Dominion Energy Kewaunee, Inc.
5000 Dominion Boulevard, Glen Allen, VA 23060

Dominion®

September 19, 2008

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555

Serial No.	08-0211A
KPS/LIC/BG:	R0
Docket No.	50-305
License No.	DPR-43

DOMINION ENERGY KEWAUNEE, INC.
KEWAUNEE POWER STATION
LICENSE AMENDMENT REQUEST 239, SUPPLEMENT 1 – REQUEST FOR REVIEW AND APPROVAL OF SEISMIC ANALYSIS METHODOLOGY FOR AUXILIARY BUILDING CRANE

By letter dated July 7, 2008 (Reference 1) Dominion Energy Kewaunee, Inc. (DEK) requested an amendment to facility operating license number DPR-43 for Kewaunee Power Station (KPS). The proposed amendment would allow the use of a new methodology to determine the seismic loads on the recently upgraded Auxiliary Building (AB) crane. The AB crane has recently been upgraded to a single-failure-proof design through replacement of the crane trolley and modification of the existing crane bridge. The proposed new methodology is not currently described in the KPS Updated Safety Analysis Report (USAR) or the codes of reference applicable to the upgraded AB crane.

The new methodology uses a nonlinear analysis technique to model the rolling of the trolley and bridge drive wheels on their respective rails after sufficient force is developed to exceed the drive wheel brake force during a seismic event. In DEK License Amendment Request (LAR) 239 (Reference 1), DEK provided a description of the approach, inputs, assumptions, and modeling used in the nonlinear analysis to determine the seismic loads on the AB crane. DEK also committed to the following actions:

- Provide the results of the AB crane seismic analysis, including a detailed discussion of the nonlinear analysis methodology and sensitivity studies for the various input parameters.
- Perform a "push" test to provide empirical data documenting the actual force required to induce AB crane trolley and bridge drive wheel rolling with the brakes applied and provide the results of the testing to the NRC.
- Conduct a third-party peer review of the nonlinear seismic analysis and provide the results of that review to the NRC.

Additionally, DEK stated in Reference 1 that the follow-up information discussed above was scheduled for submittal by August 8, 2008. However, during the third-party peer review, comments were received that required additional work to be performed. This

A001
NRR

additional work included sensitivity studies and an improved presentation of the calculation results to facilitate NRC technical review.

The attachment and enclosures to this letter provide the information necessary to fulfill the above three commitments and complete the proposed LAR.

DEK has reviewed the information provided in this letter and concludes that the no significant hazards consideration evaluation contained in Reference 1 remains valid. The requested date for NRC approval of the subject license amendment request, as delineated in Reference 1, remains unchanged.

If you have any questions or require any additional information, please contact Mr. Craig Sly at 804-273-2784.

Sincerely,

J. Alan Price
Vice President-Nuclear Engineering

COMMONWEALTH OF VIRGINIA)
)
COUNTY OF HENRICO)

The foregoing document was acknowledged before me, in and for the County and Commonwealth aforesaid today by J. Alan Price, who is the Vice President – Nuclear Engineering of Dominion Energy Kewaunee, Inc. He has affirmed before me that he is duly authorized to execute and file the foregoing document in behalf of that Company, and the statements in the document are true to the best of his knowledge and belief.

Acknowledged before me this 19TH day of September, 2008.

My Commission Expires: May 31, 2010.

Vicki L. Hull
Notary Public

VICKI L. HULL
Notary Public
Commonwealth of Virginia
140542
My Commission Expires May 31, 2010

Attachment:

Supplemental Information Supporting Kewaunee License Amendment Request 239

Enclosures:

1. ACECO Calculation No. CAL-20776-SE-007
2. Third Party Review of Seismic Analysis Method

Commitments made by this letter:

1. DEK will change appropriate maintenance procedures to require the push test be re-performed after any rebuild of the crane brakes. A rebuild of the brakes is defined as any work that could result in an increase in the brake force, such as a replacement of the springs or brake shoes.

References:

1. Letter from Gerald T. Bischof (DEK) to NRC Document Control Desk, "License Amendment Request 239 – Request for Review and Approval of Seismic Analysis Methodology for Auxiliary Building Crane," dated July 7, 2008.

cc:

Regional Administrator
U.S. Nuclear Regulatory Commission
Region III
2443 Warrenville Rd.
Suite 210
Lisle, IL 60532-4532

Mr. P. S. Tam
Senior Project Manager
U.S. Nuclear Regulatory Commission
One White Flint North
Mail Stop O8-H4A
11555 Rockville Pike
Rockville, MD 20852-2738

Resident Inspector
Kewaunee Power Station

Public Service Commission of Wisconsin
Electric Division
P.O. Box 7854
Madison, WI 53707

ATTACHMENT

LICENSE AMENDMENT REQUEST 239, SUPPLEMENT 1
REQUEST FOR REVIEW AND APPROVAL OF SEISMIC ANALYSIS METHODOLOGY FOR AUXILIARY BUILDING CRANE

SUPPLEMENTAL INFORMATION SUPPORTING KEWAUNEE LICENSE AMENDMENT REQUEST 239

KEWAUNEE POWER STATION

DOMINION ENERGY KEWAUNEE, INC.

Supplemental Information Supporting Kewaunee License Amendment Request 239

1.0 Auxiliary Building Crane Seismic Analysis

1.1 General

The seismic analysis of the Kewaunee Power Station (KPS) Auxiliary Building (AB) crane was performed using the Nonlinear Modal Time History Analysis (FNA) method described in the SAP 2000 Analysis Reference Manual, Version 11. It is an extension of the Fast Nonlinear Analysis (FNA) method developed by Wilson (Reference 2). The nonlinear behavior is restricted to the limited resistance offered by the bridge and trolley drive wheel braking system to transmit inertial forces prior to rolling during a seismic event. The nonlinear behavior of the drive wheels was modeled utilizing the SAP 2000 Link/Support Element. All other structural components of the AB crane were modeled using beam elements and remain in the elastic range during the seismic event. With the exception of the nonlinear behavior of the drive wheels (which is discussed below), the structural model conforms to the requirements of ASME NOG-1-2004, "Rules for Construction of Overhead and Gantry Cranes (Top Running Bridge, Multiple Girder)."

The time history input motion used for the nonlinear analysis conforms to the requirements contained in Standard Review Plan 3.7.1, Option II, and is described in detail in Reference 1. The response of the AB crane was obtained by taking the average of the absolute maximum value of five time history analysis cases as recommended by ASCE/SEI 43-05, "Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities."

1.2 Modeling the Nonlinear Behavior of the Drive Wheels

Modeling the nonlinear behavior of the drive wheels within SAP 2000 is accomplished using the SAP 2000 Link/Support Element. The SAP 2000 Analysis Reference Manual provides a description of the various types of Link/Support Elements that are available to the user. A detailed explanation of how the SAP 2000 Link/Support Element was used in this analysis along with the applicable chapters of the SAP 2000 Analysis Reference Manual is provided in Attachment O of Enclosure 1.

The SAP 2000 Support Element is used to connect a single node to the ground and the Link Element is used to connect two nodes. For this analysis a zero length Link Element is used to model the nonlinear behavior of both bridge drive wheels and the trolley drive wheels where they connect to their respective rails. The nonlinear behavior is restricted to the longitudinal direction of the crane runway girder and bridge girder. The nonlinearity represents the limited capability of the bridge and trolley drive wheels to transmit seismic inertia forces to the structural system. This limited resistance is based on the maximum brake torque that can be applied to the drive wheels. The maximum brake torque results in a maximum force that can be resisted by the drive wheels prior to rolling. The calculation used to develop the maximum drive wheel resisting force is provided in Attachment B of Enclosure 1. Section 2.0 below discusses the field testing performed to demonstrate that the brake resistance force assumptions used in the analysis are bounding and conservative.

SAP 2000 has various properties that can be assigned to a Link Element. The properties are used to model the behavior of the element. For this analysis, the Wen Plasticity Property was utilized, which is based on the hysteretic behavior proposed by Wen (1976). Figure 1 shows the Wen Plasticity Property Type used for this analysis.

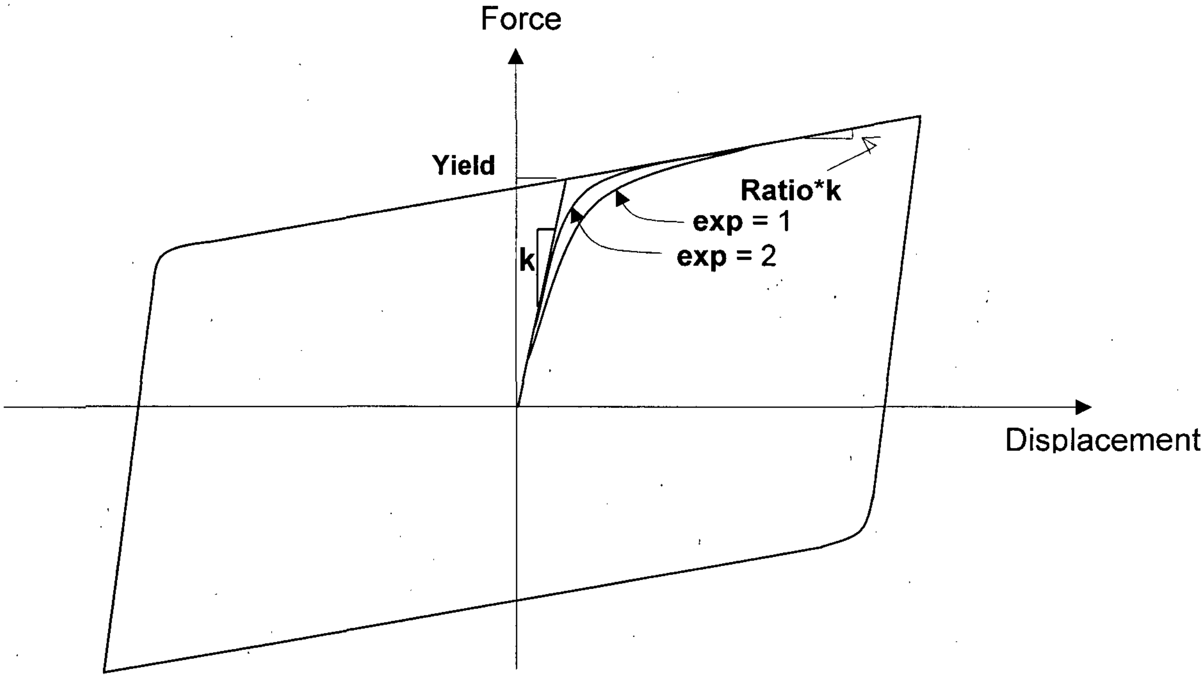


Figure 1

Wen Plasticity Property for Uniaxial Deformation

The key input parameters for the Wen Plasticity Property are the terms **k**[1], **Yield**, **Ratio**, and **exp**.

- The **Yield** term represents the constant rolling resistance of the bridge drive wheels. Because the inertia forces that will be transmitted to the crane structure increase with increasing values of the **Yield** term, the value of **Yield** used in the analysis is an upper bound when compared to both the calculated value and the value obtained from field testing.

