Memorandum

U.S. Department of Transportation
Federal Highway Administration

Subject: Determination of Strengthened Guardrail Deflection

Date: MAY 18 1989

From: Director, Office of Highway Safety
Washington, D.C. 20590

Reply to Attn. of: HHS-12

To: Mr. Leon N. Larson
Regional Federal Highway Administrator (HRA-04)
Atlanta, Georgia

On July 6, 1988, Mr. Terry Woodworth of your staff requested assistance regarding a problem on the Georgia Interstate System with W-beam guardrail (G4) used to shield bridge piers when a deflection distance of only 2 feet was available. When adequate deflection distance is not available, the use of a concrete safety shape barrier is the preferable treatment, but since the Georgia Department of Transportation wanted to use a semi-rigid barrier, we were asked if reducing the post spacing of the G4 barrier to 3 feet, 1.5 inches would provide a deflection less than 2 feet. We, in turn, requested our office of R&D to conduct a computer simulation using the Numerical Analysis of Roadside Design (NARD). Because of the availability of the new barrier impact computer simulation program, NARD, and crash tests in the range of which we were interested, we believe computer simulation might provide an approximate solution.

Attached is a letter report from Mrs. Kathy Hancock to Mr. Leonard Meczkowski which gives the result of using the NARD program to determine the deflections of various guardrail configurations.

We believe the results to be reasonably accurate; however, as they were generated by computer simulation, they may not be as precise as indicated in Table 1. This table should be used to indicate a safe range and not an exact placement guide for fixed objects beyond the barrier. Note that the table assumes adequate anchorage and a strong soil. (A strong soil is the S1 soil from NCHRP Report 230.) If both of these conditions are not at a specific installation, the deflection will be more and the expected deflection will have to be adjusted.

R. Clarke Bennett

Attachment

FHWA:HHS-12:HWTaylor:mdh:62175:5/4/89 (Rev. 5/15/89)
cc: Regions 1-3, 5-10, HDF-1, HHS-12 (Taylor),
HSR-20 (Mr. Meczkowski), HNG-14 (Mr. Sillan),
HNG-14 (Mr. Schlicht), HSA-1, HHS-1,
Chron-3407, Readers-3401/3407

DF (5201) File: B2:\HWT\GRDRLDEF

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January 6, 1989

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Mr. Ian Meczkowski
Turner-Fairbank Highway Research Center
6300 Georgetown Pike, HSR-20
McLean, Virginia 22101

Subject: Modification of Letter Report dated September 15, 1988
'Determination of Strengthened Guardrail Deflection'

Reference: FHWA Contract No. DTFH61-87-Z-00018
Scientex Contract No. 8200

Dear Mr. Meczkowski:

As you requested, this letter presents a report of the results for the computer simulations using NARD to determine the deflections of various guardrail configurations. This work was performed under the referenced "Maintenance and Operation of the Roadside Library" contract. This is an update to the previous work reported in the September 15, 1988 letter.

Rail Description. Computer simulations were performed for both W-beam and thrie beam guardrail on standard W6x8.5 steel posts. The height of the W-beam rail was 27 inches and the height of the thrie beam rail was 32 inches. The post spacing for each system was varied from the standard 6'-3" spacing to a minimum of 1'-6 3/4" spacing. The rail was assumed to be 12-gauge material and both single and nested rails were simulated. The nested rails consisted of two W- or thrie beams, one inside the other.

Impact Conditions. The simulated impacts consisted of a 4500-lb sedan impacting the rail at 60 mph and at both 15 and 25 degrees. The point of impact was at midspan between two posts.

Modifications from September 1988 Report. The new simulations were performed with a modified version of NARD which included upgrades to the post-soil interaction model. The validation simulation results compared well with actual test results for permanent deflections. However, after attempting to simulate the

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railing to more accurately predict the dynamic deflection by placing a node midspan in the rail, the permanent deflections did not correlate well to actual test results. Therefore, a the original guardrail model with the improved soil model was used.

Maximum Dynamic Deflection. After looking at the test results from the SWRI test in the AASHTO "Guide for Selecting, Locating, and Designing Traffic Barriers" which reports a 4.05-foot dynamic deflection, it was determined to disregard this test. The large deflection was due to extensive movement of the posts in poorly compacted soil. Subsequent tests have shown that the maximum dynamic deflection should be closer to 3 feet.

