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Measurements and Assessment of Structural Members in Selected Spans of Amtrak's Susquehanna River Bridge

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Executive Summary

The ATLSS Engineering Research Center at Lehigh University conducted strain- and displacement-gage measurements on structural members of Amtrak's Susquehanna River Bridge No. 60.07 between October 1997 and August 1998. The purpose of the measurements was threefold: (1) in October and November 1997, to evaluate the bridge for its capability to carry Conrail coal trains with cars loaded to a gross weight of 286,000 lb (286K), in contrast to the normal gross-weight limit of 263K; (2) in January 1998, to obtain data that would extend earlier data, further aid in an analytical modeling of the bridge structure, and provide baseline data relevant to later retrofits; and (3) in August 1998, to assess the performance of retrofits installed and lubrication maintenance conducted on selected bridge members during July 1998. ATLSS conducted its studies in cooperation with Amtrak Engineering and with Modjeski & Masters, Inc. (M&M), Harrisburg, PA, who was simultaneously engaged in evaluating and rating the bridge through inspections and analytical modeling, and implementing some retrofits.

ATLSS made measurements in Span 10, the swing span, and in Spans 9, 7, 2, and 1. Strain-gage locations for determining stresses were generally selected on the basis of M&M inspection data, discrepancies between prior measurements and M&M's modeling, retrofit actions, and experience. Data were obtained for selected lower-chord eyebars, diagonal eyebars, top chords, stringers, floorbeams, and vertical posts.

In the October and November study, nine bridge crossings (in both directions on both tracks) were made by a 90-car test train that was nominally a 286K-car coal train. All other trains were normal train traffic, but a few trains were directed to run on a specified track. These other trains included five that were identified as 263K-car coal trains. The loaded-car weights with the 263K-car trains varied significantly, however, and all five of the trains included cars with loaded weights exceeding 270K and three of the five had one or more cars with a loaded weight exceeding 280K. Moreover, the 286K-car train had some loaded-car weights approaching a low of 270K. These variations in weight would tend to reduce the differences in stress that might occur between totally 286K-car trains and totally 263K-car trains. With awareness of these factors, the October/November study found that stresses from the 286K-car train normally exceeded stresses from the 263K-car trains by only 1000 lb per sq in (1.0 ksi) or less, and would not have a fatigue-life-shortening effect on the bridge beyond the effect already due to 263K-car trains. The study also found problems with some bridge members that affirmed the need for corrective measures, even with 263K-car trains. Foremost among these were: Bending stresses in excess of the axial stresses occurred in the lower-chord eyebars adjacent to abutments at Spans 1 and 9, indicating that there is considerable pin restraint at the panel points that should be alleviated. Looseness in the diagonal eyebars was causing load shedding to other components and was likely contributing to damage at top chord/floorbeam junctions. This was particularly prevalent in Span 2 at members L5U6. The AREA constant amplitude fatigue resistance was being exceeded in Span 2 by stress ranges in the top chord U8U9, when trains crossed with either 263K- or 286K-coal cars. The fatigue limit stress range was also occasionally exceeded in floorbeams in Span 10. In Spans 2 and 7, at panel point U5 where fatigue cracks were already present, the floorbeam/top chord/diagonal eyebar stresses at the west truss were all affected by the member connections, particularly the vertical-post-to-lower-chord connection at L5, and by the amount of relative distortion that could occur. This also contributed to the load shedding in the diagonal eyebars.

In the January study, to extend earlier data and gain data relevant to later retrofits, ATLSS obtained new and additional stress data for members in Spans 2 and 1. Only normal coal, freight, and passenger train traffic was utilized. The study found that biaxial (in-plane and out-of-plane) vertical post bending was occurring. It was also found that due to relative movement involving the vertical posts and top-chord flange angles, the transverse stresses in the bottom flange angles of the top chords were high: 25.5 ksi in the west top-chord flange angle over floorbeam 5 in Span 2, and 10.5 ksi similarly over floorbeam 8 in Span 1. These distortion-related stress ranges were a significant factor in the subsequent design of retrofit assemblies by M&M.

In the August study, after retrofits had been installed at several panel points in Span 2 and lubrication of end panel pins had been performed in Spans 1 and 2, ATLSS obtained new and additional data in these spans to assess the effectiveness of the retrofits and lubrication. Again, only normal train traffic was utilized. The retrofits, designed by M&M, were of two types. A rigid bearing assembly (Retrofit Type 1) was installed at lower panel points (east and west) L4 and L5 in Span 2; and a modified lateral connection plate between the top chords and floorbeams (Retrofit Type 2) was installed, replacing an existing plate, at upper panel points U4 and U5 (east and west) and U6 and U7 (east only) in Span 2. The Type 1 retrofit was designed to minimize vertical displacement at lower panel points and to restore uniform tightness in the diagonal eyebars of the adjacent panels. The Type 2 retrofit was designed to increase flexibility and reduce distortions causing high flange stresses at the top chord/floorbeam junctions.

The August study showed that the retrofits in Span 2 had several benefits. Specifically, the Type 1 retrofits at the lower panel points had the benefit of increasing the tautness and parallelism of the diagonal eyebars; these retrofits may have benefitted the lower chord eyebars, too, inasmuch as no significant bending was evident in the lower chords framing into the retrofitted panel points (although pre-retrofit data had not been obtained on these eyebars). The Type 1 retrofit also strongly curtailed the downward movement of the L5U5-West post which was so evident before the retrofit. These retrofits had some effect, too, on the stress magnitudes in the vertical posts and on the nature of the bending of the posts but, although increasing the compression stresses in the posts, did not eliminate the bending. The Type 2 retrofits at the upper panel points may have contributed to the curtailed vertical post motion. More importantly, the upper-panel retrofits had the benefit of markedly reducing the stress near the crack tip of an existing floorbeam crack, suggesting that repeated crack opening during train passage was reduced. In addition, out-of-plane bending of the top chord was nil with the retrofit.

Only one week or less before the August stress measurements were made, pin lubrication was performed at end-panel points L9-West in both Spans 1 and 2. Because the lubricant probably requires time to work into the panel point joints and become effective, it may not have had sufficient working time when the measurements were made to maximize effectiveness. Nevertheless, it appeared to be effective. In Span 1, it did not eliminate rotational restraint but was found to lower both the axial and bending stresses in the L8L9 lower-chord eyebars by 50 percent. As prior measurements had not been obtained at L9 in Span 2, no comparison was possible. However, the measured bending stresses were about one-third those observed in Span 1. Hence, lubrication should be extended to all spans and end-panel joints to reduce the rotational restraint. The amount and frequency of lubrication to be used, however, will be a matter of engineering judgment. A six-month frequency seems reasonable.

In the August study, it was also observed that coal cars without hydraulic snubbers on their wheel trucks (GCCX cars leased from Consol) caused larger stress cycles in a number of bridge members than did newer cars with snubbers.

On the basis of the measurement results, the discussions among Amtrak, ATLSS, and M&M, and the M&M inspection reports, there are the following recommendations concerning the Susquehanna River Bridge.

- There are no conditions requiring emergency or as-soon-as-possible retrofits. Moreover, there are no conditions that should preclude increasing the limiting coal-car weight to 286K.

- Amtrak should proceed with the short-term retrofits described in M&M drawings S3 to S6, S11 to S19 and S21 to S23, dated October 1998, as funding becomes available. These drawings describe top chord repairs, lower-chord repairs, retrofits at interior lower-chord panel points, at upper-chord/floorbeam junctions, and at crack sites and would be cost effective.

- Another complete inspection of the entire bridge should be made, during suitable weather. The most recent interim inspection of this type was made in December 1997, and reported to Amtrak by M&M in January 1998. Another inspection would assist in defining expanding deficiencies and would assist in determining whether the July 1998 retrofits effectively arrested deficiencies near the retrofit panel points.

- A joint-by joint inspection of interior top -chord and lower-chord joints should also be performed in the reasonably near future, preferably during coal-train traffic. Joints with detectable vertical movement should be identified for later lower-chord retrofit using the Type 1 retrofit. Both east and west lower chords should be identified for retrofit when detectable movement occurs at either lower chord.

- When the lower-chord retrofits are later installed, the modified lateral connection plates (Type 2 retrofits) should be installed at all upper-chord locations where detectable lower-chord movement occurs, and at all locations that have evidence of floorbeam web cracking and/or top-chord bottom flange angle cracks.

- These recommendations should apply to both the northern Spans 1-9 and the southern Spans 11-18.

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Introduction

Background

On April 28, 1997, Modjeski and Masters Inc. of Harrisburg, PA, submitted a structural inspection and rating report to AMTRAK for the Susquehanna River Bridge No. 60.07 over the Susquehanna River between Havre de Grace, MD, on the south and Perryville, MD, on the north. [1] The report identified specific deficiencies in bridge members in the seventeen fixed spans and the one swing span of the bridge; rated the members according to A.R.E.A. provisions for load capacity and fatigue resistance; and compared these ratings to as-built ratings. In large part, the deficiencies and diminished ratings that resulted were the consequence of corrosion causing loss of section, the addition of welded repairs and reinforcement, and cracking causing decreased fatigue resistance. Other deficiencies cited were looseness and misalignment of eyebars and eyebar pins, of rivets in built-up sections, and of bolts that had replaced rivets in earlier rehabilitations. This resulted in assumptions on the effective area for many of the diagonal and chord members.

Also, in 1997, Conrail proposed that AMTRAK allow more heavily loaded coal cars to travel over AMTRAK's Northeast Corridor line. These cars would have a gross loaded weight of 286,000 lb, compared to the limit of 263,000 lb that was imposed on the Corridor. On August 11, 1997, Modjeski & Masters amplified their previous report with a second report [2] that provided a fatigue damage assessment of the bridge for three cases of coal-train traffic. Conrail uses the AMTRAK bridge for various freight traffic, including unit coal trains, container freight trains, and trains with mixed freight. This latter report concluded that critical members including floorbeams, stringers, and end panel top chords would be susceptible to increased fatigue damage as a result of more heavily loaded coal cars.

These issues, the existing bridge deficiencies and fatigue damage susceptibility cited by the Modjeski & Masters (M&M) reports and Conrail's proposed 286,000 pound coal cars, prompted AMTRAK to request the ATLSS Center to make in-service measurements and assess the data, so as to assist AMTRAK in responding to the Conrail proposal and in assessing retrofits proposed by M&M. Following preliminary meetings at AMTRAK's 30th Street Station in Philadelphia on September 3 and September 12, 1997, and at the Susquehanna Bridge site on September 17, 1997, involving ATLSS, AMTRAK, M&M, and Conrail personnel, ATLSS submitted a proposal to AMTRAK on September 22 [3] to (a) conduct an instrumentation study of the Susquehanna River Bridge and (b) lead an engineering investigation of the suitability of the bridge for 286,000 lb coal car service. The proposal was accepted by AMTRAK, and implemented as Modification No. 1 to an existing AMTRAK/ATLSS Contract No. PMMM 7174-0001. The specific objectives cited in the ATLSS proposal were:

1. To be the chief investigator and evaluator of the bridge by implementing field testing in order to validate and/or revise the Modjeski & Masters' 1996 In-Depth Evaluation and the Fatigue Assessment reports, including both their Short and the Long Term Recommendations, and the economic impacts.

2. To conduct field testing on the swing span and on fixed spans 1,2,7, and 9 north of the swing span, at locations justified by the M&M reports and applicable to the entire bridge.

3. Furnish a report evaluating the bridge's ability in its existing condition to carry the proposed load without compromising the safety and the integrity of the bridge;and evaluating the incremental impacts of heavy loads on asset life and replacement cycles. The evaluations would pertain only to the bridge and not to appurtenances such as turnouts.

Later, in December 1997, following meetings on December 1 involving AMTRAK, ATLSS and Conrail [4] and on December 10 involving AMTRAK, ATLSS, and M&M personnel [5] at which preliminary reviews of the measurement data and of proposed retrofits were conducted, ATLSS submitted a supplemental proposal [6] to AMTRAK to extend the instrumentation study and make additional field measurements in Spans 1 and 2 related to analytical modeling and retrofit concepts for the bridge being developed by M&M. This proposal was accepted by AMTRAK, and implemented as Modification No. 2 to the existing AMTRAK/ATLSS contract.

In June 1998, following a meeting on June 11 involving AMTRAK, ATLSS, M&M, Conrail, and Norfolk & Southern personnel at which the prior measurement data were summarized, conclusions were identified, and the status of retrofits was reviewed. AMTRAK then extended the contract with ATLSS through contract Modifications No. 3 and 6 in order to incorporate new measurements in Spans 1 and 2 and enable an assessment of the retrofits in improving bridge performance.

In October 1998, ATLSS submitted a preliminary copy of this report to AMTRAK; and in December 1998, also transmitted a letter with recommendations regarding rehabilitations for the bridge. These were reviewed at the AMTRAK office on March 15, 1999, jointly among AMTRAK, ATLSS, and Modjeski & Masters. This final report describes the complete evaluation program by ATLSS and final recommendations.

Bridge History

Construction of the existing Susquehanna River Bridge was completed in 1906, and the bridge has been in operation since. The bridge replaced a previous bridge which opened in November 1866 and which, in turn, had replaced steamboat connections across the Susquehanna River which had begun in July 1837. Until becoming part of Amtrak in May, 1971, the existing bridge was owned by the Pennsylvania Railroad (PRR). PRR had gained ownership of the Susquehanna Bridge when it purchased a majority interest in the original bridge in 1881 from the Philadelphia, Wilmington & Baltimore Railroad. [7]

Spanning from Havre de Grace, MD, on the south to Perryville, MD, on the north, the present two-track bridge consists of 18 spans of predominantly riveted steel construction, Figure 1a. The central span, Span 10, is a 277' 2" - long through-truss swing span, Figure 1b. Spans 1 through 9, to the north of the swing span, and Spans 11 through 18, to the south of the swing span, are pin-connected Pratt deck-truss spans. End Spans 1 and 18 are each 192' 0" long; Spans 2-9 are each 255' 0" long; and Spans 11-17 are each 195' 5" long. The spans are supported on stone piers and end abutments, and provide the bridge with a total length of 4,153' 8" between the abutment-wall faces.

Although the original construction of the existing bridge was generally with riveted and eyebar steel members, major repairs have been performed over the life of the bridge and a significant number of welded coverplates and high-strength bolted coverplates have been added. The dates and types of major repairs since 1933 have been presented by Modjeski & Masters [1, pp. 4-6].

The swing span of the bridge is infrequently opened - less than once a week, on average. Its rail equipment and machinery mechanisms for accommodating swings are significantly different and less automated than at other AMTRAK swing bridges [8], but they are not part of the current study.

Bridge Instrumentation

Scope of Measurements

Selected bridge structural members in selected spans were instrumented with sensors, predominantly strain gages, to obtain data establishing their response under trains traveling with the proposed 286K coal cars, as well as with normal 263K coal cars, mixed freight and passenger traffic. The members were selected from those found to be critical from the previous fatigue damage assessment, from those with extensive section loss, from those with excessive looseness or offsets which reduced the strength rating capacity, from those identified to have distortion-related cracking, and, later, from those involved with retrofits. The measurement locations were selected to help establish the 3D behavior of the structural system and provide a better definition of the live-load response and capacity, to provide data that help to confirm or modify previous fatigue analyses of the bridge, to assist in determining whether the proposed heavy axle loads might accelerate the bridge degradation, and to assess the effectiveness of the retrofits.

Members in five spans were instrumented: deck-truss spans 1, 2, 7, and 9 and the through-truss swing span 10. These spans and specific members to be instrumented were discussed in various meetings with Amtrak. In general, the members selected for instrumentation include eyebars, to aid in establishing the effectiveness of eyebars in the diagonals and lower chord truss members which have various degrees of tightness and offsets, and components such as stringers, floorbeams and top chord angle-to-floorbeam connections which show section loss and distortion-related cracking, possibly from movements due to worn pins or poorly defined restraint conditions.

Gage Locations

Span 10. On the 277' - 2" long (c-c end bearings) through-truss swing span, 20 strain gages were mounted between September 23 to 26, 1997, and monitored in October and November 1997. Gages were installed at Floorbeams 2 and 10 and on Stringers A and B between Floorbeams 1 and 2; their general location is shown in Figure 2. Specific gage locations and their rationale are given in Table 1, as are figure numbers where the gages are depicted:

Table 1. Gage Locations and Rationale for Span 10.

Gage No.	Figure No.	Location / Details	Rationale
		Floorbeam (FB) 10	
17	4	• North (N) side of FB, 2 ½ " W of flange tip of west exterior stringer (Stringer A), on edge of bottom coverplate at its endpoint, 62" from the FB end support.	• To examine cyclic stresses at different sections of FB. FB 10 had section loss ranging from 1/8" to 1/4" in the bottom flange angles and top flanges angle and the bottom CPs. • The Cooper E normal rating for the as-inspected FB was E-59, vs. E-65 as-built [1]. • Also, the bearings at the wedges under this FB were loose at the time gages were installed. However, Amtrak corrected this before measurements occurred.
24	4	• South (S) side of FB, opposite #17.	
18	3	• N side of FB, 42" W of W flange tip of west interior stringer (stringer B) on edge of bottom CP at end of CP.	
19	3	• Above #18 on edge of top CP.	
20	3	• N side of FB, 26" W of ℄, on edge of bottom CP just above where 3/4" bearing plate for center post ends.	
21	3	• Above #20 on edge of top CP	
22	3	• N side of FB, at ℄ on the same CP edge as #20	
23	3	• Above #22 on edge of top CP	
25	4	• S side of FB, 44" W of interior Stringer B on top surface of middle CP where top CP has severe section loss.	
		Floorbeam 2, Bottom (Tension) Flange	
30	5	• S side of FB, on top surface of top CP adjacent to section loss, between track 3 rails	• To examine stresses at different sections of FB. FB2 had the same flange deficiencies as FB 10, and had web pitting and section loss. • The Cooper E normal rating for the as-inspected FB was E-51, vs. E-56 as-built [1].
31	5	• Near to #30, on edge of top CP at midlength of section loss	
32	5	• Under #31, on edge of middle CP, at end of bottom CP.	
39	5	• N side of FB, 52" from stringer A on bottom flange angle	
40	5	• Below #39 on edge of bottom CP, 18" from end of CP	
		Stringers Between FB 1 and 2	
33	6	• E side of Stringer A, on top surface of bottom flange angle at end of stringer CP near FB2.	• To compare midspan stresses with stresses at stringer/floorbeam junction where welded coverplates terminated.
34	6	• W side of stringer B similar to #33	
37	6	• W side of stringer A, close to opposite #33.	• The stringers had section loss both along the bottom flange and on the bottom-flange CPs which were added by welding.
35	6	• E side of stringer A, on top of bottom flange angle, midway between FBs.	
36	--	• W side of stringer B, similar to #35	• The Cooper E normal rating for the stringers was E-66, as-inspected and as-built
38	--	• W side of stringer A, opposite #35.	

Span 9. On the 255' - 0" long (c-c end bearings) deck-truss span northerly adjacent to the swing span, 16 strain gages were mounted between September 23 and October 1, 1997, and monitored in October and November 1997. All the gages were on the lower chord eyebars L0L1 (4 eyebars per truss @ 12"x 1-5/8") near end panel point L0 at Pier 9, as shown in Figure 7. Table 2 details the gage locations, their rationale, and figure numbers depicting the gages.

Table 2. Gage Locations and Rational For Span 9

Gage No.	Figure No.	Location / Details	Rationale
		West Truss Chord L0L1@L0	
1	8	Outboard eyebar (Eyebar 4), top edge	• To examine chord tension, possibility of bending, and variability among bars and trusses. • Section loss at eyebars had reduced normal Cooper E rating from E-55 as-built to E-43 as-inspected for 40 mph freight. • The eyebars were all rated "tight" on the east truss; one was rated moderate on the west truss.
2	8	Eyebar 3, top edge	
3	8	Eyebar 2, top edge	
4	8	Inboard eyebar (Eyebar 1), top edge	
5	-	Eyebar 4, bottom edge, below #1	
6	-	Eyebar 3, bottom edge, below #2	
7	-	Eyebar 2, bottom edge, below #3	
8	-	Eyebar 1, bottom edge, below #4	
		East Truss Chord L0L1@L0	
9	8	Eyebar 4, top edge	
10	8	Eyebar 3, top edge	
11	8	Eyebar 2, top edge	
12	8	Eyebar 1, top edge	
13	8	Eyebar 4, bottom edge, below #9	
14	8	Eyebar 3, bottom edge, below #10	
15	8	Eyebar 2, bottom edge, below #11	
16	8	Eyebar 1, bottom edge, below #12	

Span 7. On this 255' - 0" long (c-c end bearings) deck-truss span, 20 strain gages were mounted during the period from September 26 to October 1, 1997, and monitored in October and November 1997. Gages were installed on eyebar diagonals L7U8 near panel point L7 (4 eyebars per truss @ 12" x 1-13/16") and at Floorbeam 5; their general location is shown in Figure 9. Although Span 7 had individual conditions, it also was selected as representative of many of the over-water deck-truss spans. Table 3 details the gage locations, their rationale, and figure numbers depicting the gages.

Table 3. Gage Locations and Rationale for Span 7.

Gage No.	Figure No.	Location/Details	Rationale
		West Truss Diagonal L7U8@L7	
70	10	Outboard eyebar (Eyebar 4), top edge	• To examine eyebar tensions and variability among bars. • Some section loss and wear from contact between eyebars 2 and 3. • Eyebars 1 and 4 rated loose; 2 and 3 moderate. • Section loss had reduced normal Cooper E rating from E-52 as-built to E-49 as-inspected for 40 mph.
71	10	Eyebar 3, top edge	
72	10	Eyebar 2, top edge	
73	10	Inboard Eyebar 1, top edge	
78	10	Eyebar 4, bottom edge, below #70	
79	10	Eyebar 3, bottom edge, below #71	
80	10	Eyebar 2, bottom edge, below #72	
81	10	Eyebar 1, bottom edge, below #73	
		East Truss Diagonal L7U8@L7	
74	-	Eyebar 4, top edge	• To compare with west truss and study effects of both NB and SB trains. • Eyebars 1 and 2 misaligned > 3" and only moderately tight. • Bar misalignment reduced normal Cooper E rating to E-15.
75	-	Eyebar 3, top edge	
76	-	Eyebar 2, top edge	
77	-	Eyebar 1, top edge	
82	-	Eyebar 4, bottom edge below #74	
83	-	Eyebar 3, bottom edge below #75	
84	-	Eyebar 2, bottom edge below #76	
85	-	Eyebar 1, bottom edge below #77	
		West Truss, Floorbeam 5	
88	11	• Above FB5 on the top chord bottom flange angle at N end of long crack, 3½" S of end of lateral gusset plate, 1" from fillet of flange angle. Gage roughly perpendicular to crack and slightly skewed to flange length.	• To examine stress on top chord at FB junction near crack ends.
89	11	• Similar to #88, but at S end of crack and 2½" S of gusset plate and 3/4" from flange angle fillet.	
86	11	• N side of FB near tip of vertical crack, 1-5/8" below top FB flange and 1" from weld for web-plate repair.	• To examine stresses near cracked top flange angle on FB. • Normal Cooper E rating was reduced from E-80 as-built to E-69 as-built.
87	11	• On tip of FB flange, 8" E of lateral gusset plate.	

Span 2. On this 255' - 0" long (c-c end bearings) deck-truss span, 76 strain gages and 2 displacement gages were initially mounted during the period from September 25 to October 9, 1997, for monitoring in November 1997. This span was selected for the largest number of installed gages because, it being mostly over land, gages could be installed here most economically in order to address the major deficiency conditions that had been cited for other, similar spans. In addition, the span itself had critical areas of concern. Gages were installed on eyebar diagonals L3U2 near panel points L3 (4 eyebars per truss @ 10" x 1-11/16"), L5U6 near panel points L5 (4 eyebars per truss @ 10" x 1-5/16"), and L7U8 near panel points L7 and U8 (four eyebars per truss @ 12" x 1-13/16"). Gages were also installed on top chord U8U9, the adjacent stringer, and at Floorbeams 5 and 8. Their general locations are shown in Figure 12, and Table 4 details the gage locations, their rationale, and figure numbers depicting the gages.

Subsequently, after a review of the November data from the initial gages and meetings with Amtrak and Modjeski & Masters, it was decided to mount an additional 24 strain gages in Span 2 and to relocate the two displacement transducers. The new installation was done in the period from December 17 to 19, 1997, for monitoring in January 1998. The additional gages, noted with a prefix D, were installed at Floorbeams 5, 6, and 8, at midspan of the west top chord and stringer U8U9, and on vertical posts L5U5. Their general locations appear in Figure 12. Table 4 also details the gage locations, their rationale, and figure numbers depicting the gages. A few of the initial Span 2 gages were also included for monitoring in January as a reference.

Table 4: Gage Locations and Rationale for Span 2

Gage No.	Figure No.	Location/Details	Rationale
		West Truss Diagonal L3U2@L3	
200	-	Outboard eyebar (Eyebar 4), top edge	• To examine eyebar tensions and variability among bars. • Eyebars 2 and 3 rated loose; Bars 1 and 4 moderate. • Normal Cooper E rating was reduced from E-59 as-built to E-53 as inspected for L3U2 bars.
201	-	Eyebar 3, top edge	
202	-	Eyebar 2, top edge	
203	-	Inboard eyebar (Eyebar 1), top edge	
252	-	Eyebar 4, bottom edge below #200	
253	-	Eyebar 3, bottom edge below #201	
254	-	Eyebar 2, bottom edge below #202	
255	-	Eyebar 3, bottom edge below #203	

Gage No.	Figure No.	Location/Details	Rationale
		East Truss Diagonal L3U2 at L3	
204	-	Eyebar 4, top edge	• To examine eyebar tensions and variability among bars. • Eyebar 2 rated very loose; Bars 3 and 4 moderate. • Normal Cooper E rating was reduced from E-59 as-built to E-53 as inspected.
205	-	Eyebar 3, top edge	
206	-	Eyebar 2, top edge	
207	-	Eyebar 1, top edge	
256	-	Eyebar 4, bottom edge below #204	
257	-	Eyebar 3, bottom edge below #205	
258	-	Eyebar 2, bottom edge below #206	
259	-	Eyebar 1, bottom edge below #207	
		West Truss Diagonal L5U6 at L5	
208	41	Eyebar 4, top edge	• To examine eyebar tensions and variability among bars. • Section loss and wear from contact reported. • Eyebar 1 rated very loose, bar 3 loose, and bars 2 and 4 moderate. • Bar misalignment reduced normal Cooper E-rating from E-71 as-built to E-44 as-inspected.
209	41	Eyebar 3, top edge	
210	41	Eyebar 2, top edge	
211	41	Eyebar 1, top edge	
244	-	Eyebar 4, bottom edge below # 208	
245	-	Eyebar 3, bottom edge below #209	
246	-	Eyebar 2, bottom edge below # 210	
247	-	Eyebar 1, bottom edge below # 211	
		East Truss Diagonal L5U6 at L5	
212	41	Eyebar 4, top edge	• To examine eyebar tensions and variability among bars. • All eyebars rated loose
213	41	Eyebar 3, top edge	
214	41	Eyebar 2, top edge	
215	41	Eyebar 1, top edge	
248	-	Eyebar 4, bottom edge below #212	
249	-	Eyebar 3, bottom edge below #213	
250	-	Eyebar 2, bottom edge below #214	
251	-	Eyebar 1, bottom edge below #215	

Gage No.	Figure No.	Location/Details	Rationale
		West Truss Diagonal L7U8 at L7	
216	-	Eyebar 4, top edge	• To examine eyebar tensions and variability among bars. • Eyebars 1, 2, 3 rated loose. • Normal Cooper E rating reduced from E-52 as-built to E-49 as-inspected. • Evaluate in-plane bending
217	-	Eyebar 3, top edge	
218	-	Eyebar 2, top edge	
219	-	Eyebar 1, top edge	
224	-	Eyebar 4, bottom edge below # 216	
225	-	Eyebar 3, bottom edge below # 217	
226	-	Eyebar 2, bottom edge below # 218	
227	-	Eyebar 1, bottom edge below # 219	
		West Truss Diagonal L7U8 at U8	
300	-	Eyebar 4, top edge	
304	-	Eyebar 3, top edge	
305	-	Eyebar 2, top edge	
306	-	Eyebar 1, top edge	
307	-	Eyebar 4, bottom edge below # 300	
236	-	Eyebar 3, bottom edge below # 304	
237	-	Eyebar 2, bottom edge below # 305	
238	-	Eyebar 1, bottom edge below # 306	
		East Truss Diagonal L7U8 at L7	
220	-	Eyebar 4, top edge	• To examine eyebar tensions and variability among bars. • Eyebar 2 rated loose, others moderate. • Section loss and wear from contact. • Bar misalignment reduced normal Cooper E rating to E-31 as-inspected.
221	-	Eyebar 3, top edge	
222	-	Eyebar 2, top edge	
223	-	Eyebar 1, top edge	
228	-	Eyebar 4, bottom edge below # 220	
229	-	Eyebar 3, bottom edge below # 221	
230	-	Eyebar 2, bottom edge below # 222	
231	-	Eyebar 1, bottom edge below # 223	

Gage No.	Figure No.	Location/Details	Rationale
		East Truss Diagonal L7U8 at U8	
240	-	Eyebar 4, bottom edge	
241	-	Eyebar 3, bottom edge	
242	-	Eyebar 2, bottom edge	
243	-	Eyebar 1, bottom edge	
		West Top Chord U8U9	
276	13	Midspan between U8 and U9 at ℄ top chord flange	• To examine top chord stresses at and near midspan between panel points.
277	13	Same, 14" E of # 276	•Many deficient rivets at Panel Pt U8, U9
278	13	Same, 7" E of # 277 on top of gusset plate for stringer lateral bracing	• Cooper E rating for Fatigue reduced from E-48 as-built to E-33 as-inspected.
279	13	Like # 276, 32" N of midspan	
280	13	Like # 277, 32" N of midspan	
		Stringer B, U8U9	
281	13	Midspan, ℄ top of flange	• To compare stringer and top chord stresses.
282	13	Same, W edge, top of flange	
283	13	Same, E edge, top of flange	
		Floorbeam 8 at West Top Chord	
301	14	On top side of top chord's bottom flange at S end of lateral gusset plate.	• To measure stresses near FB/top chord junction.
302	14	On ℄ of top flange of FB, 30" W of edge of stringer seat.	
303	14	On top side of bottom flange at same cross section as # 302	
		Floorbeam 5 at West Top Chord	
308	15	N side of FB, perpendicular to crack on angle leg midway between fillet and edge of angle.	• To measure stresses near FB/top chord junction, and near crack tip. • Crack existed in FB top flange angle.
309	15	Near # 308, near crack tip adjacent to vertical weld for earlier repair plate.	
310	15	S side of FB, perpendicular to repair plate weld just below a 3/8 to 1/2" diameter existing crack arrest hole.	• To measure effect of crack on either side of FB and see if top chord was rocking over FB.
397	16	Displacement gage at N side of FB, from vertical post to top flange of FB.	
398	16	Displacement gage at S side of FB, opposite #397.	

Gage No.	Figure No.	Location/Details	Rationale
		Floorbeam 5 at East Top Chord	
311	15	N side of FB, similar to # 308, although no crack is evident at E top chord. 2" W of rivet on angle flange and oriented vertically.	• To determine stress difference between cracked and uncracked FB/top chord junctions.
312	15	N side of FB, similar to #309. 3-3/4" below FB flange and 1-1/8" W of vertical edge of angle.	
		Gages for January Measurements	• To obtain data further defining behavior before proposed retrofits and in affirming retrofit details.
		Top Chord U8U9	
D5	17,18	East bottom flange of W top chord at midspan. Gage longitudinal.	• To examine midspan stresses from axial and bending effects.
D6	17,18	Opposite D5 on west flange.	
D276	17	Same as prior # 276	• Prior gage was damaged by crosstie motion.
D30	17	Same as prior # 277	• Gages D30 and D29 were to enable a study of biaxial stresses in the top chord flange; however, #D30 malfunctioned.
D29	17	Adjacent and transverse to # D30	
		West Truss Diagonal L5U6 @ L5	• For reference with earlier data
208	41	Eyebar 4, top edge	
		East Truss Diagonal L5U6 @ L5	
212	41	Eyebar 4, top edge	
		West Truss Diagonal L7U8 @ U8	
300	-	Eyebar 4, top edge	
		Floorbeam 8	
D3	19	At E truss, on west bottom flange of top chord, transverse to chord, offset from ℄ of FB 1-1/2" due to rivets.	• To examine strain from top chord / floorbeam / vertical post interaction from trains traveling both N and S.
D4	19	Same as D3, except 18" S of #D3	
D7	18,19	Same as # D3 at W truss, gage on east bottom flange.	
D8	18,19	Same as #D7, except 18" S of FB ℄.	
D9	20	Displacement gage at S side of FB, from vertical post to bottom of doubler plates on W top chord web.	
301	14	Prior #301	• For reference with earlier data
302	14	Prior #302	

Gage No.	Figure No.	Location/Details	Rationale
		Floorbeam 6	
D10	21	At W truss, on east bottom flange of top chord, transverse to chord, offset S 2-1/8" from ℄ of FB due to rivets.	• To examine strain from top chord / FB / vertical post interaction.
D11	21	Same as #D10, except 18" S of FB ℄. Just S of edge of pin gusset plate. 5 bolts between D10 and D11.	
		Floorbeam 5	
D12	22,23	At E truss, on west bottom flange of top chord, transverse to chord, 13" (or 3 bolts) N of ℄ of FB. Just S of edge of gusset plate for pin.	• To examine strain from top chord / FB / vertical post interaction from trains traveling both N and S.
D13	22,23	Same as #D12, but 1-1/2" S of FB ℄.	
D16	22,24	Same as #D13, but at W truss.	
D17	22,24	Same as #D16, but 3 bolts N of FB ℄.	
D14	25,26	At ℄ of FB, at ℄ of bottom flange of FB. Gage longitudinal.	• To examine ℄ stresses in FB.
D15	25,26	Same as D14, except on top flange.	• Gage D15 malfunctioned in January.
D97	24,27	Displacement gage on N side of FB at W truss. Same mounting as previous gage # 397, but contacted plates between FB and hanger.	• To examine motion of plates relative to vertical post.
		Vertical Posts L5U5	
		Gages on N and S faces of posts between 5th and 6th lattice pairs.	• To measure vertical post stresses and influence of bottom chord connection. • To obtain baseline stresses prior to proposed retrofit at L5.
D18	28	NE corner angle, E post	
D19	28	NW corner angle, E post	
D20	28,29	SW corner angle, E post	
D21	28,29	SE corner angle, E post	
D22	28	NW corner angle, W post	
D23	28	NE corner angle, W post	
D24	28,29	SE corner angle, W post	
D25	28,29	SW corner angle, W post	

Span 2 with Retrofits. Later, following discussions with Amtrak and Modjeski & Masters (M&M) and a June 11, 1998 meeting in Philadelphia involving Amtrak, ATLSS, Conrail, Modjeski & Masters, and Norfolk & Southern, ATLSS installed additional gages in Span 2, between July 15 and August 11 to enable (a) an assessment of retrofits installed in Span 2, and (b) further assessment of a few key areas in Span 2 involved in earlier measurements. The retrofits were designed by

M&M, fabricated by High Steel Structures, and installed by High Steel between June 27 and July 28. The retrofits included the addition of a rigid compression assembly bearing on the eyebar heads at the bottom chord at several lower panel points (type 1 retrofits) and revised lateral connection plates (type 2 retrofits) at several floorbeam/top chord intersections. Details are included on M&M drawing Sheets No. 1 through 22, Design No. 6650, File No. MD 060.07.[9.1].

The **Type 2 retrofits** included removing the existing lateral connection plates between the top chords and Floorbeams 4 and 5 at the west truss and Floorbeams 4, 5, 6 and 7 at the east truss and replacing them with new lateral connection plates that provided significantly more flexibility between floorbeam and top chord. The new trapezoidal-shaped plates were 21″ x ½″ x 114″, Figure 30, with the latter dimension parallel to the top chord. To connect to the top chord, the lateral plates were bolted to short (7″ x ½″ x 18-24″) splice plates at each end of the lateral connection plate; these, in turn, were bolted through tie plates and the fill plate to the bottom flange of the top chord. After the new lateral connection plates were in place, new strain gages were installed on and adjacent to the plates at panel points U5-west and U6-east. Also, a new displacement gage was installed at U5-west between the top chord web plate and the new lateral connection plate.

The retrofit connection plates, although similar at all panel points where they were installed, are associated with different diagonal members at different panel points. Figure 31 is a sketch of the diagonal geometry at the two strain-gaged panel points. At U5-West the diagonals were built-up angle members (towards panel point L4) and counter rods (towards panel point L6). At U6-East, there were only eyebar diagonals towards panel point L5.

The **Type 1 retrofit** assemblies were installed at lower panel points L4 and L5, both east and west trusses, to minimize vertical displacement of these points under train traffic and to restore uniform tightness of the eyebars that are pin connected at the panel point. The assemblies were designed to accomplish their tasks by drawing the eyebars and eyebar pin tight against their pin plates in the bottom of the post. In this retrofit, a temporary yoke assembly consisting of a built-up bottom plate, bearing against the bottom of the vertical post and adjoining gusset plate, was initially connected to two top bearing plates (one over each group of exterior eyebars — which are those outside the legs of the vertical posts) through four 1-¼″ diameter threadbars. Two sets of these assemblies are shown in Figure 32a, and Figure 32b shows a top bearing bar in position at Panel Point L4-West. The nuts and washers at each end of the threadbars are used to tighten the assembly and push down on the top edges of the exterior eyebars until the eyebars displace to their original design position. Then, across the interior eyebars (those between the legs of the vertical posts), a rigid bearing assembly, Figure 33, was bolted to the vertical post after removing, as needed, tie plates and lattice bars; at the lower end of this assembly, a bearing plate ground to the 13″ radius of the eyebar heads was seated against the top edges of the eyebars. An epoxy compound was then placed between the bearing plate and eyebar heads to provide a uniform bearing condition. After the previously removed tie plates and lattice bars were reinstalled on the vertical post, the lower temporary yoke assemblies were removed. Figure 34 shows a vertical post with a retrofit assembly.

The general locations of the post-retrofit July/August gages in Span 2 are given in Figure 36, and Table 5 details the locations of the new gages, their rationale, and figure numbers depicting them; the new gages have the suffix .98. Table 5 also provides details about 29 strain gages (some of which had to be repaired or replaced) existing from earlier measurements which were included for the new assessments.

Table 5: Gage Locations and Rationale for Span 2, July/August 1998

Gage No.	Figure No.	Location/Details	Rationale
		West Top Chord U8U9	
1.98	37	2″ S of Midspan between U8 and U9, 4" from tip of E top chord flange pl.	• Top chord behavior needs better definition. • See earlier rationale for west top chord U8U9 gages, Table 4.
2.98	37	Same, at ℄ top chord flange pl.	
3.98	37	Same, 4" from tip of W top chord flange pl.	
D5	17, 18, 37	Same, east bottom flange of top chord.	
D6	17, 18, 37	Same, west bottom flange of top chord	
		Floorbeam 5 at West Top Chord At 1/2" Lateral Retrofit Pl.	
4.98	38	Longitudinal atop E bottom flange of top chord adjacent to lateral pl, about 18″ N of FB ℄	• Assess performance of retrofit system using less stiff assembly between top chord and FB.
5.98	38	Longitudinal on lateral pl, above edge of new N splice pl.	
6.98	-	Transverse, next to #5.98	
7.98	38	Longitudinal on lateral pl, transverse to FB above edge of FB flange 1½″ W of edge of lateral pl.	
8.98	-	Similar to #6.98, except above edge of S splice pl.	
70.98	40	Displacement gage, between top of new lateral pl and web of top chord. Above FB flange.	
309	15	N side of FB, near crack tip adjacent to vertical weld for earlier repair plate	• Compare crack-tip strains for retrofit and original assemblies
		At ℄ of Floorbeam 5	
D14	25, 26	At ℄ of bottom flange of FB	• Compare FB strains for retrofit and original assemblies. • #D15 was repaired for retrofit trials.
D15	25, 26	Same as D14, except on top flange	
		Floorbeam 6 at E Top Chord at 1/2" Lateral Retrofit Pl	
9.98	39	Longitudinal atop W bottom flange of top chord adjacent to lateral pl, about 18″ S of ℄ of FB	• Assess performance of retrofit system using less stiff assembly between top chord and FB.
10.98	39	Longitudinal on lateral pl, above edge of S new splice pl.	

Gage No.	Figure No.	Location/Details	Rationale
11.98	39	Transverse., next to #10.98	• Assess performance of retrofit system using less stiff assembly between top chord and FB.
12.98	-	Longitudinal on lateral pl, transverse to FB above edge of FB flange 1½″ E of edge of lateral pl.	
13.98	-	Similar to #11.98, except above edge of N new splice pl.	
		West Truss Diagonal L5U6 at L5	
208	41	Eyebar 4, top edge	• To examine eyebar tensions and variability among bars after retrofits. • For comparison with pre-retrofit measurements. • Also see earlier rationale in Table 4.
209	41	Eyebar 3, top edge	
210	41	Eyebar 2, top edge	
211	41	Eyebar 1, top edge	
244	-	Eyebar 4, bottom edge below # 208	
245	-	Eyebar 3, bottom edge below #209	
246	-	Eyebar 2, bottom edge below # 210	
247	-	Eyebar 1, bottom edge below # 211	
		East Truss Diagonal L5U6 at L5	
212	41	Eyebar 4, top edge	• To examine eyebar tensions and variability among bars after retrofits. • For comparison with pre-retrofit measurements. • Also see earlier rationale in Table 4.
213	41	Eyebar 3, top edge	
214	41	Eyebar 2, top edge	
215	41	Eyebar 1, top edge	
248	-	Eyebar 4, bottom edge below #212	
249	-	Eyebar 3, bottom edge below #213	
250	-	Eyebar 2, bottom edge below #214	
251	-	Eyebar 1, bottom edge below #215	
		West Truss Lower Chord L4L5 at L5	
14.98	42	Eyebar 5, top edge	• Assess effect of yoke retrofit at L5 on interior L4L5 eyebars. (Previously, eyebars 5 and 6 were rated tight). Note: Eyebar 1 is inboard, Eyebar 10 is outboard.
15.98	-	Eyebar 5, bottom edge	
16.98	42	Eyebar 6, top edge	
17.98	-	Eyebar 6, bottom edge	

Gage No.	Figure No.	Location/Details	Rationale
		West Truss Lower Chord L5L6@ L5	
18.98	-	Eyebar 4, top edge	• Assess effect of yoke retrofit at L5 on interior eyebars. (The 8 L5L6 eyebars were all previously rated tight). Note: Eyebar 1 is inboard; Eyebar 8 is outboard.
19.98	42	Eyebar 4, bottom edge	
20.98	-	Eyebar 5, top edge	
21.98	42	Eyebar 5, bottom edge	
		Vertical Posts L5U5	
		Gages on N and S faces of posts between 5th and 6th lattice pairs.	
D18	28	NE corner angle, E post	• Assess effect of yoke retrofit at L5 E & W on the vertical post stresses and bottom chord connection. • For comparison with pre-retrofit measurements.
D19	28	NW corner angle, E post	
D20	28,29	SW corner angle, E post	
D21	28,29	SE corner angle, E post	
D22	28	NW corner angle, W post	
D23	28	NE corner angle, W post	
D24	28,29	SE corner angle, W post	
D25	28,29	SW corner angle, W post	
		West Truss Lower Chord L8L9@ L9	
22.98	43	Eyebar 3, top edge	• Assess effect of pin lubrication at end panel point on eyebar bending. (Previously, the four L8L9 eyebars were rated tight) Note: Eyebar 1 is inboard; Eyebar 4 is outboard.
23.98	-	Eyebar 3, bottom edge	
24.98	43	Eyebar 2, top edge	
25.98	-	Eyebar 2, bottom edge	
		West Vertical Post L9U9	
27.98	44, 44a	SW corner on S face, between 4th and 5th lattice pair	Assess behavior of end panel post.
26.98	44, 44a	NW corner at same elevation as 27.98, but lattice geometry is different.	

Span 1. On the 192' - 0" long (c-c end bearings) northernmost deck-truss span, 8 strain gages were initially mounted during the period from September 25 to October 1, 1997, for monitoring in November 1997. All the gages were on the lower chord eyebars L8L9 (4 eyebars per truss @ 10" x 1-1/4") on the west truss near panel point L9 at the abutment. Their general location is shown in Figure 45, and Table 6 gives the gage locations, their rationale, and figure numbers depicting the gages.

Subsequently, as for Span 2, additional gages were installed in the period from December 17 to 19, 1997, to enable further information to be obtained in January 1998. Three additional gages (with prefix D) were installed at Floorbeam 8 at the west truss. Their general location and details are also given in Figure 45 and Table 6.

Although Span 1 did not receive the retrofits accorded to Span 2, the lower chord pin at the Span 1 west truss end panel L9-W was lubricated by Amtrak personnel at about the same time as retrofits were occurring in Span 2. Because of this maintenance, all Span 1 gages were monitored again in August 1998 in order to determine the benefit of the lubrication.

Table 6. Gage Locations and Rationale for Span 1

Gage No.	Figure No.	Location / Details	Rationale
		West Truss Chord L8L9 @ L9	
100	46	Eyebar 4 (outboard), top edge	• To examine chord tension, possibility of bending, and variability among bars. • Eyebars 3 and 4 were rated "tight," Eyebars 1 and 2 were rated "moderate." • Section loss at eyebars had reduced normal Cooper E rating from E-52 as-built to E-29 as-inspected. • In July/August 1998, to assess effect of pin lubrication on eyebar bending. • #101 also used in January 1998 for reference with earlier measurements.
101	46	Eyebar 3, top edge	
102	46	Eyebar 2, top edge	
103	46	Eyebar 1 (inboard), top edge	
104	46	Eyebar 4, bottom edge, below #100	
105	46	Eyebar 3, bottom edge, below #101	
106	46	Eyebar 2, bottom edge, below #102	
107	46	Eyebar 1, bottom edge, below #103	
		Gages for January Measurements	
		Floorbeam 8, West truss	
D26	47, 48, 49	On bottom flange of top chord at ℄ of FB. Gage transverse to chord.	• To examine strain pattern in region where cracked angle exists on N side of FB 8, and to examine top chord/FB interaction. • In July/August 1998, to assess effect of pin lubrication at L9 on top chord / FB stresses.
D27	47, 49	S side of FB on flange angle projection. Transverse to flange.	
D28	47, 49	Adjacent to D27, but vertical on fill plate next to FB flange.	

Instrumentation Details

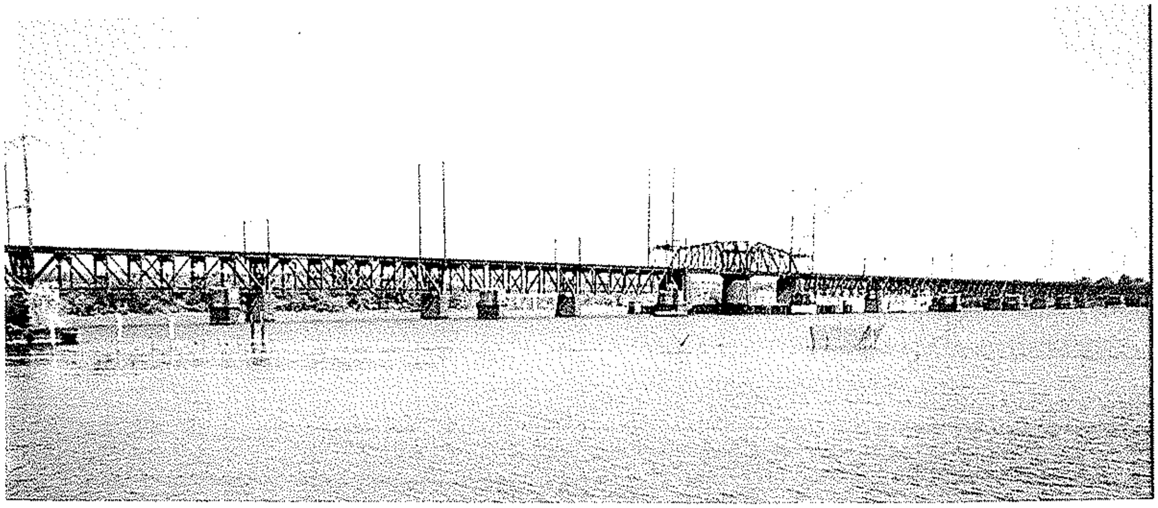
The strain gages used in the measurements were a standard product of the Micro-Measurements Division of Vishay Measurements Group, Inc. The gage designation was CAE-06-W250A-350, representing a general purpose, uniaxial, weldable gage with 350-ohm resistance, and an 0.25-inch gage length. These gages are temperature compensated for use on structural steel. The displacement gages were commercial linear potentiometers with a 1- ½ -inch-stroke capability.

According to availability of each system and the number of channels to be recorded in each span, three different data acquisition systems were used. In no case, however, was the quality of the measurements sacrificed by the choice of instrumentation. Measurements from both passenger and freight-train traffic were made at each location. Data for Spans 7, 9, and 10 were recorded on October 20 and 23 and November 12-13, 1997. Data for Spans 1 and 2 were recorded on November 13-14, 1997, and later on January 8 and 9, July 17 and August 12, 1998. Conrail heavy-axle (286,000 lb.) coal cars were not specifically included during the 1998 measurements.

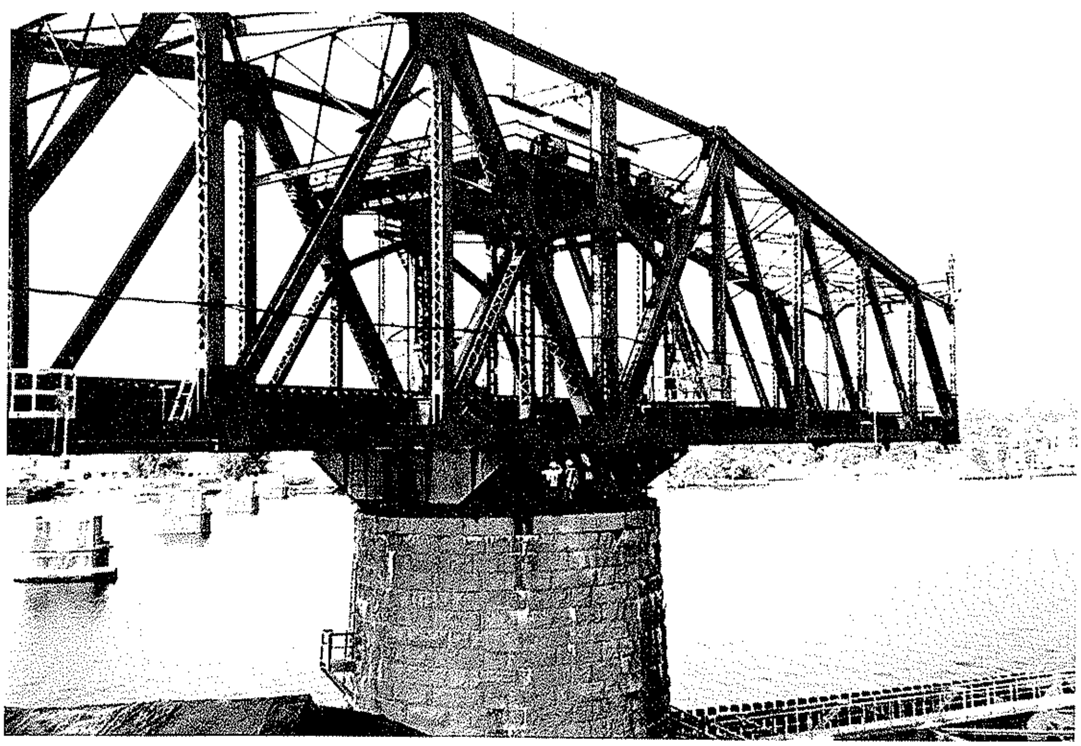
Although data were recorded simultaneously at Spans 7,9, and 10, separate recording systems were used. At all sites, strain gage conditioning was provided by Vishay Model 2100 Signal Conditioning Systems. At Span 7, the conditioned analog signals were recorded on analog tape cassettes using a 21-channel Kyowa data recorder Model RTP-652A. The instrumentation for Span 7 was located on the pier between Spans 6 and 7. Spans 9 and 10 were treated as one measurement unit, with the instrumentation located in the bridge house atop the swing span. The conditioned analog signals were recorded using two 32-channel 12-bit analog to digital data acquisition boards produced by Keithley Instruments Inc. The sampling rates used were 40 samples per second per channel for coal (or freight) trains and 400 samples/sec/channel for commuter trains.

At Spans 1 and 2, when 88 channels were recorded in November 1997, two systems were used in order to accommodate the large number of gages. The same 21-channel analog Kyowa system used at Span 7 was combined with an 84-channel, 12-bit digital data acquisition/conditioning system produced by Campbell Scientific. The data were not filtered during signal conditioning, but some smoothing was done later to minimize noise. With the digital system, a laptop computer with special data reduction software was also used to look at the data in "real time." The sampling rates used with the Campbell system were 50 and 400 samples/sec/channel for coal (or freight) and commuter trains, respectively. For control, a few gages at Spans 1 and 2 were recorded simultaneously by both systems, raising the number of recorded channels to 94. The measurements made in Spans 1 and 2 in January, July and August, 1998, were made using the Campbell Scientific system. In January, 33 channels were recorded; 27 from gages installed during December 1997 and 6 from the November 1997 recordings. In July, 24 of the new gages were recorded. In August, 57 channels were recorded; 28 from gages installed during July and August and 29 from pre-existing gages. The instrumentation systems for Spans 1 and 2 were located on the ground beneath Span 2.

For visual display, the recorded data were later transcribed at ATLSS into hard-copy graphs. The data obtained with the Kyowa analog recorder was transcribed through an 8-channel strip-chart recorder. The data obtained by the digital systems were transcribed through a laptop computer and a laser printer.



a) View looking Northwest from Havre de Grace, MD



b) Span 10, the swing span, in open position

Figure 1: Amtrak's Susquehanna River Bridge

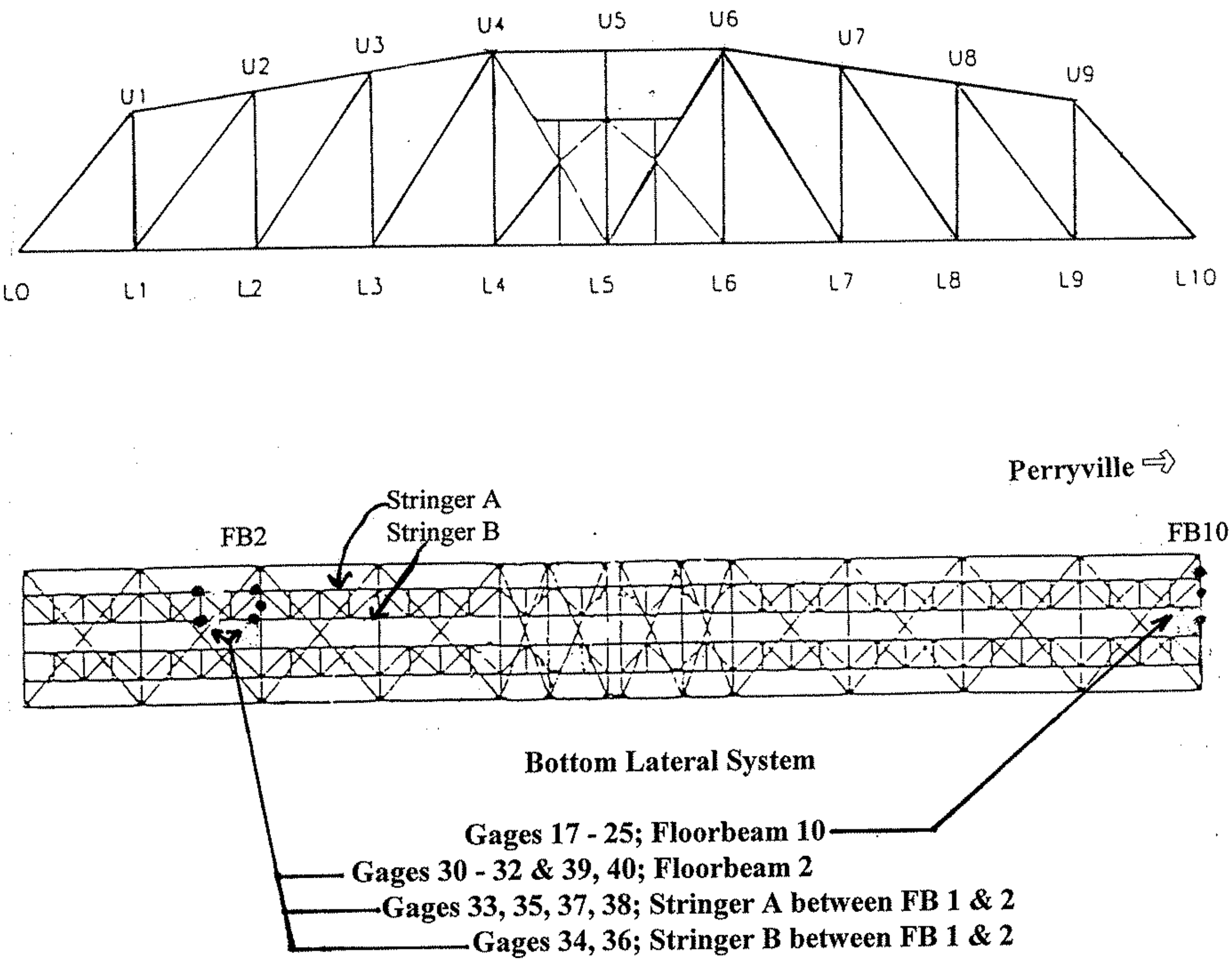
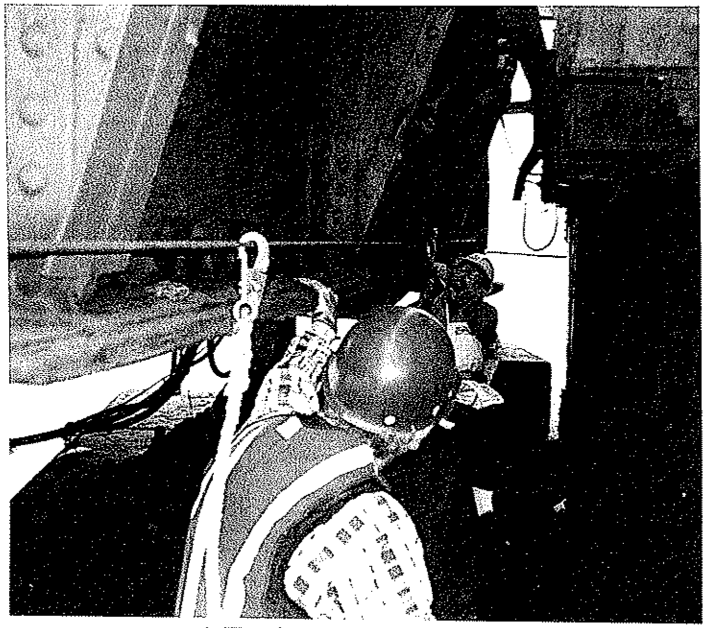
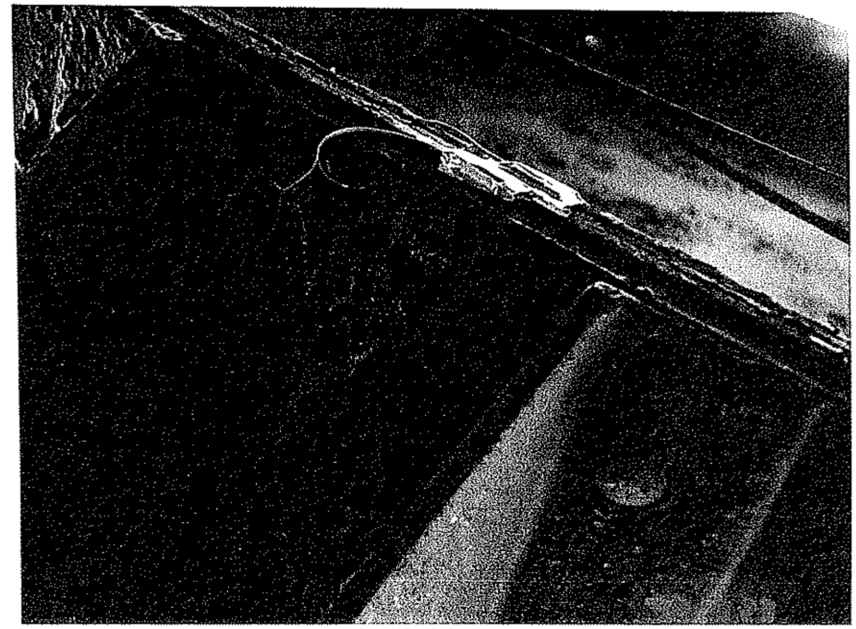


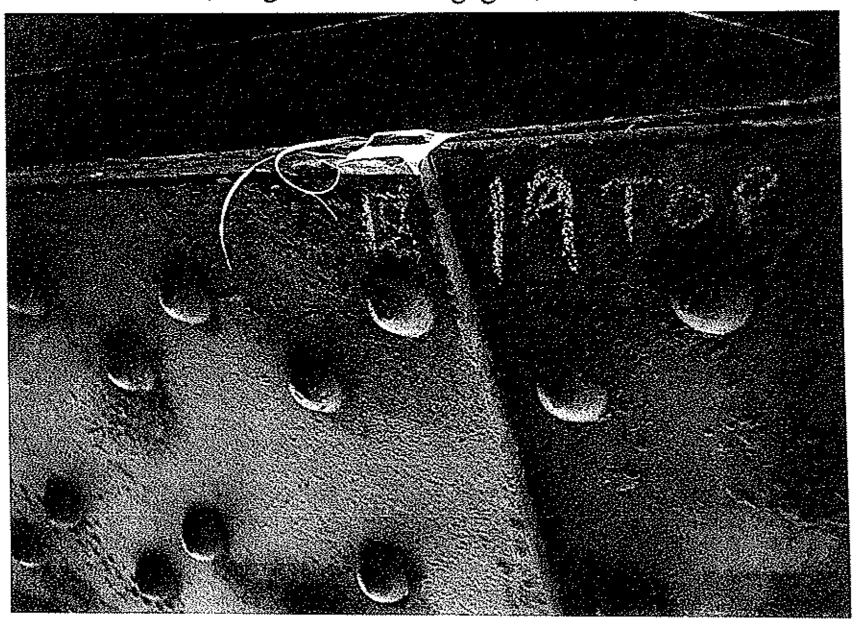
Figure 2: General Gage Locations in Through - Truss Swing Span 10



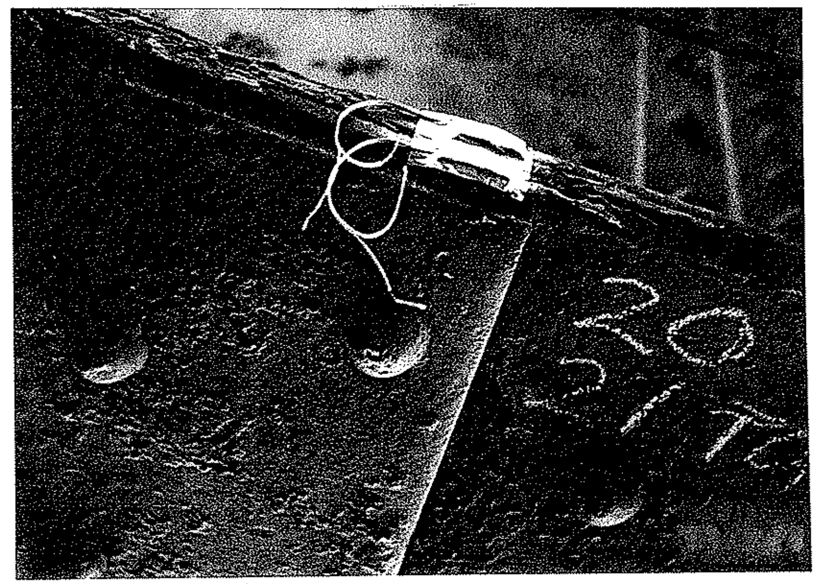
a) Engineers install gages (10/97/13-5)



b) Gages 22 & 23, North side of FB at ℄ (10/97/13-10)

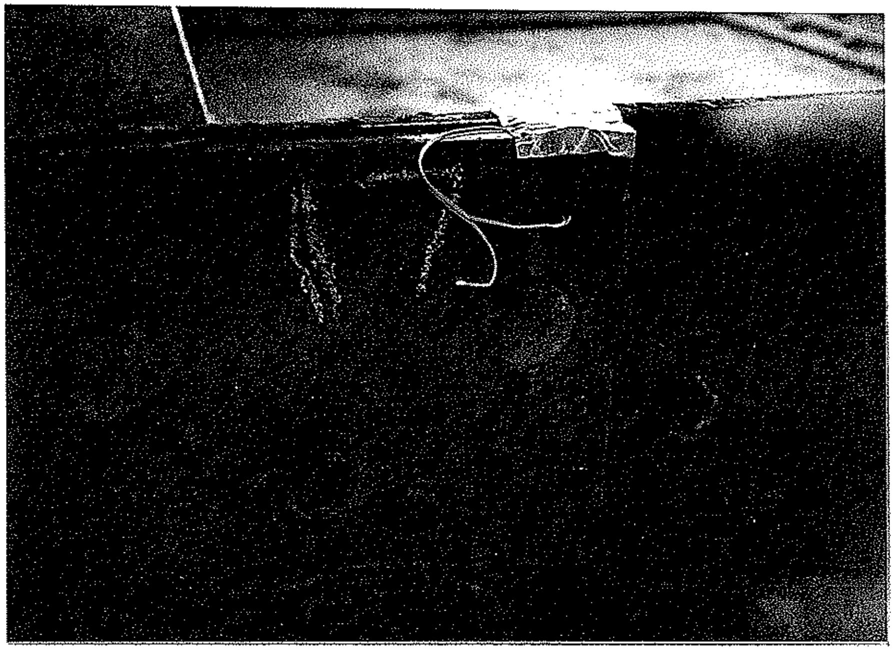


c) Gages 18 and 19, 42" W of Stringer B (10/97/13-9)

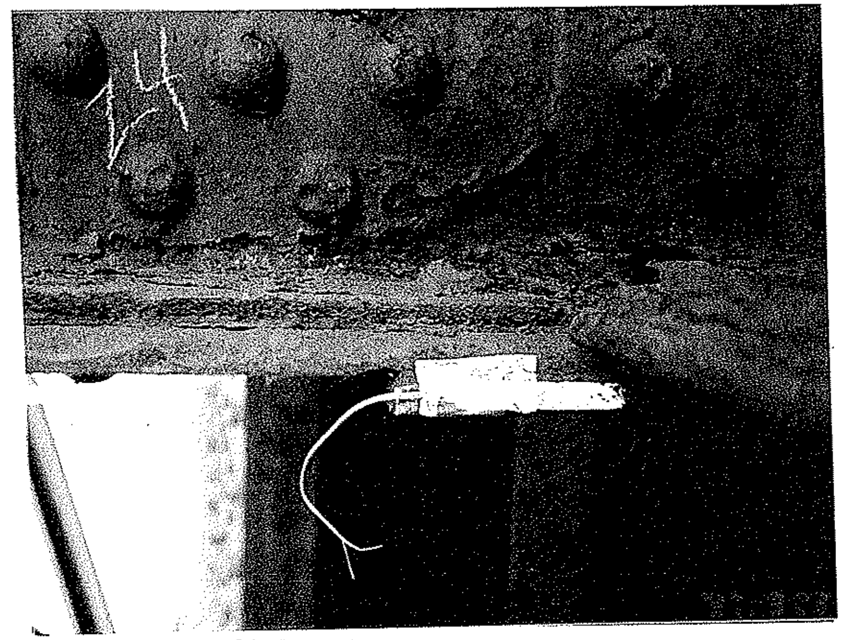


d) Gages 20 and 21, 26" W of ℄ (10/97/13-4)

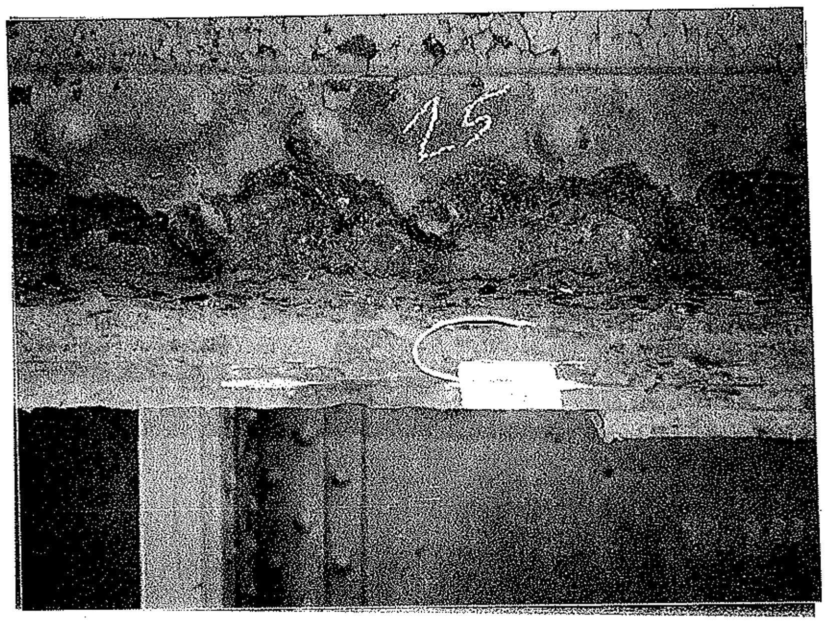
Figure 3: Span 10, North side of Floorbeam 10, Gage Installations 18 to 23



a) Gage 17, North side of FB,
2½" W of Exterior Stringer A flange tip (10/97/13-8)



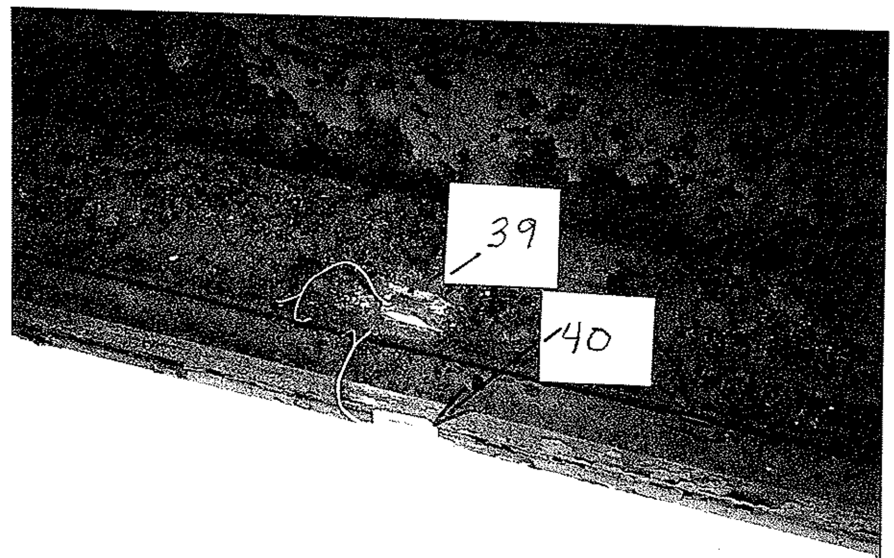
b) Gage 24, South side of FB,
2½" W of Exterior Stringer A flange tip (10/97/13-12)



c) Gage 25, South side of FB, 44" W of Interior Stringer (10/97/13-13)

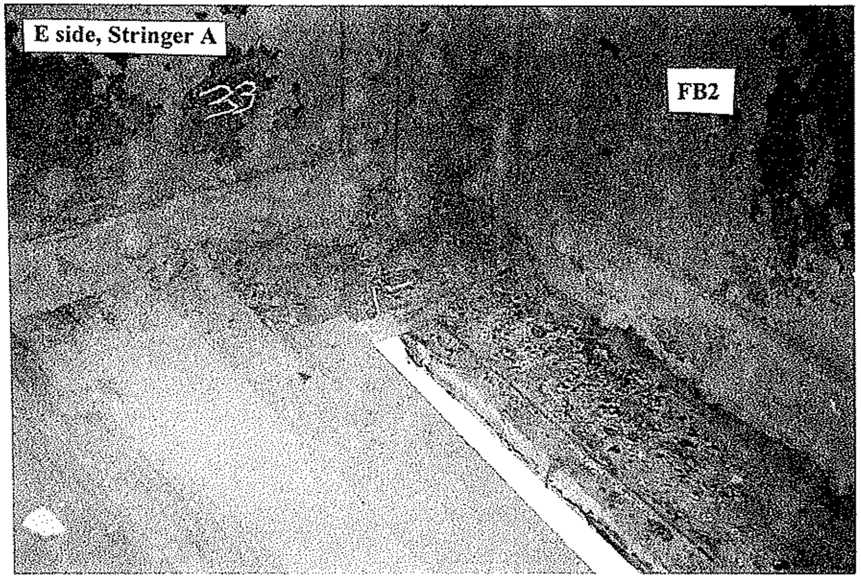
Figure 4: Span 10, Floorbeam 10, Gages 17, 24, and 25

a) Gages 30 to 32 (10/97/13-17)

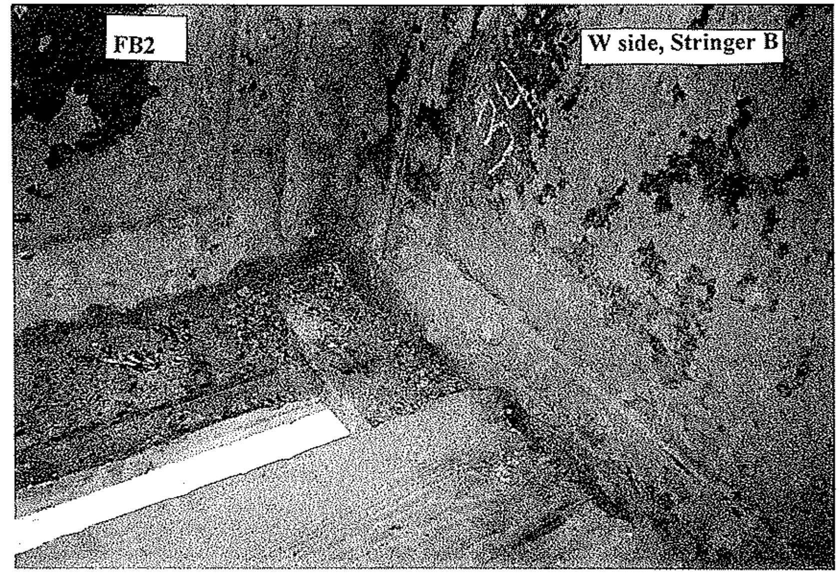


b) Gages 39 and 40 (10/97/13-15)

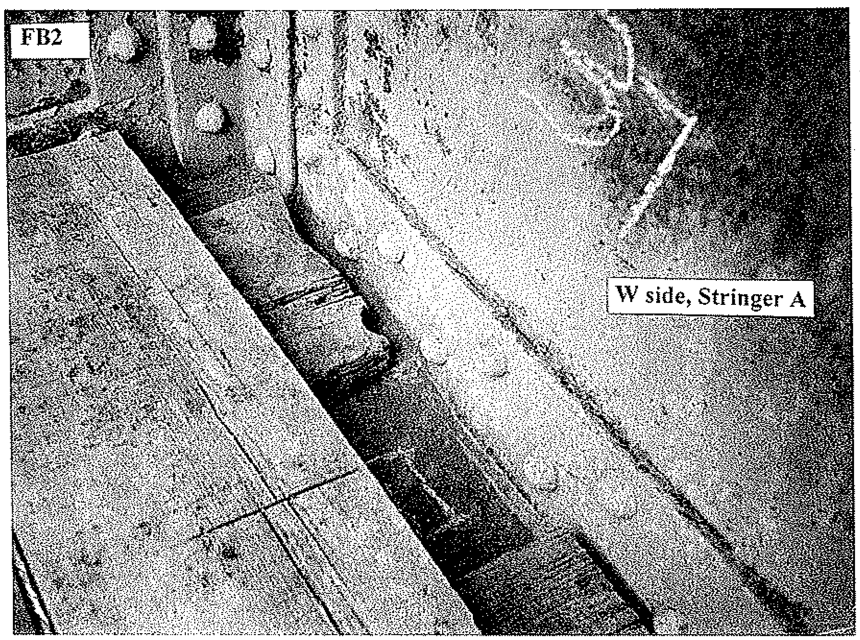
Figure 5: Span 10, Floorbeam 2, and Gage Installations 30 to 32, 39 and 40



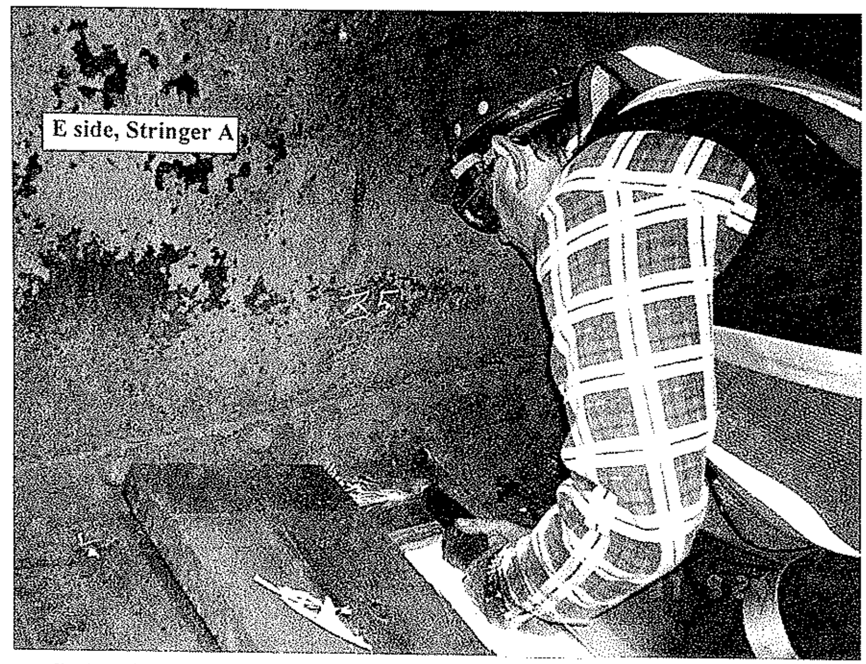
a) Gage 33, Stringer A at FB 2 (10/97/13-18)



b) Location for gage 34, Stringer B at FB 2 (10/97/13-19)



c) Location for gage 37, Stringer A near FB 2 (10/97/13-21)



d) Engineer prepares for gage 35 at Stringer A, midway between FBs (10/97/13-20)

Figure 6: Span 10, Gage Installations 33 to 37 for Stringer A & B, between Floorbeams 1 & 2

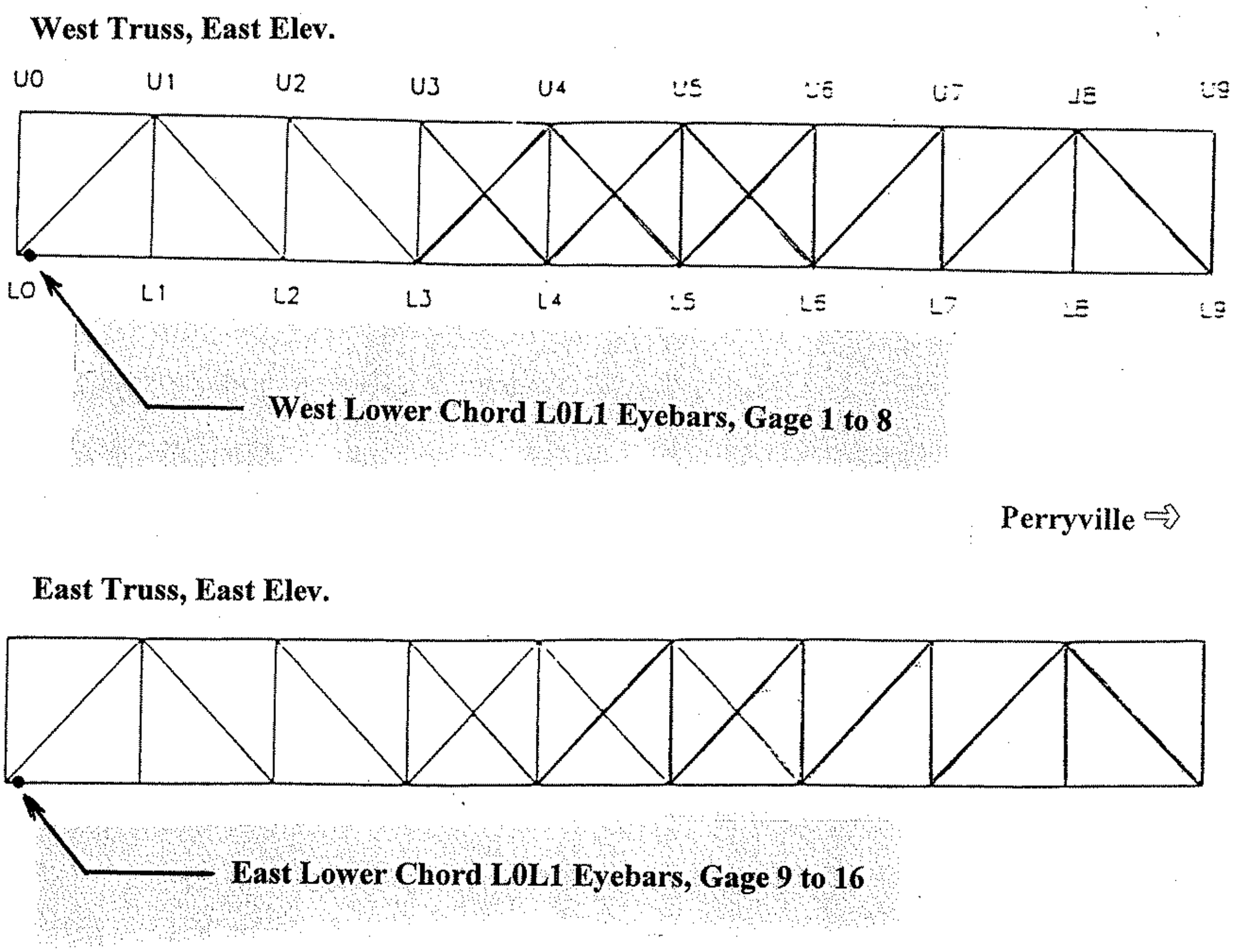
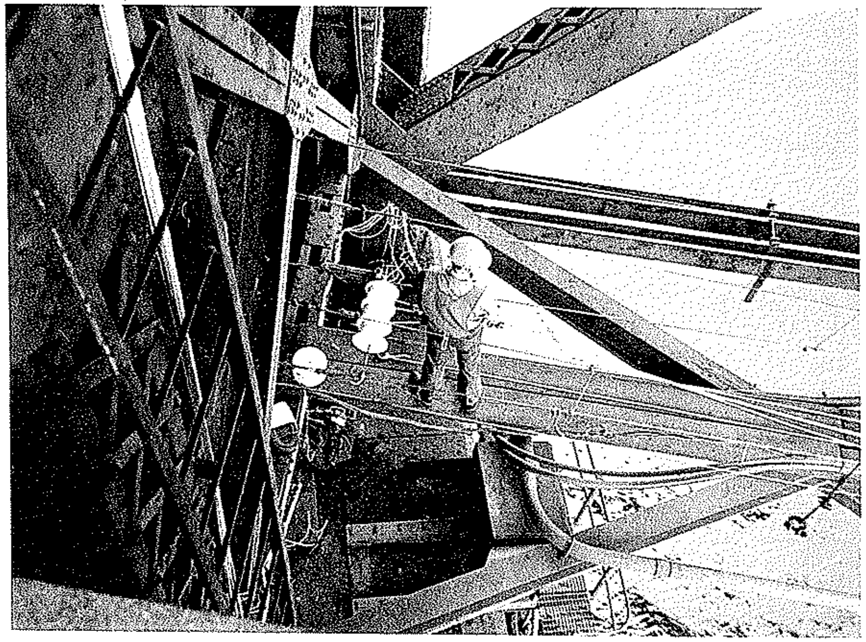
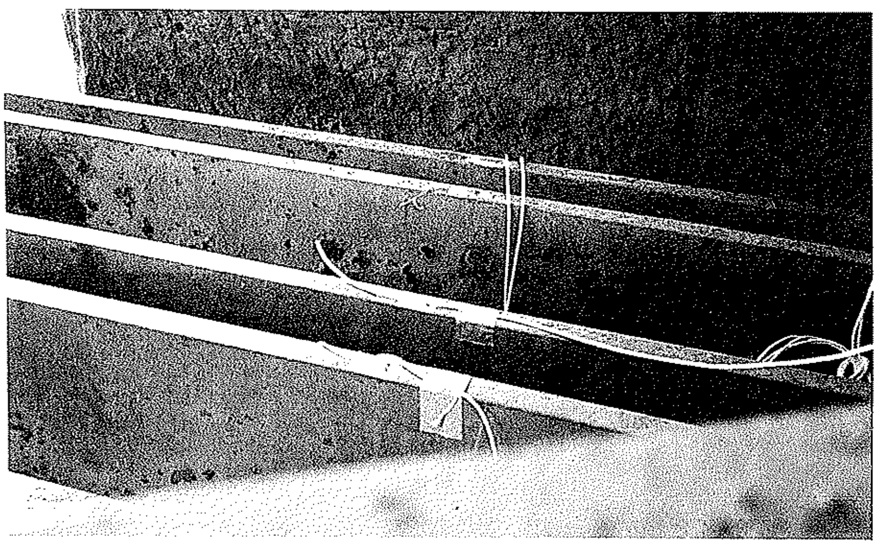


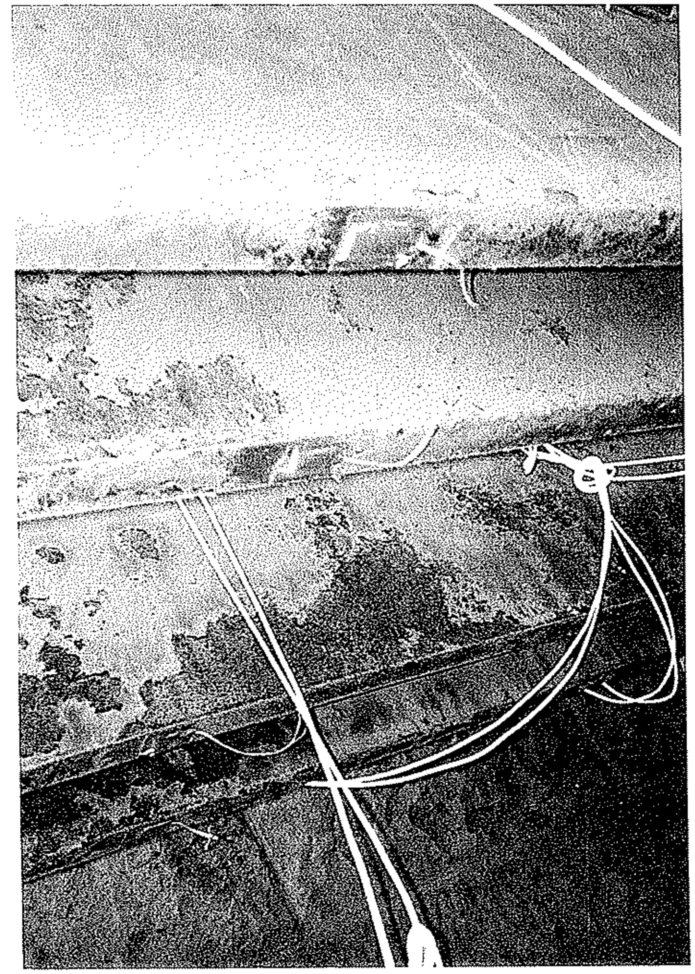
Figure 7: General Gage Locations in Deck - Truss Span 9



a) Engineers install cabling for span 9 and gages 1 - 4, West truss (10/97/13-7)



b) Gages 9 - 12, East truss (10/97/13-1)



c) Gages 13 - 16, East truss (10/97/13-2)

Figure 8: Span 9, Lower chords L0L1, Gage Installations 1 - 16

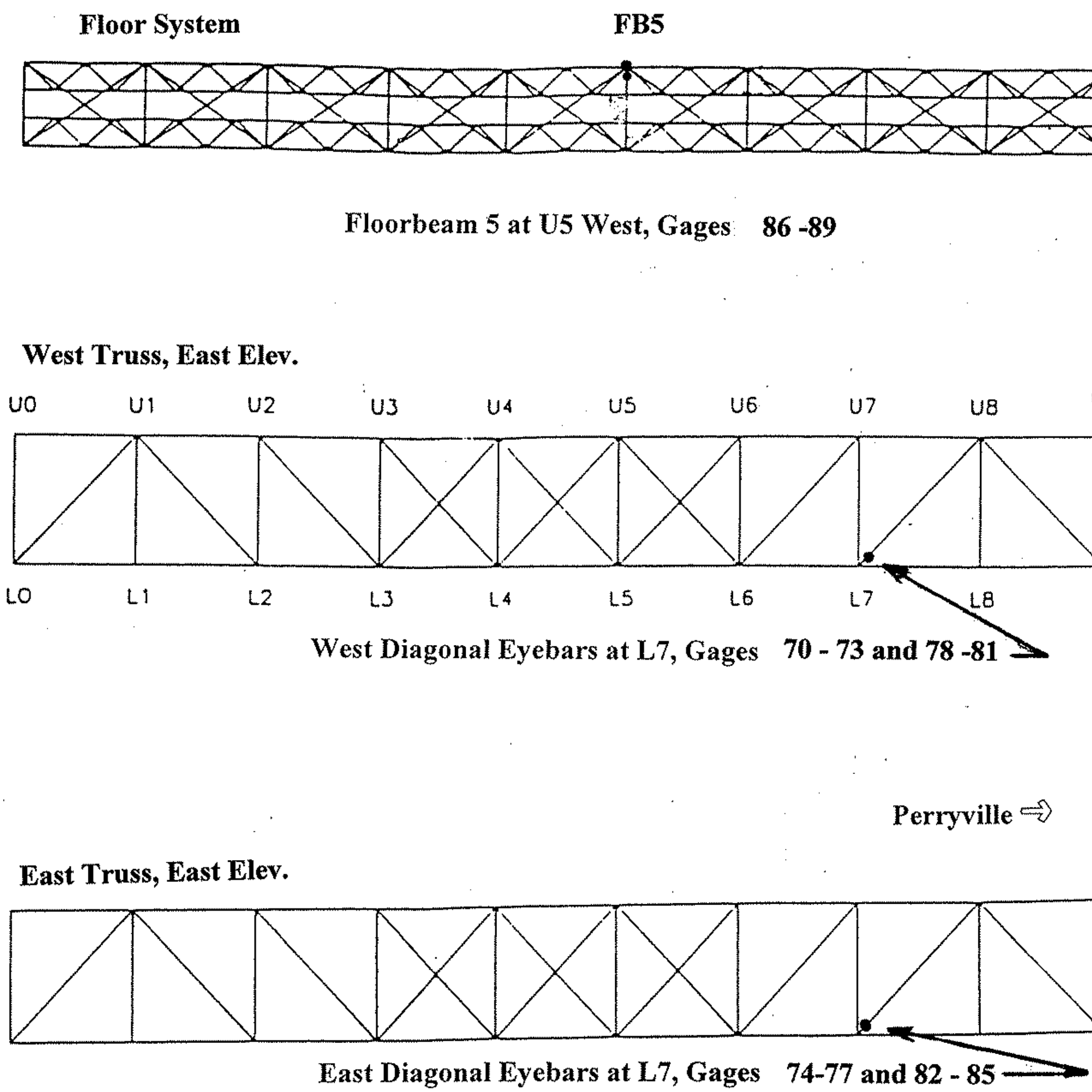
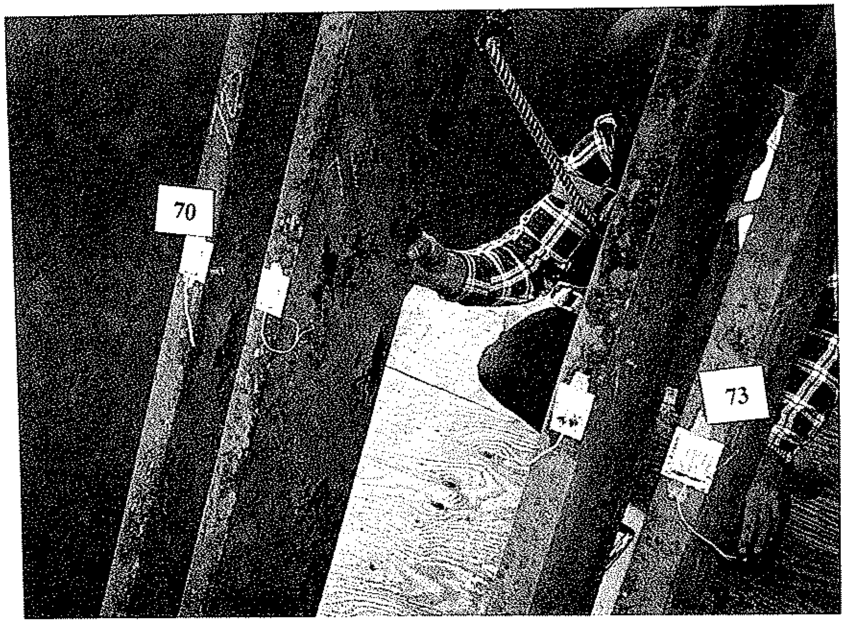
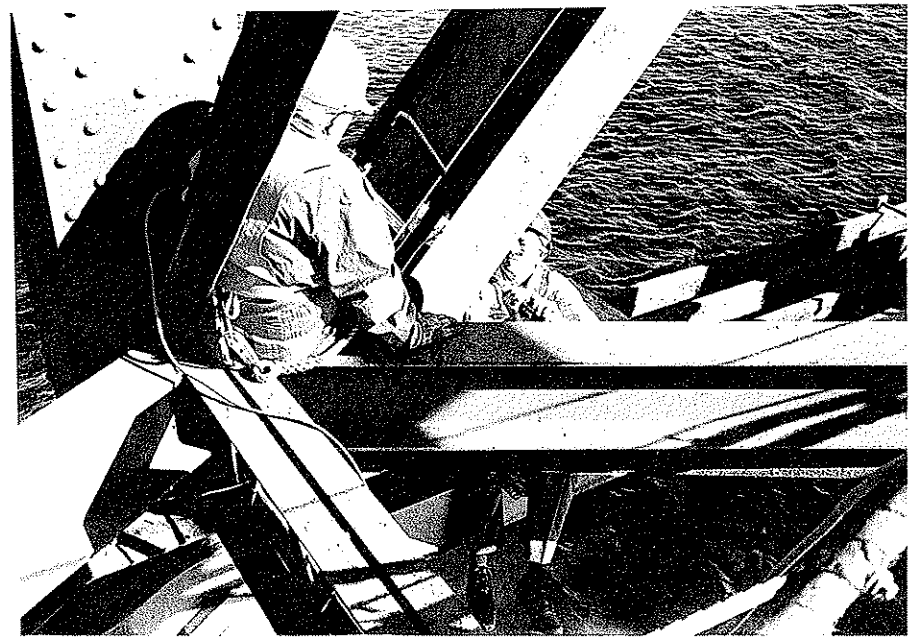


