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1	SNF-5984	all	0	Multi-Canister Overpack Handling Machine Trolley Seismic Uplift Constraint Design Loads	S	1	1	1

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Multi-Canister Overpack Handling Machine Trolley Seismic Uplift Constraint Design Loads

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

Project Hanford Management Contractor for the
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Richland, Washington

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Multi-Canister Overpack Handling Machine Trolley Seismic Uplift Constraint Design Loads

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M&D Professional Services, Inc.	CALCULATION COVER SHEET	Page 1 Calculation No. 00-0002-C Revision No. 0

PROJECT NAME:	CLIENT:
SNF	Fluor Daniel Hanford

TITLE:

MHM TROLLEY SEISMIC UPLIFT CONSTRAINT DESIGN LOADS

PROBLEM STATEMENT:

This calculation addresses the bounding design loads for the trolley seismic uplift constraints of the MCO Handling Machine (MHM).

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0	1–15 A1-A5 B1-B4 C1-C10	Initial issue	Bob Winkel BWinkel BW. 3-7-00	Mike Northey Mike Northey MDN 3/7/00

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1.0 INTRODUCTION

The MCO Handling Machine (MHM) trolley moves along the top of the MHM bridge girders on east-west oriented rails. To prevent trolley wheel uplift during a seismic event, passive uplift constraints are provided as shown in Figure 1-1. North-south trolley wheel movement is prevented by 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 a plunger, which is inserted into slots positioned along the tracks as shown in Figure 1-1. When the MHM trolley is moving between storage tube positions, the active seismic restraints are not engaged.

The MHM has been designed and analyzed in accordance with ASME NOG-1-1995. The ALSTHOM seismic analysis (Reference 3) reported seismic uplift restraint loading and EDERER performed corresponding structural calculations. The ALSTHOM and EDERER calculations were performed with the east-west seismic restraints activated and the uplift restraints experiencing only vertical loading. 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 east-west trolley restraints are not engaged. For this case, the associated trolley movements would result in east-west lateral loads on the uplift constraints due to friction, as shown in Figure 1-2.

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 modified to account for lateral loading. The disposition of NCR 00-SNFP-0008 will track the redesign and modification effort.

The purpose of this calculation is to establish bounding seismic loads (vertical and horizontal) for input into the uplift restraint hardware redesign calculations. To minimize iterations on the uplift redesign effort, efforts were made to assure that the final loading input was reasonable but unquestionably on the conservative side.

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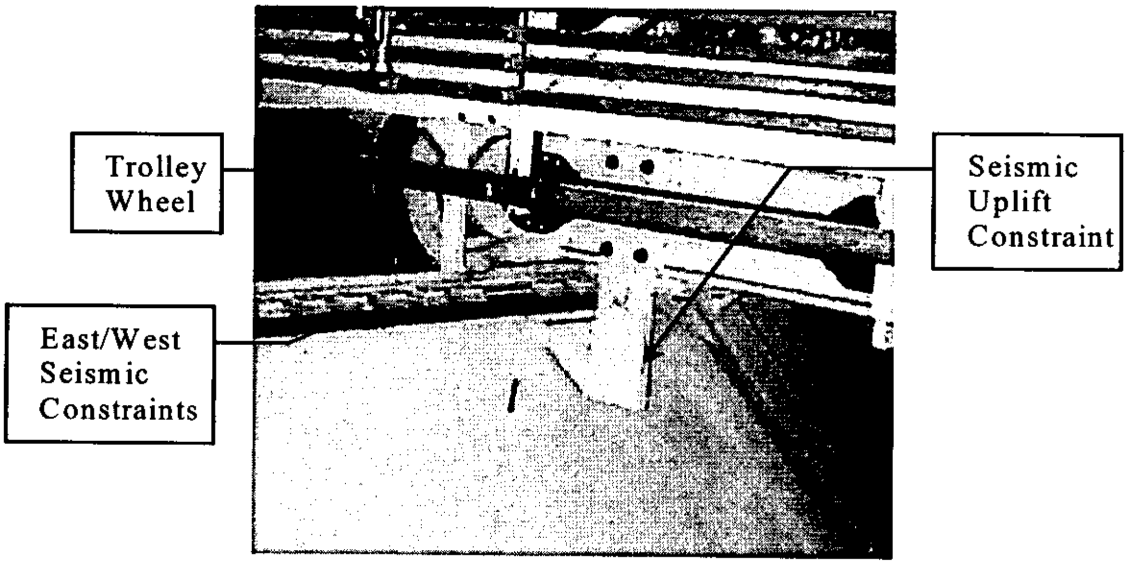

Figure 1-1 - MHM Trolley Seismic Constraints

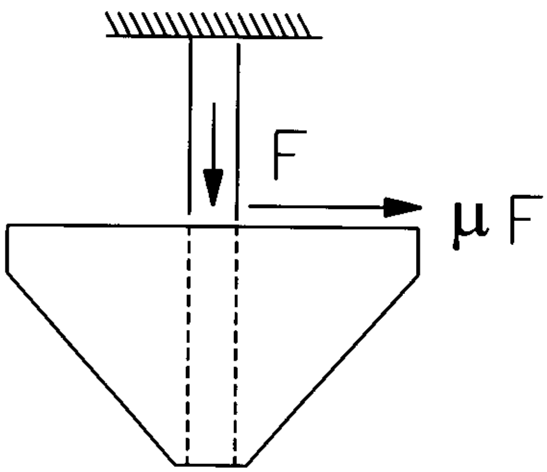

Figure 1-2 - Seismic Uplift Constraint Geometry and Loading

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2.0 SUMMARY AND RECOMMENDATIONS

