are about 23 in. apart.

The ANSYSTM COMBIN40 gap element was initially selected for the interface elements because it has both gap (wheel interface) and hook (uplift restraint) capability. For linear runs, the COMBIN40 "GAP" real constant was set to exactly zero which prevents separation at the interface. For the nonlinear time history runs, which introduced sliding/friction at the wheel/rail interface, the CONTAC52 interface element was used at the wheel/rail locations because CONTAC52 has friction capability.

The vertical line projecting downward from near the center of the trolley connects the trolley frame elements to the trolley/turret center of gravity located 40 in. below the top of the rails. A concentrated mass of 398,200-lb was placed at the center of gravity location.

M&D Professional Services	CALCULATION SHEET	Page No. 13 of 26
Client / Location Fluor Daniel Hanford	Prepared By / Date <i>BW</i> 4-18-00	Calculation No. 00-0002-E
Subject MHM Trolley Uplift Constraint Loading	Checked By / Date <i>MDN</i> 4/18/00	Revision No. 0
Ref. Drawing(s) EDERER Drawing No. C-3466	Revised By / Date	Supporting Document No.

Figure 6-1 - Beam Centerline Plot of MHM Simplified Model

M&D Professional Services	CALCULATION SHEET		Page No. 14 of 26
Client / Location Fluor Daniel Hanford	Prepared By / Date <i>BW</i> 4-18-00	Calculation No. 00-0002-E	
Subject MHM Trolley Uplift Constraint Loading	Checked By / Date <i>MDN</i> 4/18/00	Revision No. 0	
Ref. Drawing(s) EDERER Drawing No. C-3466	Revised By / Date	Supporting Document No.

Figure 6-2 - Model Plot Showing Beam Element Cross-Sectional Dimensions

M&D Professional Services	CALCULATION SHEET		Page No. _____ of _____
			15 26
Client / Location Fluor Daniel Hanford		Prepared By / Date <i>BN 4-18-00</i>	Calculation No. 00-0002-E
Subject MHM Trolley Uplift Constraint Loading		Checked By / Date <i>MON 4/18/00</i>	Revision No. 0
Ref. Drawing(s) EDERER Drawing No. C-3466		Revised By / Date	Supporting Document No.

Figure 6-3 - Simplified Model Fundamental Mode Shape

6.2 SIMPLIFIED MODEL ADEQUACY EVALUATION

To verify the adequacy of the simplified model for performing a nonlinear seismic analysis, comparisons were made with the ALSTHOM linear seismic analysis results. In an effort to bound the nonlinear response at the trolley/bridge interface locations, ALSTHOM developed five different models with various combinations of interface coupling. The maximum uplift restraint loads from the ALSTHOM analysis results were associated with Case C, which couples the uplift restraints on

M&D Professional Services	CALCULATION SHEET	Page No. 16 of 26
Client / Location Fluor Daniel Hanford	Prepared By / Date <i>BW</i> 4-18-00	Calculation No. 00-0002-E
Subject MHM Trolley Uplift Constraint Loading	Checked By / Date <i>MDN</i> 4/18/00	Revision No. 0
Ref. Drawing(s) EDERER Drawing No. C-3466	Revised By / Date	Supporting Document No.

the northern bridge girder and the wheels at the south girder. This Case C linear model was selected as a benchmark case for evaluating the adequacy of the simplified model.

As an initial check on the simplified model adequacy, a modal analysis was performed, resulting in the mode 1 fundamental frequency of 2.589 hz, as shown in Figure 6-3. This frequency compares very favorably with the ALSTHOM quarter-point seismic model fundamental frequency of 2.597 hz (Figure F22, Reference 3).

A response spectrum seismic analysis was also performed using the simplified model for the Case C interface configuration. The simplified model results are compared with the ALSTHOM results in Figure 6-4. Note that at two locations the simplified model forces are higher and at the other two locations, the ALSTHOM model predictions are higher. The average interface forces are almost identical. A similar comparison was found for a comparison of bridge wheel reactions, as indicated in Figure 6-5. This interface force comparison is judged to be favorable when considering the difference in detail between the two models.

Figure 6-4 - Comparison of ALSTHOM and Simplified Model Seismic Trolley/Bridge Interface Force Predictions

M&D Professional Services	CALCULATION SHEET		Page No. 17 of 26
Client / Location Fluor Daniel Hanford	Prepared By / Date <i>BW</i> 4-18-00	Calculation No. 00-0002-E	
Subject MHM Trolley Uplift Constraint Loading	Checked By / Date <i>MON</i> 4/18/00	Revision No. 0	
Ref. Drawing(s) EDERER Drawing No. C-3466	Revised By / Date	Supporting Document No.

Figure 6-5 - Comparison of ALSTHOM and the Simplified Model Bridge Wheel Reaction Loads

With the interface elements locked (linear configuration), the interface forces are sensitive to the interface stiffness (interface element spring constant). The above results are associated with an interface spring constant of 1×10^8 lb/in. The results were found to be sensitive to the interface stiffness, which is due to fact that the linear models lock the trolley wheels to the rails, forcing the trolley frame to artificially follow the same deflection pattern as the supporting rails (bridge girders). This interface sensitivity emphasizes the difficulty of using a linear model to predict the trolley/bridge interface seismic loading. The actual MHM interface configuration is very compliant, due to the ability of the wheels to separate from the rails at a wheel/rail interface. Also, as discussed in Section 1.0, the uplift restraints are loaded only when wheel uplifts exceed 0.5 in. A nonlinear seismic analysis, which allows for wheel separation and uplift restraint gap closure follows below.

M&D Professional Services	CALCULATION SHEET		Page No. 18 of 26
Client / Location Fluor Daniel Hanford	Prepared By / Date <i>BW</i> 4-18-00	Calculation No. 00-0002-E	
Subject MHM Trolley Uplift Constraint Loading	Checked By / Date <i>MDR</i> 4/18/00	Revision No. 0	
Ref. Drawing(s) EDERER Drawing No. C-3466	Revised By / Date	Supporting Document No.	

7.0 NONLINEAR TIME HISTORY ANALYSIS

7.1 TIME HISTORY INPUT

Acceleration time histories at the CSB floor elevation were generated by the soil-structural interaction (SSI) analyses (Reference 13) for the east-west, north-south, and vertical directions. However, the three SSI time histories do not meet the "statistically independent" requirement specified in Section 2.3.1 (d) of Reference 9. Therefore, uncorrelated time histories were generated which bounded the CSB floor elevation design response spectra. Time history development details are provided in Appendix D. For a nonlinear analysis, Section 3.2.2.3 (d) of Reference 9 requires that "more than one set of acceleration time histories...should be used". Therefore, the Appendix D time history development documentation addresses the development of two independent sets of acceleration time histories.

7.2 NONLINEAR TIME HISTORY ANALYSIS DETAILS

The simplified model shown in Figure 6-1 and Figure 6-2 was used in the nonlinear time history analysis with some minor modifications to the trolley/bridge interface elements. Referring to Figure 7-2, the friction/gap elements at the wheel/rail interface are ANSYSTM CONTAC52 elements and the hook elements at the uplift restraint locations are ANSYSTM COMBIN40 elements. The use of friction/gap elements at the wheels allows for wheel sliding along the rails if the east/west force exceeds the frictional resistance. The drive wheels at the west end of the trolley, were assume to be locked against rotation. Locked wheels, with frictional sliding, is a conservative representation of the actual drive wheel response, which may experience some wheel rolling.

A bounding friction coefficient of 0.8 was conservatively used for the trolley drive wheels. For the free rolling east trolley wheels, a friction coefficient of 0.1 was used. Appendix F contains friction data for crane wheels on rails obtained from a vendor, plus friction data taken from NUREG/CR-5912, Reference 10. The crane wheel static friction coefficients range from 0.45 to 0.55, and sliding coefficients as low as 0.21 are reported. For fuel racks on stainless steel pool liners, a friction coefficient range of 0.2 to 0.8 is recommended in the NUREG document. This upper bound value of 0.8 also corresponds to the bounding steel-to-steel coefficient of 0.78 found in Mark's Handbook, Reference 6.

The eastern side quarter point trolley location was selected as the bounding location, based upon the ALSTHOM analysis (Appendix C). The two sets of east/west, north/south, and vertical time histories described in Appendix D were used for the time history analyses. Three time histories plus a 1 g dead weight loading were simultaneously applied.

Structural damping was introduced using the ANSYSTM ALPHAD and BETAD factors corresponding to a critical damping of 7%. Based upon the modal analyses, the dominant MHM

M&D Professional Services	CALCULATION SHEET		Page No. 19 of 26
Client / Location Fluor Daniel Hanford	Prepared By / Date <i>BW</i> 4-18-00	Calculation No. 00-0002-E	
Subject MHM Trolley Uplift Constraint Loading	Checked By / Date <i>MOR</i> 4/18/00	Revision No. 0	
Ref. Drawing(s) EDERER Drawing No. C-3466	Revised By / Date	Supporting Document No.	

modes were between 2 and 10 hz. Using an ALPHAD factor of 1.47 and a BETAD factor of 0.00185 results in the damping versus frequency curve shown in Figure 7-1.

Figure 7-1 - Damping Versus Frequency, Alpha-Beta Damping

A damping level of 7% is consistent with the value specified for an SSE in ASME NOG-1, Para. NOG-4153.8 (Reference 1). The 7% damping also corresponds to the damping specified in Table 2-3 of DOE Standard 1020 (Reference 12) for a bolted structure, response level 2. A “response level 2” is justified on the basis that the seismic stresses are greater than half of the “code specified capacity”. In the EDERER design calculations (Reference 11), the reported stress levels are typically greater than half of the allowables. For example, from page SG4, for the main girders, a seismic stress level of 28 ksi is reported versus an allowable of 34 ksi (90% of the material yield strength). The ANSYSTM input listing is provided in Appendix A.

M&D Professional Services	CALCULATION SHEET	Page No. 20 of 26
Client / Location Fluor Daniel Hanford	Prepared By / Date <i>BW</i> 4-18-00	Calculation No. 00-0002-E
Subject MHM Trolley Uplift Constraint Loading	Checked By / Date <i>MDN</i> 4/18/00	Revision No. 0
Ref. Drawing(s) EDERER Drawing No. C-3466	Revised By / Date	Supporting Document No.

The nonlinear time history analysis results are summarized in Figure 7-3 and Figure 7-4. The shown wheel forces and wheel uplift displacements are the maximum predictions (forces: 2nd time histories, displacement: 1st time histories) Note that a maximum wheel interface force of 276 kips was predicted along with a maximum wheel/rail separation of 0.05 in. This maximum wheel lift off prediction is well below the nominal uplift restraint design gap of 0.5 in. Since the uplift restraint gap does not close, the uplift restraint experiences no loading. The 276 kip wheel load is less than the maximum wheel load prediction of 333 kips (1480.8 KN), listed in Table E1 of the ALSTHOM results (See Appendix C).

Another analysis output item of interest is the degree of east-west sliding of the trolley on the trolley rails. The predicted east-west deformations of the trolley is illustrated in Figure 7-5. Note that the range of movement is 2.7 in.

M&D Professional Services	CALCULATION SHEET		Page No.	of
			21	26
Client / Location Fluor Daniel Hanford		Prepared By / Date <i>BW 4-18-00</i>	Calculation No. 00-0002-E	
Subject MHM Trolley Uplift Constraint Loading		Checked By / Date <i>MDL 4/18/00</i>	Revision No. 0	
Ref. Drawing(s) EDERER Drawing No. C-3466		Revised By / Date	Supporting Document No.	

Figure 7-2 - Trolley/Bridge Interface Elements for Nonlinear Time History Analysis

Figure 7-3 - Trolley Wheel Interface Force Predictions, 2nd Time History

M&D Professional Services	CALCULATION SHEET		Page No.	of
			22	26
Client / Location Fluor Daniel Hanford		Prepared By / Date <i>BW</i> 4-18-00	Calculation No. 00-0002-E	
Subject MHM Trolley Uplift Constraint Loading		Checked By / Date <i>MDN</i> 4/18/00	Revision No. 0	
Ref. Drawing(s) EDERER Drawing No. C-3466		Revised By / Date	Supporting Document No.

Figure 7-4 - Wheel Interface Gap Predictions, 1st Time History

M&D Professional Services	CALCULATION SHEET		Page No. 23 of 26
Client / Location Fluor Daniel Hanford	Prepared By / Date <i>BA</i> 4-18-00	Calculation No. 00-0002-E	
Subject MHM Trolley Uplift Constraint Loading	Checked By / Date <i>MDT</i> 4/18/00	Revision No. 0	
Ref. Drawing(s) EDERER Drawing No. C-3466	Revised By / Date	Supporting Document No.

Figure 7-5 - Trolley East-West Movement Predictions, 2nd Time History

M&D Professional Services	CALCULATION SHEET		Page No. 24 of 26
Client / Location Fluor Daniel Hanford	Prepared By / Date <i>BW</i> 4-18-00	Calculation No. 00-0002-E	
Subject MHM Trolley Uplift Constraint Loading	Checked By / Date <i>MPN</i> 4/18/00	Revision No. 0	
Ref. Drawing(s) EDERER Drawing No. C-3466	Revised By / Date	Supporting Document No.	

7.3 BRIDGE UPLIFT RESTRAINT STRUCTURAL EVALUATION

If a seismic event occurred during MHM repositioning operations, the bridge wheels could potentially lift off and load the bridge seismic uplift restraints. With the bridge active seismic restraints are not activated, bridge movement in the direction of the bridge rails could result in lateral friction loading on the uplift restraints. This combined vertical/lateral seismic load condition is addressed in the Appendix E calculations. A brief summary of the results follows below.

As illustrated in Appendix E, the bridge uplift restraint consists of two two-inch uplift plates, two toe plates, two 3/4-in. assembly bolts, and a 2-3/4-in. attachment pin. From the calculation results, the minimum safety margin for the seismic design loading is associated with bending in the attachment pin. A bending stress of 24 ksi is predicted, which compares to an allowable bending stress of 79.2 ksi. The resulting safety margin is

$$MS = \frac{79.2}{24} - 1 = +2.30$$

Thus, the bridge uplift restraint hardware is structurally adequate for the combined vertical/lateral seismic loading.

M&D Professional Services	CALCULATION SHEET		Page No. 25 of 26
Client / Location Fluor Daniel Hanford	Prepared By / Date <i>BW</i> 4-18-00	Calculation No. 00-0002-E	
Subject MHM Trolley Uplift Constraint Loading	Checked By / Date <i>MON</i> 4/18/00	Revision No. 0	
Ref. Drawing(s) EDERER Drawing No. C-3466	Revised By / Date	Supporting Document No.	