[1] The terms for variables used in the model are in boldface type to coincide with the terms in the SAP 2000 Analysis Reference Manual.

- The **k** term represents the initial stiffness of the drive wheel prior to rolling. This value was selected to be high enough to represent the essentially infinite initial stiffness before rolling starts, yet small enough to avoid numerical instabilities during the analysis. A sensitivity study was conducted by varying **k** by a factor of 2 and 0.5 in order to demonstrate that the solution is not sensitive to the value of **k** that was used for the analysis.

- The parameter **exp** is used to define the shape of the transition curve from elastic to plastic behavior. For this analysis the desired behavior is elasto-plastic and therefore the upper limit of 20 recommended in the SAP 2000 Analysis Reference Manual was selected for **exp.** In order to demonstrate that the solution is not sensitive to the value of **exp**, a value of 10 was also tested to demonstrate that the solution did not vary by more the 5%.

- The term **Ratio** is used to define the ratio between the elastic and plastic stiffness. For this analysis elasto-plastic behavior is desired; therefore the value of **Ratio** is set to zero.

- The last input parameter required for the Wen Plasticity Property Type is the **Linear Effective Stiffness, ke.** When used in conjunction with the nonlinear modal time-history analysis method the **Linear Effective Stiffness** is not used directly for nonlinear degrees of freedom. If the nonlinear analysis starts from zero initial conditions, as this analysis does, the nonlinear solution does make use of the vibration modes computed based on this stiffness. However, during integration at each time step, the behavior of these modes is modified so that the structural response reflects the actual stiffness. As is the case for this analysis where a relatively large value of **k** is being used, a much smaller value of **ke** has been selected in accordance with the recommendations contained in the SAP 2000 Analysis Reference Manual. The **Linear Effective Stiffness** can affect the rate of convergence of the nonlinear solution process but should have little effect on the converged results. A sensitivity study was conducted to demonstrate that the **Linear Effective Stiffness** has no impact on the solution for this analysis by varying the parameter **ke** by a factor of 2 and 0.5. The results of the sensitivity study show that the solution is not sensitive to the value of **ke.**

Sensitivity studies for the various input parameters for the Wen Plasticity Property Type are provided in Attachment M of Enclosure 1.

1.3 Nonlinear Solution Method

The solution method used to solve the nonlinear problem is the Nonlinear Modal Time History Analysis Method (FNA). This solution method is applicable for structural systems that are primarily elastic and where the nonlinearity is confined to pre-defined nonlinear elements. This method of solution is applicable to the AB crane because the crane structural components remain linear throughout the analysis. The predefined nonlinearity is restricted to the bridge/trolley drive wheels, which are modeled using the SAP 2000 Link/Support Element.

The method of solution for the nonlinear equations of motion requires that a Ritz-Vector Analysis be performed first. The starting load vectors used for the Ritz-Vector Analysis include nonlinear deformation loads for each nonlinear degree of freedom as recommended in the SAP 2000 Analysis Reference Manual. The nonlinear equations are then solved iteratively at each time step utilizing modal superposition. Iterations are performed at each time step until the solution converges. The solution method automatically adjusts the time step if convergence is not achieved. Sensitivity studies were performed to demonstrate that the solution was unaffected by the convergence parameters. A more detailed discussion of the solution method is contained in Attachment N of Enclosure 1.

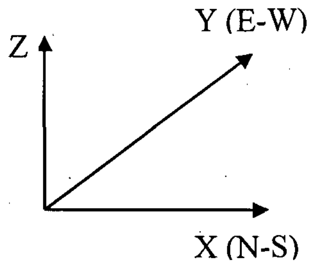
1.4 Results of the Nonlinear Time History Analysis

Five separate time history analysis cases were run, each with its own unique time history input motion that enveloped the amplified response spectra at the crane rail location. Input time history motions were developed in accordance with the guidance in NRC Standard Review Plan (SRP) 3.7.1, Option II. A detailed report discussing the development of these time histories is contained in Enclosure 2 to Reference 1. The average of the absolute maximum value obtained from each analysis case was used as the design value from the nonlinear time history analysis in accordance with the recommendations contained in ASCE 43-05, "Seismic Design Criteria for Structures, Systems and Components in Nuclear Facilities." The trolley location and hook positions used for the analysis comply with the recommendations contained in ASME NOG-1-2004.

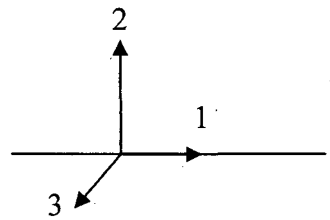
Table 1 is provided to demonstrate how the loads were developed for the governing load combinations. Only Case 7 (trolley at mid-span, load on the hook, hook in the down position) is shown here. Tables for all the load cases are included in Enclosure 1. Table 1 provides the maximum values of vertical and horizontal shear, strong and weak axis bending moment, torsion and axial force for each of the five time history analysis cases for the bridge drive girder. In addition, Table 1 shows the same maximum values for the dead load and live load cases. The absolute maximum value for each of the five seismic cases is also listed. The average of the absolute maximum value is listed along with the governing load combination which combines DL+LL+EQ. Figure 2 presents the sign convention for the tabular results listed in Table 1 for the bridge drive girder. Figure 3 presents the frame element numbers that correspond to the tabular data presented in Table 1. Code stress checks will be performed in accordance with the acceptance criteria given in the Kewaunee USAR for the design basis earthquake load condition.

Figure 2

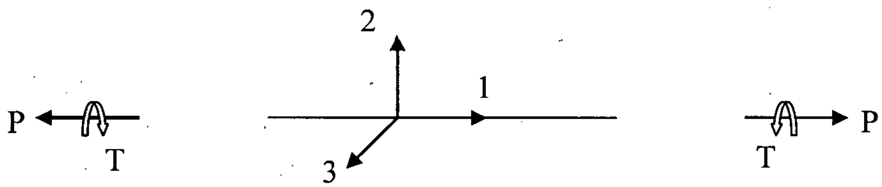
Sign Convention - Bridge Drive Girder Member Forces



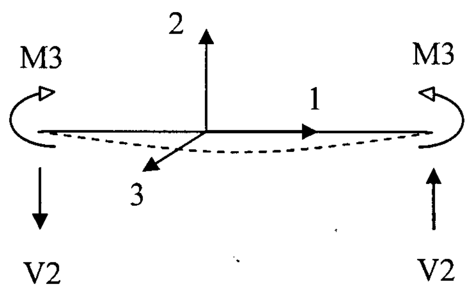
Global Axis



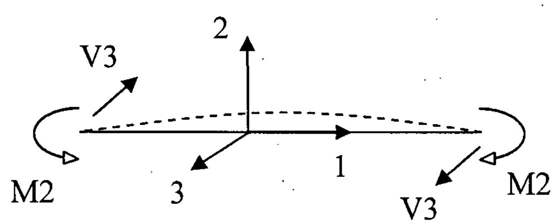
Member Local Axis



Positive Axial Forces & Torsion Torque



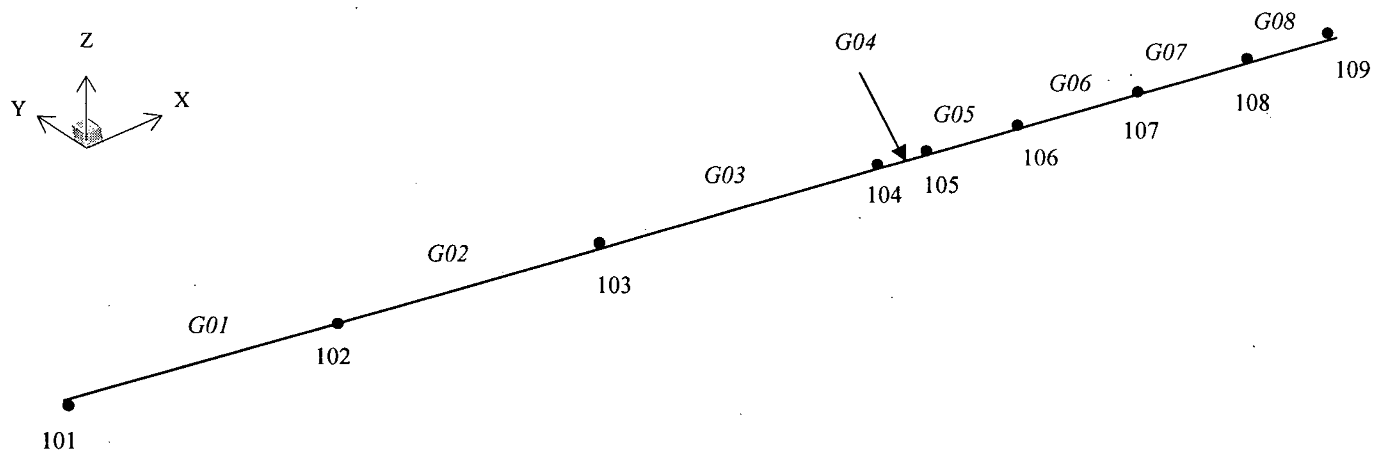
Positive Moment & Shear in 1-2 Plane
(Strong Axis Moment & Shear)
Positive M3 causes compression on + Local 2 face



Positive Moment & Shear in 1-3 Plane
(Weak Axis Moment & Shear)
Positive M2 causes compression on + Local 3 face

Figure 3

Bridge Drive Girder Member Numbers and Joint Numbers



Note: SAP 2000 reports frame member force at station locations rather than at joint numbers. Station 0 inches corresponds to the I-joint of the member; Station "XX" inches corresponds to the J-joint of the member. The local 1 axis is directed from the lower joint number to the higher joint number for all members.

Notes for Table 1:

The definition of output cases is as follows:

- DL: Self weight of the trolley and bridge as defined in ASME NOG-1-2004
- LL: Design rated lifted load (250 kips)
- A1, A2, A3, A4, A5: Response of the 5 individual time histories. The response is presented as a maximum/minimum response which corresponds to the SAP 2000 output
- EQ: Average of the absolute value of A1, A2, A3, A4, A5. The output is presented as a maximum and minimum value, which corresponds to the output presented in SAP 2000 for this Load Combination.
- C07: Represents the design load combination for seismic. It corresponds to the load combination as presented in SAP 2000. It consists of the previously defined load combination EQ plus (DL +LL).

The next few rows in the table demonstrate how SAP 2000 internally calculated the design load combination C07. First, the absolute values for each force/moment component for each time history are presented. They are labeled as **"Maximum Absolute for Case A1"** through **"Maximum Absolute for Case A5"**. Then, the average of the absolute value for each force/moment component is calculated. It is labeled as **"Average of Maximum Absolutes for Cases A1-A5"**. The next row simply adds the label **"Maximum Absolute for Case 'EQ'"** for the averaged absolute value. The **DL** and **LL** components are the listed values. The DL, LL and EQ components are then added together to form the design seismic load combination **C07**, which is labeled **"DL+LL+EQ for Element and Case"**.