Figure 9: General Gage Locations in Deck - Truss Span 7



a) Gages 70 - 73 at L7 (10/97/14-0)


b) Installation of gages 78 - 81 (10/97/14-2)


c) Installing cabling for gages 86 - 89 (10/97/14-5)

Figure 10: Span 7, Gage Installations at Eyebars L7U8 and Floorbeam 5

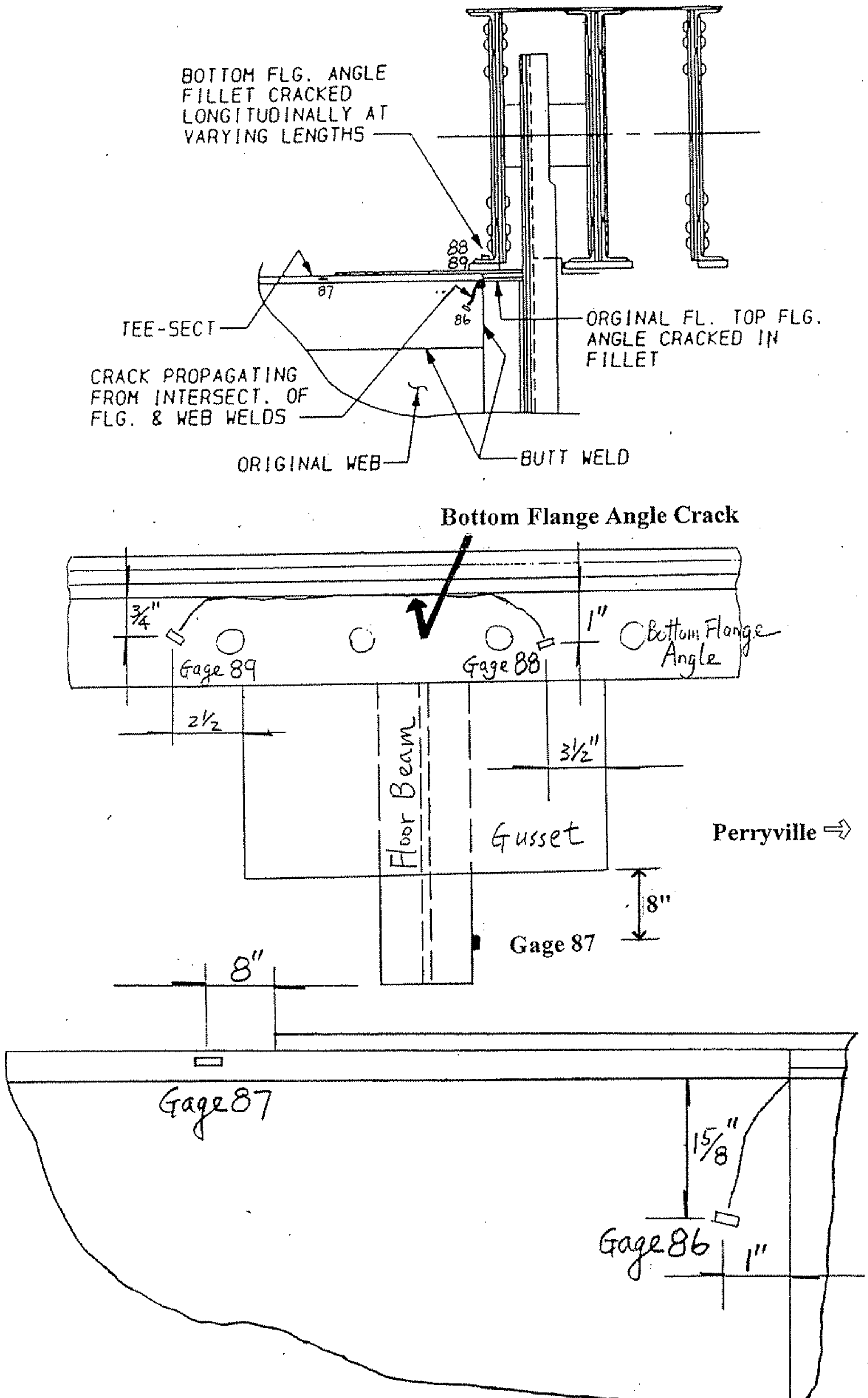


Figure 11: Span 7, Floorbeam 5, Gage Installations 86 - 89

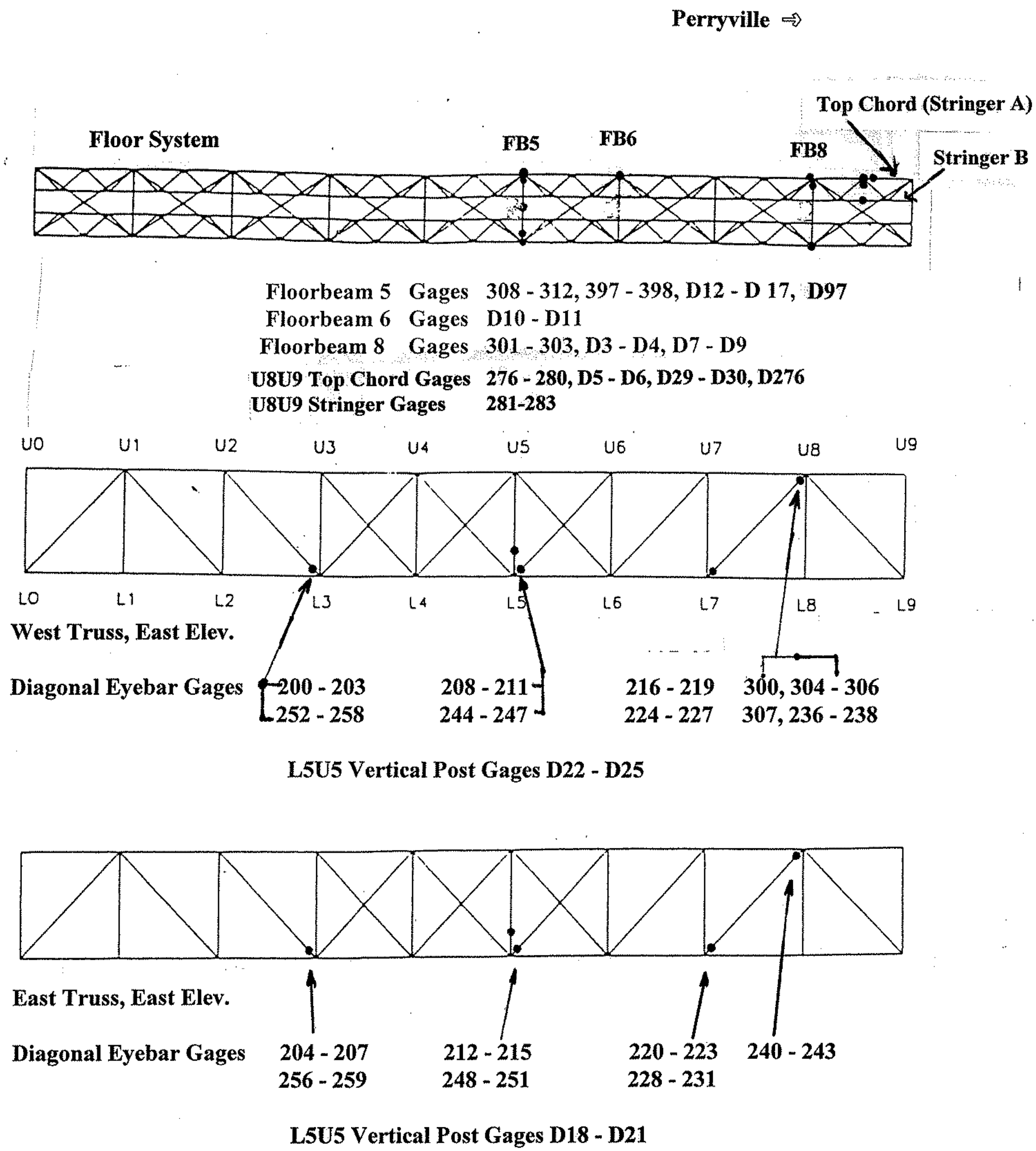
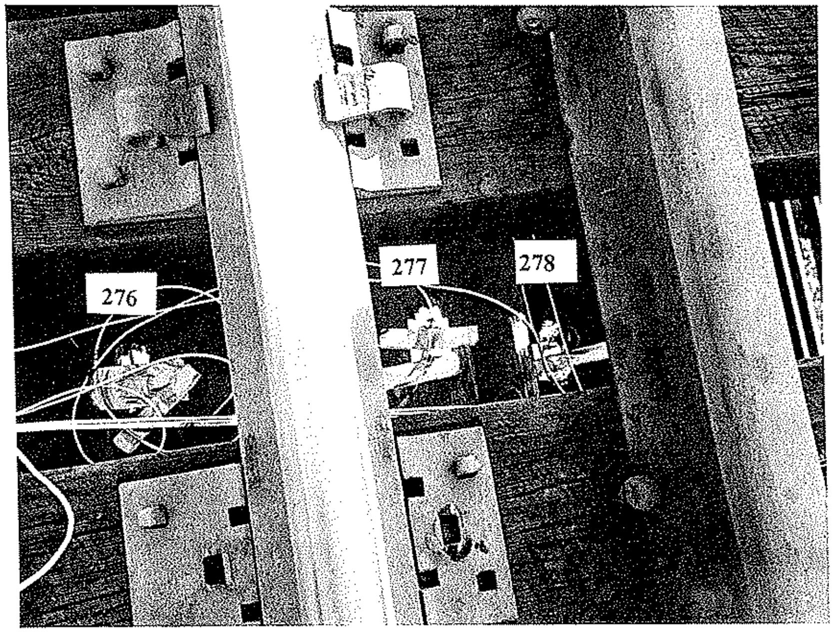
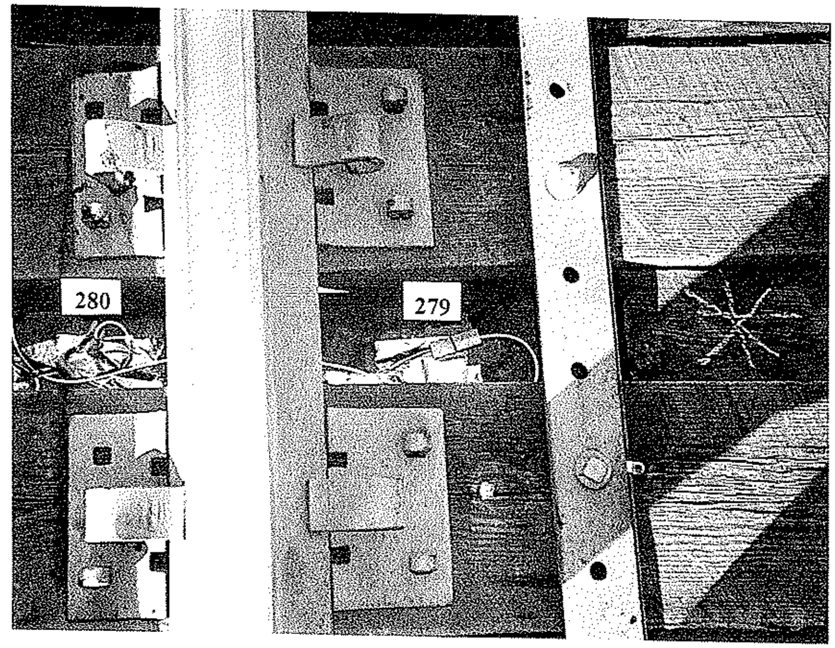


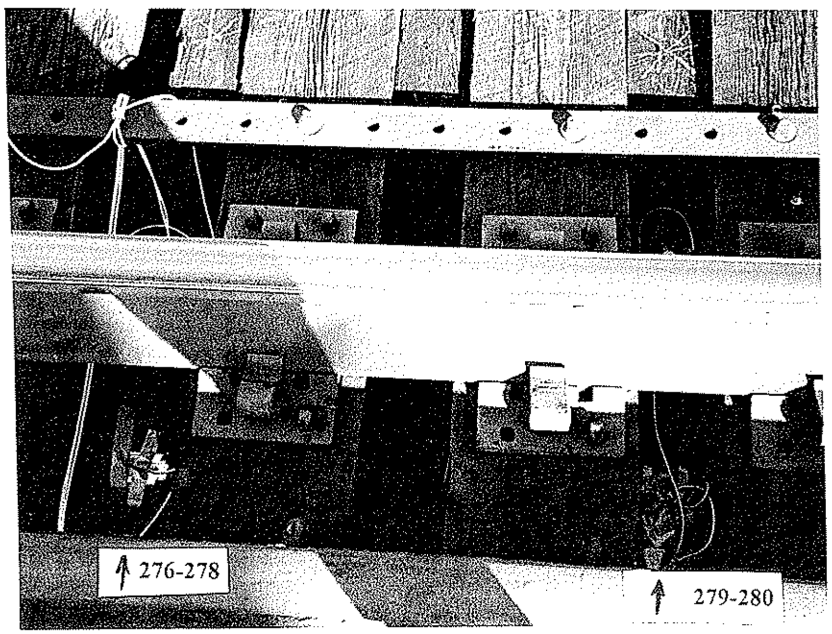
Figure 12: General Gage Locations in Deck - Truss Span 2



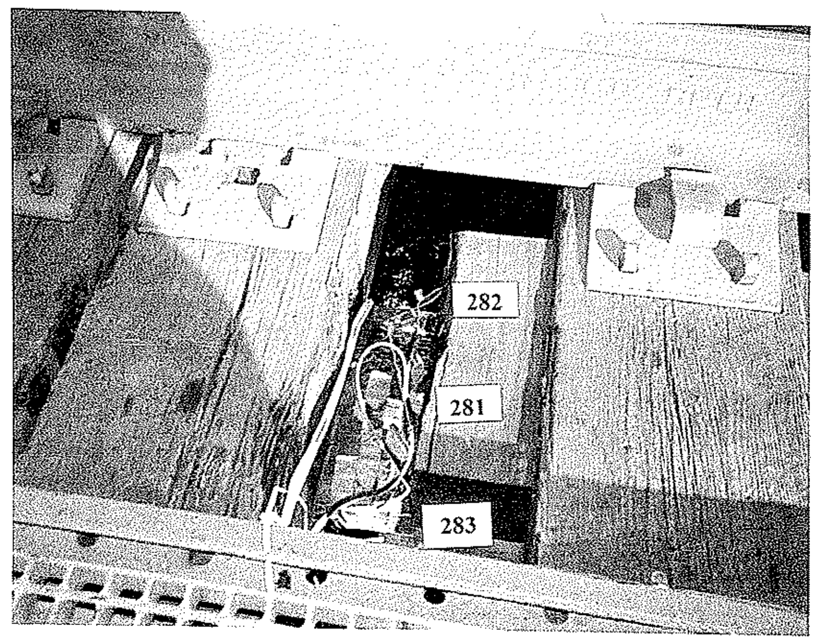
a) Gages 276 - 278 at midspan of
of Top Chord between U8 & U9 (10/97/17-13)



b) Gages 279 and 280 at 32" North
of # 276 - 278 (10/97/17-15)

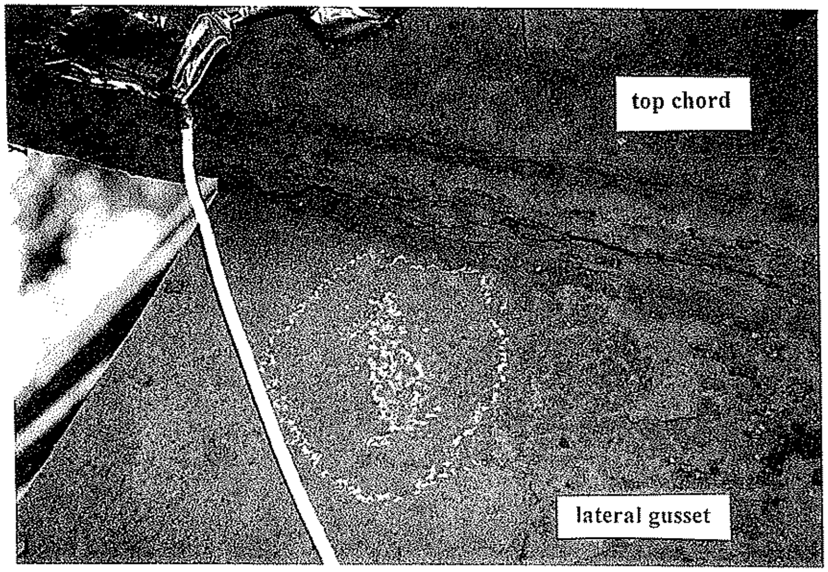


c) Gages 276 - 278 relative
to Gages 279 & 280 (10/97/17-14)

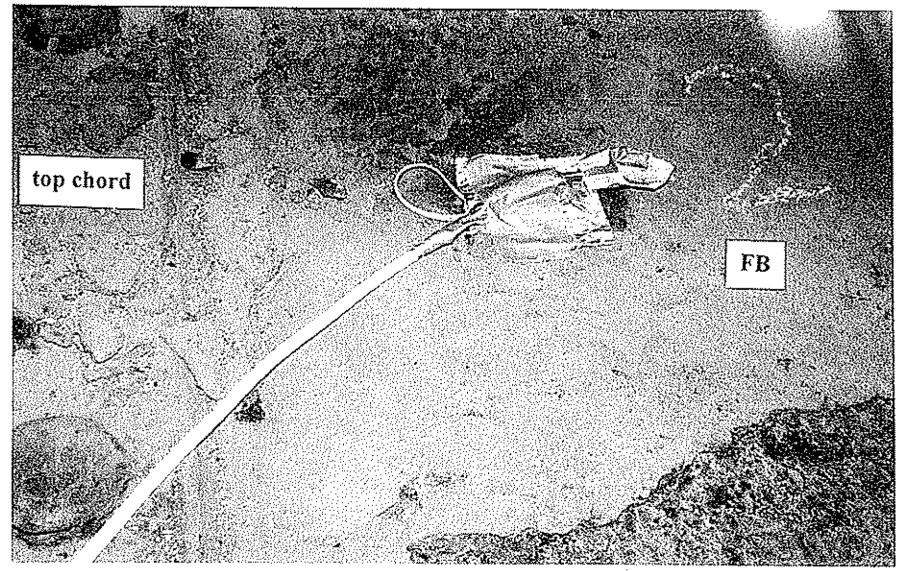


d) Gages 281 - 283 at midspan of
Stringer B between U8 & U9 (10/97/17-12)

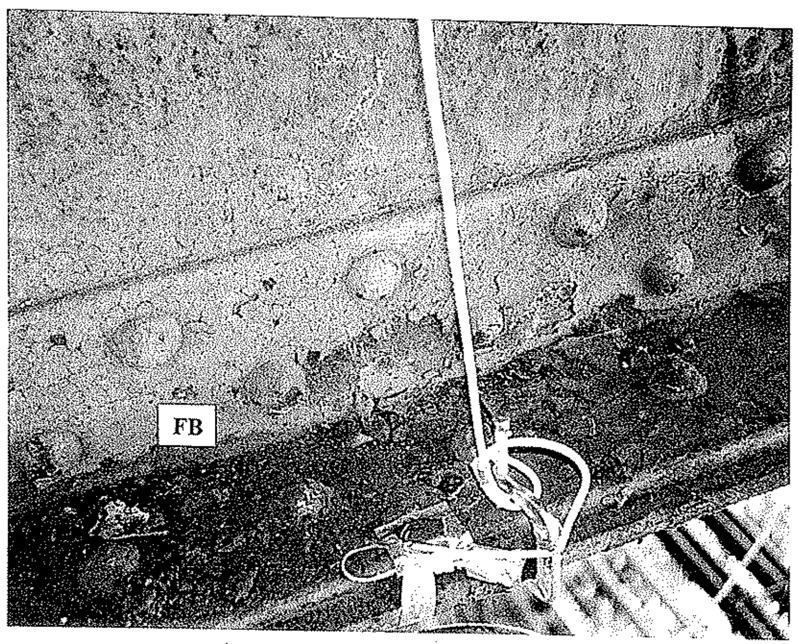
Figure 13: Span 2, Gages 276 - 283 at West Top Chord and Stringer U8U9



a) Gage 301 on top chord bottom flange
at South end of lateral gusset plate (10/97/17-7)

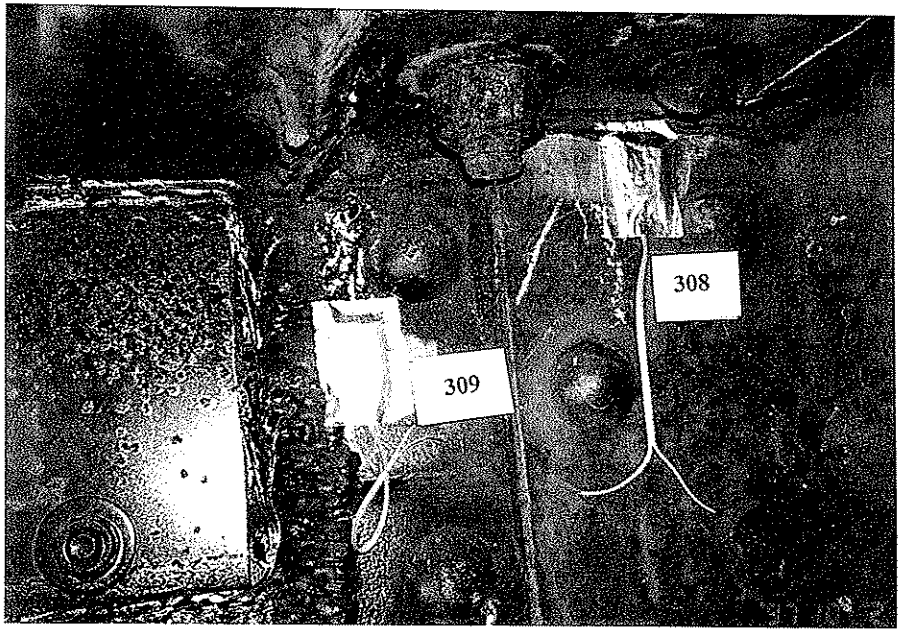


b) Gage 302 on top flange of FB at flange ℄.
West top chord bottom flange at left (10/97/17-8)

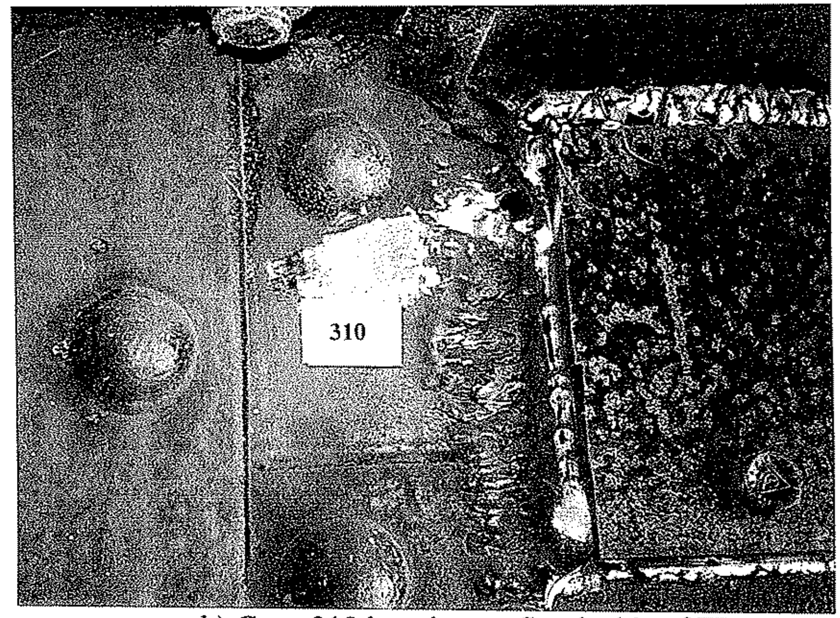


c) Gage 303 on South bottom flange of FB
on same cross section as #302 (10/97/17/-5)

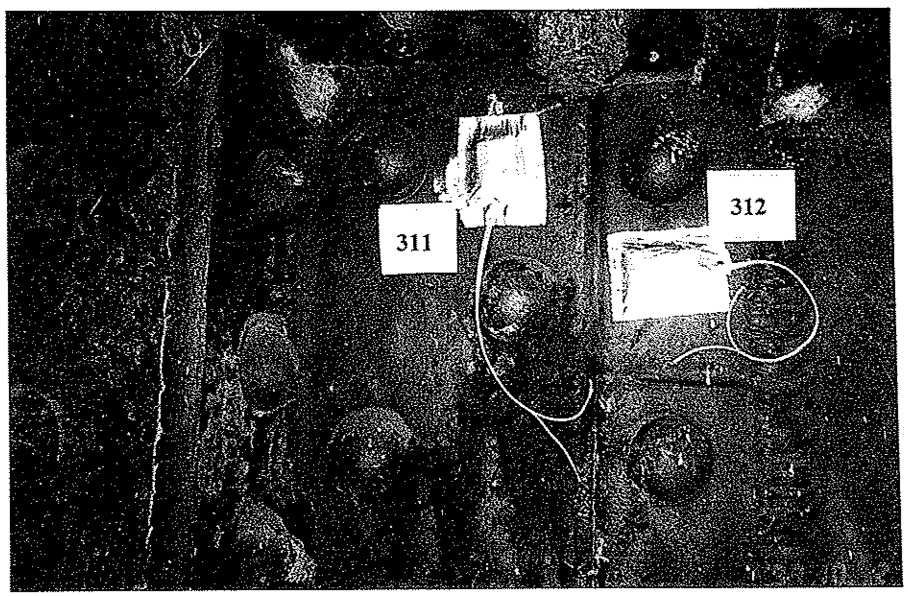
Figure 14: Span 2, Gages 301 - 303 at Floorbeam 8 and West Top Chord



a) Gages 308 & 309 on North side of FB
at West top chord (10/97/16-7)

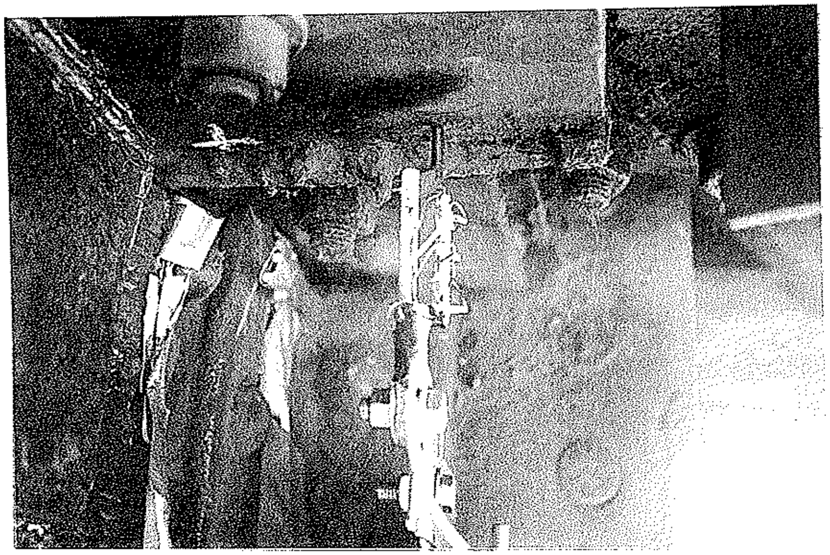


b) Gage 310 location on South side of FB
near crack arrest hole, at West top chord, (10/97/16-8)

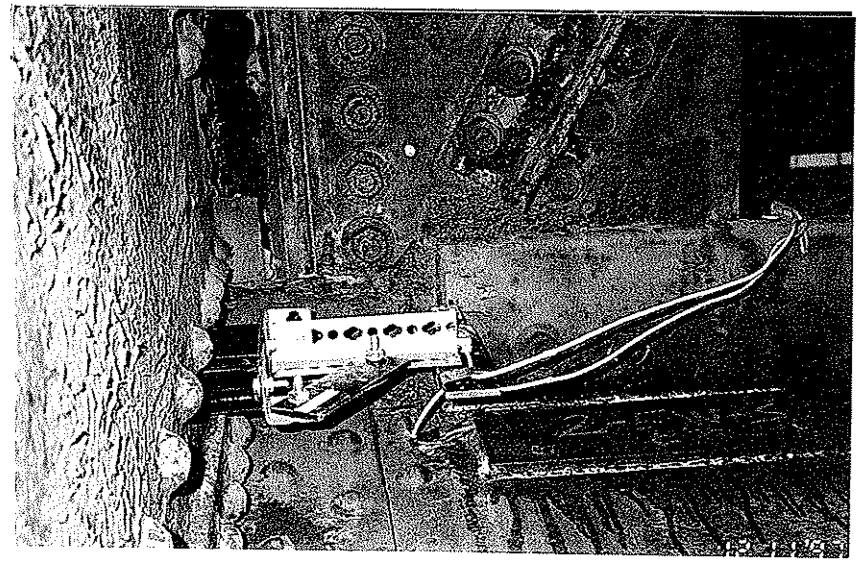


c) Gages 311 & 312 on North side of FB
at East top chord (10/97/16-10)

Figure 15: Span 2, Gages 308 - 312 at Floorbeam 5 and East & West Top Chords

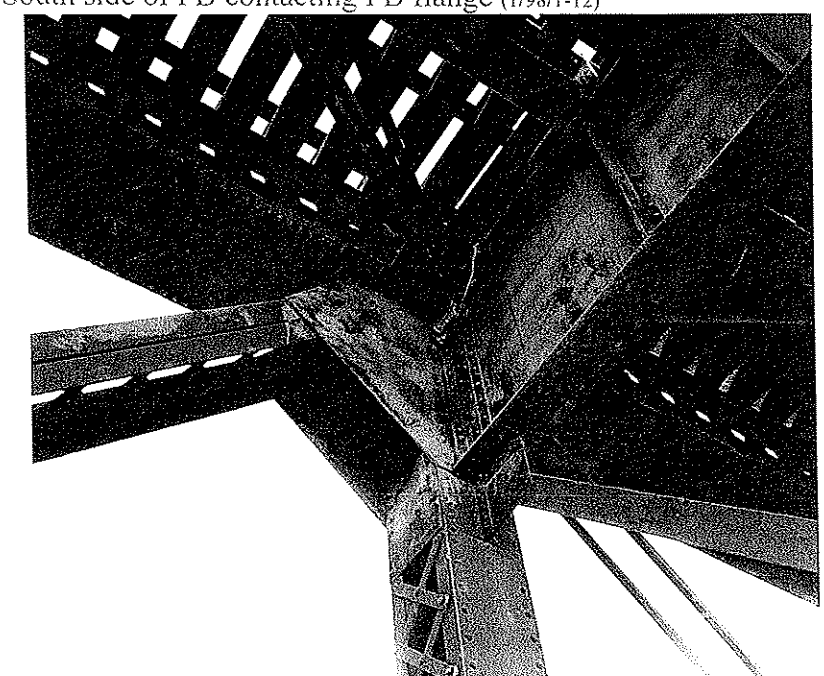


a) Gage 397 on North side of FB contacting FB flange (10/97/18-5)



c) Lookin upward at Gage 398 on South side of FB contacting FB flange (1/98/1-12)

b) Gage 397 shown mounted on fill plate on vertical post (12/97/16-8)



d) Gage 398 shown mounted on gusset plate for vertical post and diagonal strut (12/97/16-7)

Figure 16: Span 2. Displacement Gages 397 and 398 at Floorbeam 5 and West Top Chord

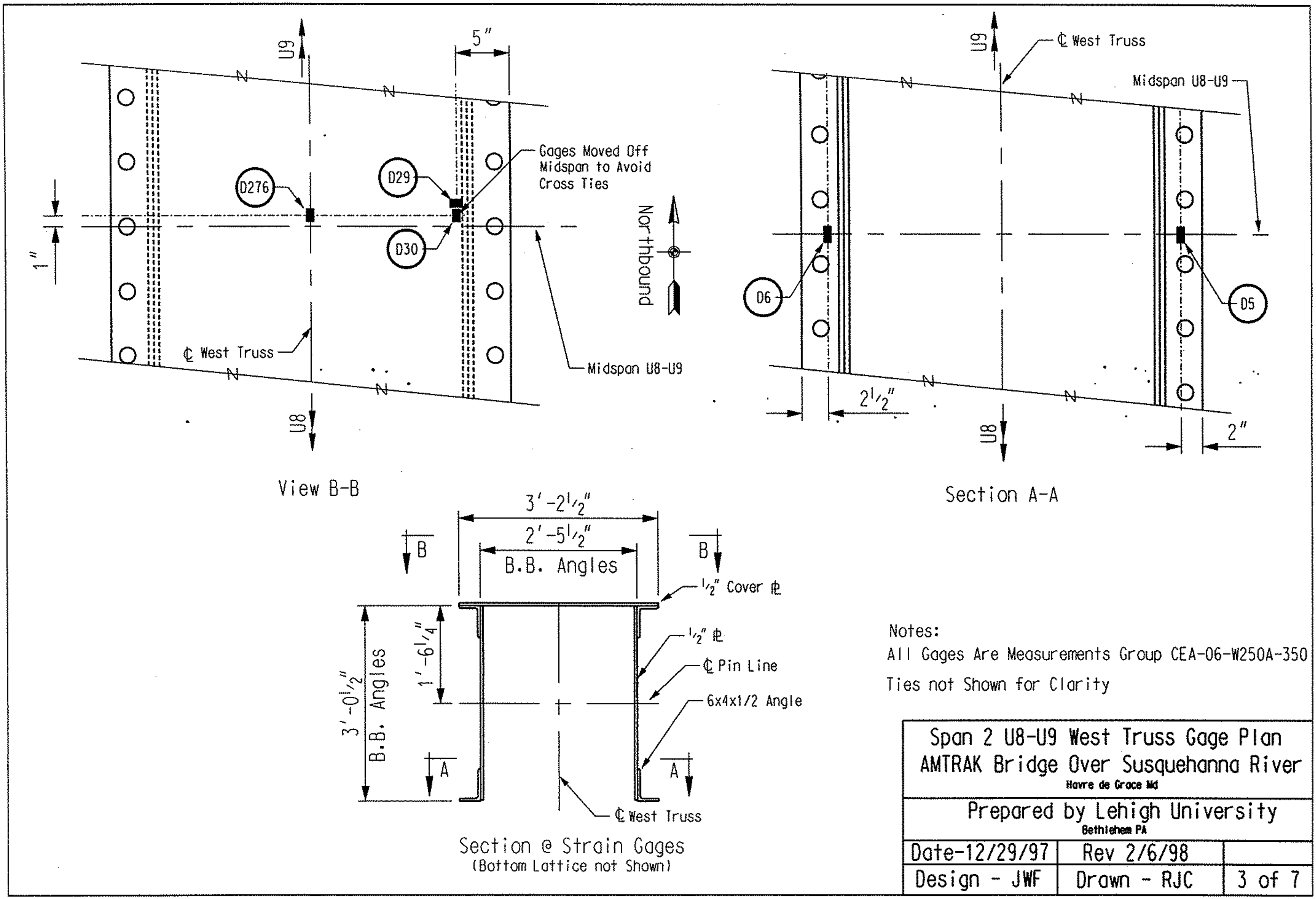
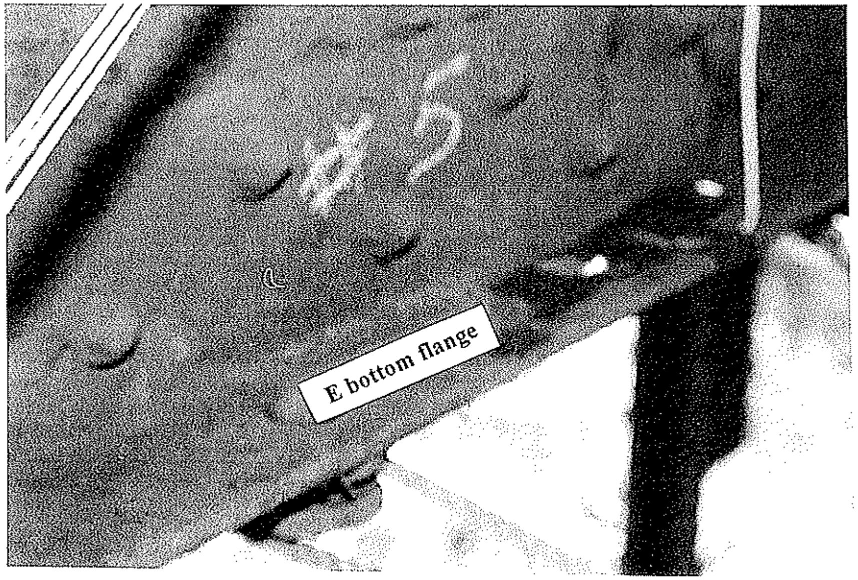
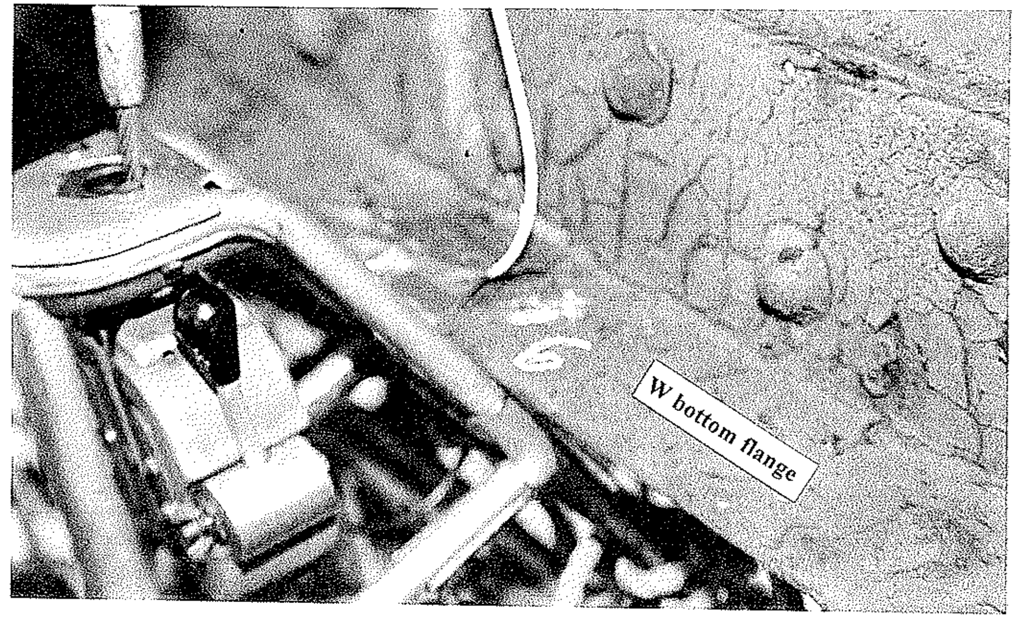


Figure 17 Span 2; December Gage Installations at Top Chord U8U9

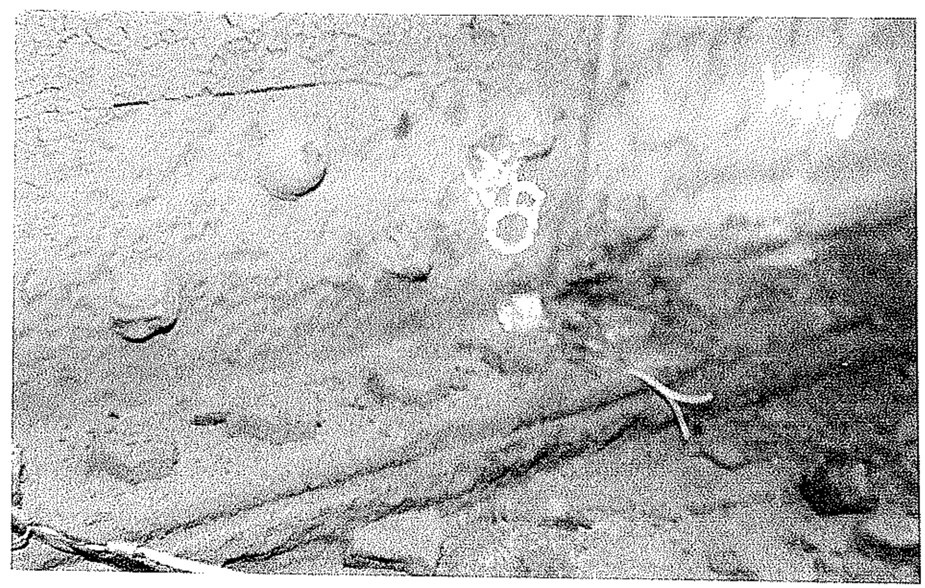


a) Gage D5 at midspan of U8U9 (1/98/8-1)



b) Gage D6 at midspan of U8U9 (1/98/8-3)

c) Gage D7 on top chord flange **near FB ℄** (1/98/8-6)



d) Gage D8 on top chord flange near edge of pin gusset plate (1/98/8-5)

Figure 18: Span 2, West Top Chord U8U9, Gages D5 & D6, and Floorbeam 8, Gages D7 & D8

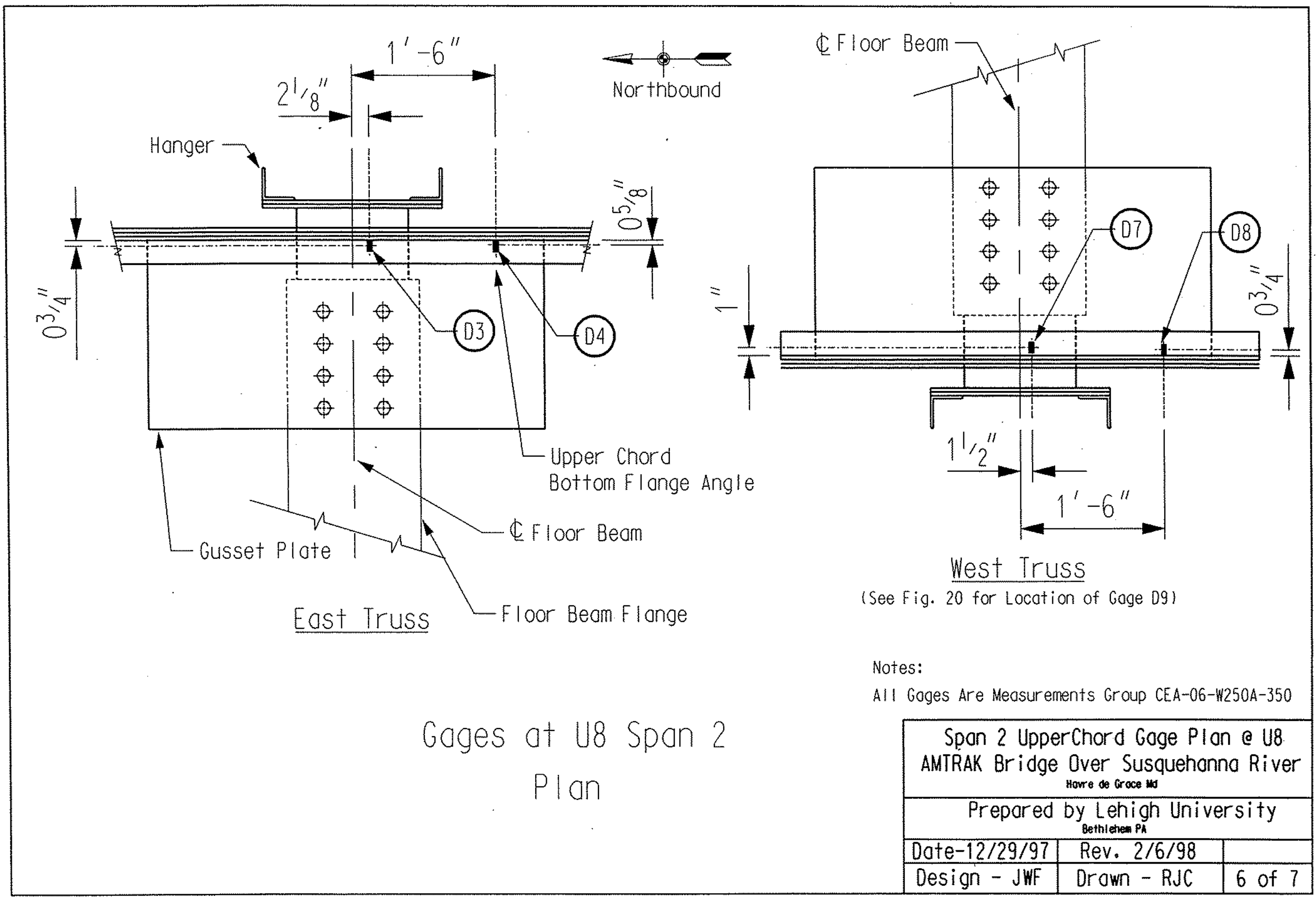
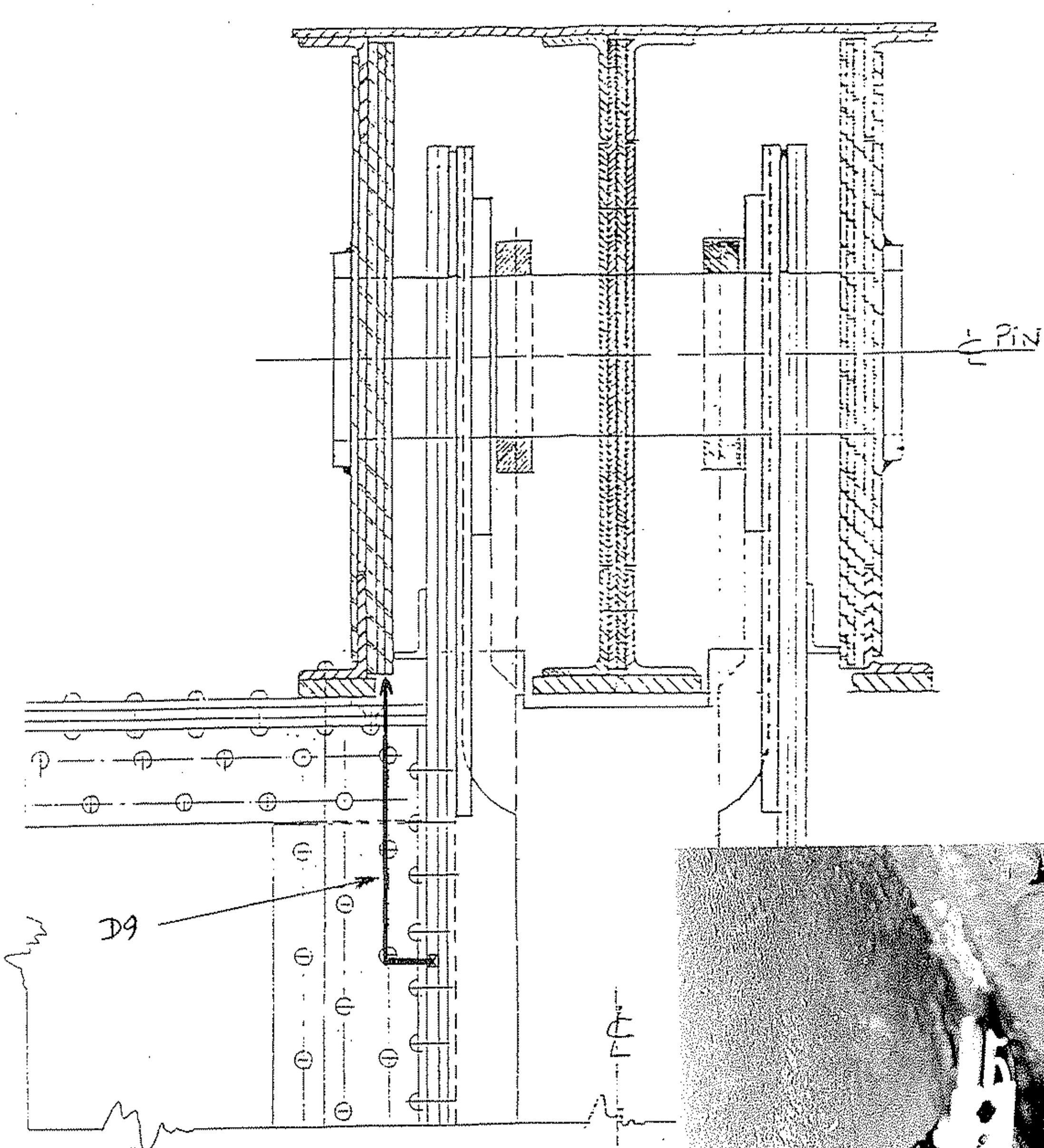
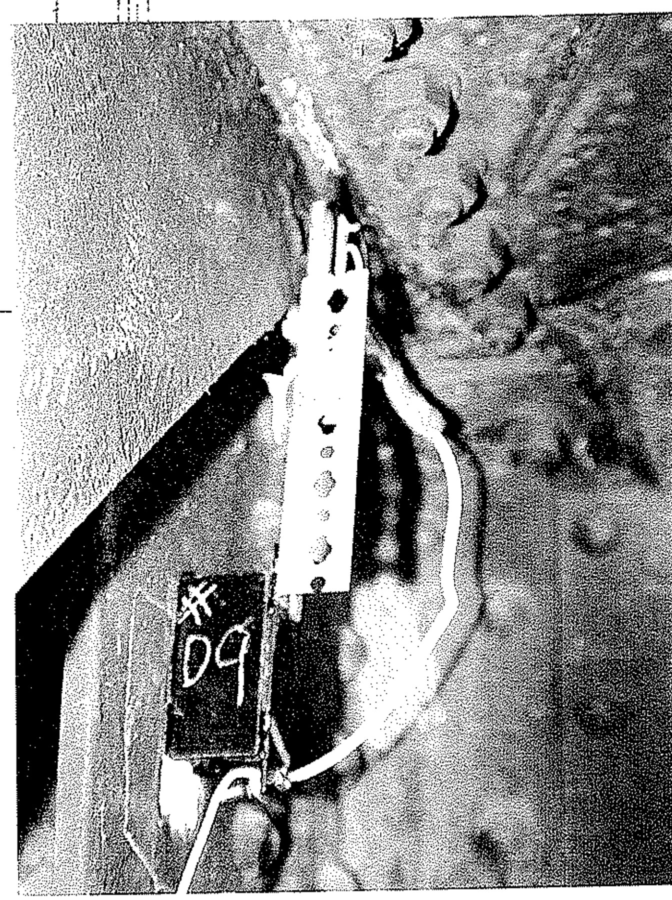


Fig. 19. Span 2; December Gage Installations at Floorbeam 8





Gage at South Side of FB8 West (1/98/8-7)

Figure 20: Span 2, December Displacement, Gage Installation D9

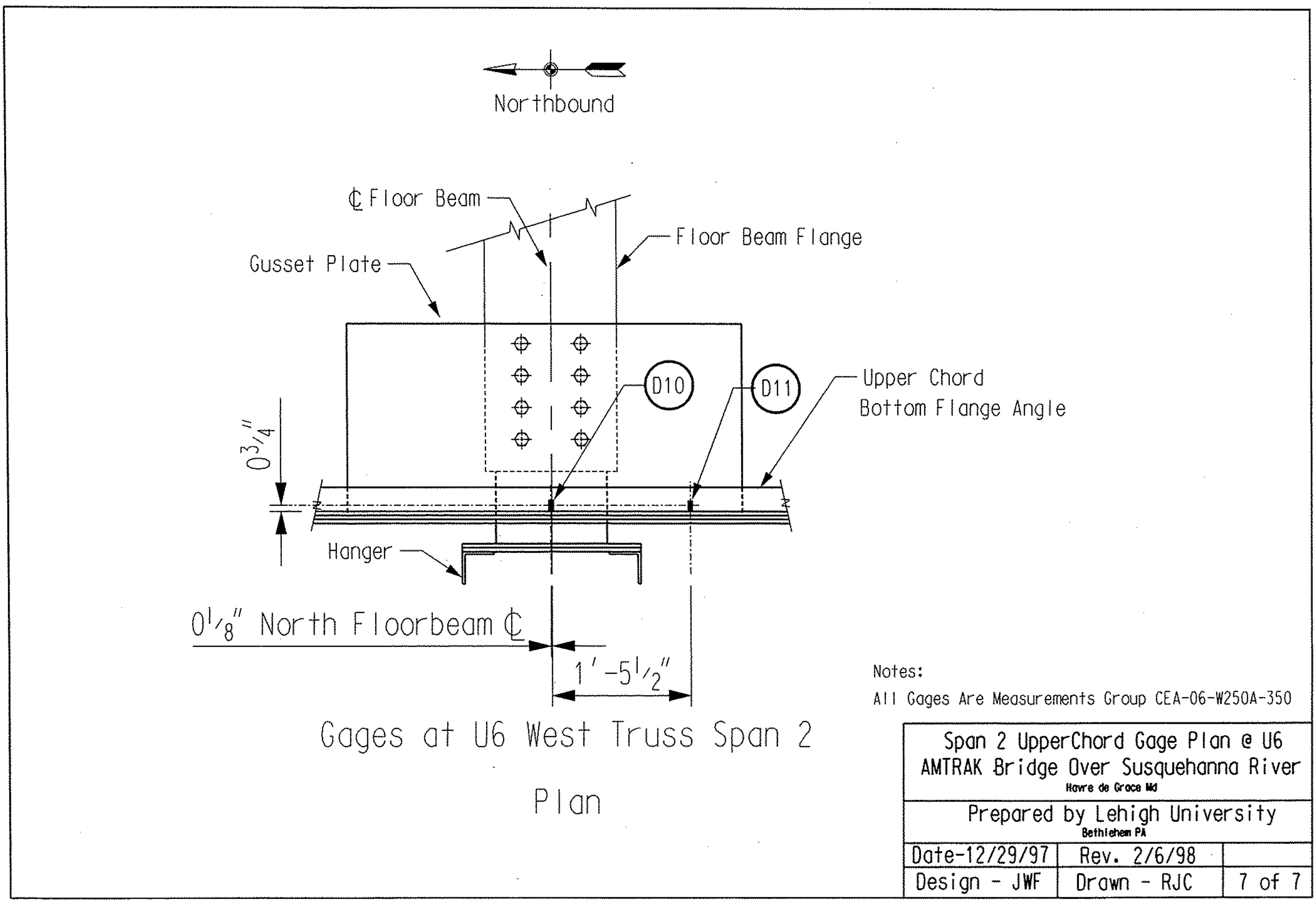


Fig. 21. Span 2; December Gage Installations at Floorbeam 6

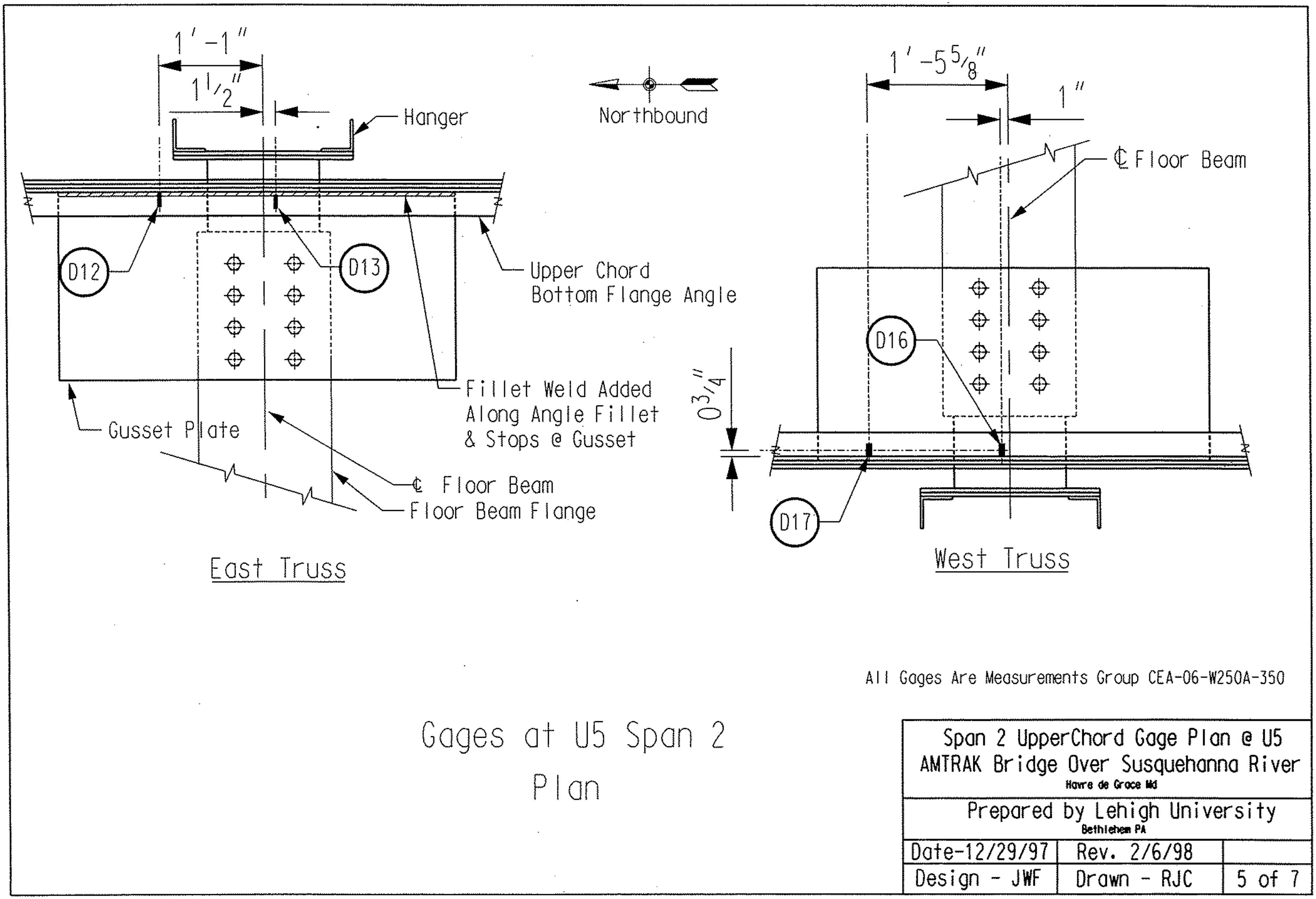
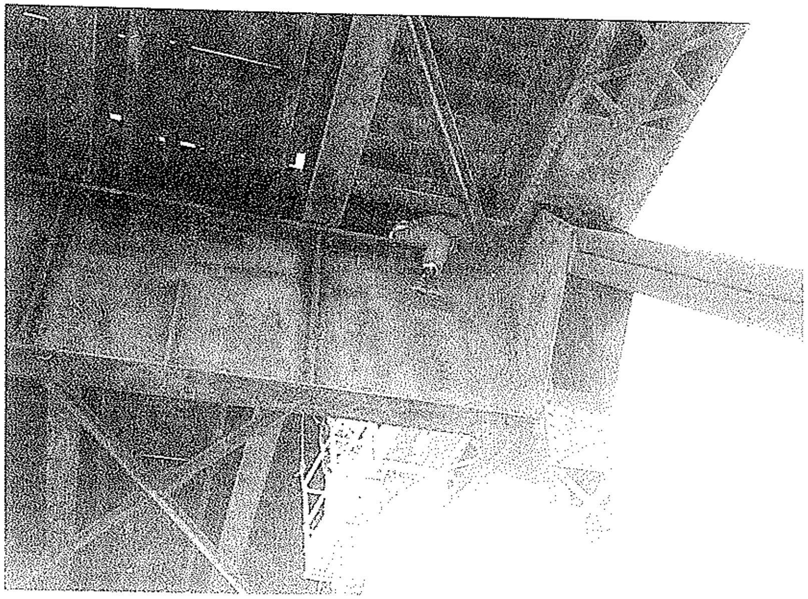
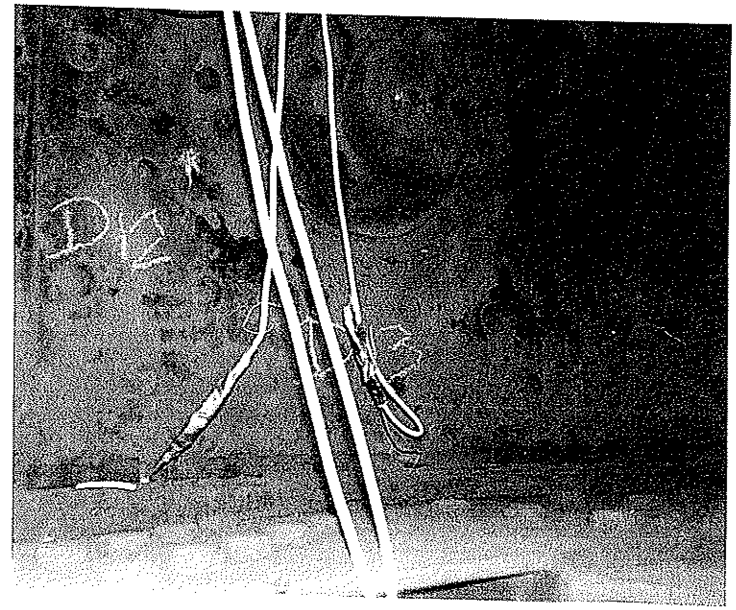


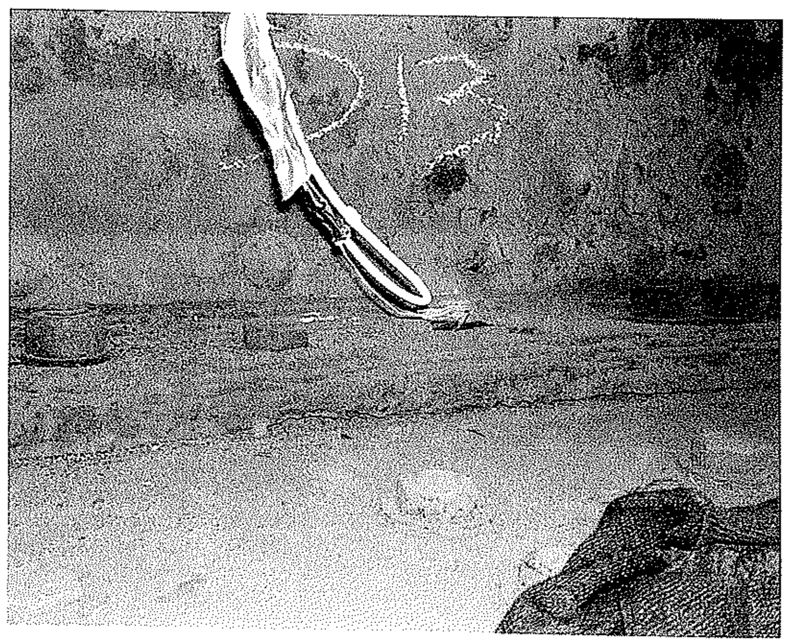
Fig. 22. Span 2; December Gage Installations at Floorbeam 5



a) Engineer installing gages
at FB 5 East (12/97/16-19)

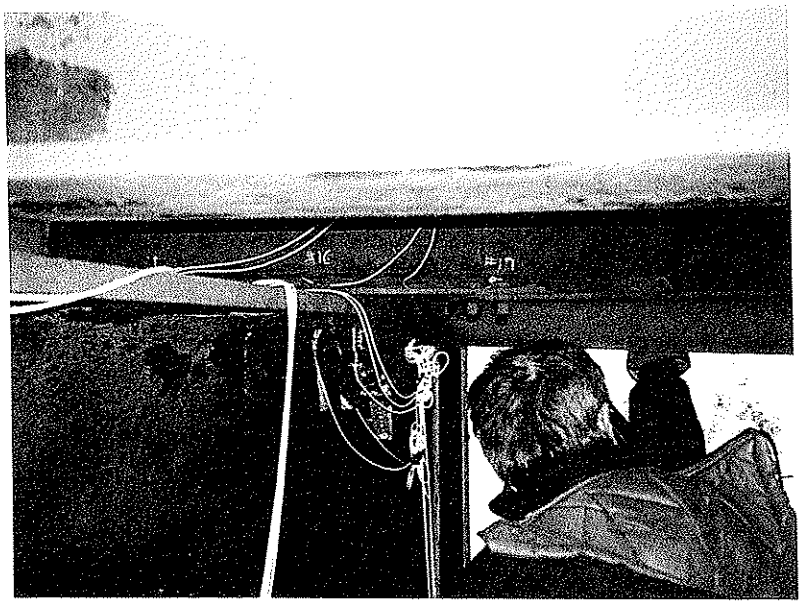


b) Gages D12 and D13 on
top chord flange (12/97/16-24)

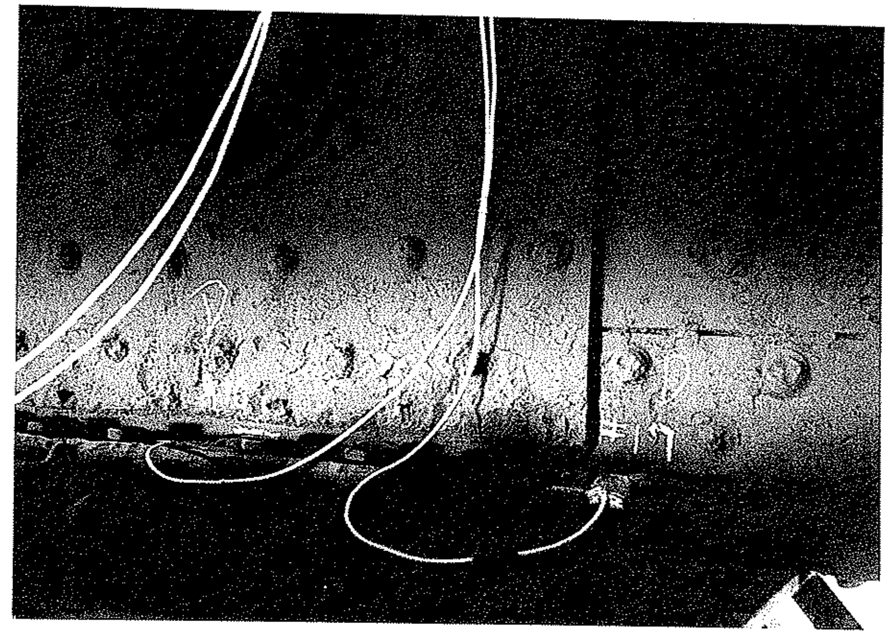


c) Closeup of GageD13 showing local
condition in gage area (12/97/16-21)

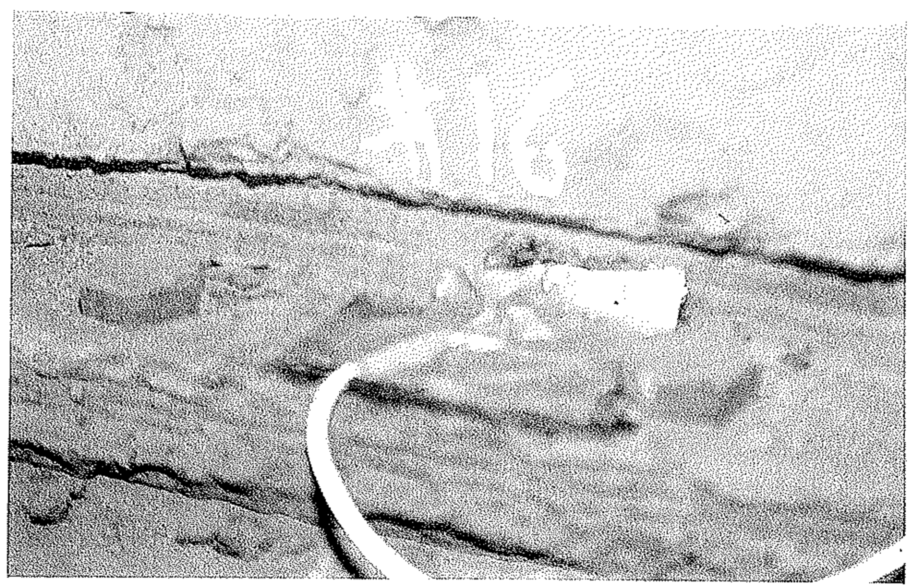
Figure 23: Span 2, Floorbeam 5 East, Gages D12 and D13



a) Overall view of D16, D17, and D97 at
Floorbeam / top chord junction (1/98/6-7)



b) Gages D16 & D17 on top chord
bottom flange (1/98/6-11)



c) Close up of Gage D16 showing
local flange condition (1/98/8-14)

Figure24: Span 2, Floorbeam 5 / West Top Chord, Gage Installations D16 -D17

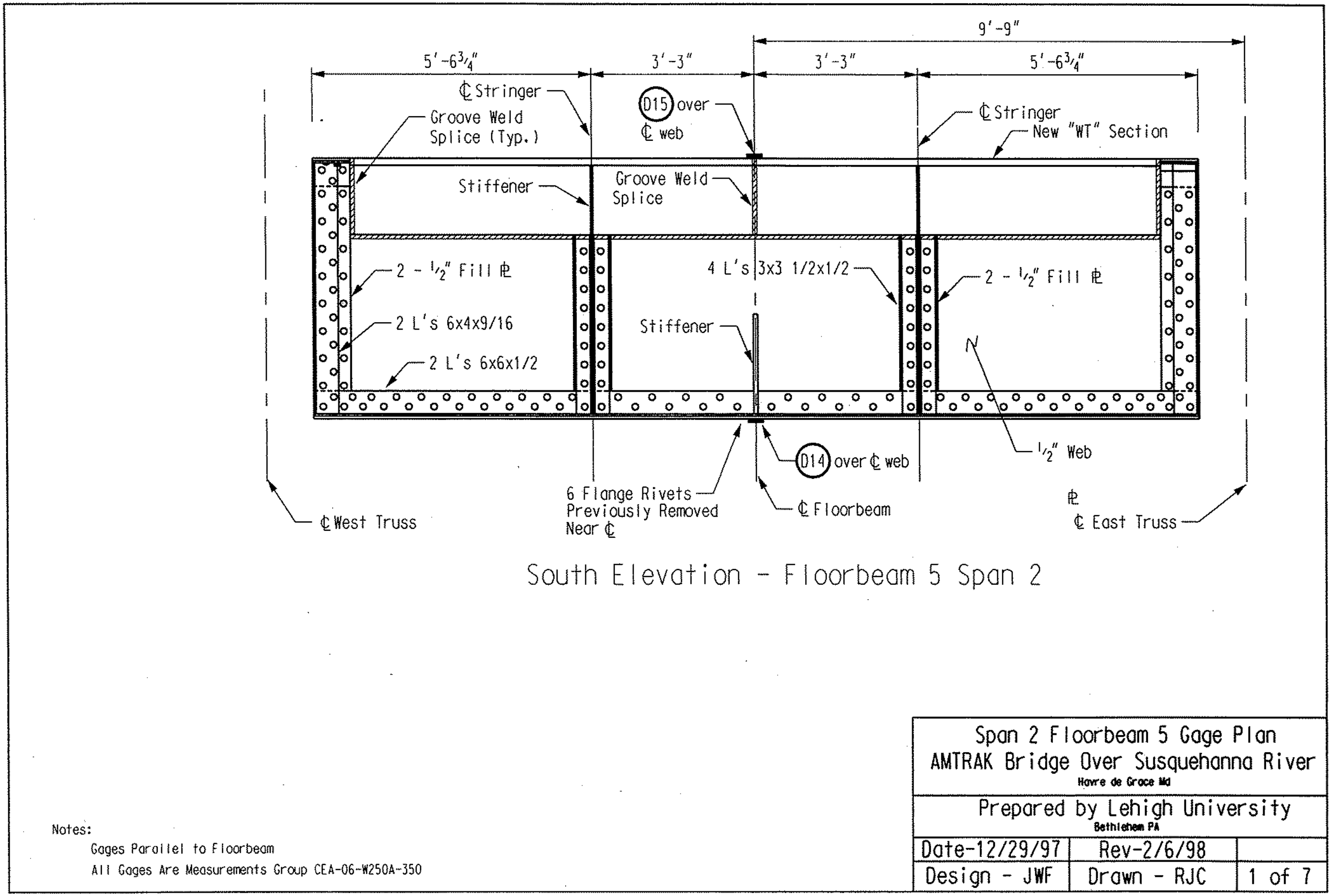
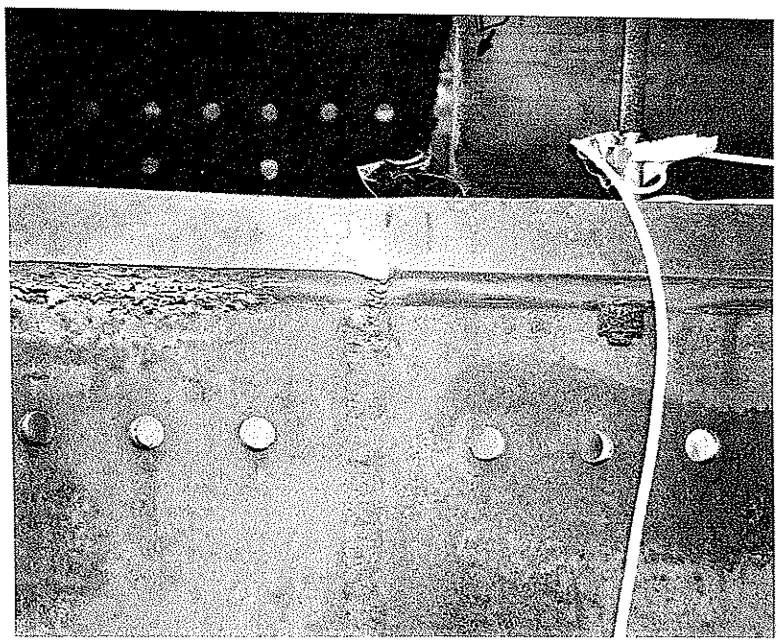
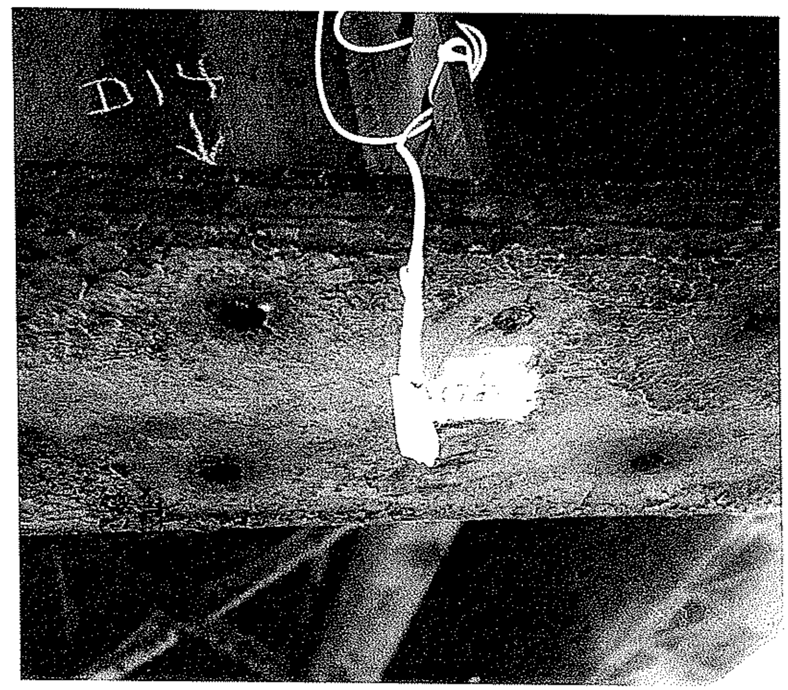


Fig. 25. Span 2; December Gage Installations at ℄ of Floorbeam 5

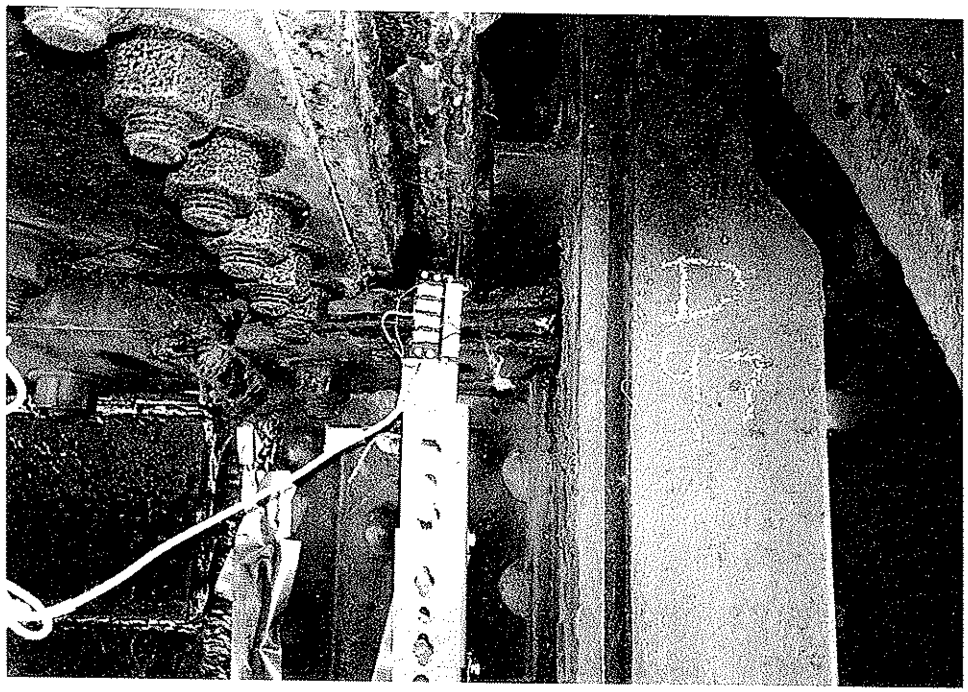


a) Upper part of FB at midwidth weld splice.
Gage D15 atop Flange at FB ℄ (1/98/6-6)



b) View of Gage D14 on bottom flange surface
Note missing or beheaded rivets (1/98/6-9)

Figure26: Span 2, Floorbeam 5 Midwidth Gages D14 and D15



a) Gage D97 contacting bottom of web
doubler plater on top chord at FB 5 West (1/98/6-14)

Figure 27: Span 2, Displacement Gages D97 at Floorbeam 5

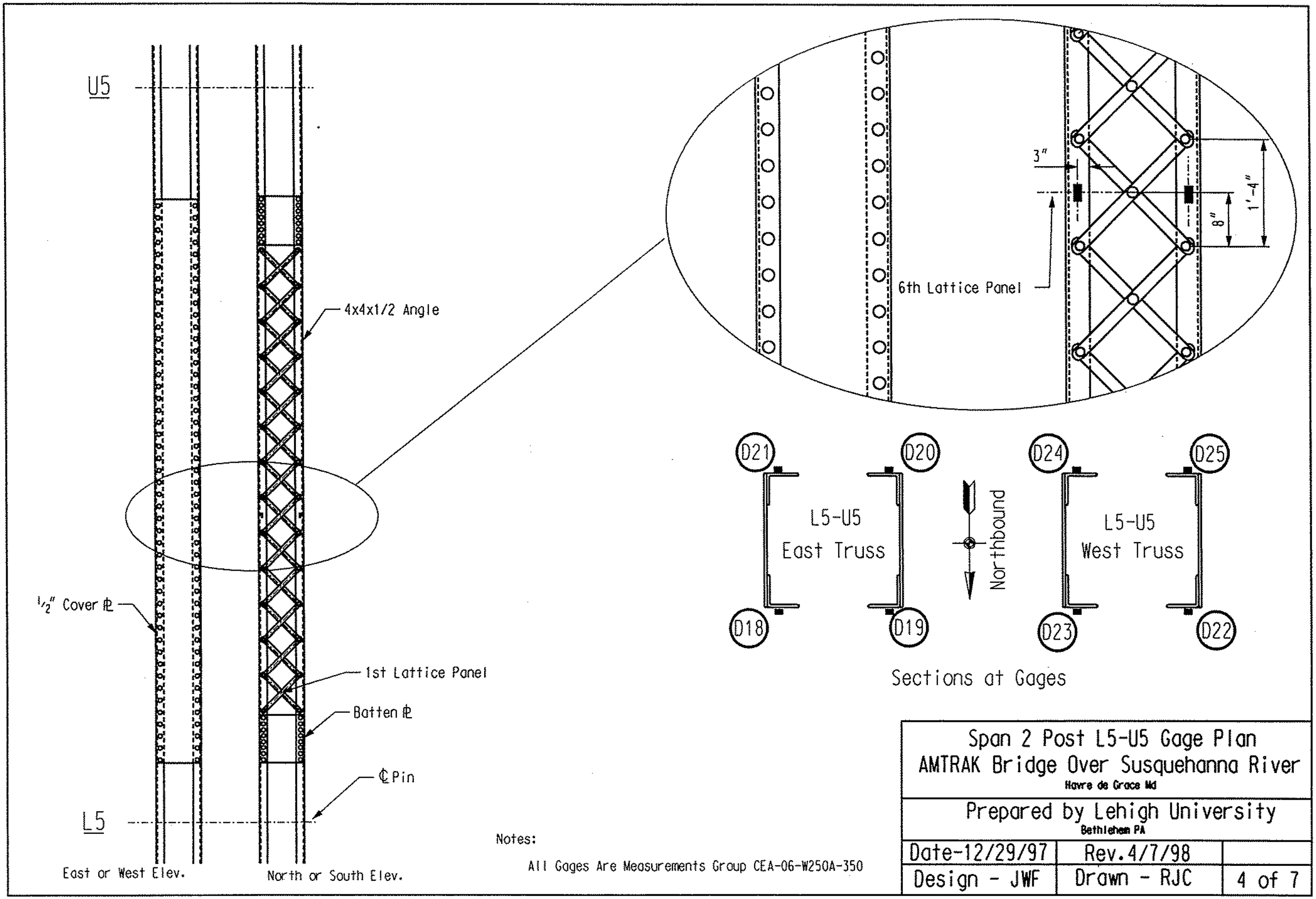
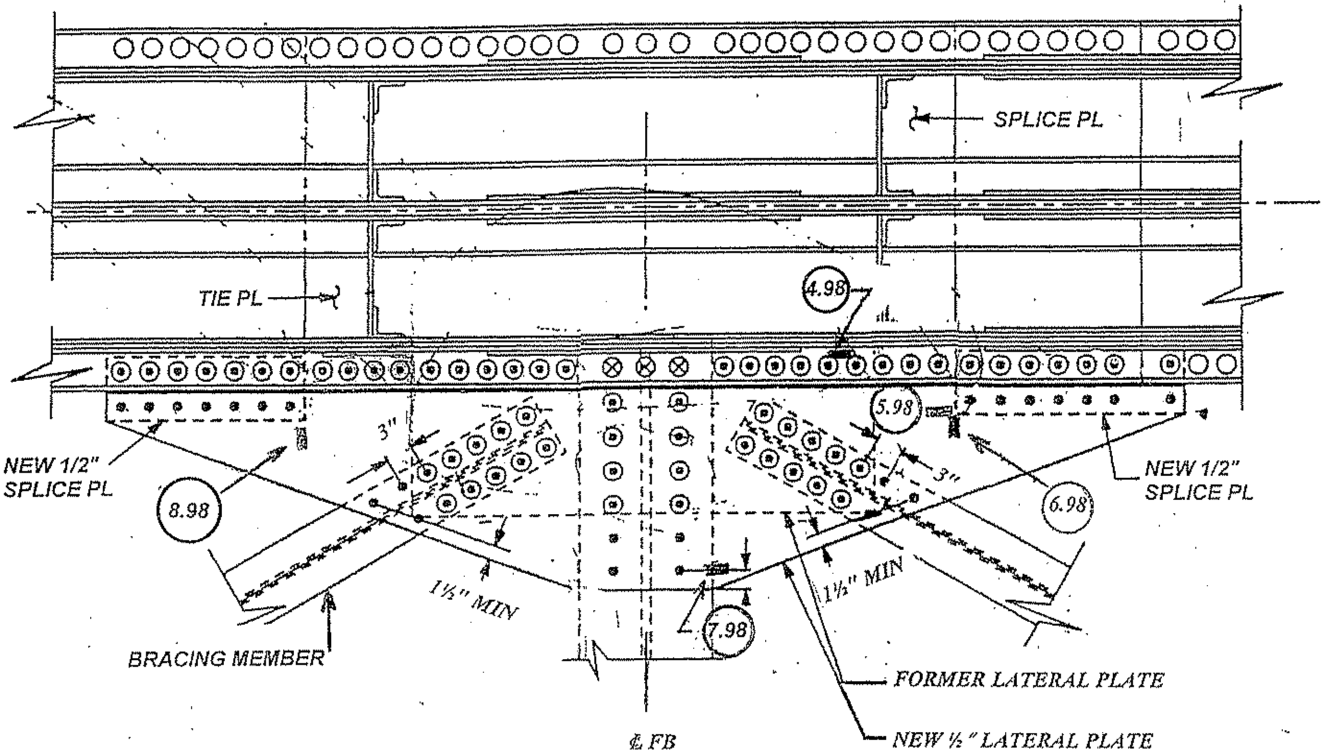


Figure 28: Span 2; December Gage Installations on Vertical Posts L5U5

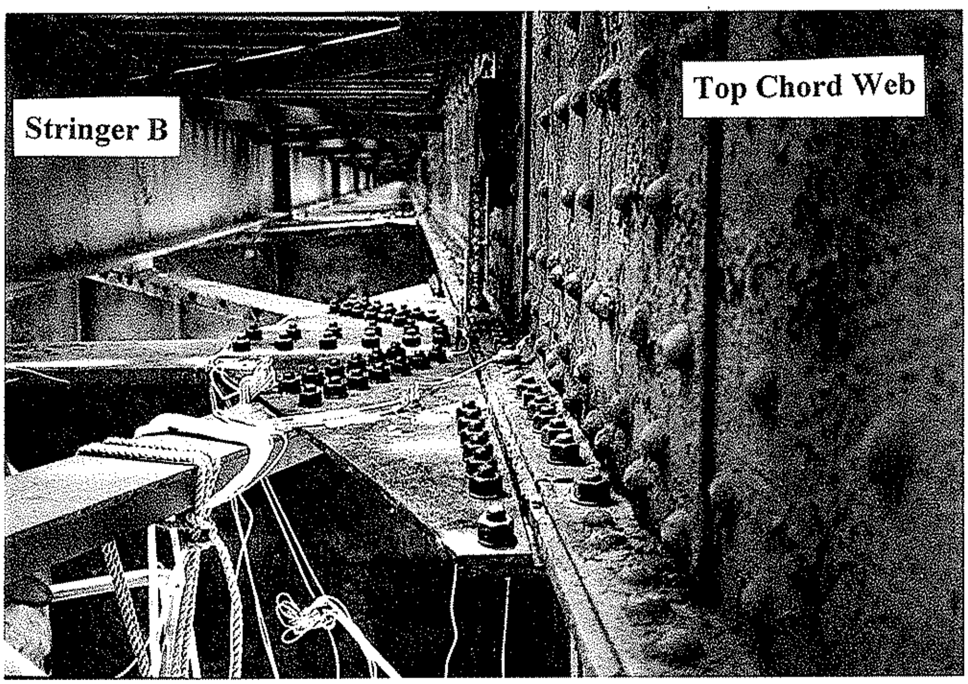
a) East Post L5U5 showing
Gages D20 and D21 (1/98/6-20)

b) West Post L5U5 showing
Gages D24 and D25 (1/98/6-16)

Figure 29: Span 2, Gages on Vertical Posts L5U5



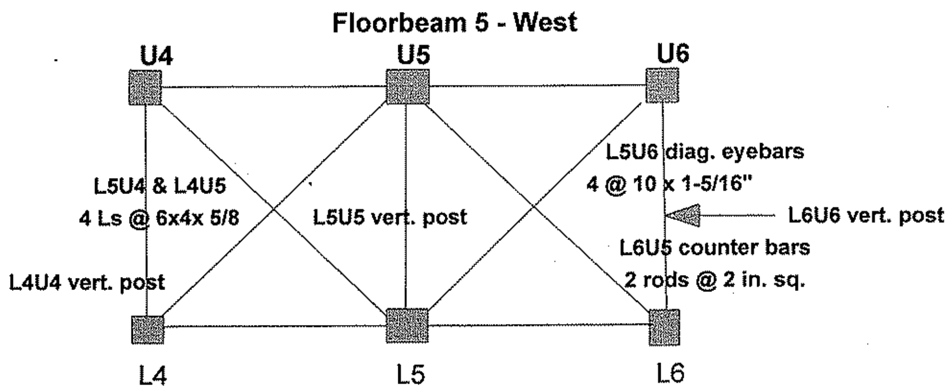
(a) Drawing for Retrofit Plate at Panel Point U5;
(adapted from Modjeski & Masters Dwg. S20, Sheet 21, File MD 060.07)



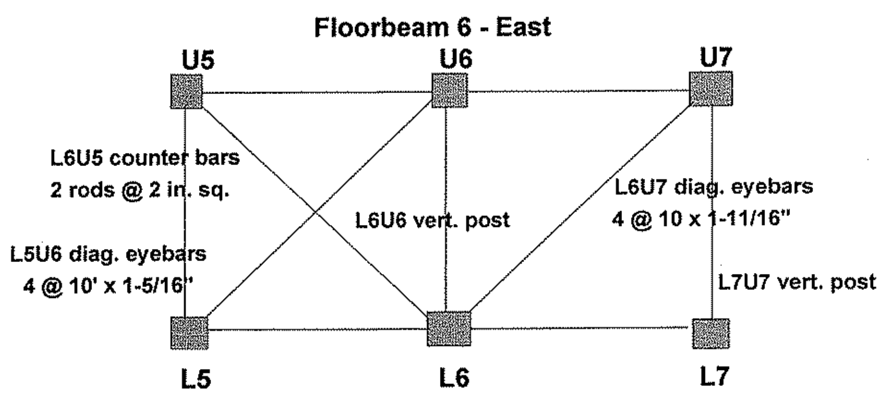
Note retrofit plate at U4-West in background

b) Photo of Retrofit Plate and New Gages at Panel Point U5-West (8/98/8-14)

Figure 30. Type 2 Retrofit; Lateral Connection Plate Used at Floorbeams 4, 5, 6, and 7 in Span 2, July/August 1998



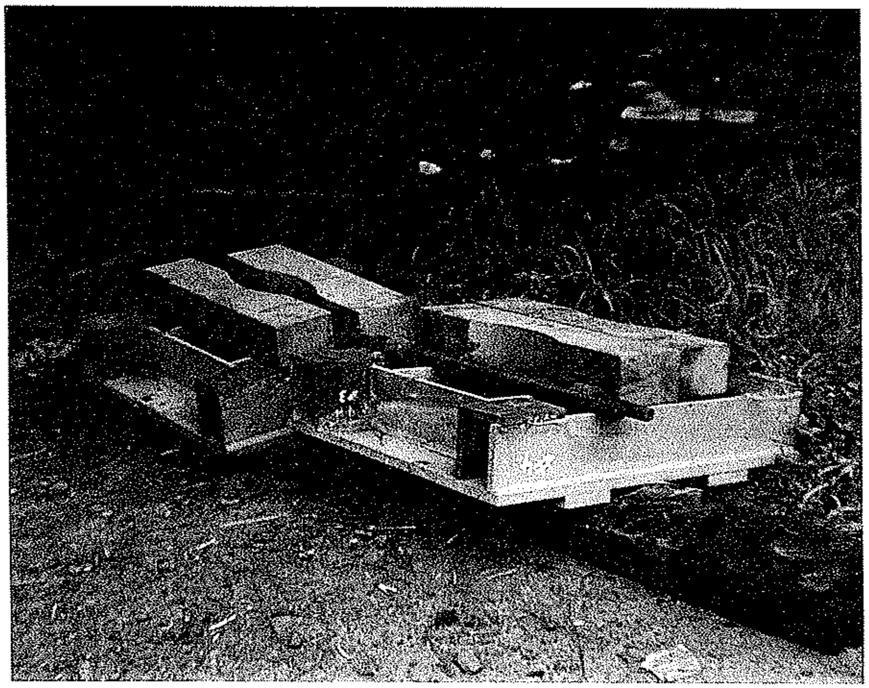
West truss elevation looking west



East truss elevation looking west

Figure 31. Panel Point Differences in Span 2 at U5-West and U6-East where Type 2 retrofits (lateral connection plates) were strain gaged

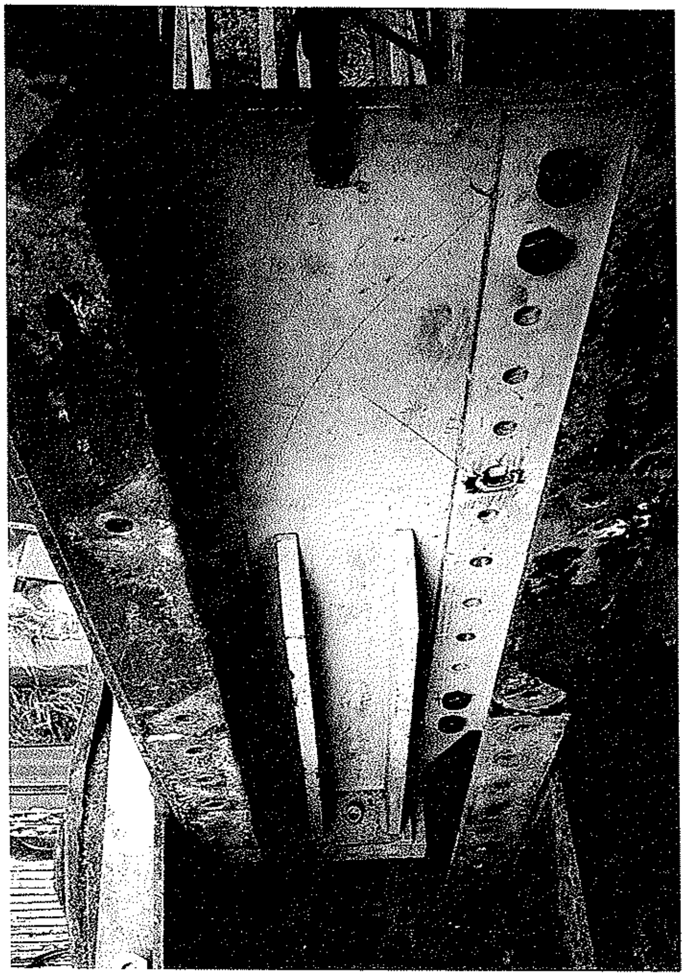
c:\AMTRAK Drawing 2.wb3



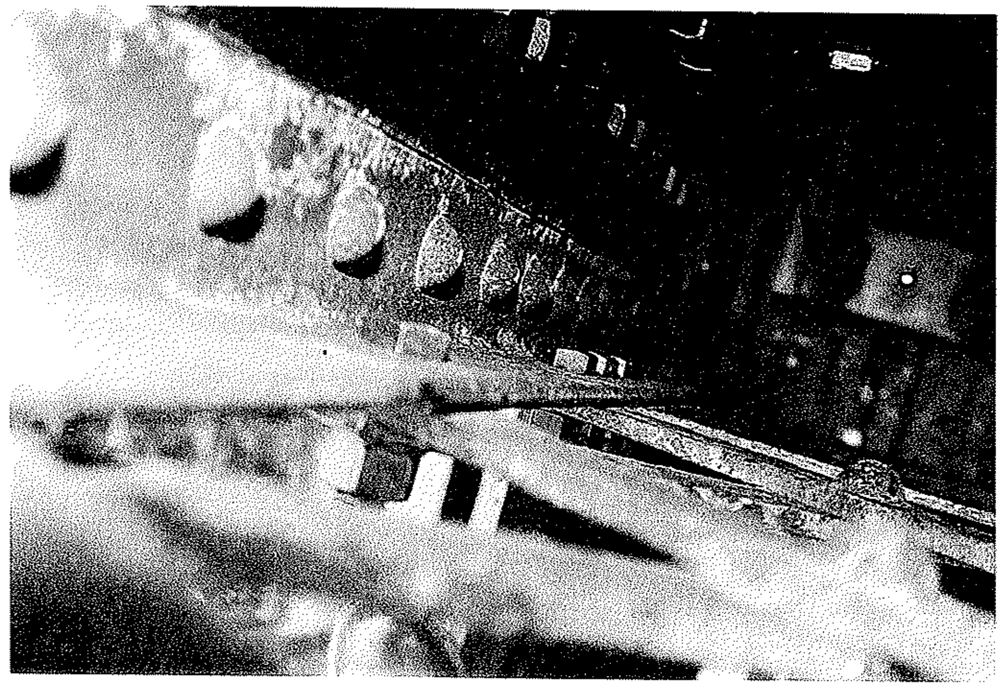
a) Two sets of yoke assemblies after removal.
(8/98/7-2)

b) Top bearing plate of yoke, and rigid bearing assembly, in position at L4-West (8/98/7-x)

Figure 32: Type 1 Retrofit; Temporary Yoke Assembly Used at Lower Panel Points L4 and L5 in Span 2

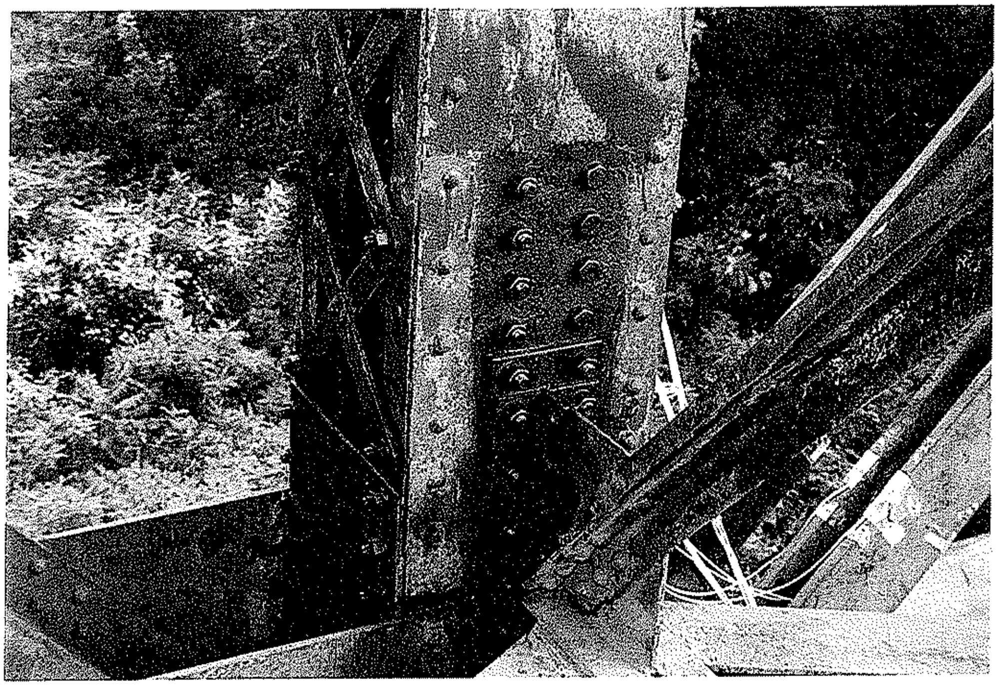


a) During installation, with tie plate and lattice bars removed from post.