8.0 REFERENCES

1. NOG-1-1995. *Rules for Construction of Overhead and Gantry Cranes (Top Running Bridge Multiple Girder)*, American Society of Mechanical Engineers. ANSI/ASME NOG-1-1995.
2. EDERER Drawing C-34966 Rev. D Seismic Restraint Uplift trolley.
3. ALSTHOM-1998, *Seismic Analysis of Hanford MCO Handling Machine* Report August 1998 Rev. 3
4. ALSTHOM-2000, e-mail, "Uplift on Trolley Wheels and Hooks" (Appendix C)
5. FDH 1999, Nonconformance Report No. 00-SNFP-0008, SNF Program, W-379 Project, Fluor Daniel Hanford Company, Richland, Washington.
6. *Mark's Standard Handbook for Mechanical Engineers*, Ninth Edition, McGraw-Hill.
7. M&D 2000, *Structural Analysis of MCO for Accidental Movement of MHM During MCO Lifting Operations*, Rev. 1, Calculation No. 00-003, M&D Professional Services, Richland, Washington.
8. US Nuclear Regulatory Commission Standard Review Plan, Section 3.7.2, 1981.
9. ASCE 1986, *Seismic Analysis of Safety-Related Nuclear Structures and Commentary on Standard for Seismic Analysis of Safety Related Nuclear Structures*, American Society of Civil Engineers, New York City, New York.
10. DeGrassi, G., 1992, Review of the Technical Basis and Verification of Current Analysis Methods Used to Predict Seismic Response of Spent Fuel Storage Racks, NUREG/CR-5912, Brookhaven National Laboratory, Upton, New York.
11. EDERER 1997, *Section D, Components: Bridge Girder and End Tie Beam, Loading: Seismic*, Rev. 2, Project No. F-2566, EDERER Services Inc., Seattle, Washington.
12. DOE 1994, *Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities*, DOE-STD-1020-94, U.S. Department of Energy, Washington D.C.
13. CEC 1997, Three-Dimensional Seismic Soil-Structure Interaction Analyses of SNF-CSB Using SASSI Computer Program, International Civil Engineering Consultants, Inc., Berkeley, California.
14. MHM Drawings:

Description of Assembly

ALSTHOM/ EDERER Drawing No.

Turret Assembly	362A0558
Alignment Cylinder Assembly	-
Anti-collision System Assembly	362A0568
Base Locking Pin Assembly	362A0554
Base Shielding Assembly	362A0697

M&D Professional Services	CALCULATION SHEET		Page No. 26 of 26
Client / Location Fluor Daniel Hanford	Prepared By / Date <i>BN</i> 4-18-00	Calculation No. 00-0002-E	
Subject MHM Trolley Uplift Constraint Loading	Checked By / Date <i>MDR</i> 4/18/00	Revision No. 0	
Ref. Drawing(s) EDERER Drawing No. C-3466	Revised By / Date	Supporting Document No.	

Description of Assembly

ALSTHOM/
EDDERER
Drawing No.

Base Torsion Link Assembly	362A0555
Bridge Erection Drawing MHM Gantry Crane	D-35205
Extract System General Arrangement	362A0863
Lower Access Platform	362A0822
Lower Mid Shielding Assembly	362A0696
Lower Platform Assembly	362A0812
Lower Shield Body	362A0657
MCO Grapple Assembly	362A0563
MCO Grapple Pneumatic Panel Assembly	362A0866
MCO Hoist Assembly	362A0578
Middle Shielding Assembly	362A0695
Nose Shield Body Fab	362A0658
Plug Hoist Guard Assembly	362A0821
Retractable Nose Unit Assembly	362A0561
Retractable Shield Skirt Assembly	362A0556
Seismic Restraint Jack (2)	362A0560
Shield Plug Hoist & Grapple Assembly	362A0557
Shield Plug Shielding	362A0664
Shielding Cylinder	362A0663
Shielding Flange	362A0663
Transition Shield Body	362A0656
Trolley Arrangement Drawing	D-34960
Trolley Seismic Restraint "X" Dir (2)	362A0559
Turret Assembly	362A0551
Upper Containment Hoist Assembly	362A0578
Upper Mid Shielding Assembly	362A0694
Upper Platform Assembly	362A0820
Upper Shield Body	362A0655
Upper Shielding Assembly	362A0693

M&D Professional Services	CALCULATION SHEET		Page No. of A1 A6
Client / Location Fluor Daniel Hanford	Prepared By / Date <i>MDL 4/18/00</i>	Calculation No. 00-0002-E	
Subject MHM Trolley Uplift Constraint Loading	Checked By / Date <i>BW 4-18-00</i>	Revision No. 0	
Ref. Drawing(s)	Revised By / Date	Supporting Document No.	

APPENDIX A CENTER OF GRAVITY CALCULATION

M&D Professional Services	CALCULATION SHEET		Page No. of A2 A6
Client / Location Fluor Daniel Hanford	Prepared By / Date <i>MDA</i> 4/18/00	Calculation No. 00-0002-E	
Subject MHM Trolley Uplift Constraint Loading	Checked By / Date <i>BW</i> 4-18-00	Revision No. 0	
Ref. Drawing(s)	Revised By / Date	Supporting Document No.

ALSTHOM TROLLEY/TURRET MODEL

M&D Professional Services	CALCULATION SHEET		Page No. A3 of A6
Client / Location Fluor Daniel Hanford	Prepared By / Date <i>MON</i> 4/18/00	Calculation No. 00-0002-E	
Subject MHM Trolley Uplift Constraint Loading	Checked By / Date <i>BN</i> 4-18-00	Revision No. 0	
Ref. Drawing(s)	Revised By / Date	Supporting Document No.	

1 "G" LOAD IN "X" DIRECTION

THE FOLLOWING X,Y,Z SOLUTIONS ARE IN GLOBAL COORDINATES

POUNDS

NODE	FX	FY	FZ	MX	MY	MZ
383		-38642.	44429.	0.60374E-03	0.33874E-03	-0.25727E-05
393	-0.19921E+06			-0.41003E-04	-0.51455E-05	0.87902E-05
394		59122.	-44425.	0.13413E-02	0.14740E-03	0.40135E-03
408		37021.	46088.	0.59345E-03	0.10771E-02	0.43522E-04
413	-0.19897E+06			0.82542E-05	0.32588E-04	0.10720E-06
418		-57501.	-46092.	-0.18266E-02	0.30015E-04	-0.36533E-03

TOTAL VALUES

VALUE -0.39818E+06 -0.38730E-01 -0.62548E-02 0.67904E-03 0.16207E-02 0.85865E-04

THE FOLLOWING X,Y,Z SOLUTIONS ARE IN GLOBAL COORDINATES

NEWTONS

NODE	FX	FY	FZ	MX	MY	MZ
383		-0.17189E+06	0.19763E+06	0.26855E-02	0.15068E-02	-0.11444E-04
393	-0.88614E+06			-0.18239E-03	-0.22888E-04	0.39101E-04
394		0.26298E+06	-0.19761E+06	0.59662E-02	0.65565E-03	0.17853E-02
408		0.16468E+06	0.20501E+06	0.26398E-02	0.47913E-02	0.19360E-03
413	-0.88504E+06			0.36716E-04	0.14496E-03	0.47684E-06
418		-0.25578E+06	-0.20503E+06	-0.81253E-02	0.13351E-03	-0.16251E-02

M&D Professional Services	CALCULATION SHEET		Page No. of A4 A6
			Calculation No. 00-0002-E
Client / Location Fluor Daniel Hanford	Prepared By / Date MON 4/18/00	Calculation No. 00-0002-E	
Subject MHM Trolley Uplift Constraint Loading	Checked By / Date BW 4-18-00	Revision No. 0	
Ref. Drawing(s)	Revised By / Date	Supporting Document No.	

TOTAL VALUES

VALUE -0.17712E+07-0.17228 -0.27823E-01 0.30205E-02 0.72093E-02 0.38195E-03

Sum moments about Axis_Z:

$$(177.2)(44425+46092)=(CG_z)(398180)$$

$$CG_z=40.3 \text{ inches}$$

Sum moments about Axis_Y:

$$(173.2)(198970)+(177.2/2)(57501+37021-38642-59122)=(CG_y)(398180) \quad CG_y=85.8 \text{ inches}$$

1 "G" LOAD IN "Y" DIRECTION

THE FOLLOWING X,Y,Z SOLUTIONS ARE IN GLOBAL COORDINATES

POUNDS

NODE	FX	FY	FZ	MX	MY	MZ
383	-0.49740E-04	-96617.	-31664.	-0.60511E-02	-0.71694E-03	0.34303E-05
393	17358.	-0.11500E-02		0.11615E-01	-0.60974E-03	0.13614E-04
394	0.37734E-04	-0.10283E+06	-61033.	-0.12898E-02	0.43565E-03	-0.54799E-03
408	-0.32588E-04	-93742.	31650.	0.10291E-03	0.26070E-03	-0.51455E-05
413	-17358.	0.24270E-03		-0.27854E-02	0.56600E-04	-0.16080E-06
418	-0.49740E-04	-0.10499E+06	61046.	-0.17975E-02	-0.84386E-03	0.61403E-03

TOTAL VALUES

VALUE -0.15022 -0.39818E+06 0.10527E-01-0.20582E-03-0.14176E-02 0.77772E-04

M&D Professional Services	CALCULATION SHEET	Page No. of A5 A6
Client / Location Fluor Daniel Hanford	Prepared By / Date MON 7/18/00	Calculation No. 00-0002-E
Subject MHM Trolley Uplift Constraint Loading	Checked By / Date BW 4-18-00	Revision No. 0
Ref. Drawing(s)	Revised By / Date	Supporting Document No.

THE FOLLOWING X,Y,Z SOLUTIONS ARE IN GLOBAL COORDINATES

NEWTONS

NODE	FX	FY	FZ	MX	MY	MZ
383	-0.22125E-03	-0.42977E+06	-0.14085E+06	-0.26917E-01	-0.31891E-02	0.15259E-04
393	77213.	-0.51155E-02		0.51666E-01	-0.27122E-02	0.60558E-04
394	0.16785E-03	-0.45742E+06	-0.27149E+06	-0.57373E-02	0.19379E-02	-0.24376E-02
408	-0.14496E-03	-0.41698E+06	0.14079E+06	0.45776E-03	0.11597E-02	-0.22888E-04
413	-77213.	0.10796E-02		-0.12390E-01	0.25177E-03	-0.71526E-06
418	-0.22125E-03	-0.46700E+06	0.27155E+06	-0.79956E-02	-0.37537E-02	0.27313E-02
TOTAL VALUES						
VALUE	-0.66822	-0.17712E+07	0.46826E-01	-0.91553E-03	-0.63057E-02	0.34595E-03

Sum moments about Axis X:

$$(173.2)(61046+31650)=(CG_z)(398179)$$

$$CG_z=40.3 \text{ inches}$$

Sum moments about Axis Y:

$$(173.2)(17358)+(177.2/2)(-96617-93742+102830+104990)=(CG_x)(398179)$$

$$CG_x=11.4 \text{ inches}$$

1 "G" LOAD IN "Z" DIRECTION

M&D Professional Services	CALCULATION SHEET		Page No.	of
			A6	A6
Client / Location Fluor Daniel Hanford		Prepared By / Date <i>MDN</i> 4/18/00	Calculation No. 00-0002-E	
Subject MHM Trolley Uplift Constraint Loading		Checked By / Date <i>BW</i> 4-18-00	Revision No. 0	
Ref. Drawing(s)		Revised By / Date	Supporting Document No.	

THE FOLLOWING X,Y,Z SOLUTIONS ARE IN GLOBAL COORDINATES **POUNDS**

NODE	FX	FY	FZ	MX	MY	MZ
383	-0.34732E-04	36925.	-81005.	0.32931E-03	-0.55914E-03	0.21868E-04
393	3810.2	0.14236E-03		-0.12761E-02	0.72894E-04	0.40199E-06
394	0.10720E-04	63108.	-0.10627E+06	0.54885E-04	0.10634E-03	-0.47167E-05
408	0.17580E-04	-40650.	-82744.	0.27957E-03	-0.13721E-03	-0.64319E-05
413	-3810.3			-0.55571E-03	-0.24655E-04	0.53599E-07
418	-0.15265E-03	-59382.	-0.10102E+06	0.39620E-03	-0.16020E-02	-0.66463E-04
TOTAL VALUES						
VALUE	-0.65229E-02	0.14113E-01	-0.37103E+06	-0.77182E-03	-0.21437E-02	-0.55287E-04

THE FOLLOWING X,Y,Z SOLUTIONS ARE IN GLOBAL COORDINATES **NEWTONS**

NODE	FX	FY	FZ	MX	MY	MZ
383	-0.15450E-03	0.16425E+06	-0.36033E+06	0.14648E-02	-0.24872E-02	0.97275E-04
393	16949.	0.63324E-03		-0.56763E-02	0.32425E-03	0.17881E-05
394	0.47684E-04	0.28072E+06	-0.47269E+06	0.24414E-03	0.47302E-03	-0.20981E-04
408	0.78201E-04	-0.18082E+06	-0.36806E+06	0.12436E-02	-0.61035E-03	-0.28610E-04
413	-16949.			-0.24719E-02	-0.10967E-03	0.23842E-06
418	-0.67902E-03	-0.26414E+06	-0.44934E+06	0.17624E-02	-0.71259E-02	-0.29564E-03
TOTAL VALUES						
VALUE	-0.29015E-01	0.62778E-01	-0.16504E+07	-0.34332E-02	-0.95358E-02	-0.24593E-03

Sum moments about Axis X:

$$(173.2)(101020+82744)=(CGy)(371039)$$

$$CGy=85.8 \text{ inches}$$

Sum moments about Axis Z:

$$(177.2)(106270+101020)=(CGx+177.2/2)(371039)$$

$$CGx=10.4 \text{ inches}$$

M&D Professional Services	CALCULATION SHEET		Page No. of B1 B9
Client / Location Fluor Daniel Hanford	Prepared By / Date <i>CBW 4-18-00</i>	Calculation No. 00-0002-E	
Subject MHM Trolley Uplift Constraint Loading	Checked By / Date <i>MDN 4/18/00</i>	Revision No. 0	
Ref. Drawing(s)	Revised By / Date	Supporting Document No.	

APPENDIX B ANSYS™ INPUT LISTINGS

M&D Professional Services	CALCULATION SHEET		Page No. of B2 B9
Client / Location Fluor Daniel Hanford	Prepared By / Date <i>BW</i> 4-18-00	Calculation No. 00-0002-E	
Subject MHM Trolley Uplift Constraint Loading	Checked By / Date <i>MDR</i> 4/18/00	Revision No. 0	
Ref. Drawing(s)	Revised By / Date	Supporting Document No.	

A. Response Spectra Analysis, Case C

/prep7

/title, MHM Trolley Uplift Constraint Evaluation, k = 1e8
alls

!element types

et,1, BEAM4

et,2, MASS21,,,2

et,3, COMBIN40,,,3 !*****

!real constants

r,1,306.9,252500,463100,90.5,78.76,0 !Bridge Girders
rmore,,473600,2.79,1.56r,2,155.3,22003,114484,58.9,39,0 !Bridge Cross Beam
rmore,,43204,1.77,2.3r,3,226.3,24990,23002,28.5,27.32,0 !E/W Trolley Beam
rmore,,22485,1.46,3.17r,4,67.4,1745,8224,31.5,15.5,0 !N/S Trolley Beam
rmore,,3007,2.72,1.58r,5,24.8,21.1,2676,30.4,4.5,0 !Trolley Diag. Braces
rmore,,3.8,2,2

r,6,1000,1e7,1e7,10,10 !Rigid Links

r,11,1000,1e7,1e7,10,10 !Link to Trolley Mass

r,7,398200/g,398200/g,371000/g !Trolley/Turret Mass

(Weight: g units)

r,8,1e8,,,0.0 !Locked Gap Element

r,9,1e8,,,0.5 !Free Gap Element

r,10,10 !Soft spring for stability

!material prop.