Table 1
Summary of Forces/Moments
(Trolley at Mid-Span, Load on Hook, Hook in Down Position)

Case-07: Element Forces - Frames										
Frame Element	Station in	Output Case	Case Type	Step Type	P Kip	V2 Kip	V3 Kip	T Kip-in	M2 Kip-in	M3 Kip-in
G01	0	DL	LinStatic		0	-49	0	1	4	-4
G01	146	DL	LinStatic		0	-42	0	1	3	6,664
G01	0	LL	LinStatic		0	-58	0	1	3	0
G01	146	LL	LinStatic		0	-58	0	1	2	8,452
G01	0	A1	NonModHist	Max	73	64	9	500	2,454	427
G01	146	A1	NonModHist	Max	73	64	9	500	1,106	9,320
G01	0	A1	NonModHist	Min	-75	-63	-10	-450	-2,320	-474
G01	146	A1	NonModHist	Min	-75	-63	-10	-450	-937	-9,517
G01	0	A2	NonModHist	Max	60	62	10	407	2,252	445
G01	146	A2	NonModHist	Max	60	62	10	407	922	8,324
G01	0	A2	NonModHist	Min	-71	-56	-10	-428	-2,273	-443
G01	146	A2	NonModHist	Min	-71	-56	-10	-428	-955	-8,966
G01	0	A3	NonModHist	Max	77	63	8	390	1,903	557
G01	146	A3	NonModHist	Max	77	63	8	390	799	8,904
G01	0	A3	NonModHist	Min	-62	-61	-10	-601	-2,727	-534
G01	146	A3	NonModHist	Min	-62	-61	-10	-601	-1,228	-9,242
G01	0	A4	NonModHist	Max	68	59	10	511	2,581	432
G01	146	A4	NonModHist	Max	68	59	10	511	1,174	8,681
G01	0	A4	NonModHist	Min	-94	-59	-9	-443	-2,147	-485
G01	146	A4	NonModHist	Min	-94	-59	-9	-443	-915	-8,552
G01	0	A5	NonModHist	Max	73	70	10	480	2,476	538
G01	146	A5	NonModHist	Max	73	70	10	480	1,073	9,858
G01	0	A5	NonModHist	Min	-66	-69	-11	-530	-2,704	-413
G01	146	A5	NonModHist	Min	-66	-69	-11	-530	-1,200	-9,961
G01	0	EQ	Combination	Max	78	64	10	514	2,548	500
G01	146	EQ	Combination	Max	78	64	10	514	1,133	9,274
G01	0	EQ	Combination	Min	-78	-64	-10	-514	-2,548	-500
G01	146	EQ	Combination	Min	-78	-64	-10	-514	-1,133	-9,274
G01	0	C07	Combination	Max	78	-43	10	515	2,555	496
G01	146	C07	Combination	Max	78	-37	10	515	1,137	24,390
G01	0	C07	Combination	Min	-78	-171	-10	-513	-2,540	-504
G01	146	C07	Combination	Min	-78	-164	-10	-513	-1,128	5,842
Maximum Absolute for Case A1:					**75**	**64**	**10**	**500**	**2,454**	**9,517**
Maximum Absolute for Case A2:					**71**	**62**	**10**	**428**	**2,273**	**8,966**
Maximum Absolute for Case A3:					**77**	**63**	**10**	**601**	**2,727**	**9,242**
Maximum Absolute for Case A4:					**94**	**59**	**10**	**511**	**2,581**	**8,681**
Maximum Absolute for Case A5:					**73**	**70**	**11**	**530**	**2,704**	**9,961**
Average of Maximum Absolutes for Cases A1- A5:					**78**	**64**	**10**	**514**	**2,548**	**9,274**
Maximum Absolute for Case "EQ":					**78**	**64**	**10**	**514**	**2,548**	**9,274**
"DL":					**0**	**49**	**0**	**1**	**4**	**6,664**
"LL":					**0**	**58**	**0**	**1**	**3**	**8,452**
DL+LL+EQ for Element and Case:			**G01**	**C07**	**78**	**171**	**10**	**515**	**2,555**	**24,390**

Table 1 (Continued)

Case-07: Element Forces - Frames										
Frame Element	Station in	Output Case	Case Type	Step Type	P Kip	V2 Kip	V3 Kip	T Kip-in	M2 Kip-in	M3 Kip-in
G02	0	DL	LinStatic		0	-42	0	1	3	6,664
G02	138	DL	LinStatic		0	-36	0	1	1	12,076
G02	0	LL	LinStatic		0	-58	0	1	2	8,452
G02	138	LL	LinStatic		0	-58	0	1	0	16,441
G02	0	A1	NonModHist	Max	63	63	12	500	1,106	9,320
G02	138	A1	NonModHist	Max	63	63	12	500	561	17,770
G02	0	A1	NonModHist	Min	-65	-61	-10	-450	-937	-9,517
G02	138	A1	NonModHist	Min	-65	-61	-10	-450	-528	-18,231
G02	0	A2	NonModHist	Max	53	61	10	407	922	8,324
G02	138	A2	NonModHist	Max	53	61	10	407	631	15,882
G02	0	A2	NonModHist	Min	-63	-55	-10	-428	-955	-8,966
G02	138	A2	NonModHist	Min	-63	-55	-10	-428	-548	-17,357
G02	0	A3	NonModHist	Max	68	61	9	390	799	8,904
G02	138	A3	NonModHist	Max	68	61	9	390	640	16,965
G02	0	A3	NonModHist	Min	-53	-59	-13	-601	-1,228	-9,242
G02	138	A3	NonModHist	Min	-53	-59	-13	-601	-520	-17,684
G02	0	A4	NonModHist	Max	59	58	12	511	1,174	8,681
G02	138	A4	NonModHist	Max	59	58	12	511	559	16,601
G02	0	A4	NonModHist	Min	-83	-58	-10	-443	-915	-8,552
G02	138	A4	NonModHist	Min	-83	-58	-10	-443	-578	-16,550
G02	0	A5	NonModHist	Max	65	69	12	480	1,073	9,858
G02	138	A5	NonModHist	Max	65	69	12	480	615	19,332
G02	0	A5	NonModHist	Min	-60	-69	-12	-530	-1,200	-9,961
G02	138	A5	NonModHist	Min	-60	-69	-12	-530	-572	-19,499
G02	0	EQ	Combination	Max	69	63	12	514	1,133	9,274
G02	138	EQ	Combination	Max	69	63	12	514	605	17,875
G02	0	EQ	Combination	Min	-69	-63	-12	-514	-1,133	-9,274
G02	138	EQ	Combination	Min	-69	-63	-12	-514	-605	-17,875
G02	0	C07	Combination	Max	69	-38	12	515	1,137	24,390
G02	138	C07	Combination	Max	69	-31	12	515	606	46,392
G02	0	C07	Combination	Min	-68	-163	-12	-513	-1,128	5,842
G02	138	C07	Combination	Min	-68	-157	-12	-513	-604	10,642
Maximum Absolute for Case A1:					**65**	**63**	**12**	**500**	**1,106**	**18,231**
Maximum Absolute for Case A2:					**63**	**61**	**10**	**428**	**955**	**17,357**
Maximum Absolute for Case A3:					**68**	**61**	**13**	**601**	**1,228**	**17,684**
Maximum Absolute for Case A4:					**83**	**58**	**12**	**511**	**1,174**	**16,601**
Maximum Absolute for Case A5:					**65**	**69**	**12**	**530**	**1,200**	**19,499**
Average of Maximum Absolutes for Cases A1- A5:					**69**	**63**	**12**	**514**	**1,133**	**17,875**
Maximum Absolute for Case "EQ":					**69**	**63**	**12**	**514**	**1,133**	**17,875**
"DL":					**0**	**42**	**0**	**1**	**3**	**12,076**
"LL":					**0**	**58**	**0**	**1**	**2**	**16,441**
DL+LL+EQ for Element and Case:			**G02**	**C07**	**69**	**163**	**12**	**515**	**1,137**	**46,392**

Table 1 (Continued)

Case-07: Element Forces - Frames										
Frame	Station	Output	Case	Step	P	V2	V3	T	M2	M3
Element	in	Case	Type	Type	Kip	Kip	Kip	Kip-in	Kip-in	Kip-in
G03	0	DL	LinStatic		0	-36	0	1	1	12,076
G03	174.5	DL	LinStatic		0	-28	0	1	1	17,680
G03	0	LL	LinStatic		0	-58	0	1	1	16,441
G03	174.5	LL	LinStatic		0	-58	0	1	1	26,543
G03	0	A1	NonModHist	Max	53	62	11	500	1	17,770
G03	174.5	A1	NonModHist	Max	53	62	11	500	1	28,083
G03	0	A1	NonModHist	Min	-58	-59	-10	-450	1	-18,231
G03	174.5	A1	NonModHist	Min	-58	-59	-10	-450	1	-28,988
G03	0	A2	NonModHist	Max	46	58	10	407	1	15,882
G03	174.5	A2	NonModHist	Max	46	58	10	407	1	25,093
G03	0	A2	NonModHist	Min	-53	-53	-10	-428	1	-17,357
G03	174.5	A2	NonModHist	Min	-53	-53	-10	-428	1	-27,520
G03	0	A3	NonModHist	Max	56	59	9	390	1	16,965
G03	174.5	A3	NonModHist	Max	56	59	9	390	1	26,566
G03	0	A3	NonModHist	Min	-45	-57	-13	-601	1	-17,684
G03	174.5	A3	NonModHist	Min	-45	-57	-13	-601	1	-27,845
G03	0	A4	NonModHist	Max	50	58	12	511	1	16,601
G03	174.5	A4	NonModHist	Max	50	58	12	511	1	26,519
G03	0	A4	NonModHist	Min	-71	-57	-10	-443	1	-16,550
G03	174.5	A4	NonModHist	Min	-71	-57	-10	-443	1	-26,380
G03	0	A5	NonModHist	Max	56	68	11	480	1	19,332
G03	174.5	A5	NonModHist	Max	56	68	11	480	1	30,986
G03	0	A5	NonModHist	Min	-53	-67	-12	-530	1	-19,499
G03	174.5	A5	NonModHist	Min	-53	-67	-12	-530	1	-31,315
G03	0	EQ	Combination	Max	59	61	12	514	1	17,875
G03	174.5	EQ	Combination	Max	59	61	12	514	1	28,438
G03	0	EQ	Combination	Min	-59	-61	-12	-514	1	-17,875
G03	174.5	EQ	Combination	Min	-59	-61	-12	-514	1	-28,438
G03	0	C07	Combination	Max	59	-33	12	515	1	46,392
G03	174.5	C07	Combination	Max	59	-25	12	515	1	72,661
G03	0	C07	Combination	Min	-59	-155	-12	-513	1	10,642
G03	174.5	C07	Combination	Min	-59	-147	-12	-513	1	15,785
Maximum Absolute for Case A1:					**58**	**62**	**11**	**500**	1	**28,988**
Maximum Absolute for Case A2:					**53**	**58**	**10**	**428**	1	**27,520**
Maximum Absolute for Case A3:					**56**	**59**	**13**	**601**	1	**27,845**
Maximum Absolute for Case A4:					**71**	**58**	**12**	**511**	1	**26,519**
Maximum Absolute for Case A5:					**56**	**68**	**12**	**530**	1	**31,315**
Average of Maximum Absolutes for Cases A1- A5:					**59**	**61**	**12**	**514**	1	**28,438**
Maximum Absolute for Case "EQ":					**59**	**61**	**12**	**514**	1	**28,438**
				"DL":	**0**	**36**	**0**	**1**	1	**17,680**
				"LL":	**0**	**58**	**0**	**1**	1	**26,543**
DL+LL+EQ for Element and Case:			**G03**	**C07**	**59**	**155**	**12**	**515**	1	**72,661**