Dynamic Deflection Factor. Several tests of W-beam guardrails on W6x8.5 steel posts were reviewed to determine an appropriate dynamic deflection factor. These are listed below with the maximum dynamic deflection, maximum permanent deflection, the difference between the deflections and the test severity as defined by "NCHRP Report 230".

Test No.	Dynamic Defl. (in)	Static Defl. (in)	Difference (in)	Severity (ft-kips)
SPI-1	35.6	27.3	8.3	[illegible]
BH-1	35.2	24.3	10.9	112.7
BH-9	22.8	9.6	13.2	24.8
BH-10	25.2	15.6	9.6	28.8
BH-15	15.7	[illegible]	3.4	33.9
BH-12	21.9	13.6	8.3	37.0
BH-8	27.6	18.0	9.6	61.4
BH-4	27.6	25.0	[illegible]	97.4
121	37.2	25.2	12.0	100.1

The distance from the face of the guardrail to the face of the post is approximately 3" + 8" = 11". This compares to the greater deflection differences shown above. For the simulation results this value was used as the dynamic deflection factor and was added to the permanent deflections predicted by NARD.

Assumptions. The assumptions for the simulations are listed below.

1. The ends of the rails were considered to be rigid. The actual modeling of end treatments was outside the scope of this work.
2. Possible rub-rails were not accounted for in these models due to a limitation in the number of rail and post elements allowed by NARD.
3. Impacts at transitions between post spacings were not simulated.
4. The lengths of rails for each system were as follows:
    a. 6'-3" spacing all spaces — 87'-6" total length
    b. 3'-1 1/2" spacing 7 spaces — 75'-0" total length
    c. 1'-6 3/4" spacing 8 spaces — 57'-9 3/4" total length
5. The soil was assumed to be strong soil.

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6. The maximum deflections were calculated by adding the dynamic deflection factor derived above to the predicted permanent deflection.

<u>Simulation Results.</u> A summary of the maximum deflections are presented in Table 1. Figure 1 provides a graphic representation of the deflections for each series of different post spacings. Figure 2 provides a graph of the maximum deflections for the 25-degree impact simulations. Simulations of the 15-degree impacts for the 1'-6 3/4" spacing were not performed because of limitations in the modeling capability of NARD.

<u>Validation.</u> The initial simulation was compared to two tests performed for separate contracts at Southwest Research Institute. Figure 3 gives the specifics about each test and the deflections at each post along with the maximum dynamic deflection. The predicted behavior of the vehicle compared well with both test results.

If you have any questions about this report please call me at 301/770-1288.

Sincerely,

The Scientex Corporation

Kathleen L. Hancock
Senior Research Engineer

cc. M McNamara, Scientex

TABLE 1. SUMMARY OF MAXIMUM DEFLECTIONS

Nard Simulation Runs To Determine Maximum Deflections For Standard G4(1S) and G9 Systems By Varying Post Spacing and Using Single or Double Rails
(Deflections include 11 inch dynamic deflection factor)

Simulation of 4500-lb Sedan at 60 mph

Run No.	Post Spacing (ft in)	Beam Description	Impact Angle (deg)	Maximum Deflection (in)
1	6'-3"	Sgl W-beam	15	23.2
2	6'-3"	Sgl W-beam	25	35.7
3	3'-1 1/2"	Sgl W-beam	15	15.3
4	3'-1 1/2"	Sgl W-beam	25	21.3
5	3'-1 1/2"	Dbl W-Beam	15	14.1
6	3'-1 1/2"	Dbl W-Beam	25	17.2
7	1'-6 3/4"	Dbl W-Beam	15	NA
8	1'-6 3/4"	Dbl W-Beam	25	12.6
9	6'-3"	Sgl Thrie-Bm	15	19.2
10	6'-3"	Sgl Thrie-Bm	25	28.2
11	3'-1 1/2"	Sgl Thrie-Bm	15	15.2
12	3'-1 1/2"	Sgl Thrie-Bm	25	18.9
13	3'-1 1/2"	Dbl Thrie-Bm	15	13.1
14	3'-1 1/2"	Dbl Thrie-Bm	25	16.3
15	1'-6 3/4"	Sgl Thrie-Bm	15	NA
16	1'-6 3/4"	Sgl Thrie-Bm	25	13.9
17	1'-6 3/4"	Dbl Thrie-Bm	15	NA
18	1'-6 3/4"	Dbl Thrie-Bm	25	12.1