!Bridge

mp,ex,1,29e6

mp,nuxy,1,0.3

!Rigid Links

mp,dens,1,,535/g !g units, 1.88 factor for misc.

mp,ex,2,29e6

mp,nuxy,2,0.3

mp,dens,2,0 !Rigid Links, Massless

!Trolley

mp,ex,3,29e6

mp,nuxy,3,0.3

mp,dens,3,0 !Trolley Beams, Massless

!Keypoints

!Bridge

k,1,0,215.3,0

k,2,0,0,0

k,3,0,215.3,140

k,4,0,0,140

k,5,1049.9,215.3,140

k,6,1049.9,194.2,140

k,7,1049.9,194.2,190

k,107,1049.9,194.2,191

k,207,1062.9,176.2,190 !200's & 300's: uplift restr. offsets

k,307,1062.9,176.2,191

k,8,1049.9,0,140

k,9,1049.9,21.1,140

k,10,1049.9,21.1,190

k,110,1049.9,21.1,191

k,210,1062.9,39.1,190

k,310,1062.9,39.1,191

k,11,1227.1,215.3,140

k,12,1227.1,194.2,140

k,13,1227.1,194.2,190

k,113,1227.1,194.2,191

k,213,1214.1,176.2,190

k,313,1214.1,176.2,191

k,14,1227.1,0,140

k,15,1227.1,21.1,140

k,16,1227.1,21.1,190

k,116,1227.1,21.1,191

k,216,1214.1,39.1,190

k,316,1214.1,39.1,191

k,17,1518,215.3,140

k,18,1518,0,140

k,19,1518,215.3,0

k,20,1518,0,0

k,101,0,215.3,70

k,102,0,0,70

k,119,1518,215.3,70

k,120,1518,0,70

!Trolley

k,21,1049.9,194.2,205.3

k,22,1049.9,136.5,205.3

k,23,1049.9,78.8,205.3

k,24,1049.9,21.2,205.3

k,25,1097.7,194.2,205.3

k,26,1097.7,21.1,205.3

k,27,1179.3,194.2,205.3

k,28,1179.3,21.1,205.3

k,29,1227.1,194.2,205.3

k,30,1227.1,136.5,205.3

k,31,1227.1,78.8,205.3

k,32,1227.1,21.1,205.3

k,33,1148.9,108.5,205.3

k,34,1148.9,108.5,145 !Trolley Mass

!Lines

!Bridge

l,1,101

l,101,3

l,2,102

l,102,4

l,101,102

l,3,5

l,4,8

M&D Professional Services	CALCULATION SHEET		Page No. of
			B3 B9
Client / Location Fluor Daniel Hanford	Prepared By / Date <i>BW</i> 4-18-00	Calculation No. 00-0002-E	
Subject MHM Trolley Uplift Constraint Loading	Checked By / Date <i>MDN</i> 4/18/00	Revision No. 0	
Ref. Drawing(s)	Revised By / Date	Supporting Document No.	

1,5,6	1,16,216
1,6,7	1,116,316
1,8,9	
1,9,10	/VIEW, 1, -0.570429549819 , -0.691644654110 ,
1,5,11	0.442987360016
1,8,14	/ANG, 1, 67.3683334857
1,11,12	!plo
1,12,13	
1,14,15	!Mesh Generation
1,15,16	!Bridge
1,11,17	real,6 !rigid end cols.
1,14,18	mat,2
1,19,119	esize,,1
1,119,17	lmesh,1,4
1,20,120	lmesh,20,23
1,120,18	real,2, !Bridge End Beams
1,119,120	mat,1
!Trolley	esize,,4
1,107,21 !Line 25	lmesh,5,24,19
1,110,24	real,1 !Bridge Girders
1,21,22	esize,50
1,22,23	lmesh,6,7
1,23,24	lmesh,12,13
1,21,25	lmesh,18,19
1,22,25	real,6 !rigid links to rails
1,22,33	mat,2
1,23,33	esize,,1
1,23,26	lmesh,8,11
1,24,26	lmesh,14,17
1,25,27	!Trolley
1,25,33	real,6 !rigid links
1,26,33	mat,2
1,26,28	esize,,1
1,27,33	lmesh,25,26
1,28,33	lmesh,51
1,27,29	real,11
1,27,30	lmesh,52
1,30,33	real,6
1,31,33	lmesh,32,33
1,28,31	lmesh,37,38
1,28,32	lmesh,40,41
1,29,30	lmesh,44,45
1,30,31	lmesh,53
1,31,32	real,3 !Trolley E/W Beams
1,113,29	mat,3
1,116,32	esize,25
1,33,34 !Link to Trolley Mass	lmesh,30
!Constraint Offsets	lmesh,35,36
1,7,207 !Line 53	lmesh,39,42,3
1,107,307	lmesh,47
1,10,210	real,4 !Trolley N/S Beams
1,110,310	lmesh,27,29
1,13,213	lmesh,48,50
1,113,313	real,5 !Trolley Diags.

M&D Professional Services	CALCULATION SHEET		Page No. of B4 B9
Client / Location Fluor Daniel Hanford	Prepared By / Date <i>BW 4-18-00</i>	Calculation No. 00-0002-E	
Subject MHM Trolley Uplift Constraint Loading	Checked By / Date <i>MON 4/18/00</i>	Revision No. 0	
Ref. Drawing(s)	Revised By / Date	Supporting Document No.	

lmesh,31,34,3
lmesh,43,46,3
real,7 !Turret Mass
type,2
e,104
real,6 !rigid links to uplift constraints
type,1
mat,2
esize,,1
lmesh,54,61
!Gap Elements
type,3
!Compression Eles.
real,9
e,80,87
real,8
e,82,89 !Wheel Locked on A
real,9
e,84,91
real,8
e,86,93 !Wheel Locked on A
!Tension Eles.
real,8
e,134,133 !Restraint Locked on B
real,9
e,136,135
real,8
e,138,137 !Restraint Locked on B
real,9
e,140,139
!Soft Springs
real,10
e,80,87
e,82,89
e,84,91
e,86,93

!Constraints
!d,1,ux,,,,uy,uz !all hooked up
!d,4,ux,,,,uz !all hooked up
d,1,uy,,,,uz !release
d,4,uz
d,7,ux,,,,uy,uz
d,10,ux,,,,uz

!dk,1,ux,,,,uy,uz
!dk,2,ux,,,,uz
!dk,19,ux,,,,uy,uz
!dk,20,ux,,,,uz
!dtran
cp,1,ux,80,87
cp,2,uy,80,87
cp,4,ux,82,89
cp,5,uy,82,89

cp,7,uy,84,91
cp,9,uy,86,93

!make component of reaction nodes
nset,s,node,,89,93,4
nset,a,node,,133,137,4
cm,modes,node
alls
epplot

fini
save
/solu
outpr,basic,none
outres,esol,all ! output element solution to result file
outres,nsol,all ! output nodal solution to results file
outres,rsol,all

/output,modal,out
antype,modal
modopt,subsp,20
mxpand,20,0,34,yes
/com,
/com, Case C wheels on Girder A, uplifts on Girder B
solve
fini
/out

/out,response,out
c***
c*** APPLY X FREQUENCY SPECTRUM East-West
c***
/solu

antype,spectrum
spopt,sprs ! single-point response spectrum
svtype,2,g ! acceleration scaled to in/sec^2
grp,,disp
sed,1 ! x direction
freq
freq,0.1 ,0.248 ,1.6 ,2.53 ,3.55 ,3.95 ,5.61 ,6.4 ,8.75 !freq
change points
freq,9.6 ,11.5 ,12.9 ,14.4 ,22.0 ,34.0 ,100
sv,1,0.017,0.102 ,0.66 ,0.66 ,0.59 ,0.64 ,0.64 ,0.55 ,0.55
!accel val in g
sv,1,0.46 ,0.46 ,0.43 ,0.37 ,0.28 ,0.24 ,0.24
c***
mcomb,grp,0.0001 ! combine modes with a
significance > 0.001
outpr,nsol,all
outres,nsol,all
outres,esol,all
solve
sed,,1 ! y direction

M&D Professional Services	CALCULATION SHEET		Page No. B5 of B9
Client / Location Fluor Daniel Hanford	Prepared By / Date <i>BW 7-18-00</i>	Calculation No. 00-0002-E	
Subject MHM Trolley Uplift Constraint Loading	Checked By / Date <i>MON 4/18/00</i>	Revision No. 0	
Ref. Drawing(s)	Revised By / Date	Supporting Document No.	

```

freq          ! erase previous table
freq,0.1 ,0.248 ,1.6 ,2.07 ,2.53 ,3.45 ,4.5 ,5.67 ,5.85 !freq
change points
freq,6.35 ,7.15 ,8.55 ,10.0 ,11.5 ,12.9 ,16.0 ,20.0 ,27.0
freq,34.0 ,100
sv,1,0.017,0.102 ,0.68 ,0.7 ,0.7 ,0.64 ,0.77 ,0.77 ,0.75 !accel
val in g
sv,1,0.75 ,0.65 ,0.65 ,0.46 ,0.46 ,0.41 ,0.31 ,0.29 ,0.29
sv,1,0.26 ,0.26
solve
sed,,1          * z direction
freq          * erase previous table
freq,0.1 ,0.248 ,1.6 ,4.5 ,5.31 ,9.03 ,12.32 ,15.7 ,18.0 !freq
change points
freq,29.0 ,34.0 ,100
sv,1,0.011,0.068 ,0.445 ,0.53 ,0.585,0.585,0.555,0.505,0.36
!accel val in g
sv,1,0.265,0.25 ,0.25
solve
save
fini
/post1
/input,,mcom
!lcooper,lprin
prnsol,dof
prrsol
lcwrite,1,,l09          ! write to file L09

fini
/out

```

M&D Professional Services	CALCULATION SHEET		Page No. B6 of B9
			Calculation No. 00-0002-E
Client / Location Fluor Daniel Hanford	Prepared By / Date <i>BW</i> 4-18-00	Revision No. 0	
Subject MHM Trolley Uplift Constraint Loading	Checked By / Date <i>MON</i> 4/18/00	Supporting Document No.	
Ref. Drawing(s)	Revised By / Date		

B. Nonlinear Time History, mmm Combin.

/config,nres,6000
 /output,uplift,out
 /prep7
 /title, MHM Nonlinear Seismic Analysis
 !element types
 et,1,BEAM4
 et,2,MASS21,,,2
 et,3,COMBIN40,,,3 !Uplift Gap Eles.
 et,4,CONTAC52 !Wheel Gap/Friction Eles.

g=386.4
 !real constants
 r,1,306.9,252500,463100,90.5,78.76,0 !Bridge Girders
 rmore,,473600,2.79,1.56
 r,2,155.3,22003,114484,58.9,39,0 !Bridge Cross Beam
 rmore,,43204,1.77,2.3
 r,3,226.3,2499,23002,28.5,27.32,0 !E/W Trolley Beam
 rmore,,22485,1.46,3.17
 r,4,67.4,1745,8224,31.5,15.5,0 !N/S Trolley Beam
 rmore,,3007,2.72,1.58
 r,5,24.8,21.1,2676,30.4,4.5,0 !Trolley Diag. Braces
 rmore,,3.8,2.2
 r,6,1000,1e7,1e7,10,10 !Rigid Links
 r,7,398200/g !Trolley/Turret Mass (Weight: g units)
 r,8,1e7,0 !Wheel/Compression Gap Element
 r,9,1e7,,,0.5 !Uplift/Tension Gap Element
 r,10,10 !Soft spring for stability
 r,11,1000,1e7,1e7,10,10 !Link to Trolley Mass

!material prop.
 !Bridge
 mp,ex,1,29e6
 mp,nuxy,1,0.3
 !Rigid Links
 mp,dens,1,.535/g !g units, 1.88 factor for misc.
 mp,ex,2,29e6
 mp,nuxy,2,0.3
 mp,dens,2,0 !Rigid Links, Massless
 !Trolley
 mp,ex,3,29e6
 mp,nuxy,3,0.3
 mp,dens,3,0 !Trolley Beams, Massless
 !Wheel Gap/Friction Eles.
 mp,mu,4,0.8 !Drive Wheels
 mp,mu,5,0.1 !Rolling Wheels

!Bridge
 k,1,0,215.3,0
 k,2,0,0,0
 k,3,0,215.3,140
 k,4,0,0,140
 k,5,1049.9,215.3,140

k,6,1049.9,194.2,140
 k,7,1049.9,194.2,190
 k,107,1049.9,194.2,191
 k,207,1062.9,176.2,190 !200's & 300's: uplift restr. offsets
 k,307,1062.9,176.2,191
 k,8,1049.9,0,140
 k,9,1049.9,21.1,140
 k,10,1049.9,21.1,190
 k,110,1049.9,21.1,191
 k,210,1062.9,39.1,190
 k,310,1062.9,39.1,191
 k,11,1227.1,215.3,140
 k,12,1227.1,194.2,140
 k,13,1227.1,194.2,190
 k,113,1227.1,194.2,191
 k,213,1214.1,176.2,190
 k,313,1214.1,176.2,191
 k,14,1227.1,0,140
 k,15,1227.1,21.1,140
 k,16,1227.1,21.1,190
 k,116,1227.1,21.1,191
 k,216,1214.1,39.1,190
 k,316,1214.1,39.1,191
 k,17,1518,215.3,140
 k,18,1518,0,140
 k,19,1518,215.3,0
 k,20,1518,0,0
 k,101,0,215.3,70
 k,102,0,0,70
 k,119,1518,215.3,70
 k,120,1518,0,70
 !Trolley
 k,21,1049.9,194.2,205.3
 k,22,1049.9,136.5,205.3
 k,23,1049.9,78.8,205.3
 k,24,1049.9,21.2,205.3
 k,25,1097.7,194.2,205.3
 k,26,1097.7,21.1,205.3
 k,27,1179.3,194.2,205.3
 k,28,1179.3,21.1,205.3
 k,29,1227.1,194.2,205.3
 k,30,1227.1,136.5,205.3
 k,31,1227.1,78.8,205.3
 k,32,1227.1,21.1,205.3
 k,33,1148.9,108.5,205.3
 k,34,1148.9,108.5,145 !Trolley Mass

!Lines
 !Bridge
 l,1,101
 l,101,3
 l,2,102
 l,102,4

M&D Professional Services	CALCULATION SHEET		Page No. B7 of B9
Client / Location Fluor Daniel Hanford	Prepared By / Date <i>BN 4-18-00</i>	Calculation No. 00-0002-E	
Subject MHM Trolley Uplift Constraint Loading	Checked By / Date <i>MON 4/18/00</i>	Revision No. 0	
Ref. Drawing(s)	Revised By / Date	Supporting Document No.	