The maximum vertical uplift loading on the MHM trolley uplift constraint reported by ALSTHOM is 97 kips. The adequacy and conservative nature of this bounding load value was confirmed by performing independent seismic calculations as described below. Therefore, for uplift restraint design purposes, a vertical uplift load value of 100 kips is recommended. Using an upper bound friction coefficient of 0.9, a horizontal (east-west) loading of 90 kips is recommended (force "μF" in Figure 1-2).

3.0 DESIGN INPUT AND ASSUMPTIONS

The seismic analyses performed in the remainder of this report utilized the design/analysis input information summarized in Table 3-1.

Table 3-1 – Analysis Input Parameters

Input Item	Value/Reference
MHM Drawings	Reference 10
MHM Assembly Weight	932,000 lbf
MHM Trolley/Turret Weight (Including MCO)	398,000 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, resulting in an east-west coupling of the two western trolley wheels to the bridge. This assumption anchors the trolley in the east-west direction and results in a stable computer solution. During MHM repositioning, the east-west trolley constraints are not active. However, some constraining of two of the wheels is likely due to braking and/or gear/motor resistance. Relative to the uplift restraint load magnitude, it is conservative to assume that the trolley wheels do not move relative to the bridge rails.
2) The ALSTHOM seismic model details are assumed to be correct. The ALSTHOM seismic model was used to develop a simplified seismic model described below.
3) An equivalent static seismic analysis approach is assumed to provide a conservative estimate of the uplift restraint loading. It was also conservatively assumed that the peak directional seismic loads coincide in time.

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4.0 MHM/MCO HARDWARE DISCUSSION

The MHM assembly consists of a bridge, trolley, and turret, as shown in Figure 4-1. The 126-ft long bridge rides on north-south directed rails. The trolley rides on east-west rails which are positioned on top of the bridge girders. 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 trolley wheel liftoff and/or falling of the trolley assembly during a seismic event.

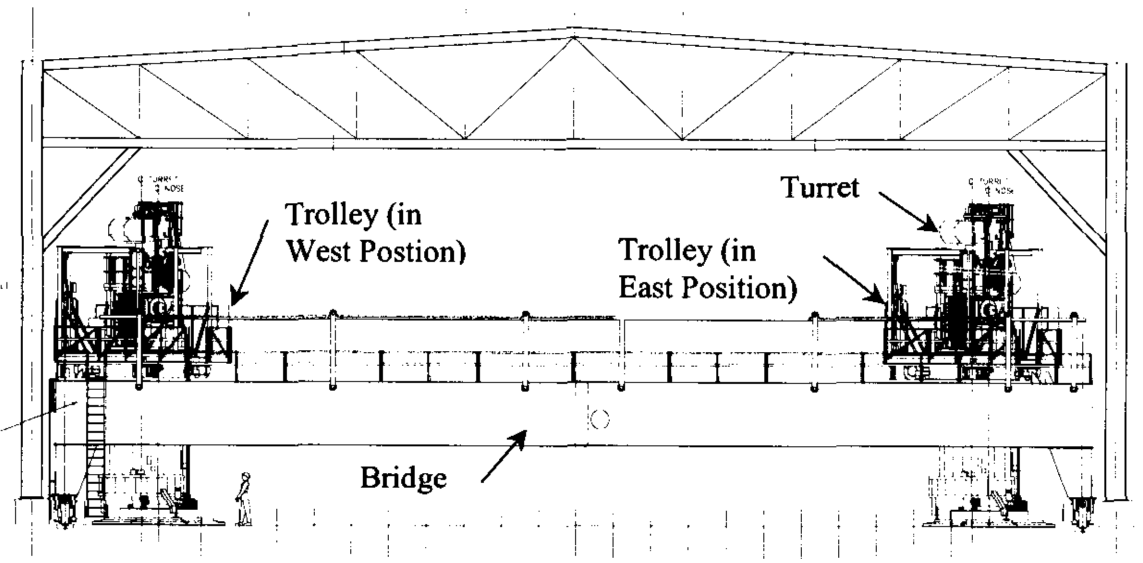

Figure 4-1 - Trolley, Bridge, and Turret Illustration

5.0 TROLLEY UPLIFT RESTRAINT LOAD DEVELOPMENT

5.1 EVALUATION APPROACH

The evaluation documented in this report corresponded to the following steps:

1) The ALSTHOM seismic analysis was reviewed and evaluated relative to the trolley uplift restraint seismic loading.