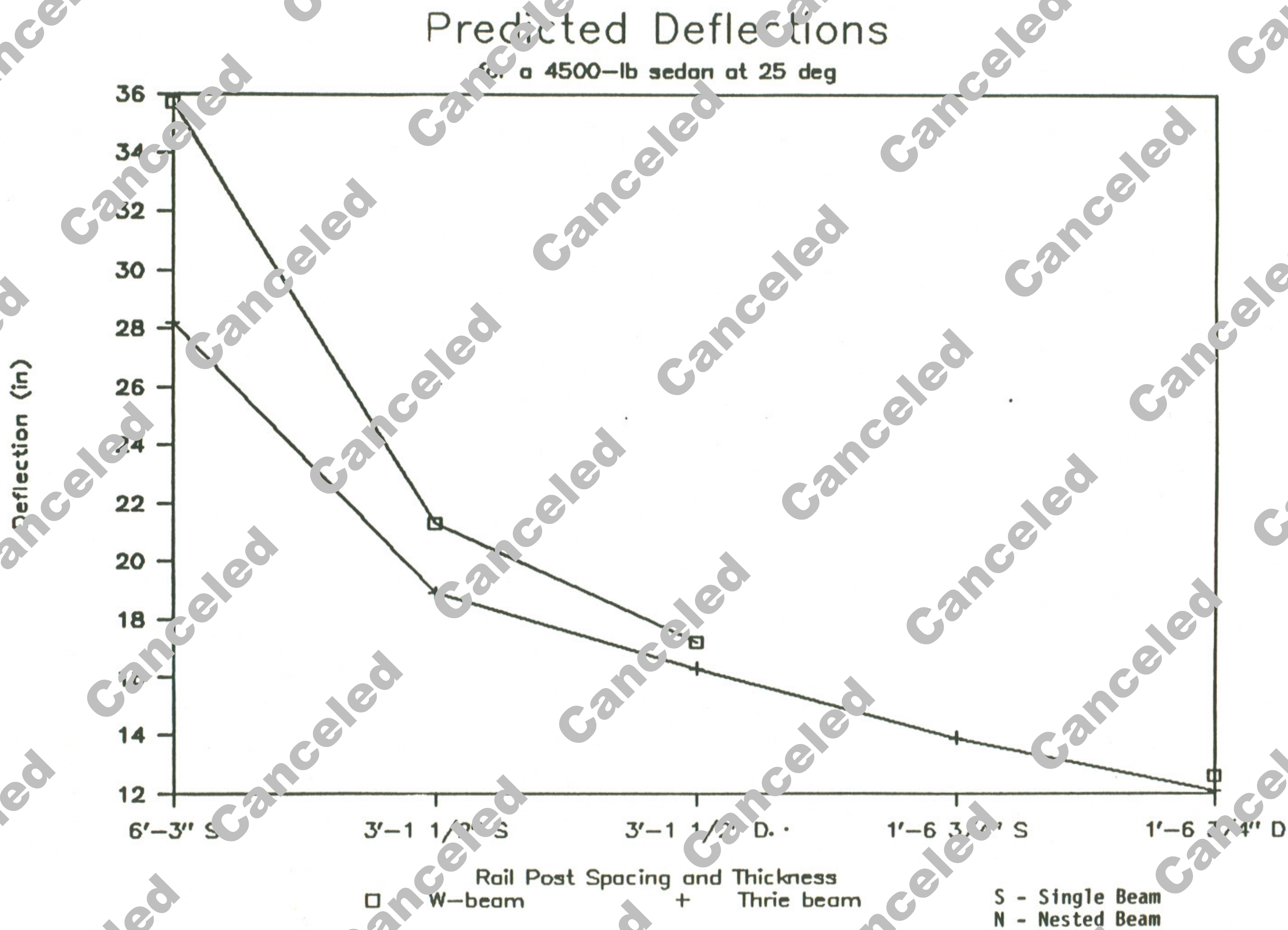


Figure 1. Maximum Deflections

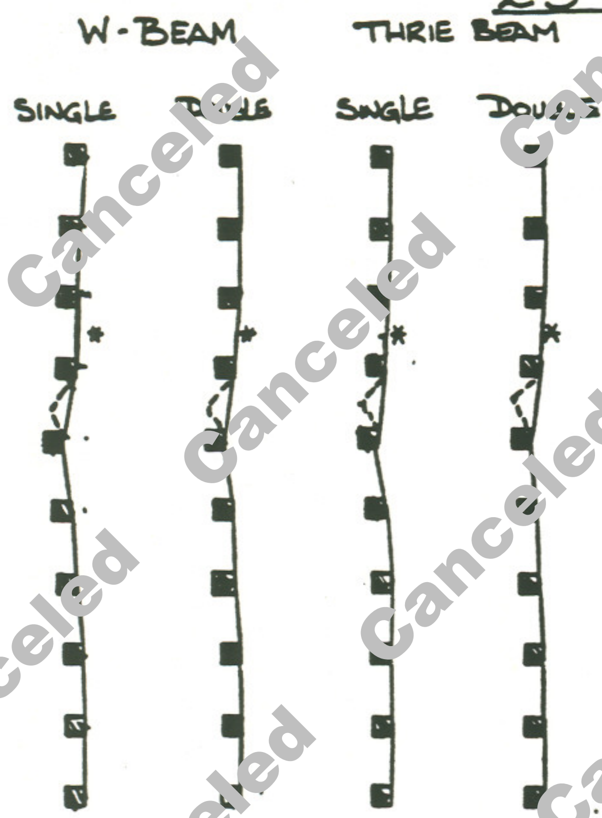
Single W-Beam 15-degree	Single W-Beam 25-degree	Single Thrie Beam 15-deg.	Single Thrie Beam 25-degree
Deflections (inches)			
0.0	0.0	0.0	0.0
0.0	0.1	[illegible]	0.0
2.1	[illegible]	1.0	3.2
8.8	16.1	4.3	10.7
23.2**	35.7**	[illegible]	28.2**
12.2	24.7	8.2	17.2
10.3	22.1	6.4	[illegible]
3.4	6.9	[illegible]	4.1
0.3	[illegible]	0.2	0.4
0.0	0.0	0.0	0.0

* Impact Point

** Maximum dynamic deflection = deflection at post + 11 inches.

Figure 2. Post Deflections from NARD Simulation
a. 6'-3" spaced posts

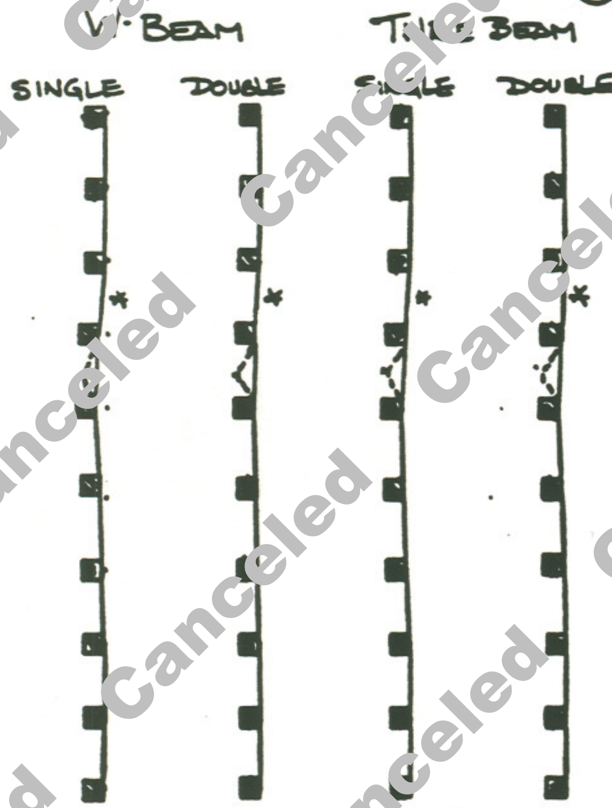
25-Degree Impact Angle



DEFLECTIONS (inches)

0.0	0.0	0.0	0.0
0.8	0.2	0.4	0.0
[illegible].3	1.0	3.[illegible]	0.2
6.2	3.1	[illegible].0	1.8
21.3**	17.2**	[illegible].9**	16.3**
10.3	[illegible]	7.9	5.3
9.1	4.9	6.2	4.[illegible]
3.[illegible]	1.8	2.0	[illegible].1
[illegible].8	0.2	0.[illegible]	0.0
0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0

15 Degree Impact Angle



0.0	0.0	[illegible]	0.0
0.0	0.0	0.0	0.0
0.4	0.[illegible]	0.2	0.1
2.4	1.8	2.2	[illegible]
15.3**	14.1**	15.2**	[illegible]**
[illegible].3	3.1	4.2	2.1
3.8	2.9	3.5	1.5
1.5	0.9	1.0	0.4
0.4	[illegible].0	0.1	0.0
0.[illegible]	0.0	0.0	[illegible].0
0.0	0.0	0.0	0.0