I,101,102

I,3,5

I,4,8

I,5,6

I,6,7

I,8,9

I,9,10

I,5,11

I,8,14

I,11,12

I,12,13

I,14,15

I,15,16

I,11,17

I,14,18

I,19,119

I,119,17

I,20,120

I,120,18

I,119,120

!Trolley

I,107,21 !Line 25

I,110,24

I,21,22

I,22,23

I,23,24

I,21,25

I,22,25

I,22,33

I,23,33

I,23,26

I,24,26

I,25,27

I,25,33

I,26,33

I,26,28

I,27,33

I,28,33

I,27,29

I,27,30

I,30,33

I,31,33

I,28,31

I,28,32

I,29,30

I,30,31

I,31,32

I,113,29

I,116,32

I,33,34 !Link to Trolley Mass

!Seismic Restraint Offsets

I,7,207 !Line 53

I,107,307

I,10,210

I,110,310

I,13,213

I,113,313

I,16,216

I,116,316

/VIEW, 1, -0.570429549819 , -0.691644654110 ,
0.442987360016

/ANG, 1, 67.3683334857

!plo

!Mesh Generation

!Bridge

real,6 !rigid end cols.

mat,2

esize,,1

lmesh,1,4

lmesh,20,23

real,2, !Bridge End Beams

mat,1

esize,,4

lmesh,5,24,19

real,1 !Bridge Girders

esize,50

lmesh,6,7

lmesh,12,13

lmesh,18,19

real,6 !rigid links to rails

mat,2

esize,,1

lmesh,8,11

lmesh,14,17

!Trolley

real,6 !rigid links

mat,2

esize,,1

lmesh,25,26

lmesh,51

real,11

lmesh,52

real,6

lmesh,32,33

lmesh,37,38

lmesh,40,41

lmesh,44,45

lmesh,53

real,3 !Trolley E/W Beams

mat,3

esize,25

lmesh,30

lmesh,35,36

lmesh,39,42,3

lmesh,47

real,4 !Trolley N/S Beams

M&D Professional Services	CALCULATION SHEET		Page No. of B8 B9
Client / Location Fluor Daniel Hanford	Prepared By / Date <i>DSW</i> 4-18-00	Calculation No. 00-0002-E	
Subject MHM Trolley Uplift Constraint Loading	Checked By / Date <i>MDR</i> 4/18/00	Revision No. 0	
Ref. Drawing(s)	Revised By / Date	Supporting Document No.	

lmesh,27,29
lmesh,48,50
real,5 !Trolley Diags.
lmesh,31,34,3
lmesh,43,46,3
real,7 !Turret Mass
type,2
e,104
real,6 !rigid links to uplift constraints
type,1
mat,2
esize,,1
lmesh,54,61
!Gap Elements
type,3
!Compression Eles.
real,8
type,4
mat,4
e,80,87
e,82,89
mat,5
e,84,91
e,86,93
!Tension Eles.
real,9
type,3
e,134,133
e,136,135
e,138,137
e,140,139
!Soft Springs
real,10
e,80,87
e,82,89
e,84,91
e,86,93

!Constraints per ASME NOG1

dk,1,uy,,,uz
dk,2,uz,,,uz
dk,19,ux,,,uy,uz
dk,20,ux,,,uz
dtran
cp,1,ux,80,87
cp,2,uy,80,87
cp,4,ux,82,89
cp,5,uy,82,89
cp,7,uy,84,91
cp,9,uy,86,93

fini
/solu
alls

/out,trans,out
ANTYPE,trans
timint,off
time,1e-6
nsubst,4
kbc,1
acel,,,386.4 !dead weight
solve

timint,on
cpdele,1,4,3
cnvtol,f,,.05
neqit,50
NTIM=2304
DT=.01
OUTPR,BASIC,none
kbc,0
/COM,-----READIN G-LOADS
*DIM,GLOADX,,NTIM
*DIM,GLOADY,,NTIM
*DIM,GLOADZ,,NTIM

*VREAD,GLOADX(1),csbmxd,dat,,
(8(1X,F8.0))
*VREAD,GLOADZ(1),csbmzd,dat,,
(8(1X,F8.0))
*VREAD,GLOADY(1),csbmzd,dat,,
(8(1X,F8.0))

outres,basic,2

! Time History Input Multipliers
f3=1.18*1.15
f2=1.1*1.15
f1=1.07*1.15

SAVE
ITIM=1
deltim,0.005
autots,on
alphan,2.2

*DO,ITIM,2,2300,1
GZ=GLOADZ(ITIM)*f3
GY=GLOADY(ITIM)*f2
GX=GLOADX(ITIM)*f1
acel,g*GX,g*GY,g*(GZ+1)

TIM=DT*ITIM

TIME,TIM
SOLVE
SAVE
*ENDDO

M&D Professional Services	CALCULATION SHEET		Page No. B9 of B9
Client / Location Fluor Daniel Hanford	Prepared By / Date BW 4-18-00	Calculation No. 00-0002-E	
Subject MHM Trolley Uplift Constraint Loading	Checked By / Date MON 4/18/00	Revision No. 0	
Ref. Drawing(s)	Revised By / Date	Supporting Document No.	

FINISH
save

/post26
/out.post,out
NSOL,2,80,U,Z,uznwbot
NSOL,3,87,U,Z,uznwtop
NSOL,4,82,U,Z,uzswbot
NSOL,5,89,U,Z,uzswtop
NSOL,6,84,U,Z,uznebot
NSOL,7,91,U,Z,uznetop
NSOL,8,86,U,Z,uzsebot
NSOL,9,93,U,Z,uzsetop
ADD,2,2,3, ,nw_wheel, , -1,1,1,

ADD,3,4,5, ,sw_wheel, , -1,1,1,
ADD,4,6,7, ,ne_wheel, , -1,1,1,
ADD,5,8,9, ,se_wheel, , -1,1,1,
esol,6,153,,smis,1,fnw
add,6,2,6,,nw_wheel,,,1,-1e-7
esol,7,154,,smis,1,fsw
add,7,3,7,,sw_wheel,,,1,-1e-7
esol,8,155,,smis,1,fnw
add,8,4,8,,ne_wheel,,,1,-1e-7
esol,9,156,,smis,1,fsw
add,9,5,9,,se_wheel,,,1,-1e-7
plvar,6,7,8,9
EXTREM,6,9,1
/out

M&D Professional Services	CALCULATION SHEET		Page No. of C1 C10
Client / Location Fluor Daniel Hanford	Prepared By / Date <i>BW</i> 4-18-00	Calculation No. 00-0002-E	
Subject MHM Trolley Uplift Constraint Loading	Checked By / Date <i>MOR</i> 4/18/00	Revision No. 0	
Ref. Drawing(s)	Revised By / Date	Supporting Document No.	

APPENDIX C ALSTHOM EMAIL CORRESPONDENCE

Swenson, Craig E

From: chris.carter@ind.alstom.com
Sent: Monday, February 07, 2000 11:03 AM
To: Craig_E_Swenson@rl.gov; roberts@fwenc.com; dtulberg@fwenc.com
Cc: dave.cluskey@ind.alstom.com; david.burton@ind.alstom.com;
alex.macmillan@ind.alstom.com
Subject: Re: MHM Trolley Uplift Hooks

Mac Word 3.0

Craig,

Hopefully the attached will answer your concerns.

(See attached file: MHMUPLIF.DOC)

Regards,
Chris

Hanford MHM – response to Craig Swenson e-mail

Uplift on Trolley Wheels and Hooks

> -----Original Message-----

> From: Swenson, Craig E
 > Sent: Monday, January 24, 2000 5:24 PM
 > To: 'chris.carter@ind.alstom.com'
 > Cc: Swenson, Craig E
 > Subject: FW: MHM Trolley Uplift Hooks
 >
 > Chris - Thought you should know what we're kicking around here that
 > concerns your MHM Seismic Analysis. Ederer says there can't be any uplift
 > loads at wheels and some values in Report ESL/R(96)083 Rev 3 for the
 > analysis summary on Tables B1, C1, D1, and E1 can't physically happen.
 > Larry Hudak struggled with this when he was completing his structural
 > calculations for seismic loads in 1997. Please confirm or comment
 > regarding vertical uplift loads for the trolley seismic hooks.
 >
 > Craig E Swenson, P.E.
 > MHM BTR & Design Authority
 > 509-376-0288

Reply:

Reference 1: Hanford MHM – Seismic Analysis, ESL/R(96)083 Rev 3.

The MHM trolley vertical (Z) direction seismic restraint is provided downwards through each of the four wheels for a net downwards force and upwards through each of the four hooks for a net upwards force. In the analysis, the Response Spectrum Method assumes that the model behaves as a linear elastic system. Therefore a vertical restraint is similarly active both for an upwards force and for a downwards force.

For the MHM seismic analysis FE model, the first analysis was for the basic boundary condition case where the trolley vertical seismic restraint is provided at the location of each of the four wheels only. This complies with Fig. NOG-4154.3-1. However, this restraint case is valid only if all of the wheels remain in continuous contact with the rails throughout the seismic event, since the hooks are neither immediately adjacent to or in line with the wheels. The

restraint loads associated with this case are reported in Table A1 of Ref.1 and the results indicate that there is an uplift force at each of the wheel vertical restraints at some time during the seismic event. Table A1 is reproduced and attached to this memo.

Past investigations of the response spectra results have shown that the upwards vertical acceleration of the trolley is less than 1g. Therefore the trolley does not lift up completely from the girders i.e. all of the wheels do not lift off at the same point in time. However the combination of horizontal and vertical accelerations may cause uplift (or tipping) on one side or one end of the trolley. This may cause various wheels to momentarily lift and hooks to become momentarily active at various times during the duration of the seismic event. This means that the loadpath and therefore the stiffness of the structure changes.

To address this behaviour, four additional trolley restraint conditions have also been analysed in order to model the tipping behaviour of the trolley and the effect this has on the stiffness of the trolley to gantry beam vertical connection. These analyses are described in section 2.2 a) cases ii), iii), iv) & v), of Ref.1 and are considered to bound the most likely scenarios of trolley tipping. The restraint loads for these cases were reported in tables B1, C1, D1 & E1 respectively of Ref.1 but are presented here again in a clearer format. Note that the unrealistic results at the hooks and wheels (which originally appeared in Ref.1, Rev3) are now discarded, i.e. no downward forces at hooks and no upward forces at wheels.

The maximum hook and wheel loads on the MHM trolley are as follows:

Max uplift force at a hook = 430.6 kN	Table C1
Max downward force at a wheel = 1480.8 kN	Table E1

C.C.Carter
Monday, 07 February 2000

Table A1. Forces at Trolley Seismic Restraints

LOADCASE	ELEMENT NUMBERS	STATIC LOAD (KN)			DYNAMIC LOAD (KN)			UPLIFT FORCE AT A SINGLE WHEEL (KN) (DYNAMIC - STATIC)	DOWNWARD FORCE AT A SINGLE WHEEL (KN) (DYNAMIC + STATIC)
		Fx	Fy	Fz	Fx	Fy	Fz		
TROLLEY MIDSPAN	323			363.7		283.9	486.7	123.0	850.4
	324			0.0			0.0	0.0	0.0
	326				477.1				
	328			0.0			0.0	0.0	0.0
	329			469.4		427.0	632.8	163.4	1102.2
	330			365.4		427.3	484.1	118.7	849.5
	331			0.0			0.0	0.0	0.0
	333				475.0				
	335			0.0			0.0	0.0	0.0
	336			451.9		427.3	622.2	170.3	1074.1
TROLLEY QUARTER SPAN	321			360.5		273.3	415.9	55.4	776.4
	322			0.0			0.0	0.0	0.0
	324				681.5				
	326			0.0			0.0	0.0	0.0
	327			472.6		527.7	747.4	274.8	1220.0
	328			358.0		518.0	410.0	52.0	768.0
	329			0.0			0.0	0.0	0.0
	331				682.4				
	333			0.0			0.0	0.0	0.0
	334			459.2		518.0	741.5	282.3	1200.7
TROLLEY END SPAN	325			361.3		186.4	395.0	33.7	756.3
	326			0.0			0.0	0.0	0.0
	328				543.1				
	330			0.0			0.0	0.0	0.0
	331			471.8		432.0	572.0	100.2	1043.8
	332			356.3		438.5	379.0	22.7	735.3
	333			0.0			0.0	0.0	0.0
	335				528.8				
	337			0.0			0.0	0.0	0.0
	338			461.0		438.5	572.5	111.5	1033.5

NOTE:- UPLIFT FORCES are Positive for an upward load and Negative for a downward load.

Table B1. Forces at Trolley Seismic Restraints

LOADCASE	ELEMENT NUMBERS	STATIC LOAD (KN)			DYNAMIC LOAD (KN)			UPLIFT FORCE AT A SINGLE HOOK (KN) (DYNAMIC - STATIC)	DOWNWARD FORCE AT A SINGLE WHEEL (KN) (DYNAMIC + STATIC)
		Fx	Fy	Fz	Fx	Fy	Fz		
TROLLEY MIDSPAN	323			316.9		280.2	465.8		782.7
	324			0.0			0.0	0.0	
	326				600.3				
	328			0.0			0.0	0.0	
	329			394.7		418.9	664.7		1059.4
	330			0.0		418.5	0.0		0.0
	331			396.2			614.8	218.6	
	333				579.3				
	335			542.6			841.9	299.3	
	336			0.0		418.5	0.0		0.0
TROLLEY QUARTER SPAN	321			335.3		353.1	405.9		741.2
	322			0.0			0.0	0.0	
	324				770.0				
	326			0.0			0.0	0.0	
	327			372.3		552.6	978.6		1350.9
	328			0.0		555.8	0.0		0.0
	329			358.5			524.2	165.7	
	331				753.1				
	333			584.3			1007.0	422.7	
	334			0.0		555.8	0.0		0.0
TROLLEY END SPAN	325			327.9		244.2	382.3		710.2
	326			0.0			0.0	0.0	
	328				598.9				
	330			0.0			0.0	0.0	
	331			376.6		413.3	690.1		1066.7
	332			0.0		415.6	0.0		0.0
	333			366.1			480.8	114.7	
	335				619.0				
	337			579.9			816.8	236.9	
	338			0.0		415.6	0.0		0.0

NOTE:- UPLIFT FORCES are Positive for an upward load and Negative for a downward load.

Table C1. Forces at Trolley Seismic Restraints

LOADCASE	ELEMENT NUMBERS	STATIC LOAD (KN)			DYNAMIC LOAD (KN)			UPLIFT FORCE AT A SINGLE HOOK (KN) (DYNAMIC - STATIC)	DOWNWARD FORCE AT A SINGLE WHEEL (KN) (DYNAMIC + STATIC)
		Fx	Fy	Fz	Fx	Fy	Fz		
TROLLEY MIDSPAN	323			0.0		278.2	0.0		0.0
	324			395.2			621.5	226.3	
	326				581.6				
	328			561.8			854.0	292.2	
	329			0.0		420.6	0.0		0.0
	330			315.6		417.5	462.9		778.5
	331			0.0			0.0	0.0	
	333				598.7				
	335			0.0			0.0	0.0	
	336			377.7		417.5	648.6		1026.3
TROLLEY QUARTER SPAN	321			0.0		327.8	0.0		0.0
	322			362.7			532.2	169.5	
	324				748.9				
	326			598.4			1029.0	430.6	
	327			0.0		554.5	0.0	96.8 k	0.0
	328			330.0		542.5	403.2		733.2
	329			0.0			0.0	0.0	
	331				770.6				
	333			0.0			0.0	0.0	
	334			359.3		542.5	955.5		1314.8
TROLLEY END SPAN	325			0.0		200.8	0.0		0.0
	326			373.5			495.0	121.5	
	328				583.4				
	330			590.5			777.3	186.8	
	331			0.0		391.7	0.0		0.0
	332			320.1		423.1	366.0		686.1
	333			0.0			0.0	0.0	
	335				545.5				
	337			0.0			0.0	0.0	
	338			366.3		423.1	677.1		1043.4

NOTE:- UPLIFT FORCES are Positive for an upward load and Negative for a downward load.