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2) Using the trolley/turret portion of the ALSTHOM seismic computer model, the ALSTHOM model was used to determine the center of gravity of the trolley/turret hardware. From fixed-wheel reaction loads developed in the center of gravity calculations an estimate of the seismic uplift loading can be made using an equivalent static seismic analysis approach. A factor of 1.5 times the peak of the response spectrum is used, as specified by the "Equivalent Static Load Method" discussed in Section II of Reference 8.
3) Using 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, Figure NOG-4154.3-1.
4) Using the model developed in Step 3, an equivalent static seismic analysis was performed considering all possible combinations of seismic loading directions. From the analysis results, bounding uplift restraint loads were obtained.
5) Based upon a comparison of the ALSTHOM results and the simplified model results, plus adding a margin to assure conservatism, the uplift restraint redesign loading was established. The horizontal loading was established by multiplying the bounding vertical load by a conservative estimate of the friction coefficient.

The remainder of this section documents the details of the above evaluation steps.

5.2 ALSTHOM SEISMIC ANALYSIS EVALUATION

The trolley seismic uplift restraints introduce a nonlinearity into the trolley seismic response in the sense that the trolley/bridge interface vertical loading changes location if the load path is upward versus downward. That is, an uplift load is carried by the uplift restraints and a downward load is carried through the wheel/track interface. The uplift restraint is located at the edge of the bridge girder at a distance of about two feet from the nearest wheel. There is a half-inch gap between the uplift restraint and the bridge girder interface.

The ALSTHOM linear seismic model did not fully account for the up/down vertical load location shift or the half-inch restraint gap. Due, in part, to this vertical load complexity, the Reference 3) ALSTHOM analysis results were somewhat confusing and questions were raised relative to the bounding nature of the uplift restraint design loading. See NCR 00-SNFP-0008, Reference 5). The ALSTHOM position was clarified in an email message (Reference 4)). From the ALSTHOM email communication, a bounding vertical uplift restraint loading of 97 kips was obtained.

Due to the above-mentioned load complexity, plus other uncertainties in the relatively complex ALSTHOM computer model, it appeared that an independent analysis was in order to obtain the desired confidence level in establishing the uplift restraint redesign loads.

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5.3 TROLLEY/TURRET ASSEMBLY CENTER OF GRAVITY

The calculation establishing the trolley/turret assembly center of gravity is 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 trolley rail top. From the Appendix A 1g wheel reaction loading, an estimate of the seismic uplift loading can be obtained. From Figures 16-18 of Reference 3), the following peak spectral g loads are obtained:

Accelx = 0.74 g's (East/West)
Accely = 0.77 g's (North/South)
Accelz = 0.59 g's (Vertical)

From the 1g Appendix A results, the following maximum vertical wheel reactions are obtained:

Fx Loading: Fzmax = 46.1 kips
Fy Loading: Fzmax = 61.0 kips
Fz Loading: Fzmax = 106 kips
Fz Loading: Fzmin = 81 kips

Multiplying the 1g results by the appropriate seismic g levels and using a standard "equivalent static" seismic analysis multiplier of 1.5, the following seismic uplift loads are obtained:

Fx Loading: Fzmax = 1.5(0.74)(46.1) = 51.2
Fy Loading: Fzmax = 1.5(0.77)(61.0) = 70.5
Fz Loading: Fzmax = 1.5(0.59)(106) = 93.8

To account for the fact that the peak uplift forces for the three directions do not occur at the same time, the uplift loads from the three directions are combined using the square root of the sum of the squares (SRSS, see Section3.2.7.1.2 of Reference 9):

$$F_{sum} = \sqrt{(51.2)^2 + (70.5)^2 + (93.8)^2} = 128 \text{ kips.}$$

From the 1g vertical results in Appendix A, the minimum vertical wheel reaction is 81 kips. Subtracting the minimum dead weight reaction, results in a maximum uplift of 128 – 81 = 47 kips. Thus, the approximate static approach with the wheels fixed is well below the ALSTHOM result of 96 kips. Neither of the above approaches accounts for the off-set nature of the uplift/wheel offset, nor do they account for the half-inch gap between the uplift restraint and the girder flange. These concerns are addressed in the section that follows.

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5.4 MHM ASSEMBLY FINITE ELEMENT MODEL

A simplified finite element model of the MHM accounting for the uplift/wheel offset and the half-inch gap is shown in Figure 5-1 and Figure 5-2. The model configuration and boundary 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 was selected to correspond to the highest seismic uplift force configuration reported in the ALSTHOM seismic analysis (Reference 3)). 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 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. Rigid links were used to bridge between the trolley wheel/rail (compressive) interface and the uplift constraint (tensile) locations. The compressive and tensile interface locations are about 23 in. apart.

The trolley/turret 398,000-lb mass was concentrated at the center of gravity location. The location of the trolley/turret center of gravity was obtained from Appendix A. Rigid links are used to connect the trolley frame to the mass element at the center of gravity.

As an additional check on the model adequacy, a modal analysis was performed, resulting in a fundamental frequency of 2.2 hz. This compares favorably with the the ALSTHOM seismic model fundamental frequency of 2.6 hz.