Table 1 (Continued)

Case-07: Element Forces - Frames										
Frame Element	Station in	Output Case	Case Type	Step Type	P Kip	V2 Kip	V3 Kip	T Kip-in	M2 Kip-in	M3 Kip-in
G04	0	DL	LinStatic		0	4	0	-1	0	17,680
G04	36.5	DL	LinStatic		0	5	0	-1	0	17,518
G04	0	LL	LinStatic		0	5	0	1	-2	26,543
G04	36.5	LL	LinStatic		0	5	0	1	-3	26,375
G04	0	A1	NonModHist	Max	48	6	1	126	2,136	28,317
G04	36.5	A1	NonModHist	Max	48	6	1	126	2,107	28,137
G04	0	A1	NonModHist	Min	-44	-6	-1	-155	-2,459	-29,308
G04	36.5	A1	NonModHist	Min	-44	-6	-1	-155	-2,418	-29,110
G04	0	A2	NonModHist	Max	43	6	2	196	2,125	24,858
G04	36.5	A2	NonModHist	Max	43	6	2	196	2,064	24,686
G04	0	A2	NonModHist	Min	-44	-6	-2	-149	-2,069	-27,391
G04	36.5	A2	NonModHist	Min	-44	-6	-2	-149	-2,039	-27,158
G04	0	A3	NonModHist	Max	45	7	2	131	2,960	26,605
G04	36.5	A3	NonModHist	Max	45	7	2	131	2,899	26,422
G04	0	A3	NonModHist	Min	-35	-6	-1	-147	-2,008	-27,710
G04	36.5	A3	NonModHist	Min	-35	-6	-1	-147	-1,956	-27,482
G04	0	A4	NonModHist	Max	41	6	2	113	2,190	26,751
G04	36.5	A4	NonModHist	Max	41	6	2	113	2,132	26,588
G04	0	A4	NonModHist	Min	-58	-7	-1	-127	-2,557	-26,115
G04	36.5	A4	NonModHist	Min	-58	-7	-1	-127	-2,531	-25,962
G04	0	A5	NonModHist	Max	45	7	1	160	2,505	30,773
G04	36.5	A5	NonModHist	Max	45	7	1	160	2,459	30,541
G04	0	A5	NonModHist	Min	-44	-7	-2	-143	-2,438	-31,101
G04	36.5	A5	NonModHist	Min	-44	-7	-2	-143	-2,413	-30,879
G04	0	EQ	Combination	Max	48	7	2	157	2,521	28,452
G04	36.5	EQ	Combination	Max	48	7	2	157	2,474	28,243
G04	0	EQ	Combination	Min	-48	-7	-2	-157	-2,521	-28,452
G04	36.5	EQ	Combination	Min	-48	-7	-2	-157	-2,474	-28,243
G04	0	C07	Combination	Max	48	15	2	158	2,519	72,675
G04	36.5	C07	Combination	Max	48	16	2	158	2,471	72,137
G04	0	C07	Combination	Min	-48	2	-2	-156	-2,524	15,771
G04	36.5	C07	Combination	Min	-48	3	-2	-156	-2,477	15,650
Maximum Absolute for Case A1:					**48**	**6**	**1**	**155**	**2,459**	**29,308**
Maximum Absolute for Case A2:					**44**	**6**	**2**	**196**	**2,125**	**27,391**
Maximum Absolute for Case A3:					**45**	**7**	**2**	**147**	**2,960**	**27,710**
Maximum Absolute for Case A4:					**58**	**7**	**2**	**127**	**2,557**	**26,751**
Maximum Absolute for Case A5:					**45**	**7**	**2**	**160**	**2,505**	**31,101**
Average of Maximum Absolutes for Cases A1- A5:					**48**	**7**	**2**	**157**	**2,521**	**28,452**
Maximum Absolute for Case "EQ":					**48**	**7**	**2**	**157**	**2,521**	**28,452**
"DL":					**0**	**5**	**0**	**1**	**0**	**17,680**
"LL":					**0**	**5**	**0**	**1**	**3**	**26,543**
DL+LL+EQ for Element and Case:			**G04**	**C07**	**48**	**16**	**2**	**159**	**2,525**	**72,675**

Table 1 (Continued)

Case-07: Element Forces - Frames										
Frame Element	Station in	Output Case	Case Type	Step Type	P Kip	V2 Kip	V3 Kip	T Kip-in	M2 Kip-in	M3 Kip-in
G05	0	DL	LinStatic		0	5	0	-1	0	17,518
G05	109.5	DL	LinStatic		0	10	0	-1	2	16,671
G05	0	LL	LinStatic		0	5	0	1	-3	26,375
G05	109.5	LL	LinStatic		0	5	0	1	-6	25,870
G05	0	A1	NonModHist	Max	43	7	2	126	2,107	28,137
G05	109.5	A1	NonModHist	Max	43	7	2	126	1,913	27,469
G05	0	A1	NonModHist	Min	-40	-7	-2	-155	-2,418	-29,110
G05	109.5	A1	NonModHist	Min	-40	-7	-2	-155	-2,170	-28,389
G05	0	A2	NonModHist	Max	39	7	3	196	2,064	24,686
G05	109.5	A2	NonModHist	Max	39	7	3	196	1,910	24,044
G05	0	A2	NonModHist	Min	-40	-8	-2	-149	-2,039	-27,158
G05	109.5	A2	NonModHist	Min	-40	-8	-2	-149	-1,844	-26,319
G05	0	A3	NonModHist	Max	40	8	3	131	2,899	26,422
G05	109.5	A3	NonModHist	Max	40	8	3	131	2,564	25,734
G05	0	A3	NonModHist	Min	-33	-7	-2	-147	-1,956	-27,482
G05	109.5	A3	NonModHist	Min	-33	-7	-2	-147	-1,750	-26,740
G05	0	A4	NonModHist	Max	37	7	3	113	2,132	26,588
G05	109.5	A4	NonModHist	Max	37	7	3	113	1,867	25,984
G05	0	A4	NonModHist	Min	-53	-8	-2	-127	-2,531	-25,962
G05	109.5	A4	NonModHist	Min	-53	-8	-2	-127	-2,338	-25,380
G05	0	A5	NonModHist	Max	41	8	3	160	2,459	30,541
G05	109.5	A5	NonModHist	Max	41	8	3	160	2,307	29,711
G05	0	A5	NonModHist	Min	-40	-8	-3	-143	-2,413	-30,879
G05	109.5	A5	NonModHist	Min	-40	-8	-3	-143	-2,213	-30,068
G05	0	EQ	Combination	Max	43	8	3	157	2,474	28,243
G05	109.5	EQ	Combination	Max	43	8	3	157	2,258	27,500
G05	0	EQ	Combination	Min	-43	-8	-3	-157	-2,474	-28,243
G05	109.5	EQ	Combination	Min	-43	-8	-3	-157	-2,258	-27,500
G05	0	C07	Combination	Max	43	18	3	158	2,471	72,137
G05	109.5	C07	Combination	Max	43	23	3	158	2,253	70,042
G05	0	C07	Combination	Min	-43	2	-3	-156	-2,477	15,650
G05	109.5	C07	Combination	Min	-43	7	-3	-156	-2,262	15,041
Maximum Absolute for Case A1:					**43**	**7**	**2**	**155**	**2,418**	**29,110**
Maximum Absolute for Case A2:					**40**	**8**	**3**	**196**	**2,064**	**27,158**
Maximum Absolute for Case A3:					**40**	**8**	**3**	**147**	**2,899**	**27,482**
Maximum Absolute for Case A4:					**53**	**8**	**3**	**127**	**2,531**	**26,588**
Maximum Absolute for Case A5:					**41**	**8**	**3**	**160**	**2,459**	**30,879**
Average of Maximum Absolutes for Cases A1- A5:					**43**	**8**	**3**	**157**	**2,474**	**28,243**
Maximum Absolute for Case "EQ":					**43**	**8**	**3**	**157**	**2,474**	**28,243**
"DL":					**0**	**10**	**0**	**1**	**2**	**17,518**
"LL":					**0**	**5**	**0**	**1**	**6**	**26,375**
DL+LL+EQ for Element and Case:		**G05**		**C07**	**43**	**23**	**3**	**159**	**2,482**	**72,137**

Table 1 (Continued)

Case-07: Element Forces - Frames										
Frame Element	Station in	Output Case	Case Type	Step Type	P Kip	V2 Kip	V3 Kip	T Kip-in	M2 Kip-in	M3 Kip-in
G06	0	DL	LinStatic		0	34	0	0	2	16,671
G06	101.5	DL	LinStatic		0	39	0	0	2	12,937
G06	0	LL	LinStatic		0	67	0	-1	-6	25,870
G06	101.5	LL	LinStatic		0	67	0	-1	-4	19,059
G06	0	A1	NonModHist	Max	37	68	10	499	1,913	27,469
G06	101.5	A1	NonModHist	Max	37	68	10	499	1,070	20,530
G06	0	A1	NonModHist	Min	-34	-73	-11	-562	-2,170	-28,389
G06	101.5	A1	NonModHist	Min	-34	-73	-11	-562	-1,122	-21,011
G06	0	A2	NonModHist	Max	34	61	10	487	1,910	24,044
G06	101.5	A2	NonModHist	Max	34	61	10	487	1,086	18,066
G06	0	A2	NonModHist	Min	-35	-68	-9	-461	-1,844	-26,319
G06	101.5	A2	NonModHist	Min	-35	-68	-9	-461	-945	-19,426
G06	0	A3	NonModHist	Max	34	65	14	672	2,564	25,734
G06	101.5	A3	NonModHist	Max	34	65	14	672	1,202	19,097
G06	0	A3	NonModHist	Min	-30	-67	-9	-445	-1,750	-26,740
G06	101.5	A3	NonModHist	Min	-30	-67	-9	-445	-902	-20,046
G06	0	A4	NonModHist	Max	32	66	10	507	1,867	25,984
G06	101.5	A4	NonModHist	Max	32	66	10	507	917	19,311
G06	0	A4	NonModHist	Min	-46	-64	-11	-575	-2,338	-25,380
G06	101.5	A4	NonModHist	Min	-46	-64	-11	-575	-1,197	-18,937
G06	0	A5	NonModHist	Max	34	77	12	598	2,307	29,711
G06	101.5	A5	NonModHist	Max	34	77	12	598	1,298	21,931
G06	0	A5	NonModHist	Min	-35	-77	-11	-539	-2,213	-30,068
G06	101.5	A5	NonModHist	Min	-35	-77	-11	-539	-1,076	-22,226
G06	0	EQ	Combination	Max	37	70	12	579	2,258	27,500
G06	101.5	EQ	Combination	Max	37	70	12	579	1,181	20,404
G06	0	EQ	Combination	Min	-37	-70	-12	-579	-2,258	-27,500
G06	101.5	EQ	Combination	Min	-37	-70	-12	-579	-1,181	-20,404
G06	0	C07	Combination	Max	37	172	12	577	2,253	70,042
G06	101.5	C07	Combination	Max	37	176	12	577	1,179	52,400
G06	0	C07	Combination	Min	-37	31	-12	-581	-2,262	15,041
G06	101.5	C07	Combination	Min	-37	36	-12	-581	-1,183	11,591
Maximum Absolute for Case A1:					**37**	**73**	**11**	**562**	**2,170**	**28,389**
Maximum Absolute for Case A2:					**35**	**68**	**10**	**487**	**1,910**	**26,319**
Maximum Absolute for Case A3:					**34**	**67**	**14**	**672**	**2,564**	**26,740**
Maximum Absolute for Case A4:					**46**	**66**	**11**	**575**	**2,338**	**25,984**
Maximum Absolute for Case A5:					**35**	**77**	**12**	**598**	**2,307**	**30,068**
Average of Maximum Absolutes for Cases A1- A5:					**37**	**70**	**12**	**579**	**2,258**	**27,500**
Maximum Absolute for Case "EQ":					**37**	**70**	**12**	**579**	**2,258**	**27,500**
"DL":					**0**	**39**	**0**	**0**	**2**	**16,671**
"LL":					**0**	**67**	**0**	**1**	**6**	**25,870**
DL+LL+EQ for Element and Case:			**G06**	**C07**	**37**	**176**	**12**	**581**	**2,266**	**70,042**