Table D1. Forces at Trolley Seismic Restraints

LOADCASE	ELEMENT NUMBERS	STATIC LOAD (KN)			DYNAMIC LOAD (KN)			UPLIFT FORCE AT A SINGLE HOOK (KN) (DYNAMIC - STATIC)	DOWNWARD FORCE AT A SINGLE WHEEL (KN) (DYNAMIC + STATIC)
		Fx	Fy	Fz	Fx	Fy	Fz		
TROLLEY MIDSPAN	323			308.3		187.4	751.0		1059.3
	324			0.0			0.0	0.0	
	326				500.3				
	328			527.5			522.8		
	329			0.0		424.0	0.0		0.0
	330			307.9		423.3	748.7		1056.6
	331			0.0			0.0	0.0	
	333				496.4				
	335			506.6			503.7		
	336			0.0		423.3	0.0		0.0
TROLLEY QUARTER SPAN	321			303.5		302.7	493.9		797.4
	322			0.0			0.0	0.0	
	324				789.7				
	326			532.0			812.4	280.4	
	327			0.0		545.1	0.0		0.0
	328			300.7		539.8	491.6		792.3
	329			0.0			0.0	0.0	
	331				791.3				
	333			514.2			789.7	275.5	
	334			0.0		539.8	0.0		0.0
TROLLEY END SPAN	325			304.5		224.3	410.7		715.2
	326			0.0			0.0	0.0	
	328				553.7				
	330			530.3			774.4	244.1	
	331			0.0		386.7	0.0		0.0
	332			298.2		398.7	390.6		688.8
	333			0.0			0.0	0.0	
	335				562.4				
	337			517.5			780.6	263.1	
	338			0.0		398.7	0.0		0.0

NOTE:- UPLIFT FORCES are Positive for an upward load and Negative for a downward load.

Table E1. Forces at Trolley Seismic Restraints

LOAD CASE	ELEMENT NUMBERS	STATIC LOAD (KN)			DYNAMIC LOAD (KN)			UPLIFT FORCE AT A SINGLE HOOK (KN) (DYNAMIC - STATIC)	DOWNWARD FORCE AT A SINGLE WHEEL (KN) (DYNAMIC + STATIC)
		Fx	Fy	Fz	Fx	Fy	Fz		
TROLLEY MIDSPAN	323			0.0		348.8	0.0		0.0
	324			410.8			454.0	43.2	
	326				571.7				
	328			0.0			0.0	0.0	
	329			422.8		384.6	915.7		1338.5
	330			0.0		383.4	0.0		0.0
	331			407.6			446.4	38.8	
	333				571.4				
	335			0.0			0.0	0.0	
	336			409.3		383.4	907.5		1316.8
TROLLEY QUARTER SPAN	321			0.0		323.1	0.0		0.0
	322			407.3			443.2	35.9	
	324				713.5				
	326			0.0			0.0	0.0	
	327			426.9		566.4	945.2		1372.1
	328			0.0		544.3	0.0		0.0
	329			399.4			415.9	16.5	
	331				695.3				
	333			0.0			0.0	0.0	
	334			416.8		544.3	1064.0		1480.8
TROLLEY END SPAN	325			0.0		201.6	0.0		0.0
	326			407.6			432.7	25.1	
	328				534.7				
	330			0.0			0.0	0.0	
	331			426.8		407.3	634.5		1061.3
	332			0.0		412.3	0.0		0.0
	333			398.1			410.3	12.2	
	335				524.1				
	337			0.0			0.0	0.0	
	338			417.9		412.3	637.9		1055.8

NOTE:- UPLIFT FORCES are Positive for an upward load and Negative for a downward load.

M&D Professional Services	CALCULATION SHEET		Page No. of D1 D18
Client / Location Fluor Daniel Hanford	Prepared By / Date <i>MDR</i> 4/18/00	Calculation No. 00-0002-E	
Subject MHM Trolley Uplift Constraint Loading	Checked By / Date <i>MM</i> 4/18/01	Revision No. 0	
Ref. Drawing(s)	Revised By / Date	Supporting Document No.	

APPENDIX D TIME HISTORY ANALYSIS INPUT

M&D Professional Services	CALCULATION SHEET		Page No. _____ of _____ D2 D18
Client / Location Fluor Daniel Hanford	Prepared By / Date MON 4/18/00	Calculation No. 00-0002-E	
Subject MHM Trolley Uplift Constraint Loading	Checked By / Date M/ N 4/18/00	Revision No. 0	
Ref. Drawing(s)	Revised By / Date	Supporting Document No.	

Background of Seismic Design Criteria

A considerable amount of work has been previously performed in the area of seismic design requirements and specifically in the development of time histories for the Hanford Area. The following is a brief review of the supporting used in the development of time histories for the MHM at the CSB facility.

Hanford Engineering Development Laboratory (HEDL) developed a series of computer programs for providing the capability of generating time histories and characterizing their properties. These programs are documented in Reference G-4. MODQKE was written to provide new time histories with special attention to short seismic records. A program, SPECTR, generates spectra from a given time history. ACONST also reads in each of the time histories and constructs a triangular correlation matrix. Configuration software control was documented in Reference G-5. These programs were used in the development of the time histories for the MHM at the CSB.

Discussion of WHC-SD-GN-DA-30018 (Reference G-11)

Standards and criteria have been adopted for the seismic analysis of Hanford facilities and are specified in DOE Orders governing the design of non-reactor nuclear facilities, commercial nuclear industry standards and consensus industry standards. A complete discussion of these criteria is provided in WHC-SD-GN-DA-30018, Rev. 0, which provides the Design Basis Earthquake Time Histories for the 1992 SDC-4.1 (rev12). This report describes the generation and acceptance testing of synthetic earthquake time histories for inclusion into the Rev. 12 of SDC-4.1. The following criteria documents were used to develop the time histories.

Hanford Standard Arch-Civil Design Criteria Design Loads for Facilities (SDC-4.1/Rev. 12/Reference. G-11)

Design and Evaluation Guidelines for DOE Facilities Subjected to Natural Phenomena Hazards (UCRL-15910, June 1990/ Reference G-2)

Seismic Analysis of Safety-Related Nuclear Structures and Commentary on Standard for Seismic Analysis of Safety-Related Nuclear Structures (ASCE 4-86, 1987/ Reference G-10)

Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants (NUREG-0800) Sections 2.5.2, Vibratory Ground Motion (Rev 2) and 3.7.1 Seismic Design Parameters (Rev 2, Aug 1989/ Reference G-3)

Development of Criteria for Seismic Review of Selected Nuclear Power Plants (NUREG/CR-0098)

M&D Professional Services	CALCULATION SHEET		Page No. of D3 D18
Client / Location Fluor Daniel Hanford	Prepared By / Date MDR 4/18/00	Calculation No. 00-0002-E	
Subject MHM Trolley Uplift Constraint Loading	Checked By / Date HJH 7/18/00	Revision No. 0	
Ref. Drawing(s)	Revised By / Date	Supporting Document No.	

Development of Acceleration Time Histories to simulate postulated Design Basis Earthquake (DBE) for MHM at CSB Facility

Before discussing the details of the time histories, a basic understanding of the use of the time histories is important. First, the seismic analysis performed in this calculation is not used to qualify the MHM because Alstom (reference 3) has provided qualification of the MHM for design bases conditions using the boundary support conditions specified in NOG-1. Loads developed in this report are only used to determine if the uplift restraints are required for the unrestrained MHM condition, which is not identified in NOG-1.

The SRP permits two options for computing acceleration time histories. Option 2 was selected because of the complexity of satisfying the PSD requirement in Option 1. A review of the SPR is provided below.

Reference SRP 3.7.1 Section I.1.b

"For computing the response of Category I structures and equipment, acceleration time histories may be used." The SRP suggests two options

Option 1: Single Time History must be justified by satisfying a target power spectral density (PSD) requirement in addition to the design response spectra enveloping requirements.

Option 2: Multiple Time Histories may be used in lieu of the single time history. This is the option which will be used in the analysis associated with the trailer analysis in this calculation.

Multiple Acceleration Time Histories (First Set)

Two sets of input were created, each set contains three time histories. For the first set, three (two horizontal and one vertical) time histories were generated using the computer program MODQKE, which was developed by Westinghouse and documented in WHC-SD-GN-CSWD-006. This program was used to generate acceleration time histories for the simulation of a Design Basis Earthquake specifically at the base of the MHM. Note: Low frequency is important for the MHM. Following are the input decks used to run the MODQKE program.

M&D Professional Services	CALCULATION SHEET		Page No.	of
			D4	D18
Client / Location Fluor Daniel Hanford	Prepared By / Date MON 4/18/00		Calculation No. 00-0002-E	
Subject MHM Trolley Uplift Constraint Loading	Checked By / Date M M 4/18/00		Revision No. 0	
Ref. Drawing(s)	Revised By / Date		Supporting Document No.	

MODQKE input to North / South direction is as follows

```

MHM CSB 7% mhmns.inp
151 .07 .1 100 /
20 4 , , .1 30 .1 /
2048 .01 1 0 4 77665 4 /
0.10 0.248 1.6 2.07 2.53 3.45 4.5 5.67 5.85 6.35 7.15 8.55 10.0 11.5 12.9 16.0
20.0 27.0 34.0 100.
0.017 0.102 0.68 0.70 0.70 0.64 0.77 0.77 0.75 0.75 0.65 0.65 0.46 0.46 0.41
0.31 0.29 0.29 0.26 0.26
MHM at CSB n=2048 dt=.01 zeta=.07 mhmns seed=77665
0 1 18 20.48
0 1 1 0

```

MODQKE input to East / West direction is as follows

```

MHM CSB 7% mhmew
151 .07 .1 100 /
16 4 , , .1 30 .1 /
2048 .01 1 0 4 65534 4 /
0.10 0.248 1.6 2.53 3.55 3.95 5.61 6.40 8.75 9.6 11.5 12.9 14.4 22.0 34.0 100.
0.017 0.102 0.66 0.66 0.59 0.64 0.64 0.55 0.55 0.46 0.46 0.43 0.37 0.28 0.24
0.24
MHM at CSB n=2048 dt=.01 zeta=.07 mhmew seed=65534
0 1 18 20.48
0 1 1 0

```

MODQKE input to Vertical direction are as follows

```

MHM CSB 7% mhmrv
151 .07 .1 100 /
12 4 , , .1 30 .1 /
2048 .01 1 0 4 84350 4 /
0.10 0.248 1.6 4.5 5.31 9.03 12.32 15.7 18.0 29.0 34.0 100.
0.011 0.068 0.445 0.53 .585 0.585 0.555 0.505 0.36 0.265 0.25 0.25
MHM at CSB n=2048 dt=.01 zeta=.07 mhmrv seed=84350
0 1 18 20.48
0 1 1 0

```

M&D Professional Services	CALCULATION SHEET		Page No.	of
			D5	D18
Client / Location Fluor Daniel Hanford		Prepared By / Date MDN 4/18/00	Calculation No. 00-0002-E	
Subject MHM Trolley Uplift Constraint Loading		Checked By / Date MDN 4/18/00	Revision No. 0	
Ref. Drawing(s)		Revised By / Date	Supporting Document No.	

In addition to development of the time histories statistical correlation data and NRC/ASCE scale factors were developed to assure all of the NRC/ASCE criteria is satisfied. PC programs (SPECTRA, ACONST and RSFACT) were run to check the NRC/ASCE criteria as follows:

Statistical Cross-Correlation

In order to show that the three time histories are uncorrelated, the ACONST program is used. The program reads in each of the time histories and from them constructs a triangular correlation matrix. Time histories are uncorrelated, having the following correlation matrix shown below. All cross-correlation coefficients are less than 0.16 as suggested by reference to NRC 1.92.

```

correlations -
hst lop      1          2          3
  1  1  1.000
  2  2  0.3866E-01  1.000
  3  3 -0.2776E-01 -0.1591  1.000

```

NRC/ASCE Scale Factors

The RSFACT program calculates scale factors. In order to use RSFACT, the original time histories must be converted into response spectra. The SPECTR program accomplishes this.

RSFACT is executed from the DOS command line as with syntax similar to the following:

RSFACT results for North/South direction is shown below

Response Spectrum Calculated/Target Factors
Factors Scale T/H to Meet ASCE and NRC Requirements
Version 10/13/94

Ref: ASCE 4-86, NRC SRP 3.7.1 Rev 2

Output - one line per damping value as input with:

```

Average calc/target ratio in .5 - 33 Hz, ASCE 4-86
Minimum calc/target ratio in .5 - 33 Hz, ASCE 4-86
6th smallest calc/target ratio in .2 - 34 Hz, NRC SRP
Minimum calc/target ratio in .2 - 34 Hz, NRC SRP
Factor, for ASCE ave ratio >= 1
Factor, for ASCE min ratio >= .9
Factor, for NRC SRP <= 5 pts < target
Factor, for NRC SRP min ratio >= .9

```

2 20 8 / MHM Horizontal Spectra: 7 damping NS

Using 8 points for NRC 5 pts below target.

2 151 /

damp	ASCE ratios		NRC ratios		ASCE factors		NRC factors	
case	mean	min	five	min	mean	min	five	min
1	1.037	.855	.909	.855	1.000	1.052	1.100	1.052

M&D Professional Services	CALCULATION SHEET		Page No. of D6 D18
Client / Location Fluor Daniel Hanford	Prepared By / Date mon 4/18/00	Calculation No. 00-0002-E	
Subject MHM Trolley Uplift Constraint Loading	Checked By / Date Jm 4/18/00	Revision No. 0	
Ref. Drawing(s)	Revised By / Date	Supporting Document No.	