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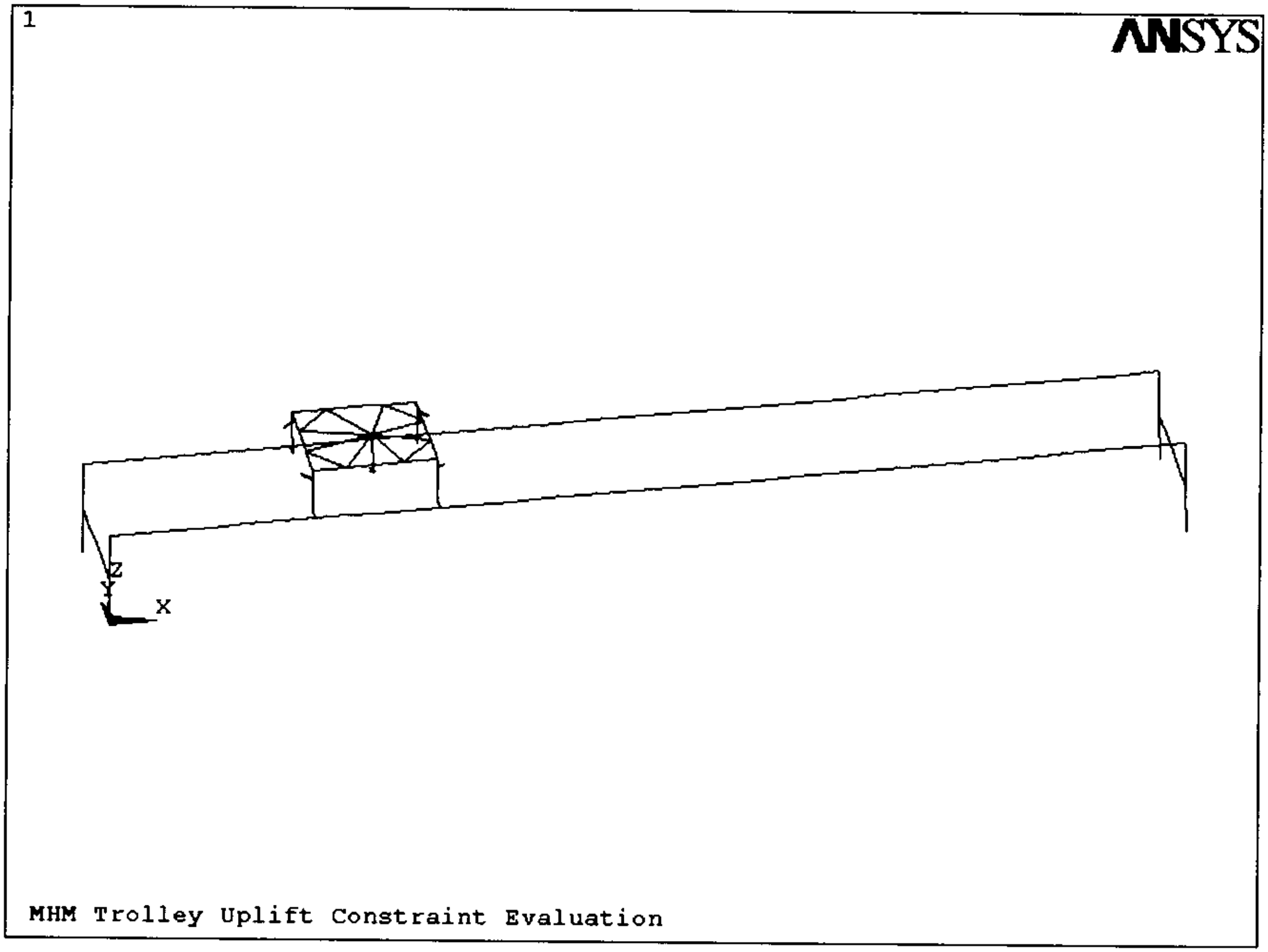