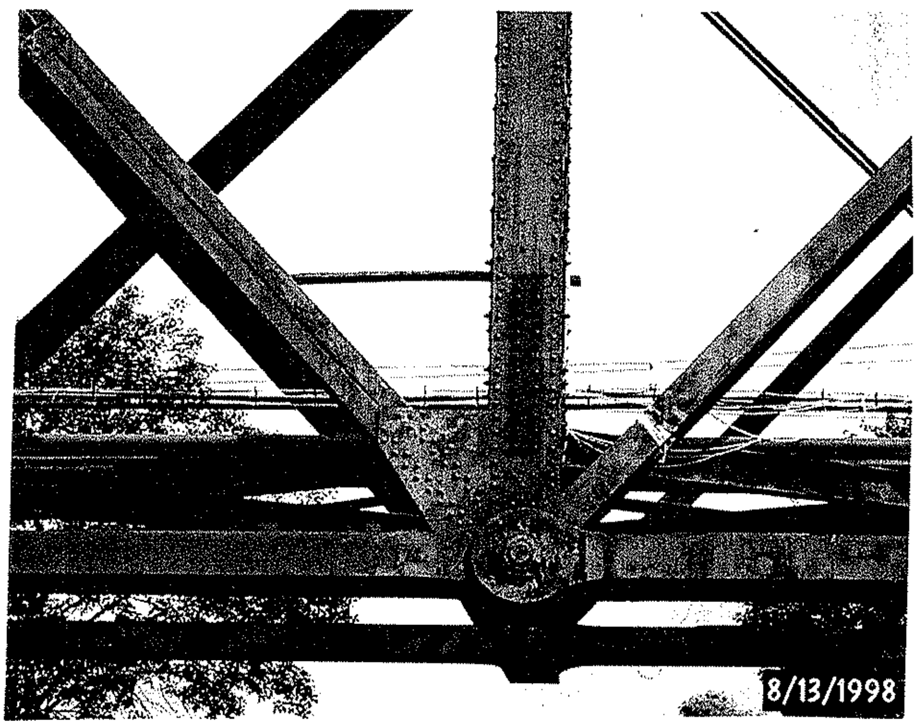


b) After installation, with tie plate and lattice bars reinstated with bolts. Looking down towards bearing plate atop eyebars (8/98/13-5)

Figure 33: Views of Rigid Bearing Retrofit Assembly Used in Posts at Lower Panel Points L4 and L5 in Span 2



(a) South and east sides of Post L5U5-West after retrofit (8/98/13-6)



(b) East side of Post L5U5-East after retrofit

Figure 34. Vertical Posts L5U5 in Span 2 After Installation of Retrofit at Lower Panel Points

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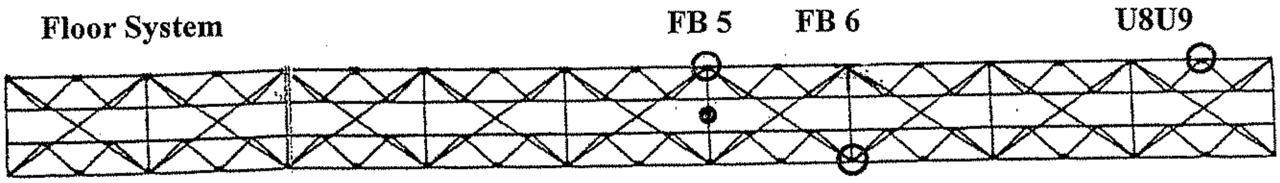
Figure 35.

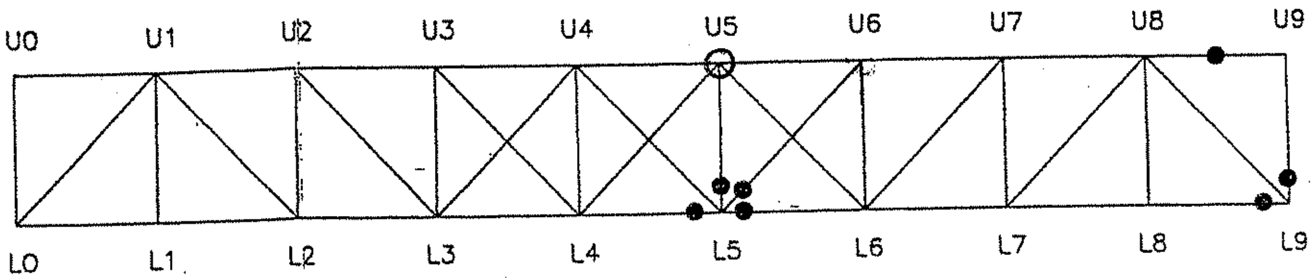
Floor System



Top Chord U8U9: Gages D5, D6, 1.98 - 3.98
Floorbeam 5: Gages 309, D14, 4.98 - 8.98, 70.98
Floorbeam 6: Gages 9.98 - 13.98

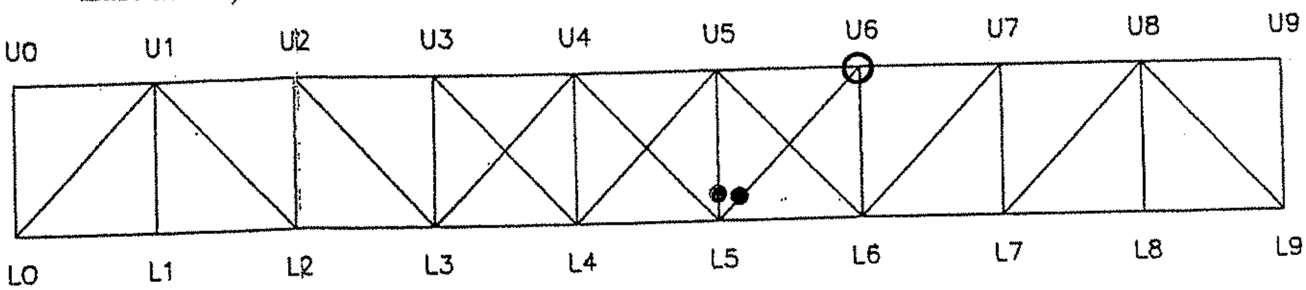
Note: Gages xx.98 are new gages.
For specific locations, see Table 5.

West Truss, East Elev. **Perryville ⇨**



Diagonal Eyebars L5U6: Gages 208 - 211 & 244 - 247
Lower Chord Eyebars L4L5: Gages 14.98 - 17.98
Lower Chord Eyebars L5L6: Gages 18.98 - 21.98
Lower Chord Eyebars L8L9: Gages 22.98 - 25.98
Vertical Post L5U5: Gages D22 - D25
Vertical Post L9U9: Gages 26.98, 27.98

East Truss, East Elev.



Diagonal Eyebars L5U6: Gages 212 - 215 & 248 - 251
Vertical Post L5U5: Gages D18 - D21

Figure 36. Post-Retrofit Gage Locations in Span 2, August 1998

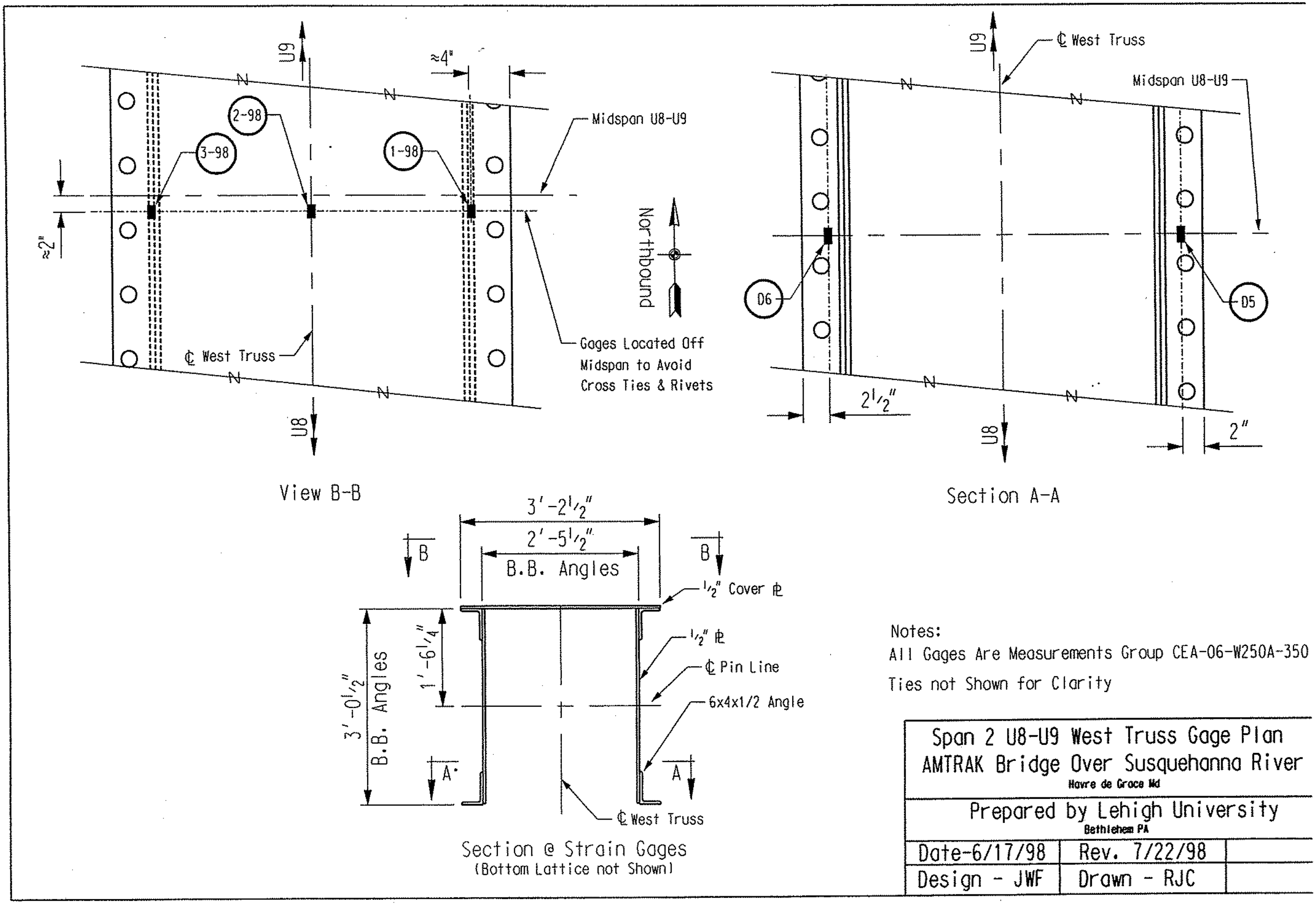
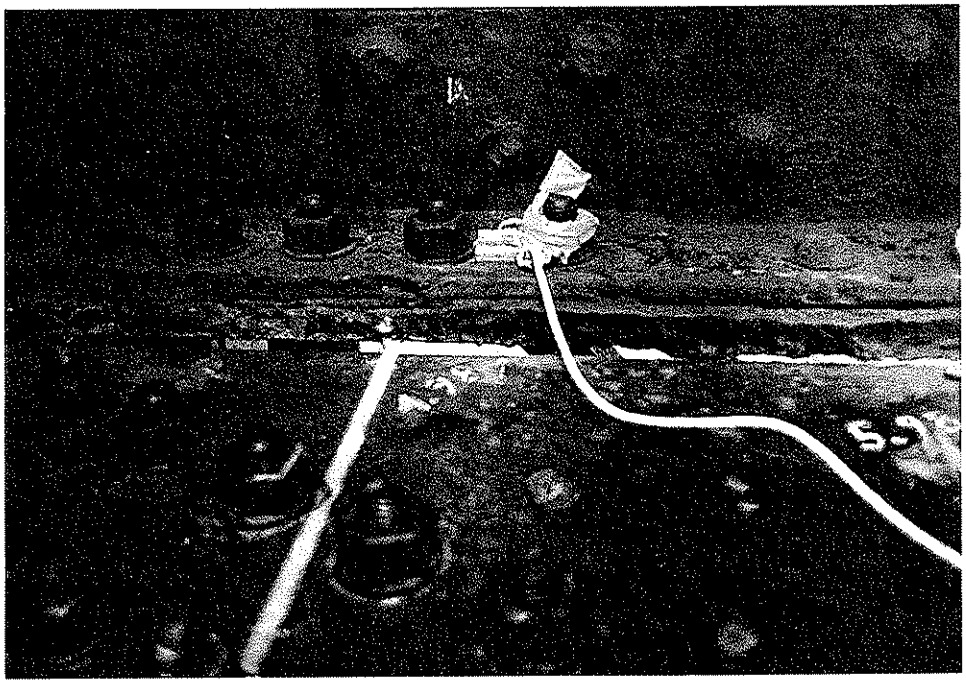
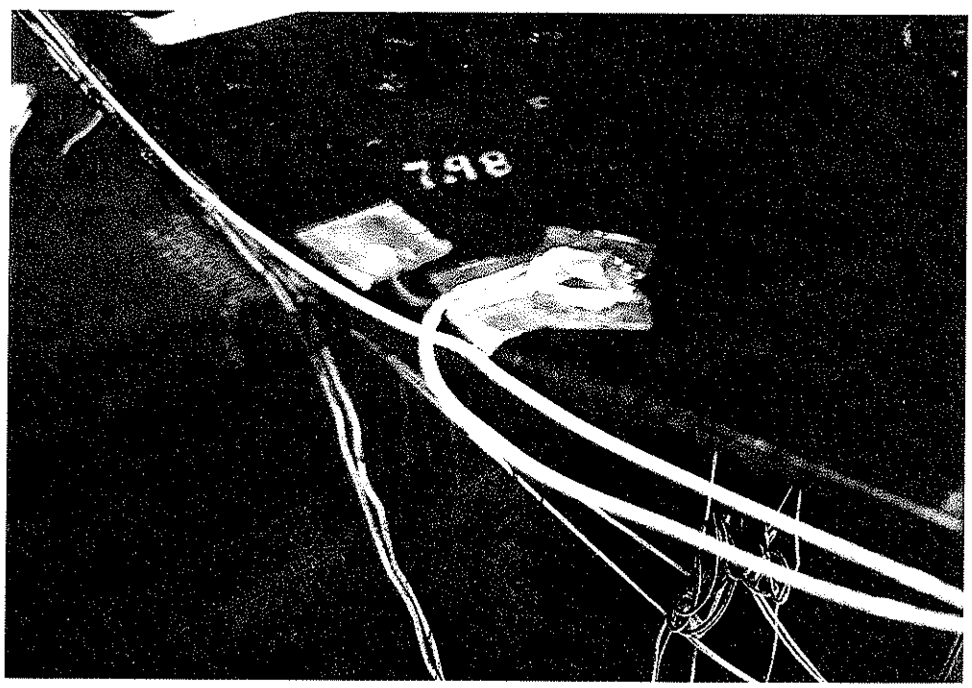


Figure 37. Gage Details for Span 2, Top Chord U8U9, July/August 1998

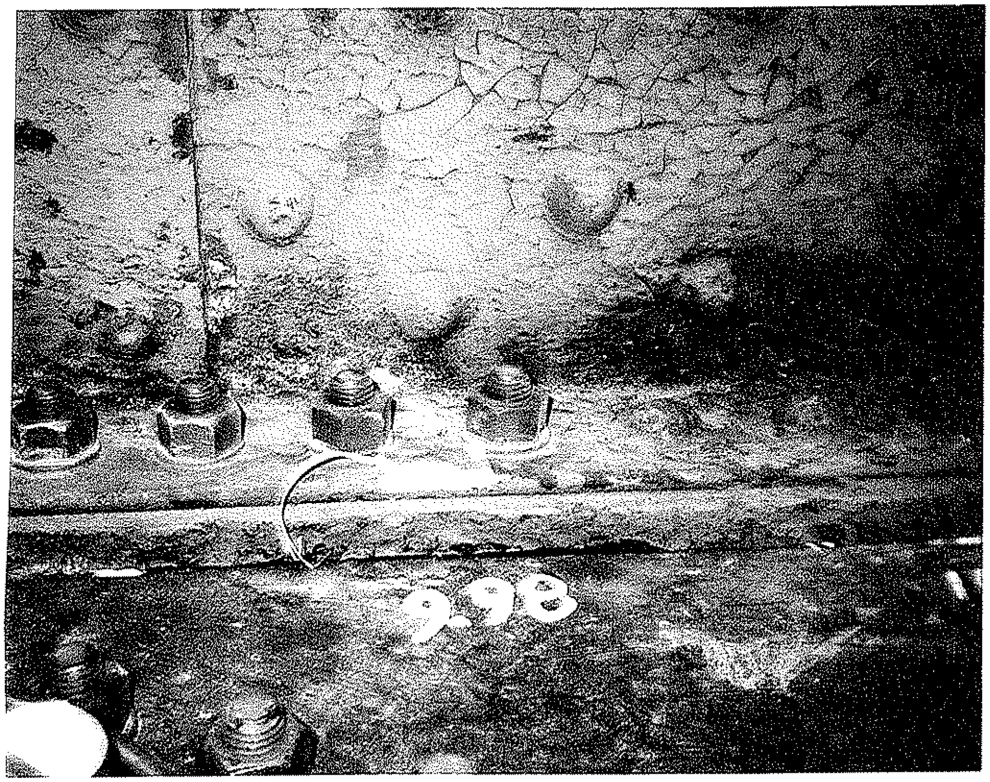


a) Gages 4.98 (on top chord flange) and 5.98 (on lateral connection plate) (8/98/8-8)

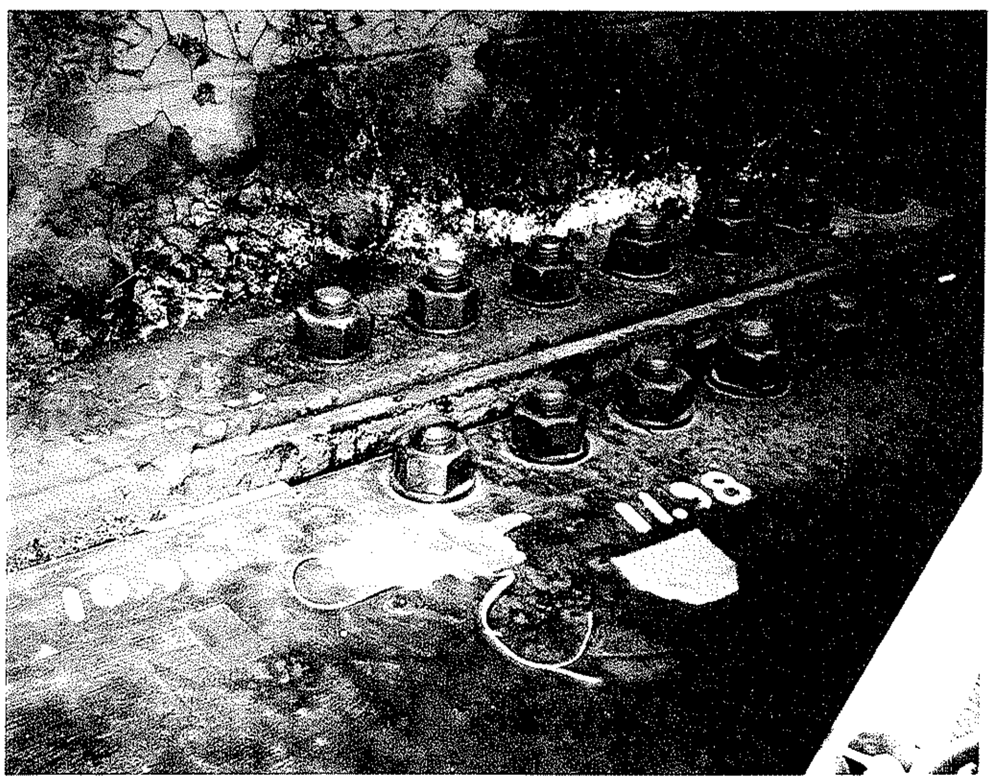


b) Gage 7.98 (8/98/8-9)

Figure 38. Post-Retrofit Gage Installations on New Lateral Connection Plate in Span 2 at Panel Point U5-West



(8/98/9-15)



(8/98/9-14A)

Figure 39. Post Retrofit Gage Installations on New Lateral Connection Plate in Span 2 at Panel Point U6-East

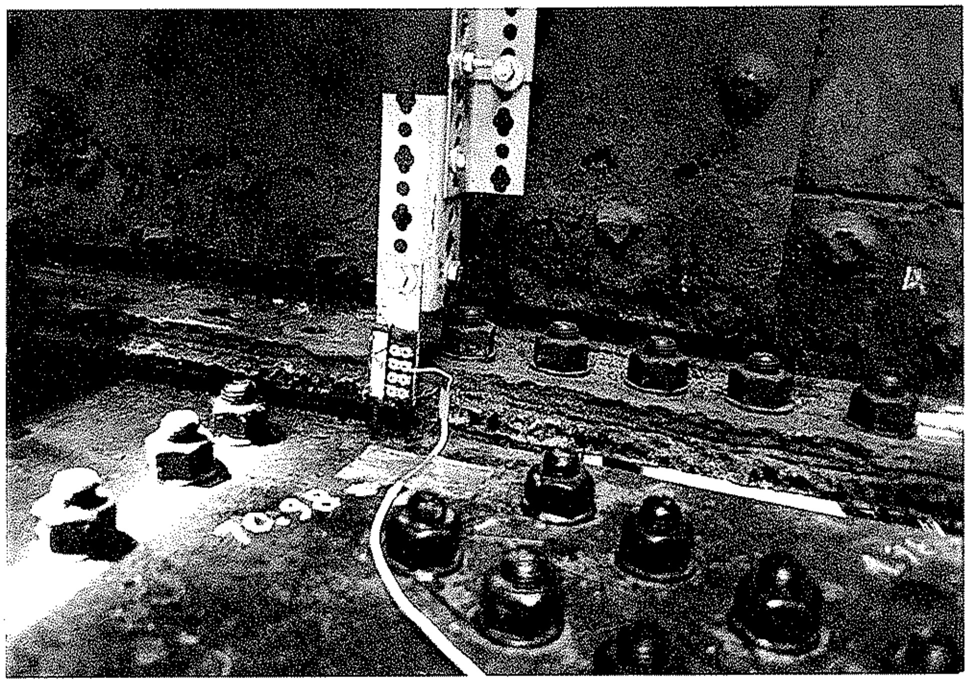
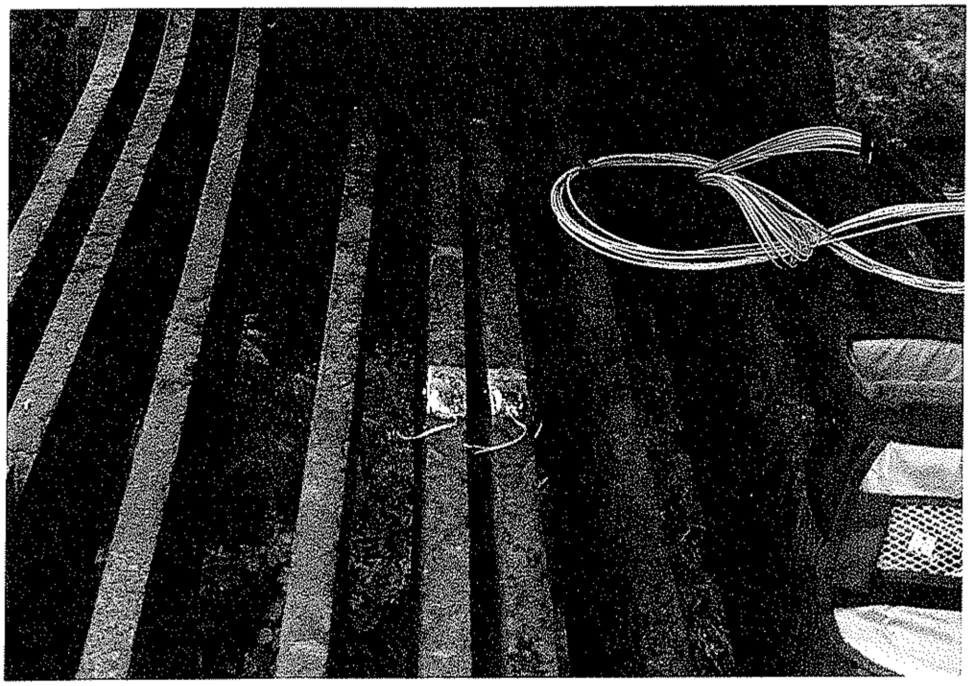


Figure 40. Post-Retrofit Displacement Gage in Span 2 at U5-West Between New Lateral Connection Plate at Floorbeam and Top Chord Web (8/98/8-12)

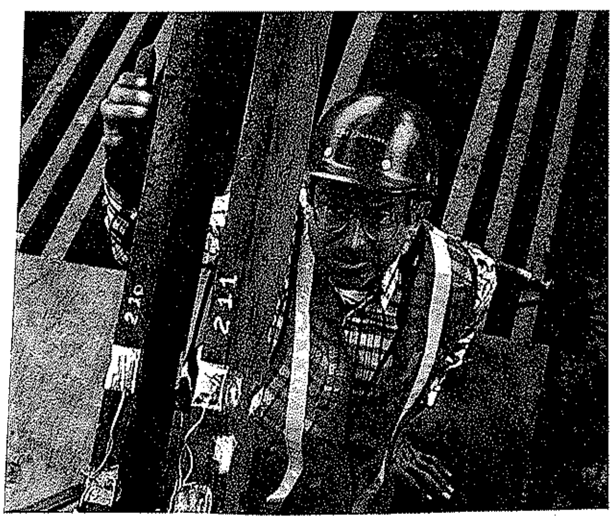
a) Gages 208 to 211 at L5U6-West (8/98/7-8)

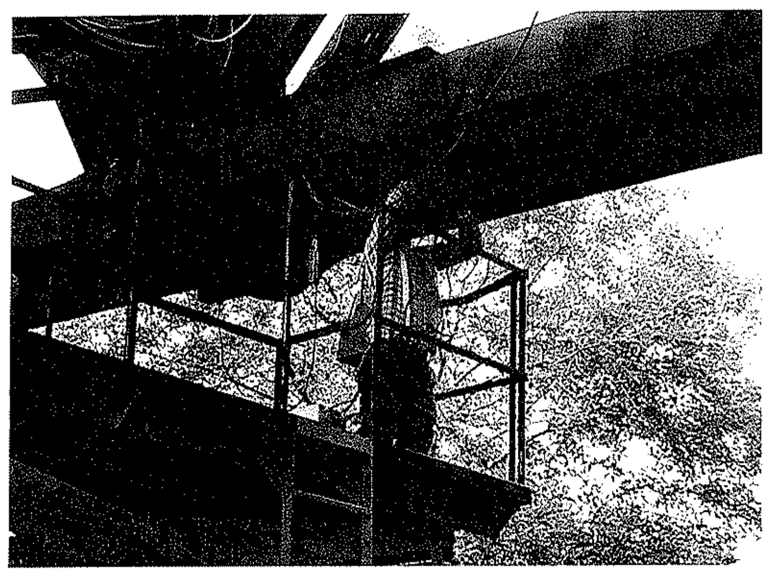
b) Gages 212 to 215 at L5U6-East (8/98/7-14)

Figure 41. Gage Installations in Span 2 on Eyebar Diagonals L5U6 at L5 (after reinstallation in 08/98)



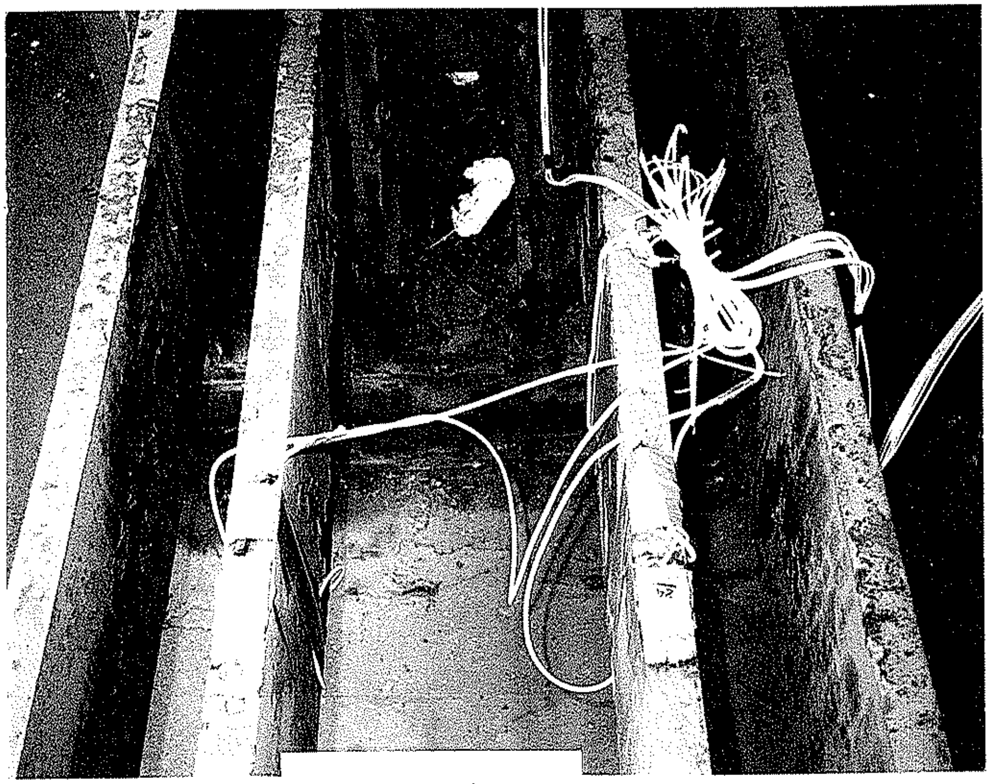
a) **Gages 14.98 and 16.98 on Lower-Chord Eyebars L4L5** (8/98/7-18)





Left: Top View of Group of 8 Lower-Chord Eyebars (8/98/7-5)
(Diagonal eyebars L5U6 in foreground)
Right: Installation of Gages 19.98 and 21.98 on Lower-Chord Eyebars (8/98/7-10)

Figure 42. Post-Retrofit Gage Installations on Lower-Chord Eyebars in Span 2 at L5-West



L8L9@L9, Span 2

Figure 43. Post-Retrofit Gages 22.98 and 24.98 on Lower-Chord Eyebars in Span 2 at L8L9-West at L9 (8/98/9-10A)

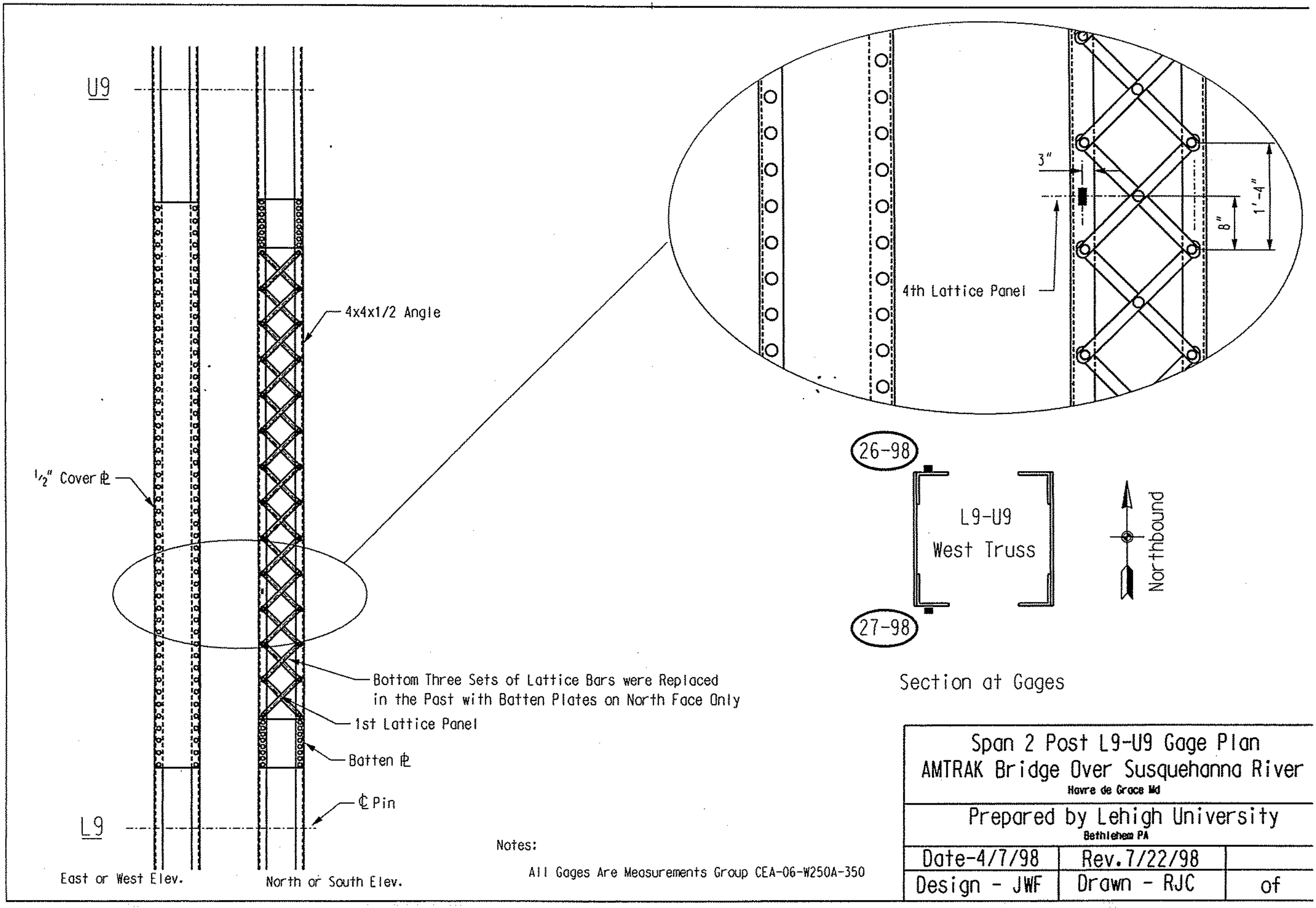
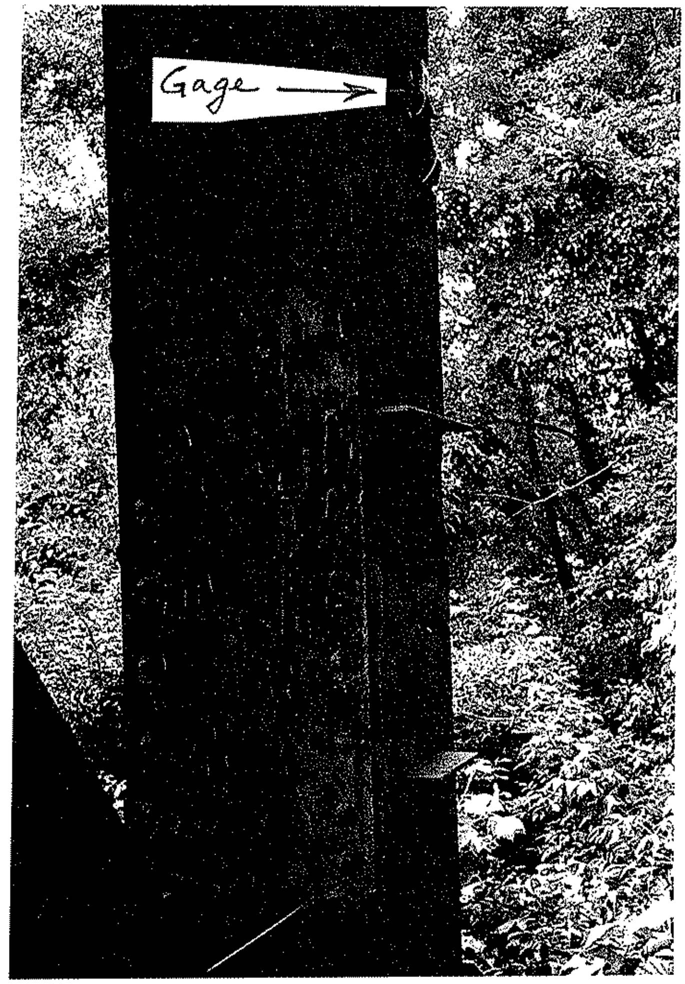


Figure 44. Post-Lubrication Gage Installations at Span 2, Vertical Post L9U9 - West

(a) Gage 27.98 at SW corner of post
(8/98/9-3)



(b) Gage 26.98 at NW corner of post
(8/98/9-4)

Figure 44a. Post-Lubrication Gages on Vertical Post L9U9-West, Span 2

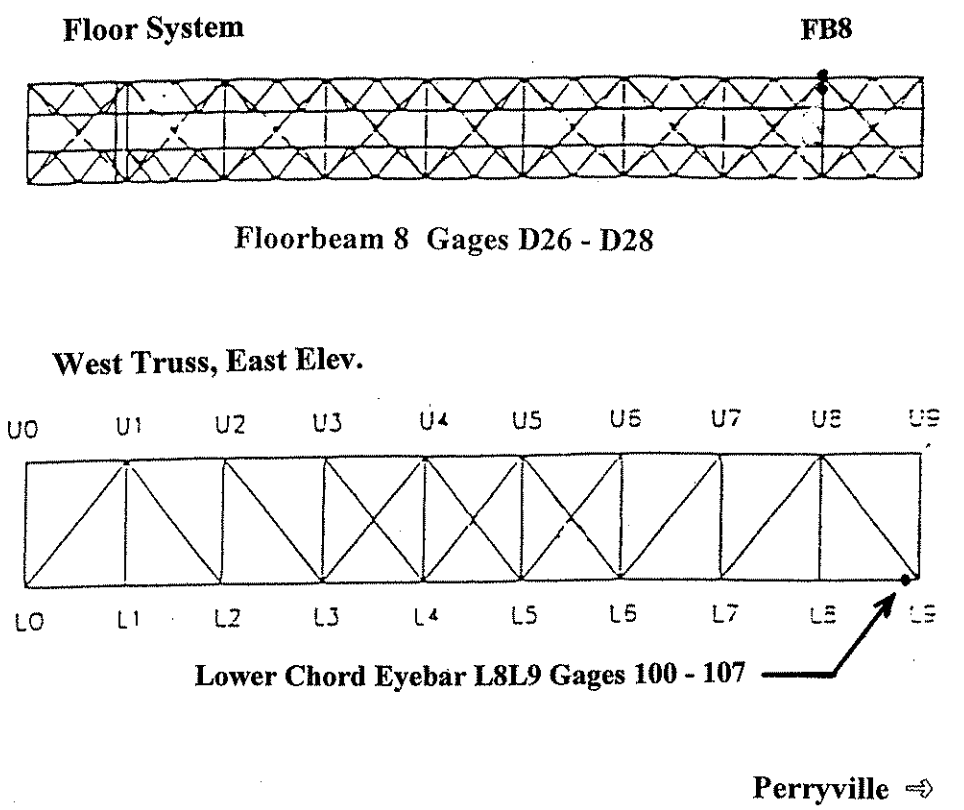
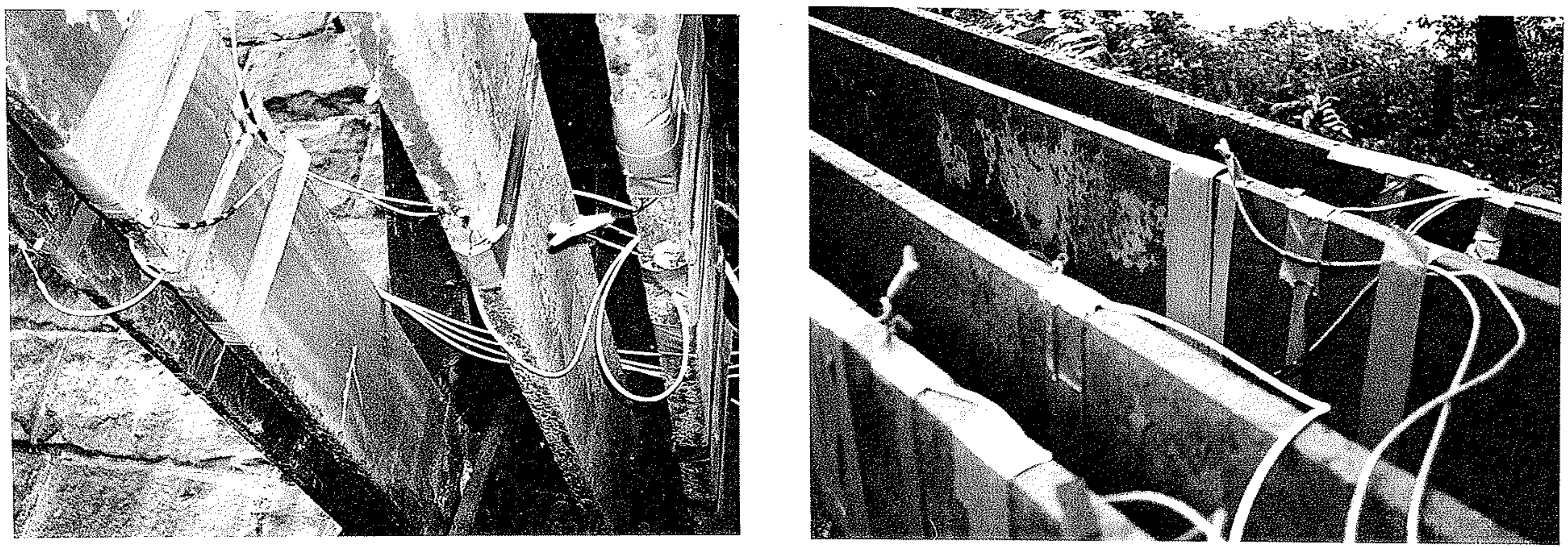


Figure 45. General Gage Locations in Deck - Truss Span 1



a) Bottom Edge Gages 104 - 107 (10/97/18-1)

b) Top Edge Gages 100 - 103 (10/97/18-0)

Figure 46. Span 1, Lower chord L8L9 Gage Installations 100 - 107

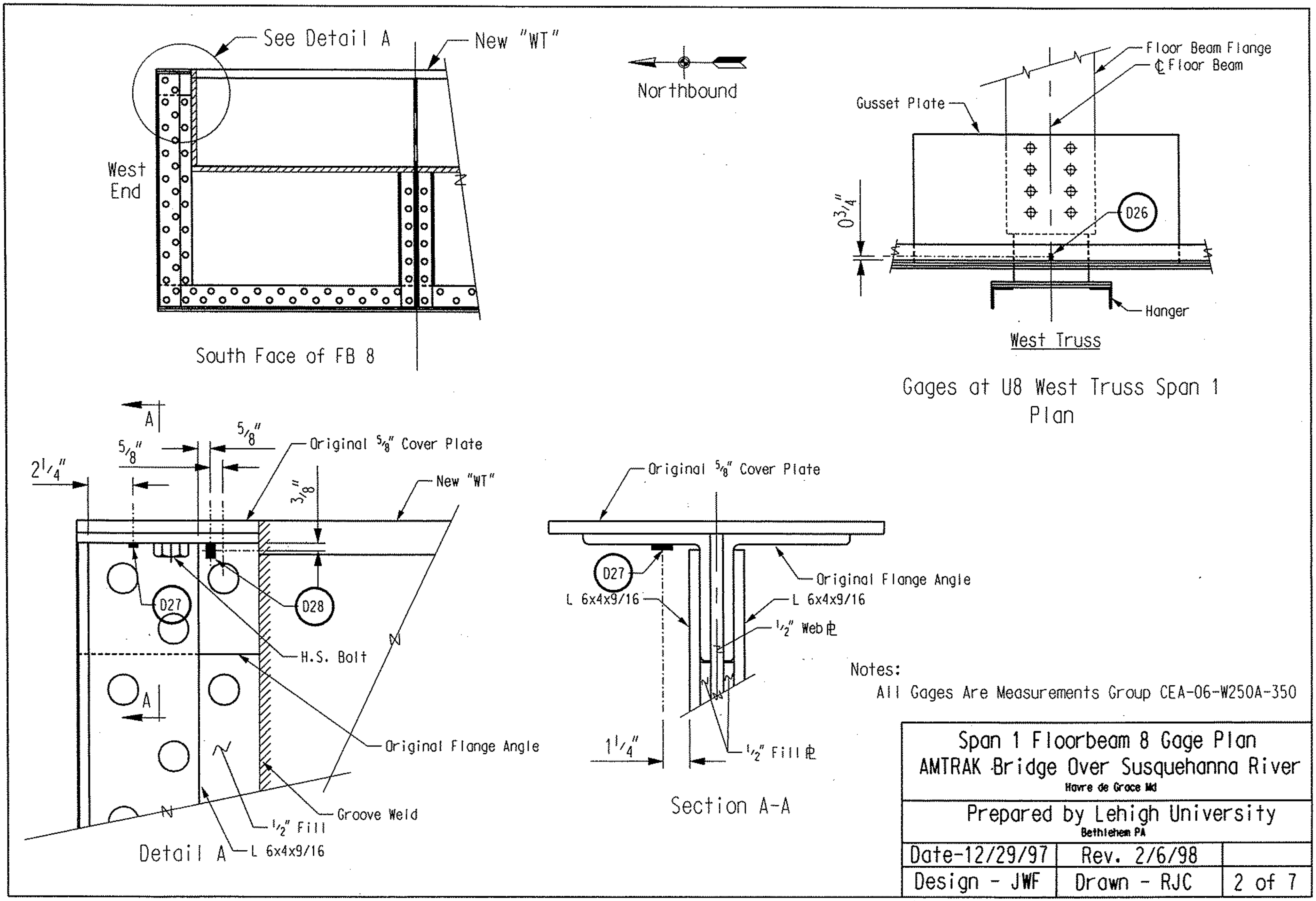
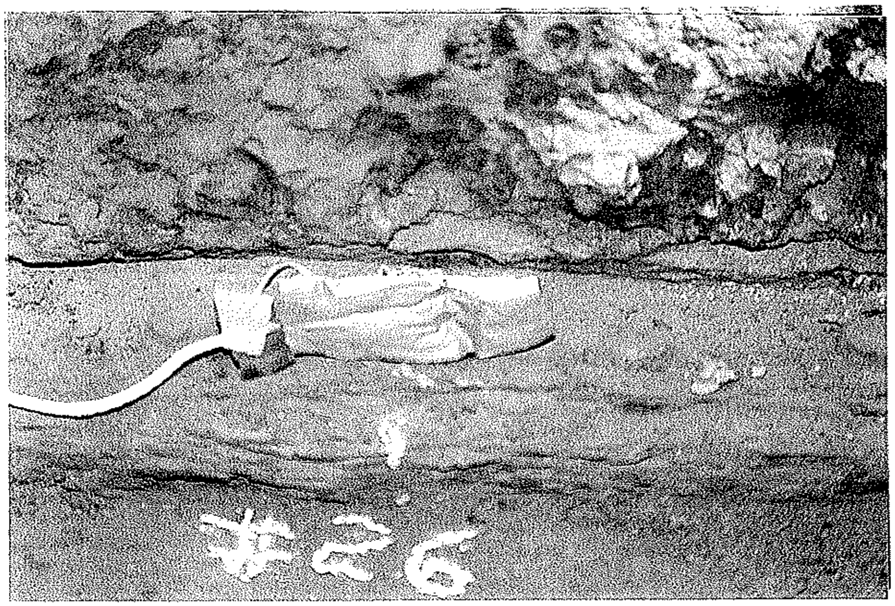
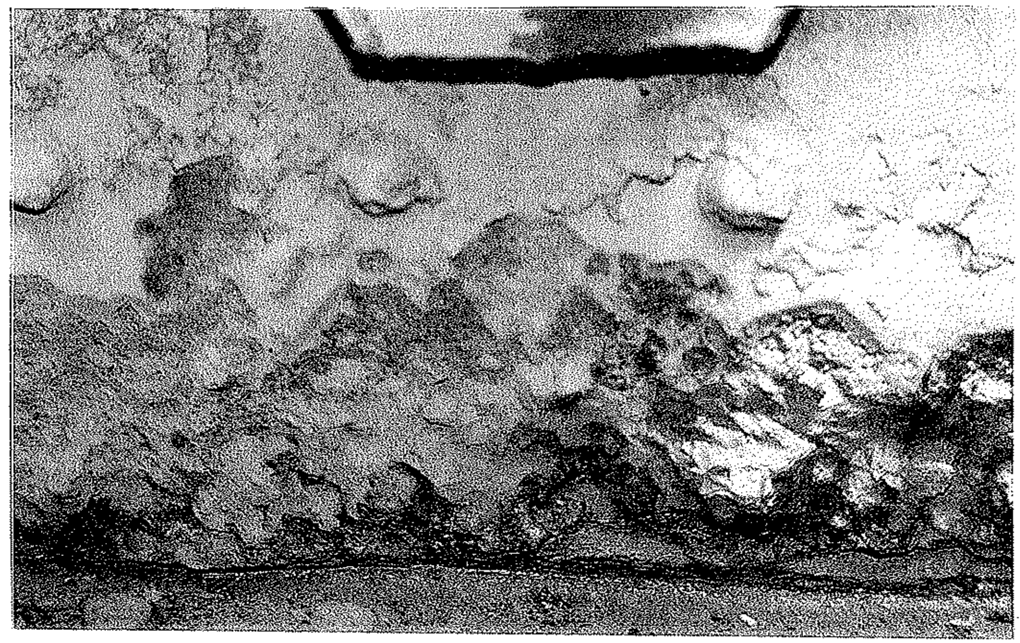


Figure 47. Span 1, Gage Installations at Floorbeam 8 West

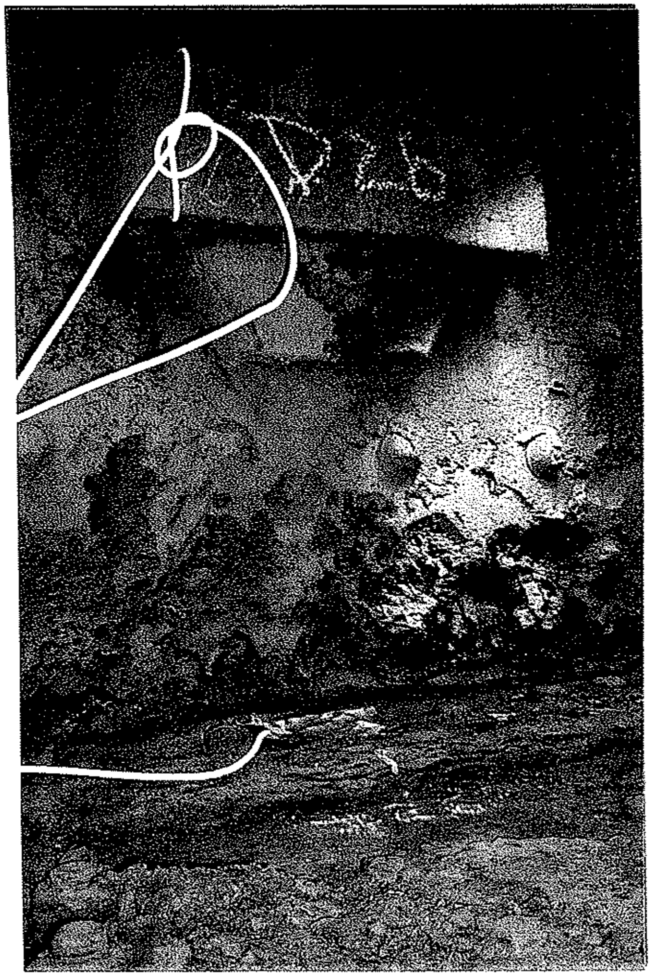


a) Gage D26 on bottom flange
of top chord at ℄ of FB (1/98/8-22)



b) Closeup of section loss in region
of D26 (1/98/8-21)

Figure 48. Span 1, Gage D26 at Floorbeam 8, West Truss



a) Top chord gage D26 (1/98/6-22)

b) Floorbeam gages D27 and D28 (1/98/8-24)

Figure 49. Span 1, Panel Point U8-West Gage Installations D26 - D28

Measurement Variables

Because an assessment of the effect of heavy 286,000 lb (286K) Conrail coal cars on the structural rating of the bridge was the primary intent of the 1997 measurements, the only variable imposed into these measurements was the inclusion of a Conrail "test" train in November which traveled in both directions on both tracks with 286K coal cars. No imposed variables were included in the January 1998 measurements. During the August 1998 measurements, the variables represented post-retrofit conditions in Span 2 and lubrication maintenance in Span 1. Moreover, to assess the retrofits at both east and west trusses, one southbound coal train traveled on Track 2 instead of on the normal Track 3. No other imposed variables existed in August.

Other variables were routine ones: Type of train (Amtrak and MARC passenger trains, normal weight Conrail coal trains, Conrail trains with mixed freight); railcar configurations; number of locomotives; train direction and track; train speed (5 to 15 mph for freight and coal trains, roughly 30 mph for MARC trains, and up to 90 mph for Amtrak trains); and the weather during different measurement periods. Summaries of the train traffic during the measurements provide a review of the variables. Table 7 shows the traffic during October 1997 measurements; Tables 8A and 8B for November 1997 measurements; Table 9 for January and August 1998 measurements. Table 10 shows the distribution of car weights for Conrail trains, where it was available. As shown, the test train (UIR 236) actually had over half its cars weighing less than 286K (between 263K and 286K); and 263K-car trains had many cars weighing over 263K, a few as high as 286K.

Details and characteristics of the recorded measurement data will be illustrated and discussed with reference to type of member and span location, and with reference to the train variables. All pre-retrofit/lubrication results (October-January) are discussed first; then all post-retrofit/lubrication results (July-August) are discussed.

Pre-Retrofit/Lubrication Measurement Data

Lower-Chord Eyebar Stresses

Stresses in lower-chord eyebars were initially measured only in deck-truss Spans 1 and 9. In Span 1, measurements were at L9-west adjacent to the abutment and, in Span 9, they were at L0-east and L0-west adjacent to the swing-span pier. At each location, the chords consisted of four parallel eyebars. The Span 9 eyebars were heavier (12" x 1-5/8") than those at Span 1 (10" x 1-1/4").

Figures 50, 51, and 52 depict characteristics of data from lower-chord eyebars as trains crossed Spans 9 and 1. Figures 50 and 51 show records for complete train crossings at Span 9; Figure 52 for Span 1. With coal and freight trains, the cycle of maximum stress range generally occurred once per train in the lower chords, that is, the stress reached a maximum as the train entered the gage region and returned to zero as the train exited the gage region. It varied only moderately during a train's passage. Occasionally, however, there was a rebound phenomenon in which stress increased as a coal train entered and exited the gage area, as seen in Figure 51. Secondary stress cycles also occurred as the axles of individual cars crossed the gage region but their stress range was small, exceeding 1.0 ksi only infrequently. Figure 50b is descriptive of passenger trains. The effect of the front-end locomotive is apparent since it caused a primary stress range about twice that of the coaches. The secondary stress range due to the coaches is also clear. Figure 52 shows that similar behavior occurred in Span 1, except that the rebound phenomenon did not occur.

Tables 11 to 13 summarize the measured stresses in the lower chords. Recalling that these chords are designed only for axial stresses, it is noteworthy that the chords in both spans exhibited considerable bending, as evidenced by the differences in stresses at the top and bottom surfaces of the eyebars. This is also seen in Figure 51 for one eyebar. At the Span 1 and 9 west trusses, Tables 11 and 12, the bending stresses always exceeded the axial chord stresses; at the Span 9 east truss, Table 13, the condition varied with train direction.

Tables 11 to 13 also show the effect that a train on a specific track had on both the nearby truss and on the opposite truss. A train on Track 2 (the eastmost track) produced stresses in the west truss lower chords no greater than one-half those produced by a train on Track 3 (the westmost track). Similarly, a train on Track 3 induced stresses in the east truss lower chords about fifty percent of those produced in the west truss.

The instrumented lower chords in Spans 1 and 9 were highly rated in the tightness inventory [7]. In Span 1, at L8L9-west, eyebars 1 and 2 were rated moderate and eyebars 3 and 4 were tight. Table 11 shows no effect of this difference. In Span 9, eyebar 1 at L0L1-west was rated moderate while eyebars 2 to 4 at L0L1-west and all eyebars at L0L1-east were tight. In conformity with these ratings, Tables 12 and 13 show an essentially uniform distribution of stress in the eyebars.

Based on these measured data, the effects of the test train (UIR 236) with 286K coal cars on the lower-chord eyebar stresses in Spans 1 and 9 can be summarized as:

- the test train as well as other coal trains produced a single large stress cycle with all other stress cycles during the train passage equal to about 1 ksi.
- the stresses resulting from the test train had no significant difference from those resulting from a train with 263K coal cars.
- both 286K and 263K coal trains resulted in higher stresses than mixed-freight or passenger trains.
- there was no discernible difference in the stresses resulting from the test train when that train had two locomotives at each end or only two front-end locomotives.

Diagonal Eyebar Stresses

The stresses in diagonal eyebars were measured in the deck- truss Spans 7 and 2. In Span 7, measurements were at L7-east and west. In Span 2, they were at L3, L5, L7, and U8, each east and west. At each location, the diagonals consisted of four parallel eyebars, but their size varied from location to location.

Span 7. Figure 53 depicts characteristics of data from the L7U8 diagonal eyebars as the 286K coal-car test train crossed Span 7. The figure shows records for a complete train crossing. The cross-section of each L7U8 eyebar is 12" x 1-13/16". Tables 14 and 15 give their measured stresses, at the west and east trusses respectively, for several trains. In general, with coal and freight trains, the stresses varied with the pattern shown in Figure 53. A rise to a high stress level occurred as a train entered the gage region, and this stress attenuated rapidly as the train exited the gage region. In between, consistent secondary stress cycles occurred as each car passed.

At the west truss, Table 14, the test train with 286K coal cars traveling on Track 3 induced an average axial stress in the eyebars of 5.7 ksi for travel both north and south. Regular heavy coal trains on Track 3 (UBT 352 and ULK 80E) induced average axial stresses of similar magnitude, 5.4 to 5.6 ksi. On one occasion, the simultaneous passage of an Amtrak train on Track 2 with UBT 352 raised the axial stress to 5.8 ksi. A coal train with less heavily filled cars (UBC 20) on Track 3 induced an average axial stress of 5.3 ksi. An Amtrak train traveling alone on Track 3 induced an average axial eyebar stress of 2.3 ksi at the west truss.

When the test train traveled on Track 2, the average axial stress in the west truss diagonal eyebars was reduced to 1.9 ksi.

A corresponding condition occurred at the east truss diagonal eyebars in Span 7, Table 15. When the test train traveled on Track 2, an average axial stress of 5.6 ksi again occurred. But when coal trains traveled on Track 3, the average axial stress in the east truss diagonal eyebars was reduced to 1.8-1.9 ksi with the test train and to 1.6-1.7 ksi with less heavily loaded coal trains. An exception was when the heavy coal train (UBT 352) on Track 3 and the Amtrak train on Track 2 crossed simultaneously and induced a stress of 3.6 ksi in the east truss diagonal eyebars.

The L7U8 diagonal eyebars in Span 7 exhibited little bending. The bending stress reached a 1-ksi level with the test train, but generally was about 0.5 ksi.

In terms of individual eyebars, the stresses at the west truss were slightly greater in Eyebars 2 and 3 than in Eyebars 1 and 4. This correlates with the tightness inventory [7] for the eyebars, where Eyebars 2 and 3 were rated moderate and 1 and 4 were loose. At the east truss, the correlation is less definite. There, Eyebar 1 had significantly lower stress than the others, while rated very loose and misaligned. But Eyebars 2, 3, and 4 had similar stresses although Eyebar 2 was rated loose and Eyebars 3 and 4 were tight.

Span 2. Tables 16 to 23 give the measured stresses in the Span 2 eyebar diagonals; Tables 16 and 17 for the 10" x 1-11/16" L3U2 eyebars, Tables 18 and 19 for the 10" x 1-5/16" L5U6 eyebars, and Tables 20 to 23 for the 12" x 1-13/16" L7U8 eyebars. Figures 54, 55, and 56 illustrate some specific pre-retrofit behaviors.

Figure 54 compares, for the 286K coal-car test train, the stress patterns that occurred at the three instrumented diagonal eyebar locations in Span 2; Figure 54a for the west truss and Figure 54b for the east truss. As seen, the behavior at both trusses at L5U6 was different from that at L3U2 and L7U8, and the latter two were similar. At L5U6, a stress reversal "spike" is evident at each end of the record, as the train entered and exited the gage region. These spikes significantly increased the maximum stress range. The secondary stress range was fairly consistent, however. The "spike" or rebound did not occur at L3U2 and L7U8. Small stress reversals sometimes occurred, as trains exited L3U2 and entered L7U8, but these were quite minor by comparison.

Figure 55 shows that a stress reversal at train entry also occurred at L5U6 east and west for passenger trains, but a rebound at train exit did not occur.

The big difference in diagonal eyebar behavior at L5U6 is not thought to be totally due to eyebar looseness or misalignment. According to the tightness inventory [7], the L5U6 eyebars, east and west, were rated very loose (2), loose (2), and moderate (4). For comparison, the L3U2 eyebars, E and W, were rated loose (1), moderate (5), and tight (2); and the L7U8 eyebars, E and W, were rated loose (1), moderate (6), and tight (1). Although tightness was least at L5U6, the difference is thought inadequate to cause the rebound. Instead, we believe the difference is due to vertical motion that occurs at post L5U5, and which was one subject of the additional gages placed at FB5 in December 1997 and used in January 1998 measurements, and which is being addressed in retrofits that have been authorized for Span 2 at Panel Point 5 and adjacent panel points.

The L3U2 diagonal eyebars had average axial stresses, Tables 16 and 17, up to 5.3-5.4 ksi under both the 286K-car test train and a 263K train in both trusses. The peak axial stress range in an individual eyebar was 5.8-5.9 ksi, only slightly higher than the average. The east and west trusses were not much different in their behavior. Eyebar tightness did not appear to be a factor in the L3U2 members.

Distinctly different behaviors occurred in the east- and west-truss L5U6 members, Tables 18 and 19. The average axial stress in the west truss members was 3.1 ksi under the 286 K-car test train and 2.8 ksi under a 263K-car train. The corresponding peak axial stress in an individual bar was 4.8 ksi under the 286K train and 4.5 ksi under the 263K train. The east truss members had an average axial stress of 5.2 ksi under the 286K train with a peak individual eyebar value of 5.4 ksi. Comparable data was not acquired at the east truss for 263K-car trains because they generally were not on Track 2. However, in one event in January 1998, a 263K-car train produced a stress of 6.0 ksi at the top of Eyebar 4 at L5U6-east. The bottom gage on the eyebar was not monitored. Corresponding data from the same gage in November 1997 for the 286K-test train gave a stress of 6.1 ksi.

The axial stresses observed in the east-truss L5U6 members were more comparable to those in the diagonals at L3U2-east and west and, as will be seen, at L7U8-west than to the stresses in the west-truss L5U6 members. Under the 286K train the average axial stress values were 5.2 - 5.3 ksi at all locations except L5U6-west, where it was about 2.8 ksi. It was also apparent, when the train was on Track 3 adjacent to the west truss, that L5U6-east absorbed a higher proportion of the load than was apparent at other locations.

Tables 20 to 23 summarize the stresses that developed in the east- and west-truss L7U8 members. Gages installed at each end of the diagonals provided similar results. The average axial stress in the west truss members was 5.5 ksi (5.3@L7 and 5.7@U8) under the 286K train and 5.2 ksi (5.2@L7 and 5.1@U8) under a 263K train. The peak axial stress in an individual bar was 6.2 ksi under the 286K train and 5.5 ksi under the 263K train. The east truss axial stresses were higher; the average being 6.2 ksi (6.3@L7 and 6.1@U8) under the 286K train with individual bar stresses of 7.5 ksi at L7 and 8.0 ksi at U8. Bending in all these members was limited; not exceeding 0.7 ksi in L3U2 members, 2.0 ksi in L5U6 members, and 1.3 ksi in L7U8 members.

In one instance, a southbound MARC passenger train on Track 3 entered Span 2 just as the southbound 286K-car test train (UIR 236) was exiting on Track 2. The stress results are shown in Tables 20 and 21 for the west and east truss L7U8 members, respectively; and Figure 56 shows the stress patterns at L7U8 east and west as well as at L5U6 east. The tables show the stresses that occurred both before and during the passenger-train travel. At the east truss (near Track 2), the passenger train increased the axial stress only from 6.3 to 6.5 ksi; but at the west truss (near Track 3), the stress increased from 1.7 to 3.0 ksi. At west-truss panel point U8, the stresses in member L7U8 due to the test train, which were low because of the train's being on Track 2, were doubled by the effect of the passenger train. At east-truss panel point U8, however, the passenger train had little effect because it was on the westmost track. At a third panel point, east-truss panel point L5 on member L5U6, the passenger train again doubled the stress due to the test train. Since this is contrary to what happened at U8-east, the behavior at L5 possibly has the same cause as the rebound noted earlier as occurring at panel point 5. Overall, however, the results indicate that simultaneous trains have some additive effect at both trusses.

Summary. Based on these measured data, the effects of the 263K- and 286K-car coal trains on the diagonal eye bar members can be summarized as:

- the coal trains produce a stress response that is similar to that produced in the lower chord eyebars. A single large stress cycle results from the continuous train with smaller cycles corresponding to each car. The individual car cycles were generally less than 1 ksi.

- the variation in eyebar tightness at a particular truss did not have a major impact on the force carried by the individual eyebars when the train was on a track adjacent to the truss. The force variation was greater at the truss opposite the train.

- the largest force variations occurred at west-truss diagonals L5U6. These diagonals also resisted less force and had substantial bending stresses introduced during the entrance and exit of the train from the panel.

- the 286K coal train increased the average stress in the diagonals from 0.1 to 0.6 ksi beyond the response of a 263K coal train.

- the diagonals at L5U6 in Span 2 are shedding load to other components of the span due to the lack of engagement of vertical post at L5U5-West. This can be seen from the sums, below, of average axial stresses in east and west truss diagonal members under the 286K train. For L5U6 diagonals, the sum (which reflects the sum of the forces) is markedly less for Track 3 trains than for Track 2 trains. This is the consequence of load shedding. In contrast, the sums for Tracks 3 and 2 are about equal at other diagonals.

		Stress for Train on	
Span	Members	Track 3	Track 2
2	L3U2	6.9 ksi	7.1 ksi
2	L5U6	5.3 ksi	6.0 ksi
2	L7U8	7.3 ksi	8.0 ksi
7	L7U8	7.5 ksi	7.5 ksi

This load shedding is contributing to the observed damage in the floorbeam and its connection to the top chord. It is more pronounced when the trains are on Track 3 as the west truss is the primary source of the softening.

Stringer Stresses in Span 10

Stringer stresses midway between floorbeams and near floorbeam junctions were measured in the through-truss swing Span 10. The stringers were the exterior (A) and first interior (B) stringers at the west-truss or Track 3 side of the bridge. The stringer measurements were made between floorbeams 1 and 2, using gages mounted parallel to the stringers on the top surface of bottom flange angles. Stringers A and B are each built-up from a 51" x 1/2" web plate, four flange angles at 6" x 6" x 9/16", and one bottom flange coverplate at 16" x ½". As such, they each have a strong-axis moment of inertia of 24,760 in^4 and a corresponding section modulus of 1100 in^3 at the bottom surface. The coverplates were not part of the original construction but were added subsequently. Their effect is discussed later.

Between Floorbeams. Figure 57 depicts characteristic stringer data from midpoint between Floorbeams 1 and 2 as coal and freight trains crossed the through-truss swing span. Figure 57a is a partial record for the 286K test coal train and Figure 57b is for a regular coal train. The stress cycle that occurs with each coal car is the maximum stress cycle, and exhibits partial stress reversal (e.g. -0.75 ksi to + 4.5 ksi) indicating a degree of continuity for the "simple span" end connections. Moreover, it is greater than the stress cycle that occurs as the front locomotives entered the gage region. Figure 57c depicts data from the same gage for a passenger train. The primary stress range reverts to that due to the locomotive; and while the coaches exhibit a consistent, significant stress cycle, including some stress reversal, it is much less than that due to coal cars. The characteristics shown in Figure 57 are representative of all Span 10 stringer data from gages midway between floorbeams for trains traveling on Track 3, the west-most track. A major stress cycle occurred with each rail car or coach, and a smaller stress cycle occurred between the axles of adjacent cars or coaches. Trains traveling on Track 2 caused a flatter cyclic response than trains on Track 3 with a stress range that was an order of magnitude smaller.

Table 24 gives the maximum stress range and the mean stress that occurred with the test train (286K coal cars), other coal trains, and passenger trains. When the test train was on Track 3, the maximum stress range varied between 4.7 and 5.4 ksi. With other coal trains, the maximum range was essentially the same, 4.1 to 5.3 ksi. There was generally some difference in stress measured on the opposite flanges of a stringer. This is probably a function of a difference in the amount of section loss on each flange. The magnitude of measured stress ranges in the stringers suggests that the cross-section properties of the welded coverplates and angles were fully effective.

While the exterior stringer A generally had a slightly greater stress range than the interior stringer B, the difference was only about 0.5 ksi. The mean stress, shown in Table 24, was always a tensile stress and was also less than half the maximum stress range, for trains on Track 3. This is indicative of the maximum stress range at the gages being primarily a tensile stress cycle but also including some stress reversal into compression, as is apparent in Figure 57.

Adjacent to Floorbeam. Table 25 gives the maximum stress range and the mean stress that occurred at stringer gages adjacent to Floorbeam 2 where the welded coverplate terminated. The general character of the data records was the same as depicted in Figure 57; only the values of mean stress and maximum stress range changed, as illustrated in Figure 58 for both the 286K-car test train and a 263K coal train. Adjacent to the floorbeam, trains on Track 3 induced negative bending and, consequently, compressive mean stresses and primarily compression stress cycles in the stringers, as seen in Figure 58a. Moreover, as would be expected, the maximum stress range adjacent to the floorbeam was less (33 to 67 percent) than at midway between floorbeams. One difference noted in Table 25, however, was that the stresses in the interior stringer B were consistently greater than in stringer A.

Trains on Track 2 induced smaller stresses in the stringers adjacent to the floorbeam than did trains on Track 3, but these stresses were at least double those induced by Track 2 trains in stringers midway between floorbeams. Nevertheless, stresses from Track 2 trains did not exceed about 2 ksi.

Effect of Stringer Coverplates. The coverplates on the stringers were welded to the outstanding legs of the bottom flange angles after severely corroded flange areas had been trimmed away. In some cases, a considerable part of an outstanding angle leg was involved (Figure 6c). In other locations, a smaller part of the outstanding leg was cut away, usually with a transition. The 16" x 1/2" coverplates were welded to the stringers with continuous fillet welds along the edge of the remaining outstanding legs. This provided a continuous longitudinal weld that deviates at the trim areas but does not terminate. The compatibility condition is satisfied for flexural conformance so that the flange angles and attached coverplate are equally stressed. This condition is analogous to the use of intermittent fillet welds between the web and flanges of built-up beams, which has been well studied. When varying weld-segment lengths of 2 or 4 inches with gaps of 4 or 5 inches were tested in flexure, the test data all exceeded the category C fatigue resistance S-N curve [12]. We believe that the conditions that exist at the welded coverplated stringers along the length of the coverplate similarly provide a fatigue resistance that is Category C. At the weld termination, however, where the coverplate ends at the edge of the floorbeam flange, the fatigue resistance is defined by category E; that is, the classical coverplate termination with a large stress concentration effect.

Summary. Based on the measurements on the stringers in Span 10, the effects of trains on stringer stresses can be summarized as:

- The stringers acted as continuous beams with partial end fixity. This caused the end of the coverplates that were welded to the original trimmed flange angles to be subjected to a compression stress-range cycle. The stress range at the end of the coverplate provided a single cycle for each pair of adjacent trucks.

- At the stringer midspan where the coverplate was continuous, distinct partial reversal stress cycles occurred that corresponded to each pair of adjacent trucks. The 286K coal cars provided stress cycles that were 0.1 to 0.3 ksi larger than the 263K coal cars. The stress range for outside stringer A varied from 4.7 ksi to 5.4 ksi for all coal cars.

• Inside stringer B had consistently lower stresses that varied from 4.7 to 5.0 ksi.

• Because of the continuity of the stringers and their semi-rigid attachment to the floorbeam, distinct small stress cycles occurred when trains crossed on Track 2. The stress cycles were 0.4 to 0.5 ksi for coal cars and Amtrak trains.

• The level of stress range experienced by the stringers indicated that the welded coverplates were fully effective for cross-section properties as was a substantial portion of the flange angles.

• The possibility of fatigue damage appears to be small at the coverplate ends and along the continuous edge welds connecting the coverplates to the trimmed flange angles.

Stringer Stresses in Span 2

Top chord and interior stringer stresses were measured midway between floorbeams in deck-truss Span 2, at the west-truss or Track 3 side of the bridge. In Span 2, the top chord also serves as the outside stringer (see Figures 13 and 17). Stringer measurements were made between Floorbeams 8 and 9 where the axial stress in the chord is small and the flexural stresses can be assessed. Gages were mounted parallel to the west top chord (Stringer A) and west interior stringer (Stringer B) on the top surface of each and, in January 1998, also on the top surface of the bottom flanges for the top chord and transversely on the top surface of the top chord.

In panel U8U9 of Span 2 (and Spans 3 through 9), the top chord is built-up from a 38" x 1/2" top plate, two web plates each at 36" x 9/16", and four flange angles (two top and two bottom each at 6" x 4" x 1/2". Its strong-axis moment of inertia is, thus, about 14,110 in^4. Its top surface section modulus is, hence, 1002 in^3 and its bottom surface section modulus is 629 in^3. Stringer B is a W36 x 194 shape with a strong-axis moment of inertia of 12,100 in^4 and section modulus of 664 in^3.

Figures 59 and 60 show data records for the top chord and stringer, respectively, during the November measurements, for different trains. The records are generally similar. The primary stress cycle with coal trains is that recurring with each set of adjacent trucks, and the coal cars induce a larger stress cycle than the locomotives. With passenger trains, the locomotive induces the maximum stress cycle, however. Because the records in Figures 59 and 60 are for the top surfaces of the chord and stringer midway between floorbeams, the bending produces large compression stresses, as the figures show. The data records also show that, at the top chord, the primary stress cycle due to the rail cars included a partial stress reversal; whereas a stress reversal did not occur at the interior stringer.

The upper part of Table 26 lists maximum stress ranges for the various trains and gage locations during November. The maximum stress range at the top-chord centerline was 6.7 ksi, and at Stringer B was 8.4 ksi, for the 286K test train on Track 3. The table and Figures 59 and 60 indicate that the test train with 286K coal cars caused higher (about 1.0 ksi) stresses than a coal train with 263K coal cars. Stresses due to passenger trains were less. Table 26 shows, too, that the test train on Track 2 caused very little stress on the west top chord and interior stringer.

Some data from January measurements at the top chord are shown in Figure 61 and in the lower part of Table 26. Only limited data was obtained, and none from coal trains on Track 3. The records in the figure are for the west bottom flange of the top chord. The data shown at the top of the figure is for a mixed freight train and there is high variability in the magnitude of the railcar stress cycle due to a variability of car weights. (Conrail was unable to supply the car weights). The maximum stress cycles were, however, about 6.5 to 6.8 ksi at the top chord. A transverse stress of 2.7 ksi compression also occurred in the top chord with the Track 3 train (Table 26).

The data in Table 26 and the data records in Figure 61 also indicate that a longitudinal axial compression stress is introduced into top chord U8U9 when trains are on Track 2. Trains on Track 3 appear to cause higher axial stresses. This reduces the stress range in the bottom flange angles. Although the section modulus for the top chord's bottom surface is only 60 percent of that at the top surface, Table 26 demonstrates that the top chord tension-stress range in the bottom flange angles is less than the compression-stress range in the top flange plate surface. Stresses in the top flange plate are complex because of the deformation of the wood crossties that bear on it. Their end rotation introduces transverse bending stresses as well as local distortion which has resulted in fatigue cracking of the coverplate.

Summary. Based on the measurements on the top chord and stringer in Span 2, the effects of trains on the top chord and stringer stresses can be summarized as:

- The end panel top chord U8U9 acts as a continuous beam in a frame consisting of the chord, end post, and bottom chord. The fixity of the end post to the bottom chord was verified in Spans 1 and 9.

- The end frame introduces axial force into the top chord which is apparent from the response of the west truss when trains are on Track 2.

- The top chord bending-stress ranges appeared to be similar in magnitude on the top surface coverplate and the bottom surface angles, contrary to their section modulus. The peak tensile stress range for the gross-section riveted bottom flange angle was 6.8 ksi under a mixed freight. The maximum stress range in the top flange under the 286K coal train was 7.0 ksi and under the 263K coal train was 6.7 ksi. The extrapolated bottom tension flange stresses appear comparable based on the locomotive responses in November and January.

- The maximum stress range on the net section of the bottom flange angles is estimated to be 7.3 ksi for the 286K coal cars and 7 ksi for the 263K coal cars, which exceed the constant amplitude fatigue resistance of AREA Section 7.3.4.2. Damage can be assessed using Section 7.3.4.2 for up to 10^8 cycles.

- Interior stringer B is a W36x194 shape without reinforcement. Lateral bracing consisting of single 3 ½ " x 3 ½ " x ½ " angles is attached to web plates on the stringer and top chord at about 1/3 of the depth (from the top) of the stringer. The maximum stress range at midspan between U8 and U9 was 8.4 ksi under the 286K coal cars and 7.6 ksi under the 263K coal cars.

Floorbeam Stresses in Swing Span 10

During October and November 1997, floorbeam stresses were measured in the swing Span 10 at Floorbeams 2 and 10 at the west truss.

Interior Floorbeam 2. Table 27 and Figure 62 provide data and partial records of the stresses measured on Floorbeam 2 beneath Track 3 for various trains. There was a primary stress cycle (tensile since the gages were at the bottom flange of the floorbeam), but the secondary cycles from each railcar were significant - generally being about one-half the primary cycle. The highest stress ocurred under the 286K coal-car test train (5.8 ksi). With the test train, the highest stress always occurred during railcar passage. However, as shown in Figure 62, for 263K-car coal train ULK 80E, the locomotives caused the highest stresses for lighter trains at some gage locations.

End Floorbeam 10. Table 28 and Figure 63 provide data and partial records of the stresses measured on Floorbeam 10 beneath Track 3 for the 286K-car test train and for a 263K-car coal train. The records show the variation in floorbeam stress from 26 inches west of midlength to about 43 inches west of the west flange tip of Stringer B, and on both sides of the floorbeam. The maximum measured stress generally occurred (Gage 25) in a region of heavy corrosion and was up to 5.3 ksi. The maximum cyclic railcar range occurred, however, at the end point of the bottom coverplate (Gage 19) and was about 4.2 ksi with the 286K-car test train.

Summary. Based on the measurements in Span 10, the fatigue limit is occasionally exceeded when the 286K train crosses the structure. The maximum gross section stress range is 6 ksi. However, this magnitude is only reached once per train, since the individual cars only cause up to 2.3 ksi at the interior floorbeam and up to 3.3 ksi at the end floorbeam.

The effective stress range on the net section for the variable load spectrum is less than 6 ksi. Hence, the floorbeams can resist 10^8 variable load cycles without cracking as noted in AREA 7.3.4.2.

Top Chord/Floorbeam Stresses in Span 2

During the November 1997 measurements, stresses at top chord/interior floorbeam junctions were measured in Span 2 at Floorbeam 5 east and west trusses and at Floorbeam 8 at the west truss. In January 1998, similar stresses were measured in Span 2 at Floorbeam 6, west truss; at Floorbeam 5, east and west trusses and midway between trusses, and at Floorbeam 8, east and west trusses. All of these interior floorbeams have the same configuration: An upper section that is a WT 18 x 150; a 42-½" x ½" web plate that is planar with the tee stem; two bottom flange angles at 6" x 6" x ½ "; and a bottom 14" x 5/8" coverplate. The computed gross-section moment of inertia is 52,998 in^4 and the section modulus for the bottom of the floorbeams is 1,500 in^3.

During the November and January measurements, the junctions between the floorbeams and top chord consisted of a lateral connection plate riveted to the cover-plated floorbeam below and, through a fill plate, to the bottom flange of the top chord above. At Floorbeams 5 and 6, the lateral plate was 18″ x ½ ″ x 49″, the last dimension parallel to the top chord, and symmetric over the floorbeam. At Floorbeam 8, the lateral connection plate was 22″ x ½ ″ x 69″, with some non-symmetry in width and length at the floorbeam.

Floorbeam 5. During the November measurements, the Floorbeam 5 strain gages were located only on the floorbeam near its junction with the top chords, and not on the top chords. At the west truss, the gages were near the tip of an existing crack (N side) and near an existing crack arrest hole (S side), both being below the crack. At the east truss, even though no crack existed, gages were placed similarly to those at the west truss for comparison. Also, displacement gages were mounted at the west truss on both sides of the floorbeam to sense displacement between the vertical posts and the upper flange of the floorbeam (Figure 16).

Table 29 summarizes the measured stresses. At the west truss, the maximum primary stress range during two runs of the 286K coal-car test train was 4.1 ksi for trains on Track 3 and 3.5 ksi for trains on Track 2. For a 263K coal-car train on Track 3, the corresponding maximum stress range was 4.0 ksi. At the east truss, the corresponding maximum stress ranges were 0.5 ksi for the test trains on Track 3 and 1.0 for the test trains on Track 2. For the 263K coal train on Track 3, the maximum east-truss stress range was 0.6 ksi. With regard to the secondary stress ranges occurring with each coal car, the maximums at the west truss were 0.7 ksi with the 286K test trains and 0.5 ksi with the 263K coal train. At the east truss, the maximum was 0.4 ksi with the 286K test train. Figures 64 and 65 illustrate some data records from the floorbeam stress measurements.

The above measured stresses suggest that:

- There were only slight increases (0.2 ksi or less) in stress range caused by a 286K-car train compared to a 263K-car train, and
- The crack at the west truss is altering the load transfer in the floorbeam, since Track 2 trains induced larger stress ranges at the west truss than Track 3 trains induced at the east truss.

The upper part of Table 30 summarizes the November measured displacements between the vertical post and the floorbeam flange angle at the west truss, and Figures 66 and 67 show displacement records. With trains on Track 3, Figure 66, nominal compression occurred from the arrival of the train until its exit, corresponding to downward motion of the floorbeam flange relative to the vertical post. This suggests that the crack in the floorbeam web was open from the dead load and was pushed closed as the train crossed on Track 3. As the trains exited, however, there was one cycle of reversed motion. This exhibited the same characteristics as the diagonal member L5U6 of the west truss. There was no difference in behavior between the 286K- and the 263K-car trains. With trains on Track 2, Figure 67, nominal extension occurred and was prevalent for most the train's passage. This extension was about equal in value to the compression with Track 3 trains. There was a slight variation in behavior with Track 2 trains, depending on their direction of travel, Figure 67. A northbound train caused extension immediately upon arrival with a small reversal in motion upon exiting. A southbound train, however, had the small reversal in motion at its arrival. Figure 67 also shows that a coincident train, even a passenger train, alters the behavior significantly including the secondary cyclic displacement and the reversal in motion. This suggests that coincident trains may be an important serviceability consideration.

The measurement results verify that the relative movement between the vertical post and the top chord flange angle as a result of the gusset connection was introducing large distortion related stresses into the flange angle sufficient to initiate and propagate fatigue cracks.

During the January measurements, the Floorbeam 5/top chord strain gages were located on the interior bottom flange of the top chord, transverse to the flange, at both the east and west trusses (Figure 22). There were two flange locations for the gages; near the centerline of the floorbeam and near the north edge of the horizontal gusset plate between floorbeam and chord. In addition, there were longitudinal gages on the top and bottom flanges of the floorbeam midway between the east and west trusses (however, the top-flange gage system malfunctioned). Also, one displacement gage, used in November, was relocated to sense displacement between the vertical post and the web doubler plates on the top chord (Figure 27).

Table 31 summarizes the measured stresses for the limited data that was recorded. There were no 286K-car test trains in this period, and only one 263K-car train (UMP 108), which was on Track 2. The other trains were mixed freight and passenger trains. With the PIBA mixed freight train on Track 3, the maximum stress range on the top-chord flanges was 25.5 ksi at the west truss (Gage D16) and 6.8 ksi at the east truss (Gage D13). With an Amtrak passenger train, the corresponding results were maximum stress ranges of 23.0 ksi and 4.7 ksi. With trains on Track 2, the maximum stress ranges at the west truss on the top-chord flange at Gage D16 were 14.0 ksi for the 263 K -car train, 12.5 ksi for the BAPI mixed freight train, and 8.0 ksi for a passenger train. At the east truss, a corresponding result was obtained only for the passenger train and was 3.2 ksi. The secondary stress ranges at the west truss resulting from individual rail cars reached 12.0 ksi with a mixed freight train on Track 3 and 5.0 ksi with a 263K-car train on Track 2.

The stresses measured on the west top-chord bottom flange at Gage D16 and, to a lesser extent, at the east top-chord bottom flange at Gage D13 were high stresses. The stress records are shown in Figure 68a. Both gages were transverse to the flange length which suggests that significant flange bending was occurring where the top chord crossed over the floorbeam. As mentioned above, relative movement involving the vertical post and the top-chord flange was occurring at panel point 5, and these displacements are thought to have been the cause of the high top-chord bottom flange stresses.

The lower part of Table 30 summarizes the displacement data during January (at Gage D97) at the west truss, and Figure 68b shows the displacement records. There is one comparable case with the November data (the upper part of Table 30). Displacements for January 263K-car train UMP 108, southbound on Track 2, can be compared to 286K-test train UIR 236, run 7. The extensions during January at the top-chord web doubler plate (Figure 27) were greater than those during November at the floorbeam top flange (Figure 16); both, however, were less than 0.12 in.