RSFACT results for East/West direction is shown below

Response Spectrum Calculated/Target Factors
 Factors Scale T/H to Meet ASCE and NRC Requirements
 Version 10/13/94

Ref: ASCE 4-86, NRC SRP 3.7.1 Rev 2

Output - one line per damping value as input with:

Average calc/target ratio in .5 - 33 Hz, ASCE 4-86
 Minimum calc/target ratio in .5 - 33 Hz, ASCE 4-86
 6th smallest calc/target ratio in .2 - 34 Hz, NRC SRP
 Minimum calc/target ratio in .2 - 34 Hz, NRC SRP
 Factor, for ASCE ave ratio ≥ 1
 Factor, for ASCE min ratio $\geq .9$
 Factor, for NRC SRP ≤ 5 pts < target
 Factor, for NRC SRP min ratio $\geq .9$

2 16 8 / MHM Horizontal Spectra: 7 damping E/W

Using 8 points for NRC 5 pts below target.

damp	ASCE ratios		NRC ratios		ASCE factors		NRC factors	
case	mean	min	five	min	mean	min	five	min
1	1.102	.877	.933	.877	1.000	1.026	1.072	1.026

RSFACT results for Vertical direction is shown below

Response Spectrum Calculated/Target Factors
 Factors Scale T/H to Meet ASCE and NRC Requirements
 Version 10/13/94

Ref: ASCE 4-86, NRC SRP 3.7.1 Rev 2

Output - one line per damping value as input with:

Average calc/target ratio in .5 - 33 Hz, ASCE 4-86
 Minimum calc/target ratio in .5 - 33 Hz, ASCE 4-86
 6th smallest calc/target ratio in .2 - 34 Hz, NRC SRP
 Minimum calc/target ratio in .2 - 34 Hz, NRC SRP
 Factor, for ASCE ave ratio ≥ 1
 Factor, for ASCE min ratio $\geq .9$
 Factor, for NRC SRP ≤ 5 pts < target
 Factor, for NRC SRP min ratio $\geq .9$

.2 12 8 / MHM CSB Vertical Spectra: 7% damping

Using 8 points for NRC 5 pts below target.

2 151 /

damp	ASCE ratios		NRC ratios		ASCE factors		NRC factors	
case	mean	min	five	min	mean	min	five	min
1	1.014	.846	.846	.759	1.000	1.063	1.181	1.186

M&D Professional Services	CALCULATION SHEET		Page No.	of
			D7	D18
Client / Location Fluor Daniel Hanford	Prepared By / Date <i>mon</i> 4/18/00	Calculation No. 00-0002-E		
Subject MHM Trolley Uplift Constraint Loading	Checked By / Date <i>MA</i> 7/15/00	Revision No. 0		
Ref. Drawing(s)	Revised By / Date	Supporting Document No.		

Note: The computer programs used in this analysis were all verified on M&D Professional Services, Inc. computers by running the sample problems provided in WHC-SD-GN-CSWD-006.

Conclusion: The time histories developed in this section satisfy the applicable standards when the following factors are included.

North/South factor = $1.10 \times 1.15 = 1.265$

East / West factor = $1.07 \times 1.15 = 1.23$

Vertical factor = $1.18 \times 1.15 = 1.357$

Note: An additional 15% increase has been applied above the RSFACT calculated values. The following time histories represent accelerations at time steps of 0.01 seconds. The time histories each contain 2048 data points for a total time of 20.48 seconds. Excerpts from the three orthogonal directions are shown in the following pages.

NORTH/SOUTH HORIZONTAL DIRECTION

MHM at CSB n=2048 dt=.01 zeta=.07 mhms seed=77665

-0.0077	-0.0079	-0.0081	-0.0044	-0.0021	-0.0039	-0.0025	0.0031
0.0052	0.0081	0.0211	0.0339	0.0309	0.0203	0.0184	0.0211
0.0188	0.0156	0.0153	0.0127	0.0101	0.0147	0.0191	0.0121
0.0001	-0.0054	-0.0051	-0.0019	0.0051	0.0095	0.0025	-0.0107
-0.0197	-0.0263	-0.0345	-0.0379	-0.0330	-0.0278	-0.0250	-0.0174
-0.0050	0.0037	0.0082	0.0155	0.0251	0.0323	0.0393	0.0484
0.0526	0.0451	0.0287	0.0075	-0.0171	-0.0390	-0.0508	-0.0549
-0.0558	-0.0458	-0.0183	0.0142	0.0323	0.0311	0.0153	-0.0132
-0.0491	-0.0817	-0.1064	-0.1290	-0.1525	-0.1724	-0.1844	-0.1865

-0.0254	-0.0208	-0.0115	-0.0027	0.0013	0.0048	0.0068	0.0006
-0.0111	-0.0163	-0.0121	-0.0030	0.0100	0.0244	0.0316	0.0307
0.0302	0.0295	0.0219	0.0127	0.0137	0.0231	0.0296	0.0290
0.0253	0.0235	0.0263	0.0298	0.0270	0.0203	0.0195	0.0252
0.0311	0.0357	0.0375	0.0299	0.0169	0.0129	0.0168	0.0134
0.0028	-0.0015	0.0002	-0.0009	-0.0009	0.0039	0.0035	-0.0070
-0.0157	-0.0158	-0.0139	-0.0115	-0.0050	-0.0006	-0.0043	-0.0062
0.0010	0.0066	0.0005	-0.0092	-0.0132	-0.0140	-0.0135	-0.0085

EAST/WEST HORIZONTAL DIRECTION

MHM at CSB n=2048 dt=.01 zeta=.07 mhms seed=65534

-0.0120	-0.0035	-0.0011	-0.0102	-0.0240	-0.0290	-0.0200	-0.0083
-0.0095	-0.0207	-0.0188	0.0047	0.0245	0.0167	-0.0047	-0.0086
0.0064	0.0135	0.0024	-0.0032	0.0144	0.0309	0.0139	-0.0214
-0.0308	-0.0087	0.0093	0.0094	0.0127	0.0249	0.0225	-0.0055

M&D	Professional Services	CALCULATION SHEET		Page No. D8 of D18
Client / Location Fluor Daniel Hanford		Prepared By / Date <i>MON 4/18/00</i>		Calculation No. 00-0002-E
Subject MHM Trolley Uplift Constraint Loading		Checked By / Date <i>PM 4/18/00</i>		Revision No. 0
Ref. Drawing(s)		Revised By / Date		Supporting Document No.

-0.0405	-0.0621	-0.0661	-0.0596	-0.0522	-0.0480	-0.0445	-0.0418
-0.0448	-0.0495	-0.0450	-0.0309	-0.0162	-0.0006	0.0222	0.0447
0.0481	0.0273	0.0007	-0.0097	-0.0013	0.0140	0.0323	0.0580
0.0812	0.0806	0.0560	0.0326	0.0252	0.0229	0.0178	0.0219
0.0491	0.0926	0.1287	0.1398	0.1299	0.1097	0.0766	0.0304
-0.0021	0.0037	0.0241	0.0125	-0.0360	-0.0864	-0.1182	-0.1394

....

....

....

0.0256	0.0419	0.0425	0.0462	0.0665	0.0913	0.0975	0.0816
0.0636	0.0576	0.0545	0.0454	0.0432	0.0575	0.0668	0.0460
0.0082	-0.0094	0.0072	0.0359	0.0481	0.0404	0.0295	0.0221
0.0081	-0.0094	-0.0053	0.0245	0.0455	0.0348	0.0124	-0.0014
-0.0191	-0.0502	-0.0714	-0.0615	-0.0336	-0.0128	-0.0040	0.0042
0.0165	0.0274	0.0350	0.0466	0.0635	0.0725	0.0616	0.0375
0.0152	-0.0009	-0.0135	-0.0198	-0.0120	0.0106	0.0320	0.0295
0.0014	-0.0270	-0.0351	-0.0299	-0.0210	-0.0022	0.0236	0.0308
0.0068	-0.0257	-0.0380	-0.0285	-0.0130	-0.0001	0.0152	0.0356
0.0471	0.0326	0.0016	-0.0152	-0.0084	0.0021	0.0086	0.0262
0.0542	0.0630	0.0368	0.0004	-0.0135	-0.0036	0.0089	0.0156
0.0272	0.0439	0.0445	0.0161	-0.0233	-0.0460	-0.0420	-0.0188
0.0078	0.0213	0.0190	0.0146	0.0131	0.0019	-0.0219	-0.0357
-0.0194	0.0178	0.0475	0.0488	0.0258	0.0001	-0.0151	-0.0260

VERTICAL DIRECTION

MHM at CSB n=2048 dt=.01 zeta=.07 mhmV seed=84350

-0.0058	-0.0009	0.0004	0.0008	0.0018	0.0028	0.0049	0.0084
0.0097	0.0069	0.0022	-0.0024	-0.0049	-0.0012	0.0089	0.0188
0.0230	0.0200	0.0077	-0.0147	-0.0404	-0.0584	-0.0611	-0.0475
-0.0250	-0.0068	0.0009	0.0024	0.0007	-0.0070	-0.0166	-0.0157
-0.0018	0.0109	0.0062	-0.0154	-0.0355	-0.0357	-0.0178	0.0003
0.0078	0.0093	0.0082	0.0020	-0.0068	-0.0115	-0.0142	-0.0235
-0.0399	-0.0533	-0.0539	-0.0408	-0.0231	-0.0115	-0.0077	-0.0049
0.0014	0.0114	0.0234	0.0326	0.0351	0.0380	0.0522	0.0741
0.0866	0.0799	0.0589	0.0353	0.0197	0.0163	0.0194	0.0211
0.0227	0.0329	0.0569	0.0873	0.1059	0.0984	0.0725	0.0519

....

-0.0246	-0.0335	-0.0537	-0.0655	-0.0547	-0.0273	-0.0005	0.0164
0.0245	0.0265	0.0264	0.0289	0.0316	0.0259	0.0099	-0.0064
-0.0112	-0.0010	0.0164	0.0276	0.0289	0.0312	0.0420	0.0524
0.0496	0.0330	0.0106	-0.0106	-0.0251	-0.0279	-0.0184	-0.0012
0.0145	0.0205	0.0193	0.0224	0.0326	0.0381	0.0295	0.0103
-0.0101	-0.0243	-0.0263	-0.0168	-0.0040	0.0043	0.0078	0.0096
0.0137	0.0219	0.0294	0.0296	0.0217	0.0100	-0.0029	-0.0129
-0.0136	-0.0057	0.0012	0.0000	-0.0078	-0.0176	-0.0241	-0.0225
-0.0136	-0.0033	0.0056	0.0132	0.0185	0.0208	0.0220	0.0217
0.0188	0.0158	0.0149	0.0134	0.0101	0.0075	0.0056	0.0015
-0.0041	-0.0085	-0.0125	-0.0168	-0.0202	-0.0235	-0.0277	-0.0300
-0.0286	-0.0258	-0.0229	-0.0186	-0.0142	-0.0125	-0.0129	-0.0147
-0.0187	-0.0228	-0.0227	-0.0187	-0.0138	-0.0085	-0.0043	-0.0044

M&D Professional Services	CALCULATION SHEET		Page No. of D9 D18
Client / Location Fluor Daniel Hanford	Prepared By / Date MON 4/10/00	Calculation No. 00-0002-E	
Subject MHM Trolley Uplift Constraint Loading	Checked By / Date [Signature] 4/11/00	Revision No. 0	
Ref. Drawing(s)	Revised By / Date	Supporting Document No.	

The following plots show the comparison between the response spectra of the generated time histories versus the input Design Basis Response Spectra. Note that the generated time history response spectra has the appropriate multiplication factor applied.

SPECTRA for NORTH / SOUTH DIRECTION

M&D Professional Services	CALCULATION SHEET		Page No. D10 of D18
Client / Location Fluor Daniel Hanford	Prepared By / Date MON 4/18/00	Calculation No. 00-0002-E	
Subject MHM Trolley Uplift Constraint Loading	Checked By / Date JMA 4/18/00	Revision No. 0	
Ref. Drawing(s)	Revised By / Date	Supporting Document No.	

SPECTRA for EAST / WEST DIRECTION

SPECTRA for VERTICAL DIRECTION

M&D Professional Services	CALCULATION SHEET		Page No. D11 of D18
Client / Location Fluor Daniel Hanford	Prepared By / Date <i>MDN</i> 4/18/00	Calculation No. 00-0002-E	
Subject MHM Trolley Uplift Constraint Loading	Checked By / Date <i>MDN</i> 4/18/00	Revision No. 0	
Ref. Drawing(s)	Revised By / Date	Supporting Document No.	

Multiple Acceleration Time Histories (Second Set)

A second set of three (two horizontal and one vertical) time histories were generated using the computer program MODQKE, which was developed by Westinghouse and documented in WHC-SD-GN-CSWD-006. This program was used to generate acceleration time histories for the simulation of a Design Basis Earthquake specifically at the base of the MHM. Note: Low frequency is important for the MHM. Following are the input decks used to run the MODQKE program.

MODQKE INPUT TO NORTH/SOUTH DIRECTION

```
MHM CSB 7% mhmns.inp
151 .07 .1 100 /
20 4 , , .1 30 .1 /
2048 .01 1 0 4 86775 4 /
0.10 0.248 1.6 2.07 2.53 3.45 4.5 5.67 5.85 6.35 7.15 8.55 10.0 11.5
12.9 16.0 20.0 27.0 34.0 100.
0.017 0.102 0.68 0.70 0.70 0.64 0.77 0.77 0.75 0.75 0.65 0.65 0.46 0.46 0.41
0.31 0.29 0.29 0.26 0.26
MHM at CSB n=2048 dt=.01 zeta=.07 mhmns seed=86775
0 1 18 20.48
0 1 1 0
```

MODQKE INPUT TO EAST/WEST DIRECTION

```
MHM CSB 7% mhmew
151 .07 .1 100 /
16 4 , , .1 30 .1 /
2048 .01 1 0 4 35634 4 /
0.10 0.248 1.6 2.53 3.55 3.95 5.61 6.40 8.75 9.6 11.5 12.9 14.4 22.0 34.0
100.
0.017 0.102 0.66 0.66 0.59 0.64 0.64 0.55 0.55 0.46 0.46 0.43 0.37 0.28 0.24
0.24
MHM at CSB n=2048 dt=.01 zeta=.07 mhmew seed=35634
0 1 18 20.48
0 1 1 0
```

MODQKE INPUT TO VERTICAL DIRECTION

```
MHM CSB 7% mhm v
151 .07 .1 100 /
12 4 , , .1 30 .1 /
2048 .01 1 0 4 35840 4 /
0.10 0.248 1.6 4.5 5.31 9.03 12.32 15.7 18.0 29.0 34.0 100.
```

M&D Professional Services	CALCULATION SHEET		Page No. of D12 D18
Client / Location Fluor Daniel Hanford	Prepared By / Date mon 4/18/00	Calculation No. 00-0002-E	
Subject MHM Trolley Uplift Constraint Loading	Checked By / Date Jm 4/18/00	Revision No. 0	
Ref. Drawing(s)	Revised By / Date	Supporting Document No.	

0.011 0.068 0.445 0.53 .585 0.585 0.555 0.505 0.36 0.265 0.25 0.25
 MHM at CSB n=2048 dt=.01 zeta=.07 mhm seed=35840
 0 1 18 20.48
 0 1 1 0

In addition to development of the time histories statistical correlation data and NRC/ASCE scale factors were developed to assure all of the NRC/ASCE criteria is satisfied. PC programs (SPECTRA, ACONST and RSFACT) were run to check the NRC/ASCE criteria as follows:

Statistical Cross-Correlation

In order to show that the three time histories are uncorrelated, the ACONST program is used. The program reads in each of the time histories and from them constructs a triangular correlation matrix. Time histories are uncorrelated, having the following correlation matrix shown below. All cross-correlation coefficients are less than 0.16 as suggested by reference to NRC 1.92.

```

correlations ~
hst lop      1          2          3
  1  1      1.000
  2  2 -0.5078E-01    1.000
  3  3 -0.2747E-01 -0.2036E-01    1.000

```

FINI

NRC/ASCE Scale Factors

The RSFACT program calculates scale factors. In order to use RSFACT, the original time histories must be converted into response spectra. The SPECTR program accomplishes this.