Figure 5-1 - Beam Centerline Plot of MHM Seismic Model

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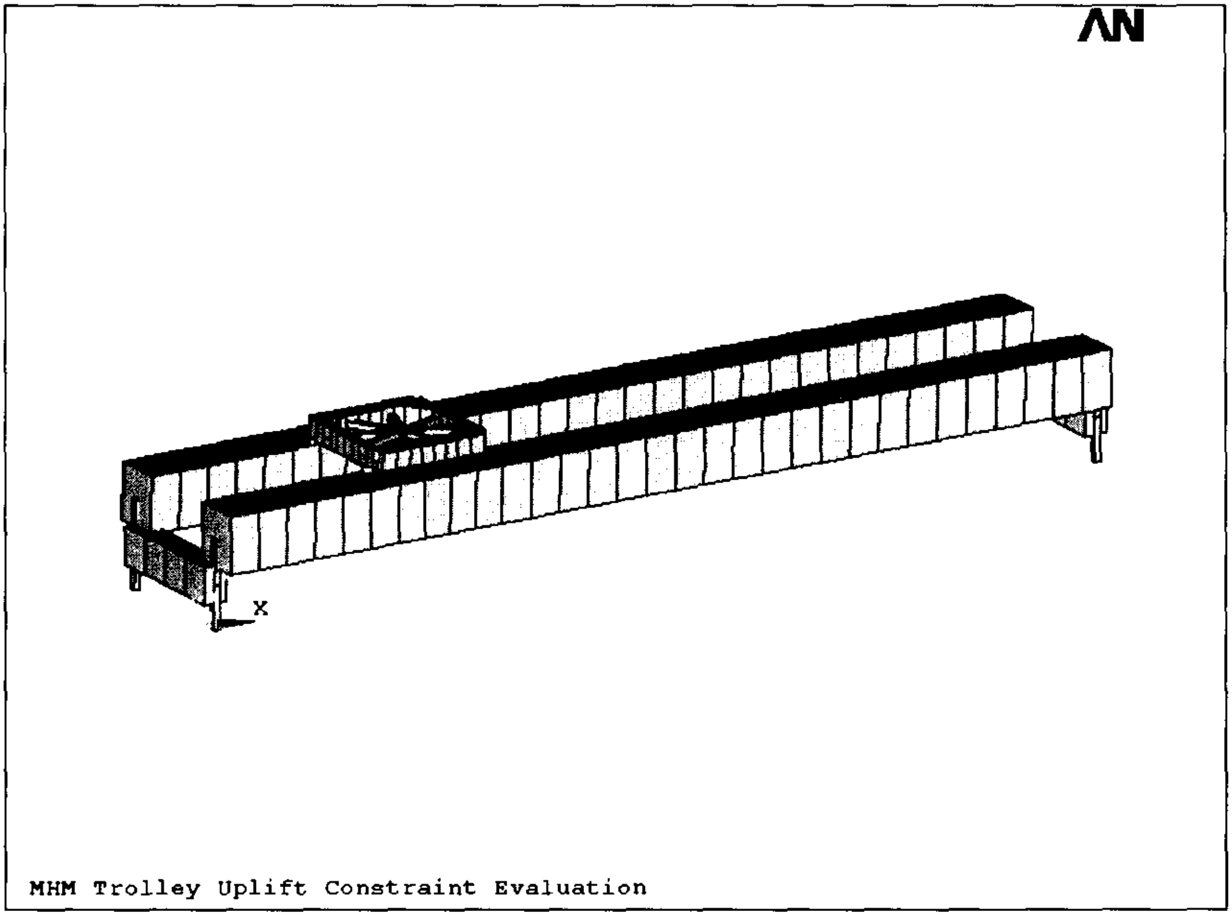

Figure 5-2 - Model Plot Showing Beam Cross Sectional Dimensions

5.5 MHM SEISMIC ANALYSIS

Using the 1.5 times the peak spectral values from Section 5.3, the seismic model described in the previous section was used to perform an equivalent static seismic analysis, using the ANSYS™ finite element code. The ANSYS™ input listing is provided in Appendix B. The seismic loading for each direction can be either positive or negative. To obtain the maximum uplift, a positive (upward) z acceleration is assumed. For the two horizontal directions, various combinations of positive and negative accelerations were considered to obtain a bounding value.

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From the ANSYS™ output, the following maximum uplift reactions were obtained:

X Direction: 50 kips
Y Direction: 77 kips
Z Direction: 96 kips

The SRSS combination of directions results in the following seismic uplift:

$$F_{sum} = \sqrt{(50)^2 + (77)^2 + (96)^2} = 133 \text{ kips.}$$

The minimum dead weight wheel reaction calculated was 87 kips (downward). Subtracting the minimum dead weight wheel reaction results in a net uplift load of 133 – 87 = 46 kips, which again confirms the conservatism of the ALSTHOM analysis.

5.6 HORIZONTAL UPLIFT RESTRAINT LOADING

From Table 1 of Chapter 3 of Mark's Handbook (Reference 6)), the maximum dry steel-to-steel friction coefficient listed is 0.78. To account for uncertainties, a bounding friction coefficient of 0.9 is used. Using a bounding vertical load of 100 kips, a horizontal design load of 0.9(100) = 90 kips is obtained.

6.0 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.
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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

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Ref. Drawing(s) EDERER Drawing No. C-3466	Revised By / Date	Supporting Document No.

Engineers, New York City, New York.

10) MHM Drawings:

Description of Assembly	ALSTHOM/ EDDERER Drawing No.
Turret Assembly	362A0558
Alignment Cylinder Assembly	-
Anti-collision System Assembly	362A0568
Base Locking Pin Assembly	362A0554
Base Shielding Assembly	362A0697
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

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Ref. Drawing(s) EDERER Drawing No. C-3466	Revised By / Date	Supporting Document No.