* Impact Point
** Maximum Dynamic Deflection = Maximum post deflection + 11 inches

Figure 2. Post Deflections from NARD Simulation (continued)
b. 3' 1 1/2" spaces posts

25-Degree Impact Angle

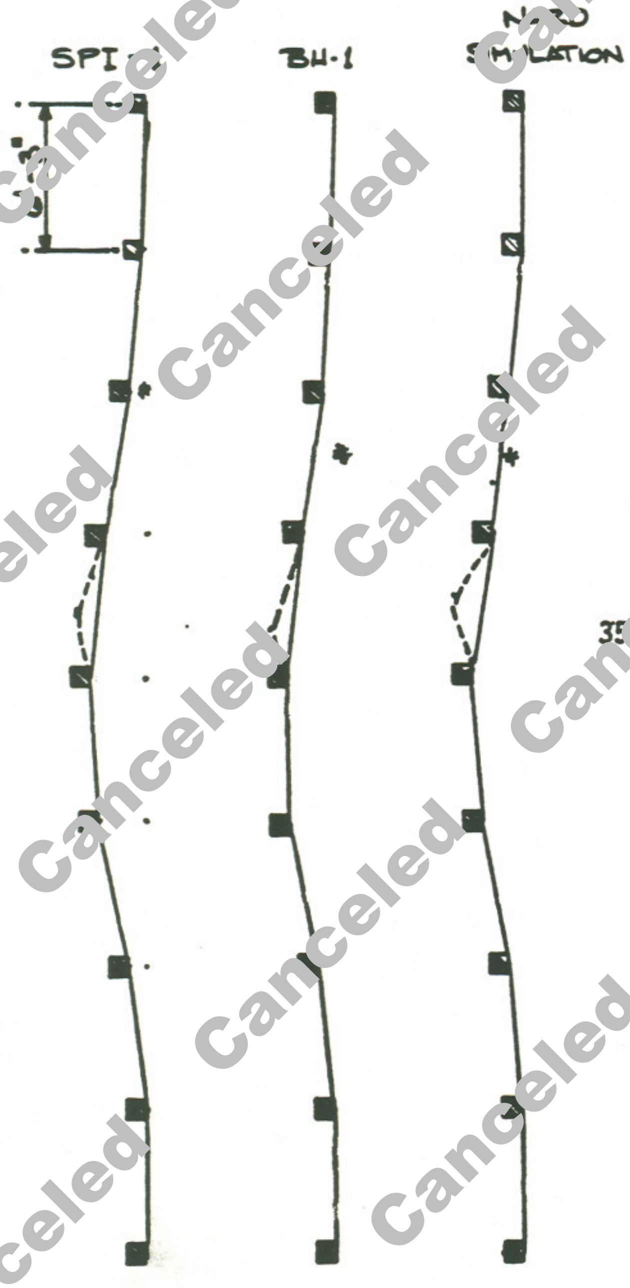
DEFLECTIONS (inches)

W-Beam Double	Thrie Beam Single	Thrie Beam Double	
0.0	0.0	0.0	
0.0	0.0	0.0	
0.0	[illegible]	0.0	
1.0	2.0	0.5	
1.6	2.9	1.1	**
1.2	2.6	0.9	
0.9	1.4	0.1	
0.1	0.9	0.0	
0.0	0.1	0.0	
0.0	0.0	[illegible]	

* Impact Point

** Maximum Dynamic Deflection not shown because post spacing makes the 11" factor unreasonable.

Figure 2. Post Deflections from NARD Simulation (continued)
c. 1'-6 3/4" spaced posts



SP-1	BH-1	Simulation	
4490	4735	4735	Vehicle Weight
59.6	61.1	61.1	Impact Speed
25.3	[illegible]	25.9	Impact Angle

DEFLECTIONS

SP-1	BH-1	Simulation
0.0	0.0	0.0
1.5	0.9	[illegible]
8.0	[illegible]	7.0
[illegible]	15.8	17.1
[illegible]	35.2	35.9**
27.3	24.3	24.9
24.5	23.5	22.7
8.0	9.0	[illegible]
0.75	1.0	1.1
[illegible]	0.0	[illegible]

* Point of Impact

** Maximum Dynamic Deflection of Rail calculated by adding 11 inches to maximum permanent deflection.

Figure 3. Validation Results