RSFACT is executed from the DOS command line as with syntax similar to the following:

RSFACT RESULTS FOR NORTH/SOUTH DIRECTION

Response Spectrum Calculated/Target Factors
 Factors Scale T/H to Meet ASCE and NRC Requirements
 Version 10/13/94
 Ref: ASCE 4-86, NRC SRP 3.7.1 Rev 2
 Output - one line per damping value as input with:
 Average calc/target ratio in .5 - 33 Hz, ASCE 4-86
 Minimum calc/target ratio in .5 - 33 Hz, ASCE 4-86

M&D Professional Services		CALCULATION SHEET		Page No.	of
				D13	D18
Client / Location Fluor Daniel Hanford		Prepared By / Date MDR 4/18/00		Calculation No. 00-0002-E	
Subject MHM Trolley Uplift Constraint Loading		Checked By / Date M H 4/18/00		Revision No. 0	
Ref. Drawing(s)		Revised By / Date		Supporting Document No.	

6th smallest calc/target ratio in .2 - 34 Hz, NRC SRP
 Minimum calc/target ratio in .2 - 34 Hz, NRC SRP
 Factor, for ASCE ave ratio ≥ 1
 Factor, for ASCE min ratio $\geq .9$
 Factor, for NRC SRP ≤ 5 pts $<$ target
 Factor, for NRC SRP min ratio $\geq .9$
 2 20 8 / MHM Horizontal Spectra: 7 damping NS
 Using 8 points for NRC 5 pts below target.
 2 151 /

damp	ASCE ratios		NRC ratios		ASCE factors		NRC factors	
case	mean	min	five	min	mean	min	five	min
1	1.020	.816	.834	.791	1.000	1.103	1.199	1.138

RSFACT RESULTS FOR EAST/WEST DIRECTION

Response Spectrum Calculated/Target Factors
 Factors Scale T/H to Meet ASCE and NRC Requirements
 Version 10/13/94

Ref: ASCE 4-86, NRC SRP 3.7.1 Rev 2

Output - one line per damping value as input with:

Average calc/target ratio in .5 - 33 Hz, ASCE 4-86
 Minimum calc/target ratio in .5 - 33 Hz, ASCE 4-86
 6th smallest calc/target ratio in .2 - 34 Hz, NRC SRP
 Minimum calc/target ratio in .2 - 34 Hz, NRC SRP
 Factor, for ASCE ave ratio ≥ 1
 Factor, for ASCE min ratio $\geq .9$
 Factor, for NRC SRP ≤ 5 pts $<$ target
 Factor, for NRC SRP min ratio $\geq .9$

2 16 8 / MHM Horizontal Spectra: 7 damping E/W
 Using 8 points for NRC 5 pts below target.

damp	ASCE ratios		NRC ratios		ASCE factors		NRC factors	
case	mean	min	five	min	mean	min	five	min
1	1.023	.807	.858	.749	1.000	1.115	1.165	1.202

RSFACT RESULTS FOR VERTICAL DIRECTION

Response Spectrum Calculated/Target Factors
 Factors Scale T/H to Meet ASCE and NRC Requirements
 Version 10/13/94

Ref: ASCE 4-86, NRC SRP 3.7.1 Rev 2

Output - one line per damping value as input with:

Average calc/target ratio in .5 - 33 Hz, ASCE 4-86
 Minimum calc/target ratio in .5 - 33 Hz, ASCE 4-86

M&D Professional Services	CALCULATION SHEET		Page No.	of
			D14	D18
Client / Location Fluor Daniel Hanford	Prepared By / Date MON 4/18/00	Calculation No. 00-0002-E		
Subject MHM Trolley Uplift Constraint Loading	Checked By / Date [Signature] 4/18/00	Revision No. 0		
Ref. Drawing(s)	Revised By / Date	Supporting Document No.		

6th smallest calc/target ratio in .2 - 34 Hz, NRC SRP
 Minimum calc/target ratio in .2 - 34 Hz, NRC SRP
 Factor, for ASCE ave ratio ≥ 1
 Factor, for ASCE min ratio $\geq .9$
 Factor, for NRC SRP ≤ 5 pts $<$ target
 Factor, for NRC SRP min ratio $\geq .9$
 2 12 8 / MHM CSB Vertical Spectra: 7% damping
 Using 8 points for NRC 5 pts below target.
 2 151 /

damp	ASCE ratios		NRC ratios		ASCE factors		NRC factors	
case	mean	min	five	min	mean	min	five	min
1	.993	.730	.873	.730	1.007	1.233	1.145	1.233

Note: The computer programs used in this analysis were all verified on M&D Professional Services, Inc. computers by running the sample problems provided in WHC-SD-GN-CSWD-006.

Conclusion: The time histories developed in this section satisfy the applicable standards when the following factors are included.

North/South factor = 1.2
 East / West factor = 1.2
 Vertical factor = 1.2

NORTH/SOUTH HORIZONTAL DIRECTION

MHM at CSB n=2048 dt=.01 zeta=.07 mhmns seed=86775

0.0026	-0.0031	-0.0177	-0.0181	-0.0088	-0.0100	-0.0243	-0.0336
-0.0247	-0.0041	0.0099	0.0089	0.0034	0.0052	0.0081	0.0010
-0.0093	-0.0082	0.0019	0.0102	0.0186	0.0323	0.0440	0.0468
0.0494	0.0569	0.0593	0.0526	0.0495	0.0563	0.0637	0.0664
0.0683	0.0678	0.0609	0.0505	0.0361	0.0077	-0.0328	-0.0652
-0.0783	-0.0832	-0.0909	-0.0972	-0.0934	-0.0800	-0.0687	-0.0725

0.0026	0.0074	0.0075	0.0129	0.0211	0.0195	0.0048	-0.0102
-0.0118	-0.0006	0.0082	0.0023	-0.0101	-0.0097	0.0035	0.0074
-0.0065	-0.0162	-0.0029	0.0202	0.0305	0.0258	0.0187	0.0163
0.0168	0.0142	0.0034	-0.0093	-0.0080	0.0099	0.0249	0.0240
0.0180	0.0183	0.0176	0.0064	-0.0110	-0.0245	-0.0288	-0.0244
-0.0175	-0.0140	-0.0102	-0.0009	0.0057	0.0015	-0.0036	0.0000

EAST/WEST HORIZONTAL DIRECTION

MHM at CSB n=2048 dt=.01 zeta=.07 mhmew seed=35634

M&D Professional Services	CALCULATION SHEET		Page No.	of
			D15	D18
Client / Location Fluor Daniel Hanford		Prepared By / Date <i>MON</i> 4/18/00	Calculation No. 00-0002-E	
Subject MHM Trolley Uplift Constraint Loading		Checked By / Date <i>MAH</i> 4/18/00	Revision No. 0	
Ref. Drawing(s)		Revised By / Date	Supporting Document No.	

-0.0111	-0.0100	-0.0180	-0.0282	-0.0342	-0.0383	-0.0413	-0.0419
-0.0456	-0.0549	-0.0622	-0.0638	-0.0650	-0.0652	-0.0584	-0.0481
-0.0410	-0.0358	-0.0309	-0.0255	-0.0142	0.0018	0.0085	0.0014
-0.0039	0.0006	0.0053	0.0046	0.0038	0.0058	0.0105	0.0180
0.0250	0.0319	0.0484	0.0729	0.0842	0.0734	0.0593	0.0585
0.0660	0.0727	0.0777	0.0830	0.0882	0.0861	0.0696	0.0496

-0.0259	-0.0315	-0.0363	-0.0360	-0.0331	-0.0293	-0.0232	-0.0163
-0.0137	-0.0160	-0.0144	-0.0062	-0.0004	-0.0002	0.0023	0.0059
0.0005	-0.0095	-0.0111	-0.0064	-0.0036	-0.0009	0.0019	-0.0014
-0.0062	-0.0015	0.0081	0.0121	0.0140	0.0195	0.0232	0.0227
0.0224	0.0223	0.0218	0.0245	0.0270	0.0220	0.0154	0.0176
0.0242	0.0265	0.0251	0.0213	0.0136	0.0080	0.0078	0.0045

VERTICAL DIRECTION

MHM at CSB n=2048 dt=.01 zeta=.07 mhm v seed=35840

-0.0220	-0.0088	0.0105	0.0174	0.0084	-0.0014	-0.0018	0.0039
0.0107	0.0124	0.0010	-0.0184	-0.0274	-0.0203	-0.0084	-0.0001
0.0029	-0.0017	-0.0086	-0.0081	-0.0050	-0.0108	-0.0163	-0.0058
0.0124	0.0204	0.0177	0.0115	0.0049	0.0062	0.0222	0.0410
0.0461	0.0383	0.0267	0.0169	0.0142	0.0199	0.0242	0.0208
0.0154	0.0092	-0.0018	-0.0109	-0.0080	0.0026	0.0109	0.0134

-0.0024	0.0011	0.0041	0.0066	0.0076	0.0061	0.0032	0.0009
0.0019	0.0057	0.0037	-0.0091	-0.0216	-0.0221	-0.0152	-0.0094
-0.0030	0.0025	0.0011	-0.0023	0.0015	0.0074	0.0073	0.0039
-0.0018	-0.0126	-0.0201	-0.0144	-0.0060	-0.0073	-0.0093	-0.0033
0.0021	0.0016	0.0005	-0.0033	-0.0144	-0.0232	-0.0208	-0.0152
-0.0144	-0.0148	-0.0141	-0.0132	-0.0079	0.0016	0.0054	0.0017

The following plots show the comparison between the response spectra of the generated time histories versus the input Design Basis Response Spectra. Note that the generated time history response spectra has the appropriate multiplication factor applied.

M&D	Professional Services	CALCULATION SHEET		Page No.	of
				D16	D18
Client / Location Fluor Daniel Hanford		Prepared By / Date <i>MON</i> 4/18/00		Calculation No. 00-0002-E	
Subject MHM Trolley Uplift Constraint Loading		Checked By / Date <i>[Signature]</i> 4/18/00		Revision No. 0	
Ref. Drawing(s)		Revised By / Date		Supporting Document No.	

SPECTRA for NORTH/SOUTH DIRECTION

M&D Professional Services	CALCULATION SHEET	Page No. D17 of D18
Client / Location Fluor Daniel Hanford	Prepared By / Date MON 4/18/00	Calculation No. 00-0002-E
Subject MHM Trolley Uplift Constraint Loading	Checked By / Date HHS 4/18/00	Revision No. 0
Ref. Drawing(s)	Revised By / Date	Supporting Document No.

SPECTRA for EAST/WEST DIRECTION

SPECTRA for VERTICAL DIRECTION

M&D Professional Services	CALCULATION SHEET		Page No. of D18 D18
Client / Location Fluor Daniel Hanford	Prepared By / Date <i>MON</i> 4/18/00		Calculation No. 00-0002-E
Subject MHM Trolley Uplift Constraint Loading	Checked By / Date <i>MM</i> 4/18/00		Revision No. 0
Ref. Drawing(s)	Revised By / Date		Supporting Document No.

References for Appendix D

- 1) Hanford Standard Arch-Civil Design Criteria Design Loads for Facilities (SDC-4.1/Rev.11)
- 2) Design and Evaluation Guidelines for DOE Facilities Subjected to Natural Phenomena Hazards (UCRL-15910, June 1990)
- 3) Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants (NUREG-0800) Sections 2.5.2, Vibratory Ground Motion (Rev 2) and 3.7.1 Seismic Design Parameters (Rev 2, Aug 1989)
- 4) TC-1961 "Computer Programs for Developing Design Response Spectra from Input Spectra", Hanford Engineering Development Laboratory, by E.O. Weiner April 1981
- 5) WHC-SD-GN-CSWD-006, rev 0, "Seismic System Software Configuration", October 1989
- 6) NRC Regulatory Guide 1.92, Revision 1 "Combining Modal Responses and Spatial Components in Seismic Response Analysis", February 1976
- 7) NRC Standard Review Plan NUREG-0800, Rev 2, "2.5.2 Vibratory Ground Motion", August 1989
- 8) NRC Standard Review Plan NUREG-0800, Rev 2, "3.7.1 Seismic Design Parameters", August 1989
- 9) NRC Standard Review Plan NUREG-0800, Rev 2, "3.7.2 Seismic System Analysis", August 1989
- 10) ASCE 4-86 "Seismic Analysis of Safety-Related Nuclear Structures and Commentary on Standard for Seismic Analysis of Safety Related Nuclear Structures, September 1986
- 11) WHC-SD-GN-DA-30018 Rev. 0 "Design Basis Earthquake Time Histories for 1992 SDC-4.1 Rev12 by Rohay and Evan Weiner

M&D Professional Services	CALCULATION SHEET		Page No. of E1 E7
Client / Location Fluor Daniel Hanford	Prepared By / Date <i>MDN</i> 4/18/00	Calculation No. 00-0002-E	
Subject MHM Trolley Uplift Constraint Loading	Checked By / Date <i>DSW</i> 4-18-00	Revision No. 0	
Ref. Drawing(s)	Revised By / Date	Supporting Document No.	

APPENDIX E BRIDGE UPLIFT RESTRAINT CALCULATIONS

M&D	Professional Services	CALCULATION SHEET	Page No. E2	of E7
Client / Location Fluor Daniel Hanford		Prepared By / Date <i>MON</i> 4/18/00	Calculation No. 00-0002-E	
Subject MHM Trolley Uplift Constraint Loading		Checked By / Date <i>BSW</i> 4-18-00	Revision No. 0	
Ref. Drawing(s)		Revised By / Date	Supporting Document No.	

DISCUSSION

The following calculation determines the adequacy of the MHM Bridge Seismic Restraints against the seismic loads reported in the Seismic Analysis ESL/R(96)083. This analysis includes a friction force term to account for the possibility of the MHM sliding down the bridge rails during a seismic event.

Load Summary: Max. uplift load = 14,800 lbf (66 kN)
 Horz. Component due to angle in rail $(7.4 \text{ kips})(\tan(38.7)) = 5.9 \text{ kips}$
 Normal Force on rail $= (7.4 \text{ kips})/(\cos(38.7)) = 9.5 \text{ kips}$
 Friction Force on rail $= (.8)(9.5) = 7.6 \text{ kips}$ friction coeff. = 0.8

Figure 2.

M&D Professional Services	CALCULATION SHEET	Page No. E3 of E7
Client / Location Fluor Daniel Hanford	Prepared By / Date <i>MDV</i> 4/18/00	Calculation No. 00-0002-E
Subject MHM Trolley Uplift Constraint Loading	Checked By / Date <i>BW</i> 4-18-00	Revision No. 0
Ref. Drawing(s)	Revised By / Date	Supporting Document No.

FIGURE 1. BRIDGE SEISMIC RESTRAINT

FIGURE 2. 2 INCH PLATE (LEG)

M&D Professional Services	CALCULATION SHEET	Page No. _____ of _____ E4 E7
Client / Location Fluor Daniel Hanford	Prepared By / Date <i>MON</i> 4/18/00	Calculation No. 00-0002-E
Subject MHM Trolley Uplift Constraint Loading	Checked By / Date <i>DW</i> 4-18-00	Revision No. 0
Ref. Drawing(s)	Revised By / Date	Supporting Document No.