Floorbeam 8. During the November measurements, gages were installed at west truss locations. One gage was longitudinal on the bottom flange of the top chord near to where the horizontal gusset plate ends and two gages were on the floorbeam and parallel to its length. These latter gages were at the same cross-section, one at the top-flange centerline and the other on the bottom flange, about 30 inches from the flange tip of the interior stringer.

Table 32 summarizes the measured stresses at the gages and Figures 69 and 70 shows partial data records for trains. With trains on Track 3, the locomotives caused stress reversal cycles at the top chord gage for both the coal and passenger trains. Subsequent to the locomotives, however, the cyclic stress records for the top chord were essentially uniform under rail cars. At the floorbeam, major perturbations with the locomotives was not observed. With trains on Track 2, the stress cycles at the west truss are smoother and smaller (Figure 70). However, the nature of the floorbeam stresses changed. Whereas the top flange was in compression and the bottom flange in tension with a Track 3 train, the top flange had a near-zero compressive stress and the bottom flange stress was largely in compression with a Track 2 train, Figure 70. Thus, positive bending at the west end of the floorbeam occurred with Track 3 trains and negative bending with Track 2 trains.

The maximum stress ranges that were measured in the top chord were 2.8 ksi with the 286K-car test train and 2.5 ksi with a 263K-car train. The response observed in Figures 69a and b confirms the continuous beam behavior of the top chord at U8. Once the locomotive crossed, the subsequent coal cars produced compressive stress cycles. The Amtrak train resulted in a reversal under the locomotive but tension stress cycles under the cars. This difference in behavior appears related to the distance between trucks for the two types of cars.

In the floorbeam, the maximum stress ranges were 2.4 ksi and 2.3 ksi, respectively, for the 286K-car test train and the 263K-car train. With a passenger train, the maximum stress ranges were 1.8 ksi in the top chord and 1.6 ksi in the floorbeam.

During the January measurements, two strain gages from the earlier measurements were repeated (on the west top chord bottom flange and on the west end of the top flange of the floorbeam) and, additionally, new gages were placed on the interior bottom flange of both west and east top chords transverse to the chord length to further examine top chord/floorbeam interaction. Also, a displacement gage was mounted between the west vertical post and the bottom edges of the top chord web doubler plates, Figure 20.

Table 33 lists the measured stresses and Figure 69d shows a data record. No heavy coal trains traveled on Track 3 during the measurement period. Hence, the maximum stress range at the west top chord was only 1.5 ksi (with a mixed-freight train) compared to 2.8 ksi with a 286 K-car test train. However, the floorbeam stress range was up in January, reaching 3.0 ksi compared to 2.4 ksi.

At the new gages transverse to the chord length on the bottom flange angles, tension maximum stress ranges of 1.9 ksi and 1.0 ksi occurred at the west and east trusses, respectively, with a Track 3 mixed-freight train, confirming out-of-plane bending of these flange projections and the potential for cracking in the top-chord bottom flanges.

The displacement measurements at Floorbeam 8, Table 34, show that, with trains on Track 3, the relative motion was essentially extension between the vertical post and the web doubler plates on the top chord. For trains on Track 2, the relative motion was compression and was much less.

Floorbeam 6. Two gages were installed in December at this west-truss top chord/floorbeam junction and measurements made in January. Both gages were on the interior bottom flange of the top chord, transverse to the flange (parallel to the floorbeam), and near the centerline of the floorbeam, However, the gages performed erratically and very little reliable data was obtained as a result of extensive rainfall during the measurement period.

Figure 71 shows the reliable data records. For the mixed freight train (PABI) on Track 3, the maximum stress range (at Gage D11) of 3.7 ksi involved a minimum stress of 1.2 ksi compression and a maximum stress of 2.5 ksi tension. Due to the variability in car weights, the nominal mean stress was less than about 1.8 ksi tension and the secondary stress range due to the individual cars was less than about 2.0 ksi. With a passenger train on Track 3, the maximum stress range (at Gage D10) was 5.7 ksi involving a zero minimum stress and a maximum tensile stress due to the locomotive. The nominal mean stress due to the cars was about 2.5 ksi with a cyclic range not exceeding 2.0 ksi. With a passenger train on Track 2, the stresses were reduced and reversed in character. A maximum stress range of 1.4 ksi involved a minimum stress of 1.1 ksi compression and a maximum stress 0.3 ksi tension.

Top Chord/Floorbeam Stresses in Spans 7 and 1

During the October and November 1997 measurements, stresses at top chord/floorbeam junctions were measured in Span 7 at Floorbeam 5, west truss. In January and, after the July retrofits, in August 1998, similar stresses were measured in Span 1 at Floorbeam 8, west truss. The lateral connection plate between Floorbeam 5 and the top chord in Span 7 was identical to that at Floorbeam 5 in Span 2. At Floorbeam 8 in Span 1, the lateral connection plate was 23″ x ½ ″ x 60″, with non-symmetry in both width and length at the floorbeam. The lateral plates in Spans 7 and 1 were not involved in the July retrofits.

Span 7, Floorbeam 5. At this west-truss top chord/interior floorbeam junction, two types of cracks existed and gages were placed near the crack tips. At the top chord, a long crack was present on the interior bottom flange angle near the angle fillet, Figure 11; its length was about equal to the width of the lateral gusset plate that is between the floorbeam and the bottom flange angle. The second crack existed in the floorbeam web emanating in the original top flange of the floorbeam and moving into the tee-section that is now the upper part of the floorbeam, Figure 11. Floorbeams in Span 7 have the same as-built properties as those in Span 2.

Table 35 shows the measured stresses produced by the 286K coal-car test train, three 263K coal trains, and two passenger trains. Figures 72 to 74 show several data records for different train conditions. At the crack tip in the floorbeam web, the nominal coal-train stresses were compressive, ranging from 6.0 to 9.6 ksi. However, as a train entered and exited the gage region, large stress 'spikes' occurred and were opposite in direction at the entrance and exit times. For trains on Track 3, these stress 'spikes' ranged from 48.0 to 52.8 ksi compression, and from 19.5 to 26.4 ksi tension, producing a once-per-train stress cycle varying from 67.5 to 76.8 ksi. (Recalling that strains are measured by the gages, and simply converted to stress by multiplying by 30,000 ksi to obtain stress, it may be that these high calculated stresses are really pseudostresses suggestive of plastic flow occurring at the gage site.) For a train on Track 2, the stress spikes still occurred but their magnitudes were much smaller, 26.4 ksi compression and 12.0 ksi tension, and the resulting stress cycle was, hence, also less, 38.4 ksi.

For trains on Track 3, a variation in the 'spikes' occurred. As illustrated in Figure 72, southbound trains on Track 3 caused a compression spike upon entering and a tension spike upon leaving the gage area. With the northbound train, however, the reverse occurred.

Slow crack extension in the floorbeam web is primarily related to the tensile component of the stress cycles which occur once under each train as illustrated in Figures 72, 73 and 74 for Gage 86. The tensile cycles occurs with trains on Track 2 or Track 3. If yielding develops during the large compression excursions this will create a tensile residual stress field which in turn will cause a portion of the compression stress cycles to contribute to crack extension. The 286K-car coal trains on Track 3 produced tension stress cycles between 24 ksi and 26.4 ksi. The 263K-car coal trains on Track 3 produced stress cycles between 19.5 ksi and 24 ksi. The Amtrak train on Track 3 produced a tension stress cycle of 9.3 ksi. These large stress cycles appear to be related to a lack of engagement of post L5U5 of the west truss with lower panel point L5. The same behavior was observed in Span 2 and resulted in similar cracking of the floorbeam web and the top chord bottom flange angle.

Although no measurements were made in Span 7 on the diagonals framing into L5, it is apparent from Figure 72 that the behavior exhibited at Gage 86 on the floorbeam web at the crack tip had characteristics somewhat similar to that recorded by gages in Span 2 on diagonal eyebars for member L5U6 (see Figures 54a & b).

Span 1, Floorbeam 8. As a result of heavy rainfall limited measurements were successful at this west-truss top chord/interior floorbeam junction in January 1998. There was no test train with 286K coal cars, and while there were two 263K coal trains, as well as mixed freight and passenger trains, only one mixed freight and one passenger train were on Track 3. The interior floorbeams in Span 1 consist of an upper section that is a WT 18 x 97; a 42" x ½ " web plate that is planar with the tee stem; and two bottom flange angles at 6" x 6" x 9/16". There are no coverplates. The computed gross-section moment of inertia is 34,001 in^4 and the section modulus for the bottom of the floorbeams is 1038 in^3.

Table 36 provides data. With the mixed freight train on Track 3, the top chord, just above the floorbeam, had a maximum stress range of 10.5 ksi compression in its bottom flange angle (Gage D26). Because the gage was parallel to the floorbeam (or transverse to the flange angle leg), it appears that the angle leg was bending upward under the train load. With a passenger train on Track 3, this stress diminished to 6.5 ksi, and with all trains on Track 2 the stress did not exceed 3.8 ksi. On the floorbeam, the maximum stress range at the top flange (Gage D27) and on the fill plate near the top flange (Gage D28) did not exceed 4.5 ksi with trains on Track 3 and 2.7 ksi with trains on Track 2.

Figures 75a and b show the data records for the mixed freight train and the passenger train on Track 3. The variability in freight car weights is evident from the non-regular nature of the records in Figure 75a. Figure 75c shows the records for the 263K coal train on Track 2. The overall character of the stresses (compression or tension) is the same, but the coal train provided a primary stress cycle with a regular pattern of secondary cycles.

Floorbeam Summary for Deck Spans 1, 2 and 7.

Based on the measurements in Spans 1, 2 and 7, the effects of the 263K and 286K coal trains on the floorbeams and their connections to the top chord and hanger can be summarized as:

• Where cracking has developed in the floorbeam and its top chord connection, an inadequate connection between the vertical post and bottom chord appears to have promoted out-of-plane deformation in the floorbeam. This is most severe at panel points U5 and L5. The condition in Span 7 was more severe than in Span 2.

• The out-of-plane deformation initiates cracks in the top chord bottom flange angle and in the floorbeam top flange angles and web in the gap between the end connection angles and the flange angles.

• The damaged connections promote load shedding in the eyebar diagonals that frame into the top chord panel point connections, particularly at U5. Although no measurements were acquired at U4, similar behavior is expected.

• The measurements at panel points U6 and U8 were not as conclusive. The deformation and stresses at FB8 in Span 2 were small and would not lead to cracking. However in Span 1, limited measurements were up to 10 times as great and cracking has occurred in the floorbeam. The measurements at FB6 in Span 2 were bounded by the measurements at FB8 in Spans 1 and 2.

Vertical Post Stresses

Stresses in the vertical posts L5U5 in Span 2 were measured during January at both the west and east trusses. Four strain gages were mounted vertically on each post, one at each corner angle and midway between lattice bar connections (Figure 29), to measure axial stresses and post bending. The gages were about 10 feet above the lower-chord pins, Figure 28. Each post consists of four 4" x 4" x ½" corner angles. A plate 20" x ½" connects each pair of angles, and these pairs are then connected by laced lattice bars. Discounting the lattice bars, each post has a 35 sq-in cross section.

Tables 37 and 38 list the maximum stress, minimum stress, and maximum stress range measured at the west and east trusses, respectively. Figures 76 and 77 show data records from the west truss, and Figures 78 and 79 show data records from the east truss. There were no coal trains on Track 3 (at the west truss) during the measurements, although there was one 263K-car train on Track 2.

West Post. Here the SE corner angle invariably had a higher stress range than the other three corner angles, under both Track 3 and Track 2 trains, Table 37. The maximum stress range at the SE corner angles was 5.8 ksi (under a Track 3 PIBA mixed-freight train), while the corresponding average stress range for all four corners was 4.2 ksi. Generally, the two north corner angles had about equal stress, while the two south corner angles had higher stress ranges. This suggests that N-S bending of the post occurs under train load, but that E-W bending of the post is small.

Figure 76 shows the data records at all four corners under the PIBA train. The maximum stresses occurred as the locomotives passed, but other significant stress cycles also occurred. Moreover, the N-S bending is quite apparent, with the N-corner records clearly being out-of-phase with the S-corner records. Figure 80a shows the instantaneous stress distribution in the west post at the maximum response in Figure 76 occurred as the locomotive crossed the floorbeam. The average axial compression stress in the post was 0.68 ksi. Bending in the North-South direction is dominant. As is apparent in Figure 76, the post is primarily acting as a bending member as a result of the free movement at the lower chord Joint L5. Figure 77 compares data records for one (SE) corner angle for Track 3 and Track 2 trains, and for both NB and SB trains on Track 2. The SB coal train (UMP 108) provided a regular secondary stress cycle due to cars. It also exhibited a stress reversal while exiting the gage area. This contrasts with the NB mixed freight train (BAPI) which exhibited a stress reversal when entering the gage region.

The difference in stress reversal time and, in fact, the N-S bending could be due to the difference in members framing into post L5U5. On the north side of post L5U5, 2-in-sq diagonal counter bars frame into the post, whereas on the south side of post L5U5, a much stiffer set of four 6" x 4" x 5/8" angles frame into the post.

East Post. Results at the east post differed in some respects from those at the west post. Some N-S bending is again evident from maximum stress range data in Table 38. However, unlike the behavior at the west post, the data records in Figure 78 for the BAPI mixed-freight train show that the stresses at all four corner angles were in-phase. Figure 80b shows the instantaneous stress distribution in the east post for the maximum locomotive response shown in Figure 78. The average axial stress in the post was - 2.8 ksi which is four times greater than the axial stress found in the west post. It is also apparent in Figure 78 that the largest tension stress occurs in all four corners when the train leaves the span. Further, the north corner angles had higher stress ranges than the south corner angles with Track 2 trains. The reverse was true with Track 3 trains, Table 38. A maximum stress range of 4.0 ksi occurred at the NW corner angle under both a 263K-car coal train (UMP 108) and a mixed freight train (BAPI), while the corresponding average stress range for all four corners was 3.3 ksi and 3.2 ksi for the two trains, respectively.

Figure 79 compares the east-post data records for one (SE) corner angle for Track 3 and Track 2 trains, and for both NB and SB trains on Track 2. The only behavioral difference from the west post was that a stress reversal occurred as the coal train (UMP 108)entered the gage area and as the mixed-freight train exited the area. The west-post behavior was opposite.

Summary. N-S bending occurred at both west and east posts L5U5, probably due to the geometry and stiffness differences of members framing into the posts on their north and south sides. The bending was most pronounced at the west post, where the stresses in the north corner angles were out-of-phase with the stresses in the south corner angles. The lack of resistance at the west lower chord joint L5 reduces the axial resistance in the post and permits distortion to occur. This appears to be the primary cause for the reduction in the axial stress in the post as well as the large bending stress that is apparent in the west post. The east post behavior was consistent with the expected response of the structural system.

The maximum stress range in any corner angle was 5.8 ksi at the west post and 4.0 ksi at the east post.

Post-Retrofit/Lubrication Measurement Data

Lower-Chord Eyebar Stresses

After the retrofits, lower-chord eyebar stresses were measured again in Span 1 at L9-west; and also in Span 2 at L5-west and at L9-west. The Span 2 measurements were made on the two middle eyebars at each location; eyebars 5 and 6 on L4L5 (each 12″ x 1- ½ ″), eyebars 4 and 5 on L5L6 (each 12″ x 2- 3/16 ″), and eyebars 2 and 3 on L8L9 (each 12″ x 1-5/8″).

Span 1, Lower Chord L8L9-West. Figure 81 depicts records of measured lower-chord stresses at L8L9-west in Span 1 during coal-train passage in August 1998 after lubrication maintenance had been performed at the pin at panel point L9-west. Stresses at the top edges of the eyebars (Gages 100-103) are in each case tensile, while stresses at the bottom edges of the eyebars (Gages 104-107) are compressive. (Gage 106 drifted badly and should be ignored.) Thus, bending of these lower-chord eyebars was not eliminated by the pin lubrication. Table 39 summarizes the stresses for all the trains and shows the axial and bending components.

A comparison of the August data in Table 39 for the two 80-car coal trains southbound on Track 3 shows the variability that occurred. With train UMP 110, maximum top edge stresses of 5.2 to 7.5 ksi occurred whereas with train UMP 74B, the maximum top edge stresses were 4.8 to 6.0 ksi. This stress difference is regarded as a normal spread, since the difference in range of car weights (Table 10) and a minor difference in train speed would not cause the stress difference. The 128-car coal train ULK 66C southbound on Track 2 resulted in maximum top edge lower-chord stresses of 2.5 to 3.5 ksi, or roughly one-half the stress induced by trains on Track 3.

A comparison of the results in Table 39 with those in Table 11 for pre-lubrication conditions shows that both the axial and bending stresses after lubrication were about half those recorded in November 1997 before pin lubrication. For example, 286K coal train UIR 236 and 263K coal train ULK 84F southbound on Track 3 in November had axial and bending stresses of 3.4-3.5 and 8.4-8.5 ksi, respectively, whereas coal trains UMP 74B and UMP 110 in August had axial and bending stresses of 1.1-1.5 and 4.3-5.0 ksi, respectively. While the August trains had moderately lighter coal cars (max weights of 262K and 246K) than the November trains, the weight difference does not fully explain the diminished stress. Similar results occurred with Amtrak trains southbound on Track 3; with Amtrak M121 in November, the axial and bending stresses were 1.7 and 4.4 ksi, respectively, whereas with Amtrak 97 and 175 in August, they were 0.6-1.2 and 3.2-3.5 ksi, respectively. Similar results also occurred with trains southbound on Track 2; c.f. the results for 263K coal train ULK 66C in August (Table 39) and those for 286K coal UIR 236, run 5, in November (Table 11). Thus, the pin lubrication at L9-west in Span 1, although not eliminating bending, had an overall benefit of lowering both axial and bending stresses.

Span 2, Lower Chords at L5-West. Lower chord L4L5-West framing into retrofitted panel points L4 and L5 is characterized by having 10 parallel eyebars, equal in depth at 12 ″ but varying in width. The four middle bars in the group, including the two central ones which had strain gages, are 1 ½″ wide, one bar on each side to the four middle bars is 1 ⅞″ wide, and the external two bars on each side of the middle six are 1 ⅝″ wide. A photo of the L4L5 eyebars (with strain gages on the two central bars) is given in Figure 42a.

Table 40 summarizes the maximum stresses recorded on the L4L5 lower chord. For all the trains, the axial stress was dominant, although never exceeding 3.7 ksi. Moreover, the average bending stress was less than 0.6 ksi and never exceeded about 25 percent of the axial stress, although it always added to the axial tension at the bottom of the eyebars. The two 80-car coal trains (UMP 74B and UMP 110) southbound on Track 3 caused the maximum axial stresses of 3.7 and 3.4 ksi and bending stress of 0.6 ksi. The northbound empty coal train (XSM 43E) on Track 3 induced axial stresses of 2.8 ksi and 0.6 ksi, respectively, due to its locomotives and empty cars; these stress levels may, therefore, be considered the minimum under this type of Conrail locomotive (the locomotive was #5577) and empty coal car. The maximum stresses due to passenger trains were 2.3 ksi axial and 0.4 ksi bending, and occurred due to an Amtrak locomotive southbound on Track 3. Figure 82 shows representative stress records for coal train UMP 74B, empty train XSM 43E, and Amtrak train #97.

Lower chord <u>L5L6-West</u> framing into the retrofitted panel point L5 is characterized by having 8 parallel eyebars, equal in depth at 12″ but varying in width. The two middle bars in the group, which had strain gages, are 2 3/16″ wide, one bar on each side to the two middle bars is 1 7/8″ wide, and the external two bars on each side of the middle four are 1 ½″ wide. Photos of the L5L6 eyebars (during strain gage installation) are given in Figure 42b.

Table 41 summarizes the maximum stresses recorded on the L5L6 lower chord. For all the trains, the axial stress was dominant, although never exceeding 3.6 ksi. Moreover, the average bending stress was less than 0.5 ksi and never exceeded about 25 percent of the axial stress, although it always added to the axial tension at the bottom of the eyebars. The two 80-car coal trains (UMP 74B and UMP 110) southbound on Track 3 caused the maximum average axial stresses of 3.5 ksi and bending stress of 0.5 ksi. The northbound empty coal train (XSM 43E) on Track 3 induced an axial stresses of 3.1 ksi and 0.2 ksi, respectively, due to its locomotives and empty cars; these stress levels may, therefore, be considered the minimum under this type of Conrail locomotive (the locomotive was #5577) and empty coal car. The maximum stresses due to passenger trains was 2.2 ksi axial and 0.2 ksi bending, and occurred with an Amtrak locomotive southbound on Track 3. Figure 83 shows the stress records for coal train UMP 74B, empty train XSM 43E, and Amtrak train #97.

<u>Summary</u>. Although pre-retrofit stress records were not obtained for lower chords L4L5 and L5L6, the test results demonstrated that the Type 1 retrofit (the rigid bearing assembly) at L5 did not adversely influence the eyebar behavior. Fixity at the panel point after the retrofit was minor, as only small bending stress was measured in the lower chords.

<u>Span 2, Lower Chord L8L9-West.</u> Lower chord L8L9 is characterized by having 4 parallel eyebars, equal in depth and width at 12 ″ x 1 5/8″. The two middle bars in the group had strain gages, Figure 43.

Table 42 summarizes the maximum stresses recorded on the L8L9 lower chord. For all the trains, the axial stress was dominant, although never exceeding 1.9 ksi. The average bending stress was higher than on other lower chords, achieving a level of 1.6 ksi. Moreover, it generally was about equal to the axial stress. Also, the bending was such to add to the axial tension at the top of the eyebars, an opposite behavior to that for lower chords framing into L5 in Span 2, but a similar behavior to that for lower chords L8L9 in Span 1. The two 80-car coal trains (UMP 74B and UMP 110) southbound on Track 3 caused the maximum average bending stresses 1.4 - 1.6 ksi. But the northbound empty coal train (XSM 43E) on Track 3 induced the maximum average axial stresses of 1.9 ksi due to its locomotives. The maximum average stresses due to passenger trains was 1.2 ksi axial and 0.8 ksi bending. Figure 84 shows the stress records for coal train UMP 74B, empty train XSM 43E, and Amtrak train #97.

Pre-retrofit stress records were not attained for lower chords L8L9 in Span 2. However, a post-retrofit comparison for lower chords L8L9-West in Spans 1 and 2 may be made. A comparison of the test results summarized in Table 39 for Span 1 with those for Span 2 in Table 42 indicates that the average axial stresses in the chords were about the same for the same train. The bending stresses in Span 1 were significantly higher (about 3x), however, than in Span 2. This indicates that, after accounting for the differences in cross-sectional stiffness of the eyebars in Spans 1 and 2, the rotational stiffness (measured stress divided by modulus x moment of inertia) in Span 1 was about seven times as great as in Span 2.

Diagonal Eyebar Stresses in Span 2

In August 1998 after the retrofits, stresses in the Span 2 diagonal eyebars L5U6-east and west were again recorded by strain gages near L5, because both Type 1 and Type 2 retrofits were installed at Panel Points 5, and Type 1 retrofits were installed at Panel Point U6-east.

L5U6-West. Table 43 summarizes the post-retrofit stresses in the four eyebar diagonals L5U6-west. The peak bending stress range averaged 0.2 ksi or less, for both coal and passenger trains. The peak axial stress range was 4.3-4.4 ksi for coal trains UMP 74B and UMP 110 southbound on Track 3, and 2.5-3.5 for passenger trains southbound or northbound on Track 3. The peak axial stress range for the empty coal train XSM 43E northbound on Track 3 was 3.9 ksi. For coal train ULK 66C southbound on Track 2, the peak axial stress range was much lower, 1.6 ksi.

In the train records depicted in Figure 85, it is observed that southbound trains caused an initial compressive stress cycle upon entering the gaged region and, in the case of southbound coal trains, a spike in tensile stress cycle upon exiting the gaged region. Northbound trains, in contrast, exhibited their compressive cycle upon exiting the gaged region. These stress-spike behaviors are consistent with those observed in November 1997 before the retrofits. Figure 85c shows that the northbound empty coal train (on Track 3) exhibited two compression cycles, one as the train exited the gaged region and a larger one as the locomotive exited the gaged region. Apparently, any rapid attenuation of large load is sufficient to cause a stress reversal cycle at this panel point.

The peak bending and axial stress ranges in August after the retrofits differ in several respects from earlier stress ranges in November, as shown by a comparison of Tables 43 and 18. The post-retrofit axial stresses were greater for trains on Track 3 than in November, 4.3 ksi (Aug.) vs 2.8 to 3.1 ksi (Nov.) for coal trains and 3.5 ksi vs 0.2 ksi for passenger trains. Likewise for coal trains on Track 2, the post-retrofit axial stresses were 1.6 ksi (Aug) vs 0.8 ksi (Nov). On the other hand, the bending stresses in November, 1.3 ksi for coal trains on Track 3, were virtually eliminated by the retrofits. Also, significantly, the August stresses are quite uniform across the four bars, whereas in

November, non-uniformity was prevalent especially in Eyebars 1 and 2. Thus, relative to bending and uniformity, the retrofits restored the normal, expected behavior of these diagonals.

L5U6-East. Table 44 summarizes the post-retrofit stresses in eyebar diagonals L5U6-east. Several gages malfunctioned, but based on the active gages, the peak bending stress range, as at L5U6-West, averaged 0.2 ksi or less, for both coal and passenger trains. The peak axial stress range occurred with trains on Track 2; 4.4 ksi for 263K coal train ULK66C and 2.8 ksi for passenger train MARC 536. Coal trains on Track 3 caused lower peak axial stress ranges of 1.2 to 1.9 ksi. The post-retrofit axial stress values are slightly lower than those measured in November (Table 19), when the corresponding stresses were 5.2 ksi (Track 2 coal trains) and 2.2 ksi (Track 3 coal trains). The bending stress range was also slightly higher in November, between 0.5 and 1.0 ksi.

The August train records in Figure 86 show initial compression stress cycles for southbound coal trains, both Track 2 and Track 3, followed by a tension stress peak. A tension stress peak also occurred as the trains exited the gaged region. The northbound passenger train had an initial tension stress peak followed by a small compression cycle. These records are similar to earlier records.

Figure 86a for Train ULK 66C shows zones of smaller stress cycles due to individual cars. The peak stress in these cycles remains unchanged from the adjacent zones of larger stress cycles but the minimum stress in the cycle increases resulting in a smaller overall cycle. This behavior occurred at many gage locations with Train ULK 66C and is discussed further in the section dealing with vertical posts L5U5.

Summary. The effect of the retrofits on L5U6 diagonal eyebar stresses was positive. The pre-retrofit load shedding noted on p. 24 was eliminated. This is seen, because the post-retrofit stresses at the L5U6-East eyebars were lower than pre-retrofit stresses, whereas the reverse occurred at the L5U6-West eyebars resulting in about equal sums of average axial stresses in the east and west diagonal members. Also, at L5U6-West, where the four bars were initially (from eyebar 4 to eyebar 1) loose, loose, moderate, and very loose (Table 18), it was reported [10] that, after the retrofit, Eyebars 2 and 1, which initially were laying against each other due to looseness, were now taut and essentially parallel. This explains why the stress distribution in the four L5U6-West eyebars changed from non-uniform to uniform, and why the bending stress in them was virtually eliminated.

Top Chord Stresses in Span 2

In August 1998 after the retrofits, the longitudinal top surface and bottom flange stresses in the Span 2 top chord U8U9-west were remeasured. The remeasurements were made partly because of the retrofits made at nearby panel points and the pin lubrication at Panel Point L9, and because several top chord gages malfunctioned in January.

Table 45 summarizes the results of the August measurements, and Figure 87 provides train records. Trains on Track 2 caused insignificant stresses. Trains on Track 3, however, induced stress cycles of up to 6.8 ksi on the bottom flanges and 5.1 ksi on the top surface of the top chord. Consistently, the stresses at the west edge of the chord, both on the bottom flange and on the top surface, were greater than at the east edge of the chord. This occurs, probably, because the east web of the chord and, therefore, the east edge, although being directly beneath a train rail, receives support from the floorbeam attachments at U8 and U9, whereas the west or exterior web of the chord has no underlying support by the floorbeams.

As observed in Figure 87, the stress cycle at the top surface of the chord was predominantly compression whereas at the bottom flange of the chord it was predominantly tension. With fully loaded coal trains, the maximum stress cycle occurred with each railcar; with passenger trains, the locomotive cycle was about 30 percent longer than the car cycle.

A comparison of the results in Table 45 with the pre-retrofit results given in Table 26 indicates that: (a) at the bottom flanges of the top chord, there is essentially no difference between the January and August results; (b) at the centerline of the top surface of the top chord, coal-train stresses in November were greater than in August (6.7 to 7.0 ksi vs 2.3 to 3.0 ksi) as were passenger train stresses (3.7 ksi vs 1.3 to 1.4); (c) at the east edge of the top surface, coal-train stresses in November were also greater than in August, but to a lesser degree (4.0 to 5.5 ksi vs 4.2 to 4.6 ksi); (d) whereas in August, the stresses at the east edge of the top surface exceeded those at the centerline, the opposite was true in November for coal trains (but not for passenger trains).

In summary, although there were some differences between November, January, and August stress results, the overall result was that the maximum stress range in the top chord was about 7.0 ksi both before and after the retrofits.

Top-Chord/Floorbeam Stresses in Span 2

Floorbeam 5-West. A summary of the stress results from the gages (Figure 30) at the new lateral connection plate (Type 2 retrofit) at Panel Point U5-West is given in Table 46. For trains on westmost Track 3, the maximum stress ranges were 3.0 ksi on the top-chord bottom flange (Gage 04.98) and 2.7 ksi on the lateral connection plate. The stress cycle on the bottom flange was always compressive, as would be expected in this negative moment region of the top chord. The stress cycles in the connection plate varied depending on gage location and orientation. Adjacent to the north splice plate, the longitudinal gage had a compression cycle, but the transverse gage had a tension cycle not exceeding 2.0 ksi. Over the edge of the floorbeam, the longitudinal gage had a reversing tension-compression cycle. Adjacent to the south splice plate, the longitudinal gage had a tension cycle. Although measurements made at Panel Point U5-West are near Track 3, stress cycles were also induced there by the 263K coal-car train ULK 66C on Track 2. In general, these latter stress cycles were about half of those from equivalent Track 3 trains.

Figure 88 shows the stress records for the southbound Track 3 coal train UMP 74B and passenger train Amtrak 97. There was generally a primary stress cycle and smaller secondary cycles caused by the railcars. Over the edge of the floorbeam, however, the secondary cycle was about equal to the primary cycle.

In general, the measurements verified that no large out-of-plane bending stresses were introduced into the lateral connection plate.

Floorbeam 5. To assist in evaluating the retrofit involving the new lateral connection plate at U5-W, three strain gages previously used at Floorbeam 5 were reinstated and a fourth (a displacement gage) was relocated to account for the new connection plate: (1) Gage 309 near the existing crack tip on the north side of the web of the FB near its junction with the top chord; (2 and 3) Gages D14 and D15 on the top and bottom flanges of the FB midway between the east and west posts; and (4) Displacement gage 70.98 between the top chord web and the top of the new connection plate above the FB (in January, this gage was designated D97, but was renamed in August because of its relocation). Table 47 summarizes the measurement results from these gages, whose locations are noted in Figures 15, 25, and 40.

The maximum displacement cycle (i.e., the vertical movement) between the vertical post and the new lateral connection plate was about 0.02 in. with coals trains on Track 3 and was primarily a downward motion of the post relative to the connection plate. Figure 89 shows displacement records from Gage 70.98 for the Track 2 coal train ULK 66C, the Track 3 coal train UMP 74B, and the Track 2 passenger train MARC 536. A comparison of the tabular displacement data from Gage 70.98, Table 47, with data from its predecessor gages (Table 30 for Gage D97 in January and Gages 397 and 398 in November) shows that the post-retrofit vertical movement was reduced significantly from previously.

The maximum stresses near the existing crack tip (Gage 309) were quite small for all trains (0.5 ksi or less). This contrasts favorably with the pre-retrofit stresses at the same gage; where, in November (Table 29), the stress range was 3.5 to 4.1 ksi for both Track 3 and Track 2 trains. Thus, the retrofit appears to have effectively reduced crack opening which controls the stress at the tip of the crack.

The August stresses at the midspan of FB5 were consistent with pre-retrofit measurements; maximum bending stresses of 2.5 ksi in Aug (Table 47) vs 2.2 ksi in Nov (Table 31) with coal trains, and 1.6 ksi in Aug vs 1.7 ksi in Nov. with passenger trains. Figure 90 shows stress records for the Track 2 coal train ULK 66C, the Track 3 coal train UMP 74B, and the Track 3 passenger train Amtrak 97. The bending is evident by comparing the tension on the bottom flange (Gage D14) with the compression on the top flange (Gage D15). In each case, though, the bottom flange experiences slightly greater primary stress range and a slightly greater secondary stress range per railcar.

Floorbeam 6-East. A summary of the stress results from the gages, Figure 39, at the new lateral connection plate (Type 2 retrofit) at Panel Point U6-East is given in Table 48. For coal trains on the eastmost Track 2, the maximum stress ranges were 3.5 ksi on the top-chord bottom flange (Gage 09.98) and 5.3 ksi on the lateral connection plate. For passenger trains on Track 2, the same maximum stress ranges were less, 1.7 and 2.2 ksi, respectively. The nature of the stress cycles, tension, compression, or reversing tension-compression, was the same as at FB 5-W. None of the out-of-plane stresses in the connection plate were significant.

Figure 91 shows the stress records for Track 2 trains, 263K coal-car train ULK 66C and passenger train MARC 536. As at FB5-W, there was generally a primary stress cycle and smaller secondary cycles caused by the railcars. The trains on Track 3 induced stress cycles at U6-East that were, in general, 30 to 60 percent less than those induced by equivalent Track 2 trains.

Top-Chord/Floorbeam Stresses in Span 1, Floorbeam 8

Stresses at the floorbeam/top chord junction at FB8-West in Span 1, previously measured in January, were remeasured in August to gain further data for that region and to learn whether any effect of the pin lubrication at Panel Point L9-West would be reflected in new data at U8-West. Moreover, this particular junction was the only pre-retrofit junction design for any span included in the August measurements. Table 49 summarizes the August results; the gage locations are given in Figure 47.

The maximum stress ranges (measured at Gage D26, transverse on the flange of the top chord) due to trains on the westmost Track 3 had maximum values of 9.8 to 10.2 ksi for coal trains and 5.4 to 6.3 ksi for passenger trains. These compare closely to the January measurements of 10.5 ksi and 6.5 ksi, respectively, for equivalent trains. The stresses induced by trains on Track 2 had similar agreement; for coal trains, 3.6 ksi (Aug) vs 3.8 ksi (Jan) and for passenger trains, 1.7 ksi (Aug) vs 1.0 ksi (Jan). Figure 92 depicts the stress records for coal train UMP 74B and passenger train Amtrak 97. Thus, stresses at this floorbeam / top chord junction were not influenced by pin lubrication at Panel Point L9-West.

Vertical Post Stresses in Span 2

L5U5. In August 1998 after the retrofits, the stresses in the vertical posts L5U5-east and west were remeasured, because Type 2 retrofits were installed at Panel Points U5 and Type 1 retrofits were installed at Panel Points L5.

Table 50 summarizes the stresses measured at post L5U5-west in August. The maximum stress ranges on the westmost track (Track 3) varied from 4.8 to 5.3 ksi for the three coal trains and from 2.6 to 3.5 ksi for three passenger trains. In comparison, the pre-retrofit maximum stress ranges measured in January at L5U5-west were 5.8 ksi and 4.5 ksi for mixed freight and passenger trains, respectively (Table 37).

A significant characteristic of the stresses is that, as seen in Table 50, with Track 3 trains, the north corner stresses at the post exceeded the south corner stresses by nearly a factor of two. In January (Table 37), however, the reverse occurred, as the south corner stresses exceeded the north corner stresses with Track 3 trains. Thus, north-to-south bending of the post was not eliminated by the retrofits, but its nature was changed. With trains on Track 2, the stresses at the south corners exceeded those at the north corners during both measurement periods, but these stresses were all quite small.

Also in August with trains on Track 3, the stress range at the NE corner (Gage D23) of the post consistently exceeded that at the NW corner (Gage D22), suggesting that east-to-west bending was occurring too.

Figure 93 illustrates stress records for corners NE (Gage D23) and SE (Gage D24) on post L5U5-west during August; (a) for coal train UMP 74B southbound on Track 3, (b) for empty coal train XSM 43E northbound on Track 3, and (c) for a passenger train northbound on Track 3. Caption (a) illustrates the north-to-south bending that occurs in the post, with the NE corner stress being both greater in tension (at onset of locomotive) and greater in compression (for the duration of the coal cars) than the SE corner stress. Caption (b) shows essentially the same result, except that the northbound direction of the train moved the tension stress spike from entry of the locomotive to its exit. Caption (c) shows the same north-to-south bending result even for a passenger train.

A comparison of the post-retrofit data records shown in Figures 93 with the pre-retrofit records shown in Figures 76 and 77 shows that the west vertical post was restored to a primary compression member by the retrofits. Prior to the retrofits the degree of stress reversal was much greater than is apparent after the retrofits. Both coal and passenger traffic created primarily compression stress cycles in August.

Table 51 summarizes the stresses measured at post L5U5-east. For the east post, the maximum stress ranges occurred, as expected, with trains on the eastmost track, Track 2. With the southbound coal train ULK 66C, the maximum stress range was 4.9 ksi and with northbound passenger train MARC 536, it was 2.5 ksi. In both cases, the NE and NW corners of the post had maximum stresses which were essentially equal at both corners. Thus, bending seems to be limited to a north-to-south action due to Track 2 trains. For trains on Track 3, the east post stress ranges did not exceed 1.4 ksi. With Track 3 trains, however, the NW and SW corners had essentially equal and slightly higher stresses than the NE and SE corners. Thus, Track 3 trains seemed to induce some slight east-to-west bending in the east post.

The east post stress behavior in August were generally consistent with the pre-retrofit behavior (Table 38) in January, although the maximum stress ranges in January were less; 4.0 ksi for freight and coal trains and 2.0 ksi for passenger trains.

Figure 94 illustrates stress records for corners NW (Gage D19) and SW (Gage D20) on post L5U5-east during August; (a) for coal train ULK 66C southbound on Track 2, (b) coal train UMP 74B southbound on Track 3, and (c) a passenger train northbound on Track 2. Caption (a) illustrates that the north-to-south bending that occurs in the post, with the NW corner stress being either greater in tension (at onset of locomotive) or greater in compression (for the duration of the coal cars) than the SW corner stress. An effect of coal-car construction is also exhibited and is explained shortly. Caption (b) shows a reversed effect for a southbound train on Track 3; bending still occurs, but the SW corner stress is greater in compression than the NW corner stress. Caption (c) a passenger train shows the greater compressive stress for a locomotive at the NW corner than at the SW corner, but the car stresses contribute little bending.

The general behavior of the east post was consistent with and confirms visual observations that no significant relative movement had developed in the east post at panel point L5. This suggests that little is gained with a Type 1 retrofit if there is not evidence of relative movement at the lower chord connection.

Figure 94 shows significant steps in the stress cycle for coal train ULK 66C. This is not due to changes in train speed, which did not occur. A check of the train car records show that this was not due either to variation in loaded-car weights, which were only minor, but rather was due to the apparent construction of the cars themselves. This is clarified in Figure 95. All cars with the reduced stress cycle were labeled either "NYC" or "CR" whereas all cars with the higher stress cycle were labeled "GCCX". Further discussion of this effect is provided on p. 50.

L9U9. Stresses in the vertical end post L9U9-west were measured, because of the pin lubrication done at panel point L9. Two strain gages were mounted vertically, one at each of the NW and SW corner angles, to measure axial stresses and north/south bending in the end post. The gages were each about 9 feet above the lower chord pins; but due to differences in the construction of the north and south faces of the post, the gages on the SW corner angle were between the 4th and 5th lattice-bar rivets and those on the NW corner angle were between the 1st and 2nd lattice-bar rivets. Figures 44 and 44a depict these locations.

Table 52 summarizes the stresses measured at post L9U9-west. Although the major measurements were made in August, stresses were also recorded during two passenger train runs in July just after the gages were installed, as part of a gage checkout program. These latter measurements thus afford limited data before lubrication was performed at panel point L9-west and before retrofits were completed (they had been begun) at other locations in Span 2.

Comparing, first, the July results for the southbound passenger trains on Track 3 with similar August results, Table 52 shows there was no change whatever in the maximum and minimum stresses from the passenger trains in post L9U9-west due to lubrication at Panel Point L9.

Secondly, the tabulated results suggest that north-to-south bending occurs in Post L9U9 (data relevant to east-to-west bending was not acquired). The maximum stress at the NW corner of post is greater in tension and the minimum stress is less in compression than at the SW corner for coal and passenger trains. The maximum stress range was 3.6 ksi and occurred with coal trains southbound on Track 3.

Figure 96 illustrates the post behavior with southbound passenger trains in July and August. As the locomotive reached the post, roughly equal compression occurred at both the NW and SW corners of the post. Then, as the locomotive passed, the stress cycle at the SW post remained in compression, but that at the NW post became basically a tension cycle. This suggests that positive bending of the top chord due to the southbound train occurs, inducing positive bending on the north side of the post , and that adequate rotation of the post at pin L9 is occurring so that positive bending of the post is retained at the gage location. This is consistent with the rigid gusset connection between the post and the top chord. Also, as shown in Table 42 and illustrated in Figure 84, lower-chord eyebar bending restraint at L9 was light in Span 2 (less than half of the bending restraint introduced by lower chord eyebars L8L9 in Span 1). The geometry differences of the NW and SW corners of the post (Figure 44a) is not believed to have had a significant effect on the results.

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Table 7. Train Passage During October Stress Measurements at AMTRAK's Susquehanna River Bridge, Perryville MD

Time	Train	Direction /Track	Composition	Nom. Speed, mph
October 20, 1997: Data for Members on Spans 7, 9, and 10				
4:56 pm	Amtrak M120*	NB/2	1 locomotive, 7 coaches	91
8:11-8:17	**Conrail UBC20**	SB/3	Coke train, 161.4K - 227.0K 2 locos, 85 cars	16
8:22	Amtrak M126	NB/2	1 locomotive, 9 coaches	87
9:02	Amtrak M127*	SB/3	1 locomotive, 7 coaches	83
9:08-9:18	**Conrail ULK60A**	SB/3	Heavy coal train; 247.8K-282.4K, 2 locos, 130 cars	9
9:44	MARC 536*	NB/2	1 locomotive, 6 coaches	30
9:46	Amtrak 175	SB/3	1 locomotive, 8 coaches	90
October 23, 1997: Data for Members on Spans 7, 9, and 10				
7:45 pm	MARC*	NB/2	1 locomotive, 6 coaches	55
7:46	Amtrak 80*	NB/2	1 locomotive, 10 coaches	88
8:01	Amtrak M125*	SB/3	1 locomotive, 6 coaches	85
8:03	MARC (non-revenue)*	SB/3	6 coaches, 1 rear loco.	24
8:11-8:18	**Conrail UBT352**	SB/3	Heavy coal train; 262.3K - 292.5K, 2 locos, 109 cars	10
8:13	Amtrak M126	NB/2	1 locomotive, na coaches	83
9:49	MARC 536*	NB/2	1 locomotive, 6 coaches	30
11:08-11:16	**Conrail UXC66A**	SB/3	Regular coal train; 199.7K - 270.1K, 2 locos, 112 cars	11

***data for Span 7 only**

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Table 8A. Train Passage During November Stress Measurements at AMTRAK's Susquehanna River Bridge, Perryville MD

Time	Train	Direction /Track	Composition	Nom. Speed, mph
November 12-13, 1997: Data for Members on Spans 7, 9, and 10				
4:04 pm	Amtrak M117*	SB/3	5 coaches, 1 loco, 1 other	90
5:54	Amtrak M121**	SB/3	6 coaches, 2 locos	90
7:38	Amtrak 187*	SB/3	5 coaches, 1 loco, 1 other	90
8:01	Amtrak M125**	SB/3	7 coaches, 1 loco	90
8:45	**Conrail UCS68S**	SB/3	Regular coal train; 234.1K - 289.5K 2 loco's, 91 cars	10
9:46	Amtrak 196**	NB/2	8 coaches, 1 loco	90
9:56	**Conrail PIBA3**	SB/3	General freight; 58.4K - 268.6K 2 loco's, 77 cars	15
12:55 am	**Conrail ULK80E**	SB/3	Heavy coal train; 236.6K - 276.1K 2 loco's, 130 cars	10
1:20	**Conrail BAPI**	NB/2	General freight; 2 loco's, 98 cars weights not acquired	15
1:47	**Conrail UIR236, run 1**	SB/3	Test coal train; 272.4K - 288.2K 2 locos's at front, 90-cars	10
2:38	**Conrail UIR236, run 2**	NB/3	Same as run 1 except 4 loco's; 2 front, 2 rear.	10
3:25	**Conrail UIR236, run 3**	SB/3	Same as run 2	10
3:42	**Conrail UIR236, run 4**	NB/2	Same as run 3	10

*** data for Span 7 only**
**** data for Spans 9 and 10 only**

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Table 8B. Train Passage During November Stress Measurements at AMTRAK's Susquehanna River Bridge, Perryville MD

Time	Train	Direction /Track	Composition	Nom. Speed, mph
November 13-14, 1997: Data for Members on Spans 1 and 2				
5:54 pm	Amtrak M121	SB/3	1 loco, 7 coaches	85
8:38	**Conrail UIR236, run 5**	SB/2	Test coal train, 272.4K - 288.2K; 4 loco's; 2 front, 2 rear; 90-cars	10
9:02	**Conrail UXC580**	SB/3	Regular coal train; 241.8K - 266.5K 2 loco's, 75 cars	15
9:07	**Conrail UIR236, run 6**	NB/2	Same as run 5	10
9:29	Amtrak 175	SB/3		90
9:54	**Conrail UIR236, run 7**	SB/2	Same as run 6	10
10:01	MARC (non-revenue)	SB/3		30
10:34	**Conrail UIR236, run 8**	NB/3	Same as run 7	10
10:57	**Conrail UIR236, run 9**	SB/3	Same as run 8	10
11:23	**Conrail UIR236, run 10**	NB/3	Same as run 9	10
11:41	Amtrak 177	SB/3		85
12:25 am	**Conrail ULK84F**	SB/3	Heavy coal train; 241.1K - 271.3 2 loco's, 125 cars	10

Table 9. Train Passage During 1998 Stress Measurements at AMTRAK's Susquehanna River Bridge, Perryville, MD

Time	Train	Direction /Track	Composition	Nom. Speed, mph
January 8-9, 1998: Data for Members on Spans 1 and 2				
10:05 pm	**Conrail PIBA**	SB/3	Mixed Freight: weights not acquired 66 cars, 2 locos	20
12:08 am	**Conrail UBT 102**	SB/2	Heavy Coal Cars; 236.9K - 286.9 K 130 cars,2 locos	10
12:35	**Conrail BAPI**	NB/2	Mixed Freight; weights not acquired 94 cars, 2 locos	15
1:11	**Conrail UMP 108**	SB/2	Heavy Coal Cars; 224.2K - 288.8K 80 cars, 3 locos	20
9:22	Amtrak M104	NB/2		90
9:59	Amtrak M105	SB/3		90
10:18	Amtrak 181	SB/3	1 loco, 6 coaches	90
10:20	Amtrak M106	NB/2	1 loco, 6 coaches	90
August 12, 1998: Data for members on Spans 1 and 2				
5:47 pm	Amtrak M121	SB/3		90
8:27	**Conrail ULK 66C**	SB/2	Heavy Coal Cars; 66.5K-275.5K, 128 cars, 2 locos	10
9:20	**Conrail UMP 74B**	SB/3	Heavy Coal Cars; 214.8K-262.1K, 80 cars, 3 locos	10
9:40	Marc 536	NB/2	1 loco, 6 cars	30
9:46	Amtrak 97	SB/3	1 loco, 11 cars	90
10:40	Amtrak 175	SB/3	1 loco, 9 cars	90
10:45	Amtrak M106	NB/3	1 loco, 8 cars	90
11:15	**Conrail XSM 43E**	NB/3	Empty coal cars, 1 loco	10-20
11:36	**Conrail UMP 110**	SB/3	Coal Train; 189.4K-245.5K, 80 cars, 3 locos	10

Table 10. Car Weights for Conrail Trains on Susquehanna River Bridge

Date	Train	Total No. Cars	No. Cars at Weight (kips): less than 160	160-170	170-180	180-190	190-200	200-210	210-220	220-230	230-240	240-250	250-260	260-270	270-280	280-290
10-20-97	UBC 20	85		10	2	1	51	13	3	5						
10-20-97	ULK 60A	130										3	79	46	1	1
10-23-97	UBT 352	109												43	57	9
10-23-97	UXC 66A	112					1	0	9	7	26	18	42	8	1	
11-12-97	UCS 68S	91									12	20	4	20	27	8
11-12-97	PIBA 3	77	45	3	0	0	1	0	2	0	8	9	4	5		
11-13-97	ULK 80E	130	1								2	13	78	29	7	
11-13/14-97	UIR 236	90													55	35
11-14-97	ULK 84F	125										11	65	48	1	
01-10-98	UBT 102	130									2	5	23	61	34	5
01-10-98	UMP 108	80								1	4	17	26	25	3	4
08-12-98	ULK 66C	128	1						1	0	1	4	39	75	7	
08-12-98	UMP 74B	80							5	22	24	25	1	3		
08-12-98	UMP 110	80				1	0	2	7	4	48	18				

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Table 11

Measured Pre-Retrofit Lower-Chord Eyebar Stresses for Various Trains
(Span 1, W truss, Chord L8L9@L9)

Trains in November 1997				Stress Range, ksi						
				Maximum Range				Car Cycle Range		
Train/ Date	**Direction /Track**	**No. Loco-motives**	**Eyebar No.***	**Top, T**	**Bottom, B**	**Axial, (T+B)/2**	**Bending, (T-B)/2**	**No. Cars**	**Top**	**Bottom**
UIR 236	SB/3	4,	4	10.5	na	na	na	90	0.7	na
(286K coal	run 9	(2 front,	3	11.0	- 5.5	2.8	8.2		0.9	0.3
cars test train)		2 rear)	2	12.0	- 5.0	3.5	8.5		0.9	0.3
11-13			1	12.5	- 4.3	4.1	8.4		0.9	0.3
			Avg.			**3.5**	**8.4**			
	SB/2	4	4	5.5	- 2.4	1.6	3.9	90	0.5	0.3
	run 5		3	5.5	- 3.0	1.3	4.2		0.5	0.2
			2	6.0	- 3.3	1.4	4.6		0.5	0.3
			1	5.5	- 4.0	0.8	4.7		0.5	0.2
			Avg.			**1.3**	**4.4**			
ULK 84F	SB/3	2	4	10.5	na	na	na	125	1.0	na
(263K coal			3	11.2	- 5.5	2.8	8.4		1.0	0.3
car train)			2	12.0	- 5.0	3.5	8.5		1.2	0.3
11-14			1	12.5	- 4.5	4.0	8.5		1.3	0.3
			Avg.			**3.4**	**8.5**			
Amtrak M121	SB/3	1	4	6.0	- 3.7	1.2	4.8	6	1.2	0.5
11-13			3	6.0	- 3.0	1.5	4.5		1.2	0.5
			2	6.2	- 2.5	1.9	4.3		1.2	0.5
			1	6.2	- 2.0	2.1	4.1		1.2	0.5
			Avg.			**1.7**	**4.4**			
(Post-Retrofit Data for these eyebars are given in Table 39)										

(Continued on next sheet)

Table 11 (continued)

Trains in January 1998				Stress Range, ksi						
				Maximum Range				Car Cycle Range		
Train/ Date	Direction /Track	No. Loco-motives	Eyebar No.*	Top, T	Bottom, B	Axial, (T+B)/2	Bending, (T-B)/2	No. Cars	Top	Bottom
UMP 108 (263K Coal Car Train) 01/09/98	SB/2	3	3	2.5	na	na	na	80	0.5	na
BAPI (mixed freight) 01/09/98	NB/2	2		2.0				94	na	
Post-Retrofit Data for these eyebars are given in Table 39.										

*No. 4 eyebar is the exterior eyebar in each group;
No. 1 eyebar is the interior.

na = not acquired or reliable

Eyebar No.	Tightness [7]
4	Tight
3	Tight
2	Moderate
1	Moderate

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Table 12
Measured Lower-Chord Eyebar Stresses for Various Trains
(Span 9, W truss, Chord L0L1@L0)

				Stress Range, ksi						
				Maximum Range				Car Cycle Range		
Train/ Date	Direction /Track	No. Loco-motives	Eyebar No.*	Top, T	Bottom, B	Axial, (T+B)/2	Bending, (T-B)/2	No. Cars	Top	Bottom
UIR 236 (286K coal car test train) 11-13	SB/3 run 1	2	4	5.0	na	na	na	90	0.8	0.3
			3	5.0	- 2.8	1.1	3.9		0.8	0.3
			2	4.4	- 2.0	1.2	3.2		0.8	na
			1	5.0	- 2.0	1.5	3.5		0.8	0.3
			Avg.			**1.3**	**3.5**			
	SB/3 run 3	4	4	5.0	na	na	na	90	0.8	na
			3	5.0	- 2.5	1.3	3.7		0.8	0.3
			2	4.4	- 2.0	1.2	3.2		0.8	0.3
			1	5.1	- 2.0	1.6	3.5		0.8	0.3
			Avg.			**1.4**	**3.5**			
	NB/2 run 4	4	4	2.2	na	na	na	90	0.3	na
			3	2.2	- 0.8	0.7	1.5		0.3	0.2
			2	1.9	- 0.8	0.6	1.3		0.3	0.2
			1	2.2	- 0.8	0.7	1.5		0.3	0.2
			Avg.			**0.7**	**1.4**			
ULK80E (263K coal car train) 11-13	SB/3	2	4	4.5	na	na	na	130	0.8	na
			3	4.5	- 2.3	1.1	3.4		0.8	0.2
			2	4.2	- 1.7	1.3	2.9		0.8	0.2
			1	4.5	- 1.9	1.3	3.2		0.8	0.3
			Avg.			**1.2**	**3.2**			
Amtrak M125 11-12	SB/3	1	4	2.0	na	na	na	7	0.5	na
			3	2.0	- 0.7	0.7	1.3		0.4	0.2
			2	1.8	- 0.5	0.7	1.1		0.4	0.2
			1	1.9	- 0.5	0.7	1.2		0.4	0.2
			Avg.			**0.7**	**1.2**			

Table 12 (continued)

				Stress Range, ksi						
				Maximum Range				Car Cycle Range		
Train/ Date	Direction /Track	No. Loco-motives	Eyebar No.*	Top, T	Bottom, B	Axial, (T+B)/2	Bending, (T-B)/2	No. Cars	Top	Bottom
UXC 66A (regular coal train) 10-23	SB/3	2	4	3.9	- 1.2	1.4	2.6	112	0.4	0.1
			3	4.3	- 1.2	1.6	2.8		0.4	0.1
			2	3.9	- 0.8	1.6	2.4		0	0.2
			1	4.3	- 0.8	1.8	2.6		0.4	0.2
			Avg.			**1.6**	**2.6**			
UBT 352 (263K coal car train) 10-23	SB/3	2	4	4.3	- 1.1	1.6	2.7	109	0.5	0.2
			3	4.2	- 1.2	1.5	2.7		0.5	0.2
			2	3.9	- 0.8	1.6	2.4		0.3	0.1
			1	4.3	- 0.8	1.8	2.6		0.4	0.2
			Avg.			**1.6**	**2.6**			

na = not acquired

* No. 4 eyebar is the exterior eyebar in each group;
No. 1 eyebar is the interior.

Eyebar No.	Tightness [7]
4	Tight
3	Tight
2	Tight
1	Moderate

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Table 13
Measured Lower-Chord Eyebar Stresses for Various Trains
(Span 9, E truss, Chord L0L1@L0)

				Stress Range, ksi						
				Maximum Range				Car Cycle Range		
Train/ Date	Direction /Track	No. Loco-motives	Eyebar No.*	Top, T	Bottom, B	Axial, (T+B)/2	Bending, (T-B)/2	No. Cars	Top	Bottom
UIR 236 (286K coal car test train) 11-13	SB/3 runs 1 and 3	2 and 4	4	2.2	1.4	1.8	0.4	90	0.3	0.2
			3	2.4	1.4	1.9	0.5		0.3	na
			2	3.0	na	na	na		0.3	na
			1	2.8	1.7	2.2	0.6		0.3	0.2
			Avg.			**2.0**	**0.5**			
	NB/2 run 4	4	4	3.5	- 1.7	0.9	2.6	90	0.4	0.3
			3	4.3	- 1.7	1.3	3.0		0.4	0.3
			2	4.8	na	na	na		0.4	na
			1	4.0	0.8	2.4	1.6		0.4	na
			Avg.			**1.5**	**2.4**			
ULK 80E (263K coal car train) 11-13	SB/3	1	4	1.9	1.0	1.6	0.3	130	0.2	0.2
			3	2.2	1.3	1.8	0.4		0.2	na
			2	2.7	na	na	na		0.2	na
			1	2.7	1.5	2.2	0.5		0.2	0.2
			Avg.			**1.9**	**0.4**			
Amtrak M125 11-12	SB/3	1	4	0.8	0.4	0.6	0.2	7	0.2	0.2
			3	0.8	na	na	na		0.2	na
			2	1.0	na	na	na		0.2	na
			1	1.0	0.5	0.8	0.2		0.2	0.2
			Avg.			**0.7**	**0.2**			

na = not acquired

*No. 4 eyebar is the exterior eyebar in each group;
No. 1 eyebar is the interior.

Eyebar No.	Tightness [7]
4	Tight
3	Tight
2	Tight
1	Tight

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Table 14

Measured Diagonal Eyebar Stresses for Various Train Conditions
(Span 7, W truss, Diagonal L7U8@L7)

				Stress Range, ksi						
				Maximum Range				Car Cycle Range		
Train/ Date	Direction /Track	No. Locomotives	Eyebar No.	Top, T	Bottom, B	Axial, (T+B)/2	Bending, (T-B)/2	No. Cars	Top	Bottom
UIR 236 (286K coal cars test train) 11-13	SB/3 run 1	2	4	na	5.2	na	na	90	na	0.8
			3	5.7	5.7	5.7	0		0.8	0.6
			2	6.3	5.7	6.0	0.3		0.9	0.8
			1	5.6	5.1	5.4	0.3		1.0	0.8
			Avg.			**5.7**	**0.2**			
	NB/2 run 4	4 (2 front, 2 rear)	4	na	2.0	na	na	90	na	0.2
			3	1.0	2.5	1.8	0.7		0.2	0.3
			2	1.1	3.2	2.2	1.0		0.3	0.2
			1	0.6	2.9	1.8	1.1		0.3	0.2
			Avg.			**1.9**	**0.9**			
	NB/3 run 2	4	4	na	5.2	na	na	90	na	0.6
			3	5.6	5.7	5.7	0		0.8	0.8
			2	6.2	5.7	6.0	0.3		0.9	0.6
			1	5.2	5.1	5.2	0		0.9	0.8
			Avg.			**5.6**	**0.1**			
ULK 80E (263K coal car train) 11-13	SB/3	2	4	na	5.0	na	na	130	na	0.6
			3	5.2	5.4	5.3	0.1		0.9	0.8
			2	6.0	5.4	5.7	0.3		0.8	0.8
			1	5.2	5.0	5.1	0.1		0.9	0.8
			Avg.			**5.4**	**0.2**			

Table 14, continued

Train/ Date	Direction /Track	No. Loco-motives	Eyebar No.	Stress Range, ksi — Maximum Range: Top, T	Bottom, B	Axial, (T+B)/2	Bending, (T-B)/2	Car Cycle Range: No. Cars	Top	Bottom
UBT 352 (263K coal car train) 10-23	SB/3	2	4	na	5.2	na	na	109	na	0.6
			3	5.4	5.7	5.6	0.1		0.6	0.8
			2	6.0	5.7	5.9	0.1		0.9	0.6
			1	5.2	5.0	5.2	0.2		0.8	0.8
			Avg.			**5.6**	**0.1**			
	SB/3 with coincident NB/2 Amtrak M126	2 / 1	4	na	5.4	na	na	109 plus 9	-	-
			3	5.6	5.8	5.7	0.1		-	-
			2	6.2	6.0	6.1	0.1		-	-
			1	5.4	5.6	5.5	0.1		-	-
			Avg.			**5.8**	**0.1**			
UBC 20 (coke train) 10-20	SB/3	2	4	na	4.8	na	na	85	0.6	0.5
			3	5.1	5.6	5.4	0.3		0.6	0.6
			2	5.6	5.2	5.4	0.2		0.6	0.5
			1	4.8	5.1	5.0	0.2		0.6	0.6
			Avg.			**5.3**	**0.2**			
Amtrak M125 10-23	SB/3	1	4	na	1.9	na	na	6	na	0.5
			3	2.4	2.1	2.3	0.2		0.6	0.6
			2	2.6	2.5	2.6	0.1		0.5	0.6
			1	1.9	2.1	2.0	0.1		0.4	0.5
			Avg.			**2.3**	**0.1**			

na = not acquired

Eyebar No.	Tightness [7]
4	Loose
3	Moderate
2	Moderate
1	Loose

Table 15

<u>Measured Diagonal Eyebar Stresses for Various Train Conditions</u>
(Span 7, E truss, Diagonal L7U8@L7)

				Stress Range, ksi						
				Maximum Range				Car Cycle Range		
Train/ Date	Direction /Track	No. Loco-motives	Eyebar No.	Top, T	Bottom, B	Axial, (T+B)/2	Bending, (T-B)/2	No. Cars	Top	Bottom
UIR 236 (286K Coal Car Test Train) 11-13	SB/3 run 1	2	4	1.7	2.0	1.9	0.1	90	0.2	0.2
			3	1.8	2.3	2.1	0.2		0.2	0.2
			2	1.7	2.9	2.3	0.6		0.2	0.2
			1	0.8	0.5	0.7	0.2		0.2	0.1
			Avg.			**1.8**	**0.3**			
	NB/2 run 4	4 (2 front, 2 rear)	4	6.8	6.3	6.6	0.3	90	0.8	0.6
			3	6.4	6.2	6.3	0.1		0.8	0.8
			2	6.4	6.2	6.3	0.1		1.0	0.6
			1	4.2	2.4	3.3	0.9		0.9	0.6
			Avg.			**5.6**	**0.4**			
	NB/3 run 2	4	4	1.7	2.0	1.9	0.1	90	0.2	0.2
			3	2.0	2.5	2.3	0.2		0.2	0.2
			2	1.8	2.9	2.4	0.5		0.2	0.2
			1	1.0	0.5	0.8	0.3		0.3	0.1
			Avg.			**1.9**	**0.3**			
ULK 80E (263K coal car train) 11-13	SB/3	2	4	1.6	1.9	1.8	0.1	130	0.2	0.3
			3	1.8	2.2	2.0	0.2		0.2	0.2
			2	1.7	2.8	2.2	0.6		0.2	0.2
			1	0.8	0.5	0.7	0.2		0.2	0.1
			Avg.			**1.7**	**0.3**			

Table 15, continued

Train/ Date	Direction /Track	No. Loco-motives	Eyebar No.	Stress Range, ksi: Maximum Range: Top, T	Bottom, B	Axial, (T+B)/2	Bending, (T-B)/2	Car Cycle Range: No. Cars	Top	Bottom
UBT 352 (263K coal car train) 10-23	SB/3	2	4	1.6	1.8	1.7	0.1	109	0.3	0.3
			3	1.8	2.1	2.0	0.1		0.2	0.3
			2	1.6	2.7	2.1	0.6		0.2	0.3
			1	0.9	0.2	0.6	0.4		0.3	0.2
			Avg.			**1.6**	**0.3**			
	SB/3 with coincident NB/2 Amtrak M126	2 1	4	4.0	4.2	4.1	0.1	109 plus 9	-	-
			3	3.9	4.2	4.1	0.1		-	-
			2	3.8	4.6	4.2	0.4		-	-
			1	2.1	1.4	1.8	0.4		-	-
			Avg.			**3.6**	**0.2**			
UBC 20 (coke train) 10-20	SB/3	2	4	1.8	1.7	1.8	0	85	0.2	0.2
			3	1.6	1.9	1.8	0.1		0.2	0.2
			2	1.6	2.5	2.2	0.3		0.2	0.2
			1	0.7	0.2	0.5	0.3		0.2	0.1
			Avg.			**1.6**	**0.2**			

Eyebar No.	Tightness [7]
4	Tight
3	Tight
2	Loose
1	Very Loose

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Table 16

Measured Diagonal Eyebar Stresses For Various Train Conditions
(In Span 2, W Truss, L3U2 @ L3)

				Stress Range, ksi						
Train/ Date	Direction/ Track	No. Locos/ Cars	Eyebar/ Position	At Entry E	At Exit X	Max Pk to Pk A	Steady Nominal D	Axial $(A_T + A_B)/2$	Bending $(A_T - A_B)/2$	Car Cycle
UIR 236 (286K coal car test train) 11-13	SB/3 run 9	4/90	4T	5.0	-0.7	5.8	5.0	5.8	0	0.8
			B	4.9	-0.8	5.7	4.9			0.9
			3T	4.3	-0.6	5.0	4.3	5.1	0	0.7
			B	4.3	-0.8	5.1	4.2			0.7
			2T	4.3	-0.7	5.0	4.3	na	na	0.7
			B	na	na	na	na			na
			1T	4.0	-0.5	4.5	4.0	4.9	0.3	0.8
			B	4.1	-1.1	5.2	4.0			0.9
			Avg.					**5.3**	**0.1**	
ULK 84F (263K coal car train) 11-14	SB/3	2/125	4T	4.7	-0.7	5.8	5.5	5.9	0	0.7
			B	4.5	-0.9	5.9	4.3			0.8
			3T	4.1	-0.7	5.1	4.0	5.2	0.1	0.8
			B	4.0	-1.0	5.3	3.8			0.7
			2T	4.1	-0.6	5.1	4.0	na	na	0.7
			B	na	na	na	na			na
			1T	3.7	-0.7	4.7	3.5	5.0	0.2	0.7
			B	4.0	-1.2	5.2	3.6			0.8
			Avg.					**5.4**	**0.1**	

Table 16 (continued)

				Stress Range, ksi						
Train/ Date	Direction/ Track	No. Locos/ Cars	Eyebar/ Position	At Entry E	At Exit X	Max Pk to Pk A	Steady Nominal D	Axial $(A_T + A_B)/2$	Bending $(A_T - A_B)/2$	Car Cycle
Amtrak M121 11-13	SB/3	1/6	4T	2.8	0	2.8	1.3	2.7	0.1	0.9
			B	2.6	0	2.6	1.5			0.7
			3T	2.8	0	2.8	1.3	2.7	0.1	0.9
			B	2.3	0	2.5	1.2			0.7
			2T	2.2	0	2.4	1.1	na	na	0.8
			B	na	na	na	na			na
			1T	2.0	0	2.2	1.0	2.4	0.2	0.6
			B	2.1	-0.5	2.6	1.1			0.7
			Avg.					**2.6**	**0.1**	
UIR 236 (286K coal car test train) 11-13	SB/2 run 5	2/90	4T	1.5	0	1.5	1.5	1.9	0.4	0.2
			B	2.0	-0.3	2.3	2.0			0.2
			3T	1.5	0	1.5	1.5	1.8	0.2	0.2
			B	2.0	0	2.0	2.0			0.2
			2T	1.3	0	1.6	1.6	na	na	0.2
			B	na	na	na	na			na
			1T	1.0	0	1.0	1.0	1.7	0.7	0.2
			B	2.3	0	2.3	2.3			0.2
			Avg.					**1.8**	**0.4**	

na=not acquired

Eyebar No.	Tightness [7]
4	Tight
3	Moderate
2	Moderate
1	Loose

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Table 17

Measured Diagonal Eyebar Stresses For Various Train Conditions
(In Span 2, E Truss, L3U2 @ L3)

Train/ Date	Direction/ Track	No. Locos/ Cars	Eyebar/ Position	Stress Range, ksi						
				At Entry E	At Exit X	Max Pk to Pk A	Steady Nominal D	Axial $(A_T + A_B)/2$	Bending $(A_T - A_B)/2$	Car Cycle
UIR 236 (286K coal car test train) 11-13	SB/3 run 9	2/90	4T	1.1	0	1.1	1.1	1.4	0.3	0.1
			B	1.7	0	1.7	1.8			0.2
			3T	na	na	na	na	na	na	na
			B	2.0	0	2.0	2.0			0.2
			2T	1.1	-0.1	1.2	1.1	1.6	0.3	0.1
			B	1.7	0	1.9	1.8			0.2
			1T	1.0	-0.2	1.2	1.0	1.8	0.6	0.2
			B	2.3	0	2.3	2.3			0.2
			Avg.					**1.6**	**0.4**	
ULK 84F (263K coal car train) 11-14	SB/3	2/125	4T	1.0	0	1.0	1.0	1.5	0.5	0.1
			B	1.6	-0.3	2.0	1.6			0.2
			3T	na	na	na	na	na	na	na
			B	1.8	0	1.9	1.8			0.2
			2T	1.0	-0.3	1.3	1.0	1.6	0.4	0.1
			B	1.6	0	2.0	1.8			0.2
			1T	0.9	-0.2	1.2	0.7	1.7	0.5	0.1
			B	2.1	0	2.2	2.1			0.2
			Avg.					**1.6**	**0.5**	

Table 17 (continued)

				Stress Range, ksi						
Train/ Date	Direction/ Track	No. Locos/ Cars	Eyebar/ Position	At Entry E	At Exit X	Max Pk to Pk A	Steady Nominal D	Axial $(A_T + A_B)/2$	Bending $(A_T - A_B)/2$	Car Cycle
Amtrak M121 11-13	SB/3	1/6	4T	0.5	0	0.8	0.3	1.0	0.2	0.3
			B	1.2	0	1.2	0.5			0.3
			3T	na	na	na	na	1.2	na	na
			B	1.1	0	1.2	0.7			0.2
			2T	0.8	0	0.8	0.4	1.0	0.2	0.2
			B	0.9	0	1.2	0.5			0.2
			1T	0.4	0	0.6	0.3	0.9	0.3	0.2
			B	1.2	0	1.2	0.7			0.2
			Avg.					**1.0**	**0.2**	
UIR 236 (286K coal car test train) 11-13	SB/2 run 5	2/90	4T	4.2	-1.0	5.4	4.2	5.6	0.2	0.6
			B	4.7	-1.1	5.8	4.7			0.9
			3T	na	na	na	na	na	na	na
			B	4.7	-1.0	5.7	4.6			0.9
			2T	3.8	-1.1	4.9	3.8	4.9	0	0.7
			B	4.0	-0.9	4.9	3.9			1.0
			1T	4.0	-1.0	5.1	4.0	5.2	0	0.9
			B	4.1	-1.1	5.2	4.0			1.0
			Avg.					**5.3**	**0.1**	

Eyebar No.	Tightness [7]
4	Moderate
3	Tight
2	Moderate
1	Moderate

na=not acquired

Table 18

Measured Pre-Retrofit Diagonal Eyebar Stresses For Various Trains
(In Span 2, W Truss, L5U6 @ L5)

Trains in November 1997				Stress Range, ksi						
Train/ Date	Direction/ Track	No. Locos/ Cars	Eyebar/ Position	At Entry E	At Exit X	Max Pk to Pk A	Steady Nominal D	Axial $(A_T + A_B)/2$	Bending $(A_T - A_B)/2$	Car Cycle
UIR 236	SB/3	2/90	4T	-1.3	3.0	4.3	1.2	2.7	1.6	0.5
(286K coal car test train) 11-13	run 9		B	-0.2	1.0	1.2	0.2			0.1
			3T	-1.4	3.6	5.0	2.1	3.3	1.7	0.7
			B	-0.7	1.0	1.7	-0.6			0.5
			2T	-1.6	4.8	6.4	3.0	4.8	1.6	1.2
			B	-1.5	1.7	3.2	-1.0			1.2
			1T	-0.4	1.3	1.7	0.8	1.4	0.3	0.1
			B	0.3	0	1.1	-0.8			0.2
			Avg.					**3.1**	**1.3**	
ULK 84F	SB/3	2/125	4T	-1.2	2.7	3.9	0.7	2.4	1.5	0.5
(263K coal car train) 11-14			B	-0.2	0.7	0.9	0.2			0.2
			3T	-1.2	3.0	4.2	1.7	2.8	1.4	0.7
			B	-0.8	0.7	1.5	-0.6			0.5
			2T	-1.7	4.4	6.1	2.6	4.5	1.6	1.4
			B	-1.4	1.5	2.9	-1.0			1.2
			1T	-0.5	1.2	1.7	0.7	1.5	0.2	0.2
			B	0.3	-1.0	1.3	-0.8			0.2
			Avg.					**2.8**	**1.2**	
Post-Retrofit Data for these eyebars are given in Table 43.										

(Continued on next sheet)

Table 18 (continued)

Trains in November 1997				Stress Range, ksi						
Train/ Date	Direction/ Track	No. Locos/ Cars	Eyebar/ Position	At Entry E	At Exit X	Max Pk to Pk A	Steady Nominal D	Axial $(A_T + A_B)/2$	Bending $(A_T - A_B)/2$	Car Cycle
Amtrak M121 11-13	SB/3	1/6	4T	-0.8	0	0.8	0.3	0.4	0	0.3
			B	0	0	0	0.4			0.3
			3T	-1.0	0	1.0	0.7	0.1	0.6	0.5
			B	-0.3	0	0.3	-0.5			0.3
			2T	-1.3	0	1.3	0.9	0.3	0.6	0.7
			B	-1.0	0	1.2	-0.4			0.5
			1T	-0.5	0	0.5	0.4	0.1	0.3	0.4
			B	0.4	0	1.2	-0.3			0.5
			Avg.					**0.2**	**0.4**	
UIR 236 (286K coal car test train) 11-13	SB/2 run 5	2/90	4T	0.3	0.4	0.3	0.3	0.2	0.1	0.1
			B	0	0	0	0			0
			3T	-0.3	1.2	1.5	0.7	1.0	0.5	0.2
			B	0.2	-0.4	0.6	-0.3			0.1
			2T	-0.4	1.2	1.6	0.8	0.9	0.7	0.3
			B	-0.5	-0.6	0.1	-0.5			0
			1T	-0.1	0.7	0.8	0.5	0.9	0	0.1
			B	0.1	-0.8	0.9	-0.4			0.1
			Avg.					**0.8**	**0.3**	

Post-Retrofit Data for these eyebars are given in Table 43.

(Continued on next sheet)

Table 18 (end)

Trains in January 1998				Stress Range, ksi				
Train/ Date	**Direction/ Track**	**No. Locos/ Cars**	**Eyebar/ Position**	**At Entry E**	**At Exit X**	**Max Pk to Pk A**	**Steady Nominal D**	**Car Cycle**
PIBA (01-08)	SB/3	2/66	4T	-1.0	2.7	3.7	1.3	0.4
Amtrak 181 (01-09)	SB/3	1/6	4T	-0.6	0	1.2	0.2	0.3
Amtrak M106 (01-09)	NB/2	1/6	4T	0.4	0	0.7	0.4	0.4
UMP 108 (01-09)	SB/2	3/80	4T	na	na	na	na	na
Post-Retrofit Data for these eyebars are given in Table 43.								

na = not acquired

Eyebar No.	Tightness [7]
4	Loose
3	Loose
2	Moderate
1	Very Loose

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Table 19

Measured Pre-Retrofit Diagonal Eyebar Stresses For Various Train Conditions
(In Span 2, E Truss, L5U6 @ L5)

Trains in November 1997				Stress Range, ksi						
Train/ Date	Direction/ Track	No. Locos/ Cars	Eyebar/ Position	At Entry E	At Exit X	Max Pk to Pk A	Steady Nominal D	Axial $(A_T + A_B)/2$	Bending $(A_T - A_B)/2$	Car Cycle
UIR 236 (286K coal car test train) 11-13	SB/3 run 9	2/90	4T	-0.3	1.5	1.8	1.5	1.6	0.2	0.4
			B	-0.3	1.1	1.4	1.0			0.2
			3T	-0.3	1.5	1.8	1.5	2.0	0.2	0.3
			B	-0.5	1.7	2.2	1.4			0.3
			2T	-0.4	1.8	2.2	1.6	2.7	0.5	0.3
			B	-0.7	2.5	3.2	2.1			0.3
			1T	-1.0	3.2	4.2	3.0	2.4	1.8	0.3
			B	0	0.6	0.6	0.5			0.3
			Avg.					**2.2**	**0.7**	
ULK 84F (263K coal car train) 11-14	SB/3	2/125	4T	-0.3	1.5	1.8	1.3	1.6	0.2	0.3
			B	-0.2	1.2	1.4	1.0			0.3
			3T	-0.3	1.6	1.9	1.4	1.9	0	0.3
			B	-0.4	1.5	1.9	1.4			0.4
			2T	-0.5	1.7	2.2	1.5	2.7	0.4	0.3
			B	-0.7	2.4	3.1	2.1			0.4
			1T	-1.2	2.0	3.7	2.8	2.2	1.5	0.5
			B	0.6	0.7	0.7	0.4			0.3
			Avg.					**2.1**	**0.5**	
Post-Retrofit Data for these eyebars are given in Table 44.										

(Continued on next sheet)

Table 19 (continued)

Trains in November 1997				Stress Range, ksi						
Train/ Date	Direction/ Track	No. Locos/ Cars	Eyebar/ Position	At Entry E	At Exit X	Max Pk to Pk A	Steady Nominal D	Axial $(A_T + A_B)/2$	Bending $(A_T - A_B)/2$	Car Cycle
Amtrak M121 11-13	SB/3	1/6	4T	0	0	1.0	0.6	0.5	0.1	0.4
			B	0	0	0.9	0.3			0.3
			3T	-0.3	0	1.3	0.3	0.4	0.1	0.2
			B	-0.3	0	1.4	0.5			0.4
			2T	-0.4	0	2.2	1.0	0.8	0.2	0.3
			B	-0.5	0	2.2	1.0			0.6
			1T	-1.0	0	3.2	1.1	0.7	0.4	0.6
			B	0	0	0.2	0.2			0
			Avg.					**0.6**	**0.2**	
UIR 236 (286K coal car test train) 11-13	SB/2 run 5	2/90	4T	-1.6	4.5	6.1	3.2	5.2	0.9	0.8
			B	-1.0	3.3	4.3	2.7			0.7
			3T	-1.5	4.1	5.6	3.1	5.4	0.2	0.9
			B	-1.2	4.0	5.2	3.1			0.9
			2T	-1.3	3.7	5.0	2.6	5.4	0.4	0.7
			B	-1.5	4.3	5.8	3.2			0.9
			1T	-2.3	5.1	7.4	3.9	4.8	2.6	0.8
			B	0	2.1	2.1	1.3			0.7
			Avg.					**5.2**	**1.0**	
Post-Retrofit Data for these eyebars are given in Table 44.										

(Continued on next sheet)

Table 19 (end)

Trains in January 1998				Stress Range, ksi				
Train/ Date	Direction/ Track	No. Locos/ Cars	Eyebar/ Position	At Entry E	At Exit X	Max Pk to Pk A	Steady Nominal D	Car Cycle
PIBA (01-08)	SB/3	2/66	4T	-0.7	0	2.2	1.1	0.2
Amtrak 181 (01-09)	SB/3	1/7	4T	-0.8	0	1.5	0.5	0.5
Amtrak M106 (01-09)	NB/2	1/6	4T	0	-0.5	2.5	1.0	0.7
UMP 108 (01-09)	SB/2	3/80	4T	-1.7	4.3	6.0	3.0	0.8
Post-Retrofit Data for these eyebars are given in Table 44.								

Eyebar No.	Tightness [7]
4	Moderate
3	Moderate
2	Loose
1	Loose

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Table 20

Measured Diagonal Eyebar Stresses for Various Train Conditions
(Span 2, W truss, L7U8@L7)

				Stress Range, ksi						
				Maximum Range				Car Cycle Range		
Train/ Date	Direction /Track	No. Loco-motives	Eyebar	Top, T	Bottom, B	Axial, (T+B)/2	Bending, (T-B)/2	No. Cars	Top	Bottom
UIR 236 (286K coal cars test train) 11-13	SB/3 run 9	4, (2 front. 2 rear)	4	4.7	5.2	5.0	0.2	90	0.7	0.7
			3	4.8	5.1	5.0	0.1		0.8	0.7
			2	5.7	5.3	5.5	0.2		0.8	0.8
			1	5.1	5.8	5.5	0.3		0.9	0.9
			Avg.			**5.3**	**0.2**			
	SB/2 run 7	4	4	0.6	1.8	1.2	0.6	90	0.2	0.2
			3	0.7	2.2	1.5	0.7		0.2	0.2
			2	1.0	2.8	1.9	0.9		0.2	0.3
			1	0.7	3.3	2.0	1.3		0.2	0.3
			Avg.			**1.7**	**0.9**			
	SB/2 run 7 with coincident SB/3 MARC	4 1	4	2.0	2.7	2.4	0.3	90 plus 7	0.3	0.6
			3	2.2	3.2	2.7	0.5		0.3	0.6
			2	3.0	4.0	3.5	0.5		0.4	0.6
			1	2.4	4.6	3.5	1.1		0.4	0.6
			Avg.			**3.0**	**0.6**			
	NB/3 run 8	4	4	4.6	5.2	4.9	0.3	90	0.8	1.0
			3	4.8	5.1	5.0	0.1		0.8	1.0
			2	5.9	5.3	5.6	0.3		0.8	1.2
			1	5.1	5.7	5.4	0.3		0.9	1.2
			Avg.			**5.2**	**0.3**			
	NB/2 run 6	4	4	0.5	1.7	1.1	0.6	90	0.1	0.2
			3	0.7	2.1	1.4	0.7		0.2	0.2
			2	0.9	2.8	1.9	0.9		0.2	0.3
			1	0.7	3.3	2.0	1.3		0.2	0.3
			Avg.			**1.6**	**0.9**			

Table 20 (continued)

				Stress Range, ksi						
				Maximum Range				Car Cycle Range		
Train/ Date	Direction /Track	No. Loco-motives	Eyebar	Top, T	Bottom, B	Axial, (T+B)/2	Bending, (T-B)/2	No. Cars	Top	Bottom
ULK 84F (263K coal cars) 11-14	SB/3	2	4	4.5	5.1	4.8	0.3	125	0.7	1.0
			3	4.7	5.0	4.9	0.1		0.7	1.1
			2	5.6	5.3	5.5	0.2		0.8	1.1
			1	5.0	5.7	5.4	0.3		0.8	1.2
			Avg.			**5.2**	**0.2**			

Eyebar No.	Tightness [7]
4	Moderate
3	Moderate
2	Moderate
1	Moderate

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Table 21

<u>Measured Diagonal Eyebar Stresses for Various Train Conditions</u>
(Span 2, E truss, L7U8@L7)

				Stress Range, ksi						
				Maximum Range				Car Cycle Range		
Train/ Date	Direction /Track	No. Loco-motives	Eyebar	Top, T	Bottom, B	Axial, (T+B)/2	Bending, (T-B)/2	No. Cars	Top	Bottom
UIR 236 (286K coal cars test train) 11-13	SB/3 run 9	4, (2 front, 2 rear)	4	1.5	2.0	1.8	0.2	90	0.2	0.2
			3	1.7	1.6	1.7	0.1		0.2	0.2
			2	2.5	2.5	2.5	0		0.3	0.3
			1	1.2	na	-	-		0.1	na
			Avg.			**2.0**	**0.1**			
	SB/2 run 7	4	4	5.9	6.0	6.0	0	90	0.7	0.7
			3	5.7	5.7	5.7	0		0.7	0.6
			2	7.7	6.7	7.2	0.3		1.1	0.7
			1	3.8	na	-	-		1.1	nr
			Avg.			**6.3**	**0.1**			
	SB/2 run 7 with coincident SB/3 MARC	4 1	4	6.0	6.1	6.1	0	90 plus 7	0.8	0.8
			3	5.9	5.9	5.9	0		0.8	0.8
			2	7.9	7.0	7.5	0.5		1.1	1.0
			1	3.8	nr	-	-		1.1	nr
			Avg.			**6.5**	**0.2**			
	NB/3 run 8	4	4	1.5	2.0	1.8	0.2	90	0.2	0.2
			3	1.7	1.6	1.7	0.1		0.2	0.2
			2	2.4	2.5	2.5	0		0.3	0.3
			1	0.9	na	-	-		0.2	na
			Avg.			**2.0**	**0.1**			
	NB/2 run 6	4	4	5.8	5.8	5.8	0	90	0.8	0.8
			3	5.8	5.5	5.7	0.2		0.8	0.6
			2	5.5	6.7	6.1	0.6		1.0	0.7
			1	3.9	na	-	-		1.1	na
			Avg.			**5.9**	**0.3**			

Table 21 (continued)

				Stress Range, ksi						
				Maximum Range				Car Cycle Range		
Train/ Date	Direction /Track	No. Loco-motives	Eyebar	Top, T	Bottom, B	Axial, (T+B)/2	Bending, (T-B)/2	No. Cars	Top	Bottom
ULK 84F (263K coal cars) 11-14	SB/3	2	4	1.4	2.0	1.7	0.3	125	0.2	0.2
			3	1.7	1.7	1.7	0		0.2	0.2
			2	2.4	2.5	2.5	0		0.3	0.2
			1	0.4	na	-	-		0.1	na
			Avg.			**2.0**	**0.1**			

Eyebar No.	Tightness [7]
4	Tight
3	Tight
2	Moderate
1	Loose

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Table 22

Measured Diagonal Eyebar Stresses For Various Train Conditions
(In Span 2, W Truss, L7U8 @ U8)

Trains in November 1997				Stress Range, ksi						
Train/ Date	Direction/ Track	No. Locos/ Cars	Eyebar/ Position	At Entry E	At Exit X	Max Pk to Pk A	Steady Nominal D	Axial $(A_T + A_B)/2$	Bending $(A_T - A_B)/2$	Car Cycle
UIR 236 (286K coal car test train) 11-13	SB/3 run 9	2/90	4T	5.1	4.5	5.2	5.1	5.2	0.1	0.6
			B	4.8	4.5	5.1	4.8			0.8
			3T	5.4	5.0	5.6	5.4	5.4	0.2	0.8
			B	5.1	4.8	5.2	5.1			0.9
			2T	5.6	5.0	5.8	5.4	6.2	0.4	0.9
			B	6.4	6.0	6.6	6.4			0.9
			1T	6.0	5.6	6.1	6.0	6.0	0.1	1.0
			B	5.8	5.2	5.8	5.6			1.0
			Avg.					**5.7**	**0.2**	
	NB/3 run 8	2/90	4T	4.4	4.6	4.6	4.4	5.0	0.4	0.6
			B	4.8	5.2	5.4	4.8			0.8
			3T	4.8	5.2	5.2	5.0	5.3	0.1	0.8
			B	4.8	5.2	5.4	4.8			0.9
			2T	5.1	5.2	5.7	5.1	6.2	0.4	1.0
			B	6.0	6.6	6.6	6.0			0.8
			1T	5.6	6.0	6.3	5.6	6.2	0.2	0.9
			B	5.4	5.7	6.0	5.2			1.2
			Avg.					**5.7**	**0.3**	

(Sheet 1 of 3)

Table 22 (continued)

Trains in November 1997				Stress Range, ksi						
Train/ Date	Direction/ Track	No. Locos/ Cars	Eyebar/ Position	At Entry E	At Exit X	Max Pk to Pk A	Steady Nominal D	Axial $(A_T + A_B)/2$	Bending $(A_T - A_B)/2$	Car Cycle
ULK 84F (263K coal car train) 11-14	SB/3	2/125	4T	4.6	4.4	4.6	4.5	4.6	0	0.6
			B	4.3	4.3	4.6	4.2			0.8
			3T	4.9	4.8	4.8	4.8	4.8	0	0.8
			B	4.5	4.3	4.8	4.3			0.9
			2T	4.9	4.8	5.1	4.9	5.5	0.5	0.9
			B	5.8	5.7	6.0	5.5			0.9
			1T	5.4	5.4	5.4	5.2	5.5	0.1	0.9
			B	5.2	5.0	5.6	4.8			0.9
			Avg.					**5.1**	**0.2**	
UIR 236 (286K coal car test train) 11-13	NB/2 run 6	2/90	4T	1.1	1.3	1.4	1.1	1.2	0	0.2
			B	1.1	1.1	1.1	1.1			0.1
			3T	1.6	1.7	1.7	1.6	1.5	0.1	0.2
			B	1.2	1.3	1.3	1.3			0.1
			2T	1.8	2.1	2.1	1.9	2.1	0.1	0.2
			B	2.0	2.1	2.2	2.0			0.1
			1T	2.4	2.6	2.6	2.4	2.1	0.4	0.2
			B	1.5	1.6	1.6	1.6			0.1
			Avg.					**1.7**	**0.2**	

(Sheet 2 of 3)

Table 22 (continued)

Trains in January 1998				Stress Range, ksi	
Train/ Date	**Direction/ Track**	**No. Locos/ Cars**	**Eyebar/ Position**	**Maximum**	**Car Cycle**
PIBA (mixed freight) 01-08	SB/3	2/66	4T- Gage 300	3.6	0.6 variable
UMP 108 (263K coal cars) 01-09	SB/2	3/80		1.2	< 0.2
BAPI (mixed freight) 01-09	NB/2	2/94		1.0	0.2

(Sheet 3 of 3)

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Table 23

Measured Diagonal Eyebar Stresses For Various Train Conditions
(In Span 2, E Truss, L7U8 @ U8)

				Stress Range, ksi				
Train/ Date	Direction/ Track	No. Locos/ Cars	Eyebar/ Position	At Entry E	At Exit X	Max Pk to Pk A	Steady Nominal D	Car Cycle
UIR 236 (286k coal car test train) 11-13	SB/3 run 9	2/90	4T	1.9	1.8	2.0	1.8	0.2
			3T	1.9	1.9	2.0	1.9	0.2
			2T	2.6	2.3	2.8	2.6	0.3
			1T	0.3	0.4	0.5	0.3	0.2
			Avg.			**1.8**		
	NB/3 run 8	2/90	4T	1.8	2.0	2.0	1.9	0.2
			3T	1.9	1.9	1.9	1.9	0.2
			2T	2.6	2.9	2.9	2.7	0.4
			1T	0.3	0.7	0.7	0.2	0.3
			Avg.			**1.9**		
	NB/2 run 6	2/90	4T	6.3	6.9	7.0	6.2	0.9
			3T	6.0	6.6	6.6	6.0	0.9
			2T	7.2	7.6	7.6	7.2	1.1
			1T	2.7	3.0	3.2	2.6	1.1
			Avg.			**6.1**		
	SB/2 run 7	2/90	4T	6.9	6.8	6.9	6.8	0.9
			3T	6.4	6.3	6.4	6.4	0.9
			2T	7.6	7.8	8.0	7.6	0.9
			1T	2.7	3.3	3.3	3.0	1.0
			Avg.			**6.2**		
ULK 84F (263K coal car train) 11-14	SB/3	2/125	4T	1.7	1.7	1.9	1.6	0.2
			3T	1.8	1.7	1.9	1.6	0.2
			2T	2.5	2.4	2.6	2.4	0.4
			1T	0.4	0.3	0.5	0.3	0.3
			Avg.			**1.7**		

Eyebar No.	Tightness [7]
4	Tight
3	Tight
2	Moderate
1	Loose

Table 24

Measured Bottom Flange Stringer Stresses for Various Train Conditions
(In Span 10 Midway Between Floorbeams 1 and 2)

				Stress, ksi			
				Max Range		Mean	
Train/ Date	Direction /Track	No. Loco's/ No. Cars	Stringer	W flange	E flange	W flange	E flange
UIR 236 (286K coal car test train) 11-13	SB/3 run 1	2/90	A	5.4	4.7	+2.0	+1.5
			B	5.0	-	+1.5	-
	run 3	4/90	A	4.7	4.8	+2.0	+1.5
			B	5.0	-	+1.5	-
	NB/2 run 4	4/90	A	0.5	0.5	+0.4	+0.4
			B	0.5	-	+0.3	-
ULK 80E (263K coal train) 11-13	SB/3	2/130	A	5.0	4.1	+1.8	+1.5
			B	4.7	-	+1.4	-
UBT 352 (263K coal train) 10-23	SB/3	2/109	A	5.3	4.7	+2.0	+1.6
			B	4.7	-	+1.5	-
UXC 66A (Regular coal train) 10-23	SB/3	2/112	A	5.0	4.3	+1.9	+1.5
			B	4.7	-	+0.4	-
Amtrak M125 11-12	SB/3	1/7	A	2.7	2.3	+0.5	+0.5
			B	2.0	-	+0.4	-
Amtrak 196 11-12	NB/2	1/8	A	0.4	0.4	+0.1	+0.2
			B	0.4	-	+0.3	-

Note: Minimum stress = Mean - Range/2

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Table 25

Measured Bottom Flange Stringer Stresses for Various Train Conditions
(In Span 10 at Coverplate End Adjacent to Floorbeam 2)

				Stress, ksi			
				Max Range		Mean	
Train/ Date	Direction /Track	No. Loco's/ No. Cars	Stringer	W flange	E flange	W flange	E flange
UIR 236 (286K coal car test train) 11-13	SB/3 run 1	2/90	A	1.8	1.4	-0.2	-0.4
			B	3.2	-	-1.6	-
	run 3	4/90	A	1.9	1.3	-0.5	-0.4
			B	3.6	-	-1.7	-
	NB/2 run 4	4/90	A	1.1	0.3	+0.6	-0.1
			B	2.1	-	+0.8	-
ULK 80E (263K coal train) 11-13	SB/3	2/130	A	1.8	1.3	-0.3	-0.5
			B	3.0	-	-1.6	-
UBT 352 (263K coal train) 10-23	SB/3	2/109	A	2.0	1.4	-0.3	-0.5
			B	3.3	-	-1.5	-
UXC 66A (Regular coal train) 10-23	SB/3	2/112	A	1.7	1.1	-0.2	-0.5
			B	2.8	-	-1.5	-
Amtrak M125 11-12	SB/3	1/7	A	0.8	0.8	-0.1	-0.2
			B	1.9	-	-0.5	-
Amtrak 196 11-12	NB/2	1/8	A	0.7	0.4	+0.2	-0.1
			B	1.3	-	+0.3	-

Note: Minimum stress = Mean - Range/2

Table 26

Measured Stringer Stresses for Various Train Conditions
(Span 2 West Top Chord and Interior Stringer midway between Floorbeams 8 and 9)

Train/ Date	Direction /Track	No. Loco's /Cars	Bridge Member	Maximum* Stress Range, ksi — Top Surface/Gage — at ℄: Long/ 279 T.Ch 281 Str B	Top Surface/Gage — E edge: Long/ 280 T.Ch 283 StrB	Top Surface/Gage — E edge: Trans/ D29 T.Ch --	Top Surface/Gage — W edge: Long/ -- 282 StrB	Bottom Flanges/Gage — E: Long/ D5 --	Bottom Flanges/Gage — W: Long/ D6 --
* One primary stress cycle occurred per railcar with coal and freight trains. With passenger trains, the primary stress cycle was due to the locomotive(s). na = not acquired or not reliable									
Trains in November 1997									
UIR 236 coal (286K car test train) 11-13	SB/3 run 9	4/90	Top chord	- 7.0	- 5.5	**	na	na	na
			Stringer B	- 8.4	- 8.0	na	- 7.9		
	SB/2 run 5		Top chord	≤0.1	- 1.5	**	na		
			Stringer B	- 0.2	+ 0.2	na	+ 0.2		
ULK 84F 11-14	SB/3	2/125	Top chord	- 6.7	- 4.0	**	na		
			Stringer B	- 7.6	- 6.8	na	- 6.8		
Amtrak M121 11-13	SB/3	1/7	Top chord	- 3.7	- 5.0	**	na		
			Stringer B	- 5.5	- 4.4	na	- 4.7		
Trains in January 1998									
PIBA 01-08	SB/3	2/66	Top chord	na		- 2.7	na	+ 5.4	+ 6.8
Amtrak M105 01-09	SB/3	1/7	Top chord	na				+ 2.9	+ 3.5
BAPI 01-09	NB/2	2/94	Top chord	na		+ 0.2	na	+ 0.2	- 0.7
UMP 108 01-09	SB/2	3/80	Top chord	na		+ 0.4	na	- 0.3	- 1.0
Post-Retrofit Data for Gages D5 and D6 are given in Table 45.									