Table 1 (Continued)

Case 07: Element Forces - Frames

Frame Element	Station in	Output Case	Case Type	Step Type	P Kip	V2 Kip	V3 Kip	T Kip-in	M2 Kip-in	M3 Kip-in
G07	0	DL	LinStatic		0	39	0	0	2	12,937
G07	138	DL	LinStatic		0	45	0	0	3	7,108
G07	0	LL	LinStatic		0	67	0	-1	-4	19,059
G07	138	LL	LinStatic		0	67	0	-1	-1	9,798
G07	0	A1	NonModHist	Max	30	70	10	499	1,070	20,530
G07	138	A1	NonModHist	Max	30	70	10	499	575	10,885
G07	0	A1	NonModHist	Min	-28	-74	-11	-562	-1,122	-21,011
G07	138	A1	NonModHist	Min	-28	-74	-11	-562	-468	-10,781
G07	0	A2	NonModHist	Max	27	61	10	487	1,086	18,066
G07	138	A2	NonModHist	Max	27	61	10	487	505	9,777
G07	0	A2	NonModHist	Min	-29	-69	-9	-461	-945	-19,426
G07	138	A2	NonModHist	Min	-29	-69	-9	-461	-512	-10,025
G07	0	A3	NonModHist	Max	27	66	13	672	1,202	19,097
G07	138	A3	NonModHist	Max	27	66	13	672	507	9,935
G07	0	A3	NonModHist	Min	-26	-68	-9	-445	-902	-20,046
G07	138	A3	NonModHist	Min	-26	-68	-9	-445	-644	-10,684
G07	0	A4	NonModHist	Max	26	67	10	507	917	19,311
G07	138	A4	NonModHist	Max	26	67	10	507	511	10,244
G07	0	A4	NonModHist	Min	-37	-66	-12	-575	-1,197	-18,937
G07	138	A4	NonModHist	Min	-37	-66	-12	-575	-500	-9,931
G07	0	A5	NonModHist	Max	27	78	12	598	1,298	21,931
G07	138	A5	NonModHist	Max	27	78	12	598	676	11,184
G07	0	A5	NonModHist	Min	-29	-79	-11	-539	-1,076	-22,226
G07	138	A5	NonModHist	Min	-29	-79	-11	-539	-583	-11,351
G07	0	EQ	Combination	Max	30	71	11	579	1,181	20,404
G07	138	EQ	Combination	Max	30	71	11	579	584	10,638
G07	0	EQ	Combination	Min	-30	-71	-11	-579	-1,181	-20,404
G07	138	EQ	Combination	Min	-30	-71	-11	-579	-584	-10,638
G07	0	C07	Combination	Max	30	178	11	577	1,179	52,400
G07	138	C07	Combination	Max	30	184	11	577	586	27,544
G07	0	C07	Combination	Min	-30	35	-12	-581	-1,183	11,591
G07	138	C07	Combination	Min	-30	41	-12	-581	-581	6,268
		Maximum Absolute for Case A1:			**30**	**74**	**11**	**562**	**1,122**	**21,011**
		Maximum Absolute for Case A2:			**29**	**69**	**10**	**487**	**1,086**	**19,426**
		Maximum Absolute for Case A3:			**27**	**68**	**13**	**672**	**1,202**	**20,046**
		Maximum Absolute for Case A4:			**37**	**67**	**12**	**575**	**1,197**	**19,311**
		Maximum Absolute for Case A5:			**29**	**79**	**12**	**598**	**1,298**	**22,226**
Average of Maximum Absolutes for Cases A1- A5:					**30**	**71**	**11**	**579**	**1,181**	**20,404**
	Maximum Absolute for Case "EQ":				**30**	**71**	**11**	**579**	**1,181**	**20,404**
				"DL":	**0**	**45**	**0**	**0**	**3**	**12,937**
				"LL":	**0**	**67**	**0**	**1**	**4**	**19,059**
DL+LL+EQ for Element and Case:			**G07**	**C07**	**30**	**184**	**12**	**581**	**1,188**	**52,400**

Table 1 (Continued)

Case-07: Element Forces - Frames										
Frame Element	Station in	Output Case	Case Type	Step Type	P Kip	V2 Kip	V3 Kip	T Kip-in	M2 Kip-in	M3 Kip-in
G08	0	DL	LinStatic		0	45	0	0	3	7,108
G08	146	DL	LinStatic		0	52	0	0	4	-1
G08	0	LL	LinStatic		0	67	0	-1	-1	9,798
G08	146	LL	LinStatic		0	67	0	-1	2	0
G08	0	A1	NonModHist	Max	22	71	9	499	575	10,885
G08	146	A1	NonModHist	Max	22	71	9	499	1,754	721
G08	0	A1	NonModHist	Min	-20	-75	-9	-562	-468	-10,781
G08	146	A1	NonModHist	Min	-20	-75	-9	-562	-1,617	-705
G08	0	A2	NonModHist	Max	19	63	10	487	505	9,777
G08	146	A2	NonModHist	Max	19	63	10	487	1,504	726
G08	0	A2	NonModHist	Min	-22	-69	-8	-461	-512	-10,025
G08	146	A2	NonModHist	Min	-22	-69	-8	-461	-1,664	-617
G08	0	A3	NonModHist	Max	19	68	10	672	507	9,935
G08	146	A3	NonModHist	Max	19	68	10	672	1,558	831
G08	0	A3	NonModHist	Min	-21	-70	-8	-445	-644	-10,684
G08	146	A3	NonModHist	Min	-21	-70	-8	-445	-2,158	-670
G08	0	A4	NonModHist	Max	21	68	8	507	511	10,244
G08	146	A4	NonModHist	Max	21	68	8	507	1,855	800
G08	0	A4	NonModHist	Min	-27	-68	-10	-575	-500	-9,931
G08	146	A4	NonModHist	Min	-27	-68	-10	-575	-1,570	-789
G08	0	A5	NonModHist	Max	20	79	11	598	676	11,184
G08	146	A5	NonModHist	Max	20	79	11	598	1,737	818
G08	0	A5	NonModHist	Min	-22	-79	-9	-539	-583	-11,351
G08	146	A5	NonModHist	Min	-22	-79	-9	-539	-1,894	-746
G08	0	EQ	Combination	Max	23	72	10	579	584	10,638
G08	146	EQ	Combination	Max	23	72	10	579	1,865	779
G08	0	EQ	Combination	Min	-23	-72	-10	-579	-584	-10,638
G08	146	EQ	Combination	Min	-23	-72	-10	-579	-1,865	-779
G08	0	C07	Combination	Max	23	185	10	577	586	27,544
G08	146	C07	Combination	Max	23	191	10	577	1,872	778
G08	0	C07	Combination	Min	-23	40	-10	-581	-581	6,268
G08	146	C07	Combination	Min	-23	47	-10	-581	-1,859	-781
Maximum Absolute for Case A1:					**22**	**75**	**9**	**562**	**1,754**	**10,885**
Maximum Absolute for Case A2:					**22**	**69**	**10**	**487**	**1,664**	**10,025**
Maximum Absolute for Case A3:					**21**	**70**	**10**	**672**	**2,158**	**10,684**
Maximum Absolute for Case A4:					**27**	**68**	**10**	**575**	**1,855**	**10,244**
Maximum Absolute for Case A5:					**22**	**79**	**11**	**598**	**1,894**	**11,351**
Average of Maximum Absolutes for Cases A1- A5:					**23**	**72**	**10**	**579**	**1,865**	**10,638**
Maximum Absolute for Case "EQ":					**23**	**72**	**10**	**579**	**1,865**	**10,638**
"DL":					**0**	**52**	**0**	**0**	**4**	**7,108**
"LL":					**0**	**67**	**0**	**1**	**2**	**9,798**
DL+LL+EQ for Element and Case:		**G08**		**C07**	**23**	**191**	**10**	**581**	**1,872**	**27,544**

Plots of the moment, shear, torsion, and axial forces for the bridge drive girder are shown in Figures 4 through 13 for the mid-span, quarter-span, and end-span trolley locations.