CHECK PIN FOR BENDING/SHEAR (bending controls)

The bending load on the pin is the resultant of the vertical force and the friction force.

$$P = \sqrt{(7.4)^2 + (7.6)^2} = 10.6 \text{ kips}$$

$$S_B = \frac{2.75\pi}{32} = 2.04 \text{ in}^3$$

$$M_B = 4.625(10.6) = 49 \text{ in} - \text{kip}$$

$$\sigma_B = \frac{49}{2.04} = 24 \text{ ksi}$$

Material 1040 cold drawn ASTM A-108, yield 88 ksi

Allowable = (.9)(88) = 79.2 ksi > 24 ksi

M&D Professional Services	CALCULATION SHEET	Page No. E5 of E7
Client / Location Fluor Daniel Hanford	Prepared By / Date <i>MON 4/19/00</i>	Calculation No. 00-0002-E
Subject MHM Trolley Uplift Constraint Loading	Checked By / Date <i>DW 4-18-00</i>	Revision No. 0
Ref. Drawing(s)	Revised By / Date	Supporting Document No.

CHECK ONE LEG FOR BENDING

$$P_V = 7.4 \text{ kips} \quad P_H = 5.9 \text{ kips}$$

$$M_B = 3.8125(5.9 \text{ kips}) + 2(7.4 \text{ kips}) = 37 \text{ in} - \text{kips}$$

$$S_B = \frac{2^2(18'')}{6} = 12 \text{ in}^3$$

$$Area = 36 \text{ in}^2$$

$$\sigma_B = \frac{37}{12} = 3.1 \text{ ksi}$$

$$\sigma_N = \frac{7.4}{6} = 0.2 \text{ ksi}$$

$$\sigma_{NB} = 3.3 \text{ ksi}$$

Material ASTM A515, GR70 Yield 38 ksi

$$\sigma_{BA} = (.9)(38) = 34.2 \text{ ksi} > 3.3 \text{ ksi}$$

M&D Professional Services	CALCULATION SHEET		Page No. of E6 E7
Client / Location Fluor Daniel Hanford	Prepared By / Date MON 4/18/00	Calculation No. 00-0002-E	
Subject MHM Trolley Uplift Constraint Loading	Checked By / Date BW 4-18-00	Revision No. 0	
Ref. Drawing(s)	Revised By / Date	Supporting Document No.	

CHECK ¾ INCH BOLT

Bolt ¾ diameter SAE GR 5 Yield 85 ksi Ultimate 120 ksi

$$A_t = \pi \left(\frac{E_{s_{min}}}{2} - \frac{0.16238}{N} \right)^2$$

$E_{s_{min}}$ = minimum pitch diameter external thread = 0.6773"

N=Threads/in. = 10

$$A_t = \pi \left(\frac{0.6773}{2} - \frac{0.16238}{10} \right)^2 = 0.326 \text{ in}^2$$

$$F = \frac{5.9(8.81875) + 7.4(2)}{4.375} = 15.3 \text{ kips}$$

$$\sigma = \frac{15.3}{6(.326)} = 7.8 \text{ ksi}$$

Allowable: $(0.9)(85) = 76.5 \text{ ksi} > 7.8 \text{ ksi}$

NOG-5456.2

M&D Professional Services	CALCULATION SHEET	Page No. of E7 E7
Client / Location Fluor Daniel Hanford	Prepared By / Date <i>MDN</i> 4/18/00	Calculation No. 00-0002-E
Subject MHM Trolley Uplift Constraint Loading	Checked By / Date <i>BW</i> 4-18-00	Revision No. 0
Ref. Drawing(s)	Revised By / Date	Supporting Document No.

CHECK WELD AT TOE

NOG-4314

AWS 70 Ult rod allowable = 0.3 Ult or

NOG-4314 allows 1.5 increase in base metal : $(0.5)(1.5)(38) = 28.5$ ksi (controls)

$$F_y = \frac{7.4(2.5) + 5.9(.25)}{1.5} = 13.3 \text{ kips}$$

$$\text{kips/in} = \frac{13.3}{18"} = 0.74 \text{ kips/in} \quad \downarrow$$

$$\text{kips/in} = \frac{5.9}{36"} = 0.33 \text{ kips/in} \quad \rightarrow$$

$$\text{kips/in} = \frac{7.4}{36"} = 0.21 \text{ kips/in} \quad \downarrow$$

$$\text{kips/in} = \frac{7.6}{36"} = 0.21 \text{ kips/in} \quad \downarrow$$

$$\sqrt{0.95^2 + 0.33^2 + 0.21^2} = 1.03 \text{ kips/in}$$

$$W = \frac{1.03 \text{ kips/in}}{28.5 \text{ kips/in}^2} = 0.04 \text{ in} \quad \text{fillet weld is } 3/8"$$

M&D Professional Services	CALCULATION SHEET		Page No. of F1 F7
Client / Location Fluor Daniel Hanford	Prepared By / Date <i>[Signature]</i> 4-18-00	Calculation No. 00-0002-E	
Subject MHM Trolley Uplift Constraint Loading	Checked By / Date <i>[Signature]</i> 4-18-00	Revision No. 0	
Ref. Drawing(s)	Revised By / Date	Supporting Document No.	

APPENDIX F FRICTION COEFFICIENT DAT

KELSAN
Friction Innovators

Kelsan Technologies Corp.

1140 West 15th Street

North Vancouver, B.C.

Canada V7P 1M9

Telephone: 604.984.6100

Fax: 604.984.3419

ATTN: MR. MILON MEYER
M&D PROFESSIONAL SERVICES, INC

DEAR MILON,
THANK YOU FOR YOUR CALL BACK
THIS AFTERNOON. PLEASE FIND THE
INFORMATION YOU REQUESTED ATTACHED.
IF YOU NEED FURTHER INFORMATION PLEASE
CALL ME AT (604) 984-6100

YOURS SINCERELY

Danny Gill

Kelsan Technologies Corp.

Figure 1

Dry Sliding

Lubricated Sliding

Rolling

Typical Values of Friction Coefficient

General

Paper

Dynamic

Material or Coating	Conditions	Value
PTFE	Under high load	0.05
	Under low load	0.10
FEP	Any	0.10
PFA	Any	0.15
Nylon	Any	0.40
Polysacetal	Any	0.35
MoS ₂	In a moist atmosphere	0.20
	In dry conditions	0.10
	In a vacuum	0.02
Graphite	In a moist atmosphere	0.15
	In dry conditions	0.60
Mild Steel	At high load	0.70
	At low load	0.35
Hardened Steel	Any	0.35
Nitrocarburised Steel	Any	0.25
Stainless Steel	Any	0.80
Aluminium Alloy	Any	1.00
Anodised Al Alloy	Any	0.40
Nickel	Any	0.60
Ceramics	Any	0.50

Dynamic - Typical / actual readings direct drive outside

No product - dry

FRICITION READINGS

CRANE #12 (WITHOUT KELSAN STE)

Site Location	Reading Location	Friction Readings						Average
Long Beach Rail	Top of Rail (1)	.45 μ	.53 μ	.50 μ	.55 μ	.55 μ	.47 μ	.51 μ
	Top of Rail (2)	.45	.55	.47	.54	.55	.51	.51 μ
San Pedro Rail	Top of Rail (1)	.47	.49	.48	.55	.47	.48	.49 μ
	Top of Rail (2)	.46	.52	.55	.51	.56	.56	.53 μ

.51

NUREG/CR--5912

TI93 002055

Review of the Technical Basis and Verification of Current Analysis Methods Used to Predict Seismic Response of Spent Fuel Storage Racks

Manuscript Completed: July 1992
Date Published: October 1992

Prepared by
G. DeGrassi

Brookhaven National Laboratory
Upton, NY 11973

Prepared for
Division of Engineering
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, DC 20555
NRC FIN L1103

MASTER

Technical Basis

for single body motions for different geometries and motions were given. Using the procedure, the data can be transformed into hydrodynamic mass relations for multiple body motions. Additional restrictions on the procedure require fluid velocities to be less than 10% of the speed of sound in fluid and the flow channel length to be less than 10% of the wave length for propagating vibratory disturbances in order to avoid the possibility of standing wave effects. Fritz also provided some additional guidance to judge when a fluid may be considered frictionless. Test data was presented for various concentric cylinder vibration tests. Comparisons indicated favorable agreement. Fritz noted that more confirmation is desirable but since the information of the paper was based on basic principles, the equations should be accurate for the specified conditions.

Dong (1978) is another frequently cited reference for hydrodynamic effects in spent fuel rack seismic analysis. The author presented information based on the results of a survey of the literature and of design methods that were used by industrial firms at the time. Structures of concern were spent fuel storage racks, main steam relief valve lines, and reactor internals. The paper presented a summary of different methods and assumptions used to calculate added mass and damping due to fluid submersion. Dong found that the methods used were largely based on engineering judgment. The paper provides an extensive compilation of analytical and experimental data on added mass and added damping for single isolated members and for multiple members. For single isolated members, Dong concluded that potential theory is adequate for describing the added mass phenomenon. Added damping for single isolated structures decreases with increasing structural size and is generally small. For multiple members, he found that fluid dynamic effects are more complex. Experimental data was limited. Dong believed that the concept of added mass and added damping still applies although the formulation is more complicated. Theoretical added mass coefficients for arrays of tube bundles compared well with experimental data. Damping tends to be higher than for single isolated members and tight spaces between members can increase the damping measurably. Dong concluded that, in general, additional experimental validation is needed and the range of various analytical techniques needs to be established.

6.3 Review of Friction Coefficient Reference

The work of Rabinowicz (1976) has most frequently been cited as the basis for considering lower and upper bound friction coefficients of 0.2 and 0.8. The friction coefficients were determined from a series of experiments performed for Boston Edison Company to support their design of new spent fuel racks at the Pilgrim Nuclear Plant. A pin-on-disk friction tester was used in these experiments. In this apparatus, the top specimen, the pin, is held stationary in a dynamometer while it is pressed against the rotating disk by a dead weight load. The angular speed of the disk is adjusted to produce the desired sliding speed. The friction force is measured using a strain gage ring. In these tests, the pin was 304 stainless steel of 1/4" diameter and 1" in length. Two configurations were tested. In one case, the end of the pin was 1/4" diameter hemisphere to produce point contact. In the other case, the pin had a .09 inch diameter flat. When loaded by a dead load of 2 Kg, this configuration produced the same surface stress as that of a fuel rack pad of 6" diameter loaded by 22,000 lb. The flat specimen was a 304 stainless steel plate of dimensions 2" x 2" x 1/4". Two different surface finishes were tested. In these tests the flat specimen was mounted in a cup and immersed in 2 cm of distilled water. Two water temperatures were used, namely room temperature and an elevated temperature of 160°-180°F. In some of the tests fine iron oxide particles were introduced into the water to simulate the effect of corrosion products in the spent fuel pool. Two sliding speeds were used. A speed of 4 inches/second corresponded to the maximum sliding speed of a fuel rack. The other speed, .04 inches/second was chosen to be two orders of magnitude slower than the top speed. A total of ten sliding friction tests were carried out. Nearly all tests were of one hour duration. During each test, ten friction coefficient values were obtained at roughly uniform time intervals. In addition, a series of static friction tests were carried out on surfaces which had been stationary for times of 1, 10, 100, 1000, 10,000, and 50,000 seconds. For these tests, the speed applied to induce sliding was .0004 in/sec.

A total of 199 values of friction coefficient were measured in these tests. Rabinowicz performed statistical analyses of the data. He first separated the results of friction runs which gave high values from those which gave low values. For the 139 high friction coefficient values, he determined a

mean value of .563 and a standard deviation of .096. For the 65 low friction coefficient values, he determined a mean value of .380 and a standard deviation of .080. Lumping all values together, he determined a mean of .503 and a standard deviation of .125. Based on limits of plus and minus two standard deviations, the upper limit is .753 and the lower limit is .253. Rabinowicz noted that temperature and contact pressure had little effect as did the introduction of iron oxide particles. Surface roughness had some influence in that very rough surfaces gave somewhat lower friction. Sliding speed had a major effect, with distinctly higher friction at lower sliding speeds. Time of stick, however, had little effect. For fuel rack design, Rabinowicz recommended that the design be based on friction coefficient values between 0.20 and 0.80.

6.4 Assessment of Methodology

6.4.1 Analytical Studies

A review of the literature revealed that several papers have been written on the subject of free-standing spent fuel rack seismic analysis. A number of investigators have presented descriptions of analytical models and analysis methods used to simulate fuel rack dynamic behavior. The most detailed descriptions have been provided by Gilmore (1982), Soler and Singh (1983), Kabir et al (1987), and Pop et al (1990). While details of the analyses varied, the analytical models described by the different authors had many common features which are representative of the current analysis methods described in Section 4.0 of this report. The mathematical models include linear and nonlinear elements. Fuel rack and fuel assembly stiffnesses and mass distributions are generally represented by linear beam type elements. Nonlinear gap spring and Coulomb friction elements are used to represent interface locations such as fuel to rack cell, support pad to pool floor, and rack to adjacent rack or pool wall. Hydrodynamic mass and coupling effects are represented by incorporating added mass terms into the mass matrix of the system. Flow models used to determine the hydrodynamic mass terms assume incompressible, inviscid flow (potential theory) and small deflections. Finite element programs with nonlinear capability (ADINA, ANSYS, WECAN) have generally been used to develop and analyze the fuel rack models. The Soler and Singh paper describes an analytical method in which the governing equations of motion are developed and

solved using a special purpose computer program. All methods required a seismic time history analysis with simultaneous application of gravity, vertical seismic, and one or two horizontal seismic input accelerations or displacements at the pool floor. Because of the nonlinearities, the direct integration method is generally used to determine the dynamic response. Gilmore, however, reported the use of the nonlinear modal superposition method of the WECAN program. Seismic analysis results presented by the authors also showed a similarity of response. Fuel assemblies were shown to rattle and impact the rack cell walls, the racks had a tendency to slide and uplift, and high impact loads were transmitted to the pool floor when a rack uplifted and fell back.

Differences between the analysis methods include the degree of detail in the model, methods for determining the linear and nonlinear properties, methods of calculating hydrodynamic mass terms, etc. Some of the more obvious differences reflect an evolution of the methodology. The Gilmore model was very detailed but was two-dimensional. The Soler and Singh model had less detail but was three-dimensional. The Kabir model was a detailed three-dimensional model of a single rack with adjacent 2-D models included to account for multiple rack interaction effects. Pop recommended development of both a single rack 3-D model to evaluate 3-D effects and a 2-D multirack model to evaluate multirack effects.

The analysis methods are based on fundamental principles of structural mechanics and dynamics. The authors did not present experimental data to verify the analytical methods or their range of validity.

6.4.2 Experimental Verification

Some limited experimental work to verify the seismic response of fuel racks has been performed in France and Japan. In both cases, the tests were performed in conjunction with the development of seismic base isolation fuel rack supports. Framatome has developed a roller bearing aseismic support which significantly reduces the horizontal seismic forces. MHI has developed a sliding support pad design which utilizes graphite pellets to minimize the horizontal friction and thus reduce horizontal seismic forces.