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Table 27

Measured Floorbeam Stresses for Various Train Conditions
(In Span 10, Floorbeam 2 Between Stringers A and B)

				Stress , ksi			
Train/ Date	**Direction /Track**	**No. Loco's/ Cars**	**Gage/ FB Location**	**Maximum**	**Minimum**	**Range**	**Car Range**
UIR 236 (286K coal car test train) 11-13	SB/3 run 3	4/90 (2 front, 2 rear)	**S side of FB**				
			30 / Top surface of top CP	2.8	-0.2	3.0	1.5
			32 / Edge of middle CP at end of bottom CP	5.8	-0.2	6.0	2.2
			N side of FB				
			39 / Bottom flange angle 52" fromStringer A	2.7	0	2.7	1.3
			40 / Edge of bottom CP 18" from its end (below 39)	3.4	0	3.4	1.6
	NB/2 run 4		30	1.4	0	1.4	0.6
			32	2.0	0	2.0	1.0
			39	1.3	0	1.3	0.6
			40	1.7	0	1.7	1.2
ULK 80E (regular coal car train) 11-13	SB/3	2/130	30	2.5	-0.2	2.7	1.2
			32	4.2	-0.3	4.5	2.3
			39	2.9	0	2.9	1.3
			40	3.5	0	3.5	1.6
UXC 66A (regular coal car train) 10-23	SB/3	1/7	30	2.7	-0.2	2.9	1.2
			32	4.1	-0.3	4.4	2.0
			39	2.8	0	2.8	1.4
			40	3.3	0	3.3	1.5
Amtrak M125 11-12	SB/3	1/7	30	1.6	0	1.6	0.7
			32	2.3	0	2.3	1.4
			39	1.6	0	1.6	0.7
			40	2.0	0	2.0	0.9

Table 28

Measured Floorbeam Stresses for Various Train Conditions (In Span 10, Floorbeam 10, West Half Length)

				Stress , ksi			
Train/ Date	**Direction /Track**	**No. Loco's/ Cars**	**Gage /FB Location**	**Maximum**	**Minimum**	**Range**	**Car Range**
UIR 236 (286K coal car test train) 11-13	SB/3 run 3	4/90 (2 front, 2 rear)	**At ℄**				
			22 / N side, edge of bottom CP	2.2	0	2.2	1.8
			23 / Same, edge of top CP	2.1	0	2.1	1.7
			26" W of ℄				
			20 / N side edge of bottom CP	4.0	0	4.0	3.3
			21 / Same,edge of top CP	2.8	0	2.8	2.2
			~42" W of Stringer B				
			19 / N side edge of bottom CP where CP ends	3.7	-0.5	4.2	4.2
			25 / S side atop middle CP where top CP is corroded	5.3	0	5.3	3.2
	NB/2 run 4		22	2.3	0	2.3	1.8
			23	2.0	0	2.0	1.5
			20	2.1	0	2.1	1.4
			21	1.6	0	1.6	1.1
			19	0.8	-0.2	1.0	0.6
			25	2.7	-0.4	3.1	1.6
ULK 80E (263k coal car train) 11-13	SB/3	2/130	22	2.0	0	2.0	1.7
			23	1.9	0	1.9	1.7
			20	3.7	0	3.7	3.2
			21	2.6	0	2.6	2.0
			19	3.7	-0.7	4.4	3.7
			25	4.8	-0.5	5.3	2.8

Table 29

Measured Floorbeam Stresses for Various Train Conditions
(In Span 2, Floorbeam 5, November 1997)

				Stress , ksi			
Train/ Date	**Direction /Track**	**No. Loco's/ Cars**	**Gage/ FB Location**	**Maximum**	**Minimum**	**Range**	**Car Range**
UIR 236 (286K coal car test train) 11-13	SB/3 run 9	4/90 (2 front, 2 rear)	**at W top chord**				
			308 / N side of FB, vertical, normal to crack on angle leg	0.7	-1.2	1.9	0.2
			309 / on fill plate near crack tip & prior repair weld	2.0	-1.7	3.7	0.7
			310 / S side of FB, on fill plate normal to prior repair weld, near crack arrest hole	0.7	-0.8	1.5	0.2
			at E top chord				
			311 / N side of FB, vertical on angle leg	0.1	-0.1	0.2	0.1
			312 / N side of FB, on fill plate, normal to prior repair weld	-0.1	-0.3	0.2	0.1
	NB/3 run 8		308	1.0	-0.6	1.6	0.3
			309	2.6	-1.5	4.1	0.7
			310	0.4	-1.0	1.4	0.3
			311	0.1	-0.1	0.2	0.1
			312	0.4	-0.1	0.5	0.1
	SB/2 run 7		308	0.6	-0.6	1.2	0
			309	2.1	-1.4	3.5	-0.2
			310	0.4	-0.4	0.8	0.1
			311	0.2	-0.2	0.4	-0.1
			312	0.4	-0.6	1.0	-0.2
Post-Retrofit Data for Gage 309 are given in Table 47.							

(Continued on next sheet)

Table 29 (continued)

				Stress, ksi			
Train/ Date	**Direction /Track**	**No. Loco's/ Cars**	**Gage/ FB Location**	**Maximum**	**Minimum**	**Range**	**Car Range**
UIR 236 (286K coal car test train) 11-13	NB/2 run 6	4/90 (2 front, 2 rear)	**at W top chord**				
			308 / N side of FB, vertical, normal to crack on angle leg	0.3	-0.4	0.7	0.2
			309 / on fill plate near crack tip & prior repair weld	1.0	-1.0	2.0	0.4
			310 / S side of FB, on fill plate normal to prior repair weld, near crack arrest hole	0.4	-0.3	0.7	0.2
			at E top chord				
			311 / N side of FB, vertical on angle leg	0.2	-0.3	0.5	0.2
			312 / N side of FB, on fill plate, normal to prior repair weld	0.4	-0.5	0.9	0.3
ULK 84F (263K coal coal car Train) 11-14	SB/3	2/125	308	0.8	-0.8	1.6	0.3
			309	2.2	-1.8	4.0	0.5
			310	0.6	-0.7	1.3	0.3
			311	0.2	0.1	0.1	0.1
			312	0.4	0.2	0.2	0.2
Post-Retrofit Data for Gage 309 are given in Table 47.							

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Table 30

Measured Floorbeam Displacements for Various Train Conditions
(In Span 2, Floorbeam 5-West, November 1997 and January 1998)

				Displacement, in.			
Train/ Date	**Direction /Track**	**No. Loco's/ Cars**	**Gage/ FB Location**	**Maximum Compression, c**	**Maximum Extension, e**	**Nominal Mean**	**Car Range, loco/car**
UIR 236 (286K coal car test train) 11-13	SB/3 run 9	4/90 (2 front, 2 rear)	**397** / N side of FB, from vertical post to top flange of FB	0.080	0.047	0.055c	0.055/0.045
			398 / like 397 on S side of FB	0.090	0.070	0.060c	0.055/0.045
	NB/2 run 6		397	0.015	0.080	0.062e	0.040 /0.030
			398	0.020	0.075	0.060e	0.035 /0.025
	SB/2 run 7		397	0.010	0.075	0.062e	0.037 /0.032
			398	0.015	0.070	0.055e	0.032 /0.027
	SB/2 run 7 with MARC on SB/3		397	0.060	0.065	-	- /0.057
			398	0.075	0.065	-	- /0.055
	NB/3 run 8		397	0.090	0.040	0.055c	0.060/0.040
			398	0.100	0.060	0.065c	0.060/0.045
ULK 84F (heavy coal train) 11-14	SB/3	2/125	397	0.080	0.045	0.050c	0.070 /0.040
			398	0.095	0.060	0.060c	0.080 /0.040
UMP 108 (heavy coal train) 01-09	SB/2	3/80	**D97** / N side of FB from vertical post to plates between FB and hanger	0.012	0.115	0.085e	0.040
BAPI (mixed freight) 01-09	NB/2	2/94	D97	0.010	0.110	≤ 0.065e	≤ 0.050
Amtrak 181 01-09	SB/3	1/6	D97	0.050	0.035	0.01c	0.03
Amtrak M106 01-09	NB/2	1/6	D97	0	0.075	0.02e	0.03

Table 31

Measured Floorbeam Stresses for Various Train Conditions
(In Span 2, Floorbeam 5, January 1998)

				Stress, ksi			
Train/ Date	**Direction /Track**	**No. Loco's/ Cars**	**Gage /FB Location**	**Maximum**	**Minimum**	**Range**	**Car Range**
			At East Truss				
PIBA (mixed freight) 01-09	SB/3	2/66	**D12** / W bottom flange of top chord, transverse to chord, 13" N of FB ℄	+4.0	-1.0	5.0	≤ 2.0
			D13 / like D12, but 1½ S of FB ℄	+5.5	-1.3	6.8	≤ 2.0
			At West Truss				
			D17 / E bottom flange of top chord, like D12	+1.3	-5.0	6.3	≤ 4.0
			D16 / like D17, but at FB ℄	+5.0	-20.5	25.5	≤ 12.0
			At midlength				
			D14 / ℄ bottom flange, parallel FB	+2.1	0	2.1	≤ 1.5
Amtrak 181 01-09	SB/3	1/6	D12	+2.7	-2.0	4.7	1.5
			D13	+3.5	-1.0	4.5	2.0
			D17	+1.5	-3.5	5.0	1.5
			D16	+4.0	-19.0	23.0	5.0
			D14	+1.5	-0.2	1.7	0.8
Amtrak M106 01-09	NB/2	1/6	D12	bad gage			
			D13	+1.9	-1.3	3.2	2.0
			D17	+2.0	0	2.0	1.0
			D16	+8.0	0	8.0	4.0
			D14	+1.2	-0.2	1.4	1.0
Post-Retrofit Data for Gage D14 are given in Table 47.							

(Continued on next sheet)

Table 31 (continued)

Train/ Date	Direction /Track	No. Loco's/ Cars	Gage /FB Location	Stress, ksi Maximum	Minimum	Range	Car Range
			At East Truss				
BAPI (mixed freight) 01-09	NB/2	2/94	**D12** / W bottom flange of top chord, transverse to chord, 13" N of FB ℄	bad gage			
			D13 / like D12, but 1½ S of FB ℄	bad gage			
			At West Truss				
			D17 / E bottom flange of top chord, like D12	bad gage			
			D16 / like D17, but at FB ℄	+11.0	-1.5	12.5	≤ 6.0
			At midlength				
			D14 / ℄ bottom flange, parallel FB	+2.1	-0.1	2.2	≤ 1.5
UMP 108 01-09	SB/2	3/80	D12	bad gage			
			D13	bad gage			
			D17	bad gage			
			D16	+12.0	-2.0	14.0	5.0
			D14	+2.1	0	2.1	2.0
Post-Retrofit Data for Gage D14 are given in Table 47.							

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Table 32

Measured Floorbeam/Top Chord Stresses for Various Train Conditions
(In Span 2, West Truss at Floorbeam 8, November 1997)

				Stress , ksi			
Train/ Date	**Direction /Track**	**No. Loco's/ Cars**	**Gage/ Member**	**Maximum**	**Minimum**	**Range**	**Car Range**
UIR 236 (286K coal car test train) 11-13	SB/3 run 9	4/90 (2 front, 2 rear)	**301** / Top chord E bottom flange, S of FB, parallel to chord	0.5	-2.3	2.8	1.8
			302 / Top Flange of FB at ℄, parallel to FB	-0.5	-1.4	0.9	0.5
			303 / Bottom FB Flange below 302, parallel to FB	2.4	0	2.4	1.3
	SB/2 run 5		**301**	0.3	-1.5	1.8	0.5
			302	0	-0.4	0.4	0.2
			303	0.3	-0.9	1.2	0.3
ULK 84F (263K coal car train) 11-14 11-14	SB/3	2/125	**301**	0.3	-2.2	2.5	1.7
			302	-0.4	-1.3	0.9	0.5
			303	2.3	0	2.3	1.3
Amtrak M121 11-13	SB/3	1/7	**301**	1.0	-0.8	1.8	0.6
			302	0.5	-1.1	1.6	0.6
			303	1.2	-0.2	1.4	0.7

Table 33

Measured Floorbeam/Top Chord Stresses for Various Train Conditions
(In Span 2, West & East Trusses at Floorbeam 8, January 1998)

				Stress, ksi			
Train/ Date	**Direction /Track**	**No. Loco's/ Cars**	**Gage/ Member**	**Maximum**	**Minimum**	**Range**	**Car Range**
			West Truss				
PIBA (mixed freight) 01-08	SB/3	2/66	**301** / Top chord E bottom flange, S of FB, parallel to chord	0.2	-1.3	1.5	≤ 0.7
			302 / Top Flange of FB at ℄, parallel to FB	3.0	0	3.0	≤ 0.5
			D7 / E bottom flange of top chord, transverse to chord, 1½" from FB ℄	1.9	0	1.9	0.6
			East Truss				
			D4 / W bottom flange of top chord, transverse to chord, 18" S of FB ℄	1.0	0	1.0	0.3
BAPI (mixed freight) 01-09	NB/2	2/94	301	0.2	-0.3	0.5	≤ 0.2
			302	2.1	0	2.1	≤ 0.3
			D7	0.1	-0.1	0.2	0.2
			D4	bad gage			
UMP 108 (heavy coal train) 01-09	SB/2	3/80	301	0.2	-0.5	0.7	0.2
			302	2.3	0	2.3	0.3
			D7	0	-0.2	0.2	0.2
			D4	bad gage			

Table 34

Measured Floorbeam/Top Chord Displacements for Various Train Conditions
(In Span 2, West Truss at Floorbeam 8, January 1998)

				Displacement, in.			
Train/ Date	**Direction /Track**	**No. Loco's/ Cars**	**Gage/ Member**	**Maximum extension e**	**Minimum contraction c**	**Range**	**Car Range**
PIBA (mixed freight) 01-08	SB/3	2/66	**D9** / S side of FB from vertical post to bottom of doubler plates on top chord web	0.012e	0.003c	0.015	0.010
BAPI (mixed freight) 01-09	NB/2	2/94	D9	0	0.003c	0.003	0.001
UMP 108 (heavy coal train) 01-09	SB/2	3/80	D9	0	0.003c	0.003	0.001
Amtrak 181 01-09	SB/3	1/6	D9	0.003e	0.001c	0.004	0.002
Amtrak M106 01-09	NB/2	1/6	D9	0	0.002c	0.002	0.001

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Table 35
Measured Floorbeam Stresses for Various Train Conditions
(In Span 7, Floorbeam 5, October and November 1997)

				Stress , ksi			
Train/ Date	**Direction /Track**	**No. Loco's/ Cars**	**Gage/ FB Location**	**Maximum**	**Minimum**	**Range**	**Car Range**
UIR 236 (286K coal car test train) 11-13	SB/3 run 1	2/90	**at W end of FB**				
			86 / N side of FB, near crack tip.	+24.0	-50.4	74.4	12.0
			87 / N edge of FB flange, 8" E of lateral gusset	0	-1.6	1.6	0.6
			at W top				
			88 / N end of long crack on bottom flange angle, normal to crack	0	-13.5	13.5	8.1
			89 / like 88,but at S end of crack	0	-39.6	39.6	6.0
	NB/3 run 2	4/90 (2 front, 2 rear)	86	+26.4	-48.0	74.4	12.0
			87	0	-1.8	1.8	0.8
			88	0	-14.4	14.4	7.5
			89	0	-28.8	28.8	4.8
	NB/2 run 4		86	+12.0	-26.4	38.4	3.6
			87	+0.2	-1.0	1.2	0.8
			88	+2.4	-1.7	4.1	1.2
			89	+3.6	-5.4	9.0	2.4
UBC 20 10/20	SB/3	2/85	86	+19.5	-48.0	67.5	9.0
			87	0	-1.5	1.5	0.4
			88	0	-12.6	12.6	≤5.7
			89	0	-31.5	31.5	≤7.5
UBT 352 10/23	SB/3	2/109	86	+21.6	-50.4	72.0	10.8 / 16.8*
			87	0	-1.8	1.8	0.7 / 0.8*
			88	0	-12.6	12.6	6.6 / 8.1*
			89	0	-28.8	28.8	6.0 / 7.2*

* when combined with coincident Amtrak train M126

Table 35 (continued)

				Stress , ksi			
Train/ Date	**Direction /Track**	**No. Loco's/ Cars**	**Gage/ FB Location**	**Maximum**	**Minimum**	**Range**	**Car Range**
ULK 80E (263K coal car train) 11-13	SB/3	2/130	**at W end of FB**				
			86 / N side of FB, near crack tip.	+24.0	-52.8	76.8	12.0
			87 / N edge of FB flange, 8" E of lateral gusset plate	0	-1.6	1.6	0.8
			at W top chord				
			88 / N end of long crack on bottom flange angle, normal to crack	0	-13.5	13.5	≤8.1
			89 / like 88,but at S end of crack	0	-28.8	28.8	≤6.0
Amtrak M127 10/20	SB/3	1/7	86	+9.6	-48.9	58.5	13.2
			87	0	-0.8	0.8	0.5
			88	0	-8.1	8.1	1.8
			89	0	-17.4	17.4	7.8
Amtrak M126 10/20	NB/2	1/9	86	+4.8	-9.0	13.8	5.4
			87	+0.1	-0.4	0.5	0.4
			88	+0.6	-0.2	0.8	0.2
			89	+0.8	-2.6	3.4	2.0

Table 36

Measured Floorbeam/Top Chord Stresses for Various Train Conditions
(In Span 1, West Truss at Floorbeam 8, January 1998)

				Stress , ksi			
Train/ Date	**Direction /Track**	**No. Loco's/ Cars**	**Gage/ Member**	**Maximum**	**Minimum**	**Range**	**Car Range**
UMP 108 (263K coal car train) 01-09	SB/2	3/80	**D26** / Top chord E bottom flange, at ℄ of FB, parallel to FB	+1.2	-2.6	3.8	1.6
			D27 / S side of FB on bottom of flange, transverse to FB	0	-0.4	0.4	0.1
			D28 / Near D27, vertical on fill plate close to FB flange	+2.7	0	2.7	0.2
PIBA (Mixed freight) 01-08	SB/3	2/66	D26	0	-10.5	10.5	≤ 8.5
			D27	+0.2	-1.7	1.9	≤ 1.9
			D28	+4.5	0	4.5	≤ 3.8
BAPI (Mixed freight) 01-09	NB/2	2/94	D26	+0.6	-2.5	3.1	≤ 2.3
			D27	0	-0.3	0.3	≤ 0.1
			D28	+2.2	0	2.2	≤ 0.4
Amtrak 181 01-09	SB/3	1/6	D26	0	-6.5	6.5	2.5
			D27	0	-0.8	0.8	0.5
			D28	+3.5	0	3.5	1.6
Amtrak M106 01-09	NB/2	1/6	D26	0	-1.0	1.0	0.6
			D27	signal too noisy			
			D28	+1.5	0	1.5	0.5
Post-Retrofit Data for these gages are given in Table 49.							

Table 37

Measured Pre-Retrofit Vertical Post Stresses for Various Trains
(In Span 2, Post L5U5-West Truss, January 1998)

Trains in January 1998				Stress, ksi		
Train/ Date	**Direction /Track**	**No. Loco's/ Cars**	**Gage/ FB Location**	**Maximum**	**Minimum**	**Range**
PIBA (mixed freight) 01-08	SB/3	2/66	**D22**/NW Corner **D23**/NE Corner **D24**/SE Corner **D25**/SW Corner	1.5 1.1 2.5 1.5	- 2.3 - 2.7 - 3.3 - 2.0	3.8 3.8 5.8 3.5
AM 181 01-09	SB/3	1/6	D22 D23 D24 D25	1.2 1.3 2.0 1.3	- 1.1 - 1.2 - 2.5 - 1.7	2.3 2.5 4.5 3.0
AM M106 01-09	NB/2	1/6	D22 D23 D24 D25	signal too noisy signal too noisy 0.6 0.4	signal too noisy signal too noisy - 1.0 - 0.4	signal too noisy signal too noisy 1.6 0.8
BAPI (mixed freight) 01-09	NB/2	2/94	D22 D23 D24 D25	0.5 0.3 0.6 0.5	- 0.3 - 0.5 - 1.2 - 0.6	0.8 0.8 1.8 1.1
UMP 108 (263K-car coal train) 01-09	SB/2	3/80	D22 D23 D24 D25	0.6 0.3 0.8 0.6	- 0.3 - 0.3 - 1.3 - 0.7	0.9 0.6 2.1 1.3
Post-Retrofit Data from these gages are given in Table 50.						

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Table 38

Measured Pre-Retrofit Vertical Post Stresses for Various Trains
(In Span 2, Post L5U5-East Truss, January 1998)

Trains in January 1998				Stress , ksi		
Train/ Date	**Direction /Track**	**No. Loco's/ Cars**	**Gage/ FB Location**	**Maximum**	**Minimum**	**Range**
PIBA (mixed freight) 01-08	SB/3	2/66	**D18** / NE Corner	0	- 0.5	0.5
			D19 / NW Corner	0	- 1.1	1.1
			D20 / SW Corner	0.7	- 1.6	2.3
			D21 / SE Corner	0.4	- 1.0	1.4
AM 181 01-09	SB/3	1/6	D18	signal too noisy	signal too noisy	signal too noisy
			D19	0.2	- 0.9	1.1
			D20	0.5	- 1.0	1.5
			D21	0.4	- 0.6	1.0
AM M106 01-09	NB/2	1/6	D18	0.1	- 1.7	1.8
			D19	0.2	-1.8	2.0
			D20	0.1	- 1.8	1.9
			D21	0.2	- 1.3	1.5
BAPI (mixed freight) 01-09	NB/2	2/94	D18	0.7	- 2.8	3.5
			D19	0.7	- 3.3	4.0
			D20	0.1	- 2.8	2.9
			D21	0.3	- 2.3	2.6
UMP 108 (263K-car coal train) 01-09	SB/2	3/80	D18	1.0	- 2.7	3.7
			D19	0.9	- 3.1	4.0
			D20	0.1	- 2.8	2.9
			D21	0.4	- 2.4	2.8
Post-Retrofit Data from these gages are given in Table 51.						

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Table 39

Measured Post-Lubrication Lower-Chord Eyebar Stresses for Various Trains
(Span 1, W truss, Chord L8L9@L9)

Trains on August 12, 1998				Stress Range, ksi					
				Maximum Range				Car Cycle Range	
Train	Direction /Track	No. Locos /Cars	Eyebar No.*	Top, T	Bottom, B	Axial, (T+B)/2	Bending, (T-B)/2	Top	Bottom
ULK 66C (263K coal car train)	SB/2	2/128	4	3.0	-2.0	0.5	2.5	0.6	0
			3	4.0	-2.5	0.8	3.2	0.7	0.4
			2	3.7	na	na	na	0.6	na
			1	3.0	-3.4	-0.2	3.2	0.5	0
			Avg.			0.4	3.0		
UMP 74B (263K coal car train)	SB/3	3/80	4	4.0	-4.2	-0.1	4.1	0.7	0.
			3	6.0	- 3.5	1.3	4.7	0.8	0.3
			2	6.0	na	na	na	0.8	na
			1	6.0	-2.0	2.0	4.0	0.8	0.3
			Avg.			1.1	4.3		
UMP 110 (263K coal car train)	SB/3	3/80	4	5.2	-4.5	0.4	4.8	0.7	0
			3	6.8	-3.4	1.7	5.1	0.9	0.2
			2	7.0	na	na	na	0.9	na
			1	7.5	-2.6	2.5	5.0	0.8	0.4
			Avg.			1.5	5.0		
XSM 43E (empty coal train)	NB/3	2/na	4	5.3	-4.0	0.6	4.7	-	-
			3	6.8	- 3.1	1.8	5.0	-	-
			2	6.5	na	na	na	-	-
			1	6.3	-2.5	1.9	4.4	-	-
			Avg.			1.4	4.7		
Pre-Retrofit Data for these eyebars are given in Table 11.									

(Continued on next sheet)

Table 39 (continued)

Trains on August 12, 1998				Stress Range, ksi					
				Maximum Range				Car Cycle Range	
Train	Direction /Track	No. Loco-motives	Eyebar No.*	Top, T	Bottom, B	Axial, (T+B)/2	Bending, (T-B)/2	Top	Bottom
AM 97	SB/3	1/11	4	3.3	-3.3	0	3.3	1.0	na
			3	5.0	-2.6	1.2	3.8	1.1	0.8
			2	4.7	na	na	na	0.7	na
			1	4.6	-2.0	1.2	3.4	1.0	0.7
			Avg.			1.2	3.5		
AM 175	SB/3	1/9	4	3.1	-3.1	0	3.1	1.0	0.6
			3	4.2	-2.5	0.8	3.4	1.0	0.9
			2	4.1	na	na	na	1.0	na
			1	4.0	-2.0	-1.0	3.0	0.7	0.5
			Avg.			0.6	3.2		
AM M106	NB/3	1/8	4	4.0	-3.4	0.3	3.7	1.0	0.4
			3	5.0	-2.3	1.4	3.6	1.0	1.0
			2	5.0	na	na	na	0.7	na
			1	5.0	-2.0	1.5	3.5	1.0	0.5
			Avg.			1.1	3.6		
MARC 536	NB/2	1/6	4	2.0	-1.6	0.2	1.8	0.5	0.5
			3	2.5	-1.5	0.5	2.0	0.7	0.5
			2	2.7	na	na	na	0.5	na
			1	2.2	-1.8	0.2	2.0	0.8	0.5
						0.3	2.0		
Pre-Retrofit Data for these eyebars are given in Table 11.									

*No. 4 eyebar is the exterior eyebar in each group; No. 1 eyebar is the interior.

na = not acquired

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Table 40

Measured Post-Retrofit Lower Chord Eyebar Stresses for Various Trains

(Span 2, W truss, Chord L4L5@L5)

Trains on August 12, 1998				Stress Range, ksi					
				Maximum Range				Car Cycle Range +	
Train	Direction /Track	No: Locos /cars	Eyebar No.*	Top, T	Bottom, B	Axial, (T+B)/2	Bending, (T-B)/2	Top	Bottom
ULK 66C (263K coal car train)	SB/2	2/128	5	1.5	2.0	1.7	0.2	-	-
			6	1.5	1.5	1.5	0	-	-
			Avg.			**1.6**	**0.1**		
UMP 74B (coal train, cars 215 - 262K)	SB/3	3/80	5	3.0	4.3	3.7	0.7	-	-
			6	3.1	4.2	3.7	0.7	-	-
			Avg.			**3.7**	**0.6**		
UMP 110 (coal train, cars 189-246K)	SB/3	3/80	5	2.5	4.0	3.2	0.7	-	-
			6	3.0	4.0	3.5	0.5	-	-
			Avg.			**3.4**	**0.6**		
XSM 43E (empty coal cars)	NB/3	1/na	5	2.0	3.4	2.7	0.7	-	-
			6	2.5	3.4	3.0	0.5	-	-
			Avg.			**2.8**	**0.6**		
Marc 536	NB/2	1/6	5	1.0	1.0	1.0	0	-	-
			6	1.0	1.0	1.0	0	-	-
			Avg.			**1.0**	**0**		
AM 97	SB/3	1/11	5	1.8	2.6	2.2	0.4	-	-
			6	2.0	2.8	2.4	0.4	-	-
			Avg.			**2.3**	**0.4**		
AM 175	SB/3	1/9	5	1.3	2.0	1.7	0.4	-	-
			6	1.4	2.0	1.7	0.3	-	-
			Avg.			**1.7**	**0.4**		
AM M106	NB/3	1/8	5	1.2	1.8	1.5	0.3	-	-
			6	1.5	1.8	1.7	0.2	-	-
			Avg.			**1.6**	**0.2**		

na = not acquired

* No. 5 and No. 6 eyebars are the middle two in a group of 10. No. 6 is more outboard.

\+ Less than 0.5 ksi, so not listed.

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Table 41
Measured Post-Retrofit Lower-Chord Eyebar Stresses for Various Trains
(Span 2, W truss, Chord L5L6@L5)

Trains on August 12, 1998				Stress Range, ksi					
				Maximum Range				Car Cycle Range +	
Train	Direction /Track	No. Locos /cars	Eyebar No.*	Top, T	Bottom, B	Axial, (T+B)/2	Bending, (T-B)/2	Top	Bottom
ULK 66C (263K coal car train)	SB/2	2/128	4	1.5	2.3	1.9	0.4	-	-
			5	1.5	2.3	1.9	0.4	-	-
			Avg.			**1.9**	**0.4**		
UMP 74B (coal train, cars 215 - 262K)	SB/3	3/80	4	3.2	4.0	3.6	0.4	-	-
			5	3.1	3.6	3.4	0.3	-	-
			Avg.			**3.5**	**0.4**		
UMP 110 (coal train, cars 189 - 246K)	SB/3	3/80	4	3.0	4.0	3.5	0.5	-	-
			5	3.0	3.9	3.5	0.5	-	-
			Avg.			**3.5**	**0.5**		
XSM 43E (empty coal cars)	NB/3	1/na	4	2.9	3.2	3.1	0.2	-	-
			5	2.7	3.2	3.0	0.3	-	-
			Avg.			**3.1**	**0.2**		
Marc 536	NB/2	1/6	4	0.8	1.0	0.9	0.1	-	-
			5	0.7	0.9	0.8	0.1	-	-
			Avg.			**0.9**	**0.1**		
AM 97	SB/3	1/11	4	2.0	2.3	2.2	0.2	-	-
			5	2.0	2.0	2.0	0	-	-
			Avg.			**2.1**	**0.1**		
AM 175	SB/3	1/9	4	na	1.5	na	na	-	-
			5	1.5	1.5	1.5	0	-	-
			Avg.			**1.5**	**0**		
AM M106	NB/3	1/8	4	na	2.2	na	na	-	-
			5	1.4	1.7	1.6	0.2	-	-
			Avg.			**1.6**	**0.2**		

* No. 4 and No. 5 eyebars are the middle two in a group of 8.
No. 5 is more outboard.
\+ Less than 0.5 ksi, so not listed
na = not acquired or not reliable.

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Table 42
Measured Post-Retrofit Lower-Chord Eyebar Stresses for Various Trains
(Span 2, W truss, Lower Chord L8L9@L9)

Trains on August 12, 1998				Stress Range, ksi					
				Maximum Range				Car Cycle Range	
Train	Direction /Track	No. Locos /cars	Eyebar No.*	Top, T	Bottom, B	Axial, (T+B)/2	Bending, (T-B)/2	Top	Bottom
ULK 66C (263K coal car train)	SB/2	2/128	3	1.6	-0.7	0.5	1.1	0.5	0.2
			2	1.2	-1.2	0	1.2	0.5	0.2
			Avg.			**0.3**	**1.2**		
UMP 74B (coal train, cars 215 - 262K)	SB/3	3/80	3	3.0	-0.8	1.1	1.9	0.4	0.2
			2	2.5	1.0	1.7	0.8	0.3	0.2
			Avg.			**1.4**	**1.4**		
UMP 110 (coal train, cars 189 - 246K)	SB/3	3/80	3	3.2	-1.0	1.1	2.1	0.5	0.2
			2	3.2	0.8	2.0	1.2	0.4	0.2
			Avg.			**1.6**	**1.6**		
XSM 43E (empty coal train)	NB/3	1/na	3	3.1	0.7	1.9	1.2	-	-
			2	2.7	1.0	1.9	0.8	-	-
			Avg.			**1.9**	**1.0**		
Marc 536	NB/2	1/6	3	1.0	0.2	0.6	0.4	0.4	0.3
			2	0.9	0.3	0.6	0.3	0.3	0.3
			Avg.			**0.6**	**0.4**		
AM 97	SB/3	1/11	3	2.2	0.3	1.2	1.0	0.7	0.5
			2	1.7	0.8	1.2	0.5	0.7	0.5
			Avg.			**1.2**	**0.8**		
AM 175	SB/3	1/9	3	1.9	0.8	1.3	0.6	0.7	0.3
			2	1.5	0.6	1.1	0.4	0.6	0.3
			Avg.			**1.2**	**0.5**		
AM M106	NB/3	1/8	3	2.0	0.2	1.1	0.9	0.7	0.3
			2	1.4	0.6	1.0	0.4	0.5	0.4
			Avg.			**1.0**	**0.7**		

* No. 2 and No. 3 eyebars are the middle two in a group of 4.
No. 3 is more outboard.
na = not acquired.

C:\My Documents\Susquehanna Bridge\Table 42.wpd

Table 43

Measured Post-Retrofit Diagonal Eyebar Stresses For Various Trains
(In Span 2, W Truss, L5U6 @ L5)

Trains on August 12, 1998				Stress, ksi			Stress Range, ksi			
Train	Direction/ Track	No. Locos/ Cars	Eyebar/ Position	Min.	Max.	Steady Nominal D	Max Pk to Pk A	Axial $(A_T + A_B)/2$	Bending $(A_T - A_B)/2$	Car Cycle
ULK 66C (263K coal car train)	SB/2	2/128	4T	-0.2	1.1	0.7	1.3	1.3	0	0.4
			B	-0.2	1.1	0.7	1.3			0.4
			3T	-0.4	1.2	0.8	1.6	1.5	0.1	0.5
			B	-0.2	1.2	0.7	1.4			0.4
			2T	-0.3	1.5	0.9	1.8	1.9	0.1	0.5
			B	-0.3	1.7	1.2	2.0			0.5
			1T	-0.2	1.4	0.9	1.6	1.8	0.2	0.4
			B	-0.4	1.6	1.0	2.0			0.6
			Avg.					**1.6**	**0.1**	
UMP 74B (coal train, cars 215-262K)	SB/3	3/80	4T	-1.3	3.0	2.0	4.3	4.2	0.1	0.5
			B	-1.0	3.0	1.8	4.0			0.2
			3T	-1.5	3.6	2.2	5.1	4.5	0.6	0.7
			B	-1.0	2.8	1.6	3.8			0.5
			2T	-1.3	3.6	2.2	4.9	4.7	0.2	1.4
			B	-1.5	3.0	1.7	4.5			1.2
			1T	-1.0	3.0	1.8	4.0	4.1	0.1	0.2
			B	-1.2	3.0	1.6	4.2			0.2
			Avg.					**4.4**	**0.2**	

Pre-Retrofit Data for these eyebars is given in Table 18.

(Sheet 1 of 4)

Table 43 (continued)

Trains on August 12, 1998			Stress, ksi				Stress Range, ksi			
Train	Direction/ Track	No. Locos/ Cars	Eyebar/ Position	Min.	Max.	Steady Nominal D	Max Pk to Pk A	Axial $(A_T + A_B)/2$	Bending $(A_T - A_B)/2$	Car Cycle
UMP 110 (coal train, cars 189-246K)	SB/3	3/80	4T	-1.0	3.1	2.2	4.1	4.1	0	0.6
			B	-1.2	2.9	1.8	4.1			0.6
			3T	-1.6	3.3	2.3	4.9	4.2	0.7	0.7
			B	-1.1	2.4	1.7	3.5			0.4
			2T	-1.7	3.2	2.2	4.9	4.8	0.1	0.6
			B	-1.6	3.0	1.9	4.6			0.7
			1T	-1.2	2.9	1.8	4.1	4.3	0.1	0.5
			B	-1.5	3.0	1.8	4.5			0.7
			Avg.					**4.3**	**0.2**	
XSM 43E (empty coal car train)	NB/2	1/na	4T	-0.5	3.6	0.4	4.1	3.8	0.3	-
			B	-0.4	3.2	0.4	3.6			-
			3T	-0.5	3.7	0.7	4.2	3.7	0.5	-
			B	-0.5	2.7	0.4	3.2			-
			2T	-0.6	3.8	0.8	4.4	4.2	0.2	-
			B	-0.9	3.2	0.5	4.1			-
			1T	-0.6	3.3	0.7	3.9	4.0	0	-
			B	-0.8	3.2	0.5	4.0			-
			Avg.					**3.9**	**0.2**	

Pre-Retrofit Data for these eyebars is given in Table 18.

(Sheet 2 of 4)

Table 43 (continued)

Trains on August 12, 1998			Stress, ksi				Stress Range, ksi			
Train	Direction/ Track	No. Locos/ Cars	Eyebar/ Position	Min.	Max.	Steady Nominal D	Max Pk to Pk A	Axial $(A_T + A_B)/2$	Bending $(A_T - A_B)/2$	Car Cycle
AM 97	SB/3	1/11	4T	-1.0	2.5	0.6	3.5	3.4	0.1	1.1
			B	-1.0	2.3	0.5	3.3			1.0
			3T	-1.3	2.7	0.6	4.0	3.5	0.5	1.2
			B	-1.0	2.0	0.6	3.0			1.0
			2T	-1.2	2.8	0.6	4.0	3.8	0.2	1.1
			B	-1.3	2.3	0.5	3.6			1.2
			1T	-1.0	2.1	0.6	3.1	3.2	0.2	0.9
			B	-1.1	2.3	0.5	3.4			1.0
			Avg.					**3.5**	**0.2**	
AM 175	SB/3	1/9	4T	-1.0	1.6	0.6	2.6	2.5	0.2	1.1
			B	-0.9	1.4	0.5	2.3			1.0
			3T	-1.0	1.5	0.5	2.5	2.3	0.2	1.1
			B	-1.0	1.0	0.4	2.0			0.8
			2T	-1.0	2.0	0.6	3.0	2.7	0.3	1.0
			B	-1.0	1.4	0.5	2.4			0.9
			1T	-1.0	1.3	0.5	2.3	2.4	0.1	1.0
			B	-1.1	1.4	0.5	2.5			0.9
			Avg.					**2.5**	**0.2**	
Pre-Retrofit Data for these eyebars are given in Table 18.										

(Sheet 3 of 4)

Table 43 (end)

Trains on August 12, 1998			Stress, ksi				Stress Range, ksi			
Train	Direction/ Track	No. Locos/ Cars	Eyebar/ Position	Min.	Max.	Steady Nominal D	Max Pk to Pk A	Axial $(A_T + A_B)/2$	Bending $(A_T - A_B)/2$	Car Cycle
AM M106	NB/3	1/8	4T	-0.5	2.0	0.5	2.5	2.4	0.1	1.0
			B	-0.6	1.7	0.5	2.3			1.0
			3T	-0.4	2.5	0.5	2.9	2.7	0.2	1.0
			B	-0.6	1.8	0.5	2.4			1.0
			2T	-0.7	2.3	0.5	3.0	3.0	0.1	1.0
			B	-0.8	2.1	0.5	2.9			1.1
			1T	-0.5	2.0	0.5	2.5	2.4	0.2	1.0
			B	-0.6	1.6	0.5	2.2			1.0
			Avg.					2.6	0.2	
Marc 536	NB/2	1/6	4T	0	0.6	0.2	0.6	0.6	0	signal too noisy
			B	0	0.6	0.1	0.6			
			3T	0	0.6	0.1	0.6	0.6	0	
			B	0	0.6	0.2	0.6			
			2T	0	0.8	0.2	0.8	0.9	0.1	
			B	0	1.0	0.3	1.0			
			1T	0	0.6	0.2	0.6	0.6	0	
			B	0	1.0	0.2	0.6			
			Avg.					0.7	0	
Pre-Retrofit Data for these eyebars are given in Table 18.										

(Sheet 4 of 4)

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Table 44

Measured Post-Retrofit Diagonal Eyebar Stresses For Various Trains
(In Span 2, E Truss, L5U6@L5)

Trains on August 12, 1998			Stress, ksi				Stress Range, ksi			
Train	Direction/ Track	No. Locos/ Cars	Eyebar/ Position	Min.	Max.	Steady Nominal D	Max Pk to Pk A	Axial $(A_T + A_B)/2$	Bending $(A_T - A_B)/2$	Car Cycle
ULK 66C (263K coal-car train)	SB/2	2/128	3T	na			na	na	na	na
			B	-1.2	3.1	2.0	4.3			0.8
			2T	-1.3	2.9	1.6	4.2	4.4	0.2	1.0
			B	-1.6	3.0	1.7	4.6			0.8
			1T	-2.0	2.8	1.7	4.8	na	na	0.9
			B	na			na			na
			Avg.					**4.4**	**0.2**	
UMP 110 (Coal train, cars 189 - 246K)	SB/3	3/80	3T	na			na	na	na	na
			B	-0.3	0.9	0.5	1.2			0.2
			2T	-0.8	1.3	0.7	2.1	1.9	0.2	0.3
			B	-0.5	1.2	0.8	1.7			0.3
			1T	-0.5	1.2	0.7	1.7	na	na	0.3
			B	na			na			na
			Avg.					**1.9**	**0.2**	
Pre-Retrofit Data for these eyebars is given in Table 19.										

(Sheet 1 of 4)

Table 44 (continued)

Trains on August 12, 1998			Stress, ksi				Stress Range, ksi			
Train	Direction/ Track	No. Locos/ Cars	Eyebar/ Position	Min.	Max.	Steady Nominal D	Max Pk to Pk A	Axial $(A_T + A_B)/2$	Bending $(A_T - A_B)/2$	Car Cycle
UMP 74B (Coal train, cars 215 - 262K)	SB/3	3/80	3T	na			na	na	na	na
			B	-0.2	1.0	0.5	1.2			0.2
			2T	-0.2	1.3	0.7	1.5	1.7	0.2	0.3
			B	-0.5	1.4	0.8	1.9			0.4
			1T	-0.5	1.2	0.8	1.7	na	na	0.3
			B	na			na			na
			Avg.					**1.7**	**0.2**	
XSM 43E (Empty coal cars)	NB/3	1/na	3T	na			na	na	na	na
			B	0	1.0	0.1	3.2			-
			2T	0	1.2	0.2	4.4	1.2	0	-
			B	0	1.2	0.2	4.1			-
			1T	0	1.2	0.2	3.9	na	na	-
			B	na			na			na
			Avg.					**1.2**	**0**	

Pre-Retrofit Data for these eyebars are given in Table 19.

(Sheet 2 of 4)

Table 44 (continued)

Trains on August 12, 1998			Stress, ksi				Stress Range, ksi			
Train	Direction/ Track	No. Locos/ Cars	Eyebar/ Position	Min.	Max.	Steady Nominal D	Max Pk to Pk A	Axial $(A_T + A_B)/2$	Bending $(A_T - A_B)/2$	Car Cycle
Marc 536	NB/2	1/6	3T	na			na	na	na	na
			B	-0.2	2.2	0.5	2.4			0.4
			2T	-0.6	2.2	0.4	2.8	2.8	0	1.0
			B	-0.5	2.4	0.5	2.9			1.0
			1T	-0.8	2.0	0.5	2.4	na	na	0.9
			B	na			na			na
			Avg.					**2.8**	**0**	
AM M106	NB/3	1/8	3T	na			na	na	na	na
			B	-0.1	0.8	0.2	0.9			0.5
			2T	0	1.1	0.3	1.1	2.7	0.3	0.5
			B	0	0.9	0.2	0.9			0.4
			1T	0	0.8	0.3	0.8	2.4	0.1	0.5
			B	na			na			na
			Avg.					**1.0**	**0.1**	
Pre-Retrofit Data for these eyebars are given in Table 19.										

(Sheet 3 of 4)

Table 44 (end)

Trains on August 12, 1998			Stress, ksi				Stress Range, ksi			
Train	Direction/ Track	No. Locos/ Cars	Eyebar/ Position	Min.	Max.	Steady Nominal D	Max Pk to Pk A	Axial $(A_T + A_B)/2$	Bending $(A_T - A_B)/2$	Car Cycle
AM 97	SB/3	1/11	3T	na			na	na	na	na
			B	-0.1	0.7	0.2	0.8			0.3
			2T	0	1.0	0.2	1.0	1.1	0.2	0.3
			B	-0.5	0.8	0.2	1.3			0.3
			1T	-0.3	0.9	0.2	1.2	na	na	0.3
			B	na			na			na
			Avg.					**1.1**	**0.2**	
AM 175	SB/3	1/9	3T	na			na	na	na	na
			B	-0.2	0.5	0.2	0.7			0.3
			2T	0	0.8	0.5	0.8	0.8	0.1	0.5
			B	-0.2	0.7	0.3	0.9			0.3
			1T	-0.5	0.7	0.3	1.2	na	na	0.4
			B	na			na			na
			Avg.					**0.8**	**0.1**	
Pre-Retrofit Data for these eyebars are given in Table 19.										

(Sheet 4 of 4)

na = not acquired or not reliable.
Also, Eyebar 4 data not available due to gage malfunction.

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Table 45

Measured Post-Retrofit Top Chord Stress for Various Trains
(Span 2, Top Chord U8U9-West, midway between Floorbeams 8 and 9)

Trains on August 12, 1998			Maximum Stress Range, ksi				
			Top Surface / Gage			Bottom Flanges / Gage	
Train	Direction /Track	No. Loco's /Cars	E edge / 1.98	℄ / 2.98	W edge / 3.98	E / D5	W / D6
ULK 66C (263K coal car train)	SB/2	2/128	0.4	0.3	0.4	0.5	0.6
UMP 74B (coal train, cars 215 - 262K)	SB/3	3/80	4.2	3.0	5.0	4.7	6.8
UMP 110 (coal train, cars 189 - 246K)	SB/3	3/80	4.4	2.7	5.1	4.8	6.3
XSM 43E (empty coal car train)	NB/3	1/na	4.6	2.3	5.0	4.3	5.5
Marc 536	NB/2	1/6	0.3	0.3	0.3	0.3	0.5
AM 97	SB/3	1/11	1.5	1.4	3.2	2.7	3.5
AM 175	SB/3	1/9	1.8	1.3	3.2	2.7	3.3
AM M106	NB/3	1/8	1.5	1.3	3.5	2.2	3.1
Pre-Retrofit Data for Gages D5 and D6 are given in Table 26.							

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Table 46

Measured Post-Retrofit Floorbeam / Top Chord Stresses for Various Trains
(Span 2, Panel Point U5-West)

Trains on August 12, 1998				Stress, ksi			
Train	**Direction / Track**	**No. Locos / Cars**	**Gage / Member**	**Maximum**	**Minimum**	**Range**	**Car Range**
ULK 66C (263K coal-car train)	SB/2	2/128	**04.98** / on top chord E flange	0	-0.9	0.9	0.3
			On lateral connection pl				
			05.98 / near N splice pl	0.4	-0.5	0.9	0.5
			06.98 / transverse, next to 05.98	1.0	0	1.0	0.5
			07.98 / at edge of FB	1.5	0	1.5	0.7
			08.98 / near S splice pl	1.3	0	1.3	0.5
UMP 74B (coal train, cars 215 - 262K)	SB/3	3/80	04.98	0	-3.0	3.0	1.0
			05.98	0	-2.7	2.7	0.7
			06.98	1.8	0	1.8	0.7
			07.98	1.0	-1.2	2.2	1.3
			08.98	1.3	0	1.3	0.6
UMP 110 (coal train, cars 189 - 246K)	SB/3	3/80	04.98	0	-3.0	3.0	1.0
			05.98	0	-2.5	2.5	0.7
			06.98	2.0	0	2.0	1.0
			07.98	0.7	-1.5	2.2	1.3
			08.98	1.2	0	1.2	0.7
XSM 43E (empty coal car train)	NB/3	1/na	04.98	0	-2.4	2.4	0.3
			05.98	0	-2.0	2.0	0.2
			06.98	1.4	0	1.4	0.5
			07.98	0.7	-1.7	2.4	0.3
			08.98	1.1	0	1.1	0.3

(Sheet 1 of 2)

Table 46 (continued)

Trains on August 12, 1998				Stress, ksi			
Train	Direction / Track	No. Locos / Cars	Gage / Member	Maximum	Minimum	Range	Car Range
Marc 536	NB/2	1/6	04.98	0	-0.3	0.3	noise
			05.98	0.4	0	0.4	noise
			06.98	0.4	0	0.4	noise
			07.98	0.5	0	0.5	noise
			08.98	0.6	0	0.6	noise
AM 97	SB/3	1/11	04.98	0	-1.2	1.2	0.3
			05.98	0	-1.9	1.9	0.5
			06.98	1.2	0	1.2	0.6
			07.98	0.4	-1.0	1.4	0.6
			08.98	0.7	-0.2	0.9	0.5
AM 175	SB/3	1/9	04.98	0	-0.8	0.8	0.3
			05.98	0	-1.2	1.2	0.5
			06.98	0.8	0	0.8	0.5
			07.98	0.4	-0.9	1.3	0.6
			08.98	0.7	-0.1	0.8	0.4
AM M106	NB/3	1/8	04.98	0	-1.2	1.2	0.4
			05.98	0	-1.3	1.3	0.5
			06.98	1.0	0	1.0	-.3
			07.98	0.4	-1.0	1.4	0.6
			08.98	0.7	0	0.7	0.5

(Sheet 2 of 2)

Table 47

Post-Retrofit Floorbeam Measurements for Various Trains
(Span 2, Floorbeam 5)

Trains on August 12, 1998				Stress, ksi (or displacement, in.)			
Train	**Direction / Track**	**No. Locos / Cars**	**Gage / Member**	**Maximum**	**Minimum**	**Range**	**Car Range**
ULK 66C (263K coal-car train)	SB/2	2/128	**70.98** / Displacement between top of lat. connect. pl and post web	0.006 (in.)	0 (in.)	0.006 (in.)	0.005 (in.)
			309 / Near crack tip on N side of FB	0.3	-0.2	0.5	0.4
			D14 / Bottom flange of FB, at midspan	2.5	0	2.5	1.5
			D15 / Top flange of FB, at midspan.	0	-2.2	2.2	1.5
UMP 74B (coal train, cars 215 - 262K)	SB/3	3/80	70.98	0.003 (in.)	-0.016 (in.)	0.019 (in.)	0.017 (in.)
			309	0.3	-0.2	0.5	0.4
			D14	2.3	0	2.3	1.3
			D15	0	-1.8	1.8	1.0
UMP 110 (coal train, cars 189 - 246K)	SB/3	3/80	70.98	0 (in.)	-.019 (in.)	0.019 (in.)	0.18 (in.)
			309	0.3	-0.2	0.5	0.4
			D14	2.5	0	2.5	1.2
			D15	0	2.0	2.0	0.9
XSM 43E (empty coal car train)	NB/3	1/na	70.98	0.005 (in.)	-0.018 (in.)	0.023 (in.)	0.006 (in.)
			309	0.3	0	0.3	0.2
			D14	2.1	0	2.1	0.4
			D15	0	-1.9	1.9	0.3
Pre-Retrofit Data for Gage 309 are given in Table 29, and for Gage D14 in Table 31.							

(continued on next sheet)

Table 47 (continued)

Trains on August 12, 1998				Stress, ksi (or displacement, in.)			
Train	**Direction / Track**	**No. Locos / Cars**	**Gage / Member**	**Maximum**	**Minimum**	**Range**	**Car Range**
AM 97	SB/3	1/11	70.98	0.005 (in.)	-0.006 (in.)	0.011 (in.)	0.007 (in.)
			309	0.3	-0.2	0.5	0.3
			D14	1.3	-0.3	1.6	0.8
			D15	0.2	-1.2	1.4	0.7
AM 175	SB/3	1/9	70.98	signal too noisy			
			309	signal too noisy			
			D14	1.5	-0.1	1.6	1.0
			D15	0.3	-1.2	1.5	0.7
Marc 536	NB/2	1/6	70.98	0.001 (in.)	-0.003 (in.)	0.004 (in.)	0.0015 (in.)
			309	signal too noisy			
			D14	1.6	0	1.6	1.0
			D15	0.3	-1.2	1.5	0.9
AM M106	NB/3	1/8	70.98	signal too noisy			
			309	signal too noisy			
			D14	1.2	-0.2	1.4	0.9
			D15	0.3	-1.0	1.3	0.7
Pre-Retrofit Data for Gage 309 are given in Table 29, and for Gage D14 in Table 31.							

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Table 48

Measured Post-Retrofit Floorbeam / Top Chord Stresses for Various Trains
(Span 2, Panel Point U6-East)

Trains on August 12, 1998				Stress, ksi			
Train	**Direction / Track**	**No. Locos / Cars**	**Gage / Member**	**Maximum**	**Minimum**	**Range**	**Car Range**
ULK 66C (263K coal-car train)	SB/2	2/128	**09.98** / on top chord W flange	0	-3.5	3.5	0.8
			On lateral connection pl				
			10.98 / near N splice pl	0	-2.3	2.3	1.0
			11.98 / trans-verse, next to 10.98	1.5	0	1.5	0.4
			12.98 / at edge of FB	4.0	-1.3	5.3	2.5
			13.98 / near S splice pl	1.9	0	1.9	0.8
UMP 74B (coal train, cars 215 - 262K)	SB/3	3/80	09.98	0	-0.7	0.7	0.2
			10.98	0.3	-1.3	1.6	0.8
			11.98	0.5	0	0.5	0.2
			12.98	1.2	-0.2	1.4	1.0
			13.98	0.7	0	0.7	0.2
UMP 110 (coal train, cars 189 - 246K)	SB/3	3/80	09.98	0	-1.0	1.0	0.3
			10.98	0.3	-1.3	1.6	0.7
			11.98	0.5	0	0.5	0.2
			12.98	1.4	0	1.4	0.9
			13.98	0.7	0	0.7	0.3
XSM 43E (empty coal car train)	NB/3	1/na	09.98	0	-0.8	0.8	0.3
			10.98	0	-1.1	1.1	0.3
			11.98	0.2	0	0.2	0.2
			12.98	0.7	0	0.7	0.4
			13.98	0.5	0	0.5	0.2

Table 48 (continued)

Trains on August 12, 1998				Stress, ksi			
Train	Direction / Track	No. Locos / Cars	Gage / Member	Maximum	Minimum	Range	Car Range
Marc 536	NB/2	1/6	09.98	0	-1.7	1.7	0.5
			10.98	0	-1.6	1.6	0.6
			11.98	0.9	0	0.9	0.4
			12.98	2.0	-0.2	2.2	0.6
			13.98	1.2	0	1.2	0.4
AM 97	SB/3	1/11	09.98	0.2	-0.5	0.7	0.5
			10.98	0.4	-1.0	1.4	0.7
			11.98	0.4	0	0.4	0.3
			12.98	0.7	-0.4	1.1	0.8
			13.98	0.6	-0.2	0.8	0.4
AM 175	SB/3	1/9	09.98	0.2	-0.4	0.6	0.4
			10.98	0.2	-0.7	0.9	0.6
			11.98	0.4	-0.3	0.7	0.6
			12.98	0.7	-0.3	1.0	0.5
			13.98	0.4	-0.3	0.7	0.4
AM M106	NB/3	1/8	09.98	0.3	-0.4	0.7	0.4
			10.98	0.2	-0.8	1.0	0.6
			11.98	0.3	-0.2	0.5	0.4
			12.98	0.4	-0.5	0.9	0.6
			13.98	0.5	-0.1	0.6	0.4

(Sheet 2 of 2)

Table 49

Measured Post-Retrofit Floorbeam / Top Chord Stresses for Various Trains
(Span 1, West Truss at Floorbeam 8)

Trains on August 12, 1998				Stress, ksi			
Train	**Direction / Track**	**No. Locos / Cars**	**Gage / Member**	**Maximum**	**Minimum**	**Range**	**Car Range**
ULK 66C (263K coal-car train)	SB/2	2/128	**D26** / Top Ch, E bottom fl, at ℄ of FB, parallel to FB	1.0	-2.6	3.6	2.1
			D27 / S side of FB on bottom of top fl, transverse to FB	0	-0.4	0.4	0.2
			D28 / Near D27, vertical on fill plate close to FB fl.	2.6	0	2.6	0.5
UMP 74B (coal train, cars 215 - 262K)	SB/3	3/80	D26	0	-9.8	9.8	6.0
			D27	1.7	-1.7	3.4	2.7
			D28	4.0	-3.0	7.0	5.5
UMP 110 (coal train, cars 189 - 246K)	SB/3	3/80	D26	0	-10.0	10.0	4.0
			D27	1.8	-2.0	3.8	2.8
			D28	4.1	-3.3	7.4	5.0
XSM 43E (empty coal car train)	NB/3	1/na	D26	0	-10.2	10.2	1.5
			D27	0.5	-1.7	2.2	0.2
			D28	4.7	-1.5	6.2	0.5
Marc 536	NB/2	1/6	D26	0.5	-1.2	1.7	0.7
			D27	signal too noisy (stn)			
			D28	1.5	-0.3	1.8	stn
AM 97	SB/3	1/11	D26	0	-5.8	5.8	3.3
			D27	0	-1.1	1.1	0.4
			D28	4.7	0	4.7	1.6
Pre-Retrofit Data from these gages are given in Table 36.							

(Sheet 1 of 2)

Table 49 (continued)

Trains on August 12, 1998				**Stress, ksi**			
Train	**Direction / Track**	**No. Locos / Cars**	**Gage / Member**	**Maximum**	**Minimum**	**Range**	**Car Range**
AM 175	SB/3	1/9	D26	0	-5.4	5.4	2.7
			D27	0	-1.0	1.0	0.6
			D28	3.3	0	3.3	1.4
AM M106	NB/3	1/8	D26	0	-6.3	6.3	3.0
			D27	0	-1.0	1.0	0.6
			D28	4.0	0	4.0	1.0
Pre-Retrofit Data from these gages are given in Table 36.							

(Sheet 2 of 2)

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Table 50

Measured Post-Retrofit Vertical Post Stresses for Various Trains (In Span 2, Post L5U5-West Truss, August 1998)

Trains on August 12, 1998				Stress , ksi		
Train	**Direction /Track**	**No. Loco's/ Cars**	**Gage/ FB Location**	**Maximum**	**Minimum**	**Range**
ULK 66C (263K coal car train)	SB/2	2/128	**D22**/NW Corner	0.2	-0.5	0.7
			D23/NE Corner	0	-0.8	0.8
			D24/SE Corner	0.3	-1.6	1.9
			D25/SW Corner	0.2	-0.8	1.0
UMP 74B (coal train, cars 215 - 262K)	SB/3	3/80	D22 D23 D24 D25	1.2 1.2 0.3 0.7	-3.7 -4.1 -2.3 -2.2	4.9 5.3 2.6 2.9
UMP 110 (coal train, cars 189 - 246K)	SB/3	3/80	D22 D23 D24 D25	1.0 1.0 0.2 0.7	-3.8 -4.5 -2.4 -2.0	4.8 5.5 2.6 2.7
XSM 43E (empty coal cars)	NB/3	1/na	D22 D23 D24 D25	0.5 0.4 0.3 0.2	-3.7 -4.4 -2.1 -1.8	4.2 4.8 2.4 2.0
Amtrak 97	SB/3	1/11	D22 D23 D24 D25	0.7 0.8 0.5 0.5	-2.4 -2.7 - 1.3 -1.5	3.1 3.5 1.8 2.0
Amtrak 175	SB/3	1/9	D22 D23 D24 D25	1.0 1.1 0.3 0.5	-1.5 -1.5 -1.3 -1.2	2.5 2.6 1.6 1.7
Amtrak M106	NB/3	1/8	D22 D23 D24 D25	0 0.3 0.3 0.2	-2.3 -2.6 -1.4 -1.3	2.3 2.9 1.7 1.5
Marc 536	NB/2	1/6	D22 D23 D24 D25	0.4 0.3 0 0.2	-0.2 -0.4 -1.0 -0.6	0.6 0.7 1.0 0.8
Pre-Retrofit Data from these gages are given in Table 37.						

Table 51

Measured Post-Retrofit Vertical Post Stresses for Various Trains (In Span 2, Post L5U5-East Truss, August 1998)

Trains on August 12, 1998				Stress , ksi		
Train/ Date	**Direction /Track**	**No. Loco's/ Cars**	**Gage/ FB Location**	**Maximum**	**Minimum**	**Range**
ULK 66C (263K coal car train)	SB/2	2/128	**D18**/NW Corner	1.1	-3.5	4.6
			D19/NE Corner	1.0	-3.9	4.9
			D20/SE Corner	0	-3.0	3.0
			D21/SW Corner	0.4	-2.4	2.8
UMP 74B (coal train, cars 215 - 262K)	SB/3	3/80	D18	0	-0.5	0.5
			D19	0	-1.4	1.4
			D20	0.3	-1.0	1.3
			D21	0.2	-0.3	0.5
UMP 110 (coal train, cars 189 - 246K)	SB/3	3/80	D18	0	-0.6	0.6
			D19	0	-1.3	1.3
			D20	0.2	-1.0	1.2
			D21	0	-0.4	0.4
XSM 43E (empty coal cars)	NB/3	1/na	D18	0	-0.7	0.7
			D19	0	-1.3	1.3
			D20	0	-1.0	1.0
			D21	0.1	-0.5	0.6
Amtrak 97	SB/3	1/11	D18	0.2	-0.6	0.8
			D19	0.2	-0.7	0.9
			D20	0.3	-0.8	1.1
			D21	0.3	-0.4	0.7
Amtrak 175	SB/3	1/9	D18	0.2	-0.2	0.4
			D19	0.3	-0.8	1.1
			D20	0.4	-0.8	1.2
			D21	0.3	-0.2	0.5
Amtrak M106	NB/3	1/8	D18	0.2	-0.6	0.8
			D19	0.1	-0.8	0.9
			D20	0.2	-0.7	0.9
			D21	0.2	-0.3	0.5
Marc 536	NB/2	1/6	D18	0.5	-2.0	2.5
			D19	0.5	-2.0	2.5
			D20	0.2	-1.5	1.7
			D21	0.4	-1.0	1.4
Pre-Retrofit Data from these gages are given in Table 38.						

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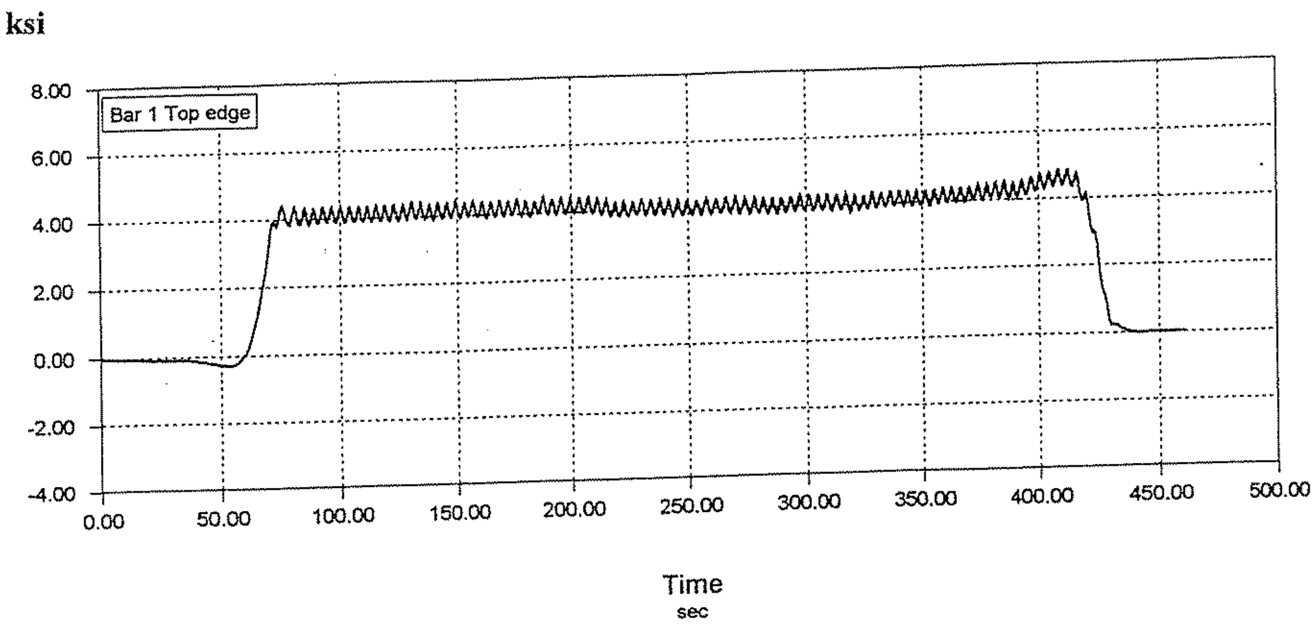
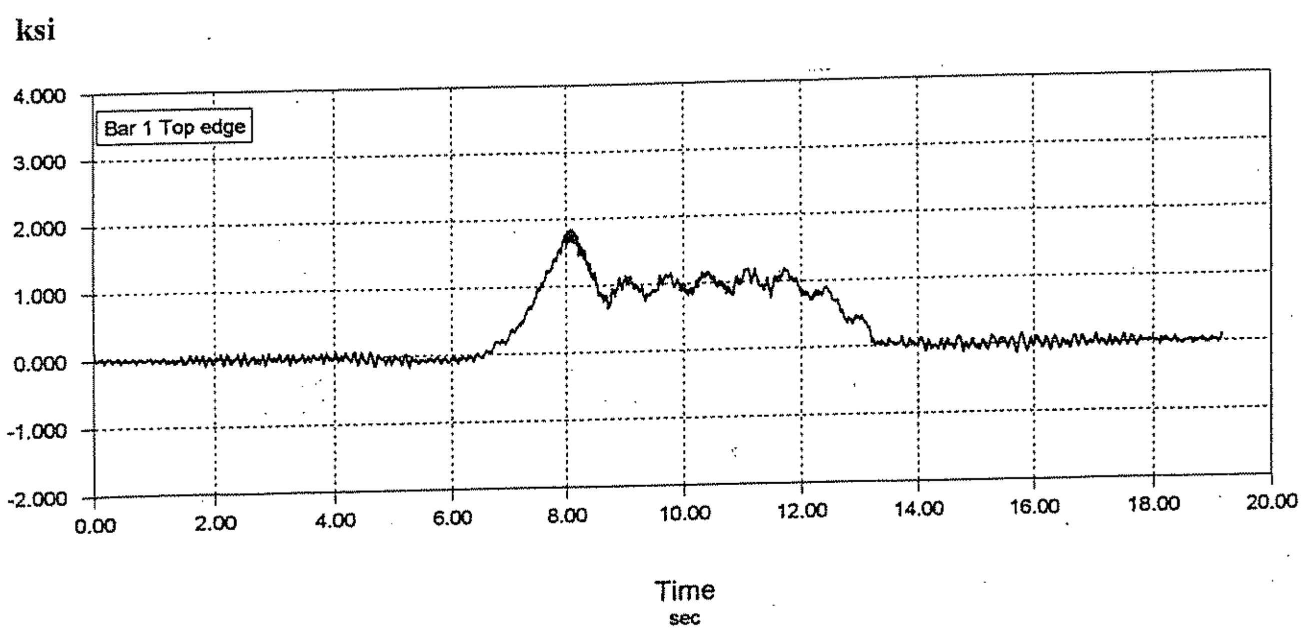
Table 52

Measured Vertical Post Stresses for Various Trains
(In Span 2, Post L9U9-West Truss, July and August 1998)

				Stress , ksi		
Train/ Date	**Direction /Track**	**No. Loco's/ Cars**	**Gage/ FB Location**	**Maximum**	**Minimum**	**Range**
Trains on July 17, 1998, before lubrication or retrofit						
Amtrak	SB/3	1/6	26.98/NW Corner	1.2	-1.3	2.5
			27.98/SW Corner	0.1	-1.3	1.4
Amtrak	NB/2	1/6	26.98	1.0	0	1.0
			27.98	0	-0.4	0.4
Trains on August 12, 1998, after lubrication and retrofit						
ULK 66C (263K coal car train)	SB/2	2/128	26.98	2.5	0	2.5
			27.98	0	-1.0	1.0
UMP 74B (coal train, cars 215 - 262K)	SB/3	3/80	26.98	1.5	-1.9	3.4
			27.98	0	-3.6	3.6
UMP 110 (coal train, cars 189 - 246K)	SB/3	3/80	26.98	1.5	-2.0	3.5
			27.98	0	-3.4	3.4
XSM 43E (empty coal cars)	NB/3	1/na	26.98	1.4	-2.0	3.4
			27.98	0.3	-2.7	3.0
Amtrak 97	SB/3	1/11	26.98	1.5	-1.2	2.7
			27.98	0.1	-1.7	1.8
Amtrak 175	SB/3	1/9	26.98	1.5	-0.9	2.4
			27.98	0.2	-1.1	1.3
Amtrak M106	NB/3	1/8	26.98	1.5	-0.8	2.3
			27.98	0.3	-1.5	1.8
Marc 536	NB/2	1/6	26.98	1.0	0	1.0
			27.98	0	-0.5	0.5



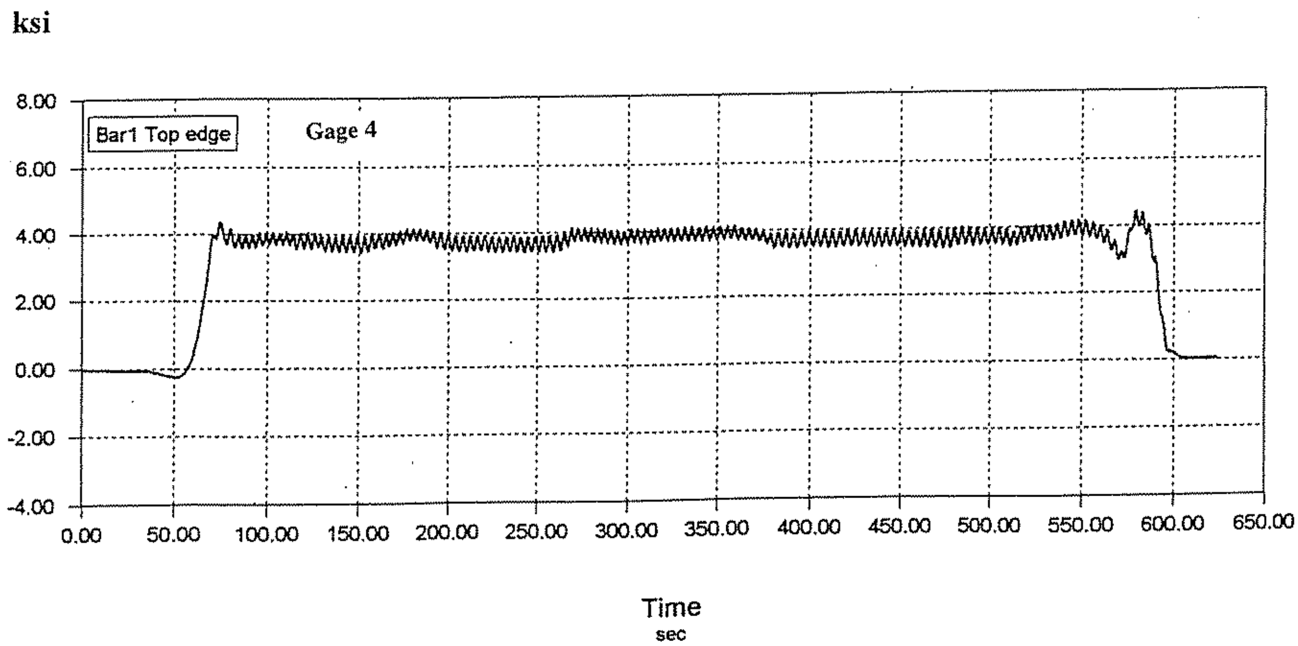
a) Conrail UIR 236, 286K Coal Car Test Train, run 1 (11-13-97)

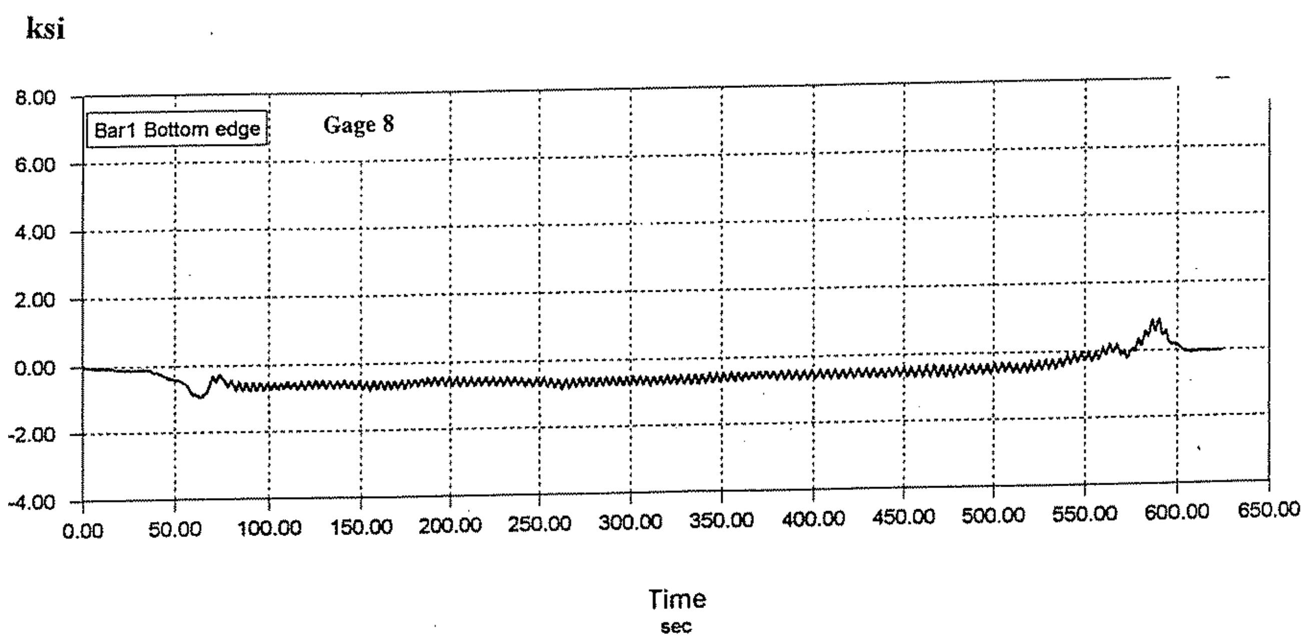


b) Amtrak Passenger Train M125 (11-12-97)

Notes:
- Trains SB on Track 3
- Data for Strain Gage 4

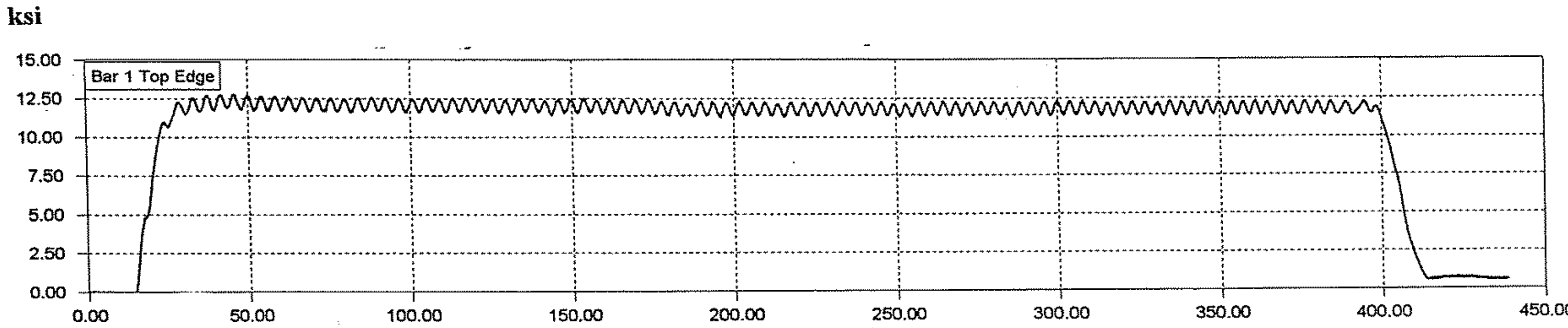
Figure 50 Span 9 Lower Chord Eyebar Data (for L0L1 at L0-west)



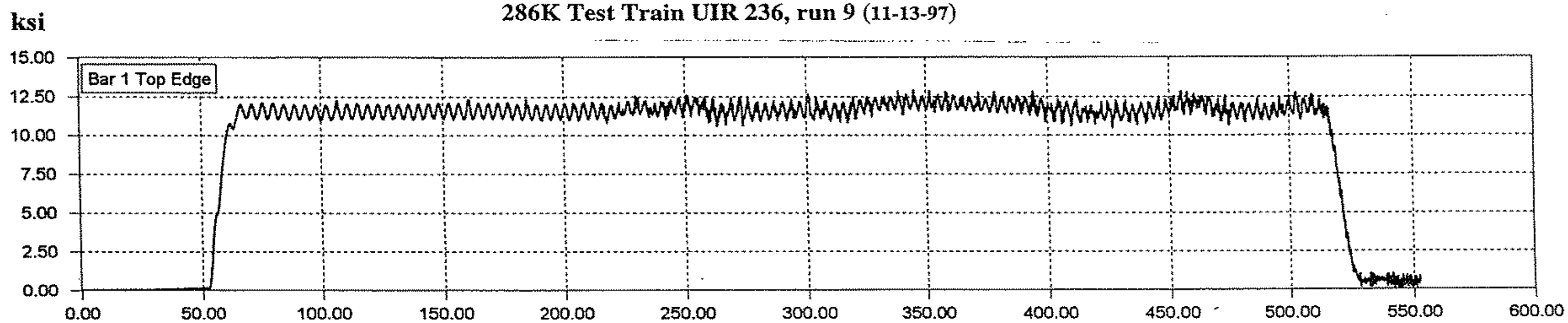


Note: Data for Chord L0L1 at L0-West
Conrail Coal Train ULK80E (263K)
Southbound on Track 3 (11-13-97)

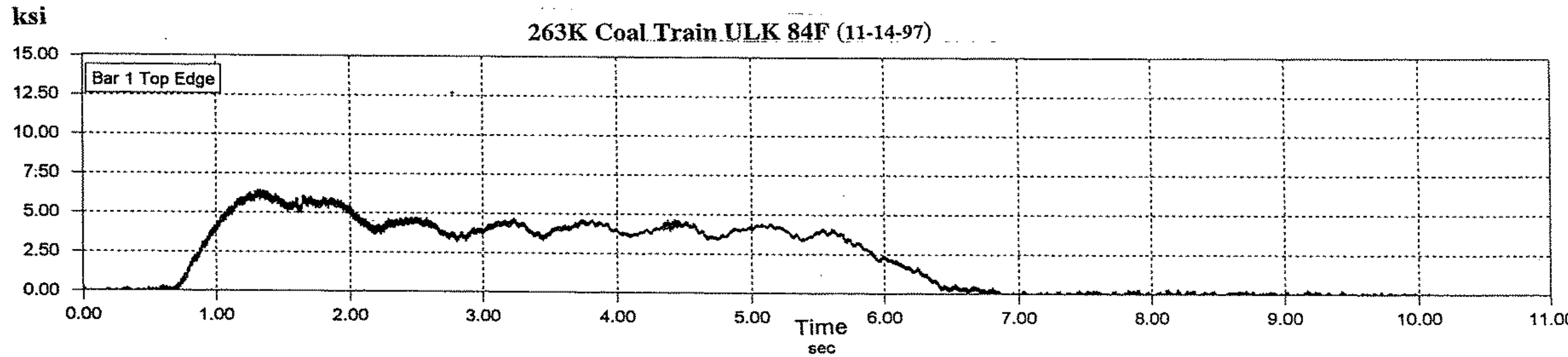
Figure 51 Rebound in Stress as Coal Train Enters and Exits Gage Area, Lower-Chord Eyebars in Span 9



286K Test Train UIR 236, run 9 (11-13-97)



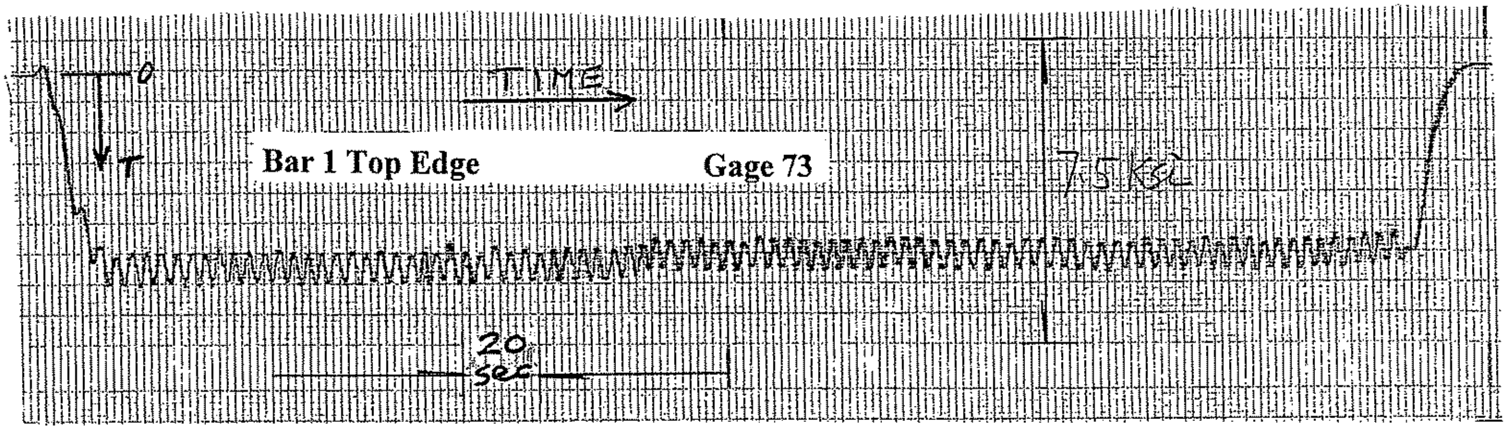
263K Coal Train ULK 84F (11-14-97)



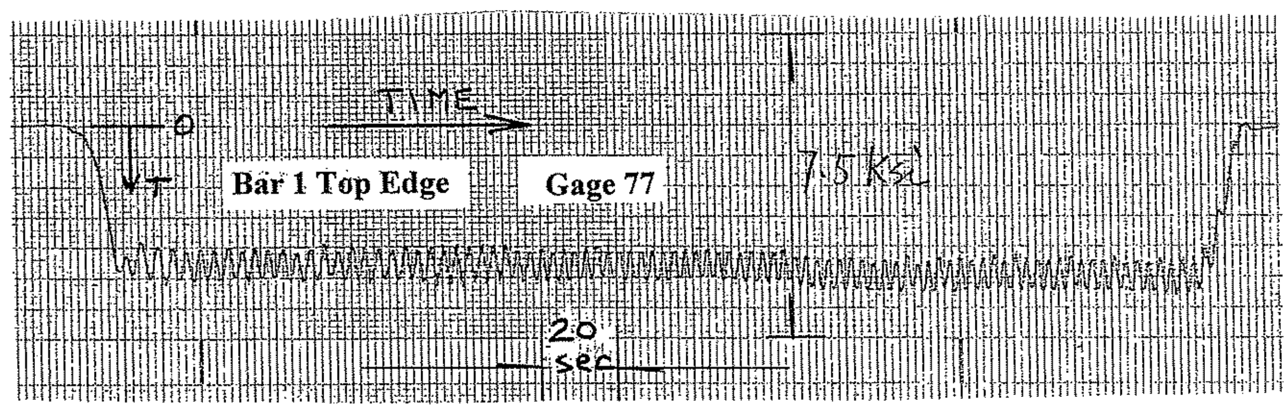
Notes:
- Trains SB on Track 3
- Data for Strain Gage 104

Amtrak Train M121 (11-13-97)

Figure 52 Span 1 Data for Lower-Chord Eyebars (L8L9 at L9-West) for Coal and Passenger Trains

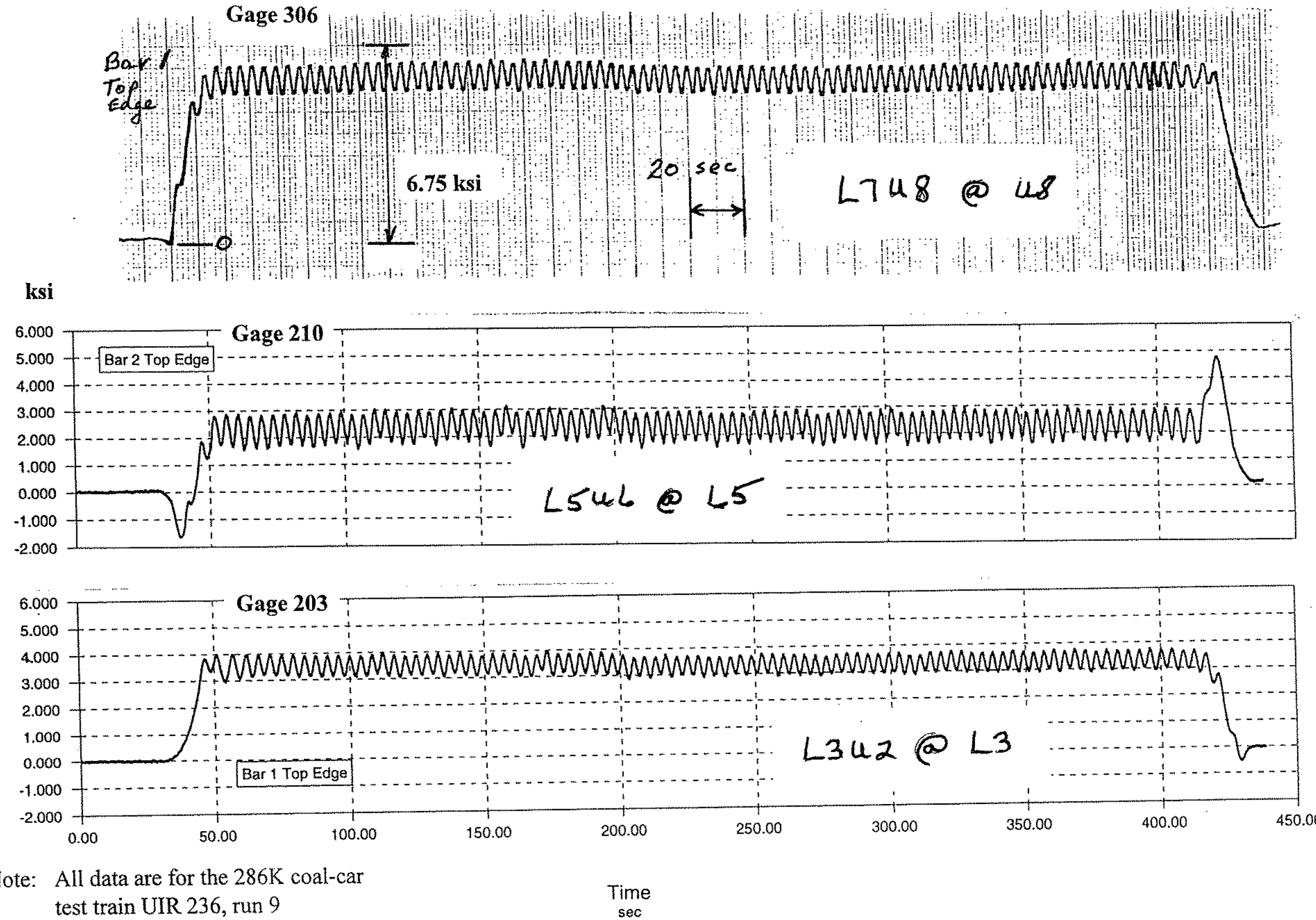


a) West Truss, Diagonal L7U8 at L7; SB Train Track 3



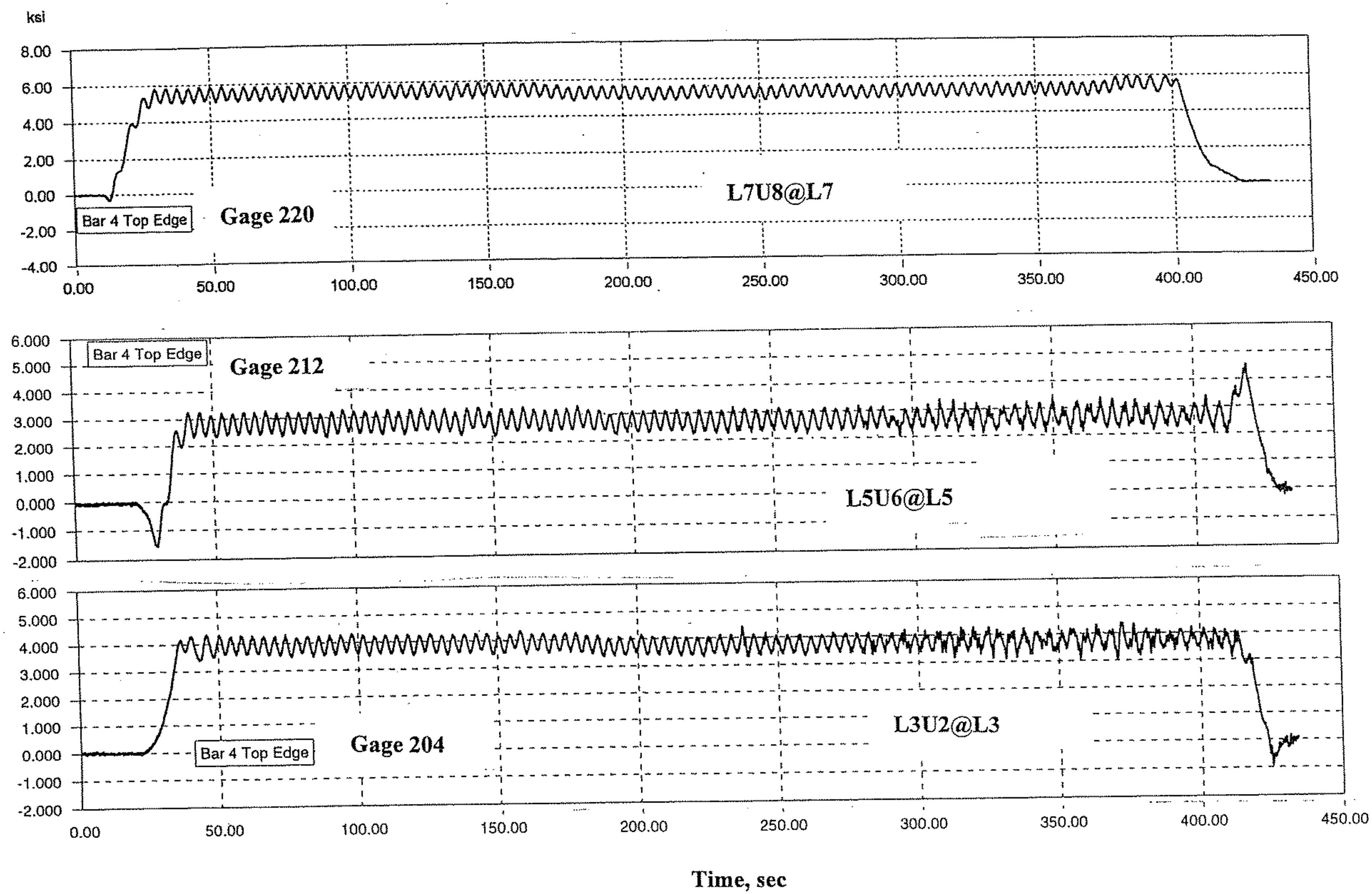
b) East Truss, Diagonal L7U8 at L7; NB Train Track 2