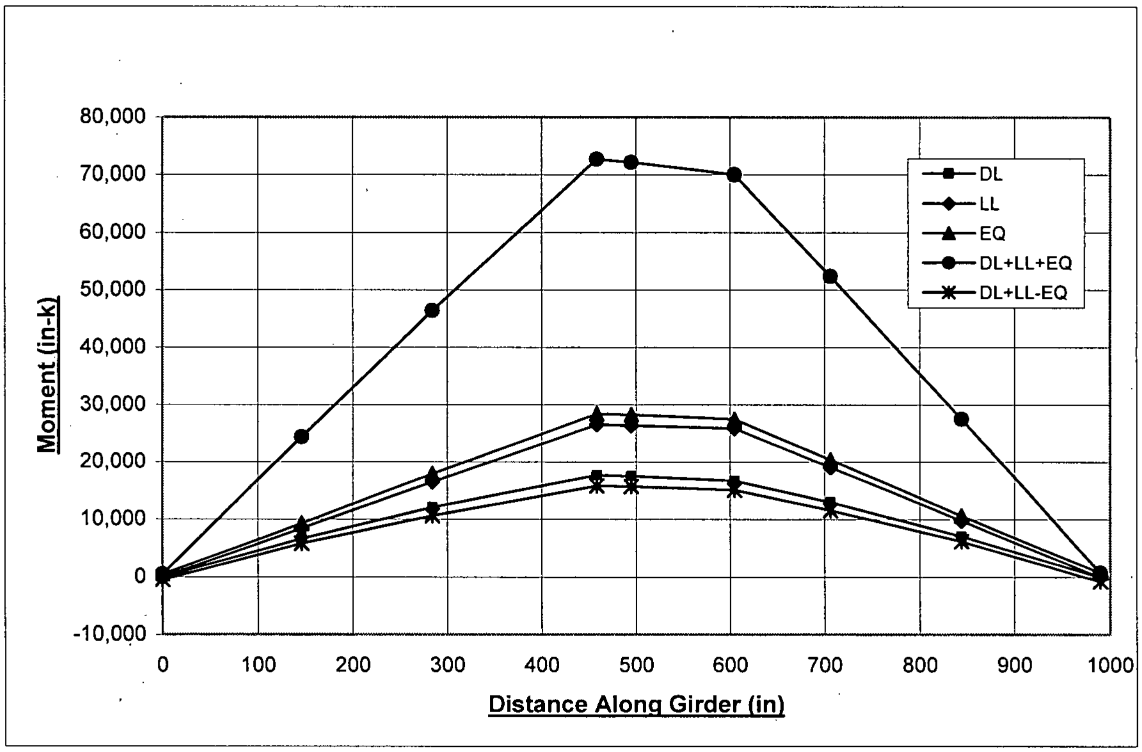


Figure 4

Bridge Drive Girder Strong Axis Bending Moment, M3
Trolley Located at Mid-Span

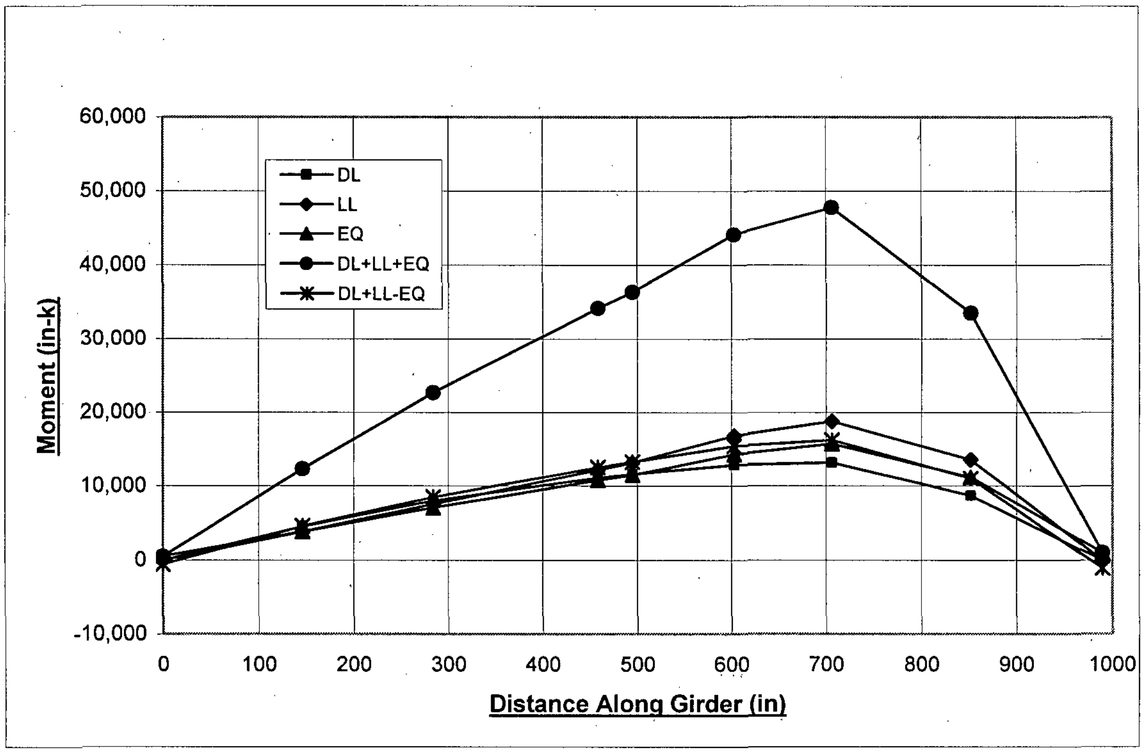


Figure 5

Bridge Drive Girder Strong Axis Bending Moment, M3
Trolley Located at Quarter-Span