Description of Assembly	ALSTHOM/ EDDERER Drawing No.
Upper Shielding Assembly	362A0693

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APPENDIX A CENTER OF GRAVITY CALCULATION

M&D Professional Services	CALCULATION SHEET	Page No. A2 of A6
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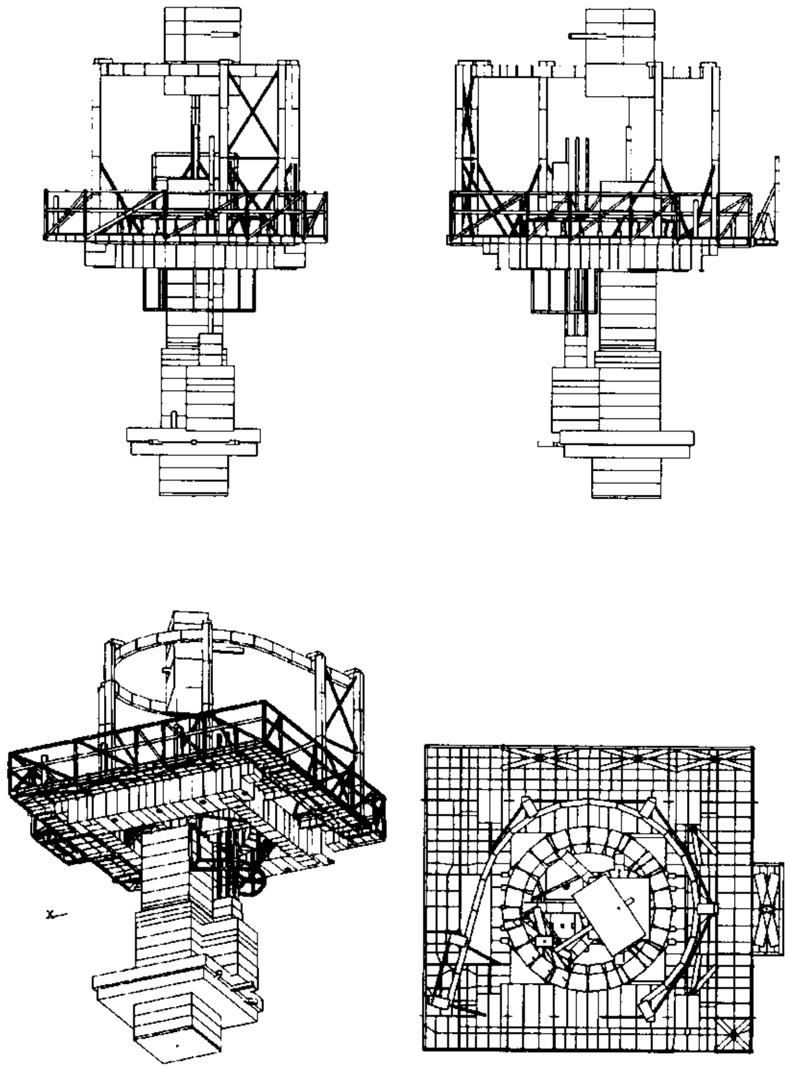

ALSTHOM TROLLEY/TURRET MODEL

M&D Professional Services	CALCULATION SHEET	Page No. A3 of A6
Client / Location Fluor Daniel Hanford	**Prepared By / Date** MDR 3/7/00	**Calculation No.** 00-0002-C
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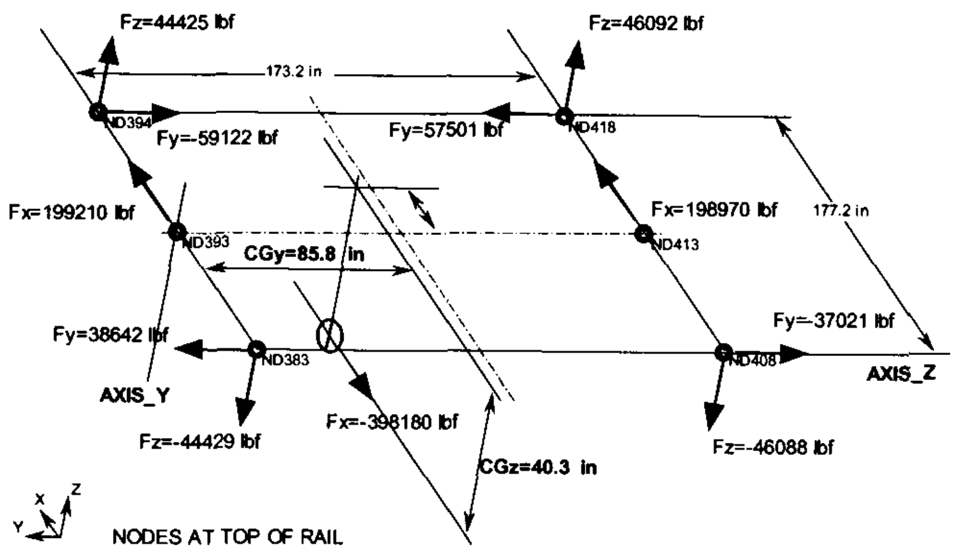
1 "G" LOAD IN "X" DIRECTION



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

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	FX	FY	FZ	MX	MY	MZ
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:

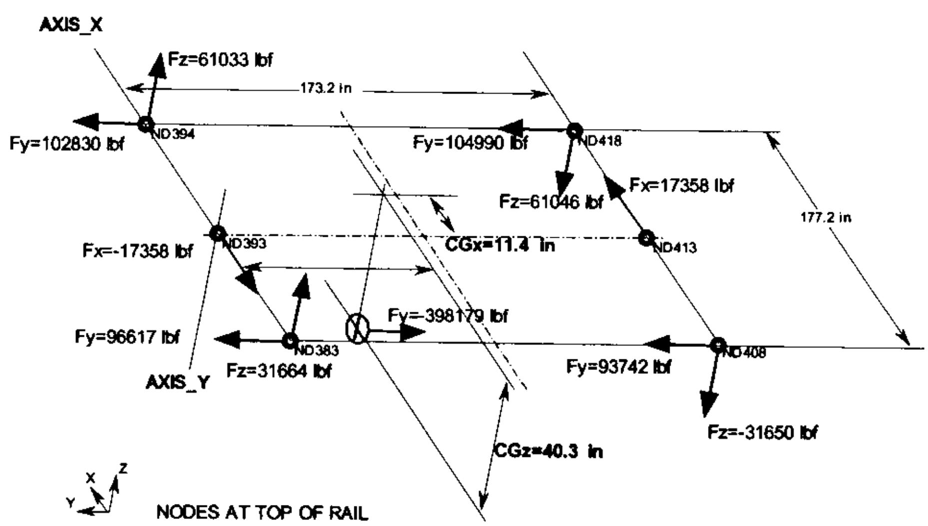
(177.2)(44425+46092)=(CGz)(398180) CGz=40.3 inches

Sum moments about Axis_Y:

(173.2)(198970)+(177.2/2)(57501+37021-38642-59122)=(CGy)(398180) CGy=85.8 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

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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:

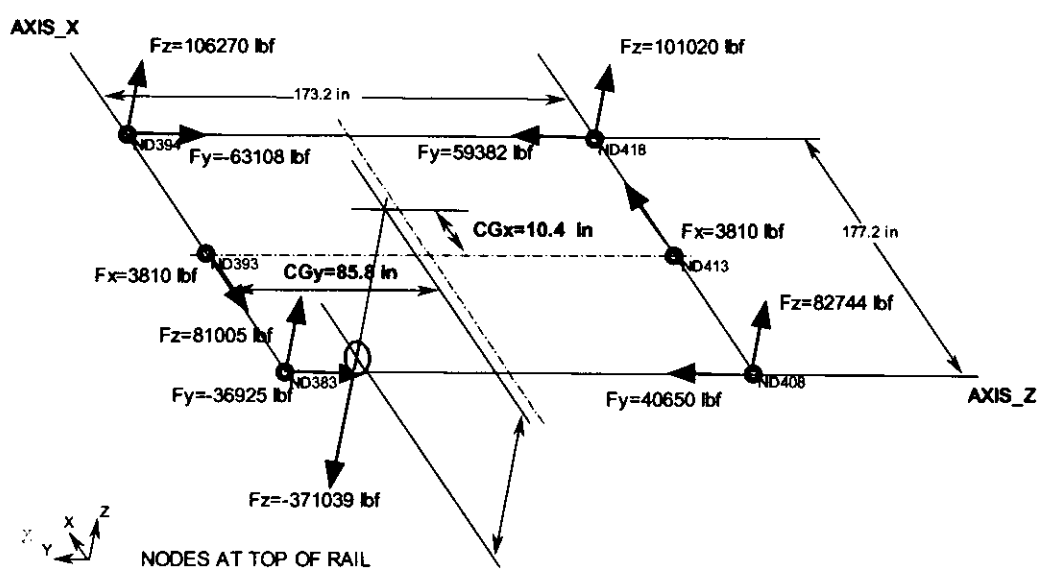
(173.2)(61046+31650)=(CGz)(398179) CGz=40.3 inches

Sum moments about Axis_Y:

(173.2)(17358)+(177.2/2)(-96617-93742+102830+104990)=(CGx)(398179)
CGx=11.4 inches

---

1 "G" LOAD IN "Z" DIRECTION



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Client / Location: Fluor Daniel Hanford	Prepared By / Date: MON 3/7/00	Calculation No.: 00-0002-C
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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:

$$(173.2)(101020+82744)=(CGy)(371039) \qquad CGy=85.8 \text{ inches}$$

Sum moments about Axis_Z:

$$(177.2)(106270+101020)=(CGx+177.2/2)(371039) \qquad CGx=10.4 \text{ inches}$$

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APPENDIX B ANSYS^{TM} INPUT LISTING

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/title, MHM Trolley Uplift Constraint Evaluation
!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,,473600,2.79,1.56
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     !Trolley/Turret Mass (Weight: g units)
r,8,1e6,,,.0001  !Compression Only Gap Element
r,9,1e6,,,.5     !Tension Only Gap Element
r,10,1000        !Soft spring for stability