Figure 53 : Diagonal Eyebar Stress Response in Span 7 with 286K Coal Car Test Train (UIR 236)



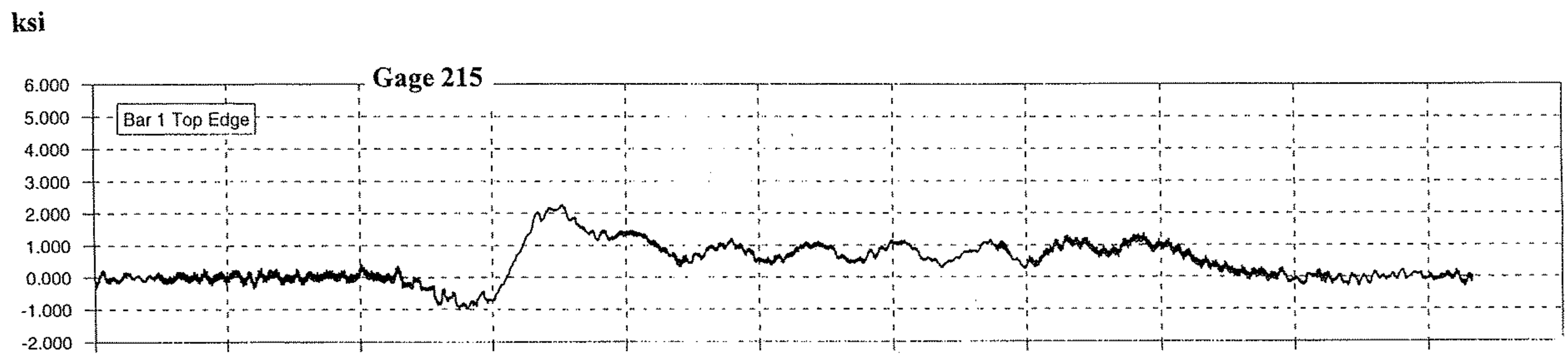
Note: All data are for the 286K coal-car test train UIR 236, run 9

Figure 54a : West Truss, Span 2, Comparative Diagonal Eyebar Stress Records

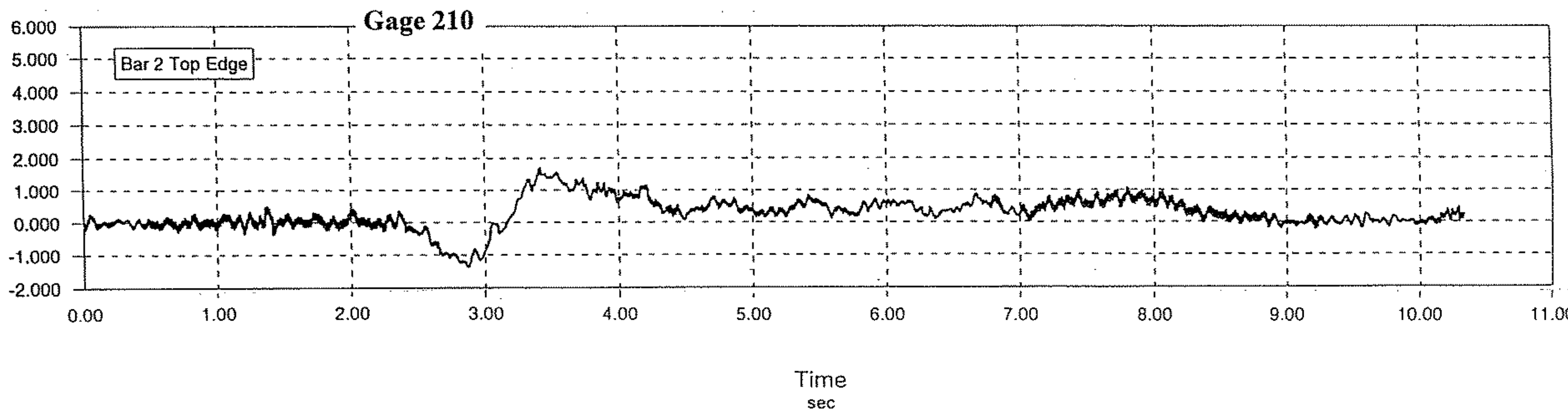


Note: All data are for the 286K coal-car test train UIR 236, run 5

Figure 54b : East Truss, Span 2, Comparative Diagonal Eyebar Stress Records



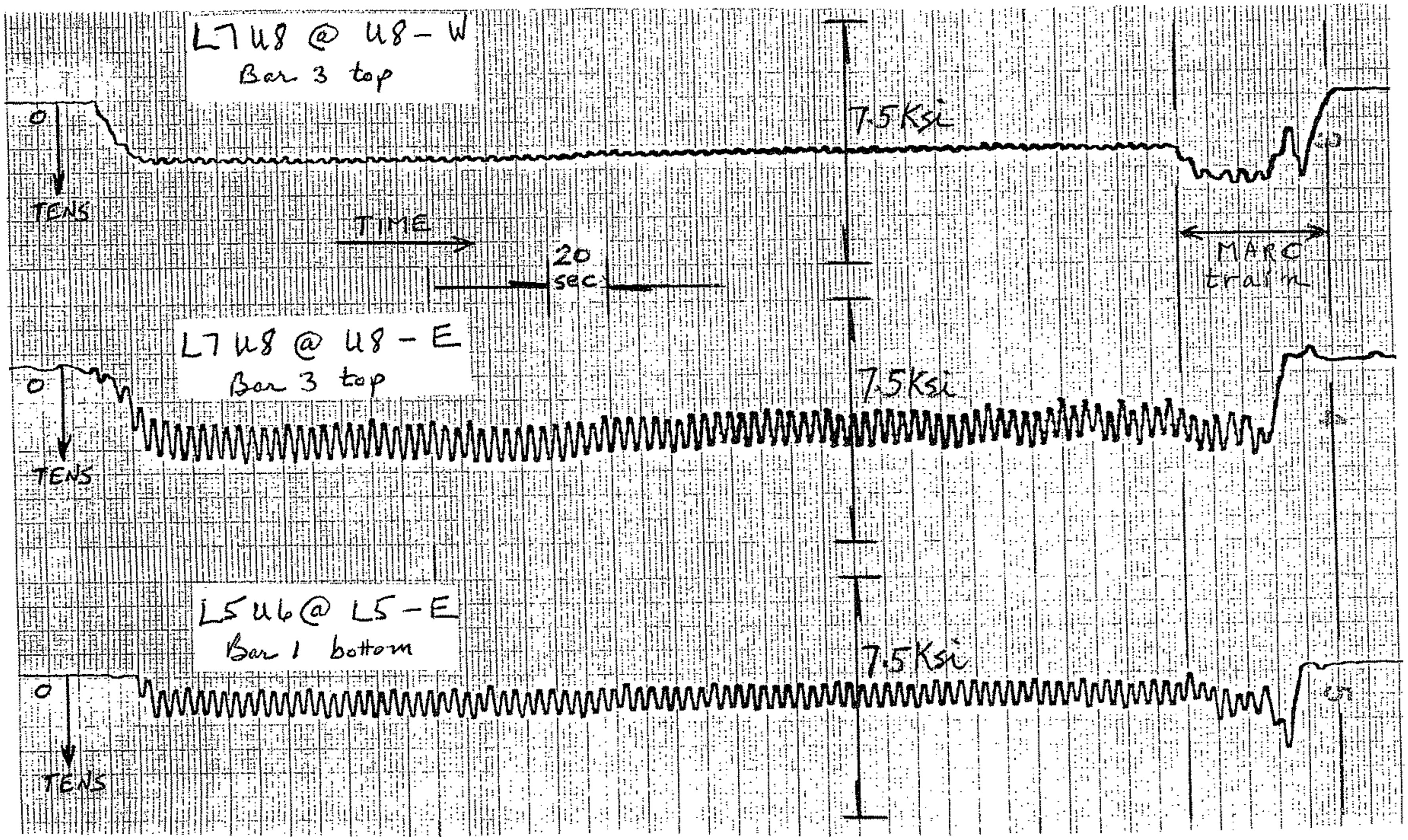
a) Data for L5U6 at L5 - East



b) Data for L5U6 at L5 - West

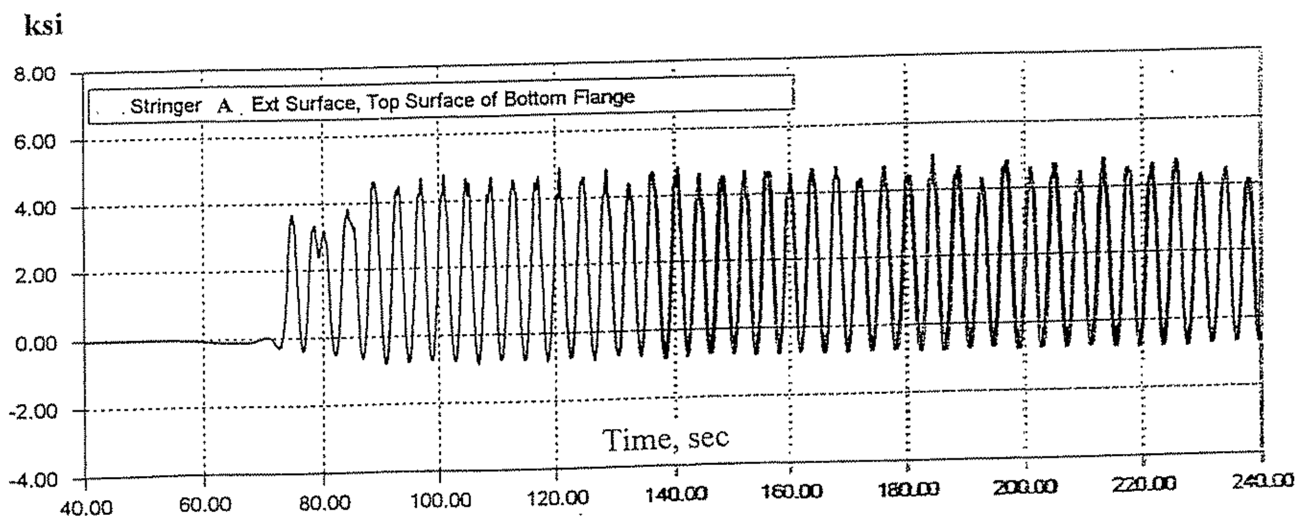
Note: Data for Amtrak Train M121,
Southbound on Track 3 (11/13/97)

Figure 55: Span 2, L5U6 Diagonal Eyebar Records for Amtrak Passenger Trains

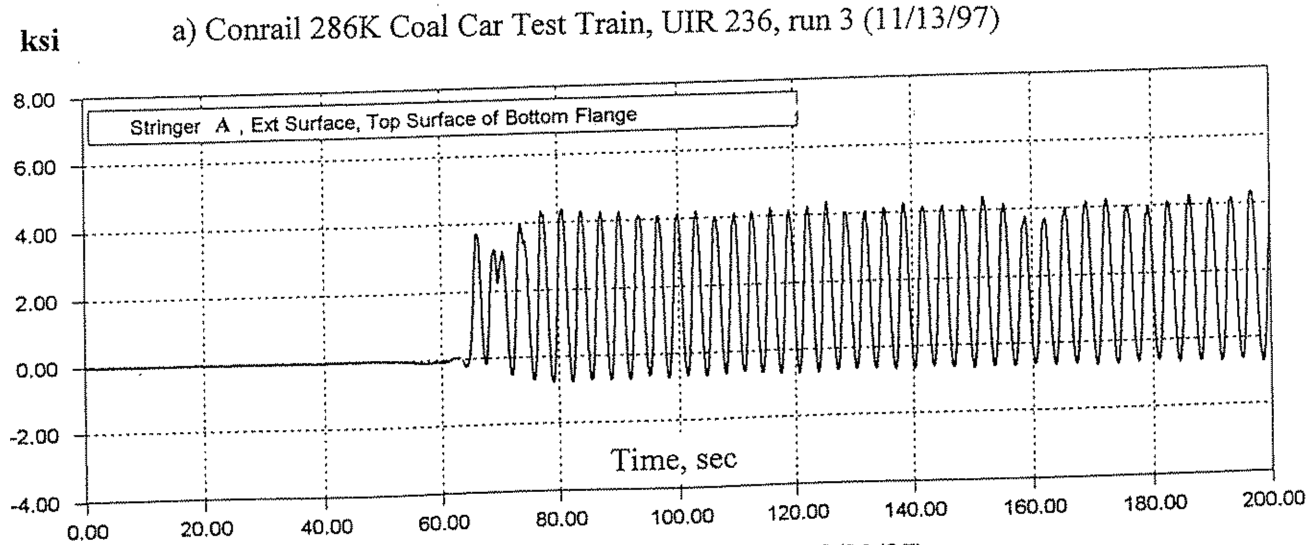


Note: Data for 286K test train, SB on Track 2, with coincident MARC train, SB on Track 3, entering gage region as coal train leaves region

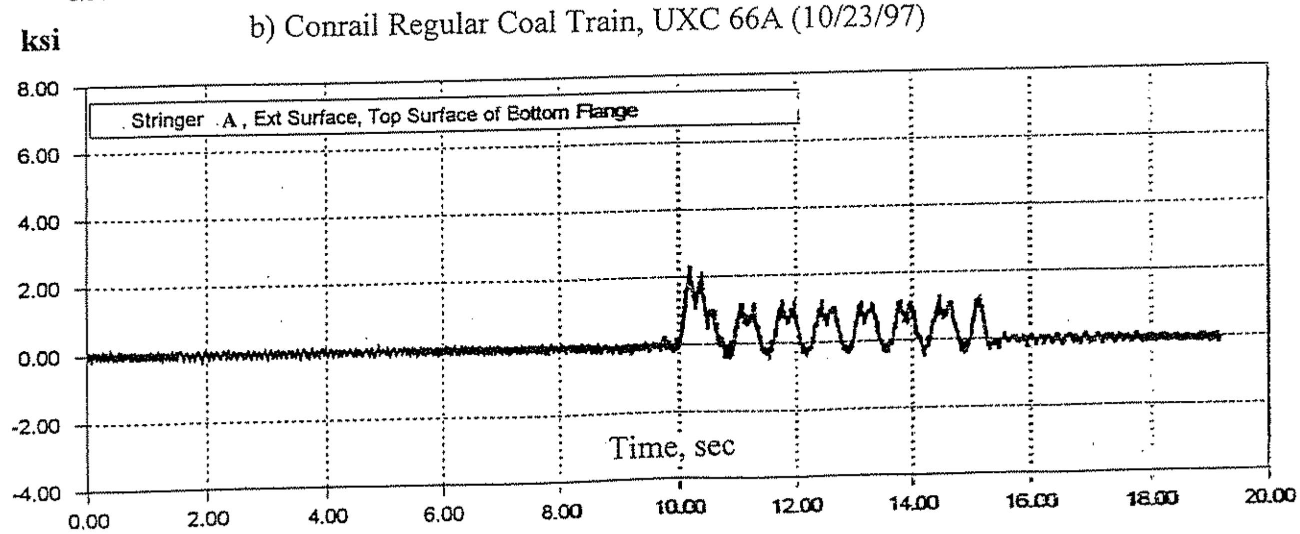
Figure 56 : Span 2: Diagonal Eyebar Stresses, MARC Train Coincident With Coal-Car Test Train (11-13-97)



a) Conrail 286K Coal Car Test Train, UIR 236, run 3 (11/13/97)



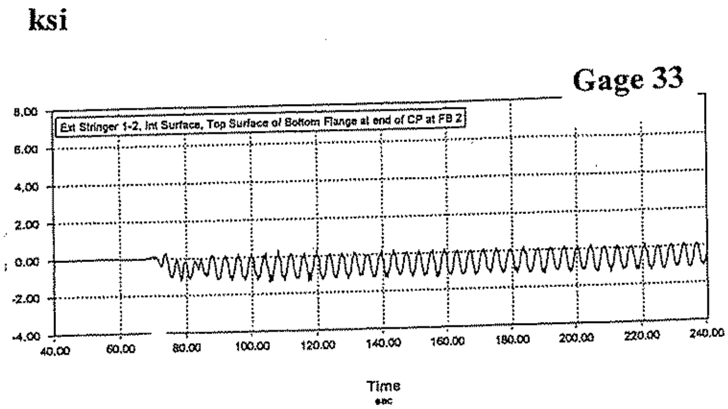
b) Conrail Regular Coal Train, UXC 66A (10/23/97)



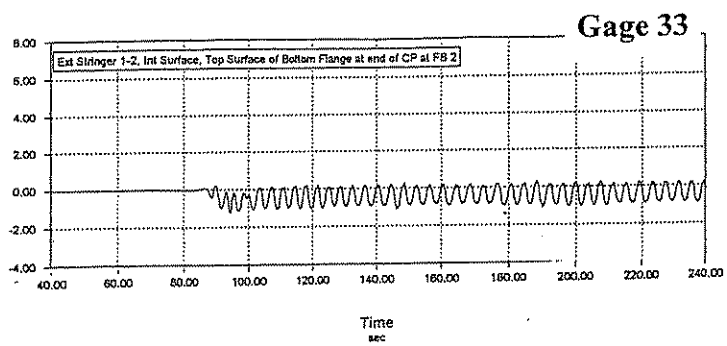
c) Amtrak M125 Passenger Train (11/12/97)

Note: All data for Gage 38

Figure 57 : Characteristic Stringer Data, Midspan Between Floorbeams 1 & 2 on Swing Span 10 for Trains Southbound on Track 3

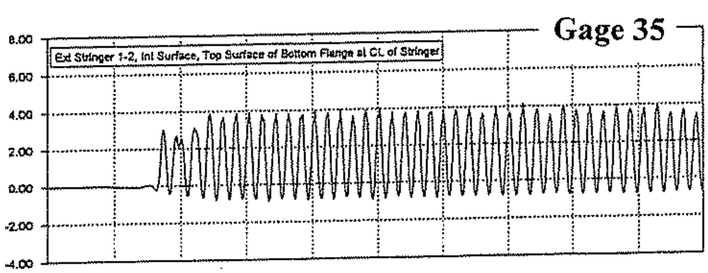


a-1) 286K Car Test Train (UIR 236)

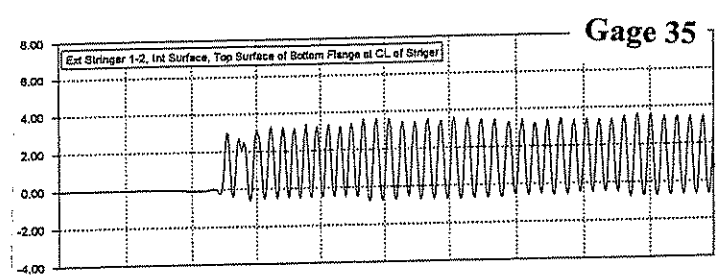


a-2) 263K Car Coal Train (ULK 80E)

a) E side of stringer near floorbeam junction



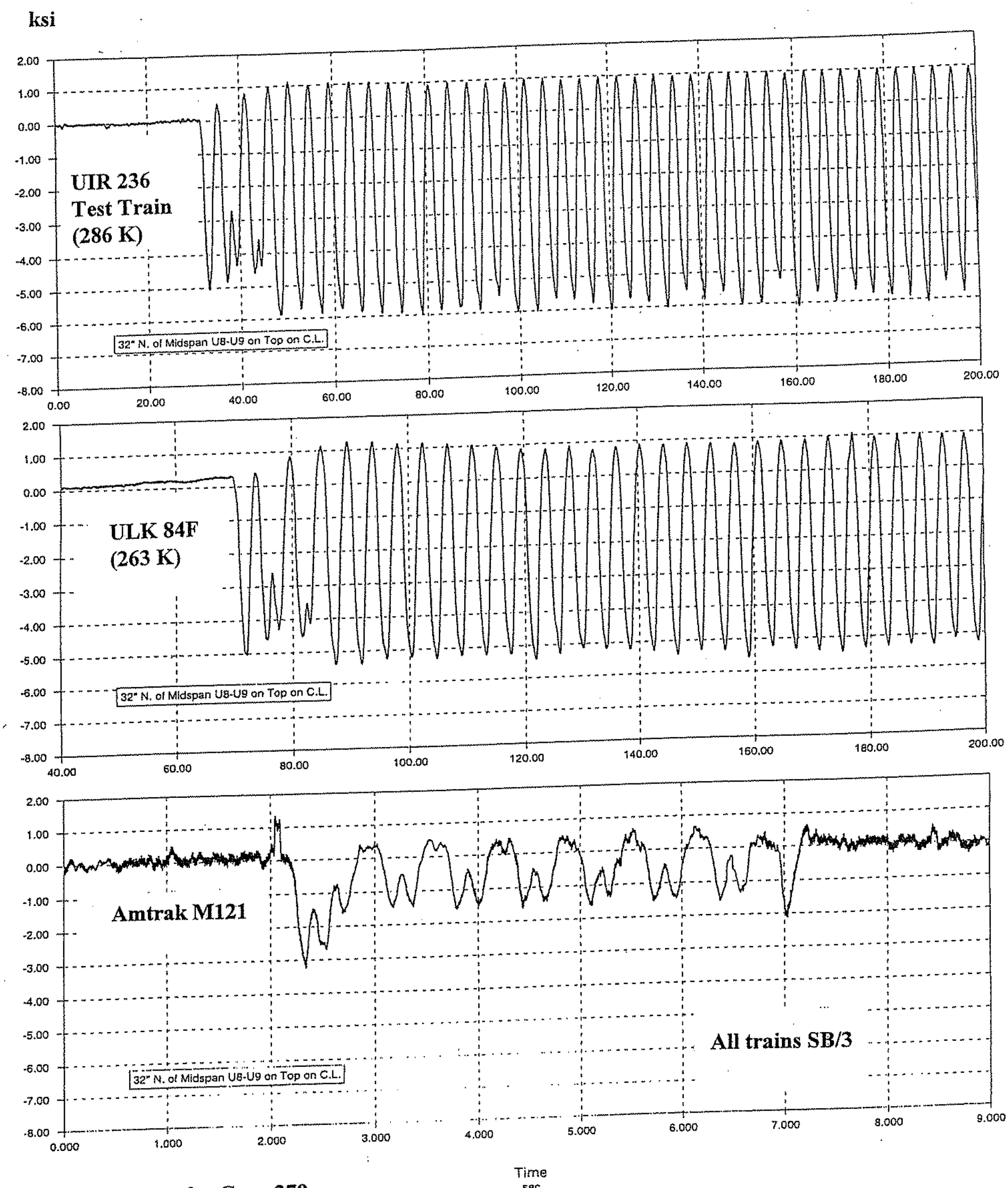
b-1) 286K Car Test Train (UIR 236)



b-2) 263K Car Coal Train (ULK 80E)

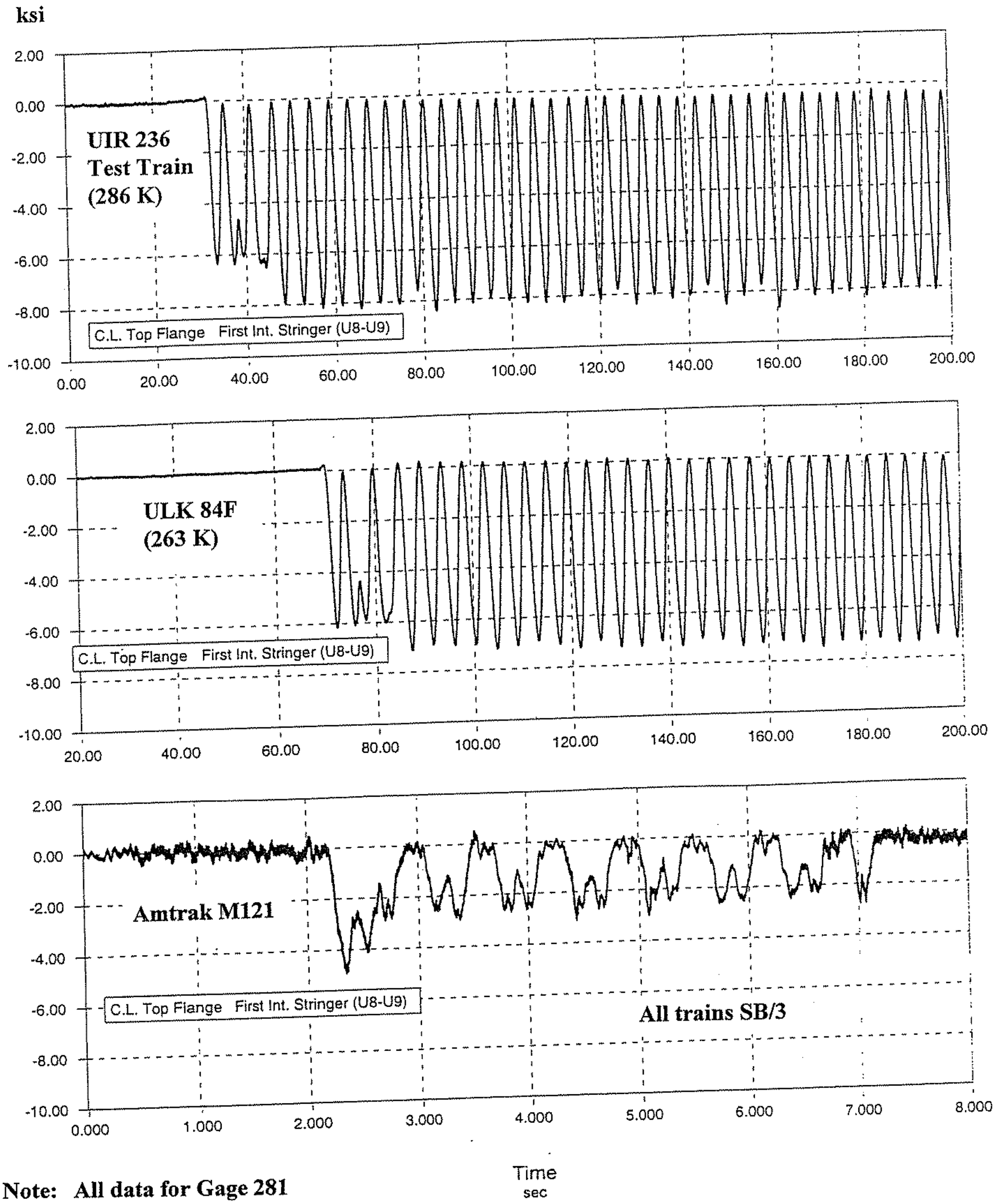
b) E side of stringer mid way between floorbeams

Figure 58 : Span 10 Data Records for Stringer A near Floorbeam 2 with Trains on Track 3 (11-97)



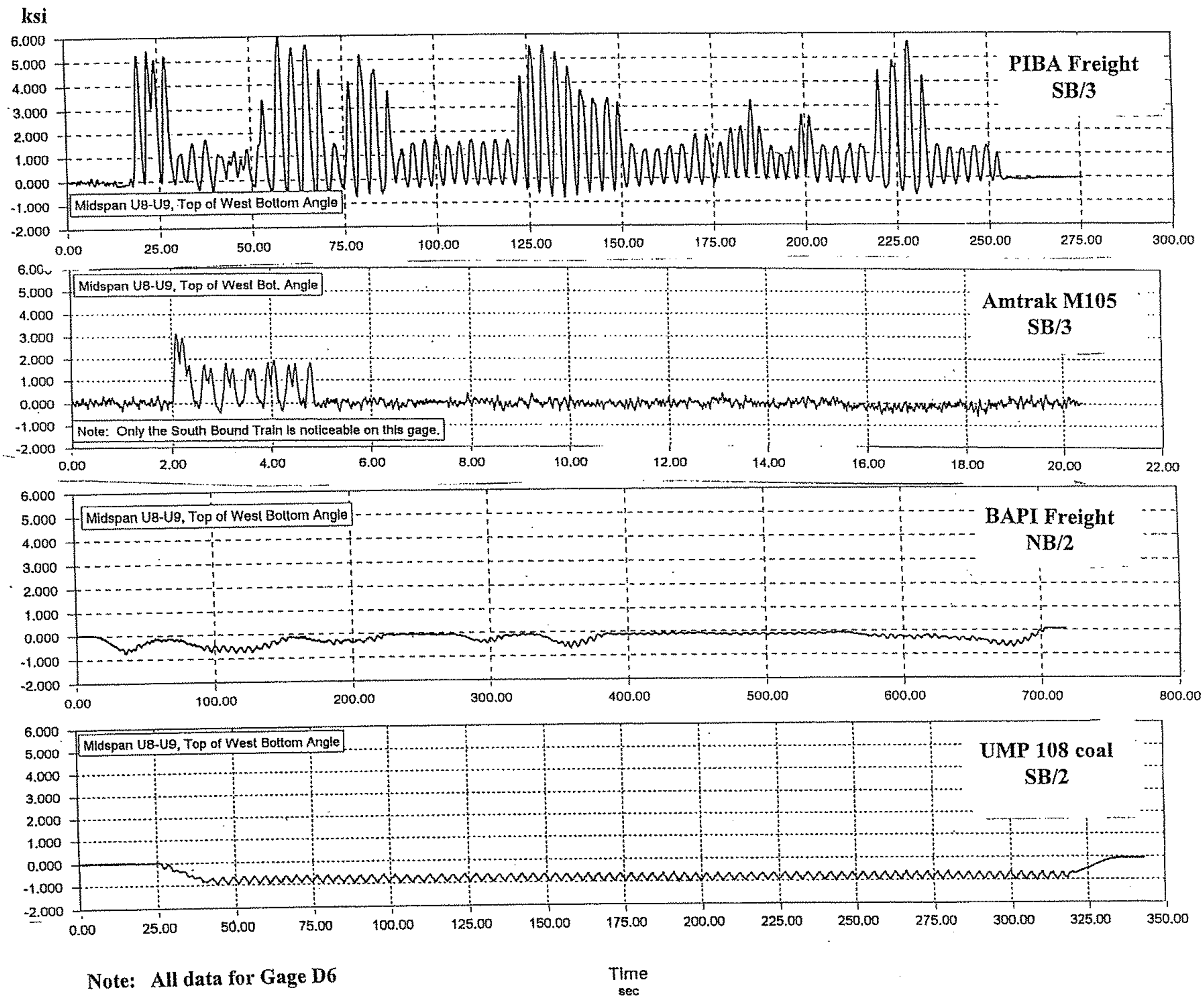
Note: All data for Gage 279

Figure 59 : Span 2 Top Chord Stresses: Top ℄ Surface of West Top Chord Midway Between Floorbeams 8 & 9 (11-97)



Note: All data for Gage 281

Figure 60 : Span 2 Stringer Stresses: Top ℄ Surface of Stringer B Midway between Floorbeams 8 & 9 (11-97)



Note: All data for Gage D6

Figure 61 : Span 2 Top Chord West Bottom Flange Stresses (01-98)

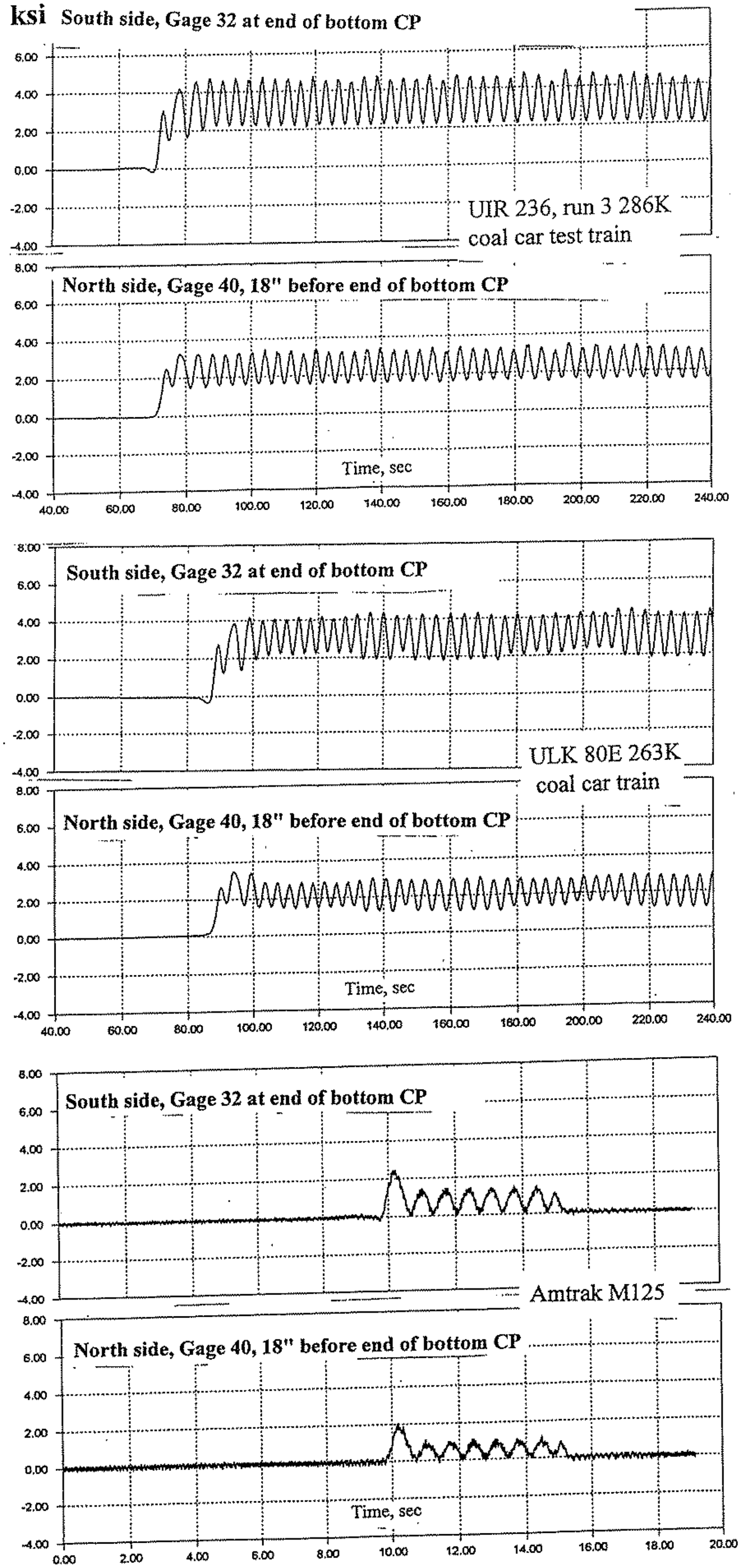
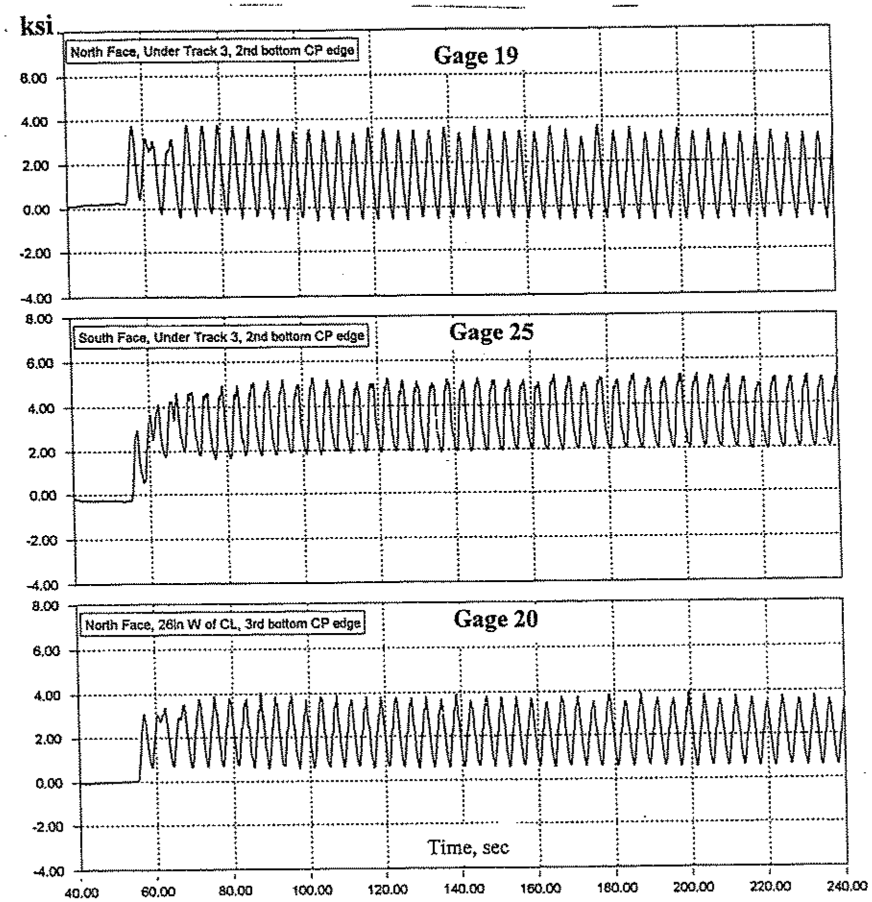
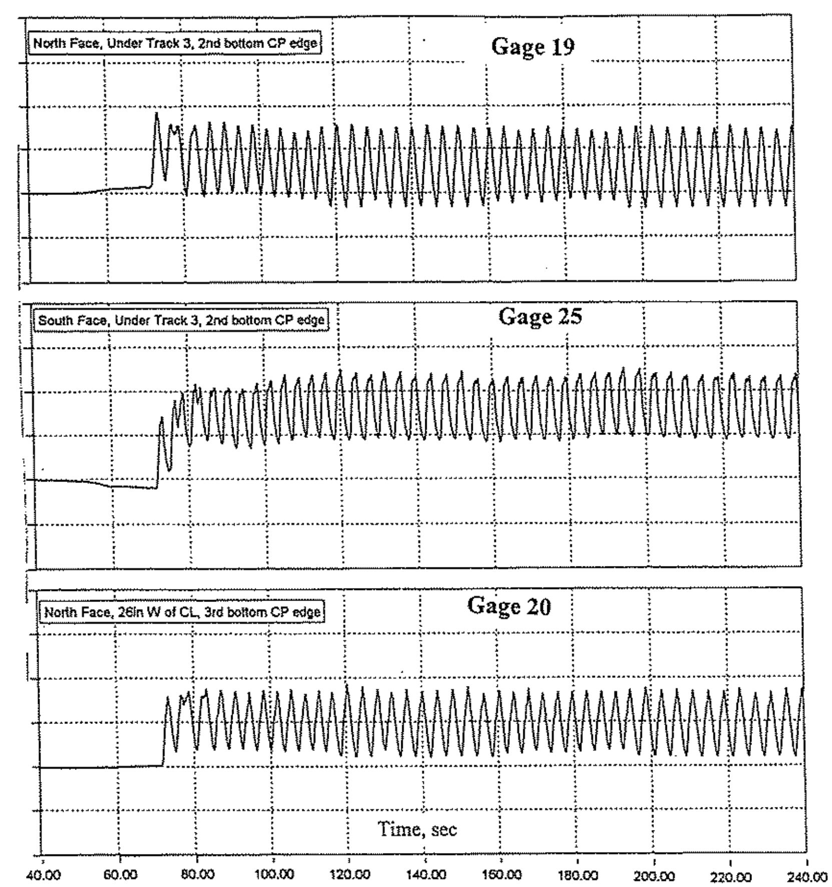


Figure 62. Span 10, Floorbeam 2 Stresses with Trains SB on Track 3

Gage 19: 43" W of Stringer B, N side of FB, edge of top CP
Gage 25: 43" W of Stringer B, S side of FB, atop middle CP
Gage 20: 26" W of midpt, N side of FB, edge of bottom CP

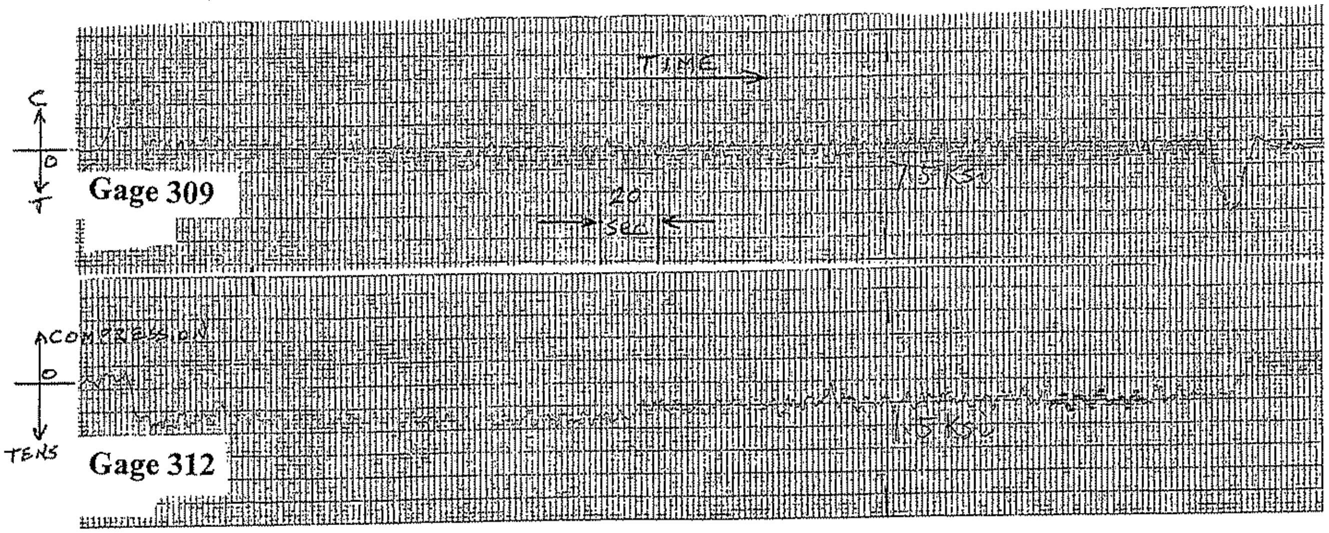


a) UIR 236 286K-car test train, run 3

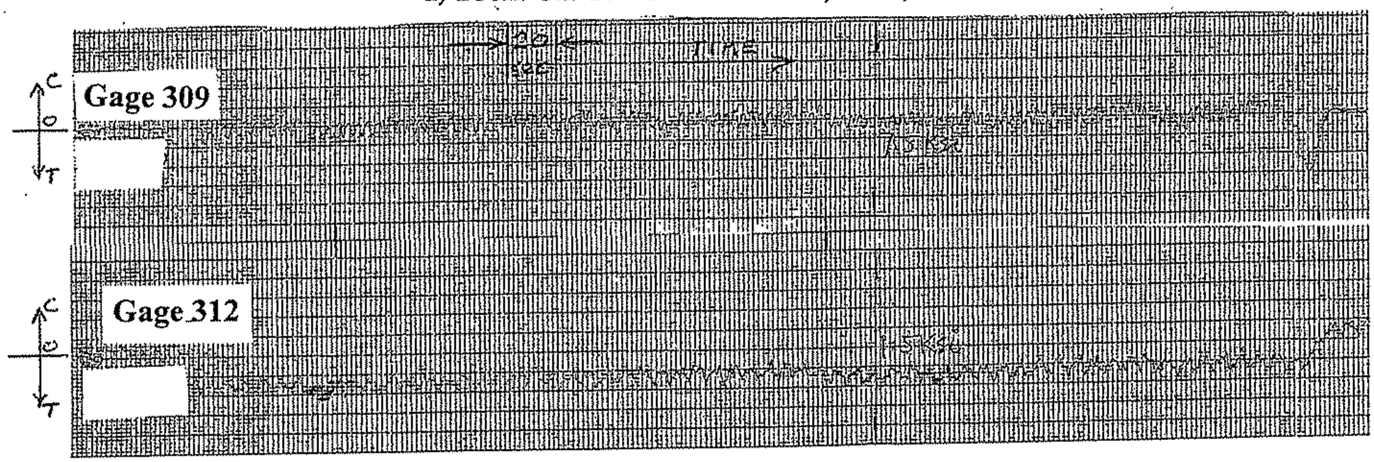


b) ULK 80E 263K-car train

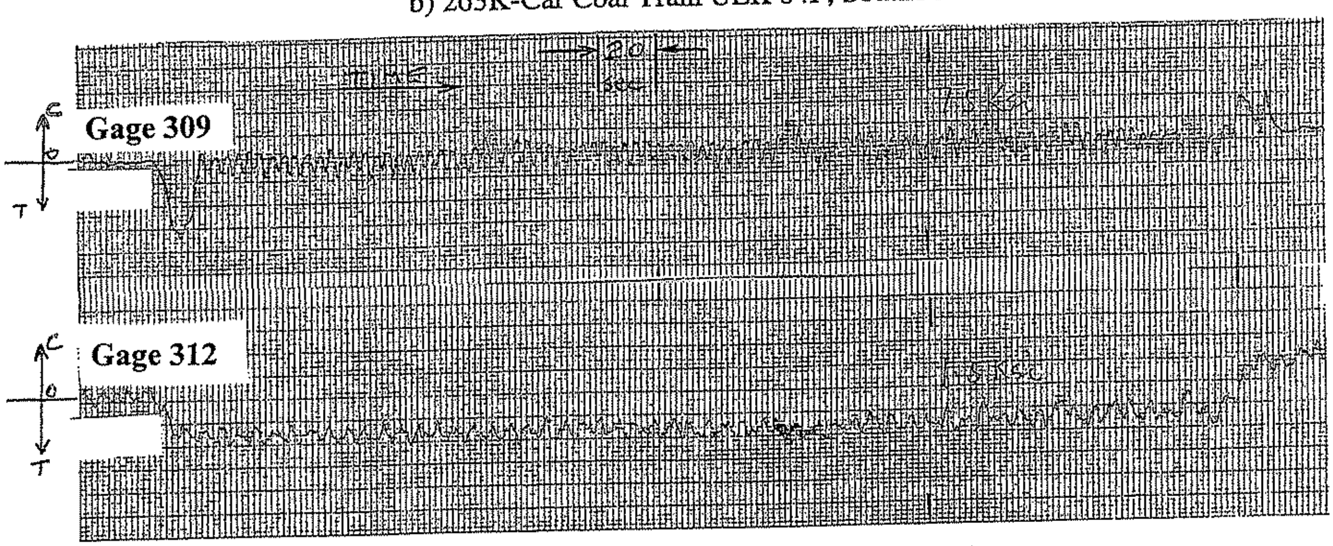
Figure 63. Span 10, Floorbeam 10 Stresses with Trains SB on Track 3



a) 286K-Car Test Train UIR 236, run 9, Southbound

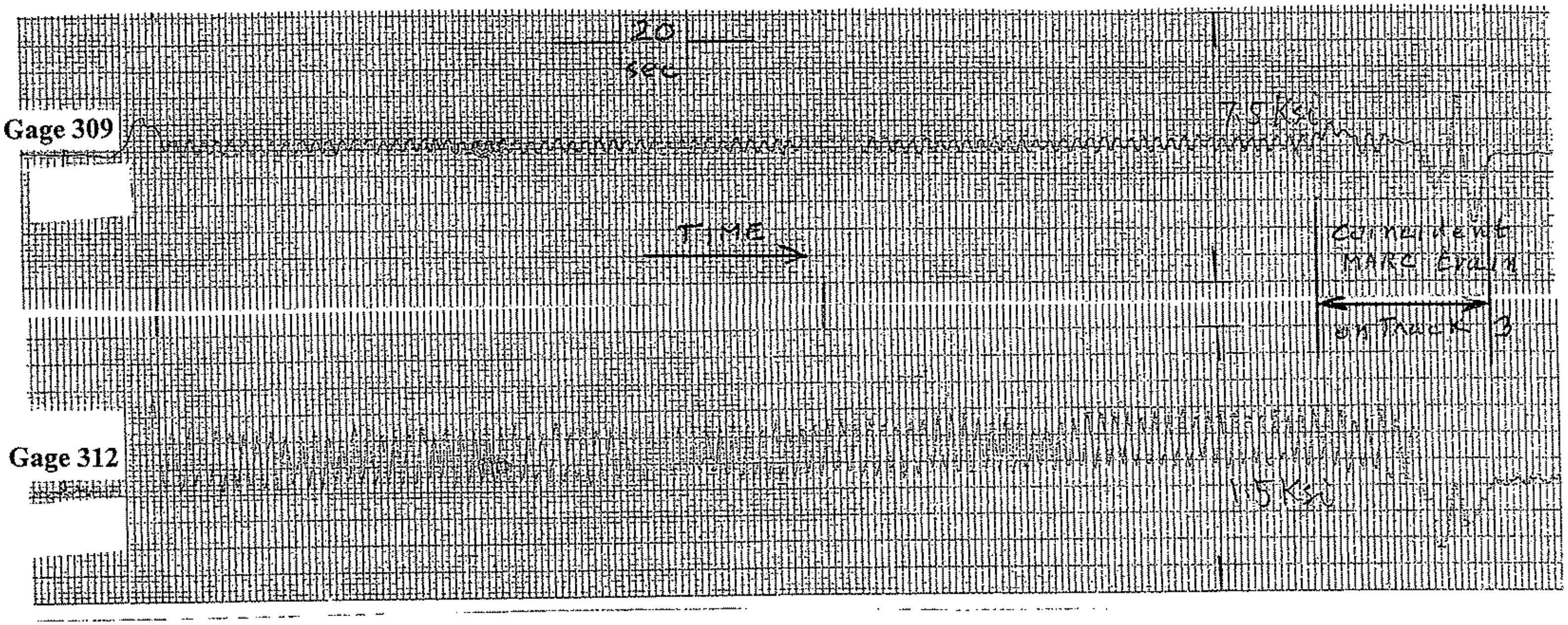


b) 263K-Car Coal Train ULK 84F, Southbound

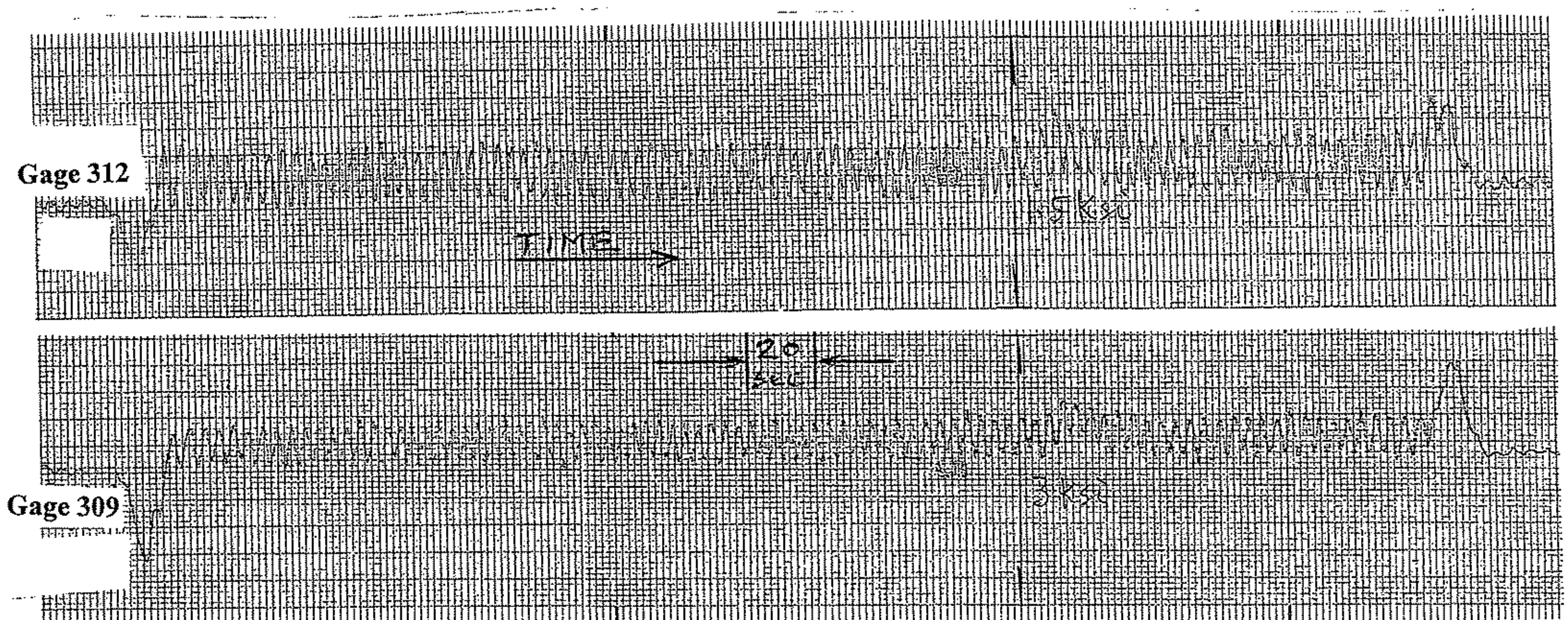


c) 286K-Car Test Train UIR 236, run 8, Northbound

Figure 64. Span 2, Floorbeam 5-West, Top Chord and Floorbeam Stresses with Trains on Track 3 (11/13-14/97)

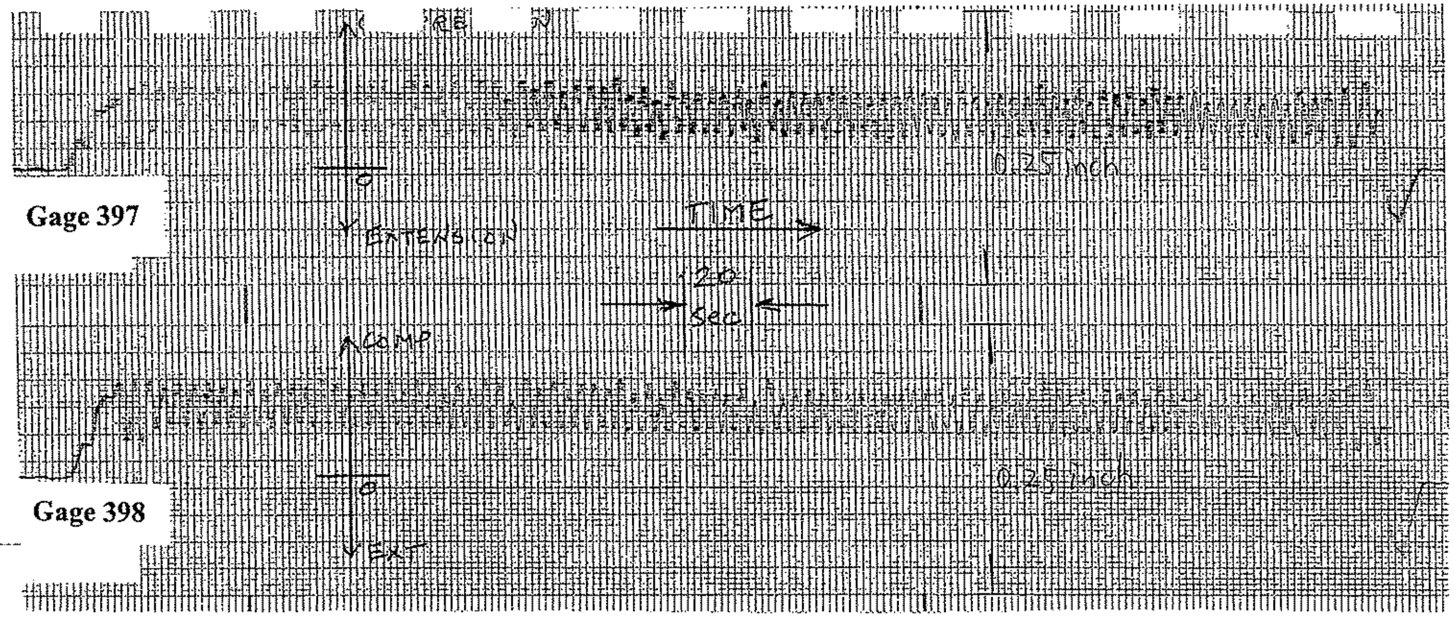


a) Test Train UIR 236, run 6; NB on Track 2

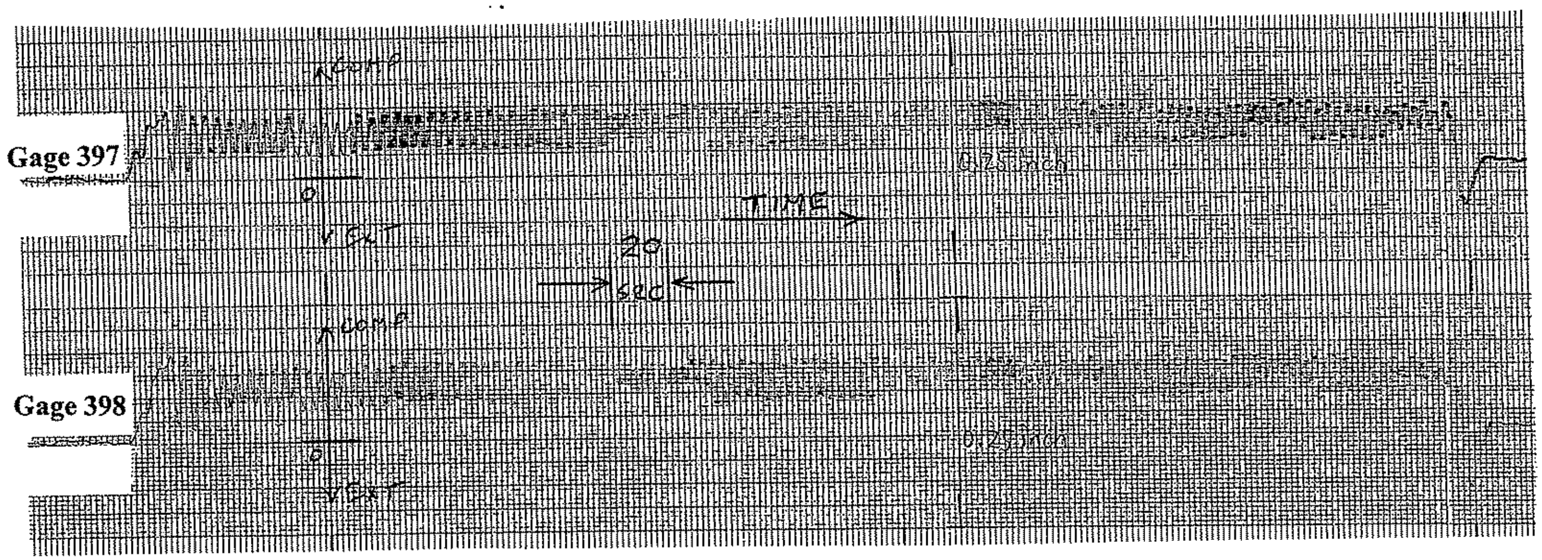


b) Test Train UIR 236, run 7; SB on Track 2

Figure 65. Span 2: Floorbeam 5-West, Data Records with Test Train on Track 2 (11-13-97)

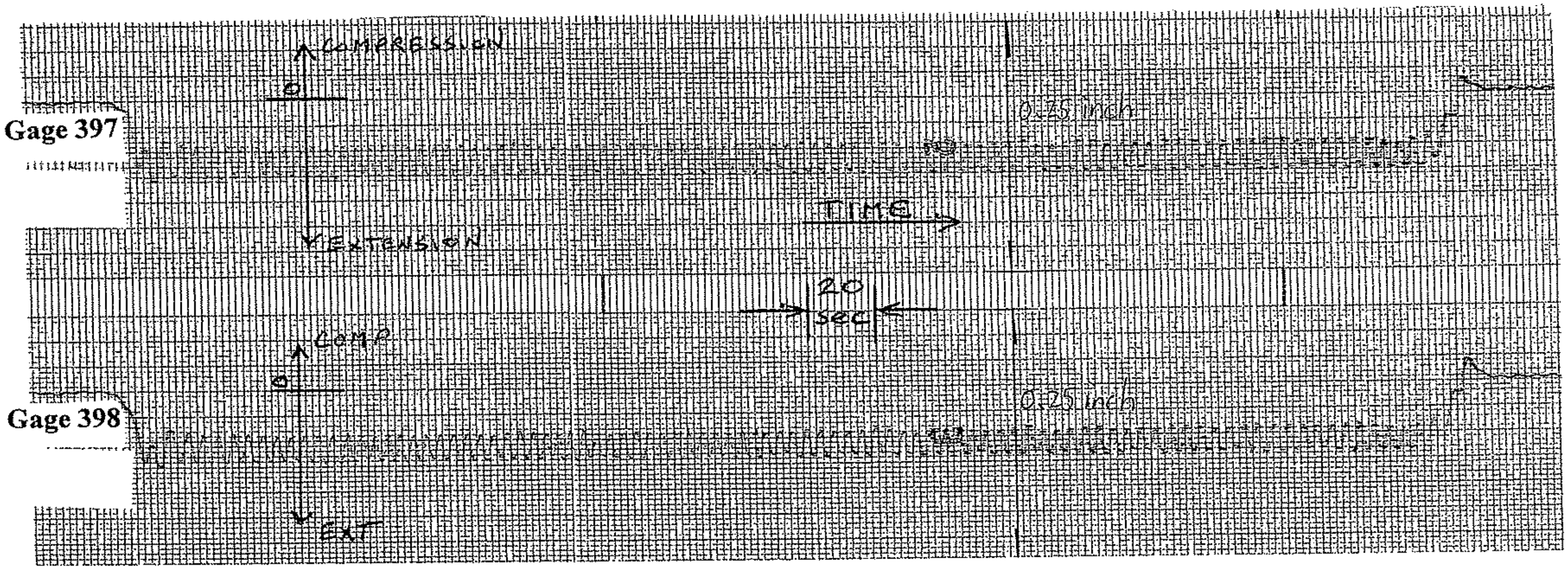


a) 286K Test Train UIR 236, run 9 (11-13-97)

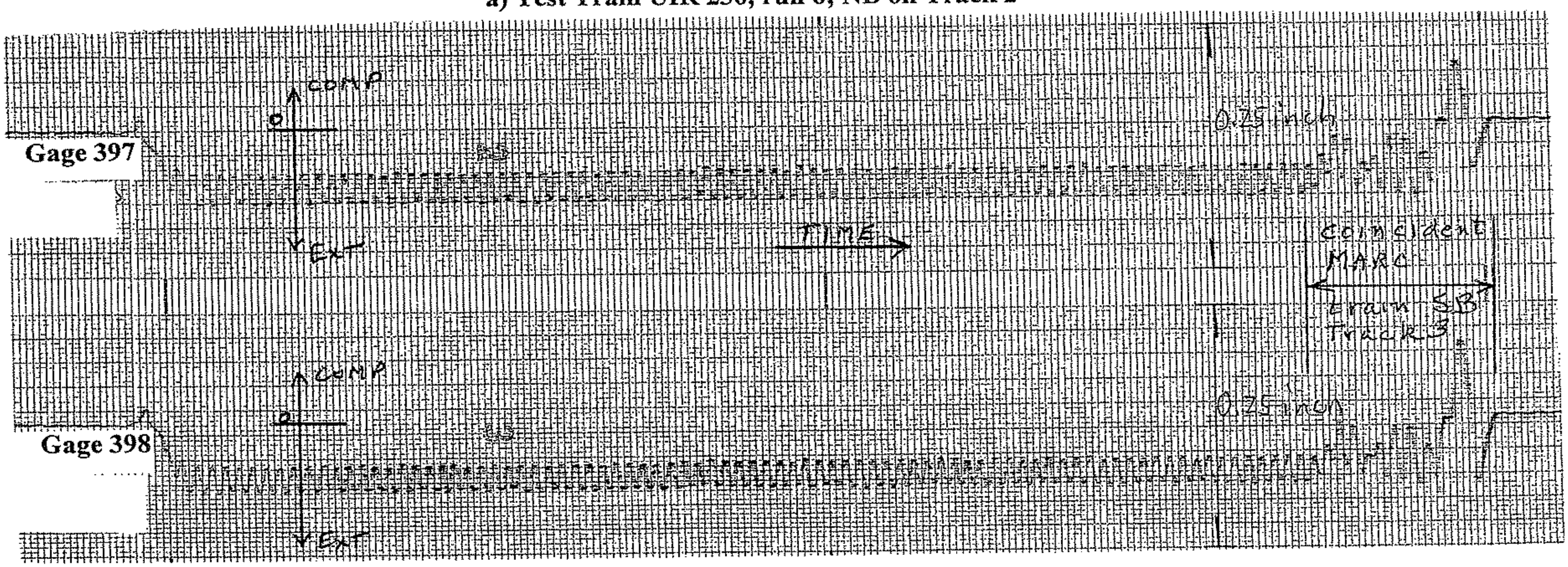


b) 263K Coal-Car Train ULK 84F (11-14-97)

Figure 66. Span 2, Floorbeam 5-west, Displacement Records with Coal Trains Southbound on Track 3

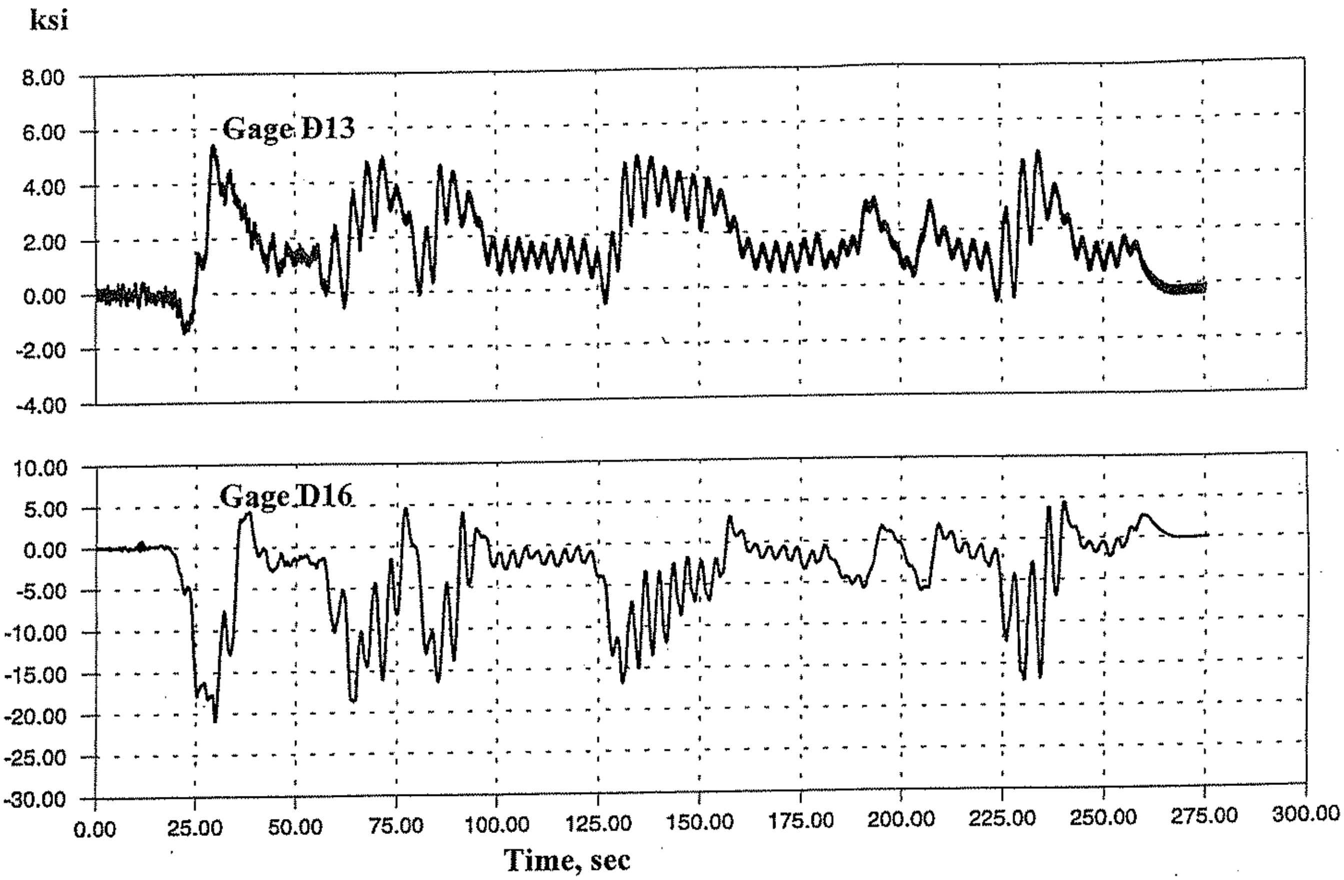


a) Test Train UIR 236, run 6; NB on Track 2

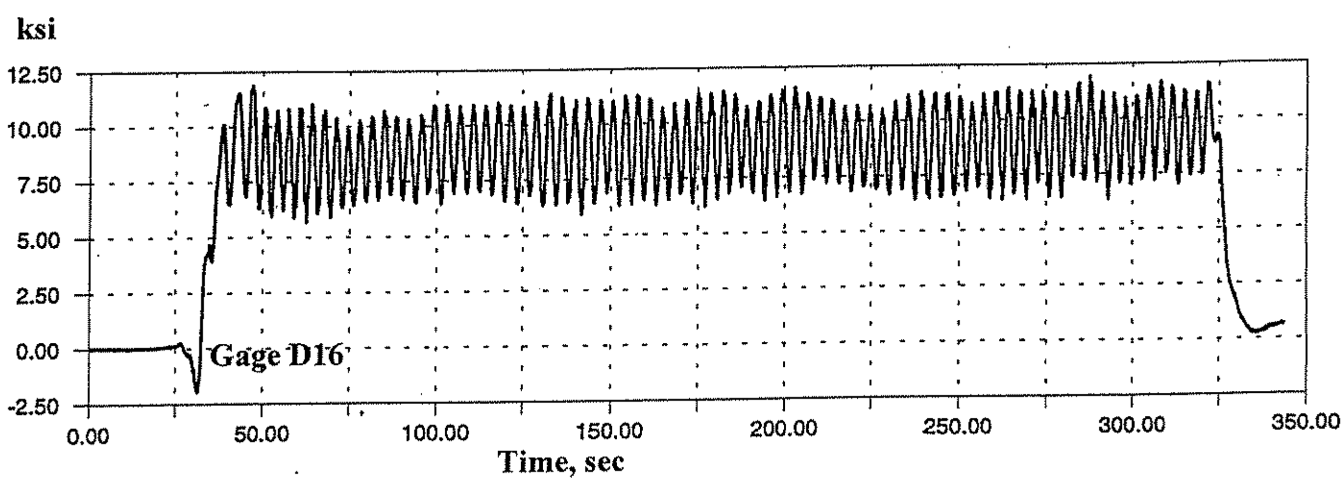


b) Test Train UIR 236, run 7; SB on Track 2

Figure 67. Span 2, Floorbeam 5-West, Displacement Records with Test Train on Track 2 (11-13-97)



a) PIBA Mixed Freight Train, Southbound on Track 3



b) UMP 108 Heavy Coal Train, Southbound on Track 2

Figure 68a. Span 2, Floorbeam 5 and West Top-Chord Stress Records in January, (01-98)

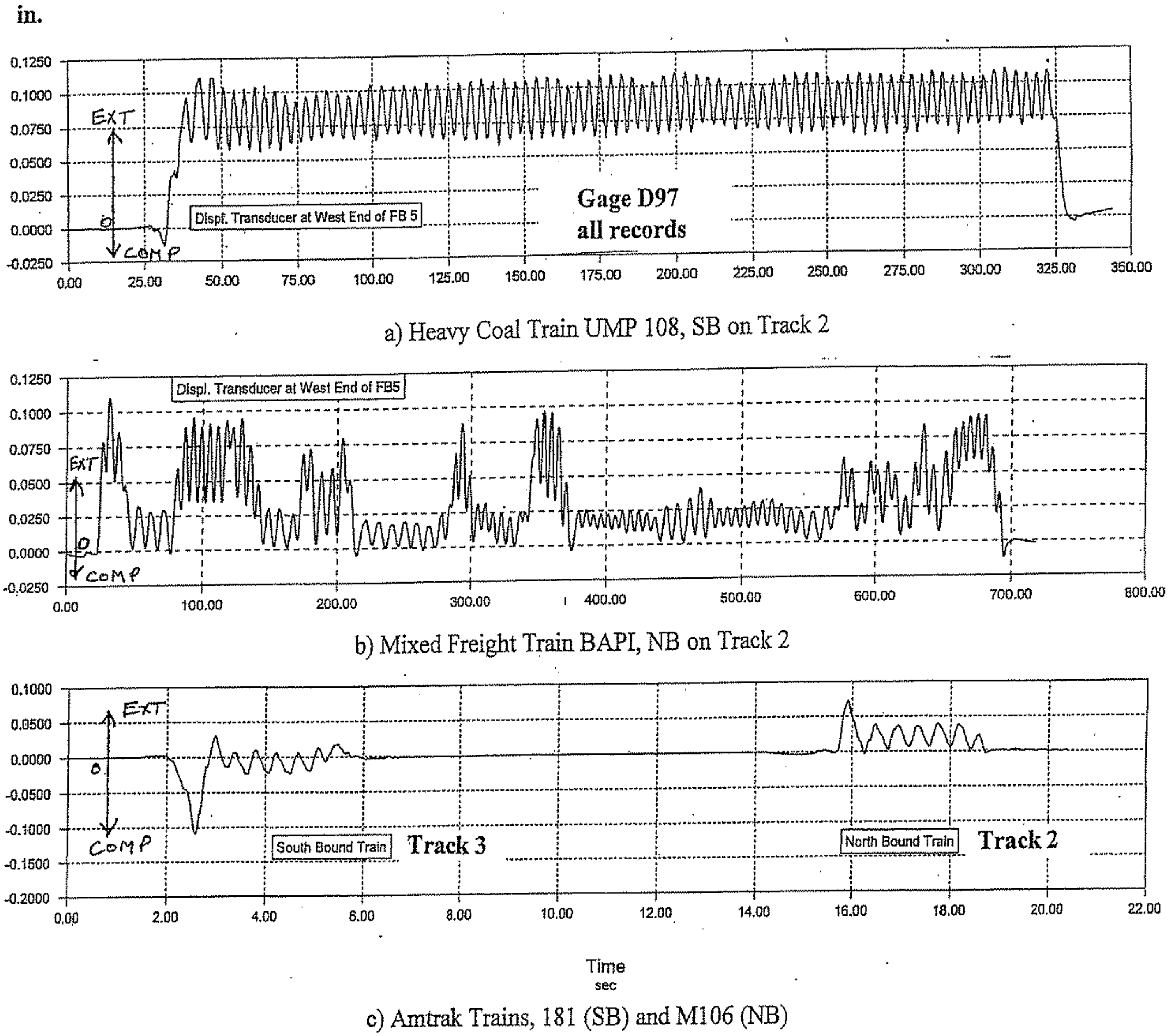
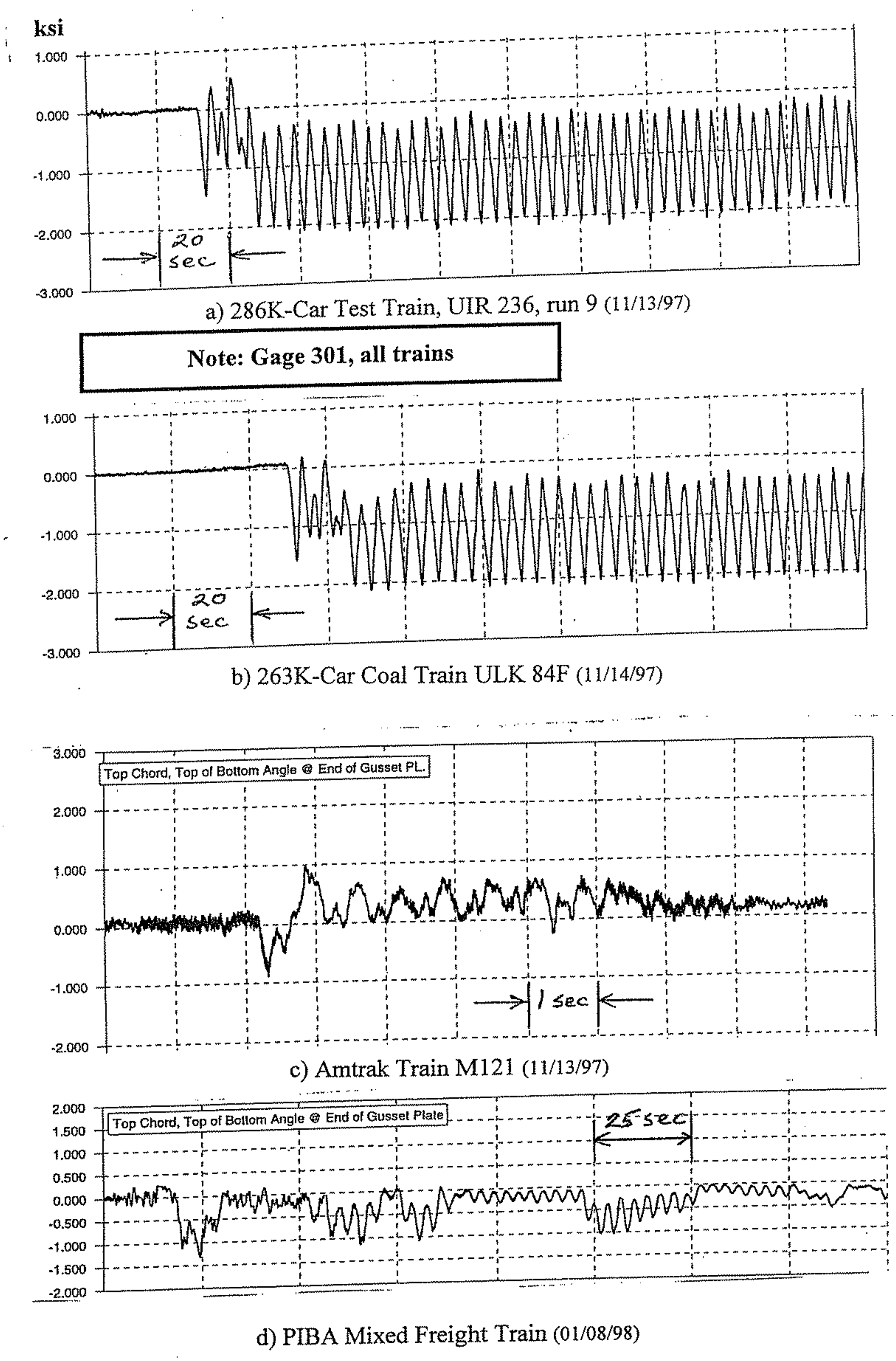


Figure 68b. Span 2, Floorbeam 5-West, Displacement Records for Trains in January, (01-98)



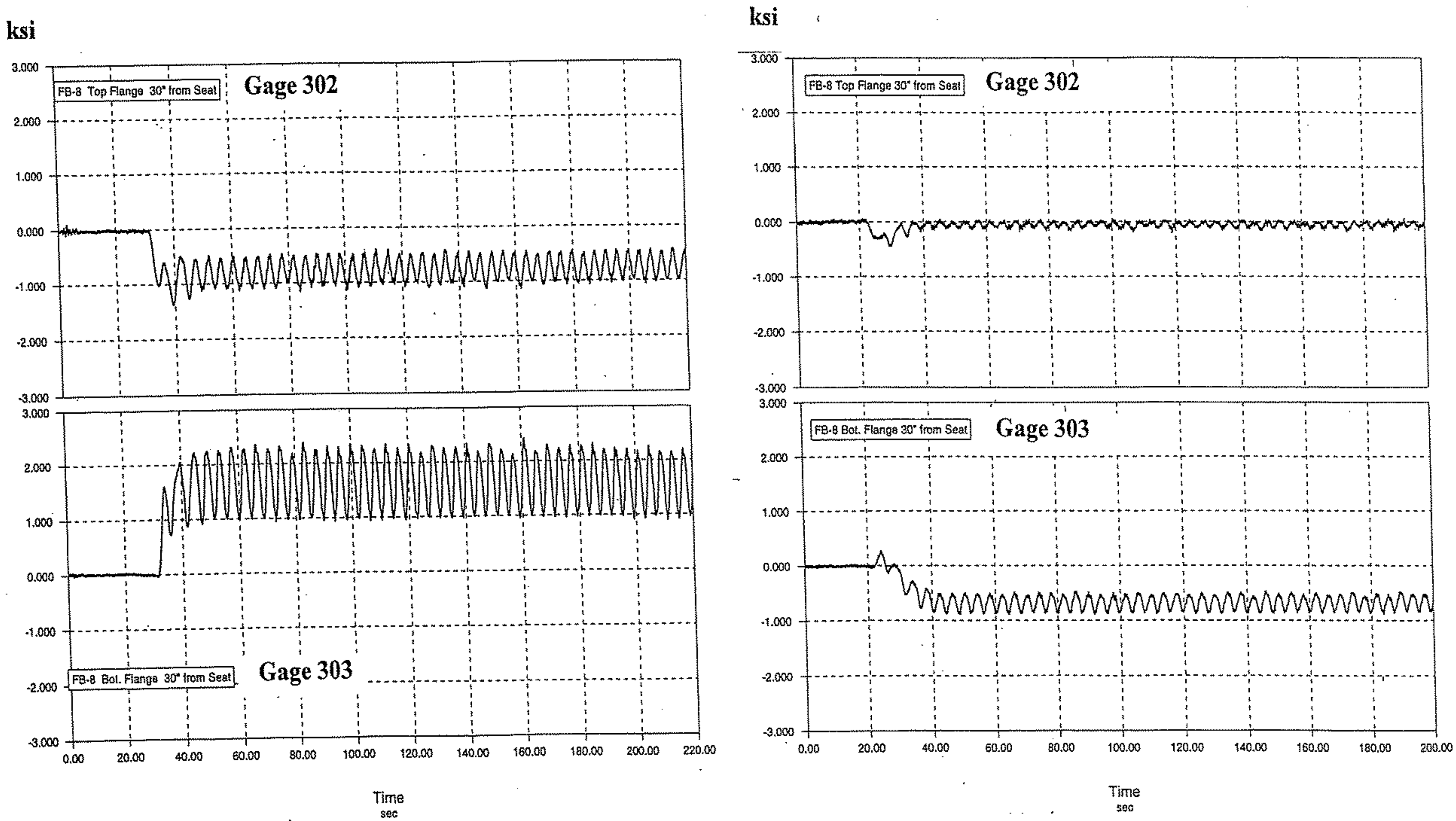
a) 286K-Car Test Train, UIR 236, run 9 (11/13/97)

b) 263K-Car Coal Train ULK 84F (11/14/97)

c) Amtrak Train M121 (11/13/97)

d) PIBA Mixed Freight Train (01/08/98)

Figure 69. Span 2, Floorbeam 8-West, Top Chord Flange Stresses with SB Track 3 Trains (Partial Records)



a) Southbound on Track 3

b) Southbound on Track 2

Figure 70. Span 2, Floorbeam 8 Stresses with 286K-Car Test Train

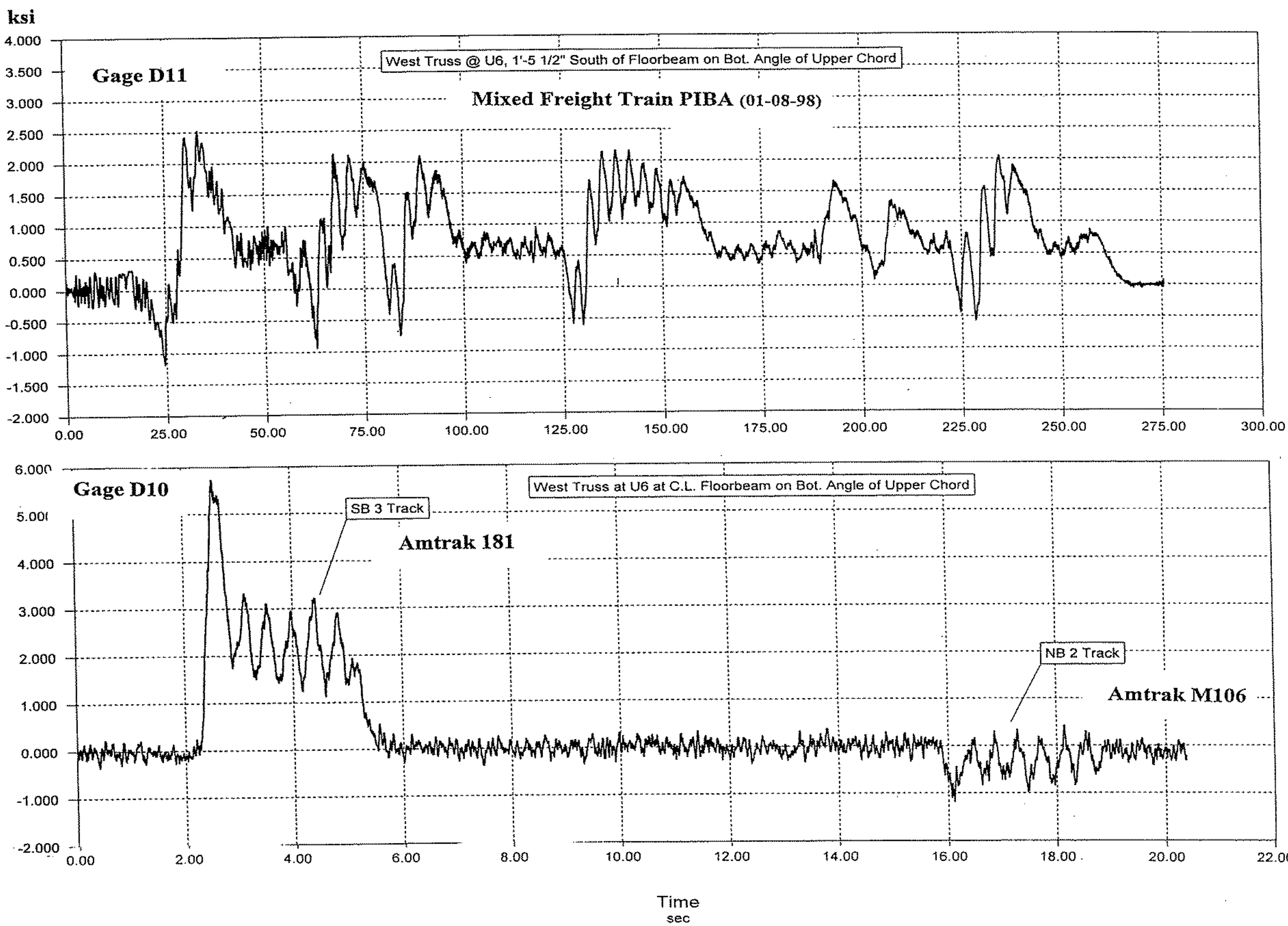
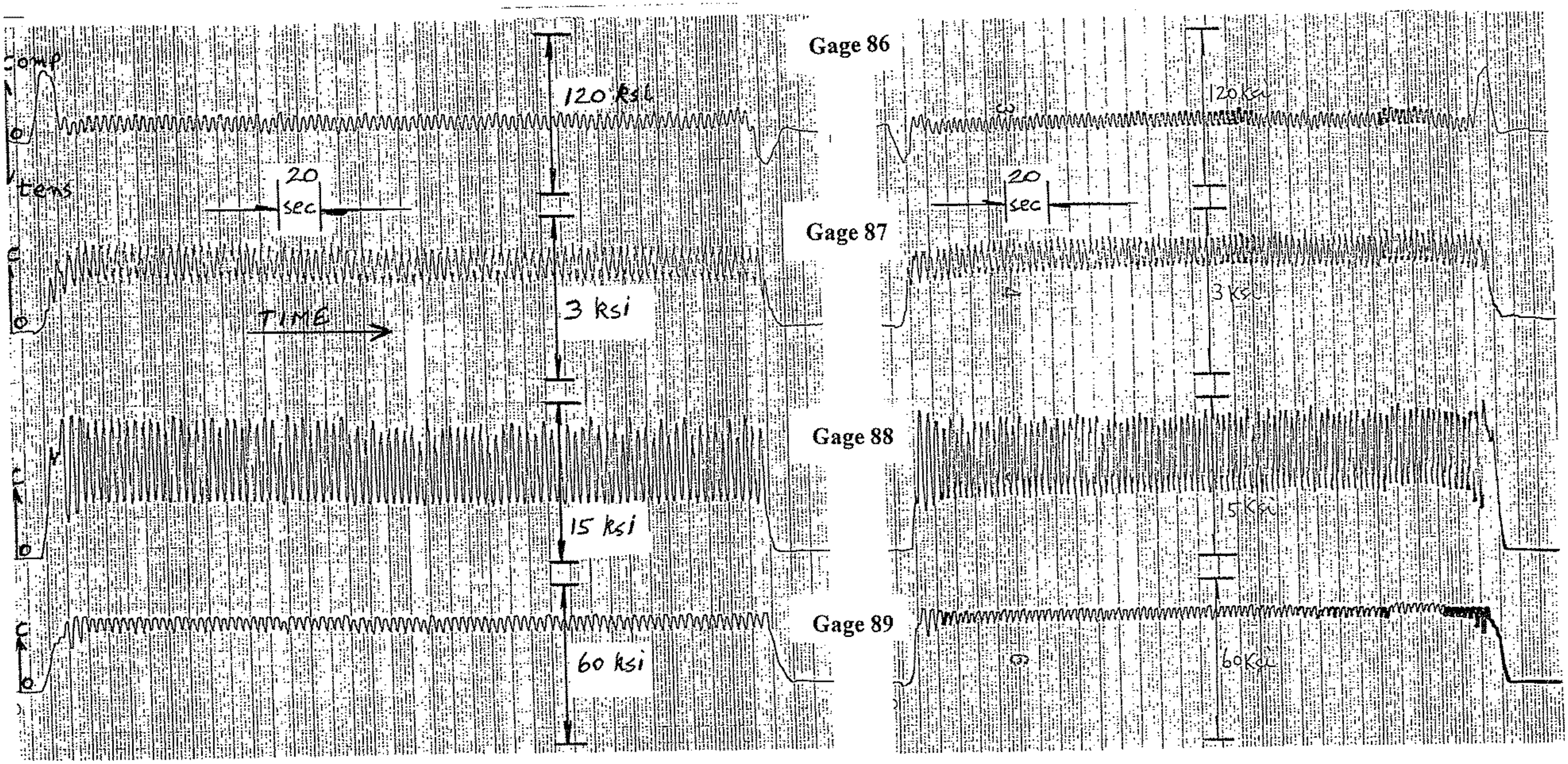