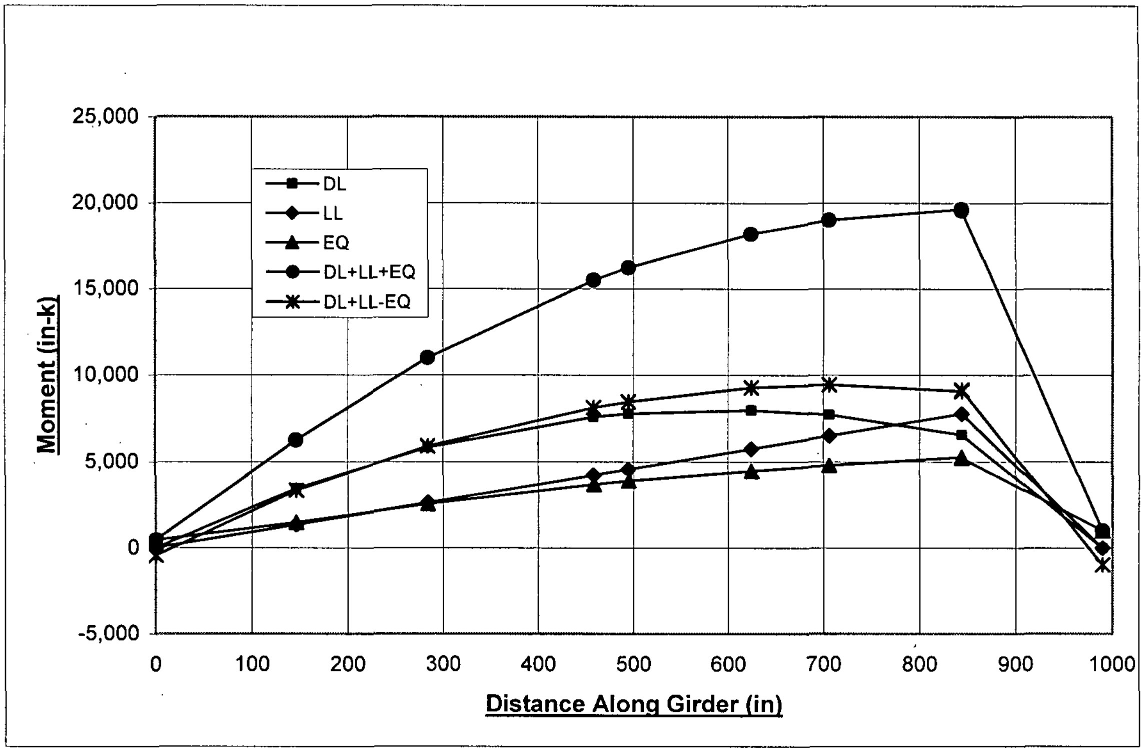


Figure 6

Bridge Drive Girder Strong Axis Bending Moment, M3
Trolley Located at End-Span

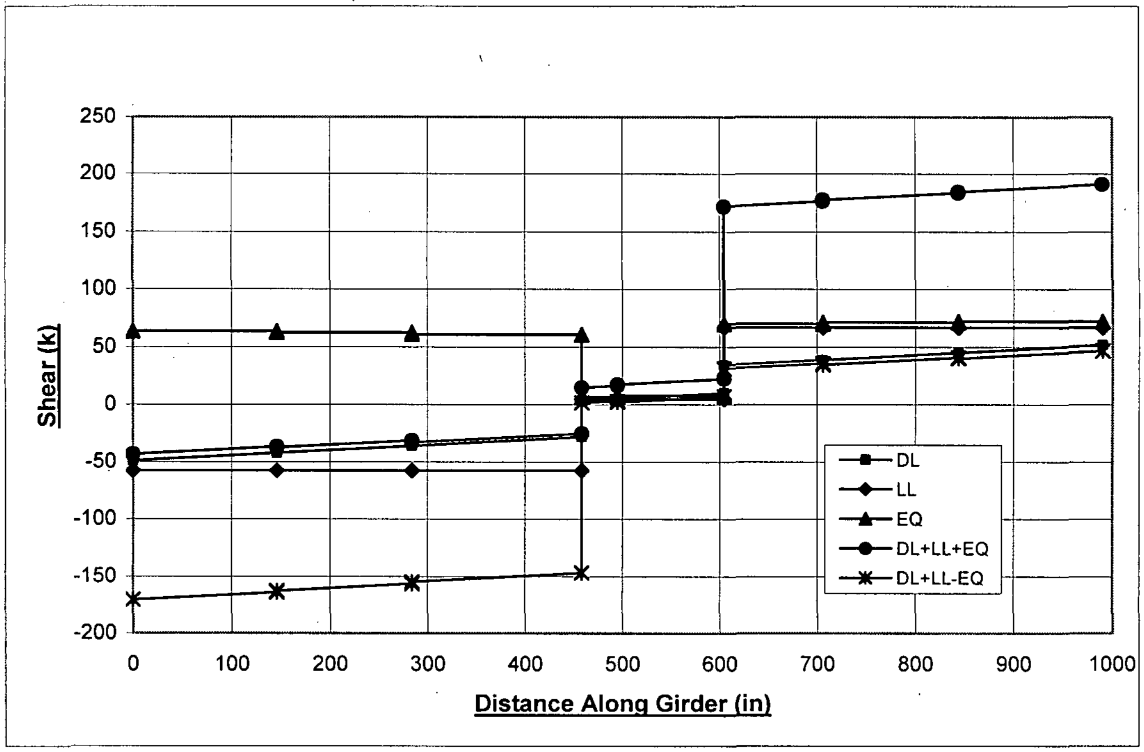


Figure 7

Bridge Drive Girder Vertical Shear, V2
Trolley Located at Mid-Span

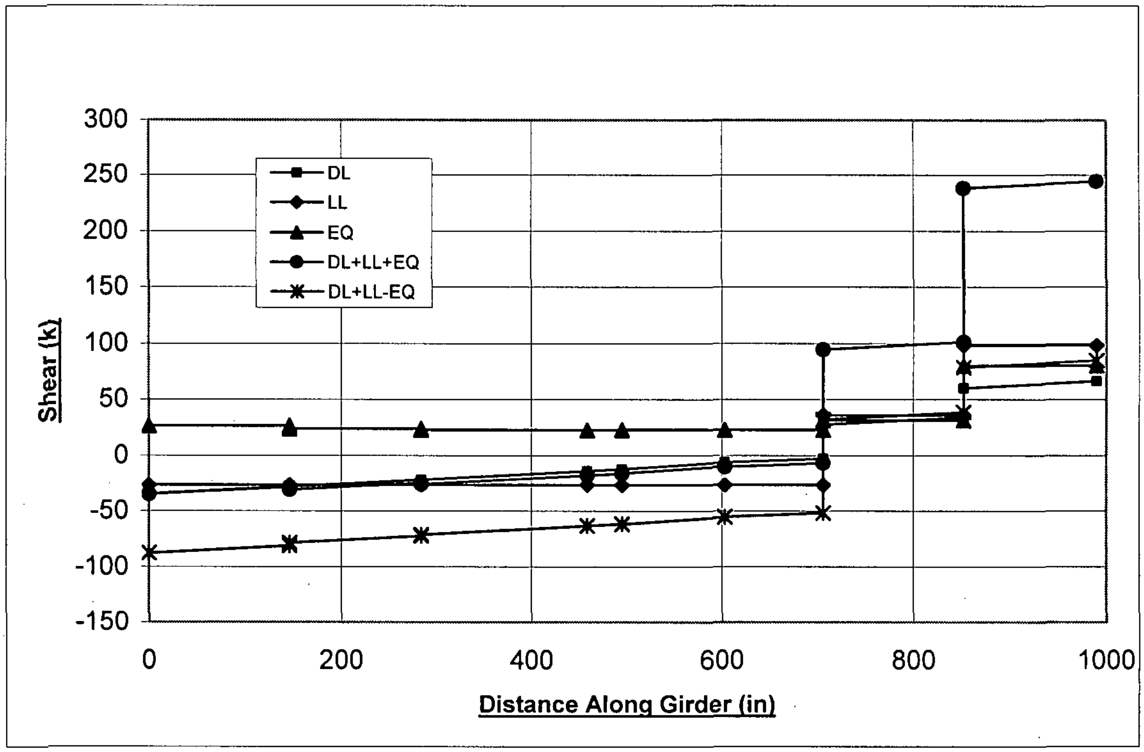


Figure 8

Bridge Drive Girder Vertical Shear, V2
Trolley Located at Quarter-Span

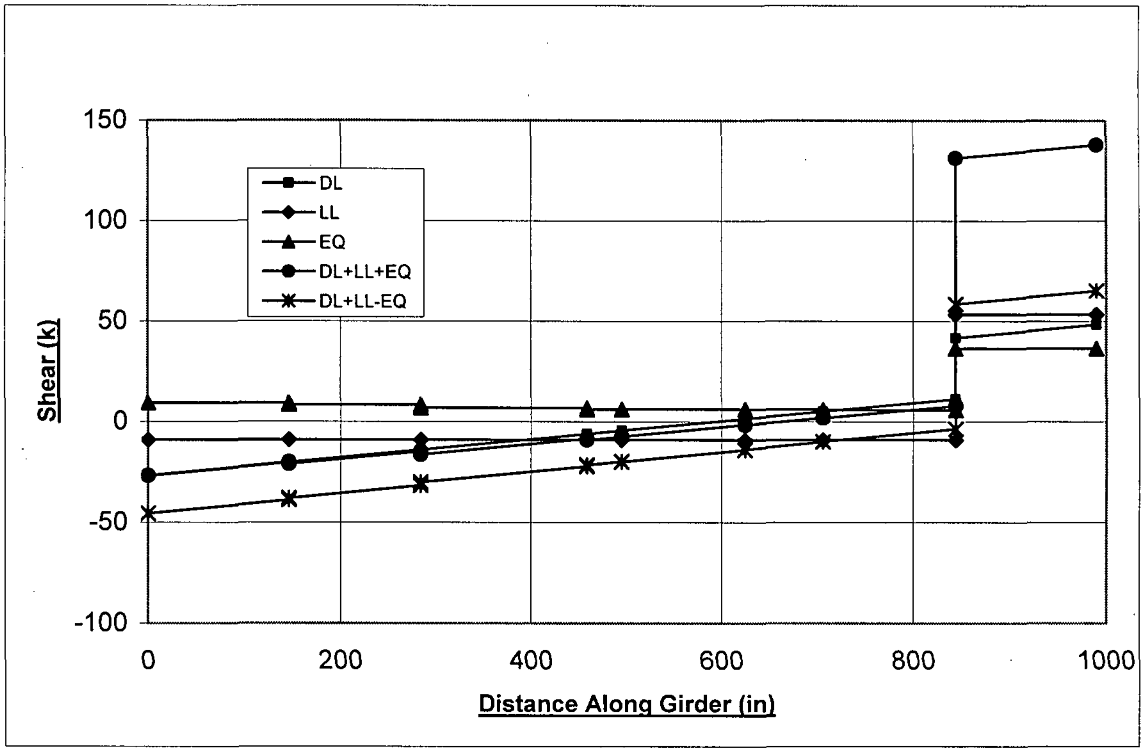


Figure 9

Bridge Drive Girder Vertical Shear, V2
Trolley Located at End-Span

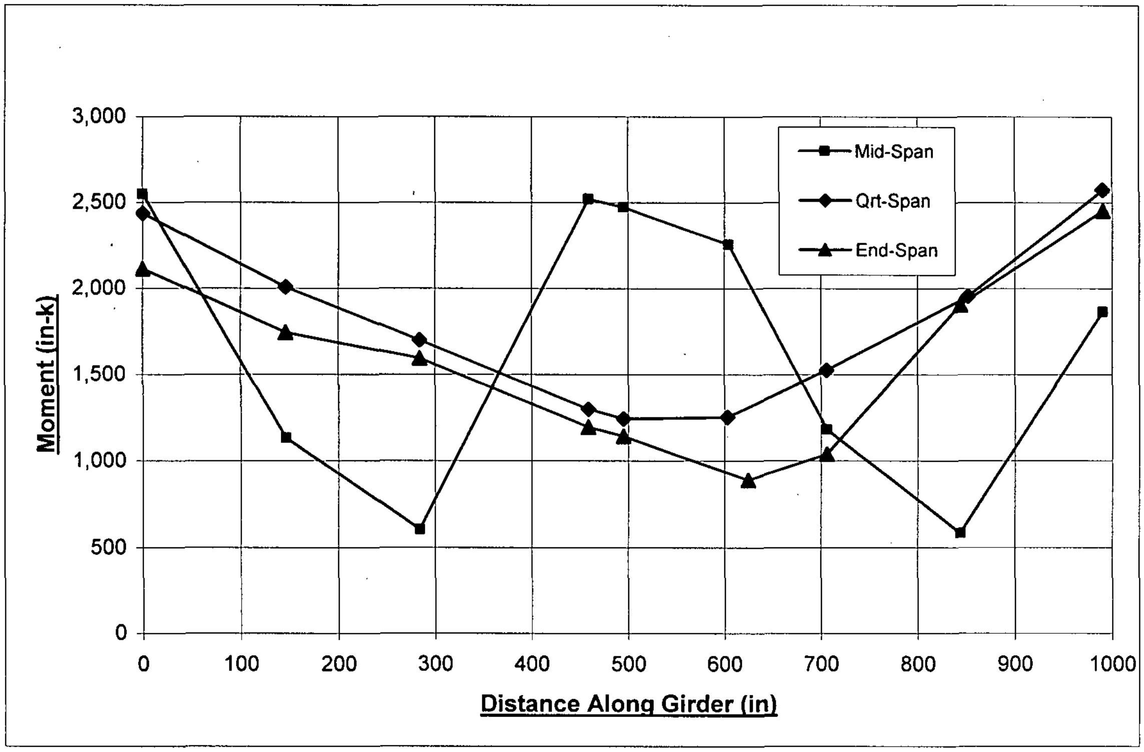


Figure 10

Bridge Drive Girder Weak Axis Moment, M2
Average Absolute Values – Seismic Loading Only

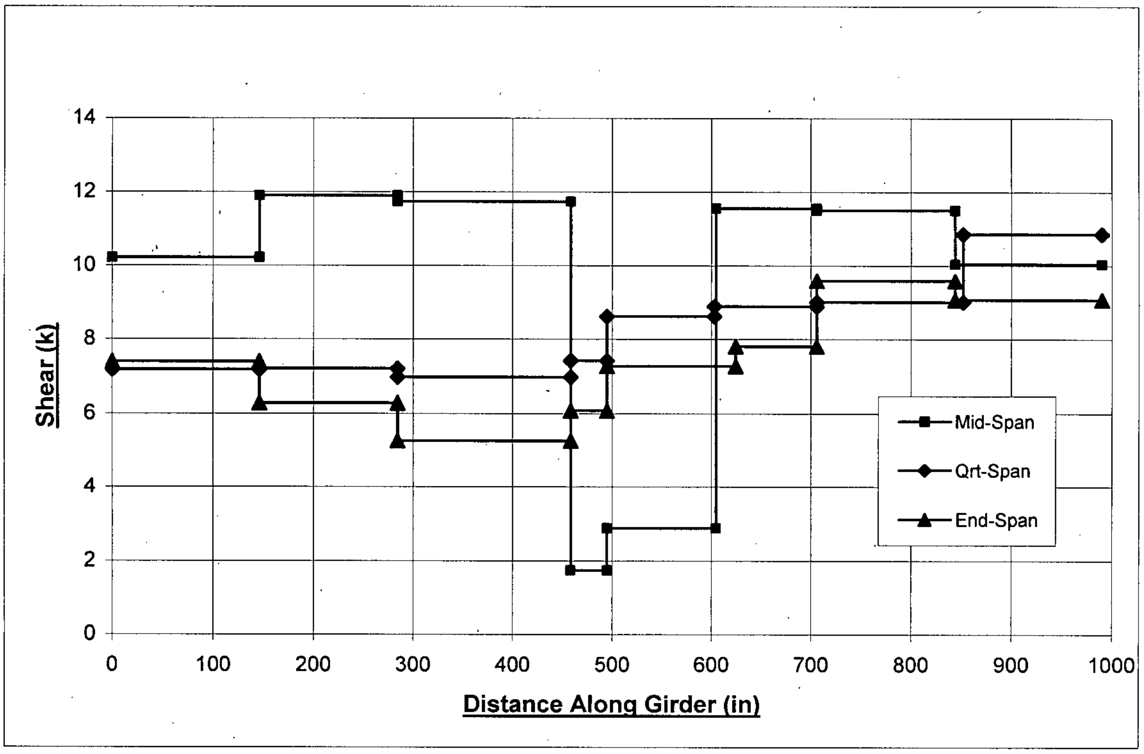


Figure 11

Bridge Drive Girder Weak Axis Shear, V3
Average Absolute Values – Seismic Loading Only