!material prop.
!Bridge
mp,ex,1,29e6
mp,nuxy,1,0.3
!Rigid Links
mp,dens,1,.535   !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,5,290.9,215.3,140
k,6,290.9,194.2,140
k,7,290.9,194.2,190
k,107,290.9,194.2,191
k,207,276.9,176.2,190
k,307,276.9,176.2,191
k,8,290.9,0,140
k,9,290.9,21.1,140
k,10,290.9,21.1,190
k,110,290.9,21.1,191
k,210,276.9,39.1,190
k,310,276.9,39.1,191
k,11,468.1,215.3,140
k,12,468.1,194.2,140
k,13,468.1,194.2,190
k,113,468.1,194.2,191
k,213,482.1,176.2,190
k,313,482.1,176.2,191
k,14,468.1,0,140
k,15,468.1,21.1,140
k,16,468.1,21.1,190
k,116,468.1,21.1,191
k,216,482.1,39.1,190
k,316,482.1,39.1,191
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,21,290.9,194.2,205.3
k,22,290.9,136.5,205.3
k,23,290.9,78.8,205.3
k,24,290.9,21.2,205.3
k,25,338.7,194.2,205.3
k,26,338.7,21.1,205.3
k,27,420.3,194.2,205.3
k,28,420.3,21.1,205.3
k,29,468.1,194.2,205.3
k,30,468.1,136.5,205.3
k,31,468.1,78.8,205.3
k,32,468.1,21.1,205.3
k,33,389.9,108.5,205.3
k,34,389.9,108.5,149.7

!Lines
!Bridge
l,1,101
l,101,3
l,2,102
l,102,4
l,101,102
l,3,5
l,4,8
l,5,6
l,6,7
l,8,9
l,9,10
l,5,11
l,8,14
l,11,12
```

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l,12,13
l,14,15
l,15,16
l,11,17
l,14,18
l,19,119
l,119,17
l,20,120
l,120,18
l,119,120
!Trolley
l,107,21
l,110,24
l,21,22
l,22,23
l,23,24
l,21,25
l,22,25
l,22,33
l,23,33
l,23,26
l,24,26
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l,31,33
l,28,31
l,28,32
l,29,30
l,30,31
l,31,32
l,113,29
l,116,32
l,33,34
!Constraint Offsets
l,7,207
l,107,307
l,10,210
l,110,310
l,13,213
l,113,313
l,16,216
l,116,316

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0.442987360016
/ANG, 1,   67.3683334857
lplo
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!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,51,52
lmesh,32,34
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
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
```

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esize,,1
lmesh,54,61
!Gap Elements
type,3
!Compression Eles.
real,8
e,80,87
e,82,89
e,84,91
e,86,93
!Tension Eles.
real,9
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
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,3,uz,80,87
cp,4,ux,82,89
cp,5,uy,82,89
!cp,6,uz,82,89
cp,7,uy,84,91
!cp,8,uz,84,91
cp,9,uy,86,93
!cp,10,uz,86,93
fini
/solu
nsubst,5
acel,,,1      !Dead Weight
solve
acel,1.155    !X Direction DBE
solve
acel,,1.111   !Y Direction DBE
solve
acel,,,-0.877 !Z Direction DBE
solve

fini
/post1
/output,uplift,out
esel,s,type,,3
esel,u,real,,10
set,1,last
ETABLE,f1,SMISC,1
ETABLE,ui,NMISC,5
ETABLE,uj,NMISC,6
PRETAB,F1,UI,UJ
set,2,last
ETABLE,f1,SMISC,1
ETABLE,ui,NMISC,5
ETABLE,uj,NMISC,6
PRETAB,F1,UI,UJ
set,3,last
ETABLE,f1,SMISC,1
ETABLE,ui,NMISC,5
ETABLE,uj,NMISC,6
PRETAB,F1,UI,UJ
set,4,last
ETABLE,f1,SMISC,1
ETABLE,ui,NMISC,5
ETABLE,uj,NMISC,6
PRETAB,F1,UI,UJ
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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; rroberts@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		
	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
TROLLEY	329			469.4		427.0	632.8	163.4	1102.2
MIDSPAN	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
	321			360.5		273.3	415.9	55.4	776.4
	322			0.0			0.0	0.0	0.0
	324				681.5				
TROLLEY	326			0.0			0.0	0.0	0.0
QUARTER	327			472.6		527.7	747.4	274.8	1220.0
SPAN	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
	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
TROLLEY	331			471.8		432.0	572.0	100.2	1043.8
END	332			356.3		438.5	379.0	22.7	735.3
SPAN	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		
	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	
TROLLEY	329			394.7		418.9	664.7		1059.4
MIDSPAN	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
	321			335.3		353.1	405.9		741.2
	322			0.0			0.0	0.0	
	324				770.0				
TROLLEY	326			0.0			0.0	0.0	
QUARTER	327			372.3		552.6	978.6		1350.9
SPAN	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
	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	
TROLLEY	331			376.6		413.3	690.1		1066.7
END	332			0.0		415.6	0.0		0.0
SPAN	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		
	323			308.3		187.4	751.0		1059.3
	324			0.0			0.0	0.0	
	326				500.3				
	328			527.5			522.8		
TROLLEY	329			0.0		424.0	0.0		0.0
MIDSPAN	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
	321			303.5		302.7	493.9		797.4
	322			0.0			0.0	0.0	
	324				789.7				
TROLLEY	326			532.0			812.4	280.4	
QUARTER	327			0.0		545.1	0.0		0.0
SPAN	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
	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	
TROLLEY	331			0.0		386.7	0.0		0.0
END	332			298.2		398.7	390.6		688.8
SPAN	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

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		
	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	
TROLLEY MIDSPAN	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
	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	
TROLLEY QUARTER SPAN	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
	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	
TROLLEY END SPAN	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.

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