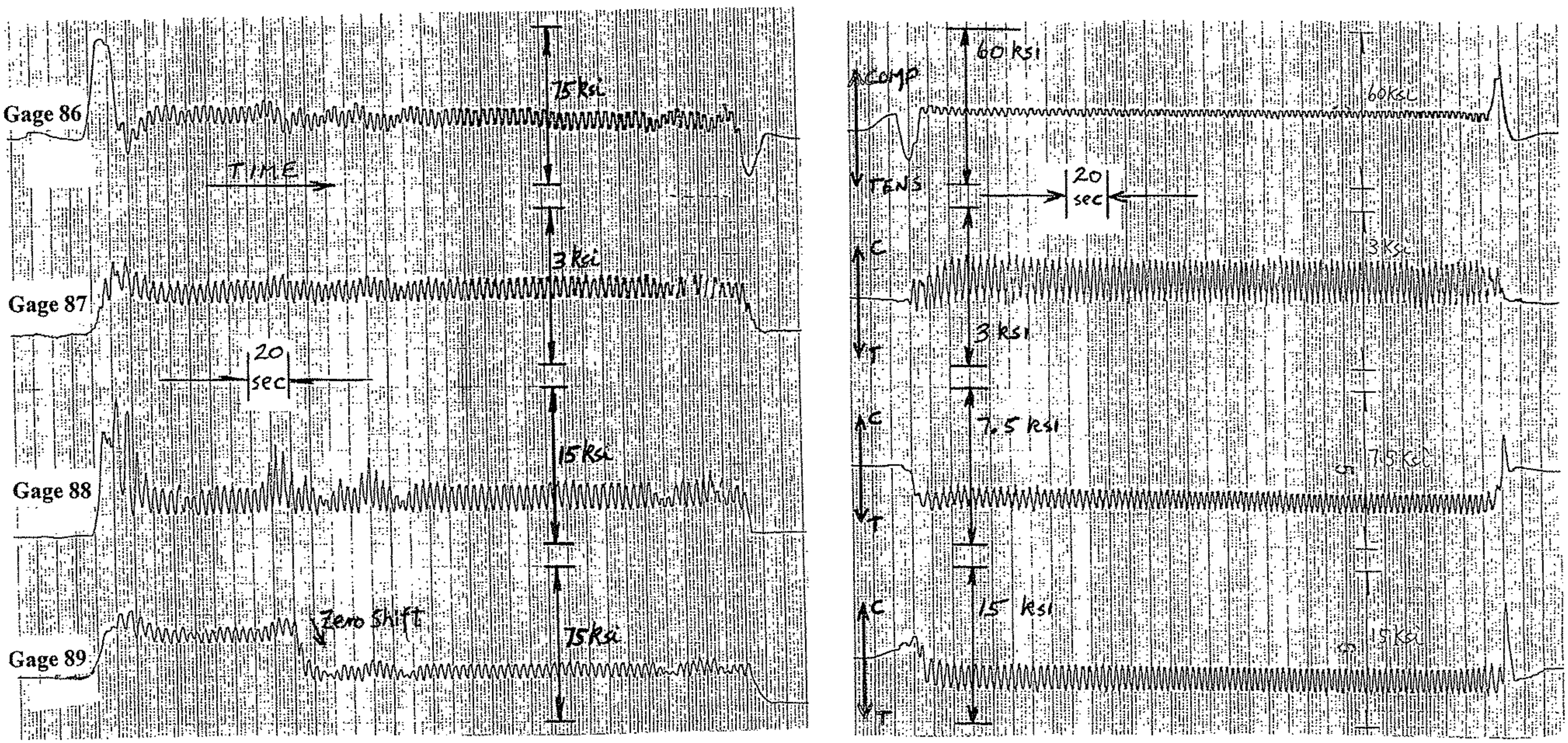
Figure 71. Span 2, Floorbeam 6-West, Data Records from top Chord Gages (01/98)



a) Test Train UIR 236, run 1; SB on Track 3

b) Test train UIR 236, run 2, NB on Track 3

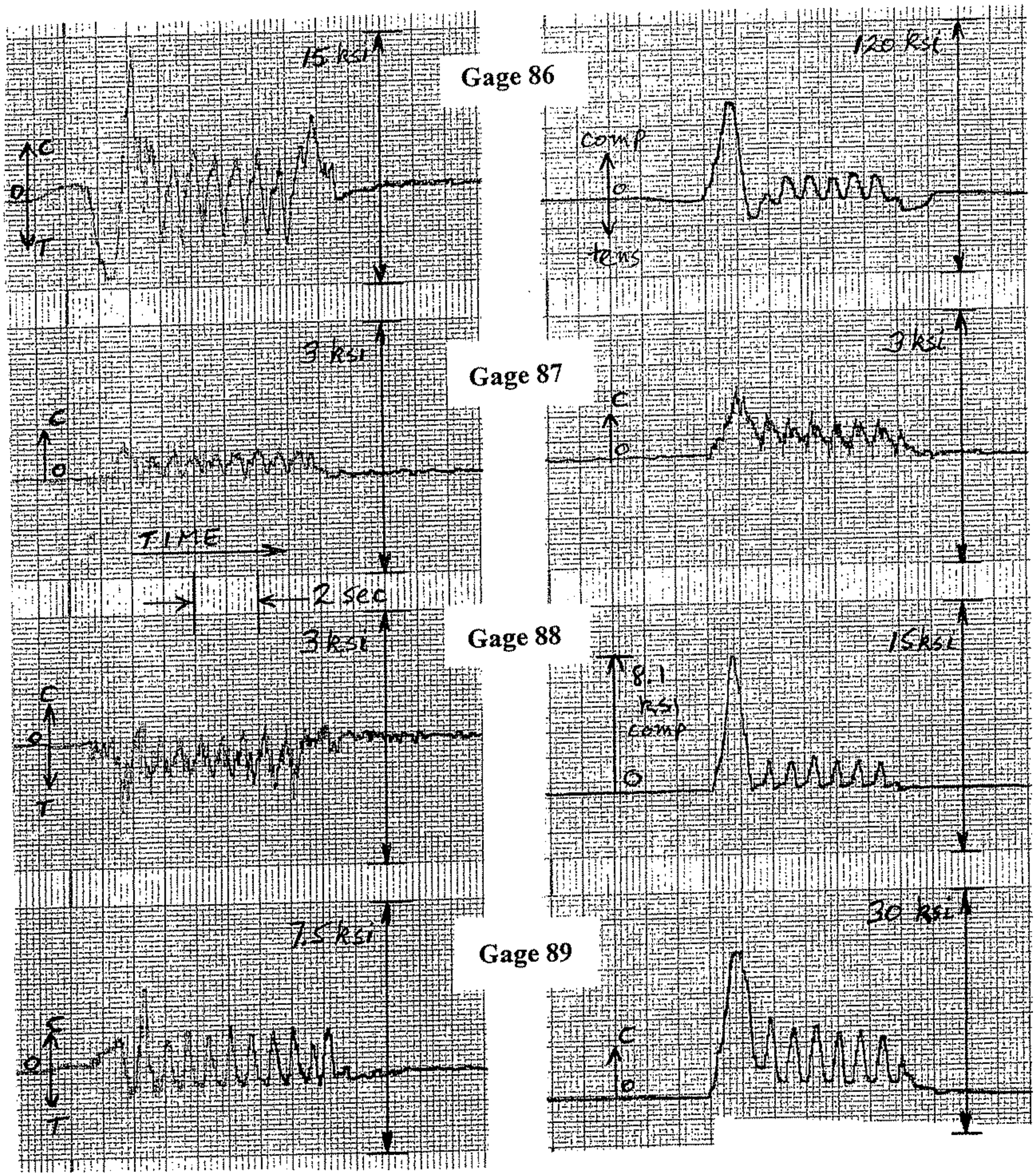
Figure 72. Span 7, Floorbeam 5-West, Data Records for Test Train (11-13-97)



a) Coal Train UBC 20 (10-20-97) SB on Track 3

b) Test train UIR 236, run 4, NB on Track 2 (11-13-97)

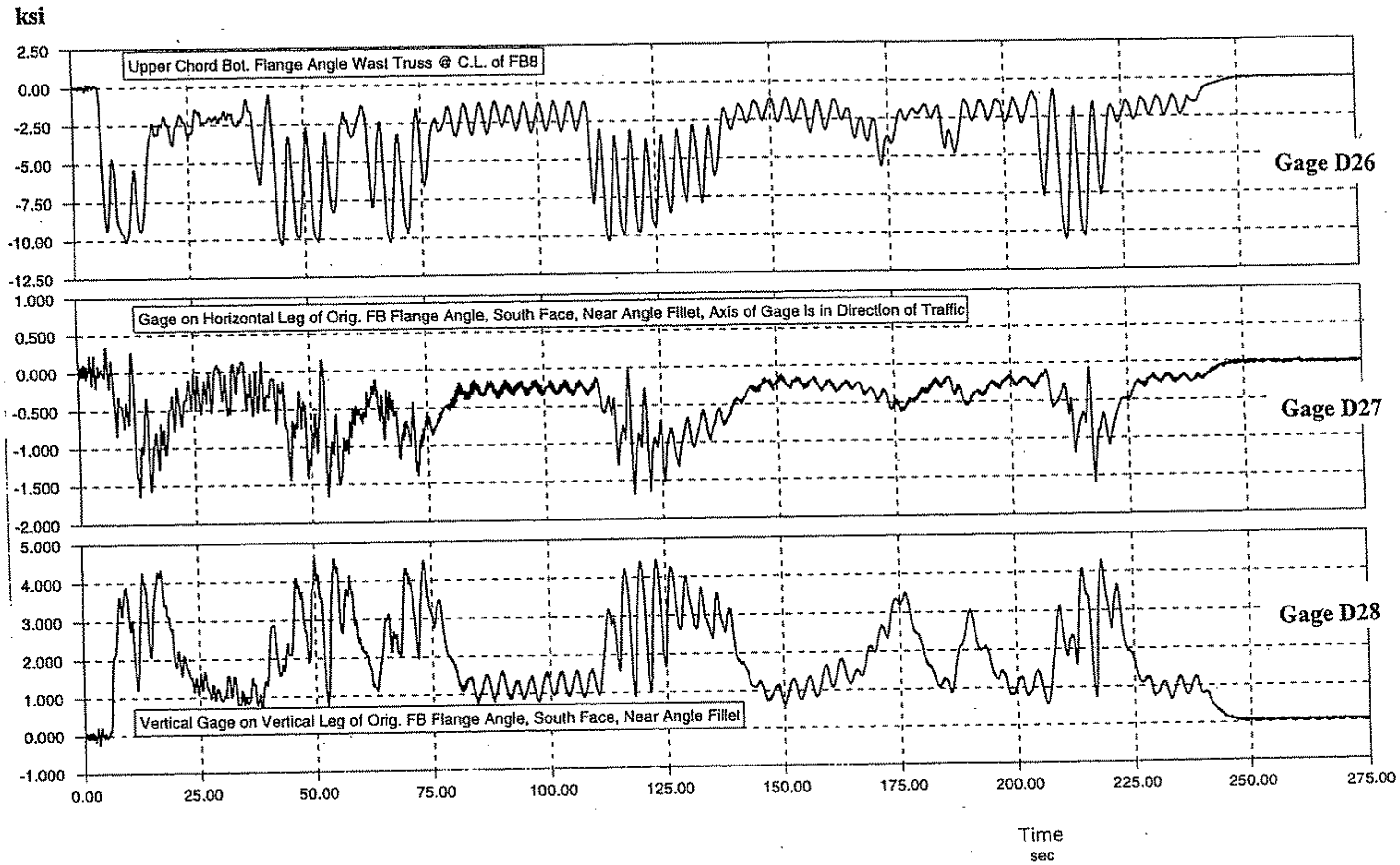
Figure 73. Span 7, Floorbeam 5-West, Data Records for Coal Trains



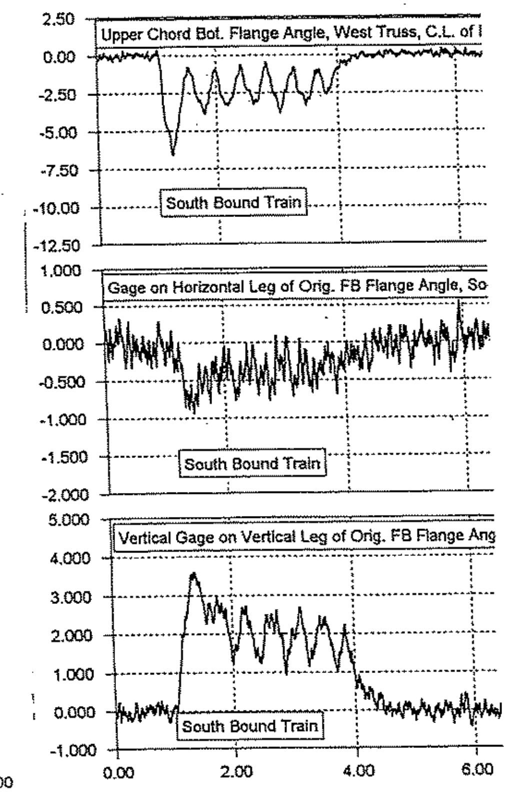
a) Northbound on Track 2, Train M126

b) Soutbound on Track 3, Train M127

Figure 74. Span 7, Floorbeam 5-West, Data Records for Amtrak Trains (10-20-97)

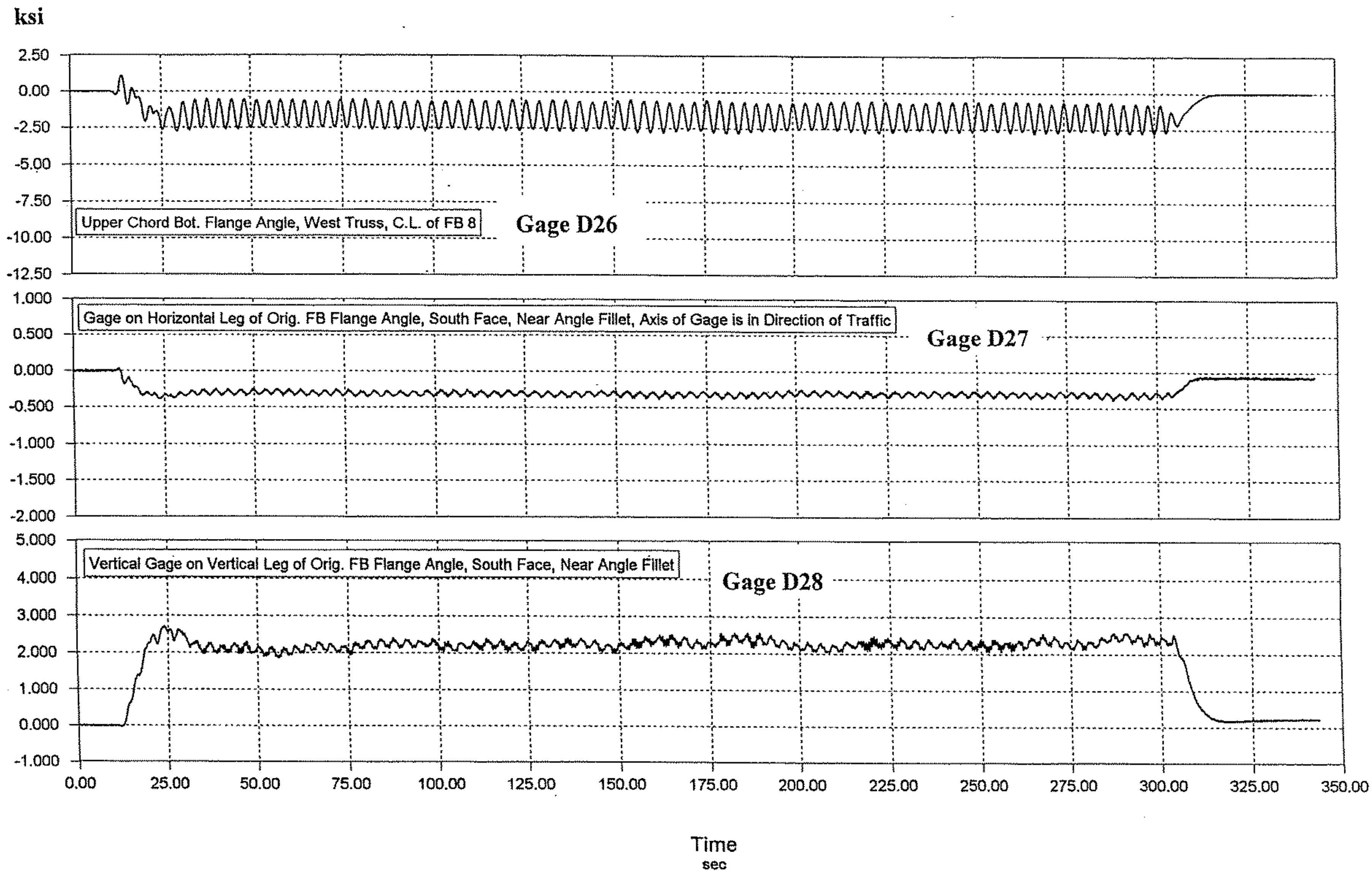


a) PIBA Mixed Freight Train



b) Amtrak Train 181

Figure 75. Span 1, Floorbeam 8-West, Data Records for Southbound Trains on Track 3 (01/09/98)
(continue)



c) Southbound Coal Train UMP 108

Figure 75 (continued): Span 1, Floorbeam 8-West, Data Records for 263K Coal Train on Track 2 (01/09/98)

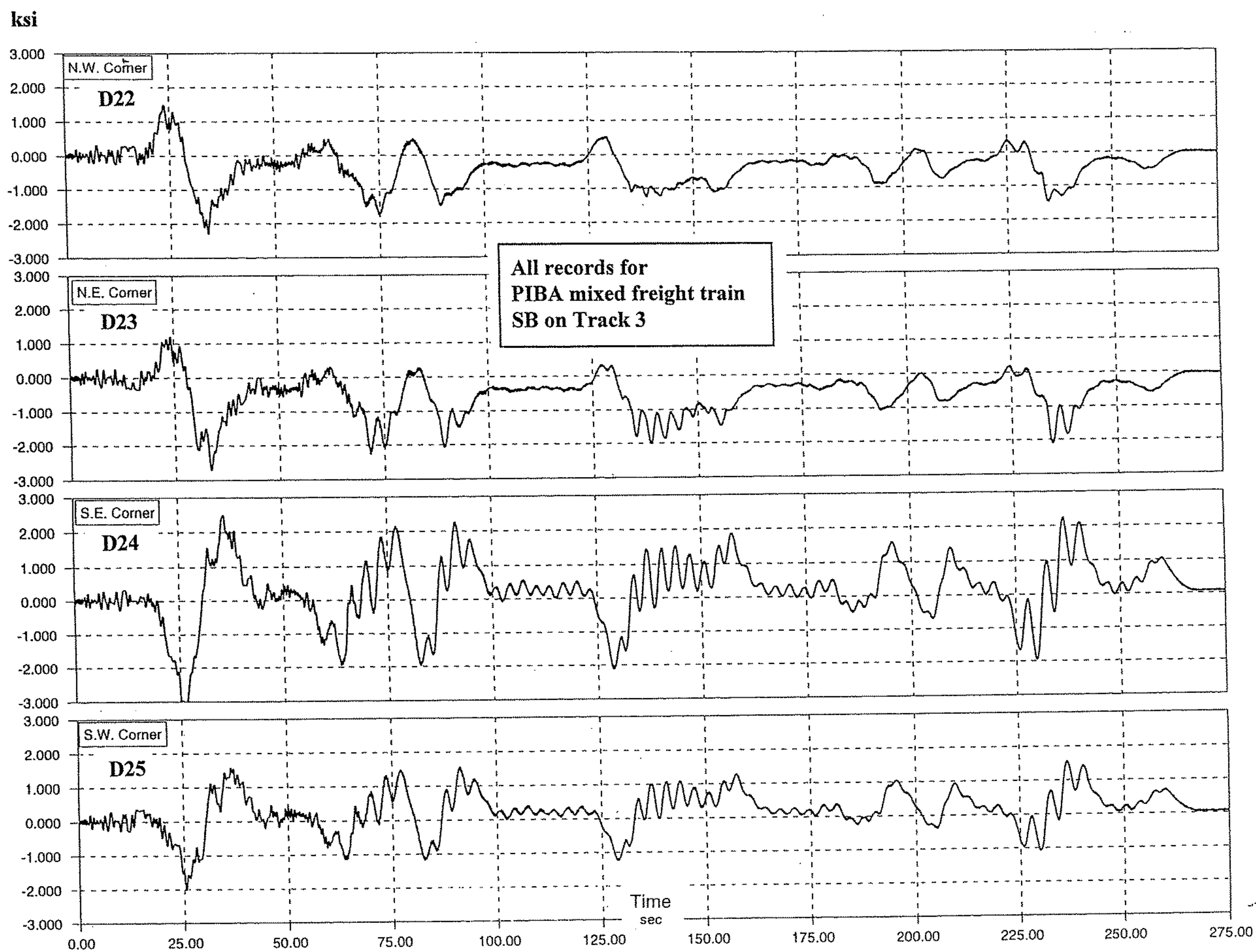


Figure 76. Stresses at West Truss Vertical Post L5U5 (01-98)

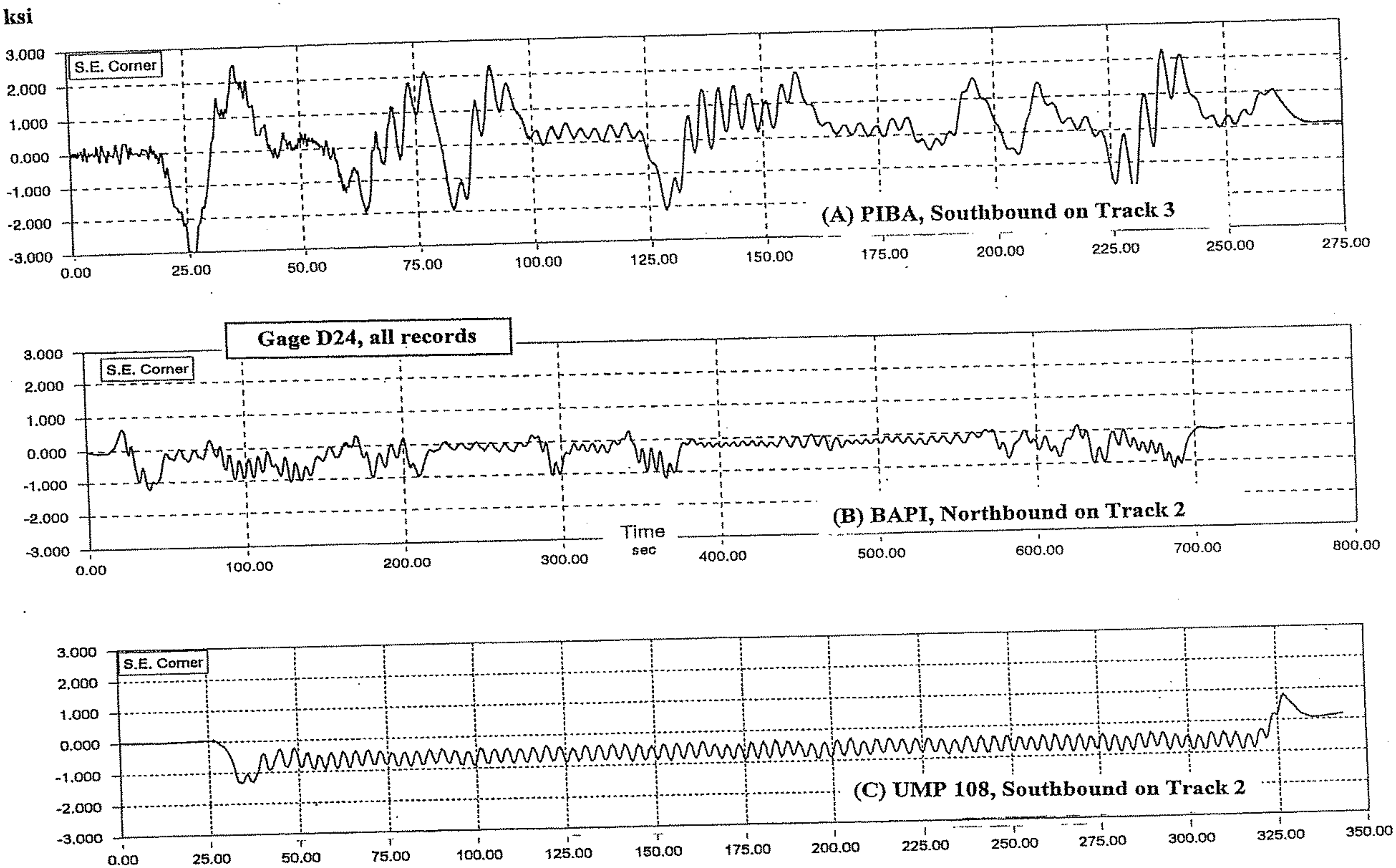


Figure 77. Stresses at West Truss Vertical Post L5U5 - Effect of Various Trains (01-98)

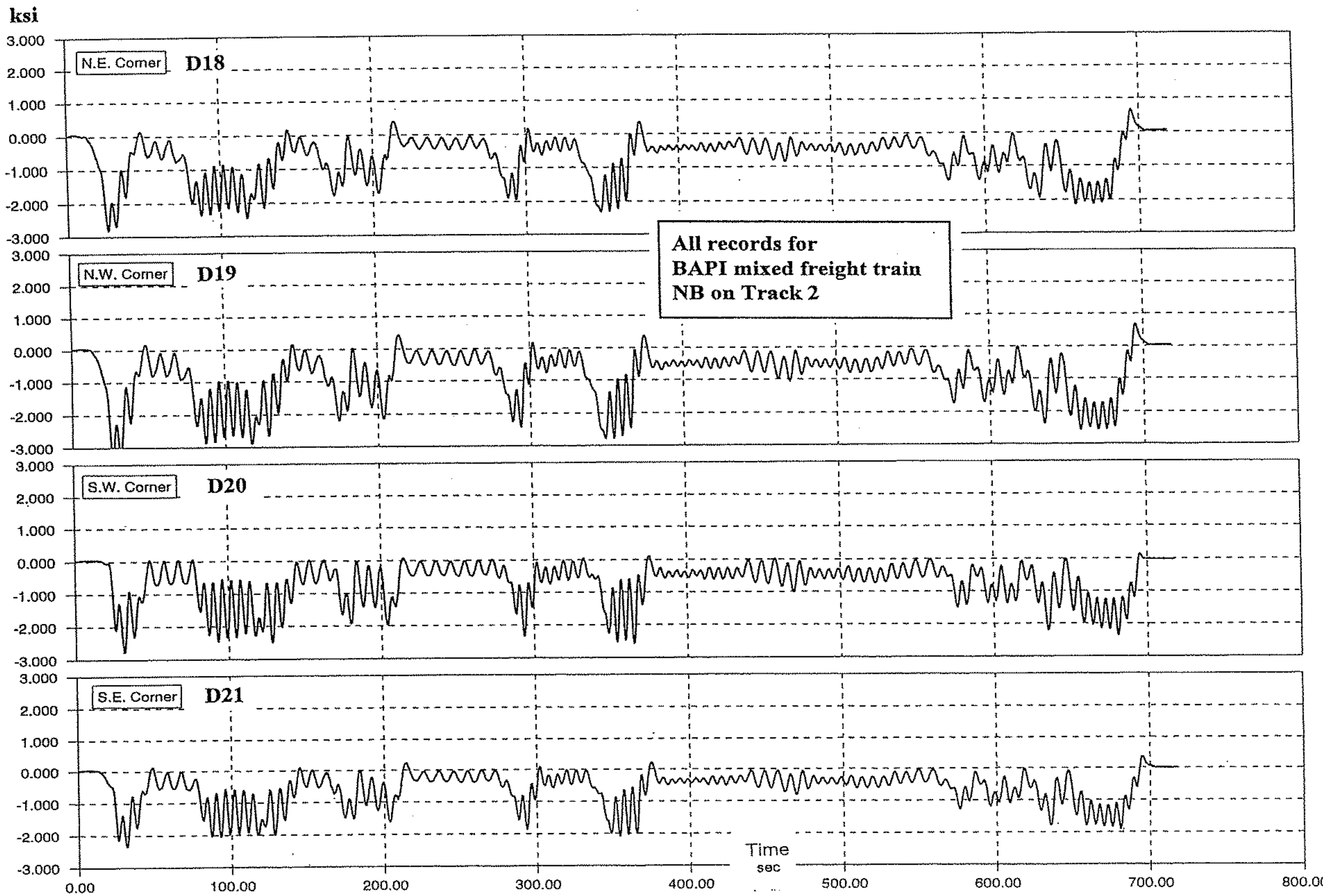


Figure 78. Stresses at Span 2 East Truss Vertical Post L5U5 (-01-98)

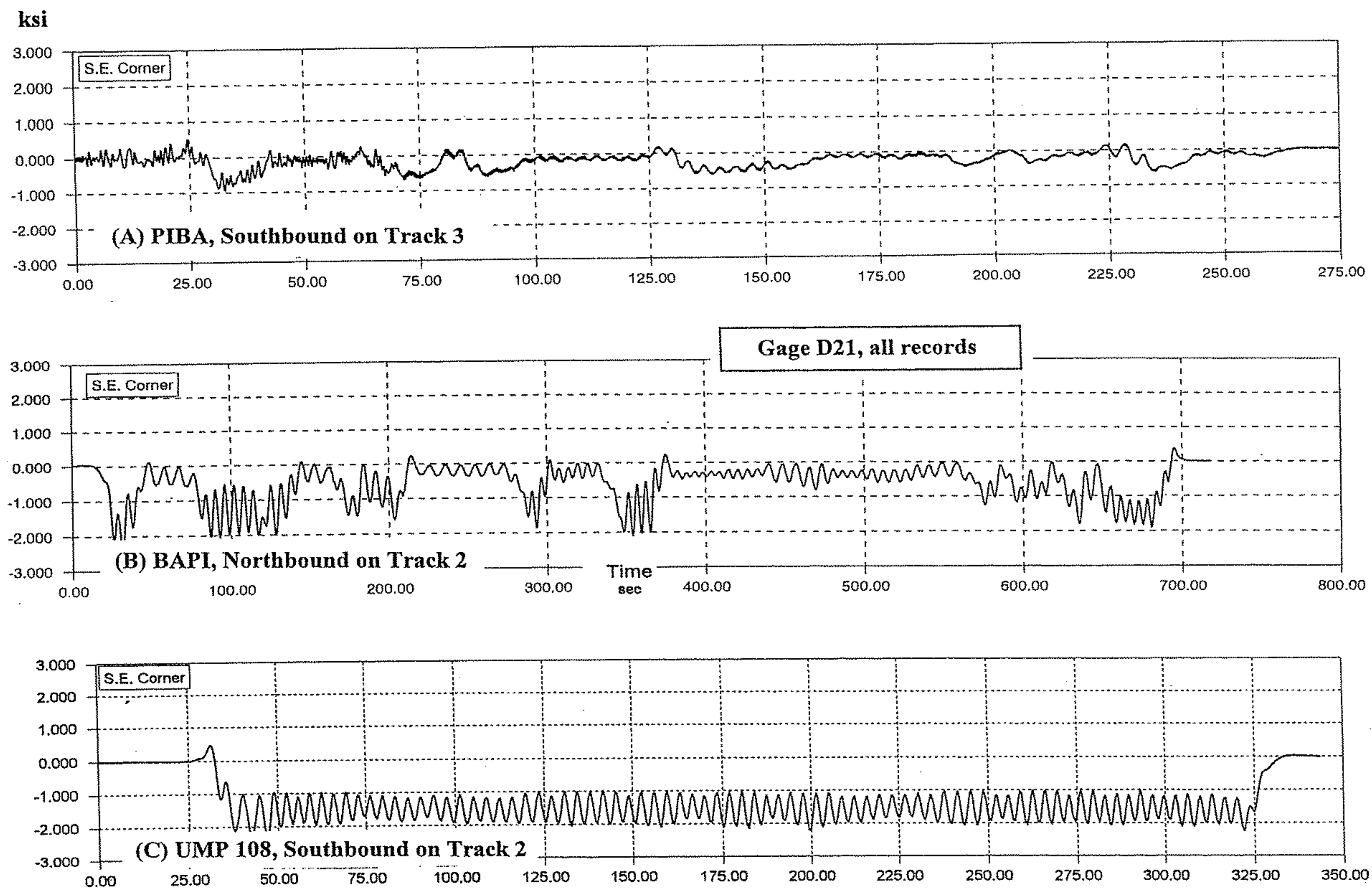


Figure 79. Stresses at East Truss Vertical Post L5U5 - Effect of Various Trains (01-98)

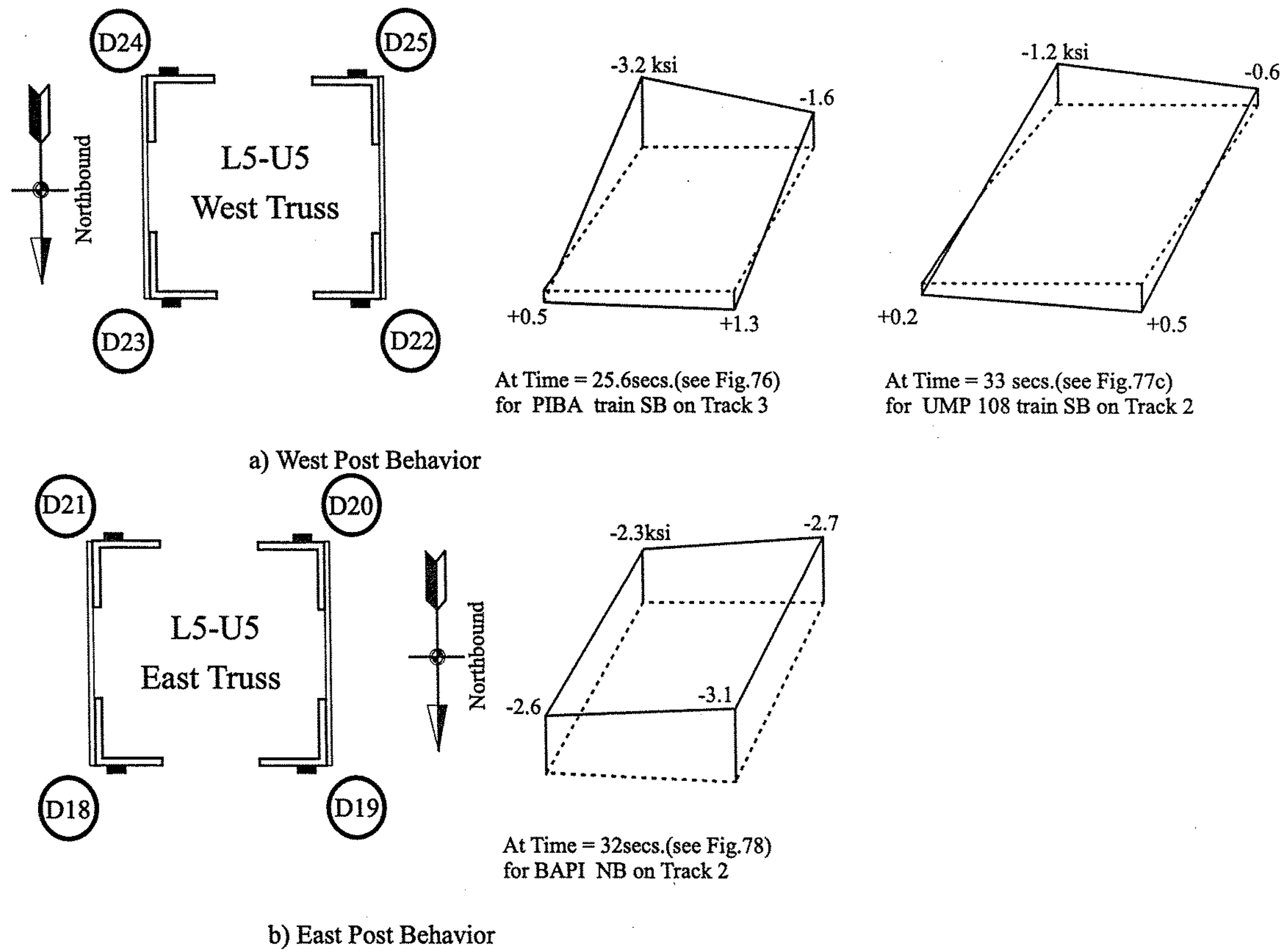
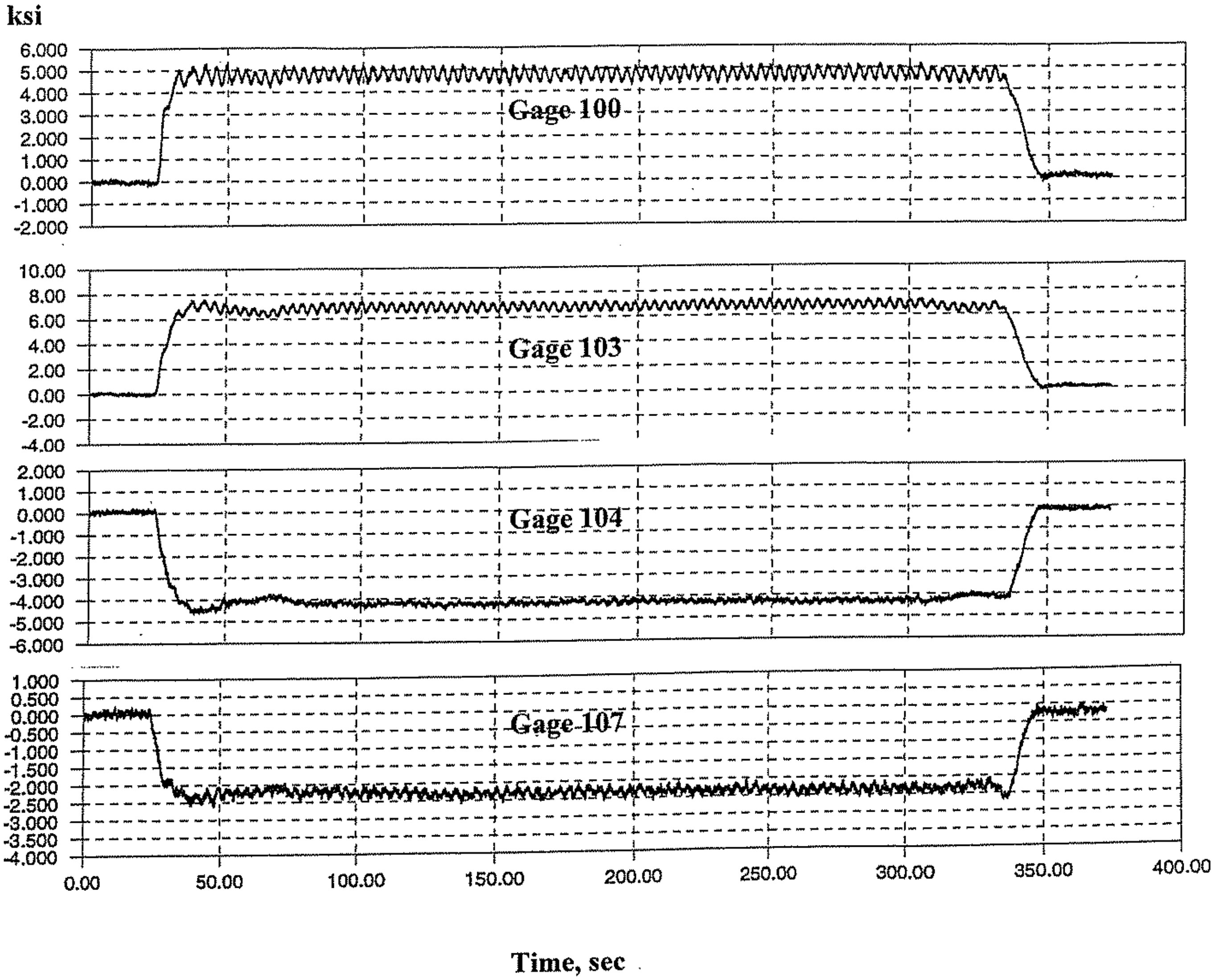
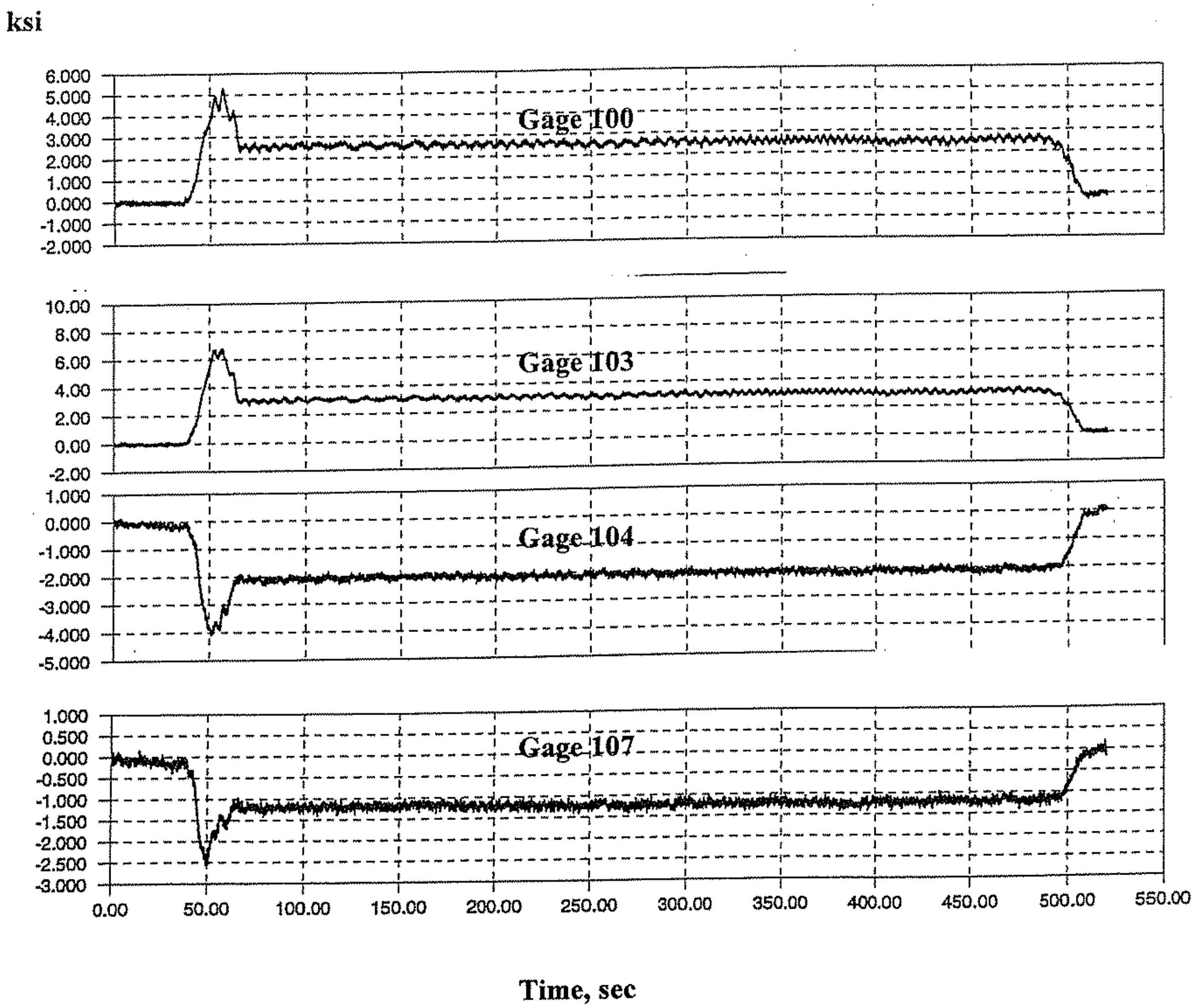


Figure 80. Span 2, Vertical Post L5-U5 Stresses (01/98)



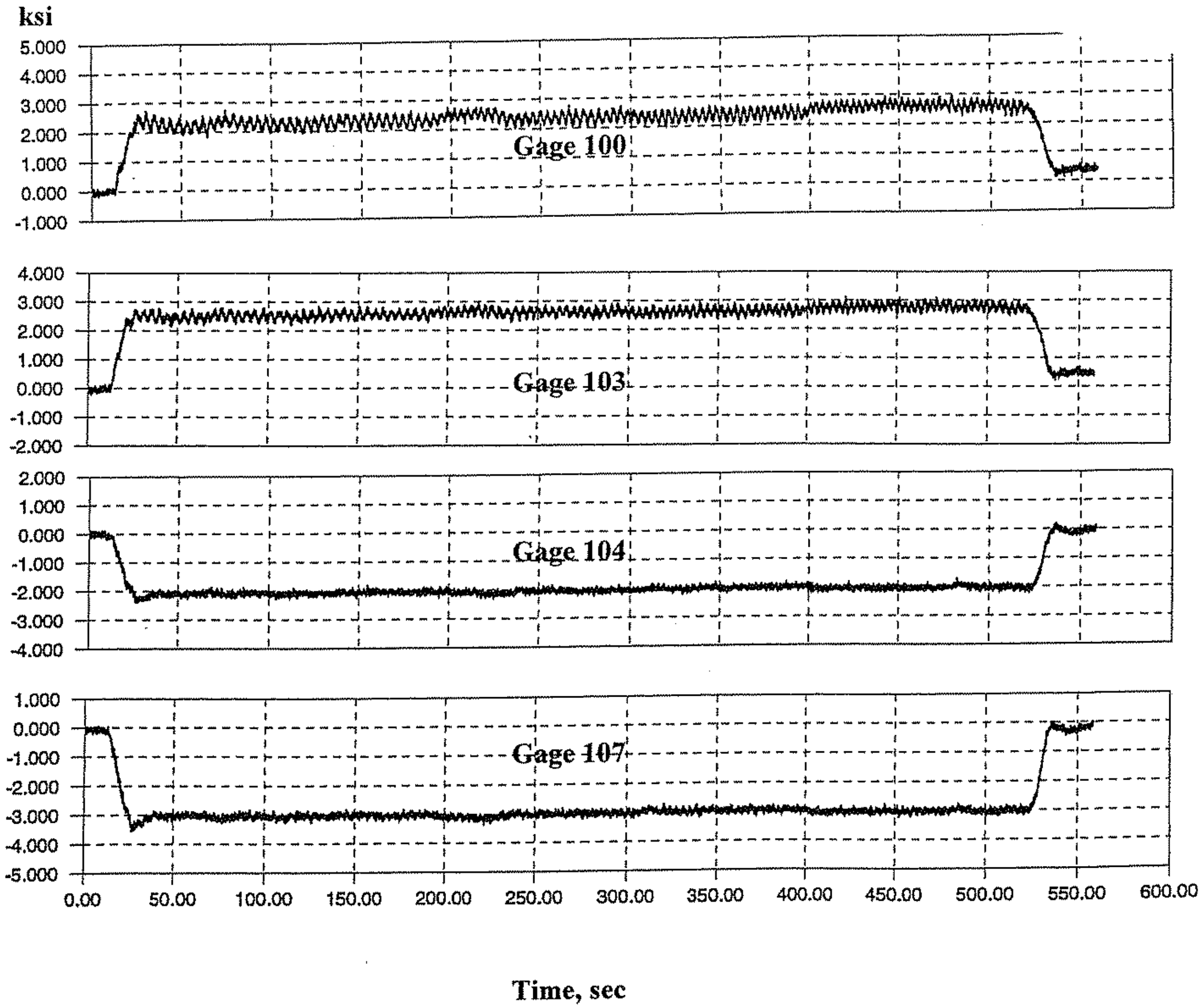
(a) Coal Train UMP 110 Southbound on Track 3

Figure 81 : August Stress Records for Lower Chord Eyebars L8L9 in Span 1 (continued)



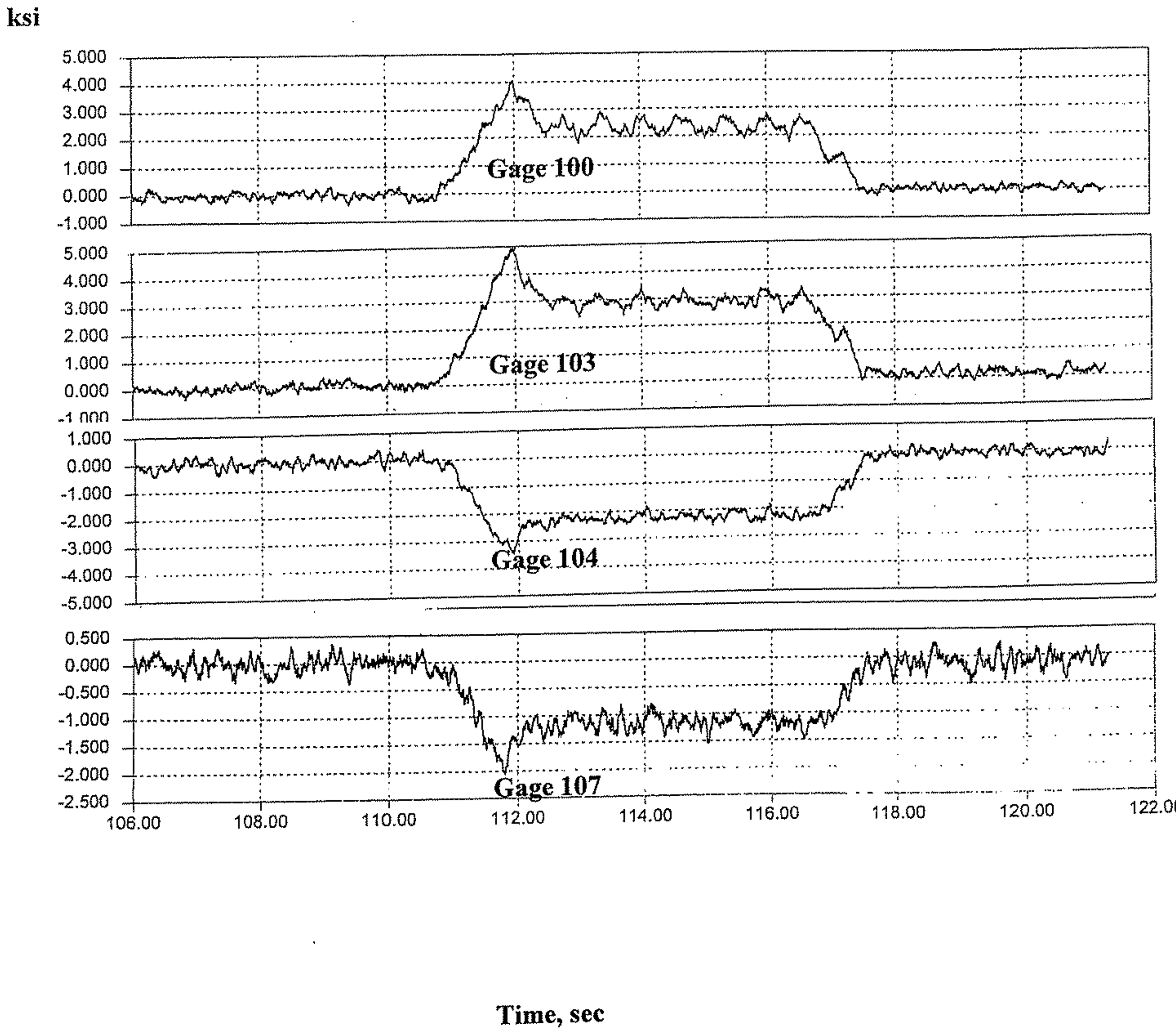
(b) Empty Coal Train XSM 43E Northbound on Track 3

Figure 81 : August Stress Records for Lower Chord Eyebars L8L9 in Span 1 (continued)



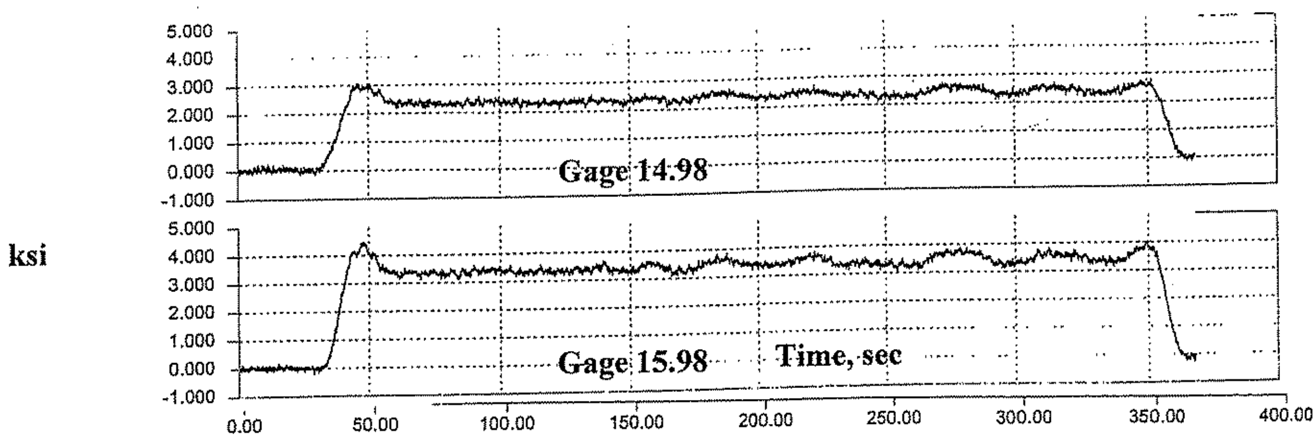
(c) 263K Coal-Car Train ULK 66C Southbound on Track 2

Figure 81 : August Stress Records for Lower Chord Eyebars L8L9 in Span 1 (continued)

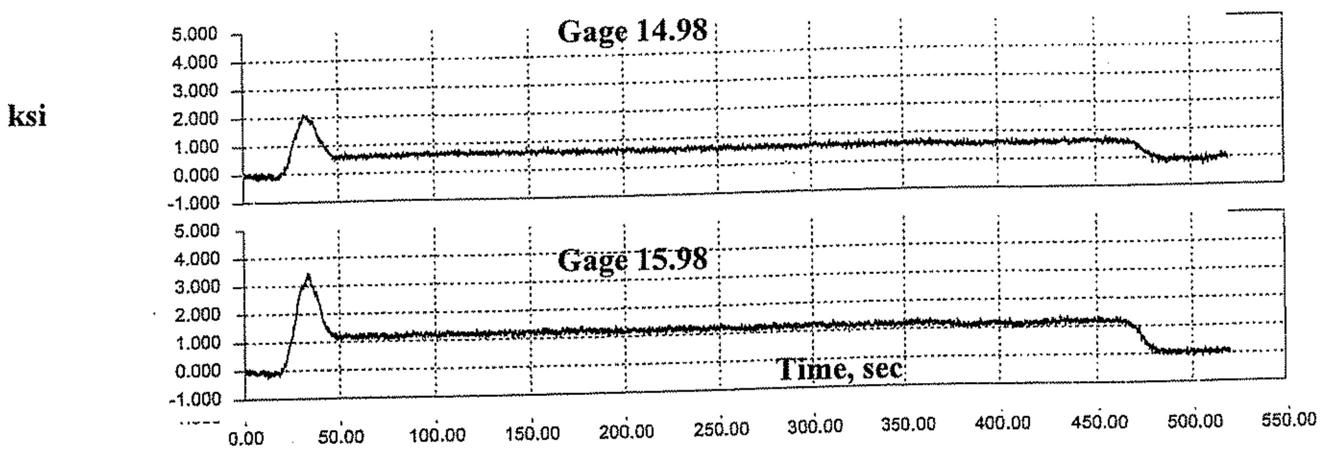


(d) Amtrak Train M106 Northbound on Track 3

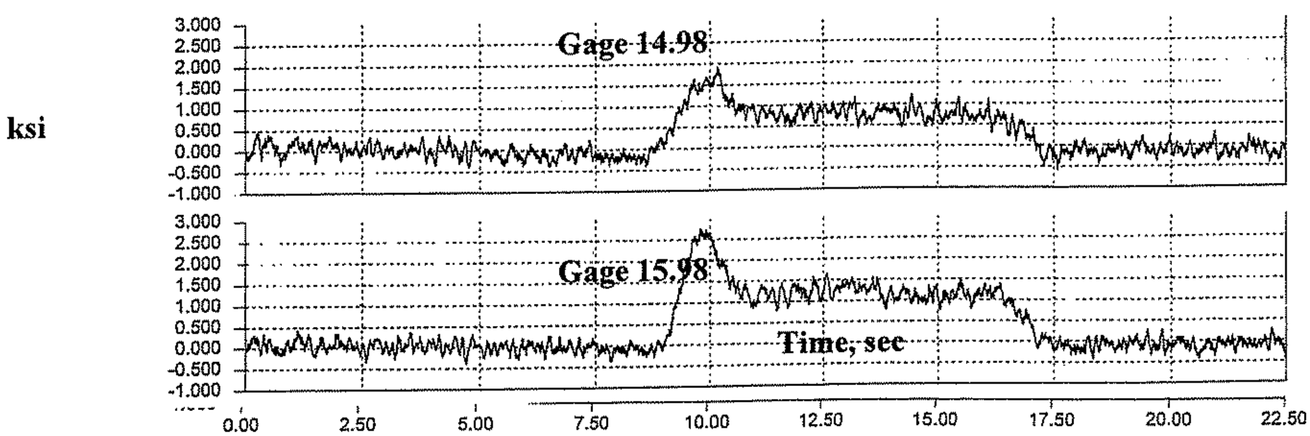
Figure 81 : August Stress Records for Lower Chord Eyebars L8L9 in Span 1 (end)



a) Coal Train UMP 74B Southbound on Track 3

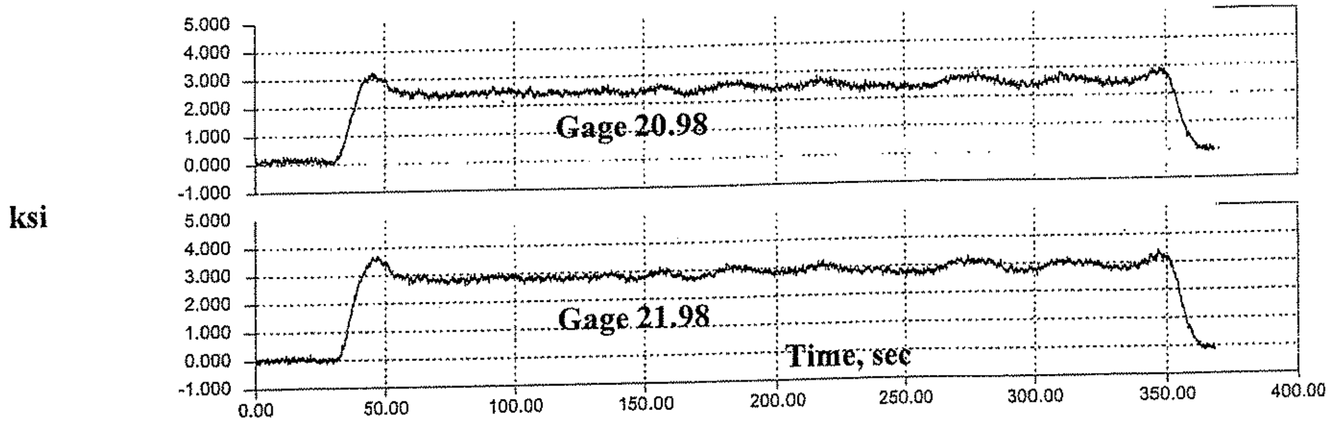


b) Empty Coal Train XSM 43E Northbound on Track 3

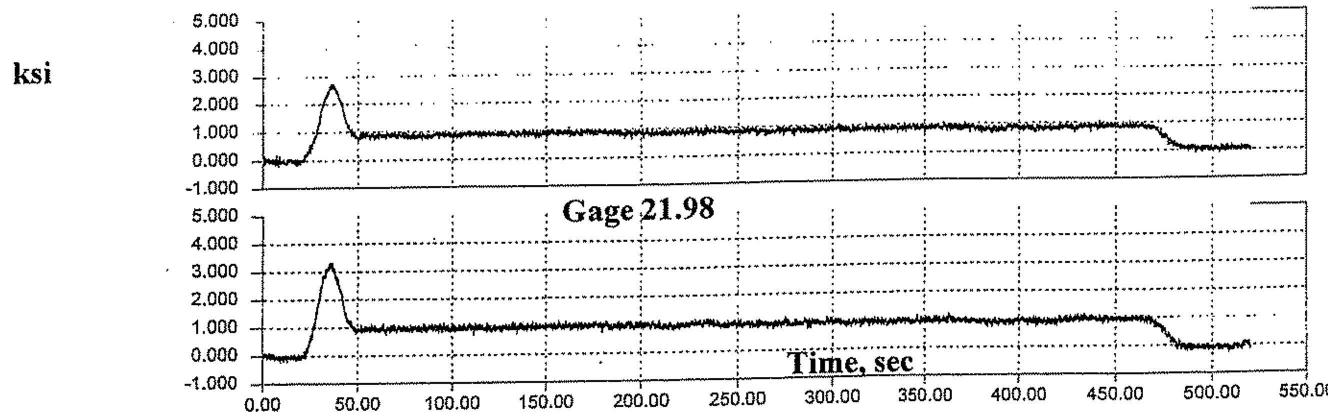


c) Amtrak Train 97 southbound on Track 3

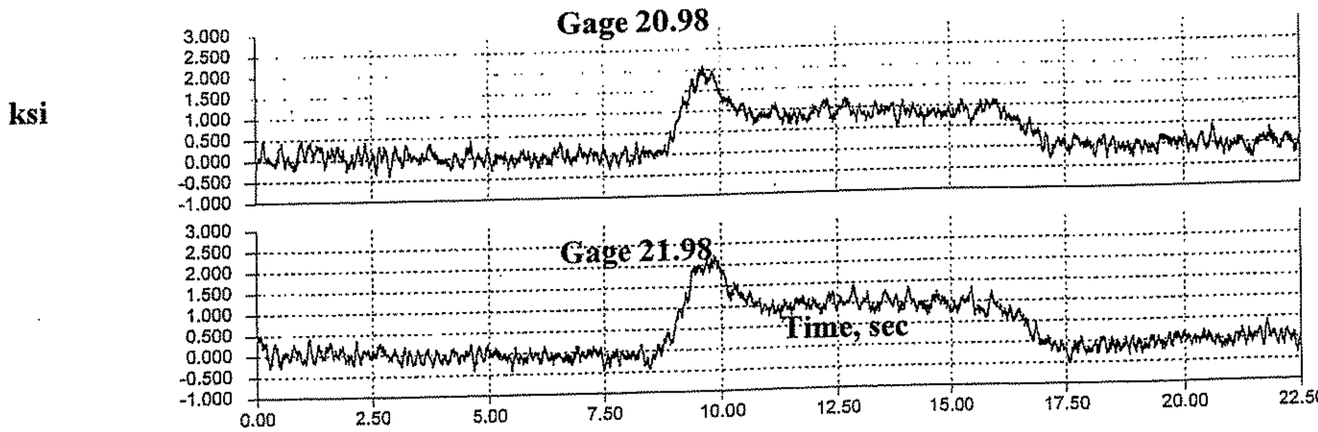
Figure 82 : August Stress Records for Lower-Chord Eyebars L4L5-West in Span 2



a) Coal Train UMP 74B Southbound on Track 3

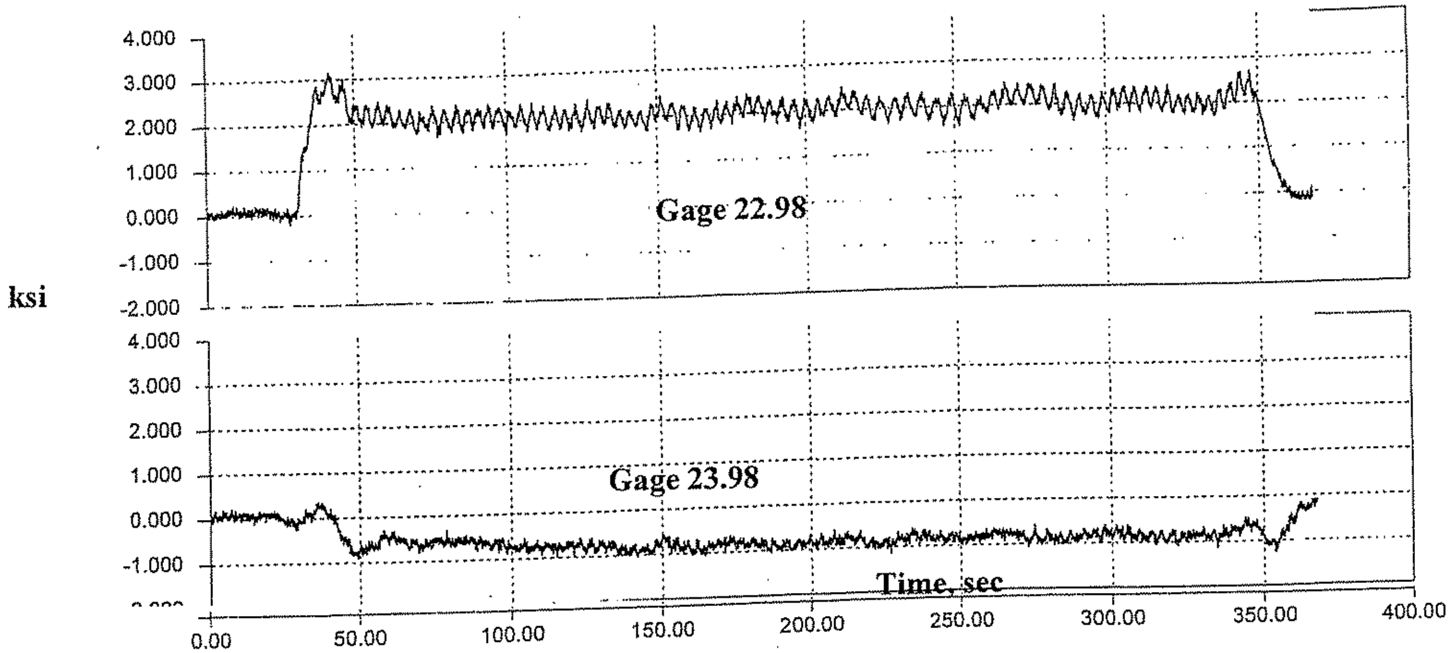


b) Empty Coal Train XSM 43E Northbound on Track 3

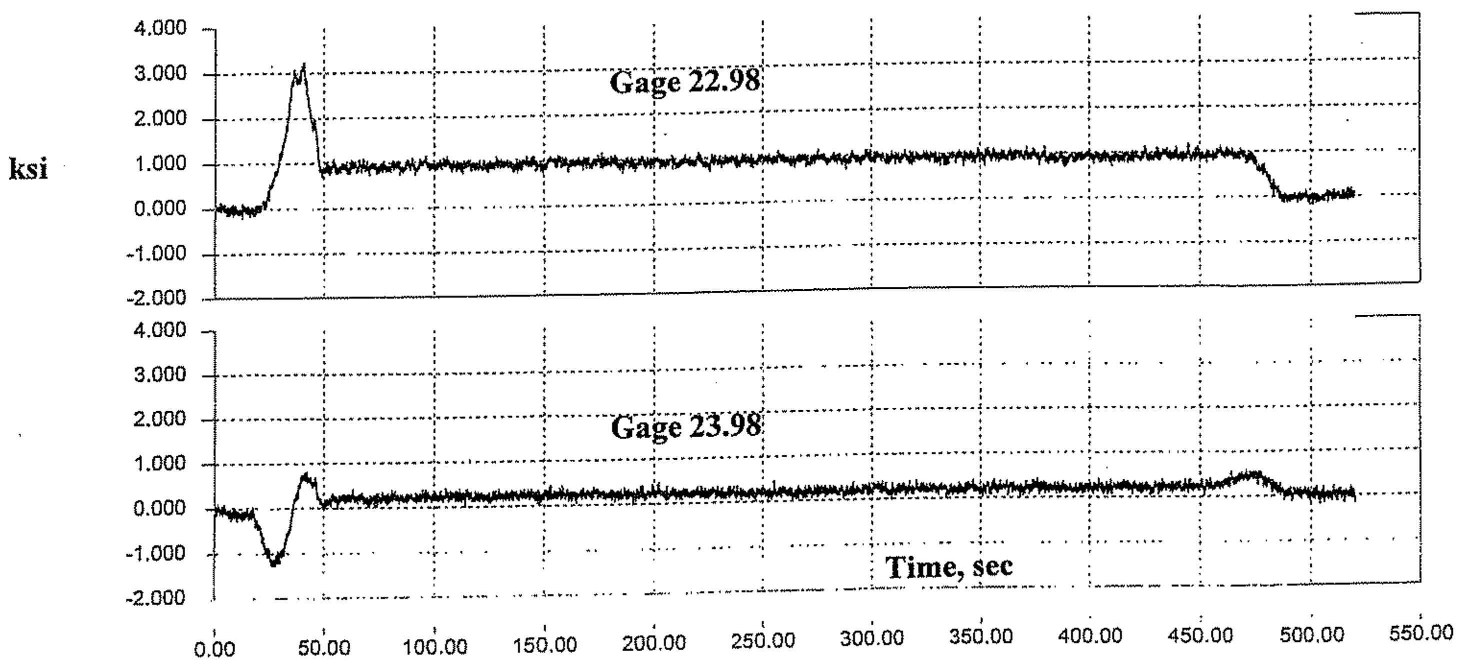


c) Amtrak Train 97 southbound on Track 3

Figure 83 : August Stress Records for Lower-Chord Eyebars L5L6-West in Span 2

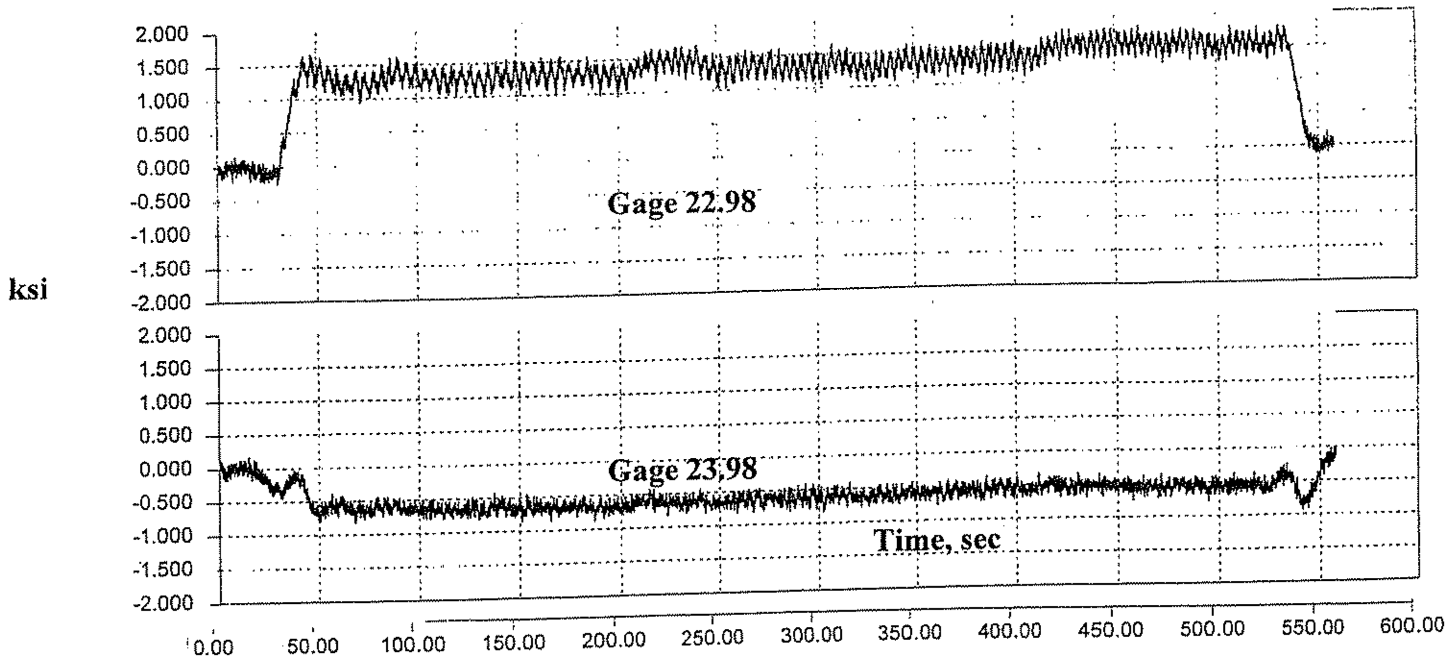


(a) Coal Train UMP 74B Southbound on Track 3

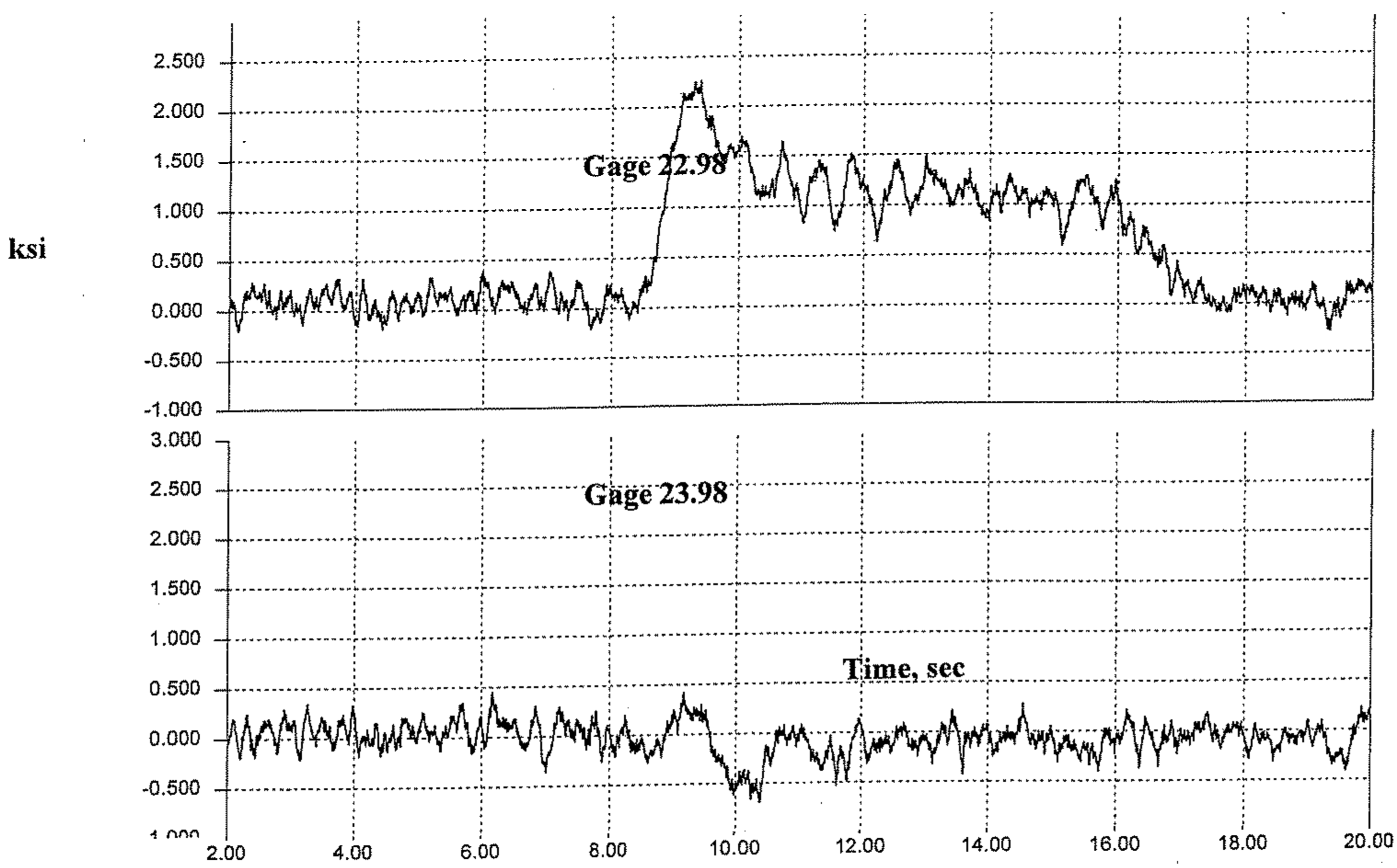


(b) Empty Coal Train XSM 43E Northbound on Track 3

Figure 84 : August Stress Records for Lower-Chord Eyebars L8L9-West in Span 2 (continued)

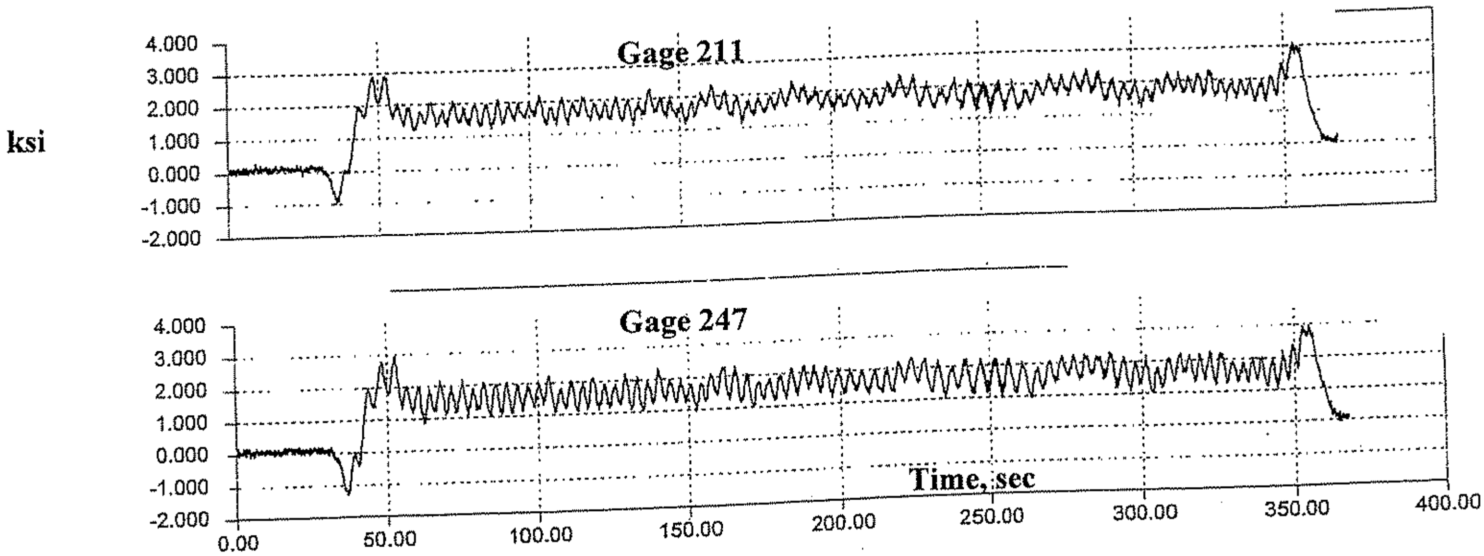


(c) 263K Coal-Car Train ULK 66C Southbound on Track 2

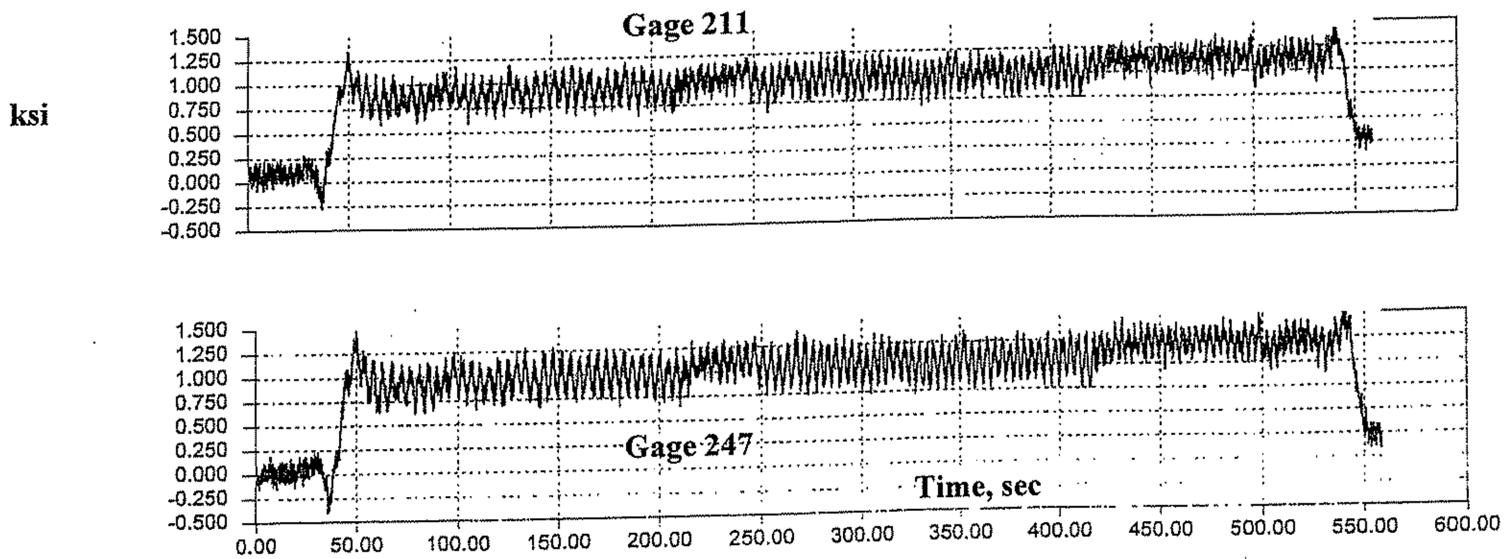


(d) Amtrak Train #97 Southbound on Track 3

Figure 84 : August Stress Records for Lower-Chord Eyebars L8L9-West in Span 2 (end)

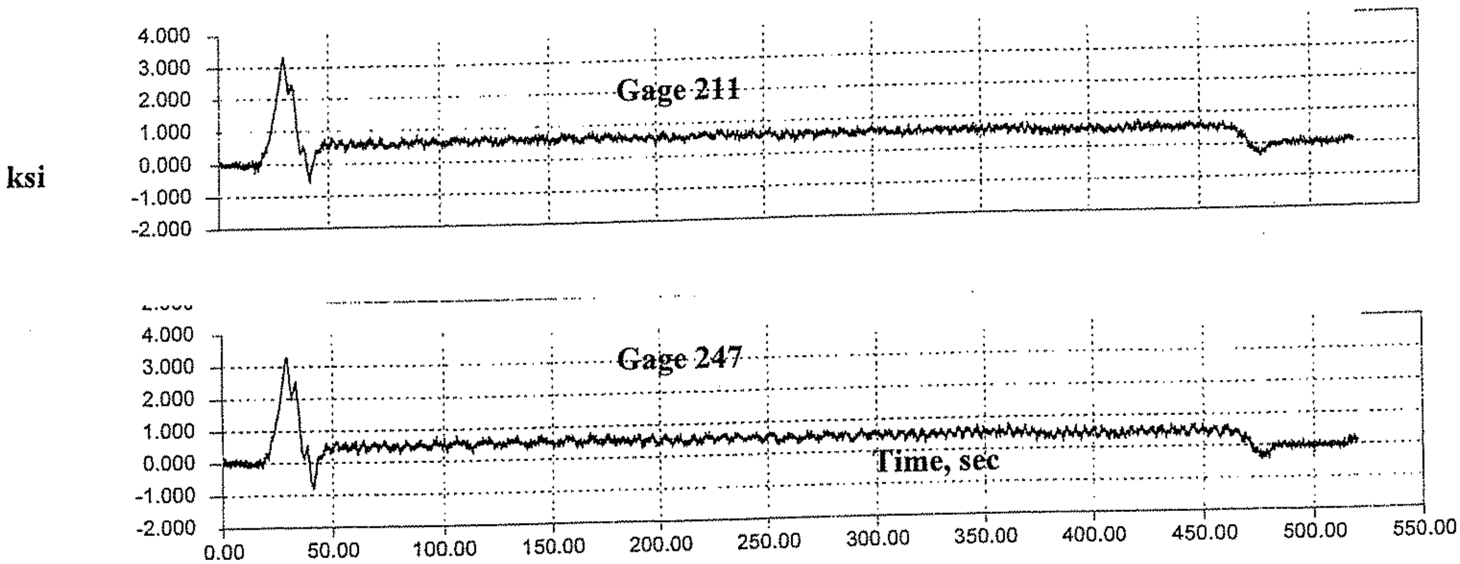


(a) Coal Train UMP 74B Southbound on Track 3

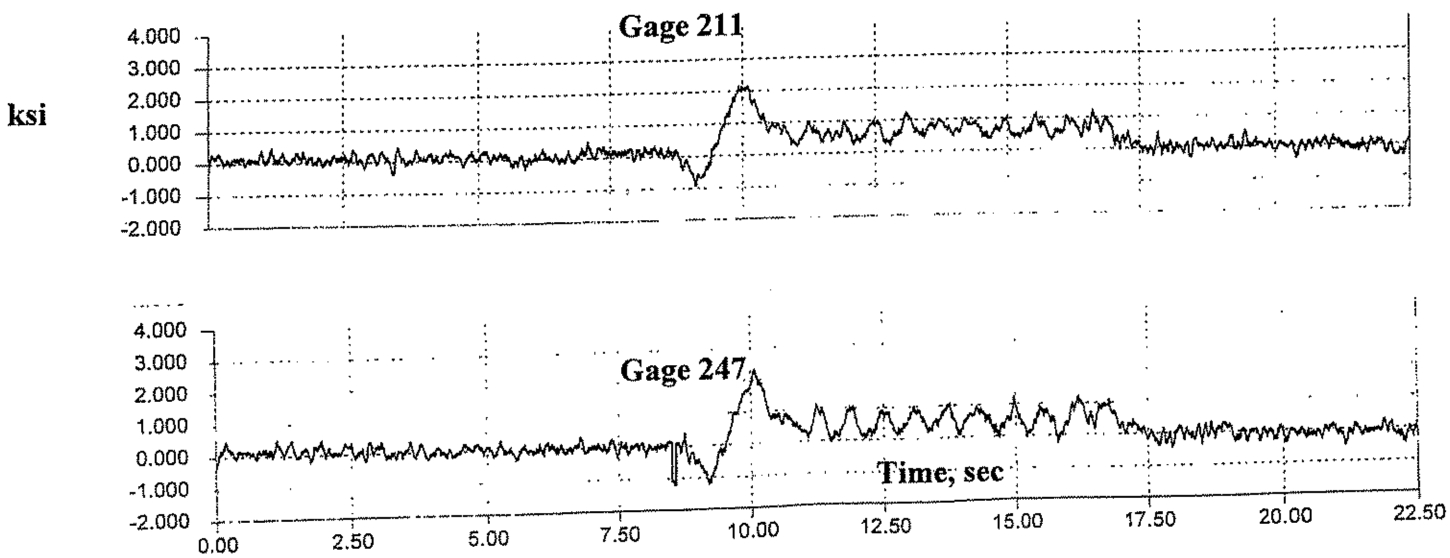


(b) 263K Coal-Car Train ULK 66C Southbound on Track 2

Figure 85: August Stress Records for Diagonal Eyebars L5U6-West in Span 2 (continue)

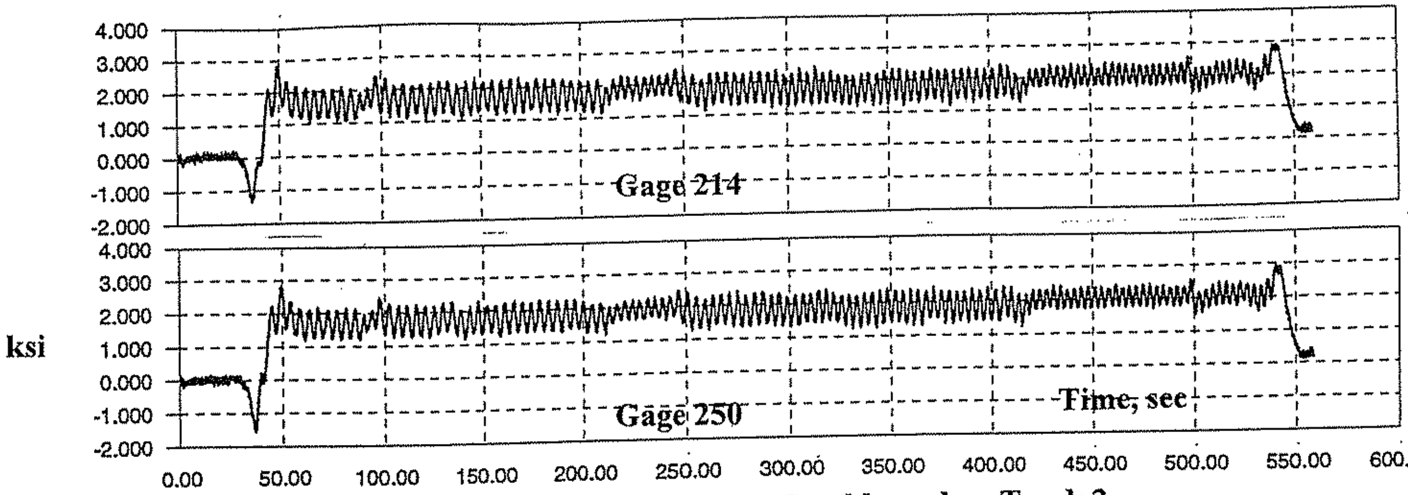


(c) Empty Coal Train XSM 43E Northbound on Track 3

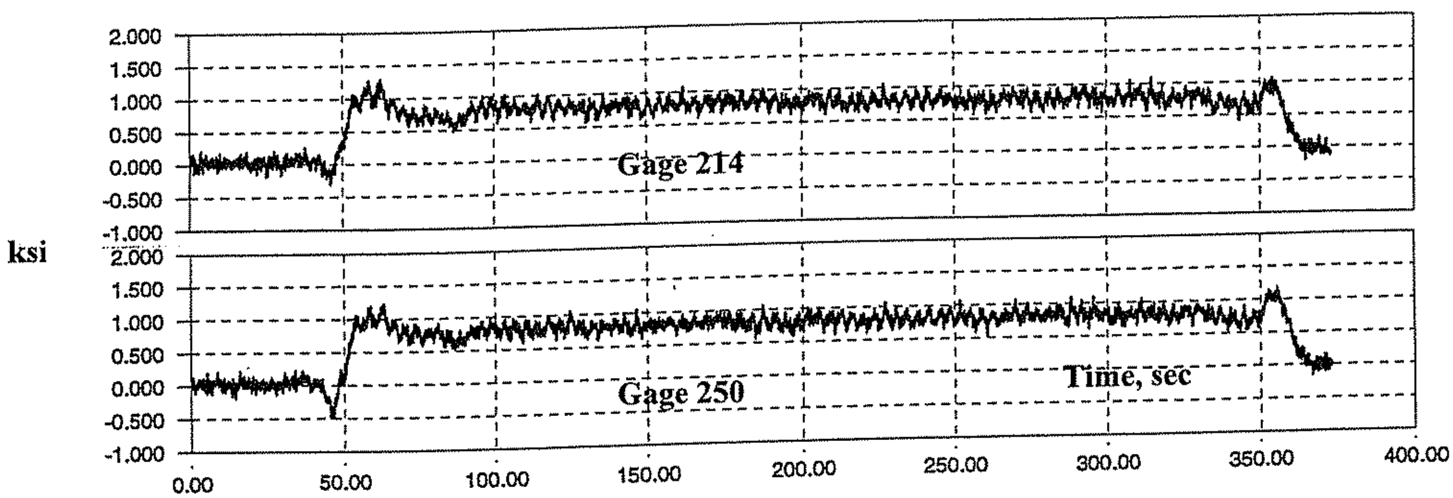


(d) Amtrak Train #97 Southbound on Track 3

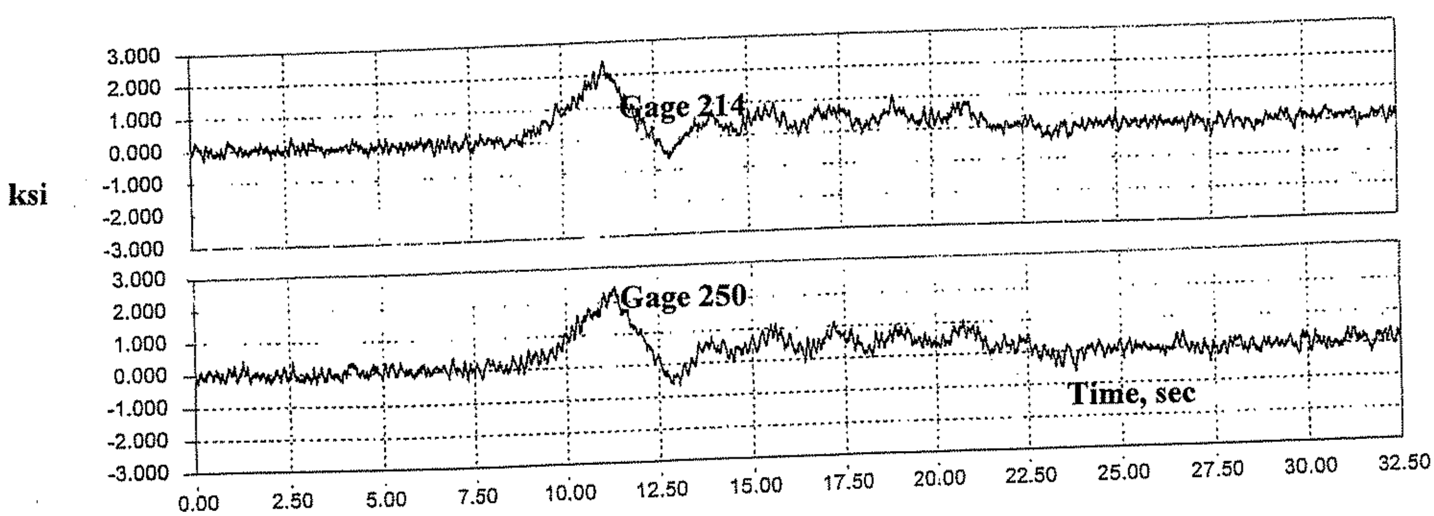
Figure 85: August Stress Records for Diagonal Eyebars L5U6-West in Span 2 (end)