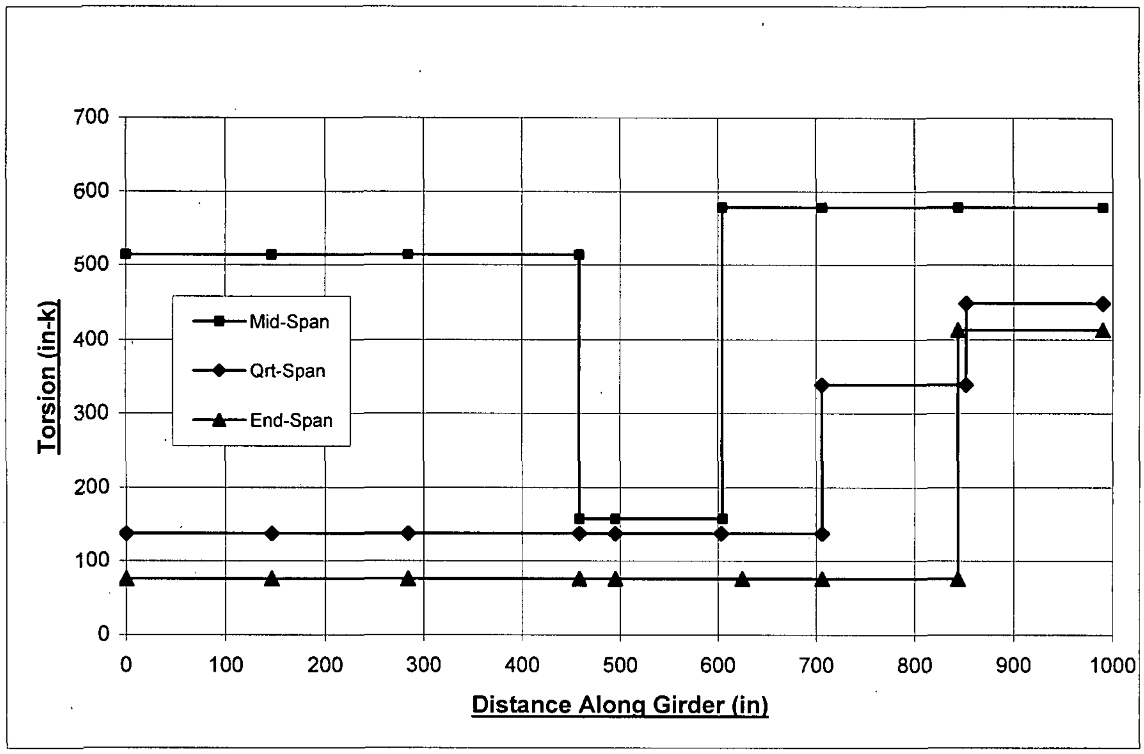


Figure 12

Bridge Drive Girder Torsion, T
Average Absolute Values – Seismic Loading Only

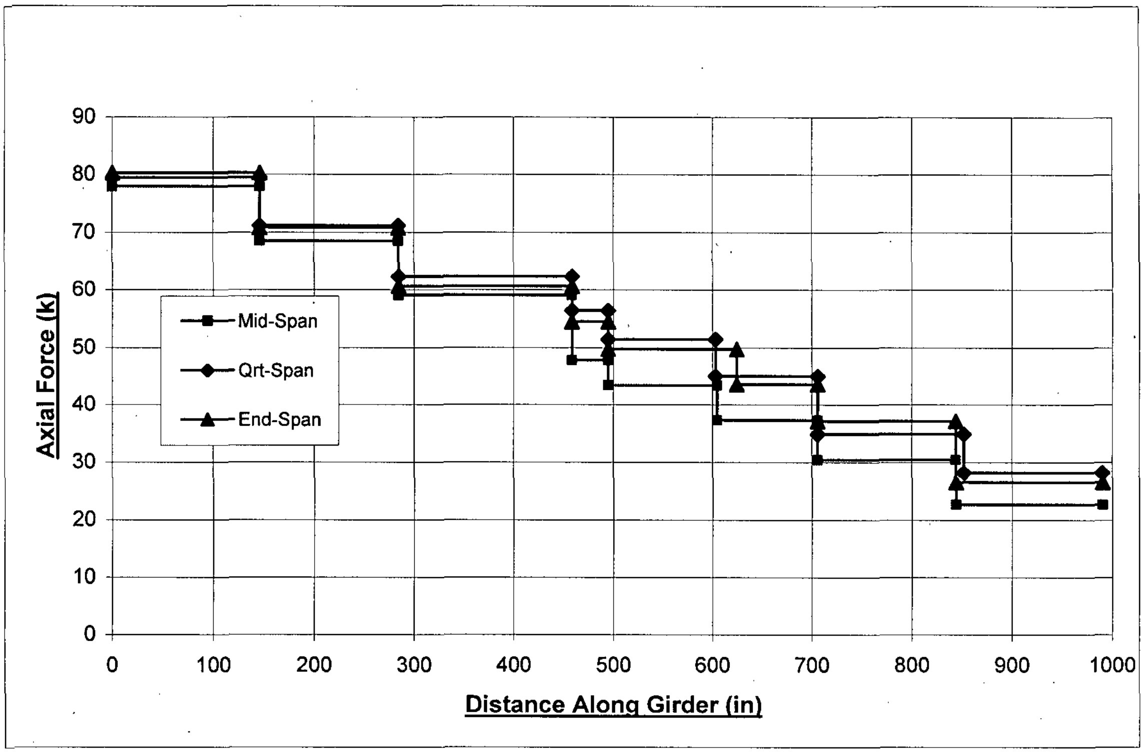


Figure 13

Bridge Drive Axial Force, P
Average Absolute Values – Seismic Loading Only

1.5 Correction of SAP 2000 Software Error

While performing our review of the seismic analysis, DEK discovered an error in the SAP 2000 computer program being used to perform the nonlinear analysis for the KPS Auxiliary Building crane. This error in SAP 2000 was confirmed by the software vendor, Computer and Structures, Inc. Resolution of this error contributed to the delay in submitting this supplement to LAR 239. The software error affected the Support Element that was originally being used to model the nonlinear behavior of the bridge girder drive wheels. The model showed that the internal shear force in the Support element was equal to the rolling resistance of the bridge girder drive wheels, which is correct. However, when SAP 2000 converted the internal Support Element shear force into a reaction force, the reaction force did not equal the internal shear in the Support Element, which is incorrect. No other output parameters were affected by this error. This problem was resolved by using a zero length Link Element for the bridge girder drive wheels. It has been confirmed that use of a zero length Link Element produces correct reaction forces. It has also been confirmed that other output parameters remain consistent with the output obtained from the Support Element.

2.0 Push Testing

Separate push tests were performed on the bridge and trolley of the crane to verify that the bridge and trolley drive wheels will roll through their brakes if sufficient force is applied and to verify that the brake force assumed in the calculation was conservative. The force required to roll the crane trolley or bridge drive wheels through their respective brakes was measured by applying an external force on the bridge and trolley until they moved. The external force was applied by use of hydraulic rams. The rams were placed between the bridge/trolley end trucks and the associated stops for each of the respective tests.

The hydraulic pressure on the rams was recorded at the point when the bridge or trolley began to move. The recorded pressure was then converted to units of force by multiplying the indicated pressure by the surface area of the ram cylinder. Rotation of the bridge drive motor was used as indication of bridge movement to ensure that gear lash in the drive train was accounted for and did not cause a false low reading. Tests were performed for each component until three repeatable measurements were obtained within the uncertainty inherent in reading the test gauges.

The crane bridge and trolley were both noted to roll through their brakes, not slide on the rails, at the forces shown in Table 2. The uncertainty of the measurement was determined as the sum of the accuracy of the gauge and the readability of the gauge. The published accuracy of the gauge is 1% of full scale. A zero-to-10,000-psi gauge was used; thus, the accuracy of the gauge is 100 psi. The scale on the gauge is displayed in 100-psi increments, and readability uncertainty is one-half of an increment, or 50 psi. Therefore, total uncertainty in each gauge reading is 150 psi. Using 2.24 in^2

as the effective area of the hydraulic cylinder and calculating force, the uncertainty in the force readings is 336 lbf. The push test for the trolley used one pump unit and gauge supplying two rams. The test for the bridge used two pump units and gauges, each supplying one ram for each end truck.

Table 2

Drive Wheel Brake Force

Component	Measured Brake Force (lbf)	Measured Brake Force plus Uncertainty (lbf)	Brake Force Assumed in Analysis (lbf)
Bridge	10,752	11,424	16,000
Trolley	3,584	3,920	8,000

To ensure that the calculation assumption on brake force remains valid after future modifications or major maintenance, DEK will perform the push test after any work resulting in a rebuild of the crane brakes. A rebuild of the brakes is defined as any work that could result in an increase in the brake force, such as a replacement of the springs or brake shoes. This requirement will be added to the crane maintenance procedures. A rebuild or replacement of the drive wheel brakes is not expected during the service life of the crane.

3.0 Third-Party Review of Nonlinear Seismic Methodology

A third-party review of the nonlinear seismic methodology was performed by Dr. Robert P. Kennedy of RPK Structural Mechanics Consulting. Dr. Kennedy reviewed the input time histories, the methodology used to model the nonlinear behavior of the drive wheels, the overall dynamic model (including the pendulum behavior of the spent fuel cask hanging from the crane), the methodology used to perform the nonlinear analysis, and the methods used to determine the maximum forces/moments on the crane structure, and the loads transmitted to the building. Dr. Kennedy concluded the results of the analysis are appropriate for their intended use for the structural evaluation of the crane and for reactions to be applied to the Auxiliary Building. The results of the third-party review are provided in Enclosure 2.

4.0 Summary and Conclusions

DEK has performed a nonlinear seismic time history analysis of the Auxiliary Building crane in accordance with the KPS design basis earthquake using the methods described in this document and in Reference 1. The nonlinearity is confined to the maximum rolling resistance that can be developed in the bridge and trolley drive wheels. The input values used to model the rolling resistance of the drive wheels were confirmed by push testing to be bounding and conservative. The resisting forces calculated from the push testing were increased by a factor of 1.4 (16,000/11,424) for the bridge drive wheels and 2.0 (8,000/3,920) for the trolley drive wheels in order to provide additional margin in the analysis.

The structural components of the bridge and trolley remain in the elastic range. Sensitivity studies were performed to demonstrate that the solution is not sensitive to variations in the key input parameters of the SAP 2000 Link/Support Elements used to model the nonlinear behavior of the drive wheels. The level of damping used in the analysis complies with the stated value in Appendix B of the Kewaunee USAR of 2 percent for steel structures. With the exception of the nonlinear behavior of the drive/trolley wheels and the damping, the modeling of the crane is in conformance with the requirements contained in ASME NOG-1-2004.

Five sets of seismic input time histories were developed in accordance with the guidance contained in SRP 3.7.1 Option II. In accordance with the recommendations contained in ASCE 43-05, the average of the absolute maximum value obtained from each time history analysis case was used for combination with other load cases for member stress checks. Member stress limits for the bridge will be in compliance with the limits set forth in the Kewaunee USAR for steel structures. An independent peer review of the seismic analysis methodology has been completed and is attached in Enclosure 2. The peer review is also summarized in Section 3.0 above.

In summary, DEK has used a nonlinear analysis method to model the response of the Kewaunee Power Station Auxiliary Building crane to a design basis earthquake event. The nonlinear analysis method complies with the applicable American Society of Civil Engineers (ASCE) standards for such analyses; the analysis inputs and assumptions were conservatively chosen; studies were performed to ascertain the sensitivity of the inputs to variation; and the results are reasonable compared to the inputs. Therefore, the nonlinear methodology is acceptable for use in this application as a means to provide reasonable assurance that, during and after a design basis earthquake at Kewaunee Power Station, the Auxiliary Building crane will retain its integrity, and the trolley and bridge will not leave their respective rails.

5.0 References

1. Letter from Gerald T. Bischof (DEK) to NRC Document Control Desk, "License Amendment Request 239 – Request for Review and Approval of Seismic Analysis Methodology for Auxiliary Building Crane," dated July 7, 2008.

2. Wilson, E. L., "An Efficient Computational Method for the Base Isolation and Energy Dissipation Analysis of Structural Systems," ATC17-1, Proceedings of the Seminar on Seismic Isolation, Passive Energy Dissipation, and Active Control, Applied Technology Council, Redwood City, CA, 1993.