(a) 263K Coal-Car Train ULK 66C Southbound on Track 2

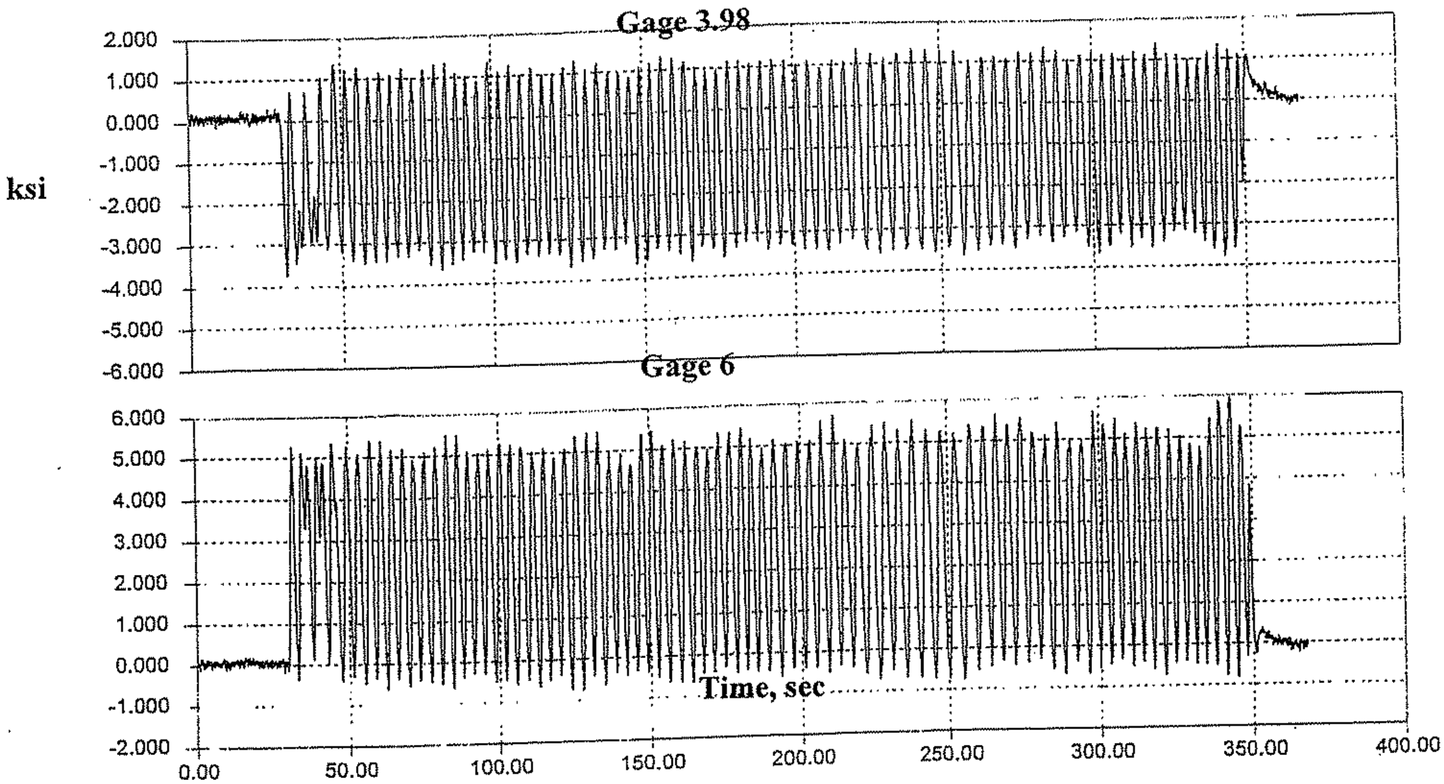


(b) Coal Train UMP 110 Southbound on Track 3

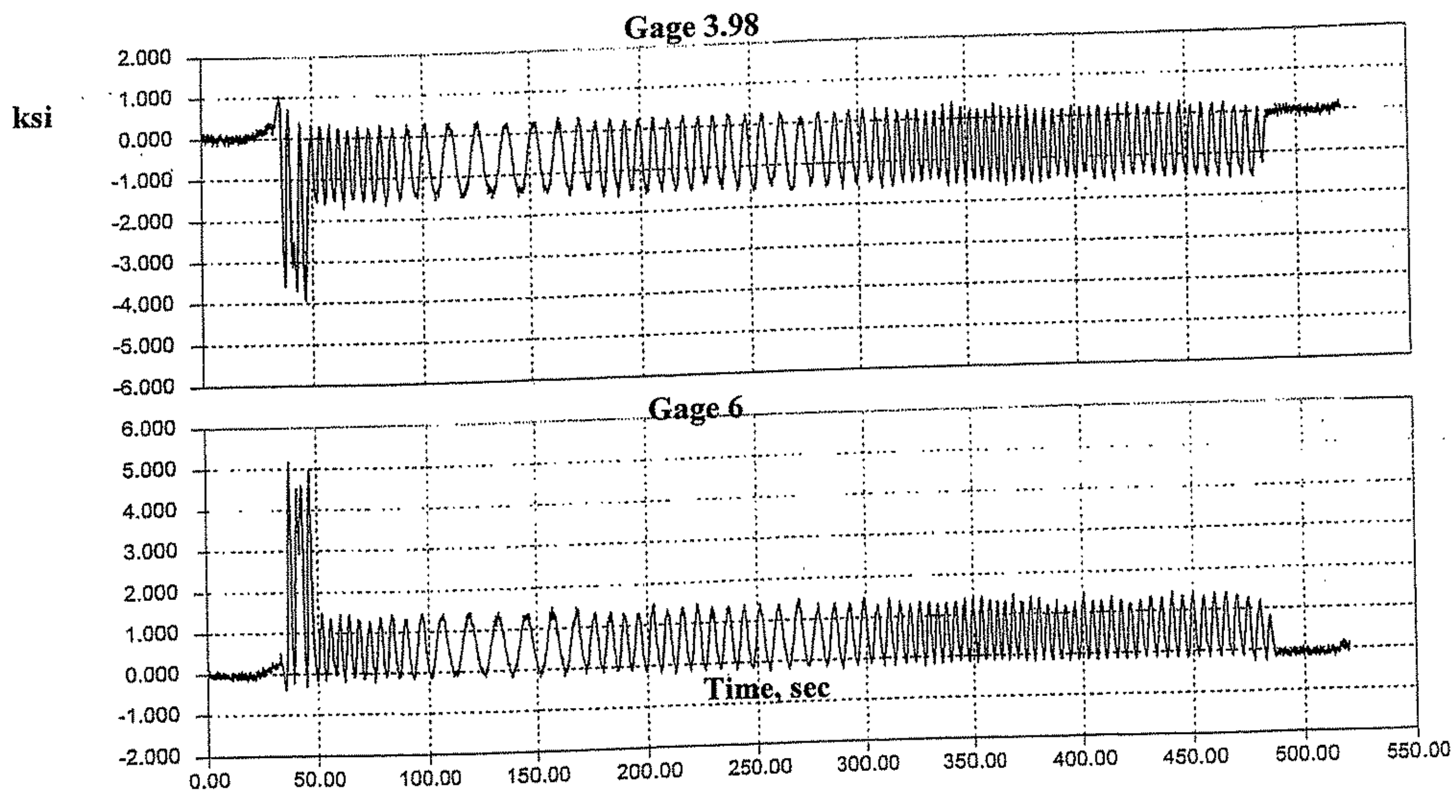


(c) Passenger Train MARC 536 Northbound on Track 2

Figure 86: August Stress Records for Diagonal Eyebars L5U6-East, Span 2

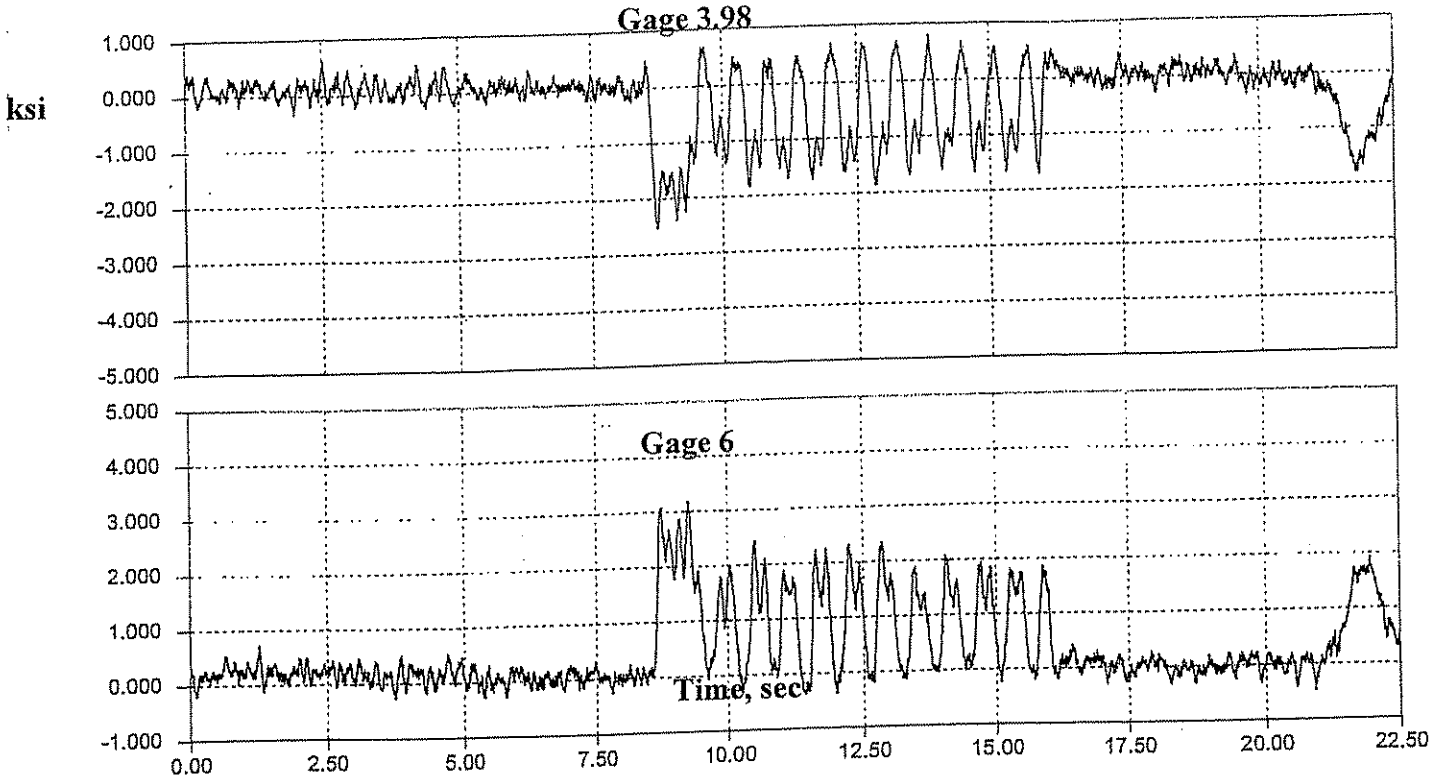


(a) Coal Train UMP 74B Southbound on Track 3



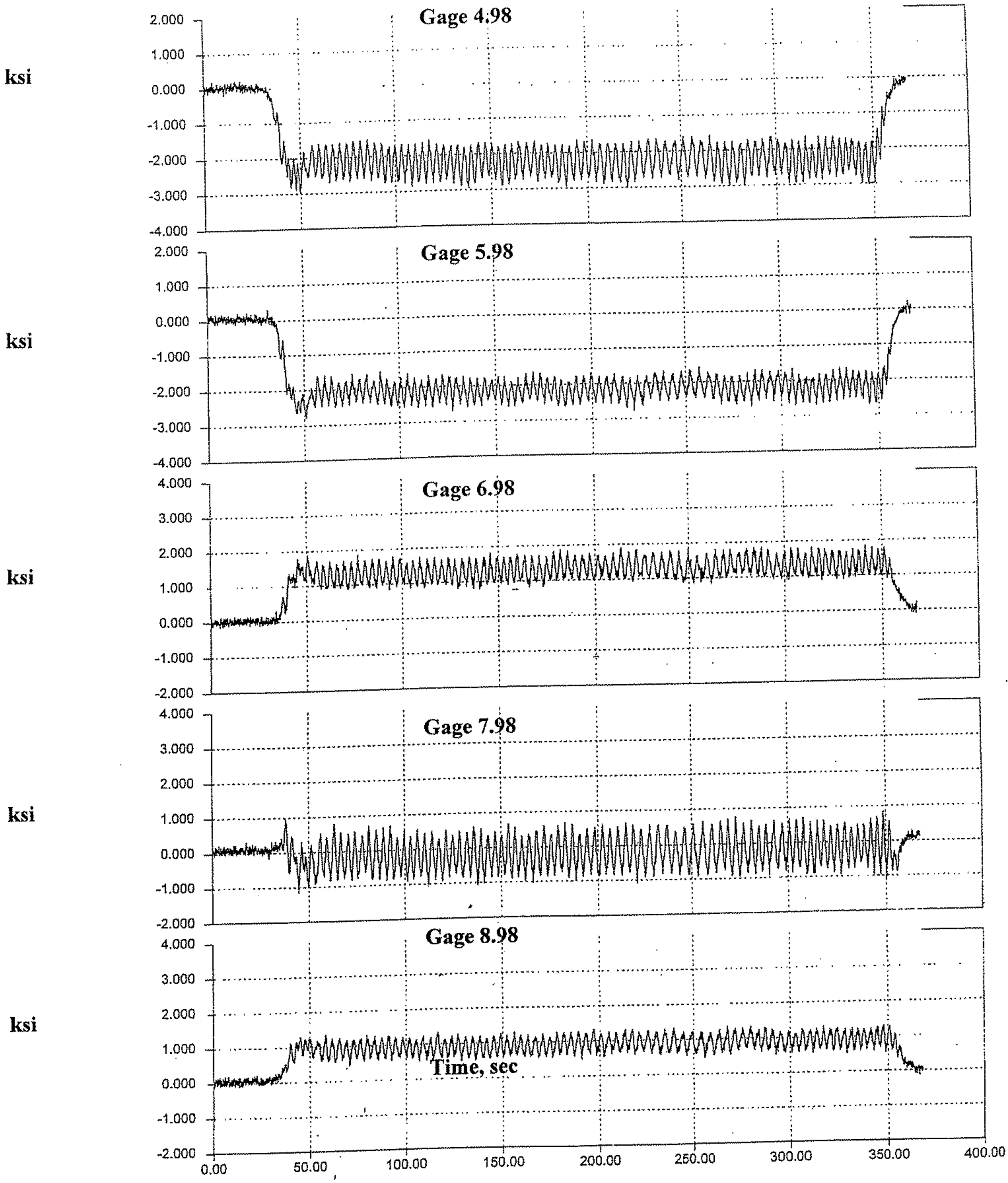
(b) Empty Coal Train XSM 43E Northbound on Track 3

Figure 87: August Stress Records in Span 2 at Top Chord U8U9-West at Midspan (continued)



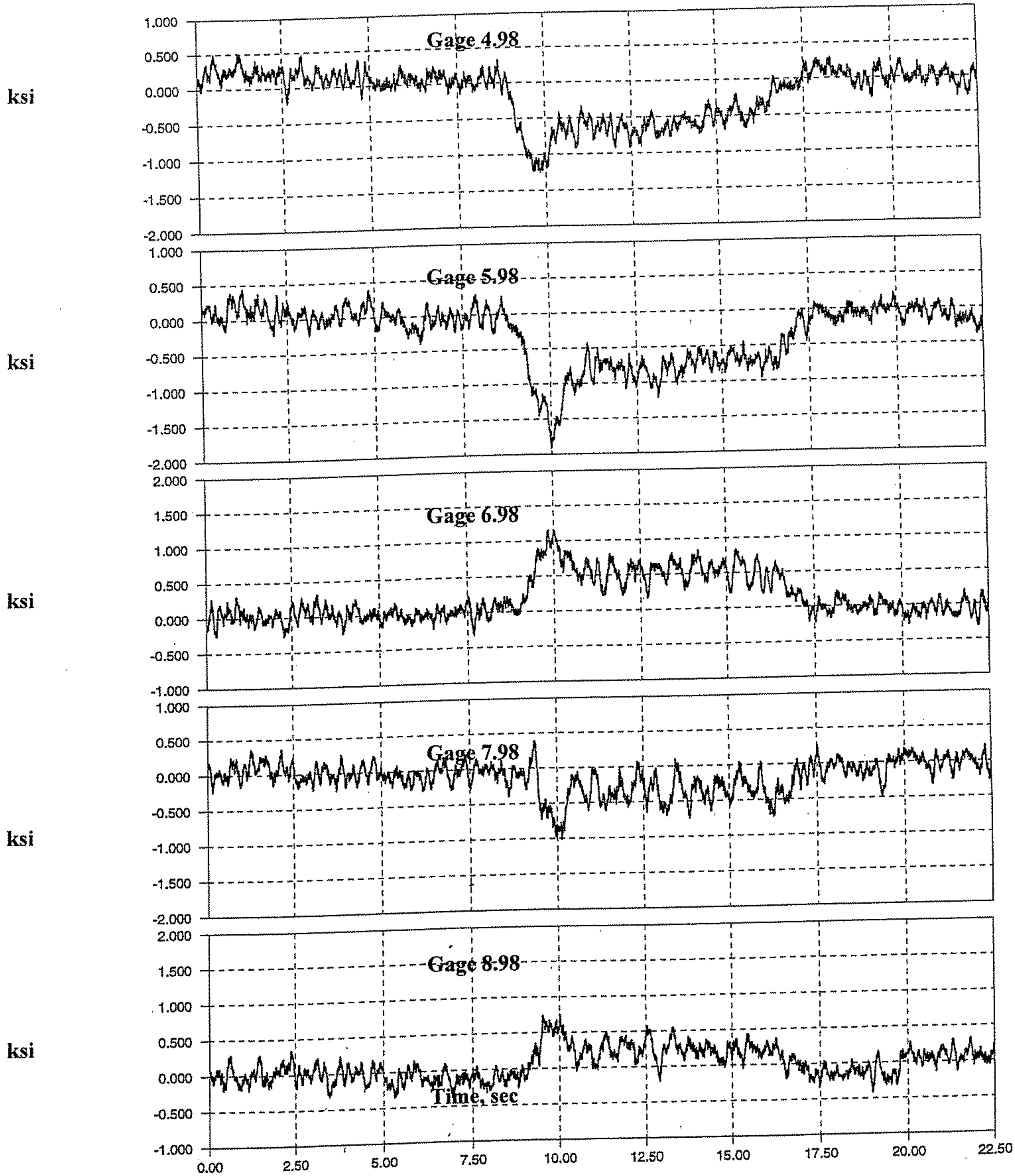
(c) Passenger Train Amtrak 97 Southbound on Track 3

Figure 87: August Stress Records in Span 2 at Top Chord U8U9-West at Midspan (end)



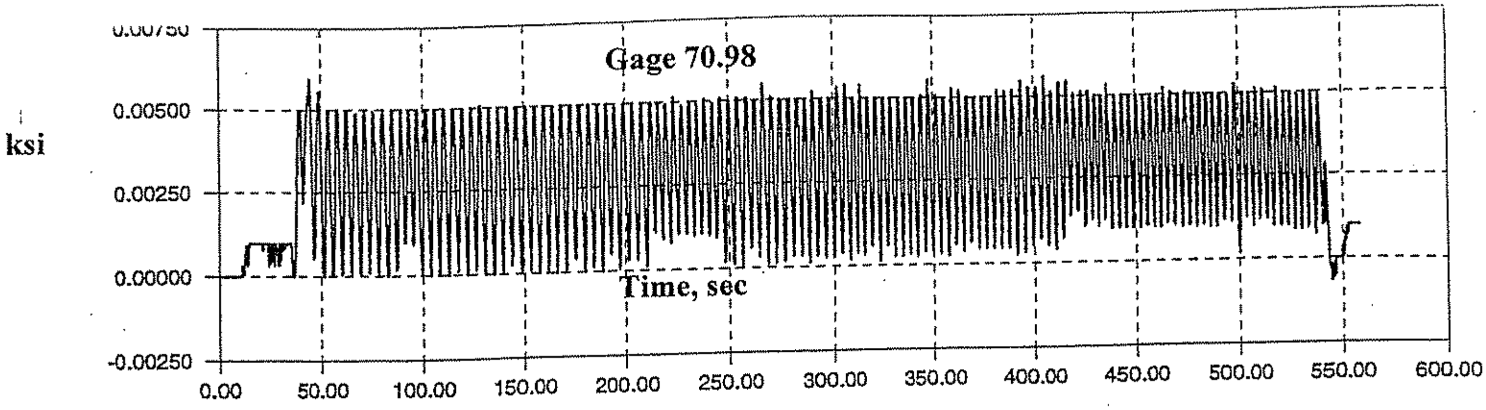
(a) Coal Train UMP 74B Southbound on Track 3

Figure 88: August Stress Records at the Retrofit Lateral Connection Plate at Panel Point U5-West, Span 2 (continue)

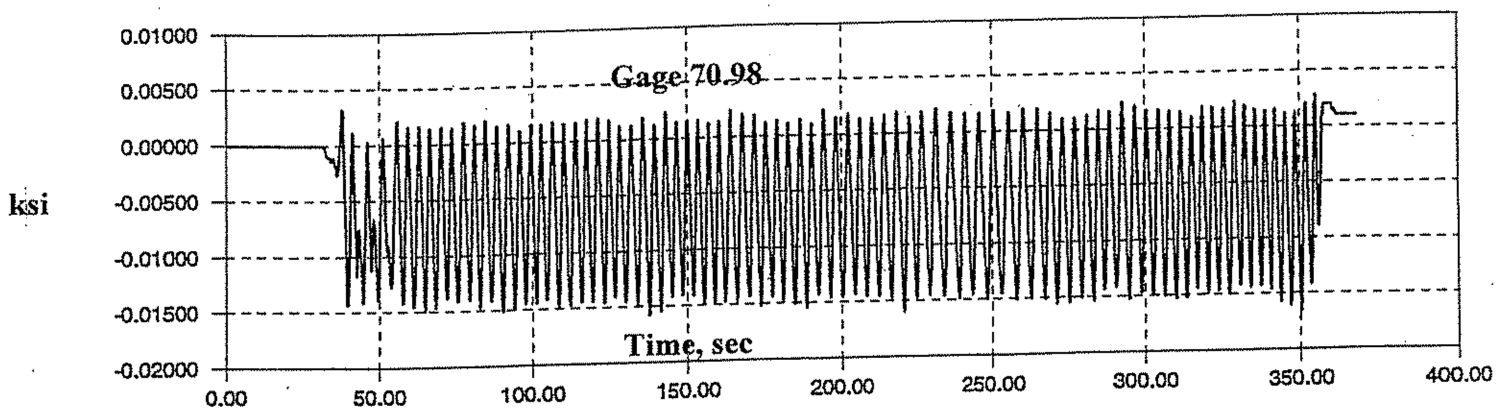


(b) Passenger Train Amtrak 97 Southbound on Track 3

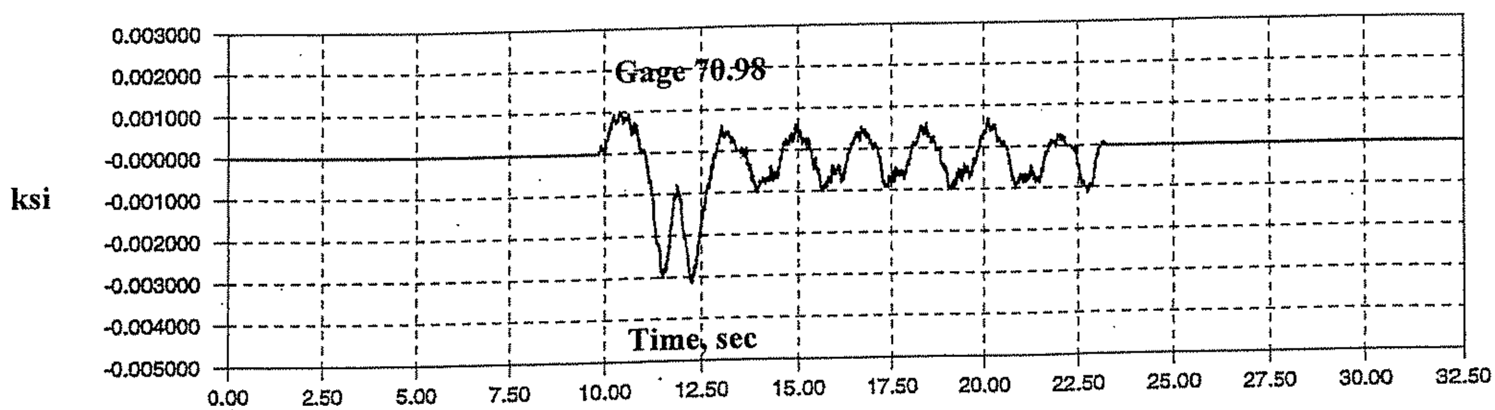
Figure 88 (continued): August Stress Records at the Retrofit Lateral Connection Plate at Panel Point U5-West, Span 2 (end)



(a) 263K Coal-Car Train ULK 66C Southbound on Track 2

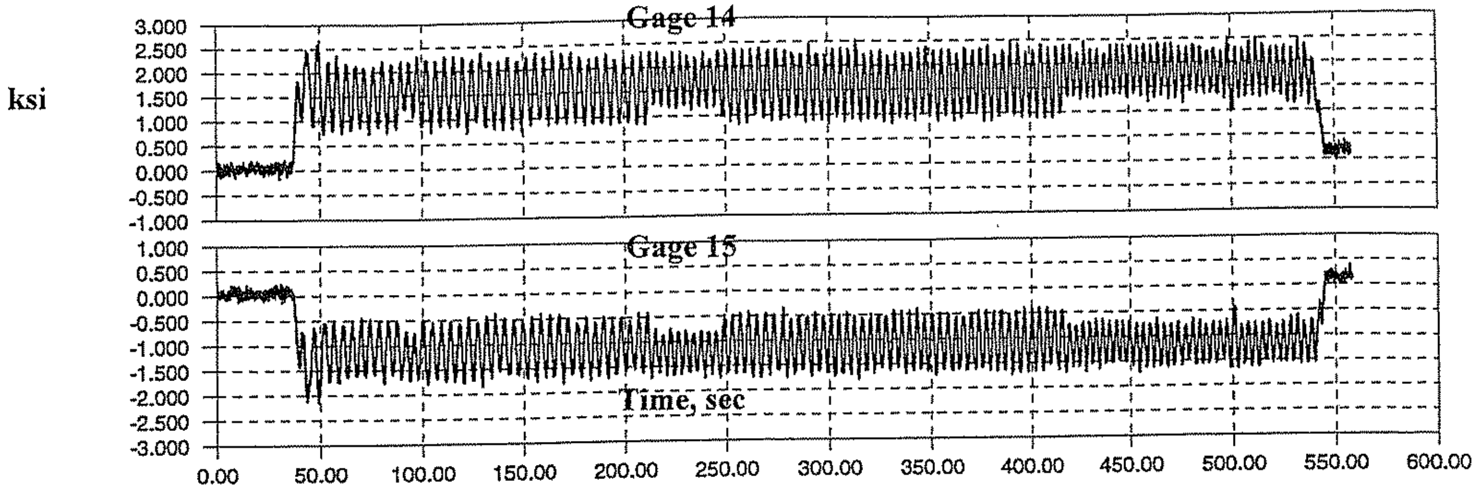


(b) Coal Train UMP 74B Southbound on Track 3

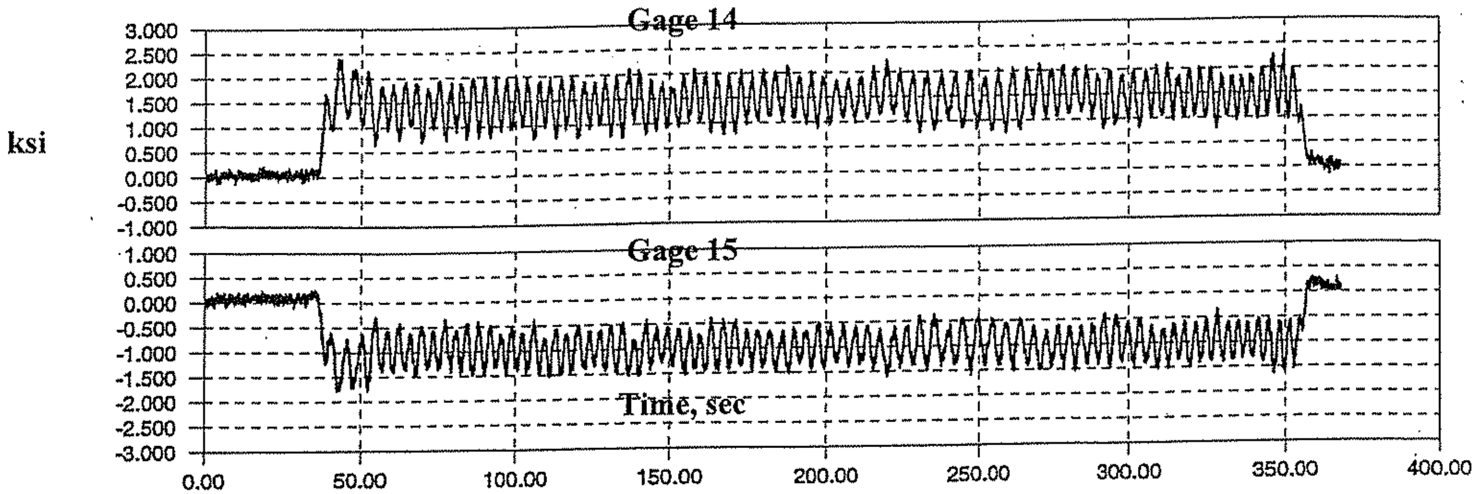


(c) Passenger Train MARC 536 Northbound on Track 2

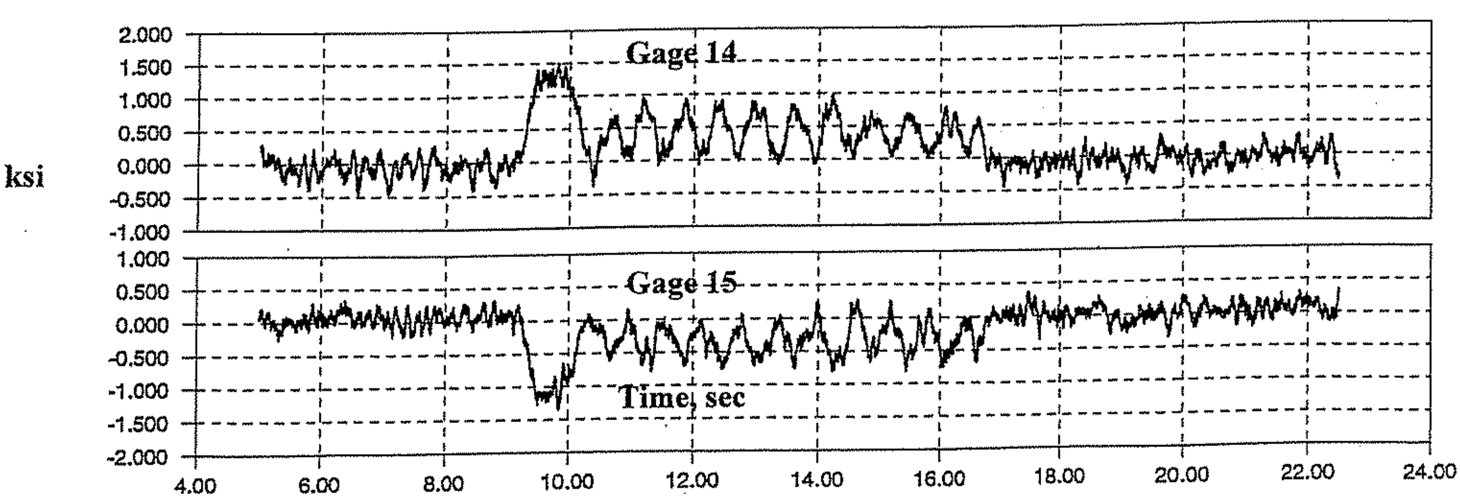
Figure 89: August Displacement Records from Floorbeam/Top Chord Panel Point U5-West in Span 2



(a) 263K Coal-Car Train ULK 66C Southbound on Track 2

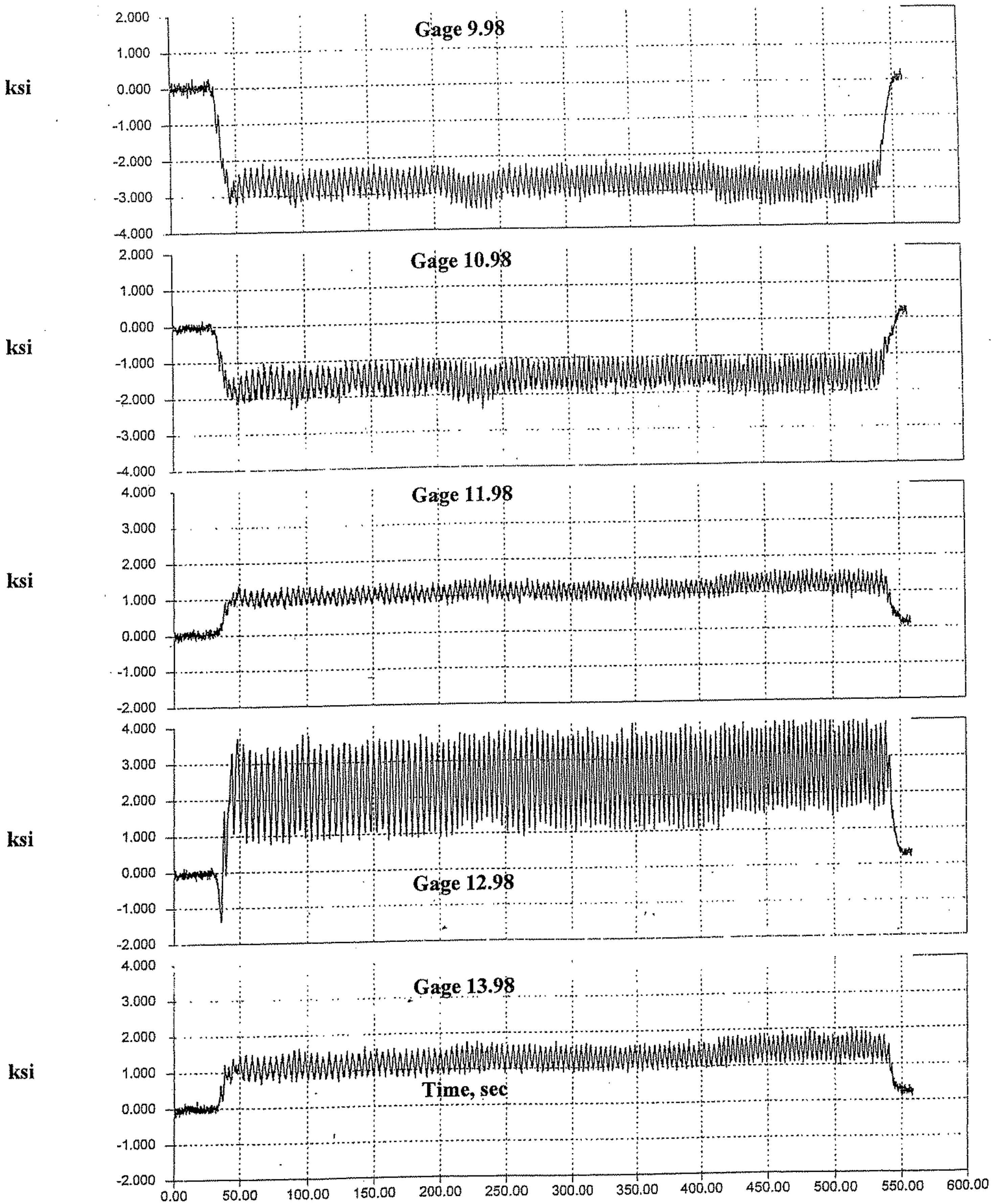


(b) Coal Train UMP 74B Southbound on Track 3



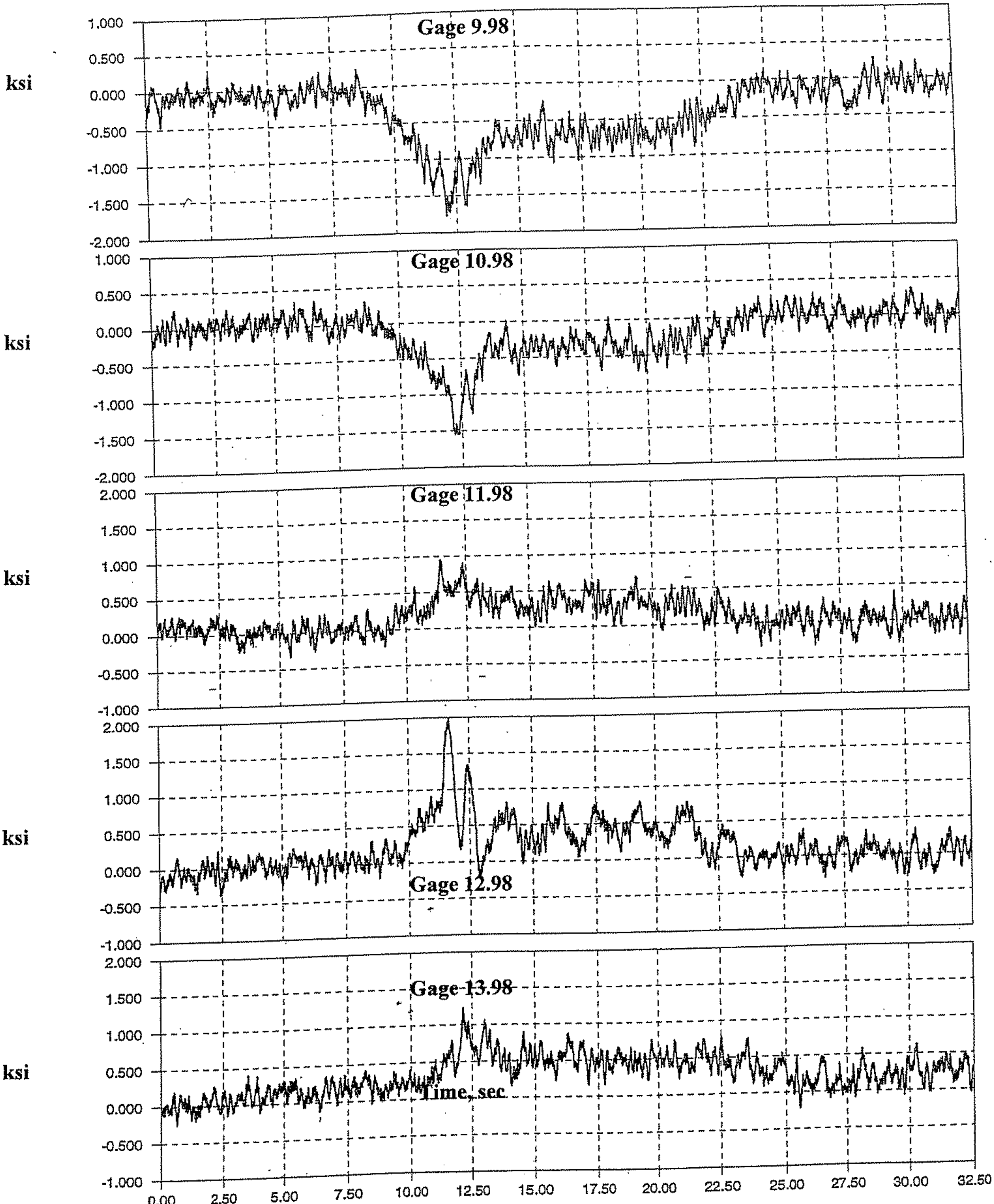
(c) Passenger Train Amtrak 97 Southbound on Track 3

Figure 90: August Records for Midspan Stresses in Floorbeam 5 in Span 2



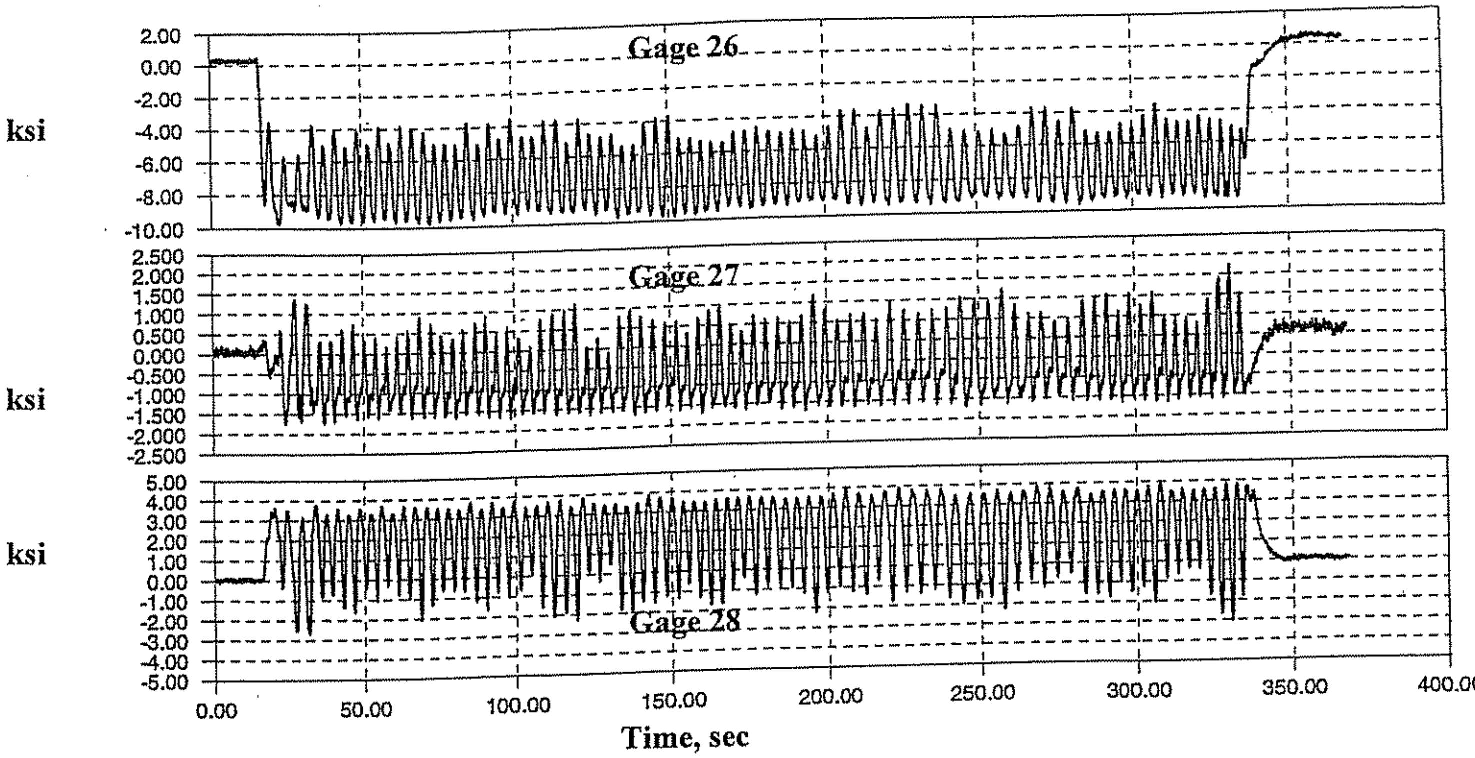
(a) 263K Coal-Car Train ULK 66C Southbound on Track 2

Figure 91: August Stress Records at the Retrofit Lateral Connection Plate at Panel Point U6-East, Span 2 (continue)

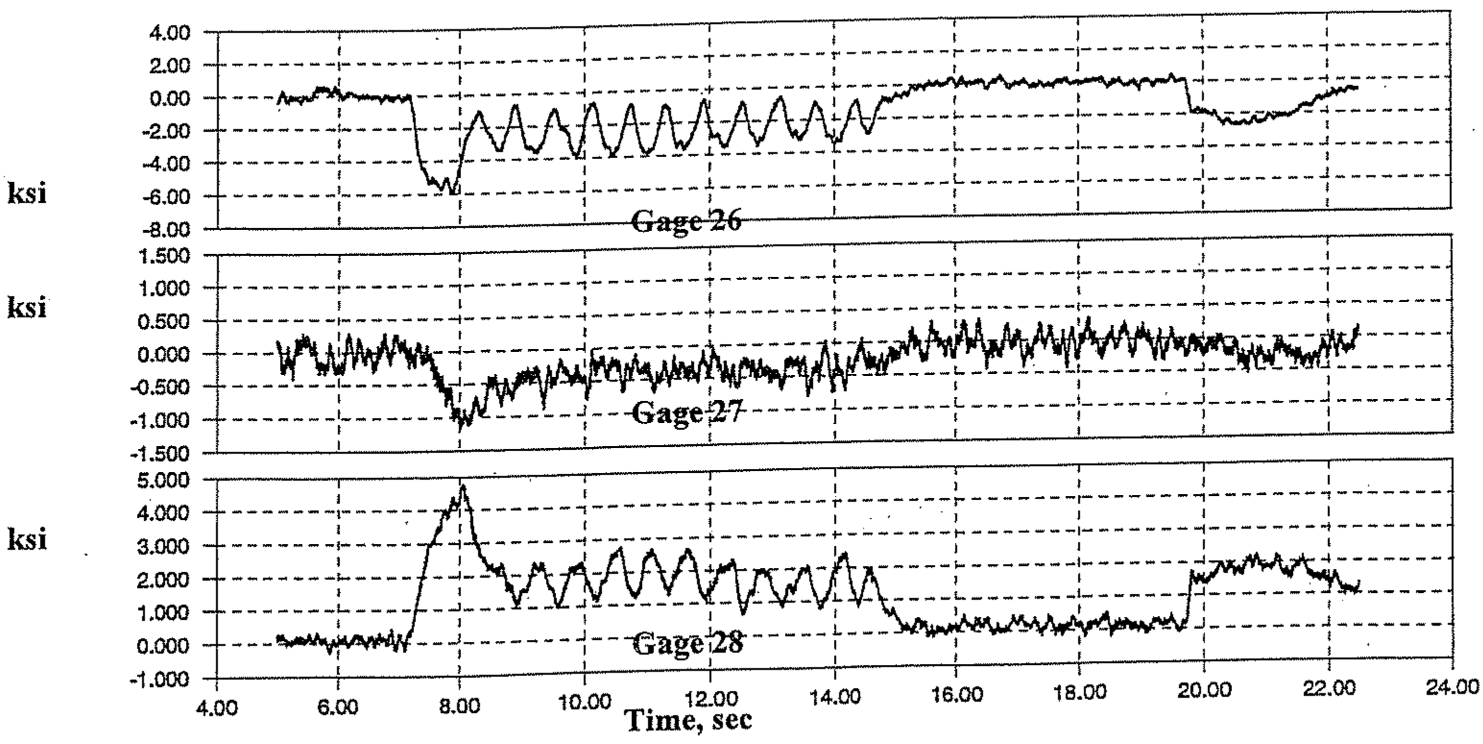


(b) Passenger Train MARC 536 Northbound on Track 2

Figure 91 (continued): August Stress Records at the Retrofit Lateral Connection Plate at Panel Point U6-East, Span 2 (end)

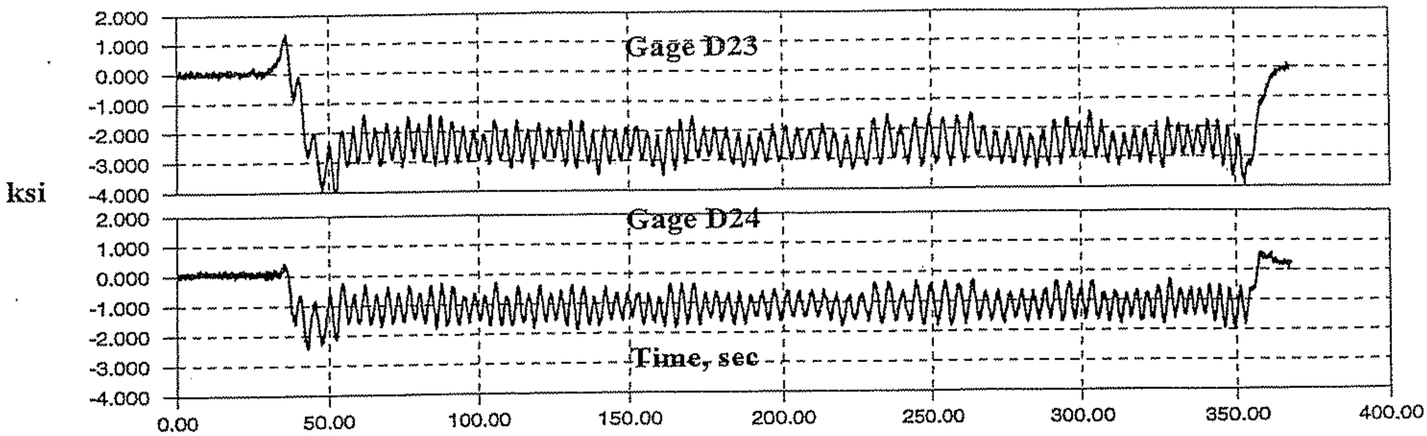


(a) Coal Train UMP 74B Southbound on Track 3

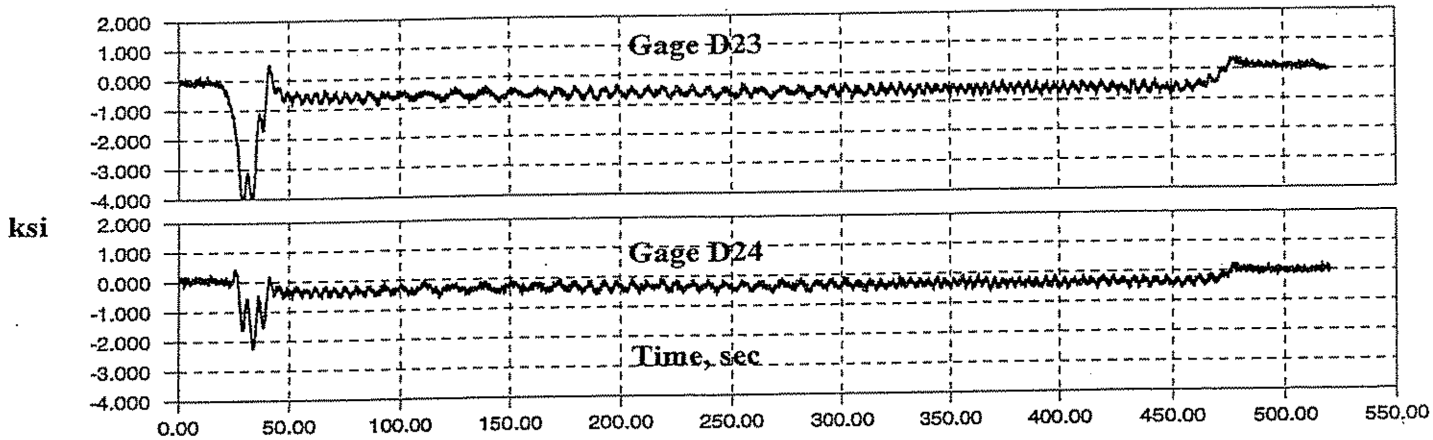


(b) Passsenger Train Amtrak 97 Southbound on Track 3

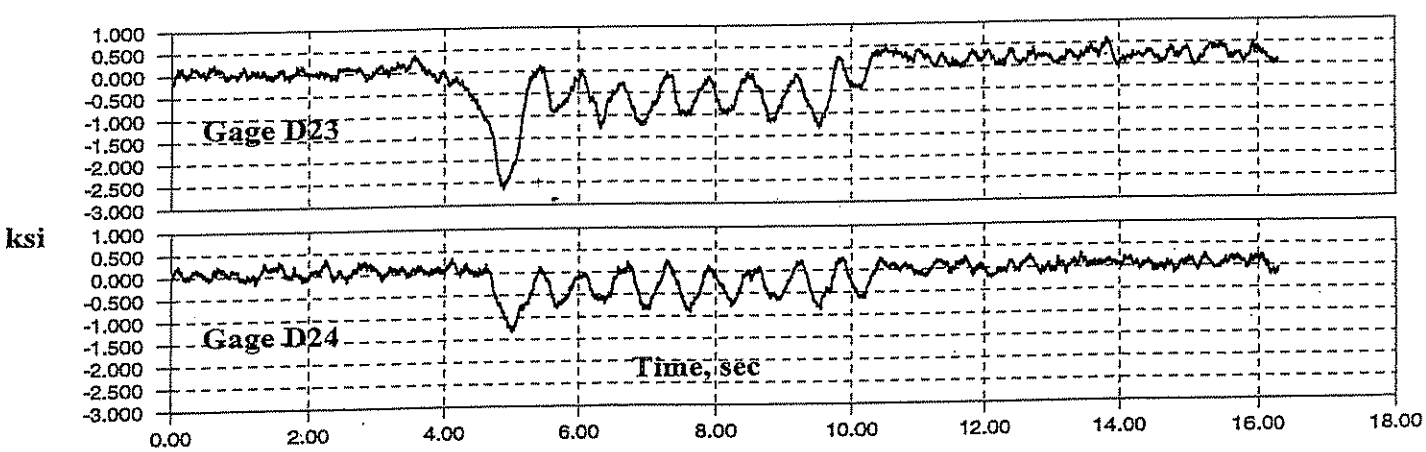
Figure 92: August Stress Records at Floorbeam/Top Chord Junction at Panel Point U8 in Span 1



(a) Coal Train UMP 74B Southbound on Track 3

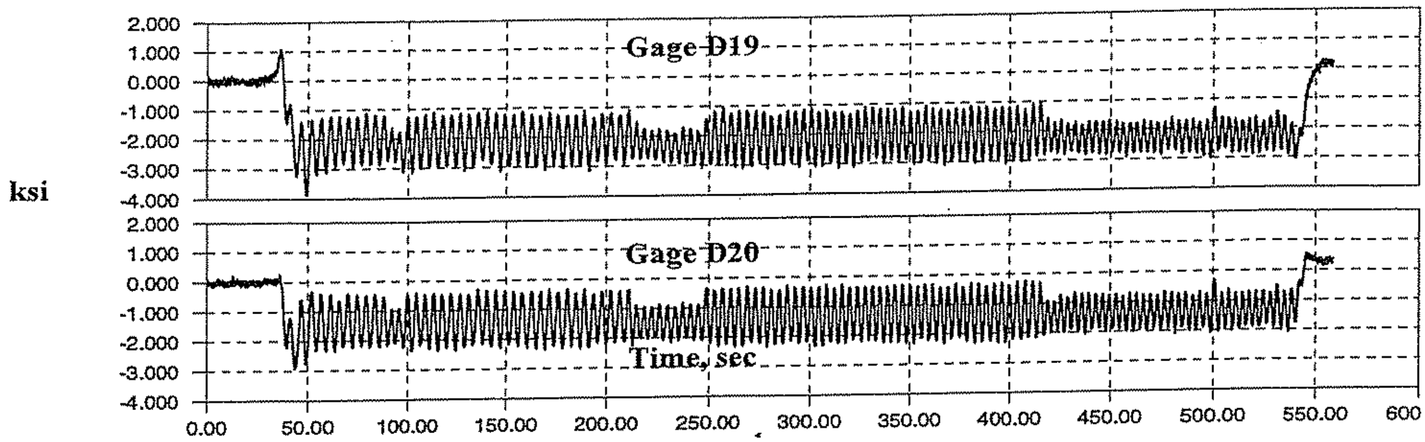


(b) Empty Coal Train XSM 43E Northbound on Track 3

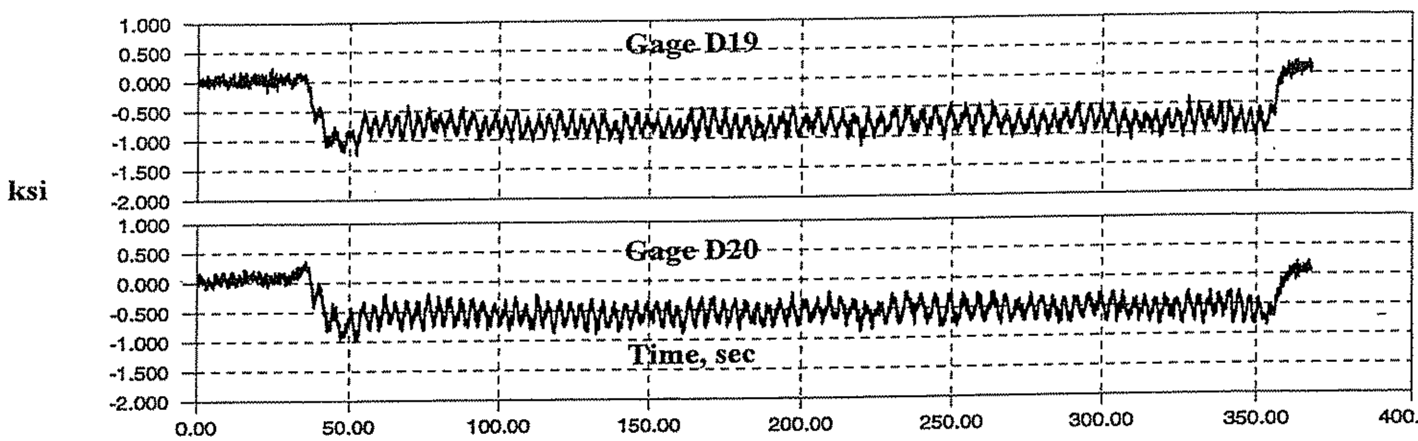


(c) Amtrak Train M106 Northbound on Track 3

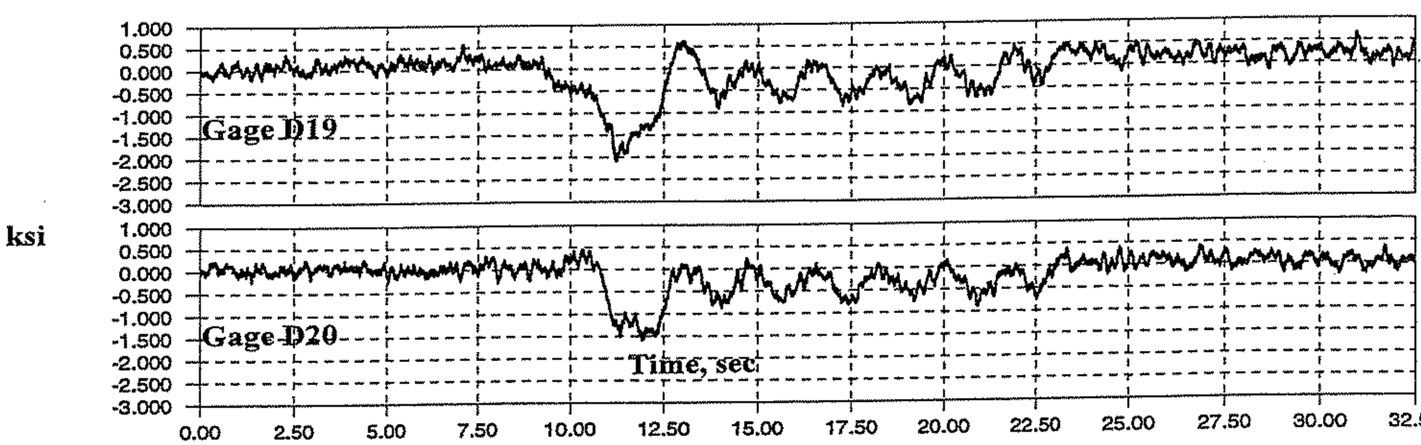
Figure 93. Post-Retrofit Stress Records in Span 2 at Vertical Post L5U5-West (NE (Gage D23) and SE (Gage D24) Corners)



(a) 263 K Coal-Car Train ULK 66C Southbound on Track 2

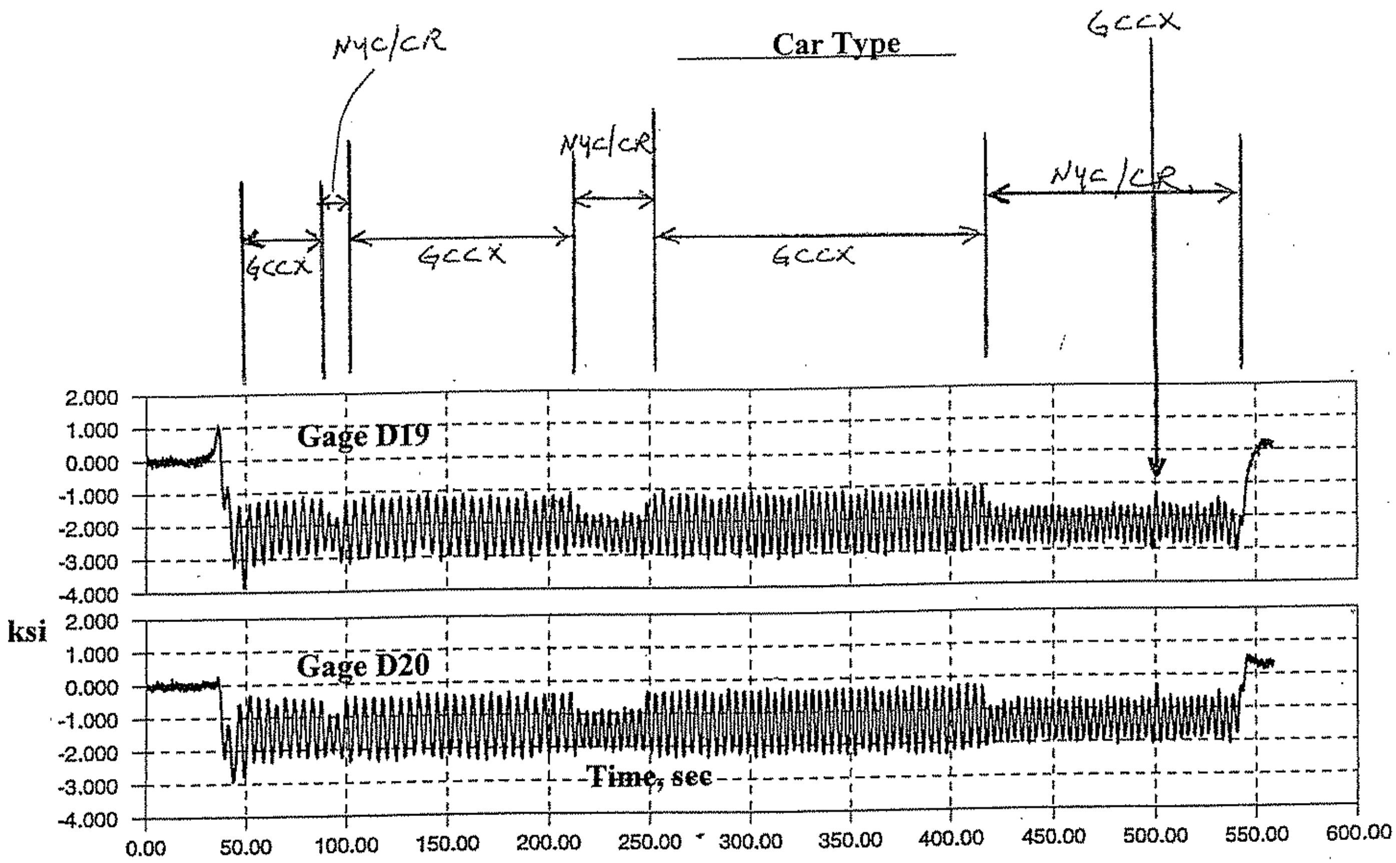


(b) Coal Train UMP 74B Southbound on Track 3



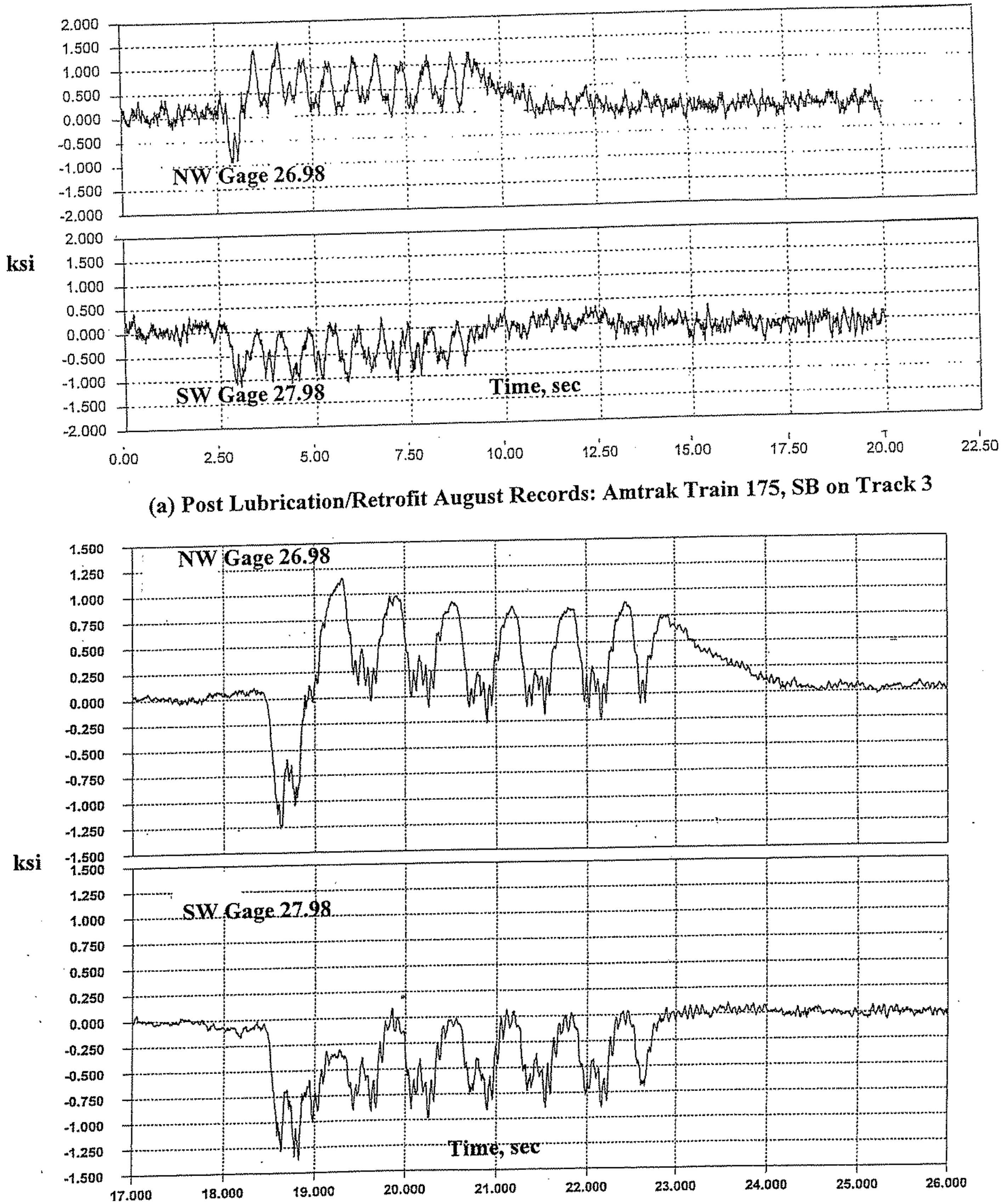
(c) Passenger Train MARC 536 Northbound on Track 2

Figure 94. Post-Retrofit Stress Records in Span 2 at Vertical Post L5U5-East (NE (Gage D19) and SW (Gage D24) Corners)



263K Coal Car Train Southbound on Track 2

Figure 95. Influence of Coal Car Construction on Data Records (shown here for vertical post L5U5-East in Span 2)



(a) Post Lubrication/Retrofit August Records: Amtrak Train 175, SB on Track 3

(b) Pre-Lubrication/Retrofit July Records: Amtrak Train M101, SB on Track 3

Figure 96. Pre- and Post- Lubrication Records for Vertical Post L9U9-West, Span 2

General Summary

During June 1998 and March 1999 review meetings in the Amtrak 30th Street offices, some interpretive summaries of the measurement results were provided, and a copy of the summarizing hand-outs discussed at those meetings is included in the Appendix. This section, however, provides a more complete general summary of all the results with reference, where applicable, to the effect of the retrofits.

Lower-Chord Eyebars

For eyebar members, the critical stress range is generally the net section stress on the eyebar head, which is classified as a Category E detail in the AREA specifications. The axial component in the eyebar causes the high stress concentration on the eyebar bore. Bending results from corrosion product and debris accumulating in the pinned joint between the lower chord, vertical post, and diagonal members. This packout causes rotation fixity at the joint and causes bending to be introduced into the eyebar shank. Since the packout acts as a bond between the surfaces of adjacent elements, the rotation restraint has no appreciable effect on stress acting on the eyebar head [11], but the bending stress in the eyebar shank is undesirable. Since the eyebar shanks are corroded at the joint on all four surfaces (top and bottom edges and each side) there is a stress concentration effect, estimated to reduce the fatigue resistance to about Category C [12].

Pre-Retrofit Condition. The bending stresses in Span 1 and Span 9 end panel lower chords were high and, when coupled with the axial stress, result in a maximum stress range of 12.5 ksi (Table 11) for both 263K and 286K coal trains. This maximum stress range exceeds the fatigue limit for Category C. Hence, fatigue damage can accumulate. Fortunately, only a single stress cycle occurs for each train.

The reason there is no significant difference between the maximum stress range from a 263K train and the 286K-car train can be attributed to the fact that the engines pulling the trains are identical and load the member to its peak value. The smaller individual car cycles are about the same as illustrated in Figure 52.

The stress range in the eyebars did not vary much even though some had moderate tightness as defined by field inspection. At Span 1, two bars in panel L8L9-West had moderate tightness and 2 bars were tight. The data in Table 11 demonstrate this had no effect on the member response to train load. About the same maximum stresses were observed in each eyebar when the coal trains were on Track 3 adjacent to the west truss. Bars identified as moderately tight had equal or higher stresses than bars that were tight. When heavy coal trains were on Track 2, the moderately tight bars carried slightly less stress than the tight bars. Similar behavior was observed in Span 9 at lower chord panel point L0 for both east and west trusses. All lower chord eyebars were considered effective in resisting the train loads. The degree of tightness was not a significant factor.

Steps need to be taken to reduce the rotation restraint at the end support panel points. This is causing bending stresses that are 2 to 3 times larger than the axial stress that the lower chord members are assumed to carry. Lubrication has been found to be effective in reducing the end restraint from corrosion product between adjacent elements of pin plates of truss hanger members;

major examples include the I-95 Susquehanna River crossing upstream of Bridge 60.07 as well as the Newburgh-Beacon bridges across the Hudson River in New York.

Post-Retrofit Condition. Lubrication of lower-chord end panel points L9 in Span 1 and Span 2 was found to reduce the rotational restraint by at least 50 percent in Span 1. In Span 2 no measurements were acquired prior to lubrication, however it was observed that the bending stresses were only about one-third those observed in Span 1. Both spans experienced about the same axial stress for a given train. Hence, the test results confirm the desirability of lubricating all end panel points in order to minimize the rotation restraint between the lower chord, end post and diagonals.

Diagonal Eyebar Members

Pre-Retrofit Condition. The diagonal eyebar members did not experience significant bending stresses. The axial stress range was dominant in nearly all of the eyebars. Bending stresses on the eyebar shank near the pin were generally less than 1 ksi except for some eyebars at panel L5U6 of Span 2. This is readily apparent in Tables 14 to 23.

The diagonals experience one dominant stress cycle for both 263K-car train and 286K-car trains, as is apparent in Figures 53 to 56. The secondary stress cycles are less than 1 ksi at all diagonal eyebars except L5U6-west in Span 2. There, the vertical L5U5 is not tightly fitted at panel point L5-West. This results in significant load shedding to other members between panel points 5 and 6. Because of the reduced force carried by the west truss diagonal, the differences between the average and the peak axial stress in an eyebar is not serious, even though two of the eyebars are identified as very loose and one resists less than 50 percent of the average stress range (Table 18). The difference between the average stress range for the 286K train and the average stress range for the 263K train was between 0.1 ksi and 0.6 ksi for all of the diagonals evaluated.

The measurements demonstrated that all of the eyebars are effective to varying degrees in resisting the diagonal tension forces due to train load. As a result, the average stress range on the shank of the eyebar group under the 286K-car trains was between 5.2 ksi and 6.2 ksi (except L5U6). Where one or two of the eyebars were observed to be loose or very loose, the adjacent eyebar was observed to be stressed between 1 ksi and 2 ksi above the average stress range in the group (Tables 15, 21 and 23).

The largest stress range occurred in eyebar 2 of L7U8 in Span 2, east truss (8.0 ksi, Table 23). This maximum stress range would cause a stress range on the eyebar head net section of 6.2 ksi, which is above the fatigue limit for Category E, the AREA classification for the net section of eyebar heads. Hence, it would be desirable to tighten the loose and very loose eyebars which will reduce the cyclic stress below the fatigue limit. Since only a single stress cycle occurs per train, the accumulated damage is negligible to date. Corrosion notching on the shank of the diagonals does not appear to reduce the fatigue resistance below Category D with a fatigue limit of 7 ksi.

Post-Retrofit Condition. The Type 1 retrofit assembly installed at lower panel points L4 and L5 was particularly effective at L5-West in Span 2 where large relative movement was previously observed between the lower chord and the vertical post. The retrofit was observed to both tighten and align very loose diagonal eyebars. Not much difference was observed in the east truss, where no significant relative movement had previously been observed. Restoring the lower chord connection in the west truss at L5 increased the average axial stress in the west truss diagonal eyebars L5U6 and nearly eliminated bending in the eyebars. The response of the east and west truss eyebars was directly comparable when the train was on Track 2 or 3; the sum of the average axial stress was the same.

Stringers in Span 10

The stringers in Span 10 experienced severe corrosion of their top and bottom flange angles prior to 1962. This led to the installation of coverplates on the top and bottom that were nearly the full length of the stringers in 1962. Prior to welding the coverplates into place, the corroded outstanding legs of the flange angles were trimmed away. The coverplates were then installed by placing continuous fillet welds along the flame cut edge of the trimmed angle leg. The ends of the coverplates terminated at the floorbeam flange edge. There was a wide variety of residual segments of the outstanding angle legs. In some instances the trim line was at the fillet. In other cases curved or triangular shaped segment were removed. The welded coverplate reinforced or replaced parts of the outstanding legs.

Measurements at midspan and at the coverplate ends of the west pair of stringers between floorbeams 1 and 2 demonstrated that the stringers acted with partial fixity at their end connections to the floorbeam. At midspan a partial reversal of the liveload stress cycle occurred for each car (coal, freight or passenger). At the coverplate ends, a compression stress cycle was observed at the bottom tension flange.

The maximum stress range at midspan of exterior stringer A was 5.4 ksi with 286K coal cars. The 263K coal cars produced stress cycles between 5 and 5.3 ksi largely because of their variation in load. The coal cars (both 263K and 286K) produced stress cycles that were 1.0 to 1.4 ksi greater than the cycles from locomotives. All of the stress cycles appear to be less than the fatigue limit for the irregular continuous fillet welds along the trimmed outstanding angle legs. An analytical model needs to utilize cross-section properties and continuity consistent with the experimental data. Fatigue cracking does not appear probable along these flange angle trim line welds.

At the coverplate end, the stress range cycle in the stringer flange was in compression; with essentially zero tensile stress. The largest stress range occurred on the west side of the interior stringers and equaled 3.6 ksi under 286K coal cars on Track 3 . All stress cycles appear to be less than the fatigue limit for Category E at the coverplate ends [13].

Top Chords in Span 2

The top chords in the deck truss spans also serve as the outside stringers for Tracks 2 and 3. In the end panels (U0U1 and U8U9), the 38" x 1/2" top flange plate forms a box section with channel shaped webs and angles. Ties rest directly on the top flange plate. These plates are not continuous as segments have cracked from local bending as well as corroded and then been replaced. The top flange is subjected to compression bending stresses that was measured to be about 7 ksi under the 286K coal cars and 6.7 ksi under the 263K coal cars. The bottom flange angle had 5.4 ksi in tension on the east side and 6.8 ksi on the west angle, although the car weights were not identified. A comparison of the locomotive response suggests that the top and bottom surfaces of the chord are subjected to about the same magnitude of stress range. The stress on the net section is estimated to be about 4 percent higher. The coal-car-induced stresses all exceed the fatigue limit on the net section as defined in AREA section 7.3.4.2. Hence, fatigue damage will accumulate in the chord angles and web plates. Part of the reason for the relatively small increment of stress range between the regular coal trains (263K) and the test trains (286K) is the variation in car weights within a train. As can be seen in Table 10, individual car weights often overlapped. Hence, the maximum responses were only 4 to 5 percent different.

Floorbeams in Span 10

The floorbeams in Span 10 are riveted built-up members with flange angles and multiple coverplates. The floorbeams have section loss in the flange angles and bottom coverplates. Stress range measurements were obtained at interior (FB2) and end (FB10) floorbeams below Track 3.

At the interior floorbeam, the maximum measured stress range of 6 ksi occurred at the end of the bottom coverplate between the Track 3 stringers. This stress range only occurred once per passage of the 286K-car train. Thereafter, the individual cycles per car were 2.3 ksi. For a 100-car train this results in an effective stress range $S_{re} = [\sum \alpha_i S_{ri}^3]^{1/3} = 2.42$ ksi on the gross section. The maximum stress range under the 263K-car train was 4.5 ksi with the individual coal car cycles between 2.0 ksi and 2.3 ksi. The effective stress range is bounded by 2.07 ksi and 2.35 ksi. Even when adjusted to the net section, the effective stress range is well below the variable cycle fatigue limit of 6 ksi as defined in AREA 7.3.4.2 for riveted members. Measurements elsewhere along the interior floorbeam were significantly smaller.

At the end floorbeam, the largest measured stress range was 5.3 ksi at the end of the coverplate under Track 3, and the maximum stress range was about the same for the 263K- and 286K-car trains. The individual car cycles were 1 to 2 ksi higher than observed at FB2. Nevertheless, the effective stress range is still below the variable cycle fatigue limit of 6 ksi, and fatigue cracking should not develop.

Floorbeams in Spans 1, 2 and 7

The floorbeams and their connection to the top chord bottom flange angle have exhibited the most fatigue damage in the bridge. All of the damage is related to distortion that is introduced into the top chord bottom flange and the floorbeam web and flange angles that are attached to it.

Pre-Retrofit Condition. The in-plane bending stress in the floorbeams at midspan (measured in Span 2) was small. The bottom flange stress was between 1.7, 2.2, and 2.5 ksi for Amtrak, mixed freight, and coal trains, respectively. This is partly because of the end restraint at the floorbeam end connections.

A great deal of variability was observed in the floorbeams and their attachment to the top-chord bottom flange angle and vertical posts. A primary contributor to this variability is the adequacy of the connection between the vertical and the bottom chord. At two of the instrumented floorbeams, FB5 in Spans 2 and 7, a tightly fit connection was absent at the west truss between the vertical post and lower chord. This increased the relative deformations that developed between the top-chord bottom flange angle and the floorbeam web. This deformation had resulted in cracking of the top-chord flange angle as well as the floorbeam web. Gages installed at the ends of cracks in the chord angle in Span 7 and at the midwidth of the gusset-chord angle connection verified that very large stress cycles were introduced by the train and individual cars.

The deformation also introduces high stresses into the floorbeam web. The cracks in the floorbeam web originate in the gap between the ends of the floorbeam-vertical end connection and the outstanding legs of the flange angles. The combination of vertical movement and rotation has resulted in cracks that are propagating into the floorbeam web as shown in Figures 11 and 15. As was noted in the discussion of the diagonal eyebar members between L5U6, the relative deformation also affects the behavior of the diagonal members. The panel shear was lower in locations where the vertical post-to-lower chord connection appeared to be ineffective.

The pre-retrofit measurements at floorbeam 5 (Spans 2 and 7), floorbeam 6 (Span 2), and floorbeam 8 (Spans 1 and 2) verified that the largest deformation-induced stress occurred at floorbeam 5 where the degree of positive connection between the vertical post and the lower chord was poor. Stresses measured at floorbeams 6 and 8 were lower, but these stresses have resulted in cracking in the floorbeam web or the top-chord bottom flange angle.

Post-Retrofit Condition. The Type 1 retrofit assembly installed at several lower panel points in Span 2 significantly reduced the relative deformation that was occurring between the upper chord and floorbeam. This, in turn, reduced the cyclic stresses near an existing floorbeam web crack to less than 0.5 ksi. Hence, the Type 1 retrofits will improve performance at the ends of the floorbeam as well as that of the diagonals that frame into the top chord connection.

Changing the lateral connection plate between the bottom of the top chord and the floorbeam as represented by the Type 2 retrofit was verified to reduce the out-of-plane deformation effects on the top-chord flange angle and the floorbeam web cracks. Trial retrofits were installed at U4 and U5 of the west truss and at U4, U5, U6 and U7 of the east truss of Span 2. Measurements were acquired at U5-West and U6-East, and the maximum stress in the lateral connection plates was observed to be less than 3 ksi from in-plane and out-of-plane response. The maximum transverse bending stress in the top-chord flange angle was 2 ksi. Also, there was no significant stress introduced into the floorbeam web, as noted in the discussion on the Type 1 retrofit.

The results with the Type 2 retrofit trials suggest that it would be beneficial to install the new lateral connection plate at all locations where cracks have developed in the floorbeam web or the top chord bottom flange angle.

Effect of Car Configuration

As clearly depicted in Figure 95, and as observed in the August data records for several types of bridge members, coal car style had a definite effect on the cyclic stress range induced by the cars. Cars identified as GCCX induced larger stress cycles than did cars identified as NYC or CR, even though GCCX cars have a lower maximum gross weight rating (270K) than NYC and CR cars (286K), [14]. As opposed to weight rating, the stress cycle behavior is thought to be due to the different stiffnesses of GCCX and NYC or CR cars. (NYC and CR cars are equivalent in design; but NYC cars will be allocated to CSX and CR cars will be allocated to Norfolk & Southern.)

Conrail records [15] indicate that the GCCX cars are about 20-year-old cars that are leased from Consol (formerly Consolidated Coal) and that the wheel trucks on these cars (termed *Ride Control* trucks) are equipped with a cluster of 14 D5 springs with a 3-11/16" travel and an overall spring stiffness of 25,875 lb/in. There are no hydraulic snubbers (dampers), but there is light friction damping through wedges. In contrast, the newer NYC and CR cars have a dissimilar cluster of 14 wheel trucks (termed *Ride Master* trucks) equipped with D7 springs with a 4-1/4" travel plus 4 smaller springs, for an overall spring stiffness of 24,850 lb/in. Although again these trucks do not have hydraulic snubbers, their configuration includes a different and more effective system of wedges which provides significant friction damping and allows the wheel trucks to pass AAR damping specifications even without snubbers. The damping action of the *Ride Master* trucks seemingly provided the reduced stress cycle for NYC and CR cars observed in the measurements.

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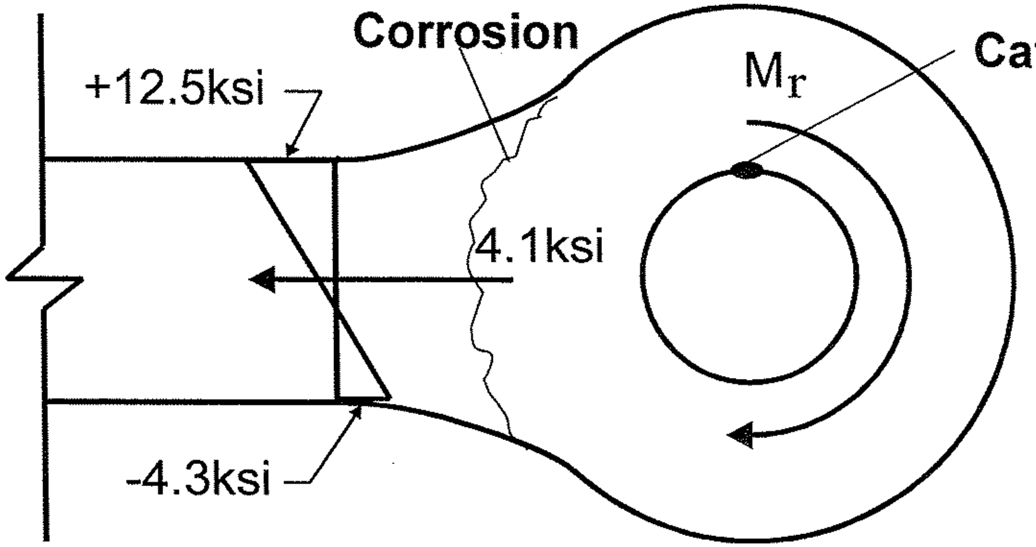
Appendix

During the June 11, 1998, and March 15, 1999, review meetings at Amtrak's 30th Street Station offices, J.E. Bower and J.W. Fisher reviewed the measurement results and provided interpretive summaries. At the request of Amtrak, the hand-outs used by Dr. Fisher for the interpretive summaries are provided in the succeeding sheets.

Span 1 Lower Chord



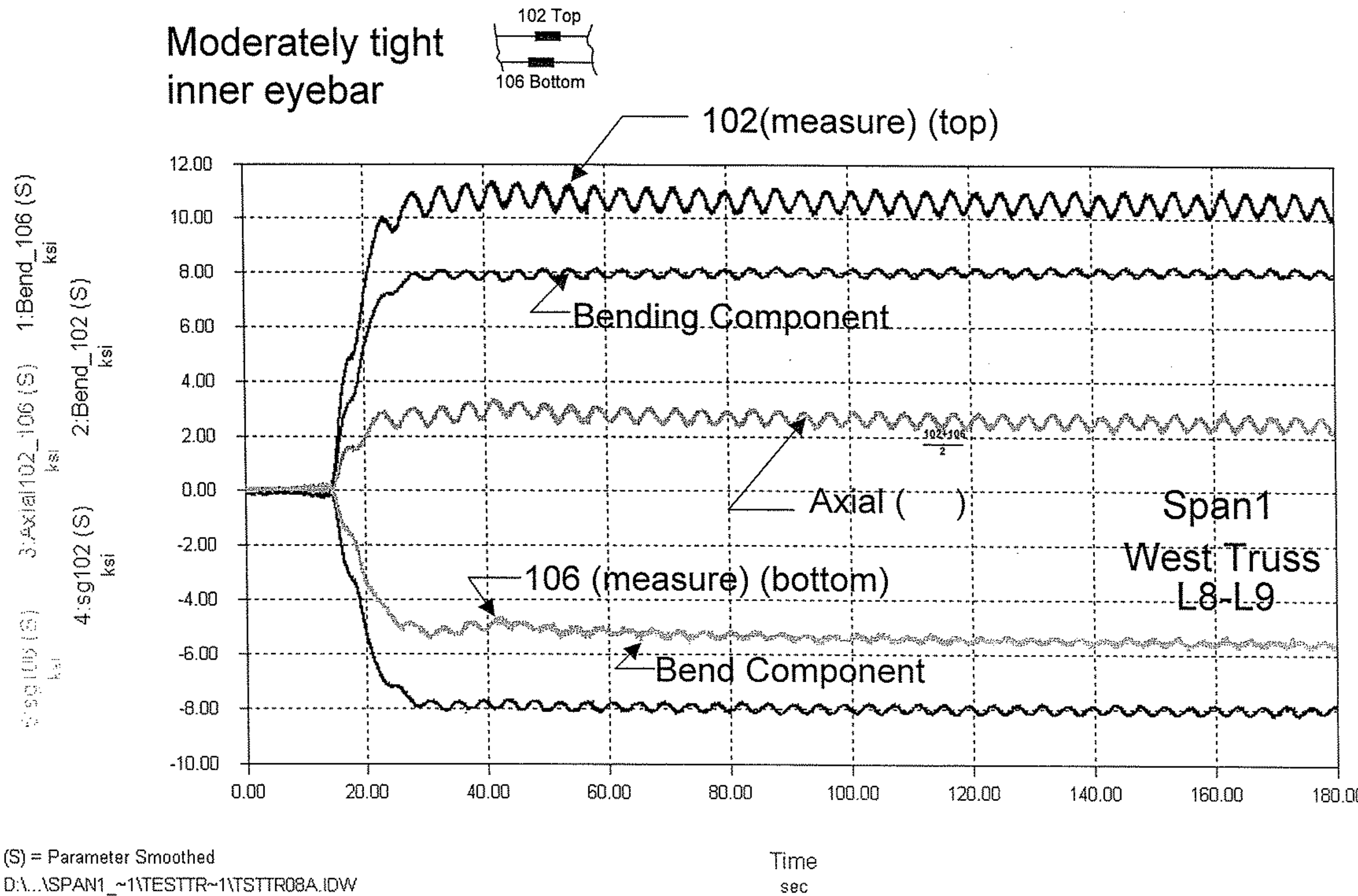
At corrosion,
¼" notch Category C;
never below Category D

Primary Pre-Lubrication Stress Range = 12.5 ksi (see eyebar 1, Table 11)

Car cycles; ~ 0.9ksi (286k) and ~ 1.3ksi (263k)

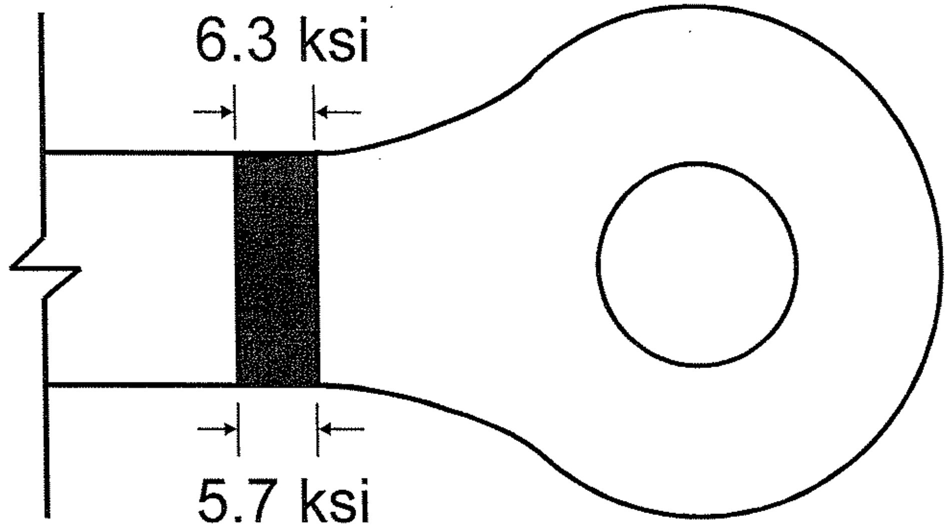
Post-Lubrication Stress Range = 7.5 ksi; (see eyebar 1, Table 39)

- All eye-bars participate in group and experience about the same S_r.
- Maximum response when train is adjacent to truss
- Eye-bar head/shank ~0.74 to 0.77



(S) = Parameter Smoothed
D:\...\SPAN1_~1\TESTTR~1\TSTTR08A.IDW

Diagonals

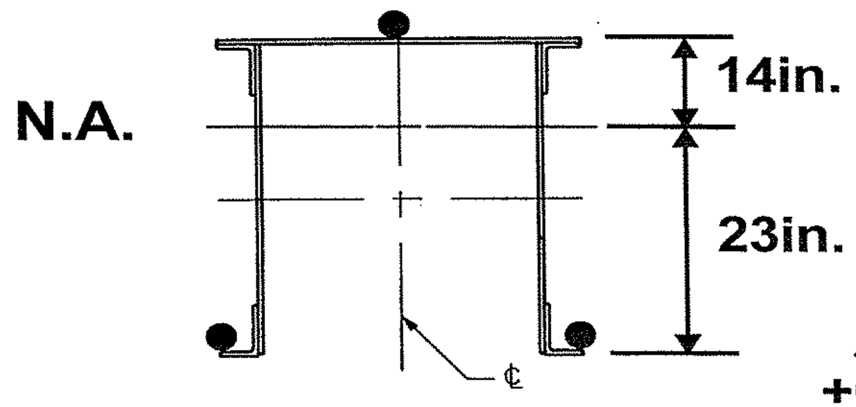


- Typically, loose and moderately tight bars have nearly thesame stress range; 1 cycle per train
- Very little bending unless bottom chord - vertical post connection ineffective, with relative movement occurring
  - Retrofitting will eliminate this
- Individual car cycles < 1 ksi
- 286k trains ~ 0.1 ksi > 263k trains
- Very loose bars increase stress in adjacent bar

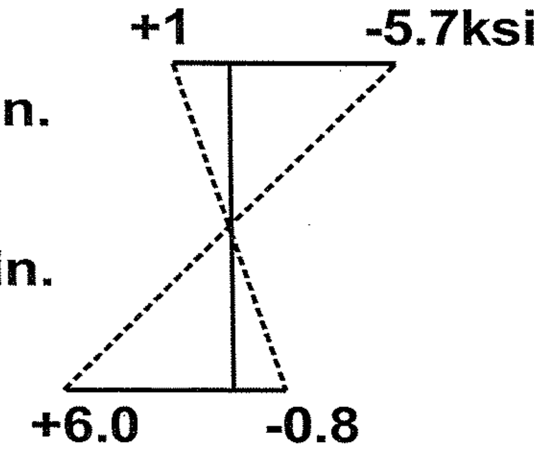
Stringers - Span 10

- Continuous beams with partial end fixed
- Weld reinforcement fully effective for x-section properties
- Floor & truss participation further sheds load
- Coverplate termination: Category E compression stress cycles, $S_{r\,max}$ = 3.6ksi
- Continuous welds along scalloped flange angles: Category C $S_{r\,max}$ ~5.4ksi

Top Chord / Stringer Span 2



℄ U8 - U9



S_r = 6.8ksi (W)
5.4ksi (E)

4-5% difference in S_r between 263 K and 286K cars due in part to distribution of car wts.

- **Frame Behavior**
- **Some Axial Force**
- Behavior affected by eyebar restraint and corrosion

FLOORBEAMS - SPAN 10

$$S_{r\max} \sim 6ksi \;\; once/train(286)$$

$$S_r \; (cars) \sim 2.3ksi$$

$$S_{r\max} \sim 4.5ksi \;\; once/train(263)$$

$$S_r \;\; (cars) = 2.0 - 2.3ksi$$

$$S_{re} \; (net) \leq S_{rfe} \;\leq 6ksi$$

FLOORBEAMS - DECK TRUSSES

- In - plane bending small
- Secondary out - of - plane bending source of cracking

  -- Distortion of top chord bottom flange angle at lateral gusset connection

  -- Floorbeam web gap at end connections also affected by gusset connection
- Trial retrofits

INTERACTION EFFECTS

- Deficient vertical post / bottom chord connection
  - -- Sheds load to diagonals,stringers,top chord,bracing
  - -- Promotes relative movement between floorbeam and top chord
- Results in deformation induced cracking in top chord flange angle
- Results in floorbeam end connection cracks and web
  - -- Introduces bending into diagonals
- Lateral gusset connection between floorbeam and chord promotes distortion